Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

HTT006-08 Room:201A Time:May 25 18:15-18:30

A method for estimating threshold wind speed of dust outbreaks using thermal inertia over a non-vegetated surface

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1. Introduction

Soil moisture is one of the important surface conditions of dust outbreak. An operational estimation of potential areas of dust outbreak will be demanded for estimating and forecasting source, transport, and sink of aeolian dust over regional and continental scales. Among methods for estimating soil moisture, methods using thermal inertia is a confidential one using the radiative land surface temperature in an infrared band. Matsushima et al. (submitted) developed a thermal inertia method using a two-layer surface heat budget model incorporating field data, and showed the model has practical feasibility to estimate subsurface soil moisture with an accuracy of 3-4 vol.% when data frequency was equivalent to that of routine meteorological observations and polar orbit satellites.

This study aims to clarify that the threshold wind speed over a non-vegetated surface can be estimated by the thermal inertia retrieved from the model. Thermal inertia is theoretically and practically a function of the soil moisture. Namely, subsurface thermal inertia can be a proxy of subsurface soil moisture for estimating the threshold wind speed of dust outbreak.

2. Materials and Methods

2.1 Site description

The experimental site was located in a flat field with some senescent grass in Bayan Unjuul, Mongolia. Data analysed in this study were obtained 27 April through 24 May 2008 during the 2008 Dust-Vegetation Interaction Experiment (DUVEX) (Shinoda et al.,2010, SOLA). In this site, 4-component radiation, wind speed, temperature and humidity of air, soil moisture, and dust concentration (PM10) were measured.

2.2 Model

A linear surface heat budget model was employed in this study. This model is a two-layer model consisting of vegetation canopy and underlying soil surface, which requires diurnal time series of the insolation, the longwave radiation, air temperature, wind speed, and specific humidity as input variables with associated land surface parameters. The model calculates time series of the surface radiative temperature employing the finite difference method. The simplex algorithm is employed for optimizing model parameters to retrieve thermal inertia. All parameters including the optimized parameters kept constant in a calculation of one diurnal change. Details are referred to Matsushima (2007, J. Hydrology).

2.3 Threshold wind speed of dust outbreak

The threshold wind speed of dust outbreak of PM10 using the following statistical method. Each sample of dust concentration (1 minute average) in an event of dust outbreak was categorized by corresponding wind speed by every 1 m/s. Distribution of the PM10 concentration in each category was fit by a logarithmic normal distribution function. There existed the point of 10 % significant level on the side less than the average concentration of every distribution function. The threshold wind speed was determined as the point at which the curve connecting the 10 % levels intercepted the criterion of dust outbreak which was defined as 0.05 mg/m^3 of the PM10 concentration.

3. Results and Discussion

The curve of the 10 % level of the PM10 concentration was almost an envelope of the scatters of the samples. The threshold wind speeds of 18 events were determined and ranged between 7 and 9.5 m/s.

The estimated threshold wind speed showed an almost linear relation to the daily values of the subsurface thermal inertia retrieved from the model. Threshold wind speed was correlated well with subsurface thermal inertia ($r = 0.74$) even when the data frequency was equivalent to the routine observations and the polar orbit satellites. On the other hand, the correlation between threshold wind speed and the soil water content was comparable ($r = 0.67$). Therefore, thermal inertia can be a proxy of soil moisture as a criterion of dust outbreak, which implys feasibility of estimating potential areas of dust outbreak by using the heat budget model incorporating field and remote sensing data.

Keywords: thermal inertia, thershold wind speed, dust outbreak, heat budget model, radiative surface temperature