Supporting Information for

An investigation into the processes controlling the global distribution of dissolved ^{231}Pa and ^{230}Th in the ocean and the sedimentary ^{231}Pa/^{230}Th ratios by using an ocean general circulation model

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Introduction

The supporting information given here shows additional Table and Figures. They are prepared for detail comparison with the observations and our simulations, which is needed to improve the comprehension of the discussion.

Experiment	^{231}Pad Global slope	R	RMSD	^{231}Pap Global slope	R	RMSD
Siddall_EXP	1.57 (1.88)	0.58 (0.72)	0.25 (0.15)	0.10 (0.07)	0.19 (0.10)	1.4e-2 (1.6e-2)
CTRL_EXP	0.76 (1.04)	0.75 (0.90)	0.08 (0.05)	0.06 (0.06)	0.19 (0.14)	1.4e-2 (1.4e-2)
3D_EXP	1.57 (1.88)	0.58 (0.72)	0.25 (0.15)	0.10 (0.07)	0.19 (0.10)	1.4e-2 (1.6e-2)

Experiment	^{230}Thd Global Slope	R	RMSD	^{230}Thp Global Slope	R	RMSD
Siddall_EXP	3.85 (4.44)	0.71 (0.89)	1.31 (1.17)	0.04 (0.13)	0.17 (0.23)	0.24 (8.6e-2)
KREF_EXP	0.64 (0.88)	0.70 (0.81)	0.23 (0.20)	0.04 (0.17)	0.28 (0.42)	0.24 (7.9e-2)
CTRL_EXP	0.76 (0.98)	0.82 (0.84)	0.17 (0.16)	0.03 (0.17)	0.28 (0.49)	0.24 (7.8e-2)
3D_EXP	1.22 (1.73)	0.73 (0.83)	0.28 (0.30)	0.04 (0.17)	0.28 (0.43)	0.24 (7.9e-2)

Table S1. Metrics of model-data misfits about ^{31}Pa and ^{230}Th simulated in our CTRL_EXP are displayed; the slope of linear regression (slope), the linear correlation coefficient (R), and the root mean square deviation (RMSD) of our CTRL against all of available data from GEOTRACES Intermediate Data Product 2017 (Schlitzer et al., 2018) are calculated and shown in the table. ^{231}Pad and ^{230}Thd denote dissolved ^{231}Pa and ^{230}Th, respectively. ^{231}Pap and ^{230}Thp denote particulate ^{231}Pa and ^{230}Th, respectively. For dissolved ^{231}Pa and ^{230}Th, the data from GEOTRACES GA02, GA03, GIPY05, GPc01 and GP16 sections are used. For particulate ^{231}Pa and ^{230}Th, the data from GEOTRACES GA03, GIPY05, and GP16 sections are used. Numbers in parentheses of dissolved ^{231}Pa and ^{230}Th indicate comparisons only with the GEOTRACES GA02 data. Numbers in parentheses of particulate ^{231}Pa and ^{230}Th indicate comparisons with pre-GEOTRACES data shown in Fig. S1c.
