ATMOSPHERIC SCIENCE

Pacific trade wind intensifier

The unprecedented recent intensification of the Pacific trade winds cannot simply be explained by natural variability alone. Now research finds that the more local influence of sulfate aerosols of human and volcanic origin play a significant role, in addition to the Pacific's coupling to the Atlantic Ocean via the 'atmospheric bridge'.

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Sea-surface temperatures (SSTs) in the western North Pacific (WNP) decreased from the 1930s to the early 1990s before increasing rapidly over the past two decades[1,2]. In addition, the past 25 years have seen a persistent strengthening of the Pacific trade winds, which is reflected in multiple observational and reanalysis datasets[3]. Understanding the factors that may influence trade winds is important as they have been utilized by hunters, merchants and adventurers for centuries, and their cycles have been understood to regulate life-supporting rainfall regimes by indigenous peoples since time immemorial. Writing in *Nature Climate Change*, Chiharu Takahashi and Masahiro Watanabe show that one-third of the Pacific trade wind intensification between 1991 and 2010 can be attributed to sulfate aerosols, in connection with SST increases in the WNP[4].

Rangiora, French Polynesia. The tropical Pacific is known for its scenic landscapes of palm trees and beaches.

Human-related activity has continued to release sulfate aerosols into the atmosphere, particularly the western Pacific Asian regions, but natural sulfate aerosol emissions have been low since the Pinatubo eruption in 1991. In order to investigate the influence of aerosols, Takahashi and Watanabe simulate the twentieth and early twenty-first century climate using all forcings, while several experiments with a subset of known forcing were run to quantify the impact of volcanic and anthropogenic sulfate aerosols since pre-industrial times. Using statistical techniques, the authors separate multidecadal SST variabilities in the modelled tropical Pacific, namely, natural (the Interdecadal Pacific Oscillation, IPO), and natural external (the trans-basin variability, TBV; the connection between the tropical Pacific and Atlantic Oceans).

The attribution analysis in this study[4] shows that volcanic aerosols contributed much to the positive decadal WNP SST trends during the 1990s. However, the 'spring-back' associated with Pinatubo cannot explain the warming in the late 1990s and early 2000s. This is likely to be caused by a remote connection to the Atlantic Ocean warming (supported by heat-budget analysis of the WNP region[4]). The mechanisms of the decadal SST variability associated with the TBV are still not fully understood and model responses vary[5–7]; however, the emerging picture is of closer interaction than once thought[8].

The IPO pattern emerges as a dominant mode of natural decadal SST variability intrinsic to the Pacific basin[9,10]. Understanding the nonlinear response of the winds to the WNP SST trend is central to this study, and is embedded in the warming trend in both the observational record and the model experiment designed to best reproduce it. Greenhouse gases are discounted as a driver as the WNP SST time series shows a near linear increase in their experiments when sulfate aerosols are fixed. However, in the eastern Pacific where the negative phase of the IPO has led to widespread La-Niña-like cooling, they stop short of claiming that this cooling (which models have difficulty capturing), combined with the slowdown in the global mean temperature increase, is associated with sulfate aerosols. That should be the focus of separate studies, and the upper ocean temperature variability is more likely to be a manifestation of the IPO. Consequently, the focus was kept on the western Pacific where the TBV is strongest, the IPO influence is low, and the aerosol link seems to be most compelling.

Takahashi and Watanabe's main conclusion[4] is that the natural aerosol-induced SST warming accounts for a substantial fraction of the wind intensification in the central Pacific; the remainder, especially since the mid-1990s, is mostly attributable to natural cooling in the eastern Pacific and physical exchanges with the Atlantic. It is this strengthening of zonal SST gradients that intensifies the equatorial easterlies that are principally forced from the Earth's rotation. As the results could vary between models, further modelling is required to understand the warming-induced fraction of the trade wind intensification and, for example, its association with the rapid Atlantic warming since the 1990s[2].

The growing body of research (including the study by Takahashi and Watanabe[4]) examining aerosols as a driver of climate change raises concern regarding the magnitude of the aerosol effect in the first place. Aerosol forcing has large uncertainties, and so it poses a fundamental challenge of using observations to quantitatively constrain model behaviour such as the equilibrium climate sensitivity, namely the global surface temperature change resulting from a doubling of carbon dioxide. Some years ago, a study made the claim that "aerosol uncertainty is the principal barrier to quantitative understanding of ongoing climate change"[11]. From a modelling point of view this represents a dual challenge — the uncertainty associated with the observed aerosol sources and sinks, and how to best represent aerosols in a model framework.

The study by Takahashi and Watanabe[4] is the first attempt to link the release of sulfate aerosols with changes to the Pacific basin's wide and seasonally varying (predominantly) tropical wind phenomena. The importance of this research is clear as the associated changes will have a bearing (mostly detrimental) on the communities living there — especially those already facing difficulties because of rapidly increasing sea-level rise and abrupt changes to rainfall regimes. In addition, by looking at the bigger picture it is clear that important questions remain, for example, what is the relationship of these intensifying trade winds to the changes seen in other critical climate drivers, such as the El Niño–Southern Oscilliation and the monsoon systems that also seem to be changing? Also, what is their combined impact on agriculture and often fragile ecosystems such as coral reefs and their inhabitants?

From here it will be interesting to see if the results reported by Takahashi and Watanabe[4] are evident in the multi-model ensemble that will begin to appear as the Coupled Model Intercomparison Project (CMIP) Phase 6 activity steps up during the 2016–2020 modelling period. ❐

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