Modeling hourly solar radiation over rugged terrains, based on DEM

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Abstract—**Solar radiation is the principal energy source of the Earth's surface，it provides important data for runoff simulation and forecasting, and ecological evaluation. In this paper, a distributed hourly solar radiation model is built by combining Yang Kun clear-sky solar radiation model and digital elevation model. This model introduced the shadows - sun factor firstly, which characterizes the effect from the slope itself and the surrounding topography, then added topographic correction parameters, which make received direct solar radiation closer to the actual value to slope, and lastly introduced the sky view factor to calculate the possible scattering value from the surroundings in calculating diffuse radiation. The model was successfully used to simulate hourly instantaneous solar irradiance by a spatial resolution of 30 m, at the head of Ürümqi river, and the result suggest that: 1) the model has the high accuracy, and the determination coefficients (R^2) between simulated and measured radiation in Daxigou and Kongbingdou are 0.94 and 0.83, respectively; 2) the model is highly depend on sunshine hours, and the accuracy of simulation at Kongbingdou is less than that at Daxigou in cloudy day; 3) the model has good accuracy of simulation in clear day except the sunrise and sunset hours, and the determination coefficients between the simulated radiation values with the measured values are 0.96 and 0.89, respectively.**

Keywords —**rugged terrain; solar radiation; sky view factor; terrain shading**

INTRODUCTION

Solar radiation provides the primary energy resources to the earth, which distribution is the basic power of the physical processes in nature, such as snow/ice melting, photosynthesis and evaporate-transpiration. Thus, it is extremely necessary to explore the solar radiation variation in the researches on hydrological and thermal regimes, land surface geographical processes and the use of solar energy. With the rugged terrain in the mountain regions on basis of current conditions, the terrain factors of slope, aspect and hill shade by surrounding terrain varies, and the received solar energy on the land surface varies with different conditions, which causes the complex spatial distribution of solar radiation.

Taking the influence of topographical factor on the solar radiation distribution into consideration, the distributed solar radiation models based on terrain analysis were built to simulate the total solar radiation over rugged terrains since 1980s(Fu, 1983; Bonan, 1989; Dozier, 1990; Dubayah et al, 1990). Latter，the impact of surrounding terrain and weather condition on the received solar radiation considered, several methods such as amending sunshine hours (Li et al, 1999), introducing transform indexes (Zeng et al, 2008; Gu et al, 2010), sky view factor (Chen et al, 2007; Manners et al, 2011) and topographic correction index (Helbig et al, 2010), were used to improve the simulated values of distributed solar radiation models. Nevertheless, the calculated values of hillshade in the current researches exists the certain bias, due to the spatial scale of DEM and the accuracy of the measured meteorological data, and the accuracy and temporal resolution of solar radiation model needed to be improved.

DATA AND METHOD

A new hourly distributed solar radiation model over mountains is built in this paper, making use of ASTER GDEM data to amend the current Yang-Kun solar radiation model at single point under clear weather conditions. The total solar radiation is divided into the direct solar radiation and diffuse solar radiation. Shade-sunshine judgment factor is introduced into the calculation of direct solar radiation, as well as topographic correction parameter, with aim to quantify the hillshade effects of slope itself and its surrounding terrains.

Meanwhile, the parameter of sky view factor is also introduced to simulate the values of possible diffuse solar radiation which comes from nearby eight directions.

Then the meteorological variables of atmospheric pressure, air temperature, air relative humidity and sunshine hours provided by two automatic weather stations (AWS) named Daxigou and Kongbingdou (Figure 1), as well as ASTER GDEM, are collected as the input parameters of the model, and the model is used to simulate hourly instantaneous solar radiation with the resolution of 30 meters at the head of Ürümqi river basin in Xinjiang province. Lastly, the simulated values of solar radiation at AWS positions are validated against the measurements of solar radiation to assess the applicability of the model.

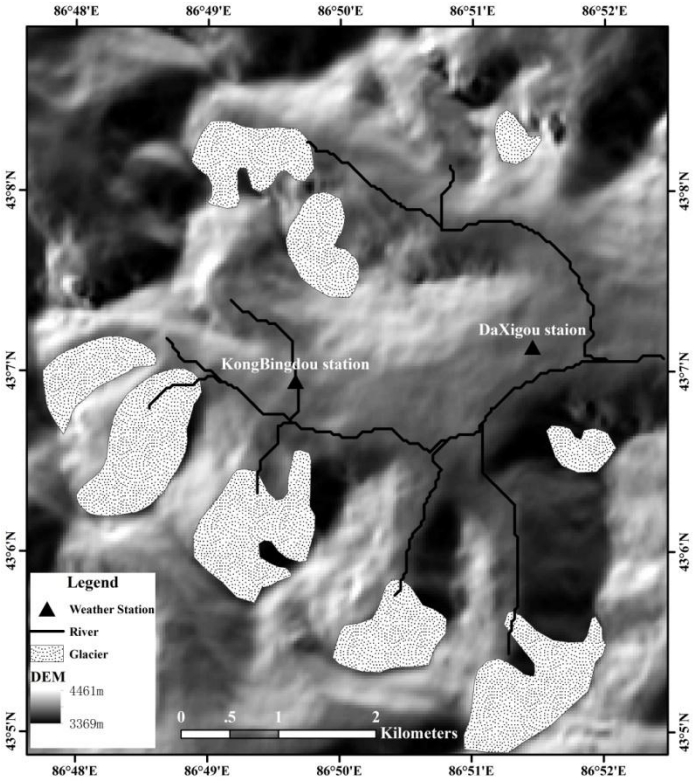

Figure 1. Locations of DaXigou station and KongBingdou station at the head of Ürümqi river basin in Xinjiang province

