Investigating δ^{13}C values in stalagmites from tropical South America for the last two millennia

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Abstract

Due to the many factors controlling δ^{13}C values in stalagmites, complicating their paleoclimatic and paleoenvironmental interpretation, most studies do not present d13C values, but instead focus mainly on δ^{18}O values. This is also the case for most cave studies from tropical South America, where many new δ^{18}O stalagmite records covering the last millennia were recently published. Here, we review the d^{13}C values in stalagmites, investigating the influence on this proxy of local hydroclimate, altitude, temperature and vegetation types, by employing a new dataset composed of published and unpublished carbon isotope records from various sites in tropical South America. The main factors influencing δ^{13}C values are associated with the local hydroclimate, followed by minor effects from temperature. Most of the isotopic records show a significant correlation between the δ^{13}C and δ^{18}O values, indicating a close relationship between local hydroclimate and atmospheric convective processes related to the South American Monsoon System. The predominance of C3 plants above most of the karst systems studied here is responsible for the low δ^{13}C values ([?]6speleothems, while local hydroclimate associated with prior calcite precipitation process is the main driver behind its variability during the last two millennia. Using Monte Carlo Principal Component Analysis, we produce an index of the mean hydrologic conditions and its changes over tropical South America for the last two millennia, which is closely related to monsoon variability for the period prior to 1750 CE. The recent break-down in the relationship between monsoon and local hydroclimate may have been caused by the increase in temperature, CO_2, deforestation and fire during the current warm period.

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Introduction and Objectives

Due to the many factors controlling $\delta^{13}C$ values in stalagmites, complicating their paleoclimatic and paleoenvironmental interpretation, most studies do not present $\delta^{13}C$ values, but instead focus mainly on $\delta^{18}O$ values. This is also the case for most cave studies from tropical South America, where many new $\delta^{18}O$ stalagmite records covering the last millennia were recently published. Here, we review the $\delta^{13}C$ values in stalagmites, investigating the influence on this proxy of local hydroclimate, altitude, temperature and vegetation types, by employing a new dataset composed of 25 $\delta^{13}C$ records (13 of them hitherto unpublished) from stalagmites collected at different sites throughout tropical South America (Fig. 1, $\delta^{13}C$_2k_SA dataset) with aims to revise and characterize the main factors controlling $\delta^{13}C$ variability in these stalagmites and provide possible paleoclimate and paleoenvironmental reconstructions for the region.

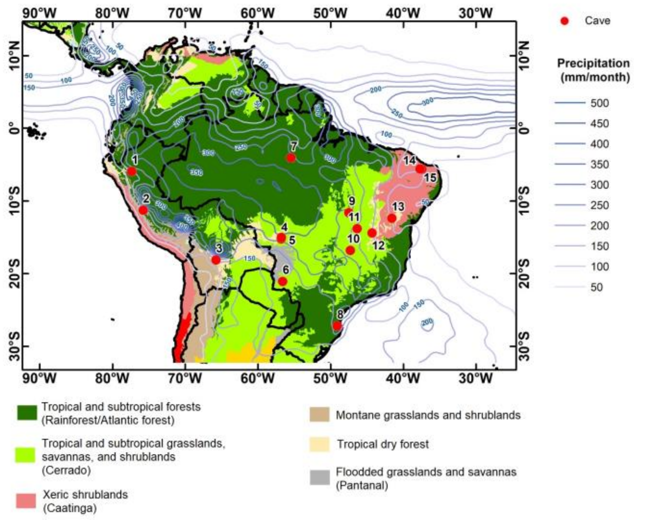

Fig. 1. Map of tropical South America with vegetation types, precipitation (blue isolines - mm/month, derived from the annual mean for the period from 1998 to 2017 and location of the study sites from the $\delta^{13}C$_2k_SA dataset.

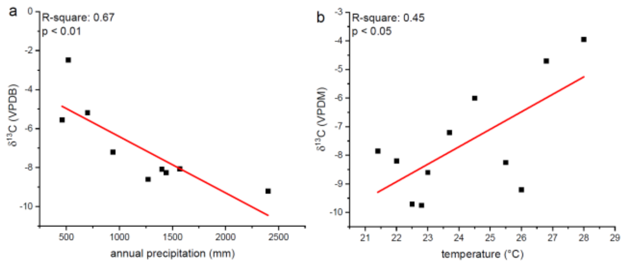

Fig. 2. Relationship between the $\delta^{13}C$ from the $\delta^{13}C$ _2k_SA dataset with annual precipitation (a) and annual mean temperature (b) of each study site.

