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TITLE

INVESTIGATION OF

LANDSAT D THEMATIC MAPPER

GEOMETRIC PERFORMANCE :

LINE TO LINE AND BAND TO BAND REGISTRATION

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Our objectives in that study were to test LANDSAT D Thematic Mapper geometric accuracy and more precisely line to line and band to band registration problems.

This analysis has been performed on three digital images :

— Landsat TM raw data of TOULOUSE (France)
(scene 198/30 of 23 January 1983) (*)

— Landsat TM raw data of MISSISSIPI (A-type)

— Landsat TM preprocessed data of MISSISSIPI (P-type).

Our investigation has been performed on the CNES CDC Computer. Analog images have been restituted on the VIZIR SEP device.

All digital images have been copied from the Landsat format (two tapes for raw data, three tapes for preprocessed data) to the CNES standard format (one tape for each spectral band).

This preprocessing has no effects on the geometric or radiometric qualities of the original images.

The methods we used for these two studies (line to line and band to band registration) are based on automatic correlation techniques and widely used in automated image to image registration purpose in CNES.

Let us now give a brief description of the methodology we implemented :

Initially we planned to test band to band registration looking at the best matching between two identical zones in two different bands : after translating the first zone in both x and y directions (u for x direction, and v for y direction), we can compute a similarity coefficient R (u,v). Then the translation for which that coefficient is maximum define the best matching between the two bands for that particular zone (we can note that interpolation techniques allow a 1/10 pixel accuracy .

(*) This raw image have been preprocessed in order to adjust forward and reverse scans.

We have yet studied only the x direction (rows) translation so we only have a 1D similarity coefficient.

In the case of intraband line to line registration, since we compare radiometric data for two contignous lines in the same band, the method we use is roughly the same.

If necessary, a filtering process can be previously applied to radiometric data in the band to band registration case in order to get rid of the possible contrast inversion problem.

Previous studies show that the best similarity coefficient R (u,v) is the classical correlation function.

Before we go on we must note here an radiometric anomaly we detected on Toulouse image : Band 1 and Band 2 detectors restitute saturated radiometries over the snow cover in the pyrenees mountains. In the same bands an hysteresis effect (slow recovery from saturation) produces striping anomalies with important variations between forward and reverse scans. This fact will be investigated more in details in a further investigation.

I. METHODOLOGY DETAILED DESCRIPTION

As we are processing on the line by line basis (intraband line to line registration, or interband registration for one given line), in all cases we shall have to test the best fit from one line to another.

Our problem will then be to store up the existing pixel offsets from one line to the following one. In order to achieve that, we first isolate the two concerned lines (the two contiguous consecutive lines in the case of line to line misregistrations estimation, the two corresponding lines in each band in the band to band misregistration estimation).

We divide these two lines in nine overlapping equally distributed segments (1025 pixels long).

Let us call IP et IP1 the two integer arrays representing the two lines, then an example of the nine segment pairs is given below :

IP (105) ..... IP (1129)
IP1 (105) ..... IP (1129)

IP (722) ..... IP (1746)
IP1 (722) IP1 (1746)

IP (1339)..... IP (2363)
IP1 (1339)..... IP1 (2363)

IP (1956)..... IP (2980)
IP1 (1956)..... IP1 (2980)

IP (2573)..... IP (3597)
IP1 (2573)..... IP1 (3597)

IP (3190)..... IP (4214)
IP1 (3190)..... IP1 (4214)

IP (3807)..... IP (4831)
IP1 (3807)..... IP1 (4831)

IP (4424)..... IP (5448)
IP1 (4424)..... IP1 (5448)

IP (5041)..... IP (6065)
IP1 (5041)..... IP1 (6065)

This choice will permit to estimate the various misregistrations all along one line.

For each such segments pair (let us call them X and Y arrays, each consisting of 1025 pixels), we carry out the following process.

The basic idea is to choose a 512 pixel segment centered in the midst of Y(1025) and to shift that 512 pixels segment in a Nc pixel long segment (Nc $>$ 512) centered in the midst of X(1025).

We compute then, the Nc-512 correlation function values between the two 512 pixels segments.

For example, if we choose N_C = 652, we are then able to show off a misregistration up to $\pm$ 70 pixels (because 652 - 512 = 140).