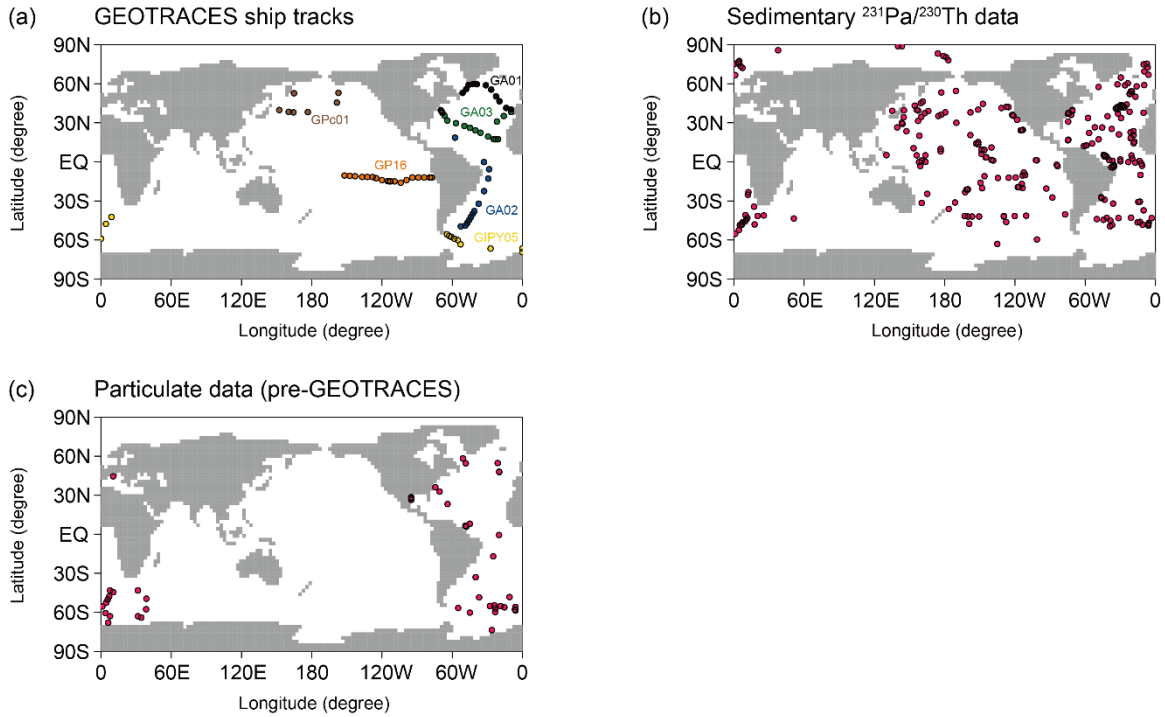
Figure S1. (a) Ship tracks of GEOTRACES data used in this study. (b) Sedimentary ^{231}Pa/^{230}Th data obtained in pre-GEOTRACES studies (Mangianini & Sonntag, 1977; Muller & Mangini, 1980; Anderson et al., 1983; Shimmield et al., 1986; Schmitz et al., 1986; Yang et al., 1986; Shimmield & Price, 1988; Yong Lao et al., 1992; François et al., 1993; Frank et al., 1994; Frank, 1996; Bradtmiller et al., 2014, and their supplemental data). (c) Particulate ^{231}Pa and ^{230}Th data obtained in pre-GEOTRACES studies (Colley et al., 1995; Moran et al., 1997; Moran et al., 2001; Rutgers van der Loeff and Berger, 1993; Vogler et al., 1998; Walter et al., 1997; Cochran et al., 1987; Moran et al., 2002; Guo et al., 1995).
