# FINER REGISTRATION AND RECTIFICATION OF AIRBORNE MSS REMOTE SENSING DATA USING VISUAL DYNAMIC CORRELATION METHOD AND APPLICATIONS OF THE RESULTS

Mitsuru Nasu
Kohei Shimamoto
Masataka Fuchimoto
Asia Air Survey Company Ltd., Tokyo, Japan
Commission III

## 1. INTRODUCTION

Mathematical aspects of registration, rectification and enhancement is the main theme of Commission III-4. In this field, modeling of geometric property of image data is a key factor. As summarized by Mikhail (1), parametric and non-parametric methods had been studied. While, it is felt that more studies with practical data are needed, in particular for airborne MSS imagery, to understand the image distortion characteristics.
According to the results of practical data processing, however, it is known that the overall image distortion is quite random and has a very complex nature. Thus, the use of the parametric model based on the collinearity condition combined with orientation polynomials is not always satisfactry. A finer and rectification and registration procedure has been developed to meet such accuracy requirement. The method has been applied to practical data and the discussions are given to the results.

## 2. RECTIFICATION AND REGISTRATION PROCEDURE

The overall procedure used for rectification and registration of airborne MSS data are given in Fig. 1. In this paper, a combination of parametric and visual correlation methods is discussed in detail. The ordinary parametric model shown in Fig. 1 employs the collinearity condition model of scanner data to estimate orientation parameters of a MSS strip. In the image rectification, image distortion due to terrain relief is corrected by using the orientation parameters and DTM data. As reported previously by authors (2), the accuracy obtained at ground control points (GCPs) is 3 to 4 pixels in standard deviation. This is so called image-to-map positioning. When two MSS strips are positioned independently, accurate overlaying is often very difficult to do. Therefore, some adjustment of image-to-image registration should be done.
With these circumstances, a meshwise linear correction model was adopted in the present system so that a common algorithm can be applied to both the rectification and registration problems.

Generation of the correction meshes needs tedious work and is sometimes time consuming. Although it may be possible to use an automatic digital image correlation technique and automatic mesh generation method (1, 3), a simple visual image matching is employed in the present system. Using photographic imageries, mesh points established on the master imagery are transfered to the registration imagery so as to form correction meshes. And then, the meshwise linear interpolation is applied to the digital MSS data.

Detection of blunder is a common problem in practical work. Two types of error sources may exist. i.e. errors in GCPs and visual image matching of mesh points. The former has an effect on absolute accuracy of mapping. Furthermore, if the orientation errors are combined with relief displacement correction errors due to mismatching of DTM, complex and unreversible image distortions may be introduced in the rectification result. Thus, accurate point identification and good quality of ground coordinates of GCPs are indispensable although probability for detecting point identification error may become higher under multiple coverages.

Due to the fact that no definite model of image distortion exists yet, it is usually difficult to establish a standard criterion for error detection of the visually matched correction meshes. Thus, comparison of local trend of image distortion vectors is practically applied for blunder filtering. Goodness of the visual correlation is simply judged by the amount of irregularity of distortion vectors.

