Naval Ocean Systems Center
San Diego, CA 92152-5000

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Infrared Sky and Terrain Radiances in a Coastal Region

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ADMINISTRATIVE INFORMATION

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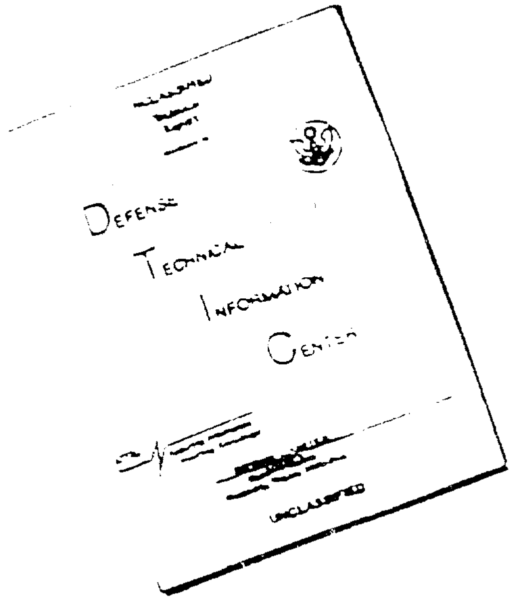

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This document presents examples of infrared background scenes to demonstrate the utility of a calibrated AGA Thermovision Model 780 thermal imaging system to provide a database of the mean-terrain and mean-sky temperatures in a coastal region.

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INTRODUCTION

Models of atmospheric and terrain infrared backgrounds in coastal regions are of special importance to designers of electro-optical systems to aid in sensor specification, and to ship commanders in optimizing the use of smart weapons against an adversary in different locales. Fleet units operating in costal regions in support of amphibious operations must be able to determine the standoff ranges at which they can detect and track incoming aircraft or guided weaponry using passive infrared sensors (low-light level TV, FLIR, or IRST). Determination of these standoff ranges is important in order to estimate the times allowable for evasive action and the deployment of countermeasures. To predict the allowable times, the infrared radiance contrast between a target, its natural background, and the atmospheric transmittance for the wavelength band of the sensor must be known. In most situations, threat vehicles approaching from the land will have a smaller radiance contrast with their background than those approaching from the colder regions of the sky, thus allowing less time for target acquisition or evasive actions. Models of expected sky/terrain backgrounds and meteorological conditions in different locales need to be developed for use in real-time system performance prediction codes and for use in system design.

~~In~~ this report presents atmospheric and terrestrial infrared (8 to 12 μm) radiances measured in the San Diego, California coastal region using an AGA Model 780 THERMOVISON infrared imaging system ~~are presented~~. Examples of daytime background radiances ~~acquired on two days~~ are analyzed to compare the mean equivalent blackbody temperatures of the terrain and the overlying sky during different solar heating conditions. Recommendations for further measurements and improvements to the present data acquisition system are discussed.

MEASUREMENTS

For these measurements, the AGA system was equipped with a 2.95° field-of-view lens. The response of the system is determined by placing a blackbody of known temperature (±0.1°C for temperatures <50°C) in front of the lens aperture. The digitized video signal transfer function of the system then allows the blackbody temperature to be reproduced to within ±0.2°C. The Thermal Video Processor System (THERMOTEKNIX), available with the AGA system, allows the thermal scene to be displayed in a computer screen format consisting of 128 pixel lines (0.023°/pixel line). The software also allows the pixels, whose temperatures are either above or below a certain level to be deleted from the thermal image and a temperature histogram of the remaining pixels in any selected area on the image to be displayed. With this process, the pixels contributing to the sky and terrain radiances can be displayed separately and their mean temperatures determined.