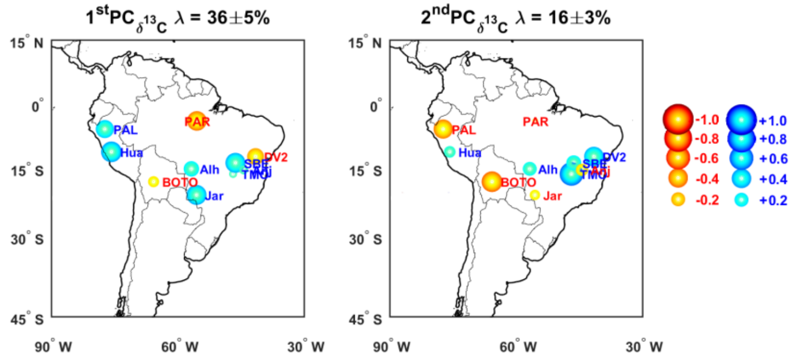

Fig. 3. Maps of South America with the main loadings of the Principal Component Analysis (PCA) and explained total variance. Blue and red dots represent positive and negative loadings, respectively. The magnitude of the loadings is represented by the size of the dots. The larger the dot, the more representative it's loading is of the respective PC.

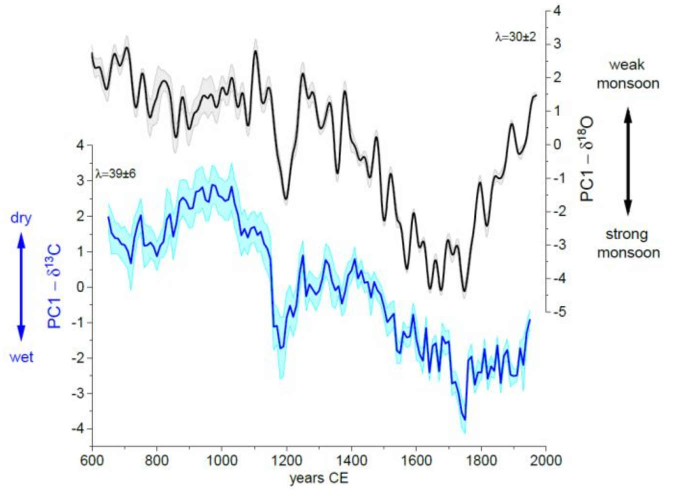

Fig. 4. Comparison between the first Principal Component (PC1) derived from the $\delta^{13}C$ _2k_SA dataset (this study) representing the main mode of hydroclimate variability and PC1 based on the $\delta^{18}O$ from stalagmites from South America (PC1 of $\delta^{18}O$) representing the main mode of variability of the South American Monsoon System. The uncertainties associated with the PC1s are shown by the colored and gray shading. λ indicates the percentage of explained variance by each PC.

Conclusion

The predominance of C3 plants above most of the karst systems studied here is responsible for the low $\delta^{13}C$ values (<6‰) in most of the speleothems, while local hydroclimate associated with PCP process is the main driver behind its variability during the last two millennia (Fif.2 a). Local temperature and growth rate play only a minor role in shaping the $\delta^{13}C$ values in the $\delta^{13}C$ _2k_SA dataset (Fig. 2b). The probable reason for this is that most of the speleothems in our database formed under tropical conditions, characterized by a limited temperature range.

Using Monte Carlo Principal Component Analysis, we produce an index of the mean hydrologic conditions and its changes over tropical South America for the last two millennia (Fig. 3), which is closely related to monsoon variability for the period prior to 1750 CE (Fig. 4). The recent break-down in the relationship between monsoon and local hydroclimate may have been caused by the increase in temperature, CO_2, deforestation and fire during the current warm period; however, further studies are required to test this hypothesis.

Related paper:

Novello V. F.; Cruz, F. W.; Vuille, M.; Campos, J. L. P. S.; Stríkis, N. M.; Apaéstegui, J.; Moquet, S. J.; Azevedo, V.; Ampuero, A.; Utida, G.; Wang, X.; Paula-Santos, G. M.; Jaqueto, P.; Pessenda, L. C. R.; Breecker, D. O.; Karmann, I. (2021). Investigating $\delta^{13}C$ values in stalagmites from tropical South America for the last two millennia. *Quaternary Science Reviews*, 255, 106822, https://doi.org/10.1016/j.quascirev.2021.106822.