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Validation of Passive Microwave Remotely Sensed Soil Moisture (AMSR-E) Products in the Yihe Catchment, Shandong Province of China

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ABSTRACT
The surface soil moisture content (SSMC) is of great importance to the discipline of hydrology as well as to the other relevant studies and applications. Pioneer studies have pointed out that the most promising technique to retrieve SSMC regarding to accuracy and cost-effective belongs to the micro-wave remote sensing. By means of field observed SSMC dataset collected from the Yihe watershed located on the Linyi district, Shangdong province, China, we analyzed and validated the daily AMSR-E SSMC products for the year of 2006 with the focus to examine the products quality of AMSR-E SSMC for further studies by using the products. The results suggested that the temporal variation trend of AMSR-E remotely sensed SSMC is reasonably consistent to the field observed, but is systematic lower than the ground truth in value in the whole year. The correspondence of AMSR-E SSMC product is significant enough compared with the field observed for the whole year except of the month of July and August.
Index Terms: AMSR-E, surface soil moisture content (SSMC), validation, micro-wave remote sensing

I. INTRODUCTION

Spatial distribution of SSMC, especially at watershed scale, is very important for watershed hydrological simulation, flood prediction, and is helpful for improving our understanding on soil-vegetation-atmospheric interactions. As a key factor in hydrological modeling and a land surface boundary condition, soil moisture poses an evident effect on surface–atmospheric interactions and subsequently has great potential to influence the weather and change hydrological processes [1,2]. Studies on spatial and temporal variations of SSMC at watershed and regional scales have drawn great attentions in hydrological and meteorological as well as environmental disciplines, and techniques for retrieval SSMC much cost effectively have became a hot topic in relevant studies. Located in the middle-eastern part of China of monsoonal Asia, studies on moderate and macro-scale water and energy cycle of this region is very important and meaningful for exploring unknown inherent mechanism of drought trend in North China [3]. However, limited studies on land surface processes in this region are yet preliminary and many unknown difficult questions concerning with the nature of atmosphere-land surface interactions remain unsolved.

Remote sensing techniques as the most reliable and feasible means for mapping the spatial and temporal patterns of land surface state variables have been recognized in recent science advances. Unfortunately, till now, few researches by using such techniques to retrieve these important state variables of land surface and hydrological processes of this region have been conducted.

Visible, infrared, passive and active microwave sensors have long been used in retrieving the soil moisture in the past decades[4]. Among the remote sensing techniques used for retrieving soil moisture, passive microwave remote sensing techniques have been studied for quite a long time for several decades and are recognized as the most promising means for quickly, extensively and cost effectively mapping surface soil moisture with satisfactory accuracy. The AMSR-E soil moisture data, owning to its high re-visit time (once per day) at any place of the Earth, favorite its applications of great potential in downscaling or assimilating studies at watershed and regional scale hydrological modeling and four dimensional data assimilation purpose [5, 6]. At present, the AMSR-E SSMC products has been opened for public, however, systematic validations of such global data product in regional scale, especially in China are seldom found in literatures.

In this study, the spatial pattern of surface moisture content over the Yihe catchment, a typical semi-humid region in northern China, was investigated by using AMSR-E retrieved data. Validation of AMSR-E SSMC product using field observations collected from the whole year of 2006 were conducted and the data quality of the AMSR-E

SSMC product was preliminary evaluated in spatial and temporal scales.

II. DATA AND METHODS

2.1. Study site

The study site selected in present study located in the Yihe catchment of the Yishusi River Basin in the Linyi district, southern part of Shandong Province, China (Fig.1). The Yihe catchment is about 1,0000 km2 with geographic location from 117°E - 119°E to 34.5°N - 36.5°N. For the AMSR-E SSMC product with spatial resolution of 25km, there are totally about 5 * 5 grids cover the whole catchment of the region (Fig. 2). The climate of the Yihe catchment belongs to semi-humid type, as one of the main study areas selected for the project of National Key Developing Program for Basic Sciences of China, the region has been studied for many years and was administrated by the Huaihe River Conservancy Commission.

Fig.1. Location of the study area, the Yihe Catchment in the Linyi District, Shangdong Province, China.

