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SPACE SCIENCES LABORATORY

ANALYSIS OF THE QUALITY OF IMAGE DATA ACQUIRED BY THE LANDSAT-4 THEMATIC MAPPER AND MULTISPECTRAL SCANNERS

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TABLE OF CONTENTS

TECHNICAL ABSTRACT

The geometric quality of TM film and digital products was evaluated by making selective photomeasurements and by measuring the coordinates of known features on both the TM products and map products. These paired observations were related using standard linear least squares regression approach. Using regression equations and coefficients developed from 225 (TM film product) and 20 (TM digital product) control points, map coordinates of "test" points were predicted. The residual error vectors and analysis of variance (ANOVA) were performed on the east and north residuals using nine image segments (blocks) as treatments. Based on the root mean square error of the 223 (TM film product) and 22 (TM digital product) test points, we conclude that users of TM data could expect the planimetric accuracy of mapped points to be within 91 meters ($RMSE_x$) and within 117 meters ($RMSE_y$) for the film products, and to be within 12 meters ($RMSE_x$) and within 14 meters ($RMSE_y$) for the digital products. The differences are the result of reduced control-point measurement errors when using the digital product at full resolution as opposed to the manual interpretation and digitizing of control points on the enlarged photo product.

TECHNICAL PROGRESS REPORT

Our research during this quarter focused on (1) completing the geometric analysis of TM film and digital products; (2) initiating the design and production of materials for the TM color composite photo-interpretation materials for photo-interpretation tests; (3) clustering TM data for forest cover type mapping; and (4) inititiating a small-scale evaluation of Landsat-4 TM and MSS data for classifying agricultural fields using both a Bayesian and a contextural algorithm. This latter work has been done in cooperation with Mr. Ralph Bernstein and Dr. Sylvano di Zenzo at the IBM-Palo Alto Scientific Center. Progress on the interpretation tests, clustering, and evaluation of the Bayesian and contextural algorithms will be reported in the next Quarterly Status and Technical Progress Report (#6, 1 April - 30 June 1984).

1.0 GEOMETRIC ANALYSIS OF TM FILM PRODUCTS

1.1 INTRODUCTION

The geometric quality of the TM and MSS film products are being evaluated by making selective photo measurements such as scale, linear, and area determinations; and by measuring the coordinates of known features on both the TM film products and map products, and then relating these paired observations using a standard linear least squares regression approach. The major emphasis of our work is to analyze the TM film products from Landsat-4 that are generally accessible to the user community. There were three types of Landsat-4 film products being generated at the EROS Data Center (EDC) and the Goddard Space Flight Center (GSFC): (1) standard multispectral scanner (MSS) film products, (2) "interim" Thematic Mapper (TM) analytical film products, and (3) LAS-Scrounge TM "engineering" film products. The standard MSS film products are generated at EDC using the CCT-PM digital data with a Laser Beam Recorder (LBR) to produce master film copies for black-and-white and color composite reproduction. The "interim" TM analytical film products were generated at EDC using the return beam vidicon (RBV) image production system to make the first generation working masters during the Scrounge environment and prior to the operational film generation under the TIPS environment. The LAS-Scrounge TM "engineering" film products were generated at GSFC for engineering purposes, archiving, and routing with CCT orders for LIDQA investigators.

The interim TM film products are being used for our analysis because they were the only film products available at the time of our investigation. Originally, film products were to be generated by the LAS-Scrounge during the pre-TIPS environment, but as the demand for these products increased, arrangements were made to have the EDC produce the products using the RBV image production system. Using the CCT-PT data, EDC produced the film masters using the LBR and the supporting computer system formerly dedicated to RBV film production. In order to adapt the TM data to this system, the resulting "interim" TM analytical film product represented only a sub-area of a full TM scene produced under operational conditions (Figure 1.1). The interim TM film product represents approximately 72 percent of the area of a

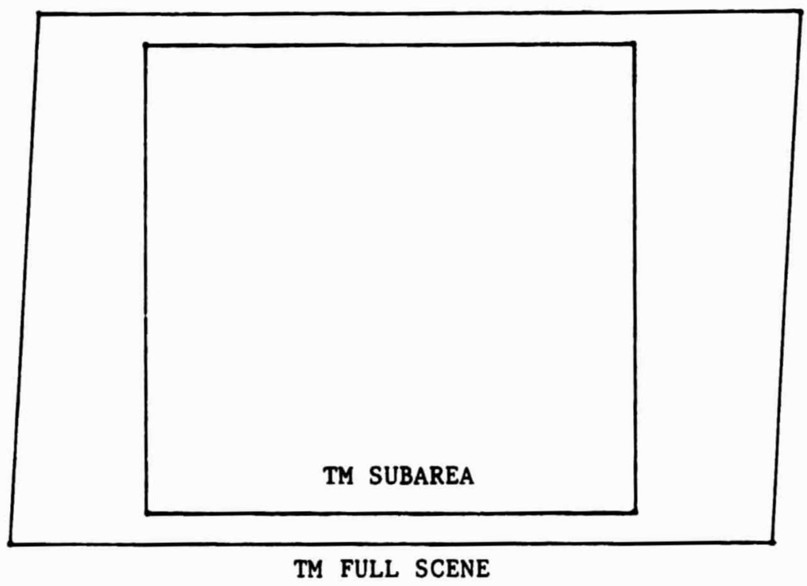

Figure 1.1 Relative size of the interim Thematic Mapper image with respect to the full frame image. A two-time enlargement of an image covering the northern Sacramento Valley, California, was used to evaluate the geometric properties of the Thematic Mapper photo products (Path 44, Row 33).

full TM scene. The format is 5322 x 5322 pixels, centered on the full scene, with a resulting image of 20.2 x 20.2 cm covering a land surface area of approximately 2,300,590 ha. (5,684,760 ac.)

