Estimating shortwave radiation based on DEM and MODIS atmospheric products in rugged terrain

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Abstract—**A method was proposed to estimate shortwave irradiance in rugged terrain, which was integrated to accurately consider the terrain and atmospheric key factors based on fine resolution DEM and MODIS atmospheric products. Experiments showed that the relative radiation deviation between the measured and the estimated data was 9.2% in Guantan Forest Observatory, Qilian Mountains.**

INTRODUCTION

Accurate estimation of Surface Shortwave Radiation (SSR) is essential in various disciplines, including climate monitoring, biomass estimation, solar energy applications, and topographic normalization. Various algorithms have been proposed to simulate it. The parametric approach retains the same physical principles from radiative transfer models, but with a set of simplified key atmospheric parameters, which may be readily available on the flat surface. But estimating the SSR in the rugged terrain remains a significant challenge. Some models had serious limitations due to incorrect transmittance equations or simplistic assumptions (Ruiz-Arias *et al*., 2010).

The difference in terrain orientation and atmospheric environment often leads to significant difference in radiances of pixels in the steep mountainous. Complex terrain introduces significant variations, and influence of terrain features was already described by many authors (Dozier and Frew, 1990; Li *et al*., 2002; Wen *et al*., 2009) with the aid of DEM, which accounted for some terrain parameters such as slope and illumination angle. However, these models use simplified atmospheric parametrizations and require ground measurements, and some even assume that the transmittance is a constant.

In this paper, we will explore a method to estimate surface shortwave radiation based on DEM and MODIS atmospheric products in complex mountains.

DATA AND METHODS

A. Data

The selected study area is located in Dayekou watershed (DYK) in the upper stream of the Heihe river basin, Qilian Mountains, China. It is a hilly terrain, and the altitude varies from 1804 m to 4613 m above sea level. The dataset for this study consisted of high resolution ASTER GDEM (30m), Landsat TM images, MODIS water and aerosol productions, which were obtained from the United States Geological Survey (USGS) Earth Resources Observation System (EROS) Data Center. Also, Guantan Forest Observatory ground measurements (Li et al., 2009) were selected for the model validation.

B. Methods

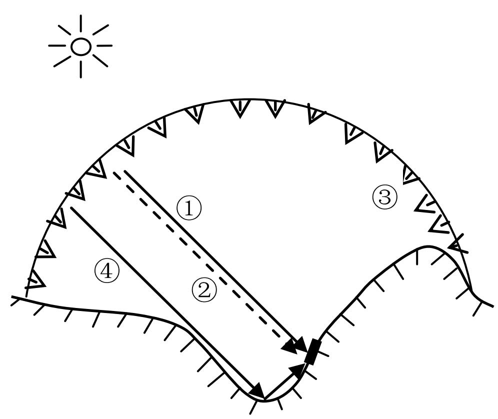

Figure 1. Global irradiance on the slope surface : ①direct, ② anisotropic diffuse, ③isotropic diffuse, ④surrounding-reflected.

In mountains, global irradiance at the surface consists of the direct, isotropic diffuse, anisotropic diffuse and surrounding-reflected irradiance, as shown in fig. 1. The amount of isotropic diffuse irradiance obscured by the mountain is estimated by considering the sky-view factor. The reflected radiation from the around terrain can be sometimes important, which is affected by the shape factor between two mutually seen pixels and its reflectance (Li *et al*., 2002).

On the other hand, a major portion of solar radiation transmits through the atmosphere and ultimately interacts with the Earth's surface. Thus surface solar radiation flux is mainly affected by atmospheric properties in addition to topographical variables. The factors contributing to atmospheric attenuation of solar radiation include five types: Rayleigh scattering，aerosol extinction, ozone absorption, water vapor and permanent gas absorption (Yang *et al.*, 2001). The atmospheric transmittance model is obtained as the sum of the contributions of these components. But, downward radiative fluxes are more sensitive to the aerosol, followed by the water vapor, which are strongly influenced by their spatial and temporal distribution.

The study estimated the complex surface solar radiation by making comprehensive use of Li (2002) mountainous radiation scheme and Yang (2001) atmospheric transmittance model, and MODIS aerosol and water vapor atmospheric products as input parameters. A detailed description and discussion of the algorithms were given in the above-mentioned two articles.

RESULTS AND ANALYSIS

In order to prove the effectiveness of this method, we choose this time period at 11:30 on August 14, 2010 to simulate solar radiation of the study area. Fig. 2 showed the same day of MODIS aerosol and water vapor atmospheric products.

The global irradiance and each component were obtained, and the results of total radiation and surface-reflected radiation were shown as Fig. 3. It is easy to see radiation estimated seriously influenced by terrain.

The total irradiance difference between the measured and the estimated data was 89.2 W m^{-2}, and the relative radiation deviation was 9.2% in Guantan Forest Observatory.

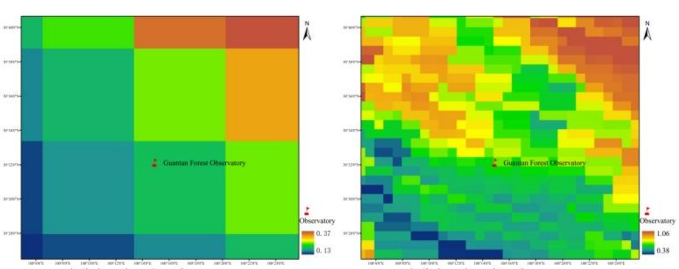

Figure 2. MODIS atmospheric products of aerosol and water vapor. (from left to right)

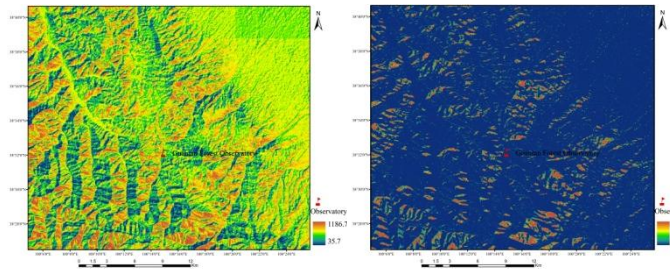

Figure 3. total radiation and surface-reflected radiation (from left to right)

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