Analysis of the SMOS, MODIS and GCOM-W1 Data during the Growing Season in the Southern Part of the Western Siberia

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Abstract— A vegetation layer on soil surface makes significant contribution to the surface radiothermal emission. The SMOS Soil Moisture Retrieval Algorithm estimates vegetation attenuation (optical depth) to the soil emission at L-band by LAI data using semi-empirical equations. There are several vegetation indexes calculated by another satellite data. This paper presents the analysis of the SMOS level 2 optical depth data, normalized microwave polarization difference index (MPDI), microwave vegetation index (MVI) derived from GCOM-W1 data and optical vegetation indexes (LAI and NDVI).

1. INTRODUCTION

Soil moisture, as the fundamental parameter for the water resource formation on the land surface, plays an important role in climate changing. At this moment, there are two functioning satellites on orbit suitable for the determination of soil moisture with acceptable accuracy in global scale. The first is the Advanced Microwave Scanning Radiometer (AMSR2) on the GCOM-W1 satellite was launched on May 17, 2012. The second is the Soil Moisture and Ocean Salinity Mission (SMOS) launched on November 2, 2009. A distinguishing feature of SMOS radiometer (MIRAS) is its multi angular measurement capability at L-band (1.4 GHz) on full polarization [1]. The AMSR2 instrument measures radiation at six frequencies in the range of 6.9–89 GHz on dual polarization by conical scan at a fixed incidence angle of 55° [2].

The vegetation layer over the soil surface attenuates soil emission and adds its own contribution to the emitted radiation. These effects at low frequencies can be approximated by a simple model (τ-ω model). Emission from the two-layer medium consists of three terms: 1) the vegetation emission; 2) the vegetation emission reflected by the soil surface; 3) soil emission attenuated by the vegetation canopy. In this case radio brightness temperature is calculated by equation:

$$T_B = (1-\omega)\cdot(1-\gamma)\cdot(1+\gamma R)\cdot T_V + (1-R)\cdot\gamma T_S, \tag{1}$$

where ω is the single scattering albedo of the canopy; T_S, T_V is temperatures of the soil surface and canopy, respectively, R is the soil reflectivity, $\gamma = \exp(-\tau/\cos\theta)$ is the transmissivity of the vegetation layer, τ is the optical depth.

The vegetation attenuation factor can be computed from the optical depth related to the total vegetation water content (VWC) [3]. However, estimation of VWC at global scale is very difficult. The SMOS Level 2 algorithm uses optical depth data parameterized as a function of the LAI [4]. However, there are other indexes describing the state of vegetation. In this paper we study their relationship for territory of the Southern Part of the Western Siberia.

2. RESULT OF STUDIES

We used SMOS Level 2, AMSR2 Level 1R and MODIS (LAI and NDVI) data during analysis. The SMOS Level 2 data have fixed coordinates of the center pixel (discrete global grid — DGG) in contrast to AMSR2 1R data. We selected the AMSR2-1R pixel with coordinates not to differ from the coordinates of the SMOS Level 1C pixel more than 0.03 degrees on latitude and 0.06 on longitude. The MODIS NDVI data with higher spatial resolution were averaged within a SMOS Level 2 pixel. The GCOM-W1 and MODIS data available in HDF format are in contrast to the SMOS data available in biary XML format. The software for simultaneous processing of flow data in these formats wasn't found. The authors were carried out processing data from different satellites using program created by themselves in MATLAB.

The earliest studies for using satellite microwave radiometer data to assess the state of vegetation has been in [5]. Later microwave vegetation indexes calculated by AMSR-E data with equations [6] has been proposed

$$\mathrm{MDPI}(f_1) = \frac{T_{BV}(f_1) - T_{BH}(f_1)}{T_{BV}(f_1) + T_{BH}(f_1)}; \quad (2)$$

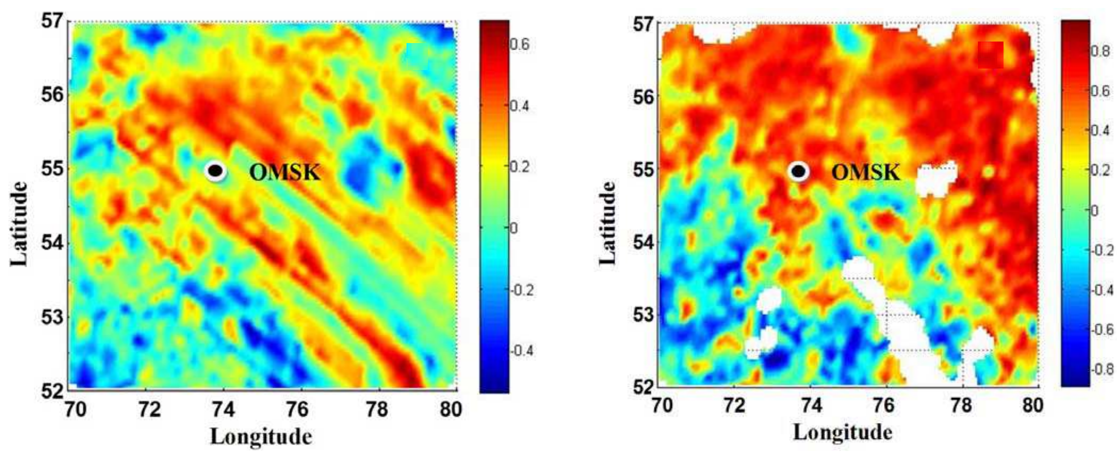
$$B(f_1 f_2) = \frac{T_{BV}(f_2) - T_{BH}(f_2)}{T_{BV}(f_1) - T_{BH}(f_1)}; \quad (3)$$

