Distal and proximal controls on the silicon stable isotope signature of North Atlantic Deep Water

SUPPLEMENTARY INFORMATION TO

"Distal and proximal controls on the silicon stable isotope composition of North Atlantic Deep Water"

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1. MOM3 model suite parameters

Table S1: Key parameter values and forcings for the OGCMs in this study. In all three models, diapycnal diffusivity increases from the pycnocline values listed to a deep-ocean value of 1.3×10^{-4} m^2/s with a hyperbolic tangent transition at 2500m (Bryan and Lewis, 1979). *SO*: Southern Ocean; *GM*: Gent-McWilliams.

	HH	**LL**	**P2A**
Pycnocline diapycnal diffusivity [m^2/s]	6×10^{-5}	1.5×10^{-5}	1.5×10^{-5} *1.3×10^{-4} in SO* *5×10^{-3} from 0-50m*
Isopycnal diffusivity; GM coefficient [m^2/s]	2000	1000	1000
Wind forcing	HR83[1]	HR83[1]	ECMWF[2]
Surface fluxes	DS94[3]	DS94[3]	DS94[3] *plus correction globally*[4]
Specific changes relative to LL	-	-	Narrower Drake Passage; winter surface salinity correction near Antarctica[4]

[1]Hellerman and Rosenstein (1983); [2]Trenberth et al., (1989); [3]Da Silva et al. (1994) [4]see Gnanadesikan et al. (2004).

2. CYCLOPS

The version of CYCLOPS used in this study is the 18-box model modified by Robinson et al. (2005) and Hain et al. (2014b) from Keir (1988). A representation of the marine cycle of Si and its isotopes is incorporated into the model in this study. External inputs as well as loss to sediments are not included, such that this model only investigates the internal cycling of Si. Biological uptake of Si is parameterized by restoring Si concentrations in the surface boxes to values typical for the oceanic regions they represent (see Table S2). Isotope fractionation during uptake is simulated by scaling the uptake rate constant of the heavy isotope by the fractionation factor α=0.9989 (De La Rocha et al., 1997). The opal dissolution length-scale determines the fraction of the sinking opal flux that dissolves within the intermediate vs. deep ocean boxes.

Table S2: Main parameter values utilised in the CYCLOPS box model sensitivity study.

Parameter	Value	Unit
Mean ocean [Si]	92	μM
Surface PAZ [Si]	80	μM
Surface AZ [Si]	30	μM
Surface SAZ [Si]	*0 – 25*	μM
Surface low-latitude [Si]	0.5	μM
Surface boreal Atlantic [Si]	5	μM
Opal dissolution lengthscale	*250 – 10000*	m

3. Defining freshly-ventilated NADW

A volume of recently-ventilated NADW was defined in each model variant using the signal of ventilation observed in two tracers, radiocarbon ($\Delta^{14}C$) and dissolved oxygen (O_2). Threshold values for each tracer were defined for the model variants (see Table 1 in the main text) to delineate the freshly-ventilated water mass focused at mid-depths and along the western boundary of the North Atlantic Ocean, as can be seen in the maps of Fig. S1 and the depth sections of Fig. S2. Only the ocean interior below a depth of 500m was included in this volume, so as to exclude the shallow ocean. The geographic extent of the resulting NADW volume is shown in Figs. S1 and S2.

