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Holocene East Asian summer monsoon records in northern China and their inconsistency with Chinese stalagmite δ18O records

Jianbao Liu, Jianhui Chen, Xiaojian Zhang, and Fahu Chen

Key Laboratory of West China's Environmental System (Ministry of Education), Lanzhou University, Lanzhou 730000, China

Monsoon precipitation over China exhibits large spatial differences. It has been found that a significantly enhanced East Asian summer monsoon (EASM) is characterized by increased rainfall in northern China and by reduced rainfall in southern China, and this relationship occurs on different time scales during the Holocene. This study presents results from a diverse range of proxy paleoclimatic records from northern China where precipitation variability is traditionally considered as an EASM proxy. Our aim is to evaluate the evolution of the EASM during the Holocene and to compare it with all of the published stalagmite δ18O records from the Asian Monsoon region in order to explore the potential mechanism(s) controlling the Chinese stalagmite δ18O. We found that the intensity of the EASM during the Holocene recorded by the traditional EASM proxy of moisture (or precipitation) records from northern China are significantly different from the Chinese stalagmite δ18O records. The EASM maximum occurred during the mid-Holocene, challenging the prevailing view of an early Holocene EASM maximum mainly inferred from stalagmite δ18O records in eastern China. In addition, all of the well-dated Holocene stalagmite δ18O records, covering a broad geographical region, exhibit a remarkably similar trend of variation and are statistically well-correlated on different time scales, thus indicating a common signal. However, in contrast with the clear consistency in the δ18O values in all of the cave records, both instrumental and paleoclimatic records exhibit significant spatial variations in rainfall on decadal-to- centennial time scales over eastern China. In addition, both paleoclimatic records and modeling results suggest that Holocene East Asian summer monsoon precipitation reached a maximum at different periods in different regions of China. Thus the stalagmite δ18O records from the EASM region should not be regarded as a reliable indicator of the strength of the East Asian summer monsoon. Furthermore, modern observations indicate that the moisture for precipitation in the East Asian monsoon region is mainly derived from the Indian Ocean. The moisture transport route from the Indian Ocean to the East Asian monsoon region during the Holocene is almost identical to that of modern precipitation. Therefore the strong correlation of δ18O records in the EASM and Indian summer monsoon (ISM) regions, and the similarity of the pattern of latitudinal changes in δ18O values in stalagmites and in modern meteoric precipitation along the water vapor transport route, further suggests that the stalagmite δ18O records from the EASM region are essentially a signal of the isotopic composition of precipitation, which is determined mainly by changes in the δ18O of atmospheric vapour in the upstream source region over the Indian Ocean and Indian Monsoon region via the upstream depletion mechanism. Finally, the main trends of the stalagmite δ18O records are strongly correlated with the known evolution of the ISM, and therefore these records reflect the history of the ISM rather than that of the EASM. Our findings support the conclusion that EASM variability is mainly controlled by Northern Hemisphere summer insolation and was strongly modulated by ice volume during the last deglaciation and early Holocene, which delayed the response of the EASM maximum to peak insolation forcing.