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Simulation Evaluation of Transpiration Ratio (T/ET) in the Yellow River Basin

Shoubo Cui*

School of Resources and Environment, Henan Polytechnic University, Jiaozuo 454000, China
* Corresponding author

Abstract: It is of great significance to improve the simulation accuracy of vegetation dynamics in land surface models for the study of dynamic changes of vegetation on land surface water and heat cycling. Parameter optimization is an effective means to improve the simulation accuracy of land surface model. Aiming at the application of Noah-MP land surface model in the Yellow River Basin, this paper improves the simulation performance of regional evAPOtranspiration and transpiration ratio by parameter optimization.

Keywords: Yellow River Basin; Noah-MP model; Dynamic vegetation model;T/ET.

1. Introduction

The fresh water resources on the surface of the earth mainly come from atmospheric precipitation, and 60% of the falling water returns to the atmosphere in the form of biogenic evapotranspiration [1]. Terrestrial ecosystem evapotranspiration (ET) includes interception evaporation (Ei) and soil evaporation (Es) and vegetation transpiration (T), in which vegetation transpiration is the largest component of evapotranspiration [2, 3], and its proportion in evapotranspiration (T/ET) is about 60% on the global average [4]. Therefore, the study of T/ET has received extensive attention in recent years. Many studies have reported T/ET in different ecosystem types around the world, but there are still few studies on T/ET at regional scale in China.

The Yellow River Basin in China is characterized by complex topography and unique arid and semi-arid climatic conditions, and vegetation is sensitive to climate, which provides a natural experimental field for simulating and analyzing the temporal and spatial distribution of ecosystem T/ET and its driving mechanism. Based on the meteorological driving data of GLDAS land surface model, Noah-MP model was used to simulate regional scale ET and its components in the Yellow River Basin ecosystem in China. Moreover, the accuracy of the spatial simulation results of ET and T was verified by using the observational data of ET and T respectively, and then the model parameters were adjusted to improve the accuracy of the simulation of ET and T. Finally, the spatio-temporal variation of ecosystem T/ET and its influencing factors were analyzed, providing support for further quantifying and understanding the spatio-temporal variation of ecosystem transpiration water use efficiency in China.

2. Data and Methods

2.1. Overview of the study area

As the second largest river basin in China, the Yellow River Basin covers an area of 79.5×104km2 and is located between latitude 32.025° ~ 42.025°N and longitude 95.525° ~ 108.525°E. According to the land use classification of MODIS satellite data (extracted from the WRF/WPS 3.8 database of the United States Mesoscale weather forecast model, using IGBP classification code) in this study, various vegetation types are mainly classified as deciduous broadleaf forest, mixed forest, shrub, grassland and farmland.

2.2. NOA-MP Model Introduction

The Noah-MP model details the process of carbon, water and heat exchange between vegetation, soil, snow cover, and the atmosphere, and provides multiple parameterization options for key biogeophysical processes. Researchers can choose one of the parameterized options of each subprocess according to their needs, and "combine" it into a model to carry out simulation research. This paper only focuses on the dynamic vegetation simulation problem in Noah-MP, and only studies option 2. It should be noted that the dynamic vegetation module needs to set the parameterization option of stomatal resistance to the first option, namely the Ball-Berry option module. The other parameterization options covered in this study are set to default.

2.3. Research Data

2.3.1. Land surface driving data

The Land surface model weather driver Data used in this study are derived from the Global Land Data Assimilation System (GLDAS) dataset developed by NASA, which combines the Princeton weather driver data, model simulation and observation data. The initial field data is generated by integrating satellite data, surface observation data and land surface model simulation data. The data set includes 2m air temperature, 2m air specific humidity, 10m wind speed, barometric pressure, short-wave downward radiation, long-wave downward radiation and precipitation rate required by Noah-MP model. The temporal resolution is 3h, the spatial resolution is 0.25°, and the resampler is 0.05° by bilinear internal interpolation method in this study.

2.3.2. Observed data

The evapotranspiration product (ET) and transpiration product (T) used in this paper are the transpiration and evapotranspiration data simulated by Dr. Niu Zhongen, researcher He Honglin et al., using the PT-JPL model driven by optimized parameters, providing two temporal resolutions (8 days and years), with a spatial resolution of 0.05° × 0.05°.

2.4. Noah-MP land surface model numerical simulation experiment

In this paper, we completed a complete long-term simulation for 1980-2016 using optimized parameters. The simulation results from 1982 to 2016 were compared with the measured T/ET to test the actual effect of parameter optimization

Three parameters were used to evaluate the performance of the modified model: root mean square error (RMSE), Nash-Sutcliffe efficiency (NSE) coefficient, and Pearson correlation coefficient R. These three indicators are defined as

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(M_i - O_i)^2}{N}} \quad (1)$$

$$NSE = 1 - \frac{\sum_{i=1}^{N}(M_i - O_i)^2}{\sum_{i=1}^{N}(O_i - \bar{O})^2} \quad (2)$$

$$R = \frac{\sum_{i=1}^{N}(M_i - \bar{M})(O_i - \bar{O})}{\sqrt{\sum_{i=1}^{N}(M_i - \bar{M})^2}\sqrt{\sum_{i=1}^{N}(O_i - \bar{O})^2}} \quad (3)$$

3. Result

3.1. Optimization and verification of model parameters

The accuracy of T/ET simulation depends on the estimation accuracy of transpiration and evapotranspiration. This paper uses ET and T remote sensing data to verify the accuracy of ET and T data simulated before and after Noah-MP model parameter optimization. Under default parameters, the NSE value of ET simulated by dynamic vegetation module in the Yellow River Basin was greater than 0 in 87.94% of the regions, and the NSE(median) increased from 0.367 to 0.451 in 96.5% of the regions of the Yellow River basin under optimal parameters. The NSE value of T simulated by dynamic vegetation module is less than 0 in the whole Yellow River basin under the default parameters. Under the optimal parameters, the NSE was increased in 99.8% of the Yellow River basin, and the NSE(median) was increased from -0.416 to 0.124. These results indicate that parameter optimization has indeed improved Noah-MP model to simulate regional scale evapotranspiration and its components in the ecosystem of the Yellow River Basin.

3.2. T/ET simulation evaluation

By calculating simulated T/ET and measured T/ET in the Yellow River Basin of China from 1982 to 2015, the NSE, R and RMSE values of T/ET in different seasons of vegetation in the Yellow River Basin were obtained. It was found that the NSE and R values of deciduous broadleaf forest, mixed forest, grassland and farmland in the source of the Yellow River in autumn were higher than those in other seasons, while the RMSE values were lower.

4. Discuss and Conclusion

In order to improve the simulation performance of Noah-MP model, this paper optimized the parameters of Noah-MP model, evaluated the ET and T values of default parameters and optimization parameters, and further evaluated the T/ET values of optimization parameters. The following findings are found:

(1) The simulation study of Noah-MP model with optimized parameters found that the annual mean sequence NSE and R were larger and RMSE was smaller in autumn, while the annual mean sequence NSE and R were smaller and RMSE was larger in other seasons, mainly because Noah-MP model still had a large parameter optimization space, which still affected the simulation performance of the model. Resulting in serious deviations in T/ET modeling.

(2) Parameter optimization indeed improved the performance of the model's vegetation dynamic modeling. Compared with the unmodified Noah-MP model, ET NSE(median) increased from 0.367 to 0.451 under optimized parameters. T NSE(median) increased from -0.416 to 0.124. These results indicate that parameter optimization has indeed improved Noah-MP model to simulate regional scale evapotranspiration and its components in the ecosystem of the Yellow River Basin.

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