Remote monitoring of ecologic state of supersaturated soils

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Received August 7, 2006

We revealed a stable interrelation between the intensity of radio-frequency radiation of soil cover in microwave frequency range and the level of soil water up to a depth of 2.5 m. Calculation formulas for determination of the occurrence depth of soil waters from radio-emission characteristics of soil cover are derived. Data of aircraft and satellite observations in optical and microwave frequency range allowed the remote mapping of soil water levels near settlers of concentration plants.

Measurements of intensity of radio-frequency radiation emitted by soil cover provide information on soil moisture and soil water levels (SWL). The presence of soil layers with different moisture contents due to capillary rise above SWL favors the decrease of the radio-frequency radiation intensity, characterized by the emission coefficient χ. The closer the humidified layer is to the surface and the longer the wavelength of the recorded radiation, the stronger the recorded radio-brightness contrast.

Physical foundation for the remote SWL determination is the influence of regimes of surface humidification of the skin layer L, introducing main contribution to radiation, on the radiation-moisture dependence of the soil cover in zones of filtering and submersion.[1] A stable relationship between the emission coefficient and SWL is revealed, characterized by common regularities for different soil-climatic zones, which can be followed to a depth of 1–3 m.

The following formula was obtained[2] to estimate SWL:

$$H_{\text{SWL}} = L_s + h_c \frac{W_{\max}^2 - W_\lambda^2}{W_{\max}^2 - W_{\min}^2}, \quad (1)$$

where W_λ is the volume water concentration in the soil skin layer of the depth L_s determined from data of radio measurements; h_c is the height of capillary rise above SWL; $W_{\min}$ and $W_{\max}$ are the least and total water capacities (LWC and TWC) of soil.

The dependences $\chi(W)$ on wavelengths λ_1 and λ_2 in centimeter and decimeter ranges allow constructing the dependence of emission coefficient on SWL using formula (1), which relates the occurrence depth of soil waters and soil humidification in layers $L(\lambda_1)$ and $L(\lambda_2)$. Values of W can be determined from remote measurements of $\chi(\lambda_1)$ and $\chi(\lambda_2)$. It is assumed that $W(\lambda_1) \sim W_{\min}$.

Figure 1 shows the calculated dependence $\chi(H_{\text{SWL}})$ for medium-loam soils of the Altai Krai at a capillary rise height of 2.5 m and total water capacity of 0.45. The dependence is local; however, by varying the parameters in Eq. (1), it is possible to construct similar dependences for other soils.

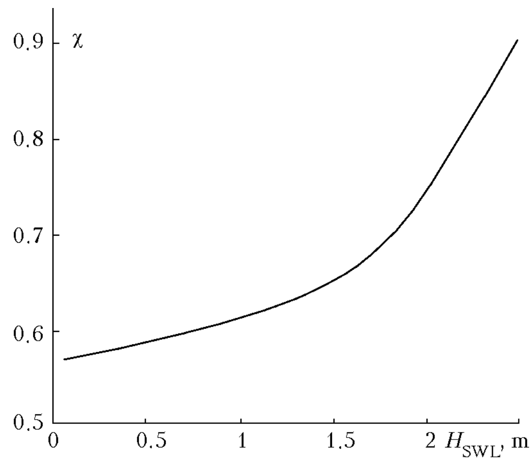

Fig. 1. Dependence of emission coefficient of soil cover on the occurrence depth of soil waters.

LWC, TWC, and h_c are constants for soil of the given type and given granulometric composition. The parameter h_c influencing the humidification regime, depends on hollow sizes and the structure of pore space, varying from a few centimeters (for sands) to a few meters (for loam).

Under field conditions, h_c is determined from soil moisture distribution between the surface and SWL; in laboratory conditions – by the method of monoliths with the use of capillarimeters. If h_c appears at the soil surface, $W_{\min}$ differs from LWC and can be determined from remote measurements of the emission coefficient χ.

