THE EUROPEAN IMAGING SPECTROSCOPY AIBORNE CAMPAIGN - EISAC REVIEW OF FIRST RESULTS AND OUTLOOK ON FUTURE ASPECTS OF DATA EVALUATION

J. Bodechtel[1] and S. Sommer[1/2]

AGF - Working Group Remote Sensing, Institut f. Allg. u. Ang. Geologie (1)
University of Munich, Luisenstr. 37, D-8000 München 2, Germany

Commission of the European Communities, Joint Research Centre (2)
Ispra Establishment, I-21020 Ispra, Italy

Abstract

The paper summarizes the activities and the first results of the European Imaging Spectroscopy Airborne Campaign (EISAC), that has been initiated jointly by the Eurpean Space Agency (ESA) and the Joint Research Centre (JRC) of the Commission of the European Communities. In the framework of the campaign flights over 7 European test sites have been performed in May/June 1989.

The EISAC data evaluation programme comprises a wide range of applications in agriculture, forestry, geology/soil science and oceanography/marine biology. In a first phase, data evaluation was concentrated on quality assessment, radiometric and atmospheric correction of the airborne data. The second phase deals with spectral signature modelling and with the definition and evaluation of relevant surface parameters, aiming towards optimized approaches for the exploitation of the data of future spaceborne imaging spectrometers with medium (MERIS, MODIS) and high spatial resolution (HIRIS, HRIS).

The first analysis of the aiborne data showed that increased efforts in the field of data processing, regarding particularly accurate radiometric and atmospheric correction, have to be made in order to optimally exploit the potential of high radiometric resolution.

1. INTRODUCTION

In the framework of the joint ESA/JRC EISAC campaign, between May 15th and the end of June 1989, imaging spectrometer flights over seven European test sites have been performed successfully using Moniteq's Fluorescence Line Imager (FLI/PMI) and the 63 band multispectral scanner of Geophysical Environmental Research Corporation (GERIS) as follows:

Test sites (see Fig. 1):

a) Oceanography:

1. Skagerrak - Monitoring of chlorophyll distribution and pollution of coastal waters (N)
2. North Sea, Waddensea, Helgoland - Coastal Ecology, Monitoring of sea water quality and algae blooms (FRG)
3. Northern Adria, Venice Lagoon, Sacca di Goro - Monitoring of coastal ecology and sea water quality (I)

b) Land applications:

4. Upper Rhine Valley - Forestry, Agriculture (F, FRG),
5. Somerset Levels - Agriculture (UK)
6. Almaden - Soil Science, Vegetation (E)
7. Ardeche - Soil Science, Land Use (F, JRC experiment)

Airborne data: The following aiborne data have been acquired:

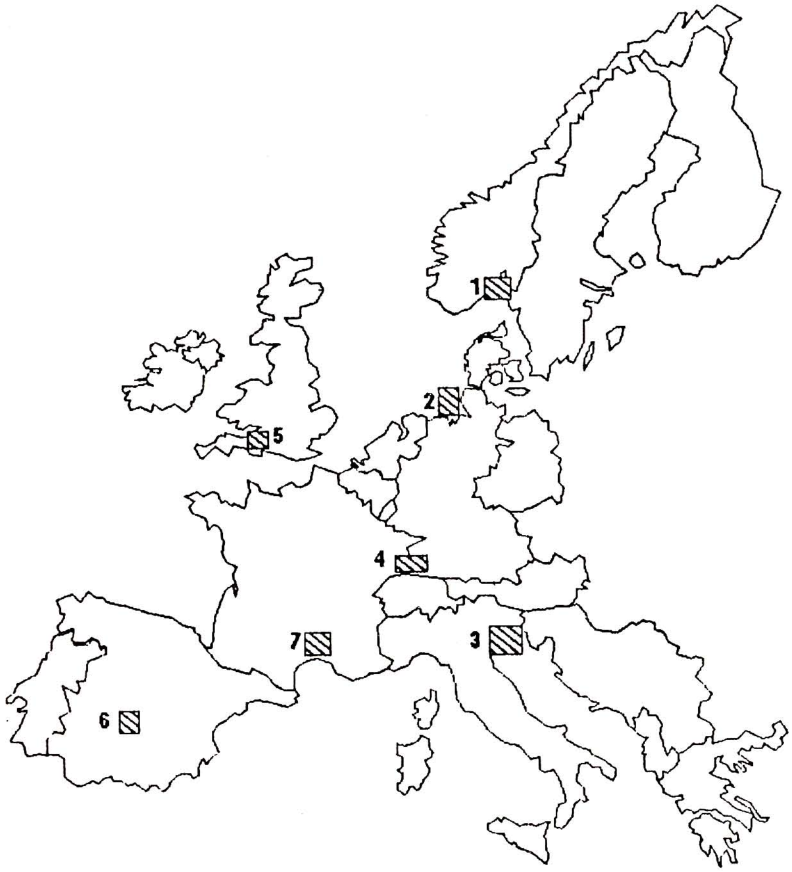

Fig. 1. EISAC TEST SITES.

1. SKAGGERRAK
2. SYLT AND HELGOLAND
3. VENICE AND SACCA DI GORO
4. UPPER RHINE VALLEY
5. SOMERSET LEVELS
6. ALMADEN
7. ARDECHE

FLI/PMI: The FLI instrument was flown, in a spatial as well as in a spectral mode, over all test sites, except the Ardeche.

Spectral range: 400 - 805 nm

Spectral sampling: spatial mode 8 selectable bands ≥2.6 nm
spectral mode 228 bands each 2.6 nm wide

Number of acquired CCTs: 77 (1650 BPI)

GER: Except the Helgoland and Somerset site, the GER instrument acquired data from all test sites.

Spectral range: 450 - 2500 nm

Spectral sampling:

VIS/NIR: 450 - 843 nm, 31 bands each 12.3 nm (nominal)
SWIR I: 1440 - 1.80 nm, 4 bands each 120 nm
SWIR II: 2005 - 2500 nm, 28 bands each 16.2 nm (nominal)
Number of acquired CCTs: 24 (6250 BPI)

Metric Camera (MC-RMK 15/23): 683 IR false colour photographs have been taken over all test sites, except Ardeche.

CASI: Two lines over the Skagerrak test site have been flown with the Compact Airborne Spectral Imager (CASI) of ITRES Rsearch.

Spectral range: 400 - 900 nm

Spectral sampling: spatial mode 8 selectable bands ≥ 1.8nm
spectral mode 228 bands each 1.8 nm wide

Ground Truth: Parallel to the overflights on each test site an extensive ground measurement programme has been executed by local coordinating investigators (CI) supported by JRC. The following principal radiometric ground measurements have been performed:

- atmospheric measurements performed in coincidence with the overflights.
- continuous incoming irradiance measurements.
- mesurements of spectral reflectance of selected sea surfaces, characteristic tidal (sandbars, algae and mud flats etc.) and land surfaces (bare soils, rocks, agricultural crops, natural vegetation, etc.)

- continuous monitoring of selected reference targets during overflights and measurements for evaluation of view angle effects.

Preprocessing and quality checks of airborne and ground truth data were carried out by DLR Oberpfaffenhofen, JRC Ispra, Moniteq and the CIs. Data distribution to 30 experimenters from 9 European countries, selected on the basis of a "Call for Experiments" sent to all EARSeL institutes in April 1989, was started in February/March 1990.

The coordination of the EISAC data evaluation was entrusted to JRC Ispra. The evaluation programme is scheduled to last one year and will be concluded with a campaign analysis workshop which is planned to result in a "pool of experiences" in the application of imaging spectrometry.