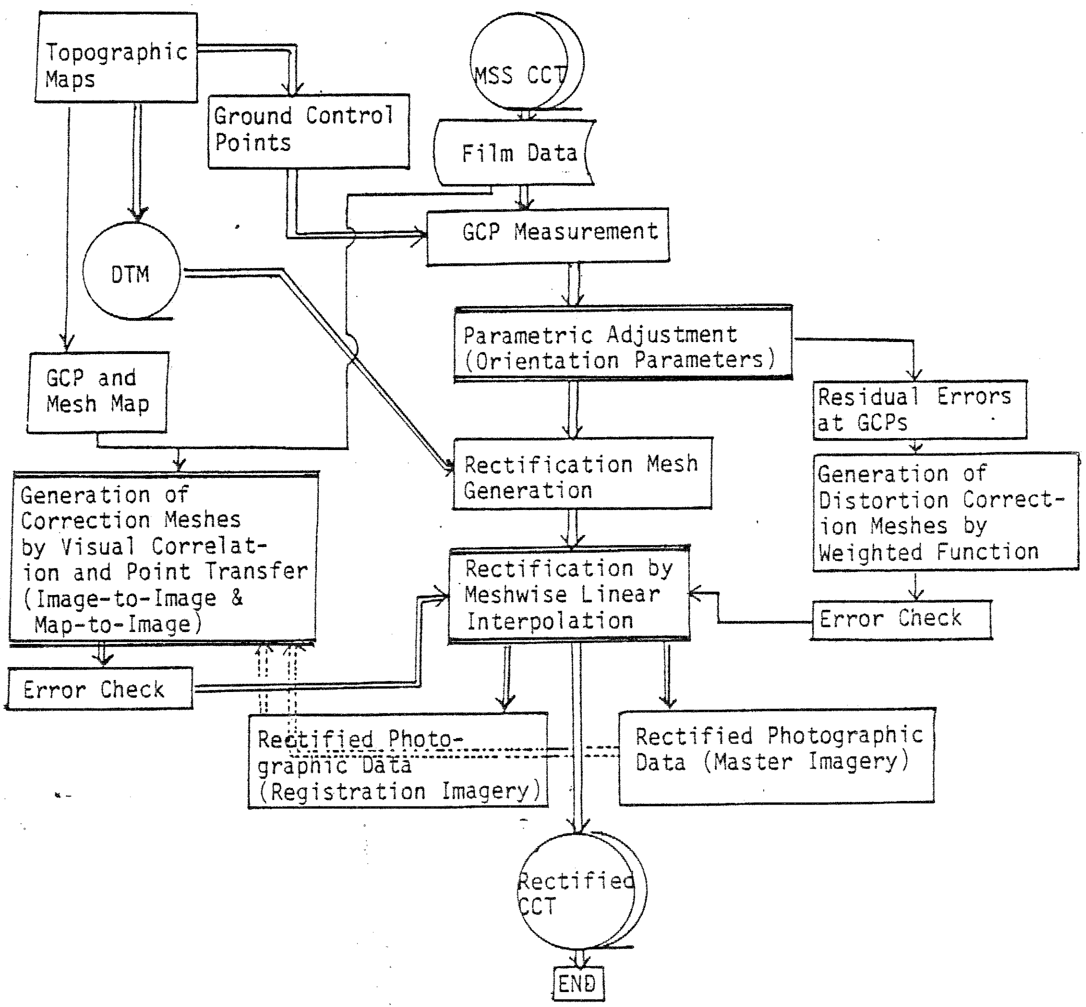



Fig. 1 Rectification and Registration Procedures.

## 3. PRACTICAL EXAMPLE

### 3.1 TEST DATA

Practical test data shown in this study were airborne MSS imageries taken in 1982 and 1983 to investigate land condition change of the subjected area. Configuration of the data acquisition is shown in Table 1.

Table 1. Configuration of Test Data

| | |
|---|---|
| Scanner: | Daedalus DS-1250 11 channel MSS |
| Flight Altitude: | 2000 m |
| MSS Strip Length: | 9 km |
| MSS Strip Width: | 3.5 km |
| Time of Data Acquisitions: | December 1982 and 1983 |
| Base Map: | 1:25,000 |
| DTM Mesh Interval: | 200 m |
| Final Mapping Pixel Size: | 5 m |

