EVALUATION OF SATELLITE DATA ON SOIL MOISTURE IN THE SOUTH-WEST REGION OF THE BAIKAL

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ABSTRACT

The present paper presents characteristics of correlation between soil moisture observations obtained from a satellite and direct observations during the warm period of 2011 and 2012 in the area of the Tunka Basin. The factors influencing the relationship are considered. It is shown that the updated satellite data on moisture of the upper soil layer and those of direct observations at a depth of 15 cm have a satisfactory relationship.

Keywords: soil moisture, the satellite observations, direct observations, the Baikal region

1. INTRODUCTION

Soil moisture determines water and thermal regimes of soil and surrounding atmosphere. Observations of changes in soil moisture are important in different fields of science and practice. They are necessary in hydrological, ecological and climate research, as well as for agricultural needs. Accounting moisture reserves in soil is essential for weather forecasting, in particular, soil moisture is used as an important parameter of mathematical models of atmosphere and the forecast accuracy depends on the completeness and the quality of the initial data. Unfortunately, on the territory of Russia, the density of the meteorological stations network is insufficient, especially in extreme northern and eastern regions. In addition, soil moisture at meteorological stations is estimated visually and instrumental agro-meteorological observations are carried out one time per decade, which is also insufficient. Since 2010, soil moisture has been included in the list of 50 essential climate variables that are recommended by the World Meteorological Organization for system monitoring.

The research related to validation of satellite observations using the measuring system MetOp – ASCAT has been conducted since 2007. Certain results have been obtained for the United States, Europe, Central Asia, the Western Equatorial Africa and the south of Australia for the period from 2007 to 2011[1,2,3,4].

Due to the lack of standard regular direct observations of soil moisture in Russia, such studies are virtually absent.

The aim of the work is to evaluate satellite measurements of soil moisture by comparing them with ground-based observations on the territory of Russia (the Tunka Basin) for the period of 2011 and 2012, when the underlying surface was characterized by positive temperatures and there was no snow or ice covering it.

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2. RESEARCH MATERIALS

As direct observations we used soil moisture measurements at 10 points in the territory of the Tunka Basin, located to the south-west of Lake Baikal.

On the territory of the Tunka Basin, the employees of the V.B. Sochava Institute of Geography SB RAS organized monitoring of hydrothermal regimes of soils. To measure the temperature and the humidity of the soil, registrars of the AIPT and RAP-A 02 modifications are used. The device was designed and manufactured at the Institute of Monitoring of Climatic and Ecological Systems SB RAS and it is used for measuring the moisture content of the soil at a depth of 15 cm, in volume units (m^3/m^3). Measurements are taken every hour.
The soil moisture measurement range is 0-100%. The inaccuracy of measurement of the soil moisture at a moisture content of 0–40% is ± 1% and at a moisture content of 40-70% – ± 2%, respectively. The obtained data allow observing seasonal changes in temperature and soil moisture, as well as the rate of freezing/thawing of the soils [5].

The study area and the names of the observation points are shown in Figure 1.

Figure 1. Study area and location of terrestrial points of soil moisture measurement

For the territory of the Tunka Basin, a visual assessment of the underlying surface nature, including the nature of vegetation, was carried out[5].

For the majority of the test points, sandy and sandy loam soils, arable land and wetlands are predominant. The observation points also have varying degrees of the vegetation cover. The distances between the ground measurement points are more than 5 km.

The satellite observations are the data of the scatterometer ASCAT installed on board of the MetOp system. The ASCAT is a scatterometer operating in the C-band at a frequency of 5.255 GHz which measures the surface moisture of the soil (at a depth of up to 2 cm) in relative units[6]. The measurements are taken 1-2 times a day with a resolution of 25×25 km. An example of a satellite observation is presented in Figure 2.

The satellite points were chosen so that the coordinates were as close to each of the selected terrestrial observation point as possible (the distance between the satellite station and the point does not exceed 6 km). After selecting the satellite points, their measurements were compared with the ground-based measurements with respect to time (the time differences may be about 0.5 hours).

Also, using the linear dependence proposed in [7], the satellite data were converted into absolute values[1] – the bulk moisture (m^3/m^3).

For getting a smoother trend, the series of satellite observations was supplemented by the Kalman filter[8].

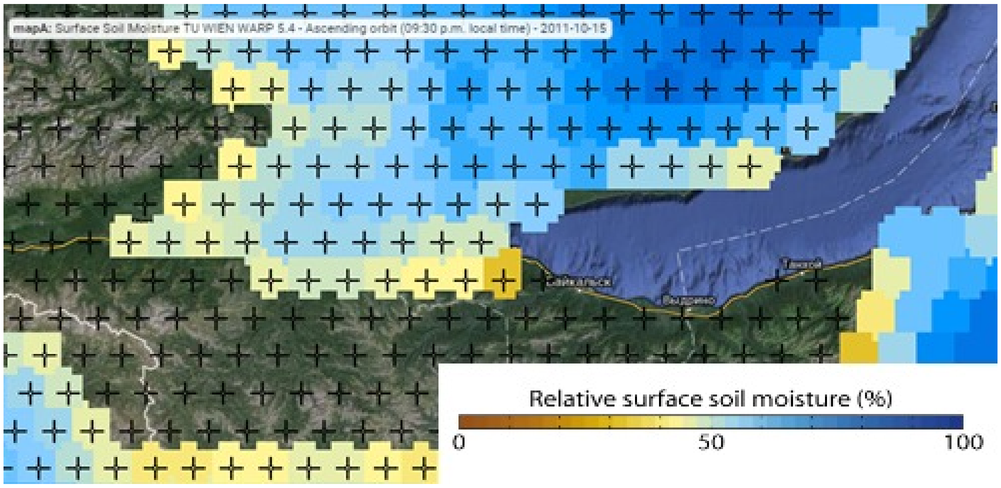

Figure 2. Example of satellite measurement of surface soil moisture; October 15, 2011 (data taken from site of Department of Geodesy and Geoinformation)

3. RESULTS AND CONCLUSIONS

The criteria for assessing the closeness of the relationship between the two series of observations were chosen as follows: the absolute error of satellite measurement, the relative error, the Pearson's correlation coefficient. The evaluation results of the data (using the Kalman filter), the difference in height between the satellite and the ground points and the underlying surface characteristics are shown in Table 1.

