OCEAN–ATMOSPHERE DYNAMICS

Atlantic origin of Pacific changes

Unprecedented strengthening of Pacific trade winds has occurred in recent decades, while both the Indian and Atlantic Ocean surface temperatures warmed. Now a study suggests that the Atlantic Ocean warming is driving this Pacific trade wind strengthening and the warming of the Indian Ocean.

Shayne McGregor

Pacific trade winds have displayed a rapid and unprecedented strengthening since the early 1990s[1]. This change has been related to sea surface cooling in the eastern Pacific[1], implicated in the Californian drought[2] and identified as contributing to the current pause in global surface warming[1,3,4]. These winds have also directly led to an accumulation of warm water in the western part of the tropical Pacific, leading to a threefold increase of sea level rise relative to the global mean[5]. Despite the global importance and implications of the trade wind acceleration, debate over the cause continues. Writing in *Nature Climate Change*, Xichen Li and colleagues[6] now propose that recent Atlantic ocean surface temperature changes are responsible for this Pacific trade wind acceleration.

Numerous studies have attempted to identify the cause of this acceleration[2,7,8,9]. The studies agree that the observed trade wind acceleration and eastern Pacific cooling are not consistent with a Pacific-only sea surface temperature (SST) driving mechanism[2,7,8,9], thus detaching themselves from the 'chicken and egg' nature of the Pacific Ocean surface temperature–wind changes (that is, changes in eastern Pacific SST lead to changes in the overlying trade winds, which then reinforce the eastern Pacific SST). Removing this premise expanded the search for drivers to the other ocean basins. The Atlantic and Indian oceans are connected to the Pacific Ocean through what is known as an atmospheric bridge[10], which means that changes in the circulation in one of these basins has downstream effects on the others. However, depending on the study, warming in either the Atlantic or Indian ocean basins has been implicated, thereby casting doubt over the role of SST in any individual basin[2,7,8,9].

To address this stalemate, Li and co-authors[6] use a state-of-the-art coupled model to examine the hypothesis of the Atlantic SST changes driving the Pacific changes. Model SSTs in the Atlantic were 'nudged' towards observed values, while SSTs in the remaining basins were left to freely interact and evolve with the overlying atmosphere. Similar experiments that separately nudged the Indian and Pacific ocean basin SSTs towards those observed were also carried out. The authors find that the SSTs and trade winds in the remaining basins best match the observations when Atlantic SSTs are nudged. In fact, more than half of the observed Pacific SST changes can be reproduced when nudging Atlantic SST, which is surprising given the size of the Pacific basin and the high variability of its SST relative to those in the other ocean basins.

The authors[6] attempt to untangle the complex processes at play and gain insight into the evolution of the Atlantic driving of the wind changes using a series of simpler models with more idealized experiments.


DONNA GREEN

Poruma Island, Torres Strait, Australia, is one of many vulnerable islands in the western Pacific Ocean experiencing sea level rise much higher than the global average. Photo taken in 2008.

They find that the changes in surface winds (through the wind–evaporation–SST effect) act to cool surface temperatures in the central equatorial Pacific and off-equatorial eastern Pacific, while warming the western Pacific and Indian oceans. Together, these changes in surface temperature then induce an atmospheric response — which, combined with ocean dynamics, acts to further amplify the central Pacific cooling and extend it towards the east, which is consistent with the observed cooling.

The obvious follow-on question is: what causes the Atlantic warming that initiates all of these global changes? Although this is not the focus of the Li *et al.*[6] paper, the authors do discuss possible causes. The warming trend is likely to be due to a combination of two factors: (1) changes in radiative forcing[11,12], where greenhouse gases have been implicated in the long-term trend, while aerosol emissions and periods of volcanic activity have been implicated in the multi-decadal variability of the surface temperatures in the North Atlantic; and (2) the natural variation in the Atlantic multi-decadal oscillation, which has been tied to the Atlantic meridional overturning circulation[13].

Given that anthropogenic greenhouse gas forcing should further warm the Atlantic Ocean, the question has to be asked: will the current trade wind intensification and eastern Pacific cooling end, and, if so, do we have any idea when? Although this was not investigated by Li *et al.*[6], they do elude to a role for Pacific basin variability, suggesting that the interactions are not unidirectional from the Atlantic to the Pacific. Further to this, there is reason to believe that the wind-driven changes to the Pacific Ocean circulation will ultimately lead to warming of the subsurface water that is eventually upwelled in the eastern Pacific[1]. So it seems that these recent Pacific changes will eventually end; presumably within decades, given the timescale of the upper-ocean changes, but it is unknown exactly when and whether the large 2015 El Niño event will play a role.

The study of Li and colleagues is based on a single state-of-the-art climate model, which can cast a shadow over the results, as all models have biases. Here, however, additional simulations with a simplified atmospheric model are presented in an effort to show that the mechanisms underlying the inter-basin connections are in fact very simple — and, as such, should be the same, regardless of the details of the model used.

Ultimately, the work of Li and co-authors[6] highlights that the tropical Atlantic, Indian and Pacific ocean basins are linked more closely than previously thought, which leads to the authors proposing that on decadal timescales the tropical oceans should really be considered as a single entity. ❐

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Published online: 2 November 2015

ARCTIC WARMING

Short-term solutions

Arctic temperatures are increasing because of long- and short-lived climate forcers, with reduction of the short-lived species potentially offering some quick mitigation. Now a regional assessment reveals the emission locations of these short-lived species and indicates international co-operation is needed to develop an effective mitigation plan.

Julia Schmale

Short-lived climate-forcing pollutants (SLCPs), such as black carbon (BC) and ozone, are substances that affect both air quality and climate. As the name suggests, they remain in the atmosphere for only short periods, that is, weeks or even days, and so their impact on climate can be mitigated almost instantaneously. Quantifying the warming impact of SLCPs is needed to aid quick and effective mitigation strategies and to slow warming as soon as possible. This is highly relevant to the Arctic, a region particularly susceptible to climate change, where warming is occurring twice as fast as the global average[1]. Writing in *Nature Climate Change*, Maria Sand and colleagues[2] show that global emissions of BC and ozone precursors — chemical compounds that react with sunlight to form ozone — cause Arctic warming of currently about 0.5 °C. They project that this warming could be reduced by 0.2 °C by 2050 under an ambitious but possible global mitigation scenario[3], thereby slowing sea-ice retreat and Greenland ice-sheet melt.

Air pollutants emitted globally can reach the Arctic and significantly change the radiative balance there. View of Spitzbergen, an island on the remote Arctic archipelago of Svalbard, on a hazy day (top), and on a clear day (bottom). Adapted from ref. 11, © 2007 Copernicus.

SLCPs can be emitted from natural sources such as wild fires, or from anthropogenic activities such as driving or generating electrical power from coal. Each of these sources emits a cocktail of SLCPs that interacts differently with sunlight. Sulphur-rich emissions form sunlight-scattering aerosols that have a cooling effect, or negative radiative forcing. Conversely, BC-rich emissions absorb light, leading to atmospheric warming, or positive radiative forcing. Therefore, understanding the effect of SLCPs on atmospheric temperatures requires identification of the various sources and quantification of their relative