

RADIOMETRIC QUALITY ENHANCEMENT OF IRS-1C PAN DATA

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ABSTRACT

This paper presents a method of reducing striping pattern seen especially over the low reflecting regions in the IRS-1C PAN data products. This is achieved by first isolating the low reflecting regions from the rest with a histogram based segmentation procedure. Image smoothing is carried out over the low reflecting regions using the local statistics of a moving average filter. The image sharpness is realized by correcting for the modulation transfer function (MTF) of the sensor. The quality of the thus corrected image is found to be much superior to that of the original image data.

1. INTRODUCTION

After the successful launch of IRS-1C satellite and subsequent operations of its payloads, viz., WIFS, PAN and LISS-3, there has been ever increasing demand for their data products from the user community all over the world. In particular, the PAN data products have received considerable impetus because of its state-of-art spatial resolution of 5.8m. with side viewing facility for the purpose of stereo products. Perceiving this well in advance, the data products team has provided the user community a variety of new options in data products, such as, shift-along track scene, 70 Km scene, geocoded and point geocoded data etc. to cater to many diverse applications where the PAN data may be of great need. Full details of the data products and their specifications can be found in IRS-1C User Manual [1995].

The PAN data products have been evaluated from time to time for their image quality, in terms of geometric and radiometric accuracies. It has been found that the PAN data products have met with all geometric specifications set by the mission. Radiometrically, the products may still seem to have 'striping' or line patterns that appear in the data in the along-track direction. Two major factors that can lead to this striping are : (1). improper correction of photoresponse

nonuniformity of CCD detectors, and (2). "hard" stretching of basically low dynamic range data. The former is a systemic error in nature, and can come mostly from odd and even pixels which are read and processed onboard independently. Earlier PAN data products have been found to have some residual errors of this kind, and were corrected subsequently with a revised radiometric correction look-up table (LUT).

The striping due to hard stretching is a scene-dependent aspect and is also a random phenomenon which basically arises out of the fact that the data products are given in 8-bit resolution from a 6-bit onboard data, and further stretched for better visual observation by the use of standard stretching software routines. Assuming that we have a highly homogenous target in a given scene for which it can have one count variation theoretically, it becomes nearly four counts due to first stretching of 6 bit to 8 bit at the data products chain. In addition, if the dynamic range of the data is quite less and needs further stretching by, say, 3 times, then it becomes 12 counts at the visual observation end. This striping thus becomes noticeable visually, and causes only problem in visual interpretation, especially when we have low reflecting targets such as ocean and deep forest. The striping is more concerned when there is a transition of high to low reflecting targets in the along track

direction as in the case of the coastal areas and water bodies and forestry regions surrounded by a land portion. Typically, such data has a bimodal histogram distribution.

This paper addresses a procedure for improving radiometric quality of the PAN data products especially for scenes that are of bimodal histogram nature. First step to improving the quality is segmentation, followed by smoothing based upon local statistics. The final step is correction for modulation transfer function (MTF) of the PAN camera. In the following, we first describe the smoothing procedure of striping.

2. DESTRIPIING PROCEDURE

As mentioned above, the removal of striping is a two-step process: segmentation and smoothing of data using local statistics. A test scene (size: 512 X 512) covering coastal and land regions of IRS-1C PAN data chosen for this study is shown in Fig. 1a. A portion of this image after hard stretching is shown in Fig. 2a.

2.1. Histogram based Image Segmentation

There are a variety of algorithms for segmenting a given image into regions [Gonzalez and Wintz, 1987]. For the present study, our main concern is to distinguish high and low reflecting targets in the scene. This can be easily accomplished by simple histogram based thresholding method. The histogram of the test scene is a bimodal distribution, as shown in Fig. 3. There is a strong peak due to low reflecting ocean water, followed by a valley, and the second peak appears due to high reflecting land portion. A simple threshold can thus be set at the valley point in order to separate two distinctly different grey features. This can be carried out either by manually or by automatically with the help of standard routines. A complete code in C for the histogram based segmentation is available in the literature [Dwayne, 1995].

