# THE DETERMINATION OF HIRS SCENE TEMPERATURES FROM AVHRR DATA

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## 1. INTRODUCTION

This paper introduces a technique for providing AVHRR estimates of the cloud-free and cloud overcast visible and window infrared radiance contributions within the field of view of the High Resolution Infrared Sounding (HIRS) instrument. The purpose is to identify uniform scenes within the HIRS field of view to facilitate cloud identification and provide surface/cloud temperatures for temperature and moisture profile processing.

## 2. COLOCATION OF AVHRR WITH HIRS

Colocation of the AVHRR and HIRS is complicated by two factors. First, the instruments scan in opposite directions. Second, the scan time for the AVHRR is 1/6 s and for the HIRS 6.4 s (including retrace). Thus, there are 38.4 AVHRR lines per HIRS line and the lines are tilted with respect to each other such that the 38.4 AVHRR lines actually overlap parts of three HIRS lines. Aoki (1980) has analyzed the geometry of this situation and provided a look-up table such that the pixel numbers of 39 AVHRR lines are identified as to where they fall within the HIRS FOV (56 spots per line; three lines). We have used Aoki's method for our colocation, without any adjustment for sensor misalignment (such as described by Aoki). To account for the timing problem, AVHRR data are processed in a repeating cycle of 38, 39, 38, 39, 38 (mean 38.4) lines. A complete cycle accommodates three complete HIRS lines and parts of another four. The geometry associated with this procedure is shown in Figure 1. Note that the first 38 lines of the next full cycle will complete HIRS line 4 which is numbered in parentheses. The entire swath is processed to output AVHRR/HIRS lines for AVHRR ch-1 (0.58-0.68 μm), ch-3 (3.55-3.93 μm) and ch-4 (10.3-11.3 μm).

## 2.2 Detection of Uniform or Multiple-Temperature Scenes

For retrieving temperature and moisture profiles, it is important that the scene be uniform, i.e. not containing multiple levels of cloud or even rugged topography. It is permissible that the FOV contain targets at two uniform temperatures since these FOVs may be reduced to a single scene by the adjacent-field-of-view correction method described in a companion paper (Hayden, et al.). The large samples (approximately 300-600) of AVHRR spots within the HIRS FOV are used to determine the uniformity by some simple statistical tests applied to channel 4. The data are then reduced to three radiances per channel per HIRS FOV to give:

- cold target;
- average;
- warm target.

All three values are filled for dual-temperature scenes, while uniform scenes have the same value in both average and warm target positions. If the warm target radiance is missing the HIRS retrieval algorithm will skip the scene.

Initially, the scatter of the data determines whether the FOV contains a single or multiple temperature scene. A standard deviation of 4 $mW\ m^{-2}\ SR^{-1}\ cm$ is used as the threshold (corresponding to 2K at a temperature of 300K). For FOVs which pass this test, average scene and warm uniform scene radiances are provided (in each channel).

FOVs failing the uniformity test are examined by the spatial coherence technique of Coakley and Bretherton (1982). Considering the AVHRR pixels to be divided into 3x3 sub-arrays, the mean radiance and standard deviation of each sub-array is found. If standard deviation is plotted against mean, the resulting scatter diagram has a characteristic form when targets at two or more temperatures are present (see for example Fig. 6). Points at the "feet" correspond to data from a single target (i.e., cloud-free or cloud overcast) while points in the "arches" represent sub-arrays containing multiple targets (i.e., partly cloudy field of views).

A rather simple algorithm (as contrasted to the method used by Coakley and Bretherton) is currently used to define the "feet." A histogram with class interval of two radiance units is assembled from the sample of subarrays. Each contribution to a class interval is weighted according to its standard deviation

$$W_i = 0 \text{ for } SD_i > 4 \qquad (1)$$

$$W_i = 0.25\ (4. - SD_i) \qquad (2)$$

Where SD is the standard deviation (trapped at 4.) and i refers to the subarray. A running mean filter of two intervals is passed over the final histogram. Cold and warm "peaks" are then located by moving in from the extremes until a class interval containing a maximum with a value of 1. or greater is located. A final cold or warm value is determined by averaging over two class intervals on either side of each peak. If this procedure finds two "feet" which are not the same, three scene radiances are passed to subsequent processing.

