

NEWS FEATURE:

Pacific puzzle

Scientists have offered numerous explanations for the recent slowdown in global surface warming. Now, one study suggests that tropical trade winds may hold the answer.

Olive Heffernan

Back in 2009, around the time when the United Nations (UN) was convening its largest ever gathering of policymakers in Copenhagen to discuss global action on climate change, a rather inconvenient question arose. Why was it, when global warming was expected to continue to 2100 and beyond, that the average global surface temperature had remained fairly static for almost ten years? Was it simply, as many scientists claimed, a short-term blip in a much longer-term — and increasingly alarming — trend of continued climate change? Or could we conclude that warming had taken a break, or even stopped, and that we too could take a break from worrying about it?

Since then, scientists have offered no end of explanations for what has commonly become known as the ‘hiatus’, but would be more accurately described as a slowdown in the rate of surface warming.

Such has been the media focus on this issue that it stole the limelight in Stockholm last September, when the UN’s climate body released its fifth report assessing the science of climate change. The panel reported that global average surface temperature could rise by as much as 4.8 °C this century and that the past decade was the hottest since records began (Box 1). But a seemingly incongruous statement dominated much of the news coverage: since 1998, warming of the planet’s surface seems to have slowed to about 0.05 °C per decade, which is roughly half the rate of 0.12 °C per decade seen since 1951 (See <http://go.nature.com/25oGYu>; <http://go.nature.com/yLEdT2>).

In its report, the Intergovernmental Panel on Climate Change (IPCC) chalked this up to several factors. One possibility is that aerosol pollutants from Chinese power plants are cooling the top of the atmosphere, reflecting more heat back into space. Aerosols emitted during volcanic eruptions could be having the same effect. Also, the Sun’s heat, which peaks and troughs in 11-year cycles, has been especially low since the start of this century, meaning that less energy has been reaching Earth. The oceans, with their vast capacity

Box 1 | Climate change continues.

Since the late nineteenth century — when industrialization began — the average global surface temperature has risen by around 0.9 °C. Far from being a steady climb upwards, however, this temperature trend has been characterized by peaks and troughs, with very rapid warming during some decades such as the 1990s, and little warming during others such as the 1940s and during the twenty-first century. Although twenty-first-century surface warming has not lived up to the predictions of climate models, or kept pace with the accumulation of greenhouse gases in the Earth’s atmosphere, the

present slowdown is normal in a historic context. Moreover, in every other way twenty-first-century climate change has continued apace. The extent of Arctic sea ice, for example, hit record lows in 2005, 2007 and 2012. And from 2003 to 2009, all of the world’s main glaciers, from the Andes to Asia, shrank, as did the massive ice sheets covering Greenland and Antarctica. The twenty-first century has also seen a sustained rise in sea level. For more on how climate change is affecting the Earth, see the headline statements from the IPCC’s most recent report: <http://go.nature.com/i3e7Eo>

