GSA Data Repository 2015317

Persistent monsoonal forcing of Mediterranean Outflow dynamics during the late Pleistocene

by A. Bahr, S. Kaboth, F.J. Jiménez-Espejo, F. J. Sierro, A.H.L. Voelker, L. Lourens, U. Röhl, G.J. Reichart, C. Escutia, F.J. Hernández-Molina, J. Pross, and O. Friedrich

1. Methods

1.1. Stable isotope analysis

Five to twenty specimens of *Globigerina bulloides* between 300 and 500 µm were hand-picked for oxygen isotope analyses. Specimens were washed with ethanol, ultrasonicated for several seconds and dried for 24 hours to eliminate all liquids. Samples were analyzed at Kiel University with a MAT 253 mass spectrometer connected to a Kiel IV carbonate preparation device. The analytical precision of international and laboratory-internal carbonate standards was better than ±0.05 ‰ ($\delta^{13}C$) and ± 0.08‰ ($\delta^{18}O$).

All data will be made available through the PANGAEA data server (www.pangaea.de).

2. Age models

The chronology of the upper part of Site U1389 is based on AMS ^{14}C dating back to ~16.3 ka (Table DR3; Sierro et al., in prep.). *G. bulloides* $\delta^{18}O$ data of Site U1389 (Sierro et al., in prep.) has been used to construct an age model for the older part of the record. We used the NGRIP on "GICC05modeletext" chronology (Andersen et al., 2006; NGRIP-Members, 2004; Rasmussen et al., 2014) corrected to BP as a tuning target for MIS 2-4, while the MIS 5 chronology (including

Termination II) is based on tying the $\delta^{18}O$ data of U1389 to the *G. bulloides* $\delta^{18}O$ record of Iberian Margin core MD01–2444 (Hodell et al., 2013; Martrat et al., 2007, Fig. DR2, Table DR2) using the stratigraphy of Hodell et al. (2013).

The Site U1389 stratigraphy was transferred to Sites U1387 and U1386 by aligning the respective XRF Br records, further constrained by matching the Br signal to NGRIP and MD01-2444 (c.f. Bahr et al., 2014; Fig. DR2, Table DR4). The resultant chronostratigraphy of Site U1387 largely agrees with a previously published age model (Bahr et al., 2014) with deviations for the late Glacial to Holocene part due to the inclusion of AMS ^{14}C dates, and for the assignment of MIS 5 stadials. Although bottom current flow speed varied considerably as indicated by high-amplitude Zr/Al fluctuations, no indication of hiatuses has been found for the discussed time interval (Stow et al. 2012). We cannot exclude, however, that deviations in the Zr/Al records between the respective Sites e.g. during MIS 3 or MIS 5 might be due to condensed sections or small-scale hiatuses.

3. Spectral analysis

Spectral analysis was performed on detrended ln(Zr/Al) data of Site U1389 with the program REDFIT (Schulz and Mudelsee, 2002) emulated in the PAST 3.04 software package (Hammer et al., 2001) using a Welch window (oversampling: 3, segments: 4). The results illustrate the dominance of precession-forcing (1/23 kyr) and millennial-scale variability on the MOW fluctuations (Fig. DR3). Note that the record only covers 6 precession cycles limiting the accuracy of phase relation estimates and prohibits reasonable estimates of phase lags.