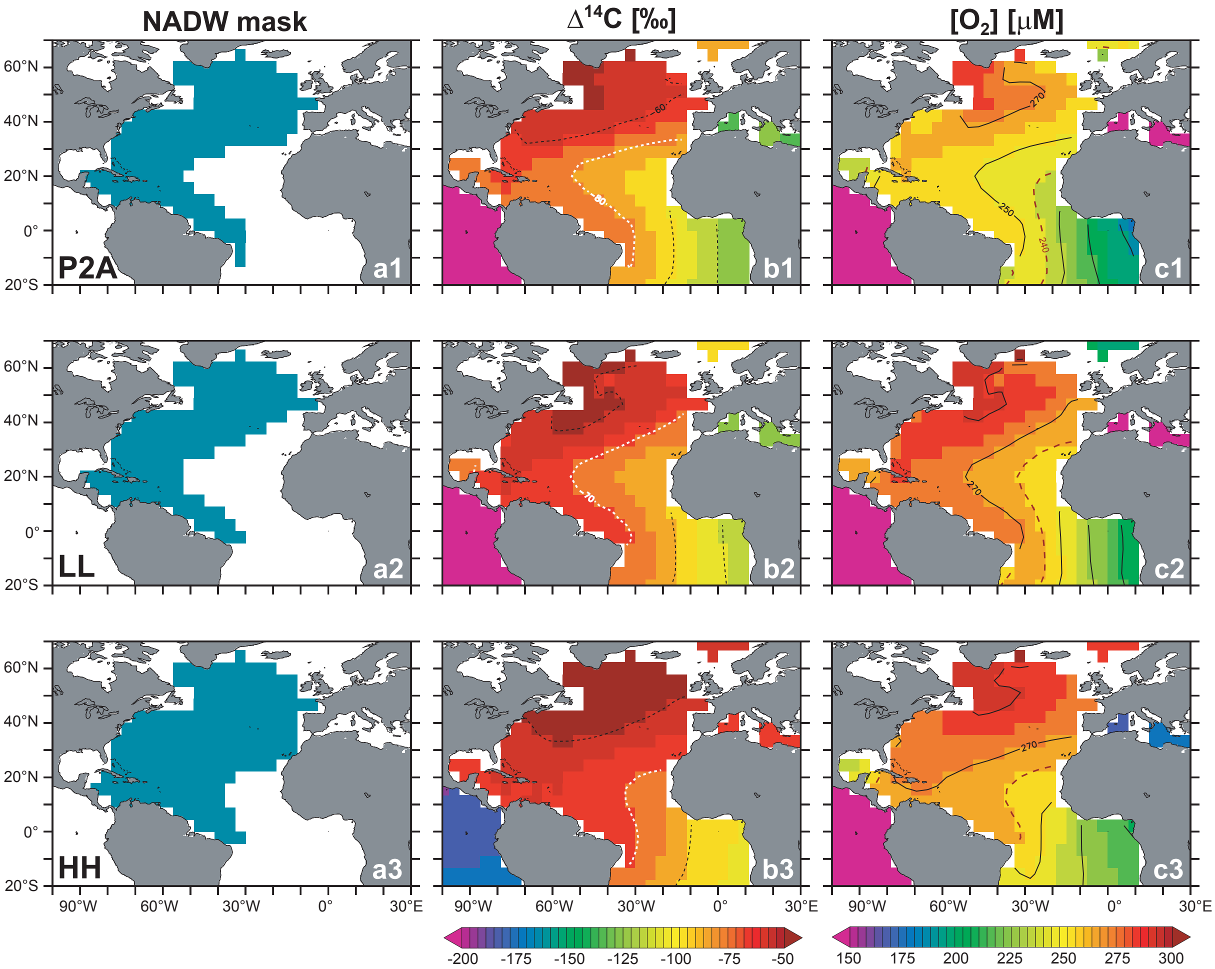


Fig. S1: Map at ~1700m in the three model variants, illustrating (a) the geographic extent of the volume defined as freshly-ventilated NADW, together with the distributions of (b) $\Delta^{14}C$ and (c) $[O_2]$ used to define this volume.

