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Supplement of

Evolution of winter precipitation in the Nile river watershed since the last glacial

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S1. Analysis of stable carbon isotopes of HMW n-alkanoic acids

The stable carbon isotopic composition ($\delta^{13}C$) of high molecular weight (HMW) *n*-alkanoic acids was performed using gas chromatography coupled to isotope ratio mass spectrometry (GC-IRMS). The samples were measured on a Thermo Trace gas chromatograph coupled via a combustion reactor to a MAT252 mass spectrometer. Isotope values were measured against a calibrated reference gas (CO_2) and are reported in per mil relative to the VPDB standards. To check the performance of the system, a standard mixture consisting of 16 *n*-alkanes was run every sixth sample. The accuracy and precision (mean deviation from offline values and the respective relative standard deviation, RSD) were 0.18 ‰ and 0.25 ‰, respectively. The machine was operated only when the average absolute deviation from offline values was <0.3 ‰. Replicate measurements of the samples yielded a standard deviation of 0.0-0.3 ‰. We report the $\delta^{13}C$ of the n-$C_{26:0}$ and n-$C_{28:0}$ alkanoic acids as they turned out to be the most abundant homologues in our samples. Since the fatty acids were methylated to facilitate GC-IRMS analysis (see section 3 of the main manuscript), the $\delta^{13}C$-signature of the respective fatty acid methyl esters were corrected for the added methyl group using isotope mass balance ($\delta^{13}C_{\text{wax } n\text{-alkanoic acid}}$).

S2. Calculating δD of precipitation (δDp)

Correcting for isotopic fractionation that takes place during biosynthesis (apparent fractionation, referred to as ε_{app}) makes possible to reconstruct the δD_p from δD_{wax} (Sachse et al., 2012 and references within, Collins et al., 2013; Tierney et al., 2017). This, in turn depends on hydrological processes including rainfall amount, evapotranspiration or the moisture source. Moreover, thermodynamic fractionation associated with temperature changes can affect the isotopic composition of the source water (Sachse et al., 2012). Therefore, the $\delta D_{wax\ n\text{-alkanoic acids}}$ (this study) and $\delta D_{wax\ n\text{-alkanes}}$ (Castañeda et al., 2016a) from core GeoB7702-3 can be used to reconstruct δD_p once ε_{app} is known. ε_{app} varies across plant-species, particularly associated with different photosynthetic pathways. C_4 grasses tend to have more negative ε_{app} than C_3 trees and shrubs (Sachse et al., 2012). In order to correct for past changes in C_4 versus C_3 plants ($\delta D_{p\text{-vc}}$, where "vc" refers to vegetation corrected) we inferred the relative abundance of C_4 plants (%C_4) from the $\delta^{13}C_{wax\ n\text{-alkanoic acids}}$ (this study) and $\delta^{13}C_{wax\ n\text{-alkanes}}$ (Castañeda et al., 2016a) according to Collins et al. (2013). We used the endmember values for C_4 and C_3 plants given in the "all Africa" compilation by Garcin et al. (2014) (C_4: -19.8 ‰ and C_3: -33.4 ‰). Next, ε_{app} was calculated using -113 ‰ and -126 ‰ as ε_{app} endmembers for C_3 and C_4 plants, respectively (Sachse et al., 2012; Tierney et al., 2017). We note that these values correspond to the n-C_{29} alkane homologue. As there are no comparable endmember data for the n-$C_{26:0}$ and n-$C_{28:0}$ alkanoic acids, we assume that alkanes and alkanoic acids have similar ε_{app} values.

We forwent to correct for temperature changes because for the Nile region temperature corrections are problematic as temperature estimates provide an inconsistent picture regarding the amplitude of glacial-Holocene warming. TEX$_{86}$-based and alkenone-based sea surface temperature (SST) reconstructions from the Mediterranean Sea and the Red Sea are available but their amplitude of change varies between 6-10°C (Castañeda et al., 2010; Arz et al., 2003; Mathews et al., 2021) which is up to 2.5 times as much as climate models suggest for the change in mean annual surface temperature in the Nile delta region (5-6°C; Kageyama et al., 2021). Moreover, effects of seasonal or other biases leading to an overestimation of the true

amplitude of deglacial warming in the SST records cannot be ruled out (Castañeda et al., 2010). Therefore, we might overcorrect by using these SST reconstructions from the Mediterranean to correct the δD_{wax} for the temperature effect.

