

ATMOSPHERIC SCIENCE

Increasing wind sinks heat

Surface global warming has stalled since around 2000 despite increasing atmospheric CO₂. A study finds that recent strengthening of Pacific trade winds has enhanced heat transport from the surface to ocean depths, explaining most of the slowed surface warming.

Yu Kosaka

Despite an increasing concentration of CO₂ in the atmosphere, global-mean surface temperature has been quite steady since around the turn of this century. A variety of causes have been proposed for this global warming hiatus¹, which fall into two categories. First is a reduction in the top-of-atmosphere radiative imbalance, which could be a result of solar variability, stratospheric water vapour increase, an increase of airborne particles or a reduction in methane emissions to name a few. In the other category, the extra heat absorbed by the climate system is not spent warming the surface but somehow is stored elsewhere, with the ocean a likely candidate. In this issue of *Nature Climate Change*,

Matthew England and co-workers² report that the strengthening of Pacific trade winds during the past two decades has facilitated heat uptake by the subsurface ocean.

Trade winds — prevailing surface winds blowing westwards over the tropical ocean — drive the underlying ocean circulation. Owing to the Earth's rotation, ocean surface currents turn to the right of the wind direction in the northern hemisphere and to the left in the southern hemisphere. Thus, trade winds induce divergent surface flow along the equator, pumping up cooler subsurface water in the central and eastern Pacific. They also blow warm water to the western

Pacific where it piles up, and the resulting east–west pressure gradient sustains equatorward subsurface flow, which brings warmer subtropical water to the equatorial subsurface (at a depth below ~100 m). This system varies with time. When trade winds are stronger, this oceanic overturning circulation effect intensifies, cooling the surface while warming the deeper ocean. The opposite change occurs when trade winds weaken. Moreover, active atmospheric convection shifts concurrently with the sea surface temperature and feeds back to the trade-wind changes.

A natural pattern of decade-to-decade variability called the Pacific Decadal Oscillation (PDO), also known as the Interdecadal Pacific Oscillation, highlights this tropical Pacific feature. The negative phase of the PDO, characterized by cooler equatorial Pacific conditions, charges heat into the subsurface ocean, and vice versa for the positive phase. The PDO was negative from the mid-1940s to 1970s, shifting to the positive phase until the late 1990s before again trending negatively so far this century (see Fig. 1). England and colleagues investigate this recent negative trend with a global ocean model. To constrain the model PDO to follow the observations, they superpose observed trends of surface winds over the Pacific from 1992 to 2011. The result accurately reproduces the active subsurface ocean heat uptake and surface cooling in the equatorial Pacific, even if increasing greenhouse gas concentrations are taken into account. Then they utilize a global ocean–atmosphere climate model forced with CO₂ emissions scenarios, again constraining the model PDO in a similar way. Through the atmosphere, the influence of surface cooling spreads out from the equatorial Pacific and cools the global surface, causing the surface warming hiatus as observed³.

Without such constraining procedures, a single simulation of a climate model, if not initialized appropriately, cannot reproduce the observed evolution of

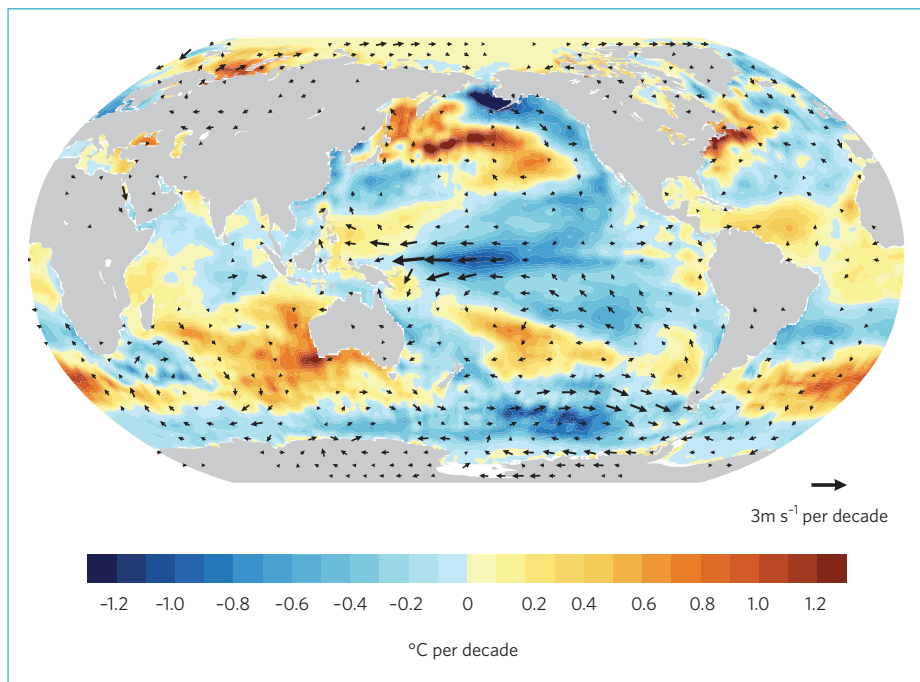


Figure 1 | Recent surface trends. Sea surface temperature (shading) from NOAA OISST¹¹ and surface wind velocity (arrows) from ERA interim¹². Trends are evaluated with monthly anomalies from January 2001 to October 2013 and scaled to ten-year changes. Note that the trade-wind strengthening resides over the surface cooling in the equatorial Pacific. The surface cooling expands polewards along the American coast while the midlatitudes have warmed in the North and South Pacific, a pattern characterizing the negative phase of the PDO. England and colleagues² find that the wind changes explain the surface global warming hiatus and enhanced heat uptake by the deeper ocean through the PDO.