See Fig. 1

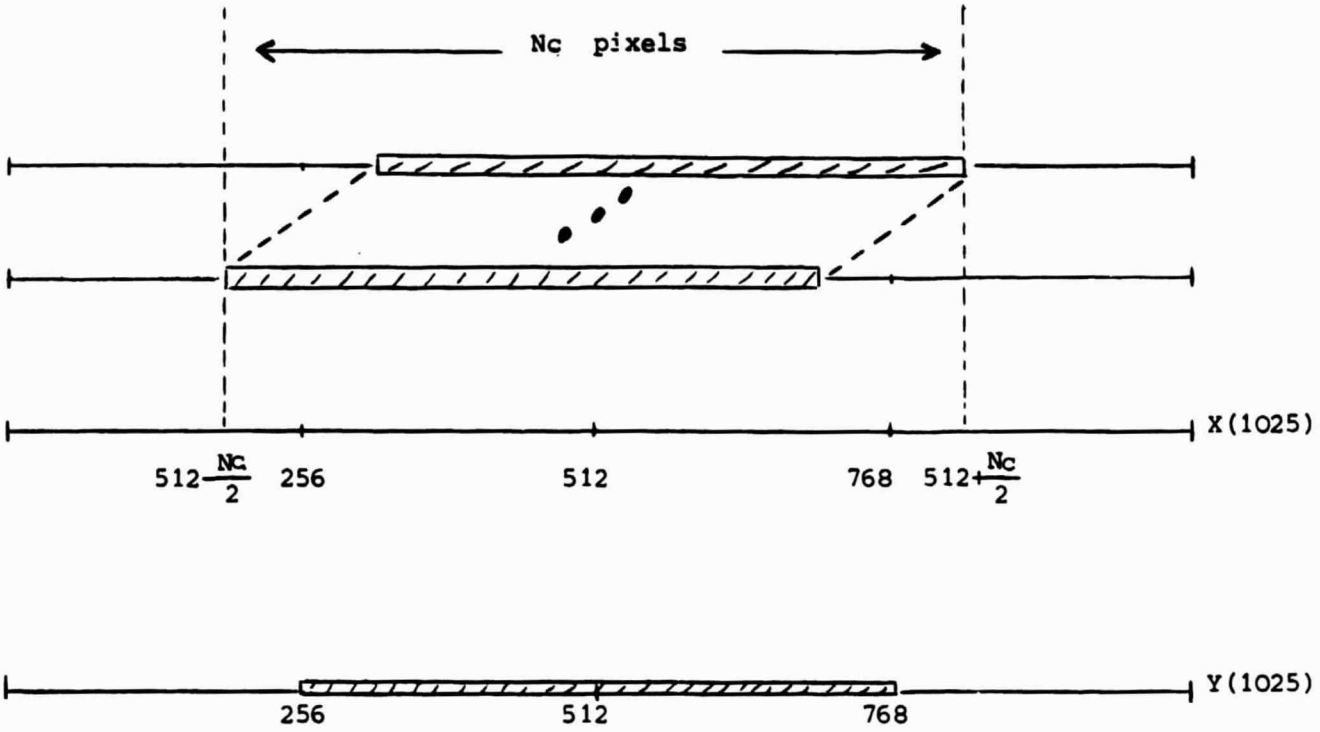

FIG. 1 - SUBSETS OF X AND Y ARRAYS CONTRIBUTING TO THE COMPUTED CORRELATION FUNCTION.

We estimate then the correlation function between the two segments X and Y by computing this function between the 512 pixels window centered in Y and the all possible 512 pixels window (unitary pixel shifts !) in the Nc pixel window centered in X.

The mathematic expression of that function is

$$R(l) = \frac{\sum_{i=256}^{768} (Y(i) - \bar{Y}) * (X(i+l) - \bar{X}_l}{\left(\sum_{i=256}^{768} (Y(i) - \bar{Y})^2 * \sum_{i=256}^{768} (X(i+l) - \bar{X}_l)^2 \right)^{1/2}}$$

With

$$\bar{Y} = \frac{1}{512} \sum_{i=256}^{768} Y(i)$$

$$\bar{X}_l = \frac{1}{512} \sum_{i=256}^{768} X(i+l)$$

And $l = -\left(\frac{Nc - 512}{2}\right) \ldots\ldots + \left(\frac{Nc - 512}{2}\right)$

We then look for the maximum of that function

See FIG. 2

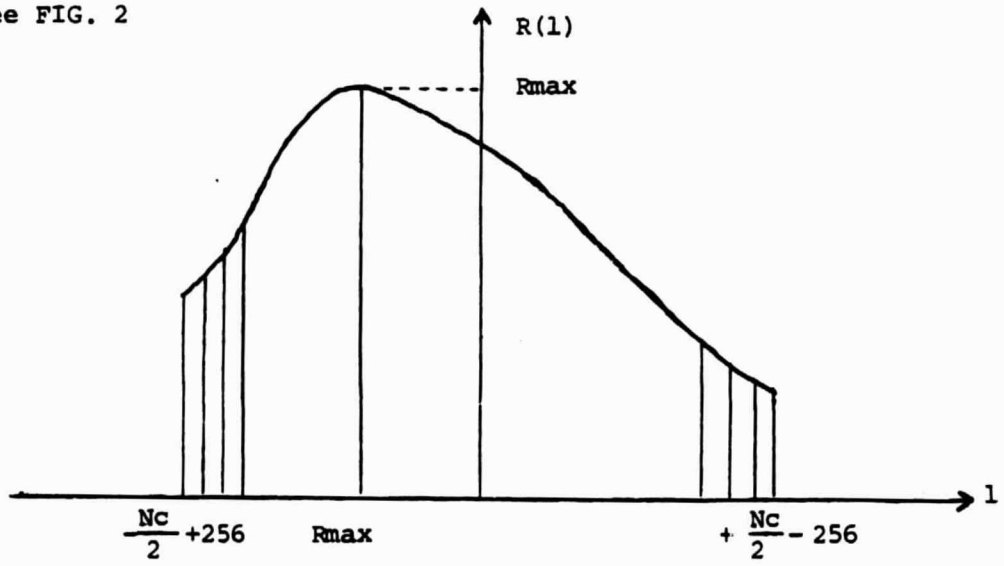

FIG. 2 - CORRELATION FUNCTION R(1)