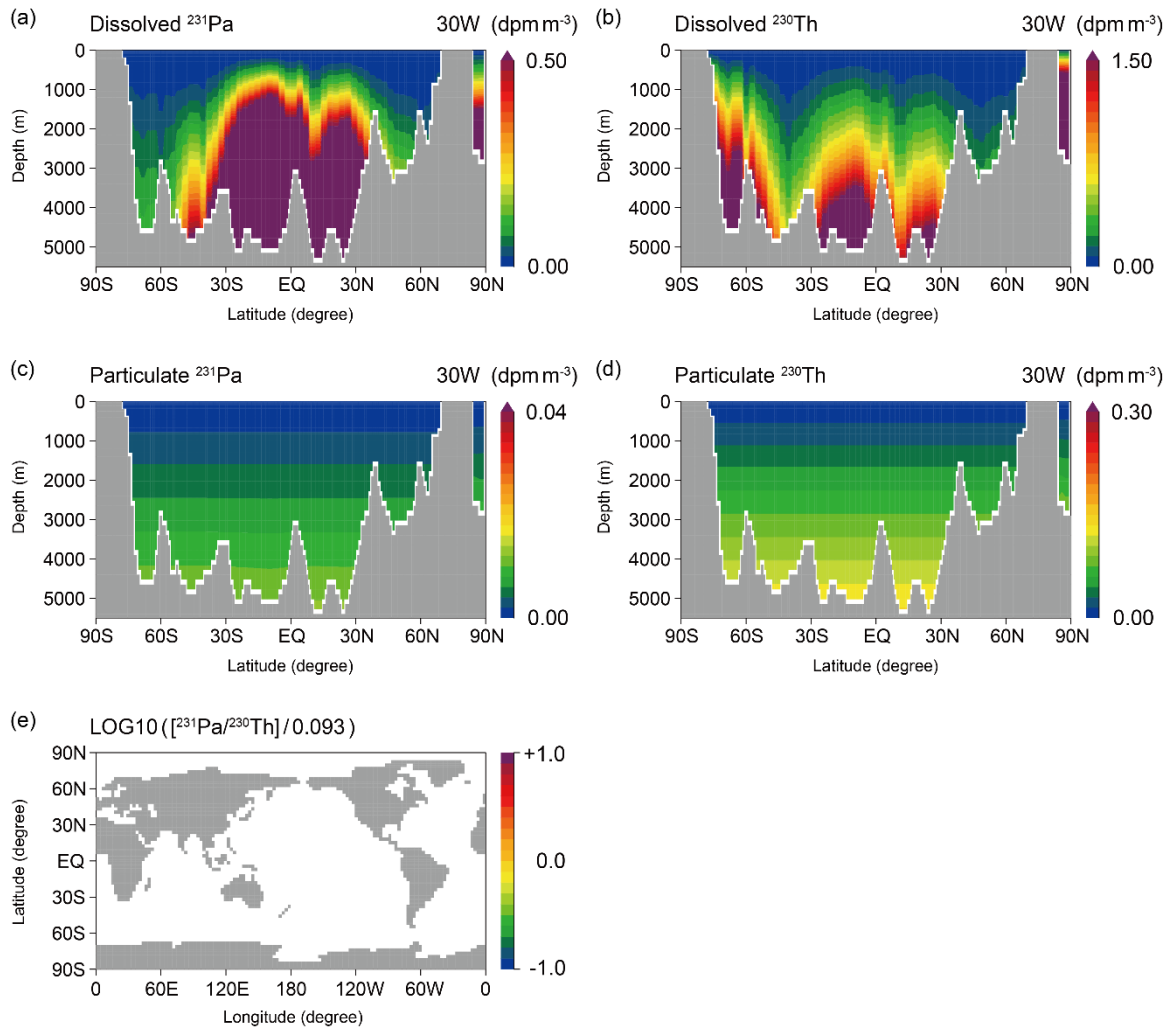
Figure S2. (a) Dissolved ^{231}Pa, (b) dissolved ^{230}Th, (c) particulate ^{231}Pa, and (d) particulate ^{230}Th along 30 °W in the Atlantic Ocean in 1D_EXP. (e) Sedimentary ^{231}Pa/^{230}Th ratios normalized by the production ratio of 0.093 in 1D_EXP.
