**Supplementary materials to:**

**Planktic 14C Plateaus, a result of short-term sedimentation pulses?**

by Sven Balmer and Michael Sarnthein

**Supplementary Text 1: 14C Plateau Tuning**

A correlation of plateau structures in glacial-to-deglacial planktic 14C records to pertinent structures in the atmospheric 14C record of Lake Suigetsu [Bronk Ramsey et al., 2012] provides up to 21 age tie points between 23 and 12 cal. ka. In this way 14C plateau tuning provides a robust and narrow spaced age model for all sediment cores discussed in this study, moreover, a quasi-continuous record of surface water reservoir ages for glacial-to-deglacial marine sediments (details in: Sarnthein et al. [2015]; Balmer et al. [2016]).

To tune a planktic 14C record to the atmospheric 14C curve several prerequisites need to be met following Sarnthein et al. [2007; 2015]:

1. Sedimentation rates should exceed 10 cm/kyr to enable the identification of short plateaus of ~300 yr marked by no more than two or three 14C dates each.
2. The sampling resolution should be better than 100–150 yr to even identify 14C plateaus as short as 300 yr.
3. In addition to a visual identification of plateaus and jumps in 14C records, a more objective mathematical method should be employed which applies the first derivative of all downcore changes in the 14C age – core depth relationship.
4. To identify the individual 14C plateaus, the entire suite of plateaus and their internal structures need to be considered. In case of alternative tuning choices the lowest possible estimates of planktic 14C reservoir ages need to be accepted, in case no other stringent evidence is suggesting a higher age value. For example, paired benthic 14C ages that are lower than coeval planktic 14C ages may necessarily imply an increased 14C reservoir age to provide an apparent benthic 14C ventilation age larger than ~400 yr [Matsumoto, 2007], since smaller and negative values are physically impossible.

**Supplementary Text 2: Plateau tuning derived estimates of hemipelagic sedimentation rate**

Sedimentation rate estimates are based on the sediment thickness between age-calibrated 14C plateau boundaries. Major jumps in hemipelagic sedimentation rates may form an artifact of too low sampling resolution that leads to insufficient precision in the definition of 14C plateau boundaries. To avoid this bias we did not specify the rates for the short sediment sections that occur in between subsequent 14C plateaus, sections that span 300–500 yr and less (Figs. 1a–e) and are smaller than resolved by our sampling density. When incorporating these small inter-plateau sections to the next subsequent or preceding 14C plateau (Table S2) we obtained a generally smooth and realistic record of modest changes in sedimentation rate.

**References**

Balmer S, Sarnthein M, Mudelsee M, Grootes PM. 2016. Refined modeling and 14C plateau tuning reveal consistent patterns of glacial and deglacial 14C reservoir ages of surfae waters in low-latitude Atlantic. *Paleoceanography*, 31, doi: 10.1002/2016PA002953.

Matsumoto K. 2007. Radiocarbon-based circulation age of the world oceans. J*. of Geophys. Res.* 112, doi: 10.1029/2007JC004095.

Bronk Ramsey C, Staff RA, Bryant CL, Brock F, Kitagawa H, van der Plicht J, Schlolaut G, Marshall MH, Brauer A, Lamb HF. 2012. A complete terrestrial radiocarbon record for 11.2 to 52.8 kyr BP. *Science* 338(6105):370–374.

Sarnthein M, Grootes PM, Kennett JP, Nadeau M. 2007. 14C Reservoir Ages Show Deglacial Changes in Ocean Currents and Carbon Cycle. *Geophysical Monograph-American Geophysical Union* 173:175–196.

Sarnthein M, Balmer S, Grootes PM, Mudelsee M. 2015. Planktic and benthic 14C reservoir ages for three ocean basins, calibrated by a suite of 14C plateaus in the glacial-to-deglacial Suigetsu atmospheric 14C record. *Radocarbon* 57(1):129–151.

