

Interpreting Paleohydrologic and Paleoclimatic Conditions for Sub-Tropical North America During the Late Holocene Through the Comparison of Speleothem and Lake Geochemical Proxy Records



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Abstract:

Late Holocene climate variability is marked by two high-frequency events, the cold Little Ice Age (LIA) and the Medieval Warm Period (MWP). During these abrupt climate events, continental hydrologic conditions are expected to have varied considerably, especially in the sub-tropics of North America, where tropical climate and temperate climate regimes interact seasonally and vary over longer time periods. Interactions between the Intertropical Convergence Zone (ITCZ), North Atlantic high (NAH), meridional jet stream, and northern frontal systems result in seasonal hydrologic trends whereas longer-term changes in hydrologic conditions includes influences associated with the mean position of the ITCZ/NAH, Atlantic Multidecadal Oscillation, El Niño intensity and solar forcing. Unraveling the complicated meteorological interactions between seasonal and longer-term controls on continental hydrologic conditions is critical for quantitative reconstructions and for developing water resource management strategies.

Ongoing isotopic calibration studies in modern Lake Tulane and the Brooksville cave in central Florida indicate that δD of lake organic matter and $\delta^{18}O$ of speleothem carbonates quantitatively record changing hydrologic conditions. This research integrates the results of the calibration studies with high-resolution (decadal-scale) lake sediment and cave speleothem records in order to evaluate meteorological controls on continental hydrology during MWP and the LIA. Inter-comparisons of the cave and lake records reveal strong coherence throughout the Late Holocene and that, relative to modern times, the MWP period was characterized by increased precipitation, greater input from southern air-masses, warmer lake waters, and increased relative humidity. In contrast, the LIA relative to today shows cooler lake temperatures, reduced relative humidity, and reduced amounts of precipitations and a greater influence of northern air masses. Results of this study will be discussed in terms of the complex interplay of meteorological factors controlling hydrologic conditions in sub-tropical North America

1. Climate Controls on Florida's Hydrologic Cycle



Role of ITCZ and NAH:

- Climate and hydrologic conditions over Florida are influenced by the annual migration of the ITCZ and NAH (Figure 1)
- Seasonal migration of the ITCZ and the NAH lead to changes in precipitation and relative humidity
- Centennial-scale migration and mean position of the ITCZ
- NAH should result in long-term change on Florida's hydrologic conditions

Figure 1

Role of Atlantic Multidecadal Oscillation (AMO)

- AMO warm and cold phases are defined by sea surface temperatures in the North Atlantic
- AMO has a periodicity of 60-80 years (Figure 2)

- Precipitation on the Florida peninsula is positively-negatively correlated with AMO warm-cold phases (Figure 3 and 4)

- Annual precipitation on the Florida peninsula can vary by over 40% between years of AMO warm and cold phases (Figure 4 and 16)

Atlantic Ocean Sea Surface Temperature 50N-60N Lat/10W-50W Long

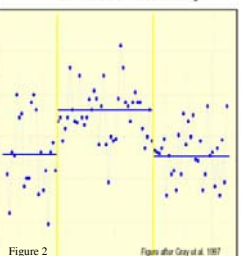


Figure 2

Figure after Gray et al. 1997

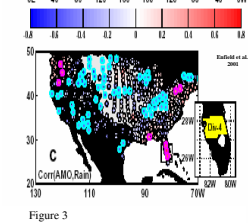


Figure 3

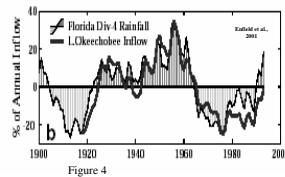


Figure 4

2. Research Questions

• Does the isotopic composition of speleothems and lake sediments record changes in hydrologic conditions on the Florida peninsula?

• What are the hydrologic changes that occur in Florida during the Little Ice Age and the Medieval Warm Period?

• How can speleothem and lake climate archives be integrated to develop a regional assessment of hydrologic conditions and can they be used to interpret long-term climate influences of the ITCZ/NAH and the AMO?

3. Cave and Lake Location Map and Research Approach

Brown Rat Cave, Florida

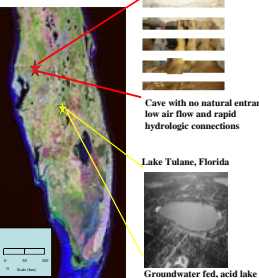


Figure 5

Research Strategy:

- Develop calibration studies to determine climatic influences on the $\delta^{18}O$ of cave carbonates and δD of lake organic matter
- Generate long-term $\delta^{18}O$ and δD record of the LIA and the MWP from cave speleothem and lake sediments
- Evaluate the role of climatic factors on the history of hydrologic change as defined by the cave and lake proxy records.

Groundwater fed, acid lake with anoxic BW and OM pres.

