**Precipitation variability within the West Pacific Warm Pool over the past 120 ka: evidence from the Davao Gulf, southern Philippines.**

**Auxiliary Material**

*1. Calibration of Uk’­37 alkenone unsaturation ratios to SST*

A comparison between two different calibrations of UK’­37 to SST in Core MD06-3075 is provided in Auxiliary Material Figure 1. The calibration of Müller et al. [1998] (temperatures denoted in this section by °CM) suggests an overall SST range between 25.9 °CM and 28.6 °CM, with a magnitude of deglacial warming of 2.3 °CM. The Sonzogni et al. [1997] calibration (temperatures denoted in this section by °CS) suggests an SST range of 25.3 °CS to 29.2 °CS with a deglacial warming of 3.4 °CS. An average of the upper three Holocene measurements gives a core-top SST estimate of 28.3 °CM or 28.7 °CS. We suggest that the Sonzogni et al. [1997] calibration performs better over our temperature spectrum based upon: (1) the consistency between core top SSTs (28.7 °C­S) compared to modern day annual SSTs at our locality (28.7 °C) [Locarnini et al., 2010], in comparison to values derived from calibration of Müller et al. [1998] (28.3 °CM), (2) the similar magnitude of deglacial warming over Termination I (3.4 °CS) to the 3.5 °C warming amplitude derived from Mg/Ca reconstructions in the nearby Core MD98-2181 [Stott et al., 2007], compared to the 2.3 °CM magnitude in the Müller et al. [1998] calibration. Additionally, it has been suggested that towards the limits of alkenone saturation the relationship between temperature and the UK’­37 index probably diverges from a linear path and displays a sigmoidal relationship [Sonzogni et al., 1997; Conte et al., 2006]. This explains the lower variability in the Müller et al. [1998] calibration, which invokes a linear UK’­37/T gradient over the full temperature range, whereas the Sonzogni et al. [1997] calibration is calibrated specifically to high temperatures (> 25 °C). For our main discussion, we therefore presented temperatures calculated from the equations of Sonzogni et al. [1997].

*2. SSTs of the tropical West Pacific*

New records of UK’37 calibrated to SST from Core MD06-3075 show a deglacial warming amplitude of 3.4 °C over Termination I (Main Text Figure 4), consistent with the 2 - 4 °C warming documented in other WPWP records from both coccolithophore-based UK’37 analysis [e.g. Pelejero and Grimalt, 1997; Shiau et al., 2012] and Mg/Ca analysis of *G. ruber* [e.g. Stott et al., 2002, 2007; Visser et al., 2003; Rosenthal et al., 2003, Medina-Elizalde and Lea, 2005]. Paired Mg/Ca and UK’37 analyses in tropical regions have demonstrated that major differences in the timing of the onset of temperature variability using the two methodologies exist over the last deglaciation [Saher et al., 2009, Western Arabian Sea; Mix, 2006, EEP; de Garidel-Thoron et al., 2007, WPWP; Steinke et al., 2008, South China Sea; Wang et al., 2013, Indian Ocean]. A comparison of our UK’37 based temperature record over Termination I with the Mg/Ca derived temperature record of Core MD98-2181 [Stott et al., 2002, 2007] allows us to assess this phenomenon (Auxiliary Material Figure 2). Both records agree on a contemporaneous temperature increase beginning between 17.5 and 18 ka, with no significant cooling trend observed in the MD06-3075 UK’37 SST record between 18 and 15 ka, as has been documented in other tropical UK’37 records [e.g. Steinke et al., 2008]. During the Bølling-Allerød (BA, ~14.6 - 12.8 ka) period, UK’37 SSTs plateau at 27.2 °C whilst Mg/Ca temperatures continue a relatively unabated warming trend. Maximum divergence between the two records occurs at the end of the BA period, with temperature differences exceeding 2.5 °C.

We suggest that these differences occur as a result of the seasonal-weighting of recorded temperatures in planktonic foraminifera versus coccolithophores, mirroring proxy mismatches that have been reported in previous comparative studies of Mg/Ca and alkenone based paleothermometry [Wang et al., 2013; Timmermann et al., 2014]. We expect Mg/Ca derived temperatures from *G. ruber* to be weighted towards summer surface conditions due to the seasonal dominance of *G. ruber* during June to October in the WPWP [Kawahata et al., 2002]. In contrast, maximum fluxes of coccolithophores generally occur in winter months [Tanaka and Kawahata, 2001] coincident with peak wind stress (Main Text Figure 2), with maximum fluxes of alkenone producing coccolithophores *E. huxleyi* and *G. oceanica* occurring between December and February. Coccolithophore-based temperatures are therefore weighted significantly towards winter months. Since seasonality (in terms of the insolation difference between summer and winter) increased at our study location between 20 and 10 ka, the resulting temperature offset between the two methodologies may be representative of the more extreme summer versus winter SSTs in the WPWP.

