CALIBRATION OF THE AFGHANISTAN HYMAP DATASET

Todd M. Hoefen, Raymond F. Kokaly, Trude V.V. King

U.S. Geological Survey, Denver, Colorado, USA

1. INTRODUCTION

The use of hyperspectral remote sensing data as a materials mapping tool continues to gain acceptance and application. As the number of spectral libraries and our understanding of spectral properties of materials expands, so does the opportunity to apply remotely sensed data to geologic investigations. To ensure the utility of a hyperspectral dataset, a rigorous calibration process to remove atmospheric absorptions and residual instrument artifacts must be applied. Proper calibration of hyperspectral data is essential to produce accurate surficial material maps. Traditionally, several techniques have been used to calibrate data and remove atmospheric effects [1]. A detailed modified method used to calibrate the 2007 Afghanistan HyMap[a] dataset [2] is described here. Because of the extreme topographic relief and restricted access to ground calibration sites, modifications to the traditional USGS calibration procedures [1] were required. To meet the challenges of the Afghanistan hyperspectral dataset, we developed a calibration process using elevation-based ACORN[a] (Atmospheric CORrection Now) [3] corrections, ground calibration sites, and atmospherically corrected cross-cutting calibration flight lines to maximize the utility and accuracy of the country-wide data.

2. BACKGROUND

HyMap is an airborne hyperspectral sensor manufactured by Integrated Spectronics Pty Ltd[a] [4]. The HyMap data were collected between August 22 and October 2, 2007. A NASA WB-57 high altitude aircraft was used to fly the HyMap sensor at an altitude of ~50,000 feet. There were 207 north-south flight lines and 11 cross-cutting calibration lines collected over the country of Afghanistan covering a surface area of ~438,012 km^2 [2]. The surface elevation within the coverage area ranges from ~300 to ~5,500 meters. Given this elevation range, the pixel size of the HyMap data ranged from 24.0 to 37.4 meters. Each HyMap spectrum contains 128 channels of data between the wavelengths of 0.43 and 2.48 microns. HyVista Corporation[a] delivered the HyMap data to the U.S. Geological Survey as geocorrected, scaled radiance data. The flight lines were flown in four blocks defined by every 2 degrees of latitude. Within each of those blocks the data were tiled into mosaics consisting of the lines flown during a single day.

For this work an ENVI/IDL[a] (Environment for Visualizing Images/Interactive Data Language) based software package called PRISM [5] (Processing Routines in IDL for Spectroscopic Measurements) was used to process and calibrate the HyMap data. To meet the needs of this dataset, additional customized programs and scripts were written in IDL.

3. CALIBRATION METHODS

When possible, the Afghanistan hyperspectral dataset was calibrated using standard USGS techniques described in [1], which includes:

1. converting data from radiance to apparent surface reflectance using a radiative transfer program called Atmospheric CORrection Now (ACORN) [3].
2. using an empirical multiplier factor to remove atmospheric residuals that weren't corrected by ACORN, where the multiplier is derived at ground calibration sites measured with a field spectrometer.

For the Afghanistan HyMap data, three ground calibration sites were measured: Kandahar Air Field, Bagram Air Base, and Mazar-e-Sharif Airport. In addition, laboratory measurements of soil samples collected from two dirt fields were used as ground calibration measurements. This procedure works best with imaging spectrometer data collected within ~100 kilometers of a calibration site and within a few days of the ground calibration measurements. The empirical correction factors work best for pixels with close to the same elevation as the ground calibration site. The ground calibration sites were located in eastern Afghanistan, and the data were collected over a two month period for surface elevations spanning 5,200 meters. As a result, the HyMap data were collected with variable atmospheric conditions and, therefore, neither the ACORN program or the multiplier generated from the ground calibration are sufficient to adequately calibrate all of the data.

