高寒草甸生态系统非生命亚系统模拟模型及应用程序

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A SIMULATION MODEL AND THE MODEL PROGRAM FOR ABIOTIC SUBSYSTEM IN THE ALPINE MEADOW ECOSYSTEM

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ABSTRACT

Ecological systems are complex and consist of multi-level subsystems that interact and are not independent of each other, therefore a system cannot be studied by isolating its parts. Using systems analysis method to construct simulation models for a ecological system is a effective method for studies on them. The use of simulation models as one of the techniques for researchers increases our knowledge on ecological systems while striving to develop tools for predicting ecosystem response to environmental change.

This model for abiotic variables influencing the alpine meadow ecosystem is structured to simulate rainfall, evapotanspiration of soil water, soil water content in the top 30 cm, soil temperature in the top 20 cm, average air temperature, wind speed, relative humidity, daily average cloud cover and solar radiation, and is presented in two parts: water submodel and heat submodel.

Climate data were determined from records of weather observations at Haibei Alpine Meadow Ecosystem Research Station.

Water submodel simulates rainfall, runoff, infiltration, evapotranspiration of soil water and soil water content, and provides feedback mechanisms between biotic and abiotic variables.

Rainfall is simulated in two approaches: (1) Stochastic rainfall generator, rainfall is as a first-order Markov process, and is determined with Mont Carlo techniques. The Markov chain is specified by the transition matrix $T\Delta t$:

$$T_{\Delta t} = \begin{array}{c} \\ R \\ NR \end{array} \begin{array}{c} \quad R \qquad NR \\ \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix} \end{array}$$

where R is rain; NR is no rain; and C_{ij} is condition probability for the occurence or nonoccurence of rainfall (j=1, 2) given by the occurence or nonoccurence of rainfall (i=1, 2) the previous day. Rainfall amount is calculated by randomly selecting from a frequency distribution. (2) Daily average rainfall, daily rainfall amount is calculated by Fourier series from monthly average rainfall amount observed.

Evaporation and transpiration of the plant are calculated as functions of the leaf area index of the living biomass, the total standing biomass, soil water content, the holding capacity of soil water, the field capacity of soil water, the wilt point of soil water and potential evapotranspiration. Runoff and infiltration into next soil layer have been determined. Soil water content is the solution of the differential eqution:

$$dsw/dt = \text{rainfall amount} - \text{evapotranspiration-runoff-infiltration}$$

where SW is soil water content.

Heat submodel simulates daily solar radiation, average air temperature, soil temperature in the top 20 cm, wind speed, relative humidity and daily average cloud cover.

The daily solar radiation simulated in heat submodel on a clear day (SLC in langlay/day) is calculated as a function of time of year, latitude, solar constant, and the transmission coefficient in the atmosphere, and the influence of cloud cover and the plant canopy on daily solar radiation on ground and net solar radiation is determined using equations:

$$SLA = SLC[1 - 0.53C_1]$$

$$SLB = SLC[1 - (R_f + 0.53C_1)]$$

where SLA s actual daily solar radiation on ground; SLB is net solar radiation; R_f is the reflective rate of the plant canopy; C_1 is the average daily fractional cloud cover.

Daily average air temperature, daily soil temperature in the top 20 cm, daily wind speed and daily relative humidity simulated in heat submodel are calculated by the expansion of Fourier series from their monthly averange values observed because of lack of some parameters for the Fourier heat conduction equation. Fourier series is expanded as follows:

$$f(t) = a_0/2 + \sum_{p=1}^{p=5} [a_p \cos(pt) + b_p \sin(pt)]$$

$$a_p = 1/\pi \int_0^{2\pi} f(t) \cos(pt) dt; \quad (p = 0, 1, \cdots, 5)$$

$$b_p = 1/\pi \int_0^{2\pi} f(t) \sin(pt) dt; \quad (p = 1, 2, \cdots, 5)$$

where f(t) is a variable expanded as a disperse function on time t; a_p, b_p are Fourier coefficients; t is time in interval $[0, 2\pi]$.

The model program is written by IBM FORTRAN 77 computer language and has about 1600 statement lines.

Validation of the water submodel and heat submodel involved comparing simulated time series of abiotic state variables with data observed at Haibei station. Except that simulated soil water cannot be validated because a primary producer model still has not been constructed, simulated values of other abiotic state variables compare well with the observations.

Because the alpine meadow ecosystem is in he especial geographical position and the especial geographical conditions, its climate has many characteristics. Simulatuion results about the climate obtained from the model may be summarrized below.

1. The air temperature is low because of 3200 metres above sea level. Yearly accumulative air temperature is —735°C; yearly average air temperature is −2°C; days above 10°C are less than 30 days and accumulative temperature above 10°C is less than 300 C. Days above 0°C almost are a half year in a year, therefore, natural season in a year may been divided into the cold (winter) half year (November—April) and the warm (summer) half year (May—October).

2. The rainfall amount is more than that in near regions because of the especial topography. Yearly rainfall amount is about 500 mm; the rainfall distribution is not uniform in seasons, rainfall concentrates on the warm season(88 percent of the yearly rainfall amount).

3. There is wind in a year and there is much wind in the cold season. Yearly average

wind speed is 2.6 m/s.

4. The sunshine is long (2629 hours) and the solar radiation on ground much intense (151.6 kcal/cm^2/year) because the air is thin and dry, and the sky is clean.

5. The evapotranspiration (1056 mm/year) is more than the rainfall amount (500 mm/year). Yearly dry coefficient (= evapotranspiration/rainfall amount) is 2.1, therefore, its climate is wet in semi-arid area.

6. The yearly average value of relative difference of daily air temperature is 14.4°C and the yearly relative difference of monthly average air temperature is 24.2°C. The climate is the continental climate and the plateau climate.

In a word, the climate is cold, dry and windy in the cold (winter) half year and is warm and wet in the warm half year.

A list of the FORTRAN 77 source program of the model was omitted, but the program diagrams of the model was drawn. The subroutines of the source program were listed and the input and output variables used in the model runs were listed, the listed variables were defined and their units were given.