**Tables**

**Table S1:** Hypothetical sedimentation rates calculated for the 10, 100, 200, and 300-yr long 14C plateau deposition cycles. Extremes at 300-yr long sedimentation pulses marked red.

a) MD08 3180 (long-turn average rate: 80 cm/kyr)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Plateau No./****Plateau length [cm]** | **10 yr cycle** | **100 yr cycle** | **200 yr cylce** | **300 yr cycle** |
| **Time span** | **Sed.rate [cm/kyr]** | **Time span** | **Sed. rate [cm/kyr]** | **Time span** | **Sed. rate [cm/kyr]** | **Time span** | **Sed. rate [cm/kyr]** |
| **1a****(15.5)** | 13640 – 13930 | 0 | 13640 – 13840 | 0 | 13640 – 13740 | 0 | - | - |
| 13930 – 13940 | 1550 | 13840 – 13940 | 155 | 13740 – 13940 | 77.5 | 13640 – 13940 | 52 |
| **1****(29.0)** | 13940 – 14911 | 3.08 | 13940 – 14821 | 3.4 | 13940 – 14721 | 3.84 | 13940 – 14621 | 4.4 |
| 14911 – 14921 | 2900 | 14821 – 14921 | 290 | 14721 – 14921 | 145 | 14621 – 14921 | 97 |
| **2a****(51.5)** | 14921 – 16040 | 4.02 | 14921 – 15650 | 4.37 | 14921 – 15850 | 4.84 | 14921 – 15750 | 5.42 |
| 16040 – 16050 | 5150 | 15950 – 16050 | 515 | 15850 – 16050 | 257.5 | 15750 –16050 | 171 |
| **2b****(41.0)** | 16050 – 16390 | 0 | 16050 – 16300 | 0 | 16050 – 16200 | 0 | 16050 – 16100 | 0 |
| 16390 – 16400 | 4100 | 16300 – 16400 | 410 | 16200 – 16400 | 205 | 16100 – 16400 | 136 |
| **3****(59.0)** | 16400 – 17570 | 14.95 | 16400 – 17480 | 16.2 | 16400 – 17380 | 17.85 | 16400 – 17280 | 19.88 |
| 17570 – 17580 | 5900 | 17480 – 17580 | 590 | 17380 – 17580 | 295 | 17280 – 17580 | 196 |
| **4****(104.5)** | 17580 – 18970 | 3.59 | 17580 – 18880 | 3.84 | 17580 – 18780 | 4.16 | 17580 – 18680 | 4.54 |
| 18970 – 18980 | 10450 | 18880 – 18980 | 1045 | 18780 – 18980 | 522.5 | 18680 – 18980 | **348** |
| **5a****(81.5)** | 18980 – 19590 | 36.06 | 18980 – 19500 | 42.3 | 18980 – 19400 | 52.38 | 18980 – 19300 | 68.75 |
| 19590 – 19600 | 8150 | 19500 – 19600 | 815 | 19400 – 19600 | 407.5 | 19300 – 19600 | **272** |
| **5b****(62.5)** | 19600 – 20140 | 0 | 19600 – 20050 | 0 | 19600 – 19950 | 0 | 19600 – 19850 | 0 |
| 20140 – 20150 | 6250 | 20050 – 20150 | 625 | 19950 – 20150 | 312.5 | 19850 – 20150 | **265** |

