Land surface model simulation on CREST forest sites using measured leaf-scale physiological parameters

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Introduction

Boreal forest, which widely extends over northern Eurasia from 45° to 70°, occupy one third of the total forest over the world in area. Although we often think that boreal forest is uniform, the climate condition (e.g. temperature, precipitation) is greatly different in the area. Thus, probably also vegetation response, and the characteristics of water and energy cycle widely vary. Here, the question is whether the physiological characteristics themselves change or just superficial response change.

This study will discuss water and energy cycle using a land surface model over/in forests in Yakutsk, Moshiri and Seto, we will base on in situ physiological and hydrometeorological observation. This study is a part of the JST/CREST project "Parameterization of the relationship between the water cycle system and plant eco-physiological properties in boreal forest areas". The outline of the project and site description can be found in Ohta (in this issue). Spatio-temporal variations of energy and water fluxes in Eastern Siberia is reported by Park et al. (in this issue).

Model

The land surface model (2LM) used in this study is that described in Yamazaki et al. (2004). 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 (Fig. 1).

Jarvis type stomatal conductance model is introduced into the 2LM. Stomatal conductance, *gs*, is written as:

$$gs / gs_{\max} = f_1(PAR)\, f_2(T_a)\, f_3(VPD)\, f_4(\theta)$$

$$f_1(PAR) = \frac{PAR}{PAR + 1/a}$$

$$f_2(T_a) = \left(\frac{T_a - T_{\min}}{To - T_{\min}}\right)\left(\frac{T_{\max} - T_a}{T_{\max} - To}\right)^{\left(\frac{T_{\max} - To}{To - T_{\min}}\right)}$$

$$f_3(VPD) = 1 \Big/ \left[1 + \left(\frac{VPD}{D_{50}}\right)^b\right]$$

$$f_4(\theta) = 1 - \exp\left[k\left(\theta_{\min} - \theta\right)\right]$$

where, gs_{max} is maximum stomatal conductance, *PAR* is photosynthetically active radiation, T_a is air temperature, *VPD* is vapor pressure deficit, and θ is soil water content. Note that Jarvis model is simple and it dose not consider photosynthesis processes, but restricting element of transpiration can be easily analyzed.

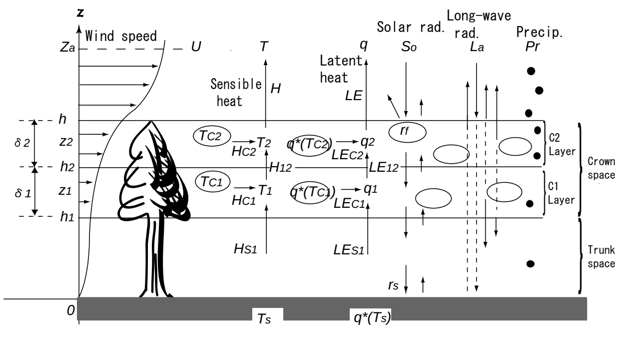

Fig.1 Schematic of the land surface model (2LM)

Table 1 Estimated parameters of Jarvis stomatal conductance model. ES: from each site data. BP/CP: from pooled data for Broadleaf/Coniferous stands. AP: from all pooled data. YL: Larch in Yakutsk. SM: Mixed forest (Quercus) in Seto. MB: Birch in Moshiri, *: spring leaf, **: summer leaf.

Parameter set	site	gs_{max} (mol m^{-2} s^{-1})	a ((μ mol m^{-2} s^{-1})$^{-1}$)	To (℃)	D_{50} (kPa)	b	k
ES	YL	0.43	0.0050	20.6	1.80	2.02	230.8
	SM	0.52	0.0063	25.0	2.13	3.43	35.5
	MB*	0.57	0.0066	25.0	1.21	2.50	144.4
	MB**	0.79	0.0150	25.0	1.19	2.50	4.6
BP		0.79	0.0327	25.0	1.50	2.12	2.7
CP		0.41	0.0166	20.5	1.80	2.03	7.7
AP		0.79	0.0316	24.8	1.50	1.95	2.9

Results

Parameters in Jarvis stomatal model were estimated with intact leaf-scale physiological measurement. The detail of the measurement procedure is described in Kato et al. (in this issue). Table 1 shows the estimated parameter values. Here, ES means parameters obtained by measurements in each site for a certain species, BP and CP are those determined by pooled all data for broadleaf or coniferous stands, respectively, and AP is those determined by all pooled data including both broadleaf and conifer. The parameters T_{min}, T_{max} and θ_{min} are fixed as 0℃, 45℃ and 0.05, respectively.

