Auxiliary material for manuscript 2013GL058999

"Astronomically forced variations in western African rainfall (21°N-20°S) during the Last Interglacial period"

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Introduction

This auxiliary material contains two additional tables (as text files) and five additional figures. Table 1 (text01) summarizes coordinates and references of cores investigated in this study. Table 2 (text02) gives tie-points and associated age uncertainties for all cores. The map in Figure 1 (fs01) shows the main source regions of terrigenous material deposited at the core sites. Figure 2 (fs02) illustrates how age models were defined in every marine sediment core considered in the study, based on the alignment of benthic stable isotopic records. Figure 3 (fs03) shows additional proxy records of African hydroclimatic conditions that support the use of ln(Al/Si) in our study. Figure 4 (fs04) shows a direct comparison based on standardized data of ln(Al/Si) records and model precipitation anomalies throughout the LIG. Finally, Figure 5 (fs05) shows the seasonal rainfall evolution simulated between 130 and 115 ka for four characteristic latitudinal bands. All references cited in the Auxiliary Material are given below.

1. text01.pdf. Marine sediment cores considered in this study.

2. text02.pdf. Tie-points defined in the studied cores for the period 142-100 ka, with associated 1σ dating uncertainties.

3. fs01.pdf. African topography map highlighting the main source regions of terrigenous material deposited at the core sites. Blue and brown shaded areas mark source regions of fluvial and eolian input, respectively. Letters refer to core labels in text01. Horizontal black lines mark latitudinal bands used in the model as characteristic time-series of zonally-averaged rainfall (the dotted line at 0° marks the alternative to the 5°N band used in the comparison with the 3°N core). North African cores A-D (14-21°N) receive large amounts of North African dust [*Engelstaedter et al.*, 2006], and suspended material from the Senegal River. Core E (9°N) also receives dust blown from the Sahara and Sahel regions, and sediments from small rivers draining the West African coast in Guinea and Sierra Leone. Core F (3°N) receives fluvial material from the main tributary (Benue River) of the Niger River [*Grove*, 1972] and from the Sanaga River. Core G (7°S) receives fluvial input from the Congo River, where most of sediments (> 70 %) seem to be transported by the southern tributaries [Upper Congo

and Kasai, *Laraque et al.*, 2009]. Finally, cores H-I receive a mixture of suspended material delivered by small coastal rivers (e.g. Kunene River) [*Bremner and Willis*, 1993] and of wind-blown dust from the Namib and Kalahari deserts [*Prospero et al.*, 2002].

4. fs02.pdf. Benthic foraminiferal δ^{18}O records (grey line = all data; black thick line = 3-point running average) presented for all marine sediment cores (a-i) for the period 142-100 ka. Unpublished benthic foraminiferal stable isotopes (text01) were measured at MARUM – Center for Marine Environmental Sciences, University of Bremen, with a Finnigan MAT 252 mass spectrometer coupled to an automatic carbonate preparation device. The working gas standard is calibrated against Vienna PDB (VPDB) using the National Bureau of Standards 18, 19 and 20 standards. The mean external reproducibility (1σ) of carbonate standards is better than 0.07%. Data presented in c, g and h are composite δ^{18}O records derived from measurements on the benthic foraminiferal *Cibicides*, *Melonis* and *Uvigerina* genus. In the other cores, stable isotopes were measured on *Cibicides* only. Benthic δ^{18}O values are presented to match δ^{18}O values measured on the reference *Uvigerina* genus*,* after correction of +0.64 ‰ for *Cibicides* [*Shackleton and Opdyke*, 1973] and +0.35 ‰ for *Melonis* [*Shackleton et al.*, 1984]. Crosses (a-c, e, g, i) and diamonds (d, f, h) highlight the defined tie-points with associated 1σ uncertainties (text02). The benthic δ^{18}O record from core MD95-2042 [*Shackleton et al.*, 2002] was used for reference and is shown in (j), together with the LR04 stack [*Lisiecki and Raymo*, 2005] (brown dashed line). The age model of core MD95-2042 has been revised [*Govin et al.*, 2013] and transferred onto the new AICC2012 ice core chronology [following the methodology described for the LIG in *Govin et al.*, 2012], which is characterized by reduced absolute dating uncertainties for the LIG (< 1.8 ka) [*Bazin et al.*, 2013]. All records are shown here on the AICC2012 time scale. Produced age models fully agree with the LR04 stack (see panel j). Absolute dating uncertainties range between 1.6 and 3.3 ka (1σ, see text02 for details). A decrease in sedimentation rate is responsible for benthic δ^{18}O gap (see b) and higher age uncertainties (text02) at 21°N during the penultimate deglaciation.

