Characteristics of hydrometeorology and its simulation over desert in the Arid Region of Northwest China

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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 the humidity inversion occurs at 2m high after 14:00 **(**Fig.1a)

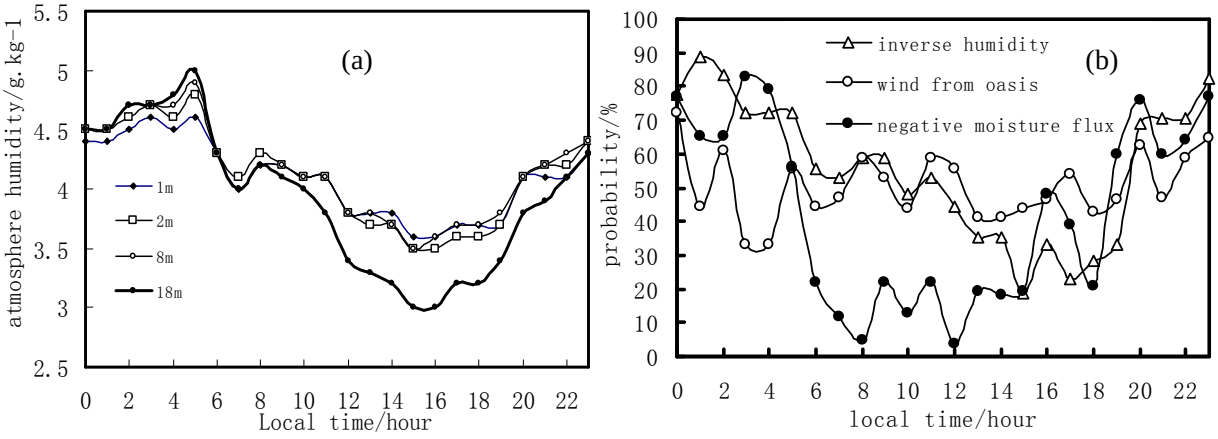

Fig.1: Daily variation of air humidity (a) and frequencies occurring wind from oasis,inverse humidity and negative moisture flux (b) over Dunhuang Desert.

By the comparison of 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, that the occurring frequencies of the atmosphere specific humidity inversion is inconsistent with those of the negative water vapor flux, and that water vapor transfer is sometimes of counter-gradient (Fig.1b).

2. Characteristics of soil water content

The diurnal variation of the soil water content at 5cm shows that the diurnal variation in the shallow layer can be divided into four stages, including wet (01h-06h), water-lose (07h-11h), dry (12h-18h), and water-gain (19h-24h). 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.