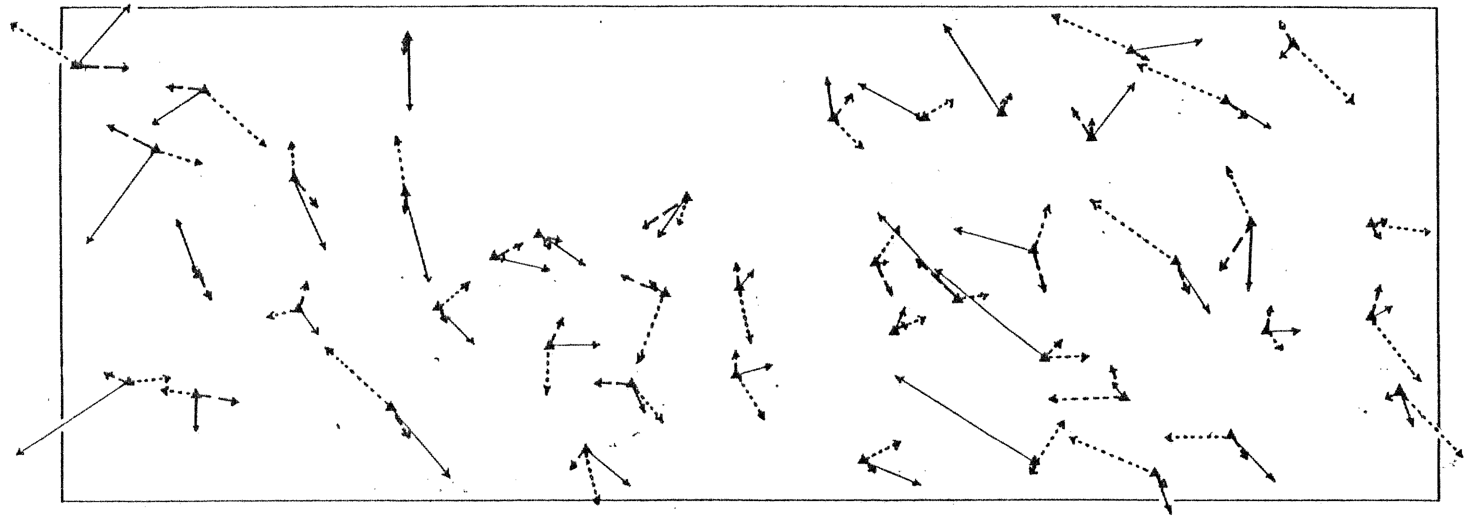
The study area contains moderately flat agricultural area and rolling hills (300 m high) as well, and is sourounded by sea at south and high mountains at the north and west. In both flights, the data acquisitions were made under rather gusty wind condition. Thus, image distortions due to deviations in aircraft attitude and ground speed were expected.

### 3.2 PARAMETRIC ADJUSTMENT AND RECTIFICATION OF MSS STRIPS

As shown in Fig.2, GCPs were established from 1:25,000 topographic maps. In Table 2, the results of parametric absolute orientation of those MSS strips using the collinearity condition model are shown. Since higher order image (strip) deformation was found in the 1982 imagery, the MSS strip was subdivided into four sections and the second order orientation polynomials were used for parametric adjustment computations. In Fig.2, parameter 2-0-2-3-3-3 indicates the number of polynomial coefficients for $\omega$-$\varphi$-$\kappa$-Xc-Yc-Zc orientation polynomials utilized in the adjustment computation. As shown in Fig.2 and Table 2, average standard deviation of residuals at GCPs is 4.9 pixels for the master (1982 strip) imagery. In order to form a continuous MSS strip, these four sections were mosaiked after completing image rectification using the DTM data and orientation parameters. A film imagery was then printed out using a film writer. 1:25,000 photographic print was used for making image match later on.

Similar to the master imagery of 1982, the registration imagery of 1983 data was processed. The parametric rectification was first applied to the data as one continuous strip as shown in Fig.2 and Table 2. The residual errors at GCPs indicate still remaining strip deformation of 7.2 pixels in standard deviation. 1:25,000 photographic imagery was produced after the rectification computation.