Figure 2 shows simulated energy fluxes and Bowen ratio at larch site in Yakutsk with ES parameters. On the other hand, figure 3 shows those with AP parameters. Although latent heat in AP simulation decreases especially in June and the first of July, both parameter sets (ES and AP) can simulate reasonable seasonal change of energy fluxes. The parameter set CP simulates almost same as AP (figure is not shown).

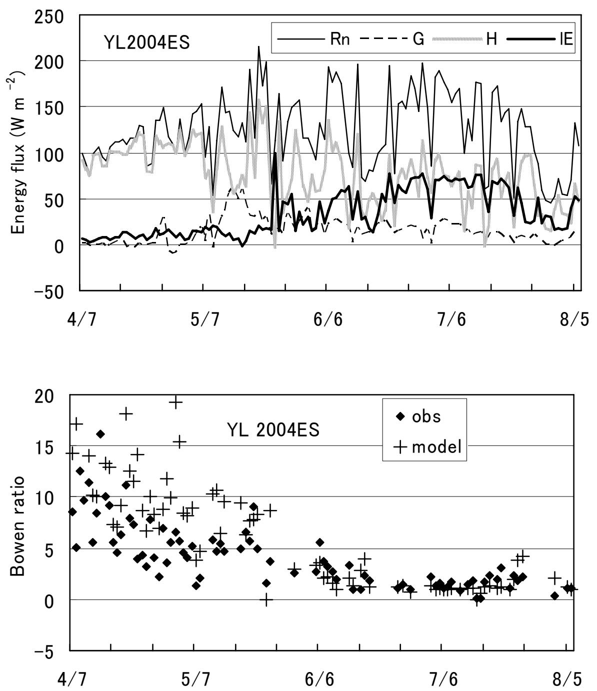

Fig. 2 Simulated energy fluxes (upper) and comparison of Bowen ratio between observation and model calculation (lower) in YL with ES parameters. Precipitation data is provided from RR2002, Hokkaido University.

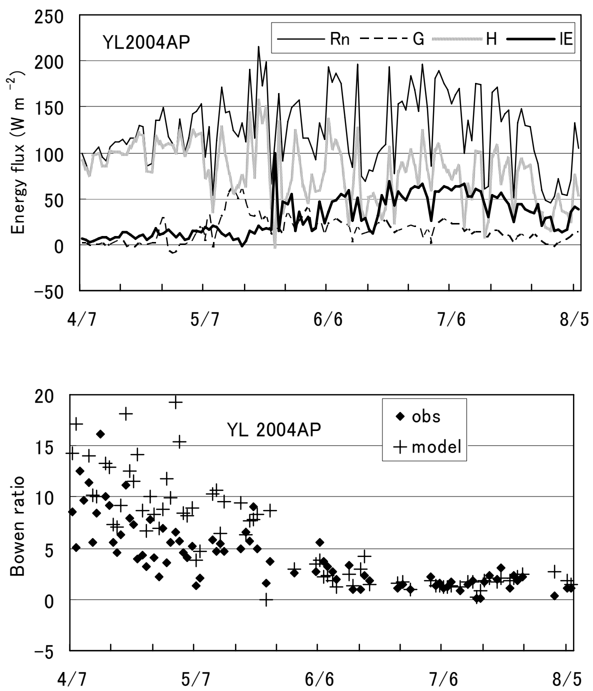

Fig. 3 Same as fig. 2 but with AP parameters.