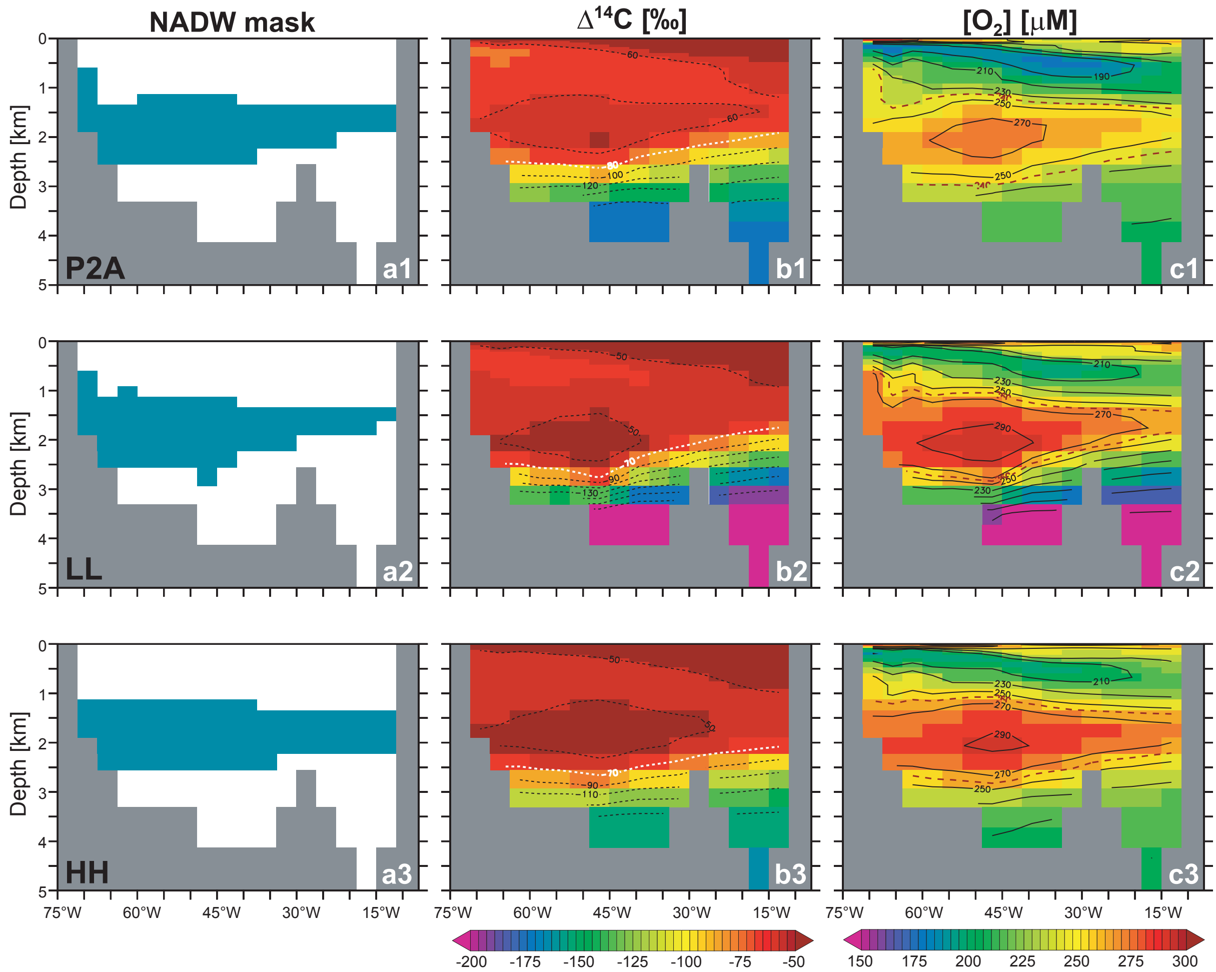


Fig. S2: Depth section at ~43°N in the three model variants, illustrating (a) the geographic extent of the volume defined as freshly-ventilated NADW, together with the distributions of (b) $\Delta^{14}C$ and (c) $[O_2]$ used to define this volume.