5. fs03.pdf. (*left panel*) Al/K log-ratios of western African cores (letters refer to labels in text01) for the period 130-115 ka. Most LIG features identified in Al/Si records are observed in Al/K records. NW African records (a-e) are characterized by high Al/K values between 127 and 123 ka, decreasing Al/K values from 123 ka on and lower Al/K values before 127 ka than between the 127-123 ka maximum (this feature is missing in the Al/K record at 21°N for unknown reasons). The Al/K record at 9°N (e) shows a delayed Al/K maximum at 124 ka, also indicated by the Al/Si record (Figure 1e). Al/K records from central and southern African cores also exhibit LIG features similar to Al/Si records: increasing Al/K values at 3°N (f), increasing followed by decreasing Al/K values at 7°S (g), relatively constant Al/K values at 12°S and variable Al/K values at 20°S (h-i). (NB: due to low

terrigenous input, K proportions are very low in the 20°S core (~10 times lower than in other cores). Slight changes in K concentrations hence induce very large Al/K variations (i).) Reflecting the relative input of kaolinite (characteristic of highly weathered material from tropical regions) versus illite (characteristic of lightly weathered material from relatively dry regions), the Al/K ratio is also a reliable tracer of past African climate conditions [e.g. *Schneider et al.*, 1997; *Zabel et al.*, 2001]. High similarities between Al/Si and Al/K variations hence support our conclusions on the LIG evolution of western African hydroclimate. (*right panel*) Additional indicators of African hydroclimatic conditions (blue), which are not based on the geochemical composition of the sediment, are compared to the Al/Si log-ratio (black) of three western African cores during the period 145-0 ka. The grey rectangle marks the interval 130-115 ka. The Al/Si record of the 20°N core (*top*) exhibits variations that are highly similar to millennial-scale and precessional changes indicated by the grain size-derived humidity index from Tjallingii et al. [2008]. In the 9°N core (*middle*), most Al/Si variations are reflected in the carbon isotopic composition ($\delta^{13}C$) of leaf-wax C29 *n*-alkane, which traces the relative proportions of C3 trees vs C4 grasses, i.e. African continental hydrology [*Castañeda et al.*, 2009]. However, Al/Si and leaf-wax $\delta^{13}C$ records exhibit different evolutions throughout the LIG, which may reflect different source regions of terrigenous material and organic matter, respectively. Whereas the Al/Si ratio agrees with the precipitation evolution simulated by the model over a large latitudinal band at 10°N (fs01), decreasing $\delta^{13}C$ values (i.e. increasing C3 tree proportions) may reflect the precipitation increase simulated by the model along the West African coast (Figure 2) and indicate a more coastal source region of organic matter (in comparison to terrigenous material). Finally, the Al/Si record at 7°S (*bottom*) shows variations that are phase with changes in the percentage of lowland rainforest pollen species [*Jahns*, 1996; *Dupont*, 2009]. Periods of high Al/Si values and increased chemical weathering such as during the LIG are also periods of expanded tropical rainforest over the Congo Basin [*Dupont*, 2009], in agreement with our interpretation of humid terrestrial conditions. This comparison hence supports the use of the Al/Si ratio as a tracer of African hydroclimatic conditions in regions where terrigenous material specifically originates.

6. fs04.pdf. Comparison of standardized proxy (in grey) and model (in blue) data throughout the LIG. Al/Si log-ratios were standardized (i.e. normalized to a mean of zero and a standard deviation of one) across the period 130-115 ka. White lines, dark grey and light grey envelopes mark Al/Si values, non-parametric 1σ (16th and 84th percentiles) and 2 σ (2.5th and 97.5th percentiles) confidence intervals, respectively. Standardized proxy data are shown for all western African cores (letters refer to labels in text01). Rainfall data from the accelerated model simulation were also normalized to a mean of zero and a standard deviation of one and are plotted in blue for the latitudinal bands at 20°N in (a-d), 10°N in (e), 5°N (plain line) and 0° (dashed turquoise line) in (f), 10°S in (g) and 20°S in (h-i).

7. fs05.pdf. Seasonal evolution of African precipitation (in blue) from 130 to 115 ka, as simulated by the CCSM3 model using fixed present-day calendar seasons. Mean December-January-February (DJF), March-April-May (MAM), June-July-August (JJA), September-October-November (SON) and annual (in black) rainfall anomalies are presented relative to pre-industrial values for the following latitudinal bands (see fs01): (a) 10°N, (b) 5°N and 0° (in turquoise for seasonal and light grey for annual anomalies) and (c) 10°S. For 10°S, the sum of MAM and SON rainfall anomalies is also shown in green. Time-series are shown for the accelerated transient simulation and were smoothed with a 1000-orbital-year (corresponding to 100 model integration years) boxcar filter. Italic numbers, which indicate pre-industrial seasonal and annual precipitation values (in cm/month) for each panel, allows identifying wet (bold numbers), dry and intermediate seasons for each latitudinal band. Finally, seasonal and annual insolation anomalies relative to modern values (dashed grey lines) were computed from Laskar [2004] at 10°N (a), 5°N (b) and 10°S (c).

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