# SOILMOISTURE RETRIEVAL USING THERMAL INERTIA METHOD IN HEIHE RIVER BASIN, CHINA

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## ABSTRACT

*MODIS data and in situ data were used to establish a real thermal inertia model to retrieve soil thermal inertia of Heihe River Basin (HRB) and a soil thermal inertia-soil moisture model to calculate the soil moisture of the basin. Meanwhile, the data of two observation stations in the basin was used to validate the result of retrieval. The correlation coefficients of those between retrieved and observed at two stations were 0.853 and 0.917, respectively. The result shows the method meet the requirement of soil moisture inversion.*

***Index terms***---*Thermal inertia, Soil moisture, Heihe River Basin, MODIS, Retrieval*

## I. INTRODUCTION

As the link of land surface process between soil and atmosphere, soil moisture is a key factor in farmland management and hydrological forecast. Heihe River Basin, which located in the northwest of China, is the second largest inland river basin in China and also one of most important bases for food production of northwest China. However, Water resource problem in this region has become a barrier to the development of economy and society. Soil moisture, the major factor concerning the growth of crops, reflects the drought extent in the region and provides an evidence for management. Therefore, it could be one of the most important indicators of drought monitoring and it is extremely important to understand the soil water content.

There are lots of approaches to collect the soil moisture, such as in situ measurement, remote sensing retrieval and artificial model simulations. In this study, real thermal inertia remote sensing information model was used to retrieve soil moisture from MODIS data and in situ data.

## II. METHODS AND MODELS

**T**he thermal inertia ($P$) of soil is a property that characterizes soil resistance to surrounding temperature change [1, 2], which is defined as:

$$P = \sqrt{k\rho c} \tag{1}$$

Where, $P$ [$Jm^{-2}K^{-1}s^{-0.5}$] is the thermal inertia of soil, $k$ [$Wm^{-1}K^{-1}$] is the thermal conductivity of soil, $\rho$ [$kgm^{-3}$] is the soil density and $c$ [$Jkg^{-1}K^{-1}$] is the soil specific heat capacity. However, the soil thermal inertia could not be obtained directly from remote sensing data, but from point measurement. That means it must be obtained from heat conduction equation. Here, we shall not solute the equation, but give the real thermal inertia model which was developed by MA [3]:

$$P = \frac{\sqrt{2a^2 - B^2} - B}{\sqrt{2\omega}} \tag{2}$$

Where,

$$a = \frac{2(1-A)S_0 C_\tau A_1}{\Delta T} = 2 * ATI * S_0 C_\tau A_1 \tag{3}$$

$$ATI = \frac{(1-A)}{\Delta T} \tag{4}$$

$\Delta T$ [K]was the temperature difference between day and night, $A_1$ was Fourier coefficients and $B, C_\tau$ were considered as constants.

Soil moisture –Thermal inertia relationship model was described as follows:

$$\theta = n\left(1 - \frac{\ln K_p}{\varepsilon}\right)^{1/-\mu} \quad (5)$$

Where $\theta$ was soil moisture, $n$ is soil porosity.

$$K_p = \frac{P - P_{dry}}{P_{sat} - P_{dry}} \quad (6)$$

Where $P$ was retrieved from Remote Sensing, $P_{dry}$ and $P_{sat}$ are measured in situ, ε and $\mu$ were soil texture dependent model parameters. Please pay attention here, the unit of $P$ was $kJm^{-2}K^{-1}s^{-0.5}$

## III. RESULTS AND VALIDATIONS

Soil thermal inertia ($P_{rs}$) was acquired from remote sensing using the model as described in equation (2). At the same time, soil heat conductivity, soil density and soil specific heat capacity were computed from the observing data of automatic weather stations (including Arou station, Yingke station and Huazhaizi station, Table 1 lists the information of the three stations.) to obtain thermal inertia of stations ($P_{st}$ ) according to the definition of thermal inertia described in equation (1). Figure 1 shows the scatter plots of $P_{rs}$ and $P_{st}$.