Rmax, the value of the correlation function for the l_{max} discrete translation value of the X window with regard to the Y window, for which that function is maximum, represents the line to line misregistration in this particular line area, with a one pixel accuracy.

In order to obtain a 1/10 pixel accuracy (except for the band 6 for which the accuracy will be four times less), we implemented Lagrange Polynomial interpolation techniques (See FIG. 3).

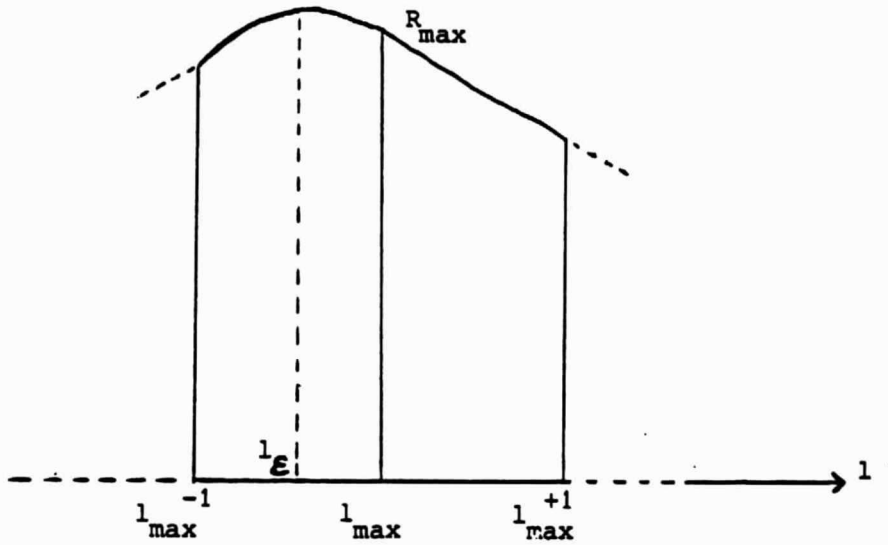

FIG. 3 - AROUND MAXIMUM R_{MAX} INTERPOLATION

Let us now consider the following non discrete values of l

$$l\gamma = l_{max} + \gamma \pm \frac{1}{20} \quad \text{with } \gamma = -20, -19, \ldots, 19, 20$$

Then we look for l_ε for which R(l) is maximum.

The value of the misregistration between X and Y windows, expressed in a decimal number of pixels is then :

$$l\varepsilon = l_{max} + \varepsilon \pm \frac{1}{20}$$

with a 1/10 pixel accuracy.

In order to check the validity of the announced 1/10 pixel accuracy of the previous result, we applied our method in the following conditions :

— On one hand, to an aerial image (1m x 1m spatial resolution) without interpolation techniques and we measured a set of line to line misregistrations.

— On the other hand, to the same preprocessed image (aerial image being divided in 10 x 10 pixels contiguous windows, we replaced each window by the average grey tone) and than using the described methodology with Lagrange interpolation technique.

Almost in all cases we obtained the same misregistration measure, validating our 1/10 pixel accuracy assertion.

II. RESULTS

We applied our process in the two cases of intraband and interband misregistrations evaluation.

Independently of jitter, satellite vibrations ..., many technical reasons can lead to misregistrations :

— detectors of bands 1 to 4 in one focal plane and detectors of bands 5 to 7 in another one ;

— forward and reverse scans are active ones ;

— scan mirror profile and its compass and length ;

— interval between the 16 detectors of each band (4 for band 6) and interval between odd and even detectors for one given band.

In each case, we shall try to find out the existing correlations if any between computed misregistrations values and the above technical realities.

Let us remember some of the designed TM registration specifications for the band to band registration in the P-type digital images :

Bands 1 to 4 : within 0.2 pixel
Bands 1 to 4 to band 5 : within 0.3 pixel
Band 6 to band 5 and 7 : within 0.2 pixel of band 6
(0.8 band 5 or 7 pixel).

II.1 INTRABAND MISREGISTRATIONS

First, we looked for line to line misregistrations in the case of the contiguous lines in one given band, the first line belonging to a forward scan, the second one belonging to a reverse one.

FIGURE 4 shows the misregistrations we computed on Band 1 of A-type MISSISSIPI image (both left and right for two contiguous lines of the previously described type).

FIGURE 5 shows the left and right misregistrations in raw MISSISSIPI imagery.

FIGURE 6 shows the left and right misregistrations in preprocessed MISSISSIPI imagery.

