AVIRIS DATA FOR THE DOLLY VARDEN MOUNTAINS, NEVADA: HIRIS ANALOG

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ABSTRACT

A HIRIS analog data set is being produced from Dolly Varden, Nevada AVIRIS data. HIRIS parameters will be simulated and the data will be used to investigate handling and analysis of HIRIS data. The Dolly Varden area contains interesting geology, vegetation and topographic features which will allow use in a variety of disciplines. The first simulation of a HIRIS data set was produced by calibrating and registering three overlapping AVIRIS flight lines. Problems were encountered because the three flight lines were obtained at different sun angles and atmospheric conditions. Each flight line showed a 10-15% variation in radiance across track. This variation was dominated by shadowing effects resulting from the scan angle of AVIRIS. Rayleigh scattering and vignetting also contribute to the radiance differences, but not by more than 1% each. Once the radiance differences are removed, the resulting HIRIS analog data set will allow for scientific and equipment preparations.

INTRODUCTION

A HIRIS analog data set is being produced for use in a variety of disciplines. The data will simulate as best as possible HIRIS coverage, spectral resolution, spatial resolution and signal-to-noise ratio. It will be used to gain experience in data handling and analysis of a data set the size of a HIRIS scene. Both hardware and software requirements can be determined using these data. Each scene requires approximately 290 Mbytes of disk space plus additional space for analysis. The HIRIS analog data set will be available for distribution to the scientific community.

The High Resolution Imaging Spectrometer, HIRIS, will be flown on the EOS platform slated for launch in 1997. It has a ground instantaneous field of view of 30 meters and a swath width of 24 km. It has a spectral range of .4-2.5 μm, with an average spectral sampling interval of 10 nm. The data encoding for HIRIS is 12 bits instead of the 10 bits of AVIRIS to account for its higher signal-to-noise ratio (Goetz and Herring, 1989).

The Dolly Varden AVIRIS data were chosen for the creation of the HIRIS analog because it was the only data set currently available with a large enough swath coverage to simulate HIRIS. The Dolly Varden area also contains interesting geology, a variety of vegetation coverage, and has a large elevation variation. The three AVIRIS flight lines shown in Figure 1 were used to create the HIRIS swath. They were flown from south to north, and overlap by approximately one kilometer. The AVIRIS data were obtained June 2, 1989 within a period of one hour, before solar noon, and the sun was in the southeast quadrant.

SETTING

The Dolly Varden Mountains and Currie Hills are located in the semi-arid environment of the northeastern Great Basin. The area ranges in elevation from 1750 to 2600 meters. Other than some high relief areas of bare outcrop, vegetation cover typically ranges from 20% to 50%.
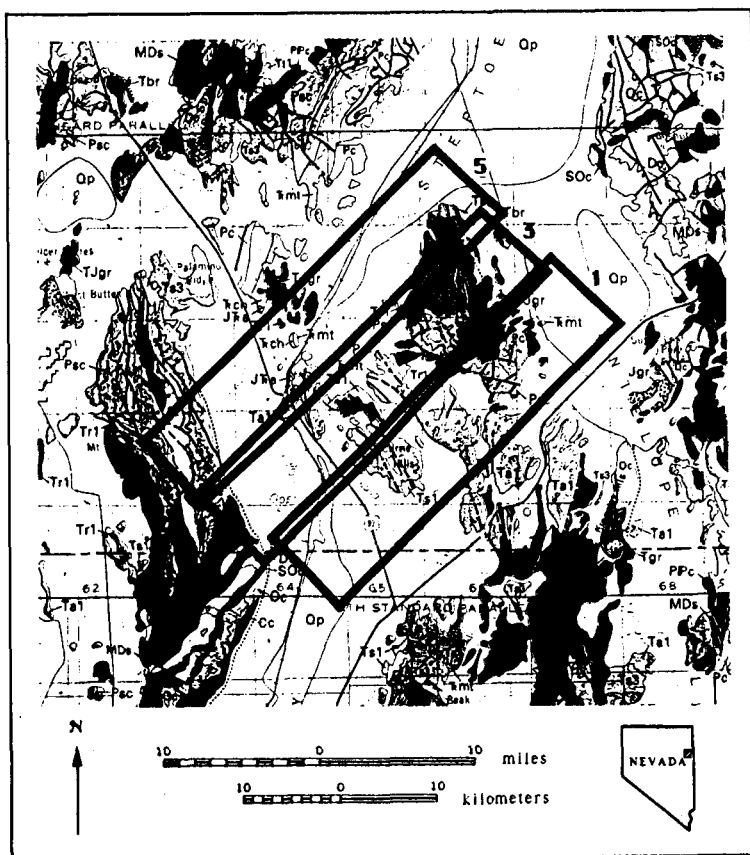
Figure 1. Location and geologic map of the Dolly Varden AVIRIS flight lines.

