Temporal and spatial variation of $\delta^{18}O$ in China since medieval warm period

Peter C. Chu
Department of Oceanography
Naval Postgraduate School, USA

Hong-Chun Li
Department of Earth Sciences
National Cheng-Kung University, Taiwan

Western Pacific Geophysics Meeting, Taipei, Taiwan 22-25 June 2010
Outlines

• High-resolution (yearly) $\delta^{18}O$ Data since AD 900 from the Six Caves

• Trends Obtained form the Empirical Mode Decomposition

• Anomalies of $\delta^{18}O$ during Four Periods: MWP, LIA-1, LIA-2, MD

• Spatial Variability of East Asian Monsoon

• Conclusions
Advantages:
1. Broad distribution; 2. Long time range (>500 kyr) and high resolution (1-10³ yrs); 3. Easy to date; 4. Multiple proxies.
\[ \delta^{18}O_{c} (\text{PDB}) = 0.97\delta^{18}O_{w} (\text{SMOW}) - 0.2272T(\degree \text{C}) + 4.2712 \]

\[ \delta^{18}O_{w} = f (T, \text{ppt, s, h, L}) \]
whereas \( T = \) air temperature, \( \text{ppt} = \) precipitation amount, \( s = \) moisture source
\( h = \) altitude, \( L = \) latitude. However, For a given cave location, effects of \( s, h \) and \( L \) on \( \delta^{18}O_{w} \) can be ignored.

\[ \delta^{18}O_{w} = a T + b \]
When \( a > 0.23 \), \( \delta^{18}O_{c} \) and \( T \) have positive correlation.
When \( a < 0.23 \), \( \delta^{18}O_{c} \) and \( T \) have negative correlation.

According to IAEA data base, \( a = 0.5 \sim 0.9 \) in N. America, Europe and mid-latitude where air mass is dominated by polar jet and westerly. On the other hand, \( a < 0.4 \) in monsoonal region.
Speleothem $\delta^{18}$O in EAMS area

• Speleothem records in eastern China have been used for reconstruction of EASM strength, lighter d18O, stronger summer monsoon, with more rainfall (or wet and warm climates).
High-Resolution (Yearly) $\delta^{18}O$ Data from Six Caves
Comparison of the best chronology controlled $\delta^{18}O$ records
What is the trend?

Empirical Mode Decomposition
(Huang et al., 1998) →

An Objective Method for Determining Trend
Empirical Mode Decomposition:
Methodology: Test Data
Empirical Mode Decomposition:
Methodology: data and m1
Empirical Mode Decomposition

*Sifting : to get one IMF component*

\[ x(t) - m_1(t) = h_1(t), \]
\[ m_1(t) - m_2(t) = h_2(t), \]
\[ \ldots \]
\[ m_{k-1}(t) - m_k(t) = h_k(t). \]

\[ \Rightarrow \quad x(t) = m_k(t) + \sum_{i=1}^{k} h_i(t). \]

\( h_i(t) \rightarrow \text{Intrinsic Mode Function (IMF)} \)

\( m_k(t) \rightarrow \text{Trend} \)
Trend – Buddha Cave
Trend – Dongge Cave
Trend – Furong Cave
Trend – Heshang Cave
De-trended Data (Anomaly)

- Anomaly = Original - Trend
# Four Periods

<table>
<thead>
<tr>
<th>Period</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Medieval Warm Period (MWP)</strong></td>
<td>AD 900 – AD 1100</td>
</tr>
<tr>
<td><strong>Little Ice Age Phase-1 (LIA-1)</strong></td>
<td>AD 1250 – AD 1550</td>
</tr>
<tr>
<td><strong>Little Ice Age Phase-2 (LIA-1)</strong></td>
<td>AD 1550 – AD 1850</td>
</tr>
<tr>
<td><strong>Modern Period (MD)</strong></td>
<td>AD 1850 – AD 2000</td>
</tr>
</tbody>
</table>
Averaged $\delta^{18}O$ Anomaly in MWP

- The $d^{18}O$ anomaly are all positive in six sites
Averaged $\delta^{18}O$ Anomaly in LIA-1

- Northern China $\rightarrow$ Positive Anomaly
- Southern China $\rightarrow$ Negative Anomaly
Averaged $\delta^{18}O$ Anomaly in LIA-2

- Northern China $\rightarrow$ Negative Anomaly
- Southern China $\rightarrow$ Positive Anomaly
Averaged $\delta^{18}O$ Anomaly in MD

- Northern China $\rightarrow$ Positive Anomaly
- Southern China $\rightarrow$ Negative Anomaly
Influence of EASM on June-August rainfall in China during 1951-2000 (Redraw from Guo et al.)

No simple correlation bet. EASM and rainfall

Stronger EASM led to more rainfall in North China but less rainfall in Jiang-Hui and many parts of South China

Using the rainfall during the weakest EASM period (1988-97) minus the rainfall during the strongest EASM period (1955-64). Total 160 stations
Conclusions

• Both instrumental and historical climate records show strong spatial variations of rainfall and regional disparities of rainfall-EAM intensity relationship on 1-10 yrs scales over eastern China.

• Taking paleo-proxy records from a single locality in eastern China to imply changes in drought/wetness as to affect the cultural and political history of China is fraught with uncertainty.

• On 1-10 yrs scales, the thesis that $\delta^{18}O$ in speleothem can be used as a proxy for the EAM strength lacks empirical underpinnings.
Thank you!