Flux variation in a Siberian taiga forest near Yakutsk from 1986 to 2000 estimated by a one-dimensional model with routine data

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Abstract

Energy and water fluxes are estimated and their variations are investigated in a larch forest site near Yakutsk using a one-dimensional model with daily basis routine data. Estimated period is 1986 to 2000 including the period before start of tower observation (1997) on the left bank of Lena River. The land surface model includes three submodels; vegetation, snow cover, and soil. It can calculate water and energy fluxes above and within forest, if meteorological data over the forest are given as input. The data used in this study is Baseline Meteorological Data in Siberia (BMDS) Version 3; it consists of daily data of main meteorological elements. Procedure is as follows: 1) preparing equations between routine Yakutsk data and larch tower data, 2) estimating past meteorological data over taiga by the equations, and 3) estimating fluxes using the one-dimensional model. Date of leaf-out start is parameterized with soil temperature and daily maximum air temperature; it corresponds to green-up time obtained from satellite NDVI data. Monthly deviation of net radiation, *Rn*, is 10 Wm^{-2}, maximum is 20 Wm^{-2}. Monthly deviation of latent heat flux, *lE*, is less than 10 Wm^{-2}, its warm season average is less than 5 Wm^{-2}. Although magnitude of *lE* is almost zero in December and January, it is several Wm^{-2} and sensible heat flux, *H*, sometimes becomes negative in cold season except these two month. The variation of evapotranspiration is significantly small compared with that of precipitation. The evapotranspiration (E) normalized by potential evaporation (E_p), E/E_p is from 0.37 to 0.44 in warm season, it tends to be large when the leaf-out starts early. The amount of evapotranspiration in warm season can be estimated from E_p in an error of 5 mm using this relationship.

Keyword: flux variation, land surface model, leaf out, potential evaporation, Siberia

1. Introduction

Intensive meteorological and hydrological observation in GAME/Siberia was carried out from 1998 to 2000 at Spasskaya Pad in a taiga larch forest near Yakutsk with a tower (Ohta et al., 2001). What is the position of these three years compared with average? What is the variation of fluxes year to year? It is difficult to answer these questions only from observed data in intensive observation period. Thus we estimated fluxes over the taiga forest and investigated their variation before start of the tower observation using a one-dimensional land surface model with routine data. Furthermore, we will discuss the characteristics of evapotranspiration normalized by potential evaporation and possibility of estimating total evapotranspiration in warm season without land surface model.

2. Method

The estimation method is as follows:

1) The relationships of meteorological data between Yakutsk and the tower are established from 1998 to 2000.

2) Past meteorological conditions over the taiga forest are estimated using the equations obtained step 1). Diurnal variations are given with empirical equations.

3) The fluxes are estimated using a one-dimensional land surface model.

The land surface model used in this study is that described in Yamazaki et al. (2004) with addition of snow interception process (Yamazaki et al., 2005). It includes three submodels; vegetation, snow cover, and soil. It can calculate water and energy fluxes above and within forest, if meteorological data over the forest are given as input.

The data used in this study is Baseline Meteorological Data in Siberia (BMDS) Version 3 completed as GAME/Siberia project. It consists of daily mean, maximum and minimum air temperature, precipitation amount, water vapor pressure, mean and maximum wind speed, duration of sunshine, snow depth, and other elements from 1986 to 2000.

Linear relationships are recognized on daily each meteorological data between Yakutsk and the tower. Therefore those linear regression equations are used. Daily precipitation amount is assumed as 1.12 times of that in Yakutsk.

The leaf-out date is parameterized as the date of ‘soil temperature at 10 cm becomes greater than 5 C’ and ‘accumulated daily mean air temperature becomes greater than 100 Cday after daily mean air temperature is beyond 0 C’. The period until leaf-out finish is assumed as 16 days. It is assumed that the fallen leaf starts at 1 Sep. and finishes 30 Sep. in every year.

Because the purpose of this study is to investigate long-term variation of fluxes, hourly data measured at the tower is used after 1998, when tower data are exist. There is a long data missing in later half of 1997. Thus just one year from 15 March 1997 is skipped in the estimation to connect the calculation smoothly before and after the data missing.