b) GeoB 1711-4 (long-term average rate: 13 cm/kyr)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Plateau No./****Plateau length [cm]** | **10 yr cycle** | **100 yr cycle** | **200 yr cycle** | **300 yr cylce** |
| **Time span** | **Sed. rate [cm/ky]** | **Time span** | **Sed. rate [cm/ky]** | **Time span** | **D Sed. rate [cm/ky]** | **Time span** | **Sed. rate [cm/ky]** |
| **1****(10.0)** | 14050 – 14911 | 0 | 14050 – 14821 | 0 | 14050 – 14721 | 0 | 14050 – 14621 | 0 |
| 14911 – 14921 | 1000 | 14821 – 14921 | 100 | 14721 – 14921 | 50 | 14621 – 14921 | 33 |
| **2a****(16.0)** | 14921 – 16040 | 2.23 | 14921 – 15950 | 2.42 | 14921 – 15850 | 2.69 | 14921 – 15750 | 3.01 |
| 16040 – 16050 | 1600 | 15950 – 16050 | 160 | 15850 – 16050 | 80 | 15750 – 16050 | **53** |
| **2b****(6.5)** | 16050 – 16390 | 0 | 16050 – 16300 | 0 | 16050 – 16200 | 0 | 16050 – 16100 | 0 |
| 16390 –16400 | 650 | 16300 – 16400 | 65 | 16200 – 16400 | 32.5 | 16100 –16400 | 22 |
| **3****(8.5)** | 16400 – 17570 | 1.28 | 16400 – 17480 | 1.38 | 16400 – 17380 | 1.53 | 16400 – 17280 | 1.7 |
| 17570 – 17580 | 850 | 17480 – 17580 | 85 | 17380 – 17580 | 42.5 | 17280 – 17580 | 28 |
| **4****(5.0)** | 17580 – 18970 | 7.19 | 17580 –18880 | 7.69 | 17580 – 18780 | 8.33 | 17580 – 18680 | 9.09 |
| 18970 – 18980 | 500 | 18880 – 18980 | 50 | 18780 – 18980 | 25 | 18680 – 18980 | 17 |
| **5a****(11.0)** | 18980 – 19590 | 4.09 | 18980 – 19500 | 4.8 | 18980 – 19400 | 5.95 | 18980 – 19300 | 7.91 |
| 19590 – 19600 | 1100 | 19500 – 19600 | 110 | 19400 – 19600 | 55 | 19300 – 19600 | **37** |
| **5b****(6.5)** | 19600 – 20140 | 0 | 19600 – 20050 | 0 | 19600 – 19950 | 0 | 19600 – 19850 | 0 |
| 20140 – 20150 | 650 | 20050 – 20150 | 65 | 19950 – 20150 | 32.5 | 19850 – 20150 | 22 |
| **6a****(11.0)** | 20150 – 21410 | 1.98 | 20150 – 21320 | 2.13 | 20150 – 21220 | 2.33 | 20150 – 21120 | 2.57 |
| 21410 – 21420 | 1100 | 21320 – 21420 | 110 | 21220 – 21420 | 55 | 21120 – 21420 | 37 |

c) GeoB 3910-1 (long-term average rate: 17 cm/kyr)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Plateau No./****Plateau length [cm]** | **10 yr cycle** | **100 yr cycle** | **200 yr cycle** | **300 yr cycle** |
| **Time span** | **Sed. rate [cm/ky]** | **Time span** | **Sed. rate [cm/ky]** | **Time span** | **Sed. rate [cm/ky]** | **Time span** | **Sed. rate [cm/ky]** |
| **1a****(5.0)** | 13640 – 13930 | 0 | 13640 – 13840 | 0 | 13640 – 13740 | 0 | - | - |
| 13930 – 13940 | 500 | 13840 –13940 | 50 | 13740 – 13940 | 25 | 13640 – 13940 | 17 |
| **1****(5.5)** | 13940 – 14911 | 1.02 | 13940 – 14821 | 1.13 | 13940 – 14721 | 1.28 | 13940 – 14621 | 1.46 |
| 14911 – 14921 | 1550 | 14821 – 14921 | 155 | 14721 –14921 | 77.5 | 14621 – 14921 | **52** |
| **2a****(30.5)** | 14921 – 16040 | 0.89 | 14921 – 15950 | 0.97 | 14921 – 15850 | 1.07 | 14921 –15750 | 1.2 |
| 16040 – 16050 | 3050 | 15950 – 16050 | 305 | 15850 – 16050 | 152.5 | 15750 – 16050 | **102** |
| **2b****(7.5)** | 16050 – 16390 | 0 | 16950 – 16300 | 0 | 16050 – 16200 | 0 | 16050 – 16100 | 0 |
| 16390 – 16400 | 700 | 16300 – 16400 | 70 | 16200 – 16400 | 35 | 16100 –16400 | 23 |
| **3****(6.5)** | 16400 – 17570 | 1.28 | 16400 – 17480 | 1.38 | 16400 – 17380 | 1.53 | 16400 – 17280 | 1.7 |
| 17570 – 17580 | 650 | 17480 – 17580 | 65 | 17380 – 17580 | 32.5 | 17280 – 17580 | 22 |

