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Carbon cycle dynamics and solar activity embedded in a high-resolution ^{14}C speleothem record from Belize, Central America

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Speleothem ^{14}C has recently emerged as a potentially powerful proxy for climate reconstruction. Several studies have highlighted the link between karst hydrology and speleothem ^{14}C content, and a number of possible causes for this relationship have been proposed, such as dripwater flow dynamics in the karst and changes in soil organic matter (SOM) turnover time (e.g. Griffiths et al., 2012). Here we present a high resolution ^{14}C record for a stalagmite (YOK-I) from Yok Balum cave in southern Belize, Central America. YOK-I grew continuously over the last 2000 years, and has been dated very precisely with the U-Th method (40 dates, mean uncertainty < 10 years). The excellent chronological control for this stalagmite allows us to calculate ^{14}C activity ($a^{14}C$) at the time of speleothem deposition ($a^{14}C_{init}$), as well as the dead carbon fraction (DCF), predominantly a measure of the reservoir effect introduced by limestone dissolution in the karst (Genty et al., 2001). Both records show striking similarities to atmospheric $a^{14}C$ (IntCal13) and reconstructions of solar activity and ^{14}C production rate. We infer close coupling between cave environment and atmosphere, with minimal signal dampening, an observation supported by monitoring data (Ridley et al., in press). DCF fluctuates between approximately 10% and 16% over the entire record, with distinctly lower DCF values and higher $a^{14}C_{init}$ during a period of reduced rainfall between ca. 700-1100 AD (linked to the Classic Maya Collapse). This behavior is consistent with observations made elsewhere, and suggests that DCF responds to karst hydrological variability, specifically open-closed system transitions. YOK-I $a^{14}C_{init}$ typically lags atmospheric values by 10-100 cal years. A shorter lag appears to be linked to periods of drought, suggesting a response of SOM dynamics above the cave to rainfall reduction. Specifically, drought is inferred to lead to reduced bioproductivity and soil carbon turnover, lowering contributions of old recalcitrant carbon to the soil water, and resulting in closer coupling between atmosphere and cave environment. The resolution of the record (0.3-0.7 mm/sample) permits identification of the dominant drivers of stalagmite ^{14}C during different intervals. For example, hydrologic control on ^{14}C appears dominant during the 11th century drought, while in the 16th to 18th century a clear solar influence exists. Solar activity is reflected in YOK-I as lower $a^{14}C_{init}$, reflecting the atmospheric $a^{14}C$. We apply simple hydrological models to investigate the different factors influencing ^{14}C in YOK-I. We estimate the importance of mean SOM age to signal dampening, and quantify the strength of the solar influence and the global carbon cycle on the record.

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