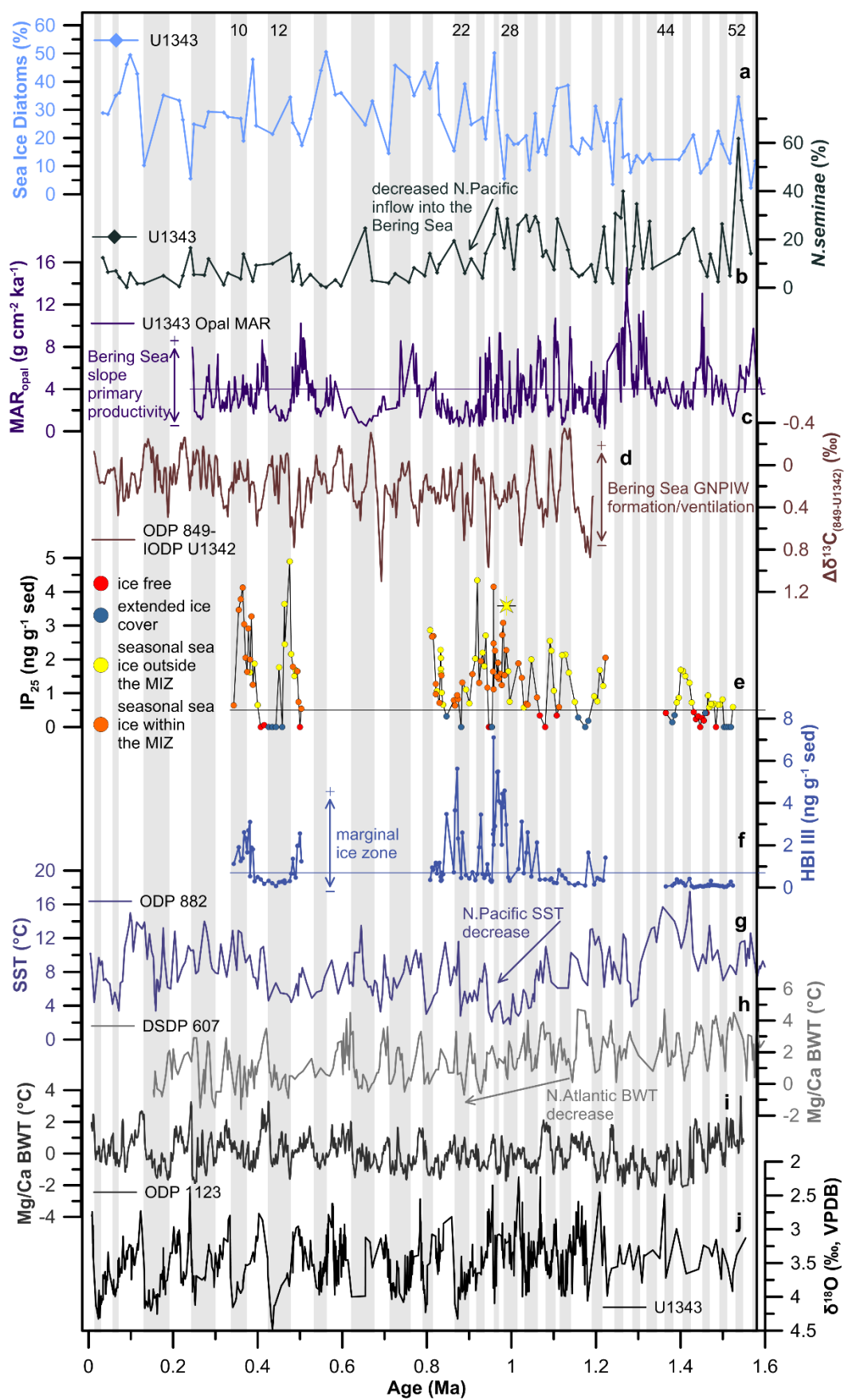