d) KNR 159-5-36GGC (long-term average rate: 16 cm/kyr)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Plateau No./****Plateau length [cm|** | **10 yr cycle** | **100 yr cycle** | **200 yr** | **300 yr** |
| **Time span** | **Sed. rate [cm/ky]** | **Time span** | **Sed. rate [cm/ky]** | **Time span** | **Sed. rate [cm/ky]** | **Time span** | **Sed. rate [cm/ky]** |
| **YD****(8.0)** | 12570 – 12840 | 0 | 12570 – 12750 | 0 | 12570 – 12650 | 0 | - | - |
| 12840 –12850 | 800 | 12750 – 12850 | 80 | 12650 – 12850 | 40 | 12550 – 12850 | 26.6 |
| **1a****(5.75)** | 12850 – 13930 | 3.7 | 12850 – 13840 | 4.04 | 12850 – 13740 | 4.49 | 12850 – 13640 | 5.06 |
| 13920 – 13940 | 575 | 13840 – 13940 | 57.5 | 13740 – 13940 | 28.75 | 13640 – 13940 | 19 |
| **1****(2.25)** | 13940 – 14911 | 0 | 13940 – 14821 | 0 | 13940 – 14821 | 0 | 13940 – 14621 | 0 |
| 14911 – 14921 | 1225 | 14821 – 14921 | 122.5 | 14821 –14921 | 61.25 | 14621 – 14921 | 41 |
| **2a****(28.5)** | 14921 – 16040 | 1.78 | 14921 – 15950 | 1.94 | 14921 – 15850 | 2.15 | 14921 – 15750 | 2.41 |
| 16040 – 16050 | 2850 | 15950 – 16050 | 285 | 15850 – 16050 | 142.5 | 15750 – 16050 | **95** |
| **2b****(9.75)** | 16050 – 16390 | 0 | 16050 – 16300 | 0 | 16050 – 16200 | 0 | 16050 – 16100 | 0 |
| 16390 –16400 | 975 | 16300 – 16400 | 97.5 | 16200 – 16400 | 48.75 | 16100 – 16400 | 33 |
| **3****(16.0)** | 16400 – 17570 | 4.91 | 16400 – 17480 | 5.32 | 16400 – 17380 | 5.86 | 16400 – 17280 | 6.53 |
| 17570 – 17580 | 1600 | 17480 – 17580 | 160 | 17380 – 17580 | 78.75 | 17280 – 17580 | 53 |
| **4****(11.25)** | 17580 – 18970 | 1.79 | 17580 – 18880 | 1.73 | 17580 – 18780 | 1.87 | 17580 – 18680 | 2.04 |
| 18970 – 18980 | 1125 | 18880 – 18980 | 112.5 | 18780 – 18980 | 56.25 | 18680 – 18980 | **38** |
| **5a****(5.0)** | 18980 – 19590 | 2.45 | 18980 – 19500 | 2.88 | 18980 – 19400 | 3.57 | 18980 – 19300 | 4.68 |
| 19590 – 19600 | 500 | 19500 – 19600 | 50 | 19400 – 19600 | 25 | 19300 – 19600 | 17 |

