SOME METHODS FOR STANDARDIZATION ENHANCEMENT AND HANDLING OF SATELLITE DATA IN CHINA RSGS

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II

Abstract

Current and potential products of China RSGS are introduced, including routine and specially ordered ones.

First generation film products are discussed in respect of film recorder used, and also policy in using color films and B/W ones, band combinations, enhancement methods, etc. Color composite 4, 5, 1 is strongly recommended.

1. A lot of Landsat TM images about China have been received and processed, and their correspoding products have been supplied to foreign and domestic customers. The quality of the film and paper print products were highly appreciated as of high fidelity, rich in information, accurate in grey levels, and well color balanced.

2.The digital CCT products produced by China RSGS are 6250 bpi or 1600 bpi, 4 lines/rec routinely. 1600 bpi , 1 line/rec can be produced by special order but without HAAT. The domestic customers are all governmental. Most of them request full TM scenes. Sometimes some of them request 2/3, 1/2, 1/4 or a window. All these can be provided by special orders, even mosaiced scenes, such as mosaiced Beijing administrative area, forest fire area in the Northeast of China in 1987. Products on floppy disks are not on time schedule of the Station, because there have not been many requests for just research purposes. The situation up to now is that if any project is approved, it is probably an immediately required application. We expect CCT's will be used even in microprocessor systems, when a tape drive and disks with enough capacity to handle TM scenes, say, 500-1000 MB, are hooked on. HDT's are used for archiving raw data, and CCT's for system corrected data. A small amount of specially processed images, full or windows are also archived on CCT's. Optical disks are under consideration to be used to archive P-data. Some tests are being carried on in another lab at China station. About 80% income of the Station comes from CCT products, but 80% of customers request photo products. So particular attention is

paid to the production and service of photo products. We just announced 70mm, 35mm film products, which are made from 240mm working masters. They can be used for education purposes, or for applications, where high geometric and radiometric accuracies are not critical. We are trying to announce more , for example, color composites made with more than three bands.

3. The importance of digital enhancement for remote sensing satellite image is well known. The prominent purpose is to obtain new images to facilitate visual interpretation. Thus, more potentially useful information can be actually be used. The usual digital enhancement methods are shown as follows:

A. Spatial domain
  a. Contrast stretching
     histogram adjustment (equalization, specification, thresholding)
     fuctional transform (linear; nonlinear: Look-up tables, logarithmic, exponential, normalization)
  b. Color treatment
     false color composites
     pseudo-color slicing
     transform from grey levels to colors
     digital enlargement (cubic convolution, bilinear interpolation, nearest neighbor)
  c. Filtering
     sharping, smoothing, homomorphic filtering
B. Frequency domain
  a. Highpass filtering
  b. Lowpass filtering
  c. Bandpass filtering

Some of the above mentioned methods are used for routine and specially ordered products at China Station. In a similar way to the most of the remote sensing ground stations, routine or standard photo products at China Station include 240mm B/W, color transparencies and false color composites with scales from 1:1,000,000 to 1:50,000. All the first generation films are made by Color Fire 240 film recorder on films B/W negative SO-239[positive is under way], coLor negative Vericolor III, color positive Ektachrome 200. We can provide products of second generation on request. To our knowledge, this is unique among the World's ground stations. Most of them produce color composites products routinely by using optical enlarger and B/W films. For these three first generation films, the density tolerance is controlled in our station within 0.1, and for specially ordered porducts it can be as good as 0.05-0.08. This means excellent color balance and color fidelity, which is difficult to obtain by optical methods. In the process of development of these films, some key problems were resolved. We will discuss about LUT's method here, which is widely used in remote sensing satellite data processing, especially for nonlinear transformation. It

is simple, clear, and effective. It is well known that originally received images, if visually interpreted directly, may hardly yield satisfactory results. That is the way data are received at the ground stations. It is determined by the dynamic range of the satellite detectors. The detectors will not get saturated when the average brightness values are low, but it causes too low contrast. The histogram of an original image is shown on fig. 1. For a routine product, the LUT's method is straightforward, convenient, advantageous especially that customer can evaluate the original data. Our enhancenent LUT's for B/W films were developed with reference to those published by NASA and NOAA on Landsat Data Users Notes, but the LUT's for color EK-200 and VR-III were developed at China RSGS. The LUT's for EK-200 are listed in table 1. Some pictures after enhancement will be shown. Histograms of a typical image were calculated. It can be seen from the historgams that the average image brightness values have been increased, the contrast has been stretched. The picture is now very adequqte for visual interpretations. The details and many gray levels can be seen very well. The texture is clear. The color balance and fidelity is satisfactory. Thus, more abundant information is available. We would like to mention several points regarding the LUT's in table 1.