In some places along drainages and on high, north-facing slopes, vegetation cover approaches 100%. Sagebrush is present at lower elevations and piñon pine and juniper are prevalent at elevations above 2000 meters. Also, some deciduous vegetation is present around springs in the area.

The study area contains a variety of geologic materials exposed at the surface. A sequence of Late Paleozoic through early Jurassic sedimentary rocks includes limestone, dolomite, sandstone, siltstone and shale (Coats, 1987). Igneous rocks in the area include a two-phase monzogranite and quartz monzonite intrusion and volcanic rocks with compositions ranging from andesite to quartz latite to rhyolite. The igneous intrusion produced a calc-silicate contact metamorphic aureole in the sedimentary section. Minerals such as andradite, diopside, tremolite, epidote, serpentine, sepiolite and saponite resulted from this metamorphism. Alluvial fans slope down from the ranges to the relatively flat valley floors. Cenozoic lacustrine deposits occur locally, especially to the northeast of the Dolly Varden Mountains. A playa lies along a generally dry stream bed to the northwest of the range.

CALIBRATION

The first step in producing the HIRIS analog data set was to reduce the 15-meter AVIRIS pixels to 30-meter HIRIS resolution. A HIRIS pixel was created by averaging four pixels in the AVIRIS data. Next, five AVIRIS segments were appended to produce three long flight lines of data, which then were registered together. A problem encountered in trying to produce the HIRIS data set was that the three runs were obtained at different times of day and different sun angles. Therefore, the three runs could not be registered together without some kind of calibration that would account for the differences in atmospheric scattering and shadowing. As a first approximation, areas in the overlapping parts of the images were used to calibrate the outer two runs, Run 1 and Run 5, to the center run, Run 3, using gains and offsets. The gains and offsets were calculated using a method similar to the empirical line method used for

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conversion to reflectance. Areas in the center run were used as the reference spectra and the other runs were calibrated by applying gains and offsets. The offsets that were applied to the outer runs are shown in Figure 2. These curves look like solar radiance curves indicating that that the calibration is adding or subtracting radiance. This is due to differential Rayleigh scattering because of differences in the solar zenith angles between the three runs. Table 1 shows the values for the solar zenith angles for the three runs calculated based on the latitude, longitude, date and time.
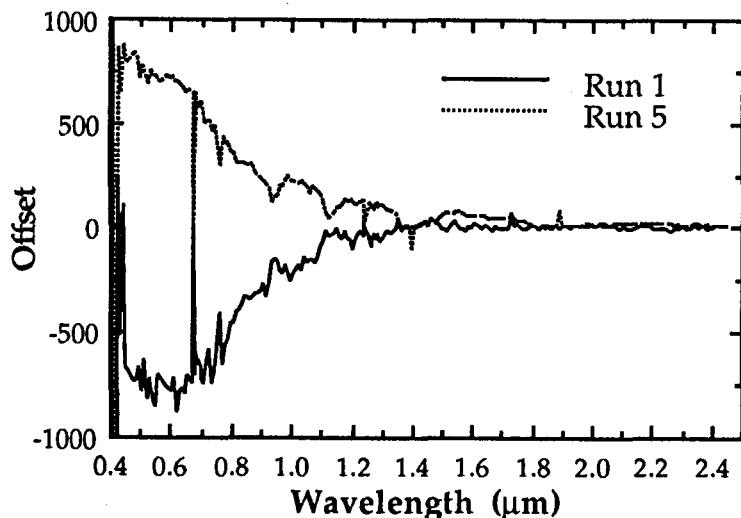

Table 1. Solar zenith angles.
Run 1   21.94°
Run 3   19.73°
Run 5   18.27°

Figure 2. Offsets for calibration to Run 3.