e) ODP 1002 (long-term average rate: 62 cm/kyr)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Plateau No./****Plateau length [cm]** | **10 yr cycle** | **100yr cycle** | **200 yr** | **300 yr** |
| **Time span** | **Sed. rate [cm/ky]** | **Time span** | **Sed. rate [cm/ky]** | **Time span** | **Sed. rate [cm/ky]** | **Time span** | **Sed. rate [cm/ky]** |
| **1a****(21.0)** | 13640 – 13930 | 0 | 13640 – 13840 | 0 | 13640 – 13740 | 0 | – | – |
| 13930 – 13940 | 2100 | 13840 – 13940 | 210 | 13740 – 13940 | 105 | 13640  – 13940 | 70 |
| **1****(28.0)** | 13940 – 14911 | 17.5 | 13940 – 14821 | 19.29 | 13940 –14721 | 21.76 | 13940 – 14621 | 24.96 |
| 14911 – 14921 | 2770 | 14821 – 14921 | 277 | 14721 – 14921 | 138.5 | 14621 – 14921 | 93 |
| **2a****(98.0)** | 14921 – 16040 | 16.97 | 14921 – 15950 | 18.46 | 14921 –15850 | 20.45 | 14921 – 15750 | 22.91 |
| 16040 – 16050 | 9830 | 15950 – 16050 | 983 | 15850 – 16050 | 491.5 | 15750 – 16050 | **326** |
| **2b****(30.0)** | 16050 – 16390 | 0 | 16050 – 16300 | 0 | 16050 – 16200 | 0 | 16050 – 16100 | 0 |
| 16390 – 16400 | 3000 | 16300 – 16400 | 300 | 16200 – 16400 | 150 | 16100 – 16400 | 100 |
| **3****(27.0)** | 16400 – 17570 | 12.82 | 16400 – 17480 | 13.88 | 16400 – 17380 | 25.51 | 16400 – 17280 | 17.04 |
| 17570 – 17580 | 2670 | 17480 – 17580 | 267 | 17380 – 17580 | 133.5 | 17280 – 17580 | 90 |
| **4****(25.0)** | 17580 – 18970 | 17.98 | 17580 – 18880 | 19.23 | 17580 – 18780 | 20.83 | 17580 – 18680 | 22.72 |
| 18970 – 18980 | 2500 | 18880 – 18980 | 250 | 18780 – 18980 | 125 | 18680 – 18980 | 83 |
| **5a****(23.0)** | 18980 – 19590 | 62.29 | 18980 – 19500 | 73.07 | 18980 – 19400 | 90.47 | 18980 – 19300 | 118.75 |
| 19590 – 19600 | 2270 | 19500 – 19600 | 227 | 19400 – 19600 | 113.5 | 19300 – 19600 | 76 |
| **5b****(22.0)** | 19600 – 20140 | 0 | 19600 – 20050 | 0 | 19600 – 19950 | 0 | 19600 – 19850 | 0 |
| 20140 – 20150 | 2230 | 20050 – 20150 | 223 | 19950 – 20150 | 111.5 | 19850 – 20150 | 73 |
| **6a****(70.0)** | 20150 – 21390 | 14.51 | 20150 – 21300 | 15.65 | 20150 – 21200 | 17.14 | 20150 – 21100 | 18.94 |
| 21390 – 21400 | 4400 | 21300 – 21400 | 440 | 21200 – 21400 | 220 | 21100 – 21400 | 146 |
| **6b****(35.0)** | 21400 – 21860 | 0 | 21400 – 21770 | 0 | 21400 – 21670 | 0 | 21400 – 21570 | 0 |
| 21860 – 21870 | 6100 | 21770 – 21870 | 610 | 21670 –21870 | 305 | 21570 – 21870 | **203** |
| **7****(34.0)** | 21870 – 22305 | 9.19 | 21870 – 22215 | 11.59 | 21870 – 22115 | 16.32 | 21870 – 22015 | 27.58 |
| 22305 – 22315 | 3400 | 22215 – 22315 | 340 | 22115 – 22315 | 170 | 22015 – 22315 | 113 |

**Table S2:** Age control points for sedimentation rates estimated by means of 14C plateau tuning. Data sets from a) – c) Balmer et al. (subm); d) Balmer and Sarnthein (subm, revised), e) Sarnthein et al. (2015).

a) GeoB 1711-4

|  |  |  |  |
| --- | --- | --- | --- |
| **14C Plateau boundaries****used as tie points** | **Calendar age [yr]** | **Core depth [cm]** | **Sedimentation rate [cm/kyr]** |
| Top 1 – Base 1 | 14050 - 14921 | 115 – 125 | 11.4 |
| Base 1 – Base 2a / Top 2b | 14921 - 16050 | 125 – 143.5 | 16.3 |
| Top 2b – Top 3 | 16050 - 16890 | 143.5 – 151.5 | 9.5 |
| Top 3 – Base 3 | 16890 - 17580 | 151.5 – 160 | 12.3 |
| Base 3 – Base 4 | 17580 - 18980 | 160 – 175 | 10.7 |
| Base 4 – Base 5a / Top 5b | 18980 - 19600 | 175 – 188.5 | 21.7 |
| Top 5b – Base 5b | 19600 - 20150 | 188.5 – 208.5 | 11.8 |
| Base 5b – Base 6a | 20150 - 21420 | 195 – 208.5 | 10.6 |

