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ANALYSIS OF AIS DATA OF THE RECLUSE OIL FIELD, RECLUSE, WYOMING

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ABSTRACT

AIS data were flown over the Recluse, Wyoming oil field on September 9, 1984. Processing software has been developed at Earth Satellite Corporation (EarthSat) for interactive analysis of the AIS data. EarthSat's AIS processing capabilities include destriping, solar irradiance corrections, residual calculations, geometric resampling, equal energy normalization, interactive spectral classifications and a variety of compressive algorithms to reduce the data to 8-bit format with a minimum of information loss. The in-house photolab facilities of EarthSat can routinely produce high-quality color renditions of the enhanced AIS data. EarthSat's AIS processing capabilities are available to fellow investigators through our Chevy Chase, Maryland office.

A total of 80 lithologic samples were collected under the AIS flight lines. Correlation (within the atmospheric windows) between the laboratory and the AIS spectra of sample sites was generally poor. Reasonable correlation was only possible in large, freshly plowed fields. We believe mixed pixels and contrast between the natural and sample's surfaces are mainly responsible for the poor correlation. Finally, a drift of approximately three channels was observed in the diffraction grating position within the 1.8 - 2.1 micron quadrant. The drift appears to be sinusoidal in nature.

AIS DATA

Four flight lines of AIS data, and contemporaneous TMS data, were flown over the Recluse, Wyoming oil field. The Recluse oil field is located along the northeastern flank of the Powder River Basin. Figure 1 is a location map for the Recluse oil field and gives the approximate position of the four flight lines. For this flight, the AIS spectral range extended from 1.155 to 2.337 microns.

AIS DATA PROCESSING

A flow diagram of EarthSat AIS processing software is shown in Figure 2. On this figure, EarthSat's processing begins at the DESTRIPE position.

Destripe

The corrected data, as provided by JPL, still contains a residual banding (or striping) along the flight direction. The banding is apparently caused by imbalances in the dark current (DC bias) of the detectors across the pixel direction of the detector. If a sufficiently large area of homogeneous, spectrally flat material is present along the flight line it is possible to use the average radiance values, collected over several along-track pixels, to adjust the bias differences between the cross-track elements of the array. This is the approach commonly used by JPL, and one which produced the "flat field corrected" data for the Cuprite, Nevada scene described in the AIS User's Guide.

