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# Summer drought over East Asia during the warm Pliocene: evidence from clumped isotope and triple oxygen isotope compositions of soil carbonate

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The East Asian monsoon system plays a key role in the climate system and impacts billions of people's lives. However, the understanding of regional hydroclimate is hampered by the discrepancy among various paleoclimate records as well as a series of dynamic processes operating at different time scales. The Pliocene shares similar boundary conditions as the present, and paleoclimate information during this time offers additional insights into regional hydrologic dynamics in a warmer climate. However, the Pliocene hydroclimate over East Asia remains highly debated due to the contrasting results from various paleoclimate records as well as a variety of factors at control (i.e., meridional thermal gradient, land-surface feedbacks, topography).

The triple oxygen isotope composition ($\Delta'^{17}O$) of soil carbonate records that of soil water, the latter of which is dominated by evaporation, thus acting as a robust proxy of regional aridity and providing invaluable information about the regional water cycle. In this study, we reconstructed $\Delta'^{17}O$ of soil water based on the clumped isotope and triple oxygen isotope compositions of soil carbonates collected from three Miocene-Pliocene Red Clay sections across the Chinese Loess Plateau. The results reveal significant warming and enhanced evaporation over this region at the Miocene-Pliocene boundary (5.5-5 Ma), which aligns with global warming indicated by marine records.

We propose that the warming-induced aridification during the warm early Pliocene can be explained by the "jet transition hypothesis". The poleward shift of the westerlies, caused by the reduced meridional thermal gradient, led to an earlier termination of the Meiyu rains and, in combination with land warming, resulted in summer drought during the warm Pliocene. This jet transition hypothesis reconciles the discrepancy among different proxy-based hydrological records, and is further supported by the high agreement between regional aridity and the meridional temperature gradient, as well as the tripole pattern seen in climate models. For the first time, our work presents the triple oxygen isotope data of Pliocene soil carbonates and addresses the key role of westerlies on the East Asian hydroclimate over tectonic timescales.