1.2 APPROACH AND RESULTS

A seven-step procedure was used to evaluate the geometric properties of the interim TM film products.

1. Select the image product to be analyzed. A two-times enlargement of interim Band 7 image T0318-007 (Path 044, Row 033) covering the southern Sacramento Valley on 1 February 1983 was selected for this study. This particular scene was selected because (1) it was currently available, (2) with the exception of small portions of the image, it was cloud free, (3) Band 7 provided a sharp, moderate contrast image, and (4) the area covered represented a wide range of land use and elevational zones. The major limitation of using this image was that due to the low sun elevation at the time of image acqusition (26 degrees) many of the steep canyons in the wildland areas in the western and northern portions of the scene were deeply shadowed. We felt that this limitation was outweighed by the facts that (1) the image in its two-time enlarged format was available, and (2) all the small water bodies were at the maximum water levels which would allow for better precision in selecting control points.

2. Grid the image into nine equal area blocks. The TM image was gridded to ensure that the control points would be evenly distributed throughout the photo (Figure 1.2).

3. Select control points. The control points represented those natural and cultural features that could be located reliably on both the TM image and on United States Geological Survey 7½' quadrangle maps. In the agricultural areas, these features were predominantly field intersections or irrigation ditches; in the urban areas they were predominantly major road intersection or airfield runways; in the wildland areas they were water bodies, stream courses, and converging points of ridges and canyons. Each control point was pin-pricked on the image with a corresponding annotation made on the map sheet with a .30mm pen. Initially, 476 control points were selected from 144 map sheets. All of these map sheets fell within the Universal Transverse Mercator (UTM) Zone 10 (Table 1.1).

4. Measure image and map coordinates. The "x" and "y" coordinates of the image control points were measured to the nearest .001 inch using a Talos plane table digitizer. The corresponding UTM east and north map coordinates were scaled off the map sheets to the nearest 10 meters ground distance.

5. Check for image and map coordinate errors. In order to check for digitizing and map scaling errors, a first order regression between map and image coordinates was performed using the program developed by Daniel (1971). For those coordinate pairs for which the residuals were excessive, the digitized and map coordinates were verified, changed where appropriate, or discarded if map or digitizing errors were probable. The final number of control points totaled 448 (Table 1.1).

SCENE T0318-007, PATH 044,ROW 033, 01 FEBRUARY 83

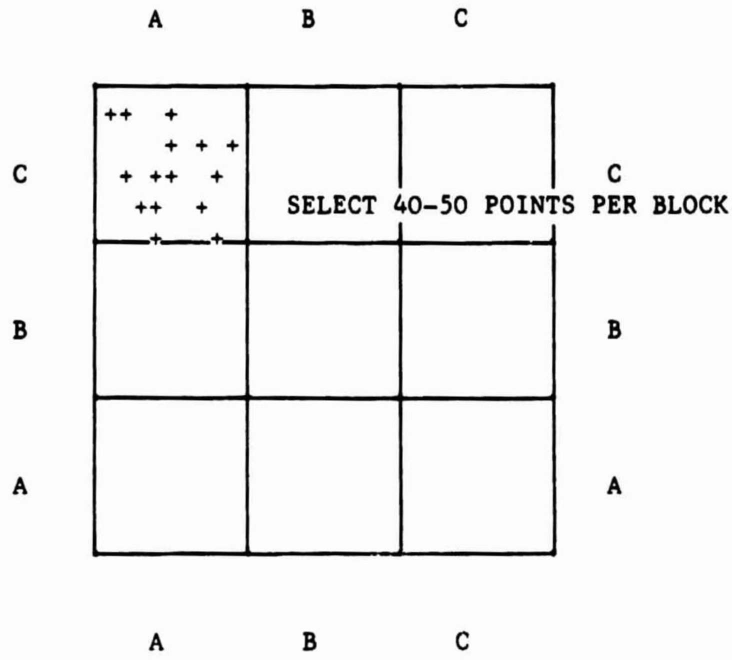

Figure 1.2 Schematic of a the gridded interim TM image. The 5322-by-5322 pixel image was gridded into nine equal area blocks to ensure that the control points would be evenly distributed throughout the image.

Table 1.1 Summary of Control Point Selection for Scene T0318-007 (Path 044, Row 033), 01 February 1983.