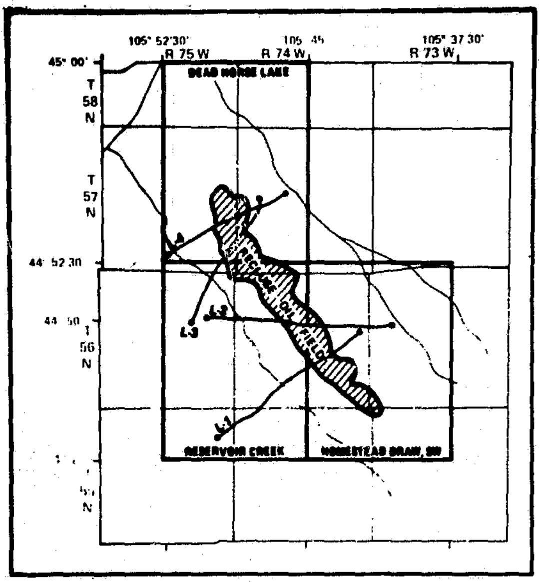

Fig. 1 Location Map

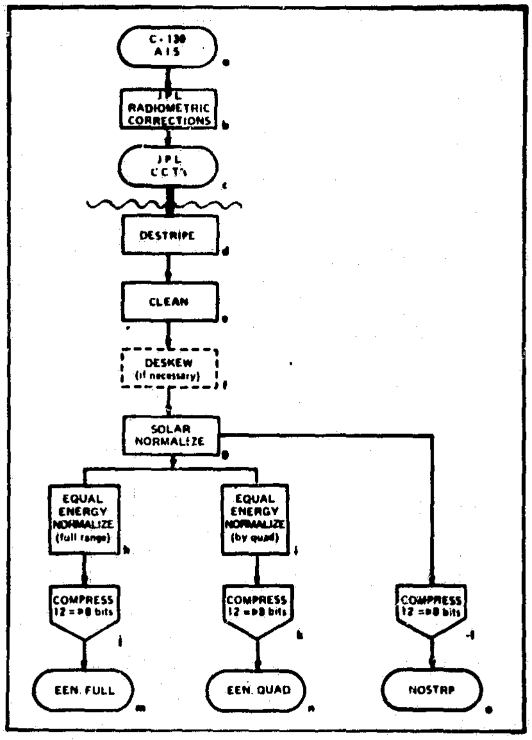

Fig. 2 Flow diagram of EarthSat's AIS processing

Unfortunately, no such area was found on any of our four flight lines. Therefore, we used a different approach for the destriping. Our approach is based on histogram matching. The assumption is that, over the course of a complete flight line, each of the 32 cross-track detectors has covered, on the average, very similar surface materials. As long as the individual detectors are reasonably well behaved, this technique works extremely well in removing intra-band striping. By way of example, Figures 3 and 4 show several AIS channels before and after destriping.

This method however can induce serious problems in terms of the inter-band radiometrics. Within a given band (i.e., one of the 128 spectral channels) matching of the 32 AIS detectors is totally dependent upon the shape of each bands' unique reference histogram. If there are fundamental differences between any two bands' reference histograms, these differences will be expressed in the output (destriped) data.

In our first attempt to describe the AIS data we chose a single detector within each band from which to collect the reference histogram. The criteria for selecting the reference detector were that it show a low variance and appear, in other ways, to be well behaved. However, a problem arose because of the presence of an inaccurate "dark current correction" applied during data collection. The net effect of the erroneous dark current correction was to add random DC bias values to the individual detectors. Thus, during our original destriping process, a false bias was applied to each band; the magnitude of the bias was proportional to the level of the random noise at the detector for which we collected the reference histogram. The final result was 128 well-destriped bands; however, in many cases each of these bands had biases which were equal to or greater than the absorption features comprising the desired spectral information. Figure 5 is a strongly stretched version of the normalized destriped data showing the obvious DC bias differences between the spectral channels. To prevent the undesirable effects induced by the random DC biases, we have modified the destriping program to collect an average reference histogram as an average of all detectors, rather than for a single detector. The results (Figure 6) produce much more uniform inter-band radiometrics.