To improve the data quality and the calibration we developed several techniques to address the difference in atmospheric conditions. First, extremes in elevation were addressed. ACORN models the atmospheric water based on a pixel-by-pixel analysis of the 0.94 and 1.14 micron water bands in the dataset. The atmospheric CO_2 is modeled on the assigned average elevation. If there are significant elevation differences within a line, using a single average elevation value will result in undercorrected data at lower elevations and overcorrected data at higher elevations. As a result, we developed a program that applies ACORN analysis multiple times on the same line of data using a different average elevation each time it runs. The analysis begins at the minimum elevation as determined by a DEM (Digital Elevation Model) and increases in 100 meter increments until it reaches the maximum elevation. For example, if the elevation difference in a single line is 1,600 meters the program will perform 16 ACORN iterations and produce 16 corrected lines of data (one at every 100 meters of elevation change). Then, based on the 100 meter increments and using the DEM data, the program generates a single cube made up of pixels extracted from the various ACORN elevation-corrected cubes. By applying ACORN corrections as a function of elevation, it is possible to generate a single image cube of data that limits the artifacts resulting from poor modeling of atmospheric CO_2 and water vapor. To ensure the most accurate dataset, this process was done for all 218 flight lines.

While running ACORN at the different elevations improves the data quality, it still does not remove all of the atmospheric components (Fig. 1). To further improve data quality, a multiplier is generated using a ground calibration [1]. The multiplier corrects any residual atmospheric contamination in the hyperspectral data that is not present in the spectra of the ground calibration site. For this dataset, field calibration samples were collected at Kandahar Air Field, Bagram Air Base and Mazar-e-Sharif Airport. Ground calibration was performed on all lines covering any of the calibration sites. In the calibration procedure, an average spectrum of the HyMap data is calculated for the pixels covering the calibration site. The average ground spectrum from the field calibration site, convolved to HyMap spectral characteristics, is then divided by the ACORN-corrected HyMap spectrum to produce a multiplier. The multiplier is then applied to all of the HyMap pixels in the flight line (Fig. 1). One of the multipliers was then applied to each flight line depending on its proximity to the calibration site or its time of acquisition.

As mentioned previously, the farther away from a calibration site a line is, or the longer the time between ground calibration and data acquisition, the greater the atmospheric effects. To overcome some of these issues, we developed another technique involving cross-cutting lines, "cross cutting" meaning they are not north-south oriented and cross the north-south lines. Most of the cross-cutting lines cover one of the ground calibration sites and are thus ground calibrated. In most cases, a line that covers a calibration site is very well calibrated. Using a well-calibrated cross-cutting calibration line, we cross-calibrate any of the north-south lines that cover the same area. In essence, the overlap in the cross-cutting line becomes a new "ground" calibration site. The pixels used to calculate a cross-calibration multiplier are a subset of all the pixels in the overlap. In the cross-cutting line, pixels with large, residual water vapor absorptions and on steep slopes are not used. An average spectrum is calculated using the remaining pixels in the cross cutting line. An average spectrum of the corresponding pixels from the north-south line is also calculated. A multiplier correction is calculated by dividing the average of the cross-cutting line by the average of the north-south line. This final correction factor is applied to the entire north-south line (Fig. 1). This cross-cutting calibration technique was applied on a line-by-line basis depending on the intensity of the residual atmospheric bands. Using this combination of calibration techniques has resulted in the largest ground-calibrated imaging spectrometer dataset ever produced.

