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Late Pleistocene East Asian monsoon intensity variations and driving mechanisms: Evidence from a multi-proxy analysis of loess deposits on an East China Sea island

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Shengshan Island (SSD), located in East China Sea, contains loess deposits that serve as an excellent carrier for recording environmental changes in the eastern subtropical region of China. Different from the continental Loess Plateau, SSD loess possesses distinctive characteristics due to its coastal location. Here we conducted the first pollen analysis to reconstruct vegetation dynamics in the SSD region during the middle to late Late Pleistocene period (75-40 ka). Biological indicators (i.e., total organic concentration and $\delta^{13}C_{org}$), along with geochemical proxies (i.e., quartz grain size, magnetic susceptibility, iron oxide ratios, clay minerals, and trace elements), were employed to reconstruct climatic dynamics in the SSD area. The study identified two stages in the evolution of the East Asian Monsoon. In Stage I (75-60 ka), various indicators (i.e., pollen concentration, *Pinus* concentration, magnetic susceptibility, C_4 abundance, K/(I+Ch), Illite crystallinity, CII, Hm/Gt, quartz median grain size, Zr/Rb) increased, suggesting a strengthening of both winter and summer monsoons. In Stage II (60-40 ka), some indicators (i.e., pollen concentration, *Pinus* concentration, quartz median grain size, Zr/Rb) continued to increase while others (i.e., magnetic susceptibility, C_4 abundance, K/(I+Ch), Illite crystallinity, CII, Hm/Gt) decreased, indicating a continued intensification of the winter monsoon but a weakening of the summer monsoon. Further, we explored the driving forces behind variations in monsoon intensity, analyzing changes in various $\delta^{18}O$ proxies and sea-level fluctuations. The findings suggest that different mechanisms influence the winter and summer monsoons. Summer monsoon intensity is linked to changes in summer solar radiation at mid-latitudes in the Northern Hemisphere, while winter monsoon dynamic is affected by changes in ice volume and ice sheets. These insights contribute to our understanding of environmental changes related to the East Asian Monsoon, offering valuable perspectives on how these mechanisms could respond to future climate changes.