$$A(f_1 f_2) = \frac{T_{BV}(f_2) + T_{BH}(f_2) - B \cdot (T_{BV}(f_2) + T_{BH}(f_2))}{2}; \quad (4)$$

where T_{BP} is radio brightness temperature on p-polarization and n-frequency; A and B are microwave vegetation index.

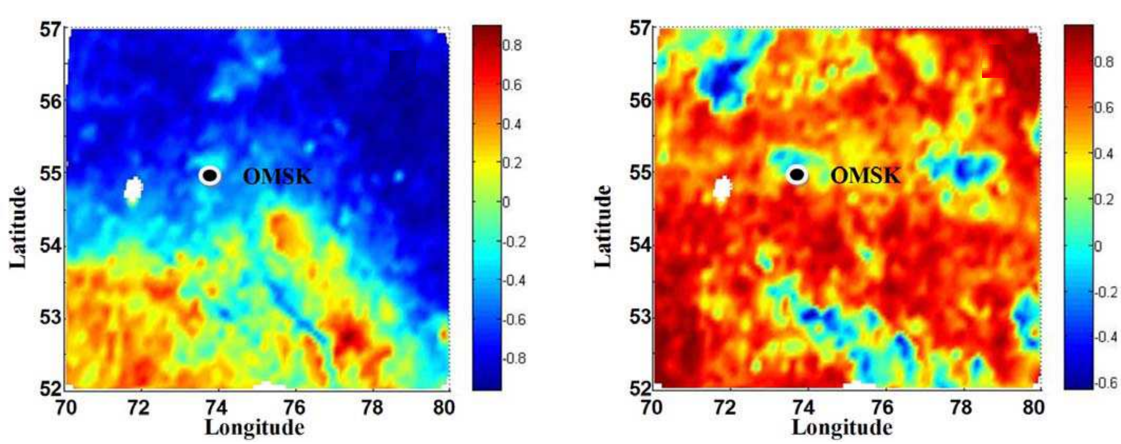
The relationship between MVI, MPDI and SMOS Level 2 optical depth was very weak at the any type of surface (Fig. 1(a)). Moreover, correlation coefficient has a small value and his sign varies from one pixel to another. The relationship between SMOS Level 2 and NDVI was slightly better (Fig. 1(b)).

MODIS 16-day composite NDVI data including MOD and MYD products shifted in time at 8 days. We collected this data into an 8-day composite NDVI product. The AMSR2 data in the time interval of 8 days were averaged. The correlation relation between microwave vegetation index calculated according to Equations (2), (3), (4) by GCOM-W1 data and NDVI was better than it is shown in Figs. 1(a), 1(b) but depends on the type of surface (Figs. 2(a), 2(b)). Among them,



(a) (b)

Figure 1: Map of correlation coefficient between (a) MVI_A (6.9, 10.7 GHz) and SMOS Level 2 optical depth; (b) SMOS Level 2 optical depth and NDVI during the growing season 2013.

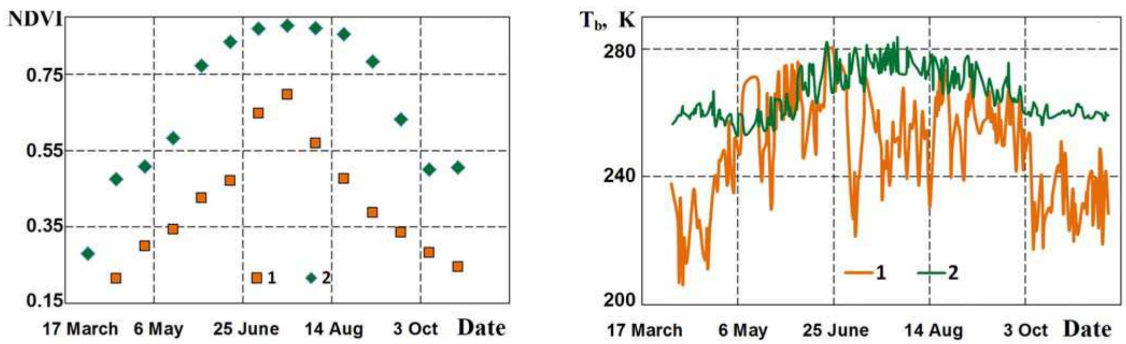


(a) (b)

Figure 2: Map of correlation coefficient between (a) MPDI (6.9 GHz) and NDVI; (b) MVI_A (6.9, 10.7 GHz) and NDVI during the growing season 2013.

