Comparative Analysis of Radiometric Images of the Earth Surface Obtained from a Spacecraft, Aircraft or Unmanned Copter

Maria Sidorova, Igor Sidorov, Vitaliy Leushin, Svetlana Agasieva, Alexander Gudkov and Sergey Chizhikov

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COMPARATIVE ANALYSIS OF RADIOMETRIC IMAGES OF THE EARTH'S SURFACE OBTAINED FROM A SPACECRAFT, AIRCRAFT OR UNMANNED COPTER

Maria I. Sidorova,[*] Igor A. Sidorov,[†] Vitaliy Yu. Leushin,[‡] Svetlana V. Agasieva,[§] Alexander G. Gudkov,[**] Sergey V. Chizhikov[††]

The possibility of remote measurement of soil moisture during probing from a spacecraft, from an airplane or an unmanned aerial vehicle is being considered. Maps of soil moisture content obtained by radiometers based on various types of carriers are presented. The relevance of remote measurement of soil moisture for the needs of agriculture, in particular, for precision farming systems is substantiated. The purpose of the report is to give a comparative characteristic of the obtained maps of soil moisture content during remote sensing of the Earth's surface from a spacecraft, from an airplane and an unmanned aerial vehicle. And to evaluate the prospects of integrating the results of remotely obtained data of soil moisture into a precision farming system for guaranteed sustainable crop yield growth. As a result of the conducted research, the following conclusions can be drawn: the resolution of the track space radiometers depends on the altitude of the flight and at best has a resolution up to 30 km., shooting from an unmanned aerial vehicle has an acceptable resolution, can be performed at any time, unlike space shooting, which is possible only when the spacecraft flies over a given area and in no precipitation conditions, the obtained data of soil moisture measurement using a microwave radiometer based on an unmanned aerial vehicle, together with data from ground-based weather stations and field samples, can be used to calibrate and refine data obtained by space systems on a global scale.

INTRODUCTION

The yield of agricultural crops in field crop production is determined by three main factors – the amount of soil moisture, the amount of soil heat and soil the mineral-organic composition. Monitoring and optimal management of these parameters using the latest methods of precision farming is necessary for the predicted high yield and sustainable development of agricultural production. Therefore, the task of remote determination of humidity and surface temperature of soils is relevant. The remote sensing methods, in particular, microwave radiometric sensing are one of the ways to solve this problem. At the moment, various systems of space monitoring of the

[*] RUDN University, masha__sidorova@mail.ru
[†] Bauman Moscow State Technical University, igorasidorov@yandex.ru
[‡] RUDN University, ra3bu@yandex.ru
[§] RUDN University, s.agasieva@mail.ru
[**] Bauman Moscow State Technical University, profgudkov@gmail.com
[††] Bauman Moscow State Technical University, chigikov95@mail.ru

Earth's surface are known. However, the size of the resolved element of the known space systems is more than fifty by fifty kilometers, therefore is insufficient for dealing with the many problems of the precision farming system (see References 1 and 2). Aviation monitoring systems are too expensive to operate. An alternative variant is to use the unmanned aerial vehicles. Since the operation of a small-class unmanned aerial vehicle with a payload of up to five kilograms is significantly cheaper, thus reducing the weight and size parameters of the onboard radiometer is actual.

COSMIC RARIOMETRIC SYSTEMS

Over the past half century, a wealth of experience has been accumulated in the field of remote sensing of the Earth's surface by means of microwave radiometry using various carriers – space, aviation and mobile ground platforms (see References 3-6). Space radiometry began with the launch of the Kosmos-243 satellite, launched on September 23, 1968. For the first time, the satellite transmitted to Earth trace images of the Earth's surface in the centimeter and millimeter bands (Figure 1).