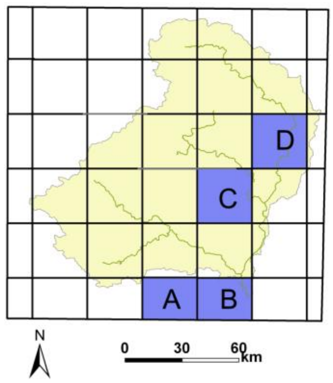

Fig.2. Locations of the study area within the AMSR-E SSMC products. The Grids of A, B, C and D illustrate the geo-locations of the field SSMC observation site in the region. The time series variation of the averaged SSMC for these four Grids are plotted in the Fig.3

The predominant soil type of this region is cinnamon soil and brown soil and the land cover is mainly composed of bare soil, low grass land and wheat farmland. The annual precipitation is approximately 820 mm and the rainy days are concentrated in July and August in summer. The climate is subtropical monsoon with the long term annual averaged air temperature of 13 ℃.

2.2. Data materials

Datasets used in this study include AMSR-E level3 global soil moisture products at 25km resolution and field measured SSMC data in the same period of the whole year 2006. SSMC observed data collected within the watershed of the Yihe catchment, linyi district are mainly from the cornfield site, which was regularly measured on the 8th, 18th and 28th of each month of a year, for the soil moisture observed data obtained at the other measurement sites such as plain, hill and swale site, the soil moisture were measured once a month. The AMSR-E level3 global soil moisture products at 25km resolution images [7] are daily products and totally 363 AMSR-E images are used here for analyses, except for the 2006-8-22 and 2006-11-18. The top 10-cm, 20cm, 30cm, 40cm, and 50cm soil moisture was measured for this data product, but only the top 10-cm data was used for comparison and validation with field observed SSMC. The field measurements of SSMC within the gird of AMSR-E were averaged for comparison and validation in this study.

2.3. Data processing

Firstly, the AMSR-E SSMC product images were scaled by multiplying 0.001 for unit conversion, and then the data file is geo-referenced using standard GLT file provided by NSIDC in order to project to the geographic coordinate systems. Finally the images were subset via (Region of Interest) ROI to mask out the studied region. The same processes were repeated for all AMSR-E SSMC product by batch process under the IDL programming environment until all the datasets were processed.

III. RESULTS AND DISCUSSIONS

3.1. Time series of the AMSR-E SSMC product

Four girds as shown in Fig.2 within the Yihe catchment shown in the AMSR-E SSMC product images were selected for time series analysis. The temporal variation of the AMSR-E SSMC data at Grads A, B, C and D, as seen from the Fig.3, suggests that the soil moisture is very stable in the whole year with slight fluctuations such that quickly increases in value attributed to short term precipitation but returns to normal soon with the gradual drying after precipitation. The general variation pattern of the time series of SSMC for these four girds looks very similar, which may be attributed to the flat terrain and the rather similar land covers all over the basin. The further discussion on this issue will be given latter in detail. It's interesting to find that the heavy rainfall taken place in the July and August have little influence on the surface soil moisture. The yearly peak value of SSMC appears at the end of June. This is not in accordance with the ground measurements. This may be related to the errors definitely involved in the remotely sensed SSMC for the primary reason and the low spatial resolution of 25km of the AMSR-E SSMC product for the second. The measured SSMC increases from the early June, and lasted about 20 days in general, and then decreases afterwards until reaches to the lowest value of the whole year in July. The other significant characteristics of the field measured time series of SSMC is that there is a long decrease stage which starts at the 15th of September, end at 10th of November. This period corresponds to the relative arid season lasted about 2 months of the year. After that the SSMC increase again in December with some fluctuations. These trends were found quite similar for all above examined four grids as shown in Fig. 3.

