Supplementary Information

For

Modal shift in North Atlantic seasonality during the last deglaciation

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Data.xlsx – XRF; IRD %; Single specimen $\delta^{18}O$ and $\delta^{13}C$ of *G. bulloides* and *N. pachyderma*; and Pooled specimen $\delta^{18}O$ of *G. bulloides* and *G. glutinata* data.

S1. Age Model

The age model of core APNAP II T88-3P is based upon a series of six radiocarbon measurements (1; 150; 295; 340; 380; and 500 cm depth in core) of *Globigerina bulloides* and *Neogloboquadrina pachyderma*, as outlined in Table 1, and the pooled oxygen isotope ($\delta^{18}O_c$) values of *G. bulloides* and *Globigerinita glutinata* both of which are considered 'surface' cosmopolitan species.

For radiocarbon dating of core T88-3P pristine specimens of *G. bulloides* and *N. pachyderma* were picked from six samples of core T88-3P and analysed by Accelerated Mass Spectrometry (AMS) at the AMS laboratories of Beta Analytic (Table 1; Fig. 2). A single date was excluded at 500 cm because of the limitations of the calibration curve >35 kyr (Reimer et al., 2016). Each date was calibrated in the open source MatLab function *MatCal* (Lougheed and Obrochta, 2016) to convert conventional radiocarbon age to a calendar age using the Marine13 Calibration curve (Reimer et al., 2013) and a reservoir age of 400 ^{14}C years with an error of 200 ^{14}C years, expressed mathematically as ΔR: 0 ± 200 ^{14}C yr. The 95% confidence limits for the calendar age, in kyr BP, of each sample is given in Table 1. Despite its removal, the upper 500 cm of core T88-3P remained within the limit of radiocarbon dating (<50kyr) and constrained the time represented in core T88-3P.

For a down-core $\delta^{18}O$ stratigraphy, the cosmopolitan upper ocean dweller *G. glutinata* and the subpolar-temperate upper ocean dweller *G. bulloides* were measured for $\delta^{18}O$ and $\delta^{13}C$ using pooled specimens picked from the 250 - 300 μm size fraction, which were placed in mono-specific groups within a 15 ml exetainer vial. Analyses followed the same procedures as for single shell analysis, but with considerably better reproducibility of international standards for the larger sample mass (~100 μg).

The record's chosen as the tuning targets are the benthic foraminifera $\delta^{18}O$ stack (Lisiecki and Raymo, 2005) herein LR04 and the ice core record NGRIP (North Greenland Ice Core Project members et al., 2004). Comparison between the record produced and the tuning (Waelbroeck et al., 2002, 2005) targets selected for this study was done in Mathworks MatLab 2018a. The ice core record represents a high resolution record, therefore to take into account potential smearing, bioturbation or filtering of the climatic signal inherent within deep-sea archives (Lougheed et al., 2018) a simple filter was passed through the data (Figure S1). Given the 'low resolution' of LR04 it was not necessary to pass a filter over this record. The error on tuning is estimated to be 5000 years (Martinson et al., 1987).

First the radiocarbon-age model (Figure S2) was produced using only the six ^{14}C dates as tie-points, following this a LR04 age model was produced (Figure S3) using 14 tie-points based upon assigning ages of T88-3P with LR04, and finally a NGRIP age model was produced (Figure S4) using 11 tie-points based upon assigning ages of T88-3P with NGRIP. The LR04 is a common tuning target in palaeoceanography (Lisiecki and Raymo, 2005) however, analysis has shown that correlation of planktonic foraminiferal $\delta^{18}O$ to the benthic stack (LR04) led to an increased age-depth discrepancy between radiocarbon measurements of core T88-3P. It is worth noting there has been shown to be regional discrepancies (Lisiecki and Raymo, 2009) and here we utilise a planktonic species which may further exacerbate these problems. Therefore, NGRIP was chosen as a tuning target because of its similarity with the 14C based age model and its geographic proximity to the core location. However, it is worth noting that this age model is constructed to aid the reviewer in interpreting the IFA $\delta^{18}O$ and maybe subject to circular reasoning if used for palaeoclimate interpretation (Blaauw, 2012).