a.The denstity range 0.2-2.78 is evidently wider than that set by NOAA Table [0.2-2.2]. The performance of EK-200 film itself is being taken advantage of, which results in more stretched contrast. The LUT's was got after many "cut and try".

b. The LUT's were first aimed for routine color compostite TM bands 4, 3, 2. But it was found that they were also adequate for bands 5 and 7, MSS bands 1-4, and TM band 1, when there are no special requirements. They are not very satisfactory for TM band 6. So another LUT's is used.

c. Photo products with above mentioned LUT's meet requirements of various customers.

d. We are developing second kind routine products to facilitate visual interpretation. We think we should consider if different LUT's shall be used for each band individually according to the data distribution of each band.

4. Some speacil photo products

We will discuss some examples.

A. Piecewise linear extention or stretching
This is simple and effective for contrast stretching enhancement, shown in fig. 2. The principal and

mathematical formulas are:

$$g(x, y)= \begin{cases} k1*f(x, y) & 0 < L < a1 \\ k2*f(x, y)+(a2*b1-a1*b2)/(a2-a1) & a1 < L < a2 \\ K3*f(X, Y)+(a3*b2-a2*b3)/(a3-a2) & a2 < L < a3 \end{cases}$$

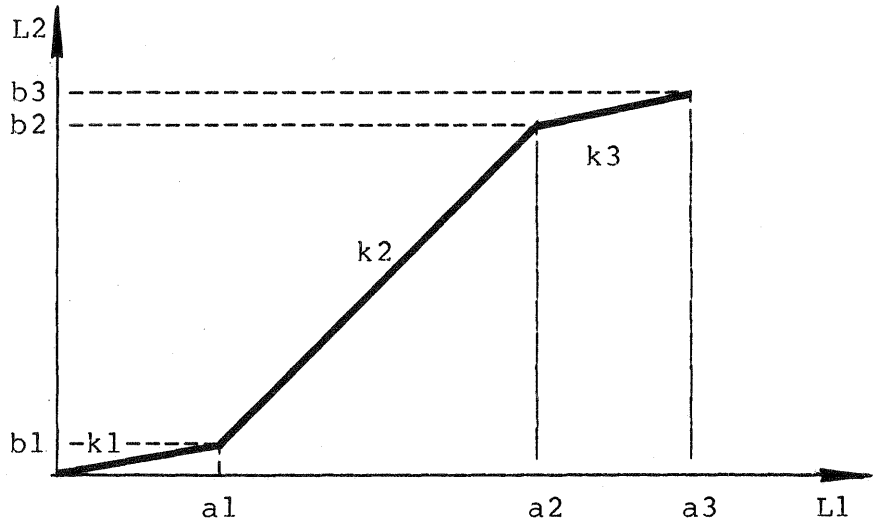


Fig. 2. Piecewise linear stretching

The only enhancement we did for the Yellow River Mouth scene [D860605.T020601.L5TM 4 3 2] was just this one. The results were unexpectedly excellent. The enhancement requirements were specified for newly growing land, so the brightness range of this part of the image were stretched as much as possible while the others were compressed. This enhanced image was appreciated by the customer and Prof. Shunji Murai, visiting China at that time.

