Estimation of Evapotranspiration in Northeastern Mongolia combining Satellite data and Ground data

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Introduction

The climate of Mongolia is characterized by a dry-cold term and a wet-hot term. In such condition the activity of vegetation changes dramatically through a year. Evapotranspiration is one of the most important elements in water cycle, especially in arid area. In order to research the water cycle, it is important to quantify the amount of evapotranspiration. In this study, by using MODIS data and 4 automatic weather station (AWS) data, seasonal change of evapotranspiration in year 2003 is investigated.

Method

Study Area

The subject area of this study is a transition area of Kherlen River basin in northeastern Mongolia, where the vegetation changes from northern forest region to southern arid region. The segment for present analysis is divided between latitudes 46゜N and 48゜N and longitudes between 108゜E and 111゜E. Annual mean temperature is about –2゜C, and the range of temperature change is as large as 50゜C in a year. Annual precipitation is about 200mm, and most of which fall during summer.

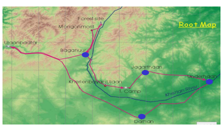

Figure 1. Subject area and AWS point

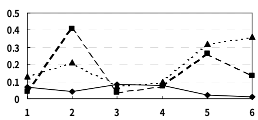

Figure 2. Basic spectrum patterns for each land

water vegetation soil

Pattern Decomposition Method

We use 6 bands of visible and near-infrared parts whose highest spatial resolution is 500m. One pixel can include many types of land cover, which is called "mixed pixels", and a spectrum of a "mixed pixels" is considered as a superposition of basic spectrum patterns, which corresponds to land cover elements. Using these patterns, the mixed spectrum can be decomposed into basic spectrum patterns (Muramatsu et al. 2000). In this study three land covers, "water", "vegetation", and "soil" are adopted as basic land covers

$$A_i = c_w P_w + c_v P_v + c_s P_s$$

The ratios are calculated using the least-squares method

$$\kappa^2 = \sum_{i=1}^{6} [A_i - (c_w P_{iw} + c_v P_{iv} + c_s P_{is})]^2$$

A combination of the land area ratios is determined when κ^2 is minimum with the conditions $c_w \geq 0, c_v \geq 0$ and $c_s \geq 0$. To estimate the accuracy, the relative error is defined as

$$\Delta A = \sqrt{\kappa^2} / \sum_{i=1}^{6} A_i$$

We use the Moderate-Resolution Imaging Spectroradiometer (MODIS) sensor in the "Terra" satellite which was launched by NASA in December 1999. It passes and scans over Mongolia at about 11:30 a.m.(1 hour) LST.

Observing data

Meteorological data have been observed in 4 AWS since March 25th , 2003. They are available for bulk formulae. Whereas during intensive observing period (IOP, one day per one month for each AWS), some meteorological data, wind speed and air temperature for example, are observed with a high frequency (10Hz), which are available for eddy-correlation method. Some parameters in bulk formulae are unknown. So, they need to be quantified through equating estimations of those two ways.

Parameterization of Evapotranspiration

	Bulk Formula	Eddy-correlation Method
C_H	$H = \rho c_p C_H (T_s - T_a)$	$H = \rho c_p \overline{w'T_a'}$
β	$E = \rho \beta C_H U (q_{sat} - q)$	$E = \rho \overline{w'q'}$

When we apply bulk formulae to places other than the AWS, meteorological data are interpolated which are weighed with the distances from the AWS. Indeed, this approach is inappropriate to evaluate the amount of an instantaneous evapotranspira- tion. However, it is appropriate if we quantify that of a monthly evapotranspiration because the locality weakens.

The amount of evapotranspiration is estimated $E = c_w E_w + (c_v + c_s) E_g$ ・・・(*)

E_w : Evaporation from water surface. $\beta = 1$

E_g : Evaporation from grassland. β is quantified at section Results

Both of C_H are 0.0017 and 0.0013 in July and October, respectively.

Results

Pattern Decomposition Method to MODIS data

Figure 3 shows the output of the pattern docomposition method applied to data on July 28th. The transition of vegetation from north to south and some springs around Kherlen River are found. Figure 4 shows the output of the pattern docomposition method applied to data on October 17th. Most area are no vegetation and water area are smaller than that in July. They must be caused by less precipitation and cooler temperature.

