region. Considering the temporal change of 3H concentration in the precipitation (Fig. 1), the groundwater in upper stream region was recharged by precipitation in 1970s to 1980s, whereas that of down stream region (^{3}H of 0 to 10 T.U.) was recharged before 1950s.

Consequently, the groundwater is relatively young in the upper stream region, and is old in the down stream region.

References:

(1) Tsujimura et al., 2007: J. Hydrol., doi: 10. 1016/ j. jhydrol. 2006. 07. 026

(2) Higuchi et al., 2004: Proc., 3rd Intern. Workshop on Terrestrial Change in Mongolia, 66-69

Where does Kherlen River water come from?

The origin of river water is a main concern from the view point of water resources especially in arid and semi-arid regions. The Kherlen River is originated in a forested headwater region near the border between Mongolia and Russia, flows toward south in the grassland region, then changes the direction to east near the Kherlenbayan-Ulaan, and finally discharges into Dalay Lake in China. The discharge rate does not increase so much from the upper stream region to the down stream region as shown in Fig. 1, though catchment area of Choibalsan (down stream region) is more than 10 times of that of Baganuur (upper stream region). This suggests that interaction between Kherlen River water and groundwater might not be dominant.

Stable isotope of oxygen (oxygen 18) is effective tool for tracing an origin of river water and groundwater, because oxygen 18 behaves as a water molecule. Fig. 2 shows a relationship between altitude and δ^{18}O (equivalent to oxygen 18 content in water) of Kherlen River water, annual precipitation and summer precipitation. The δ^{18}O decreases with altitude in river water and precipitation, and δ^{18}O of river water is considerably lower than that of precipitation at the same altitude. Considering the trend line of annual precipitation, δ^{18}O of river water at the highest altitude of 1400 m agrees with that of precipitation which should fall at the altitude higher than 1650 m. The altitude higher than 1650 m corresponds to the headwater region of Kherlen River basin. Therefore, the precipitation fallen at the altitude more than 1650 m should recharge the Kherlen River

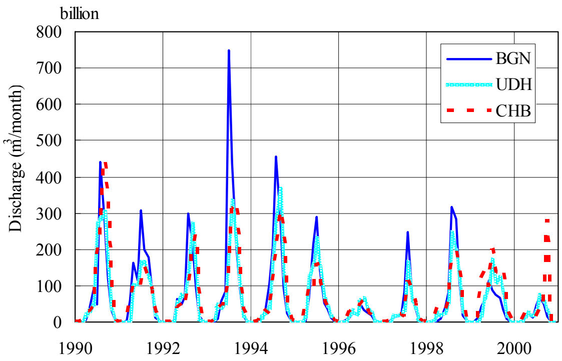

Fig. 1 Temporal and spatial variation of discharge in Kherlen River (main stream) from the upatream (BGN: Baganuur) to down stream (CHB: Choibalsan) via mid-stream (UDH: Underhaan). The discharge was monitored by Institute of Meteorology and Hydrology, Mongolia.

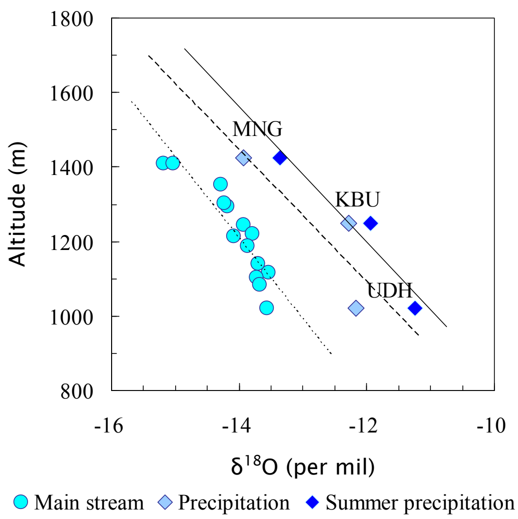

Fig. 2 Relationship between altitude and δ18O of Kherlen River water, annual and summer precipitation. MNG: Mongonmorit; KBU: Kherlenbayan-Ulaan; UDH: Underhaan.

water. The groundwater in the floodplain of Kherlen River might also recharge the river water, though the recharge rate is a few. Thus, the Kherlen River water originates from the precipitation fallen in the headwater region without dominant recharge by the groundwater in the mid-stream and lower stream region of the basin.

References:

(1) Tsujimura et al., 2006: J. Hydrol., doi: 10. 1016/ j. jhydrol. 2006. 07. 026

How much groundwater is available in a well?

Available volume of groundwater in a well is main concern especially for users (nomadic people and also domestic animals) of that well.

If the catchment area of a specific well is determined, the water balance of the well is described as equation (1) (Fig. 1).

$$A(P-E)-G_{out}-U=\Delta S \quad (1)$$

where A: catchment area, P: precipitation, E: evapotranspiration, G_{out}: groundwater discharge, U: pumping rate, ΔS: change of water storage (change of water table).

Under the steady state, the pumping rate U must be so restricted that the ΔS keeps zero for sustainable use of groundwater resource. Thus, the available volume U of the groundwater for a specific well can be evaluated.

The estimated available volume U of groundwater in some wells in the regions of mid-stream and down stream is listed in Table 1. The available volume of groundwater is estimated to be ranging from 20 to 187 m^3/day. Given the daily water consumption by the nomadic people to be 15 L, one well can feed 1333 to 12466 nomadic people. If the domestic animals (sheep, goat, cow, horse etc.) consume water of 50 L/day, one well can maintain 400 to 3740 animals. The volume seems to be enough, if the groundwater recharge is steady. Considering deviation of annual precipitation in Mongolia, the estimated available volume is fragile. We have to collect more data to generalize the estimated value. However, it should be noted that the balance of water resource depends on variable hydrological cycle regime.

