南大洋の大西洋―インド洋域における降雪の酸素安定同位体比の分布

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Distribution of Oxygen Isotope Ratio of Precipitation in the Atlantic-Indian Sectors of the Southern Ocean

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Herein, the spatial distribution of stable oxygen isotope ratios ($\delta^{18}O$) of precipitation in the Atlantic to Indian sectors of the Southern Ocean is examined using the results of in situ observations and numerical modeling. In situ observations of 59 precipitation events reveal poleward decrease of $\delta^{18}O$, with a larger meridional gradient south of 60 ºS. Moreover, the estimates from the observations and model (IsoGSM) agree reasonably well, with a mean absolute difference of 4.3‰. Thus, the IsoGSM results generally support the observed poleward increase in the meridional gradient. These results will prove valuable in investigating the atmospheric water cycle and in studying oceanic processes of water mass formation and transport.

The global hydrological cycle plays a vital role in characterizing the surface environment of the high-latitude Southern Hemisphere. Precipitation dominates evaporation over the Southern Ocean (e.g., Josey et al.1999), contributing to the relatively fresh salinity at the ocean surface in the high latitudes (e.g., Talley, 2002). Moreover, precipitation on the Antarctic continent supplies the fresh water that constitutes the vast ice sheet. This ice sheet slides outward to form ice streams and ice shelves, and the terminuses of which are eventually melted and calved (e.g., G. de Q. Robin, 1979), supplying continental freshwater to the ocean. In the Southern Ocean surrounding the Antarctic continent, the estimation of the abovementioned freshwater fluxes is important in understanding sea water property and hence global ocean circulation.
The oxygen isotopic content in water ($H_2{}^{18}O$) is a useful tracer to identify the origin of fresh water, because it retains information about the history of water transport (e.g., Weiss et al., 1979).
To obtain sufficient spatiotemporal coverage of oxygen isotopes in precipitation over the Southern Ocean, a reliable interpolation method with numerical modeling is required. Recently, several isotope-enabled GCMs have become available, and they can reproduce the general isotopic patterns of global precipitation reasonably (e.g., Yoshimura et al., 2008). However, because of a lack of comparison with observation data, it is not yet clear whether these GCMs can successfully simulate the isotopic content in precipitation over the Southern Ocean. To address this, in the present study, we conducted observation to collect precipitation samples for isotope analysis and examine whether the isotope-enabled GCM is useful in estimating the spatiotemporal pattern of oxygen isotopes in precipitation over the Southern Ocean.

We collected 59 precipitation samples (44 samples from 5 summer cruises and 15 samples from 2 winter cruises) during 7 research cruises (5 and 2 cruises in summer and winter). After the snowfall events, we sampled snows fallen on the ship’s deck. Isotope analysis was undertaken with a mass spectrometer (Finnigan DELTA plus) coupled with an equilibrium device.
As the output of an AGCM-based isotopic model, IsoGCM was used in the present study. IsoGCM was developed by Yoshimura et al. (2008) by incorporating the heavier water isotopologues in the Global Spectral Model originally developed by the National Center of Environmental Prediction (NCEP).

The spatial precipitation reveals a general tendency with lower (higher) values in the higher- (lower-) latitudes (Fig. 1). Although anomalously high values (-5 – 0‰) happened around 60 ºS, 140 ºE in January 2012, the estimates equatorward of 60 ºS are generally high of -10 – 0‰. The lowest value of -25‰ was found in October 2006 around 65 ºS east of Antarctic Peninsula. Standard deviation (std) of all summer measurements is 7.05 ‰ and that of winter measurements is 8.26 ‰.

The meridional gradient of isotopes is not, however, monotonous (Fig. 2a). The observed rate of decrease is relatively low from the lower latitudes to around 60 ºS, whereas the meridional gradient of $\delta^{18}O$ was found to increase poleward from 60 ºS toward the Antarctic continent. In particular, a quadratic curve fitted to all data, including those in both summer and winter, reveals a decrease of 5.5 ‰ from 60 ºS to 65 ºS, with a negligible decrease obtained from 55 ºS to 60 ºS.

The present observations fill the gaps in the land-based observations and reinforce the presence of obtained increase in meridional gradient (Fig. 3). The climatological zonal average from the IsoGSM also captures the overall decrease and its gradient acceleration towards the higher latitudes. The range of seasonal variation in the model climatology is smaller than that obtained from available observations. Although the number of observations are small, especially in winter, the oxygen isotopic contents are widely scattered in the higher latitude region (>60 ºS).

The results are published as Nakamura et al. (2014, SOLA).

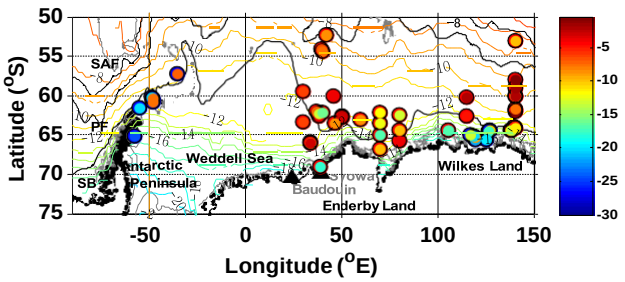

Figure 1. Distribution (circles) and estimate (color in circles) of oxygen isotope ratio of precipitation derived from in situ observations. Contours are climatological mean (2001-2010) estimate of oxygen isotope ratio of precipitation derived from IsoGSM. Triangles denote the available Antarctic Coastal stations.

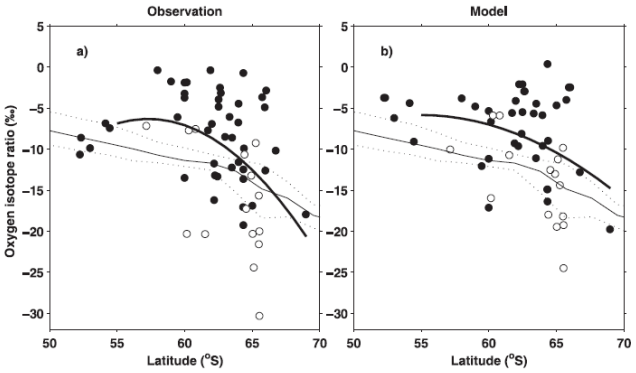

Figure 2. Meridional distribution of the oxygen isotope ratio of precipitation obtained from a) observations and b) model.

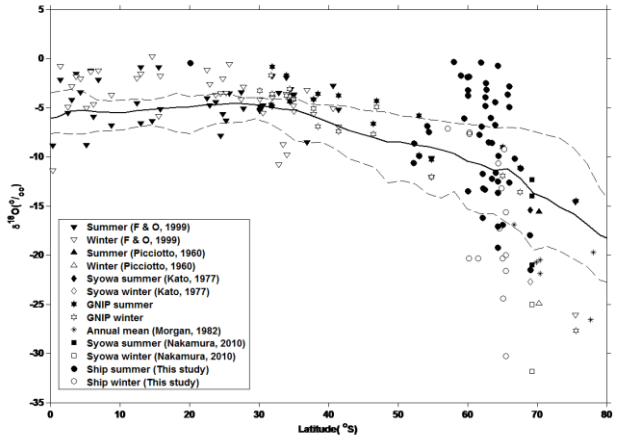

Figure 3. Meridional distribution of the oxygen isotope ratio of precipitation obtained from maritime observations in this study and from compilation of climatological land-based observational.

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