The scanner was located at the end of the Point Loma peninsula at a height of approximately 30 meters and directed southeasterly toward the shore line. From this vantage point, the shore line distances vary between 8 and 15 km. A photograph of the coastal region (taken during mid-afternoon on 4 March 1988) is shown in figure 1 with a Spruance class destroyer [the USS David R. Ray (DD971)] appearing in the foreground at a distance of approximately 2 km from the AGA recording site. At that distance, the background scene shown would be approximately the same as that viewed from on board the ship. On this day, the visibility was estimated to be less than 30 km, and inland mountainous regions are not visible in the photograph. However, during good visibility conditions, several peaks (such as CERRO GORDO, 1150 meters high, and at a distance of 60 km) are clearly visible. An infrared background scene recorded by the AGA system near 1500 PST on 18 May 1988 is shown in figure 2. In this example, a guided missile cruiser [the USS W. H. Standly (CG32)], located approximately 2 km from the AGA site, is in the foreground of CERRO GORDO. The temperatures of the different colors in the scene are identified by the color bars displayed on the left which correspond to the midpoints of the temperatures printed above and below each bar. In figure 3A, pixels with temperatures below 17.4°C were deleted from the scene, and the remaining terrain radiance pixels enclosed within a rectangular area are shown. To the left of the radiance scene, the frequency of occurence (histogram) of the pixels with a specific temperature within the enclosed area is displayed with the mean temperature and its standard deviation. Similarly, in figure 3B, pixels with temperatures above 17.2°C were deleted from the scene and the sky-temperature histogram is calculated as shown. In this example, the mean temperature of the terrain is 19.3°C and that of the sky is 14.5°C, with the sky temperature distribution being much broader than that of the terrain.

These data were acquired in the late afternoon under cloudless skies such that both the terrain and sky temperatures were influenced by solar heating. Data acquired earlier on the same day gives some indication of the heating effects on each of the backgrounds relative to the sun's position. Histograms measured at 1220 PST are shown in figure 4A and 4B, and those measured at 1335 PST are shown in figures 5A and 5B. [While some of the detail is lost, these color-printer (PRISM 80) reproductions of the AGA computer screen provide a more readily accessible record of the temperature histogram than do the photographs.] In figure 6, the mean terrain and sky temperature variation with time are shown. Both increase with time at about the same rate, with the sky temperature remaining less than the terrain temperature by 5°C or 6°C. Histograms calculated from a thermogram taken shortly after sunrise on 1 April 1988 at 0656 PST are shown in figures 7A and 7B. Here, solar heating was just beginning to take effect and the mean terrain temperature was 12.4°C and that of the sky was 5.2°C. By early afternoon (1320 PST), the mean terrain and sky temperatures had increased to 19.3°C and 12.9°C as shown in figures 8A and 8B, respectively. The variations with time (figure 9) show a heating rate of about 1°C/hour for both the terrain and sky temperatures. These data are summarized in the following table with the ambient air temperature, T(Air), and relative humidity, RH, at the times of observation:

Table 1. Measured sky and terrain average temperatures with existing air and relative humidities.

Date(1988)	Time(PST)	T(Air)	RH	T(Terr.)	T(Sky)
18 MARCH	1220	23.3°C	46%	16.1°C	10.1°C
	1335	23.8	50	18.3	12.7
	1503	23.8	54	19.5	14.5
1 APRIL	0656	16.1	35	12.4	5.2
	1320	24.0	38	19.3	12.9

DISCUSSION AND RECOMMENDATIONS

The computer associated with the AGA system is a BMC IF800 Model 20 with a floppy disc capability. This computer uses the CP/M2.2 operating system and allows the temperature values (°C) of each pixel to be written to a file in the form of an array, which is a simple way to archive the raw data. However, to read the data, a compatible operating system must be available. Since the present system is incompatible with IBM computers, programs would have to be written to transfer the data from the AGA disk through the RS-232 port to an IBM compatible computer.

For the archived data to be useful, it must be accompanied by the vertical profiles of meteorological parameters (temperature, pressure, and relative humidity) taken simultaneously with the background scenes. NOSC has the capability of obtaining the required parameters (including aerosol-size distributions and actual sea-surface temperatures) using an instrumented Piper Navajo aircraft and surface-based measurements of wind speed. These data are available on either floppy disc or magetic tape for processsing on any IBM compatible media.

These limited data are shown to demonstrate the utility of the AGA system to acquire a database of sky and terrain infrared backgrounds in a coastal region. It is recommended that additional data be taken to include the diurnal and seasonal backgrounds occurring in the San Diego coastal region. This data set should also include the effects of clouds. During overcast stratus conditions, the terrain and sky are apt to be in equilibrium making their temperatures unresolvable. In many instances in the Southern California area (as is to be expected in many coastal regions of the world), the humidity and aerosol effects prohibit the terrain background scene from being detected at large ranges. In these situations the major contributor to the background scene is the atmospheric path emission and data are needed to model these effects and address wavelength band trade-off options, i.e., 8-12 μm versus 3-5 μm. The present AGA system has this capability.

