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Insolation and ice volume induced extreme cooling events in East Asia during glacial times

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Our current understanding of past changes in East Asian monsoon climate variability is largely based on loess-paleosol sequences and speleothem $\delta^{18}O$ records. Although most records have provided insight on the strength of summer monsoon precipitation, past temperature variations over East Asia are so far relatively poorly understood. Here we quantitatively reconstruct a high-resolution land temperature for central China covering the past 250 kyr, based on soil bacterial lipid signatures, co-called branched glycerol dialkyl glycerol tetraethers (brGDGTs) preserved in a loess-paleosol sequence at Mangshan on the eastern Chinese Loess Plateau (CLP). We find that the brGDGT-based temperature is dominated by precession cycles (21 kyr), except during the last deglaciation when temperature change was mainly driven by obliquity due to low eccentricity, consistent with model outputs. Notably, our record provides first evidence of extreme cooling events during glacial times when summer insolation decreases to a critical value as predicted by model simulations. Furthermore, the degree of cyclization (DC) of brGDGTs, which is suggested to indicate moisture availability, also shows clear precession cycles but does not show extreme events in response to the critical low insolation values. Our results thus indicate that the warm season temperature and moisture are mainly forced by precession, and extreme cooling events could be triggered by low summer insolation during glacial times.