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Supporting Online Material for

Four Climate Cycles of Recurring Deep and Surface Water Destabilizations on the Iberian Margin

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Original Data File (txt format, zipped)

Materials and Methods.

Materials. The topography database from (*S1*) was used as a source for location of the sediment cores mentioned in the print manuscript (Fig. 1). The sediment cores studied were retrieved at the south-western Iberian Margin: MD01-2444 (37°33.68'N, 10°08.53'W, -2637 meters below sea-level) and MD01-2443 (37°52.85'N, 10°10.57'W, -2925 m bsl). Existing relevant Iberian Margin paleoarchives are MD95-2042 (*S2, S3*), MD95-2043 (*S4*) and ODP-977A (*S5*).

Chronology. Analysis of down-core profiles on their depth-scales emphasizes the fact that climatic events recorded in the incremental layers do not vary in shape after application of dating techniques (Fig. S1). In this study, conclusions are mainly based on evolution and relative phasing between different indicators measured along each individual core and are consequently irrespective of the absolute time scale chosen, which is continually being improved by the various work teams (*S6, S7*). However, the chronology in which the Iberian Margin cores are presented in the print manuscript (Fig. 2) is as precise as it can possible be for marine data covering this time span within the limits of the interhemispheric connections highlighted by recent works (*S8*) [i.e. a combination between radiometric dates and a Monte-Carlo statistical correlation (*S9*) between Iberian Margin proxies and reference isotopic profiles from polar ice]:

First climate cycle. The gicc05 and ss09sea Greenland chronologies of the past 120 ky (*S10-S13*) were chosen as guide for the age model of surface indicators at cores MD01-2444 (this study) and MD95-2042 (*S2, S3*), given that the northern events were more clearly defined than their counterparts in Antarctica (*S6, S13*). However, close comparison between the ice core time-scales and accurate radiometric dated cores MD95-2042 [27 AMS-^{14}C measurements; (*S6*, *S7*)] and MD95-2043 [21 AMS-^{14}C measurements; (*S4*)] evidenced that the glaciological modelling was showing younger dates than it should; this was particularly unacceptable around the last glacial maximum, given that the existing data over this time span were firmly dated at the Iberian cores (*S4, S6*, *S7*), including the position of the Heinrich layers (*S15*); our approach here was to maintain the Monte-Carlo correlation, if it proved to be consistent with the radiocarbon dates following the criterion that the differences between the published calibrated ^{14}C date (*S4, S6*, *S7*) and the Monte-Carlo age were less than twice the individual radiocarbon error ($\pm 2\sigma$); on doing so, important divergences were identified by spurious jumps in sedimentation rates between 29 and 15 ky before the present; consequently, the radiometric proposal of cores MD95-2042 (*S6*, *S7*) and MD95-2043 (*S4*) was adopted as the template for this time bracket.

Second, third and fourth climate cycles. The ages of sections older than 120 ky ago were obtained by comparison between the MD01-2443 benthic δ^{18}O profile (*S16, S17,* this study) and the Antarctica Dome C isotopic record in the edc2 age-scale (*S18, S19*). The new edc3 beta6 chronology is essentially modifying the timing of some events over the first and second climate cycles (*S20, S21*). However, during some periods, discrepancies are observed between the Antarctica chronologies (*S18-S21*) and the orbitally tuned forest development in the Mediterranean region (*S22-S24*) or sea-level reconstructions based on U/Th ages (*S25*) [specifically, during the penultimate deglaciation (around 150 ky ago) and marine isotope stage 7d (between 225 and 220 ky ago)]; to avoid these divergences, core ODP-977A was used as a guide for the second climate cycle. The age model of core ODP-977A for this time span was practically the one originally published (*S5*) [i.e. ^{14}C dating and Monte-Carlo correlation for the last 80 ky between surface temperature estimates and the Greenland Ice-core Project record (*S10*), and for older periods defined isotopic events (*S23*), with an improved age model around the last glacial maximum and marine isotope stage 5c (between 106 and 89 ky ago)].

