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Characteristics of Hydrometeorology and its Simulation over Desert in the Arid Region of Northwest China

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Abstract: In the paper, by using the data observed in "The Field Experiment on Land - atmosphere Interaction over Arid Region of Northwest China", characteristics of atmospheric humidity, characteristics of soil water content, characteristics of land surface parameters with soil water content and other land surface parameters are analyzed. To validate the new surface parameters and parameterization formulae, the comparison is done between simulation and observation. It is found that the new surface parameters and parameterization formulae are better.

Key words: arid region of Northwest China; hydrometeorology; surface parameter; simulation

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"The Field Experiment on Land - atmosphere Interaction over Arid Region of Northwest China" was carried out in Northwest China from May 2000. There is a micrometeorological observation station in Dunhuang, Gansu province. Its data are used in this paper.

1 Characteristics of atmospheric humidity

It is found[1] that the atmospheric specific humidity over the Gobi is inverted from 0:00 to 6:00 because of the influence of the oasis. And in the daytime, the atmospheric specific humidity decreases basically with height, but its inversion occurs at 2 m height after 14:00 (Fig. 1a).

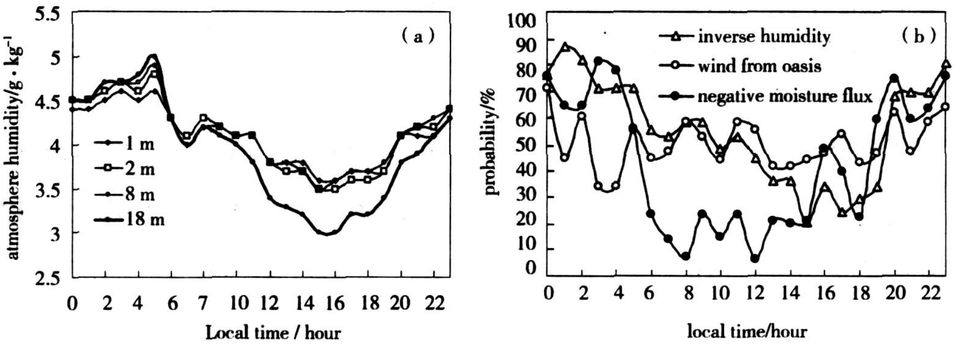

Fig. 1 The daily variation of air humidity (a) and frequencies occurring wind from oasis, inverse humidity and negative moisture flux (b) over Dunhuang Desert

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By comparing the characteristics in different wind directions, It is shown that both of the atmosphere specific humidity inversion and downward water vapor flux are relative to the oasis effect, and the occurring frequencies of the atmosphere specific humidity inversion are inconsistent with those of the negative water vapor flux, and water vapor transfer is sometimes counter - gradient(Fig 1b).

2 Characteristics of soil water content

The diurnal variation of the soil water content at 5 cm shows that the variation in the shallow layer can be divided into four stages, including wet (01: 00 - 06: 00), water - lose (07: 00 - 11: 00), dry (12: 00 - 18: 00), and water - gain (19: 00 - 24: 00). The soil always keeps wet in the first stage, and obviously dry in the second stage, also, the soil always keeps drier in the third stage, and is gradually wetting in the fourth stage. However, the diurnal variation of atmospheric specific humidity is not the same as that of soil water content and its fluctuation is weaker. This shows that atmospheric humidity is affected by more factors other than a clear diurnal cycle.