b) GeoB 3910-1

|  |  |  |  |
| --- | --- | --- | --- |
| **14C Plateau boundaries****used as tie points** | **Calendar age [yr]** | **Core depth [cm]** | **Sedimentation rate [cm/kyr]** |
| Top 1a– Base 1a | 13640 - 13940 | 83 – 88.5 | 16.7 |
| Base 1a – Base 1 | 13940 - 14921 | 88.5 – 105 | 16.8 |
| Base 1 – Base 2a / Top 2b | 14921 - 16050 | 105– 136.5 | 27.9 |
| Top 2b – Top 3 | 16050 - 16890 | 136.5– 145 | 10.1 |
| Top 3 – Base 3 | 16890 - 17580 | 145 – 151.5 | 9.4 |

c) KNR-159-5-36GGC

|  |  |  |  |
| --- | --- | --- | --- |
| **14C Plateau boundaries****used as tie points** | **Calendar age [yr]** | **Core depth [cm]** | **Sedimentation rate [cm/kyr]** |
| Top YD– Base YD | 12570 - 13000 | 70 – 78.5 | 18.6 |
| Base YD – Base 1a | 13000 - 13940 | 78.5 – 88.25 | 10.3 |
| Base 1a – Base 1 | 13940 - 14921 | 88.25– 100.5 | 12.4 |
| Base 1 – Base 2a / Top 2b | 14921 - 16050 | 100.5– 131 | 27 |
| Top 2b – Top 3 | 16050 - 16890 | 131 – 146.5 | 18.4 |
| Top 3 – Top 4 | 16890 – 18000 | 146.5 – 164.75 | 16.4 |
| Top 4 – Top 5a | 18000 – 19130 | 164.75 – 177.5 | 11.2 |
| Top 5a – Base 5a | 19130 - 19600 | 177.5 – 182.5 | 10.6 |

d) MD08-3180

|  |  |  |  |
| --- | --- | --- | --- |
| **14C plateau boundaries****used as tie points** | **Calendar age [yr]** | **Core depth [cm]** | **Sedimentation rate [cm/kyr]** |
| Top 1a – Top 1 | 13640 – 14050 | 272.5 – 291 | 45.1 |
| Top 1 – Top 2a | 14050 – 15272 | 291 – 324.5 | 27.4 |
| Top 2a – Base 2a/ Top 2b | 15272 – 16050 | 324.5 – 376 | 66.0 |
| Top 2b – Top 3 | 16050 – 16900 | 376 – 434.5 | 68.8 |
| Top 3 – Top 4 | 16900 – 18000 | 434.5 – 498.5 | 58.1 |
| Top 4 – Base 4 | 18000 – 18980 | 498.5 – 603 | 106.6 |
| Base 4 – Base 5a / Top 5b | 18980 – 19600 | 603 – 706.5 | 166.9 |
| Top 5b – Base 5b | 19600 – 20150 | 706.5 – 769 | 113.6 |

e) ODP 1002

|  |  |  |  |
| --- | --- | --- | --- |
| **14C plateau boundaries****used as tie points** | **Calendar age [yr]** | **Core depth [cm]** | **Sedimentation rate [cm/kyr]** |
| Top 1 – Base 1 | 14050 – 14921 | 526 – 554 | 46.7 |
| Base 1 – Base 2a / Top 2b | 14921 – 16050 | 554 – 671 | 98.3 |
| Base 2a/ Top 2b – Base 2b | 16050 – 16400 | 671 – 701 | 30 |
| Base 2b – Base 3 | 16400 – 17580 | 701– 743 | 41.7 |
| Base 3 – Base 4 | 17580 – 18980 | 743 – 793 | 50 |
| Base 4 – Base 5a / Top 5b | 18980 – 19600 | 793 – 854 | 61 |
| Base 5a / Top 5b – Base 5b | 19600 – 20150 | 854 – 876 | 22.3 |
| Base 5b– Base 6a / Top 6b | 20150 – 21400 | 876 – 938 | 61.7 |
| Base 6a / Top 6b – Base 6b | 21400 – 21870 | 938 – 999 | 52 |
| Base 6b – Base 7 | 21870 – 223315 | 999 – 1039 | 49 |