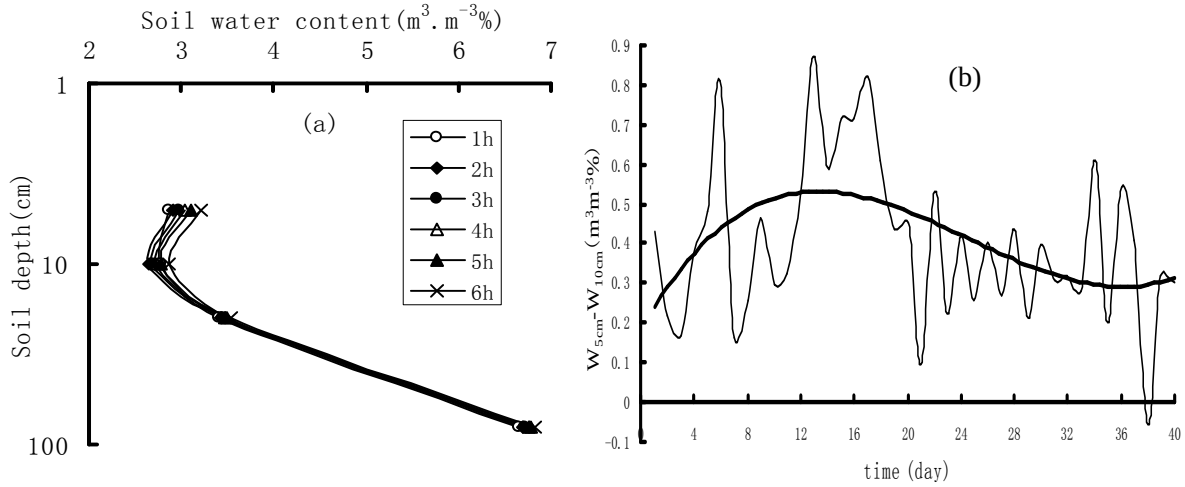

Fig.2: Profiles of soil water content during the nighttime on a typical clear day (a), and variation of daily maximum intensity of soil water content inversion in the shallow layer during 22 August and 30 September 2000 in the Dunhuang desert (b).

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 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 5cm depth increases. Figure 2b shows the variation of daily maximum intensity of soil water content inversion in the 5cm 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 $0.4 m^3 m^{-3}$ % approximately. This means that the process that surface absorbs water from atmosphere is through condensation [2,3]

3. Characteristics of Land Surface Parameters with soil water content

3.1 Surface albedo

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

$$\alpha = (1 - 0.0041 \times w_s) \times (0.20 + 0.090 \times e^{-0.01 \times h_\theta}) \quad (1)$$

It is found that there is a relatively evident difference between the formulas 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 heat conductivity

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

$$\lambda_s = 0.28 + 0.01 \times w_s - 0.000057 \times w_s^{\,2} \quad (2)$$

It is shown that soil heat conductivity is in good with soil moisture, and the correlation

coefficient of fitted curve get to 0.91 and standard deviation is only 0.022 $W.m^{-1}k^{-1}$. But there is great difference between empirical relationship fitted by using the data observed in Dunhuang region and the typical values given by Stull, and in general the heat conductivity observed in Dunhuang region is only one third or so of the typical values (Fig.3)

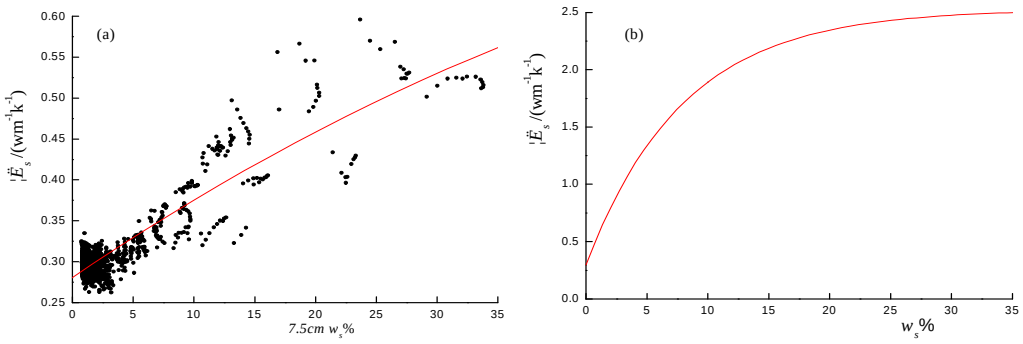

Fig. 3: Comparison between relationship of soil heat conductivity with soil moisture in Dunhuang desert (a) and typical relationship given by Stull (b).

4. Other parameters

Soil parameters over desert are 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±0.00071m. After removing the influence of the oasis, the soil wetness factor computed with data under condition of no precipitation is 0.0045, the mean values of soil heat capacity, thermal conductivity and thermal diffusivity are $(1.12\pm0.27)\times10^{6}$ $J.m^{-3}K^{-1}$, 0.177±0.019 $W.m^{-1}K^{-1}$ and$(1.65\pm0.49)\times10^{-7}$ $m^{2}s^{-1}$,respectively .The soil heat capacity is a bit smaller than those observed in Gobi in HEIFE. Both the soil heat conductivity and diffusivity are about a half of that observed in desert in HEIFE.

