# 海氷生成に伴う酸素安定同位体分別係数について

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# Oxygen-isotope fractionation during the freezing of seawater

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The dependence of oxygen stable isotope fractionation during the freezing of seawater on the ice growth rate was studied on the basis of laboratory experiments and field observations in the McMurdo Sound, Antarctica, and the Sea of Okhotsk. The laboratory experiments were performed in a tank filled with seawater, with sea ice grown under calm conditions at various room temperatures, ranging from -5 to -20 $^{o}$C. In the McMurdo Sound, the ice growth rate was monitored using thermistor probes for first-year land-fast ice that grew to a thickness of about 2 m. In the Sea of Okhotsk, the growth rate was obtained by estimating the thermodynamic growth with in-situ meteorological data. By combining these data sets, the fractionation at growth rates ranging from 0.3 mm hour$^{-1}$ to 3.3 mm hour$^{-1}$ were examined. In the analysis, the focus was placed on columnar ice and a stagnant boundary-layer fractionation model was used to derive the relating formula between growth rates and fractionation coefficients.

**Introduction** During the freezing of seawater, heavier oxygen isotope ($^{18}$O) is entrapped more into sea ice than seawater. The degree of surplus entrapment (fractionation coefficient) depends on the freezing conditions, mainly freezing rate. Therefoere, this parameter is useful to retrieve the growth history of ice from the δ$^{18}$O profile of an ice core sample. It is also an important parameter for the estimation of meteoric ice fraction within snow ice. The relation between fractionation and ice growth rate has been investigated theoretically based on the stagnant boundary-layer model (SBL; Eicken, 1998). However, due to lack of observational data, the parameters used in the model still remain to be examined. In this study, a wide range of growth rates were first obtained by combining the observational data and the tank experiments. Based on this data set, the relation between fractionation and ice growth rate is discussed.

**Data** For the experiments, we prepared a thermally insulated tank (inner dimensions of 0.3 m width and 0.65 m height) and filled it with natural seawater of 32.5 psu in salinity. Sea ice was grown at various growth rates, ranging from 0.8 to 3.3 mm/hour, and the columnar layer was used for analysis. Rayleigh process was also taken into account. From field observations, the growth rates ranging from 0.3 to 0.9 mm/hour were obtained.

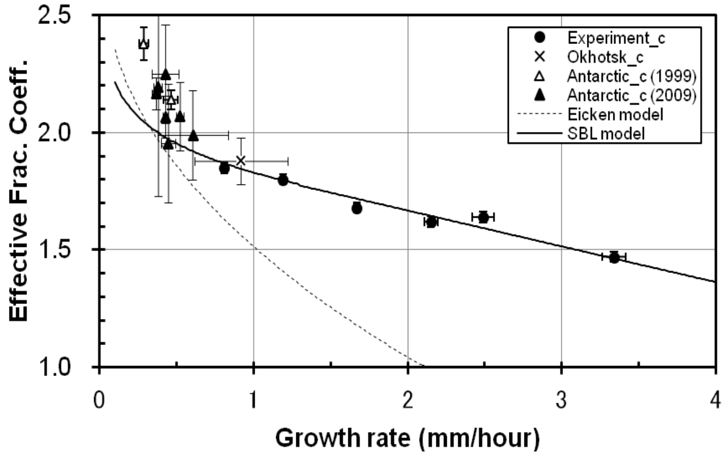

Figure 1. Effective fractionation coefficients as a function of ice growth rate with a regression curve obtained from experiments.

**Results** It is shown in Fig.1 that the obtained data are far away from the Eicken's model and some modification is required and that when the SBL model is applied, the optimum values of equilibrium pure ice fractionation factor and boundary layer thickness are estimated to be 2.66 ‰ and 0.10 mm for diffusion coefficient of 1.2x10$^{-3}$ mm$^2$/s, respectively. These values were 2.91 ‰ and 1.3 mm in the Eicken's model, but some modification may be needed for a very slow growth rate (< about 0.5 mm/h).

## Reference

Eicken, H., Deriving modes and rates of ice growth in the Weddell Sea from microstructural, salinity and stable-isotope data, *Antarctic Sea Ice*: Physical processes, interactions and variability, Antarctic Research Series, Vol.74, 89-122, 1998.