Figures DR1-DR4

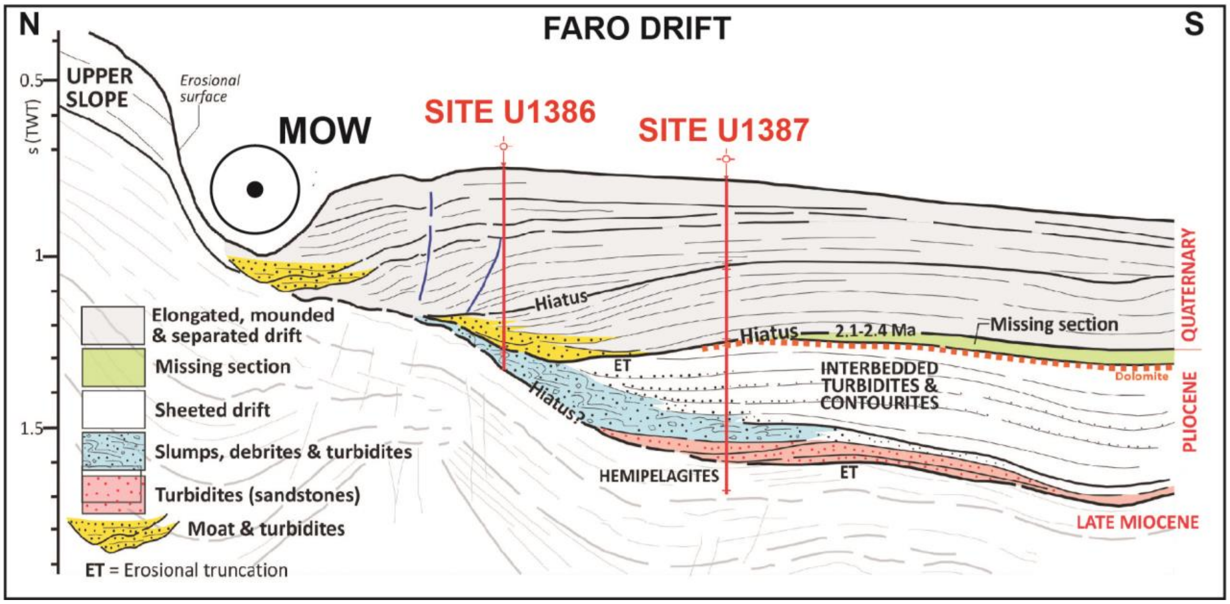

Figure DR1. N-S Section through Faro Drift (interpreted seismic profile, modified after Hernández-Molina et al., 2014). Position of Sites U1386 and U1387 are indicated as well as the present-day core of the MOW. Note that U1386 is located closer to the moat generated by the bottom current activity of the MOW.