Registration of the 1983 imagery over the master imagery was done by visual image correlation. To do this, a transparent mesh overlay of 1 cm interval was fixed on the master imagery, and corresponding image points on the 1983 imagery were marked one by one. The dimension of the unit pixel is 0.2 mm on the 1:25,000 photo. Thus, positioning of the corresponding points was not so difficult although it was time consuming. Planimetric coordinates of the correlated mesh points on the 1983 imagery were measured in a tablet digitizer of which least reading is 40 micrometers. Corresponding line and pixel coordinates of these mesh points were obtained by coordinate transform-



- Master Image Data....Adjusted as one strip using parameters 2-0-2-3-3-3: $\sigma_{L,P} = 8.5$ PIXELS
- " " " ....Adjusted by four sections using 2-0-2-3-3-3: $\sigma_{L,P} = 4.9$
- Registered Image Data....Adjusted as one strip using 2-0-2-3-3-3: $\sigma_{L,P} = 7.2$

0 10 20 PIXELS

Fig. 2. Residual Errors at GCPs after the Parametric Adjustments of the Master (1982) and Registration (1983) MSS Strips.

ation utilizing reference points as controls. These procedures produce distorted correction meshes on the 1983 imagery of which ground coordinates (X, Y, Z) from DTM and the image coordinates (line and pixel) are given. Resampling of the 1983 image data by meshwise interpolations gives the final registration MSS data.

Table 2. Standard Deviations of Residual Errors and Discrepancies at GCPs.

| | Master Imagery (1982 MSS Strip) | | | Registration Imagery (1983 MSS Strip) | | |
|---|---|---|---|---|---|---|
| | $\sigma_{line}$ | $\sigma_{pixel}$ | $\sigma_{l,p}$ | $\sigma_{line}$ | $\sigma_{pixel}$ | $\sigma_{l,p}$ |
| Residual Errors at GCPs (Whole Strip Adjustment) | pixels 8.7 | 8.4 | 8.5 | pixels 7.9 | 6.7 | 7.2 |
| Residuals at GCPs (4 Sections Adjustment) | 4.9 | 4.6 | 4.9 | --- | --- | --- |
| Discrepancies at GCPs (1983 - 1982/4 Sect.) | --- | --- | --- | 9.0 | 8.5 | 8.7 |
| Image Distortions obtained by Visual Image Matching of Correction Meshes | --- | --- | --- | 9.6 | 10.8 | 10.2 |
| Discrepancies at GCPs after Applying Image Distortion Corrections | --- | --- | --- | 4.4 (+0.9)* | 6.0 (-4.3) | 5.3 |
| Remaining Residuals at GCPs after Image Distortion Corrections for 1983 Imagery | --- | --- | --- | 2.6 (+1.0) | 5.5 (-4.5) | 4.3 |

*( ): Mean Value

### 3.3 ANALYSES OF IMAGE DISTORTION CHARACTERISTICS

Figs.3 and 4 show image distortions which remain after parametric rectification between the master imagery (1982) and the registration imagery (1983). In these Figures, the results of the error analyses are given as follows:

(1) Image distortions are shown by contour lines (5 pixel interval).
(2) GCPs and discrepancies of residuals at these GCPs after adjustment computations of two MSS strips are given as black dots and spot heights.
(3) Linewise and pixelwise average distortion and its standard deviation ($\pm 1\sigma$) are also given as two profiles.