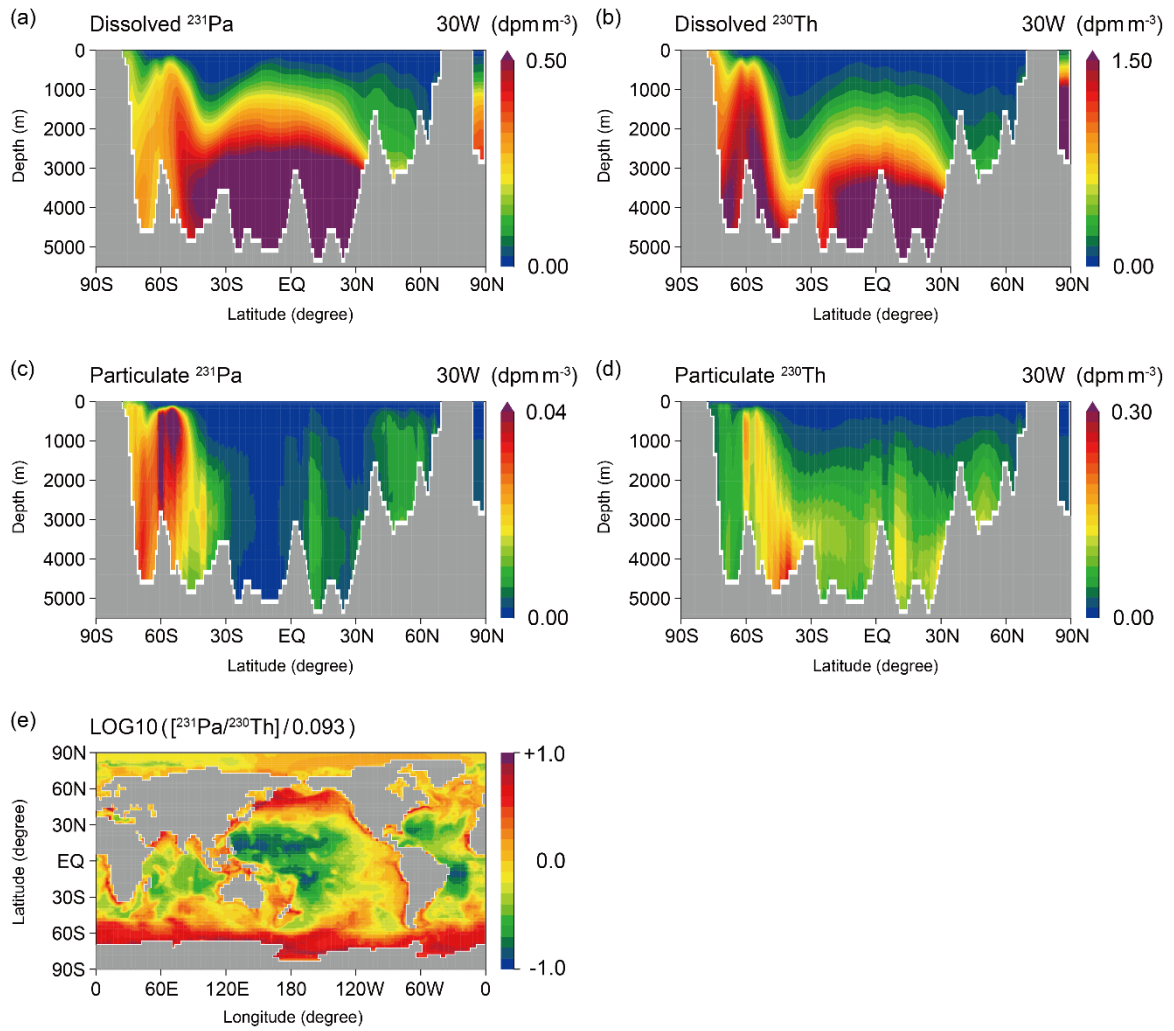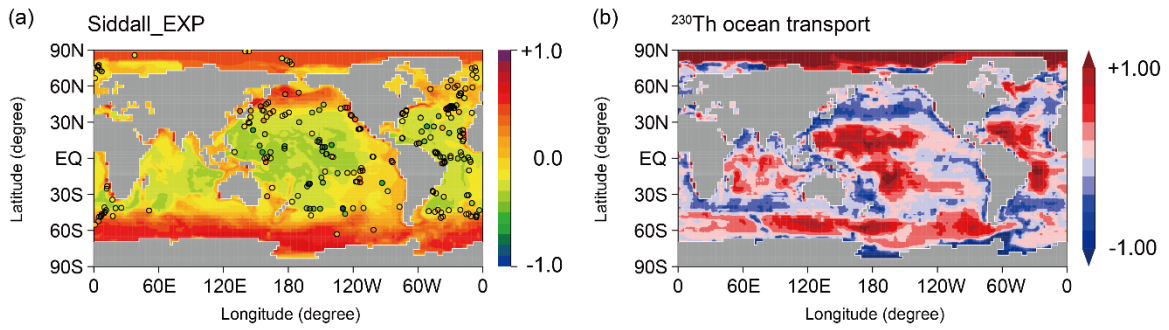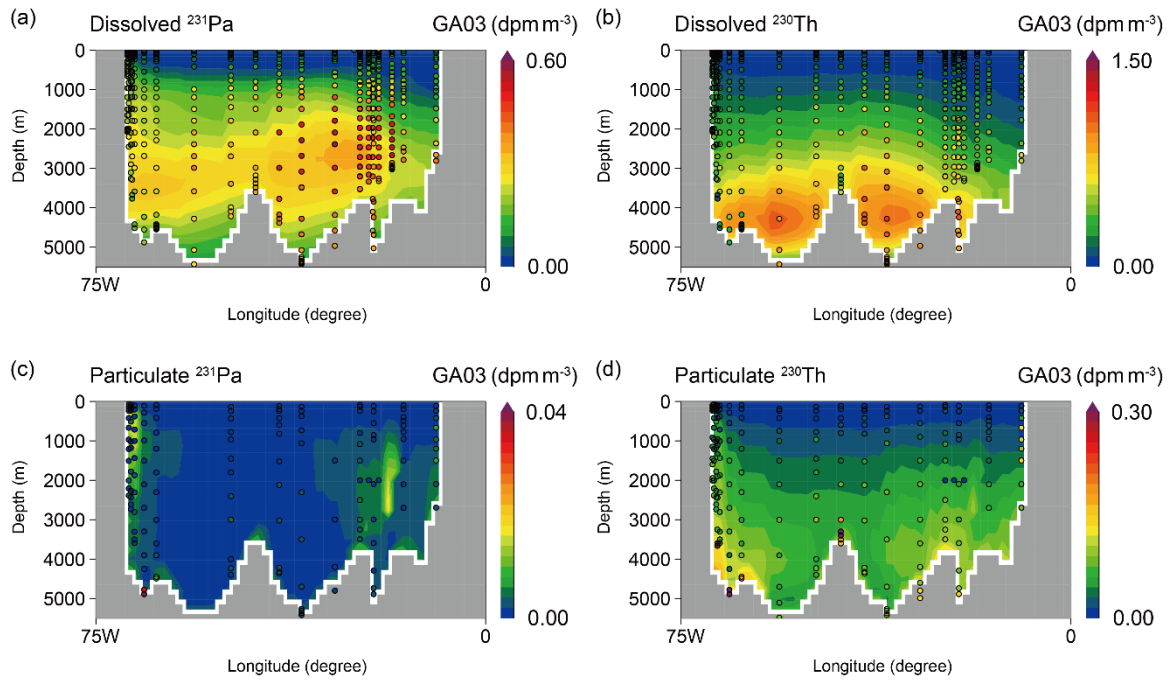
Figure S3. The same as Fig. S2 except for 3D_EXP.

Figure S4. (a) Sedimentary ^{231}Pa/^{230}Th ratios normalized by the production ratio of 0.093 in Siddall_EXP. (b) Contributions to the sedimentary ^{231}Pa/^{230}Th ratios of Siddell_EXP from ocean transport solely from ^{230}Th (i.e., ^{231}Pa(1D)/^{230}Th(Siddall)).

Figure S5. (a) Dissolved ^{231}Pa, (b) dissolved ^{230}Th, (c) particulate ^{231}Pa, and (d) particulate ^{230}Th along the Atlantic GEOTRACES GA03 transect in CTRL_EXP. The coloured circles represent the GEOTRACES data (GA03; Hayes et al., 2015).
