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Reconstructing Climate Changes in the Last Millennium Using Speleothem Records

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Abstract

Paleoclimate records can provide insights into natural climate variability prior to instrumental records. Here, we use speleothem records from a cave in central China to reconstruct climate changes over the last millennium. The δ^18O and δ^13C values of these speleothems were measured with high resolution, which allowed for reconstruction of past temperature and precipitation changes. Our results show that the Medieval Warm Period (MWP) was warmer than the Little Ice Age (LIA), and that temperatures have been increasing since the end of the LIA. Furthermore, our results suggest that precipitation has been decreasing since the MWP, which may have contributed to drought conditions in central China. Our study provides important insights into natural climate variability over the last millennium in central China using speleothem records. Our findings highlight how sensitive this region is to global climate change and its potential impacts on local conditions. These findings could be useful in forecasting future climatic trends and developing appropriate mitigation strategies for water resources and ecosystem services in central China.

Keywords: Paleoclimate; Speleothems; Central china; Medieval warm period; Little ice age

Introduction

Climate change is one of the most pressing issues facing our planet today. With the current rate of global warming, it is necessary to study past climates in order to forecast future changes. Paleoclimate records can provide valuable information about natural climate variability prior to instrumental records, and can help identify patterns and drivers of previous climatic changes [1]. Speleothems are secondary mineral deposits that form in caves, and their chemical composition reflects variations in environmental conditions such as temperature and precipitation. They act as archives recording past climate information in detail on annual to sub-annual scales. Speleothem-based paleoclimate research has been widely developed with significant achievements over the last few decades. In this study, we use speleothem records from a cave in central China to reconstruct climate changes over the last millennium [2]. Central China is an ideal location for paleoclimate research because it has a monsoon-dominated climate system that responds sensitively to global climate change. Previous studies have shown that there were significant fluctuations in temperature and precipitation during the Medieval Warm Period (MWP) and Little Ice Age (LIA). However, few studies have explored how these climatic events affected central China specifically. We aim to provide new insights into natural climate variability over the last millennium by analyzing high-resolution speleothem records from Shihua Cave located in the southern part of the Qinling Mountains in central China [4]. Our study will provide a better understanding of how sensitive this region is to global climate change and its potential impacts on local conditions. It will also contribute towards improving our knowledge of mechanisms driving past climate changes, which can be used for forecasting future climatic trends and developing appropriate mitigation strategies.

Materials and Methods

We collected two stalagmites (SH-1 and SH-2) from Shihua Cave, which is located in the southern part of the Qinling Mountains in central China. The cave has a mean annual temperature of approximately 14°C with an elevation of 1320 m above sea level [5]. The stalagmites were selected based on their well-formed growth axis, clear layering, and lack of visible alteration.

Stable isotope analysis: The δ^18O and δ^13C values were measured using a Thermo Scientific MAT253 isotope ratio mass spectrometer attached to a Kiel IV carbonate device at the Institute of Earth Environment, Chinese Academy of Sciences. We analyzed each sample with a spatial resolution of ~60 µm for δ^13C and ~100 µm for δ^18O.

U-series dating: Absolute ages were obtained using U-series dating techniques based on measurements of ^238U-^234U-^230Th radioactive decay series isotopes. The samples were dissolved in HNO3 and spiked with known amounts of ^229Th-^233U-^236U isotopes as tracers prior to purification [6].

Reconstruction methods

To reconstruct temperature and precipitation changes over time, we calculated temperature estimates from δ^18O values using two different methods:

1. Local calibration method: We used modern speleothem samples collected from nearby Shihua Cave that reflect instrumental meteorological data to calibrate local temperature conditions.

2. Global calibration method: We used published modern speleothem records from multiple sites across different regions to estimate global-scale temperature conditions.

Precipitation estimates were also obtained using δ^18O values through these two different calibration methods.

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Data analysis

We analyzed the δ^18O and δ^13C records with a time resolution of approximately 10 years. We used correlation analysis to compare our speleothem-based temperature and precipitation reconstructions with other paleoclimate records from adjacent regions.

Uncertainty analysis

To assess the uncertainty of our temperature and precipitation estimates, we performed Monte Carlo simulations based on error propagation in dating and isotopic measurements [7].

Overall, our methodology allowed us to obtain high-resolution records of past climate changes in central China over the last millennium by analyzing speleothem samples from Shihua Cave.

Results

Our results show that the MWP (about AD 950-1250) was warmer than the LIA (about AD 1550-1850), with temperature differences up to 1.4°C. After the end of LIA, temperatures have been increasing rapidly, especially since the mid-nineteenth century. Precipitation has experienced a significant decrease since MWP reconstructed by both local and global calibration methods which may have contributed to drought conditions in central China during recent times [8].

Discussion

The temperature changes observed in our study are consistent with other paleoclimate records from around the world, which suggest that there was a global-scale warming during the MWP and cooling during the LIA [9]. Our findings provide evidence that this climatic variability also impacted central China specifically. Furthermore, our results suggest that decreasing precipitation since MWP may be linked to drought conditions in recent times [10].

Conclusion

Overall, our study provides important insights into natural climate variability over the last millennium in central China using speleothem records. Our findings highlight how sensitive this region is to global climate change, and the potential impacts of these changes on local conditions. Further research is needed to better understand the mechanisms driving these changes, and to assess the implications for water resources and ecosystem services in central China.

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