B. Equalized linear contrast stretching

Histogram equalization is a widely used method. But it was found that the results were not so satisfactory as generally expected. In fact, the contrast of an image after histogram equalization is often too high, especially the middle part, then much useful information in the first and last parts are compressed so much that even bright areas and dark areas cannot be distinguished easily. We think the application of histogram equalization straightforward to remote sensing sastellite image enhancement might not give good pictures. In practical applications we combine histogram equalization with the above mentioned piecewise linearization flexibly together. We first get broken points from accumulated histogram by equalization principal, then apply linear stretching to each segment. Good results were obtained by using this method, for example, the typical Yellow River Mouth picture [bands 4 3 1]. The psychological characteristics of human being eyes are taken into account of. It is often the case

that the customer raises an issue that they looked at the monitor , the pictures were very good, but why the quality of the pictures was not as nice, such and such feature had disappeared after the film was generated. They suspected the film generation people were not experienced enough. In fact, this is because the customers are not aware of that the adaptive range of light intensity of human being visual system is as high as 10 to the 10th power levels , but under certain current conditions only 20 levels. They were most probably turning the brightness control of the monitor, being consiciously or not consiciously. Actually, the intensity of the light entering the eyes has a logarithmic relationship with the subjective brightness [visual brightness] of the eye response. Therefore we have two choices of LUT's, one is linear , the other is nonlinear, to compensate the visual system characteristics. Besides, the ability of human being eyes can distinguish more than 100 colors but only about 20 grey levels, so false color composites are used for 3 bands composites, and pseudo color picture is used. The latter is obtained by applying `grey levels to colors transform' to single band B/W image. They greatly facilitate the visual interpretation We took an aerial like image and did logarithmic , exponential transform, histogram equalization. R G B colors were assigned. Films were generated. It became easier to interpret them than the original pictures. Filtering has not been used a lot, because the customer requests have not been much. However, some tests were done. The experience was that one must be cautious about using filtering in spatial domain. Customer did not like the ringing effect on the edges. When highpass was applied for edge enhancement, edge information was shown on pictures with better continuity, and the contrast became more stretched.

5. Band combinations

It is well known that the most `representative standard' false color composites is made with TM band 4 3 2. To our understanding it was due to the history of MSS data. But the seven bands advantages of TM data should be paid more attention to. On the basis of statistical analysis for hundreds of scenes, we suppose TM band 1 and 5 are very valuable. The spectrum bands of them are absent both in MSS and also in SPOT data. TM band 1 is good potentially for coastal water mapping, deciduous/coniferous and soil/vegetation differentiation, and TM band 5 for vegetation moisture measurement, vegetation classification, distinguishing cloud from snow cover, when compared with other bands. We anticipate band 4 3 2 would be substituted by 4 5 1 or 4 3 1. It is evident by looking at the pictures that 4 5 1 and 4 3 1 are better than routine 4 3 2 in respect of visually available information, and it is more pleasant to the eyes. Moreover, the basic hue are not too far from the traditional

band 4 3 2 and might be acceptable to ordinary users. Of course, customers must in some degree adapt themselves to new products. Pingu county of Beijing TM scene was acquired in 1987. This image is a representative one. There are enough various ground things. The TM band correlation calculated supports our view-point. The histograms and statistical values were calculated. The lower triangle correlation matrix is listed in table 2. It is known that TM band 4 is the most independent and the most important for biomass survey. It is also very useful for waterbody delineation. Having had band 4, we had to choose two other bands. It was found that the correlation factor of band 5 was in the middle of the rest bands, so the next band chosen was band 5. Considering then the correlation of other bands with band 4 and 5, band 1 was selected. Comparison was made: 1(4), 0.447(5), 0.099(1), and 1(4), 0.067(3), 0.017(2). Because the correlation between band 3 and 2 is as high as 0.977, it is sure there is too much redundant information. It is supposed that band combination 4 5 1 is better than 4 3 2. False color composites 4 5 1 were compared with classification map, it seemed that 4 5 1 could be used to do a preliminary classification in certain cases. By the way, digital enhancement had been applied.

TM Band 1 is more seriously affected by atmospheric diffusion, so compensation must be taken into account. One method we used is as follows. First, we looked for the darkest point in TM band 4 image, which is least affected by atmospheric diffusion (for example, water surface over deep sea area, or shadow of a high mountain). The brightness value of this point for each band should approach zero. Thus, the brightness values of different bands should be the same, that is, atmospheric diffusion effect could be neglected. The diffusion effect is inversely proportional to the wavelength. The use of this method to the Yellow River Mouth image turned out to be successful.