For this case study, FOVs successfully processed are assumed to consist of targets at two temperatures only, corresponding to the warmest and coldest feet. A further test to eliminate scenes with more than two targets is available; regression of channel 3 against channel 4 may reject FOVs on the basis of excessive standard error of regression. However, this proved severe and was suspended to maximize the number of FOVs available for downstream processing by the retrieval algorithm.

## 3. DATA

Data for 7 June 1984 were obtained for a case study. TOVS data are available from 13:56:03 GMT to 14:04:16 GMT. The AVHRR data are available from 13:54:10 GMT to 14:01:15 GMT, but the infrared channels are missing or excessively noisy until 13:56:48 GMT. Hence, the period when AVHRR data may be used to assist the TOVS retrieval processing is from 13:56:48 GMT to 14:01:15 GMT. This period contains the 37 HIRS lines between the first and second HIRS calibration gaps.

## 4. RESULTS

### 4.1 Colocation

Figures 2 and 3 show, respectively, an image of the HIRS channel-8 (11.1 micrometer) and the corresponding average value from the colocated AVHRR channel-4. Each square represents a HIRS FOV. Over the full sample, the brightness temperatures from each source produced a correlation of 0.994. Visually, it is apparent that the colocation is quite successful.

### 4.2 Scene Discrimination

With the present algorithms and quality-control thresholds, 90% of the FOVs yielded uniform or dual radiances (approximately half of each).

Figure 4 shows, for part of the scene, the positions and types of classifiable FOVs superimposed over the AVHRR image. Note that despite the ragged nature of the clouds, most of the HIRS FOVs are deemed adequate for further processing. It is not obvious at this resolution why an FOV has been selected as uniform or dual-temperature, but at higher magnification the eye can usually verify the decision of the algorithm. For example, in Figure 5, three scenes are shown from the left central portion of Figure 4. Only spot (18'11) was successfully processed as a uniform scene. The other two were correctly identified as multiple scene.

Figure 6 shows a graphic of the AVHRR distribution as processed by the Coakley-Bretherton algorithm. The ordinate is a standard deviation and the abscissa is mean radiance. In the diagram, a cold and warm "foot" are clearly evident and there is even a hint of an intermediate foot although the last is not sufficiently distinct to cause a multiple scene categorization. These features are consistent with the imagery (Figure 4) which shows in FOV (line 17' spot 9) a nearly even division between clear air and high cloud, the latter showing a cellular structure, affording a view of lower cloud (the intermediate foot).

Figure 7 shows superimposed points for three adjacent FOVs which cross the edge of the main cumulonimbus anvil at the top centre of Figure 4. The FOV (11'16) has a well-defined low radiance from the anvil while 11'14 has a well-defined higher radiance from the surrounding lower layer. FOV (11'15) spans the two layers and produces the expected arch structure with feet located precisely at the two layer radiances.

## 5. SUMMARY

Preliminary results are encouraging in that sensor colocation accuracy is acceptable and scene discrimination/temperature determination algorithms yield results which generally agree with subjective interpretation of the data. This work is not yet complete, however; and additional effort is required to adjust the various quality control checks for optimum performance on this and other cases. The example of the use of these AVHRR uniform scene radiances in the processing of TOVS data is given in a companion paper by Hayden, et al. (1985).

## 6. REFERENCES

Aoki, T., 1980: A method for matching the HIRS/2 and AVHRR pictures of TIROS-N satellites. Tech. Note No. 2, Met. Sat. Center, Japan, 15-26.

Coakley, J. A. Jr. and Bretherton, F. P., 1982: Cloud cover from high resolution scanner data: detecting and allowing for partially-filled fields of view. J. Geophys. Res., 87, 4917-4932.

Hayden, C. M., W. L. Smith, H. M. Woolf, B. F. Taylor, 1985: An application of AVHRR data to TOVS retrievals. Submitted to TOVS-II Conference.

