Title
Long-distance relationship

Journal
Nature Geoscience, 4(7)

ISSN
1752-0894

Author
Johnson, Kathleen R

Publication Date
2011-07-01

DOI
10.1038/ngeo1190

Peer reviewed

PALAEOCLIMATE

Long-distance relationship

Oxygen isotope variations in Chinese cave deposits have been interpreted as proxies for the East Asian summer monsoon. Numerical simulations suggest the deposits may instead record remote climate changes over India and the Indian Ocean.

Kathleen R. Johnson

In the past decade, oxygen isotope variations preserved in precisely dated calcite deposits in caves, known as speleothems, have provided an increasingly detailed record of past climate variability. Speleothems from locations influenced by the East Asian summer monsoon span the past four glacial–interglacial cycles[1,2]. Abrupt climate anomalies during the glacial periods are clearly observed in these records, as are lower-frequency, orbital-scale variations. The associated changes in the oxygen isotope ratios are often interpreted as variations in the intensity of the East Asian summer monsoon. Writing in *Nature Geoscience*, Pausata *et al.*[3] present results from a general circulation model that challenge this interpretation, suggesting that Chinese speleothem isotope excursions during Heinrich events actually reflect remote changes in the Indian summer monsoon.

The interpretation of speleothem oxygen isotopes ($\delta^{18}O$) is more complicated than initially assumed. The isotopic signature of carbonates in cave deposits depends on the cave temperature and the $\delta^{18}O$ values of precipitation. The precipitation's $\delta^{18}O$ at a given location in turn represents an integrated signal of source composition, evaporation, transport, precipitation and moisture recycling that occurred between the moisture source and the cave site. In some sites, there is a statistically significant relationship between the amount of rainfall and the $\delta^{18}O$ of precipitation, but this so-called amount effect cannot explain the variations found in East Asian speleothems. Furthermore, speleothem records from across southern Asia show a strong similarity in $\delta^{18}O$ signals, despite being influenced by different climatological regimes. It is difficult to reconcile these broad regional shifts with local precipitation responses[4,5]. Chinese speleothem $\delta^{18}O$ variability is therefore often attributed to changes in the seasonal distribution of precipitation[1,2], which reflects a change in the intensity of the Asian monsoon circulation.

The landmark Hulu cave record[6] was the first of several Chinese speleothem $\delta^{18}O$ records to show a large and rapid response to abrupt climate changes during the last glacial period, such as Heinrich events. Heinrich events are defined by a rapid release of icebergs to the North Atlantic Ocean, which resulted in reduced Atlantic Meridional Overturning Circulation, cool Northern Hemisphere temperatures and a warming in the Southern Hemisphere. The effects of Heinrich events were once thought to be limited to the high northern latitudes, but the identification of variations in Asian speleothem $\delta^{18}O$ during Heinrich events showed that the effects of the climate shifts extended into the mid latitudes. The $\delta^{18}O$ excursions in the Chinese speleothems were subsequently interpreted as a period of weak summer monsoon intensity forced by oceanic and atmospheric teleconnections from the North Atlantic.

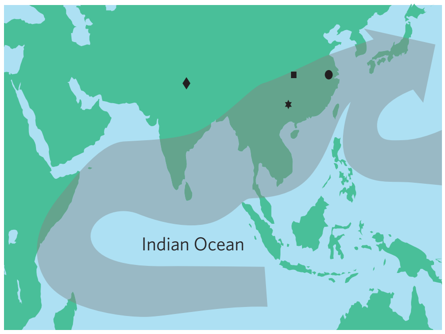

Figure 1 | The Asian monsoon system. Water vapour that precipitates over China during the East Asian summer monsoon comes primarily from the Indian Ocean[7]. Model simulations from Pausata *et al.*[3] suggest that that the isotopic values recorded by Chinese stalagmites (circle, Hulu cave; star, Dongge cave; square, Songjia cave; diamond, Timta cave) reflect processes over the Indian Ocean and subcontinent, rather than the intensity of the summer monsoon precipitation as previously suggested.

Pausata *et al.*[3] address the source of isotope variations using an isotopically enabled general circulation model set to simulate the climate of the Last Glacial Maximum and the climate of a Heinrich-like event. In line with previous studies, the Heinrich event simulation shows a decline in temperature and precipitation throughout much of the Northern Hemisphere, but no change in either the timing or the amount of precipitation at the location of the Chinese caves. The $\delta^{18}O$ of precipitation over China, however, does change, rising approximately as much as that observed in the speleothem records.

Sensitivity tests indicate that the Heinrich event triggered cooling in the northern Indian Ocean and reduced convective precipitation over the Indian Ocean. As a result, moisture with a higher $\delta^{18}O$ value was transported over India during the summer monsoon. The amount of precipitation during the Indian summer monsoon was also lower than that of the Last Glacial Maximum, and water vapour with a high $\delta^{18}O$ signature was exported eastwards to China. According to the simulations, the signal ultimately preserved as positive $\delta^{18}O$ excursions in the Chinese speleothems reflects these variations in the $\delta^{18}O$ value of moisture exported from India (Fig. 1).

