

Methods of Microwave Radiometric Monitoring and Modeling for Assessment and Prognosis of Land Emergency Hydrological Situations Development in Regional Scale

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Abstract — The paper is devoted to indicating the ways of resolving an important problem of the assessment and the prognosis of land emergency hydrological situations occurrence and development by means of methods of microwave radiometry and mathematical modeling.

Keywords — microwave radiometry, mathematical modeling, emergency hydrological situations, risk assessment..

I. INTRODUCTION

AMONG the natural and anthropogenous accidents bringing heavy disasters for the population, are such which in particular are connected with the following hydrological phenomena:

- 1) Soil overmoistening (soil moisture exceeds field capacity) happening due to precipitation and the broken drainage;
- 2) High level of ground waters, underflooding, bogging;
- 3) Water seepage through hydroengineering constructions (dams, pipe subways, weirs, etc.), railway embankments;
- 4) Freshet and flooding.

Catastrophic development of hydrological situations can lead to the following consequences:

- 1) Breaks of dams, ruptures of boards of channels, aqueducts, other hydro-engineering constructions and as result – landslides, flooding, mud-flows;
- 2) Flooding of the coastal lands, bogging of territories, penetration of water into the basements of residential and technical buildings and as result – destruction of building basements, loosing agricultural fields;
- 3) Underflooding of highways and railroad ways and as result – catastrophes, accidents.

It is very important to assess and the forecast of such emergency hydrological situations development. Conditions for formation of soil emergency hydrological situations are studied in a number of research projects and programs; however, the problem of operative revealing of such situations and the forecast of their development till now has not been solved.

This paper presents the project devoted to the resolving the problem of operative revealing of emergency

hydrological situations and the forecast of their development by means of methods of microwave radiometry and mathematical modeling. Microwave radiometry is a powerful and important method/tool for obtaining objective operative information about moisture conditions in soils.

The given work has priority character. Analogues of such works do not exist. Known works on microwave radiometry of terrestrial covers concern mainly surface moistening of soils in 2-3 cm thick layer. *Uniqueness* of the given work consists in use of achievements of project participants in obtaining:

- profiles of moisture and estimation of a moisture content in a meter layer of soil,
- ground water table to the depth of 1 m in humid (overmoistened) zones and down to 5 m in arid (deserted) zones.

The information about soils radiophysical properties revealed in spectral characteristics of natural radiation of soils and penetration depth of radio-waves of microwave range, along with the information about hydrological and hydrophysical properties of soils with an account for their peculiarities in different soil-climatic zones is involved in developed technology.

It gives the possibility of operative definition of hydrological condition of soils and together with the methods of mathematical modeling and geoinformation systems allows to create complete system of monitoring and risk assessment of occurrence and development of emergency hydrological situations.

In this project, the information technology based on a joint use of remote sensing methods and mathematical modeling, realized by creation of Geoinformatic Monitoring System (GIMS) with functions of assessment and forecast of emergency hydrological situations development will be elaborated.

II. GENERAL APPROACH

The project main objective consists in development of technologies for assessment and forecasting of emergency hydrological situations occurrence and development by means of microwave radiometry, geoinformation systems and mathematical modeling.

The basic idea of the project consists in use of microwave radiometric measurements as most direct operative source of data about moisture characteristics of soils:

- integral soil moisture content in surface soil layer (50-100 cm thickness);
- vertical profile of soil moisture;
- ground water table down to 2-5 m depth;
- accumulation of water at soil surface, etc.

Combination of this data with the data of geoinformation systems (GIS) and mathematical modeling will allow revealing risks of occurrence of two typical emergency hydrological situations:

- **the first situation** arises when soil overmoistening brings to occurrence of surface water flows and water accumulation on a surface and as a result - freshets, flooding, underflooding;
- **the second situation** arises at excess of admissible subsurface moisture content near hydrotechnical constructions, road beds and as result - eventuality of their destruction

III. EXPERIENCE

Leading participants of the project, Shutko Anatolij, Novichikhin Eugenij, Krapivin Vladimir, Milshin Alexander, Grankov Alexander, Golovachev Sergey, Sidorov Igor, Pljushchev Victor, few others, have long-term experience in carrying out theoretical and experimental researches on the given subjects in USSR/Russia, as well as in foreign countries from the beginning of 1980s till present. Results of their scientific activity in the specified area were published in monographs and numerous articles and are widely known in Russia and abroad.