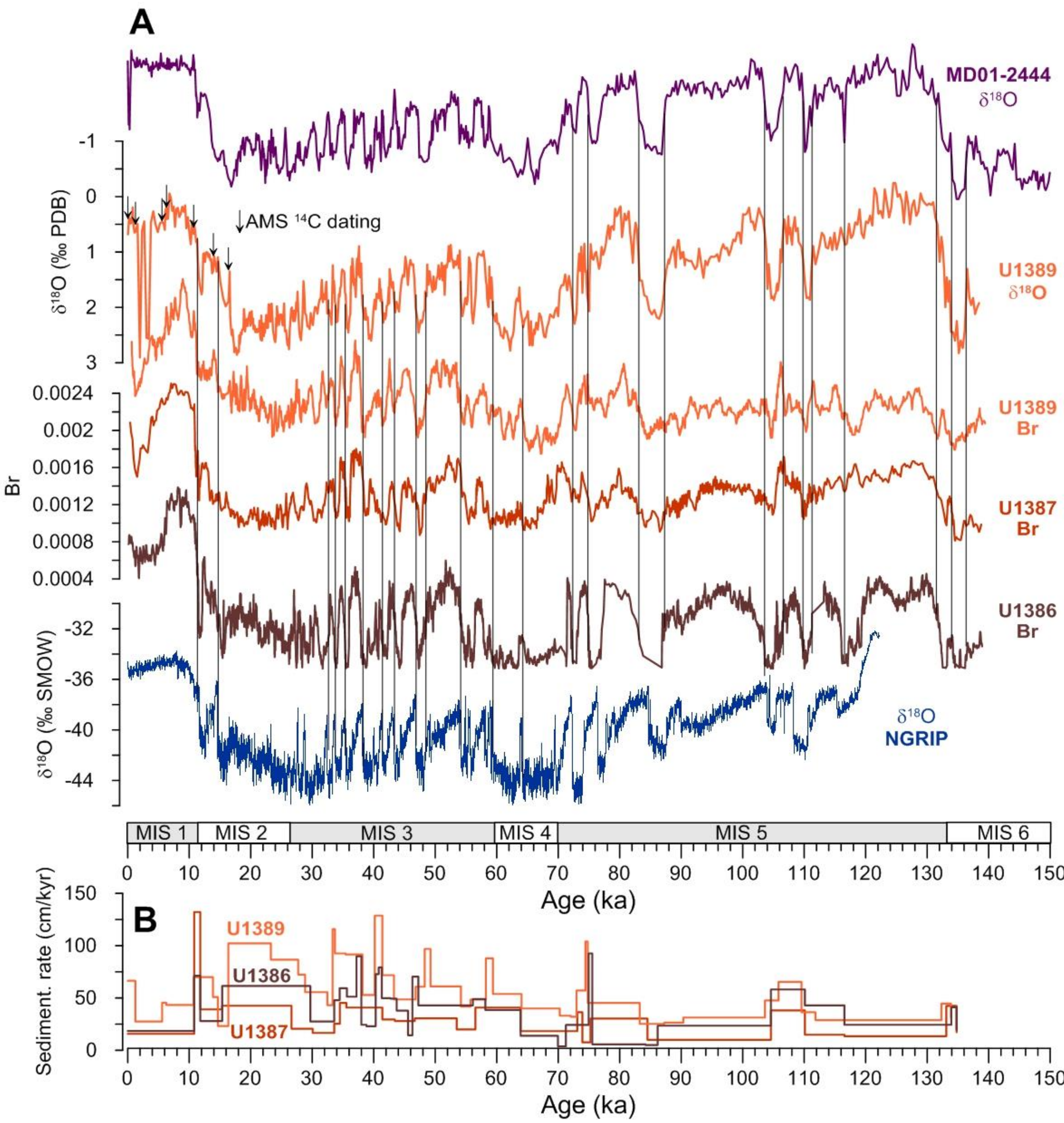

Figure DR2. (A) Planktonic $\delta^{18}O$ *G. bulloides* record of Site U1389 (Sierro et al., in prep.) and normalized bromine records from Gulf of Cadiz sites (U1386 and U1387: 3pt running means, U1389: 11 pt running mean) in relation to the tuning targets, Iberian Margin core MD01-2444 ($\delta^{18}O$ of *G. bulloides*, Martrat et al., 2007) on the stratigraphy of Hodell et al. (2013) and the NGRIP Greenland ice core (Seierstad et al., 2014), 3 pt. running average, on the INTIMATE stratigraphy, (Rasmussen et al., 2014). Selected tie points are indicated relative to the respective reference curve (c.f. Tables DR2 and DR3). Arrows denote AMS ^{14}C dates. (B) Calculated sedimentation rate for each site. MIS – Marine Isotope Stage.

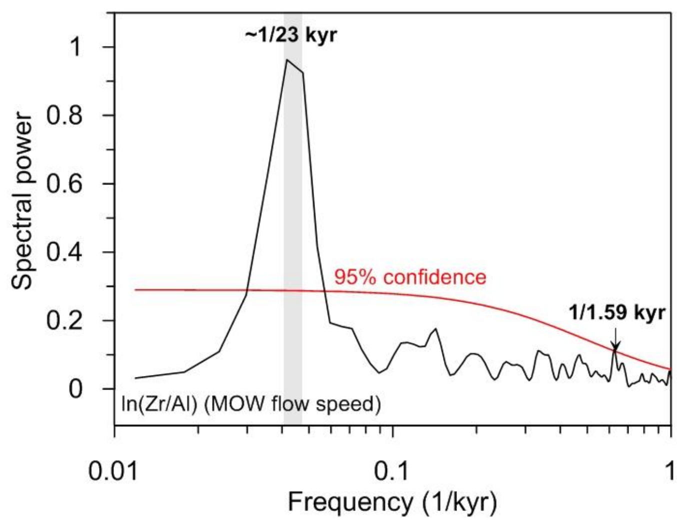

Figure DR3**.** Frequency analysis of the ln(Zr/Al) ratio of Site U1389 illustrating the dominance of precession-forcing (1/23 kyr). Millennial-scale variations are represented by a peak at 1/1.59 kyr.

