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DEW POINT ELEVATION AND OXYGEN AND HYDROGEN ISOTOPIC RATIOS FOR PRECIPITATION SAMPLED AT OSAKA AND MATSUE, JAPAN

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ABSTRACT: Dew point elevation was clarified to be an important factor determining stable isotope values of precipitation. When dew point elevation is high, stable isotope values for precipitation were clarified to increase due to the evaporation process which occurred during dropping from dew point elevation to the ground. In winter wet air from the Japan Sea passes over mountains in the center of Japan and dry air after precipitated at the mountains reaches at the Inland Sea. Subsequently, it is thought that when dew point elevation increases, stable isotope values for precipitation increase with the distance from dew point elevation to the ground then high dew point elevation raises the average isotope value of precipitation. Therefore, the elevation of the precipitation point decreases with an increase of the isotope value. Consequently, altitude effect is thought to be caused by precipitation with high dew point elevation. High dew point elevation and high stable isotope values for precipitation in winter were observed at Osaka in the Inland Sea. On the other hand, these high values at Matsue on the Japan Sea side in winter were rarely observed because of low dew point elevation with wet air.

Keywords: Isotopic ratio, Altitude effect, Dew point elevation, Evaporation, Precipitation

1. INTRODUCTION

It is known that stable isotopic ratios of hydrogen and oxygen of precipitations change with temperature, amount of precipitation, altitude, distance from coast line, and latitude [1], [2], [3]. Stable isotopic ratios of hydrogen and oxygen of precipitations at the same event gradually change with time and increase with evaporation because of isotope effect [4]. Therefore, stable oxygen and hydrogen isotopic ratios of precipitation are useful as tracers for determining the source of water and analyzing the evaporation and precipitation process [2], [3].

Japan has four seasons and the Japan Sea side climate is different from that of the Inland Sea side climate. The difference between the Japan Sea side and the Inland Sea side was thought to be due to the distance and wind direction from the continent so sampling at both the Japan Sea side and the Inland Sea side is important. Thus, stable isotropic ratios of oxygen and hydrogen of precipitation were studied for water circulation process sampling at Matsue City on the Japan Sea side and at Osaka Prefecture on the Inland Sea side.

2. EXPERIMENT AND ANALYSIS

Precipitation waters were sampled at Matsue City and the south area of Osaka Prefecture from July 2012 to June 2013. The number of samples was 56. Stable isotopic ratios of hydrogen and oxygen of precipitation were analyzed by mass spectrometer.

The sampling points in the south area of Osaka are Sakai City, Izumiohtsu City, Kishiwada City, Kaizuka City and Izumisano City, and their elevations are less than 20 meters above sea level and their distances from the coast are less than 3 km. The sampling points at Osaka are the same climate condition influenced by the Pacific Ocean. The Matsue sampling point is a main city of Shimane Prefecture located on the Japan Sea side. The average temperature and annual precipitation at Osaka are 16 degrees C and 1300mm [5]. There are two wet seasons, June and September. The winter season is dry season, one fourth of wet season. On the other hand, the average temperature and annual precipitation at Matsue are 15 degrees C and 1700mm [6]. There are two wet seasons, July and September; however, winter season also maintains a high precipitation. Air pollution gathered at Osaka sampling points is heavier than in Matsue because Osaka has a bigger population.

2.1 Sampling of Precipitation

The first 9mm of precipitation was only sampled at each rain event because stable isotopic ratios of both hydrogen and oxygen of precipitation gradually changed from the start of precipitation as shown in Fig.2. The isotope change with precipitation volume varied greatly with temperature, air pressure and humidity and each total precipitation volume was also variable [4], [7]. Consequently, in this study, each first 9mm precipitation for each rain event was sampled because a 9mm precipitation with the sampler was enough volume to analyze.