The influence of temperature on δD_p is generally considered negligible in low latitudes (Sachse et al., 2012) and for the arid Sahara, Tierney et al. (2017) find that the temperature effect has little influence on the δD_p. Accordingly, the error introduced to our $\delta D_{p\text{-vc}}$ by avoiding a temperature correction should be small. Since colder conditions cause heavier precipitation, the inferred $\delta D_{p\text{-vc}}$ estimates for the glacial should be regarded as minimum values, respectively maximal estimates of glacial rainfall amount.

$\delta D_{p\text{-vc}}$ were corrected for deglacial changes in global ice-volume ($\delta D_{p\text{-vc-ic,}}$ where "ic" means ice volume corrected) applying stacked data of oxygen isotopic compositions ($\delta^{18}O$) of benthic foraminifera (L04-stack; Lisiecki and Raymo, 2005) using the approach described in Ruan et al. (2019). The downcore results of $\delta D_{p\text{-vc-ic}}$ are illustrated in Figure S1.
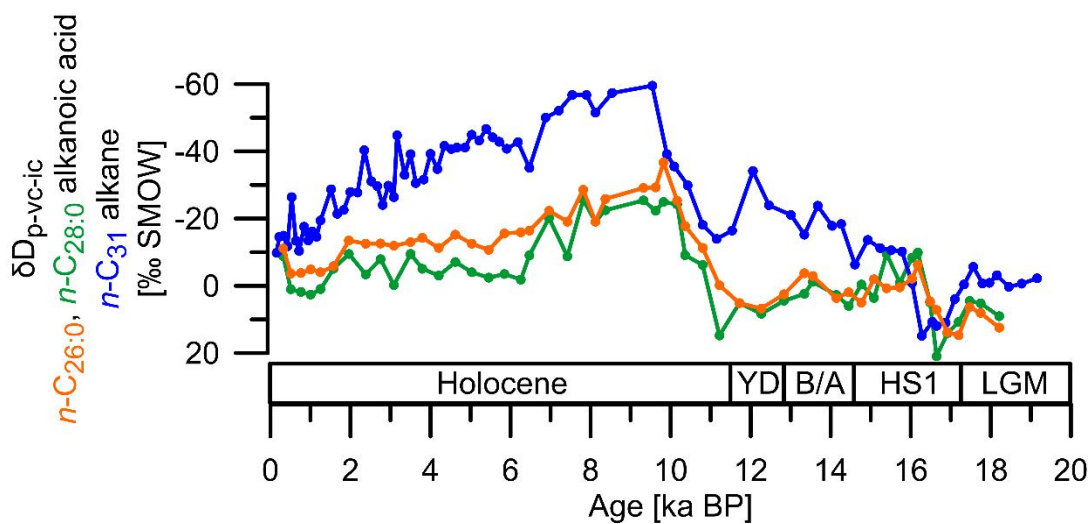
S3. Supplementary Figures

