GROUND SPECTRORADIOMETRIC MEASUREMENTS IN SUPPORT OF THE VALIDATION OF THE CALIBRATION OF DIGITAL AIRBORNE IMAGING SPECTROMETER (DAIS 7915) DATA*

M. Schaepman, D. Schläpfer
e–mail: schaep@geo.unizh.ch
Remote Sensing Laboratories, Dept. of Geography, University of Zurich
Winterthurerstrasse 190, 8057 Zurich, Switzerland

A. Müller, P. Strobl
DLR - German Aerospace Research Establishment
Institute for Optoelectronics
82234 Wessling, Germany

ABSTRACT

A standard reference test site is flown using the DAIS 7915 imaging spectrometer over Central Switzerland. Simultaneous to this overflight extensive ground measurements are carried out. A sun photometer, a radiosonde, and two spectroradiometers are used simultaneously during the overflight to support the in–flight calibration and validation of the DAIS 7915. The calibration of all instruments is discussed and the modelling process of the at–sensor radiances of the DAIS 7915 is described.

1.0 INTRODUCTION

Ground truth activities with respect to spectroradiometric measurements in support of imaging spectrometer overflights are an important issue to help to characterize, validate and calibrate the acquired data sets. A well characterized and calibrated set of ground based instruments is necessary to develop methodologies to compare the operational environment of the imaging spectrometer to its laboratory calibration environment. In the special case where an imaging spectrometer has no specific inflight calibration and no inflight characterization before and after the data acquisition can be performed, the instruments spectroradiometric behavior relies fully on the laboratory calibration and their extrapolation capabilities to the in–flight data acquisition. Recent advances have proven the need of in–situ measurements to predict the at sensor radiance [GREEN, 1996] and to allow for a validation of calibration coefficients [STROBL, 1997].

In this specific experiment the DAIS 7915 (Digital Airborne Imaging Spectrometer) was flown in a joint experiment of DLR (German Aerospace Research Establishment) and RSL (Remote Sensing Laboratories / University of Zurich) over a standard test site located in Central Switzerland.

Simultaneous data acquisition on the ground included measurements on selected reference targets using two spectroradiometers, a sun photometer and a radiosonde. The rugged terrain and the small size of the reference targets as well as the spatial inhomogeneity complicate the assessment of the best suited objects.

This paper focuses on the calibration targets, the calibration of the instruments used and discusses the results of this in–flight calibration experiment.

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2.0 EXPERIMENT DESCRIPTION

On July 23rd, 1996 the standard test site of the Remote Sensing Laboratories in Central Switzerland was flown with the DAIS imaging spectrometer. Within the area imaged by the DAIS 7915 two reference targets are selected. The major calibration target is a conventional soccer field surrounded by a red sporting ground. Adjacent to this, two medium sized artificial green soccer fields strewed with sand are located. A gravel covered construction site is selected in addition to the aforementioned targets. The second test area consists of subalpine meadows, strongly influenced by agricultural use such as pasturing. The choice of two different test areas is based on the altitude difference between the “Küssnacht” (442 m/asl) and “Rigi” (1031 m/asl) area. Priority has been given to measurements at the first site during the DAIS 7915 overflight. The visibility changes from the first reference targets way up to the second are reported using the sun photometer.

