New Technologies in Monitoring and Emergency Mapping of Water Seepage and Dangerously High Groundwaters

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Detailed and geo-referenced maps identifying the locations of saturated and dry levees can be produced using microwave radiometric measurements from a light aircraft or helicopter, and integrated with GPS for positioning and orientation. The development of synergetic remote sensing technology for raised groundwater and seepage detection by the joint use of microwave and optical data along with GIS databases is an effective and most contemporary way of supporting risk assessment and facilitating disaster prevention and management. In this paper we present a remote sensing microwave technology for monitoring and detection of areas of water seepage through irrigation constructions, levees and dykes as well as for revealing areas with dangerously high groundwater level. The possibility for emergency response mapping, integrated with GPS and GIS data, facilitates the risk assessment and management services. The passive microwave radiometry (PMR) is based on spectral measurements in the millimetre to decimetre range of wavelengths. Compared to other remote sensing techniques, such as colour and infrared photography, thermal images and lidar, PMR is the only technology taking measurements under the earth's surface and therefore is very well suited for water seepage and underground water monitoring in a fast and reliable way.

Multilateral agreement on collaboration in the field of remote sensing of the Earth has been developed in 2003-2004 on the initiative of Prof. Anatoly Shutko between the following Institutions: (1) Institute of Radioengineering and Electronics (IRE), Russian Academy of Sciences (RAS), Moscow and Friazino, Russia, (2) Microwave Radiometer Mapping Company (Miramap) - a Dutch ESA ESTEC Startup Company, Noordwijk, the Netherlands, (3) Solar-Terrestral Influences Laboratory (STIL), Bulgarian Academy of Sciences (BAS), Sofia, Bulgaria, (4) Center for Hydrology, Soil Climatology and Remote Sensing, (HSCaRS), Alabama A&M Universty (AAMU), Huntsville, the USA, (5) Institute of Applied Physics (IFAC), National Research Council (CNR), Florence, Italy, (6) Institute of Market Problems and Econo-Ecological Studies, National Academy of Sciences of Ukraine (IMPEES, NASU), Odessa, Ukraine, (7) Politechnical University of Catalunya (UPC), Barcelona, Spain.

Among the issues of collaboration: Developing technologies for water seepage detection through levees and dykes, Joint use of microwave, optical and other remote sensing devices, Developing joint scientific projects, Conducting research and teaching.

Fields of applications: multispectral remote sensing monitoring of from mobile platforms and aircraft, hydrology, agriculture, ecology, risk assessment, emergency monitoring: levees and dams damage, flooding, etc.

The goal of the proposed work is to create a powerful Centralized Information and Management Service by developing and adapting to the real environments of a new Geo-Information Monitoring System (GIMS) technology for land surface and water areas monitoring. The GIMS approach has been developed at the Institute of Radioengineering and Electronics, Russian Academy of Sciences (IRE RAS). It is based on the joint use of the following structural constituents: remotely sensed microwave and optical data, in situ measurements, GIS and other available database information, mathematical modeling of the spatial-temporal variations of land covers biophysical parameters.

Thus the efforts will be focused on the creation of a new geoinformation technology based on the combined use of GIS and measurement and modeling performance in accordance with the formula: GIMS = GIS + Measurements + Models. Final products will include information about: soil moisture, depth to shallow water table, vegetation biomass, contours of water seepage through levees, contours of flooding, contours of areas with destroyed drainage, cloudiness, rainfall, melting – freezing conditions, contours of water pollution in the outflow zones, river deltas, lakes, harbors, risk assessment and emergency monitoring of situations connected with these phenomena.

The main expected result of the project will be the development of combined synergetic methods for microwave and optical remote sensing. Their utilization along with GPS knowledge-based information will permit the creation of GIMS, will increase data informational content and improve the possibility for emergency situations predicting and mitigating.

Among the various remote sensing instrumentation used in environmental studies microwave radiometer and optical systems can be implemented for investigation of soil moisture, vegetation type and biomass, index of dryness and depth to shallow water table and buried objects location.