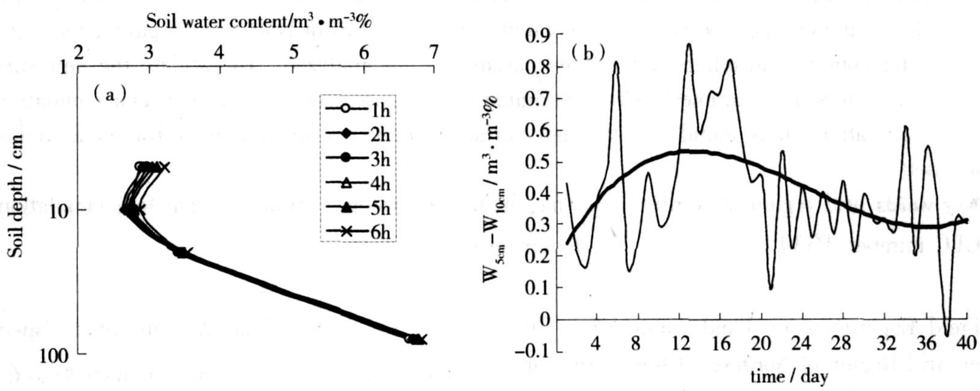

Fig 2 Profiles of soil water content during the nighttime on a typical clear day(a) and variation of daily maximum intensity of soil water content inversion in the shallow layer during 22 August and 30 September 2000 in the Dunhuang Desert

There is soil water content inversion in the shallow layer(Fig 2a). The cause of that is likely the soil obtains water from the atmospheric at surface layer. Under conditions of a clear sky, no irrigation, and no surface runoff, absorbing water from the air by condensation of water vapor at night is the exclusive way for the Gobi soil water content at the 5 cm depth increase. Fig 2b shows the variation of daily maximum intensity of soil water content inversion at the 5 cm layer. Clearly, the soil water content gradient in the shallow soil layer is inverted almost daily. The condensation process occurs almost daily on the soil surface. The average of the daily maximum intensity of soil water content inversion is often 0.4 $m^3 \cdot m^{-3}$% approximately. This means that surface absorbs water from atmosphere through condensation [2-3]

3 Characteristics of land surface parameters with soil water content

3.1 Surface albedo

The relationship of surface albedo over the desert in Dunhuang region with solar altitude angle and soil moisture is obtained[4] as follows:

$$\alpha = (1 - 0.0041 w_s) \times (0.20 + 0.090 \exp(-0.01 h_\theta)) \quad (1)$$

It is found that there is a relatively evident difference between the formulae fitted from experimental data and those being used in the existing models. By comparison with observed values it is found the parameterization formula (1) can reflect the dynamic changes induced by some climatic factors such as precipitation quite well.

3.2 **Soil thermal conductivity**

The relationship between soil thermal conductivity and soil water content in Dunhuang is:

$$\lambda_s = 0.28 + 0.01 w_s - 0.000057 w_s^2 \qquad (2)$$

It is shown that soil thermal conductivity is in good with soil moisture, and the correlation coefficient of fitted curve gets to 0.91 and the standard deviation is only 0.022 W · m^{-1} · K^{-1}. But there is great difference between empirical relationship fitted by the data observed in Dunhuang region and the typical values given by Stull, and in general the thermal conductivity observed in Dunhuang region is only one third or so of the typical values (Fig. 3).

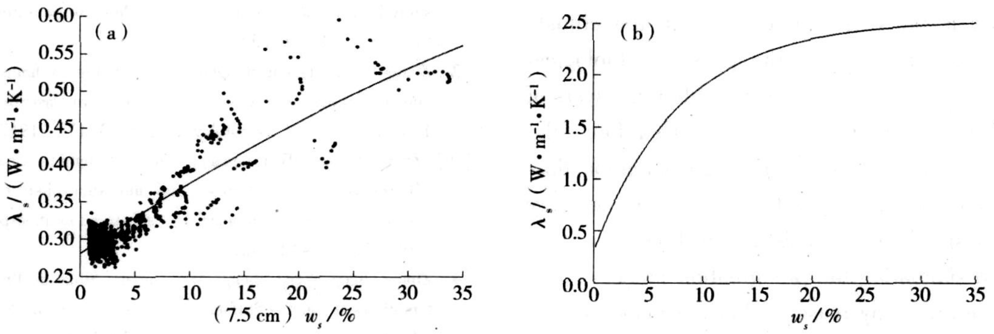

Fig. 3 Comparison between relationship of soil thermal conductivity with soil moisture in Dunhuang desert (a) and typical relationship given by Stull (b)

