Microwave Experiment on Montespertoli Area

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ABSTRACT

In summer 1991 a Multisensor Aircraft Campaign (MAC EUROPE '91) took place on Montespertoli area in Tuscany (Italy) based on the NASA-IPL airborne polarimetric SAR. In the framework of the supporting activities organized for this campaign a light Hungarian aircraft flew over the same area with the Airborne Microwave Radiometer System (AMRS). The main tasks of this experiment were the detection of soil moisture content by means of microwave radiometry under particular conditions of heterogeneity typical of Italian agricultural areas and the study of the effects of surface roughness on microwave emission of bare soils. Simultaneously with the flights, ground truth data were collected.

flew over the test site on June 22, 29 and July 14. Each flight consisted of three parallel passes in order to observe the same area at different incidence angles.

Also a light Hungarian aircraft (Pilatus-Turbo Porter) flew over this area on June 27 and 29, boarding a sensor package of the Technical University of Budapest, composed of a nadir-looking dual channel microwave radiometer (at L and S bands) and a thermal IR radiometer (8-14 μm). The same aircraft flew also at the mouth of the Arno river (Marina di Pisa) on June 26. Both a TV camera and a GPS navigation receiver were used to locate measurements on the ground.

1.2. Objectives of the experiment

The main tasks were as follows:

- detection of soil moisture content by means of microwave radiometry in particular conditions of heterogeneity typical of Italian agricultural sites,
- study of surface roughness effect on microwave emission both from bare and vegetated soils,
- checking of the reliability of ground-truth measurements of soil moisture,
- comparison between active and passive microwave sensors on retrieving the same soil and vegetation parameters,
- moreover, an investigation of the sensitivity of microwave emission to water salinity was also carried out at the mouth of the Arno river.
2. DESCRIPTION OF THE TEST-SITE

The Montespertoli area has been chosen as super test-site for hydrological purposes in the frame of the SIR-C/X-SAR experiment and it is represented by the basin of the Pesa river (an affluent of the Arno river) and of its small affluent, the Virginio river (Fig. 2.1).

![Map of Montespertoli test-site: Pesa and Virginio basins.](image)

During the MAC EUROPE '91 campaign two areas were selected inside the Montespertoli site: the first one, almost flat, is an agricultural area along the Pesa river, where fields have a square shape and dimensions of about 2-4 ha. The main crops of this area are: wheat, corn, sorghum, sunflower, alfalfa, colza, pasture, vineyards, oliveyards and some woodlands (dominated by maple and oak species). The second one, more hilly, is a sub-basin of the Virginio river and it was chosen for hydrological purposes.

Three plots of bare soils were prepared in the flat area of Pesa, with three different surface roughnesses: smooth (rolled), medium rough (tilled) and very rough (ploughed), corresponding respectively to height standard deviations of 1.4 cm, 2.2 cm and 2.8 cm. This particular experiment was carried out in order to study the effect of surface roughness on microwave emission from bare soils.

Simultaneously with the flights, ground truth data of the main parameters of soil and plants were intensively measured in some selected fields. A textural analysis of some soil samples was also carried out in the laboratory of the Department of Earth Sciences.

3. PASSIVE MICROWAVE AIRCRAFT PLATFORM AMRS

3.1. The sensor and data collection system

The block scheme of the Airborne Microwave Radiometer System is shown in Figure 3.1. The onboard system which consisted of L (1.41 GHz), S-band (2.695 GHz) microwave and thermal-infrared radiometers, IBM-PC/AT based radiometer data collection system (RDCS) and a commercial videocamcorder, was placed on a light Pilatus-Turbo Porter aircraft (id.nr: HA-YDE). The AMRS was complemented by a GLOBOS LN-2000F type GPS navigational module. The GPS navigational module provides geographical coordinates in real-time for both the RDCS and the computer which displays the electronic

![Block scheme of the Airborne Microwave Radiometer System (AMRS) complemented by a GPS navigational module.](image)
map of the area measured. All data were stored by the hard disc of the RDCS for later evaluation and processing.

The L-, S-band radiometers are noise injection type radiometers with linear characteristics. The L- and S-band microstrip radiometer antennas have 3dB beamwidth of 19.1 and 20.7 degrees respectively. The thermal infrared radiometer (Everest Interscience Model 112) is a lightweight portable and has a field of view of 3 degrees between half intensity values. The radiometer data collection system has the following modes of operation. These are: (1) radiometer test, (2) radiometer calibration, (3) data collection from radiometers, and (4) data record on hard disc.