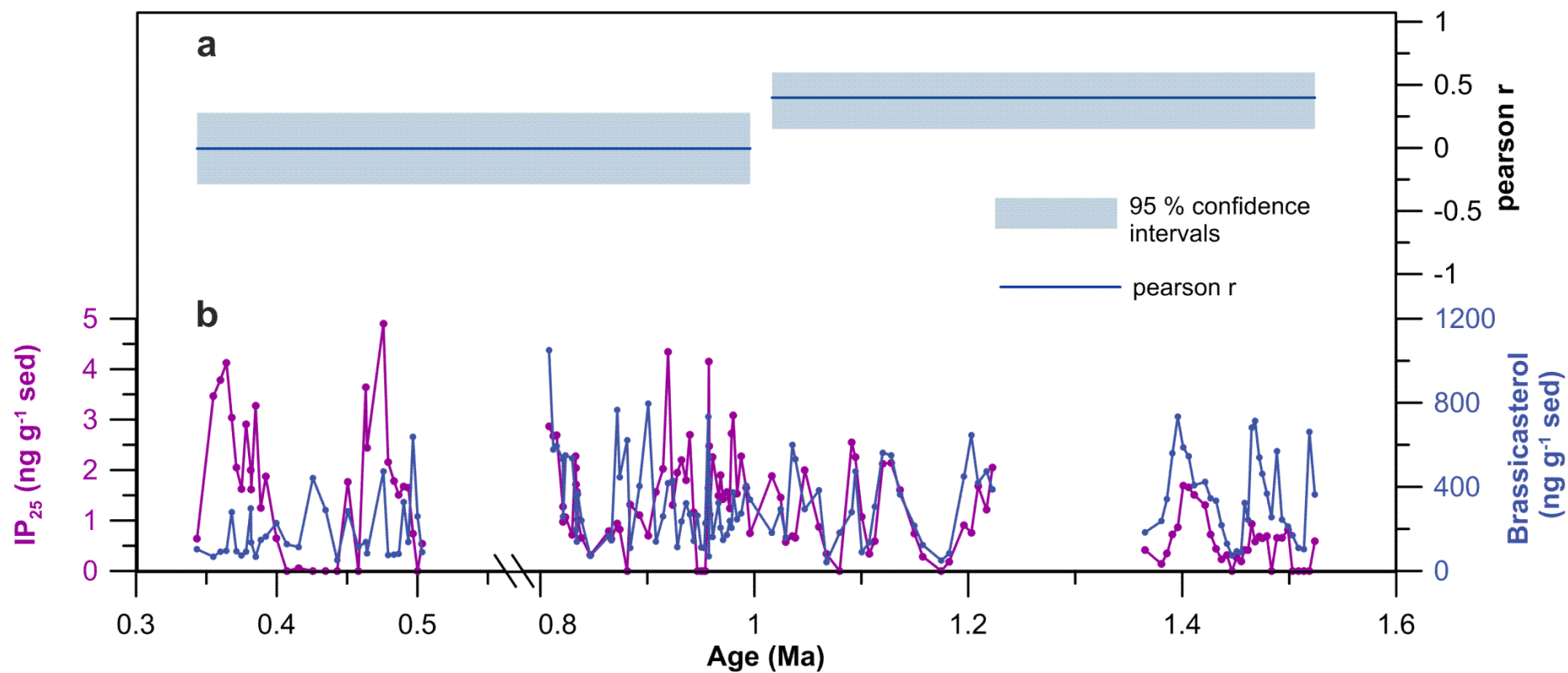