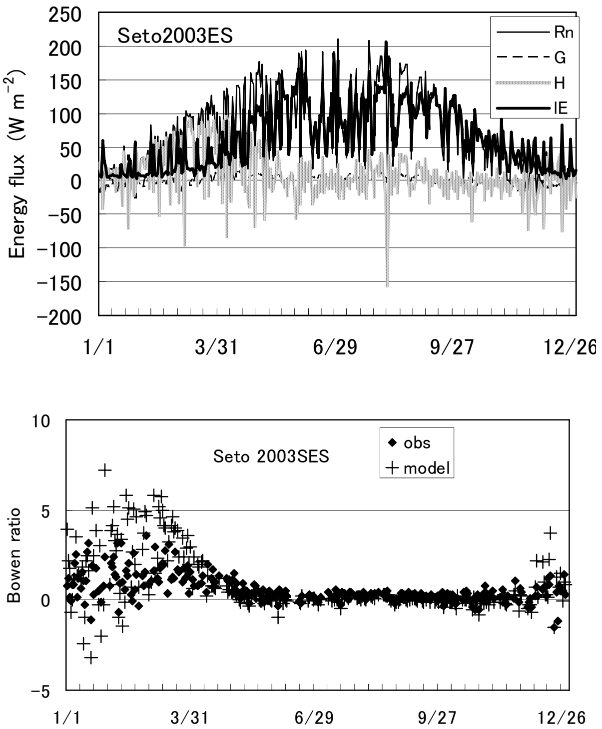

Fig. 4 Simulated energy fluxes (upper) and comparison of Bowen ratio between observation and model calculation (lower) in SM with ES parameters.

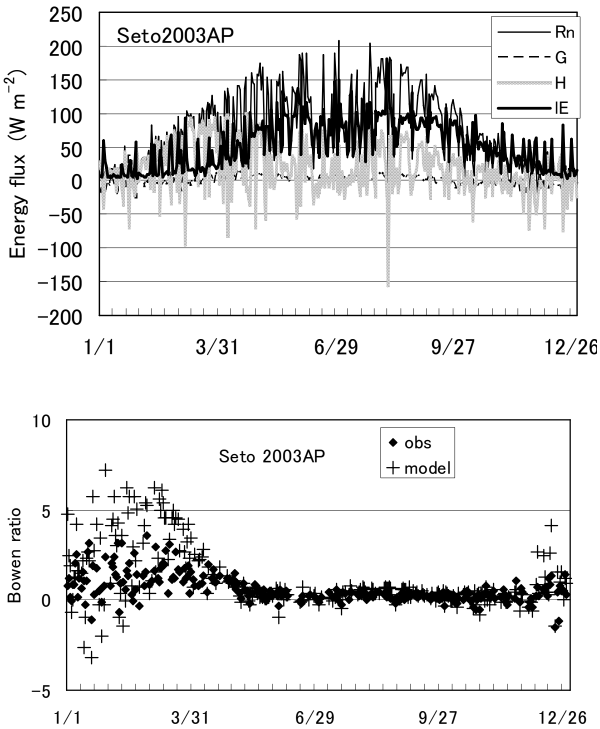

Fig. 5 Same as fig. 4 but with AP parameters.

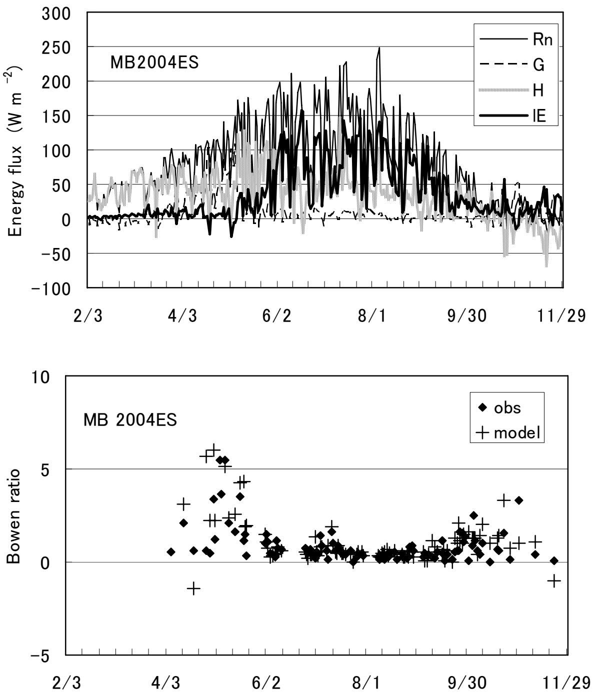

Fig. 6 Simulated energy fluxes (upper) and comparison of Bowen ratio between observation and model calculation (lower) in MB with ES parameters.