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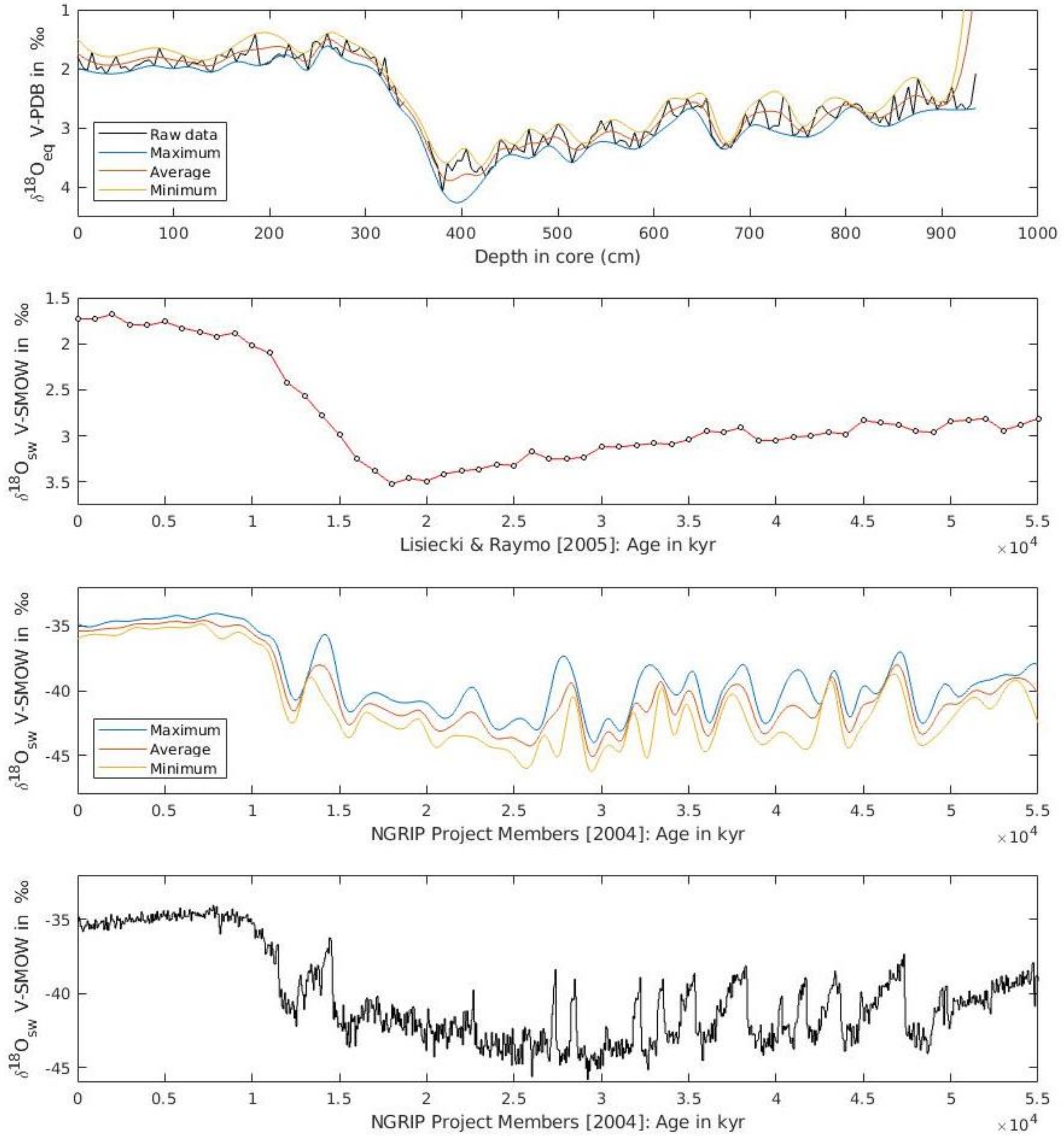

Figure S1: Core data, filters and tuning targets. Core stratigraphy of T88-3P, with (a) down core $\delta^{18}O$ of *G. bulloides* ploted against depth in core (cm) with minimum and maximum filters upon which the average filter is based, (b) the benthic stack record (LR04) of (Lisiecki and Raymo, 2005), a common stratigraphic tool, plotted against age in kyr, (c) filtered and (d) raw data North Greenland Ice Core Project (NGRIP) plotted against ice core age (North Greenland Ice Core Project members et al., 2004). All data is presented in per mil (‰) as either on the V-PDB or V-SMOW scale.