BLOCK	CLOUD COVER (%)	ELEVATION RANGE OF POINTS (FEET)	CONTROL POINTS: NUMBER OF REGRESSION POINTS	CONTROL POINTS: NUMBER OF TEST POINTS	GEOGRAPHIC DESCRIPTION	PREDOMINANT LAND USE*
AA	10	14-2080	26	25	Napa Valley; Coast Range	3,1,4
AB	50	5-384	16	17	Coast Range; Sacramento Valley	1,3,4
AC	5	0-391	20	19	Sacramento Valley; Sierra Nevada foothills	1,3,4
BA	15	43-1960	29	28	Coast Range; Sacramento Valley	3,1
BB	0	20-199	24	24	Sacramento Valley	1
BC	0	20-2000	26	27	Sacramento Valley; Sierra Nevada foothills	3,1,4
CA	0	54-1540	32	30	Coast Range; Sacramento Valley	1,3
CB	0	48-1384	24	26	Sacramento Valley; Sierra Nevada foothills	1,3
CC	0	200-3540	28	27	Sierra Nevada foothills and mountains	2,3
			225	223		

* LAND USE CODE (from: Durrenberger and Johnson, 1976.)

1	Cropland and pasture - irrigated or unirrigated
2	Forest and woodland - grazed or ungrazed
3	Open shrub woodland - grazed
4	Urban

6. Develop regression between image and map coordinates. Using the odd numbered control points, first and second order regressions were developed to predict UTM east and north map coordinates from the digitized image coordinates. Four regressions models were examined:

(1) UTM = a+b(x)+c(y)
(2) UTM = a+b(x)+c(y)+f(x*y)
(3) UTM = a+b(x)+c(y)+d(x2)+e(y2)
(4) UTM = a+b(x)+c(y)+d(x2)+e(y2)+f(x*y)

The results of this examination are summarized in Table 1.2. Based on evaluation of the root mean square errors and the range of the residuals, we selected the second order regression (3) to predict the UTM east coordinates, and the first order regression with cross term (2) to predict the UTM north coordinates.

7. Evaluate the geometric properties of the image. Using the regressions selected in 6, the map coordinates of the even numbered control points (test points) were predicted using the corresponding digitized image coordinates. The residual vectors, summarized by blocks, were plotted (Figure 1.3); and an analysis of variance (ANOVA) was performed on the east and north residuals using the nine blocks as treatments (Table 1.3).

The scales associated with each block were calculated by comparing the image area to the ground area based a sample of control points. The respective areas were calculated using the following relationship:

A = Xi[(Yi+1)-(Yi-1)]*(0.5)

where: A = area
X = coordinate value for Talos x or UTM east
Y = coordinate value for Talos y or UTM north, and
i = coordinate number

In addition, a mean scale was calculated for the whole image using this relationship with the resulting scale of 1:375,610. A nominal scale was determined by comparing the image distance (15.929 inches/line) to the ground distance (28.5 meters/pixel x 5322 pixles/line = 374,885 meters/line) with the resulting scale 1:374,885. These results have been summarized in Figure 1.4.

After examining the variability of the scales for the nine blocks, we calculated the scales for 104 line segments distributed throughout the image using the Talos and UTM map coordinates. The resulting scales were plotted at the midpoint of the line segments in order to identify any patterns in the scales (Figure 1.5).

1.3 CONCLUSIONS

Based on an examination of the root mean square error of the residual of 223 test points (Table 1.3) and the distribution of calculated image scales (Figures 1.4 and 1.5), we conclude that there is no systematic image distortion in the Thematic Mapper image that we evaluated. The analysis of variance for the east residuals showed no significant difference between the