RESULTS

The results in this research can be shown as following: 1) the model built has the high accuracy, and the determination coefficients (R^2) between the simulated and measured values of solar radiation at Daxigou and Kongbingdou weather stations are 0.94 and 0.83, respectively, shown in Figure 2; 2) for the lack of the measured sunshine hours at Kongbingdou station, the accuracy of solar radiation simulation at this station appears less than that at Daxigou station in cloudy day, which implies that this model is highly depend on the sunshine hours; 3) the model proves the perfect accuracy of simulation in the clear day except for the sunrise and sunset hours, with the determination coefficients(R^2) between the simulated values and the measurements at Daxigou and Kongbingdou stations are 0.96 and 0.89, the mean relative error of 2.6% and 0.8%, respectively (Shown in Figure 3). While the model performs the poor simulated values of solar radiation in the cloudy day, with the determination coefficients (R^2) between the simulations and the measurements at Daxigou and Kongbingdou stations are only 0.43 and 0.56, the mean relative error of 34.5% and 25.9%, respectively, which implies that the simulated values of the model built are strongly dependent on solar radiation in clear day and topographic correction indexes.

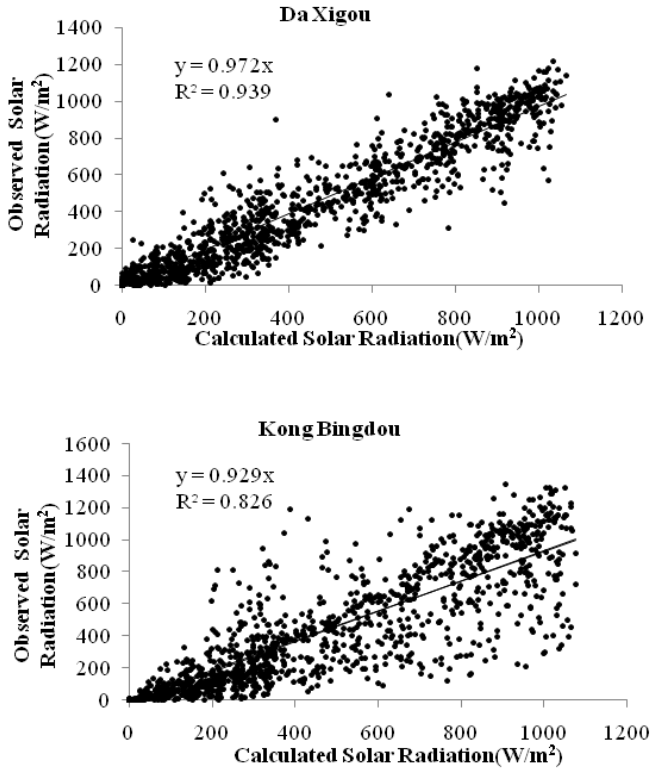

Figure 2. Relationship between the observed hourly solar radiation and the calculated series under the actual weather conditions

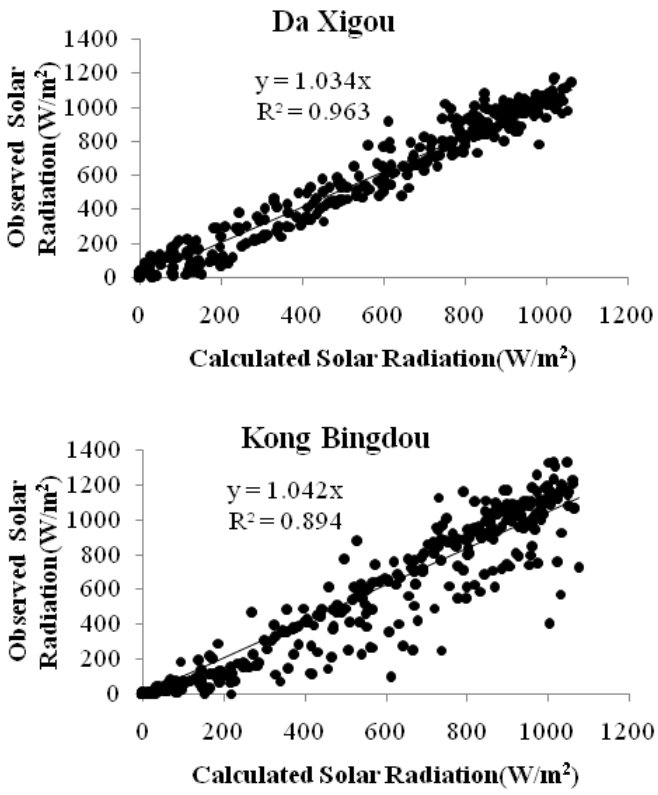

Figure 3. Relationship between the observed hourly solar radiation and the calculated series under the sunny weather conditions

PROSPECTS

Generally speaking, the distributed solar radiation model built in this paper, considering the influence of topographic factors on the received solar energy over rugged terrains, proves the high simulation of solar radiation, especially under the clear conditions. This implies that the quantification of terrain characteristic will be helpful to improve the accuracy the simulation of the physical parameters near the land surface.

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