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Supplemental Material

Figure S1. Monthly meteoric water $\delta^2\text{H}$ (blue); monthly mean temperature (red); monthly mean precipitation (green) of 6 GNIP meteorological stations from westerlies and Asian Monsoon regions (Data download from <https://nucleus.iaea.org>). Horizontal axes indicate months.

Figure S2. Chromatography of unsaturated alkenones sample ZK1405-3-4. The identification of alkenones is based on major ion fragment m/z 81, and molecular ions of m/z 530.5, 528.5, and 526.5 for $\text{C}_{37:2}$, $\text{C}_{37:3}$, and $\text{C}_{37:4}$, respectively.

Table S1. ^{14}C AMS dates of Qaidam core samples.

Table S2. UK37 of Last glacial ZK1405 core samples measured by GC-FID.

Table S3. Sample information and $\delta^2\text{H}_{n\text{-alk}}$ (‰) of ZK1405 core samples during the last glacial period.

Westerlies region

Water recycled region

East Asian Monsoon region

Fig. S1. Monthly meteoric water $\delta^2\text{H}$ (blue); monthly mean temperature (red); monthly mean precipitation (green) of 6 GNIP meteorological stations from westerlies and Asian Monsoon regions (Data download from <https://nucleus.iaea.org>). Horizontal axes indicate months.

Fig. S2. Chromatography of unsaturated alkenones sample ZK1405-3-4. The identification of alkenones is based on major ion fragment m/z 81, and molecular ions of m/z 530.5, 528.5, and 526.5 for $C_{37:2}$, $C_{37:3}$, and $C_{37:4}$, respectively.

Table S1. ^{14}C AMS dates of Qaidam core samples

Smample No.	Depth (m)	Measured ^{14}C Age	Error	Calibrated Age (cal yr BP)	1σ Error	Material
ZK1405-2-1	2.25	12510	40	11274	36	Bulk sediment
ZK1405-5-2	7.5	19080	50	19852	109	Bulk sediment
ZK1405-8-1	9	18100	70	18619	75	Bulk sediment
ZK1405-14-7	14.1	24830	90	26410	151.5	Bulk sediment
ZK1405-24-1	18.6	27100	100	28527	132	Bulk sediment
ZK1405-24-6	20	29080	150	30750	140.5	Bulk sediment
ZK1405-39-1	30	34220	260	35474	306.5	Bulk sediment
ZK1405-44-12	40	39640	440	41542	359	Bulk sediment

Table S2. U^{K}_{37} of Last glacial ZK1405 core samples measured by GC-FID.

Sample No.	Depth (m)	Age (yr)	U^{K}_{37}	T
ZK1405-2-1	2.2	10878	-0.60	10.4
ZK-1405-3-1	2.5	11473	-0.39	14.0
ZK1405-3-2	3.0	12439	-0.38	14.2
ZK1405-3-3	3.3	13004	-0.04	20.1
ZK1404-3-5	3.9	14099	-0.01	20.7
ZK1404-3-7	4.5	15150	-0.23	16.9
ZK1404-3-8	4.8	15660	-0.12	18.8
ZK1404-3-9	5.1	16159	-0.19	17.5
ZK1405-4-1	5.4	16647	-0.37	14.3
ZK1405-4-3	6.0	17593	-0.19	17.5
ZK1405-4-4	6.3	18051	-0.21	17.1
ZK1405-5-2	7.5	19786	-0.47	12.5
ZK1405-5-3	7.8	20197	-0.37	14.3
ZK1405-6-1	8.4	20990	-0.42	13.4
ZK1405-7-1	8.7	21373	-0.48	12.4
ZK1405-8-1	9.0	21748	-0.38	14.2
ZK1405-8-5	9.9	22822	-0.35	14.7
ZK1405-10-1	11.1	24141	-0.36	14.5
ZK1405-14-3	12.9	25898	-0.34	14.9
ZK1405-14-7	14.1	26935	-0.30	15.6
ZK1405-14-12	15.6	28097	-0.27	16.1
ZK1405-22-1	17.4	29319	-0.19	17.5
ZK1405-23-1	18.0	29690	-0.26	16.3
ZK1405-24-1	18.6	30044	-0.17	17.9
ZK1405-24-3	19.2	30382	-0.22	17.0
ZK1405-28-1	22.8	32161	-0.08	19.4
ZK1405-30-1	23.7	32556	-0.13	18.6
ZK1405-31-2	25.2	33190	-0.08	19.4
ZK1405-34-1	25.8	33438	-0.21	17.2
ZK1405-38-1	28.5	34560	0.01	21.0
ZK1405-42-1	31.2	35765	-0.08	19.4
ZK1405-42-9	33.6	36993	-0.02	20.5
ZK1405-42-11	34.2	37333	-0.27	16.1
ZK1405-42-14	35.1	37871	-0.27	16.1
ZK1405-43-2	36.0	38448	-0.43	13.3
ZK1405-44-2	37.2	39284	-0.46	12.8
ZK1405-44-4	37.8	39733	-0.26	16.3
ZK1405-44-8	39.0	40699	-0.15	18.1
ZK1405-44-10	39.6	41219	-0.16	18.0
ZK1405-44-20	42.6	44229	-0.11	19.0
ZK1405-44-24	43.8	45648	-0.25	16.5

