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Estimating surface heat fluxes and related parameters using a numerical model incorporating satellite data

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A regional distribution of surface heat fluxes and related parameters over a semi-arid region was estimated using a technique that incorporating the thermal-infrared brightness temperature of a satellite into a heat budget model of land surface including vegetation canopy. The subject region of this study is the western part of the Kherlen River Basin in Mongolia, where a typical steppe dominates, including forest-steppe in the northern part and dry-steppe in the southern part of the basin. The goal of this study is to estimate the temporal change of surface heat fluxes at a location in the typical steppe over a growing season in year 2003, and to estimate the spatial distribution of surface heat fluxes over the subject region.

Data used in this study are as follows: (1) L1B data of Moderate Resolution Imaging Spectroradiometer (MODIS) for brightness temperature of Earth surface and estimating leaf area index, (2) a geostational satellite GOES-9 for estimating solar radiation as an input variable of the model, (3) surface meteorology for air temperature, huimidity, wind speed, and downward longwave radiation as input variables, (4) surface heat fluxes at a flux station in a typical steppe. In the model calculation, the brightness temperature is used for optimization of parameters relevant to surface heat budget, surface heat fluxes are used for validation of model results.

Seven parameters, including the bulk transfer coefficients for sensible heat, the evaporation efficiency, and the subsurface thermal inertia, which are relevant to the surface heat fluxes, were optimized employing the simplex method, which is an iterative algorithm of optimization. To compensate for insufficient satellite data samples to reproduce the diurnal change of surface heat fluxes, the spatial distribution of the surface brightness temperature was used in the optimization rather than using diurnal change, which is referred to as spatial optimization. A diurnal change of surface heat fluxes estimated by the spatial optimization was validated by observation.

The surface heat fluxes were reasonably reproduced on a daily basis, with the root-mean-squares error of the sensible and the latent heat within 15 Wm-2 over the growing season. The evaporation efficiency of canopy and the subsurface thermal inertia optimized in this study correlated well with the volumetric soil water content in a shallow layer on a daily basis, which suggests the thermal inertia can be an indicator of water conditions in a shallow subsurface layer.

Results of spatial distribution of the surface heat fluxes after a rainfall on successive summer days showed that estimated evapotranspiration was consistent with the amount of rainfall and parameters (evaporation efficiency and thermal inertia). How the decrease in the net radiation in two days split into the sensible and latent heat depended on surface conditions, in particular, the latent heat increased in areas where a significant rainfall occured in the first day even the net radiation decreased.