Table 1. Standard product Look-up table

	DN	DENSITY
1	0	2.78
2	16	2.09
3	34	1.55
4	50	1.24
5	68	1.00
6	84	0.84
7	102	0.70
8	118	0.61
9	136	0.53
10	152	0.48
11	170	0.42
12	186	0.37
13	204	0.32
14	220	0.28
15	238	0.24
16	255	0.20

Table 2. Lower triangle correlation matrix

BAND1	1.000					
BAND2	0.985	1.000				
BAND3	0.942	0.977	1.000			
BAND4	0.099	0.170	0.067	1.000		
BAND5	0.707	0.784	0.807	0.447	1.000	
BAND7	0.852	0.902	0.949	0.121	0.896	1.000

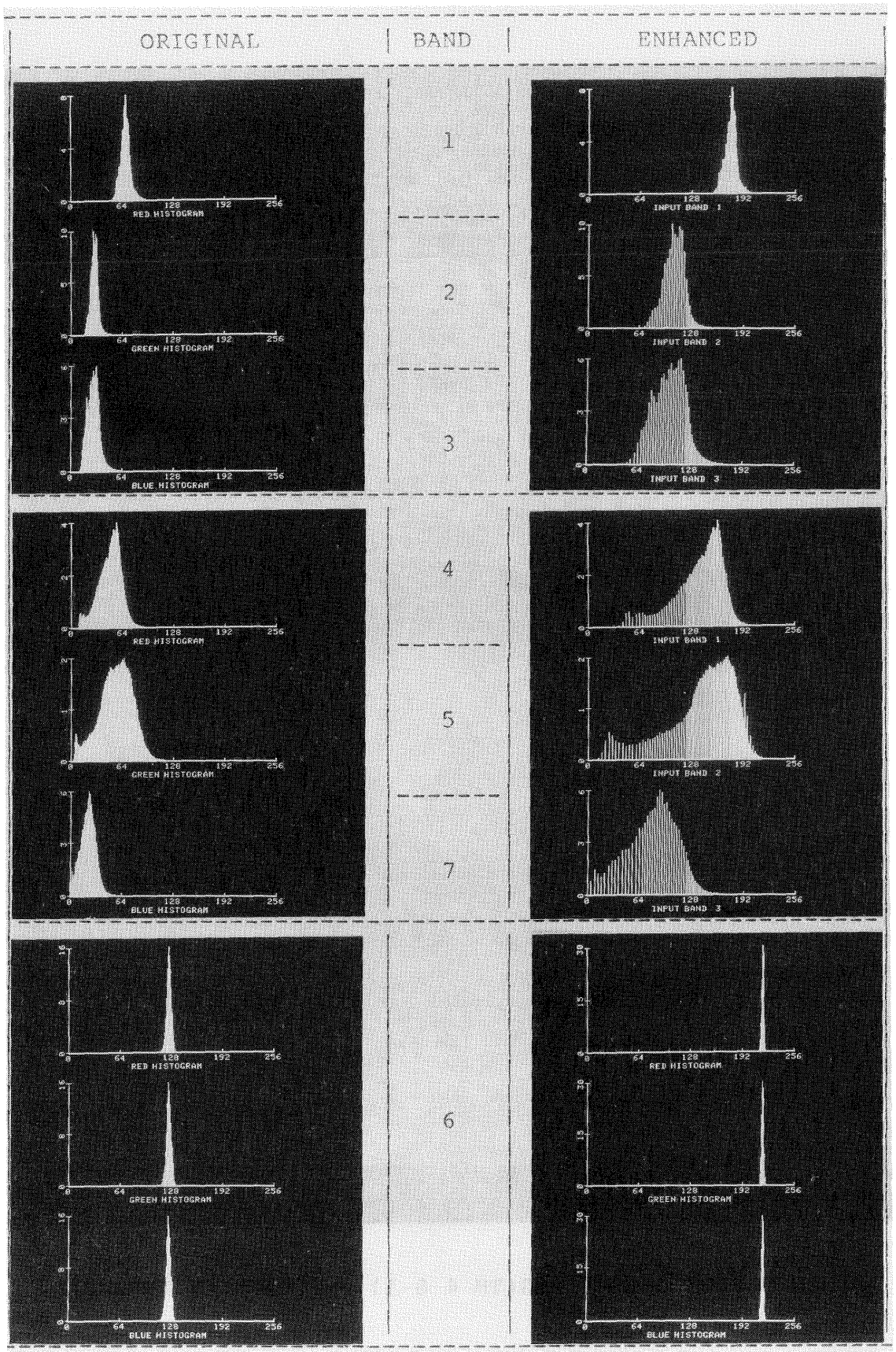
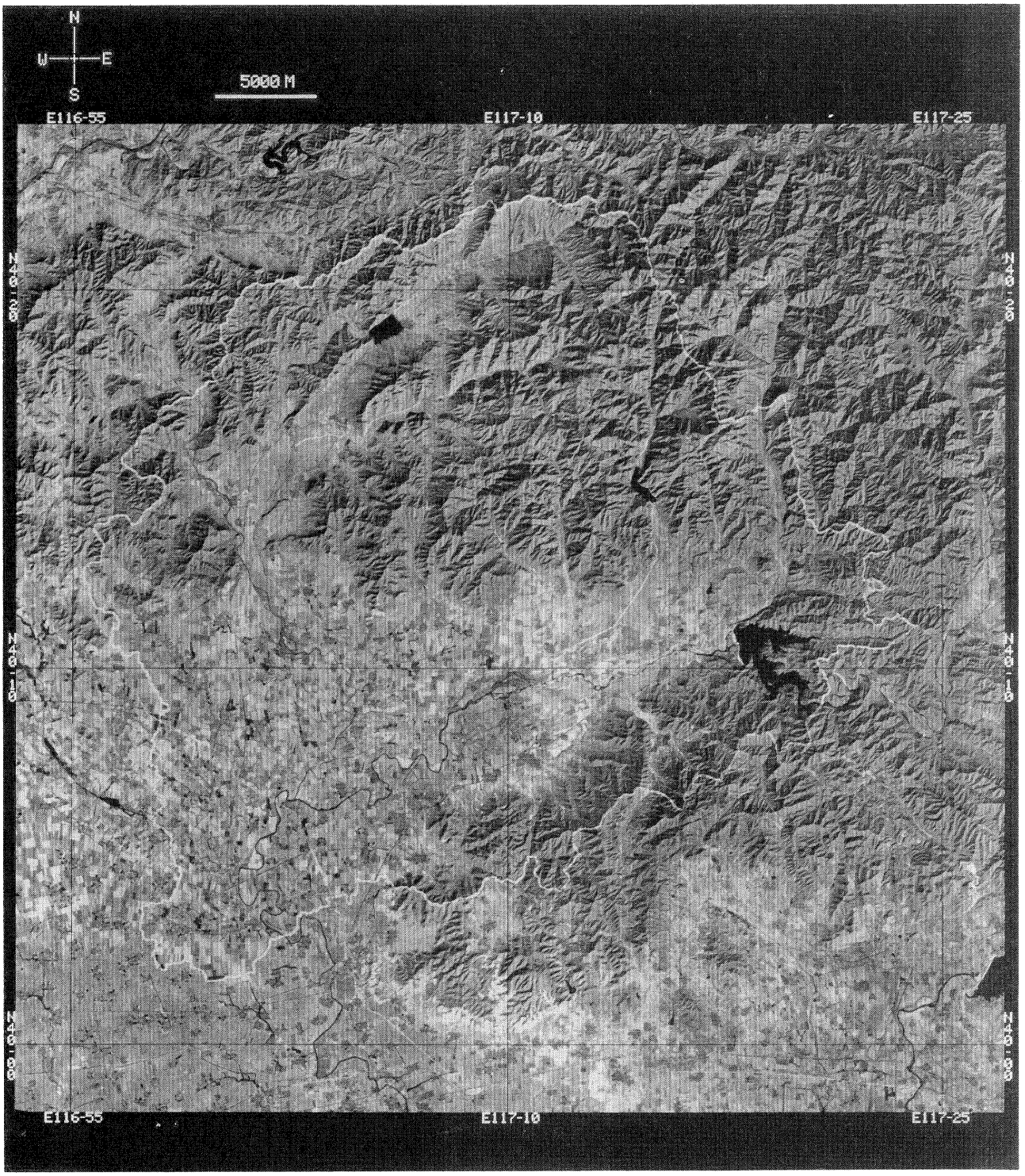


Fig. 1. Histograms of standard product



PINGU COUNTY OF BEIJING(TM 4 5 1). SPEICALLY ENHANCED.

YELLOW RIVER DELTA. TM BANDS 4 3 1. SPEICALLY ENHANCED.