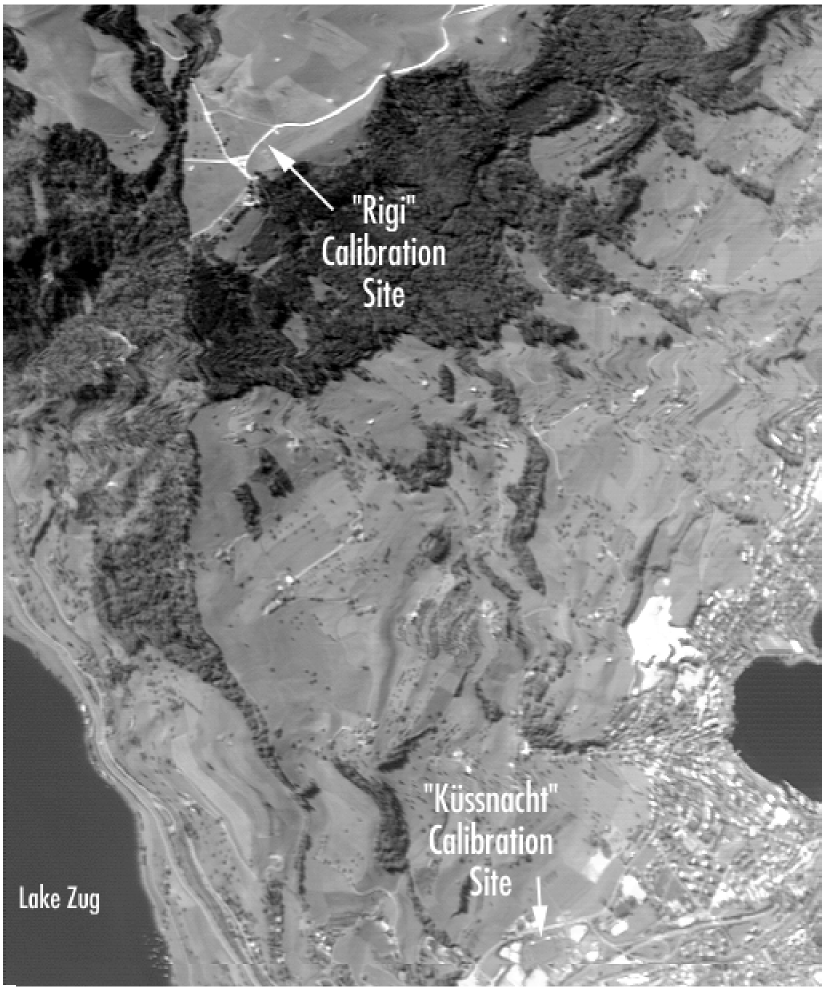

Figure 1. DAIS 7915 Image Of Central Switzerland

The spectroradiometric instrumentation includes the use of two high resolution spectro-radiometers (GER3700 and ASD FieldSpec FR) measuring surface spectral reflectance on all the reference targets mentioned above. The same Spectralon reference panel is used for both instruments measuring the same targets at the same time. They cover both the whole wavelength range of the DAIS

7915 reflective bands. Just next to the green soccer field a 10–channel sun photometer is used to collect data 2 hours prior to the overflight. 1 hour after the overflight the data acquisition was stopped due to heavy cloud coverage. A radiosonde was released twice from a gravel place just near to the green soccer field measuring humidity, temperature and pressure. This data is used to define an atmospheric model for the use with the radiative transfer code MODTRAN [BERK, 1989].

Spatial reference measurements are supported by the use of a DGPS reference station located in the standard test site and covered by the DAIS FOV. A DEM with the spatial resolution of 25 x 25 x 0.1 m in x, y, and z as well as a digitized map with 1.25 m spatial resolution supports the georeferencing of the test areas. The Do228 aircraft was tracked using a conical scanning radar (ADOUR) to locate the aircraft and track the data acquisition with an external reference.

3.0 INSTRUMENT CALIBRATION ACTIVITIES

3.1 SPECTRORADIOMETER CALIBRATION

The GER 3700 spectroradiometer is a 704 channel array–based spectroradiometer, developed by GER (Geophysical and Environmental Research Corp.) with scientific support from the CCRS (Canada Centre for Remote Sensing) and RSL [STAENZ, 1995]. The optical system consists of three spectrometers (512 element SI array, 128 element PbS array, 64 element PbS array) covering the 350 – 2450 nm wavelength range. The instrument has a spectral sampling interval of 1.5 nm (350 – 1050 nm), 6.8 nm (1030 – 2100 nm) and 8 nm (2100 – 2450 nm). The spectral sampling width of these three wavelength regions is 2.3 nm, 10.4, and 12.3 nm respectively. The RSL laboratory calibration of the GER 3700 includes the determination of the temperature sensitivity resulting in a linear relation between raw values and detector temperature. The radiometric performance is determined using an integrating sphere calibration standard that is traceable to NIST. The radiometric response of the detectors is measured and the radiometer is verified to be a real photon counting instrument over the whole dynamic range. The spectral response function is measured using a tuneable dye–laser and a monochromator. The response of the radiometer to the dye–laser is measured as the point–spread–function for a number of channels. The FWHM and the center wavelength can be determined for the channels. In addition to the characterization process the absolute radiance calibration is performed using the integrating sphere calibration standard.

The ASD (Analytical Spectral Devices) FieldSpec FR instrument covers the wavelength range between 350 – 2500 nm. A 512 element photo diode array spectrometer is used in the 350 – 1000 nm range, InGaAs detectors are used in the two SWIR spectrometers. The spectral sampling interval is 2 nm over the whole wavelength range and the spectral sampling width is 3 nm for the VIS and 10 nm for the SWIR. The calibration of the this instrument is performed at the Geo Forschungs Zentrum (GFZ) and includes the wavelength calibration using an emission line lamp standard [KRÜGER, 1997].

