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Status Report for Landsat Investigation A-35

"Geometric and Radiometric Characterization of Landsat-D Thematic Mapper and Multispectral Scanner Data"

FEB 1983 RECEIVED NASA STI FACILITY ACCESS DEPT.

Submitted by

Hugh Kieffer, U.S.G.S., Flagstaff, AZ

February 18, 1983

(E83-10212) GEOMETRIC AND RADIOMETRIC CHARACTERIZATION OF LANDSAT-D THEMATIC MAPPER AND MULTISPECTRAL SCANNER DATA Status Report (Geological Survey) 6 p HC A02/MF A01 CSCL 05B G3/43 Unclas 00212 N83-21453

The nature of this project was unfortunately, and unrecognizably, foreshadowed by events bounding my participation in the first Landsat-D Investigators Workshop: aircraft deviation around a tornado and unscheduled refueling resulted in landing at Dallas Ft. Worth Airport 30 minutes after Braniff declared bankrupty, causing, amongest other complications, missing the first half day of presentations; materials gathered at the workshop and mailed at the primary U.S. Postal Office (Union Station) never arrived at my home office. With the best intentions of many persons, the caprice and perversity of this inantimate behemoth reluctantly yields.

Our work was from the onset intended to be a detailed examination of the geometric and radiometric properties of the Landsat 4 imaging data, in contrast to an application analyses of the fully processed images. Consequently, our request for data and information have been more extensive and less well specified than probably anticipated. We initially specified some of the required data in terms of their radiometric content, rather than by specific location. This appears not to have been effective; and we will respecify these data requirements in terms of geographic and temporal constraints.

The lack of information from the project in terms of data availablility and its plans for providing data to us has been frustrating. We have thus far received data for one of the scenes specified in our data requirements (Washington, D.C.), and data tapes for two other scenes used primarily for checking our ability to handle the Thematic Mapper formats. It has required repeated personal requests to obtain a list of the Thematic Mapper scenes available or in processing.

We have thus far been unable to acquire the information necessary to examine the raw geometric properties of either MSS or TM images, nor the raw radiometric properties of the MSS. Information necessary to examine the low frequency distortions of the Thematic Mapper are not available, e.g., the start-, end-, and mid-scan times for the scan mirror are stripped out in Goddard processing and are not available on A, B, or P tapes. The high frequency spacecraft attitude control information is also not available. For the both the MSS and TM, the internal calibration signals are removed from the data before the CCTs are made.

The internal calibration data for the Thematic Mapper is thought to be available on CCT-ADDS, for which we have yet to receive any documentation. The Goddard group that generates the ADDS tape has told us that this tape is considered an "internal" tape, and they are not allowed to send us any information about it without higher level approval. For the MSS, a few calibration response points are thought to be in the trailing part of the scan line; we have not yet successfully identified these. Also, we have not yet been able to acquire a radiometrically uncorrected MSS scene.

In light of the data actually available from these two instruments, our proposal was overly ambitious in terms of examining the raw data. We will thus concentrate more on geometrically processed data, using the uncorrected data primarily for radiometric analyses.

Progress made to date is summarized in the abstracts of presentations to be given in the February meetings (Attachement A and B). Additional work underway, but not discussed in the abstracts includes the following:

Initial assessment of band-to-band registeration has been accomplished by use of color composites and small area auto-correlation techniques.

Examination of the spectral equivalency of the first four bands of the Thematic Mapper with the four bands of the Multispectral Scanner has been started.

Geometric analyses of the Washington, D.C. scene has begun. A 1:100,000 scale enlargement of an east-west strip across the middle of the scene has been made, and identification of control points begun. The 7 1/2 minute U.S.G.S. topographic quad for this area have been ordered.

A generalized routine for examining the contents of the label files and non-video data files has been implemented. Several discrepancies from the documentation have been noted and are described in Attachment C.

A nearest neighbor routine to remove the line length variations in MSS images rapidly, as well as account for all image distortion accepting spacecraft attitude has been developed.

A scene for which TM and MSS data were acquired simultaneously as well as individually has been identified, and the data ordered.