4. Supplementary Figures

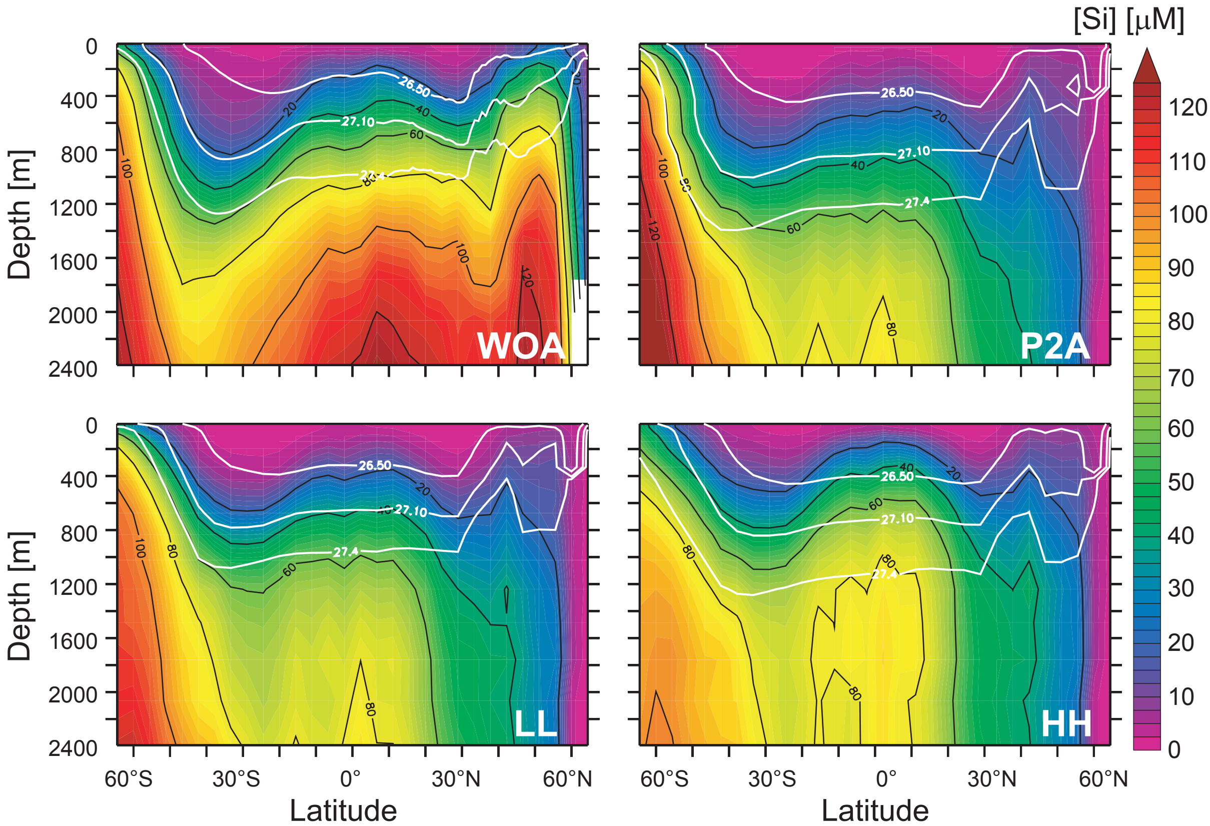


Fig. S3: Zonal-mean depth section of Si concentration, [Si], in the uppermost 2400m in World Ocean Atlas 2009 (WOA09) and the three model variants.

Fig. S4: Zonal-mean depth section of source region contributions to the total Si inventory [mol Si/mol Si, unitless] in the uppermost 2400m in the three model variants.

