Airborne Remote Sensing

ROSIS Bonn 2008
Summary Report

Authors	P. Gege, M. Bachmann, S. Holzwarth

Document ID	2008ROSIS-CRT-Vaihingen
Classification	public
Issue number	1.0
Date	11.11.2008

Changes to this document

Issue	Date	Changed Parts, Comments
1.0	11.11.2008	First issue

Table of Contents

Scope of the Document

The following document describes the ROSIS data products of the DGPF campaign in Vaihingen in 2008, including the characteristics of the ROSIS sensor.

1 Introduction

A measurement flight was performed on in the area of Vaihingen / Enz on 15th of July 2008 to acquire hyperspectral data. The airborne hyperspectral sensor ROSIS was operated on DLR's Cessna research aircraft at a typical altitude of 9700 ft (2950 m) above sea level. ROSIS was calibrated before the beginning of the flight campaign at Oberpfaffenhofen.

2 ROSIS

ROSIS (Reflective Optics System Imaging Spectrometer) is a compact airborne imaging spectrometer, which had been developed for the detection of spectral fine structures especially in coastal and inland waters. This task determined the selection of the spectral range, bandwidth, number of channels, radiometric resolution and its tilt capability for Sun glint avoidance. However, ROSIS can be used just as well for monitoring of spectral features above land and within the atmosphere. Table 1 summarizes the specifications, Fig. 1 shows a photograph of the sensor head.

Radiometric quantization	14 bit
Total field of view	± 8°
Instantaneous field of view	0.56 mrad
Pixel size at 3 km flight altitude	1.6 m x 1.6 m
Tilt capability along flight direction	± 20°
Spectral sampling interval	4.0 nm
Useful spectral range	430 - 837 nm
Useful / total number of spectral channels	102 / 115
Number of imaging elements	512

Table 1. Specifications of ROSIS-03.

The data are stored during the flight on hard disk in raw format (level 0 data). After the flight campaign, the level 0 data are transferred to the processing facility, where quicklooks are produced and the data are calibrated to at-sensor spectral radiance (level 1 data). Auxiliary information from a flight navigation system (IGI), digital elevation model (DEM) and eventually from ground measurements is used to georeference the data and eventually to correct atmospheric radiance, re-calibrate the data (vicarious calibration) and convert to at-ground spectral reflectance (level 2 data).

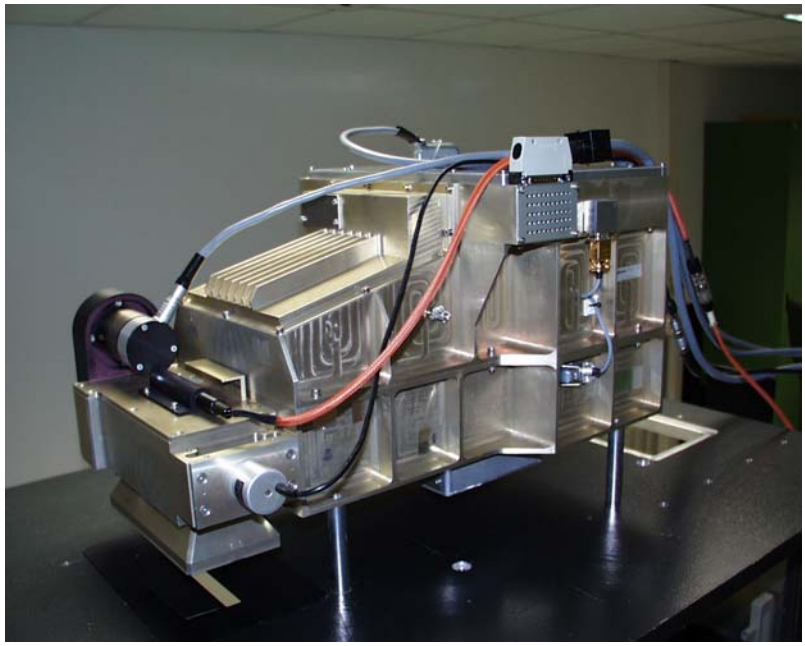

Fig. 1 Airborne imaging spectrometer ROSIS-03

3 Description of Data Products

3.1 Level 0 data

Level 0 data are the raw data obtained during the flight. These are not useful for the customer and thus not delivered. They are described anyhow since understanding of Level 0 data is the basis for understanding higher level data.

The ROSIS sensor records simultaneously 512 pixels of a scan line, and 115 spectral channels of each pixel. Each signal is digitized as 14 bit. The integration time is adjusted to the actual flight altitude and aircraft speed such that the geometric resolution along track is approximately that across track. The hyperspectral image is generated by recording a series of subsequent scan lines during the flight. Image length is thus determined by the length of data acquisition. Directly before and directly after data take 500 scan lines of dark current and 100 scan lines of a gas emission lamp (Mercury) are recorded, which are required for calibration.