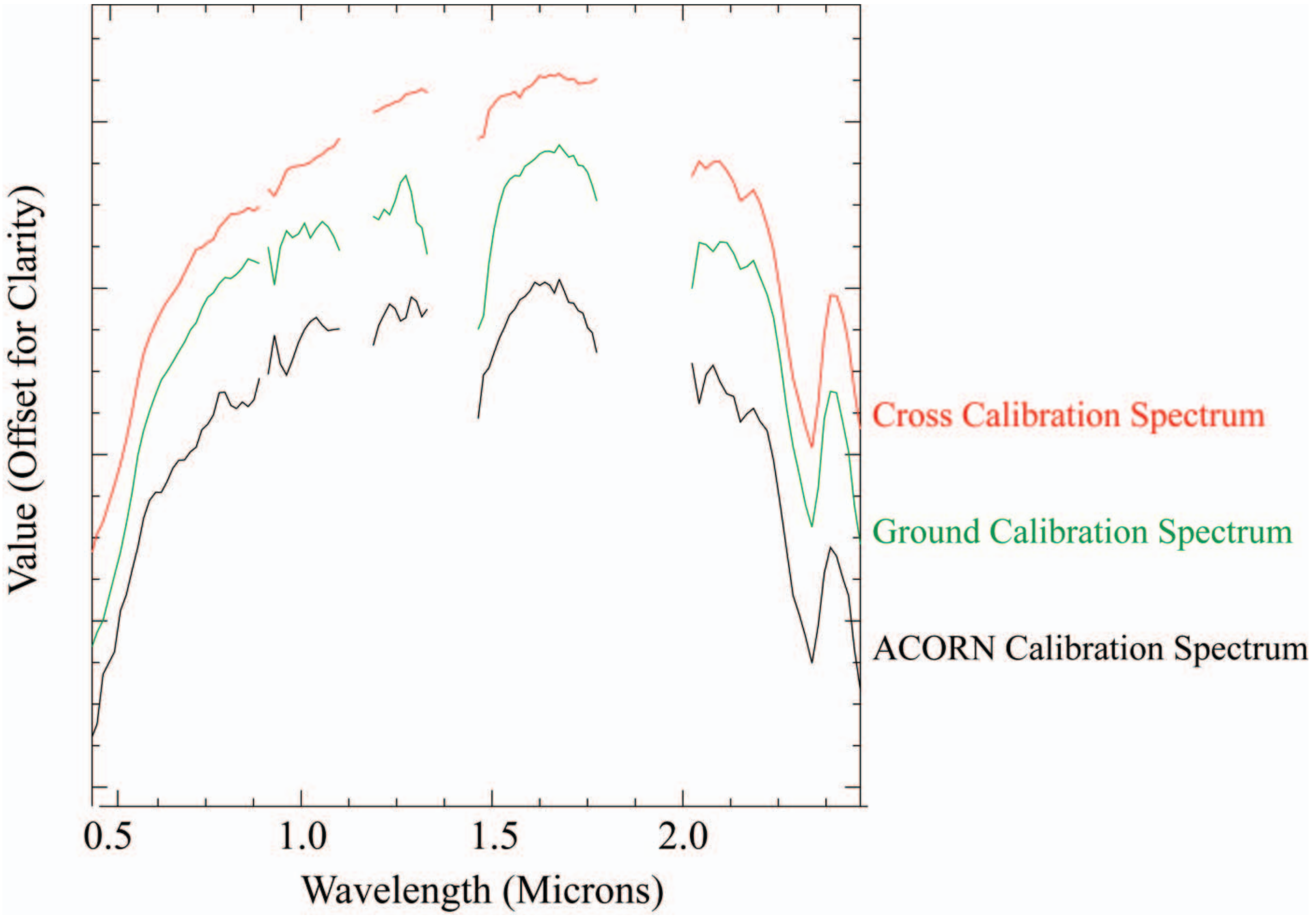

Figure 1. Example spectra from the three different calibration steps. Spectra were extracted from the same pixel in each of the calibration lines. This example demonstrates how the Cross Calibration Spectrum shows the least amount of residual bands from a flight line distal to the ground calibration site.

4. REFERENCES

[1] R.N. Clark, G.A. Swayze, K.E. Livo, R.F. Kokaly, T.V.V. King, J.B. Dalton, J.S. Vance, B.W. Rockwell, T. Hoefen,, and R.R. McDougal,, *Surface Reflectance Calibration of Terrestrial Imaging Spectroscopy Data: a Tutorial Using AVIRIS* in Proceedings of the 10th Airborne Earth Science Workshop, JPL Publication 02-1, 2002.

[2] R.F. Kokaly, T.V.V. King, and K.E. Livo, 2008, *Airborne Hyperspectral Survey of Afghanistan 2007: Flight Line Planning and HyMap Data Collection*: U.S. Geological Survey Open-File Report 2008-1235, 14 p.

[3] http://www.imspec.com/

[4] T. Cocks, R. Jenssen, A. Stewart, I. Wilson, and T. Shields, 1998, The HyMap Airborne Hyperspectral Sensor: The System, Calibration and Performance., in Schaepman, M., Schlapfer, D., and Itten, K.I., eds., Proceedings of the 1st EARSeL Workshop on Imaging Spectroscopy, 6-8 October 1998, Zurich, EARSeL, Paris, p. 37-43.

[5] R.F. Kokaly, "Spectroscopic Analysis for Material Identification and Mapping Using PRISM, an ENVI/IDL Based Software Package," *2010 IEEE International Geoscience and Remote Sensing Symposium Proceedings*, this volume, 2010.

---

[a] The use of tradenames does not imply endorsement by the U.S. Government.