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Exceptional East Asian summer monsoons during interglacials 400 kyrs ago and before

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The *vermiculated red soil* (VRS) in southern China is widely distributed in the region south of the Yangtze River, covering an area of about $2.2 \times 10^6 km^2$. Chronological studies consistently indicate a mid-Pleistocene age of the VRS, correlative to the S4 and S5 soil units in the Loess Plateau in northern China and to marine $\delta^{18}O$ stages 11, 13, and15. Soil micromorphological, mineralogical and chemical characteristics of the VRS indicate an extremely strong East Asian summer monsoon in mid-Pleistocene.

What might be the origin of these strong monsoons climate documented by VRS, S4 and S5 soils? Prell and Kutzbach (1987) concluded that under interglacial conditions, increased northern hemisphere solar radiation produce strong East Asian summer monsoon. It is remarkable that around the peak of MIS-11, -13 and -15, such maxima also occur. For example for these three MIS, at 60˚N in June, insolation is 34, 48 and 55 Wm-2 above the present-day value of 476 Wm-2. Does it mean that the conclusion of Prell and Kutzbach offering an astronomical origin to the strong monsoon East Asia may be extrapolated to the interglacials MIS-11 to MIS-15? Apparently not. Deep-sea records reveal indeed that MIS-13 and -15 are more glaciated than the following interglacials MIS-11 to -1. Moreover, ice-records from EPICA document a lower-than-average temperature for the Southern Hemisphere during these interglacials, opposite to the warm extreme reflected by the northern hemispheric soils in China. The CO2 concentration during MIS-13 and MIS-15 is also lower than during the other interglacials. Actually, the amplitude of the glacial-interglacial cycles is significantly reduced before MIS-11 in all these cores with cool interglacials and cold glacials. The great warmth and humidity of VRS, S4, S5-1 and S5-3 soils cannot therefore be easily related to global ice-volume variations as they appear to be exceptional,

especially S5-1, whereas the interglacials are on the contrary much less pronounced. Although it remains to demonstrate from modeling experiments whether insolation changes can trigger a so intense East Asian monsoon during MIS-11,-13 and -15, Guo et al. (1998) suggested that other factors , as the ocean circulation, might have operated during the formation of S4,S5-1 and S5-3 soils. This kind of climate extreme has indeed clear counterparts in marine δ^{13}C records, suggesting possible relationships with the strength of Deep Water (NADW) production in the North Atlantic. Moreover, the cooler MIS-13 in the Southern Hemisphere, as evidenced by the EPICA records, supports the explanation by the NADW strength. Stronger NADW would bring more heat from the equator and the Southern Hemisphere to the Northern Hemisphere, leading to a cooler Southern Hemisphere and a warmer Northern Hemisphere. A warmer Northern Hemisphere would possibly lead in turn to stronger monsoons.