FIGURE 7 shows the left and right misregistrations in raw TOULOUSE imagery.

(Note that all misregistrations even for band 6 are expressed in a 30m x 30m pixel size).

FIGURE 8 shows the misregistration along one line in raw MISSISSIPI imagery, from the left to the right side for band 1.

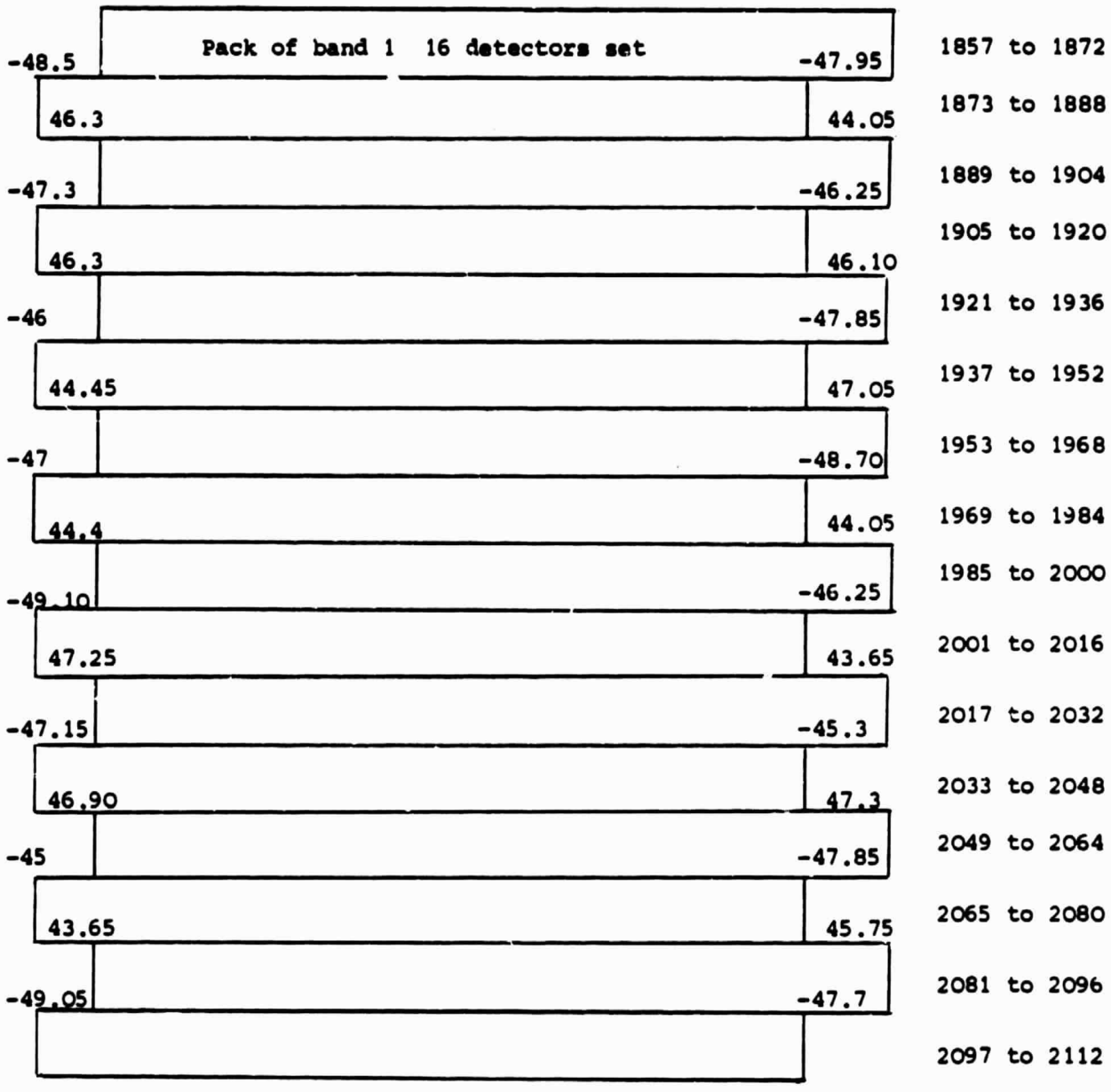

FIG. 4 - 16 CASES OF FORWARD, REVERSE INTRABAND

SCANS FOR BAND 1 OF RAW MISSISSIPI IMAGE

BAND	1		2		3		4		5		6		7	
LINES	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
1872-1873	-48.50	-47.95	-48.4	-48.1	-48.4	-48.05	-48.25	-48.15	-48.5	-47.7	-40.1	-43.8	-48.10	-47.8
1888-1889	46.3	44.05	46.6	44.3	46.4	44.20	46.45	44.25	46.7	44.15	40.1	39.85	46.85	44.3
1904-1905	-47.3	-46.25	-48.05	-46.2	-48	-46.2	-48.25	-46.05	-47.85	-45.9	-43.75	-40	-47.85	-45.95
1920-1921	46.3	46.10	47.1	46	47.05	45.9	47	45.95	47.2	45.9	40.3	39.9	47.40	46.05
1936-1937	-46	-47.85	-46.1	-47.2	-46.10	-47.15	-46.1	-47.3	-45.75	-46.85	-39.9	-40.1	-45.85	-46.95
1952-1953	44.45	47.05	44.70	47.15	44.60	47.05	44.9	47.15	44.8	47.10	40	40.15	44.85	47.25
1968-1969	-47	-48.7	-47.05	-48.90	-47.10	-48.8	-47.20	-48.8	-46.8	-48.4	-40	-40.30	-46.90	-48.6
1984-1985	44.40	44.05	44.75	44.05	44.7	43.95	45.05	44.05	45.	43.9	39.95	38.1	44.95	44.05
2000-2001	49.10	-46.25	-49.15	-46.15	-49.15	-46.05	-49.3	-46.10	-49.05	-45.5	-43.95	-40.05	-49.1	-45.70
2016-2017	47.25	43.65	47.60	44	47.45	43.9	47.4	44.	47.55	44	40.15	39.8	47.7	44.10
2032-2033	-47.15	-45.30	-47.35	-45.60	-47.4	-45.6	-47.6	-45.55	-47.10	-45.15	-40.05	-39.95	-47.2	-45.80