Figure S1: $\delta D_{p\text{-vc-ic}}$ of HMW *n*-alkanoic acids and HMW *n*-alkanes calculated from $\delta D_{wax\ n\text{-alkanoic acids}}$ (this study) and $\delta D_{wax\ n\text{-alkanes}}$ (Castañeda et al., 2016a,b) in core GeoB7702-3.
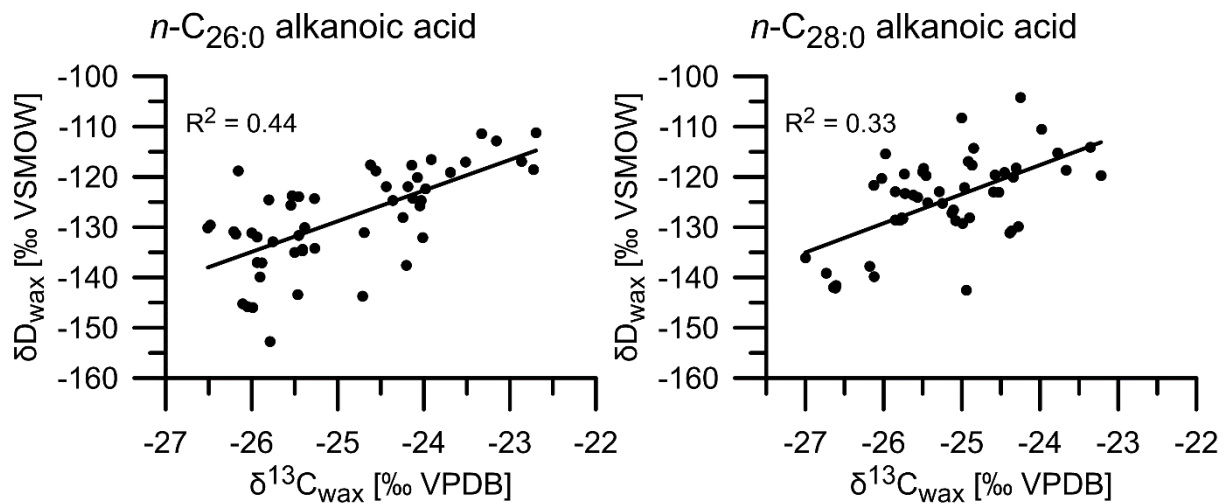
Figure S2) Correlation between $\delta D_{wax\ n\text{-alkanoic acids}}$ and $\delta^{13}C_{wax\ n\text{-alkanoic acids}}$ for the n-$C_{26:0}$ and n-$C_{28:0}$ homologues. The respective correlation coefficients (R^2) are indicated and reveal poor linear correlations. Thus, a significant impact of changes in the abundance of C_3 versus C_4 plants on $\delta D_{wax\ n\text{-alkanoic acids}}$ throughout the past 18 ka is unlikely.
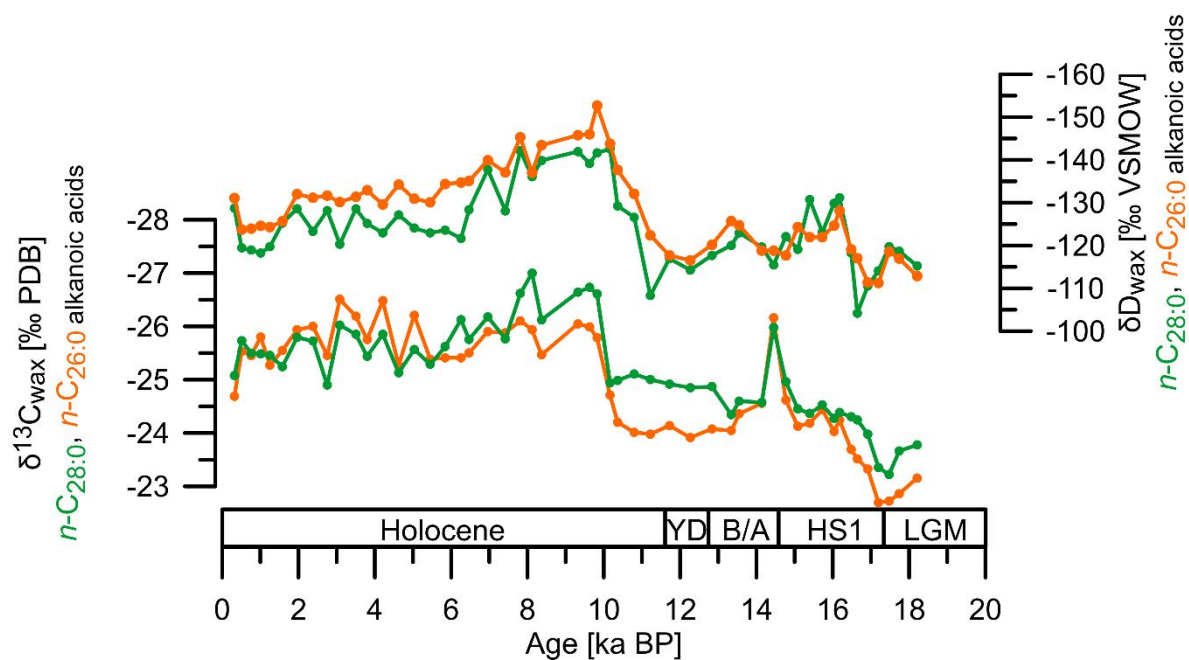
Figure S3: $\delta^{13}C_{wax\ n\text{-alkanoic acids}}$ along with $\delta D_{wax\ n\text{-alkanoic acids}}$ in core GeoB7702-3.

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