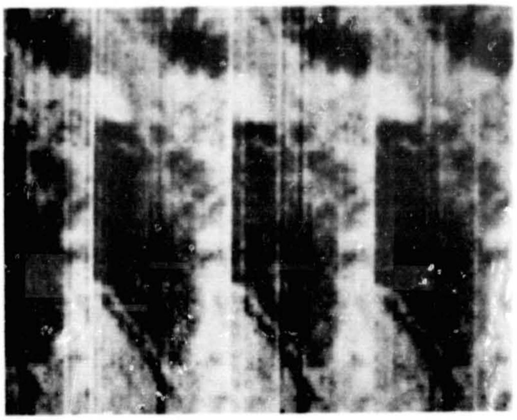

Fig. 3 Data as received from JPL

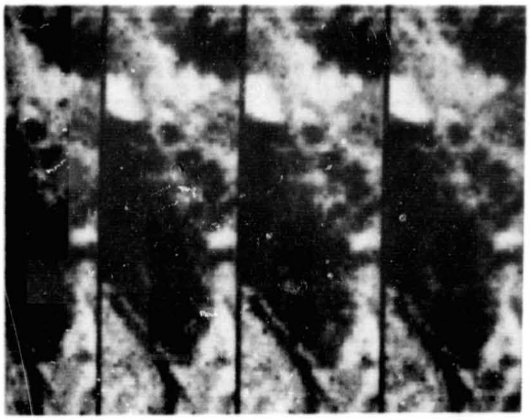

Fig. 4 Data after EarthSat's destriping

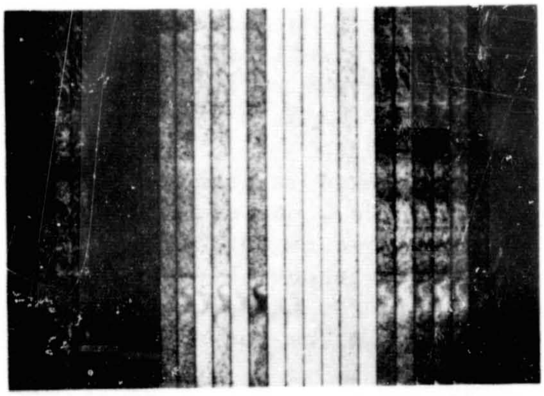

Fig. 5 Erroneous bias effects when destriping based on single detector

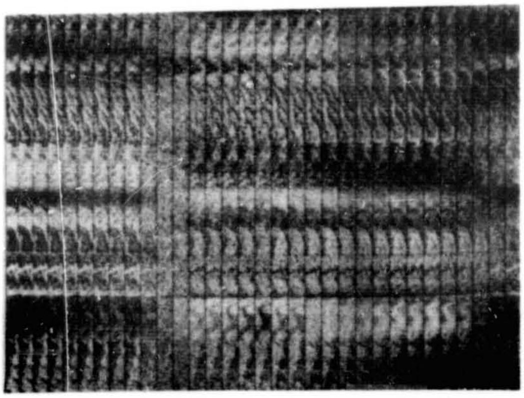

Fig. 6 Results of destriping based on all available detectors

Clean

This procedure was written to interactively remove bad data lines. Bad lines appear as cross-track lines of fully saturated (DN 4095) or anomalously low DN values. Single lines are replaced by the average of the two adjacent lines on a pixel-by-pixel basis. Multiple line corrections are performed by a weighted average of the next adjacent good data lines. If these bad data lines are not removed they can adversely affect the later compression of the AIS data from 16 to 8 bits.

Skew

The AIS sensor is fixed orthogonal to the longitudinal axis of the aircraft fuselage. Therefore, when the aircraft must crab (point into the wind in order to maintain its heading) the resulting yaw induces a skew in the geometry of the AIS data. The degree of skew is proportional to the yaw angle.

We have made a first order skew correction for those flight lines with yaw angles greater than 10 degrees. The correction is based on a nearest neighbor resampling along the flight path direction. The correction can be likened to looking edgewise at a deck of cards and sloping the top edge to the left or right to the appropriate number of degrees depending upon the sign and magnitude of the yaw angle.

Solar Normalize

The incident energy at the top of the atmosphere drops off rapidly within the spectral range of the AIS sensor (approximately 1.2 to 2.4 microns). Using the LOWTRAN program for atmospheric calculations, the incident solar radiation was found to range between approximately 530 watts/square metre at 1.2 microns down to approximately 62 watts/square metre at 2.4 microns. Therefore, with increasing wavelength, each consecutive AIS spectral channel is receiving a decreasing intensity of incident light. In order to compensate for this imbalance, the pixels of each spectral channel are multiplied by a factor proportional to the inverse of the solar radiance for the channel. This effectively normalizes the 128 spectral channels to a common incident solar baseline.

Equal Energy Normalize (Full-Range)

The purpose of the Equal Energy Normalize (EEN) calculation was to remove the effects of differing overall brightness and, thereby, accentuate the spectral, band-to-band, information. The algorithm used was identical to that described in the AIS User's Guide.

Equal Energy Normalize (By Quad)

Within the spectral range of the AIS sensor there are two major atmospheric absorption regions, one around 1.4 microns and the other around 1.9 microns. The major portions of these features fall almost entirely within grating positions 1 and 3, respectively. When calculating the EEN data using all 128 channels, these major features tend to dominate the calculations; greatly decreasing the ability to detect smaller scale features in the other grating positions. Therefore, a procedure was developed which calculates the EEN separately for each of the four grating positions.

The algorithm used is the same as the EEN for the full-range. However, instead of basing the calculation on all 128 spectral channels, the calculations are preformed four times, once for each of the 32 channel grating positions. Clearly, this procedure produces strong discontinuities at the grating boundaries. However, the presence of the discontinuities are well worth the greatly enhanced signal-to-noise ratio of the data, particularly within the 2.1 to 2.3 micron grating position.

Compress 12=>8-bits

This was the final step in the digital data enhancement. The objective was to compress the 12-bit AIS data (contained in a 16-bit I*2 format) into an 8-bit word which is then compatible with standard image display and printing devices. The compression algorithm was carefully designed to minimize the amount of information lost during the data compression.