4 Other parameters

Soil parameters over desert have been analyzed[5-7]. Using the relative reflection as weighting factor, the weighted mean of the surface albedo over Gobi is 0.255 ±0.021. The mean values of the roughness length averaged with logarithm is 0.0019 ±0.00071 m. After removing the influence of the oasis, the soil wetness factor computed with data under the condition of no precipitation is 0.0045, the mean values of soil heat capacity, thermal conductivity and thermal diffusivity are (1.12 ±0.27) ×10^{6} J · m^{-3} · K^{-1}, 0.177 ±0.019 W · m^{-1} · K^{-1} and (1.65 ±0.49) ×10^{-7} m^{2} · s^{-1}, respectively. The soil heat capacity is a bit smaller than those observed in Gobi in HEIFE. Both the soil thermal conductivity and diffusivity are about a half of those observed in desert in HEIFE.

5 Modeling results

In order to validate the above results and some other results[8], some work is done by using the land surface model into which new land surface parameters and parameterization formulae were put. Firstly, the comparison is done between simulation and observation from 14 to 16, June 2000 (Fig. 4a). Then, a year simulation is carried out. The latent heat flux of the whole year is small for little precipitation in arid region. Most precipitation distributed in summer so the latent heat flux in summer is larger than that in winter. And there is no precipitation occurred in July which results in the latent heat flux almost getting to the zero this month. Fig. 4b shows the trend is reasonable although it has no observation during the whole year. We can say that the simulation of the land surface processes over Gobi in Northwest China is successful.

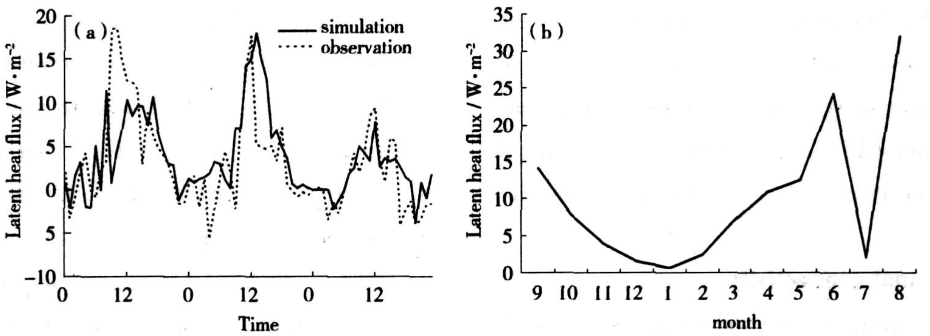

Fig 4 Latent heat variation in a few days (a) and in a full year (b) in Dunhuang desert

6 Remark

Moisture is the most active factor in the climate system. It can participate in the physical, biological and even the chemical process of the different layers of the climatic system in multi - phase Therefore, the moisture cycling attracts more and more attention during the climate simulating, but till now it is not very successful to simulate the moisture cycling, even the exact data in simulating the precipitation process cat 't be got There are many reasons, but the imperfect description of the atmosphere and soil moisture is one of the main reasons, especially the theory puzzles existing in the calculation of the surface evaporation and soil moisture transferring, which were described in many models with including many supposition and presumptions So from now on, the most key task in the research on land surface processes is to get the full reorganization and comprehension of the moisture process or hydrometeorology, which needs not only the enhancement of the research on the moisture motion mechanism but also soil moisture process experiment

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西北干旱区荒漠水分循环特征及其模拟

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摘 要:利用“中国西北干旱区陆—气相互作用实验”观测的资料,分析了大气湿度、土壤含水量、与土壤含水量相关的陆面参数及其他陆面参数特征。为了验证新的陆面参数及参数化公式,将新陆面参数与参数化公式输入陆面模式进行模拟,将模拟值与观测值进行了比较。结果表明输入新参数及参数化公式的模拟效果更好。

关键词:西北干旱区;水分循环;陆面参数;模拟