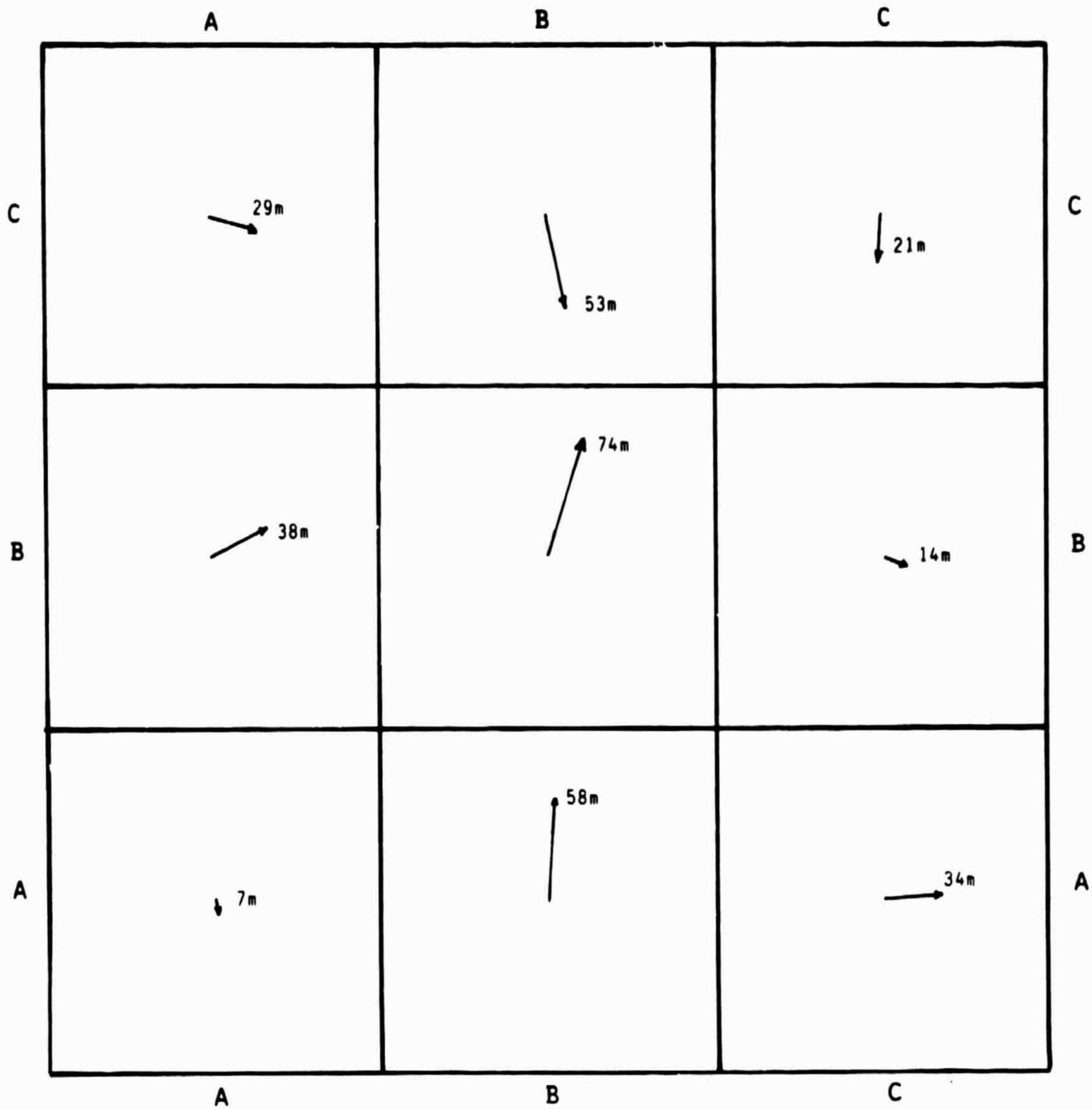

Figure 1.3. Residual vectors, summarized by blocks, of test points located throughout the TM interim image product. These residuals were the result of applying a second order regression and a first order regression with a cross term to Talos x and y tablet digitizer coordinates to predict UTM north and east coordinates, respectively. Notes: (1) the points that were used to develop the two regression equations were not used as test points, and (2) the residual vectors are not drawn to scale with respect to the interim TM image.

Table 1.2. Summary of root mean square errors for four regressions to predict UTM east and UTM north from 225 digitized observations taken from a two-times enlargement of an interim TM print.

Regression	Residual Root Mean Square (meters)	F-Value	Range of Residuals (meters east)	t-Values* for Coefficients of: x	y	x2	y2	xy
<u>UTM EAST</u>								
a+b(x)+c(y)	120.90	1.621E7	-289 to 284	5567	1012			
a+b(x)+c(y)+f(x*y)	120.76	1.083E7	-287 to 279	1885	447			1.2
a+b(x)+c(y)+d(x2)+e(y2)	76.17	2.043E7	-308 to 241	1694	267	18	4.1	
a+b(x)+c(y)+d(x2)+ e(y2)+f(x*y)	75.46	1.665E7	-312 to 244	1481	248	18	4.0	2.3
<u>UTM NORTH</u>								
a+b(x)+c(y)	156.97	7.990E6	-420 to 369	846	3932			
a+b(x)+c(y)+f(x*y)	117.62	9.487E6	-525 to 283	369	2297			13
a+b(x)+c(y)+d(x2)+e(y2)	155.55	4.068E6	-402 to 422	164	667	1.7	1.8	
a+b(x)+c(y)+d(x2)+ e(y2)+f(x*y)	112.94	6.173E6	-508 to 347	188	839	2.9	3.6	14

* If the calculated t-values exceed 1.645, the coefficients are significantly greater than zero. Note that the relative magnitude of the t-values associated with the "x" and "y" coefficients is meaningless. This relationship is a function of how the TM image was oriented with respect to the x-y grid of the Talos digitizing tablet; there is no relationship to the image's orientation with respect to true north.

Table 1.3. Summary of analysis of performed on the mean residuals of the test points.

UTM EAST SUMMARY

Regression Equation: UTM East = a+b(x)+c(y)+d(x2)+e(y2)

BLOCK	NUMBER OF OBSERVATIONS	RANGE OF RESIDUALS (METERS EAST)	MEAN RESIDUAL (METERS)	ROOT MEAN SQUARE OF RESIDUALS (METERS)
AA	25	-189 to 201	1.007	112
AB	17	-109 to 222	4.249	76
AC	19	-47 to 148	33.659	58
BA	28	-250 to 219	32.840	106
BB	24	-59 to 180	22.848	60
BC	27	-419 to 186	13.227	111
CA	30	-175 to 159	29.522	70
CB	26	-214 to 181	10.082	94
CC	27	-350 to 147	[illegible]	101
TOTAL	223		MEAN = 16.079	MEAN = 91

ANALYSIS OF VARIANCE FOR MEAN RESIDUALS

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F-VALUE
TREATMENT	40647.554	8	5080.944	.616
ERROR	1763883.875	214	8242.448	
TOTAL	1804531.430	222		

Table 1.3.(concluded) Summary of analysis of variance performed on the mean residuals of the test points.