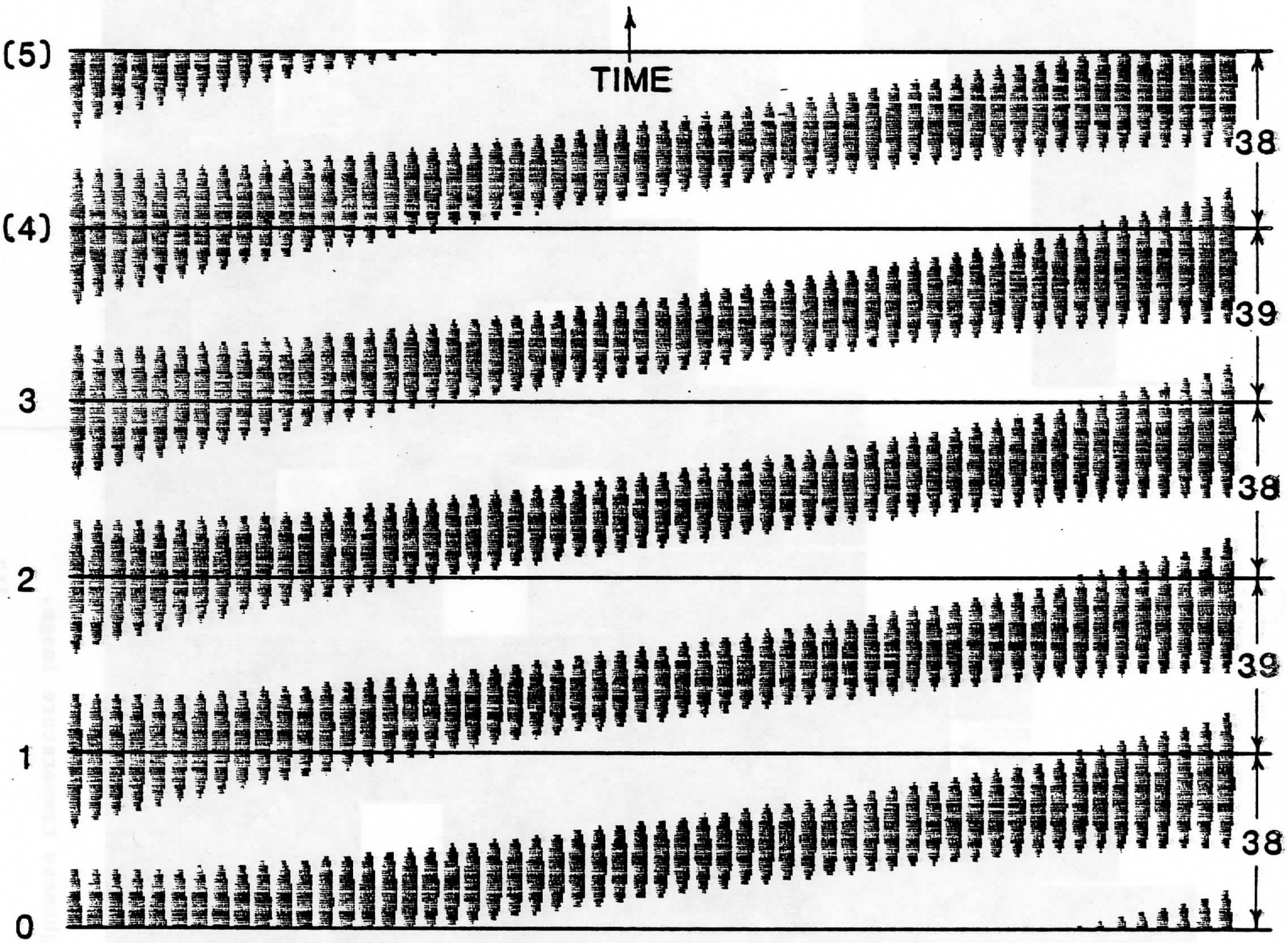


Figure 1. A schematic of the Aoki colocation of AVHRR and HIRS FOV (ovals). HIRS FOV are distorted for convenience of figure. A cycle of five batches of AVHRR lines is shown (numbered at right) corresponding to three complete lines of HIRS (numbered at left). HIRS lines numbered parenthetically will be filled in the next cycle.