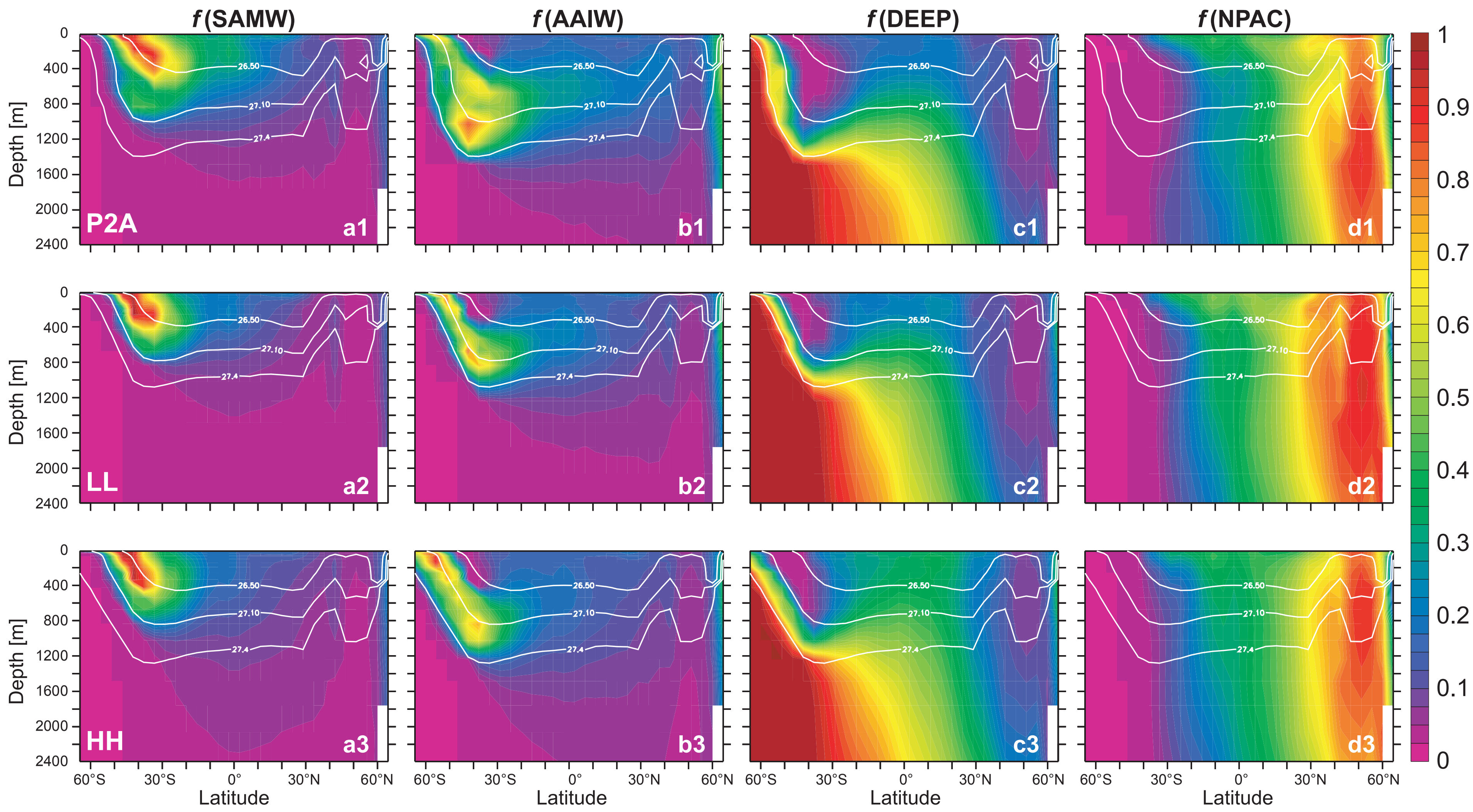


Fig. S5: Meridional section against potential density σ_θ of the Atlantic-mean contribution of the four source regions to the Si inventory [mol Si/mol Si, unitless]. The white contour in columns *a* and *b* corresponds to the median density of each tag (i.e. the density above/below which half of the water-column integral of the tag is found). Fractions are averaged over the Atlantic basin and over the Southern Ocean from 60°W to 30°E.