2048-2049	46.90	47.3	46.9	47.25	46.85	47.15	46.9	47.35	46.9	47.05	43.9	40.1	47.1	47.25
2064-2065	-45	-47.85	-45	-48.20	-44.95	-48.15	-45.3	-48.6	-44.85	-47.95	-36.05	-40.2	-44.85	-48
2080-2081	43.65	45.75	44.1	45.95	44	43.85	44.15	45.95	44.10	45.7	39.95	40	44.15	45.95
2096-2097	-49.05	-47.7	-49	-48	-49	-48	-49	-48	-48.75	-47.6	-40.10	-40.2	-48.80	-47.75

FIG. 5 - 16 CASES OF FORWARD, REVERSE INTRABAND SCANS FOR RAW MISSISSIPI IMAGE

BANDS	1		2		3		4		5		6		7	
LINES	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
1872-1873	0.05	0.05	-0.05	0.1	-0.15	-0.05	0.	-0.05	-0.15	0.	0.	0.	-0.3	-0.05
1888-1889	0.	-0.15	0.	-0.1	-0.05	-0.1	-0.1	-0.10	-0.05	0.10	0.	0.	-0.05	-0.1
1904-1905	0.	0.15	-0.05	0.05	-0.05	0.1	0.2	0.10	0.05	0.15	0.	0.05	-0.05	0.1
1920-1921	0.	0.15	0.	0.15	-0.05	0.2	-0.2	0.05	-0.05	0.	0.	0.1	0.	0.15
1936-1937	-0.05	0.	-0.05	0.	-0.05	0.	0.15	0.05	-0.05	0.05	0.	-0.05	-0.05	-0.05
1952-1953	0.05	0.05	0.05	0.	0.	0.	0.1	0.10	0.1	0.25	0.	0.2	0.	-0.1
1968-1969	0.	0.2	0.	0.10	0.	0.05	-0.05	0.05	-0.05	0.	0.	0.	0.	0.15
1984-1985	0.	-0.05	0.	0.	0.	-0.05	0.2	0.	0.15	-0.05	0.	0.15	0.	-0.05
2000-2001	0.	0.45	0.	0.20	0.	0.35	0.2	-0.1	-0.1	0.15	0.	0.	0.05	0.25
2016-2017	0.	0.1	0.	0.1	0.	0.05	0.2	0.05	0.25	0.15	0.	0.05	-0.05	-0.10
2032-2033	0.	-0.1	0.05	0.	0.	-0.1	0.1	0.	-0.15	0.	0.	0.05	0.	-0.05
2048-2049	0.	-0.15	0.	0.05	0.	-0.1	0.05	-0.1	0.	0.1	0.	0.05	-0.05	0.
2064-2065	0.	0.2	0.05	0.15	0.05	0.1	0.05	-0.05	0.05	0.	0.	0.05	0.15	0.05
2080-2081	0.	0.	0.	0.	0.	0.	0.10	0.05	0.05	0.05	0.	0.05	0.	-0.05
2096-2097	0.	0.35	0.	0.2	0.	0.20	-0.10	0.1	-0.05	0.	0.	0.	0.	0.1