In this context JRC lays its main emphasis on the following topics:

- Radiometric correction of data
- Atmospheric correction of data
- Spectral signature modelling
- Definition and evaluation of relevant surface parameters to be received by future spaceborne instruments regarding especially the modelling of a combined vegetation and ocean bandset (i.e. midband frequency, band width, number of bands?) of the Medium Resolution Imaging Spectrometer (MERIS) on the first ESA Polar Platform Mission.
- Data analysis in terms of applications in agriculture, forestry, soil science and oceanography.

2. ASSESSMENT OF DATA QUALITY

The first phase of the evaluation programme was dedicated to the assessment of the quality of airborne FLI/PMI and GER data. The data has been investigated independently by JRC and the CIs (Hill, 1990; Lehmann *et al.*, 1989), aiming mainly at the validation of noise level, effective spectral resolution and radiometric calibration.

2.1 *GER data*: The investigations of the different groups led to corresponding results for the GER instrument:

* Signal/Noise ratio (SNR): Assuming that for a homogeneous target sample

SNR = Average Signal/Standard Deviation

the following SNRs have been estimated:

- VIS/NIR module:
  low reflectance targets (4-8% at 500 - 600 nm): SNR =5-10
  high reflectance targets (20-50% at 750 - 850 nm): SNR = 20-50
- SWIR II module:
  In the SWIR II spectrometer the SNR deteriorates with decreasing radiance levels due to atmospheric absorption. The best SNR (25-40) is found in GER bands 40-50, whereas SNRs decrease to about 5-10 in bands 36 - 38 and 55 - 63 (Hill 1990).

* Effective spectral bandwidth: A comparison of Lowtran standard atmosphere absorption bands with GER spectra at band positions, potentially sensitive to gaseous absorptions, in the VIS/NIR was not kept. An effective bandwidth of about 50 nm has been estimated by modelling the appearence of the narrow oxygen absorption band at 760 nm for different band positions and bandwidths. First assuming that mechanical vibrations had caused the exceeded bandwidths, in the meantime investigations of DLR, Oberpfaffenhofen led to the conclusion that the VIS/NIR spectrometer was defocused (F. Lehmann, DLR, pers. communication).

A slight overcompensation of atmospheric CO_2- absorption can be observed in band 39 (2054 nm), which might indicate, that the given bandwidth of the SWIR II module (2000 - 2500 nm) is slightly exceeded (Hill, 1990).

* Radiometric calibration: The observation of considerable differences between GER spectra with applied pre-flight radiance factors, transferring DNs to radiances, and field spectra, measured during the overflights, required increased efforts to achieve reliable calibration factors on the basis of inflight data. DLR and JRC have been working independently on the development of above mentioned calibration files to be applied to the GER data of all EISAC test sites. In both cases the investigations led to new tables of radiance factors and offsets for all channels, which have been obtained by

fitting the achieved GER radiances to radiances modeled on the basis of radiometric field measurements and radiative transfer calculations. Differences occuring between DLR and JRC calibrations may result from the use of different atmospheric models (e.g. DLR, Lowtran 7; JRC, derivates of models developed by Tanre *et al.*, 1979, 1981, 1987 and Guzzi *et al.*, 1987). Therefore a test of available atmospheric models over characteristic calibration targets (water, bright sand, vegetation) is currently being performed.

2.2 *FLI/PMI data*: The assessment of FLI/PMI data quality is mainly based on the investigation of the Somerset data (Jones *et al.*, 1990), taking into account particularly the intercamera calibration, detector normalisation and geometric characteristics. The following main problems occurred:

* Inter-camera calibration:
  - strong differences between the four cameras, only gross errors removable.
  - no absolute, only cosmetic calibration possible.

* Detector normalisation:
  - dropped detector elements.
  - great differences between the responses of the single detector elements.
  - only cosmetic calibration working.
  - residual noise apparent as a result of data processing.

* The absolute radiance level of the EISAC Somerset data is reduced by a factor of 4 compared to 1988 data of the same site, possibly due to increasing, non-linear degradation of the detector elements (pers. communications S. Briggs and A. Jones, BNSC-NERC, UK).