UTM NORTH SUMMARY
Regression Equation: UTM North = a+b(x)+c(y)+f(x*y)

BLOCK	NUMBER OF OBSERVATIONS	RANGE OF RESIDUALS (METERS NORTH)	MEAN RESIDUAL (METERS)	ROOT MEAN SQUARE OF RESIDUALS (METERS)
AA	25	-270 to 118	-6.498	87
AB	17	-69 to 177	57.556	89
AC	19	-130 to 187	1.942	86
BA	28	-260 to 365	18.532	140
BB	24	-100 to 239	70.359	104
BC	27	-303 to 333	-3.917	120
CA	30	-468 to 257	-6.415	124
CB	26	-438 to 246	-51.792	156
CC	27	-261 to 166	-20.689	101
TOTAL	223		MEAN = 3.830	MEAN = 117

ANALYSIS OF VARIANCE FOR MEAN RESIDUALS

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F-VALUE
TREATMENT	265522.637	8	33190.330	2.565*
ERROR	2769099.374	214	12939.717	
TOTAL	3034622.011	222		

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* Although this F-value is significant at .95, no significant differences could be determined using either the Duncan's new multiple range test or the Scheffé test for possible contrasts.

SCENE T0318-007, PATH 044,ROW 033, 01 FEBRUARY 83

	A	B	C	
C	(-1.16) $\frac{1}{371,252}$	(-1.74) $\frac{1}{369,088}$	(+0.21) $\frac{1}{376,411}$	C
B	(-0.95) $\frac{1}{372,056}$	(-0.41) $\frac{1}{374,083}$	(-0.18) $\frac{1}{374,924}$	B
A	(-0.15) $\frac{1}{375,048}$	(+0.12) $\frac{1}{376,074}$	(-0.15) $\frac{1}{375,057}$	A
	A	B	C	

$$\text{CALCULATED MEAN SCALE} = \frac{1}{375,610}$$

$$\text{NOMINAL SCALE} = \frac{15.929 \text{ inches/line}}{28.5 \text{ meters/pixel} \times 5322 \text{ pixels/line}}$$

$$= \frac{1}{374,885}$$

Figure 1.4. Calculated scales and percent departures () from the mean scale for the nine blocks on TM Scene T0318-007. These scales, and the overall scene scale, were calculated based on the UTM and digitized points selected for the regression analysis described in the text. The nominal scale was calculated on the relationship of the digitized photo distance along the "x" axis (15.929 inches) to the expected ground distance (28.5 meters/pixel x 5322 pixels/line).