4. Lake Tulane: Interpreting the δD of Organic Matter

δD Cycling and Hydrology of Lake Tulane, FL

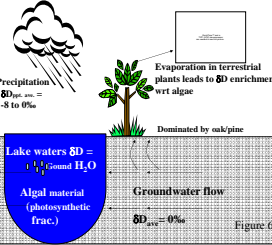


Figure 6

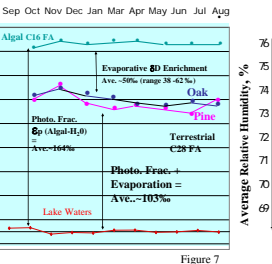


Figure 8

- δD of Algae is a direct reflection of source waters (Figure 6, 7).
- δD of terrestrial material is a reflection of both source waters and evaporative processes (Figure 6, 7).
- The δD enrichment of terrestrial biomass relative to algae reflects the intensity of evaporative processes in a given environment, and is related to relative humidity (Figure 8)

5. FL Speleothem: Interpreting the $\delta^{18}O$ Signal in Cave Carbonates

- During strong convective summer storms with high rainfall, increasing altitude/decreasing temperature of the condensation line results in depleted $\delta^{18}O$ of calcite (Figure 10)
- Drip rate in caves responds quickly to changing amount of precipitation and speleothem's isotopic composition is in equilibrium with that of drip water

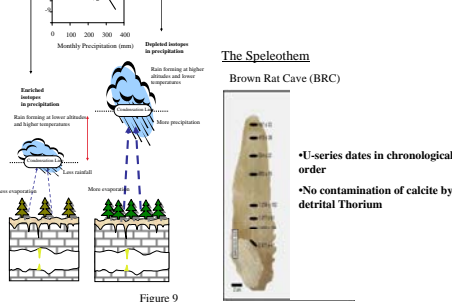


Figure 9

Figure 10

6. Correlation between Speleothem and Lake Sediment

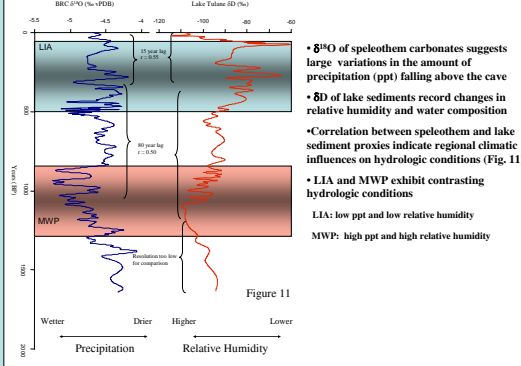


Figure 11

- $\delta^{18}O$ of speleothem carbonates suggests large variations in the amount of precipitation (ppt) falling above the cave
- δD of lake sediments record changes in relative humidity and water composition
- Correlation between speleothem and lake sediment proxies indicate regional climatic influences on hydrologic conditions (Fig. 11)
- LIA and MWP exhibit contrasting hydrologic conditions
- LIA: low ppt and low relative humidity
- MWP: high ppt and high relative humidity

7. Paleoclimate and Paleohydrologic Interpretations

Role of ITCZ/NAH on long term changes in hydrologic conditions

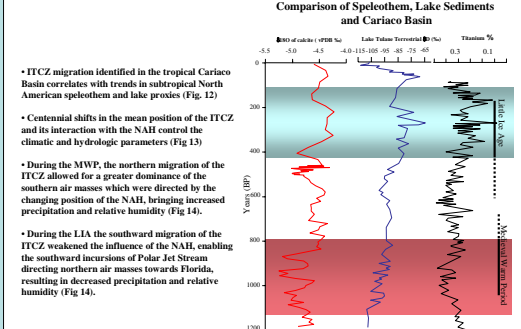


Figure 12

- ITCZ migration identified in the tropical Cariaco Basin correlates with trends in subtropical North American speleothem and lake proxies (Fig. 12)
- Centennial shifts in the mean position of the ITCZ and its interaction with the NAH control the climatic and hydrologic parameters (Fig. 13)
- During the MWP, the northern migration of the ITCZ allowed for a greater dominance of the southern air masses which were directed by the changing position of the NAH, bringing increased precipitation and relative humidity (Fig. 14)
- During the LIA the southward migration of the ITCZ weakened the influence of the NAH, enabling the southward incursions of Polar Jet Stream directing northern air masses towards Florida, resulting in decreased precipitation and relative humidity (Fig. 14).

Centennial-scale ITCZ/NAH migration



Figure 13

Influence of ITCZ Migration on Air Masses in N.A.

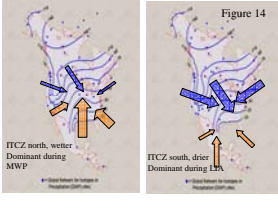


Figure 14

Role of the AMO in controlling hydrologic conditions on multidecadal time scales

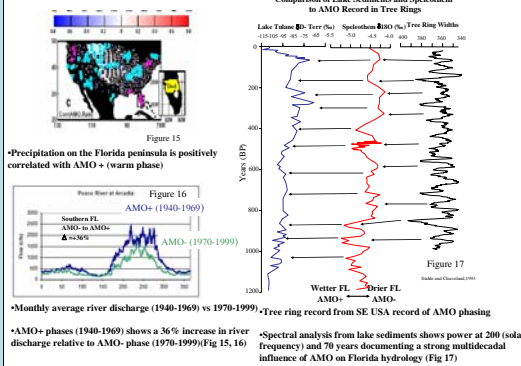


Figure 15

- Precipitation on the Florida peninsula is positively correlated with AMO + (warm phase)
- Monthly average river discharge (1940-1969) vs 1970-1999.
- Tree ring record from SE USA record of AMO phasing
- AMO+ phases (1940-1969) shows a 36% increase in river discharge relative to AMO- phase (1970-1999)(Fig. 15, 16)
- Spectral analysis from lake sediments shows power at 200 (solar frequency) and 70 years documenting a strong multidecadal influence of AMO on Florida hydrology (Fig. 17)

8. Conclusions

- Lake sediment and speleothem archives record hydrologic changes and provide the ability to reconstruct the amount of precipitation, the composition of source waters and relative humidity
- Centennial scale migration of the ITCZ/NAH strongly influences hydrologic conditions in FL during the LIA and MWP
- AMO influences in Florida are recorded in both lake sediments and speleothems and correlate with tree ring archives