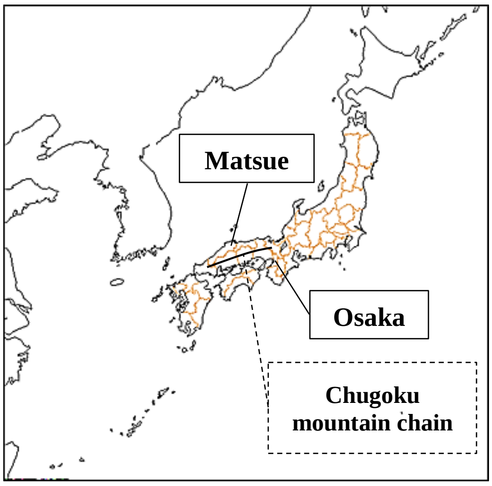

Fig.1 Sampling points

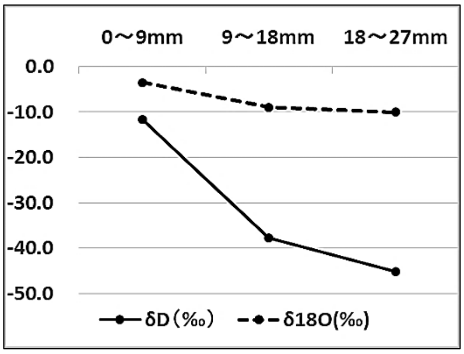

Fig.2 Isotopic ratios change with precipitation volume

Therefore the sampler gets only the first 9mm of precipitation for each event as shown in fig.3. The first 9mm precipitation water was sampled and accumulated in the bottle and then the next precipitation water overflowed through 6 small holes opened at the neck of funnel. Resultantly, the first precipitation wasn't contaminated by the next precipitation water. The diameter of sampler's funnel is 18cm and it can get 50ml of water.

Fig.3 Sampler for precipitation

2.2 Analysis

After the carbon dioxide and hydrogen gas equilibrium method, the oxygen and hydrogen isotopic ratios of the sampled precipitations were measured with mass spectrometer (Sercon Geo Wet system). The measurement error of isotopic ratio is 0.100‰.

$$\delta^{18}O = (Rosa / Rost - 1) \times 1000[‰] \quad (1)$$

$$\delta D = (Rhsa / Rhst - 1) \times 1000 \ [‰] \quad (2)$$

Rosa : $^{18}O/^{16}O$ of sample, Rost : $^{18}O/^{16}O$ of standard mean ocean water, Rhsa : $D/^{1}H$ of sample, Rhst : $D/^{1}H$ of standard mean ocean water

2.3 Dew point elevation

It is known isotopic ratios of precipitations change with elevation [2], [3]. In this study, elevations of all sampling points are almost the same, low. Dew point elevation is an important factor because ice crystallizes or rain condenses from air at the dew point and then falling precipitation starts to evaporate from dew point elevation. In this study, "Dew point elevation" means the lowest elevation at which humidity reaches 80-90%. The upper air observation data is published by the Meteorological Agency [8]. Each A.M. 9:00 data for the upper air at the Shionomisaki and Matsue observation stations were referred. Although the Shionomisaki observation station is far from Osaka, it is the nearest observation station for the Osaka sampling points [8]. Therefore, dew point elevation at the Matsue and Osaka sampling points was calculated from the upper air temperature values at each station.