## Supplementary Material



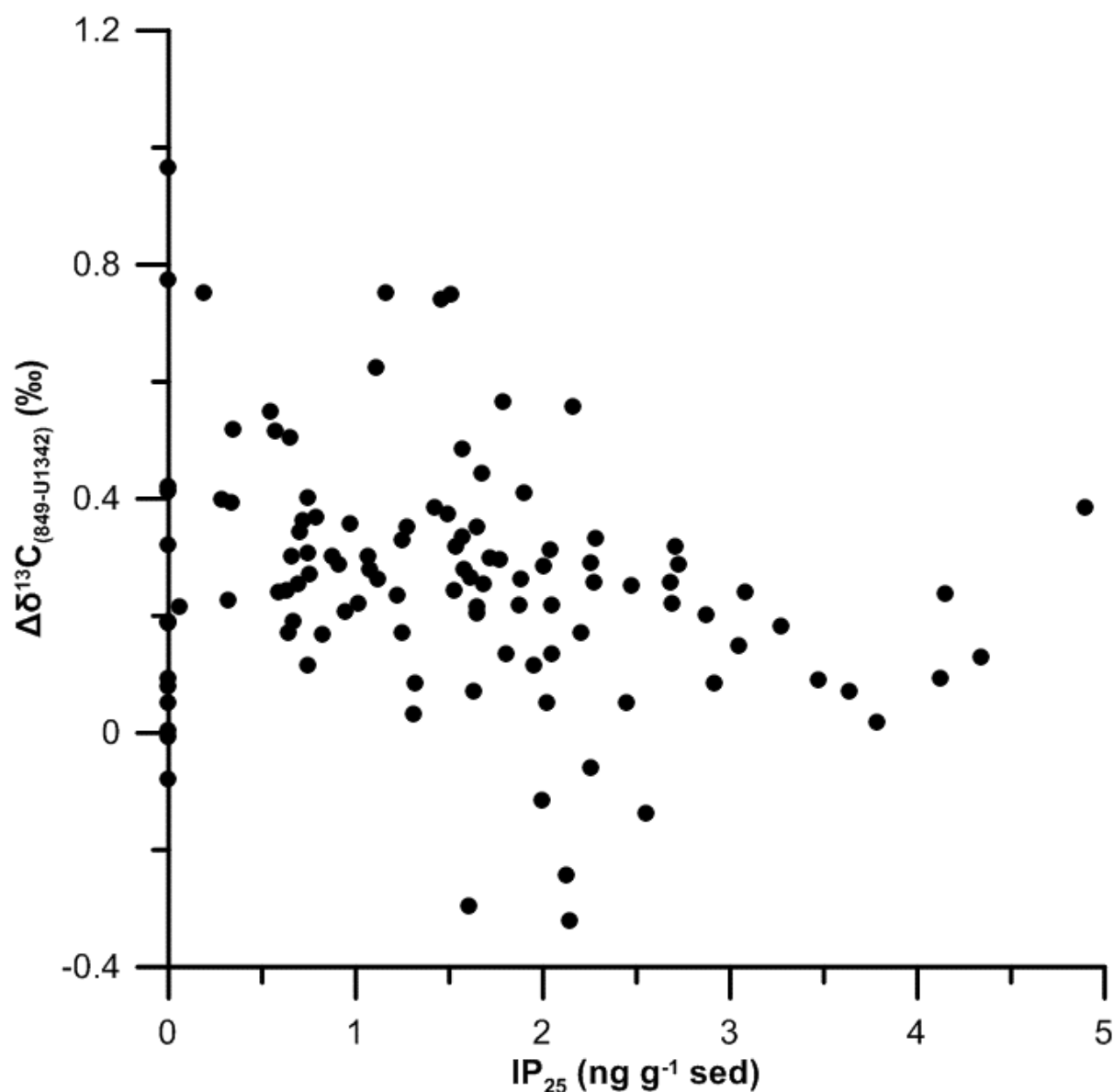
**Supplementary Figure 1. Sea ice dynamics in the Bering Sea (colour coded sea ice states) in comparison with regional and global climate records.**