Remote mapping of SWL was conducted near industrial settlers of the Altai concentration plant. The influence of settlers to a considerable degree is realized through filtering processes, leading to runoff of water, containing adverse admixtures, to the soil. The hydrologic situation in this case is characterized by the swamping of the surrounding land and anomalously high SWL.

0235-6880/06/11 880-02 $02.00

Aircraft and satellite mapping of SWL on the territory neighboring to the industrial settlers has shown that the filtering processes are observed at a distance up to 4–6 km throughout the settler perimeter.

The use of aircraft and satellite observational data in the optical and microwave regions has made it possible to obtain information on distribution of supersaturated soil surface layers and close-to-surface soil water occurrence, as well as numerical values of soil moisture and SWL on large areas.

Figure 2 presents a diagram map of SWL distribution near settlers, which was made by superimposing satellite images and data of aircraft microwave surveying on the base map; also shown are regions with $H_{\text{SWL}} < 1$ m, with contour lines plotted using data of the microwave surveying.

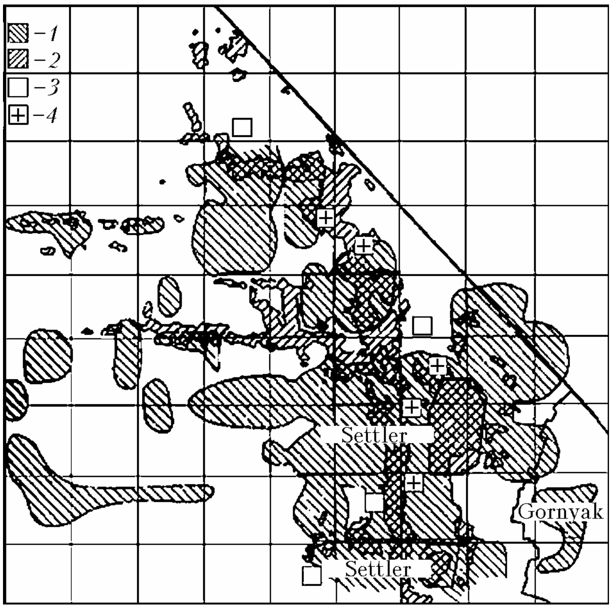

Fig. 2. Distribution of occurrence depths of soil waters near industrial settlers: (*1*) SWL < 1 m (data of aircraft microwave survey); (*2*) increased moisture of soil surface layer (satellite scanning); (*3*) boreholes with SWL > 1 m; (*4*) boreholes with SWL < 1 m.

Transverse dimensions of the filtering zone were estimated via aircraft flying of the territory along preselected 4–6-km long tacks perpendicular to the settler. The inter-tack distance was chosen so that the entire zone area was covered with tacks.

At the same time, it was found that the path measurements alone cannot reproduce the two-dimensional pattern. To solve the problem, it is possible to simultaneously use the microwave survey and scanner spectrophotometry.

Using the proposed mapping method, the satellite images taken by the MSU scanner installed onboard the Kosmos-1939 were used for preliminary assessment of the hydrologic situation. The aircraft microwave survey was used to determine the soil moisture and SWL. Simultaneously, ground-based measurements of W and SWL were made at reference points. The microwave data were interpolated to the entire area by the grid method, and then superimposed on the base map and the satellite scanner images. As a result of thematic computerized processing of the remote microwave data, diagram maps of regions with close-to-surface SWL were obtained.

Comparison of results of the aircraft–satellite sensing and ground-based SWL measurements with data of geochemical survey of soils adjacent to the settler, conducted by Geoecology Association, has shown that the regions with increased concentration of many heavy elements in the soil correspond to the territories, where the occurrence depth of soil waters is less than 1 m. This means that a part of chemical elements from the settler can be propagated by soil water flow and accumulate in points of soil water outcrop.

References

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2. A.N. Romanov, "*Some methods of interpretation of data of remote sensing of soil cover in microwave frequency range*," Cand. Phys.-Math. Sci. Dissert., Altai State University, Barnaul (1994), 124 pp.