FIELD RADIOMETRIC MEASUREMENTS FOR VALIDATION AND CALIBRATION OF AIRBORNE DATA: RELEVANT ASPECTS WITH THE EISAC '89 CAMPAIGN

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1. INTRODUCTION

The recent development of CDD sensor technology has opened the new field of imaging spectroscopy and some airborne sensors have been flown throughout the world in the past few years.

The European Space Agency (ESA) and the Institute of Remote Sensing Applications (IRSA) of the Joint Research Centre (JRC), Ispra, have jointly organized a European Imaging Spectroscopy Airborne Campaign (EISAC) in 1989 (Bodechtel *et al.* 1989) with a threefold objective:

a) to promote research of several European institutes in the field of high spectral resolution applied to agriculture, forests, sea and geology;
b) to acquire information necessary for the choice of the most suitable sensors for the future polar platforms;
c) to develop competences and prepare users for the digital processing and analysis of a large mass of spectral data as can be expected when these systems become operative.

In the EISAC '89 campaign, two different airborne imaging spectrometers have overflown several different test sites in Europe, both on land and at sea. The two scanners were the PMI/FLI (Gower *et al.* 1985) and the GER 64 from Geophysical Environment Research (Collins *et al.* 1983).

This paper gives an overview of the radiometric measurements performed by a team from the JRC during the EISAC '89 campaign.

2. LABORATORY MEASUREMENTS

Before carrying out radiometric field measurements in the EISAC '89 flight campaign, the various teams involved performed inter- calibration measurements in the DLR laboratory of Munich. These were made under the same illumination conditions using the following: - reference panels (barium sulphate and Halon); - standard samples (Gypsum-anhydride and Kaolin), - Krypton spectral calibration lamp.

The absolute reflectance of the reference panels to be used in the field was measured by each team and then compared. The instruments used were the IRIS Mark IV spectroradiometers of DLR and NERC (UK) and the SE590 spectroradiometers of the JRC and NERC. The results of these measurements are satisfactory and no significant differences in reflectance values, measured with different instruments, were found. Nevertheless, it was possible to refer the different panels of the teams present to the same standard which was taken as an absolute reference. This was the $BaSO_4$ panel (UK BZ88) of NERC, the absolute spectral reflectance of which had been determined by the National Physical Laboratory (UK). Its spectral reflectance is reported in Fig. 1 for the 400-1100 nm range.

The measurements made over the standard samples were performed with the IRIS spectroradiometers only. The results obtained using the Krypton lamp show that the spectral resolution of the various instruments is acceptable with a discrepancy of the order of 2 or 3 nanometers. The spectral resolution of the Spectron SE590 was determined to be of the order of 8-10 nm.

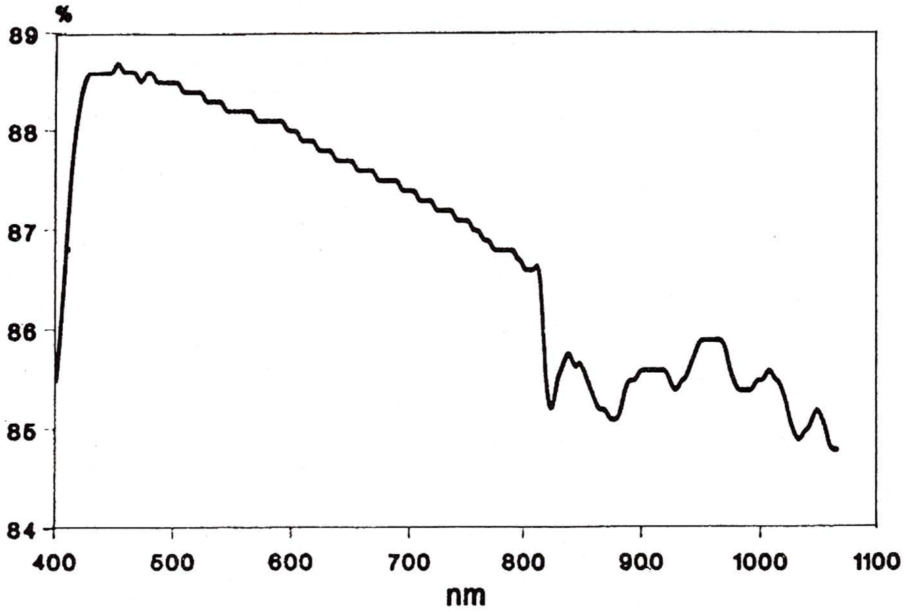

Fig. 1. Absolute reflectance of calibrated reference panel (UK BZ88).