All brightness data (TBL, TBS and TH-IR) measured, the universal time (UTC) and the geographical coordinates - latitude, longitude (fi-lambda), were stored on the hard disc of RDCS. An additional IBM-PC/AT compatible computer was used for the visualization of the electronic map. The electronic map was digitized using 1:25000 scale maps of the Pesa and Virginio subregions. The flight plans (flight lines) of the Pesa and Virginio region were loaded into the computer. In the case of proper operation of the GPS navigational receiver and the electronic mapping computer, a flashing cursor shows the temporary aircraft position. The updating time is less than 1 sec. As the flight plan also appears on the screen the aircraft can be steered along the optimal flight lines.

Besides the GPS navigational receiver a commercial Panasonic VHS-C videocamcorder (type: NV-MC10EG) with a built-in quartz clock, was used for backup site identification of the microwave data. The incidence angle of the camcorder was 5 degrees forward, the same as the incidence angle of the microwave antenna.

3.2. Data processing software and the theoretical models used

The data processing software available for soil moisture estimation on microwave emissivity was based on Wang and Schmugge (1980) and Dobson et al. (1985) model. The rough soil surface effect on microwave emission can be taken into account using Mo and Schmugge (1987) model, where the RMS height variation and the correlation length (l) are the parameters. For vegetation covered soil, the emissivity of smooth and bare field can be obtained using the Jackson et al. (1982) equation.

A recently developed software plots the color coded points of the TB (Brightness temperature) or SM (Soil moisture) maps on a prepared topographic map by a Hewlett Packard penplotter. The software places the pixels of the SM map using the fi-lambda values of each pixel, provided by the GPS navigational receiver. Finally the software provides an accurate TB or SM map in color coded form on the topographic map.

As the on-board GPS navigational receiver did not work perfectly due to strong radio interference, the geometrical correction of soil moisture and thermal infrared maps done, by means of the videofilm, concurrently recorded with the microwave measurements.

4. CALIBRATION OF THE MICROWAVE RADIOMETERS

Before transportation of the AMRS to Italy, a calibration/test measurement was carried out in the laboratory of the Space Research Group on 14 June 1991 and a test flight was carried out near Budapest on 17 June 1991. The complete system, shown in Fig.3.1. was tested. The radiometers were calibrated using microwave black body (Eccosorb) Sheets. The temperature of the sheets was measured by a hand-held digital thermometer at several points and these values were averaged. The calibration data of radiometers were stored on the hard disc of the RDCS and the average value of approximately lmin record was used for the calculation of the radiometer characteristic.

After finishing the ground radiometer test and calibration, the AMRS and the on-board GPS system were checked during a short flight. The aircraft started from the Budavars airfield and flew over the lakes at Törökbálint and Bia for water calibration. The flight altitude over the lakes was 80 m.

During the flight the GPS system operated perfectly, the temporary aircraft position could be followed on the electronic map and the positions were stored together with the radiometer data. The average value of recorded calibration data was used for the calculation of the L and S-band radiometer characteristics. After landing, a test measurement and an Eccosorb calibration was carried out again.

In Italy during the campaign, ground calibrations were carried out using the same Eccosorb sheets, before and after flight. Also water calibration was carried out over small lakes nearby before or after the measurement. All test, calibration and measurement data were recorded on disc in files.
5. FLIGHT EXPERIMENT ON MONTESPERTOLI

5.1. Flight plans

During the experiment two sub-regions were intensively investigated: a flat agricultural area along the Pesa river, and a small basin of the Virginio river (an affluent of the Pesa) chosen for hydrological studies. The draft map of these areas is shown in figure 2.1. Over the Pesa basin approx. 4 km² and over the Virginio basin an area of approximately 3 km² was measured. The planned flight altitude was 50 m and the distance between the flight lines 100 m. A very low flight altitude was chosen in order to reach high spatial resolution due to the heterogeneity of typical Italian agricultural fields and to reduce the probability of radio interference.

Also a flight measurement was planned over the beach side of Marina di Pisa, to study the salinity of water at the mouth of the Arno river.