Several data compression approaches have been used during this project. The most common was to calculate the mean and standard deviation for each of the spectral bands of a given flight line. Using the average of the means and three times the standard deviation of the channel with the largest calculated standard deviation, a minimum and maximum input value are calculated: minimum equals the average mean minus three times the largest standard deviation, the maximum equals the average plus three times the standard deviation. A linear lookup table is defined into which these minimum and maximum values are mapped to 0 and 255, respectively. This lookup table is then applied to all the pixels within each of the 128 spectral channels.

RESULTS

Correlation Between AIS and Lab Spectra

During the course of this study 80 lithologic samples were collected under the AIS flight lines. The samples were analyzed using X-ray diffraction, elemental analysis and laboratory spectral reflectance measurements. In open homogeneous areas, such as freshly plowed fields, it was possible to achieve reasonable correlations (within the atmospheric windows) between the AIS spectra and those measured in the laboratory. However, for the less disturbed areas it has been difficult to achieve much correlation between the lab and AIS spectra. We believe that this is largely due to the two phenomena: 1) The mixture of surface materials within a given pixel, and 2) natural vs. sample (laboratory) reflectance surfaces. The mixture problem is location dependent. Recluse is particularly bad in this regard. The problem of providing the laboratory spectrometer with a "natural" weathered surface is a more universal problem.

In a heterogeneous region, such as the Recluse study area, it is impossible to sample all the surface materials that fall within any given AIS pixel. Therefore, the only possible approach is to collect a hand sample at a given site which is characteristic of the general area. The approximately 100-square-metre AIS pixel will almost always contain many more different types of surface materials than are able to be represented in a hand sample. The only sites where this was not the case were in large, homogeneous, freshly plowed fields. Not surprisingly, it was within these areas that we have the best correlations between the laboratory and AIS spectra.

The second, and equally difficult problem to control, is the unavoidable fact that the AIS data is measuring sunlight reflected from the upper few microns of naturally weathered surfaces. When unconsolidated samples reach the laboratory, these weathering surfaces have been lost. The degree to which the natural chemical and physical weathering environments have modified the mineralogy and reflective properties of the surface types will adversely affect the correlation between AIS and laboratory spectra.

Grating Drift

An important observation that came from our interpretation of specially processed imagery of the AIS data is an apparent sinusoidal drift in the wavelength position of the diffraction grating. Figure 7 is a photograph of the last sixty or so juxtaposed AIS spectral channels. The flight direction is from the top to the bottom of the picture. Note the wavy zone (arrow on Figure 7), approximately 3 channels wide, which moves down the flight line in a sinusoidal nature with an amplitude of approximately three channels. This is marking the location of the 2.0-micron absorption band due to atmospheric carbon dioxide. Clearly, the channel number of this absorption ought to be constant. Its wavy appearance on the AIS imagery suggests that the electronics controlling the precise wavelength position of the diffraction grating are possibly being affected by a signal of the observed period and amplitude. There is not, to date, enough information to say whether or not this same phenomenon is affecting each of the other three grating positions; however, a similar effect, although less apparent, is observable in the second grating position (1.5 - 1.8 microns). Before more detailed analyses of absorption band placements can be performed, these apparent band shifts need to be further understood.

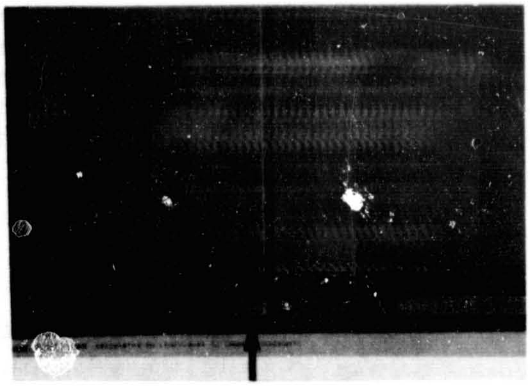

Fig. 7 Approximately 60 AIS channels between 1.8 and 2.4 microns. Arrow locates 2.0 absorption of carbon dioxide. Note wavy pattern along flight line.