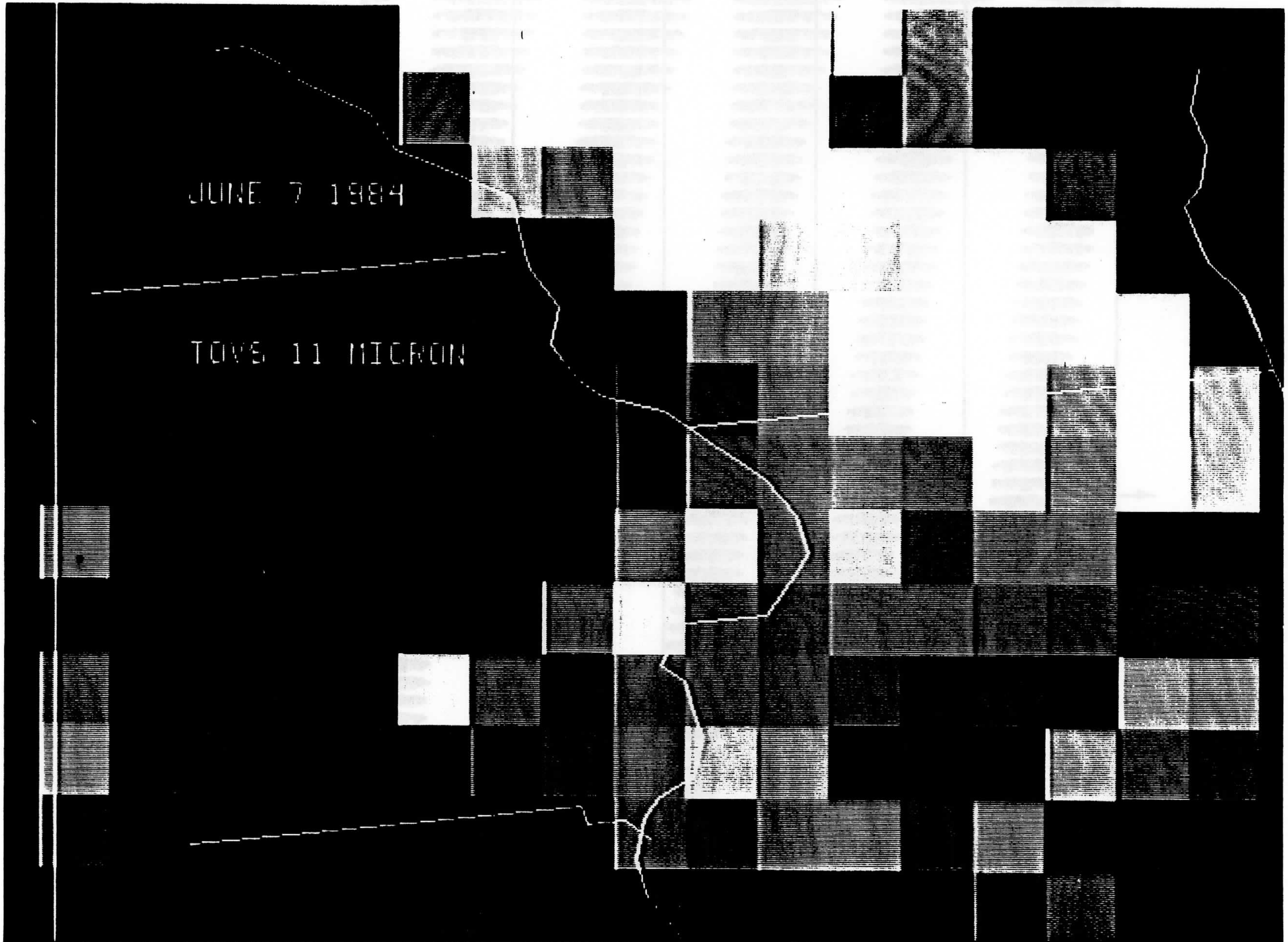


Figure 2. HIRS channel-8 brightness temperature image.

