Chapter IV Atmosphere-surface Interaction

Measuring atmospheric heating of landsurface using shimmer

Introduction

Sensible heat flux, one of the major components of the land surface heat budget, warms up the lower atmosphere during the daytime to generate the diurnal pattern of the air temperature near the surface. Usually, sensible heat flux is measured with sensors mounted on a fixed tower, and this allow us to capture the atmospheric heating of the landsurface over an upwind surface area of 1 ha to 1 km^2. There are some methods to measure this atmospheric heating as an average of larger surface than 10 km^2. Scintillometer, that is the topic of this writing, is an optical device for such an observation.

Shimmer

While the light goes straight in vacuum, it, in fact, zigzags in the atmosphere. One of the notable examples is a mirage, where an object in a distance appears to be enlarged, shortened, or distorted. This happens when the light passes an interface between hotter and colder air where it is refracted.

A shimmer is a slightly different phenomena, but is also caused by the refraction of the light at the density interface of the air. A shimmer can be found over a strongly heated surface, such as a concrete pavement in a hot summer day and an iron plate of BBQ, and through a shimmer an object is seen blurred and a light can be seen blinked. This is caused by strong atmospheric turbulence over a heated surface, by which heated air is intensely mixed with the ambient air, where successive light refraction occurs.

Schintillometer

Scintillometer measures the variation of the intensity of the infrared light at the receiver, that is transmitted from its transmitter. The variance of the measured light intensity can be taken as a strength of the shimmer, and it can be converted into the strength of the heating of the atmosphere by the landsurface, that is, the sensible heat flux. The path length between the transmitter and the receiver usually is more than hundred meters, and can be upto 5 km in with a large aperture scintillometer (LAS) whose transmitter has a disk of more than 400 LEDs.

Fig. 1. Transmitter of the large aperture sintillometer.

Fig. 2 Receiver of the large aperture scintillometer

In detail, scintillometer measures the light intensity at its receiver, and it is used to compute the spatial variance of the air temperature, which in turn is used to compute the surface heating of the atmosphere. Fig. 1 and 2 show the transmitter and the receiver of the scintillometer, respectively.

References:

(1) Asanuma and Iemoto, 2007, J. Hydrol., doi:10.1016/j.jhydrol.2006.07.031.

Heat transport from the ground to the atmosphere estimated by airplane data

Solar energy irradiating the ground surface is used for evaporation, conducted into the ground, and warms the air above. This energy distribution is one of the important factors which determine the natural environment such as climate and water cycle. To estimate energy flux from the ground to the atmosphere, we use the data obtained by airplane observations.

Airplane Observation

Around the Kherlen River basin, airplane observations were carried out 11 times from June to October 2003 (Fig. 1). With sensors setting on airplane wing, air temperature and humidity were measured and recorded at 0.1-second interval (Fig. 2). The flight levels were about 200, 500, and 1000m above the ground, and at each level the airplane flied horizontally.

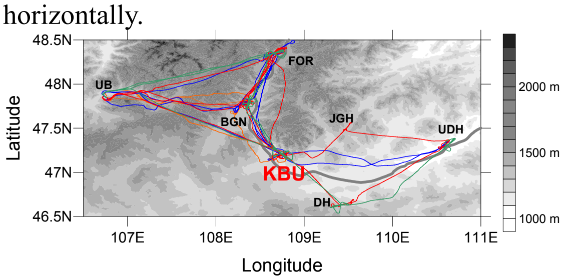

Fig.1 Flight paths of airplane observation.

Fig.2 Measurement instruments set at airplane.

Estimation of Heat Flux

From the heated ground, heat energy is transported to the atmosphere and the vertical distribution of air temperature depends on this upward flux. Vertical distribution of temperature variance, which is related to strength of heat transfer, is also effected by heat flux from the ground. This relation between heat flux from the ground and temperature variance at some height in the atmosphere is presented by several functions, and if we know temperature variance it is possible to back-calculate heat flux.

With the temperature data measured by sensors on airplane, heat flux from the ground was calculated. Compared to the ground observation at KBU, 10-20% of difference was evaluated. In spite of this remaining uncertainty, we can estimate heat flux only with temperature data at some height in the atmosphere, and it is expected for application of this method to the other area.

Then, this method was applied to the continuous measurement data. Along the flight path over the Kherlen River basin, heat flux from the ground is larger at the forest area, smaller near the river, and intermediate value is estimated at the Steppe area (Fig. 3).

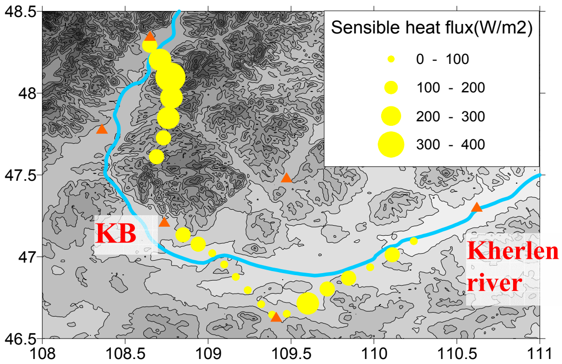

Fig.3 Estimated heat flux distribution around Kherlen River (2003 August, 22)

Reference:
(1) Kotani and Sugita, 2006: J. Hydrol., doi:10.1016 /j.jhydrol.2006.07.029.