Overview of regional and global climate records across the Pleistocene. (a) Abundance of sea ice diatoms in Site U1343<sup>1</sup> (light blue). (b) Abundance of *N.seminae* in sediments of Site U1343<sup>1</sup> (dark green). (c) Site U1343 mass accumulation rate of biogenic opal<sup>2</sup> (MAR<sub>opal</sub>) (purple). (d)  $\Delta\delta^{13}\text{C}_{(849-\text{U1342})}$ <sup>3</sup> indicative of GNPIW ventilation/formation (brown). (e) Site U1343 IP<sub>25</sub> record (this study), sea ice regimes are colour-coded as determined in the manuscript (red: ice free, blue: extended ice cover, orange: seasonal sea ice within the MIZ, yellow: seasonal sea ice outside the MIZ). The IP<sub>25</sub> peak labelled with an asterisk denotes the first glacial interval (MIS 28) characterised by a late-glacial/deglacial sea ice maximum. (f) Site U1343 HBI III (blue) record (this study). (g) Alkenone-based North Pacific SSTs ODP Site 882<sup>4</sup> (light purple). (h) BWT in DSDP Site 607<sup>5</sup> in the North Atlantic (light grey). (i) BWT in ODP Site 1123<sup>6</sup> in the southwest Pacific (dark grey). (j) Site U1343  $\delta^{18}\text{O}_b$  record (black)<sup>7</sup>. The horizontal lines in the MAR<sub>opal</sub>, IP<sub>25</sub>, and HBI III records indicate the boundary values for interpreting the sea ice states (as indicated in Table 2). Grey bars indicate glacial intervals, white bars represent interglacials (numbers at the top correspond to MIS, MIS boundaries from Lisiecki and Raymo<sup>8</sup>).



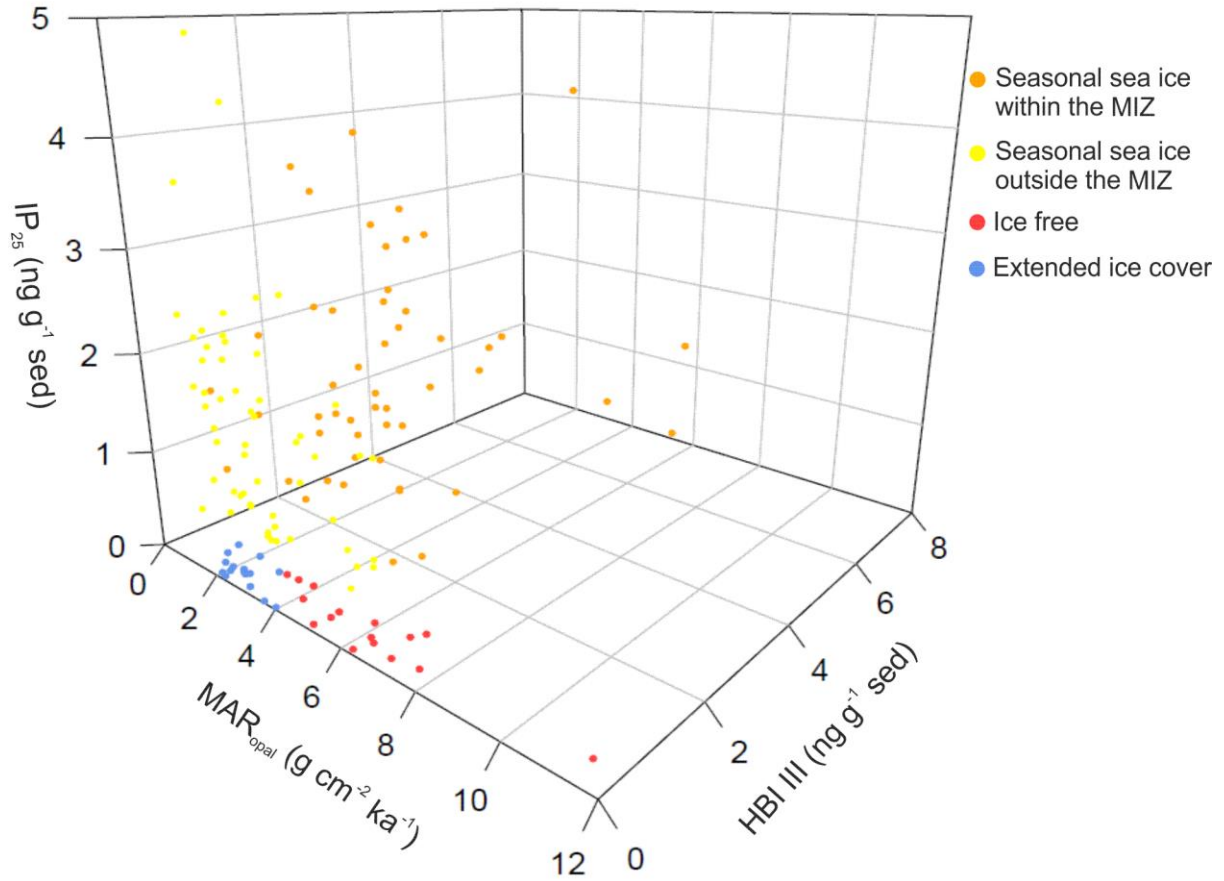
**Supplementary Figure 2. Correlation of Brassicasterol and IP<sub>25</sub> across all three measured intervals in Site U1343.**