Speleothems from India should reflect the combined influence of reduced rainfall over the Indian Ocean and decreased Indian summer monsoon precipitation, whereas Chinese speleothems seem to primarily record remotely forced changes in the isotopic composition of incoming water vapour. This suggestion makes perfect sense, given that the Indian Ocean is the primary moisture source to the Indian and East Asian summer monsoons during June, July and August[7,8]. In light of these simulations we can no longer assume a simple relationship between Northern Hemisphere temperatures and East Asian summer monsoon precipitation. Specifically, the conclusions of Pausata *et al.* suggest that the East Asian monsoon rainfall does not necessarily decline in response to abrupt cooling events in the North Atlantic, as is widely assumed.

On longer, orbital timescales, this study and previous modelling efforts[5] are pointing to changes in the source and properties of the water vapour that reaches the Chinese speleothems, rather than the intensity of the precipitation itself, as the cause of the $\delta^{18}O$ variability. It is also on these timescales that other proxy records from China suggest smaller variations in East Asian summer monsoon strength than the speleothem records, and consequently a weaker relationship between monsoon precipitation over China and Northern Hemisphere insolation[9]. Reinterpretation of the Chinese speleothem records could reconcile these differences. In particular, combining speleothem $\delta^{18}O$ records — as recorders of continental scale variability — with speleothem proxies that do definitively reflect local precipitation such as carbon isotopes, trace elements and crystal fabric, could allow us to reconstruct both regional and local precipitation dynamics.

The work by Pausata *et al.*[3] indicates that Chinese speleothems do not reflect regional East Asian monsoon strength. However, this discovery actually represents an encouraging development for the use of speleothems as palaeoclimate proxies, because it demonstrates their use in reconstructing large-scale features of the climate system, rather than simply local variability. ❒

Kathleen Johnson is in the Department of Earth System Science, University of California, Irvine, 3206 Croul Hall, Irvine, California 92697, USA.
e-mail: kathleen.johnson@uci.edu

References

1. Wang, Y. J. *et al. Nature* **451,** 1090–1093 (2008).
2. Cheng, H. *et al. Science* **236,** 248–252 (2009).
3. Pausata, F. S. R., Battisti, D. S., Nisancioglu, K. H. & Bitz, C. M. *Nature Geosci.* **4,** 474–480 (2011).
4. Dayem, K. E., Molnar, P., Battisti, D. S. & Roe, G. H. *Earth Planet. Sci. Lett.* **295,** 219–230 (2010).
5. LeGrande, A. N. & Schmidt, G. A. *Clim. Past* **5,** 441–455 (2009).
6. Wang, Y. J. *et al. Science* **294,** 2345–2348 (2001).
7. Ding, Y., Li, C. & Liu, Y. *Adv. Atmos. Sci.* **21,** 343–360 (2004).
8. Clemens, S. C., Prell, W. L. & Sun, Y. *Paleoceanography* **25,** PA4207 (2010).
9. Maher, B. A. *The Holocene* **18,** 861–866 (2008).

Published online: 19 June 2011

CLIMATE SCIENCE

Storm instigation from below

The relationship between soil moisture and rainfall has proved tricky to pin down. An analysis of close to 4,000 Sahelian storms suggests that certain soil-moisture patterns enhance the likelihood of rainfall.

Randal D. Koster

Weather forecasts of the type we see daily in the news provide estimates of precipitation several days into the future. A better understanding of feedbacks between the land and atmosphere can help in the prediction of rainfall events beyond this timeframe. The idea is simple: an anomalously large precipitation event makes the soil wetter than normal, perhaps for two months or so[1]. This, in turn, increases evaporation and reduces sensible heat flux from the surface during this time, and thereby modifies the evolution of overlying meteorological conditions, possibly stimulating more precipitation[2]. A realistic representation of soil moisture could therefore increase subseasonal forecast skill[3]. However, although the idea behind this feedback is simple, demonstrating its operation in nature is exceedingly difficult. Writing in *Nature Geoscience*, Taylor and colleagues[4] report a significant advance in its documentation, providing observational evidence that specific soil-moisture patterns instigate precipitation events in the African Sahel.

CAROLINE BAIN

Figure 1 | Rainfall over the Sahel. Taylor and colleagues[4] use satellite data to show that certain heterogeneities in soil moisture enhance the probability of convective rainfall storms in the Sahel.

Quantitative documentation of the soil-moisture–precipitation feedback has been difficult to obtain, because the feedback's signature is subtle compared with other, stronger relationships. A correlation between soil moisture and precipitation, for example, says little about the ability of soil moisture to affect precipitation; strong correlations between soil moisture and precipitation are already guaranteed, simply because precipitation wets the soil. Even correlations that allow for a time lag between soil-moisture anomalies and rainfall are difficult to interpret, given that soil moisture and subsequent precipitation may both be influenced by the same external factor, such as long-lived anomalies in sea surface temperature.