5. Modelling results

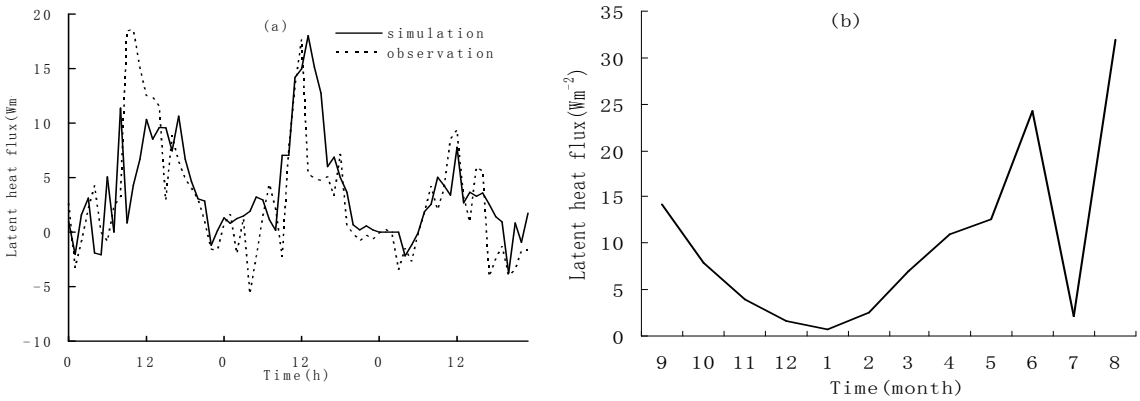

Fig.4: Latent heat variation in a few days (a) and in a full year in Dunhuang desert.

In order to validate the above results and other some results[8], 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 in summer is larger than winter. And there is no precipitation occurred in the July and that result in the latent heat flux almost getting to the zero this month. Fig.4b shows the trend is reasonable although it hasn't observations during the whole year. We can say that the simulation of the land surface processes over Gobi in Northwest China is successful.

6. Remarks

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 systems 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 can't get the exact data in simulating the precipitation process. 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 and soil moisture process experiment.

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References

[1] Zhang Qiang, Wei Guoan, Huang Ronghui,Cao Xiaoyan, Impact of oasis on the atmosphere hydrological cycle over desert or Gobi near it – a study by Dunhuang experiment, *Progress in Natural science(in Chinese)*, 2002, 12(5), 121-136

[2] Zhang Qiang, Huang Ronghui, Water Vapor Exchange Between Soil and Atmosphere over a Gobi Surface Near An Oasis in Summer, *Journal of Applied Meteorology*, 2004, 43(12), 1917-1928.

[3] Zhang Qiang, Wei Guoan, Huang Ronghui, Characteristics of Hydrologic Transfer Between Soil and Atmosphere over Gobi Near Oasis at the End of Summer, *Advances in atmospheric sciences*, 2003, 20(3), 442-452.

[4] Zhang Qiang Wang Sheng Wei Guoan, Study on Physical Parameters of Local Land-Surface Processes on Gobi in Northwest China,*Chinese Journal of Geophysics*, 2003, 46(5), 883-895.

[5] Zhang Qiang, Huang Ronghui, Parameters of land surface processes on Gobi in Northwest China, *Boundary-Layer Meteorology*, 2004, 110(3), 471-478.

[6] Zhang Qiang, Wei Guoan, Huang Ronghui,The bulk transfer coefficients of the atmospheric momentum and sensible heat over desert and Gobi in arid climate region of Northwest China, *Science in China (Series D)*, 2002, 45(5), 468-480.

[7] Zhang Qiang, Wei Guoan,Cao Xiaoyan, Huang Ronghui, Observation and study of land surface parameters over Gobi in typical arid region, *Advances in atmospheric sciences*, 2002, 19(1), 121-135.

[8] Zhang Qiang，Huang Ronghui and Tian Hui The Study on Parameterization Scheme of Surface Turbulent Momentum and Sensible over Gobi Underlying Surface, *Advances in atmospheric sciences*, 2003,20(1), 1-7.