(a) The Pearson  $r$  correlation coefficient<sup>9</sup> calculated of IP<sub>25</sub> (violet) and brassicasterol (blue). The interval has been divided into two subsections from 1.53-0.95 Ma and from 0.95-0.34 Ma. (b) Brassicasterol and IP<sub>25</sub> across all three intervals 1.53-1.36 Ma, 1.22-0.8 Ma, 0.5-0.34 Ma measured in this study.



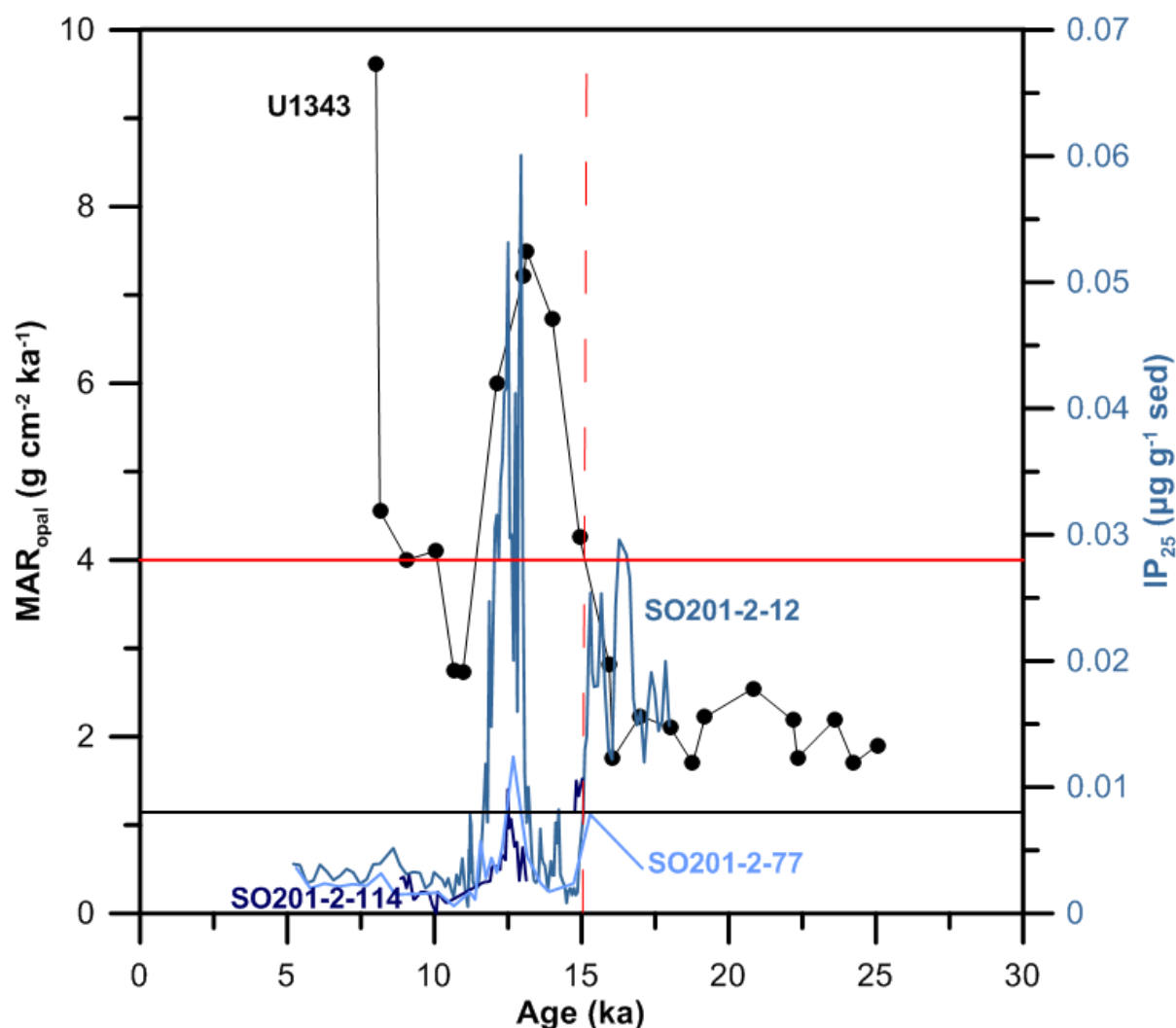
**Supplementary Figure 3. Correlation of the sea ice proxy  $IP_{25}$  with Bering Sea intermediate water ventilation.**

