

Isotopic variation of precipitation over eastern Mongolia

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Introduction

For understanding mechanisms of precipitation variability causing severe drought and heavy rain, it worth quantifying contribution ratio of local and non-local water vapors to precipitation. Hydrogen and oxygen stable-isotopes of water are powerful tool for tracing not only subsurface water flow but also atmospheric water transport.

The present study describes characteristics of precipitation isotopes in eastern Mongolia as a basic knowledge to assess the above subject. In the concrete the objectives of this study are threefold: (1) to clarify time-space structure of isotopic variation of precipitation in and around the Kherlen River basin, (2) to understand the isotopic variation in terms of atmospheric water cycle and land surface-atmosphere interaction, and (3) to detect isotopic signal indicating source of precipitation.

Methods

For isotopic measurement precipitation samples were collected at 7 sites in and around the Kherlen River basin (Fig. 1). Monthly samples were collected throughout a year (from Oct. 2002 to Sep. 2003), and daily samples were collected only during a warm period (From Apr. to Sep., 2003). Rain collectors attached with a device for preventing evaporation of stored water were utilized. Snow samples were collected using a vat installed on the ground and then melted in an airtight container within a room.

For all the samples, δD and $\delta^{18}O$ (δ (‰)) = $(R_{\text{sample}}/R_{\text{standard}} - 1) \times 10^3$; R is D/H or $^{16}O/^{18}O$ ratio and the standard is Vienna Standard Mean Ocean Water

(V-SMOW)) were determined by a mass spectrometer (MAT252, Finnigan MAT) of Hydrology Laboratory, University of Tsukuba. The hydrogen gas equilibration using platinum catalyst for 6 hours for the D/H ratio measurement and the carbon dioxide gas equilibration for 9 hours for the $^{16}O/^{18}O$ ratio measurement were adopted for preparation in advance of isotopic determination. The measurement accuracy is $\pm 1\%$ for δD and $\pm 0.1\%$ for $\delta^{18}O$.

Results and Discussion

For both monthly and daily data, linear relationship between δD and $\delta^{18}O$ can be clearly identified. The regression coefficients (i.e., slope and intercept) for each site are not different significantly from those for the whole dataset (Table 1).

δD and $\delta^{18}O$ show clearly a 1-year periodic variation with minor deviations among monitoring sites (Fig. 2). The annual variation pattern with a depression in winter is very similar to that observed in northern China (e.g. at Qiqihar, Zhangye and Wulumuqi; Yamanaka et al., 2004a) indicating strong temperature effect and less amount effect. Also, this fact means that isotopic composition of precipitating water is firstly determined by large scale atmospheric water vapor transport.

On the other hand, the d-excess ($d = \delta D - 8\delta^{18}O$) does not significantly exhibit annual variation but shows an increase of approximately 10‰ during summer (June-July-August). Such a tendency cannot be observed in northwestern China but observed in northeastern China. Although this isotopic signal may provide useful information on precipitation source, it is still unclear

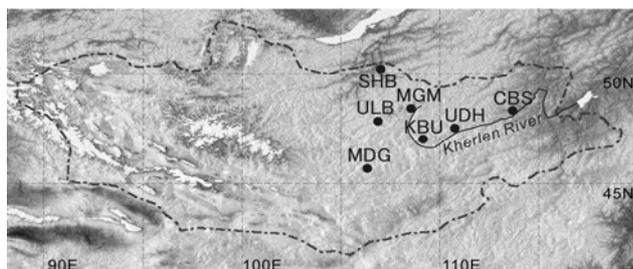


Fig. 1 Location of monitoring sites. (MGM: Mongonmorit, KBU: Kherlen-Bayan Ulaan, UDH: Underhaan, CBS: Choibalsan, ULB: Ulaanbaatar, MDG: Mandalgobi, SHB: Sukhbaatar)

Table 1 Regression coefficients (s : slope, i : intercept, r^2 : determination coefficient, n : number of data) for local meteoric water lines. The values in parentheses denote standard error of s or i estimates.

Site	Monthly data				Daily data			
	s	i	r^2	n	s	i	r^2	n
ALL	7.41 (0.15)	-1.10 (2.82)	0.975	66	7.14 (0.12)	-5.91 (1.43)	0.946	204
MGM	7.21 (0.11)	-1.72 (2.19)	0.997	12	7.04 (0.20)	-6.55 (2.44)	0.966	44
KBU	7.52 (0.19)	2.65 (3.75)	0.994	11	6.63 (0.26)	-8.92 (3.00)	0.952	36
UDH	7.71 (0.22)	3.59 (4.26)	0.992	12	6.90 (0.28)	-8.91 (2.93)	0.940	40
ULB	N/A	N/A	N/A	N/A	6.59 (0.32)	-10.98 (3.92)	0.944	27
CBS	7.01 (0.49)	-9.68 (7.80)	0.953	12	7.46 (0.67)	-7.21 (6.45)	0.912	14
MDG	7.75 (0.77)	1.47 (14.19)	0.918	11	7.17 (0.27)	-3.25 (2.96)	0.965	28
SHB	7.46 (0.18)	3.19 (4.22)	0.996	8	7.50 (1.06)	-8.23 (18.74)	0.795	15

whether the signal indicates dominant contribution of recycling water.