The relationship between band number (k) and wavelength (λ) is linear (see eq. 1):

$$\lambda_k = \lambda_0 + k \cdot \Delta\lambda. \quad \text{(eq. 1)}$$

The spectral sampling interval (band to band distance) is $\Delta\lambda$ = 4.0 nm for the entire spectral range.

The centre wavelengths λ_k are temperature dependent. The effect is in the order of 0.25 nm / °C and causes in general different λ_k values between laboratory and flight, and frequently also from one flight strip to the next. Thus, a wavelength calibration is performed for each strip using a gas emission lamp (mercury) that is build-in in ROSIS. The lamp is measured in-flight directly before and directly after each flight strip. The strip-specific value of λ_0 is determined by applying a Gaussian fit to three spectral lines of the lamp spectrum.

Since the centre wavelengths λ_k are temperature dependent, also the spectral range λ_1–λ_{115} is temperature dependent. A bandpass filter is blocking radiation below 430 nm, thus the spectral bands below 430 nm (bands no. 1 to 13) detect dark current and stray light signals only, and are not used for data analysis. **Useful information is contained in the bands no. 14 to 115.**

3.2 Level 1 data

Level 1 data are at-sensor spectral radiance data in sensor coordinates (i.e. not georeferenced).

Spectral and radiometric calibration is performed using DLR proprietary software. Inputs are the Level 0 flight data and a number of sensor parameters. The following sensor parameters are measured in-flight very close to data take (time difference less than 1 minute):

- Dark current,
- Center wavelengths of spectral channels.

The following sensor parameter is measured in the laboratory few days before ROSIS is installed in the airplane, and checked directly after ROSIS is de-installed:

- Radiometric response.

This actual information and further system parameters are taken into account for calibration, for example a detector non-uniformity map to correct pixel-to-pixel response differences, and the readout-time to correct the smear effect.

The calibration software runs on the XDibias image processing system. It produces the following files:

- _img. Hyperspectral image file. Length max. 2000 scan lines, 115 spectral bands, 512 pixels, radiance in units of mW m^{-2} nm^{-1} sr^{-1}, data format 32 bit float.
- _wav. Wavelength file. Lists the centre wavelength of each spectral band in units of nm in ASCII format.
- _header. Header file. Lists the header information of each scan line as ASCII table.
- _nav. Navigation file. Lists the navigation parameters of each scan line as ASCII table.
- _aux. Auxiliary image information used by XDibias image processing system.
- _prv. Preview image used by XDibias image processing system.

Whenever the length of a flight strip exceeds 2000 scan lines, the strip is cut into pieces during processing, such that a series of hyperspectral images is produced, each with length of 2000 scan lines, except the last.

The level-1 data set delivered to the customer comprises the files _img, _wav, and _header. The file _nav is part of the level-2 data set. The files _aux and _prv are only used for the XDibias image processing system.

The format of the data set is specific for the image processing software XDibias, thus the listed files are delivered to customers only which use XDibias. For other users a standard ENVI header is generated which allows file access in most standard image processing software, see section 3.4.

3.3 Level 2 data

DLR offers two types of level 2 data:

- Georeferenced spectral radiance data (L2a).
- Georeferenced and atmospherically corrected spectral reflectance data (L2).

3.3.1 Georeferencing

Georeferencing is based on data from a navigation system (IGI) which records simultaneously to ROSIS the flight attitude and position parameters to a separate file at a frequency of 100 Hz. The IGI system and ROSIS are connected to synchronize time: Each second the IGI system provides a synchronisation pulse to ROSIS, which is included in the ROSIS header file. The calibration software reads both the ROSIS header and the IGI file, calculates the flight attitude parameters of each scan line by linear interpolation of the IGI file values, and saves these as navigation file "_nav".

For each flight line, boresight misalignment angles have been calculated, which are used to correct the input data for georeferencing.

Georeferencing is performed using the software ORTHO. This program is based on a parametric approach determining the viewing geometry for each pixel based on sensor-specific parameters, flight parameters such as sensor position and attitude (i.e. roll, pitch, true heading), and additional terrain information from a digital terrain model (DEM). The flight attitude parameters of each scan line are taken from the file _nav. The used DEM is the laserscanning DEM acquired within the DGPF project.

Geometric accuracy of the georeferenced ROSIS flight strips has been checked using a number of ground control points from a topographic map.

3.3.2 Atmosphere correction

Atmospheric correction was carried out using ATCOR4. This physically based approach, using the MODTRAN radiative transfer code, corrects for atmospheric effects as well as adjacency scattering in order to derive nadir-normalized ground reflectance. For more information about the ATCOR4 model see http://www.rese.ch/atcor/atcor4/.