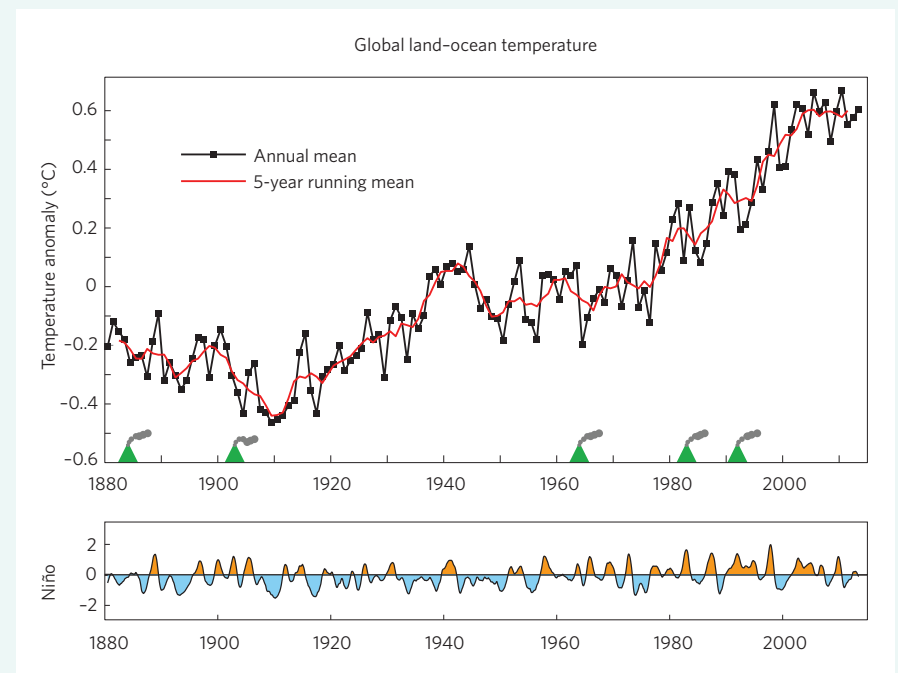


Figure B1 | Global surface temperatures relative to 1951–1980. The Niño index is based on sea surface temperature in the Niño 3.4 area (5° N – 5° S, 120° – 170° W) in the eastern tropical Pacific for 1951–1980 base period. Green triangles mark times of volcanic eruptions that produced an extensive stratospheric aerosol layer.

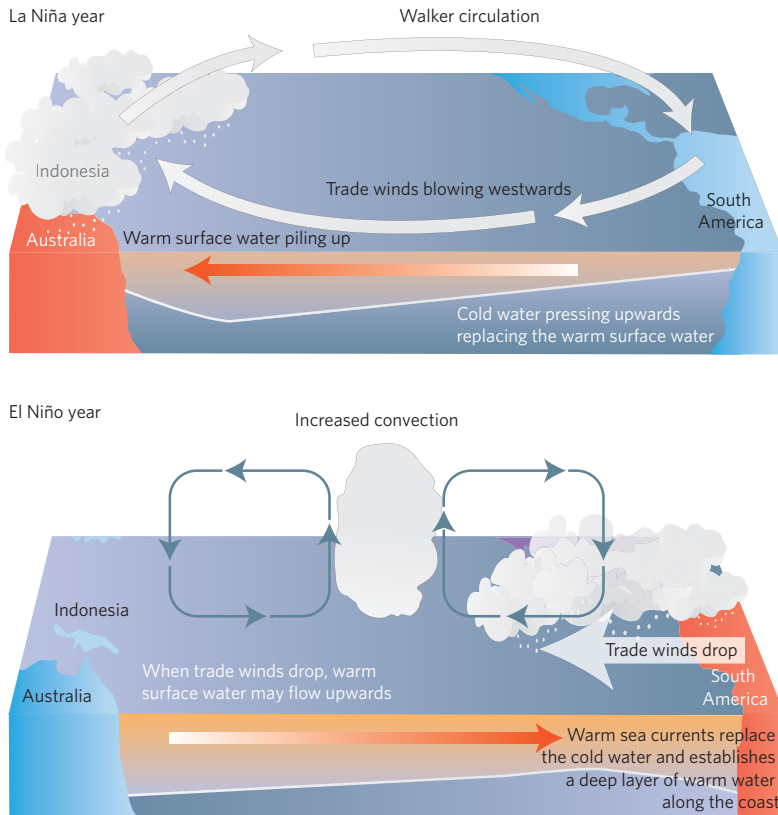


Figure 1 | The El Niño–Southern Oscillation (ENSO) affects climatic conditions in the tropical Pacific, where it originates, and also influences global climate. ENSO-like fluctuations, known as the Pacific Decadal Oscillation, can influence climatic conditions for decades at a time.

for heat storage, have played their part too. But a team of scientists now says that one aspect of the climate system can explain virtually the whole hiatus. As they report in *Nature Climate Change*, an international research team — led by Matthew England of the University of New South Wales in Sydney — have pointed to a pattern of unusually strong trade winds over the Pacific Ocean as the cause of the cooling¹. These trade winds, which have reached record speeds in the past 20 years, have lowered surface temperatures throughout the globe, say the researchers. “This paper nails it that an increase in trade winds is big enough to explain almost the whole effect of the hiatus,” says Stefan Rahmstorf, a climate scientist at the Potsdam Institute for Climate Impact Research in Germany, who was not involved in the study.

Flip-flop ocean

If strong Pacific winds are cooling the Earth’s surface it is because they are driving extra heat into the ocean — a fact that scientists have recently begun to see as central to explaining the hiatus.

Of the extra energy generated by our continued use of greenhouse gases, just

2% heats the atmosphere and more than 90% enters the deep sea². Yet for logistical reasons Earth’s surface temperature has been the standard measure of global warming. It is only recently — thanks to the advent of ocean instruments such as Argo floats — that scientists have been able to trace heat once it is subsurface. What they’ve found is that in the past decade, more than 30% of this heat has penetrated below 700 m (ref. 3). Results from climate models have backed this up; Jerry Meehl at the National Centre for Atmospheric Research (NCAR) in Boulder, Colorado, and colleagues have shown that during modelled hiatus events, when surface warming is slow or has stalled, the ocean above 300 m depth absorbs less heat and the ocean below 300 m absorbs more heat than usual⁴. So when surface warming is sluggish, it seems that heat is simply being stored in the ocean’s depths.