A cross-plot of  $IP_{25}$  from Site U1343 and  $\Delta\delta^{13}C_{(849-U1342)}$ <sup>3</sup> a proxy for intermediate water ventilation at Site U1342 ( $IP_{25}$ - $\Delta\delta^{13}C_{(849-U1342)}$ :  $r_{xy} = -0.255$  with 95% Student's t confidence intervals [-0.473; -0.009],  $n = 110$ ).  $\Delta\delta^{13}C_{(849-U1342)}$  has been re-sampled at the same age points as the U1343  $IP_{25}$  record, using AnalySeries 2.0.8<sup>10</sup>.



**Supplementary Figure 4. Characterization of sea ice states at the eastern Bering Sea slope.**

Data points are clustered according to their predominant sea ice state (for biomarker and  $MAR_{opal}$  boundaries see Table 2 in the main manuscript). Blue data points represent extended sea ice cover, red ice free conditions, orange seasonal sea ice within the MIZ, and yellow seasonal sea ice outside the MIZ. The ice free and extended ice cover scenarios are separated by  $MAR_{opal}$  of 4 g cm<sup>-2</sup> ka<sup>-1</sup>, determined from sea ice studies<sup>11</sup> and  $MAR_{opal}$  in site U1343 across Termination I (Supplementary Fig. 5).



**Supplementary Figure 5. Determination of  $MAR_{opal}$  under ice free and extended sea ice conditions using sea ice data in the eastern Bering Sea<sup>11</sup> and  $MAR_{opal}$  at Site U1343<sup>2</sup> across Termination I.**

Termination I sea ice studies based on  $IP_{25}$  from three sediment cores in the western Bering Sea and the north west Pacific<sup>11</sup> (different shades of blue) and the mass accumulation rate of biogenic opal ( $MAR_{opal}$ ) at Site U1343 (black). The black horizontal line represents  $IP_{25}$  values of  $0.008 \mu g g^{-1} sed$ , the boundary between seasonal and ice free/extended sea ice conditions in the western Bering Sea, as identified by Meheust et al.<sup>11</sup>. Seasonal/ice free conditions are observed from 15 ka BP onwards (red dashed vertical line) in the western Bering Sea. At 15 ka  $MAR_{opal}$  in U1343 is at  $4 g cm^{-2} ka^{-1}$  (red horizontal line), taken as the boundary to identify ice free versus extended sea ice conditions in Site U1343.

## Supplementary References

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