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Tracking moisture pathways to Asia since the late Cretaceous: The competing influences of westerly and monsoonal dynamics

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There remains substantial debate concerning how uplift of the Tibetan Plateau and the greater India-Asia collisional orogenic system has impacted the strength of the Asian monsoonal systems. Deciphering the extent of the Asian monsoons through time requires knowledge of the relative influence of the major circulation systems that today deliver moisture to Asia, including the Southeast Asian Monsoon, the East Asian Monsoon, and the mid-latitude westerlies. Oxygen isotopes (δ18O) in precipitation provide a promising method to evaluate these systems through time, because δ18O in precipitation records both the moisture source as well as the relative importance of rainout and evapotranspiration; as a result, δ18O can be used to track the extent of monsoonal versus westerly moisture. Presently, southern Tibet receives depleted 18O monsoonal moisture from distillation over the Himalayas, while northern Tibet and Central Asia receive enriched 18O moisture borne by the mid-latitude westerlies. Remarkably, a compilation of nearly 3,000 Cenozoic paleosol and lacustrine carbonate samples from across Asia demonstrates that this spatial distribution has remained constant for approximately the past 50 million years. Since the early Eocene, southern Tibet has received low δ18O moisture, while Central Asia has received high δ18O moisture. A constant spatial distribution through time suggests that the relative extents of the monsoon and the westerlies have remained approximately constant since the early Eocene, despite substantial paleogeographic changes, including retreat of the Paratethys and uplift of the northern Tibetan Plateau, Tian Shan, and Altai.

To extend these records back in time and further explore the role of the monsoon and westerlies in supplying moisture to Asia, we present new records of stable isotopes from late Cretaceous paleosol carbonates from the Songliao Basin (NE China) and the Gobi Desert (Mongolia), and a long, late Cretaceous to Pliocene record of stable isotopes from paleosol and lacustrine carbonates from the Zaysan Basin (Kazakhstan), which lies windward of the greater India-Asia collisional system. These data suggest that a rainfall gradient from inland to coastal Asia is a long-lasting feature of Asian climate. In contrast, stable isotope records from inland Asia track stable isotope records from basins windward of the Tian Shan and Altai ranges. We conclude that the mid-latitude westerlies have been a sustained source of moisture for much of Central Asia and that north-south monsoonal circulation has not persistently extended into Central Asia since the late Cretaceous.