



## **The East Asian winter monsoon and its changing relationship with the East Asian summer monsoon during the Holocene**

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The behavior of the East Asian winter monsoon (EAWM) during the Holocene at millennial timescales was analyzed using simulation results from an atmosphere–ocean–sea-ice coupled general circulation model—the Kiel climate model (KCM)—forced by orbital variations. The model results showed that the strength of the EAWM has gradually weakened throughout the Holocene, which is out-of-phase with boreal winter (January) insolation at 50°N and anti-correlated with Northern Hemisphere winter surface temperature. The EAWM was found to be positively correlated with the East Asian summer monsoon (EASM) during the period 9.5–0 ka BP, but with complex phase relationship during the early-middle Holocene (9.5–4.5 ka BP), especially during the period 7–5.5 ka BP when strong EAWM events were matched by an interval of relatively weak EASM. The changing EAWM–EASM relationship at 4.5 ka BP was probably due to the changing relationship between ENSO and summer Tropical Indian Ocean (TIO) sea surface temperature (SST), which was affected by the different trends in spring and winter insolation.

Also examined were the features of the EAWM under a background of North Atlantic cooling using model results from version 3 of the Community Climate System Model (CCSM3), forced by additional Laurentide Ice Sheet (LIS) and St. Lawrence meltwater flux at 8.5 ka BP. The results suggested that the EAWM in low latitudes could have been weaker because of a decrease in the zonal gradient of sea–land sea level pressure, while the Siberian High still remained stronger.