Estimating Regional Evapotranspiration over Kherlen River Basin Combining Satellite Data and a Heat Budget Model

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Introduction

This study is trying to estimate spatial distribution of evapotranspiation over Kherlen River Basin in Mongolia. The landscape in this region changes from forest to forest steppe, typical steppe, and finally dry steppe southward. It is considered that this landscape change influences and is also influenced by regional water conditions, and a precise estimate of temporal and spatial distribution of evapo- transpiration over this region is significant to determine local and regional water budget in and around this region. The subject area in this study is a square which is in the range of latitude between 46.5-49deg N and longitude 107.5-112.5deg E, where is largely the western part of Kherlen River watershed. As for vegetation distribution, typical steppe is dominant in this squared area including a little forest-steppe in northern part and dry-steppe in southern part. A practical way to realize both temporally and spatially precise estimation of land surface evapotranspiration is to establish a scheme to estimate surface heat budget using a combinations of routine satellite data and a numerical heat budget model. In this article, the combination method for estimating surface heat budget is roughly described, and an estimate of time series of surface heat budget at Kherlen-Bayan Ulaan (KBU), Khentii, is shown as well as an estimate of spatial distribution of surface heat in one summer day over the subject area.

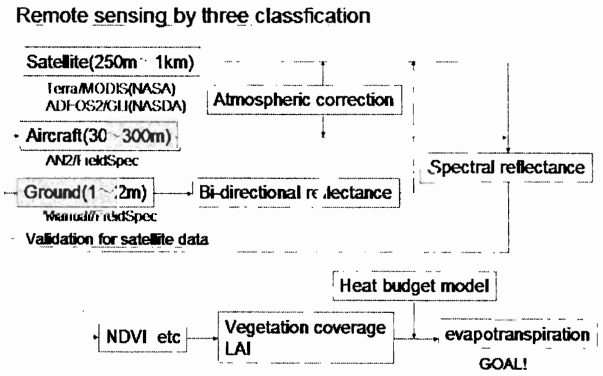

Fig.1 Schematic of estimation algorithm

Algorithm

A schematic illustration of algorithm of combination of remote sending and surface heat budget model for estimating spatial distribution of evapotranspiration in this study is shown in Fig. 1. The remote sensing consists of three classifications, which are satellite data, airborne observation, and ground-based observation. The satellite data is used for spatial distribution maps of various variables, such as surface brightness temperature, normalized difference vegetation index (NDVI), and etc. The airborne and the ground-based observations are used for validation of satellite data. Measurement conditions of satellite data are so diverse that the NDVI and other products of different conditions are not always consistent, and that may make error in estimating leaf area index (LAI), and other physical parameters. Those parameters are finally applied to the surface heat budget model to estimate spatial distribution of evapotranspiration over a steppe in the subject region.

Data

LAI and Surface Temperature from MODIS data

NASA-EOS/MODIS L1B data is an archive of 36 channels of visible and near-infrared reflectance, and thermal-infrared radiance. Spatial resolution is about 1km, and the frequency is one or two times in one daytime. The data in need are easily collected from the MODIS web server. In this study, the MODIS data are used for estimating LAI and surface temperature, which optimize the parameters of heat and water vapor transfer in the surface heat budget model. Spatial distribution of LAI is calculated by Eq.(7) in Matsushima et al. (2005) in this proceedings, using a bi-directional reflectance adjustment.

Solar Radiation from GOES-9 data

Geostational satellite GOES-9 data consists of visible reflectance and thermal- infrared temperature over East Asia and Oceania archived every one hour. The GOES-9 data are also easily collected from an archive in Kochi University by internet. Spatial resolution is originally 1.25km for visible data, and 4km for thermal-infrared data, but the resolution of archived data is 0.05deg (about 5km). The GOES-9 data are used for estimating spatial distribution of incoming solar radiation on the earth surface using an algorithm developed by Kawamura et al. (1999). This algorithm mainly considers solar flux decay caused by cloud, ozone, and aerosols by simple parameterizations. The average root-mean- squares error is around 90 Wm^{-2} on 1-hour basis.

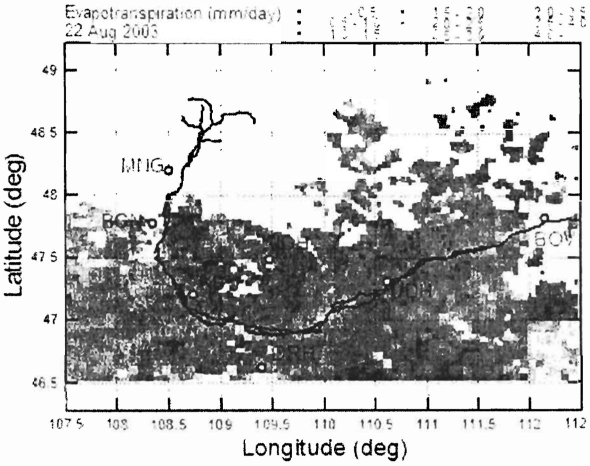

Fig. 2 Spatial distribution of daily sum of evapotranspiration on 22 Aug. 2003. White area was overclouded

Meteorological data

Some basic meteorological data, including radiation and soil temperature and moisture, are acquired in four automatic weather stations (AWSs) in the subject area. They are continuously measured and archived every 10 minutes from March 2003. Data acquired at the meteorological stations in Mongolia are also used. They are measured every 3-hours. In this study, 3-hour average data of the above are used as input variables.