2.2. Image Smoothing using Local Statistics

The smoothing is done with a simple moving average filter in which the center pixel in the window is replaced with the average value of the neighbourhood. The choice of the window size is decisive of the smoothing effect. If fairly a big size window (say, 9 X 9) is chosen, the smoothing effect is quite efficient. However, fine details (edges, lines, etc.) in the data may get smeared to an unacceptable

level. In this case, a small window (say, 3 X 3) may yield better result. For this reason, both the big and small window sizes mentioned above are employed here, depending on whether the centre pixel is deep in low reflecting region or near the boundary of the two regions.

The image smoothing has following steps. (1). The big window size (9 X 9) is selected. (2). The center pixel is first checked whether it belongs to low reflecting region from the output of the image segmentation mentioned above. (3). The local statistics, viz., mean and variance, are computed for the window. (4). If the variance of the window data is less than a preselected threshold, then the center pixel is assigned to the mean value of the window. (5). If the variance is less than the threshold, small window (3 X 3) is then selected for the same center pixel, and the process is repeated from 2 to 4 steps. (6). If the variance of the small window is also less than the threshold, then the center pixel is left uncorrected. The threshold can be selected by trial-and-error method. In the present study, a threshold value of nine for the variance was found to be quite satisfactory. While processing the small window, we have found that the noise smoothing scheme proposed by Lillesand [1987] also gives equally good results. A section of the processed image is shown in Fig. 2b.

3. MTF CORRECTION

The MTF of an imaging sensor can be defined as the attenuation of signal amplitude as a function of spatial frequency. This includes the signal transfer characteristics of the imaging optics, sensor electronics and the turbulent atmosphere. There are many approaches known to date for estimating the MTF from the satellite imagery data [Salomon, 1988].

The data acquired by a satellite imaging sensor is recorded basically by sampling the target area at sampling rates decided by the sensor design. For the IRS-1C PAN data under nadir viewing configuration, the rate is one sample in every 5.8 metres. The sensor sampling rate, f_s , is thus 172.4 cycles/km. The MTF effect is greatest when adjacent pixels show maximum contrast. This corresponds to a spatial frequency of $f_s/2$, which is known as the Nyquist frequency. Spatial frequencies above the Nyquist frequency give rise to an effect known as "aliasing" which in general corrupts the data quality. An ideal imaging sensor is one where the MTF has a value of

unity for all spatial frequencies below the Nyquist frequency and zero for all those above. This ideal case can never be met irrespective of the sensor instrument since the effect due to the atmospheric turbulence within the sensor integration time can be quite significant.

The MTF values are specified at the Nyquist frequency, prior to launch with the help of laboratory bench tests using a test target of square wave variation in intensity. These specifications are 0.16 and 0.22 in the along- and across-track directions respectively. To correct the images for MTF, however, the MTF values not only at the Nyquist frequency but also their variation as a function of spatial frequency. It is of course possible to model the effective MTF [Kaufman, 1984], but this requires several physical parameters of the atmosphere which are difficult to obtain.

Schowengerdt et.al [1985] evaluated the MTF of the Landsat-4 Thematic Mapper by a variety of experimental studies, and concluded that all the methods almost have shown a typical functional form for the MTF. This typical variation of the MTF as a function of frequency is as depicted in Fig. 4. Referring to this figure, it can be noted that the variation in MTF between $0.1 f_c$ and $0.5 f_c$ is practically linear. For frequencies less than $0.1 f_c$, the value of the MTF is almost unity. Thus a linear piecewise approximation of the MTF is made for the present study and shown in Fig.5. A circularly symmetric MTF was simulated setting for the along track MTF as the reference. The MTF was also fit with a Gaussian distribution function in order to avoid "ringing effect" near the edges of the filtered image data.

