Retrieval of the surface bulk parameters over Mongolian steppe and forest using a heat budget model incorporating remote sensing data

MATSUSHIMA Dai

Department of Architecture and Civil Engineering, Chiba Institute of Technology, Japan

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Introduction

The assimilation schemes which combine satellite data and numerical models have been generally employed in numerical prediction models. However, the schemes are not necessarily introduced into estimating surface bulk transfer coefficients and heat fluxes. This study illustrates the bulk parameters retrieved from the surface heat budget model correlates with observed physical parameters. In particular, the thermal inertia, which is a product of the heat capacity and the thermal conductivity, correlates with observed soil moisture in the shallow layer, and the bulk transfer coefficient of forest canopy for sensible heat correlates with the normalized difference vegetation index (NDVI) estimated from satellite data. This suggests feasibility of estimating spatial distribution of shallow layer soil moisture more precisely than estimations using satellite data derived from microwave radiometers. This study shows correlations between the retrieved and observed parameters or variables, and shows how the flux station data are representative in ambient region by comparing observed flux data and estimated flux distribution by the model, based on former studies (Matsushima 2006). The objective region is set in Kherlen River Basin in Mongolia, where forest and forest steppe are occupied in the northern region, while typical steppe and dry steppe are occupied in the southern region. The subject area in which the model calculation is performed is a square ranging 46.5-49N in latitude and 107.5-112.5E in longitude, where is in the western part of Kherlen River watershed. As for vegetation distribution, typical steppe is dominant in this area including a little forest-steppe in northern part and dry-steppe in southern part.

Retrieval of Parameters

The numerical model employed in the study is a combination of the surface heat budget model, in which the force-restore model is implemented, and the bulk formulation of sensible and latent heat fluxes. A two -layer canopy model developed by Kondo and Watanabe (1992) and a linear heat budget model developed by Matsushima and Kondo (1995) are applied to the model. Parameters which affect the prognostic variables are the bulk transfer coefficients for heat fluxes and the thermal inertia, and etc. These parameters are optimized by minimizing the squares of difference between calculated surface temperature and the satellite brightness temperature to estimate time series of heat fluxes. The simplex method is employed for the optimizing algorithm. Details of the model description and the optimization algorithm are referred to Matsushima (2006).

Data

MODIS-L1B data obtained at polar orbit satellites is used for estimating the leaf area index and the brightness temperature. Geostational satellite GOES-9 data are used for estimating spatial distribution of incoming solar radiation on the earth surface.

Some basic meteorological data, including radiation and soil temperature and moisture, are acquired in four automatic weather stations (AWSs) in the subject area. This data is used as input variables together with data acquired at the routine meteorological stations in the subject area.

The surface heat fluxes are precisely measured continuously at the KBU-A1 station and the data are archived every 30 minutes, which are used for verifying the model results.

Thermal Inertia and Soil Moisture

Thermal inertia increases as the soil moisture increases because the heat capacity and the thermal conductivity of water is much larger than those of the dry matter. Figure 1 illustrates daily changes of the thermal inertia (red line) and the evaporation efficiency (green) correlate well with the volumetric soil water content at the depth of 5cm (blue). Although the fluctuations of the retrieved parameters exist, this result suggests feasibility of estimating temporal and spatial changes of soil moisture in the shallow layer. Figure 2 illustrates correlations between the bulk transfer coefficient for sensible heat and NDVI in the forest region. This correlation is reflected the vegetation phenology.

Representation of Flux Observations

Figure 3 illustrates daily changes of the latent heat flux observed at the flux stations in the steppe (KBU-A1) and in the forest (plotted in green). The nearest grids of the flux stations (plotted in red), and the regional average fluxes with the standard deviation over the steppe or the forest in the subject area are also plotted in the respective figures. The observed flux values at the KBU-A1 exist almost within the range between the regional average plus/minus the standard deviation. Values of the nearest grid to the KBU-A1 exist also within the same range. Therefore, the observed flux at the KBU-A1 can be regarded as a good representation of the steppe region. On the other hand, the observed flux values at the forest site do not exist in the range between the regional average plus/minus the standard deviation. This may attribute to that the forest site exists near the edge of forest and the flux over the ambient steppe is contaminated in the observed flux, and that the model estimation of over the forest is overestimated.

Summary and Future Issues

Parameters retrieved from the optimization of a heat budget model shows correlations with other observed physical parameters or variables. This suggests feasibility of estimating those parameters like soil moisture.

Acknowledgments

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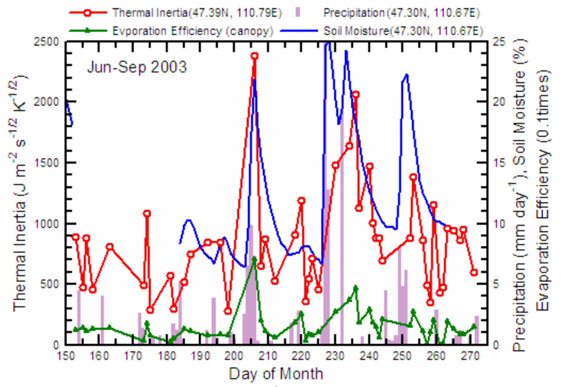


Fig.1 Daily changes of retrieved and the observed parameters.

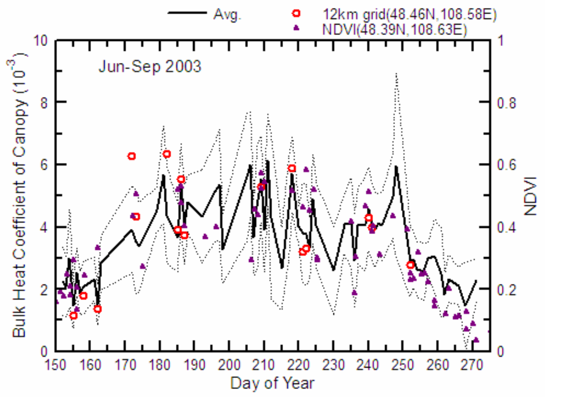
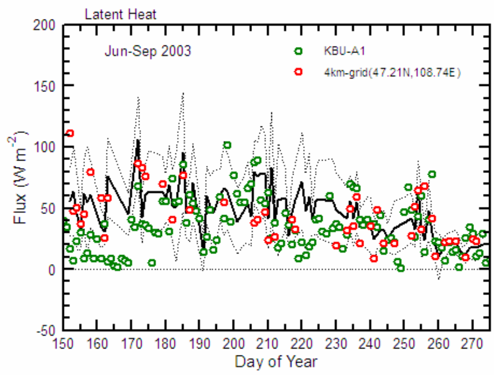


Fig.2 Daily changes of the bulk transfer coefficient and the satellite NDVI.



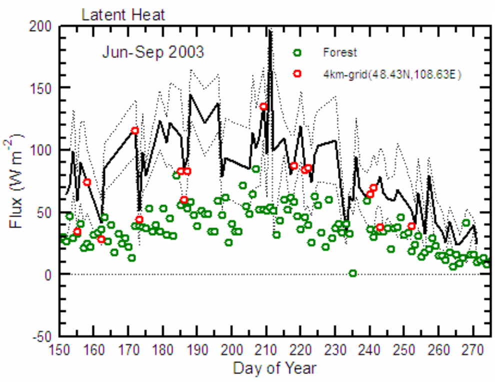


Fig.3 Daily changes of observed latent heat flux at (a) KBU-A1 and (b) Forest, compared with grid and regional fluxes estimated by the model.