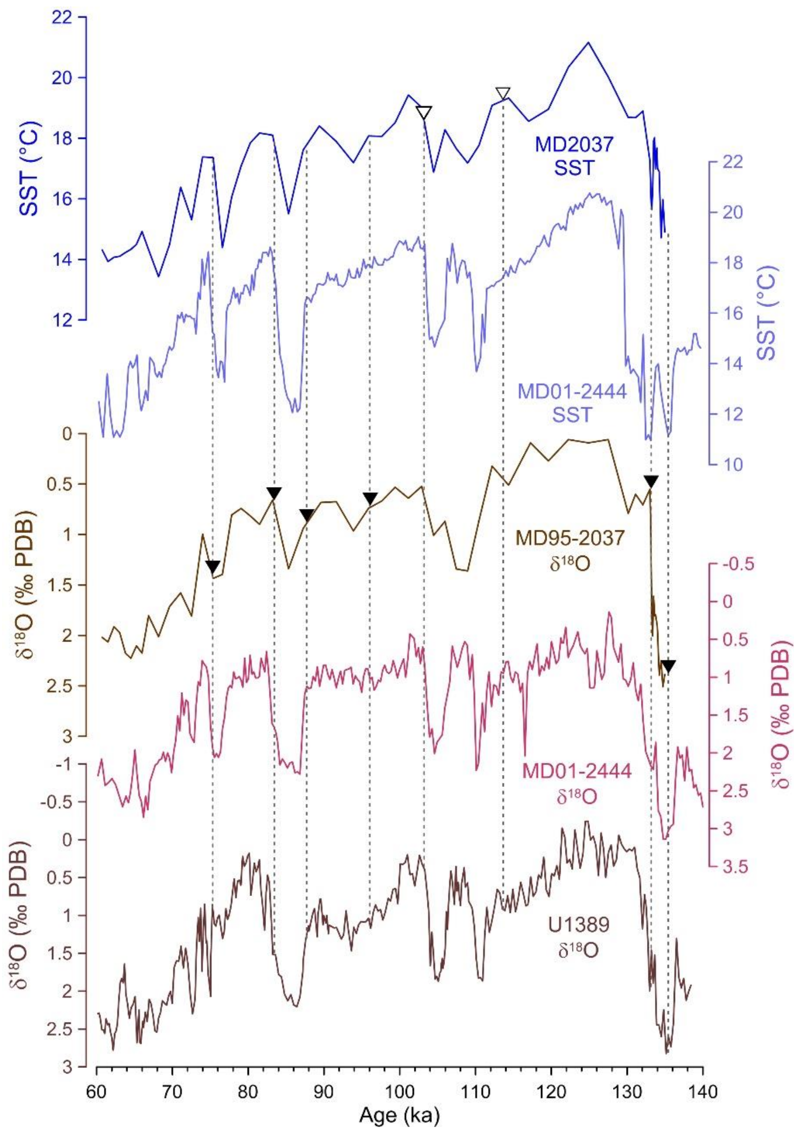

Figure DR4. Revised age model of MD95-2037 (Guihou et al., 2011) for Marine Isotope Stage 5 derived from tuning the planktonic δ^{18}O record of *G. bulloides* and alkenone-based SST data from MD95-2037 (Calvo et al., 2001) to the respective *G. bulloides* δ^{18}O (Hodell et al., 2013) and SST records (Martrat et al., 2007) of MD01-2444. The stratigraphy of MD01-2444 is based on Hodell et al. (2013). Tuning points are denoted by stippled lines and triangles (differentiated according to the respective tuning targets: open – SST; closed – δ^{18}O). For comparison the δ^{18}O record of *G. bulloides* from Site U1389 is presented as well.

Tables DR1-DR4

Table DR1. Site locations (Stow et al., 2012).

Site	Latitude	Longitude	Water depth (meters below sea floor)
U1386	36°49.7'N	7°45.3'W	561
U1387	36°48.3'N	7°43.1'W	559
U1389	36°25.5'N	7°16.7'W	644

Table DR2**.** Relative standard deviations (1s) of XRF scanning measurements for selected elements.

Site	Aluminum (Al) (%)	Bromine (Br) (%)	Zirconium (Zr) (%)
U1386	1.43	3.57	1.45
U1387	0.87	3.50	2.65
U1389	1.88	4.98	3.93

Table DR3. Age control points for Site U1389. Note that all ages are given with reference to BP. GI = Greenland Interstadial, HS – Heinrich Stadial.