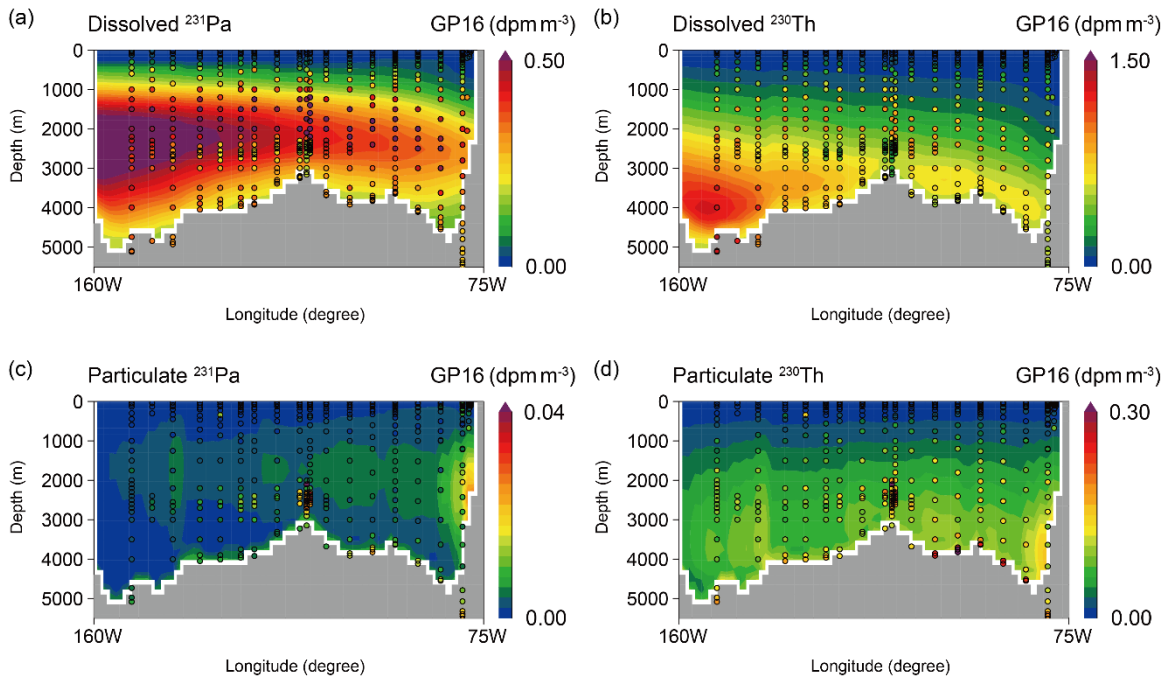
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Figure S6. (a) Dissolved ^{231}Pa, (b) dissolved ^{230}Th, (c) particulate ^{231}Pa, and (d) particulate ^{230}Th along the Pacific GEOTRACES GP16 transect in CTRL_EXP. The coloured circles represent the GEOTRACES data (GP16; Pavia et al., 2018).
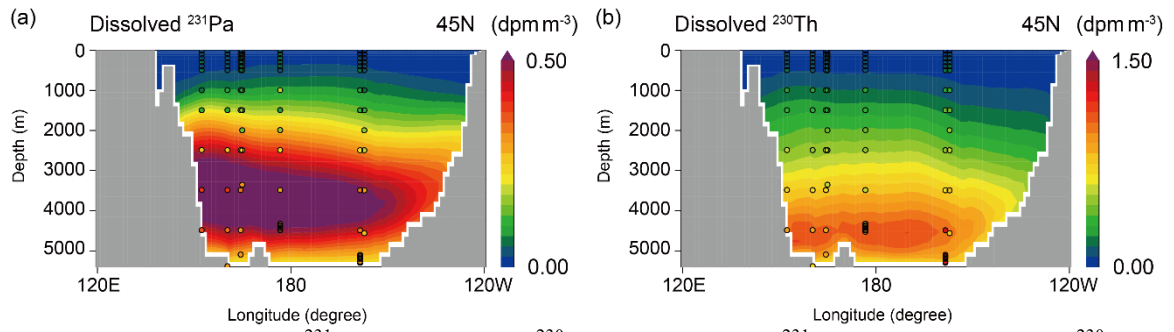
Figure S7. (a) Dissolved ^{231}Pa, (b) dissolved ^{230}Th, (c) particulate ^{231}Pa, and (d) particulate ^{230}Th along 45°N in the Pacific in CTRL_EXP. The coloured circles represent the GEOTRACES data (GPc01; Hayes et al., 2013).
