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AN-A46: Landsat Scene-to-Scene Registration Assessment

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Quarterly Report for Period: 22 January 1983 - 21 April 1983

Objectives:

- to evaluate the scene-to-scene registration performance of the Landsat-4 MSS relative to previous MSS systems
- to evaluate the scene-to-scene registration performance of the Landsat-4 Thematic Mapper (TM).

Activity this Quarter:

- Landsat MSS registration completed. Results presented at the GSFC Landsat-4 Early Results Symposium (copy of paper attached) in paper and poster display formats.
- Second Landsat-4 MSS scene (ID #840238160I0X0 - 03/11/83) ordered from EROS Data Center. This scene will permit Landsat-4 to Landsat-4 registration performance to be evaluated, and will also serve as a second data point for prior-to-Landsat-4 MSS registration.

Activity Anticipated Next Quarter:

- Receipt of 3/11/83 MSS data set
- Completion of Landsat-4 to Landsat-4 MSS registration (9/16/82 data to 3/11/83 data)
- Completion of Landsat-2 MSS to Landsat-4 MSS (3/11/83 set)
- Comparison of registration performances for all registration completed to date.
- Collection of second TM data set (February through June 1983).

Problems Encountered:

- TM data set originally processed at GSFC was found to have numerous geometric errors traced to software sources in the ground processing facility. Software corrections which would solve these problems will most likely be implemented such that expected delivery of 16 September 1982 data for New Orleans study site is mid to late July 1983. Since all other 1982 data collected over New Orleans (path 22 row 39) has similar problems, and since no cloud free data exists in 1983, this will lead to a commensurate slip in the original schedule.

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LANDSAT SCENE-TO-SCENE REGISTRATION ACCURACY ASSESSMENT

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ABSTRACT

This report documents initial results obtained from the registration of Landsat-4 MSS data to Landsat-2 MSS data. A comparison is made with results obtained from a Landsat-2 MSS-to-Landsat-2 MSS scene-to-scene registration (using the same Landsat-2 MSS data as the "base" data set in both procedures). RMS errors calculated on the control points used in the establishment of scene-to-scene mapping equations are compared to errors computed from idependently chosen verification points. Models developed to estimate actual scene-to-scene registration accuracy based on the use of electrostatic plots are also presented. This project will include analyses of TM data at a later date, and both SCROUNGE and TIPS era products will be evaluated. Analysis or results obtained indicates a statistically significant difference in the RMS errors for the element contribution. Scan line errors were not significantly different. It appears from analysis that a modification to the Landsat-4 MSS scan mirror coefficients is required to correct the situation.

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LANDSAT SCENE-TO-SCENE REGISTRATION ACCURACY ASSESSMENT

I. OBJECTIVES

The NASA/NSTL/Earth Resources Laboratory (ERL) is a participant in the NASA sponsored Landsat Image Data Quality Assessment Program. As its commitment to the program, ERL is conducting a Scene-to-Scene Registration Accuracy Assessment.

The objectives of the study described in this paper were to evaluate the scene-to-scene registration performance of the MSS on Landsat-4 relative to Landsat 1 through 3 MSS systems, and to determine the temporal registration performance of Landsat-4 Thematic Mapper (TM) data sets. Since only one TM data set has been received to date, only the MSS portion of the study will be reported on.

II. TECHNICAL APPROACH

A. Scene-to-Scene Registration

The procedure for temporarily registering MSS digital data at ERL can be summarized as follows:

1. After designating a "base" and "map" data set, manually locate six to ten uniformly distributed points which are geographically common to both data sets. The scan line/elements of these points are stored on a computer disc file for subsequent use.

2. Generate an initial mapping equation based on the points located in (1). This equation defines the fundamental relationship between points located in the map data set and identical points in the base data set. In essence, it is used to calculate the position of a map pixel relative to the base data set.

3. Based on the initial mapping equations developed in (2), locate 100 to 200 additional common points through the use of auto-correlation software. This software locates points in the base data set, and predicts their location in the map data set by using the mapping equation developed in (2). Once the first point is located, a sliding window is moved around the point and the correlation between the data in the window and a similar window containing the point in the base data set is computed. The point at the center of the window with the highest correlation to the base data set is indicated as the "best match" and is saved for subsequent analysis. This procedure continues until all points chosen in the base data have been examined, i.e., correlated with map data set locations.