3. FIELD MEASUREMENTS

The activity carried out by the JRC radiometric group is described separately in the following for the two sites where it was involved. The measurements for atmospheric corrections, which are common to both test sites, are then described in paragraph 3.3.

3.1 *North Adriatic Sea*

The test site in the North Adriatic Sea covered by the radiometric measurements of the JRC team was the Sacca di Goro which is part of the Po delta. The measurements were carried out in collaboration with the Assessorato Ambiente of the Amministrazione Provenciale di Ferrara on board the research vessel HYDRA. The measurements took place from May 23 to May 26, 1989, in coincidence with the GER/FLI overflights of May 26 and comprised the following:

- measurement of spectral reflectance of the sea surface at selected stations with a SE590 spectroradiometer;
- measurement of discrete parameters of sea water including chlorophyll concentration and total suspended matter;
- measurement of spectral reflectance of targets along the coastline such as sand and algae with a SE590 spectroradiometer;
- continuous measurement of incoming irradiance durıng overflights.

An overall description of the measurement techniques has been given in a separate report (Maracci *et al.* 1989) along with the data, provided on floppy disc. The radiometric data have been used both for comparison with the airborne data and for correlation with the above- mentioned discrete parameters. Some examples of the results have been given in a conference (Alberotanza *et al.* 1989). In general, it can be said that the radiometric measurements performed during this period are of good quality. This is partly due to local weather conditions which were ideal at the time.

Some typical examples of surface reflectance spectra are given in Fig. 2.

A correlation between the measured chlorophyll (Chl) content and the surface area of the Chl fluorescence peak, visible in the reflectance spectra around 685 nm, has been made (Bokma and Vromans 1990) yielding some promising results, as shown in Fig. 3. Although a definite trend can be observed in the reflectance spectra, the correlation obtained is not sufficient for a precise quantification of the chlorophyll content. For instance, in suçh a test site, the sea bed is often visible and is furthermore quite variable. This can have a significant influence on the characteristics of the surface reflectance data and can be misleading when only the correlation with the water properties is concerned. In order to experimentally investigate the wavelength dependence of this effect and to provide data for modelling, the spectral reflectance of sand at the water's edge has been

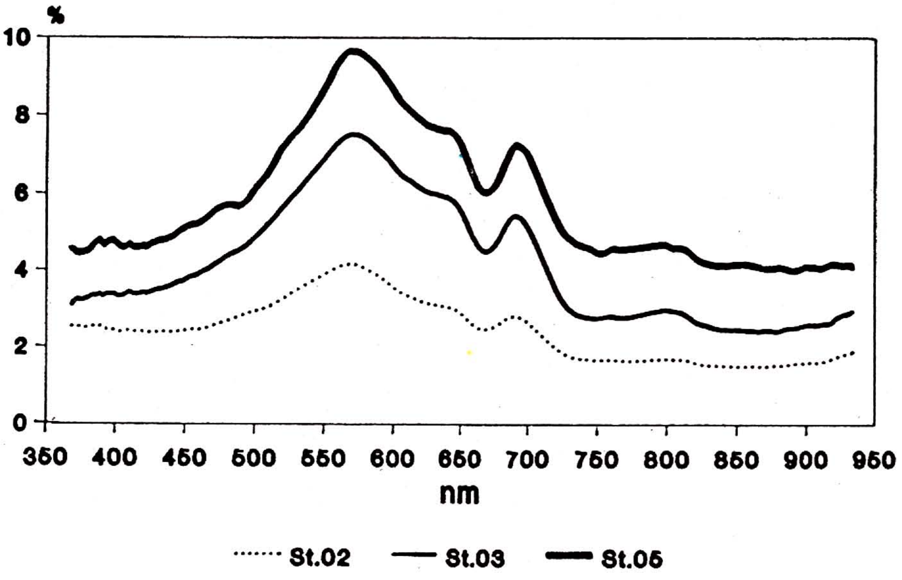

Fig. 2. Absolute reflectance sea surface (Sacca di Goro) May 1989.