Examples of works on assessment and the forecast of emergency hydrological situations development in regional scale are given below:

- 1) Assessment of hydrological situation (seepage, overmoistening) along the Central Asian irrigation canals (Soviet Union, 1980/s) by methods of microwave radiometric monitoring to study the possibility of governmental project realization to move a part of water from Siberian rivers to Central Asia. Negative decision on termination of this project was made as result of these studies;
- 2) Assessment of hydrological situation along the North Crimean canal;
- 3) Assessment of hydrological situation in Estonia, Moldova, Saratov and the Astrakhan region in 1980-1990s;
- 4) Assessment of hydrological situation along the Mississippi River together with the US Army Corps of Engineers in 1997-1998;
- 5) Assessment of hydrological situation in Holland in 2005-2007 (soil overmoistening, high level of ground waters, water seepage through hydrotechnical constructions);
- 6) Assessment of hydrological situation in Bulgaria in 2007-2008;
- 7) Assessment of hydrological situation in Russia along the railways of 2007-2008.

IV. METHODOLOGY

Key feature of project methodology is in revealing interrelation between a soil hydrological condition and its remotely measured radio-brightness temperature. This allows, by the inverse problem solution, to define operationally such important hydrological characteristics of soil as moisture content, level of ground waters, etc.

Experimental part of studies includes data acquisition from the airplane and on-ground microwave radiometric observations by means of the portable measuring complex consisting of X/C - range and L - range microwave radiometers.

The aircraft experiment on studies of critical hydrological situations at the territory of The Russia will supposedly be conducted with an aid of microwave radiometric complex of IRE RAS. Experiment will be conducted using available IRE RAS equipment and microwave radiometers designed within this project. Special software will be used for data acquisition, calibration, processing, topographic data binding, etc.

The two-level scheme of measurements of soil microwave emission is proposed, including:

- 1) The top level. A light plane with a microwave radiometric complex onboard;
- 2) The bottom level. On-ground mobile platforms for providing land microwave radiometric and contact measurements of parameters of "soil-vegetation" system.

Aircraft measurements are planned in different regions with various soil-climatic characteristics.

After conducting field measurements it is planned to realize the computer experiment on the basis of the developed scenarios for typical emergency hydrological situations development.

The acquired microwave radiometric information on spatio-temporal variations of surface and subsurface soil moisture content along with mathematical modeling and GIS information of considered hydrological processes allows solving assigned task of assessment and prognosis of emergency hydrological situations.

On the basis of GIS data and contact measurements the information on parameters of soil and a vegetation cover of considered soil-climatic zones will be obtained.

Workable in project technology will allow to conduct effectively the assessment of soil hydrological regimes and to reveal zones of possible underfloodings and seepages through dams, dikes, etc.

The theoretical part of researches assumes:

- review of possibilities of use of the data of microwave radiometric monitoring and modeling for assessment and the forecast of emergency hydrological situations development in regional scale;
- elaboration of soil and subsoil moistening model;
- elaboration of formation of soil microwave emission;
- development of models of typical emergency hydrological situations;
- working out the structure of regional hydrological geoinformation monitoring system;
- working out of procedures of integration of the microwave radiometric data in GIMS for an

assessment and the prognosis of emergency hydrological situations;
- working out the scenarios of hydrological emergency situations development.

On the basis of synthesis of theoretical and experimental studies it is supposed to develop the technologies of detection and the prognosis of typical emergency hydrological situations and risk assessment determination of their adverse development.

V. EXPECTED RESULTS

The basic expected result – working out of technologies for the assessment and the forecast of emergency hydrological situations development, dynamics and scale of their development on the basis of joint use of methods of microwave radiometric monitoring and mathematical modeling.

In the project is planned to receive the following key results, such as:

- 1) The review of possibilities of use of microwave radiometric monitoring data and modeling for estimation and the forecast of emergency hydrological situations development in regional scale;
- 2) Microwave radiometric observation data of typical emergency hydrological situations;
- 3) Models of soil surface and subsurface moistening;
- 4) Models of formation of microwave radiation of soil;
- 5) Models of typical emergency hydrological situations development;
- 6) Methodology for integration of the microwave radiometric data in geoinformation monitoring system (GIMS) of assessment and forecast of emergency hydrological situations;
- 7) Technologies of typical emergency hydrological situations detection and the forecast;
- 8) Results of approbation of the developed regional geoinformation monitoring system (GIMS) elements for assessment and forecast of emergency hydrological situations;
- 9) Methodology of the risk assessment of emergency hydrological situations occurrence.

VI. CONCLUSIONS

It is our believe that described above investigation will provide a beneficial impact on research, developing, practical application and teaching in the field of microwave and optical remote sensing for detection of areas of water seepage through irrigation constructions, levees and dykes and for revealing the areas with dangerously high groundwater level.

There exists a fundamental background for bringing together of remote sensing and informational technologies ready to use the microwave radiometry benefits for soil surface and underground moisture investigations. The applications of these instruments are very important for solving the tasks of detection of areas of water seepage through irrigation constructions, levees and dykes and the revealing of areas with dangerously high groundwater level.

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