Passive microwave radiometric systems record the naturally emitted radiation of the earth. Investigations of water and land surfaces are performed in the 0.8-2.0 cm to 18-30 cm spectral bands. Within these bands, land surface and water radiation is primarily a function of the free water content in soil, but it is also influenced by other parameters, such as shallow groundwater, vegetation above ground biomass, salinity and temperature of open water, where the sensitivity depends on the wavelength. At wavelengths shorter than 0.8 cm, the surface radiation is considerably influenced by the atmosphere (water vapour, clouds, rain). At wavelengths longer than 21 cm, the surface radiation is affected by the ionosphere, galaxy radiation, and technical communication facilities. Agricultural vegetation is practically transparent at the wavelengths longer than 21 cm and is a function of canopy type and biomass at shorter wavelengths.

Optical sensors provide information about cloudiness, precipitation, vegetation type and state, contours of water bodies, floods, runoff, humus content. A close analysis of some experimental studies reveals a high potential and advantage of combining microwave and optical remote sensing data. To find the best ways of advantageous synergetic use of microwave and optical remote sensing devices with due regard for the prior knowledge-based GPS information will be the main GIMS objective of this project.

Compared to other remote sensing techniques, such as color and infrared photography, thermal images and lidar, microwave radiometry is the only technology taking measurements under the earth's surface and therefore is very well suited for levee and hydrological parameters monitoring in a fast and reliable way.

Through both laboratory and field experiments it has been documented that the passive microwave radiometers, and the processing/retrieval algorithms developed at the IRE RAS and MNIIP VEGA are feasible to determine the following soil, water and vegetation related environmental parameters and conditions: surface soil moisture, underground moistening, depth to a shallow water table (down to 2 meters in humid areas and down to 3-5 meters in arid/dry areas), located on the surface and shallowly buried metal objects of a reasonable size under the conditions of dry ground, contours of water seepage through hydrotechnical constructions (levees, dams, destroyed drainage systems, different kinds of leaks), biomass of vegetation above water surface or wet ground, temperature increase of land, forested and volcano areas, changes in salinity/mineralization and temperature of a water surface, water surface pollution, oil slicks on water surface, on-ground snow melting, ice on a water surfaces, roads and runways.

The operating range and errors of some land cover features retrieval are listed below:

Soil Moisture Content

- operating range	0.02 - 0.5 g/cc
- maximum absolute error:	
- vegetation biomass is less than 2 kg/m²	0.05 g/cc
- vegetation biomass is greater than 2 kg/m²	0.07 g/cc

Depth to a Shallow Water Table

- operating range:	
- humid, swampy areas	0.2 – 2 m
- dry arid areas, deserts	0.2 – 5 m
- maximum absolute error	0.3 - 0.6 m

Plant Biomass (Above Wet Soil or Water Surface)

- operating range 0 – 3 kg/m²
- maximum absolute error 0.2 kg/m²

Salt and Pollutant Concentration of Water Areas (Off-Shore Zones, Lakes)

- operating range 1 – 300 ppt
- maximum absolute error 1 – 5 ppt
- relative error 0.5 ppt

There exists a fundamental background for the creation of an international team of specialists ready to conduct research, development, application and teaching in microwave radiometry for soil surface and underground moisture investigations as well as in optical spectrometry of soil-vegetation land covers. The European added-value of the collaboration is in raising the level of the studies and in the application of a completely new technology based on microwave and optical remote sensing for extremely important and urgent tasks, such as detection of areas of water seepage through irrigation constructions, levees and dykes and revealing of areas with dangerously high groundwater level.