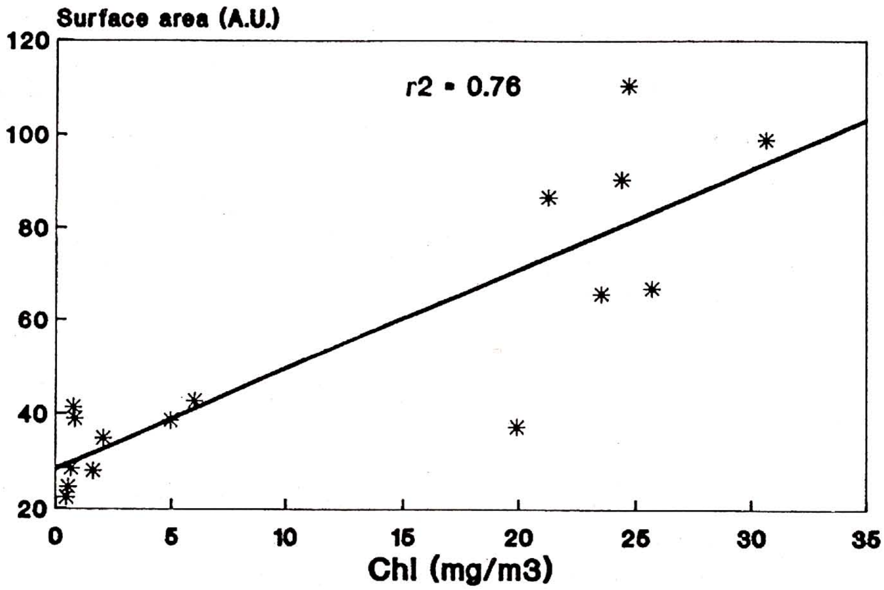

Fig. 3. Relationship between Chl and surface reflectance.

measured and the effect of varying depths of sea water on a uniform bed of sand can be noted in the resulting spectral signatures (Fig. 4).

These properties of the water body can also vary considerably within a very small area and the water sample used for measurement of discrete parameters may not correspond exactly with that covered by the radiometric measurement. Therefore, several measurements have to be taken around the same point in order to increase their statistical validity and to have a representative datum to be compared with the spaceborne data which generally averages over a larger area than that seen in the field of view of the instrument. Due to this, further investigation and measurements, both in field and controlled conditions, are necessary and have to be implemented in a modelling activity for such a complex natural system. On the day of the overflights (May 26), atmospheric measurements were also carried out from the shore. These are described in paragraph 3.3.