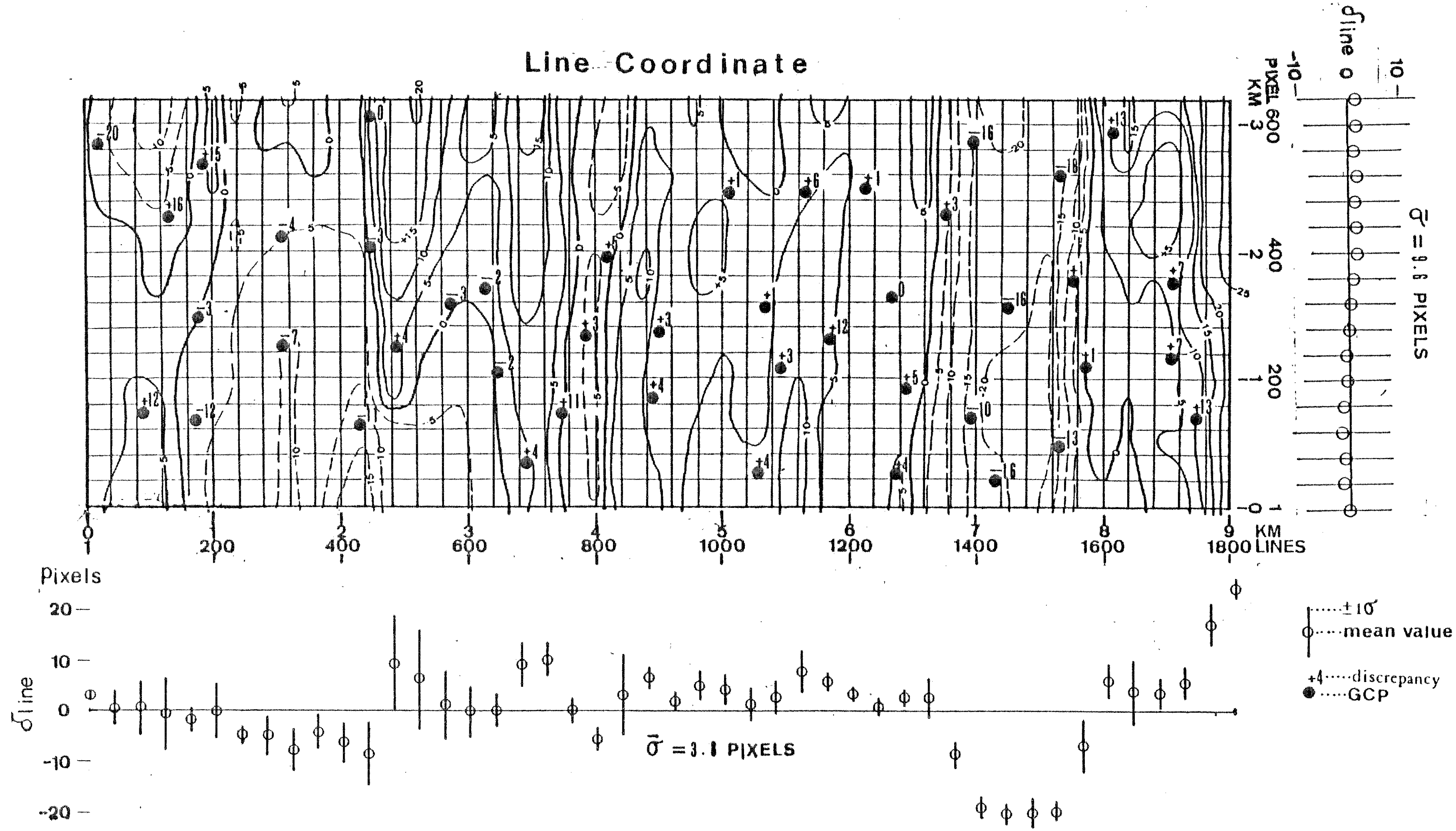



Fig. 3 Image Distortions in Line Coordinates of the Registered MSS (1983) Strip Comparing to the Master Imagery (1982) after the Parametric Adjustment.

