Role of snow playing in water cycle in semi-arid region of Mongolia – sublimation (evaporation) of snow cover –

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I Introduction

In the sub-arctic, like the northern Mongolia, the snow cover has commonly recognized to be a dominant hydrological component to affect the river discharge and regional water resource. However, both of snow-cover water equivalence and winter precipitation, even if it can sustained about half year, has been demonstrated to be range of 50 to 150 mm. Therefore, sublimation from snow cover is a non-negligible hydrological component.

Since 2002, intensive observations on snow sublimation using pan method and meteorological condition of near ground surface atmosphere were made both at experimental site of Nalaikh and Terelj. This work is attempting to aim of 1) dressing difference of snow sublimation between plain and mountain region; and also between forest understory and grassland from observations, 2) presenting seasonal and inter annual variation of snow sublimation, and reveal its proportion to snowfall from long time scale calculation using data from meteorological station.

II Observation and data

1. Site description

Observations were carried out in two areas. One is plain site, which locating on sparse grassland at Nalaikh at 47° 45' N, 107° 20' E, 40 km southeast of Ulan Bator. The site is on a sediment plain in a vast valley in the Tuul River, the topography at and around this site is very smooth.

Another is a small mountainous watershed, locating in Terelj with N47° 58, E107° 25, about 1,640 m a.m.s.l. The north slope of the valley is covered by forest, and southern is grassland. The observation were conducted on both slope.

2. Observation terms

Three site of automatic weather station were established. One is locating at Nalaikh, other two are locating in forest and on grassland in watershed of Terelj. The measuring terms including profile of wind, air temperature and humidity, and also snow depth.

Snow sublimation has been calculated at three sites using aerodynamic method. Pan-observation results, which conducted on grassland sites, are used for verifying calculation.

3. Data

Data from meteorological station of Ulan bator and Terelj, which observed by 3 hours interval, are used for long time scale estimating of snow sublimation.

III Results and analysis

1. Snow sublimation

1) Observation results

In winter of 2003/04, snow cover at all measuring sites was disappeared early April. The snow depth, however, was found to be different between plain and mountains. The maximum snow depth at site of Nalaikh was less than 10 cm, but was 18 cm at grassland site of Terelj. From Nov. 2003 to April 2004, snow sublimation was totaled to be 28.8 and 14.6 mm at grassland site and site in forest of Terelj (mountains) respectively, but to be 18.5 mm at Nalaikh site (plain).

For the bulk equation:

$$E = \rho Ce(q_S - q_Z)U_Z \quad (1)$$

where ρ is air density (kgm^{-3}), q and U are specific humidity ($kgkg^{-1}$) and wind speed (ms^{-1}), respectively. The subscripts ‘Z’ and ‘S’ mean ‘at reference height’ and ‘on the snow surface’, respectively. Ce is the bulk transfer coefficient for vapor, which has estimated from observation results: Ce = 0.0039 for forest understory snow and 0.0020 for snow cover on grassland.

2) Long time scale estimation

Employing eqs. (1) and Ce = 0.0020, using the data from Meteorological Station, snow sublimation has been estimated in daily basis at both UB (N47° 55, E 106° 52, 1,300 m a.m.s.l.) for 1980-2000 and Terelj (N 47° 57, E107° 25, 1,530 m a.m.s.l.) for 1986-2000. Mean seasonal variation is displaying in Fig. 1 Sublimation was higher at both beginning and ending snow cover period, which can be elucidated by seasonality of wind speed and humidity deficient.

Inter-annual variation has been summarized in Table 1. Sublimation in mountain region (Terelj) was higher that at Ulan bator. The proportion of sublimation to snowfall, however, was similar about 30% due to snowfall was more at Terelj as well as sublimation.

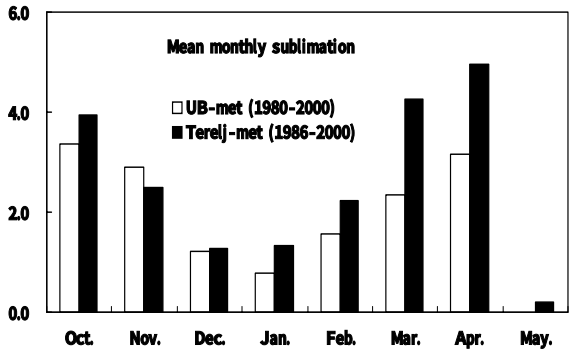

Fig. 1 Monthly snow sublimation, which average from 1980 to 2000 at UB and from 1986 to 2000 at Terelj Met. Sta.

Table 1 Inter-annual variation of snow sublimation at UB and Terelj.

		Ulan bator (1980-2000)	Terelj (1986-2000)
Snow cover days	Range	20-148	76-177
	Mean	106.1	123.1
Snow depth (cm)		4-14	3-30
Snowfall (Pr, mm)	Range	24.4-117.6	35.0-124.7
	Mean	49.9	60.8
Sublimation (Es, mm)	Range	6.4-26.2	12.8-29.7
	Mean	15.4	20.7
Es/Pr (%)	Range	11-54%	16-67%
	Mean	30	34

Table 2 Annual sublimation, snow melting-water evaporation, and its partition to the annual evapotranspiration for 2 hydrological years.

	Jul.,02-Jun., 03	Jul.,03-Jun., 04
Precipitation (Pr, mm)	122.0	150.5
Evapotranspiration (Et, mm)	123.4	178.2
Snow sublimation (Es, mm)	16.0	18.5
Snow melting-water evaporation (Em, mm)	11.4	12.7
Es/Et (%)	13%	10%
Em/Et (%)	9%	7%

2. Evaporation of snow melting water

The result of vapor flux, soil moisture and precipitation at Nalaikh site suggest that every declining process of evapotranspiration and soil moisture at the surface can be initially linked to precipitation events. Differences in the sustained period of every declining process can be related to precipitation and soil water capacity. Therefore, over semi-arid sparse grassland, precipitation events can elucidate variations in peaks of evapotranspiration. However, in the shot period just after snow disappeared, declines process also be found even if no precipitation event, related to snow-melt water. In the period 10-15 days after snowmelt, soil evaporation matched evapotranspiration perfectly, evaporated was from snowmelt penetrated the soil but was rarely related to precipitation.

3. Proportion of sublimation (evaporation) in water budget

Table 2 totaled observation result of snow sublimation and snow-melting water evaporation at Nalaikh site for two hydrological years of Jul. 2002 to Jun. 2003 and of Jul. 2002 to Jun. 2003, and also proportion to the annual amount. Sublimation and snow melting-water evaporation partitioned to annual evapotranspiration of 10-13% and 7-9% respectively.

IV Concluding marks

1) The sublimation from the snow cover in mountain region is higher than that in plain region of 35.8%. In mountain region sublimation from snow cover of grassland higher than that at forest understory of 49.3%.
2) Seasonality of snow sublimation is similar in both mountain and plain region: smaller in middle winter, which relating to seasonal variation of wind speed and humidity deficient.
3) Significant differences of snowfall and sublimation have been dressed between mountain and plain region, but proportion of sublimation to snowfall is similar to be 30%.
4) Snow-melting affect evaporation efficiently. Sublimation and snow-melting water evaporation sum to be proportion of 20% to annual evapotranspiration.