Table S3. Sample information and $\delta^2\text{H}_{\text{n-alk}}$ (‰) of ZK1405 core samples during the last glacial period

Sample No.	Depth (m)	Age (yr)	$\delta^2\text{H}_{\text{n-alk}}$ (‰)										CPI ^a	P_{aq} ^b
			$n\text{C}_{23}$	Error (1 σ)	$n\text{C}_{25}$	Error (1 σ)	$n\text{C}_{27}$	Error (1 σ)	$n\text{C}_{29}$	Error (1 σ)	$n\text{C}_{31}$	Error (1 σ)		
ZK1405-2-1	2.2	10878	-190.3	1.1	-181.4	3.6	-181.2	1.4	-167.1	0.9	-175.7	0.6	1.8	0.47
ZK-1405-3-1	2.5	11473	n/a	n/a	-158.1	2.4	-159.5	2.4	-159.9	1.3	-164.4	0.4	5.2	0.32
ZK1405-3-2	3.0	12439	-191	1.0	-193.0	0.4	-173.4	1.3	-166.0	1.5	-171.4	4.7	3.3	0.36
ZK1405-3-3	3.3	13004	n/a	n/a	-159.3	6.3	-166.6	2.9	-166.3	2.6	-169.2	2.9	5.7	0.31
ZK1405-3-4	3.6	13557	-199	1.0	-186.8	0.5	-187.7	0.6	-173.9	1.1	-188.5	1.7	1.7	0.47
ZK1404-3-5	3.9	14099	n/a	n/a	-178.9	1.5	-177.7	1.6	-172.1	2.1	-176.4	3.8	6.4	0.29
ZK1404-3-6	4.2	14630	n/a	n/a	-173.1	0.0	-173.8	n/a	-162.3	n/a	-168.6	6.6	6.1	0.31
ZK1404-3-7	4.5	15150	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-173.3	n/a	5.0	0.32
ZK1404-3-8	4.8	15660	n/a	n/a	-190.9	0.0	-189.1	0.1	-173.8	9.5	-179.8	6.7	7.3	0.27
ZK1404-3-9	5.1	16159	n/a	n/a	-191.5	0.0	-197.4	11.6	-187.0	9.1	-188.7	6.0	7.0	0.27
ZK1405-4-1	5.4	16647	-191	1.3	-188.6	3.0	-195.5	1.2	-180.4	1.0	-186.1	0.5	3.3	0.32
ZK1405-4-3	6.0	17593	-209	3.2	-209.5	0.5	-204.1	0.4	-189.4	1.3	-188.7	0.2	3.4	0.41
ZK1405-4-4	6.3	18051	n/a	n/a	-206.2	0.7	-206.6	1.4	-193.5	0.0	-193.0	0.1	7.8	0.29
ZK1405-5-1	7.2	19367	-192	1.6	-188.8	0.7	-186.5	0.6	-186.3	0.8	-187.5	0.8	1.8	0.46
ZK1405-5-2	7.5	19786	n/a	n/a	-172.4	0.0	-189.4	1.9	-193.5	3.8	-179.0	13.5	3.0	0.20
ZK1405-5-3	7.8	20197	n/a	n/a	-192.0	0.0	-216.6	8.3	-204.1	1.3	-187.0	n/a	5.8	0.15
ZK1405-6-1	8.4	20990	-181	5.8	-177.9	0.4	-172.3	0.6	-167.3	0.5	-170.4	1.0	1.4	0.57
ZK1405-8-1	9.0	21748	-162	2.5	-161.2	0.1	-148.5	0.4	-148.4	0.1	-168.3	0.7	1.2	0.62
ZK1405-8-2	9.3	22114	n/a	n/a	n/a	n/a	-196.5	3.6	-185.5	0.6	-186.9	1.5	8.1	0.16