To correct for the MTF, a 2-d Fourier transform of the data was first obtained and its real and imaginary parts are corrected by the Wiener deconvolution of the MTF [Gonzalez and Wintz, 1987]. By applying the inverse Fourier transform to thus corrected spectrum, an image corrected for the MTF is obtained. Figure 6 illustrates the result that can be achieved by this process. The overall data quality can be seen improved as evident from the fact that the coastal boundaries and linear features in the data appear much sharper and clearer in the corrected image when compared to the original image in Fig. 1.

4. CONCLUSIONS

This preliminary study reveals that the visual striping of the PAN data can be effectively

reduced using the smoothing procedure together with the image segmentation. The simple histogram thresholding is found to be quite adequate, but better improvement is possible with region based segmentation methods, but at the cost of high computational time. The MTF of the PAN was modelled using a piecewise linear approximation and applied for correcting the image. Image sharpness is found to improve considerably. By this procedure, the image quality of the final corrected image is found to be superior to the original image.

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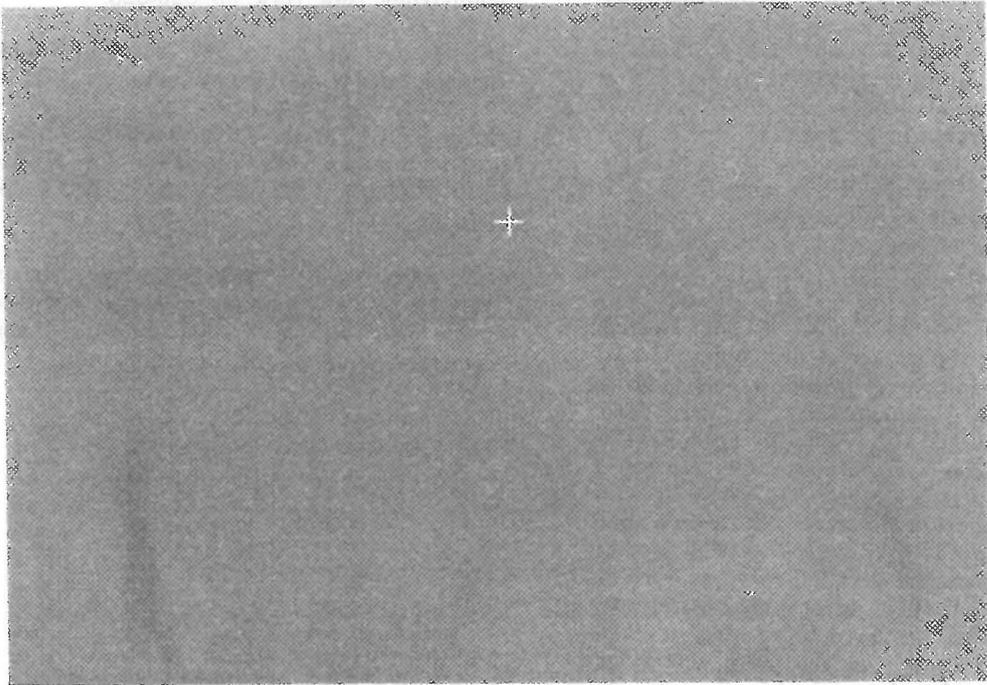
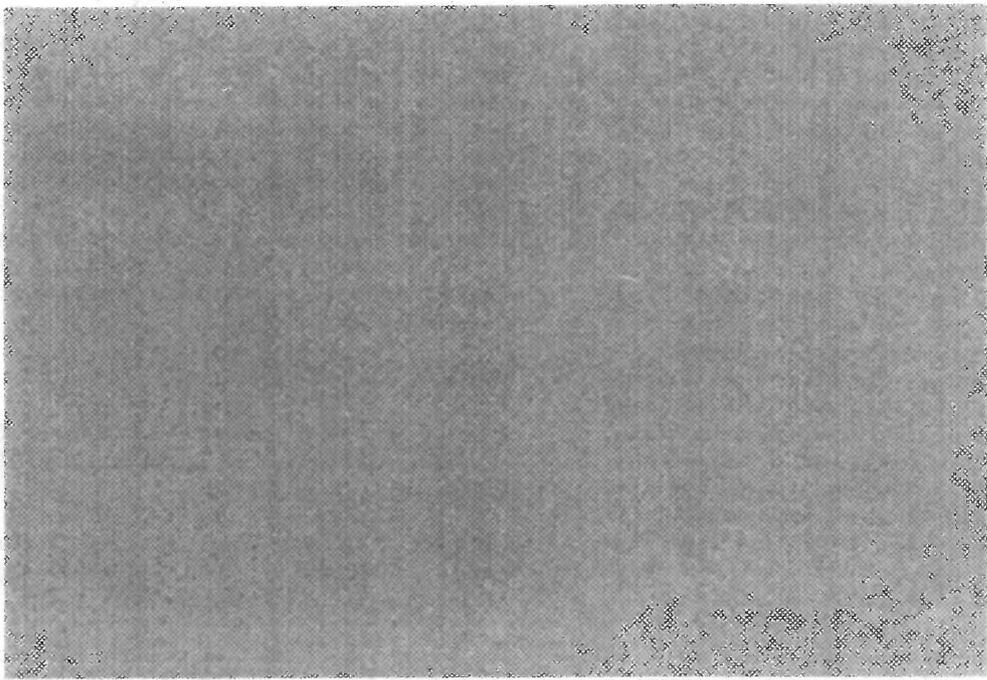
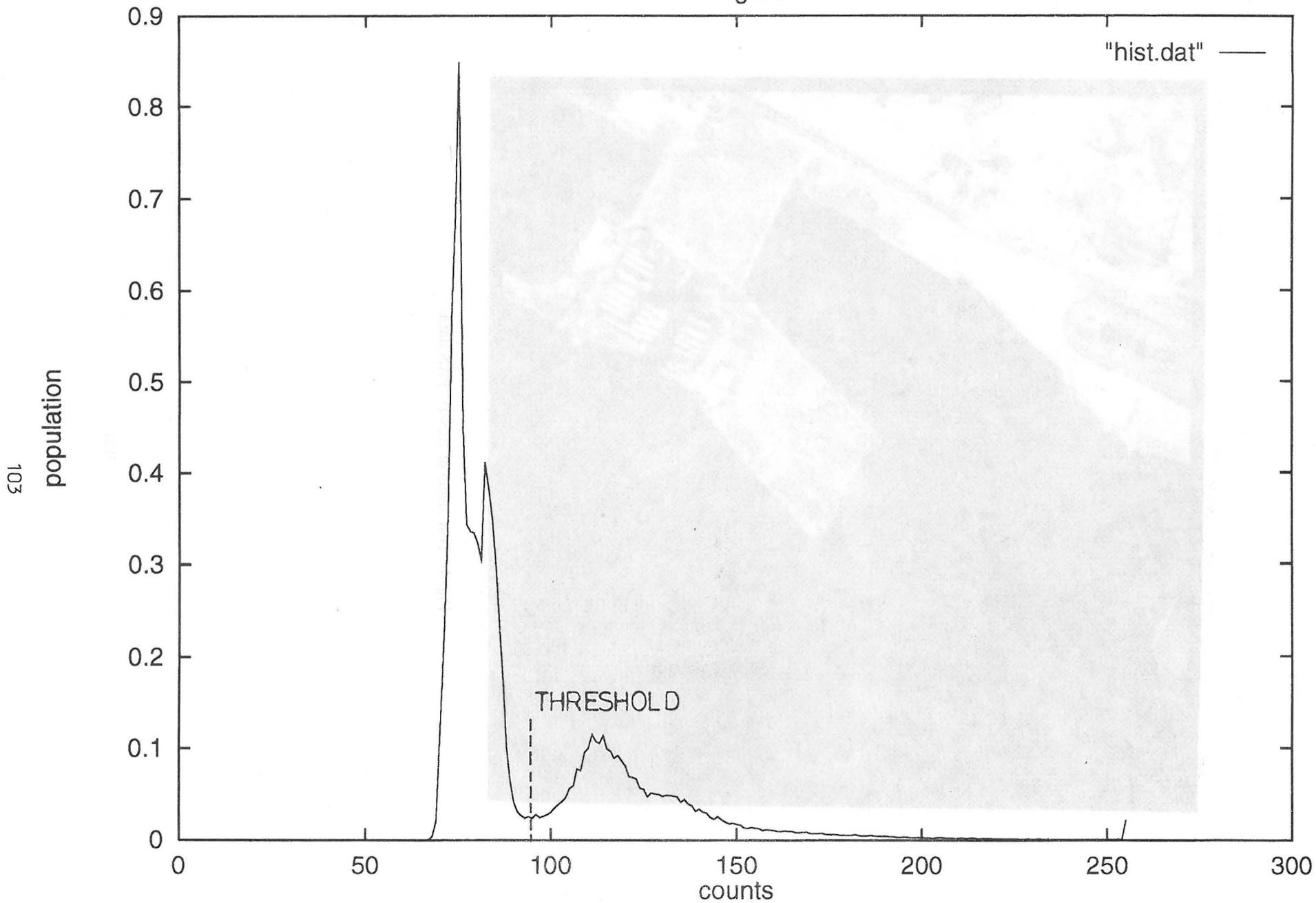


