Modeling spatio-temporal variations of energy and water fluxes in Eastern Siberia: An applicability of a lumped stomatal conductance parameter set by a land surface model

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Introduction

A major concern of the research that investigates the interaction in biosphere-atmosphere system extrapolates how vegetated surface responses to climate change in the future. Land surface model (LSM) is a useful tool to meet the need. LSM usually calculates fluxes with the size of grid ranging several km to several hundred km. A large type of tree species may appear within the grid. However, information of the grid for LSM is mostly simplified. For instance, let's note stomatal conductance. LSM has been generally used the individual parameter sets adequate to representative tree type of the grid. We had here motivated that in case of stomatal conductance, the use of potential parameter, covering responses of all trees, rather than simple one may better the representation of LSM. As an example, Wright et al (2004) analyzed a large number of tree data worldwide and found that modulation of leaf functional traits by climate is modest, while leaf economic consisting of chemical, structural and physiological properties shows variable spectrum at the global scale. This suggests that in modeling water and energy fluxes, coupling of potential parameter into LSM could reliably quantify leaf action under given environment. We had constructed a parameter set about stomatal conductance and tested how well does the parameter work set in eastern Siberia. We report an initial result of calculated 3-year.

Model Description and Method

A one-dimensional land surface model (Yamazaki et al., 2004) includes three (i.e. canopy, soil and snow) submodels. The model especially divided the canopy into two layers and then represented the fluxes above and within the canopy. LSM was applied to north-eastern Siberia bounded by 30^o - 72^oN and 90^o - 180^oE. The horizontal grid spacing is $0.5^o \times 0.5^o$. Daily forcing meteorological quantities include pressure, air temperature, mean wind, vapor pressure, downwelling shortwave and longwave radiation and precipitation. Using the daily forcing data, LSM simulated hourly water and energy fluxes, based on some of empirical models and assumptions. The spatio-temporal variation of leaf area index (LAI) was estimated by the combination of a simple model (Jolly et al. 2005) and the maximum LAI of each grid derived from MODIS image. Vegetation and soil characteristics are specified into 17 and 16 types, individually. Details about parameter set of stomatal conductance are well described by Kato et al. (in this issue). For simulations, two types of parameter sets for stomatal conductance were made: the first set separated vegetation to the two of conifer and broad-leaf types (apparent parameter) and the second lumped all of leaf data regardless of vegetation type (potential parameter). The simulation was focused on validating the practicality of the latter.

Results and Discussion

The spatial distribution of bowen ratio between two parameter sets was compared over 3-year, and showed best agreement. Considering the fact that previous most of LSM used individual parameter proper to each vegetation type, the good agreement may be unexpected. Inter-annual variability of bowen ratio was significant at above 60^oN where the ratio was larger two times than other region (data not shown). The higher bowen ratio was especially significant at the east of 140^oE. The region is arctic tundra, and plant density is generally low. Under these conditions, conversion of effective radiation into sensible heat may be easy.

It is not easy from comparison of bowen ratio between two parameter sets to quantify how the potential parameter is general. So, evapotranspiration (ET) simulated by the two parameter sets was cumulated individually over 3-year. The difference between the two ETs was ranged within about ±30 mm. Major difference was showed at specific area that was mainly dominated by coniferous tree. When considering ET varying with leaf area and canopy architecture (Landsberg and Gower, 1997), this small difference demonstrates the reliability and practicability of the potential parameter set, as well as the success of coupling of the parameter set into LSM.

In validating the soundness of spatial distribution of calculated ET, comparison with reanalysis data or climatic model's result would be a good means. However, we don't have useful data. So, the calculated ET was compared to reported station results. According to the results (Kelliher et al., 1997; Ohta et al., 2001), averaged summer ET around Yakutsk was ranged below 2 mm day^{-1}. Our result also showed similar value (data not shown). Moreover, ET showed clear spatial distribution; the difference was especially significant at the direction of the south and north.

It has been generally known that annual variation of ET is not so large. The similar tendency was actually found at our calculation. The annual ET was generalized by potential evaporation. The fashion of the generalized ET was similar to the distribution of LAI, suggesting the larger LAI intercepting the larger amount of rainfall and simultaneously increasing surface area for transpiration. The calculated ratio ranged generally within 0.6, although grids of high value were present sometimes. Ohta et al. (this issue) analyzed 6-year data of Yakutsk site and found that the ratio ranged below 0.5. Our result was higher than their one. The overestimation is attributable to both overestimated LAI and canopy interception.

The spatial distribution of the ratio between ET and precipitation showed clear inter-annual variation. The annual change is related to annual precipitation pattern. Interestingly, a concentrative zone that ET was very high was formed at the middle area of Rena watershed (data not shown). The reason why the zone was formed is not clear yet. The distribution suggests that most of runoff within Rena watershed was sourced from the headwaters of watershed. Ishii (personal communication) analyzed runoff data of Rena watershed over several ten years and represented the same trend as our result.

It has been generally known that in boreal forests, the role of evaporation from forest floor to ET is very important. According to measurement, for instance, evaporation from forest floor during summer season in Yakutsk occupied about 50% of ET. We spatially distributed the ration between evaporation from forest floor and ET. The distribution showed that there was an inversely linear relationship between the ratio and LAI. Actually, our measurement from 4 sites represented the same trend. We also compared the relationship between evaporation from forest floor and LAI through model sensitivity analysis. In sensitivity analysis, LAI was controlled to two ways, more 50% and less 50% than the present. The change rate of evaporation from forest floor was inversely proportional to one of LAI.

The relationship between ET and meteorological variables was compared. At all of computed domain, significance of ET with meteorological variables was low. So, we compared the relationship for specific area that for instance, evaporative rate was highest (58 – 63^{o}N). At there, ET was significantly dependent on temperature. In contrast, at northern area where evaporative rate was low (65 – 72^{o}N), ET was significant with precipitation and temperature. This fact suggests that the dependence of ET on meteorological variables is different according to region.

Summary

A parameter set of stomatal conductance derived from single leaf data was model-tested in Siberia. The reliability and practicality of the parameter set were validated through its coupling into LSM. The spatio-temporal distribution of ET was greatly influenced of the variance of LAI. Dependence of canopy interception and evaporation from forest floor on LAI was especially significant.

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