It is important how to fall daily amount of precipitation in a day because interception evaporation is significantly influenced by length of a rain event and precipitation intensity. We investigated hourly precipitation data but we did not recognize that rain fall occurs in certain time zone. For example, if precipitation

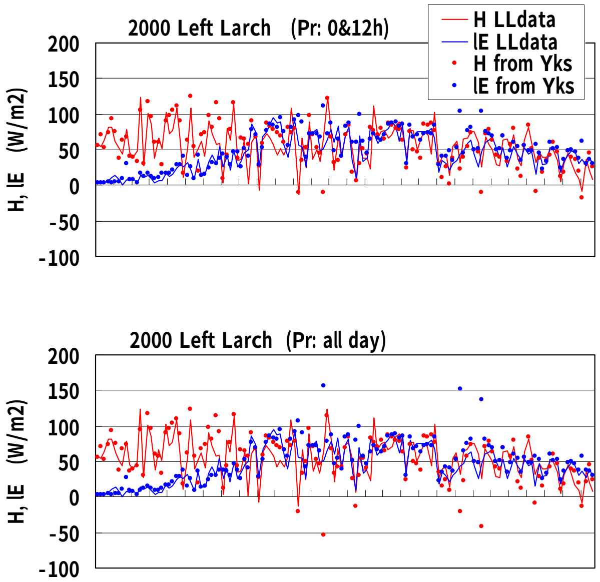

Fig. 1: Reproducibility of hourly fluxes. Upper: rainfall in 0-1h and 12-13h, lower: even rainfall in all day. Lines are using tower data, marks are from routine data.

is distributed evenly in all day, latent (sensible) heat becomes too much (less) in rainy days (Fig.1 lower). After many examinations, we choose that half of daily amount falls midnight (0-1 h) and the other half falls noon (12-13 h) (Fig.1 upper).

3. Results

Figure 2 shows date of leaf-out start estimated by the parameterization, also the date determined from ratio of solar radiation in the forest to outside is indicated. To validate the parameterization of leaf-out, NDVI data was analyzed. The 10-daily composite NDVI provided by CEReS Chiba University was averaged over 128.5E - 131.5E and 61.0E - 63.0E. Figure 3 shows estimated green-up time in 10-day of year (e.g. 15 means 21-31, May) as well as mature and senescence season. The green-up (senescence) is defined as the date when NDVI becomes greater (smaller) than the threshold of 0.25. Figure 4 shows the comparison between leaf-out start by the parameterization and green-up from NDVI. Note that NDVI includes the signal of not only larch forest but other species of tree and grassland.

Estimated monthly mean fluxes and anomaly from every month's mean during 15 years are shown in Figs 5 and 6. Monthly deviation of net radiation *Rn* and sensible heat flux *H* are about 10 Wm^{-2}, 20 Wm^{-2} in maximum. Latent heat flux *lE* deviation is less than 12 Wm^{-2}. The value of *lE* in winter is several Wm^{-2} except for December and January and sometimes *H* becomes negative. Anomalies of *H* and *lE* are not always synchronous.

Monthly normalized evapotranspiration E/E_p is shown in Fig.7. The value of E/E_p is stable in 0.4 through 0.55 in warm season (Jun-Aug). In May, it varies from 0.15 to 0.37 according to leaf-out time. On the other hand, it is scattering in cold season because the absolute values of E

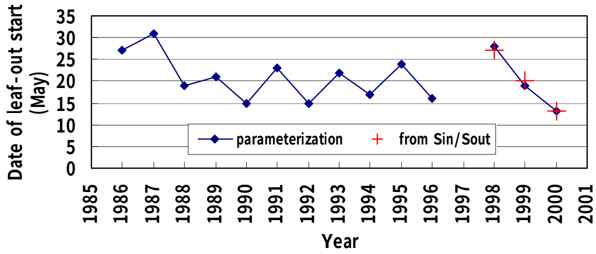

Fig. 2: Estimated date of leaf-out start with the parameterization. +: Date from measured solar radiation ratio in forest to outside.

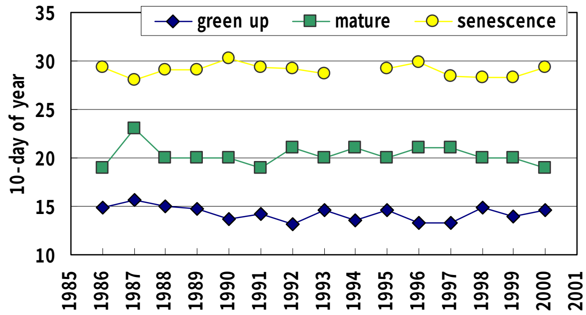

Fig. 3: Green-up, mature and senescence time from 10-daily NDVI (threshold is 0.25).