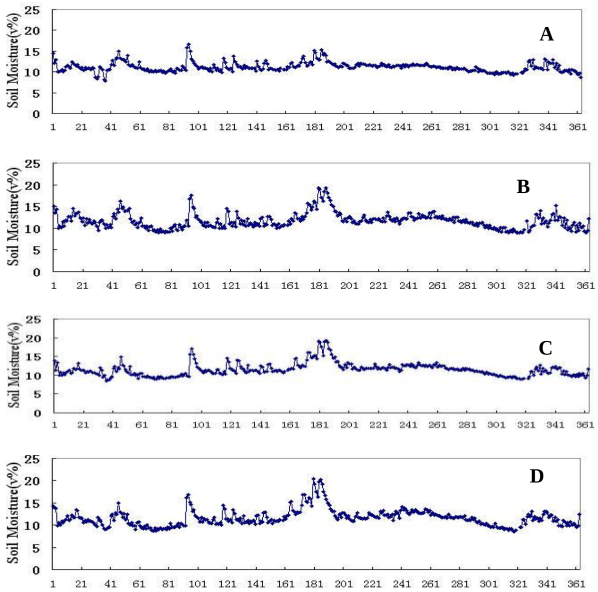

Fig.3. Time series of SSMC retrieved from the four grids of the AMSR-E SSMC product as described in Fig.2 for the Yihe catchment for whole year 2006

3.2. Spatial distribution of the AMSR-E SSMC product

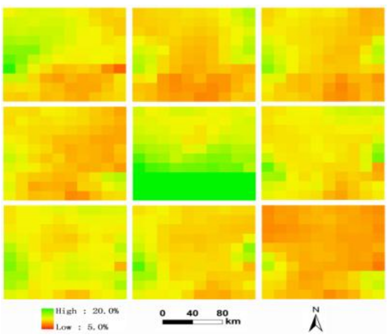

Fig.4. AMSR-E SSMC of study site for the first day of every month from March to November

To examine the spatial characteristic of SSMC of the Yihe catchment from the AMSR-E SSMC product, night images derived at the first day of every month from March to November are spatially averaged and the results were shown in Fig.4. The spatially distributed SSMC varies from 5% to 20% for the Yihe catchment for all the selected days, except for the 1st the July of which some grids exceeds the 20%. The highest value of SSMC for the other days is 19.4%. The common spatial characters is that the SSMC of center part is relatively lower than the other parts, and the SSMC values decrease from northwest to southeast with a relative wet region located in the west part of image. In general, the AMSR-E retrieved SSMC is relatively low compared with the field measurement, the majority of grid SSMC varied about 7% to 12%.

3.3. Comparison with ground truth

Local measurements were compared with the AMSR-E retrieved SSMC for temporal and spatial variations. As shown in Fig.5, all the measurement sites are located in one AMSR-E grid, but one site in hilly ground, one in plain site, one from the corn field and another in swale field.

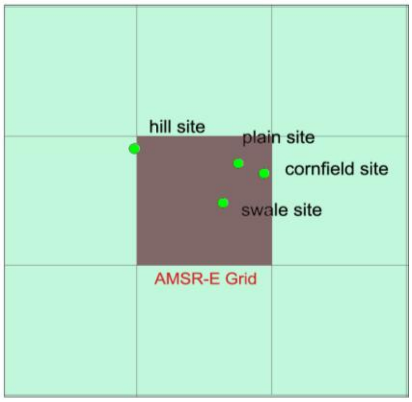

Fig.5. Location of ground measurement sites and the AMSR-E grid

3.3.1. Temporal variations of the field observed SSMC compared with the AMSR-E SSMC product for cornfield

Here we compare the temporal variations of the field observed SSMC compared with the AMSR-E SSMC product for cornfield. As seen from Fig.6, all the AMSR-E retrieved SSMC is lower than the ground measured ones. And the other important characteristic of AMSR-E SSMC data is that the fluctuation of SSMC values is much smoother than the ground measurements. Considering the rainy days in summer, the AMSR-E time series of SSMC at any examined field measurement sites is inadequate in representing soil moisture fluctuation during this rainy period. Especially this may not be rational for AMSR-

E SSMC data for the highest values appeared in this year during April and May. The ground measured moisture of cornfield site varies from 13% to 27% during the whole year, while for the AMSR-E retrieved SSMC product, its values changed from about 10% to about 15%, with the stable value of 12% during the most time of the year.