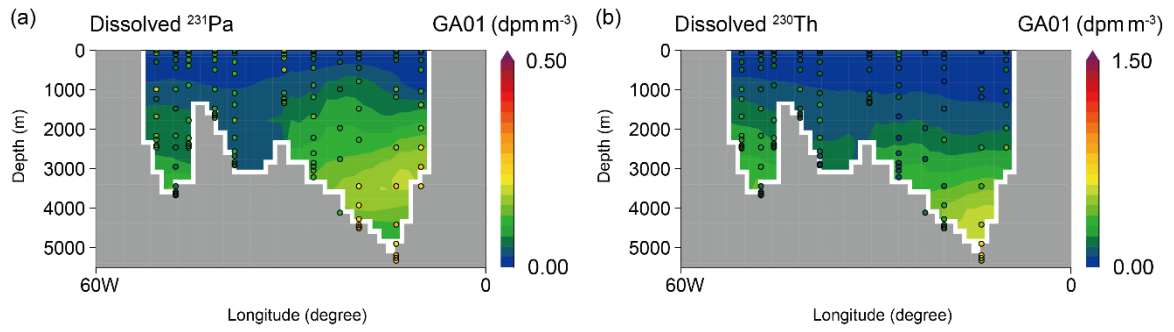
Figure S8. (a) Dissolved [231]Pa, (b) dissolved [230]Th, (c) particulate [231]Pa, and (d) particulate [230]Th along the Atlantic GEOTRACES GA01 transect in CTRL_EXP. The coloured circles represent the GEOTRACES data (GA01; Deng et al., 2018).
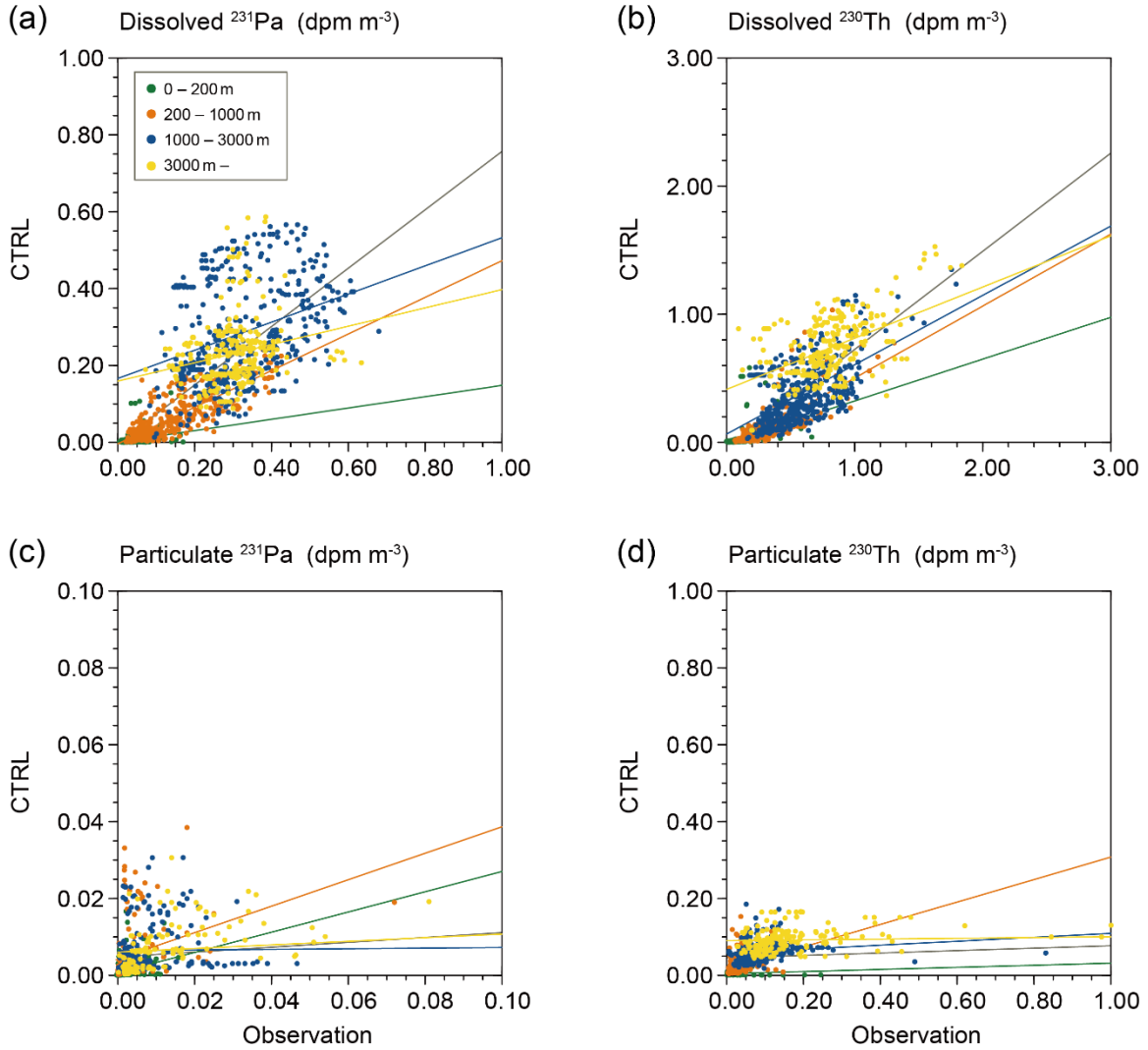
Figure S9. The scatter plot of (a) dissolved ^{231}Pa, (b) dissolved ^{230}Th, (c) particulate ^{231}Pa, and (d) particulate ^{230}Th between CTRL_EXP and available GEOTRACES data (unit: dpm m^{-3}). Plots from different ocean depth ranges are drawn with different colors: green for 0–200 m, orange