Both instruments will take a reference scan of a calibrated Spectralon panel before each measurement in the field. It is assumed that there is no significant variation of the atmospheric conditions between the target scan and the reference scan a few seconds later.

3.2 SUN PHOTOMETER CALIBRATION

A Reagan sun photometer [EHSANI, 1992] is positioned at the calibration site to record data of the optical thickness of the atmosphere and to measure water vapor contents. The Reagan sun photometer is a sun-looking radiometer, measuring the direct solar irradiance at 10 wavelength positions between 380 and 1030 nm. It is continuously monitoring the state of the atmosphere and allows conclusions on atmospheric stability and the development of aerosol contents during the course of the day. The visibility on ground level is quantified by inverting the sun photometer data using the MODTRAN model. This is the preferred method over subjective estimations of the visibility of researchers in the field. These estimations suffer from layering dependent horizontal effects whereas the sun photometer measures the vertical optical thickness that is used for visibility calculations.

The sun photometer calibration is performed on a high mountain station (Jungfraujoch or Weissfluhjoch) using the Langley–Plot method [SOUFFLET, 1992]. The direct solar irradiance during a morning hour sunrise period at stable atmospheric conditions is used to extrapolate the calibration coefficients at negligible atmospheric influences. Using these values, it is possible to derive the atmospheric transmittance and irradiance directly from the radiometer outputs.

3.3 RADIOSONDE MEASUREMENTS

A balloon based radiosonde is launched at the calibration site. It measures the layering of the atmosphere at a high vertical resolution, from the ground to heights over the tropopause level of 10 to 15 km. The standard parameters retrieved are pressure, temperature and humidity. This layering measurements are introduced to the calculation of the at sensor radiance by creating a user defined atmospheric profile for the MODTRAN code. Additionally, relative humidity, pressure and temperature are also measured with conventional ground based instruments to get a ground reference point. The sounding unit is a conventional meteorologic system with a measurement accuracy below ±10 %.

3.4 DAIS 7915 LABORATORY CALIBRATION

The calibration of the DAIS is performed in the laboratory following three major steps. The spectral response function is determined using a combination of a monochromator and a collimator. For each of the 72 reflective bands, the spectral response function is measured and the center wavelength is derived. The second step includes the radiometric calibration with the help of an integrating sphere. The calibration of the integrating sphere itself is accomplished by the comparison of an absolute calibrated diffuse source and the sphere radiance. Finally, the geometric response function is determined using the collimator and a number of pinhole targets. Oertel [OERTEL, 1994] gives a detailed description of the laboratory calibration equipment at DLR.

From the laboratory calibration measurements the radiometric calibration coefficients are derived. An estimate of the accuracy for the laboratory calibration is discussed in Strobl [STROBL, 1997]. Before the calibration coefficients can be applied to DAIS 7915 inflight measurements, these data must be system corrected. The DAIS data used in this study are pre-corrected using the standard pre-processing routines developed at DLR [STROBL, 1996]. The data are laboratory calibrated to at-sensor radiance using the coefficients as determined by the April 1997 laboratory calibration cycle.

4.0 ANALYSIS

The surface reflectance values obtained from the spectroradiometric measurements are modelled to at sensor radiance using the radiative transfer code MODTRAN3.5. A sensitivity analysis of different MODTRAN input data sets was carried out to determine the usefulness of in–situ sun photometer measurements and radiosounding. The modelling steps included the combination of the (horizontal) visibility determined by observers in the field, the visibility derived from the optical depth measured with the sun photometer, the definition of the atmosphere using the radiosonde (to its upper extend and then using a standard predefined atmosphere from MODTRAN), and finally a predefined standard atmosphere given in MODTRAN.

The predefined atmospheres in MODTRAN describe a mean state of the atmosphere for a variation of geographic regions. For the reference test site the midlatitude summer model was chosen with rural aerosol characteristics. For test area Küssnacht the observed visibility is estimated between 8 and 12 km, resulting in a meteorological visibility of about 11 to 16 km. The sun photometer data inversion yielded a theoretical range of 24 km. This big difference is explained with the atypical layering of the atmosphere: some dust was present in the lowest 300 m/ag of the boundary layer, whereas the sight was very clear at the height of the test area “Rigi”. There, the meteorological range was estimated being the same by the observers and the sun photometer.

5.0 RESULTS

The surface reflectance measurements acquired from the ground spectroradiometers are all averaged and absolute reflectance values are obtained for each reference target. The variation of the reflectance for gravel is visualized in fig. 2. These measurements are included in the MODTRAN modelling as well as the sun photometer date and radiosonde measurements.