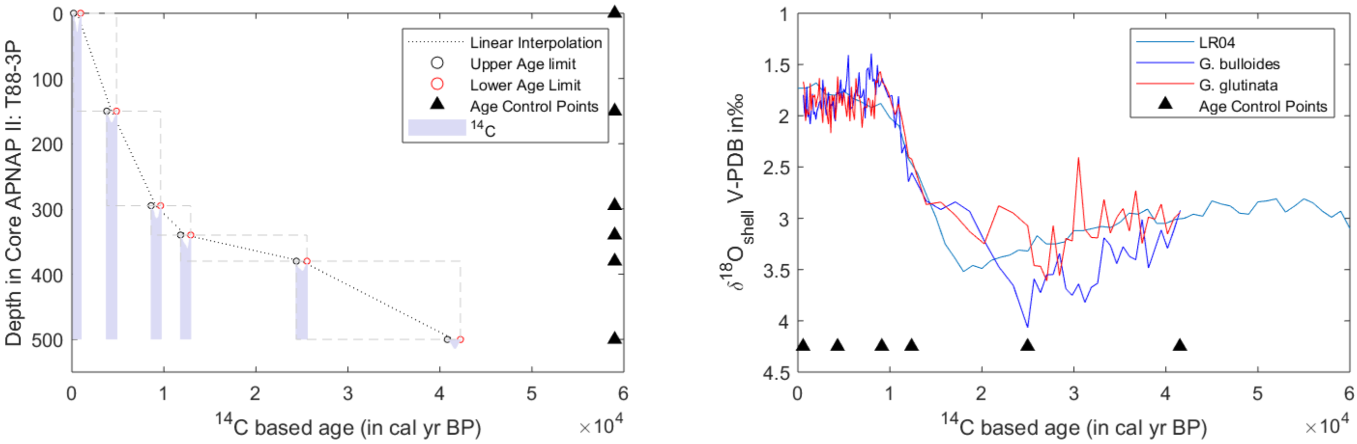

Figure S2: Core stratigraphy of T88-3P based upon ^{14}C. The (L*eft*) Radiocarbon measurements vs. depth, dashed line represents a simple linear interpolation between age-depth points, dashed rectangle indicates the age-depth limits between two tie-points. The resultant (*Right*) $\delta^{18}O_{shell}$ – age was produced, with the blue line representing the LR04 benthic stack.