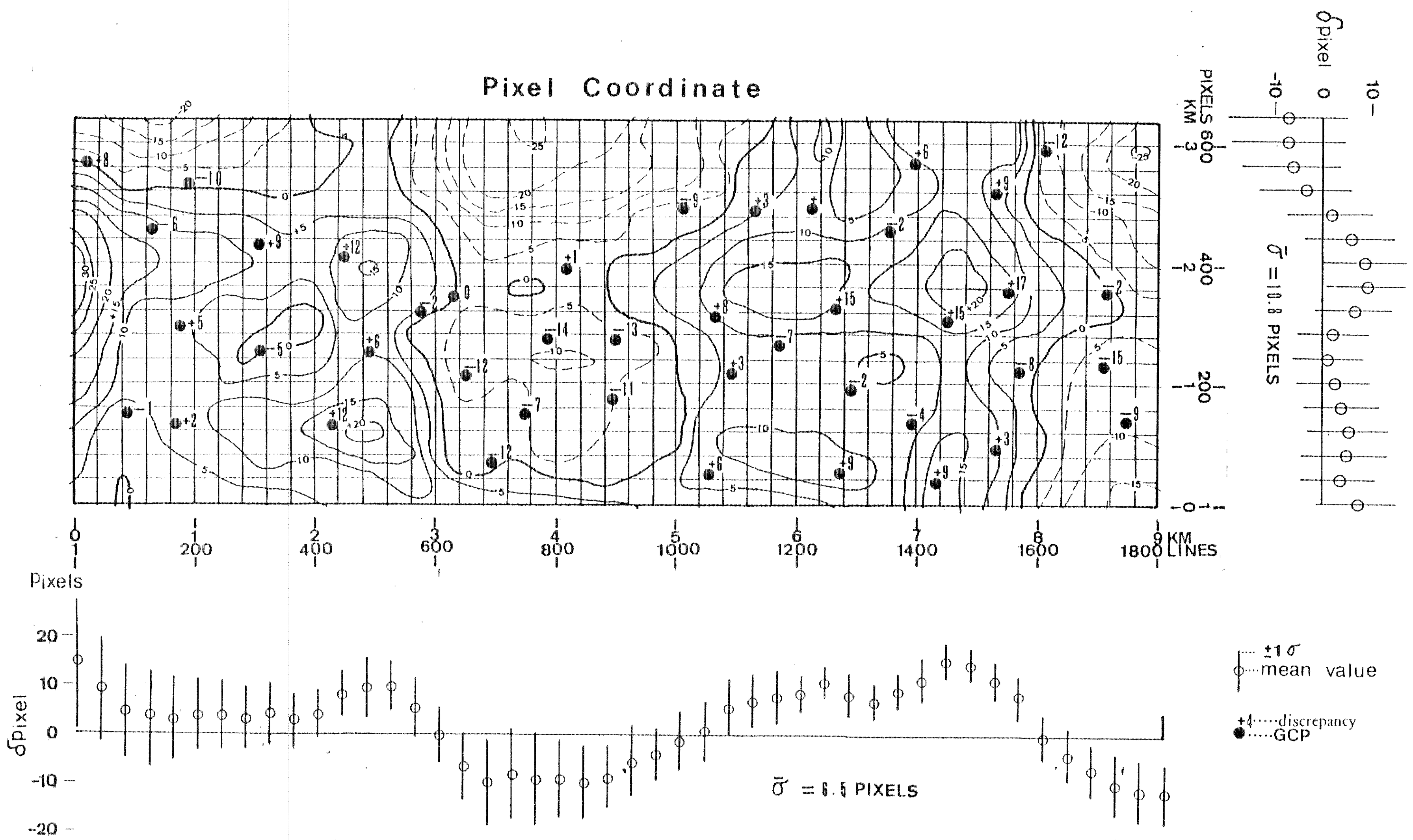



Fig. 4 Image Distortion in Pixel Coordinates of the Registered (1983) MSS Strip Comparing to the Master Imagery (1982) after Parametric Adjustment.

We can find very interesting image distortion characteristics of airborne MSS data in Figs. 3 and 4, and they are as follows:

(1) Image distortion characteristics in line and pixel coordinates seems to be quite different; i.e. the distortion in line coordinates varies as a function of line coordinate, and relatively small change of distortion can be observed along the pixel coordinate.

(2) Very dense contours can be seen in the line coordinate. This type of distortions may be results of expansion and compression of the imagery according to irregularity of aircraft ground speed due to gusty wind as previously mentioned.

(3) Variation of distortions in line coordinates is relatively small ($\bar{\sigma}$=3.8 pixels) along scan direction if compared with flight direction ($\bar{\sigma}$=9.6 pixels).