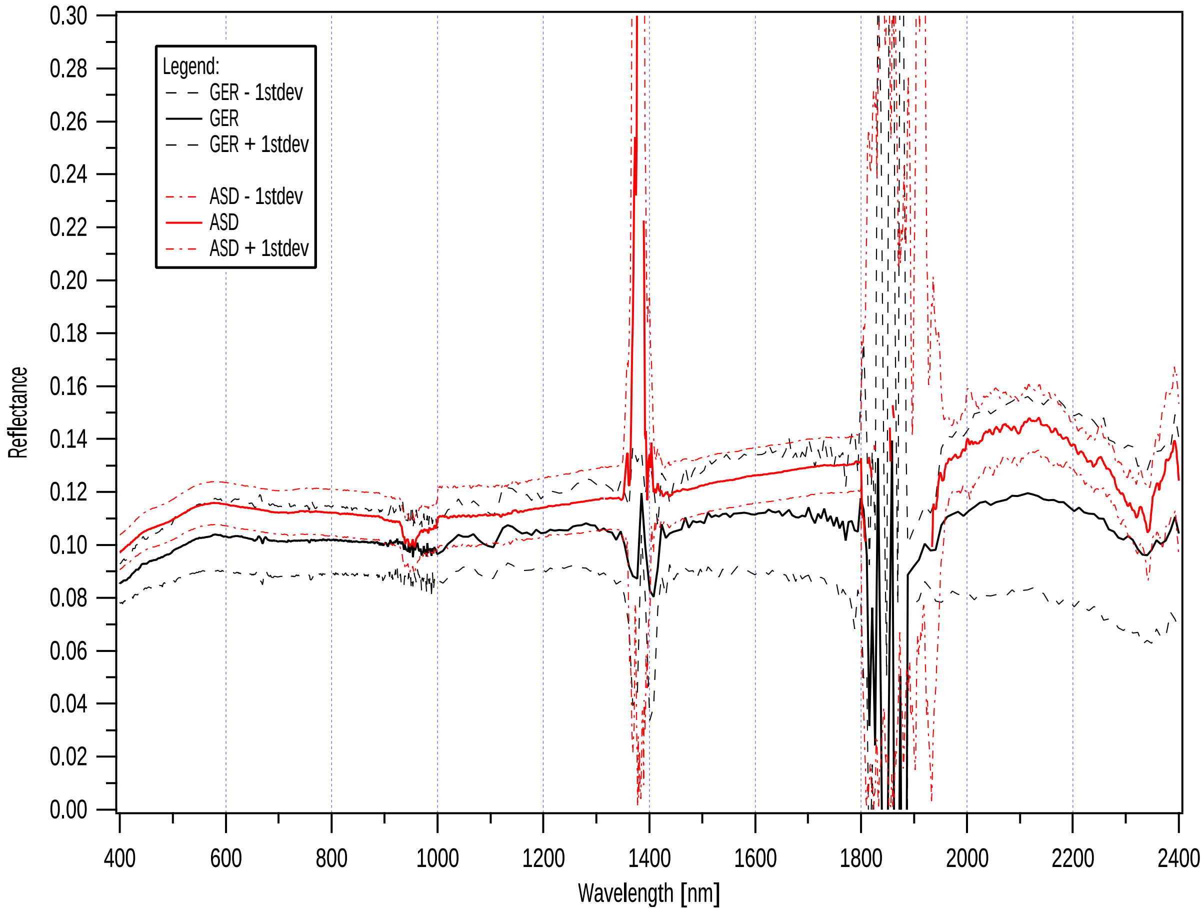

Figure 2. Spectroradiometer Measurements On Gravel

The modelled at–sensor radiances using the above mentioned input values are modelled using four different setups. In all setups, the reflectance values of the reference targets are used as input to the MODTRAN model. The variation of the modelling steps includes the use of

- the radiosonde data and the field observer estimated horizontal visibility,
- the midlatitude summer setting (MODTRAN) and the field observer estimated horizontal visibility,
- the radiosonde data and the sun photometer data, and

• the midlatitude summer setting (MODTRAN) and the sun photometer data.

The comparison of the modelled at–sensor radiances and the calibrated DAIS 7915 values is given in fig. 3.