4. Iteratively edit the registration points located in (3), until a user defined RMS error is obtained. This step in necessary, since some points located by the auto-correlation software may be erroneous. Although the auto-correlation software can be "programmed" to eliminate questionable points, some are nonetheless retained. Thus, the editing step can eliminate points which, when examined in the context of the entire set of points, have abnormally large registration errors associated with them. As each point is deleted, mapping equations are recomputed, errors for the remaining points are recalculated, and the user is given the opportunity to delete another point or end the procedure.

5. Using the final mapping equations based on only the points retained after completing (4), register (resample) the map data set to the base data set, using a piecewise linear fit and bilinear sampling.

B. Evaluation of Registration Accuracy

In order to determine the relative performance of the scene-to-scene registration produced, the following procedure is followed:

1. Produce three electrostatic (black/white) plots for numerous subscenes areas within the overall data available. Two plots are from two channels of the original base data set, the third plot is derived from a single channel of the original map data set. The plots all have identical initial/final scan line and element values, and thus represent the same "geographic" area within the now registered, composite data set.

2. Simultaneously mount three plots from one subscene area on an x-y digitizer table. After initializing the digitizer to the plots (table coordinate to scan line/element coordinate coversion), manually find numerous points which can be unambiguously located on all three plots. Digitize the scan line/element coordinates from each plot for each point used. The resulting 3 coordinates pairs are stored. Continue the process for all subscenes areas.

3. Use digitized points from (2) to calculate temporal registration performance in terms of RMS error. A mathematical model has been developed defining the registration error, which is of the form

$$\sigma_x^2 = \frac{\sum_{i=1}^{n} \left(X_{mi} - \frac{(X_{b1i} - X_{b2i})^2}{2}\right)}{n} - 3/4 \sum_{i=1}^{n} \frac{(X_{b1i} - X_{b2i})^2}{n}$$

where: σ_x^2 = misregistration error (element direction)
X_{b1i} = element value, first base channel, i^{th} point
X_{b2i} = element value, second base channel, i^{th} point
X_{mi} = element value, first map channel, i^{th} point
n = number of points digitized from all plots

A similar formula exists for the scan line value (σ_y^2, etc.). From these values, RMS errors can be calculated.

III. Data Sources:

Three MSS data sets were used in this study as defined in Table 1.

Table 1: MSS DATA ANALYZED

SATELLITE	DATE	FORMAT
LANDSAT-2	1980	PM
LANDSAT-2	1981	PM
LANDSAT-4	1982	PM

The Landsat-2 1980 data set was used as the base data set throughout the analysis.

IV. Results and Conclusions:

Results of temporal registration of MSS data are presented in Table II.

Table II. RESULTS OF ANALYSIS OF LANDSAT MSS DATA

BASE DATA	PARAMETER OF INTEREST	LANDSAT-2 1981	LANDSAT-4 1982
Landsat-2 1980	Element Error - σ_x^2	20.416 m	40.320 m
	Scan Line Error - σ_y^2	26.701 m	26.951 m
	Registration RMS Error - σ_m^2	33.612 m (74)	48.498 m (65)
	Indicated RMS Error at Time of Mapping Equation Development	34.98 m (67)	39.87 m (69)

An F test to evaluate the null hypothesis

H_o: σ_m^2 (1980/1981) = σ_m^2 (1980/1982) versus the alternate hypothesis.

H_o: σ_m^2 (1980/1981) $\neq$ σ_m^2 (1980/1982)

resulted in F(CALC) = 1.44
F(TAB).01 = 1.41

such that the null hypothesis was rejected in favoe of the alternate hypothesis, i.e., the temporal registrations evaluated were not performed to the same resulting RMS registration error.

It is interesting to note that the 1980/1982 registration resulted in an element error which was nearly twice as large as that obtained in the 1980/1981 registration (40.320 vs. 20.416 meters). This occurred even though the scan line errors were nearly identical (26.951 vs. 26.701 meters).

Subsequent analysis indicates that the large element error encountered in the 1980/1982 temporal registration may be the result of less than adequate modeling of the Landsat-4 MSS scan mirror profile. More precise coefficients have been incorporated into ground processing software and the next MSS-4 data set collected over the study area will be used to test the effectiveness of the new values.