FIGURE CAPTIONS

Figure 1. Photograph of the San Diego Coastal Region (with the USS DAVID R. RAY (DD971) in the foreground) as seen from the AGA recording site located on the end of the Point Loma peninsula.

Figure 2. Infrared background scene recorded by the AGA system at 1500 PST on 18 March 1988 with the USS W. H. STANDLY (CG32) in the foreground of CERRO GORDO.

Figure 3. Temperature histograms of the terrain (A) and sky (B) backgrounds shown in Figure 2.

Figure 4. Temperature histograms of the terrain (A) and sky (B) backgrounds recorded at 1220 PST on 18 March 1988 with the USS FIFE (DD991) in the foreground.

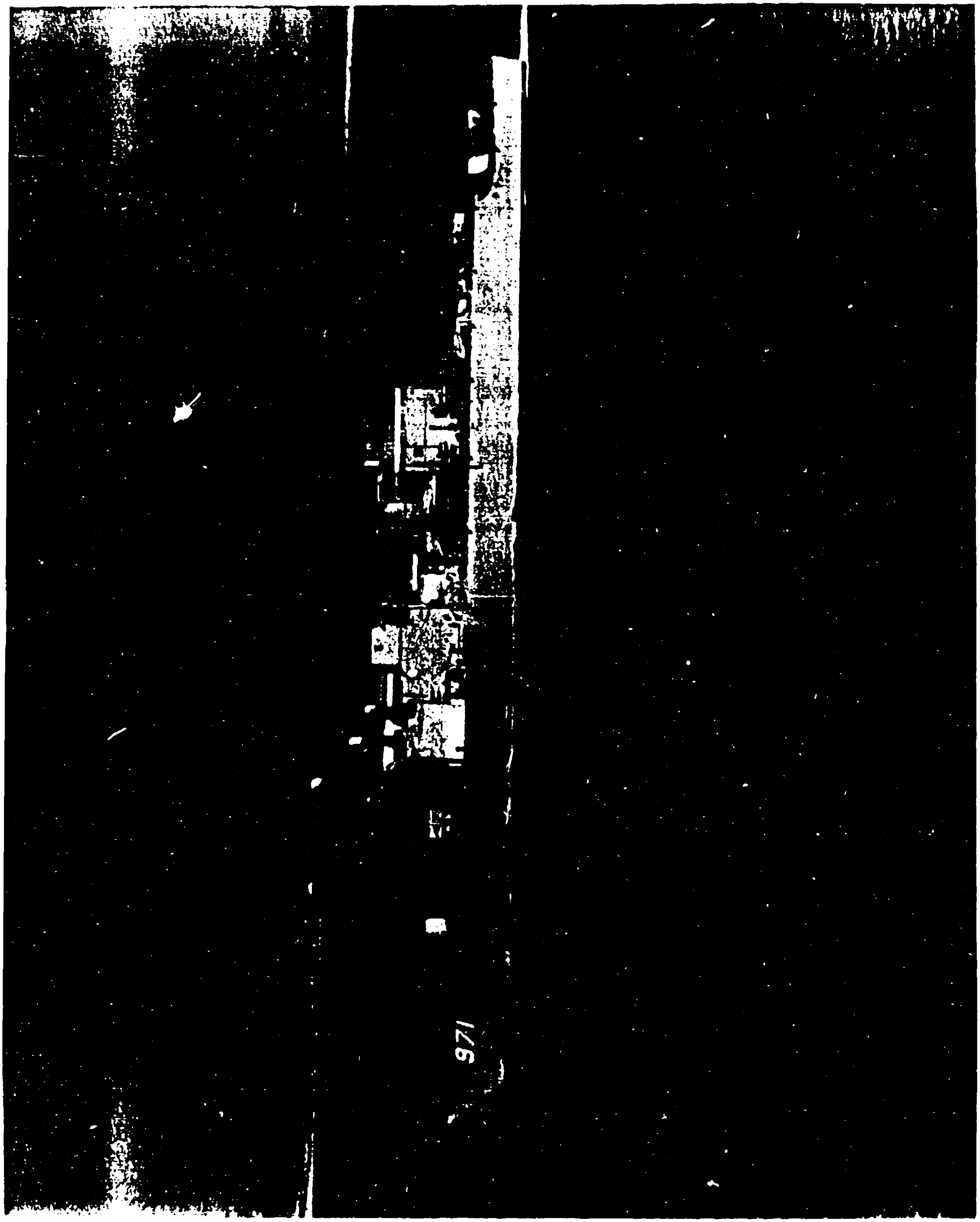
Figure 5. Temperature histograms of the terrain (A) and sky (B) backgrounds recorded at 1335 PST on 18 March 1988 with the USS SCHENECTADY (LST1195) in the foreground.