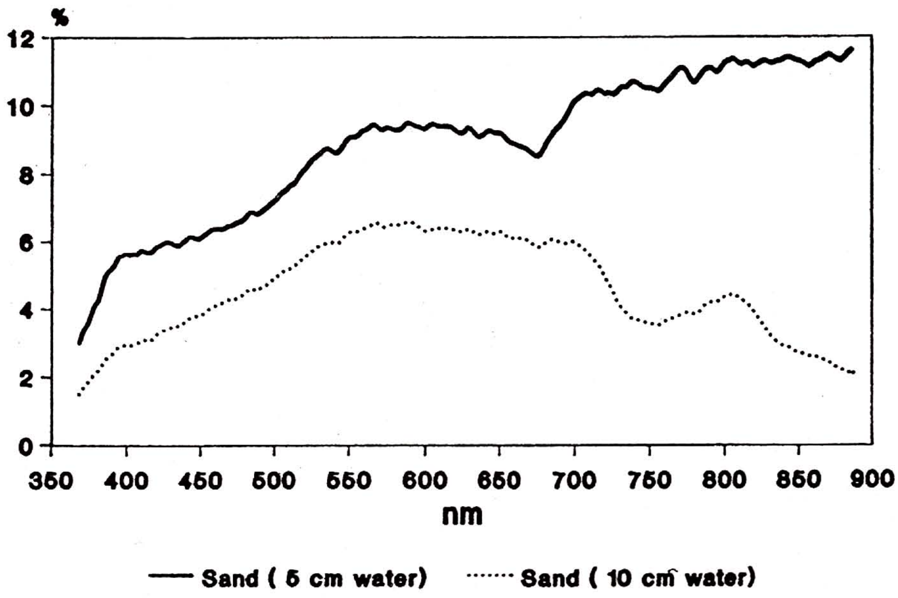

Fig. 4. Absolute reflectance of sand under water.

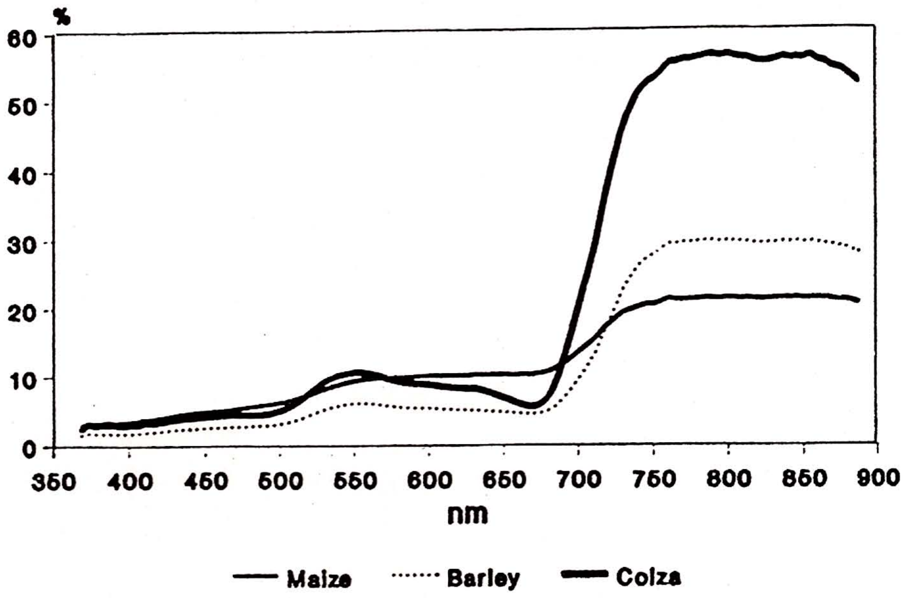

Fig. 5. Absolute reflectance COLMAR (F) 10 June 1989.

3.2 *Upper Rhine Valley*

Radiometric measurements were also carried out by the JRC team in the Upper Rhine Valley. The measurements, concentrated in an agricultural zone south of Colmar (France) and a hilly area north of Colmar containing vineyards and woodlands, took place from 8 to 14 June, 1989, and comprised the following:

measurement of spectral reflectance of the main agricultural crops in the test area (wheat, barley, maize, vines) using the SE590 spectroradiometer and the Barnes 12-1000 radiometer;

- continuous monitoring of selected reference targets during overflights and measurements for evaluation of viewing angle;
- atmospheric measurements performed in coincidence with the overflights of the GER and FLI airborne scanners (June 13);
- continuous incoming irradiance measurements (EXOTECH);
- intercalibration measurements performed at Freiburg usingthe IRIS (DLR) and SE590 (JRC) spectroradiometers during overflight.