Night scenes and day-time ocean scenes required for radiometric purposes have been identified; we plan to use the Landsat assessment system (LAS) to extract the data desired from these scenes.

The possibility of calibrating the Thematic Mapper using objects other than the Earth, and hence avoiding the uncertainities of the terrestrial atmosphere, is being examined.

A formal letter is in preparation modifying our data requirements in light of knowledge of the types of data actually available, scenes already available, and the availability of scenes in the western U.S. through the Canadian receiving station.

Recommendations. Distribute a project status report to each principal investigator on a monthly or more frequent basis; include a list of data availability. Developed the capability to produce rudimentary statistics for a scene without requiring full processing; this would allow assessment of the utility of a scene for a particular purpose with a much smaller commitment of resources. Develope the capability to readily extract and distribute a small number of lines of raw data from Thematic Mapper scenes for use in calibration and analysis studies.

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Attachment A

Thematic Mapper Intraband Radiometric Performance

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In this early report, we have concentrated on a radiometrically corrected, geometrically raw (A data) and a fully processed (P data) images of the Washington D.C. area (ID 40109-15140). In A-data, every 16th image line is from a single detector. To allow recognition of features in A data, a first order geometric correction consisting of a 46 sample shift between forward and reverse scan directions was applied. The radiometric correction incorporated in A-data consists of applying a Radiometic look-up table (RLUT) constructed to equalize throughout a scene the mean and standard deviation of each detector, with the constraint of never compressing two DN levels into one. The same RLUT is used for the forward and reverse scan directions.

For our statistical study, we used a set of lines (512 A, 1024 P) across the center of the scene. A sub-scene centered over Chesapeake Bay and approximating a flat field was used for characterizing subtle radiometric differences and noise problems.

There are small differences between the average DN for the 16 detectors in each band, typically 0.8 DN; the standard deviations also differ typically by 0.4 DN. Differences of mode in a band are as large as 6 DN. Some DN levels appear to be strongly favored over adjacent levels. Differences between forward and reverse scans are approximately 0.1 DN in the mean, and 0 to 0.6 DN in the standard deviation. Geometrically resampled images (P data), in which the fixed correspondance between lines and single detectors is lost, are statistically similiar to the ensemble of detectors in each band in A data.

The magnitude of inter-detector variation is readily seen by making an image of the first derivative in the vertical (line) direction of a flat field and stretching progressively wider ranges to gray; most detectors differ from their neighbors by 1 to 2 DN.

The effective resolution in radiance is degraded by a tendency for the TM to avoid certain DN levels by about a factor of two. These levels are consistent over all bands and detectors, and are spaced by an average of 4 DN. In band 6, level 127 is avoided by a factor of 30. This behavior is masked by resampling in the P data.

At high contrast boundaries, some of the detectors in Band 5 commonly over- or under-shoot by several DN and require on the order of 50 samples to recover; this behaviours occurs erratically.

A coherent sinusoidal noise pattern is evident in Detector 1 of Band 3. One-dimensional Fourier transforms show that this "stiching" pattern has a period of 13.8 samples with a peak-to-peak amplitude ranging from 2 to 5 DN. Oscillations of the same frequency, but about half this amplitude, occur for one other detector in this Band. Noise with a period of 3.24 samples is pronounced for most detectors in Band 1 and for 2 detectors in band 3, insignificant in Band 2, weak in Band 4, and obscured by noise in Bands 5 and 7.

A set of adjacent detectors in Band 1 has a change of response with a period of several scans. These detectors will have a reponse similiar to their neighbors for several scans, then for several scans will have higher or lower DN numbers than their neighbors. There is no apparent pattern to this drift.

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Attachment A

The random noise level of each detector was characterized by the standard deviation of the first derivative in the sample direction across a flat field. By this measure, the noise level is: Band 1, 1.8 to 2.8 DN; Band 2, 0.74 DN representative, one detector each at 1.1 and 1.7; Band 3, 0.8 representative, 4 detectors at 1.0 to 1.3; Band 4, 1.0 representative, Band 5, 1.5 to 2.1; Band 7, 1.8 representative, one detector at 3.1.