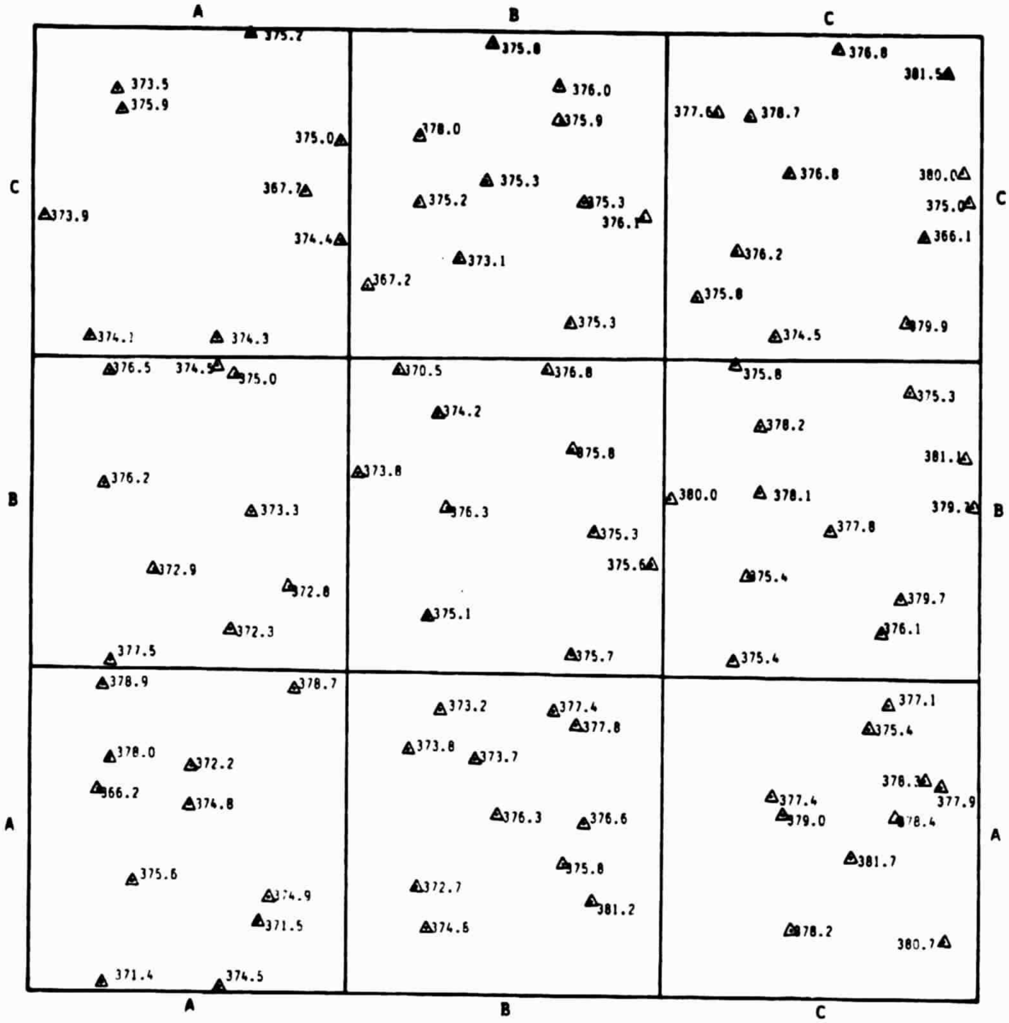

Figure 1.5. Calculated scales (in thousands) for 104 segments midpoints distributed throughout the interim TM image. Because no reasonable isolines could be drawn for these points, we concluded that there was no systematic distortion in the image.

blocks, and although a significant F value was calculated for the north residuals, no significant difference could be extracted from the data using either the Scheffé least square difference test or the Duncan's new multiple range test.

By examining the distribution of the scales calculated for individual blocks (Figure 1.4) or of those for the 104 line segments (Figure 1.5) it becomes evident that the changes in scale that occur throughout this image are random. The most probable causes of this variability in scale is digitizing and/or mapping errors. There does not appear to be any significant effect on scale as a result of elevation differences. For example, for those areas in which the highest ground elevations occur are often associated with the smallest scales such as in the northeastern corner of block CC which a mean elevation of 3,000 feet, and some of the largest scales such as the central portion of block BB which has a mean elevation of 20 feet, has some of the larger scales.

Finally, we would conclude that the user of this image product could expect that the accuracy of mapped points would be within 91 meters ground distance in the easterly direction and within 117 meters in the northerly direction based on the root mean square value for the residuals. This represents .010 mm and .012 mm, respectively, on the interim image product based on the scale calculated from the test coordinates.

1.4 LITERATURE CITED

Daniel, Cuthbert and Fred S. Wood, 1971. Fitting equations to data. Wiley-Interscience, New York.

Durrenberger, Robert W. and Robert B. Johnson, 1976. California - patterns on the land. Fifth edition. Mayfield Publishing Company.

2.0 GEOMETRIC ANALYSIS OF THEMATIC MAPPER DIGITAL DATA

2.1 INTRODUCTION

The analysis of the geometric properties of digital Thematic Mapper data has not been a major emphasis of our research at the Remote Sensing Research Program. We have had to examine this aspect of the TM products, however, in order that we could accurately extract test sites from the magnetic tapes, from which we will produce image products for interpretation testing. In addition, other research projects being conducted here, have required that we look at these properties for the purposes of constructing geographic informations systems which include TM digital data. The following paragraphs describe the results of this research which are being conducted in our forestry study site.

The 100,000 hectare forestry study site is located in Plumas County, California, approximately 265 km northeast of San Francisco, and lies in an elevational zone of 1000 to 2400 meters. This area contains a diversity of forest cover types ranging from pure stands of red and white fir (<u>Abies magnifica</u> and <u>A. concolor</u>, respectively) to mixed stands dominated by ponderosa pine (<u>Pinus ponderosa</u>). Douglas-fir (<u>Pseudotsuga menziesii</u>), and/or sugar pine(<u>P. lambertiana</u>). Several other cover types are prevalent which include low density Jeffrey pine (*P. jeffreyi*) stands on soils derived from ultramafic parent material; hardwood stands; dense shrub fields; wet and dry meadows; bare soil; granitic rock outcrops; and large water bodies.

2.2 APPROACH

A six step procedure was used to evaluate the geometric properties of the digital Thematic Mapper data.

1. Select TM coverage for study site. The first summer season Landsat-4 scene that covered the forestry study site was acquired on 12 August 1983 (#84039218143, WRS Path 44, Row 32). These data were transmitted to Goddard Space Flight Center (GSFC) via the Tracking and Data Relay Satellite System and the receiving station at White Sands, New Mexico. The TM data were processed by the Thematic Mapper Image Processing System (TIPS) at GSFC as a "P" tape.

2. Extract area of interest. Using the RSRP interactive image processing system, a 1200-by-1200 pixel sub area which covered the forestry study site was extracted from the "P" tape.

3. Select control points. These points represented those natural and cultural features that could be located reliably on both the digital display of the TM data on the RSRP image processing system and on one 7½ minute orthophoto quadrangle in the study site. A total of 42 points were allocated evenly throughout the quadrangle. The TM point and line pair counts and their respective UTM east and north coordinates were recorded for subsequent analysis.