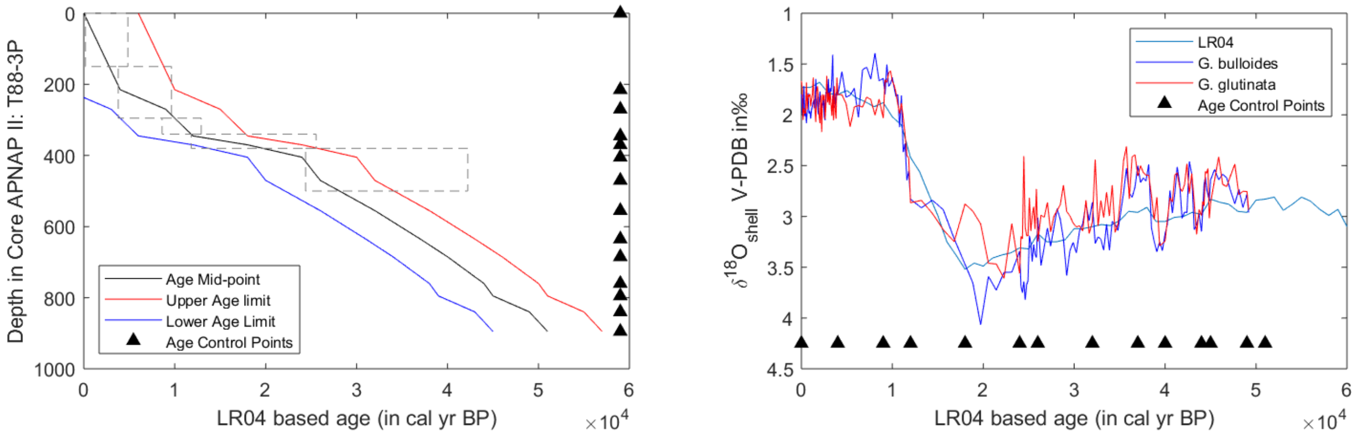

Figure S3: Core stratigraphy of T88-3P based upon LR04. In comparison, the (*left*) $\delta^{18}O$ was tuned to a LR04 (Figure S1), the radiocarbon ages and their 'age boundaries' (dashed boxes) are plotted for a visual comparison. The tuning age is given an error of 5000 years as per Martinson et al. (1987), with (bottom left) the resultant $\delta^{18}O_{shell}$ – age produced. Black triangles represent the age tie-points in (*Left*) depth or (*Right*) age in core T88-3P and the blue line representing the LR04 benthic stack.

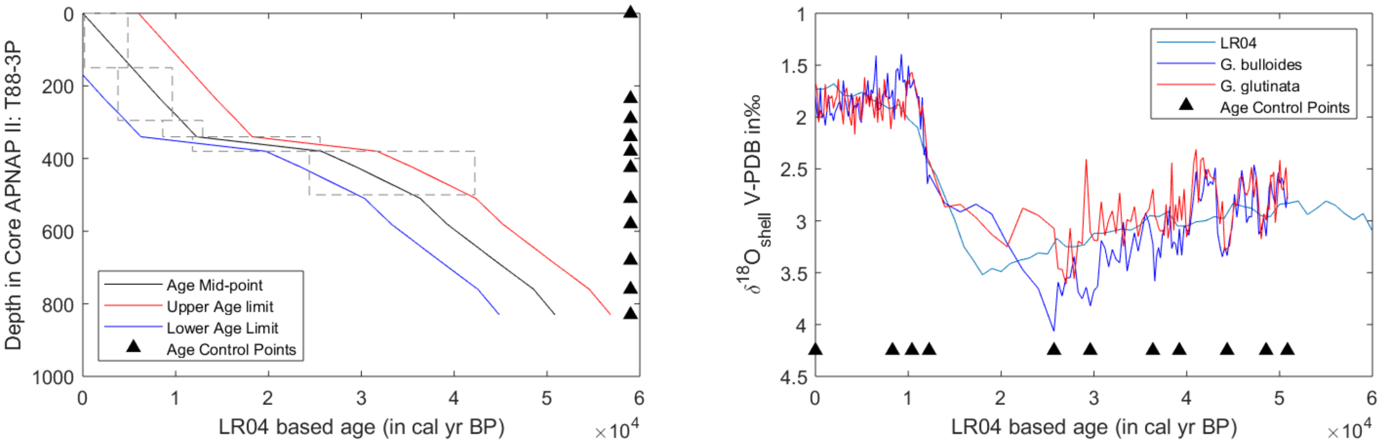

Figure S4: Core stratigraphy of T88-3P based upon NGRIP. In comparison, the (*left*) $\delta^{18}O$ was tuned to a filtered NGRIP (Figure S1), the radiocarbon ages and their 'age boundaries' (dashed boxes) are plotted for a visual comparison. The tuning age is given an error of 5000 years as per Martinson et al. (1987), with (bottom left) the resultant $\delta^{18}O_{shell}$ – age produced. Black triangles represent the age tie-points in (*Left*) depth or (*Right*) age in core T88-3P and the blue line representing the LR04 benthic stack.