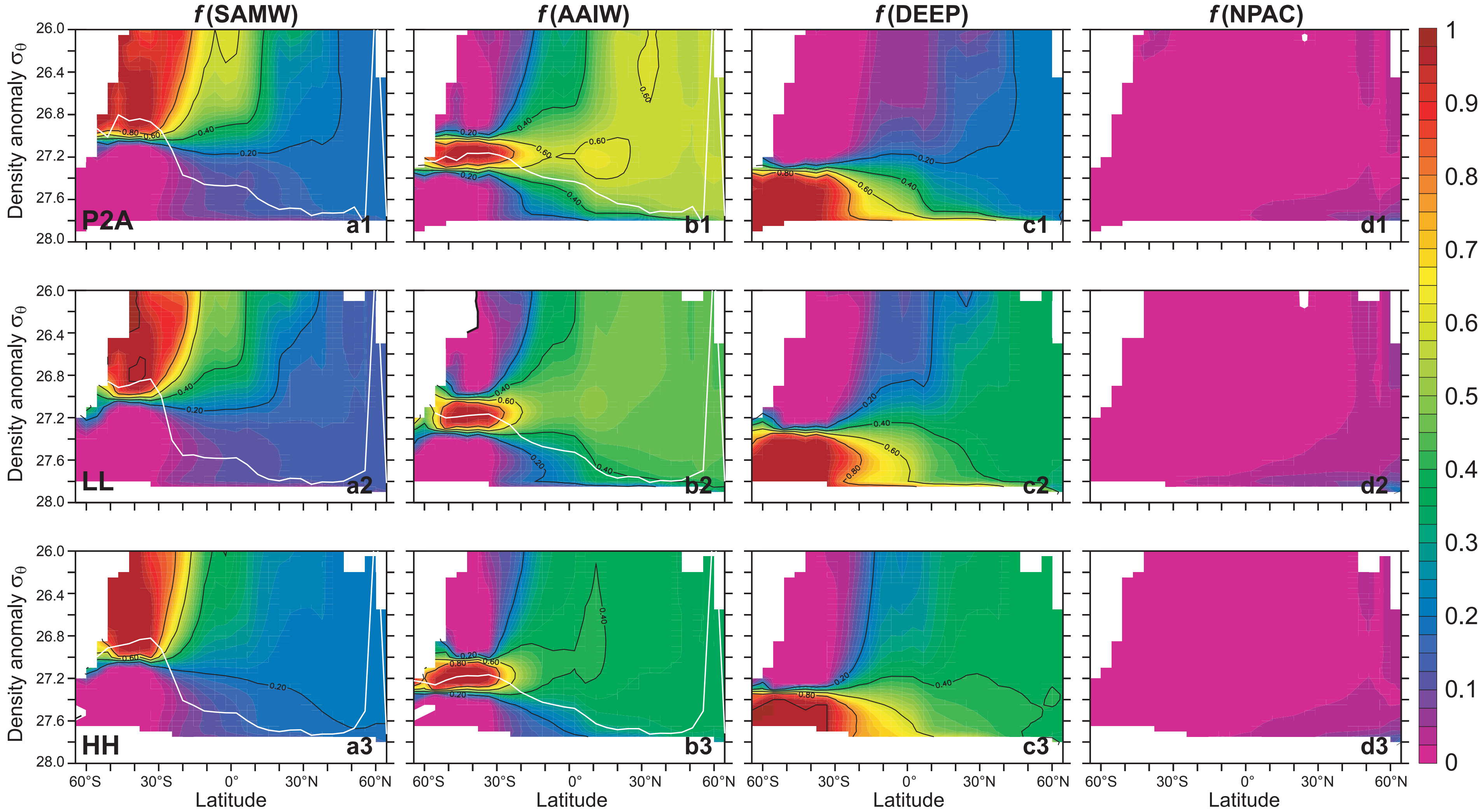


Fig. S6: Depth sections at ~43°N in the three model variants, illustrating the source region contributions [mol Si/mol Si, unitless] to the total Si inventory of the North Atlantic.