Fig. 2. Section of the image after hard stretching. (a). original, (b). after smoothing.

FIG. 3

histogram



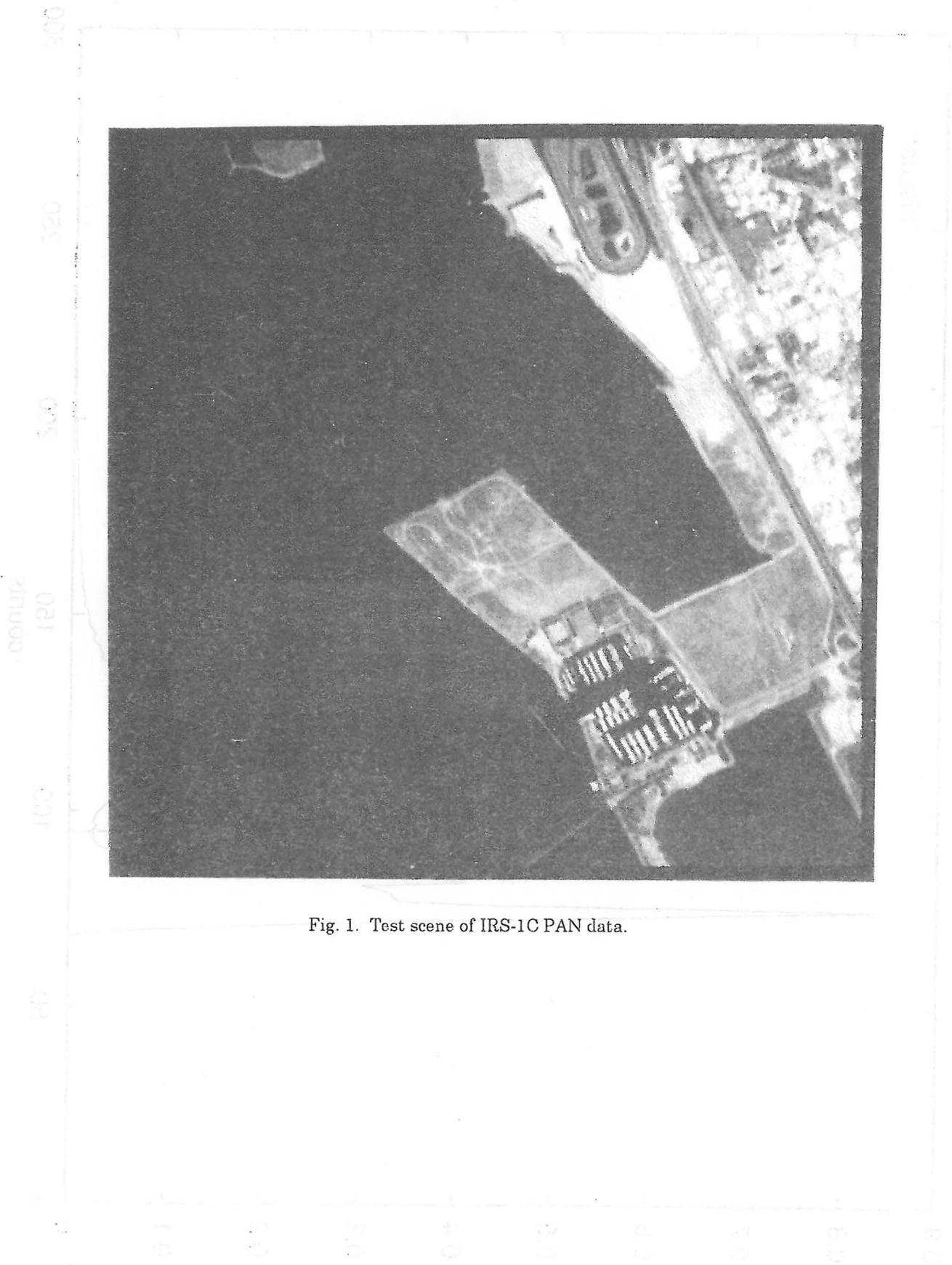


Fig. 1. Test scene of IRS-1C PAN data.