During the last glacial period, high-resolution Mg/Ca SST records from the Davao Gulf [Saikku et al., 2009] indicate a link between high latitude climate dynamics and SST, with cooler temperatures being observed during Heinrich stadials and warmer temperatures during Dansgaard-Oeschger interstadials. In contrast, records from the Sulu Sea [Dannenmann et al., 2003] indicate that SSTs were not in phase with northern hemisphere ice core δ18O records over MIS 3. UK’37 SST records from Core MD06-3075 also show little coherent response to Dansgaard-Oeschger interstadials or Heinrich stadials. However, this lack of response may be partially attributed to low sedimentation rates during the glacial period giving an average sample resolution of only ~700 yrs, which may not be high enough to resolve centennial to millennial scale variability.

An unusual feature observed in the MD06-3075 SST records is the temperatures recorded during MIS 5a and 5c, which are found to be in excess of Holocene values, when most WPWP Mg/Ca records predict temperatures ~0.5 °C cooler during MIS 5a and 5c than the Holocene [e.g. Medina-Elizalde and Lea, 2005, Bolliet et al., 2011] (Main Text Figure 4). The difference between these different WPWP SST reconstructions in MIS 5 may be partially explained by the afore-mentioned seasonality effect on Uk’37 compared to Mg/Ca reconstructions, or by the large variability in hydrological regimes and paleoproductivity (Main Text Figure 4) during these periods, which may have acted to alter the depth habitats of alkenone producing coccolithophores.

*References*

Bolliet, T., A. Holbourn, W. Kuhnt, C. Laj, C. Kissel, L. Beaufort, M. Kienast, N. Andersen, and D. Garbe-Schönberg (2011), Mindanao Dome variability over the last 160 kyr: Episodic glacial cooling of the West Pacific Warm Pool, Paleoceanography, 26, PA1208, doi:10.1029/2010PA001966.

Conte, M. H., M. A. Sicre, C. Rühlemann, J. C. Weber, S. Schulte, D. Schulz-Bull, and T. Blanz (2006), Global temperature calibration of the alkenone unsaturation index (Uk′37) in surface waters and comparison with surface sediments, Geochem. Geophys. Geosyst., 7, Q02005, doi:10.1029/2005GC001054.

Dannenmann, S., B. K. Linsley, D. W. Oppo, Y. Rosenthal, and L. Beaufort (2003), East Asian monsoon forcing of suborbital variability in the Sulu Sea during Marine Isotope Stage 3: Link to Northern Hemisphere climate, Geochemistry, Geophysics, Geosystems, 4(1), 1-13, doi: 10.1029/2002GC000390.

de Garidel-Thoron, T., Y. Rosenthal, L. Beaufort, E. Bard, C. Sonzogni, and A. C. Mix (2007), A multiproxy assessment of the western equatorial Pacific hydrography during the last 30 kyr, Paleoceanography, 22, PA3204, doi: 10.1029/2006PA001269.

Fairbanks, R. G., R. A. Mortlock, T. Chiu, L. Cao, A. Kaplan, T. P. Guilderson, T. W. Fairbanks, A. L. Bloom, P. M. Grootes, and M. -J. Nadeau (2005) Radiocarbon calibration curve spanning 0 to 50,000 years BP based on paired 230Th/234U/238U and 14C dates on pristine corals, Quaternary Science Reviews, 24(16), 1781-1796, doi: 10.1016/j.quascirev.2005.04.007.

Kawahata, H., A. Nishimura, and M. K. Gagan (2002), Seasonal change in foraminiferal production in the western equatorial Pacific warm pool: evidence from sediment trap experiments, Deep Sea Research Part II: Topical Studies in Oceanography, 49(13), 2783-2800, doi: 10.1016/S0967-0645(02)00058-9.

Khider, D., C. S. Jackson, and L. D. Stott (2014), Assessing millennial‐scale variability during the Holocene: a perspective from the western tropical Pacific, Paleoceanography, 29(3), 143-159, doi: 10.1002/2013PA002534.