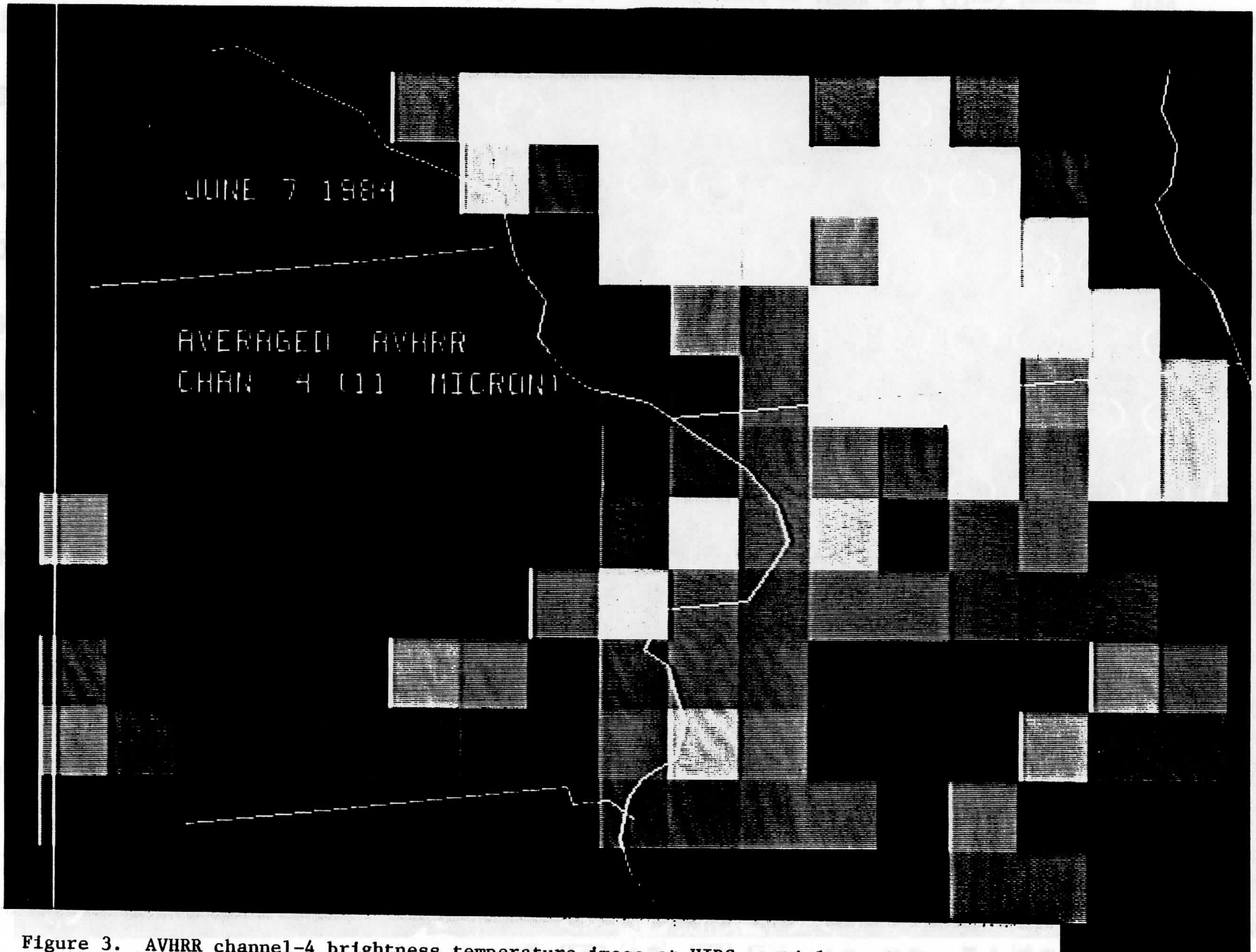


Figure 3. AVHRR channel-4 brightness temperature image at HIRS spatial resolution.


Figure 4. Positions and types of HIRS fields of view superimposed on AVHRR ch-4 (11μm) imagery. HIRS row and FOV numbers, referred to in subsequent figures, are defined at the boundaries. Grey ellipses denote uniform scenes, white ellipses denote dual-temperature scenes.