Inter-storm variability during a warm period is high and generally along the annual variation curve but with slightly higher δ and lower d . This may indicate that some samples were affected by evaporation of falling rain drop. Any remarkable characteristics cannot be found in spatial distribution patterns neither for each month nor each event.

Fig. 3 shows comparison of precipitation isotope and water vapor isotope data. The latter was observed in the atmospheric boundary layer (ABL) during only intensive observation period (Tsuji-mura et al., unpublished data). The δD and $\delta^{18}O$ for water vapor are generally lower than those for precipitation. However, estimated δ values of liquid water under isotopically equilibrium with atmospheric water vapor correspond well with observed δ values of precipitation. In addition, the d -excess of precipitation agrees very well with that of atmospheric water vapor. This fact suggests that the low d values of precipitation are not always caused by evaporation of falling rain drop and may provide useful information on precipitation source.

According to Yamanaka et al. (2004b), contribution ratio of local water vapor produced by evapotranspiration from grassland to atmospheric water vapor in the mixing layer is estimated to be 20% or less. The fact that precipitation over eastern Mongolia is in isotopically equilibrium with water vapor within the atmospheric boundary layer suggests minor contribution of locally

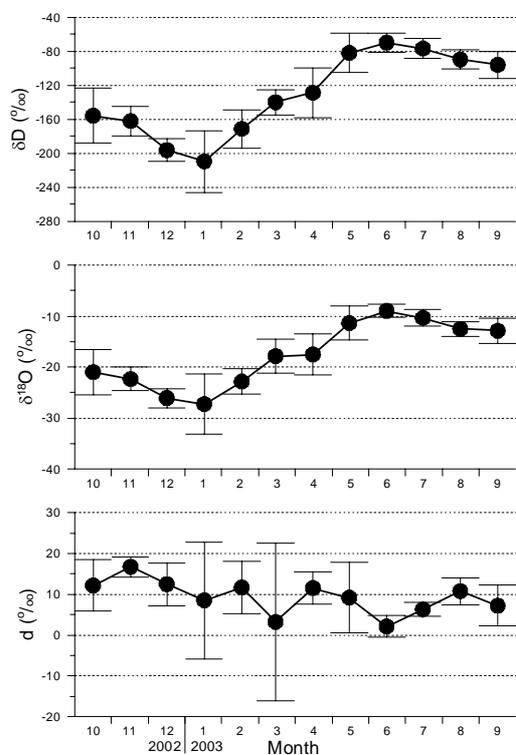


Fig. 2 Annual variation of (top) δD , (middle) $\delta^{18}O$, and (bottom) d -excess. Vertical bars denote standard deviation among the monitoring sites.

produced water vapor to precipitation.

Conclusions

Temporal variation of precipitation isotopes, which has a periodicity of 1-year, is considerably homogeneous in and around the Kherlen River basin. Local characteristics are not significant.

Precipitation is in isotopically equilibrium with water vapor within the atmospheric boundary layer. Because contribution of locally evapotranspiring water vapor to that within the ABL is not dominant, great portion of precipitation must be outside of the Kherlen River basin in origin. Any isotopic signals indicating strong recycling of water cannot be identified at the present state.

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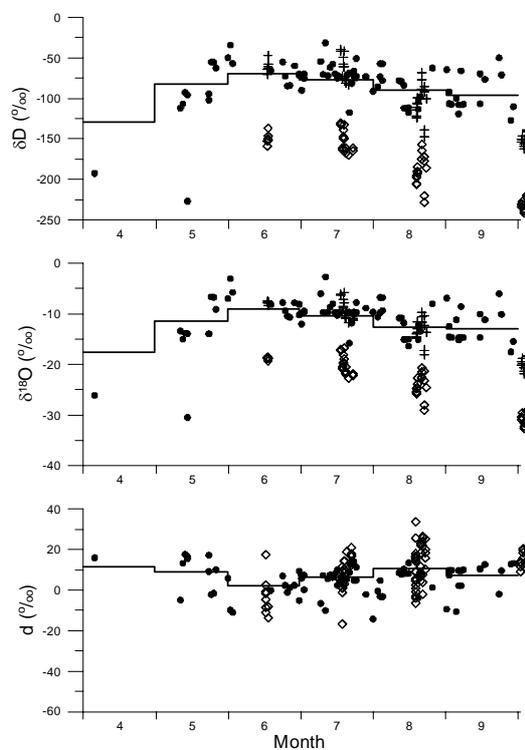


Fig. 3 Comparison of isotopic parameters among precipitation (● : monthly, ○ : daily), atmospheric water vapor (■) and liquid water in equilibrium with the vapor (+, estimated).