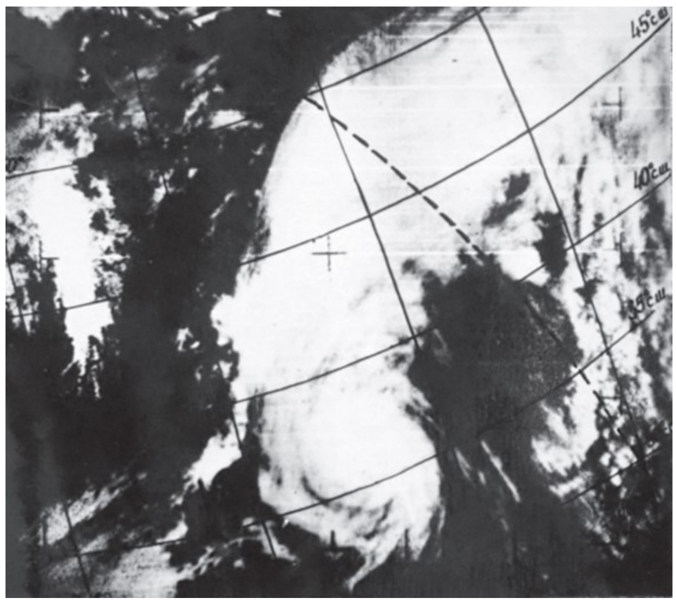

Figure 1. First satellite radiometric image

In the period from 1983 to 1999, a series of Ocean satellites was launched, also equipped with microwave radiometers (see Table 1).

Table 1. Ocean series satellites.

Number	Satelite	launched
Ocean-OE No. 1	Kosmos-1500	09.28.1983
Ocean-OE No. 2	Kosmos-1602	09.28.1984
Ocean-O1 No. 1	Kosmos-1766	07.28.1986
Ocean-O1 No.2	Cosmos-1869	07.16.1987
Ocean-O1 No.3	Ocean	05.07.1988

Ocean-O1 No.4	Ocean	09.06.1989
Ocean-O1 No.5	Ocean	02.28.1990
Ocean-O1 No.6	Ocean	04.06.1991
Ocean-O1 No. 7	Ocean	11.10.1994
Ocean-O1 No. 8	Sich-1	31.08.1995
Ocean-O No. 1	Ocean	25.10.1999

The picture of Ocean series satellite is shown on Figure 2.

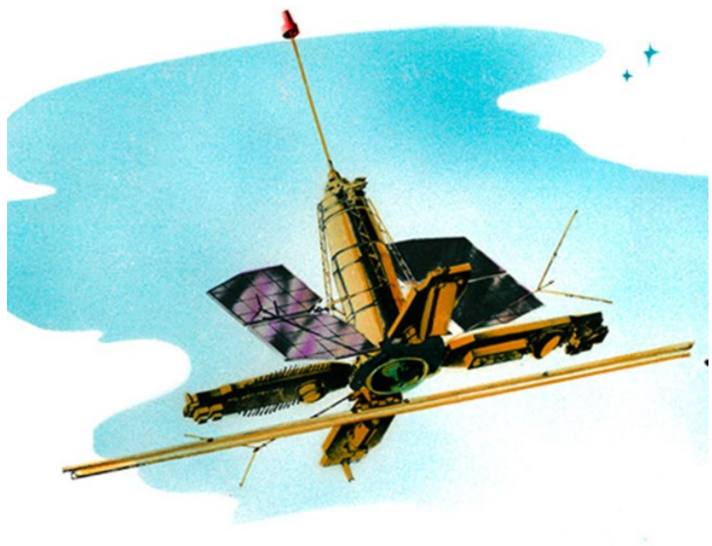

Figure 2. Ocean series satellite

Specifically for remote measurement of soil moisture, the American NASA launched the Soil Moisture Active Passive (SMAP) satellite equipped with both active radar and a radiometer on 31.01.2015. Using this satellite data the soil moisture maps were obtained (See Figure 3).