Depth (mcd)	**Age (ka BP)**	**Tuning target**	**Reference record**
0.82	1.24	(AMS ^{14}C)	
2.02	5.60	(AMS ^{14}C)	
2.32	6.26	(AMS ^{14}C)	
4.24	10.71	(AMS ^{14}C)	
6.44	13.86	(AMS ^{14}C)	
6.84	14.64	Bottom Bølling	NGRIP (GICC05, Rasmussen et al., 2014)
7.24	16.37	(AMS ^{14}C)	
14.32	23.29	Bottom GI-2	NGRIP (GICC05, Rasmussen et al., 2014)
18.17	27.73	Bottom GI-3	NGRIP (GICC05, Rasmussen et al., 2014)
18.98	28.85	Bottom GI-4	NGRIP (GICC05, Rasmussen et al., 2014)
20.98	32.45	Bottom GI-5	NGRIP (GICC05, Rasmussen et al., 2014)
21.35	33.31	Top GI-6	NGRIP (GICC05, Rasmussen et al., 2014)
21.79	33.69	Bottom GI-6	NGRIP (GICC05, Rasmussen et al., 2014)
23.40	35.43	Bottom GI-7	NGRIP (GICC05, Rasmussen et al., 2014)
25.91	38.17	Bottom GI-8	NGRIP (GICC05, Rasmussen et al., 2014)
26.96	40.16	Bottom GI-9	NGRIP (GICC05, Rasmussen et al., 2014)
28.57	41.41	Bottom GI-10	NGRIP (GICC05, Rasmussen et al., 2014)
29.92	43.29	Bottom GI-11	NGRIP (GICC05, Rasmussen et al., 2014)
31.63	46.81	Bottom GI-12	NGRIP (GICC05, Rasmussen et al., 2014)
32.53	48.29	Top GI-13	NGRIP (GICC05, Rasmussen et al., 2014)
33.44	49.23	Bottom GI-13	NGRIP (GICC05, Rasmussen et al., 2014)
36.46	54.17	Bottom GI-14	NGRIP (GICC05, Rasmussen et al., 2014)
37.12	55.75	Bottom GI-15	NGRIP (GICC05, Rasmussen et al., 2014)
38.32	58.23	Bottom GI-16	NGRIP (GICC05, Rasmussen et al., 2014)
39.34	59.39	Bottom GI-17	NGRIP (GICC05, Rasmussen et al., 2014)
41.85	64.05	Bottom GI-18	NGRIP (GICC05modelext, Rasmussen et al., 2014)
44.32	70.23	Top GI-19	MD01-2444 (Hodell et al., 2013)
44.92	72.05	Bottom GI-19	MD01-2444 (Hodell et al., 2013)
45.22	72.98	Top GI-20	MD01-2444 (Hodell et al., 2013)
46.05	74.44	Bottom GI-20	MD01-2444 (Hodell et al., 2013)
46.45	74.82	Top GI-21	MD01-2444 (Hodell et al., 2013)
50.27	83.25	Bottom 5.1	MD01-2444 (Hodell et al., 2013)
51.28	87.25	Top GI-22	MD01-2444 (Hodell et al., 2013)
52.10	90.36	Bottom GI-22	MD01-2444 (Hodell et al., 2013)
56.25	103.61	Bottom 5.3	MD01-2444 (Hodell et al., 2013)
57.31	105.84	Top GI-24	MD01-2444 (Hodell et al., 2013)
59.74	109.56	Bottom GI-24	MD01-2444 (Hodell et al., 2013)
60.56	111.82	Top GI-25	MD01-2444 (Hodell et al., 2013)
66.49	132.30	Bottom 5.5	MD01-2444 (Hodell et al., 2013)
67.19	133.87	Top HS11	MD01-2444 (Hodell et al., 2013)
67.89	136.10	Bottom HS11	MD01-2444 (Hodell et al., 2013)

Table DR4. Tie points used for transferring the stratigraphy of U1389 to U1386 and U1387, respectively, based on the XRF Br record.

Site U1386		**Site U1387**	
Depth (mcd)	**Age (ka)**	**Depth (mcd)**	**Age (ka)**
2.00	10.81	1.70	10.81
2.70	11.79	3.00	11.79
3.70	15.36	4.40	15.36
12.50	29.68	9.20	26.63
13.57	33.57	9.91	30.09
14.00	34.47	10.49	33.57
14.70	35.65	10.72	34.48
15.50	37.21	11.20	35.54
16.20	37.99	13.60	41.41
16.40	38.81	14.20	43.45
16.75	40.33	15.10	46.66
17.10	40.81	17.20	53.51
17.50	41.32	17.80	56.52
18.20	42.72	20.80	63.88
18.70	43.74	22.50	73.11
19.40	45.59	22.80	73.93
19.50	46.28	22.90	75.26
20.20	47.27	25.70	84.52
24.00	56.12	27.70	104.60
25.00	58.16	29.80	110.11
27.21	63.88	30.75	116.53
28.05	69.95	33.00	133.12
28.10	71.24	33.70	134.77
29.00	74.95	37.53	157.00
29.55	75.54		
30.05	84.19		
30.15	86.17		
34.50	104.60		
37.70	110.11		
40.45	116.53		
44.70	133.92		
45.05	134.77		
48.05	150.00		

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