The resampling algorithm used in generation of P data incorporates the 0 DN values which occupy non-data areas along the left and right edges of a frame. This causes 'fuzzy' frame edges and adds anomalous low and high DN values in the resulting frame histogram. In order to avoid adverse effects in applictions involving scene statistics, such as clustering techniques, these values should be reset to zero after the resampling.

A principal component analysis indicates that a composite of the first component of Bands 1, 2, and 3; of Band 5 and 7; and Band 4 contain 97% of the information in the reflectance bands and has reduced the effect of noise.

A periodic noise removal algorithm developed by Chavez, et. al. has been adapted and applied to the coherent noise of Band 3, detector 1; the technique appears to work quite well.

The geometric fidelity of the GSFC filmwriter used for Thematic Mapper images was assesed by measurement with accuracy better than 3 micrometers of a test grid. The film output has scale errors in both the sample and line directions corresponding to 4 pixels in a TM image, and skew corresponding to 3 pixels.

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Attachment B

Landsat-4 Multispectral Scanner Radiometric Intraband Performance

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A geometrically raw image of Washington D.C. was aquired from EROS Data Center. These data have been radiometrically corrected by GSFC; radiometrically raw data are not available. The data aquired show little of the detector striping common in earlier Multispectral Scanner images.

The radiometrically corrected data have uniform means and standard deviations for the detectors in each band; however, the data for different detectors utilize a different pattern of DN levels, (typically 1 DN level out of 3 is not used), resulting in ubiquitous striping of 1 DN amplitude.

All bands have pronounced coherent noise obvious in contrast enhanced images, and evident in natural color composites. One-dimensional Fourier transforms of a flat field show a sharp peak with a period of 3.5 samples. There is evidence of weaker period noise at other frequencies. We have attempted to remove the coherent noise by both transform techniques and by a specially designed sequence of "box" filters.

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Attachment C

Documentation errors.

GES 10033 revision B 1982 June 11

A discrepancy exists between the documentation of the Image Major Frame Format (table 3.5-15) and what actually exists on the digital data. In general the data format seems to match the documentation except as noted below.

1) Computed Cal Lamp Value — bytes 6281-6284
   This field contains no meaningful number. Bytes are filled with ones giving a floating point number oı .33908 E-19

2) Computed Shutter Value — bytes 6285-6288
   This field contains no meaningful number. Bytes are filled with ones giving as floating point number of .33908 E-19

3) The fields "Cal Lamp Gain Value", "Cal Lamp Bias Value", "Applied Gain Value" and "Applied Bias Value" do not appear to be located in the byte positions as specified in the Table 3.5-15 documentation. The probable byte positions are shown below:

   Cal Lamp Gain Value - bytes 6293-6296 - documentation says byte positions 6289-6292
   Cal Lamp Bias Value - bytes 6297-6300 - documentation says byte positions 6293-6296
   Applied Gain Value - bytes 6301-6304 - documentation says byte positions 6297-6300
   Applied Bias Value - bytes 6305-6308 - documentation says byte positions 6301-6304

4) The byte positions 6289-6292 contain an undocumented floating point number of unknown significance. This floating point value is roughly 1.00E03 and changes a few percent from one line to the next.

LANDSAT-D ASSESSMENT SYSTEM LIBRARY COMPUTER COMPATIBLE TAPE (LASLIB-CCT/LAS-CCT) TAPE FORMAT DOCUMENTFOR THEMATIC MAPPER. WBS No. 10T031, July 1982

1) Correction on Table #22 — 293-298 IMGMAJ
   298 should be 296

2) On Table #22 — Bytes 165-182 SCSTID, SCCNID, SCENID contain no meaningful number when printed with L1 or A1 formats.

3) On Table #22 — Bytes 1205-6004 DETDATA, Format not specified clearly. Values look correct when written out as (2R4, 16I2).

4) On Table #17 & #18 — Bytes 5-6276 TMHSK1.
   Values look correct when written with a format of (I4, 21R4, 721A1) only they do not match any table in Ref 2 (GES 10033 Rev B).