Soil moisture estimated from satellite data

Introduction

Artificial satellites are designed to detect various signals from the earth surface such as vegetation, soil, minerals, cloud, snow, and so on. Among them, a lot of researchers have been concentrated into detecting soil moisture, which is important, especially in Mongolia, for vegetation growing and ground water recharge. Even soil moisture observations are routinely conducted at meteorological stations in Mongolia, obtaining precise distribution of soil moisture in all over Mongolia seems difficult. Therefore, we conducted a study developing a method for retrieving earth surface soil moisture from satellite data in combination with a computer simulation.

Satellite data and simulation

Satellite data acquired by MODIS (USA) and GOES-9 (USA) are used for retrieving spatial distribution of earth surface temperature. This surface temperature is incorporated into a computer simulation model, which calculates heat budget of the earth surface. The output of this simulation is such as the evapo-transpiration and the thermal property of soil (Thermal inertia). This thermal inertia is closely related to the soil moisture. Now, we can have information of spatial distribution of soil moisture as precise as a few kilometers.

Soil moisture change and distribution

Fig. 1 illustrates a temporal change of

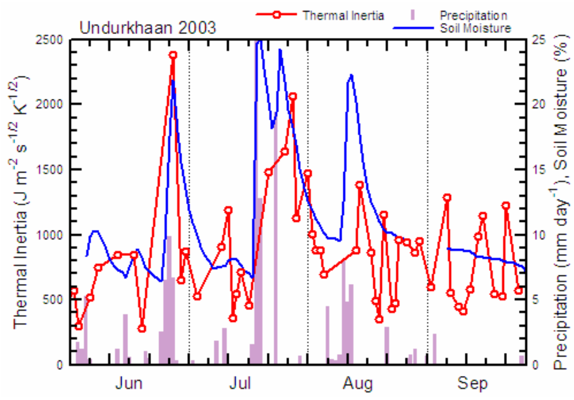

Fig. 1 Temporal change of estimated thermal inertia, observed surface soil moisture, and precipitation at Undurkhaan, Khentii Aimag during summer in 2003.

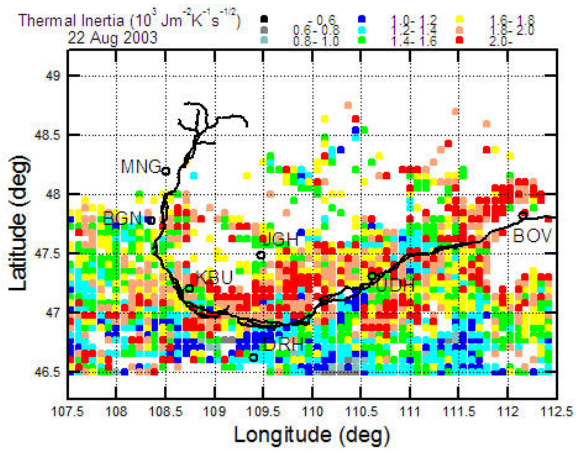

Fig. 2 Spatial distribution of the thermal inertia over Kherlen River basin in Khentii Aimag. No satellite data is available in blank area because of cloud cover.

estimated thermal inertia at Undurkhaan, Khentii Aimag, during the summer in 2003. The thermal inertia is well correlated with the observed soil moisture. A spatial distribution of the thermal inertia, in other words, soil moisture is illustrated in Fig. 2, which shows a distribution on a summer day after a major rainfall along the Kherlen River [(1)].

Those obtained thermal inertia is well compared with a 10km-scale satellite detection by the AMSR-E, which shows they agree with each other on a monthly average basis (Fig. 3).

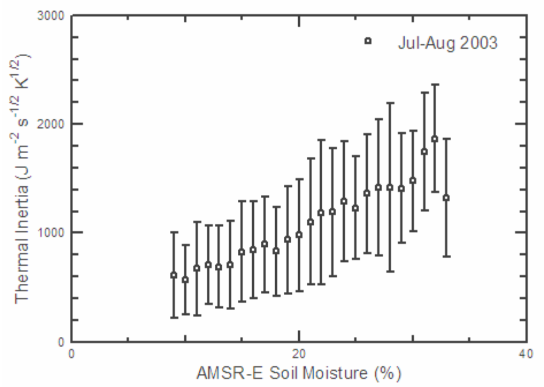

Fig. 3 Comparison of estimated thermal inertia and the AMSR-E soil moisture.

References:

(1) Matsushima, 2007: J. Hydrol., 333, 86-99