Supporting Information for

**231Pa and 230Th in the ocean model of the Community Earth System Model (CESM1.3)**

1. Vertical differentiation scheme in calculating the reversible scavenging term:

In the calculation of , we consider downward as positive ( is positive). can be calculated by Eq.(S1). Detailed notations are illustrated in Fig.S1.

(S1)

, which is the particulate isotope activity at the upper bound of the grid box, can be calculated by Eq. (S2). For the surface layer (), we assume the particulate isotope activity at surface is 0, which is true as there is no surface flux for calcite, opal and POC. For layers between the surface and the bottom, we use liner interpolation. For the bottom layer, we assume , which is the particulate isotope activity at the lower bound of the bottom cell, equals particulate isotope activity at the center of the bottom cell (). This is a reasonable assumption, as the vertical gradient in the abyssal is very small.

(S2)

Under this vertical differentiation scheme, if we do vertical integration of , we will get , which is the column removal rate of isotope activity and this simulates the process of sedimentation. Therefore, we use [231Pa]p and [230Th]p in the bottom grid box to calculate sediment 231Pa/230Th activity ratio in our model.

/Users/sifan/Documents/research/Nd/scheme/diff_PaTh.pdf

Figure S1. Schematic of model grid. k is the vertical layer. kmt is the maximum vertical layer at this location (k=kmt is the bottom layer). At is the total isotope activity. Ap is particulate isotope activity. At and Ap are located at the center of the grid box. Apu is the Ap value at the upper bound of the grid box. dz(k) is the thickness of the layer k. dzw(k) is the distance from the center of layer k to the center of layer k+1.