FIG. 6 - 16 CASES OF FORWARD, REVERSE INTRABAND SCANS FOR PREPROCESSED MISSISSIPI IMAGE

BANDS	1		2		3		4		5		6		7	
LINES	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
4352-4353	0.25	0.35	0.3	0.25	0.4	0.35	0.55	0.65	0.35	0.85			0.10	0.40
4368-4369	0.05	0.	0.2	0.	0.15	0.05	0.20	0.15	0.1	0.15			0.10	0.20
4384-4385	0.	0.65	-0.1	0.4	-0.05	0.40	0.	0.6	0.	0.75			-0.05	0.20
4400-4401	0.	0.1	-0.05	0.25	-0.05	0.20	-0.05	0.25	-0.05	0.15			0.1	0.25
4416-4417	0.	0.25	0.	0.20	0.05	0.35	0.10	0.35	0.35	0.65			0.2	0.20
4432-4433	-0.05	0.10	0.05	0.25	0.	0.20	0.05	0.70	0.	0.35			0.1	0.55
4448-4449	0.05	-0.10	0.	0.10	0.05	0.15	0.10	0.25	0.20	0.85			0.05	0.20
4464-4465	-0.1	-0.2	0.	-0.05	-0.05	-0.05	0.	0.	0.05	0.10			0.05	0.20
4480-4481	0.1	0.85	0.2	0.9	0.8	0.95	0.85	0.90	0.	1.0			-0.15	0.70
4496-4497	0.1	0.15	1.	0.2	0.95	0.15	1.	0.15	-0.10	0.35			0.	0.65
4512-4513	0.05	0.05	0.1	0.	0.15	0.05	0.2	0.05	0.35	0.70			0.15	0.15
4528-4529	0.1	0.	0.1	0.05	0.05	0.05	0.1	0.05	0.	0.20			0.10	0.65
4544-4545	0.05	0.10	-0.05	0.15	0.	0.2	0.05	0.25	0.15	0.70			-0.05	0.30
4560-4561	0.20	0.10	0.25	0.05	0.15	0.05	0.15	0.15	0.15	-0.10			0.20	0.
4576-4577	0.20	0.35	0.25	0.25	0.30	0.3	0.4	0.35	0.25	0.40			0.10	0.15

FIG. 7 - 16 CASES OF FORWARD, REVERSE INTRABAND SCANS FOR RAW TOULOUSE IMAGE

(Striping being roughly corrected)

LINES	Left								Right
1872-1873	-48.5	-48.05	-47.35	-47.50	-47.40	-47.30	-47.90	-47.75	-47.95
1888-1889	46.30	46.05	44.35	44.60	44.15	43.90	43.85	44.10	44.05
1904-1905	-47.30	-47.70	-47.05	-46.80	-46.25	-46.35	-45.85	-46.45	-46.25
1920-1921	46.30	46.25	45.75	45.65	45.40	46.20	45.45	45.90	46.10
1936-1937	-46.00	-45.95	-45.85	-45.90	-46.15	-46.20	-46.60	-46.80	-47.15
1952-1953	44.45	44.80	45.35	45.10	44.95	45.10	46.00	46.40	47.05
1968-1969	-47.	-46.85	-46.90	-47.15	-47.25	-47.70	-47.95	-48.25	-48.70
1984-1985	44.40	44.75	43.95	43.75	43.75	43.70	43.90	44.	44.05
2000-2001	-49.10	-49.05	-47.75	-47.15	-47.05	-46.95	-45.75	-45.75	-46.25
2016-2017	47.25	46.90	46.05	45.65	45.00	44.60	44.75	43.70	43.65
2032-2033	-47.15	-46.70	-46.60	-46.40	-45.95	-44.85	-45.15	-45.05	-45.30
2048-2049	46.90	46.40	46.15	45.95	46.00	46.05	46.10	48.20	47.30
2064-2065	-45	-45.80	-46.10	-45.80	-46.40	-46.80	-47.20	-47.30	-47.85
2080-2081	43.65	43.70	43.75	43.95	43.70	45.05	45.00	45.40	45.75
2096-2097	-49.05	-49.	-48.30	-47.95	-47.70	-47.15	-47.15	-47.30	-47.70

FIG. 8 - 16 CASES OF FORWARD - REVERSE AND REVERSE-FORWARD INTRABAND SCANS, ALL ALONG LINE MISREGISTRATIONS FOR BAND 1

MISSISSIPI raw image line ends misregistrations vary from -45 to -49.10 pixels between reverse and forward scans and from 43.65 to 47.25 pixels between forward and reverse scans for bands 1 to 5 et for band 7 (-36.5 to -43.95 and 39.95 to 43.9 pixels for band 6).

Independently of that systematic misregistration of about 46 pixels between consecutive scans in raw images ; it appears to be no systematic predictable variation around that value.

On a 16 scans set, we found that the misregistrations average between a reverse and a forward scan is - 47.50 pixels and 45.90 pixels between a forward and a reverse one for bands 1 to 5 and for band 7 (for band 6 we found -40.5 pixels and 40.6 pixels respectively).

On the other hand, we looked for variations between odd and even detectors for one given band. For raw images, we found that the misregistrations between odd and even detectors are rather positive, and between even and odd detectors are rather negativ which is correlated with the detectors position.

B A N D S

Misregistrations	1	2	3	4	5	6	7
$-0.3 < \quad < 0.3$	93%	88%	97%	98%	92%	94%	95%
$-0.3 \leq \quad \leq 0.3$	96%	90%	98%	99%	95%	97%	97%

FIG. 9 - PERCENTAGE OF MISREGISTRATIONS MEASURED ON 16x16 LINES (9 values per line) FOR A-TYPE MISSISSIPI IMAGE (Excepting inter-scan misregistrations).