(4) Distortion in the pixel coordinates occurs with relatively smooth variation.

(5) Large distortions can be found in the pixel coordinates located at the area of poor GCPs distribution.

(6) Similarity of image distortion and discrepancies of residual errors at GCPs can be mentioned. As shown in Table 2, residuals at GCPs were reduced from 7.2 pixels to 4.3 pixels if distortion corrections were applied based on the meshwise interpolations.

(7) There exist rather complex image distortions between those two imageries, thus it can be said that accurate image registration is only possible using relatively dense reference points or dynamic correction meshes. Denser sampling is in general needed along flight direction comparing to pixels.

Examination of the final registration accuracy is not easy. However, discrepancy at GCPs indicated about 3 pixels registration errors which is more or less reasonable in the present system.

## 4. APPLICATIONS

Overlaying of multitemporal MSS data leads to various applications of remote sensing technology. Typical examples of these applications may be mapping of land use and land condition changes, thermal difference (inertia) mapping, etc. Combination of MSS and DTM also provides additional space of information. In order to demonstrate the results of accurate image registration and rectification, two of those image mappings are shown in Figs. 5 and 6. Fig.5 is a thermal difference imagery compiled from daytime and nighttime thermal IR data taken over very steep mountainous terrain, and is a digital mosaic of four strips. A perspective imagery of the nighttime thermal data is also shown in Fig. 6.

## 5. SUMMARY

Digital rectification and registration procrdures for airborne MSS data have been discussed, it has been shown that visual image matching of dynamic correction meshes can be use to make finer adjustment of image distortions which remain after the parametric adjustment and rectification. Results of practical data analyses indicated that the image distortions are in general very complex. Thus, it is necessary to establish dense reference points for finer registration. Generally speaking, it seems image distortion in line coordinates contain higher frequency nature comparing to the pixel coordinate. The practical example showed that amount of image distortion is twice as large as the residuals at GCPs. Discrepancy of residuals at common GCPs is a good figure of the misregistration. After correcting those image distortions, registration accuracy of 3 pixels seems to be expected in the present system.