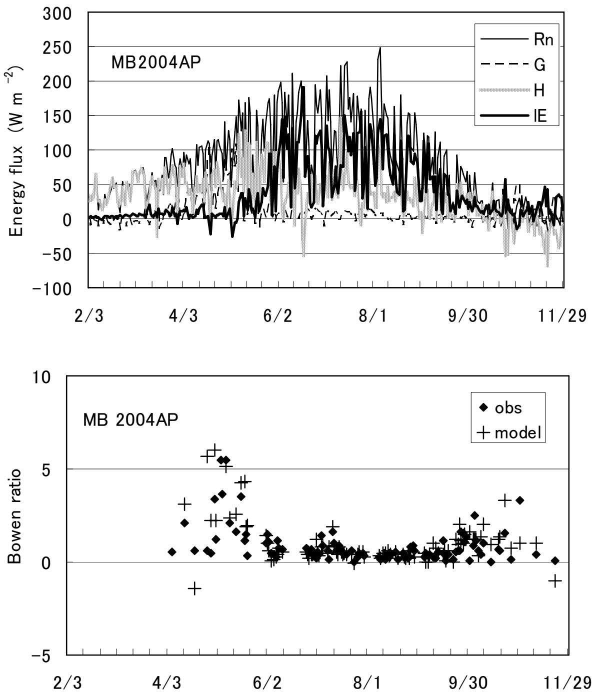

Fig. 7 Same as fig. 6 but with AP parameters.

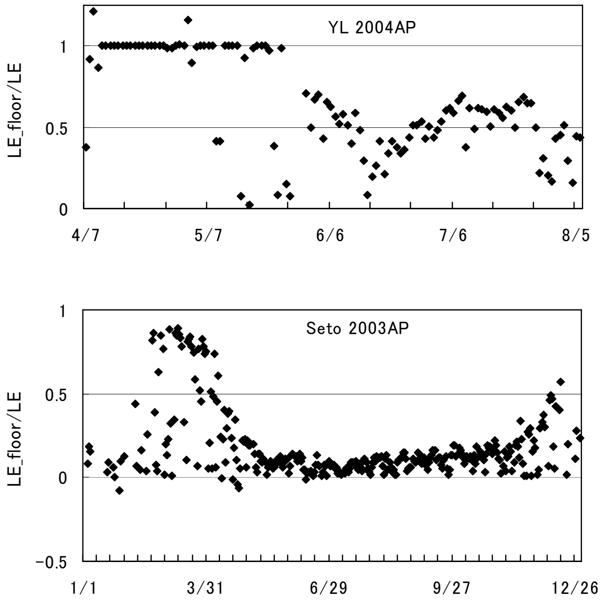

Fig. 8 Simulated ratio of evapotraspiration amount at forest floor to total evapotranspiration amount. YL in 2004 (upper) and SM in 2003 (lower) both with AP parameters.

Figures 4 and 5 show the results for Seto mixed forest. Latent heat flux in ES simulation is slightly large (small Bowen ratio). Spikes of fluxes (positive latent heat and corresponding negative sensible heat) occur because of interception evaporation in rainy day. Latent heat flux in BP decreases from that in ES. The Bowen ratio is larger than observation in August. The result in AP is almost same as BP simulation.

Figures 6 and 7 indicate the results for Moshiri birch forest. Because precipitation data was missing until 5 October 2004, calculated soil moisture is unrealistic. Thus soil moisture restrict term was excluded in this simulation ($f_4(\theta)=1$). This assumption might be reasonable to calculate transpiration because soil is always wet in observation. However interception could not be estimated. Latent heat flux in BP slightly increases from that in ES simulation. The simulation with AP parameters is almost same as BP again. Similar results are obtained for Moshiri mixed forest.

Figure 8 shows simulated ratio of evapotraspiration amount at forest floor to total evapotranspiration amount for YL2004 and SM2003 with AP parameters. The contribution of forest floor is large in Yakutsk. Especially in July, the ratio is more than 50%. On the other hand, contribution of forest floor is small in Seto site. In summer, the ratio is about 10%.

Conclusions

Water and energy exchanges on forest are simulated in Yakutsk, Moshiri and Seto sites using a land surface model with Jarvis's stomatal conductance model. Two types of simulations are conducted. One is using conductance parameters obtained by in situ physiological measurements in each site. The other is using a parameter set which is determined by pooled all physiological data, and common to all sites. Both simulate seasonal changes of energy balance (Bowen ratio) reasonably in each site without any parameter tunings. It suggests a possibility that we can simulate water and energy exchanges on forest using one common parameter set over wide region at least North-East Eurasia.

Effect of forest floor is remarkable large in Yakutsk. This is probably related to low forest density and restriction on evaporation in dry-hot condition.

Reference

Yamazaki, T., H. Yabuki, Y. Ishii, T. Ohta and T. Ohata, 2004. 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.