3. RESULT

3.1 Seasonal Change of the Oxygen and Hydrogen Isotopic Ratios of Precipitation

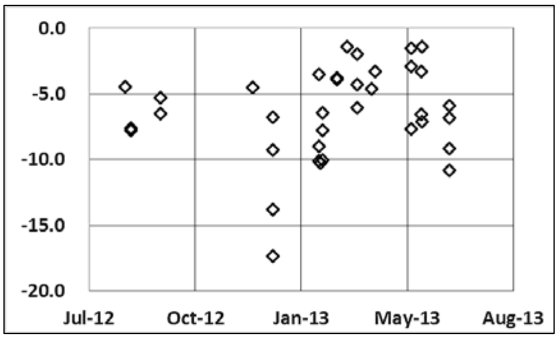

Fig.4.1 Seasonal change of δ18O at Osaka

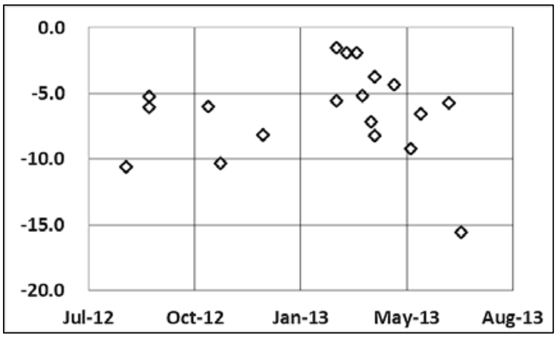

Fig.4.2 Seasonal change of δ18O at Matsue

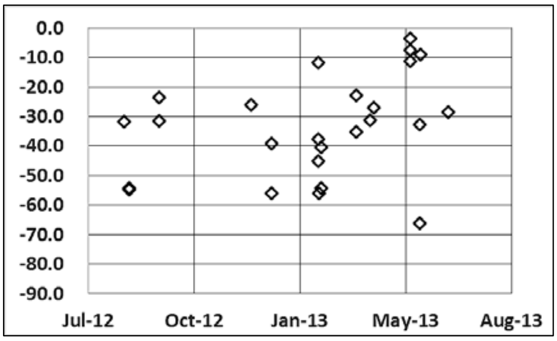

Fig.4.3 Seasonal change of δD at Osaka

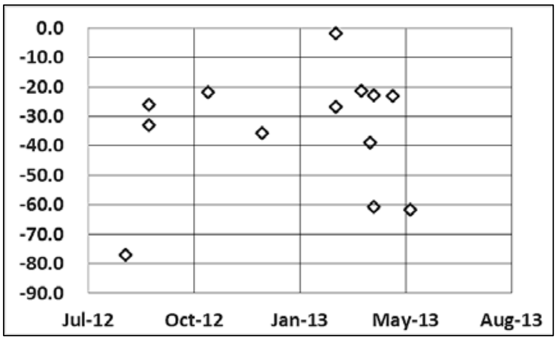

Fig.4 .4 Seasonal change of δD at Matsue

Figs.4.1, 4.2, 4.3 and 4.4 show the oxygen and hydrogen isotopic ratios for precipitation at the Matsue and Osaka sampling points from July 2012 to August 2013. They were high from February to May. Over -5.0 per mile values of $\delta^{18}O$ for precipitation at both Osaka and Matsue sampling points were observed only from February to May. Over -20 per mile values of δD for precipitation at both the Osaka and Matsue sampling points were observed only from February to May.

Then, in total both oxygen and hydrogen isotopic ratios at Osaka sampling points were low in summer and high in winter. However theses values at Matsue were not always high in winter. In Japan, oxygen and hydrogen isotopic ratios of precipitations were found to be low in summer and high in winter [4], although global oxygen and hydrogen isotopic ratios of precipitations were high in summer and low in winter [2], [3], [7].

3.2 Seasonal Change of Dew Point Elevation

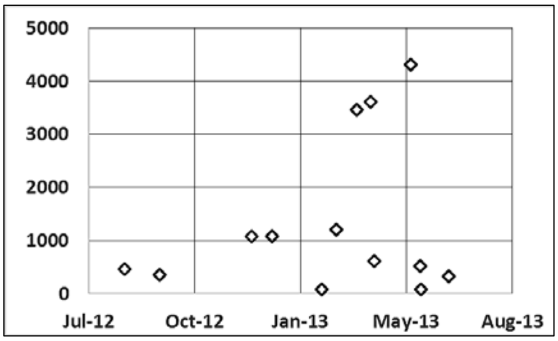

Fig.5.1 Seasonal change of calculated dew point elevations at Osaka

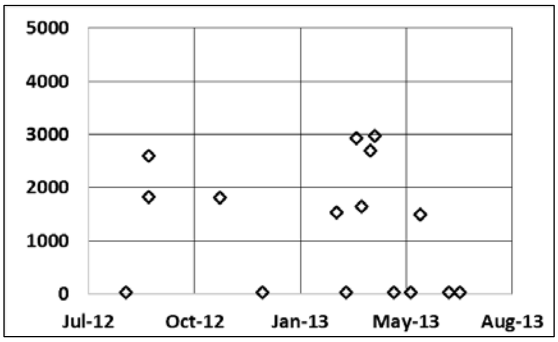

Fig.5.2 Seasonal change of calculated dew point elevation at Matsue

Fig.5.1 and 5.2 show dew point elevation calculated from upper air temperature values at the observation points. The calculated elevation at Osaka was composed of two groups, 0 to 1,000m and 3,500 to 4,500m. The high group was observed from February to May. Similarly, the calculated elevation at Matsue was also composed of two groups, 0 to 2,000m and 2,500 to 3,000m. The high group was also observed from February to May. In particular, the highest dew point elevation at Osaka is higher than at Matsue.