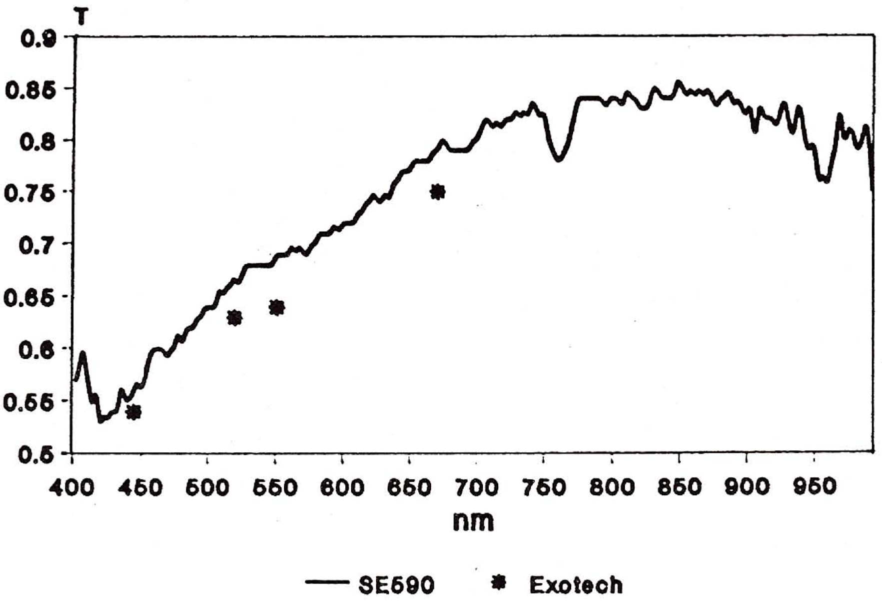

Fig. 6. Atmospheric beam transmittance Hettenschlag (Colmar) 13 June 1989.

An overall description of the measurement techniques has been given in a separate report (Maracci *et al.* 1989) along with the data, provided on floppy disc for the users. The radiometric data have been used when possible for comparison with the airborne data. However, due to a last-minute change in flight plans, the agricultural area south of Colmar was not covered by the airborne measurements.

Some examples of the reflectance spectra are given in Fig. 5.

The spectra, which are typical of these kinds of soil covers, are comparable with those made over similar soil covers in other test areas (Maracci *et al.* 1990). Weather conditions remained stable during the measurement period and the large field sizes in the area provided a consistent homogeneous data set. The ground measurements, carried out at Freiburg, were used for the adjustment of the radiometric calibration of the airborne imaging spectrometers. Here, a number of grey panels were put together to form a large reference panel (200 m.sq.) visible in the airborne data of June 13. The absolute reflectance of this assembly was measured both with the Spectron SE590 (JRC) and the IRIS (DLR) spectroradiometers.

3.3 *Atmospheric Measurements*

At both test sites, measurements of the atmospheric beam transmittance were performed using a bandpass radiometer (EXOTECH) and a spectroradiometer (SE590). The method used is that of Langley (Shaw *et al.* 1973). Some results of these measurements are shown in Fig. 6 for the Upper Rhine test site. A satisfactory agreement has been obtained between the two types of instrument although further measurements of this kind under stable atmospheric conditions are required in order to establish a fast and reliable procedure for the measurement of atmospheric beam transmittance in a continuous spectrum. In the case of the SE590 measurements, a best fit of direct irradiance values and air mass has been established for the 252 channels of the spectroradiometer. This kind of data is directly applicable to the airborne data obtained during the FLI/GER overflights over the two test sites concerned and thus atmospheric corrections can be performed in order to have a better correlation between ground and airborne data.

4. CONCLUSIONS

The radiometric measurements carried out by the various teams involved in the EISAC '89 flight campaign at ground level have proved to be a valuable and, in some cases, indispensable aid in the calibration of the airborne data. The surface reflectance data sets in particular can be said to be consistent and well correlated and have not presented any particular problems which could not be readily explained or resolved. Analysis of the data is still being carried out and a complete assessment of the results is not possible at the present time. The margin of error which exists could be further reduced by complete harmonization of the methods used and regular cross-checks. Valuable information has been obtained which can be used as a guideline for future airborne and spaceborne sensors. The correlation between the ground and airborne data has been seriously hampered, however, by the fact that no precise comparison between the two types of measurement could be obtained. This was mainly due to weather conditions at the time of the inter-calibration measurements. The experience gained throughout the campaign can certainly be put to good use in similar exercises in the coming years by all the persons involved.

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