Locarnini, R. A., A. V. Mishonov, J. I. Antonov, T. P. Boyer, H. E. Garcia, O. K. Baranova, M. M. Zweng, and D. R. Johnson (2010), World Ocean Atlas 2009, Volume 1: Temperature, S. Levitus, Ed. NOAA Atlas NESDIS 68, U.S. Government Printing Office, Washington, D.C., 1-184.

Medina-Elizalde, M. N., and D. W. Lea (2005), The mid-Pleistocene transition in the Tropical Pacific, Science, 310(5750), 1009-1012, doi: 10.1126/science.1115933.

Mix, A. C. (2006), Running hot and cold in the eastern equatorial Pacific, Quaternary Science Reviews, 25(11), 1147-1149, doi: 10.1126/science.1115933.

Müller, P. J., G. Kirst, G. Ruhland, I. von Storch, and A. Rosell-Melé (1998), Calibration of the alkenone paleotemperature index Uk'37 based on core-tops from the eastern South Atlantic and the global ocean (60°N-60°S), Geochimica et Cosmochimica Acta, 62(10), 1757-1772, doi: 10.1016/S0016-7037(98)00097-0.

Paillard, D., Labeyrie, L., Yiou, P. (1996), Macintosh program performs time-series analysis. EOS Trans. AGU, 77.

Pelejero, C., and Grimalt, J. O. (1997), The correlation between the Uk'37 index and sea surface temperatures in the warm boundary: The South China Sea, Geochimica et Cosmochimica Acta, 61(22), 4789-4797, doi: 10.1016/S0016-7037(97)00280-9.

Rosenthal, Y., D. W. Oppo, and B. K. Linsley (2003), The amplitude and phasing of climate change during the last deglaciation in the Sulu Sea, western equatorial Pacific, Geophys. Res. Lett., 30, 1428, doi:10.1029/2002GL016612.

Ruth, U., J. -M. Barnola, J. Beer, M. Bigler, T. Blunier, E. Castellano, H. Fischer, F. Fundel, P. Huybrechts, and P. Kaufmann (2007), "EDML1": a chronology for the EPICA deep ice core from Dronning Maud Land, Antarctica, over the last 150 000 years, Climate of the Past Discussions, 3(2), 549-574, doi: 10.5194/cp-3-475-2007.

Saher, M., F. Rostek, S. Jung, E. Bard, R. Schneider, M. Greaves, G. Ganssen, H. Elderfield, and D. Kroon (2009), Western Arabian Sea SST during the penultimate interglacial: A comparison of Uk'37 and Mg/Ca paleothermometry, Paleoceanography, 24(2), PA2212, doi: 10.1029/2007PA001557.

Saikku, R., L. Stott, and R. Thunell (2009), A bi-polar signal recorded in the western tropical Pacific: Northern and Southern Hemisphere climate records from the Pacific warm pool during the last Ice Age, Quaternary Science Reviews, 28(23), 2374-2385, doi: 10.1016/j.quascirev.2009.05.007.

Shiau, L. -J., M. -T. Chen, C. -A. Huh, M. Yamamoto, and Y. Yokoyama (2012), Insolation and cross-hemispheric controls on Australian monsoon variability over the past 180 ka: new evidence from offshore southeastern Papua New Guinea, Journal of Quaternary Science, 27(9), 911-920, doi: 10.1002/jqs.2581.

Sonzogni, C., E. Bard, F. Rostek, D. Dollfus, A. Rosell-Melé, and G. Eglinton (1997), Temperature and salinity effects on alkenone ratios measured in surface sediments from the Indian Ocean, Quaternary Research, 47(3), 344-355, doi: 10.1006/qres.1997.1885.

Steinke, S., M. Kienast, J. Groeneveld, L.-C. Lin, M.-T. Chen, and R. Rendle-Bühring (2008), Proxy dependence of the temporal pattern of deglacial warming in the tropical South China Sea: toward resolving seasonality, Quaternary Science Reviews, 27(7), 688-700, doi: 10.1016/j.quascirev.2007.12.003.

Stott, L., C. Poulsen, S. Lund, and R. Thunell (2002), Super ENSO and global climate oscillations at millennial time scales, Science, 297(5579), 222-226, doi: 10.1126/science.1071627.