3.3 Dew Point Elevation and Isotopic Ratio in Precipitation

Fig.6.1 and 6.2 show dew point elevation and oxygen and hydrogen isotopic ratios for precipitation at the Osaka sampling points from July 2012 to August 2013. There were two groups, high elevation and high isotope, low elevation and low isotope. Over 3,000m in height, oxygen and hydrogen isotopic ratios were -7 to -2 per mile and -38 to -2 per mile respectively. However, oxygen and hydrogen isotopic ratios less than about 1,000m in height were very variable, -18 to -2 per mile and -65 to -10 per mile respectively.

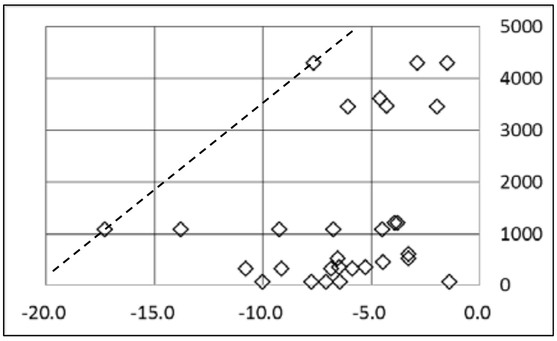

Fig.6.1 Dew point elevation and δ18O at Osaka

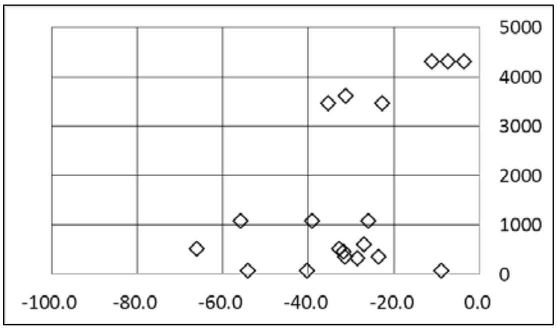

Fig.6.2 Dew point elevation and δD at Osaka

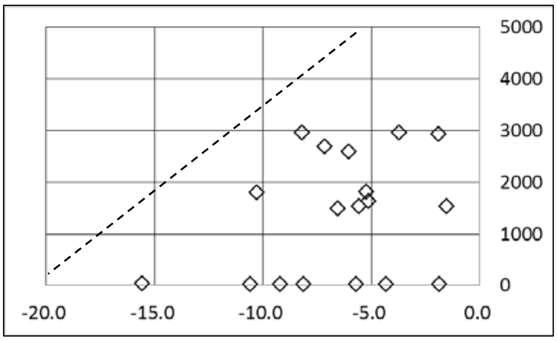

Fig.6.3 Dew point elevation and δ18O at Matsue

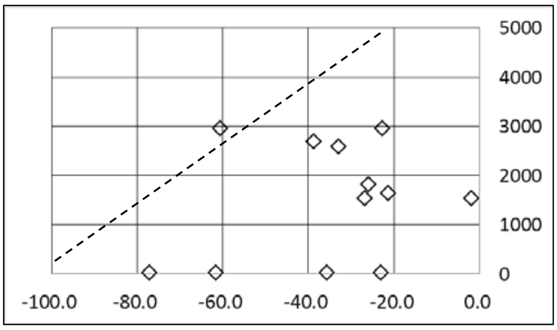

Fig.6.4 Dew point elevation and δD at Matsue

Fig.6.3 and 6.4 show dew point elevation and oxygen and hydrogen isotopic ratios for precipitation at the Matsue sampling points from July 2012 to August 2013. Similarly, there were two groups, high elevation and high isotope, low elevation and low isotope at the Matsue sampling points. Over 3,000m in height, oxygen and hydrogen isotopic ratios were -7 to -2 per mile and -38 to -2 per mile respectively. However, oxygen and hydrogen isotopic ratios less than about 1,000m in height were very variable, -18 to -2 per mile and -65 to -10 per mile respectively. Both elevation and isotope values of high group at Matsue were lower than those at Osaka.

These results indicated precipitation derived from high elevation had high isotopic ratios however precipitation derived from low elevation had wide variation isotopic ratios at both sampling points. Generally oxygen and hydrogen isotopic ratios increase with evaporation [2], [3]. When dew point elevation is high, precipitation contacts with air for a long time and then evaporates quickly. If air under the dew point is not saturated with water, precipitation derived from high elevation will evaporate largely and its isotopic ratios also will increase. Therefore, when dew point elevation is high, precipitation evaporates extensively and its isotope values are also high because surface air is unsaturated with water as shown in fig.7. Dew point elevation depends on humidity and temperature. Dew point elevation of dry air is higher than that of wet air.