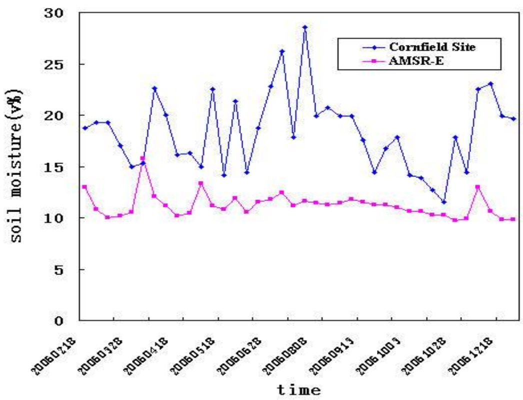

Fig.6. Field observed SSMC for the cornfield site compared with the AMSR-E product in 2006

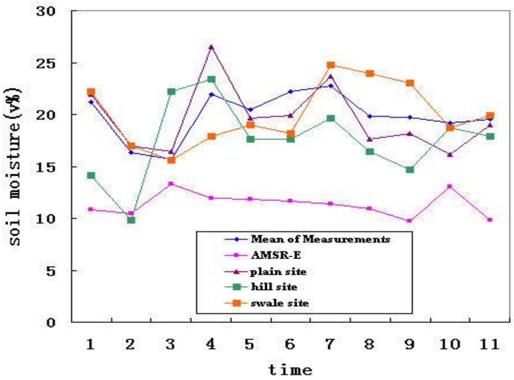

Fig.7. Soil moisture dynamics from AMSR-E and other ground measurement sites, 2006

3.3.2. Comparisons for the other measurement sites

As illustrated in Fig.7, Among all the four examined local measurement sites, the hill site measurements are mostly close to the AMSR-E SSMC product especially in view of the temporal variation trend, however, quantitatively, the AMSR-E retrieved soil moisture exhibits systematically lower than the filed measurements, with the value extent of AMSR-E is between 10% and 15%, and the value extent of local measurements are between 15% and 25% (volume content). The consistent SSMC variations and close values for four examined field observation sites can be found in Fig. 7 too, except for the hill observation site, although their locations are far from each other.

IV. CONCLUSION

Few studies till now has been conducted in validation of soil moisture estimates from remotely sensed measurement with field observations. In this study, by means of field observed SSMC collected from four different sites in the Yihe catchment, Linyi district at Shandong Province, china, validations of AMSR-E SSMC product for the whole year of 2006 were conducted. The results suggested that the trend of AMSR-E remotely sensed SSMC is reasonable in general concerning with temporal and spatial variations. Compared with the field measurements, the AMSR-E retrieved SSMC is in general lower about 5% to 10% than the observed. This may be caused by the errors definitely involved in the remotely sensed SSMC for the primary reason and the low spatial resolution of 25km of the AMSR-E SSMC product for the second.

This preliminary study suggests that there is an urgent need to calibrate the AMSR-E SSMC product for watershed applications. This work will contribute to knowledge of the compatibility between the remotely sensed SSMC and field measurements.

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REFERENCES

[1]. J. F. Mahfouf, "Analysis of Soil-Moisture from near-Surface Parameters: a Feasibility Study," Journal of Applied Meteorology, vol. 30, pp.): 1534-1547., 1991.

[2]. D. Ryu and J. S. Famiglietti, "Multi-scale spatial correlation and scaling behavior of surface soil moisture," Geophysical Research Letters, vol. 33, 2006.

[3]. D. M. Zhao, C. Kuenzer, C. B. Fu, and W. Wagner, "Evaluation of the ERS scatterometer-derived soil water index to monitor water availability and precipitation distribution at three different scales in China," Journal of Hydrometeorology, vol. 9, pp. 549-562, Jun 2008.

[4]. A. Loew, T. Holmes, and R. de Jeu, "The European heat wave 2003: Early indicators from multisensoral microwave remote sensing," Journal of Geophysical Research-Atmospheres, vol. 114, p. 14, Mar 2009.

[5]. C. S. Draper, J. P. Walker, P. J. Steinle, R. A. M. de Jeu, and T. R. H. Holmes, "An evaluation of AMSR-E derived soil moisture

over Australia," Remote Sensing of Environment, vol. 113, pp. 703-710, Apr 2009.
[6]. C. Rudiger, J. C. Calvet, C. Gruhier, T. R. H. Holmes, R. A. M. de Jeu, and W. Wagner, "An Intercomparison of ERS-Scat and AMSR-E Soil Moisture Observations with Model Simulations over France," Journal of Hydrometeorology, vol. 10, pp. 431-447, Apr 2009.
[7]. E. Njoku, "updated daily AMSR-E/Aqua Daily L3 Surface Soil Moisture, Interpretive Parameters, & QC EASE-Grids V002, 2006. Boulder, Colorado USA: National Snow and Ice Data Center. Digital media." 2004.