Surface Heat Budget

The surface heat fluxes are precisely measured continuously at KBU station and the data are archived every 30 minutes. In this study, 1-hour average data are used for verifying the model results, as well as the downward solar radiation is used as input in the time series calculation at KBU.

Surface Heat Budget Model

Prognostic equation

The heat budget model used in this study is based on the force-restore method for forecasting earth surface temperature and the two layer bulk formulation to estimate sensible and latent heat fluxes (Matsushima et al., 2005). A summarized form of the equation is given as:

$$\frac{d}{dt}\begin{pmatrix}T_g\\T_c\end{pmatrix} = A\begin{pmatrix}T_g\\T_c\end{pmatrix} + B(S,L,T_a,q,U)', \quad (1)$$

where T_g and T_c are surface temperature of bare soil and vegetation canopy, S and L are incoming solar and longwave radiation, T_a is the air temperature, q the specific humidity, and U the wind speed. Parameter matrices A and B include albedo, the bulk transfer coefficients, evaporation efficiency, and etc. Finally, the surface brightness temperature T_r is calculated from T_g and T_c.

Optimizing surface parameters

Parameters regarding land surface processes should be optimized to have reasonable estimation of evapotranspiration. In this study, the daily average of the bulk transfer coefficient for sensible heat C_H, the slope of the bulk coefficient regarding wind speed b, and the evaporation efficiency ^{2}are optimized both for bare soil and canopy, while the other parameters such as albedo are given. The optimization is achieved by minimizing the difference between estimation of T_r and the satellite brightness temperature. More than six samples of observed surface temperature are needed for optimization because there are six parameters which should be optimized. In this study, the parameters at the KBU stations are determined using time series of surface infrared temperature in daytime every day (temporal optimizing). For regional calculation, daily values of the surface parameters are determined at every 6km grid using the spatial change of satellite infrared temperature, because the satellite data is usually obtained only once or twice in a daytime (spatial optimizing). The heat budget components are calculated at every 2km grid. A 6km grid contains nine of 2km grids.

Spatial Distribution of Evapotranspiration

Figure 2 shows an estimation of the spatialdistribution of the daily amount of evapotranspiration on 22 Aug. 2003, which is the

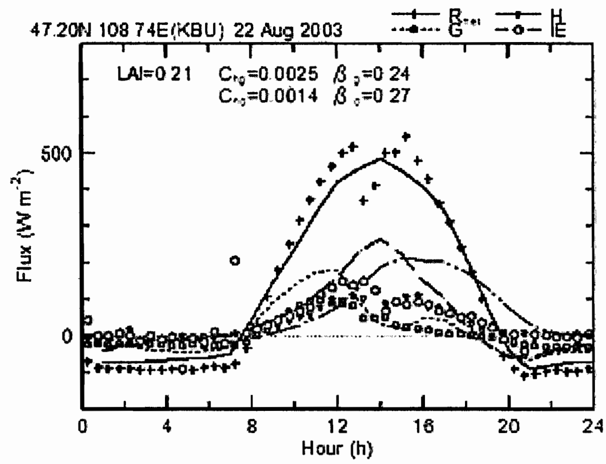

Fig. 3 Daily course of the heat budget components at KBU on 22 Aug. 2003. Lines demote estimations by the spatial optimizing same as Fig. 1, symbols do observation.

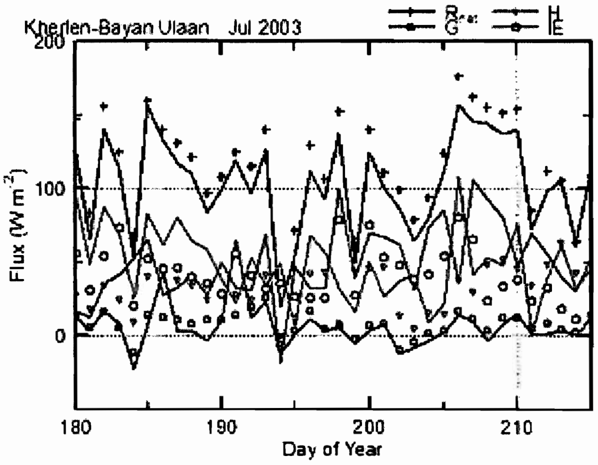

Fig. 4 Day–to-day changes of the heat budget components at KBU in July 2003. Lines and symbols are the same as Fig. 3.

