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Obliquity forcing of East Asian summer monsoon: oxygen isotopic records from Chinese loess

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East Asian summer monsoon (EASM) is the largest monsoon system out of the tropics. The temporal changes of EASM on orbital time scale have been highly debated largely due to the lack of proxy purely recording monsoonal rainfall. Oxygen isotope of rain water is a widely used hydrological tracer and has been well documented in the cave deposits of South Asia. The speleothem δ18O, which is dominated by procession cycles of ~23 kyrs, is believed to be controlled by upstream depletion that reflects tropical convections modulated by solar insolation of low latitudes. A δ18O record of monsoonal rainfall in higher latitudes of East Asia therefore is desired to investigate the variation of EASM. Here we reconstruct δ18O of summer precipitation over the past 500 kyrs based on microcodium, an authigenic carbonate in the loess deposits. Two parallel sections on Chinese Loess Plateau show consistent fluctuations of δ18O featured by strong obliquity cycles of ~41 kyrs and weaker precession cycles of ~23 kyrs. The procession signal may inherit from tropics as seen in the speleothem. However, the presence ~41 cycles in microcodium δ18O record argues that obliquity may influence the intensity of EASM and thus the integrated amount of precipitation between the speleothem sites and Chinese Loess Plateau. The obliquity signal cannot be generated by the effects of ice-volume, temperature, or pCO_2 on EASM because the predominant glacial cycles of ~100 kyrs in these variables have not been detected in the δ18O records. Summer insolation of mid-latitudes also cannot produce a higher obliquity signal compared to that of precession. We propose that the obliquity forcing of EASM may originate from the meridional gradient of summer insolation that modifies the thermal contrast between Asian inland at relatively higher latitudes and surrounding oceans at relatively lower latitudes.