Stott, L., A. Timmermann, and R. Thunell (2007), Southern hemisphere and deep-sea warming led deglacial atmospheric CO2 rise and tropical warming, Science, 318(5849), 435-438, doi: 10.1126/science.1143791.

Stuiver, M. and P. M. Grootes (2000), GISP2 oxygen isotope ratios, Quaternary Research, 53(3), 277-284. doi: 10.1006/qres.2000.2127.

Tanaka, Y., and H. Kawahata (2001), Seasonal occurrence of coccoliths in sediment traps from West Caroline Basin, equatorial West Pacific Ocean, Marine Micropaleontology, 43(3), 273-284, doi: 10.1016/S0377-8398(01)00027-5.

Timmermann, A., J. Sachs, and O. Elison Timm (2014), Assessing divergent SST behavior during the last 21 ka derived from alkenones and G.ruber-Mg/Ca in the equatorial Pacific, Paleoceanography, 29, 680–696, doi:10.1002/2013PA002598.

Visser, K., R. Thunell, and L. Stott (2003), Magnitude and timing of temperature change in the Indo-Pacific warm pool during deglaciation, Nature, 421(6919), 152-155, doi: 10.1038/nature01297.

Waelbroeck, C., L. Labeyrie, E. Michel, J. C. Duplessy, J. F. McManus, K. Lambeck, E, Balbon, and M. Labracherie( 2002), Sea-level and deep water temperature changes derived from benthic foraminifera isotopic records, Quaternary Science Review, 21, 295-305, doi: 10.1016/S0277-3791(01)00101-9.

Wang, Y. V., G. Leduc, M. Regenberg, N. Andersen, T. Larsen, T. Blanz and R. R. Schneider (2013), Northern and southern hemisphere controls on seasonal sea surface temperatures in the Indian Ocean during the last deglaciation, Paleoceanography, 28, 1-14, doi: 10.1002/palo.20053.

*Auxiliary Table Captions*

Auxiliary Table 1 -AMS 14C dates and tie points used to constrain the age model of Core MD06-3075a

a Conventional ages were converted to calendar ages following Fairbanks et al. [2005]. A reservoir age correction of 480 years was applied for samples younger than 13 ka, and 630 years for older samples. Tie points were created by correlation of δ18O events to the EDML1 Antarctic Ice Core chronology [Ruth et al.,2007]. Absolute tie point ages are given in parentheses; a subsequent 1000-year correction was applied to benthic foraminiferal ages to account for the transit time of Southern Ocean derived deep-water masses in this region [Stott et al., 2007, Khider et al., 2014].

*Auxiliary Figure Captions*

Auxiliary Figure 1 - UK'37 derived SST records calibrated with the equations of Sozogni et al. [1997] (red line) and Müller et al. [1998] (blue line). Grey vertical bars indicate major marine isotope stages, blue vertical bars indicate HS1-6 and the YD.

Auxiliary Figure 2 - Expanded isotope and SST records covering the past 20 ka. (a) Greenland (GISP2) ice core δ18O [Stuiver and Grootes, 2000]. (b) Planktonic δ18O record of Core MD06-3075 (black) and MD98-2181 (blue) [Stott et al., 2002; 2007] based upon the surface dwelling foraminifera *G. ruber.* (c) UK’37-derived SSTs of Core MD06-3075 (black), and Mg/Ca-derived SSTs from core MD98-2181 (blue). (d) Temperature and ice volume corrected δ18Osw records from MD06-3075 (black) and MD98-2181 (blue). Data from Stott et al. [2002, 2007] has been corrected for ice volume effects following Waelbroeck et al. [2002].

Auxiliary Figure 3 - XRF raw counts of elements Ca (black), Fe (red), Ti (dark blue), Al (orange), Si (green) and K (light blue), and the log-ratio of the sum of these terrigenous elements normalised by Ca (raw data in grey; 10-point smooth in purple).

Auxiliary Figure 4 - Top: Normalized power spectra of log(Fe/Ca) and boreal summer insolation (June 21st - September 21st) at 6 °N, together with cross-spectral coherency of both series. Bandwidth is shown by thick black line. 95% confidence interval of non-zero coherency is 0.551. Grey vertical band represents band of precession-scale frequencies. Bottom: Phase spectrum between log(Fe/Ca) and insolation. Positive values indicate lead of insolation over log(Fe/Ca). Cross spectral analysis was performed with Analyseries 2.0 software [Paillard et al., 2006].