Figure 6. Mean terrain and sky temperature variation with time on 18 March 1988.

Figure 7. Temperature histograms of the terrain (A) and sky (B) backgrounds recorded at 0656 PST on 1 April 1988 with the USS BROOKE (FFG1) in the foreground.

Figure 8. Temperature histograms of the terrain (A) and sky (B) backgrounds recorded at 1320 PST on 1 April 1988 with the USS ENGLAND (CG22) in the foreground.

Figure 9. Mean terrain and sky temperature variation with time on 1 April 1988.


971

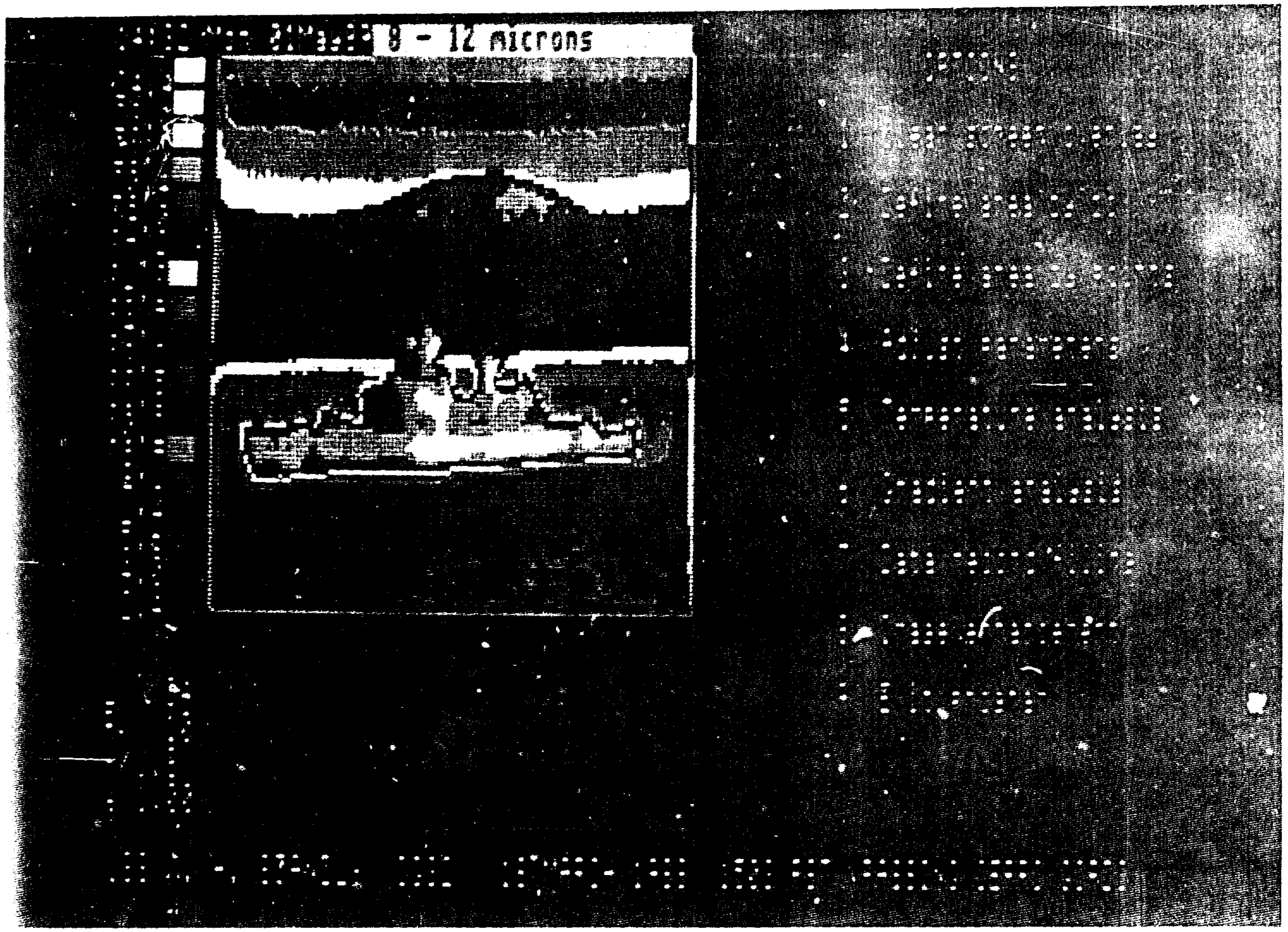
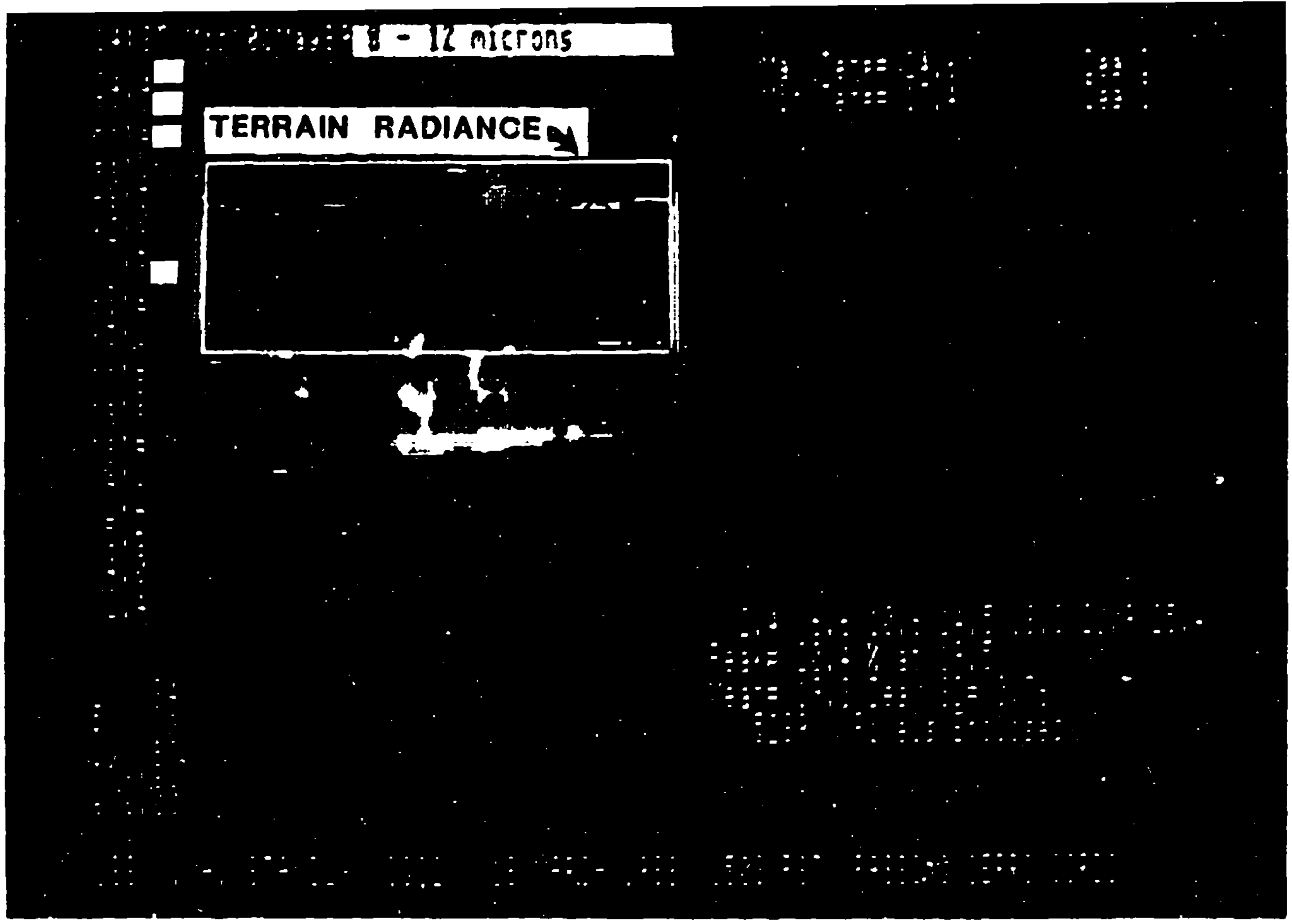