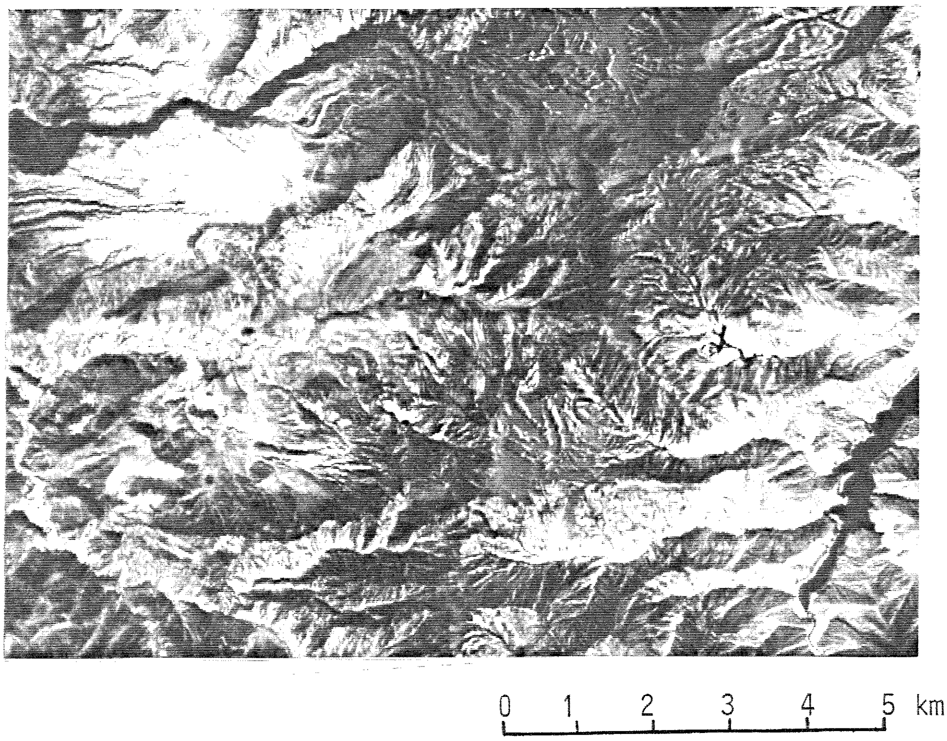



Fig. 5 Thermal Difference Imagery (Digital Mosaic of Four MSS Strips of Daytime-Nighttime Thermal Data)

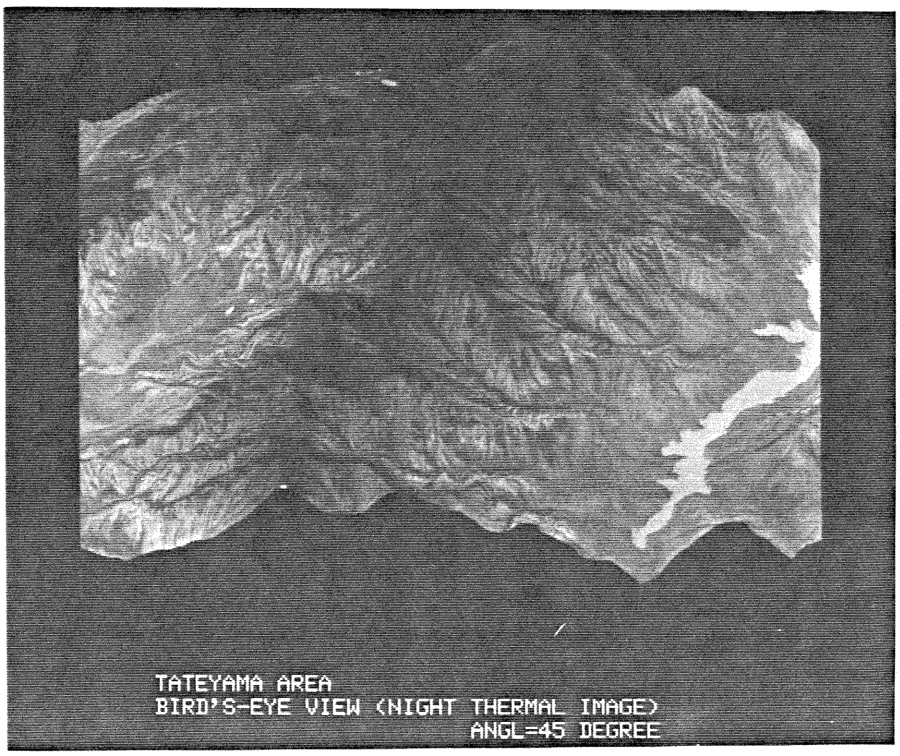



Fig. 6 Perspective Transformation Imagery of the Nighttime Thermal Imagery.

REFERENCES

1. Mikhail, E. M. and McGlone, J. C.(1980). "Present Status of Metric Reduction of (Passive) Scanner Data", Proceedings of 14th Congress of the ISP, Hamburg, FDR.
2. Nasu, M., Shimamoto, K., et al. "Digital Differential Rectification of Air-borne MSS Data for Geothermal Mapping", Proceedings of 14th Congress of the ISP, Hamburg, FDR, June 1980.
3. Göpfert, W.(1977). "High-Precision Scanner Imagery Rectification Using Dynamic Meshes of Digitally Corrected Pass Points", Proceedings of Image Processing Symposium-Interaction with Photogrammetry and Remote Sensing, Graz, Austria.
4. Teillet, P.M., Guindon, B., and Goodenough, D.G.(1980). "Integration of Remote Sensing Data Sets by Rectification to UTM Coordinates with the Use of Digital Terrain Models", Proceedings of 14th Congress of the ISP, Hamburg, FDR.