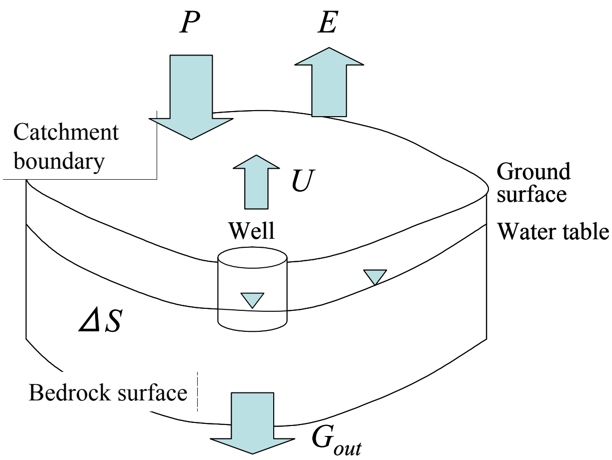

Fig. 1 Water balance of a well to evaluate available groundwater volume of that well.

References:

(1) Tsujimura et al., 2007: J. Hydrol., doi: 10. 1016/ j. jhydrol. 2006. 07. 026

Table 1 Estimated available volume of groundwater in the observed wells in Kherlen River basin. DH: Darhan, JGH: Jargalthaan, UDH: Underhaan.

Well No.	Location	Area (m^2)	P (mm/y)	G_{out} (m^3/y)	U (m^3/d)
W32	DH	772,918	216	15,552	142
W21	JGH	1,111,758	187	38,400	187
W44	JGH-UDH	668,248	207	--	143
W94	UDH	274,087	226	19,152	20

Precipitation over Mongolia may provide good isotopic thermometers

Introduction

It's well known that isotopic compositions of precipitation fallen on the polar regions are highly correlated with air temperature. Therefore, the hydrogen and oxygen stable isotopes in snow/ice in the regions have been used as so-called isotopic thermometer to reconstruct paleo-climatic conditions. Our investigation suggested that isotopic information for precipitation over eastern Mongolia may also be useful for evaluating local temperature variations and continental-scale atmospheric circulation.

Monitoring of isotopes in precipitation

We have conducted daily and/or monthly precipitation sampling for isotopic analysis at 7 sites in eastern Mongolia (Fig. 1) during two years from October, 2002, to September, 2004, with the aid of many meteorological observers of the Institute of Meteorology and Hydrology (IMH), Mongolia. Isotopic compositions of all the collected samples were measured by a mass spectrometer of University of Tsukuba, Japan.

Results

Although the isotopic variation of Mongolian precipitation contained some information relating to its origin (see Sato et al. in this booklet), one of the most remarkable features is a strong correlation between isotopic composition and air temperature(1). Such a strong correlation has never observed in Japan(2), China(3) and the other East Asian countries.

The temporal variation in precipitation isotopic composition averaged for the 7 sites was reproduced by a simple Rayleigh-type model (Fig. 2). This model assumes that subtropical, oceanic air masses having constant temperature and isotopic condition lose gradually their moisture through rainout due to cooling until they reach Mongolia. The very good agreement between observation and model implies that isotopic signal in precipitation reflects temperature depression of

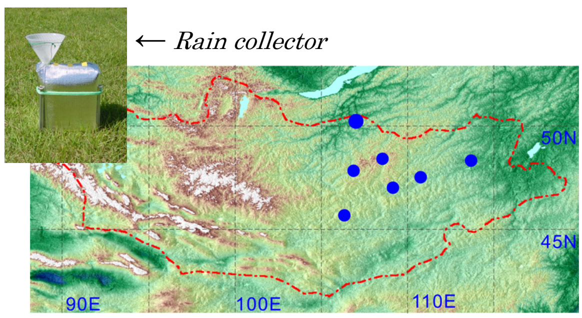

Fig. 1 Location of monitoring sites

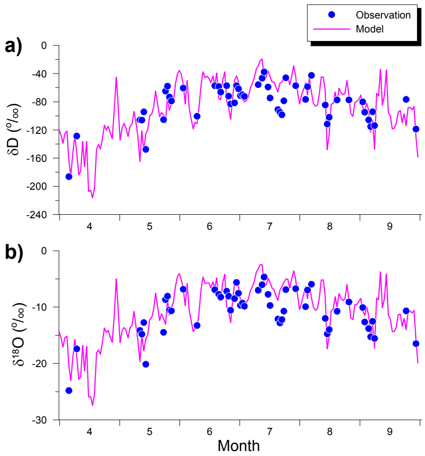

Fig. 2 Comparison of observed isotopic compositions (a: hydrogen, b: oxygen) with those computed by the model

our another numerical simulation study[4], it is likely that drastic decrease in temperature occurs around Mongolia, especially at mountainous regions in the northwest. This is because isotopic composition of precipitation highly correlates with local air temperature.

Hydrogen and oxygen isotopic signals in precipitation are partially preserved in, for instance, deep groundwater, organic matter constituting plant bodies, and minerals composing lake sediments. Thus, these materials in eastern Mongolia are expected to be good isotopic thermometers.

References:

(1) Yamanaka et al., 2006: J. Hydrol., doi:10.1016/ j.jhydrol.2006.07.022.
(2) Yamanaka et al., 2002: J. Geophys. Res., 107 (D22), 4624, doi10.1029/2001JD001187.
(3) Yamanaka et al., 2004: Hydrol. Processes, 18, 2211－2222.
(4) Sato et al., 2006: Submitted to J. Geophys. Res.