Although it might sound like good news to have the heat tucked away, the ocean offers only temporary respite for the atmosphere. In the Pacific — where much of it is stored — the heat is eventually released again as part of a natural weather pattern, the El Niño–Southern Oscillation (ENSO; Fig. 1). During one phase of ENSO, known as El Niño, winds

warm the surface of the eastern Pacific Ocean and transfer enough heat to the atmosphere to warm the whole planet. During the opposite event, known as La Niña, westerly winds drive heat into the deep waters of the western Pacific, cooling the eastern Pacific and the global atmosphere in turn. But each phase also encourages the onset of the other; changes to the jet streams and storm tracks during El Niño events eventually lead to heat loss that triggers La Niña⁵.

It is this cycle that some scientists believe is driving the hiatus². “The trigger between heat being largely taken up by the oceans and more entering the atmosphere is El Niño,” says Kevin Trenberth, another climate scientist at NCAR. The last strong El Niño event occurred in 1997–1998 and was followed by three consecutive La Niña years. Its warming effects, from coral bleaching to drought, were felt worldwide. But Trenberth believes that this flip-flop between El Niño and La Niña events is driven by a bigger force of nature. The Pacific Decadal Oscillation (PDO) is a 15–30-year cycle that, in its positive phase, favours El Niño conditions in the North Pacific Ocean and, in its negative phase, supports a La-Niña-like state. (Sometimes the term is used interchangeably with Interdecadal Pacific Oscillation, a similar pattern that affects both the North and South Pacific.) “El Niño is modulated by the PDO in the Pacific,” says Trenberth, adding, “they have to be related because their effects on the tropics are so similar”.

There is quite a bit of evidence to support this idea. A recent analysis by Trenberth and his colleague, John Fasullo, also at NCAR, shows that during past hiatus periods, such as from 1943 to 1976, the PDO was in a negative phase, whereas it was positive during periods of evident global warming such as from 1976 to 1998². The onset of the present hiatus coincided with the transition from a positive to a negative phase of the PDO and, what’s more, during this past decade it’s the Pacific that has been cooling more than anywhere. The Atlantic Ocean has continued to warm, as has Europe, in spite of some cold winters.

Writing in the journal *Nature* in 2013, Yu Kosaka and Shang-Ping Xie of Scripps Institution of Oceanography at the University of California, San Diego, pointed to yet more evidence that global cooling originates in the Pacific⁶. By feeding a climate model with eastern Pacific sea surface temperature data taken over several recent decades, they were able to bring model simulations in line with observations, such that the model recreated the recent hiatus. They also showed that the eastern Pacific — which has long-range atmospheric influence — cooled the globe during this past decade, as part of a natural cycle driven by the PDO.

Box 2 | Defining the hiatus.

For an issue that has received so much attention, the global warming hiatus is pretty poorly defined. Although scientists have made huge headway in explaining it, they have struggled to agree on when it started. Most commonly, scientists have chosen 1998 as the starting point, as has the media, because that is when global surface warming started to slow. But 1998 also marks the end of a strong El Niño event and strong El Niños are usually followed by two to three years of relative cooling. So some scientists worry that starting with an outlier makes the slowdown seem more severe than it has been. “For me, the problem with taking 1998 as a starting point is that it misrepresents the trend,” says England. “From 2001, there really is a remarkable plateau in temperature relative to the surface temperature record of the late twentieth century,” he explains. Rahmstorf thinks that the new study “is more reasonable in taking 2001 as the starting point”. As far as he’s concerned, “it’s just not the case that we’re in the sixteenth year of a hiatus”.

The other issue is how the hiatus is measured. The rate of warming most commonly cited for the hiatus period is 0.04 °C or 0.05 °C per decade from 1998 to 2012, depending on whether monthly or annual data are used. That is quite a drop-off relative to the rate of 0.18 °C per decade recorded in the 1990s. But the highly cited

rates of 0.04 °C or 0.05 °C per decade are measured from the HADCRUT4 global temperature record, compiled by the UK Hadley Centre for Climate Prediction and Research in Exeter. And, owing to a lack of on-site weather stations, that data set does not include measurements from the Arctic, which is warming twice as fast as the rest of the planet.