ZK1405-8-3	9.6	22472	-179	1.4	-190.2	2.0	-188.9	0.9	-186.9	0.5	-190.2	0.6	4.4	0.23
ZK1405-8-6	10.5	23497	n/a	n/a	n/a	n/a	-188.9	n/a	-184.9	n/a	-187.4	n/a	3.7	0.35
ZK1405-10-1	11.1	24141	-181	0.9	-183.1	2.2	-175.9	0.7	-171.6	3.1	-179.2	0.7	1.7	0.49
ZK1405-10-2	11.4	24452	n/a	n/a	-178.8	3.2	-185.3	1.7	-168.4	0.1	-174.6	3.6	7.1	0.25
ZK1405-12-1	12.0	25051	-194	1.9	-201.6	0.7	-185.7	0.5	-174.6	1.3	-182.8	0.7	2.4	0.41
ZK1405-14-1	12.3	25340	-193	0.3	-192.9	0.4	-183.2	0.3	-173.9	0.9	-181.0	0.7	2.3	0.45
ZK1405-14-3	12.9	25898	-195	0.7	-201.9	2.2	-199.7	0.0	-187.4	1.3	-184.8	1.2	3.7	0.32
ZK1405-14-5	13.5	26429	-197	0.1	-196.4	4.5	-187.8	2.3	-177.6	2.2	-180.4	2.3	2.3	0.44
ZK1405-14-7	14.1	26935	-181	4.8	-194.7	3.6	-206.0	2.1	-194.5	2.0	-189.8	0.9	4.0	0.25
ZK1405-14-12	15.6	28097	n/a	n/a	-168.0	8.9	-169.0	2.4	-176.3	1.5	-181.3	2.8	4.2	0.33
ZK1405-16-1	15.9	28313	-200	0.7	-210.0	0.8	-200.7	1.3	-190.7	2.2	-194.8	0.3	2.4	0.36
ZK1405-18-1	16.2	28524	-181	3.1	-180.8	0.5	-178.8	0.5	-176.9	1.8	-179.9	1.7	1.2	0.62
ZK1405-20-1	16.8	28931	-192	2.6	-194.6	1.2	-182.3	1.4	-177.6	1.0	-180.0	2.1	2.2	0.41
ZK1405-22-1	17.4	29319	-193	2.4	-187.3	3.7	-181.7	3.5	-178.6	0.1	-197.2	1.1	1.3	0.63
ZK1405-23-1	18.0	29690	n/a	n/a	-180.1	0.0	n/a	n/a	-182.3	2.1	-183.8	n/a	6.2	0.32
ZK1405-24-1	18.6	30044	-211	1.0	-203.9	1.6	-187.6	1.3	-179.8	1.3	-188.4	2.4	2.9	0.36
ZK1405-24-3	19.2	30382	-198	1.3	-194.3	2.6	-188.7	1.6	-181.5	2.7	-189.6	0.0	2.0	0.47
ZK1405-25-2	20.7	31170	-186	0.6	-191.4	1.1	-182.4	2.2	-172.4	1.2	-179.2	2.4	2.4	0.47
ZK1405-27-1	21.9	31750	-189	5.7	-185.1	7.6	-182.1	n/a	-168.8	n/a	-180.9	n/a	1.5	0.62
ZK1405-28-1	22.8	32161	-193	1.5	-189.1	0.6	-185.5	0.6	-181.5	0.7	-184.7	0.6	1.2	0.63
ZK1405-30-1	23.7	32556	-196	0.3	-188.6	0.4	-180.3	2.1	-172.2	0.4	-176.4	1.9	1.4	0.58
ZK1405-31-2	24.3	32812	-192	0.3	-193.7	0.2	-177.1	0.1	-168.3	0.8	-177.4	1.4	1.7	0.50
ZK1405-32-1	25.2	33190	-196	1.0	-197.9	0.5	-190.3	0.3	-182.5	0.2	-190.2	0.8	1.8	0.50
ZK1405-34-1	25.8	33438	-198	2.0	-207.2	0.4	-197.7	0.6	-189.0	1.2	-190.7	1.6	3.7	0.30