spatial optimzing result. The evapo- transpiration amount was mostly between 0.5-2.5 mm/day, which is larger than usual clear day in August because of rainfalls on the day before. To validate these results, diurnal changes of surface heat flux at Kherlen-Bayan Ulaan (KBU) are illustrated in Fig. 3 (temporal optimizing). Heat fluxes are not so sufficiently reproduced except the net radiation. Two reasons can be considered. One is observed sensible and latent heat fluxes are underestimated. The sum of the heat fluxes other than net radiation is less than the net radiation. That is because the observed values of sensible and latent heat fluxes are less than the calculation. The other is the strong wind after around 15h. The parameters are determined by satellite surface temperature observed at 1200h when the wind was relatively weak. However, strong wind blew after around 15h, which can lead overestimation of turbulent heat fluxes, because the parameters with regard to the turbulence tend to be larger under weak wind conditions.

Seasonal Change of Evapotranspiration at KBU

Figure 4 shows an estimation of the day-to-day changes of the heat budget components in July 2003 at KBU by the temporal optimizing. The estimation results reproduce the observation fairly well. Figure 5 shows monthly average of heat budget components from May to October 2003. The estimation results are almost coincident to the observations, except the evapo- transpiration, of which the estimation is mostly larger than the observation. This may be caused by a widely recognized reason which the evapotranspiration tends to be less measured. Surface moisture is not usually uniformly distributed, and that can not make

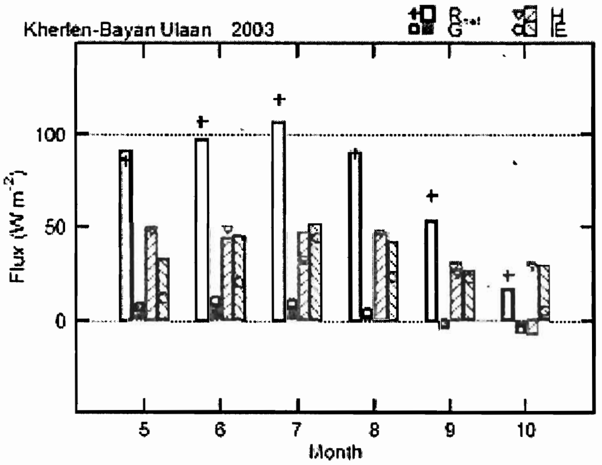

Fig. 5 Monthly amount of the heat budget components at KBU in 2003. histograms denote estimation and symbols denote observations

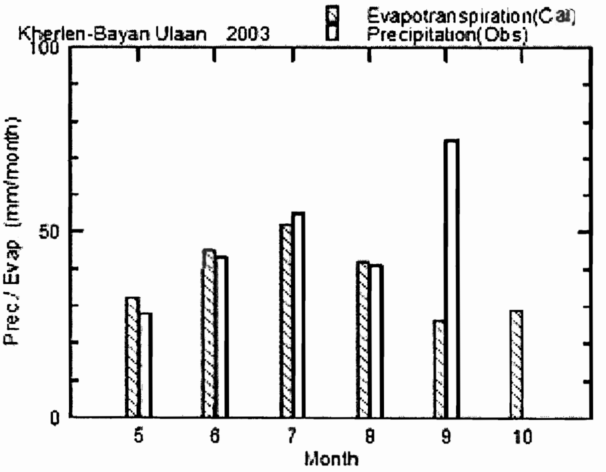

Fig. 6 Monthly amount of estimated evapo- transpiration and observed precipitation at KBU in 2003.

atmospheric moisture conditions statistically uniform. Hence, the sum of the heat budget components results to be far from 0. Figure 6 shows the monthly averages of the estimation of evapotranpiration and the observation of precipitation both at KBU. These are correlated well except September and October. Both values are comparable with each other by August. This result indicates most of the monthly precipitation evaporates within the same month, which is consistent with preceded studies (Miyazaki et al., 2004).

Summary and Future Issues

Spatial distribution and temporal change of evapotranspiration as well as surface heat budget are estimated using both satellite data and a heat budget model, Validation of the estimation found fairly good in daily and monthly amount of heat budget components. Estimation of evapotranspiration is not so coincident with observation, but observed values can be under-estimated because the heat budget was not realized in observation, and the estimation of sensible heat agrees well with observation. Monthly amount of evapo- transpiration agrees well with observed precipitation at KBU by August. However, several disagreements between estimation and observation have found especially in daily amount of heat budget in spring and autumn, which has to be improved

Acknowledgments

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