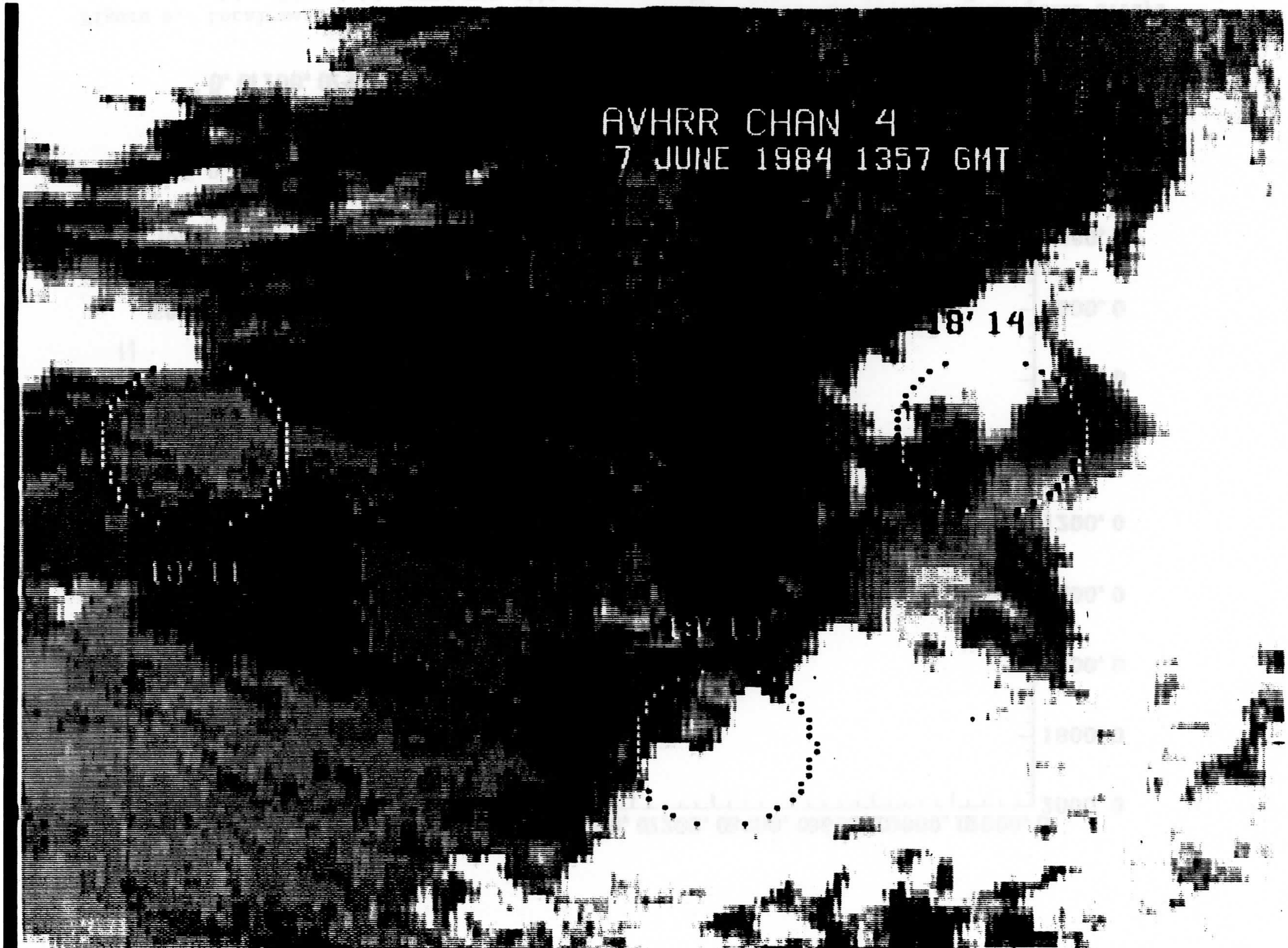


Figure 5. Blow-up of Figure 4 showing three HIRS FOV which were tested. Spot (18'11) passed as uniform scene. The other spots failed as being multiple scene.

