Hyperspectral Sensors for Military Applications

R. Richter
DLR, German Aerospace Center
Remote Sensing Data Center
D-82234 Wessling
GERMANY

ABSTRACT

This paper discusses issues related to the use of hyperspectral sensors. Key issues for interpretation are spectral databases of natural backgrounds and military targets as well as the accurate calibration and atmospheric correction. A typical application is presented and future developments are outlined.

1. INTRODUCTION

Currently, airborne hyperspectral remote sensing has a 20 year history starting with the Airborne Imaging Spectrometer (AIS) in 1985. The hyperspectral imaging spectrometers evolved from the multispectral instruments. Multispectral instruments typically have about 10 spectral bands with bandwidths between 50 - 200 nm and spectral gaps, typical representatives are Landsat TM (spaceborne, 7 bands) and Daedalus AADS1268 (airborne, 11 bands). Hyperspectral sensors typically have 100 - 300 bands with bandwidths of 2 - 20 nm, and a continuous coverage of large spectral regions (Gower et al. 1992, Vane et al. 1993, Cocks et al. 1998). Table 1 contains a list of the early first hyperspectral instruments (1985-1989) and some later developments.

Name	Year	Country	sp. range(μm)	bands	FWHM (nm)
AIS	1985	USA	0.7 - 2.5	128	10
FLI	1987	Canada	0.4 - 1.0	288	2.5
AVIRIS	1989	USA	0.4 - 2.5	224	10
CASI	1989	Canada	0.4 - 1.0	288	3
SFSI	1993	Canada	1.2 - 2.4	122	10
HyMap	1998	Australia	0.4 - 2.5	128	15
ARES	2005	Australia	0.4 - 2.5 8 - 12	128 32	15 130

Table 1: Hyperspectral airborne instruments.

With imaging hyperspectral sensors each pixel has an associated continuous spectrum that can be used to identify surface materials, quantify material constituents (unmixing) and perform a sub-pixel analysis (unmixing). For military applications the target / background discrimination is an important issue where improvements can be achieved with hyperspectral techniques.

2. REQUIREMENTS

The requirements for a successful operation of hyperspectral imaging sensors are the compilation of spectral databases containing natural and artificial targets. Some of these databases are publicly

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available, e.g. from the USGS, John Hopkins University (JHU), whereas the military databases are classified. A second requirement is the application of a radiative transfer code to be able to convert from at-sensor radiance or scaled digital numbers to surface reflectance or emissivity. Depending on the spectral resolution, MODTRAN or FASCODE are commonly employed (Berk et al. 2000, http://www.ontar.com). The third important topic is the spectral and radiometric calibration of the sensor. For use with geographic information systems the geocoding/orthorectification is essential. Fig. 1 shows a sketch of the radiation components of the atmosphere, the reflected and emitted surface radiance and the basic sensor components. Fig. 2 summarizes the processing chain from level 0 data to level 2.

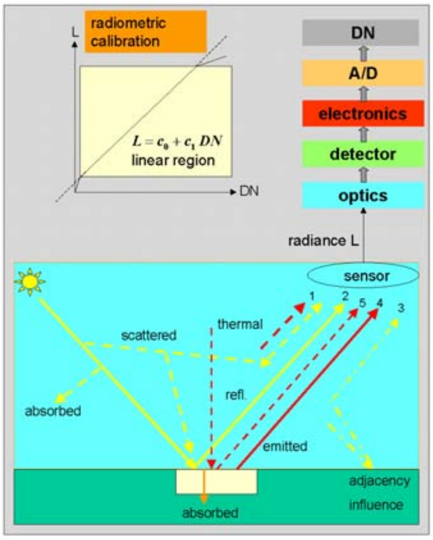


Fig. 1 Radiation components and sensor elements.