4. Check for control point errors. In order to check for errors that might have occurred coordinate extraction from either the displayed image and/or the orthophoto quadrangle, a first order regression was used to predict UTM east and north coordinates from TM point and line counts. If the resulting residual was excessive (greater than 30 meters), the respective coordinate pairs were checked on both the map and on the image display.

5. Develop regressions between point-line coordinate pairs and UTM east-north coordinate pairs. Using 20 of the control points, first and second order regressions were developed to predict UTM east and north map

coordinates from the point and line counts. Four regression models were examined:

(1) UTM = a+b(P)+c(L)
(2) UTM = a+b(P)+c(L)+f(P*L)
(3) UTM = a+b(P)+c(L)+d(P2)+e(L2)
(4) UTM = a+b(P)+c(L)+d(P2)+e(L2)+f(P*L)

where:
P = point coordinate
L = line coordinate
P2 = point coordinate squared
L2 = line coordinate squared

6. Evaluate the geometric properties of the digital data. By applying the optimum regression equation, the geometric properties of the digital data were evaluated using based on the remaining 22 control, or test, points.

2.3 RESULTS AND DISCUSSION

A summary of the four regression models that were examined is presented in Table 2.1. By examining the four statistical measures of goodness of fit of the regression, we concluded that for an area as small as one 7½ minute quadrangle, a first order regression with no cross terms was superior. This model produced (1) the lowest residual root mean square, (2) the highest F-value, (3) the narrowest range of residuals, and (4) regression coefficients that were significantly greater than zero. The resulting model that was tested took the following form:

UTM EAST = 652567+28.1675(P)-4.78209(L)
UTM NORTH = 436319-4.7076(P)-28.088(L)

The statistical results obtained by applying these regression models to the 22 test points are summarized in Table 2.2. and plotted in Figure 2.1. The mean deviation represents the average direction of geometric and plotting errors; the root mean square deviation represents the average magnitude of these errors. This latter value can be compared with those calculated for the original regression. Interestingly, the RMS for the test-point eastings was less than those for the regression-point eastings; whereas the RMS for the test-point northings exceeded those for the regression-point northings. While this paradox was unexpected, it was further confirmed by the small range of residuals associated with the east test points when compared to the regression points, and by the larger range associated by the north test points when compared to the regression-point range. We concluded that the regression did a good job predicting the test points because the calculated mean deviations for east (+0.896 meters) and north (-0.835 meters) were not significantly different than zero, which is, by definition, the expected value of the regression model. Based on these analyses, we concluded that by using a first order regression and sufficient control points, we can predict the map position of a TM pixel within 12 meters east and 14 meters north. In addition, we conclude that for geographic areas as small as a 7½ quadrangle, the addition of second order or cross term coefficients does not significantly add to the predictive power of the regression.

Table 2.1. Summary of root mean square errors for four regressions using Thematic Mapper digital point (P) and line (L) counts to predict UTM east and UTM north. These regressions were based on 20 observations located throughout one 7½ minute quadrangle.

Regression	Residual Root Mean Square (meters)	F-Value	Range of Residuals (meters east)	t-Values* for Coefficients of: P	L	P2	L2	P*L
UTM EAST								
a+b(P)+c(L)**	16.38	3.186E5	-32 to 28	786	182			
a+b(P)+c(L)+f(P*L)	16.81	2.017E5	-31 to 30	261	36			.37
a+b(P)+c(L)+d(P2)+e(L2)	16.93	1.492E5	-28 to 35	77	29	.95	.11	
a+b(P)+c(L)+d(P2)+ e(L2)+f(P*L)	17.52	1.114E5	-28 to 35	73	20			
UTM NORTH								
a+b(P)+c(L)**	9.92	1.614E6	-15 to 17	217	1768			
a+b(P)+c(L)+f(P*L)	10.04	1.051E6	-15 to 18	72	352			.78
a+b(P)+c(L)+d(P2)+e(L2)	10.31	7.468E5	-14 to 16	21	281	.61	.59	
a+b(P)+c(L)+d(P2)+ e(L2)+f(P*L)	10.28	6.007E5	-13 to 17	21	201	.97	.50	1.04

* If the calculated t-value exceeds 1.734, the coefficient is significantly greater than zero at the .95 probability level.

** Regressions selected for testing:

UTM EAST = 652567+28.167(P)-4.78209(L)

UTM NORTH = 436319-4.7076(P)-28.088(L)

Table 2.2 Summary of error analysis of 22 test points using first order regressions to predict UTM east and north from Thematic Mapper digital point (P) and line (L) counts. The regression coefficients were calculated from 20 observations that were distributed, along with the test points, throughout a 7½ minute quadrangle.

REGRESSION EQUATION TESTED	RANGE OF RESIDUALS (METERS)	MEAN DEVIATION (METERS)*	ROOT MEAN SQUARE DEVIATION (METERS)**
UTM EAST = 652567+28.1675(P)-4.78209(L)	-23 to 21	+0.896	12.0
UTM NORTH = 436319-4.7076(P)-28.088(L)	-28 to 27	-0.835	13.7

* The mean deviation represents the average direction of geometric errors. This value can be calculated only from test points, because, by definition, the sum of the deviations from the points used to develop the regression coefficients must equal zero.