5.2. Flight measurements

After finishing the necessary calibration measurements a test flight was carried out on 25 June 1991, to get some experience about the test areas and to investigate the noise environment of the PESA and VIRGINIO areas. On 26th June a flight measurement was carried out over the area of Marina di Pisa, to measure the salinity of the sea water near the mouth of the Arno river. On 27th June the soil moisture map of PESA and VIRGINIO areas was measured. On 29th June a repeat flight was carried out over the PESA and VIRGINIO test areas, concurrently with the NASA DC-8 polarimetric Synthetic Aperture Radar aircraft flights.

- plant water content was computed as the difference between fresh and dry weight for the different main constituents of plants (leaves, stems, ears or fruits if present)
- Leaf Area Index (LAI), measured by using a planimeter
- height of plants and their density
- number of leaves
- main dimensions of plant constituents: stem diameter, leaf width and length
- some information about row orientation, presence of weeds or other anomalies in the fields, phenological stage were also collected.

In the laboratory of the Department of Earth Sciences the textural analysis of some soil samples was carried out.

Other in-field measurements concerned the soil conductivity and the soil permittivity, the latter measured mainly on bare soils by using a portable L-band probe. Other geophysical measurements were carried out to characterize the dielectric properties of soil and in particular geoelectrical measurements (i.e. D.C. resistivity related to lithology and water content) and ground penetrating radar stratigraphy (at 600 MHz).

7. COMPARISON OR EXPERIMENTAL DATA WITH GROUND-TRUEH AND EVALUATION OF THE RESULTS

In this paper some preliminary results of the data evaluation are presented. The brightness temperature (T_B) at L and S band is represented in Fig. 7.1 as a function of time (seconds) along one of the flight lines of the Pesa area. The range of variation of T_B is roughly between < 250 K and 285 K at L band and between 260 K and 285 K at S band; values lower than 260 K at L band correspond to the crossing of the Pesa river.

The normalized temperature TN (namely the ratio between T_B and infrared temperature) at L band was compared with the gravimetric soil moisture content (SMC) measured in each field on June 27 and 29, as shown in Fig. 7.2. Labels represent different crops and circled labels represent data collected on June 27. We see that T_B data collected on June 29 are fairly well correlated to the SMC measurements, with a regression line T_N = 0.94 - 0.005 SMCg% (r=-0.65), corresponding to a sensitivity of about
1.5 K/°SMC, which is a quite usual value found on vegetated soils. As far as data collected on 27 June are concerned, we can easily see that the correlation is decidedly worse. The reason could be that, whereas on 29 June a very wide and close sampling of SMC data was carried out so that the SMC values represented in the diagram are an average of several sampling points, on 27 June only one sample per field was collected. In fact the scarce correlation is enhanced for sorghum (S) and colza (Co) fields which show a slight slope and where therefore the gradient of SMC should be higher with respect to other fields. Moreover, also the SMC profile can add other errors, mainly in small vegetated fields. In Fig. 7.3 the SMC profiles for corn and cut alfalfa fields are shown. The two fields have practically the same SMC value of the 0-5 cm layer, but they show quite different values of SMC of the deeper layer (5-10 cm); this fact could explain the difference found in T_N values for both fields.

To enhance the effect of the surface roughness on microwave emission at L band too, in Fig. 7.4 the T_N at L band is shown as a function of Hstd measured on the three bare soil plots. An increase of T_N can be observed, mainly for the field showing the highest surface roughness. We have

Fig. 7.2 - Normalized Temperature (TN) at L band as a function of gravimetric SMC values collected on June 27 (circled labels) and 29. Labels correspond to different crop types: A=alfalfa, s=sorghum, SF=sunflower, c=corn, CO=colza, w=wheat, p=pasture, V=vineyard, BS=bare smooth soil, BR=bare medium rough soil.

Fig. 7.1 - Brightness temperatures (TB) at L and S bands as a function of time (seconds) along a flight line of Pesa area.
to consider that the SMC values of the three fields are quite similar (respectively about 4% for very rough soil, and about 8-9% for the medium rough and the smooth one). In any case the differences in SMC are not enough to explain the strong difference in $T_N$ values.

8. CONCLUSION

In general the preliminary results confirm quite good sensitivity of microwave emission to soil moisture, at least in the flat area. The variations of $T_N$ at L band on bare and vegetated soils can be correlated to variations of surface soil moisture; however, as expected, the effects of vegetation and surface roughness cannot be eliminated even at near nadir incidence angle and especially for fields with full growth crops the sensitivity to soil moisture is considerably reduced.

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