Of the ten examined stations, two have no relationship with the satellite data, five have a weak dependence, three stations are in good agreement with the satellite measurements (correlation coefficient > 0.5). These points were dominated by sandy and sandy loam soil types, the vegetation type being: teen pine, meadow and open sandy surface amidst pine forests.

Tightness of correlation depends on the difference in height between the satellite and the ground measurement points. When the difference between the heights is of over 8 meters, the correlation data deteriorates markedly. The exceptions are the two stations AIPT34 and AIPT38, for which the height difference is only 4 m, but here the character of the underlying surface has an effect - both stations are in a swamp. The relative error is less than 34%, and for most stations – less than 10%.

Table 1. Comparison results for soil moisture data

Point name	Difference of heights, m	Surface characteristics	Absolute error, m^3/m^3	Relative error	Correlation	Average moisture m^3/m^3
AIPT 26	27	sand	0.046	0.229	0.05	0.20
AIPT 27	23	sand	0.030	0.348	0.27	0.09
AIPT 28	13	sandy loam	0.004	0.014	0.05	0.29
AIPT 29	7	sandy loam	0.010	0.042	0.57	0.24
AIPT 30	42	sandy loam	0.006	0.052	0.44	0.11
AIPT 32	5	sandy loam	0.014	0.088	0.56	0.16
AIPT 34	4	swamp	0.006	0.015	0.28	0.43
AIPT 35	8	sand	0.008	0.096	0.53	0.08
AIPT 36	76	swamp	0.029	0.031	0.20	0.95
AIPT 38	4	swamp	0.003	0.007	0.27	0.39

The accuracy of correlation coefficients r was estimated. The error of the correlation coefficient σ_r was calculated observing that its value depends on the value of the correlation coefficient and the length of the correlated series. If the ratio of the correlation coefficient to its error r/σr is greater than 2, the correlation coefficient quite reliably reflects the dependence of correlated traits with reliable probability close to 1. When $r/\sigma_r < 2$, the correctness of the suggested linear correlation relationship is to be doubted.

Table 2. Parameters of estimation for correlation coefficients reliability

Point name	r	Series length	σ_r	r/σr
AIPT 26	0.05	219	0.07	0.7
AIPT 27	0.27	218	0.06	4.3
AIPT 28	0.05	39	0.16	0.3
AIPT 29	0.57	60	0.09	6.4
AIPT 30	0.44	57	0.11	4.1
AIPT 32	0.56	26	0.17	3.3
AIPT 34	0.28	62	0.12	2.3
AIPT 35	0.53	63	0.09	5.9
AIPT 36	0.20	51	0.13	1.5
AIPT 38	0.27	37	0.16	1.6

Figure 3 shows the time course of the soil moisture at one of the points using the two types of observations and the Kalman filter.

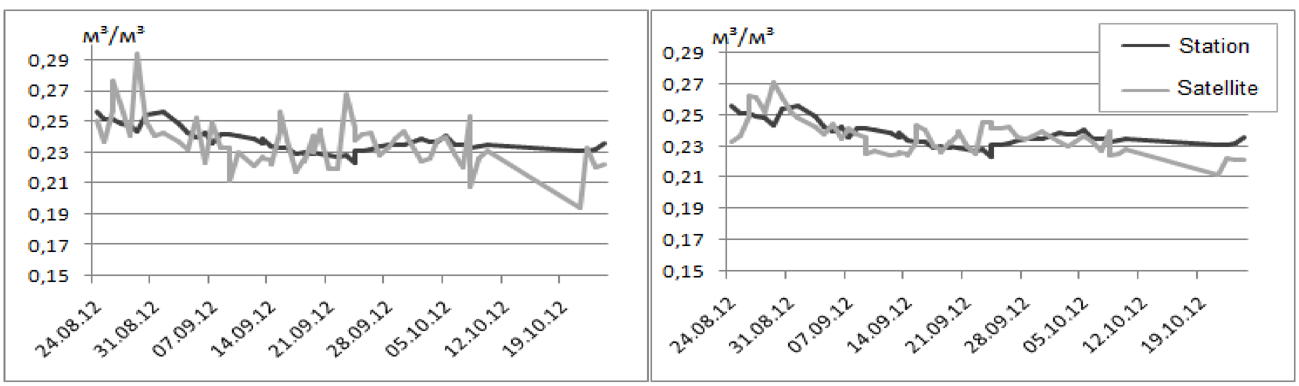

Figure 3 Time course of soil moisture according to data from satellite and station AIPT 29 with no application of filter (left) and with application of Kalman filter (right)

Using the Kalman filter significantly improves the correlation. In general, refined satellite data on the upper layer of the soil moisture and direct observation at a depth of 15 cm have a satisfactory relationship.

Thus, for the area in question, 30% of the land measuring points showed a satisfactory result. These points were dominated by sandy and sandy loam soil types, the height difference between the satellite and the ground measurement points was less than 8 m, and the type of vegetation was: teen pine trees, meadow and open sandy surface amidst pine forests.

Unsatisfactory results were obtained for the measuring sites located near swamps and marshes, as well as from the ground points for which the height difference from the satellite points was significant and was over 8 m.

4. ACKNOWLEDGMENT

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