Once the three runs were calibrated for atmospheric differences, the empirical line method was used to convert the data to reflectance (Conel et al., 1987). This involves calculating gain and offset values for each band based upon reflectance measurements taken from bright and dark targets under the same illumination conditions as the AVIRIS data. For this study, a dark andesite flow just to the southeast of the range and a bright playa to the northwest of the range were used as calibration targets. Several field spectra were taken for each target and then averaged and used in the calibration. The calibrated reflectance flight lines were registered together, producing a HIRIS image of 800x800 pixels (see Slide 19). The seams between the three flight lines were smoothed by averaging 10 pixels with a ramp function.

COMPARISON OF SPECTRA

Figure 3 compares reflectance spectra from the same area taken by a Geophysical and Environmental Research field spectrometer, from AVIRIS and from the HIRIS analog. The spectra have been vertically offset for clarity and the 1.4 and 1.9 μm water bands have been omitted. A CO_3 absorption feature around 2.31 μm is apparent in all spectra as are Fe absorption features shortwards of .7 μm. The AVIRIS pixel apparently included relatively more iron oxide as the Fe features in its spectrum are deeper. The AVIRIS and HIRIS spectra have two peaks around 0.94 and 1.13 μm that are due to over-correction for atmospheric H_2O vapor. This over-correction results from the calibration targets being located about 500 m lower in elevation than the pixel sampled in Figure 3. When using calibration targets over which there is greater atmospheric attenuation than over a particular pixel, the conversion to reflectance produces peaks in the spectrum at the atmospheric bands.
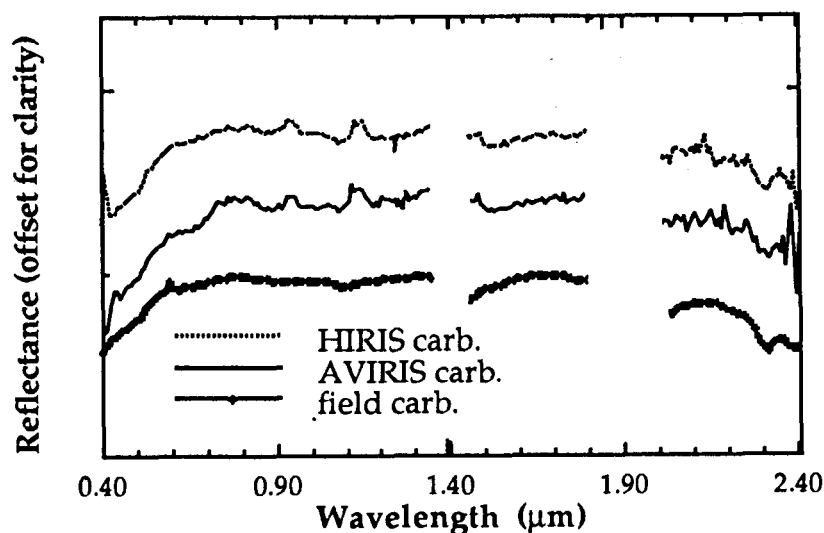
Figure 3. HIRIS analog, AVIRIS, and field spectra for a carbonate rock.