Today's participants and their currently available resources

(1) Institute of Radioengineering and Electronics (IRE), Russian Academy of Sciences (RAS), Russia: available package of microwave radiometric sensors to be delivered to the Netherlands, consisting of three non-scanning radiometers, operating at the wavelengths of 6, 18 and 21 cm (Fig. 1), a three-channel scanning radiometer operating at the wavelengths of 0.8, 2 and 5.5 cm and a twin-beam 21 cm radiometer (Tables 1 and 2, Fig. 2), software feasible to detect areas with high groundwater level and seepage of water through levees (Fig. 3, 4), data acquisition system, data mapping software.

Table 1. Instrumentation Characteristics (h - height above ground)

Frequency	***Wavelength***	***Band***	***Pixels / scan***	***Resolution***	***Mode***
37 GHz	0.8 cm	Ka	32	0.04 * h	Scanning
15.2 GHz	2 cm	X	16	0.08 * h	Scanning
5.5 GHz	5.5 cm	C	6	0.13 * h	Scanning
1.4 GHz	21 cm	L	2	0.65 * h	Twin-beam

Table 2. Instrumentation Characteristics / Requirements (h - height above ground)

Parameter	***Scanning system***
Ground swath	1.3 * h
Power consumption	300W
Power supply	27 VDC
Aircraft mounting hole	50 cm
Weight	130 kg

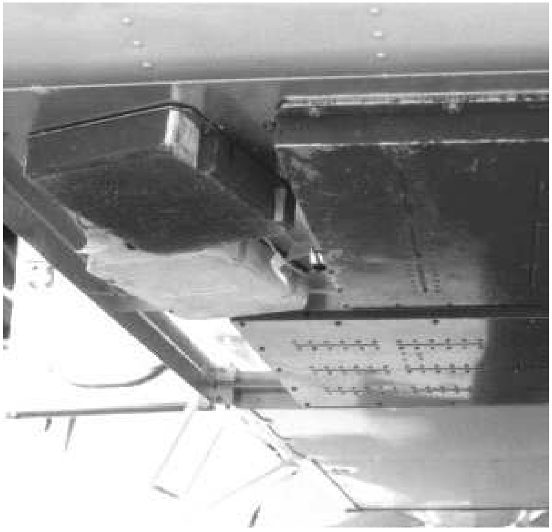

Fig. 1. Three antennas of non-scanning radiometers mounted under fixed-wing aircraft