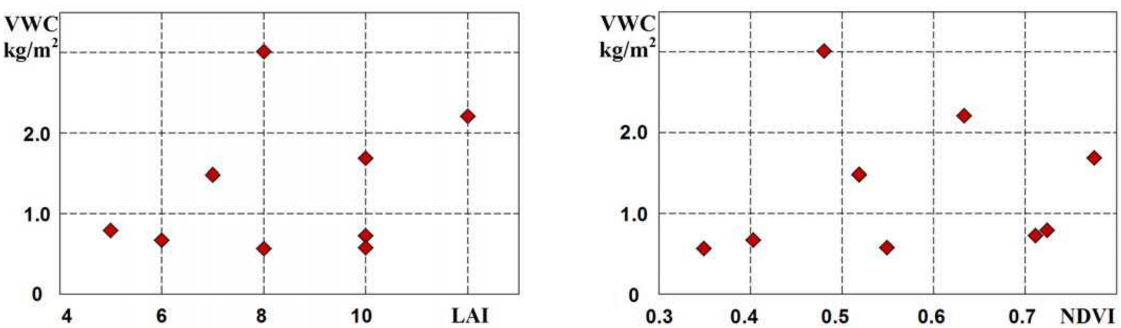
the best dependence was observed for indexes MVI and MDPI calculated according to the data at $f_1 = 6.9$ and $f_2 = 10.7\,\text{GHz}$. As well, on the map shown in Fig. 2(a) the dependence of the sign of the correlation coefficient on the type of surface is observed. This can be explained by the different changes of brightness temperature and NDVI during the growing season for different types of vegetation (Figs. 3(a), (b)). Such dependence between the MDPI and NDVI suggests a possibility of developing an algorithm of quantitative assessment of the vegetation state. The correlation relation between MVI_A (6.9, 10.7 GHz) and NDVI is weakly dependent on the type of vegetation on the surface and mainly determined by the lakes or urban territory in the pixel (Fig. 2(b)).

We also compared LAI (MODIS) and NDVI (MODIS) with ground-based measurements of the vegetation water content (VWC) taken from the southern part of forest-steppe and steppe zone. VWC was determined by thermogravimetric-weight contact method several times during the



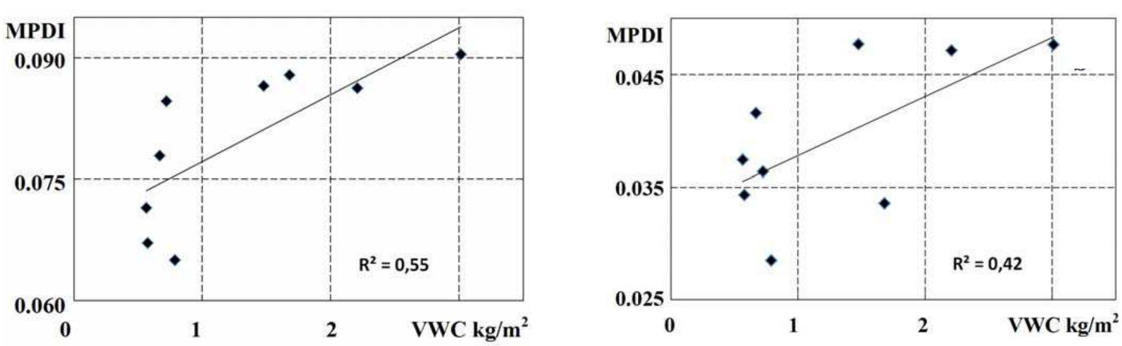
(a) (b)

Figure 3: The time dependence of the (a) NDVI and (b) radiobrightness temperature at 6.9 GHz during the growing season 2013 for steppe (1) and *s* southern taiga (2) zone.



(a) (b)

Figure 4: The relationship between (a) VWC and LAI; (b) VWC and NDVI.



(a) (b)

Figure 5: The relationship between VWC and MDPI at (a) 18 GHz; (b) 23 GHz. R^2 is accuracy of approximation, continuous line is trend.

season. Sample was carried out on agricultural fields and meadows near the center of SMOS Level 2 pixel. The correlation relation between LAI, NDVI and VWC was extremely low (Fig. 4). As it can be seen from the data the dependence between them is extremely low. However, for the final conclusions it must be a greater number of ground-based measurements.

The correlation relation between VWC and MDPI at frequencies of 18 GHz 23 GHz was better (Fig. 5). This dependence is observed despite the fact the ground measurements were carried out at a small number of points and a very large size of GCOM pixel in comparison with NDVI and LAI.

3. CONCLUSION

At this moment, a number of vegetation indexes describing the state of vegetation layer was proposed. All of them are qualitatively in good agreement with the processes occurring during the growing season. However, the relationship between the coefficients is extremely ambiguous. To the Southern Part of Western Siberia the best relationship is observed between MVI (6.9, 10.7 GHz), MPDI (6.9, 10.7 GHz) and NDVI. Preliminary data suggest about the perspective of methods of assessing state of vegetation using GCOM-W1 microwave data. The main problem appearing in the choosing of an index to assess the state of vegetation is the data validation.

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