ZK1405-36-1	27.3	34057	-193	1.8	-196.3	0.2	-188.6	0.3	-178.5	0.7	-185.4	0.9	2.4	0.41
ZK1405-38-1	28.5	34560	-193	0.8	-213.6	0.7	-198.7	0.0	-186.3	0.4	-186.9	0.6	4.5	0.29
ZK1405-38-3	29.1	34817	-205	0.8	-202.5	2.2	-200.5	1.4	-187.4	0.5	-188.5	2.2	4.1	0.34
ZK1405-40-1	30.6	35484	-178	14.0	-181.6	0.5	-182.6	1.4	-179.4	0.5	-188.7	0.2	1.6	0.60
ZK1405-42-1	31.2	35765	-191	0.4	-195.3	3.3	-187.2	0.0	-178.3	0.1	-186.4	1.4	2.0	0.46
ZK1405-42-3	31.8	36055	-182	8.8	-182.9	7.3	-180.4	2.2	-177.5	1.3	-187.4	0.0	1.5	0.54
ZK1405-42-5	32.4	36356	-193	0.8	-190.3	1.7	-182.1	0.4	-172.0	1.0	-185.7	0.7	1.8	0.39
ZK1405-42-7	33.0	36668	-195	0.7	-191.4	0.3	-180.9	0.9	-172.8	1.1	-174.5	2.5	2.7	0.34
ZK1405-42-9	33.6	36993	-191	0.3	-191.5	0.2	-174.2	1.9	-169.2	0.1	-161.8	0.2	2.4	0.34
ZK1405-42-11	34.2	37333	n/a	n/a	n/a	n/a	-176.3	n/a	-173.3	1.1	-171.2	0.6	12.8	0.05
ZK1405-42-14	35.1	37871	n/a	n/a	-171.8	0.0	-178.3	1.4	-174.2	1.7	-171.4	0.9	11.2	0.17
ZK1405-43-2	36.0	38448	-189	2.9	-175.7	7.6	-167.0	7.9	-167.1	4.8	-178.5	3.5	2.4	0.46
ZK1405-44-2	37.2	39284	-198	1.5	-198.3	0.2	-184.7	0.1	-177.2	0.2	-186.7	1.6	2.4	0.40
ZK1405-44-4	37.8	39733	-201	0.5	-214.8	2.4	-185.2	0.9	-178.3	0.9	-180.3	0.8	4.2	0.31
ZK1405-44-6	38.4	40204	-212	0.8	-212.3	0.4	-186.7	1.5	-179.8	0.7	-180.9	0.4	3.9	0.35
ZK1405-44-8	39.0	40699	-205	0.1	-205.9	1.1	-190.3	0.5	-178.5	0.2	-186.3	1.1	3.7	0.33
ZK1405-44-10	39.6	41219	-209	0.1	-208.1	1.3	-190.2	1.5	-183.6	0.6	-186.3	0.7	3.5	0.35
ZK1405-44-12	40.2	41765	-232	4.5	-212.7	0.1	-192.9	5.0	-180.2	2.0	-183.9	0.1	3.9	0.36
ZK1405-44-14	40.8	42337	-213	0.1	-215.2	1.5	-201.7	0.5	-189.7	0.2	-190.2	0.3	3.3	0.32
ZK1405-44-20	42.6	44229	n/a	n/a	-201.3	1.8	-203.3	1.2	-191.3	1.8	-188.5	1.6	5.8	0.35
ZK1405-44-24	43.8	45648	n/a	n/a	-204.9	1.8	-210.0	0.3	-194.1	0.8	-190.1	0.7	5.4	0.34

n/a: no replicate analysis and hence no reports for standard error

^a Carbon preference index (CPI) is determined using the equation (1)^b Aquatic to terrestrial plants ratio (P_{aq})