A comparable data set compiled by NASA, which extrapolates Arctic temperatures from nearby regions, gives an estimate of 0.07 °C per decade from 1998 to 2012. What’s more, a recent study⁷ by Kevin Cowtan of the University of York, UK, and Robert Way of the University of Ontario, Canada, shows that if satellite data are used to fill in missing Arctic temperature data, then the rate of warming is 0.12 °C per decade since 1998, relatively close to the long-term trend of 0.16 °C per decade. Cowtan has also developed an online tool (<http://go.nature.com/8VQXYx>) that can be used to calculate the rate of warming using various start dates and any of the available data sets. But he warns that there is little to be gained from looking at short-term trends; instead we should be focused on long-term warming. “Drawing simplistic conclusions from short-term trends is — in my opinion — bad science,” says Cowtan, adding, “it’s a distraction from the real thing”.

Another angle

But there is a whole other dimension to what is happening in the Pacific. When tropical trade winds are blowing full force, there is more upwelling of cold water near the Equator, which cools the eastern Pacific and the global atmosphere⁵. But added to this, strong winds intensify surface circulation patterns in the western Pacific, bringing more water deep into the ocean’s interior and cooling the surface layer there too.

England and colleagues looked at how Pacific trade winds, which have been gathering speed since 1992, have influenced both processes. By feeding an ocean model with 20 years of tropical wind data, they found that wind-driven changes in the Pacific Ocean alone could explain half of global cooling since 2001, the year in which they say the hiatus began (Box 2). But when they plugged the wind trend data into an ocean–atmosphere model, the total cooling effect of the winds was 0.1–0.2 °C by 2012 — enough to account for virtually all of the hiatus. “We show that Pacific cooling can explain most of the hiatus since 2001,”

says Meehl, who was involved in the study. Kosaka, whose research with Xie looked at ocean temperatures, rather than winds, says the new study takes another angle on Pacific cooling. “As the trade winds intensify, they cool the sea surface, but a cooler sea surface can intensify the trade winds, so it’s a chicken and egg scenario,” she explains.

Whichever comes first, the winds have gained impressive force in the past two decades. “It surprised me that the increase in trade winds is so exceptional,” says Rahmstorf. “It’s way outside anything seen in the past. Once you see that,” he adds, “the effect isn’t surprising”. Trenberth agrees that the trends are “startling”, but is less convinced that they offer a full explanation. “I don’t think it’s quite right that changes in the Pacific account for the whole hiatus. I still think that about 20% is a result of other factors,” he says. One of Trenberth’s concerns is that, unlike repeat patterns such as the PDO, a single trend is quite specific to the period that’s analysed. So it might be hard to say how tropical trade winds would trigger a hiatus more generally.

That is in part because the cause of the wind strength remains a mystery. The winds are partly driven by the PDO, says England, but the trend in the past 20 years is so strong that the PDO cannot account for it entirely. “The rest could be due to human-driven change such as warming of the Indian Ocean,” he says. What is evident from the new study is that it is some time before the winds take effect. Although the trade winds have been accelerating since 1992, the hiatus did not begin until at least 1999, perhaps even later (Box 2). “Through the 90s, the Pacific trade winds were accelerating, but it took about five years for them to have a global influence,” says England. He puts that down to inertia in the ocean. “It takes a while for the heat to go into the deep interior of the Pacific Ocean. The first few years are spent getting the system ready.”

Many scientists, such as Trenberth, have predicted that the hiatus will end once another El Niño comes along and pushes the PDO into its positive phase. James Hansen, former director of NASA’s Goddard Institute of Space Studies is among those and anticipates that a reasonably strong El Niño will set record global temperatures in the next year or two. Climate science blogger Dana Nuccitelli says many are hanging their hopes on it. “A lot of people are waiting for another El Niño to convince the public that global warming is still happening,” he explains. But if the powerful winds — driven in part by climate change — are behind the hiatus, it might not be that simple. “If the wind trend continues, then the hiatus will likely continue,” says England. Trenberth concedes that “it’s not a guarantee that an El Niño event will end the hiatus,” but he maintains that a strong one — like the 1997–1998 event — would do it. “If and when the winds do ease off, the global response should be rapid,” says England. “No matter how long the wind trend lasts, our models suggest that when it ends, the temperature catches up fast. So, in short,” he says, “you can’t get any comfort that the hiatus means a slowdown of global warming.” □

Olive Heffernan is a freelance environment writer based in London.

*e-mail: heffernan.olive@googlemail.com

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