Synchronic variations in terrestrial temperature and East Asian summer/winter monsoons revealed from Japanese stalagmite records

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The d^{18}O of stalagmite calcite (d^{18}O$_C$) is an important source for terrestrial paleoclimate information. However, stalagmite d^{18}O$_C$ is controlled by two major factors: the temperature of calcite formation and the d^{18}O of meteoric water (d^{18}O$_{MW}$). The temperature and precipitation often covary spatially and temporally, and it is impossible to determine their relative importance by measuring only stalagmite d^{18}O$_C$. A possible solution is estimating temperature by carbonate clumped isotope thermometry that is independent of the isotopic compositions of the environmental water from which stalagmite precipitates. We analyzed stable oxygen isotope (d^{18}O) and carbonate clumped isotopes (D$_{47}$) of two stalagmites from Hiroshima and Mie Prefectures (Kato et al., 2021; Kato et al., 2023 in press). The D$_{47}$ values of the two stalagmites exhibited time-series changes of terrestrial temperature from the latest Pleistocene to the mid-Holocene in Hiroshima (4.5-18.1 ka) and Mie (2.6-8.8 and 34.8-63.5 ka). In the period common to these two stalagmites (7.7-4.5 ka), they exhibit very similar patterns in D$_{47}$ temperature.

We reconstructed past meteoric d^{18}O$_{MW}$ by subtracting the temperature effect from d^{18}O$_C$ values of these stalagmites. The averaged d^{18}O$_{MW}$ values through the Holocene portions are less negative than those of the latest Pleistocene portions both in the study regions. Focusing on climatic changes at centennial-millennial timescale, d^{18}O$_{MW}$ values were more negative in colder periods, such as the Heinrich stadials and less negative in warmer periods such as the Hypsithermal. These relationships indicate the coevolution of terrestrial paleotemperature and paleoprecipitation.

Two major moisture sources to Japan are the Pacific Ocean and the Japan Sea, from which the East Asian summer monsoon (EASM) and East Asian winter monsoons (EAWM) bring moisture, respectively. Generally in the broad area of Japan except for south-west islands, summer rainfall has a d^{18}O$_{MW}$ value less negtive than winter rain/snowfall, and this pattern is also observed in our study regions. The intensities of EASM and EAWM are negatively correlated over multidecadal to millennial timescales, primarily as a result of internal variability in the Atlantic Meridional Overturning Circulation and its subsequent teleconnection to East Asia via land-sea thermal contrasts (Yan et al., 2020).

In our study regions, increased precipitation brought by EASM has likely increased the average d^{18}O$_{MW}$ in warmer climate stages, whereas increased precipitation brought by EAWM has decreased the averaged d^{18}O$_{MW}$ in colder climate stages. The temperature dependency of the fractionation from seawater to meteoric water is another factor determining the d^{18}O$_{MW}$ values.

The trend of more/less negative meteoric d^{18}O$_{MW}$ in warmer/colder climate stages is the opposite of that assumed in conventional stalagmite paleoclimate studies, which suggest that meteoric d^{18}O$_{MW}$ becomes more negative in warm-humid climates due to the "amount effect".

References

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