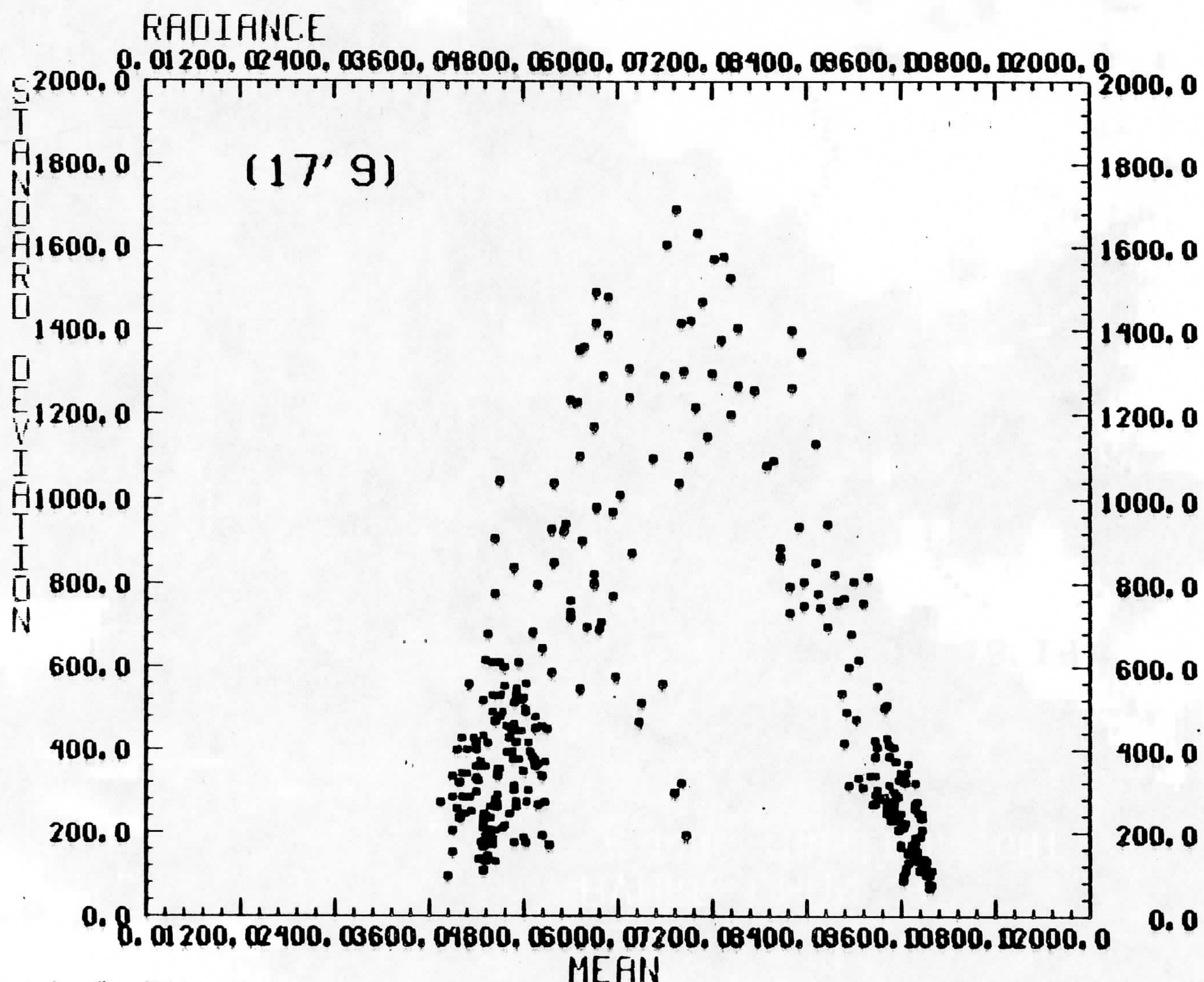


Figure 6. Local mean 11μm radiances and local standard deviations for 3x3 AVHRR pixel arrays which lie within HIRS FOV 17'9 (see Fig. 3). Units are 100 mW $m^{-2}$ $SR^{-1}$ cm.