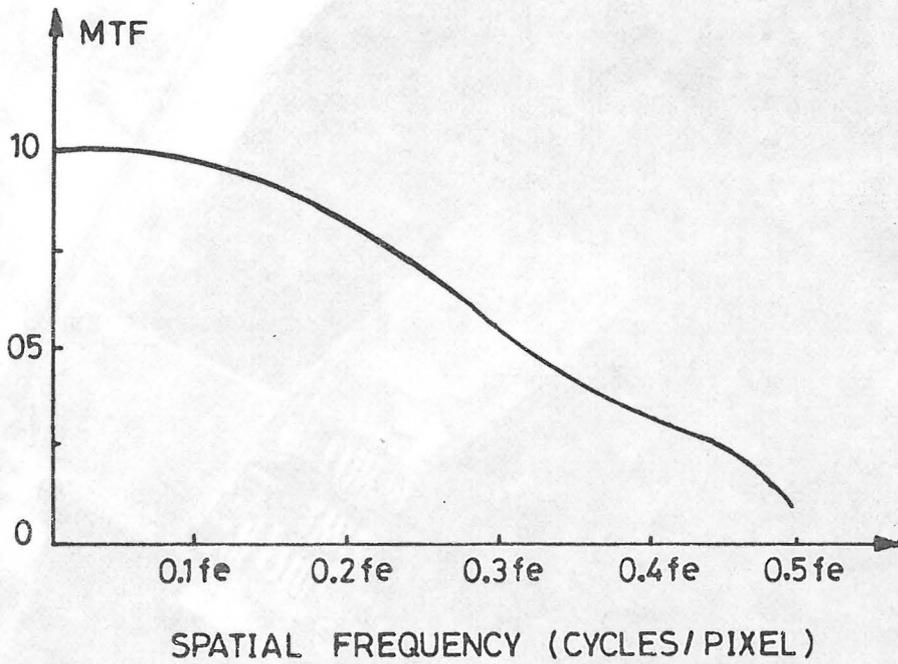
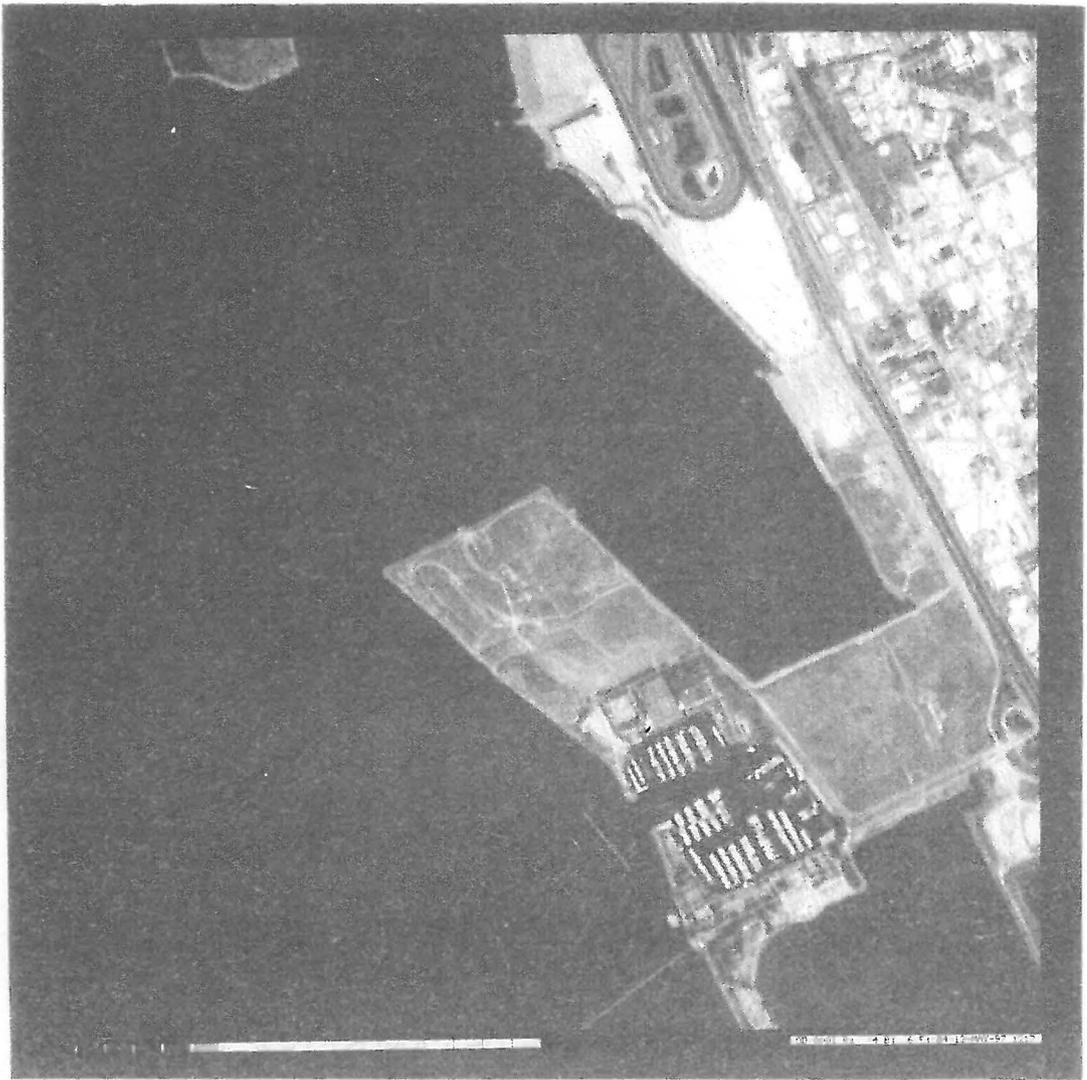


FIG. 4: VARIATION OF MTF OF LANDSAT-4 THEMATIC MAPPER AS A FUNCTION OF SPATIAL FREQUENCY (ADAPTED FROM SCHOWENGERDT *et al.*, 1985)



MAPPER AS A FUNCTION OF SPATIAL FREQUENCY
(ADAPTED FROM SCHWENBERG ET AL., 1985)

Fig.6. Test scene after smoothing and MTF correction.