for 200–1000 m, blue for 1000–3000m and yellow for deeper than 3000 m. The regression lines are also shown. The gray line represents the linear regression line for all depth ranges. For dissolved ^{231}Pa and ^{230}Th, the data from GEOTRACES GA02, GA03, GIPY05, GPc01 and GP16 sections are used. For particulate ^{231}Pa and ^{230}Th, the data from GEOTRACES GA03, GIPY05, and GP16 sections are used.
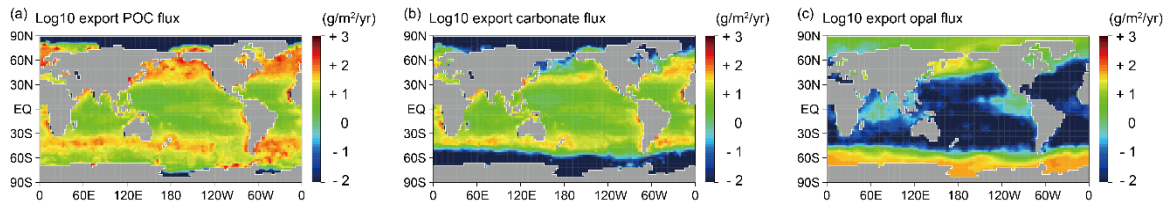
Figure S10. Surface particle fluxes used to force the [231]Pa and [230]Th model (unit: g m^{-2} yr^{-1}) of (a) particulate organic carbon, (b) calcium carbonate, and (c) opal.