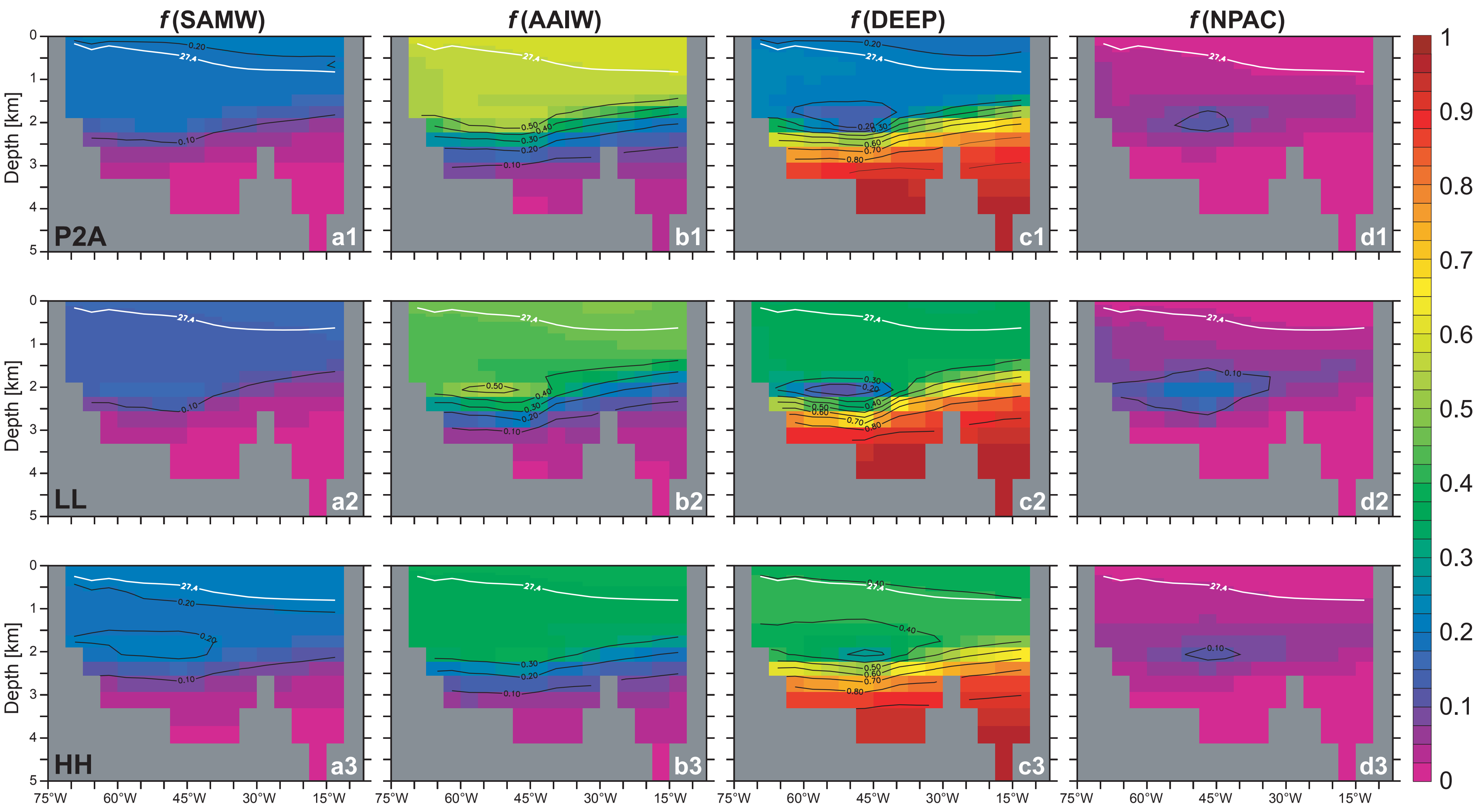
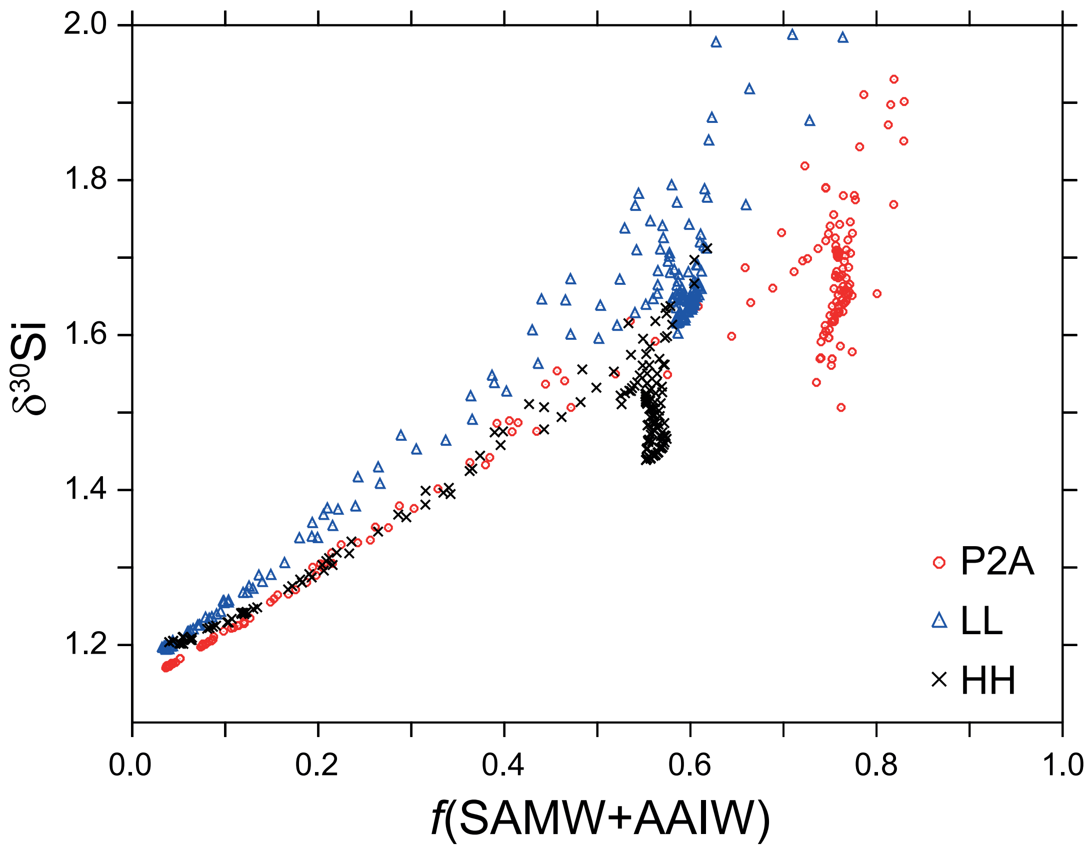


Fig. S7: Cross-plot of fractional contribution of SAMW- and AAIW-derived Si to total Si at 43°N in the deep North Atlantic (*x*-axis, cf. Fig. 8) versus the corresponding $\delta^{30}Si$ value of total Si (*y*-axis). Output is plotted for potential densities greater than 27.4, i.e. below the northward transport of SAMW- and AAIW-derived Si in the shallow ocean, in order to focus on the deep-ocean systematics. Note the close relationship between the two parameters in all three model variants. The hook to lower values at top right for P2A and HH is due to shallow recycling of SAMW- and AAIW-derived Si in the upper North Atlantic Ocean (cf. the shallow far-western Atlantic at ~1000m water depth in Fig. 8c of the main manuscript).



Supplementary References:

Bryan, K, Lewis, L. J., 1979. A water mass model of the World Ocean. J. Geophy. Res. Ocean. 84, 2503-2517.

da Silva, A., Young, A. C., Levitus, S., 1994. *Atlas of Surface Marine Data 1994, Vol. 1*. National Oceanic and Atmospheric Administration, Silver Spring, MD.