**Table.1** Information of three stations

| Stations | Locations | Texture | Surfaces |
|---|---|---|---|
| Arou | E100°27′ N38°02′ | Sandy | Grass |
| Huazhaizi | E100°19’ N38°46’ | Clay loam | Desert |
| Yingke | E100°24′ N38°51′ | loam | Farmland |

From Fig.1, we could see that the soil thermal inertia retrieved by remote sensing and computed by observations have significant consistency.

In order to understand the spatial distribution character of soil thermal inertia in Heihe River Basin, the soil thermal inertia at 6 Apr and 24 Aug, 2008 were taken as examples to illustrate as fig. 2.

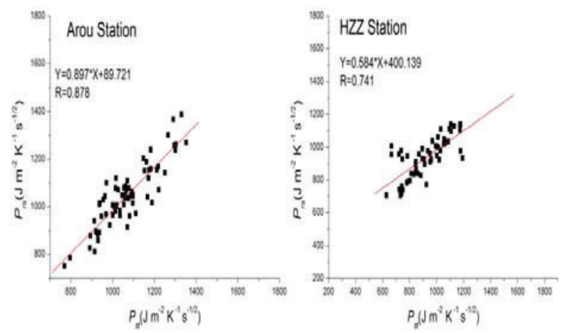
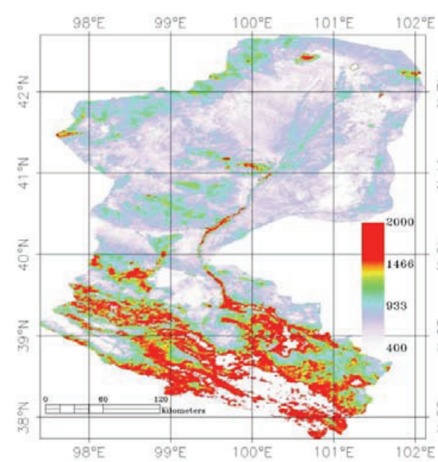



**Fig.1** Scatter for $P_{rs}$ and $P_{st}$

(a) 6th, Apr




(b) 24th, Aug

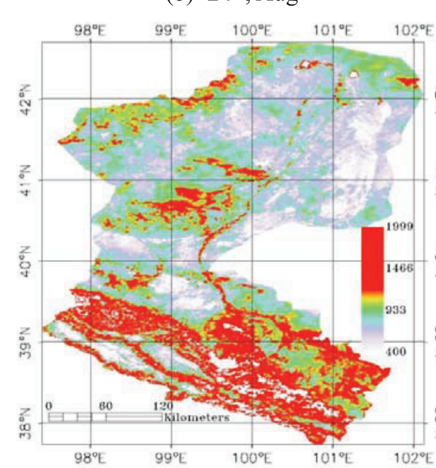



**Fig.2** Thermal inertia retrieved by remote sensing model of Heihe River Basin

Fig. 2(a) reveals the characteristic of the spatial distribution of soil thermal inertia of the Heihe River Basin in early June, 2008. It could be seen that soil thermal inertia of the upstream of basin was 800-2000 $J\ m^{-2}K^{-1}s^{-(1/2)}$ and thermal inertia of the downstream was relatively low, whose value was between 400-900 $Jm^{-2}K^{-1}s^{-(1/2)}$. Fig.2 (b) describes the soil thermal inertia in July 1st. The middle and lower reaches of the basin, and the soil thermal inertia are significantly increased because of the increase of soil moisture resulted from irrigation when compared with fig.2 (a).

Based on the retrieval of soil thermal inertia, we retrieved soil moisture of YK and Arou station in the basin and then compared them with the observations from Time Domain Reflectometry (TDR) at stations. Fig.3 shows the result of correlation between soil moisture observed and retrieved.

