Large shift of the Pacific Walker Circulation across the Cenozoic

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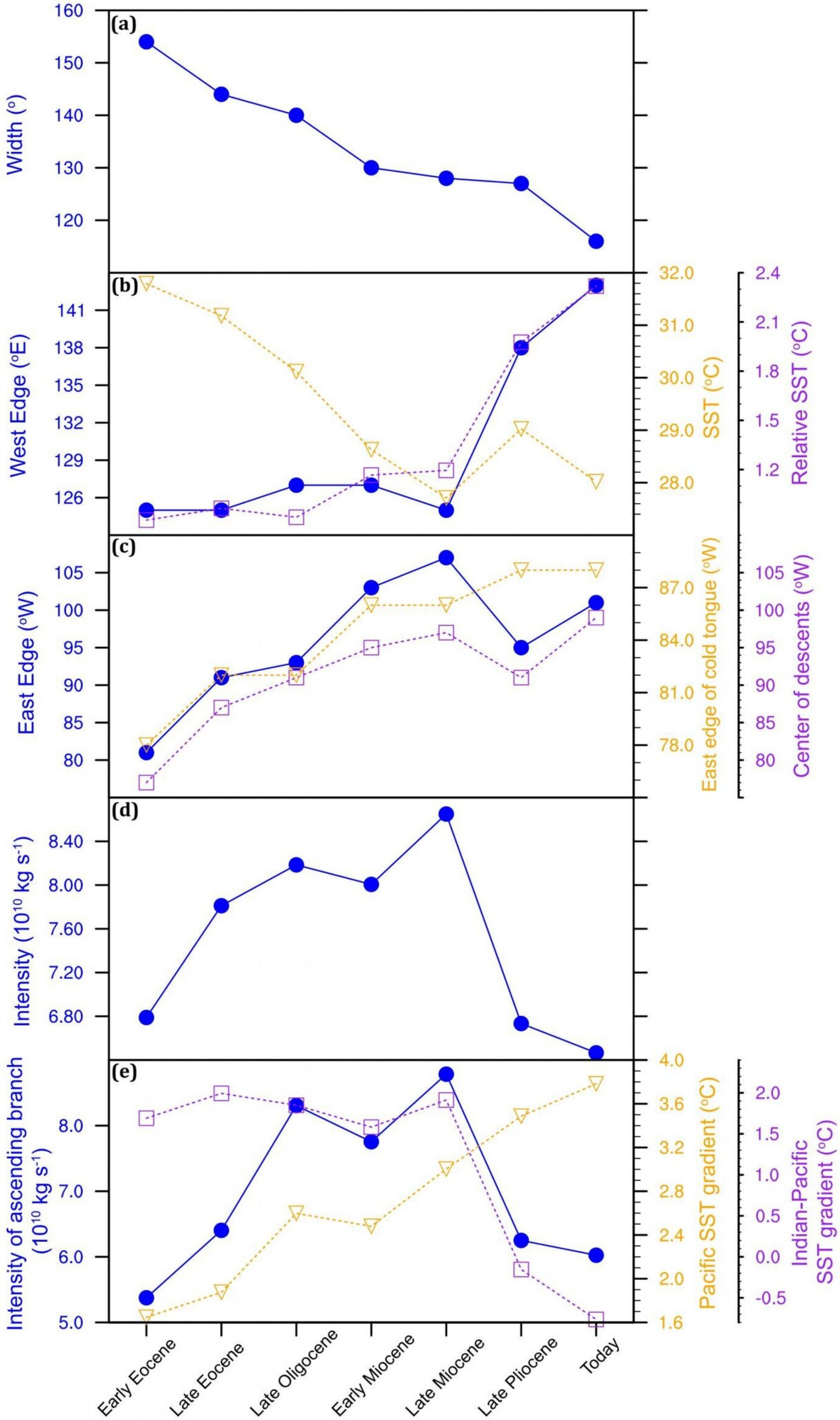
(a)
Width (°)
(b)
West Edge (°E)
SST (°C)
Relative SST (°C)
(c)
East Edge (°W)
East edge of cold tongue (°W)
Center of descents (°W)
(d)
Intensity (10^{10} kg s^{-1})
(e)
Intensity of ascending branch (10^{10} kg s^{-1})
Pacific SST gradient (°C)
Indian-Pacific SST gradient (°C)
Early Eocene
Late Eocene
Late Oligocene
Early Miocene
Late Miocene
Late Pliocene
Today

(a) The width of the PWC (degrees longitude). (b) The location of the western edge of the PWC (blue dots; °E). Orange triangles and purple squares are the SST (°C) and relative SST (°C) averaged over the western equatorial Pacific (5°S-5°N; 120°-180°E), respectively. (c) The locations of the eastern edge of the PWC (°W), the eastern edge of the "cold tongue" (defined as the position of -0.5 °C isotherm in relative SST; orange triangles; °W), and the center of descending motion over the eastern tropical Pacific (defined as the location of maximum vertical potential at 200 hPa; purple squares; VW). (d) The intensity of the PWC (1010 kg s^{-1}). (e) The intensity of the ascending branch of the PWC (1010 kg s^{-1}). Orange triangles and purple squares are the SST gradient across the equatorial Pacific (defined as the SST difference between 130°-160°E and 150°-120°W; °C) and across the Indian and Pacific oceans (defined as the SST difference between 60°-90°E and 130°-160°E; °C), respectively. Credit: Science China Press

Fluctuations in the Pacific Walker circulation (PWC), a zonally-oriented overturning cell across the tropical Pacific, can cause widespread climatic and biogeochemical perturbations. It remains unknown how the PWC developed during the Cenozoic era, with its substantial changes in greenhouse gases and continental positions.

Yan and colleagues examined the evolution of the PWC across the Cenozoic using a suite of coupled model simulations on tectonic timescales. During the Early Eocene (ca. 54-48 Ma), when the Pacific was larger in size, the western edge of the PWC was ~18° west of its present position, in tandem with a 20° eastward expansion of the eastern edge. This leads to a significant broadening of the PWC by ~38°. As the climate cooled from the Early Eocene to the Late Miocene, the width of the PWC shrank, accompanied by an increase in intensity that was tied to the enhanced Pacific zonal temperature gradient.

However, the locations of the western and eastern branches behave differently from the Early Eocene to the Late Miocene, with the western edge remained steady with time due to the relatively stable geography of the western tropical Pacific; the eastern edge migrates westward with time as the South American continent moves northwest. A transition occurs in the PWC between the Late Miocene and Late Pliocene, manifested by an eastward shift (both the western and eastern edges migrate eastward by >12V) and weakening (by ~22%), which they show here is linked with the closure of the tropical seaways.

Further sensitivity experiments that separate the influences of CO_2 and land-sea configurations illustrate that rising CO_2 alone leads to a weaker PWC, a robust feature across the large spread of Cenozoic climates considered here and therefore in a warmer future. The results also highlight that, at least on tectonic timescales, the location of the PWC is largely controlled by plate movements, with CO_2 concentrations playing a secondary role impacting solely the intensity.

Although there are uncertainties to be considered, these results provide a testable relationship between the tectonic/CO_2-induced climate change and the behavior of the PWC. The substantial changes in the PWC simulated here serve as a potential factor responsible for the reconstructed hydrological changes across the globe during the Cenozoic era. Moreover, a comprehensive understanding of the controls on the PWC could help advance its predictive skill and translate into better forecast of extreme weather conditions.

More information: Qing Yan et al, Large shift of the Pacific Walker Circulation across the Cenozoic, *National Science Review* (2020). DOI: 10.1093/nsr/nwaa101

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