* Geometric characteristics:
  - the data appears compressed due to strong undersampling.
  - residual high frequency jitter.

SNRs over dark targets have been estimated in the range from 20 to 30 (GER 5-10). Generally the geometric characteristics of the roll corrected data (correction on basis of in-flight attitude data) is considered sufficient, whereas the radiometric quality suffers from the above listed deficiencies and moderate SNR values.

3. RECENT THEMATIC DATA EVALUATION AND FUTURE ACTIVITIES

Upon the basis of clarified data quality and of reliable in-flight calibration, the second phase of the EISAC programme dedicated to thematic data evaluation was started.

First attempts concentrated on the mapping of chlorophyll distribution and pollution of coastal waters and on the spectral differentation of various land surfaces and ground covers.

Encouraging results could be achieved in the discrimination of different soils and rocks by using their characteristic spectral features in the short wave infrared (SWIR) between 2.0 and 2.5 µm. The evaluation of GER data, obtained from bare rock and soil surfaces in the Ardeche test site (F), revealed identical absorption features in airborne as well as radiometric field and laboratory measurements, which correspond to the mineral content of soil and rock samples taken in the test site (Hill, 1990).

In the Somerset test site variations between different applications of nitrogen fertilizer could be detected with evidence of a blue shift between responses of N0 and N200 treatments and in levels of green, red and NIR reflectance (Jones *et al.*, 1990).

With respect to the development of the Medium Resolution Imaging Spectrometer (MERIS), to be launched in the framework of the first ESA Polar Platform Mission, EISAC data furthermore will be used to investigate the:

- quantification of nature and physical status of vegetation communities.
- boundaries for the detection of plant spectral features in mixed soil-plant spectra.
- influence of different soil properties on the mixture of spectra.

Supplementary CASI data of the Freiburg test site to be flown in summer 1990 will be included into this part of the research programme.

In addition to these points it is now discussed how EISAC data can be used in the framework of a "Terrestrial Application Preparation and Stimulation" (TAPS) programme for MERIS, which is currently being proposed by JRC and which, as the name implies, will work towards improving the user preparedness to MERIS.

In the near future the European remote sensing community is looking forward to the implementation of European Airborne Remote Sensing Facility (EARSEF), that will include imaging spectrometers, and to a possible deployment of JPL's AVIRIS in Europe. In this context, the increased availability of imaging spectrometers covering the entire spectral region from 0.4 to 2.5 µm is desirable, not only for remote sensing of soils and rocks but also in order to derive important plant bio-physical parameters (e.g. Lignin, Protein features) in the SWIR region for vegetation studies.

4. CONCLUSIONS

The EISAC Campaign provided high radiometric resolution airborne and ground data of manifold European sea and land surfaces, covering a wide range of oceanographic and land applications. Upon this basis important experiences in the field of radiometric and atmospheric correction of imaging spectrometer data, obtained under European conditions, was gained. This new know-how enables an improved application-oriented evaluation of the EISAC data and a better definition of the requirements for future airborne imaging spectrometry campaigns in Europe.

The main problems of EISAC data evaluation are related to the following facts:

- both sensors by far didn't meet the pre-flight specifications given by the manufactures.
- due to the latter fact and due to the lack of reliable informations about the pre-flight calibration, the data of both sensors had to be calibrated on the basis of in-flight radiometric and atmospheric measurements.
- the low SNR levels make it difficult to find reliable reference targets (i.e. large and homogeneous enough) for in-flight calibration. In addition pixel-by-pixel evaluations require the application of a noise reduction algorithm, that may affect the information content of the data.

The above mentioned experiences demand a better control of preflight specifications and calibration of the sensors in the preparation phase of future campaigns. At the given level of data quality increased emphasis has to be put on detailed atmospheric and meteorological measurements and on the careful selection of large and homogeneous in-flight calibration targets.

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