** The root mean square deviation represents the average magnitude of geometric errors without respect to direction of those errors.

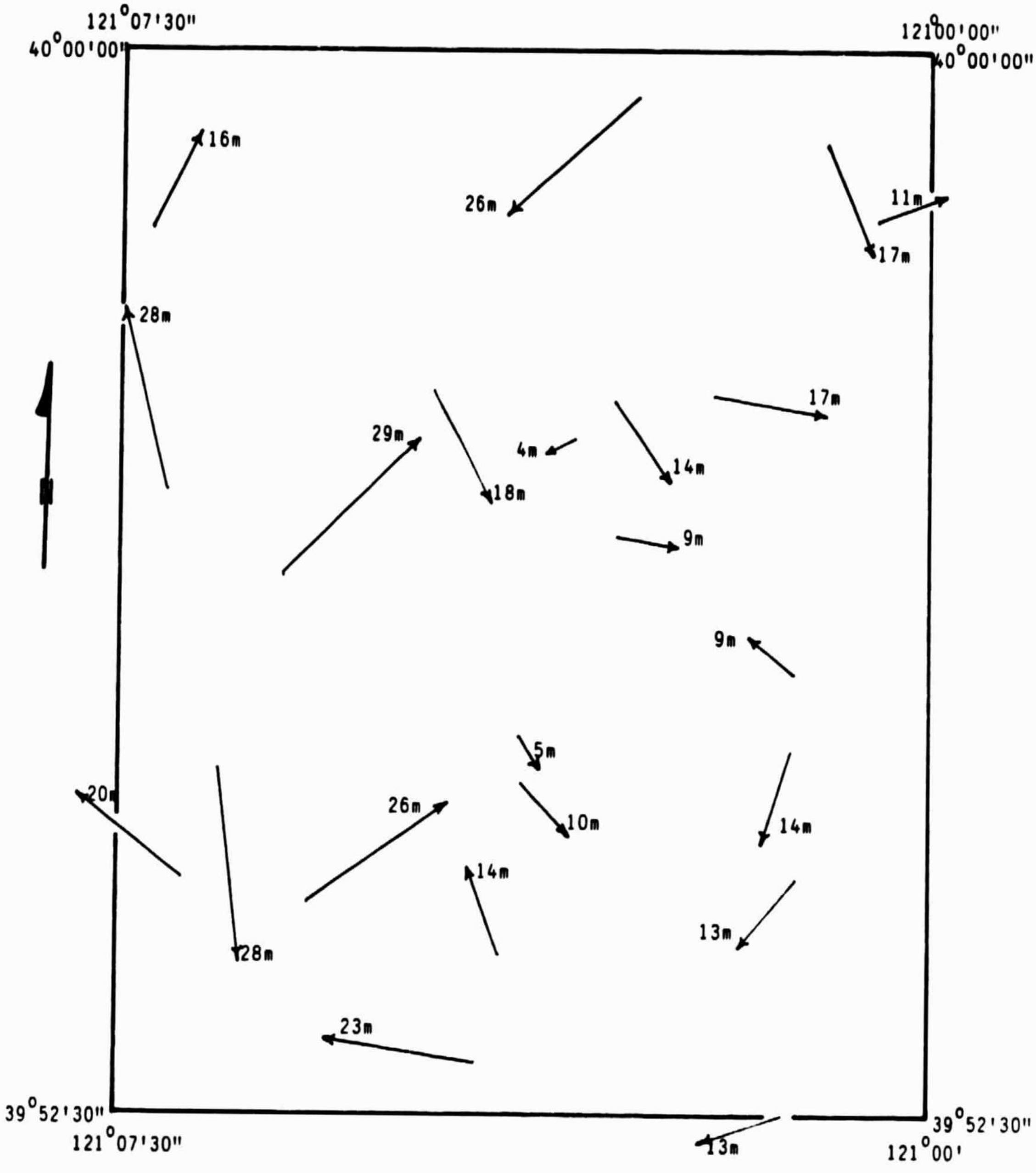

Figure 2.1. Residual vectors for 22 test points. These vectors were calculated by applying first order regressions determined from 20 control points located throughout a 7½ minute quadrangle. Note: the residual vectors are not drawn to scale with respect to the 7½ minute quadrangle.

3.0 PUBLICATIONS AND PRESENTATIONS

The following presentations related to the LIDQA investigations were made during this reporting period.

Landsat-D' Launch User Symposium, Santa Barbara, California. 28 February - 1 March 1984.

Visitor's Seminar

Dr. Sergio Vetrella
Prof. Ing.
University of Naples
Naples, Italy

Mr. Sit Bo
Department of Forestry
Rangoon, Burma

4.0 FUNDS EXPENDED TO DATE

The funds expended to 31 March 1984 under this contract are summarized on NASA Form 533M, "Monthly Contractor Financial Management Report", dated 26 April 1984.

5.0 PROBLEMS ENCOUNTERED TO DATE

Specific problem areas for this reporting period are discussed in the January, February, and March monthly reports submitted to Mr. Darrel Williams, Code 923, NASA-Goddard Space Flight Center.

DISTRIBUTION LIST

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