ATMOSPHERIC EFFECTS

Because the field of view of HIRIS is 1.8° while AVIRIS is 30°, atmospheric effects which exist across an AVIRIS scene will not greatly affect the HIRIS data. Therefore, the atmospheric effects in the AVIRIS data must be removed in order to simulate a HIRIS scene. Column averages every 30 pixels were obtained for each AVIRIS flight line to investigate the radiance changes across the flight lines. The column averages across each run show a 10-15% change in radiance from one side of the flight line to the other. Vignetting causes a reduction in radiance at the edges of the images, but is only a 1-2% effect. Figure 4 shows the column averages for Run 3.
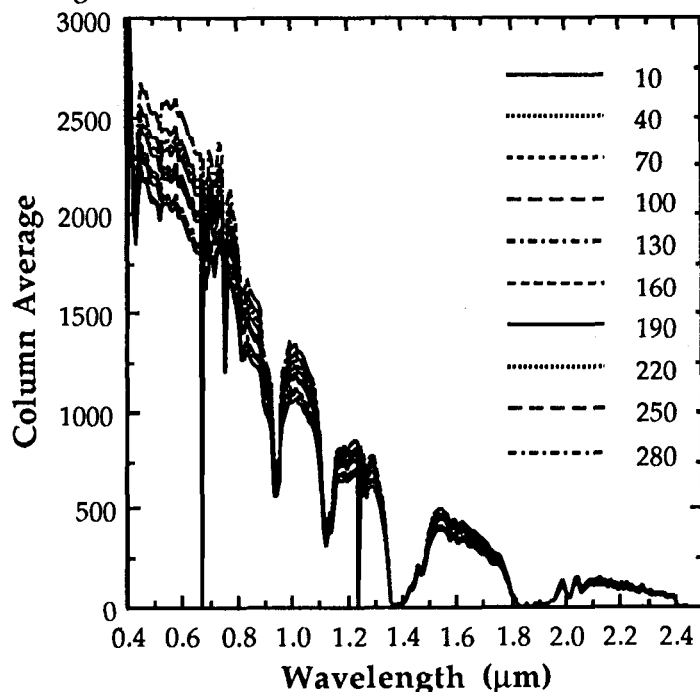

Figure 4. Column averages across Run 3.

LOWTRAN7 was used to estimate the contribution of Rayleigh and aerosol scattering to the radiance variations across the scenes. Path length changes due to scan angle causes changes in Rayleigh and aerosol scattering. LOWTRAN7 was used to simulate radiances at the 20 km AVIRIS altitude by assuming that the solar zenith angle was 20 degrees, the ground elevation was 1.8 km, and the relative azimuthal angle between the solar and the observational directions was 90 degrees. Two observational geometries were used: nadir and off-nadir by 15

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degrees. In two case studies, a rural aerosol model with a visibility of 23 km and Lambertian surface reflectances of 0.1 and .3 were assumed. Two other case studies assumed the same surface reflectance values but no aerosol. The calculated radiances in the 0.4-1.0 µm spectral region at the off-nadir viewing geometry were greater than the corresponding nadir geometry by less than 1% in all four cases. These results indicate that the observed radiance differences in the AVIRIS flight lines are not caused by atmospheric path radiance effects only.

Due to the orientation of the AVIRIS flight lines, the instrument looked either into or away from the sun during its scanning. When AVIRIS scanned toward the sun, it received a lower radiance because it was viewing shadows. When it scanned away from the sun, AVIRIS received a higher radiance because it did not view as many shadows. The changing viewing angles caused different amounts of shadow to be seen, and therefore, different radiance values are obtained across a scene. Also, because of the differing solar zenith angles, the overall radiances for each flight line are different. The run with the largest solar zenith angle has the most shadows in its data and the lowest radiance. The run with the smallest zenith angle has the highest radiance due to the least amount of shadows. It was concluded that the observed radiance differences across individual runs and between runs were dominated by shadowing effects.

DISCUSSION

This has been the first attempt at creating a HIRIS analog data set. Currently, methods for removing the atmospheric effects are being worked on to allow for a better simulation of a HIRIS scene. An attempt to correct each pixel for radiance variations due to the differing sun angles and scanning effects is in progress. A problem exists in trying to simulate the signal-to-noise ratio of HIRIS with AVIRIS data because HIRIS has 30 times the integration time per pixel than AVIRIS. The expected signal-to-noise ratio for HIRIS ranges between 150-400 for .5 reflectance. From the AVIRIS derived HIRIS data, the signal-to-noise ratio calculated for a playa with .5 reflectance ranges from 50-200. Therefore, the HIRIS signal-to-noise cannot be exactly simulated. This HIRIS analog data set will allow for experience in data handling and analysis of such a large amount of data and will be distributed to the scientific community.

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