Apart from the Iberian Margin core chronologies previously detailed, each paleoarchive shown in the print manuscript (Fig. 2) is drawn in its own published age-scale: the gicc05 and ss09sea for the North Greenland Ice-core Project chronology (*S11-S13*), edc2 for the Dome C (*S18*), the Dronning Maud Land age model (*S20*), the new Vostok modelling (*S19*) for the greenhouse gases (*S26, S27*), and orbital tuning (*S22, S23*) for the Tenaghi Phillippon lake sediments (*S24*) and the marine core ODP-980 (*S28*). The observed events are numbered following the INTIMATE group proposals (*S29*).

Biomarkers. The procedures and equipment used for the analysis of C_{37} alkenones, *n*-alkan-1-ols and *n*-alkanes in deep-sea sediments were described elsewhere (*S30*). Briefly, sediment samples were freeze-dried and extracted by sonication using dichloromethane. The extracts were hydrolysed with 6% potassium hydroxide in methanol and derivatised with *bis*(trimethylsilyl)trifluoroacetamide. They were then analysed with a Varian gas chromatograph Model 3400 equipped with a septum programmable injector and a flame ionisation detector. Selected samples were examined by GC-mass spectrometry (MS) for confirmation of compound identification and evaluation of possible coelutions. Absolute concentration errors were below 10%. Reproducibility tests showed that the uncertainty in the $U^{k'}_{37}$ determinations was lower than 0.015 (ca. ±0.5ºC). The sea surface temperature reconstruction ($U^{k'}_{37}$-SST) was obtained from the relative composition of C_{37} unsaturated alkenones [$U^{k'}_{37} = C_{37:2}/(C_{37:2}+C_{37:3})$] using a calibration equation obtained from sediment samples and annual average SST of overlying waters ($U^{k'}_{37} = 0.033*SST + 0.044$; $r^2=0.96$; n=370) (*S31*).

Stable isotope analyses. Stable isotope analyses were carried out using a VG PRISM mass spectrometer or a VG SIRA mass spectrometer. On both instruments the samples are reacted sequentially using ISOCARB systems. For the planktonic record about 25 specimens of *Globigerina bulloides* were selected from a sieved size fraction 425-355 micron. For the benthic record several different species were analyzed as no single species was present in sufficient numbers to generate a continuous record. Where possible two or three separate analyses of different species were made in each sample; a correction factor was applied according to the species and the average of all the corrected values at each level in the print manuscript (Fig. 2). The following species were analyzed, and adjusted as indicated: *Cibicidoides robertsonianus*: +0.50; *Uvigerina peregrina* and similar specimens: 0.0; *Globobulimina affinis*: -0.30; *Cibicidoides wuellerstorfi*: +0.64; *Cibicidoides kullenbergi*: +0.51; *Hoeglundina elegans*: -0.60; *Oridorsalis umbonatus*: 0.0; *Cassidulina carinata*: 0.0. These adjustments are optimised for cores in this area in accordance with the long-standing convention by which *Uvigerina peregrina* is assumed to deposit oxygen in isotopic equilibrium.