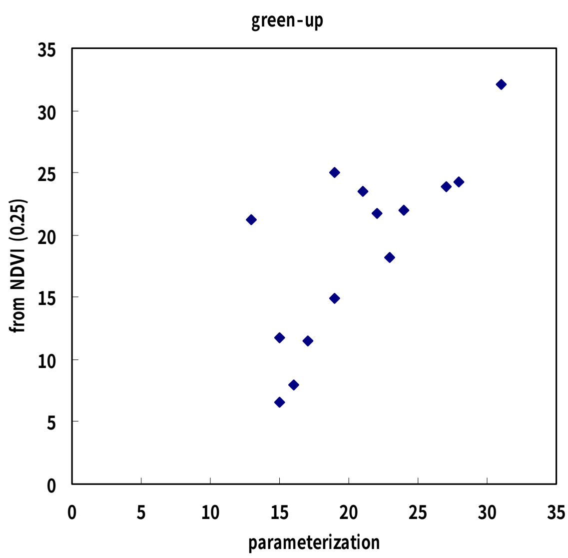

Fig. 4: Comparison between leaf-out start by the parameterization and green-up from NDVI. Both axes are indicated in the date of May.

and E_p are small (sometimes E_p is negative). Large value of E/E_p is often found in March and October because of large interception evaporation of snow.

Figure 8 shows warm season (May – Aug) averaged fluxes and anomaly including potential evaporation E_p. Deviations of *H* and *lE* are 7 Wm^{-2} or less except for *H* in 1998. It is found that 1998 is extraordinary because deviations of each flux are abnormally large in this year. Variation of E_p is similar to *Rn* variation but slightly

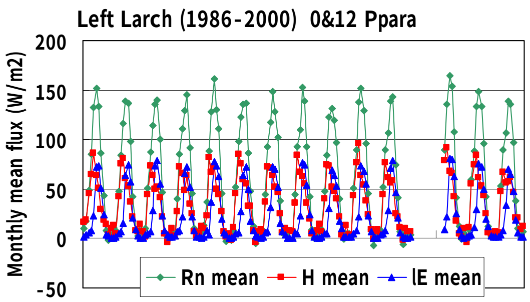

Fig. 5: Estimated monthly mean fluxes.

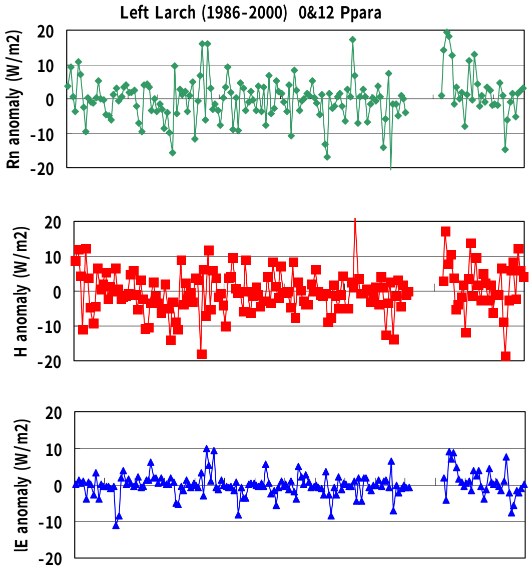

Fig. 6: Estimated monthly anomaly from every month's mean during 15 years: Net radiation, sensible heat flux and latent heat flux from the top.

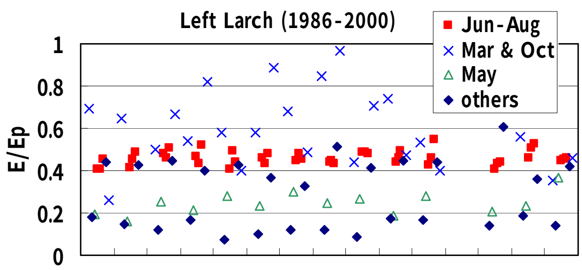

Fig. 7: Monthly evapotranspiration normalized be potential evaporation.

emphasized. The influence of water and energy balance on the deviation of leaf-out period is small compared with fixed leaf-out simulation. The total evapotranspiration increases as the leaf-out is early (maximum +5.1 mm in 2000); it decreases as the leaf-out is late (maximum -8.9 mm in 1987).

Figure 9 indicates relationship between precipitation Pr and evapotranspiration E in warm season where both variables are normalized by E_p. It is found that variation

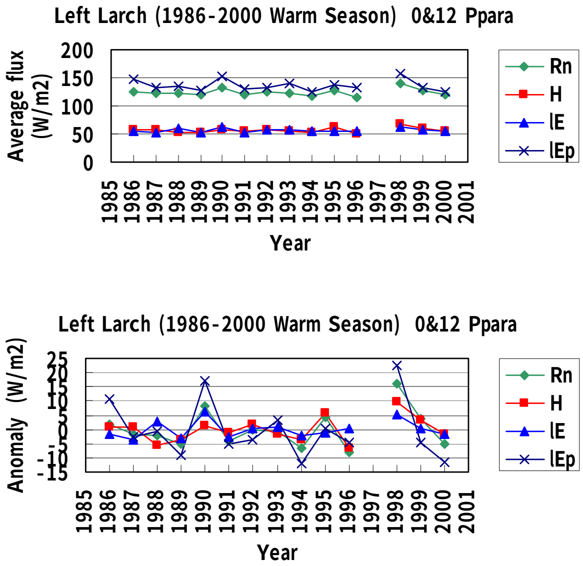

Fig. 8: Warm season (May-Aug) averaged fluxes (upper) and anomaly (lower) including potential evaporation E_p.