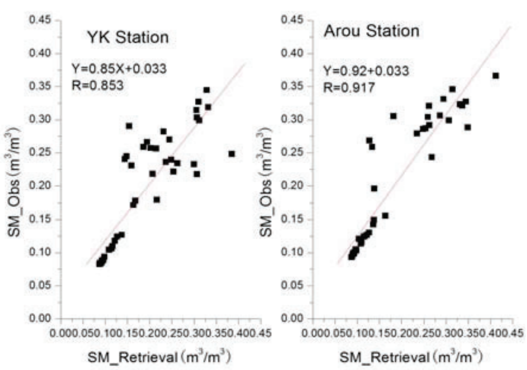
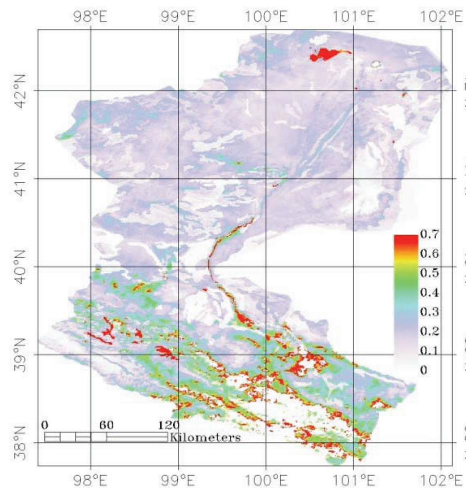



**Fig.3** Scatter for soil moisture of observation and retrieval

The soil moisture of the whole basin was retrieved to understand its characteristics. The results were as Fig.4.

Fig.4 (a) and Fig.4 (b) describes the soil moisture of the basin at 5th, July and 10th, August respectively. Both of the two figures showed that soil moisture in the upper reaches and middle reaches of the basin relatively higher than the lower reaches. This distribution characteristic is similar with that of the soil thermal inertia. This result confirmed the conclusion that soil moisture was positive related to soil thermal inertia.

(a) Soil moisture at 5th, July




(b) Soil moisture at 10th, August

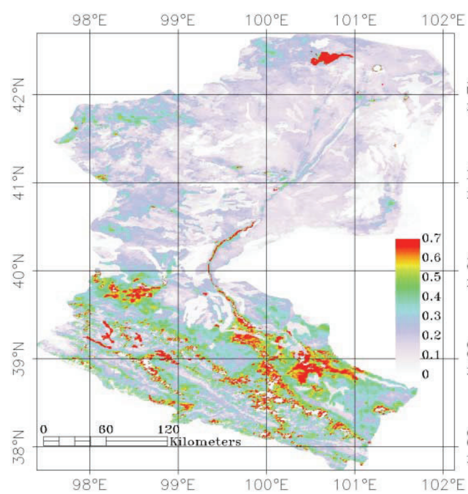



**Fig.4** Soil moisture of the whole basin

In order to study the advantages and disadvantages of the real thermal inertia model and the apparent thermal inertia model, land surface soil moisture of Yingke station was selected to compare with results of real thermal inertia model (RTI) and apparent thermal inertia model (ATI). The results indicate that RTI has significant advantage over ATI. Fig.5 showed the scatter of the results.

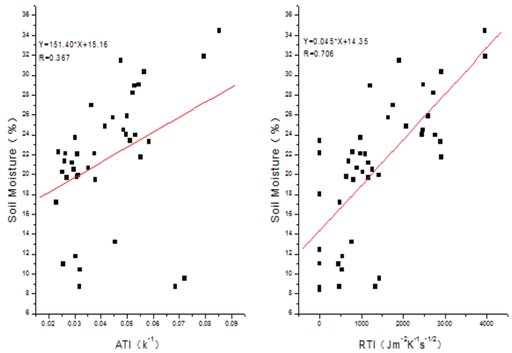



**Fig.5** Scatter for Soil Moisture between ATI and RTT

## IV. CONCLUSIONS

In this study, soil thermal inertia was retrieved in HRB by using an existed real thermal inertia model, and then a thermal inertia-soil moisture relationship model was established for soil moisture retrieval according to normalized theory described as Eq.(6). Finally, soil moisture and soil thermal inertia was validated by using of stations data. From this study, we got the follow conclusions:

Firstly, soil thermal inertia, surface albedo and temperature differences were validated by using surface observation data. Results indicate retrieval value and observation value were similar with each other. And the real thermal inertia model is applicable in the Heihe River Basin, which could provide an effective method for soil moisture estimation. Furthermore, the real thermal inertia model was much betterthan the apparent thermal inertia model in soil moisture retrieval.

Secondly, soil thermal inertia and soil moisture in the basin were analyzed. The results show that all of them had character of seasonal variations. Thermal inertia and soil moisture had similar variation trend and distribution character.

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