SpecTIR Sensor Calibration and Data Processing Overview

Radiometric and Spectral Calibration

SpecTIR's history in hyperspectral data collections and operations has led to a wealth of experience in radiometric and spectral calibration. SpecTIR's standard radiometric calibration is achieved through the use of a Labsphere USS-2000-V uniform light source. This 20-inch diameter integrating sphere is equipped with three internal 45 watt and one 75 watt externally mounted halogen light sources. Each lamp, powered by separate DC-regulated, constant-current power supplies, along with a variable attenuator, provides precise control of light levels. Luminance output is variable from 0 to 4000 foot-lamberts and measured uniformity is >98% over the entire 8-inch exit port. This sphere carries a NIST-traceable spectral radiance calibration from 400 nm to 2500 nm at a sampling interval of 5 nm. The resultant calibration allows SpecTIR to provide data within +/- 5% of absolute radiance.

Wavelength calibration and characterization of Full Width Half Maximum (FWHM) response curves is accomplished using an Oriel Cornerstone 130 1/8m monochromator. This automated, computer-controlled monochromator provides calibrated and repeatable wavelength outputs of 1 nm channels in the VNIR and 3 nm channels in the SWIR range. The central wavelength locations of these outputs are known and certified accurate within 0.5 nm. This level of accuracy of center wavelength mapping and FHWM determination is necessary to provide consistent and high quality radiance data as input into subsequent reflectance models.

Additionally, data QA/QC processing routines utilize well documented atmospheric features such as the Oxygen Fraunhoffer line at 763 nm, and CO_2 features at 2036 nm to ensure that accurate wavelength mapping is maintained.

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Standard Data Processing Procedure

SpecTIR employs a standardized, documented, Level 1 (L1) processing procedure to convert RAW sensor data to Radiance, Reflectance, and Georeferencing products.

Radiance Processing

Dark current measurements are included at the end of each flight line. The first step of processing is to remove the dark current “signal” (noise) from the image signal. In the case of ProSpecTIR-VS data, a bad element map is then applied to the SWIR bands, utilizing a proprietary compensation algorithm to restore these elements using both the spatial and spectral aspects of these elements as situated in the detector array.

The calibration gain file is then applied to convert raw data values to radiance units. Radiance data units and scaling factors are included in the header files for each processed flight line. Standard units are mW/(cm^2*steradian*µm) with a scaling factor of 1000. This setting means that for a radiance value of 4500, the converted real world value is 4.5 mW/(cm^2*steradian*µm).

Reflectance Processing

In order to convert the calibrated radiance data to surface reflectance values, SpecTIR employs a third party implementation of the industry standard MODTRAN4 radiative transfer code. The software package ATCOR4 utilizes MODTRAN4 atmospheric lookup tables and proprietary techniques to correct for atmospheric absorption and scattering components. During processing, ATCOR4 generates log files for each flight line which provide information on all input parameters and program settings. These ASCII files are included with delivered data, allowing the customer full knowledge of all settings implemented in the reflectance model.

In handling atmospheric absorption features, ATCOR4 incorporates three possible interpolation schemes. In generating the final reflectance product, SpecTIR analysts select the best combination of interpolation options for a given data set. Linear interpolation is employed in the 760, 725, and 825 nm regions. Non-linear interpolation is applied in the 940 and 1130 nm parts of the spectrum based on the function of the vegetation index to account for the leaf water content in plants. Lastly, non-linear interpolation is performed in the 1400 nm and 1900 nm water vapor absorption regions by fitting the curves with a hull of a template vegetation or soil spectrum. The interpolation parameter settings are identified in the associated log files and, in addition, all interpolated channels are marked with an "*" in the ENVI headers of reflectance files.

The raw output reflectance data is evaluated for any model or sensor related artifacts which are then compensated for via library based spectra modifications and polishing. Polishing of reflectance is achieved using a SpecTIR proprietary program based on a Savitsky-Golay algorithm with refined handling of atmospheric absorption features associated with CO^2 and water.

VELC Reflectance

Whereas MODTRAN-based modeled reflectance is an industry standard, SpecTIR has found that these procedures can often result in a loss of spectral fidelity in the far SWIR region of the spectrum (2000-2500nm), a spectral range of great interest to geologic analysis. In response to this, SpecTIR has developed a new procedure to accomplish a *virtual* empirical-line calibration (VELC). This methodology obtains pseudo-reflectance directly from the calibrated radiance data by doing numerical and statistical operations on the imagery, scene by scene. It has the advantage of developing independent corrections for each data cube, rather than a single correction based on one or, at best, a few spectral targets on the ground, such as in traditional ground-based empirical line corrections. Application of this method has been shown to produce exceptional results in the far SWIR, and is therefore offered as an additional data deliverable product.

Geocorrection Processing

Depending on the region of operation, SpecTIR's instruments incorporate either a 3-ring laser gyro-based Inertial Navigation Systems (INS) or a Fiber Optic Gyro/Mems-based system to provide for the accurate georeferencing of data. The IMUs are coupled with a 12-channel GPS system which utilizes Omnistar realtime differential corrections to feed the tightly coupled Kalman filter of the INS.

To ensure the optimal translation of INS positional data to image data, the INS and sensor must be boresighted. To achieve this, SpecTIR has established a boresight calibration site south of the Stead, NV airport. As control, 6 inch orthophotography and matching 2 foot contour data were obtained from Washoe County.

In order to provide ortho-corrected hyperspectral imagery, SpecTIR has the entire 10 meter resolution NED digital elevation model (DEM) database for the continental United States. If improved accuracies are required, client provided DEMs from alternate sources, such as LiDAR, can be incorporated into the processing stream. During processing, georeferencing performance is assessed based on USGS 1m DOQQ imagery as reference.

The georeferencing process generates an Internal Geometry Map (IGM) file which is a two-band, pixel-by-pixel identification of easting (band 1) and northing (band 2) values for the unrectified image. Also provided is the associated Geographic Lookup Table (GLT) file which is a two-band file projected into map space. Either of these files can be used by image processing software to generate fully navigated and georeferenced imagery for subsequent analysis products.