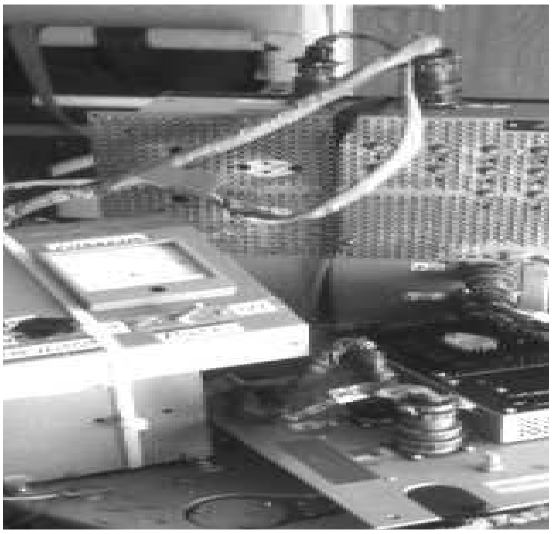

Fig. 2. Scanning microwave radiometer inside fixed-wing aircraft

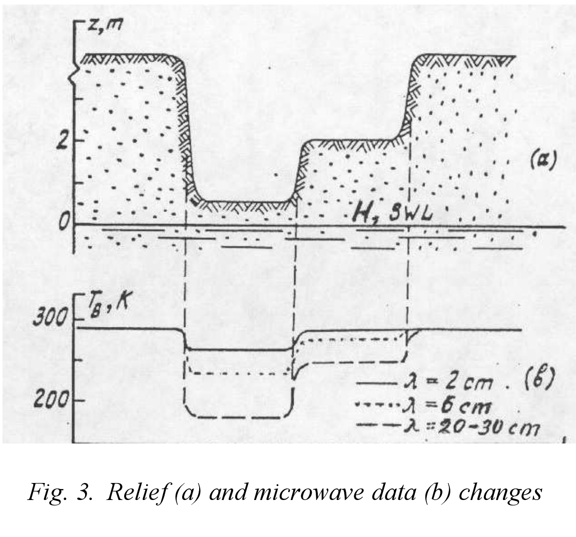

Fig. 3. Relief (a) and microwave data (b) changes

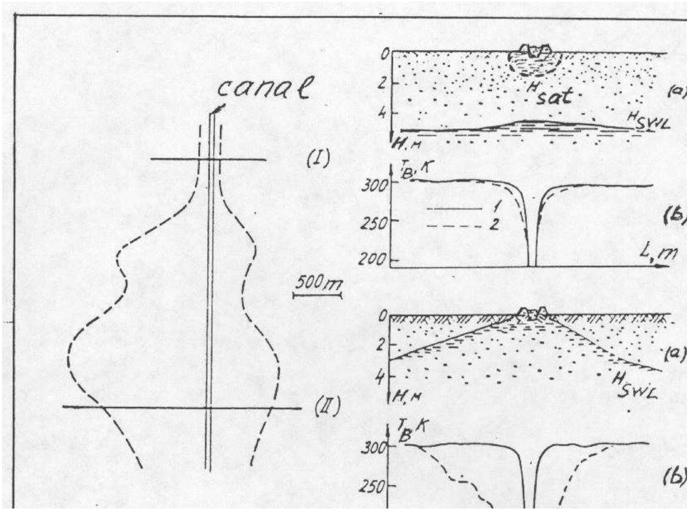

Fig. 4. Seepage zone detection. Transact I: no seepage, transact II: zone of seepage

(2) Microwave Radiometer Mapping Company (Miramap), the Netherlands: light aircraft (Fig. 5), avionics, geodetic GPS receiver, Flight Management System, portable digital optical colour camera Axis 2100 to be used for tracking on-ground objects and for use of optical data along with microwave radiometric data.

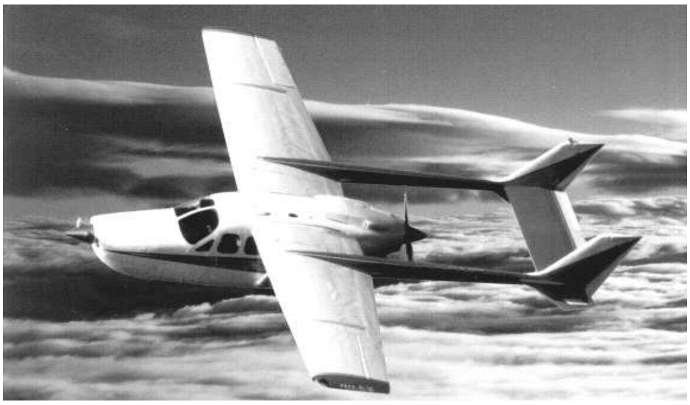

Fig. 5. Aircraft operation: Skymaster

(3) Solar-Terrestrial Influences Laboratory (STIL), Bulgarian Academy of Sciences (BAS, Sofia, Bulgaria: optical spectrometer, data interpretation.

(4) Centre for Hydrology, Soil Climatology and Remote Sensing, (HSCaRS), Alabama A&M University (AAMU), Huntsville, the USA: unmanned helicopter (Fig. 6), data interpretation.

(5) Institute of Market Problems and Econo-Ecological Studies, National Academy of Sciences of Ukraine (IMPEES, NASU), Odessa, Ukraine: hosting autumn 2005 experiments.

Fig. 6. Microwave autonomous copter system

(6) Institute of Applied Physics (IFAC), National Research Council (CNR), Florence, Italy: thematic data interpretation.

(7) Polytechnical University of Catalunya (UPC), Barcelona, Spain: thematic data interpretation.

In conclusion, it is our belief, that the above described collaboration will provide a beneficial impact on research, 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 of areas with dangerously high groundwater level.

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