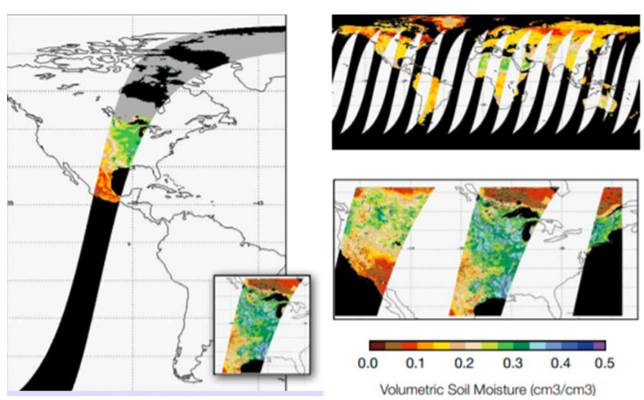

Figure 3. SMAP satellite soil moisture maps

ESA specialists has designed and launched 02.11.2009 Soil Moisture and Ocean Salinity (SMOS) satellite. This satellite was equipped with L-band radiometric system with passive synthesis of the antenna aperture. This radiometric system has the best resolution ability (about 30 km.) in comparison with other systems. The SMOS satellite map is shown on Figure 4.

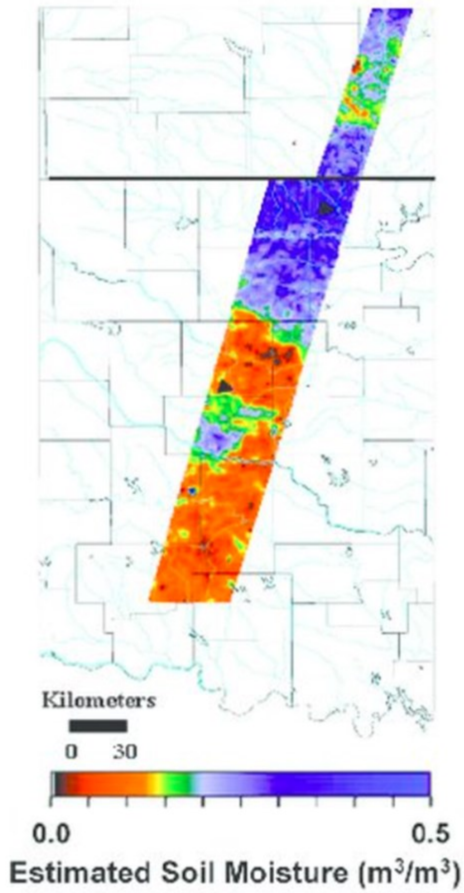

Figure 4. SMOS soil moisture map

IRE RAS Special Design Bureau designed and arranged on International Space Station "Nature" modulus the radiometric system. The IRE RAS radiometric map sample is shown on Figure 5.

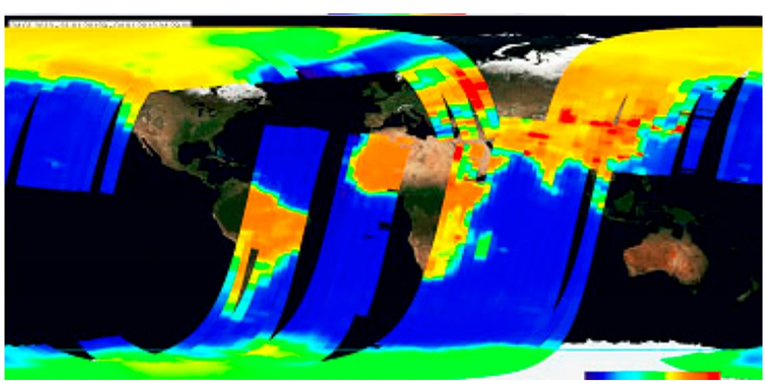

Figure 5. IRE RAS radiometric map

All radiometric systems represented above have resolution ability not exists 30 km. This resolution is enough for global tasks of meteorology and global water balance estimation, but not enough for precision farming.

UAV RARIOMETRIC SYSTEMS

The portable radiometer was designed for the earth sensing from low altitudes. It can move on a quadrocopter, agricultural machines, on carts and on human hands. The antenna's directional pattern has a main beam width about 30 degrees on 3 dB., while the resolution is approximately equal to the sensing height and can change from 1 to 1000 meters, depending on the flight altitude. The transportation methods are shown on Figure 6.