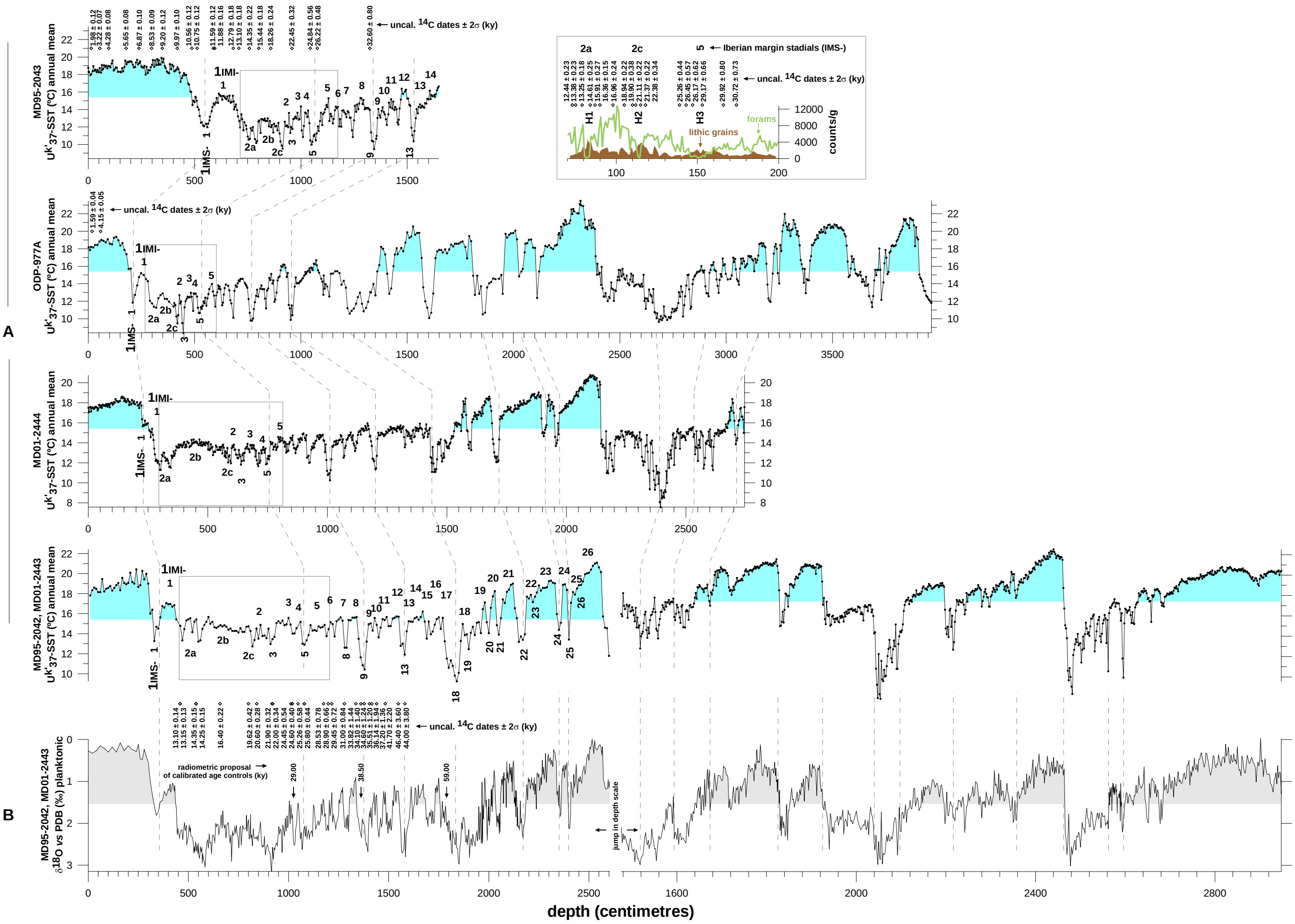

Fig. S1 Down-core Iberian profiles on their depth-scales, with particular emphasis on the events of the last climate cycle. (A) Sea surface temperature ($U^{k'}_{37}$-SST) in cores MD95-2043 (*S4*), ODP-977A (*S5*), MD95-2042 (*S3, S7*), MD01-2444 (this study) and MD01-2443 (this study). The recorded warm and cool events, respectively labelled here as Iberian margin interstadials (IMI) and stadials (IMS), exhibited a persistently repeated saw-tooth morphology. Correlation between cores is based on the ^{14}C measurements marked above the profiles, when available (*S4-S7*); an accurate identification of each event is carried out based on biomarker, grain size and isotopic information. For example, special attention was paid to locate the last three Heinrich layers (H1, H2, H3; rectangles shown by the grey line) which were formerly defined in North Atlantic sediments by an enrichment in ice-rafted debris and a scarcity of foraminifera (*S15*). (B) Relative $\delta^{18}O$ of planktonic foraminifera in core MD95-2042 (*S2, S6*) and MD01-2443 (*S16, S17,* this study). Values above average are filled in.

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Original Data.

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