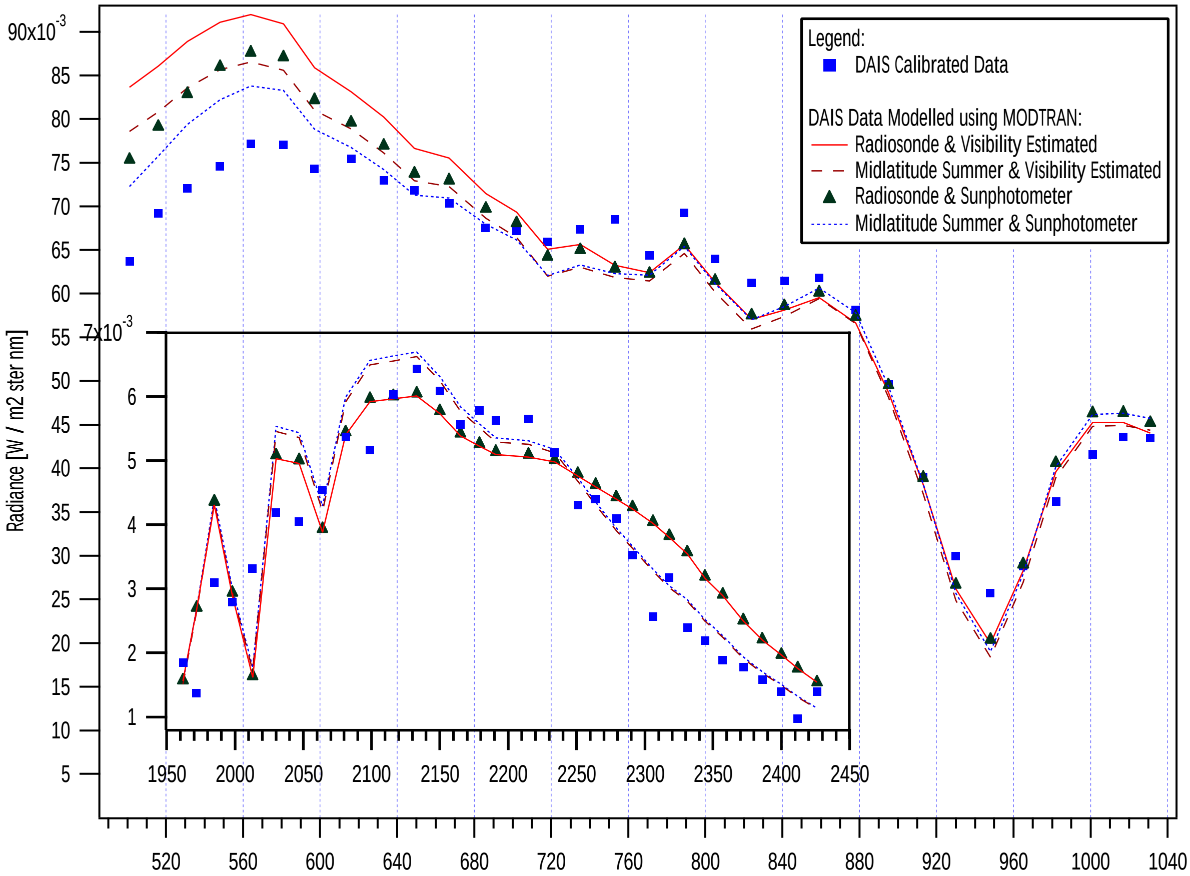

Figure 3. Modelled DAIS At–Sensor–Radiances

6.0 CONCLUSIONS AND OUTLOOK

The selection of homogenous calibration targets for in–flight calibration in a typical Swiss environment is extremely challenging. The lack of large, spatial invariant and spectral flat reference targets forces the selection of calibration targets that not necessarily meet the required specifications in spatial extend (7 x 7 pixels) and spectral inhomogeneity (< 2.5%). In addition for multitemporal calibration, temporal highly variant targets (such as vegetation) are not recommended reference targets to monitor drifts of the imaging spectrometer’s calibration coefficients.

The validation of the performance of the imaging spectrometer at a specific point in time using well characterized and calibrated support instrumentation are an important factor to verify in–flight calibration performance. In the special case of the DAIS 7915, where no in–flight calibration or characterization on a line by line basis is available, it is of major importance to verify the predefined laboratory calibration and give some better estimates if this laboratory calibration is expandable to real data flights. Radiative transfer simulation using MODTRAN is in practice the best way to perform inflight calibration using ground reflectance measurements. The optimal combination of the concurrent use of a sun photometer, a radiosonde and spectroradiometers lead to a good input for the model. Even though the calibration effort is limited to a small (compared to the total number of pixel recorded) spatial extend, it is important to compile a setup of instruments that describe the environment satisfactory. The good agreement of the modelled spectras result from an excellent agreement of the atmosphere present at the overfligth and the standard MODTRAN setting. Another calibration experiment to be carried out in summer 1997 will make use of enhanced calibration methods of the instruments involved.

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