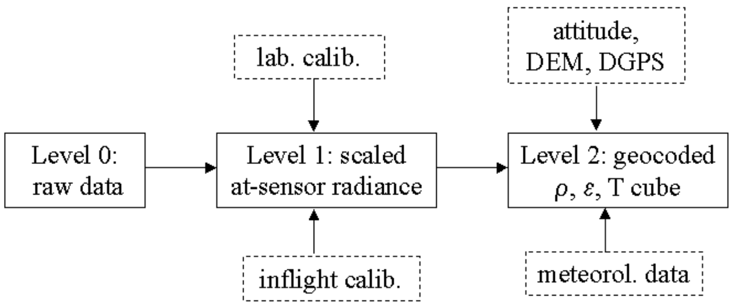
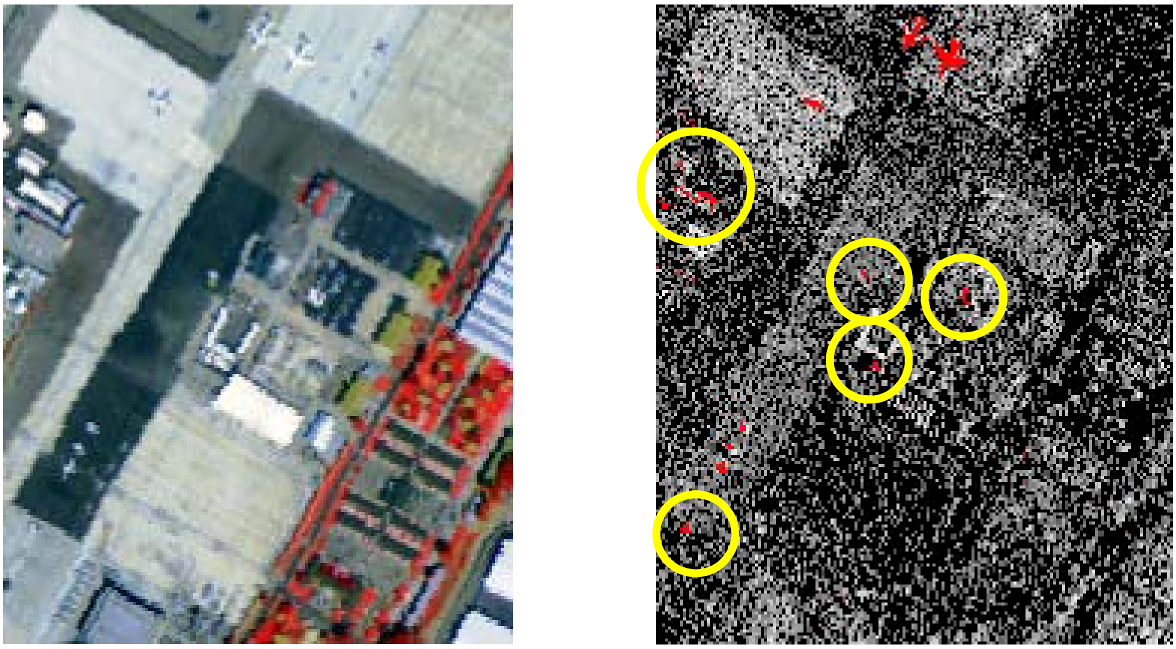


Fig. 2 Processing chain.

The target / background discrimination can be performed with a variety of methods, exploring the full spectral space or using compression algorithms (PCA, MNF). In addition, physical and statistical models are commonly used for background suppression. A popular method is the matched filter concept which can be calculated based on the covariance matrix. The concept has been used extensively in information and signal processing (Turin 1975, Poor, 1983).

3. EXAMPLE

Figure 3 shows an example of AVIRIS data with an airfield locating several small aircrafts. The targets were identified with a matched filter for the blue paint spectrum at the bottom of the figure (source: http://www.rsinc.com/envi/mil_intel_story2.asp).



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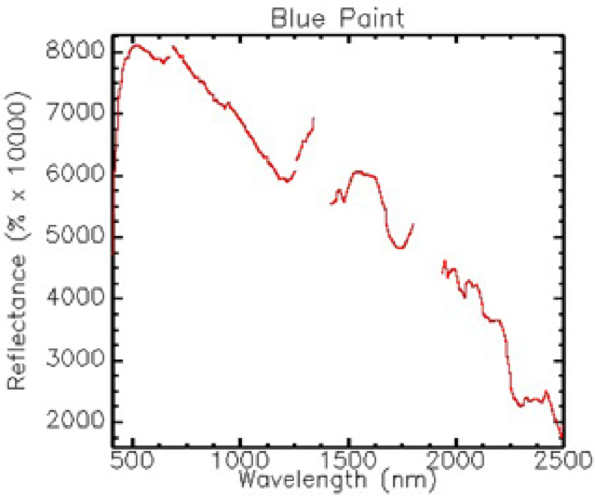

Fig. 3 Detection of aircraft with a matched filter approach.

4. FUTURE DEVELOPMENTS

Except for the experimental Hyperion no commercially available hyperspectral data is currently available from space. However, several countries are planning spaceborne hyperspectral missions. A further ambitious step will be the operation of ultraspectral instruments with a spectral bandwidth smaller than 1 nm and channel numbers around 1000 enabling trace gas detection and quantification. An example of a ground-based FTS spectrum in the thermal region is presented in Fig. 4 showing a number of narrow ozone spectral features.

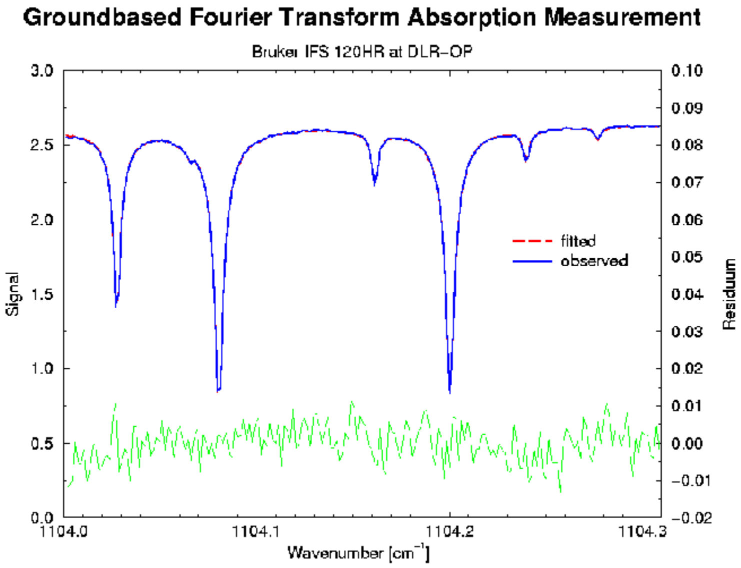

Fig. 4 Ground based Fourier Transform Absorption Spectroscopy.

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