internal climate variability because of its chaotic behaviour. Averaging many such unconstrained simulations, initialized with slightly different conditions, filters out internal variability and isolates the externally forced response. All climate models project warming in the equatorial Pacific as a forced response, many with equatorial maxima, and a consensus is emerging that forced global warming weakens trade winds. These findings suggest that the recent negative PDO trend is of internal, natural origin rather than the result of a forced response. Yet, an ensemble of model simulations should encompass all possible realizations of internal variability in its spread. However, the observed magnitude of trade-wind strengthening between 1992 and 2011 is far outside the ensemble spread of the 48 simulations examined². Consequently, the observed global-mean surface temperature trends for the past two decades is lower than all but a few of 117 simulations, which means a very low chance of the current hiatus⁴. It is inferred that the models underestimate PDO magnitude, or overestimate the trade-wind weakening and equatorial Pacific warming as the forced response. The latter affects estimates of climate sensitivity — the magnitude of global surface warming against a given CO₂ increase.

Even if the transition to the negative PDO is natural, the question of causation is not addressed by England *et al.*, but is worth examining for decadal climate predictions. Some recently suggested possibilities include the remote influence from Indian Ocean warming⁵, a phase transition in the Atlantic Multidecadal Oscillation⁶ and stochastic year-to-year variability of El Niño/La Niña¹.

The idea of the PDO influence on hiatus periods is not new. Studies have shown that hiatus events are also found in unconstrained model integrations — but not at the observed timings — and are statistically associated with the negative PDO (and other natural variability modes) and enhanced ocean heat uptake^{7,8}. The contribution of England *et al.* is to attribute the current hiatus event to the PDO. But models have limitations. How can we observationally confirm that the Earth is still gaining extra heat and that the heat is stored in the ocean? Satellite measurements do not provide the global net radiative imbalance with high accuracy because there is a small difference between the large incoming and outgoing radiation. Instead, we can use observations of ocean heat content because the ocean absorbs more than 90% of the extra heat. Studies show that the heat content has kept increasing during the current hiatus^{9,10}.

However, the result of England *et al.* favours a higher-order discrimination: the increase of heat content must be accelerated during the hiatus¹⁰, whereas a slowdown in radiative forcing would lead to deceleration. Such a perturbation in heat-content increase should manifest itself in the rate of sea-level rise due to thermal expansion. The quantification of ocean heat uptake by England *et al.* provides a basis for such attempts to attribute decadal climate change. □

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References

1. Trenberth, K. E. & Fasullo, J. T. *Earth's Future* **1**, 19–32 (2013).
2. England, M. H. *et al.* *Nature Clim. Change* **4**, 222–227 (2014).
3. Kosaka, Y. & Xie, S.-P. *Nature* **501**, 403–407 (2013).
4. Fyfe, J. C. & Gillett, N. P. *Nature Clim. Change* **4**, 150–151 (2014).
5. Luo, J.-J., Sasaki, W. & Masumoto, Y. *Proc. Natl Acad. Sci. USA* **109**, 18701–18706 (2012).
6. Chikamoto, Y., Kimoto, M., Watanabe, M., Ishii, M. & Mochizuki, T. *Geophys. Res. Lett.* **39**, L21710 (2012).
7. Meehl, G. A. *et al.* *Nature Clim. Change* **1**, 360–364 (2011).
8. Watanabe, M. *et al.* *Geophys. Res. Lett.* **40**, 3175–3179 (2013).
9. Levitus, S. *et al.* *Geophys. Res. Lett.* **39**, L10603 (2012).
10. Balmaseda, M. A., Trenberth, K. E. & Källén, E. *Geophys. Res. Lett.* **40**, 1754–1759 (2013).
11. Reynolds, R. W., Rayner, N. A., Smith, T. M., Stokes, D. C. & Wang, W. *J. Clim.* **15**, 1609–1625 (2002).
12. Dee, D. P. *et al.* *Q. J. R. Meteorol. Soc.* **137**, 553–597 (2011).

HUMAN IMPACTS

Winter weather and health

There has been much debate about whether winter warming due to climate change will substantially decrease mortality in that season. Research now finds that cold severity no longer predicts the number of excess winter deaths in England and Wales.

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For centuries, the seasons and weather have been considered fundamental determinants of human health. In temperate climates, there is a distinctive seasonal pattern of mortality — with a significant number of additional deaths in winter — known as excess winter deaths (EWDs). Assessments of the health impacts of climate change have often concluded that a reduction in the severity and length of cold weather because of global warming would substantially reduce EWDs^{1,2}. However, the accuracy of these predictions depends on how much of this winter

mortality is directly dependent on cold outdoor temperatures, as opposed to other factors. Writing in *Nature Climate Change*, Staddon and colleagues³ suggest that the association of annual variation in EWDs with the number of cold days that was observed until the mid-1970s has now disappeared, leaving only the incidence of influenza-like illnesses to explain any of the yearly variation in EWDs during the past decade. By looking at data for England and Wales, they conclude it is unlikely that EWDs will decrease in the region if winters warm with climate change.

It has long been recognized that in England and Wales mortality is much higher in the winter than the rest of the year⁴. This seasonal pattern is consistent across much of the world, and most countries suffer 10% to 30% EWDs⁵. A complex range of specific causes explains seasonal mortality, including the high incidence of cardio-respiratory and infectious diseases in the winter and the direct impact of cold weather. Understanding the causes of EWDs will help with disease prevention and save lives.