In winter, wet air from the Japan Sea passes through Honshu and then after precipitating at the mountains in the center of Japan dry air moves on Osaka. Therefore, low humid air from the Japan Sea passes through Osaka and dew point elevation is high as shown in fig.8. Subsequently, high isotope values of precipitation at Osaka were observed in winter. On the other hand, in summer, very wet and warm air from the Pacific Ocean passes through Osaka. Consequently, isotope values for precipitation at Osaka are not always high in summer although generally isotope values for precipitation are observed to be high in summer globally.

In winter, wet air directly passes through Matsue on the Japan Sea side and then dew point elevation at Matsue is low relative to Osaka. Although high isotope values for precipitation at Matsue were observed in winter, its occurrence was smaller than that at Osaka as shown in Fig.8.

Generally isotope values of precipitation decrease with the elevation of the precipitation point. This altitude effect is very popular phenomenon [2], [3], [7] and recharge area can be estimated from isotope values of groundwater and surface water based on altitude effect.

Dew point elevations for each precipitation were variable, 0 to 3,000m at Matsue or 0 to 5,000m at Osaka. Distance from dew point elevation to the precipitation point determines evaporation rate or isotope value because of evaporation for precipitation during dropping to the ground. Then precipitation of high dew point elevation raises the average isotope value of precipitation evaporation during dropping from dew point elevation to the precipitation point. Therefore, isotope value at low elevation of the precipitation point is high and isotope value at high elevation of the precipitation point is low. Consequently, altitude effect is thought to be caused by precipitation with high dew point elevation.

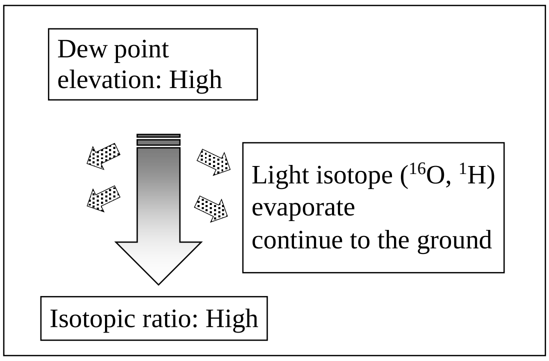

Fig.7 Schematic figure for isotope values by precipitation evaporation

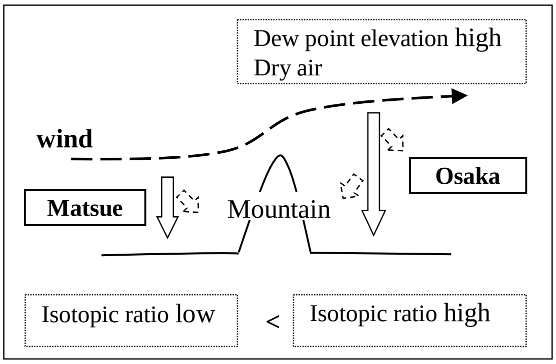

Fig.8 Schematic figure of isotope change across the mountain in winter

4. CONCLUSION

The purpose of this study is to clarify character for oxygen and hydrogen isotope of precipitations at the Japan Sea side and the Inland Sea side during precipitation process. Then, sampling of precipitation at Matsue, the Japan Sea side and Osaka, the Inland Sea was performed for one year. As a result, both elevation values of the dew point and stable isotope values of precipitation at Osaka in winter were high although isotope values of precipitation for low dew point elevation were various excluding winter season. On the other hand, both elevation values of the dew point and isotope values at Matsue on the Japan Sea side in winter were not high relative to those at Osaka.

In winter, wet air from the Japan Sea passes over Matsue and mountains in the center of Japan and then dry air after precipitated at the mountains reaches at Osaka. Therefore high isotope precipitation was thought to be caused at Osaka by evaporation process during dropping from high dew point elevation to the ground. On the other hand, elevation values of the dew point and stable isotope values at Matsue on the Japan Sea side were not high because wet air in winter directly moves on Matsue from the Japan Sea. Therefore, dew point elevation was an important factor in determining stable isotope values of precipitation.

Therefore altitude effect is thought to be caused by precipitation with high dew point elevation because precipitation of high dew point elevation can raise the average isotope value of precipitation by evaporation of precipitation during dropping from dew point elevation to the precipitation point.

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