B A N D S

Misregistrations	1	2	3	4	5	6	7
$-0.3 < \quad < 0.3$	95%	95%	96%	97%	95%	99%	96%
$-0.3 \leq \quad \leq 0.3$	97%	97%	97%	98%	96%	99%	97%

FIG. 10 - PERCENTAGE OF MISREGISTRATIONS MEASURED ON 16x16 LINES (9 values per line) FOR P-TYPE MISSISSIPI IMAGE (Excepting inter-scan misregistrations).

As one can see on figures 9 and 10, the percentage of line to line misregistrations located between -0.3 and 0.3 pixel is always greater than 90% for all bands in A-type and P-type images.

However we made the following findings :

(Note that in the following remarks, the only misregistrations we shall talk about are those which are located between -0.3 and 0.3 !), and we excluded the case of line to line registration for two successive scans.

—— First, for A-TYPE MISSISSIPI IMAGE :

BAND 1 : 81% of misregistrations are positive. One misregistration (about 2160) is greater than 1. pixel.
Most misregistrations are found around columns 1500 and 4500.

BAND 2 : 61% of misregistrations are positive. Six misregistrations (about 2160) are greater than 1. pixel.
Most misregistrations are near columns 1500 and 4500 and between detectors n° 14 and 15 and between detectors n° 15 and n° 16.

BAND 3 : 83% of misregistrations are positive. Three misregistrations (among 2160) are greater than 1. pixel (one is equal to 5.).
Most misregistrations are near columns 1500 and 4500.

BAND 4 : 83% of misregistrations are positive. No misregistration greater than 1. pixel.
Most misregistrations are near column 4500.

As one can see on figures 9 and 10, the percentage of line to line misregistrations located between -0.3 and 0.3 pixel is always greater than 90% for all bands in A-type and P-type images.

However we made the following findings :

(Note that in the following remarks, the only misregistrations we shall talk about are those which are located between -0.3 and 0.3 !), and we excluded the case of line to line registration for two successive scans.

—— First, for A-TYPE MISSISSIPI IMAGE :

BAND 1 : 81% of misregistrations are positive. One misregistration (about 2160) is greater than 1. pixel.
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BAND 2 : 61% of misregistrations are positive. Six misregistrations (about 2160) are greater than 1. pixel.
Most misregistrations are near columns 1500 and 4500 and between detectors n° 14 and 15 and between detectors n° 15 and n° 16.

BAND 3 : 83% of misregistrations are positive. Three misregistrations (among 2160) are greater than 1. pixel (one is equal to 5.).
Most misregistrations are near columns 1500 and 4500.

BAND 4 : 83% of misregistrations are positive. No misregistration greater than 1. pixel.
Most misregistrations are near column 4500.

BAND 5 : 62% of misregistrations are positive. Five values are greater than 1. (about 2160).
Most misregistrations are near columns 1500 and 4500 and between detectors n° 9 and n° 10 and between detectors n° 10 and n° 11.

BAND 6 : 38% of misregistrations are positive. Ten values are greater than 3. pixel (about 432 values).
Most misregistrations near columns 1500 and 4500.

BAND 7 : 70% of misregistrations are positive. No value is greater than 1. pixel.
Most misregistrations near columns 1500 and 4500.

— For P-TYPE MISSISSIPI IMAGE :

BAND 1 : 87% of misregistrations positive. No value greater than 1.
Most misregistrations are near column 4500.

BAND 2 : 82% of misregistrations positive. No value greater than 1.
Most misregistrations are near column 4500.

BAND 3 : 85% of misregistrations positive. No value greater than 1.
Most misregistrations near column 4500.

BAND 4 : 80% of misregistrations positive. 2 values (among 2160) are greater than 1.
Most misregistrations near column 4500.

BAND 5 : 75% of misregistrations positive. Four values greater than 1. (among 2160).
Most misregistrations near column 4500.

BAND 6 : 80% of misregistrations positive. No value greater than 1.

BAND 7 : 77% of misregistrations positive. No value greater than 1. Most misregistrations are near column 4500.

The fact that in most cases, a lot of significative misregistrations appear near columns 1500 and 4500 for A-type image is probably correlated with the mirror scan profile. It seems there are some problems with detectors 14, 15 and 16 of band 2 and for detectors 9, 10 and 11 of band 5. (misregistrations values which are higher than 1. pixel result probably of the divergence of the correlation technique in some particular cases).

II-2 BAND TO BAND REGISTRATION

We looked in this section for the existing misregistrations between different bands of the primary focal plane (bands 1 to 4) and of the cooled focal plane (bands 5 to 7).

Results are given which can present some uncertainties due to the fact we have statistics concerning a small number of measurements (about 300 for each band to band misregistrations valuation).

We present results for the TOULOUSE raw image (let us remember however that this image have been preprocessed by TELESPAZIO Center in order to rectify forward - reverse scans misregistrations by a whole number of pixels global translations), for the MISSISSIPI raw image (A-type) and for the MISSISSIPI preprocessed image (P-type).