Figure 6. Methods of radiometer transportation

Calibration of the equipment is a very important issue when conducting radiometric sensing of soil moisture. The measurement of soil moisture by a radiometer is performed indirectly. First, radio brightness temperatures are measured at vertical and horizontal polarizations, and then, according to known models, temperatures are recalculated into soil moisture. When measurements are made from ground platforms, the radiation of the celestial sphere can be used as a calibration source, since its characteristics are well known and stable. To carry out such calibration, it is enough to direct the antenna into the sky. For the second calibration point, the equivalent of a "black" body can be used – a flat material with a high absorption coefficient. Calibrations can be done periodically at the beginning and at the end of the lines along which the sensing is performed. Such calibrations can be seen on the graph Figure 7.

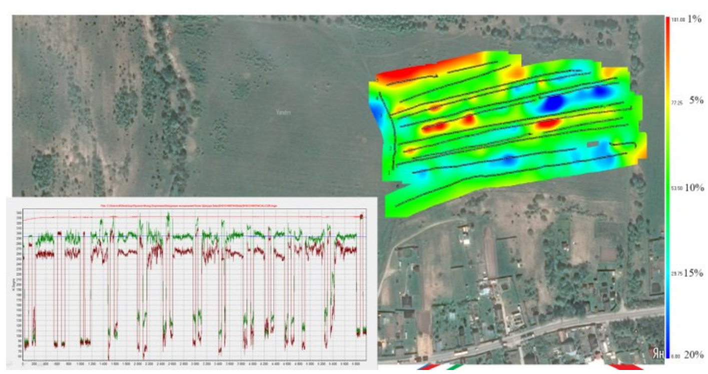

Figure 7. Remote sensing results. Map and chart.

Natural objects with known radio brightness temperatures can also be used as calibration sources. But such calibrations are possible only before or after the field are probed. As can be seen from the moisture map shown in Figure 7, the resolution of the equipment is quite sufficient to detect moisture anomalies within a single field. This makes it possible to carry out ameliorative measures in a targeted manner, taking into account the real situation.

DISCUSSION

The conducted research shows that the use of the microwave radiometry method for remote determination of the moisture profile and surface temperature of arable land is promising from any carries - both space and aviation. But the differences in the resolution of the images obtained impose certain restrictions on the use of the data obtained. Thus, soil moisture maps from space carriers are applicable for assessing global moisture reserves and meteorological estimates on the scale of continents or the earth as a whole. The data obtained from aircraft carriers or unmanned aerial vehicles are suitable for mapping the soil moisture and temperature of the fields surface and even small sites. These data can be used in the digital farming system to control the growth and development regimes of cultivated plants, as well as to optimize the management of reclamation measures in order to save water resources and create favorable conditions for the sustainable development of irrigation agriculture in crop production. The issue of calibration of radiometric soil moisture measuring instruments is very important. Calibration of aviation microwave radiometers can be carried out using reference objects available in almost every locality. Open reservoirs of sufficient size and areas of coniferous forest can be used as such objects. Also, data obtained during sampling and processing on test fields can be used for calibration. To calibrate satellite radiometric systems, it is possible to use the sea surface and large forests such as taiga or tropical forests. The data obtained by aviation and unmanned systems can also be used to refine the calibration of space systems.

CONCLUSION

As a result of the conducted research, the following conclusions can be drawn:

- the resolution of the track space radiometers depends on the altitude of the flight and at best has a resolution up to 30 km;

- shooting from an unmanned aerial vehicle has an acceptable resolution, can be performed at any time, unlike space shooting, which is possible only when the spacecraft flies over a given area and in no precipitation conditions;

- the obtained data of soil moisture measurement using a microwave radiometer based on an unmanned aerial vehicle, together with data from ground-based weather stations and field samples, can be used to calibrate and refine data obtained by space systems on a global scale.

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