The average relative error for all samples is 20%. Most of the large relative error appear in low-reflectance area such as forest and places near clouds, where noise become relatively large because of their shade. The other places are thought to be well decomposed, with the correlation between c_v and NDVI larger than 0.9.

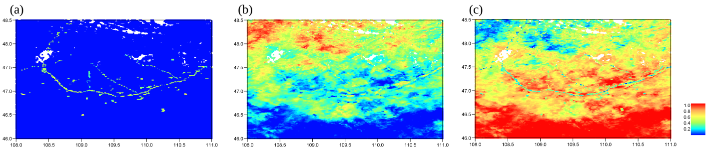

Figure 3. Pattern decomposition method for MODIS data on July 28th (a) water (b) vegetation (c) soil

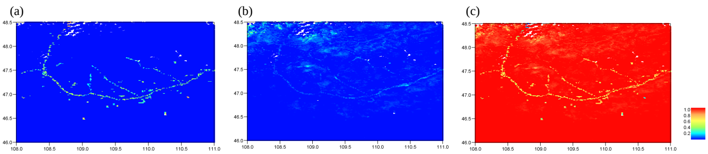

Figure 4. Pattern decomposition method for MODIS data on October 17th (a) water (b) vegetation (c) soil

Relation between evaporation efficiency and the amount of vegetation

Evaporation efficiency is divided into two terms as follows:

$$\beta = \frac{1}{1 + C_H U F(\theta) / D_{atm}} + \frac{1}{C_H U r_v}$$

The first term of right-side stands for the evaporation from soil (Kondo et al. 1990), and the second term stands for the transpiration from vegetation. We examined the relation between c_v and r_v through comparing the estimations of water vapor flux between bulk formula and eddy-correlation method, and obtained the inversely proportional relation $r_v = 146 / c_v$

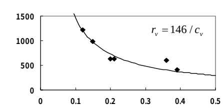

Figure 5. Relation between c_v and r_v.

For example, the first term of right-side is about 0.02 with the condition $\theta = 0.04$ and the second term is about 0.15 over grassland in summer. Whereas the second term over bare soil is 0, of course.

Estimation of a monthly evapotranspiration

We suppose that each land cover ratio keeps constant through a month. Eq.(*) was applied to the data on July 28th, substituting daily average meteorological data for bulk formula. Figure 6a shows the amount of a monthly evapotranspiration in July. Generally speaking, about 100mm of water evaporates over water surface, while 50mm evaporates from grassland, which are larger than 90% of precipitation. The same process was applied to the data in October (Figure 6b). There is very little vegetation and much less precipitation. Hence, the amount of a monthly evapotranspiration in October is much smaller than that in July.

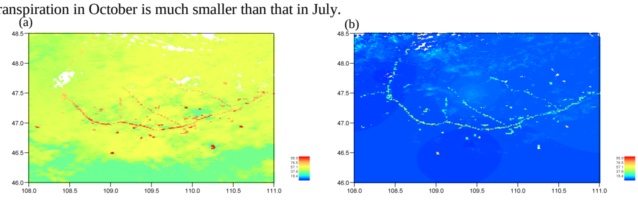

Figure 6. Distribution of the amount of a monthly evapotranspiration in July (a) and October (b).

Problem

In this study, daily averaged meteorological data were used to estimate the amount of evapotranspirration. This method seemed to overestimate, because we didn't consider the condensation process in which $\beta = 1$. At least half-daily averaged meteorological data is needed, which can roughly divided into evaporation process and condensation process.

Conclusions

Pattern decomposition method was applied with MODIS data in northeastern Mongolia on July 28th and October 17th, 2003. And we detected the surface conditions.

We parameterized water vapor flux over grassland and found that transpiration was more dominant than evaporation in amount while vegetation was active.

We estimated the distribution of the amount of a monthly evapotranspiration in July and October. These two months are quite different in amount because of the difference of a vegetation ratio as well as that of a soil moisture. A seasonal change mainly depends on these two elements. In any case, more than 90% of precipitation evaporates back to the atmosphere.

Further study

- Consider a condensation process to quantify the amount of evapotranspiration accurately.
- Evaluate bulk transfer coefficient, which depends on the static stability of the atmosphere.

Acknowledgement

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