Let us now give first results concerning misregistrations statistics between two different bands, Figure 11 for TOULOUSE image, FIGURE 12 for MISSISSIPI A-type image and FIGURE 13, for MISSISSIPI P-type image.

BANDS	MISREGISTRATIONS LIMITS (unit : Band 1 pixel)		% of MISREGISTRATIONS WITHIN LIMITS
1 - 2	-0.2 $\leq$	$\leq$ 0.2	91 %
	-0.3 $\leq$	$\leq$ 0.3	95 %
3 - 4	-0.2 $\leq$	$\leq$ 0.2	90 %
	-0.3 $\leq$	$\leq$ 0.3	98 %
4 - 5	-0.4 $\leq$	$\leq$ 0.4	65 %
	-0.5 $\leq$	$\leq$ 0.5	90 %
4 - 7	-0.3 $\leq$	$\leq$ 0.3	62 %
	-0.4 $\leq$	$\leq$ 0.4	75 %
	-0.5 $\leq$	$\leq$ 0.5	86 %
	-0.6 $\leq$	$\leq$ 0.6	94 %
5 - 7	-0.15 $\leq$	$\leq$ 0.15	93 %
	-0.2 $\leq$	$\leq$ 0.2	99 %

FIG 11 - TOULOUSE RAW IMAGE INTERBAND MISREGISTRATIONS STATISTICS

BANDS	MISREGISTRATIONS LIMITS (unit : band 1 pixel)		% OF MISREGISTRATIONS WITHIN LIMITS
1 - 2	-0.2 ≤	≤ 0.2	95 %
3 - 4	-0.2 <	< 0.2	86 %
	-0.2 ≤	≤ 0.2	91 %
5 - 7	-0.2 ≤	≤ 0.2	97 %
1 - 6	-4. ≤	≤ 4.	67 %
	-5. ≤	≤ 5.	90 %
4 - 5	-0.7 ≤	≤ 0.7	70 %
	-0.8 ≤	≤ 0.8	90 %
4 - 7	-0.6 ≤	≤ 0.6	56 %
	-0.8 ≤	≤ 0.8	88 %
	-0.9 ≤	≤ 0.9	96 %
6 - 7	-4. ≤	≤ 4.	86 %
	-4.5 ≤	≤ 4.5	94 %

FIG. 12 - MISSISSIPI A-TYPE IMAGE INTERBAND MISREGISTRATIONS STATISTICS

BANDS	MISREGISTRATIONS LIMITS (unit : band 1 pixel)	% OF MISREGISTRATIONS WITHIN LIMITS
3 - 4	$-0.2 < \quad < 0.2$	87 %
	$-0.2 \leq \quad \leq 0.2$	95 %
	$-0.3 \leq \quad \leq 0.3$	96 %
3 - 7	$-0.7 \leq \quad \leq 0.7$	90 %
4 - 7	$-0.7 \leq \quad \leq 0.7$	85 %
	$-0.8 \leq \quad \leq 0.8$	94 %

FIG. 13 - MISSISSIPI P-TYPE IMAGE INTERBAND MISREGISTRATIONS STATISTICS

We can note that within each focal plane the interband misregistrations are within the designed TM registrations specifications for all three images (with no significative difference between A-type and P-type images for the primary focal plane bands).

We should note here that when we looked for misregistrations concerning on one hand a primary focal plane band and on the other hand a cooled focal plane band, we obtained in most cases positive misregistrations (for example between bands 4 and 7, bands 4 and 5, or bands 4 and 7 of TOULOUSE image we obtained 96 % of positive misregistrations, and between bands 4 and 7 and bands 4 and 5 of MISSISSIPI A-type image we obtained 97 %).

For the MISSISSIPI P-type image, between bands 4 and 6, our correlation technique has given some deficient misregistrations values so that we can only give a rough result : the misregistration values are near those of bands 1 and 6 MISSISSIPI A-type image misregistrations.

Moreover, for that MISSISSIPI P-type image we obtained the following bad results : between bands 4 and 5, almost all misregistration values were from 1. to 2. pixels and between bands 5 and 7 too. In fact, while the MISSISSIPI A-type image does not show any remarkable default, we found that in the P-type one, all computations related to band 5 gave surprisingly high misregistration values.

It seems that some band 5 lines have been lost or the band 5 first line does not correspond to others bands first line.

III. Conclusion

Concerning all misregistrations measurements (line to line registration in one given band, or band to band registration), the correlation technique we have implemented appeared to be quite convenient.

It seems however necessary to largely reduce the translations range (actually from -70 to 70 pixels) for the correlation function computation to avoid peculiar misregistration values, and it would be interesting to note the correlation function maximum value in order to estimate the correlation strength and to detect anomalies (for example missing lines in one band as we have seen in band 5 of MISSISSIPI P-type image).

Generally, our results agree TM specified values except for the MISSISSIPI P-type image for which we shall investigate the band 5 anomalies.

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