Before carrying out the atmospheric correction, it was tested, if the existing calibration file for the ROSIS sensor is still valid. After positive validation, only the center wavelengths were adjusted using atmospheric absorption features.

Selected parameters within ATCOR4:

- Rural aerosol type
- Constant Aerosol Optical Thickness (AOT)
- No BRDF correction
- No interpolation of 760 nm oxygen absorption and 725 nm water vapour absorption
- Adjacency range: 0.3 km
- Estimated visibilities: 24 km (1a & 2), 20 km (1b)
- Correction of topographic effects

3.4 Delivered data set

All image data is delivered as ENVI compatible binary files (a BIL or BSQ file with ENVI header file). The following products are delivered.

File Type	Description
rad	
*.img	Image data in BIL format, 115 bands x 512 pixels x N lines
_wav	Wavelength file
geo	
*nav.txt	Navigation parameters of each scan line
*bsw.txt	Boresight misalignment angles
*geo.img	Ortho-rectified image data
*geo_dem.bsq	Corresponding subset of DEM
atm	
*cal	Calibration file
*asp.bsq	Aspect
*slp.bsq	Slope
*sca.bsq	Angular output file
*ilu.bsq	Ilumination file
*atm.bsq	Ortho-rectified atmospherically corrected image data
*atm.log	Logfile of ATCOR4

Table 2. Generated products.

***.img and *.hdr**

These two files are the ENVI compatible image data.

The *.img file refers to a 115 bands, 512 pixel wide image in BIL format that has been converted to physical units of at-sensor radiance in mW m^{-2} nm^{-1} sr^{-1} as described in section 3.2.

The wavelength information (in units of nanometers) is imbedded in the ENVI header file (*.hdr). Also the map information is included in the ENVI-header. Thus both the image coordinates as well as real-world coordinates are displayed when opening the file in standard image processing software.

_wav

The "wav" file is an ASCII which lists the centre wavelength λ_k of each spectral band k = 1..115 in units of nanometers [nm]. Example of the first lines of such a file:

```
383.24
387.24
391.24
395.24
```

***nav.txt**

The "nav" file is a multi-column ASCII file derived by DLR proprietary software, which synchronises times of ROSIS and IGI navigation system, and generates an output where each line corresponds to a ROSIS scan line. Example of the first lines of such a file:

```
#Roll Angle      Pitch Angle  True Heading  Longitude     Latitude     Altitude
 -0.8954646443   2.179306584  -172.9340584  9.586440647   47.8962892   3088.817195
 -0.8953802798   2.178543269  -172.9356522  9.5864404     47.89627737  3088.8166
 -0.8952959153   2.177779954  -172.937246   9.586440153   47.89626555  3088.816004
 -0.8952115507   2.17701664   -172.9388398  9.586439907   47.89625372  3088.815409
 -0.8951271862   2.176253325  -172.9404336  9.58643966    47.89624189  3088.814814
 -0.8950428217   2.17549001   -172.9420274  9.586439414   47.89623006  3088.814218
 -0.8949584572   2.174726696  -172.9436212  9.586439167   47.89621824  3088.813623
 -0.8948740927   2.173963381  -172.945215   9.58643892    47.89620641  3088.813027
```

***sca.bsq**

File with the following two bands:

1. Scan angles. Negative values refer to the right hand part of the scan line with respect to flight heading, positive for left hand part. Scale factor 100. The value 9100 indicates a background pixel.
2. Absolute azimuth angles (range 0-360 degree). Scale factor 10.

***atm.log**

ASCII file containing the atmospheric and processing parameters derived by ATCOR during atmospheric correction

Additional to the image data, the original IGI data and the original DEM is available in the corresponding folders.

3.5 Data Processing Information

Name of Project	ROSIS-Vaihingen							
Date of Acquisition	2008-07-15							
Resampling Method (orthorectification)	Bilinear							
Map projection	UTM Zone 32 N							
Geodetic datum	WGS84							
File name	**Flight Altitude**	**Flight Heading**	**Scan Frequency**	**Solar Zenith**	**Solar Azimuth**	**Pixel size**	**Wavelength channel 1**	**Wavelength channel 115**
Vaihingen-1a	9700 ft asl	360°	50 Hz	27.7°	170.9°	1 m	379.48 nm	831.48 nm
Vaihingen-1b	9700 ft asl	180°	50 Hz	27.4°	180°	1 m	379.53 nm	835.53 nm
Vaihingen-2	9700 ft asl	180°	50 Hz	27.5°	174.4°	1 m	379.57 nm	835.57 nm

Table 3. Data Processing Information of the specific Project