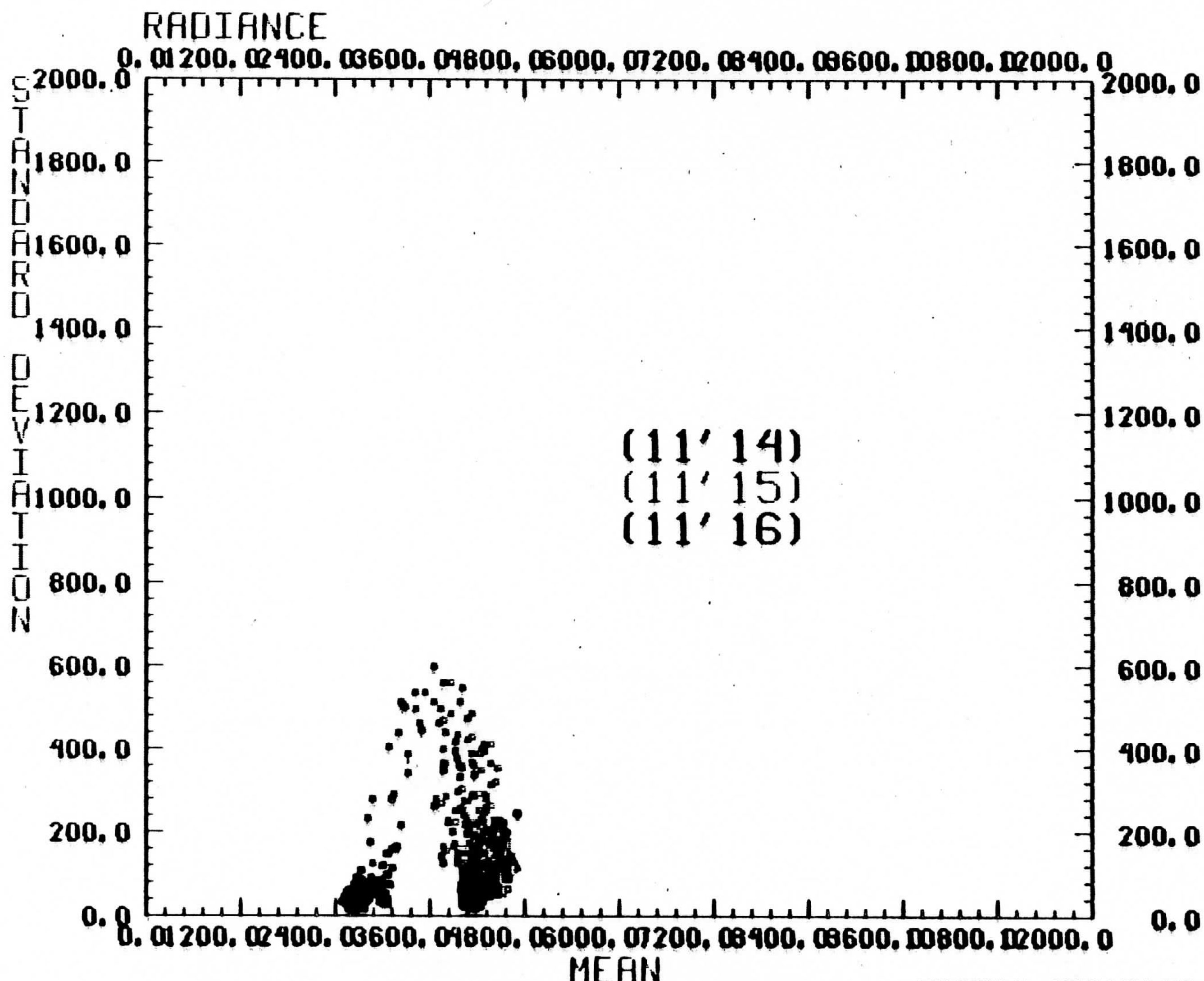


Figure 7. Local mean 11μm radiances and local standard deviations for 3x3 AVHRR pixel arrays which lie within HIRS fields of view 11'14, 11'15 and 11'16. Black points denote the two outer scenes, grey points denote the centre FOV which spans two cloud layers. Units are 100 mW $m^{-2}$ $SR^{-1}$ cm.

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