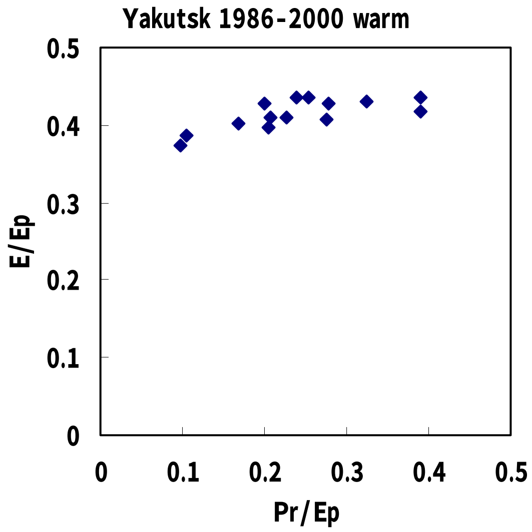

Fig. 9: The relationship between precipitation and evapotranspiration in warm season.

of E is small compared with variation of Pr. It suggests that forest and soil (including permafrost) make E variation even. The reason why evapotranspiration is larger than precipitation is that snow is not included in the precipitation.

Figure 10 shows normalized evapotranspiration E/E_p in warm season against lE_p anomaly and date of leaf-out start. The value of E/E_p is 0.37 through 0.44; it decreases as lE_p anomaly increases or leaf-out is late. It is possible that the amount of evapotranspiration in warm season is estimated using these relationships in the accuracy of 10 mm from lE_p anomaly, and 5 mm accuracy from the date of leaf-out start without land surface model.

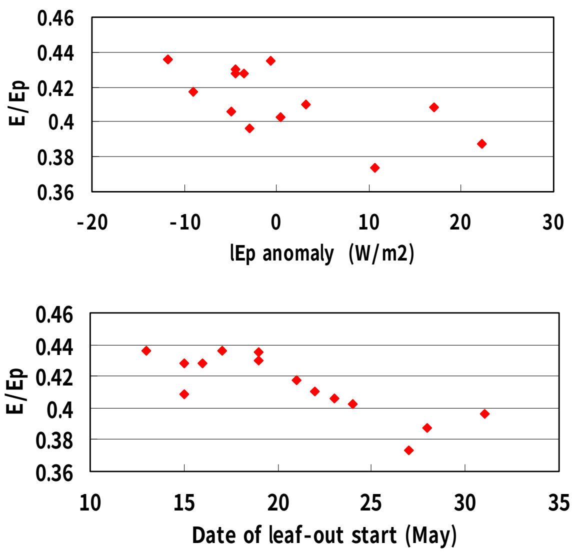

Fig. 10: Evapotranspiration normalized by potential evaporation against potential evaporation anomaly (upper) and date of leaf-out start (lower).

4. Conclusions

Flux variations are estimated using routine data in consideration of leaf-out variance. The estimated monthly variation of *Rn* is less than 10 Wm^{-2} (maximum 20 Wm^{-2}) and that of *lE* is less than 12 Wm^{-2}. The year 1986, when main observation was started in GAME/Siberia, is abnormal having positive anomalies on all fluxes. The normalized evapotranspiration E/E_p is 0.37 through 0.44 in warm season average; it tends to be small when E_p is large or leaf-out is late. The amount of evapotranspiration can be estimated from E_p and leaf-out date in the error of 5 mm.

The problems of this study are as follows:

1) The effect of soil dryness on plant physiology is not considered.

2) Also the length of the period until finishing leaf-out and the date of senescence should be parameterized.

References

Ohta, T., T. Hiyama, H. Tanaka, T. Kuwada, T.C. Maximov, T. Ohata and Y. Fukushima, Seasonal variation in the energy and water exchanges above and below a larch forest in eastern Siberia. *Hydrological Processes* **15**: 1459–1476. DOI: 10.1002/hyp.219, 2001.

Yamazaki, T., H. Yabuki, Y. Ishii, T. Ohta and T. Ohata, Water and energy exchanges at forests and a grassland in eastern Siberia evaluated using a one-dimensional land surface model. *J. Hydrometeorology* **5**: 504–515, 2004.

Yamazaki, T., H. Yabuki and T. Ohata, Hydrometeorological effects of intercepted snow at an eastern Siberian taiga forest using a land surface model. *Hydrological Processes*, (submitted), 2005.