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学 位 論 文 審 査 の 要 旨

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学 位 論 文 題 名

Study on stable isotopes of precipitation in Hokkaido, North Japan
（北海道の降水の安定同位体比に関する研究）

Stable isotopes in precipitation have been widely used as tracers for paleoclimate reconstruction, evaluation of general circulation model, evapotranspiration separation and investigation of plant water use in hydrological processes, tracing transport of water vapor in atmosphere and studies of precipitation processes of Typhoon system and Monsoon systems. Generally, stable isotopes of precipitation show positive correlation with air temperature and negative correlation with the amount of precipitation. These are well known as temperature effect and amount effect. However, typically air temperature or the amount of precipitation can account for only 50 to 60 % of the variations of stable isotopes in precipitation especially at mid-latitudes, indicating that other factors also affect the stable isotopes of precipitation in mid-latitudes.

In this study, spatial and temporal variations of the isotopic composition of precipitation were investigated to better understand their controlling factors. Precipitation was collected from six locations in Hokkaido, Japan, and event-based analyses were conducted for a period from March 2010 to February 2013. Atmospheric water vapor was sampled daily at Sapporo in 2006. Compared to the three sites at Pacific Ocean side, relatively low δ values and a high d-excess for annual averages were observed at three sites located along the Japan Sea. Lower δ values in spring and fall and higher d-excess in winter were observed for the region along the Japan Sea. Weekly $\delta^{18}O$ was positively correlated with temperature and negatively with the amount of precipitation in most season and regions.

In total, 264 precipitation events were identified. Precipitation originated predominantly from low-pressure system (LPS) events, which were classified as northwest (LPS-NW) and southeast (LPS-SE) events according to the routes of the low-pressure center, which passed northwest and southeast of Hokkaido, respectively. LPS-SE events showed relatively lower $\delta^{18}O$ than LPS-NW events,

which is attributable to the lower $\delta^{18}O$ of water vapor resulting from heavy rainfalls in the upstream region of the LPS air mass trajectories over the Pacific Ocean. Observed isotopic composition of water vapor also supports this. This phenomenon observed in Hokkaido can be found in other mid-latitude coastal regions and applied for hydrological, atmospheric and paleoclimate studies. A characteristic spatial pattern was found in LPS-NW events, in which lower $\delta^{18}O$ was observed on the Japan Sea side than on Pacific Ocean side in each season. This is likely due to the location of the sampling sites and their distance from the LPS: precipitation with lower $\delta^{18}O$ in the region along the Japan Sea occurs in a well-developed cloud system near the low-pressure center in cold and warm sectors of LPS, while precipitation with higher $\delta^{18}O$ on the Pacific side mainly occurs in a warm sector away from the low-pressure center. Air mass from the north does not always cause low δ in precipitation, and the precipitation process in the upstream region is another important factor controlling the isotopic composition of precipitation, other than the local temperature and precipitation amount.

The study titled「Study on stable isotopes of precipitation in Hokkaido, North Japan（北海道の降水の安定同位体比に関する研究）」investigated the controlling factors and underlying processes responsible for spatial and temporal variations in the isotopic composition of precipitation, by three-year daily or weekly sampling at 6 sites in Hokkaido, and their event-based analysis. Precipitation at Hokkaido was predominantly from low-pressure system (LPS) events. LPS events with a route of LPS center from southeast to southwest of Hokkaido showed lower δ values, which is attributable to the lower δ of water vapor resulting from heavy rainfalls in the upstream region of the LPS air mass trajectories over the Pacific Ocean. Generally, it is believed that air mass from the north has a low δ of water vapor. However, this study clarified that heavy precipitation in the upstream region lowered δ values of water vapor, and this water vapor was transported and resulted in the precipitation with low δ in the downstream region.

This result is a new finding, showing that precipitation process in the upstream region is important factor controlling the isotopic composition of precipitation at mid-latitude coastal regions. The applicant obtained a new knowledge on stable isotopes of precipitation, which has an enormous contribution on studies of meteorology and hydrology. All members of the dissertation committee deem this finding valuable, and judged that applicant has enough qualification to obtain doctoral degree (Environmental Science) of Hokkaido University.