Simulation of global distribution of Pa/Th using an ocean general circulation model

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The sediment 231Pa/230Th ratio is an important major proxy for studying paleo ocean circulation. However, even in the modern ocean, the only limited data about the distribution of dissolved 231Pa and 230Th was available, and it was insufficient to understand the process that controls the oceanic distribution of 231Pa and 230Th. In addition, some of previous modeling studies did not reproduce the observation data sufficiently. Recently, number of available observation data about dissolved 231Pa and 230Th is rapidly increasing owing to the recent projects like GEOTRACES. In this study, we performed simulation of 231Pa and 230Th with an ocean general circulation model (OGCM) and discussed how well dissolved 231Pa and 230Th profile of GEOTRACES data set is reproduced by the model. First, based on the previous model that incorporates reversible scavenging processes of 231Pa and 230Th by sinking ocean particles (Siddall et al., 2005), we improved the model by taking into account of additional sink at the sea floor (bottom scavenging; Okubo et al., 2012; Roy-Barman, 2009) and the dependency of scavenging efficiency on particle concentration following Henderson et al. (1999) . Second, as for our best reproduced simulation (Control simulation), we discuss processes which control the oceanic distribution of 231Pa and 230Th into three parts; the one-dimensional reversible scavenging process, the contribution from ocean advection and diffusion, and bottom scavenging. Through this analysis, we clarified how these processes effect on the global distribution of the sediment 231Pa/230Th ratio.

As a result of the improvement of model and tuning of the parameter, we simulated the distribution of 231Pa and 230Th reported from GEOTRACES dataset successfully. First, I confirmed that the profile of both dissolved 231Pa and 230Th in the deep ocean was improved by considering bottom scavenging as suggested by Rempfer et al. (2017). While the distribution of 231Pa is reproduced realistically by considering bottom scavenging, it is found to be difficult to simulate the depth profile of dissolved 230Th consistent with observations only by considering bottom scavenging. Hence, I tried to reproduce the dissolved 230Th profile by changing parameter values which control the strength of reversible scavenging by sinking ocean particles from the case in Siddall et al. (2005), and also by incorporating the dependency of scavenging efficiency on particle concentration following Henderson et al. (1999). As a result, I also reproduced the distribution of 230Th successfully.

In the latter part of this study, we discussed the process that controls the distribution of the sediment 231Pa/230Th ratio by analyzing the Control simulation. Through this analysis it was confirmed that the process that controls the distribution of the sediment 231Pa/230Th activity ratio is largely determined by the stronger influence of advection and diffusion on 231Pa than 230Th; advection and diffusion effect only on 231Pa can reproduce overall pattern of the distribution of the sediment 231Pa/230Th activity ratio similar to observation. Our analysis revealed that the bottom scavenging effect weakens the influence of advection and diffusion on 231Pa, and tends to make the contrast of 231Pa/230Th distribution smaller. We also found that the advection and diffusion of 230Th is small but not negligible, which also contributed to decrease the advection and diffusion effect on 231Pa.

This model is useful not only for reproducing 231Pa/230Th ratio in the present-day ocean but also for that in different climate such as glacial periods. Simulation of 231Pa/230Th ratio under the glacial

climate is an interesting future study. Such a study is an important step for discussing glacial changes in the ocean circulation more quantitatively.

Keywords: 231Pa/230Th ratio, proxy of ocean circulation, bottom scavenging, ocean general circulation model