FIGURE 2

(A)



(B)

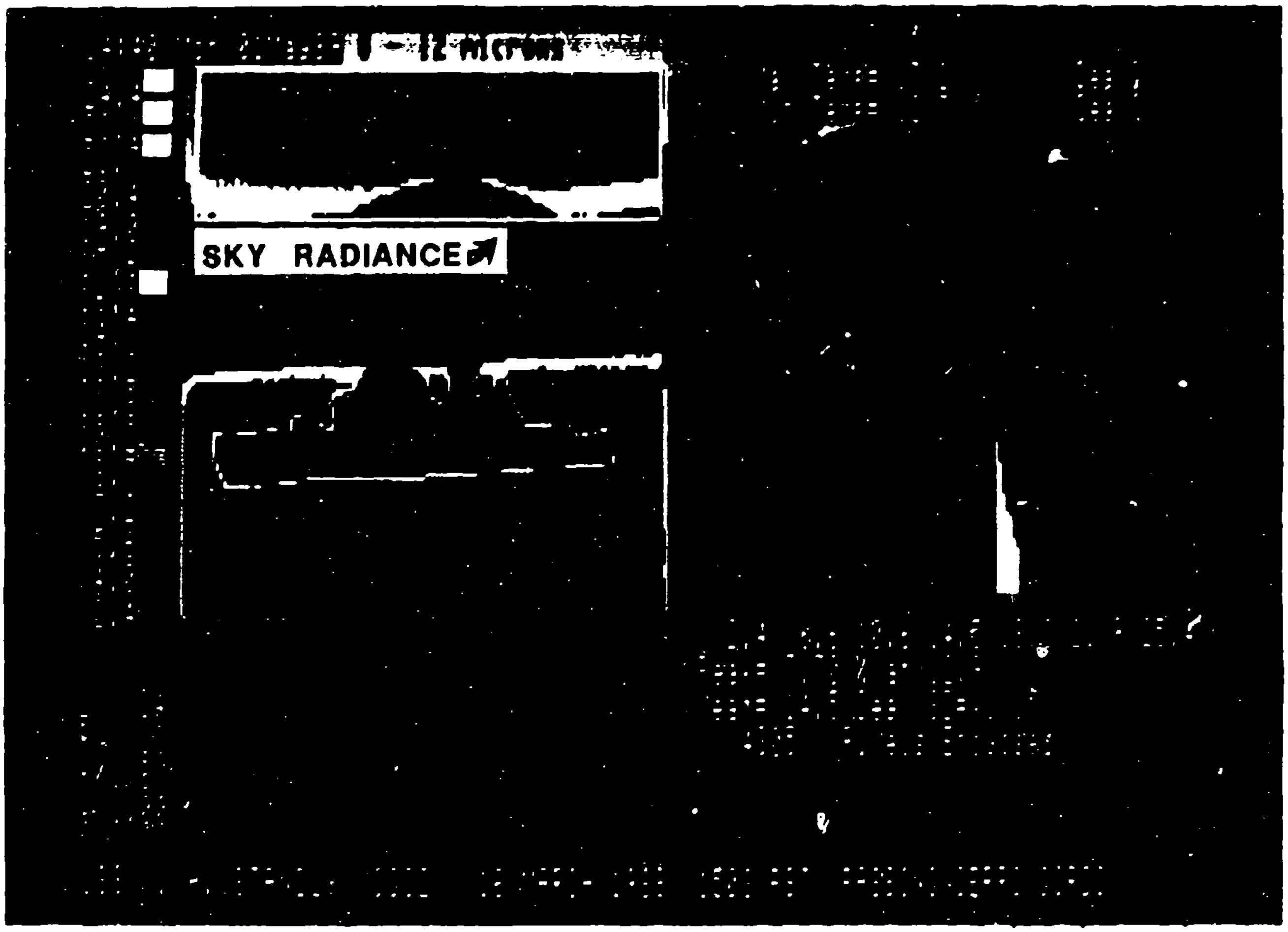


FIGURE 3

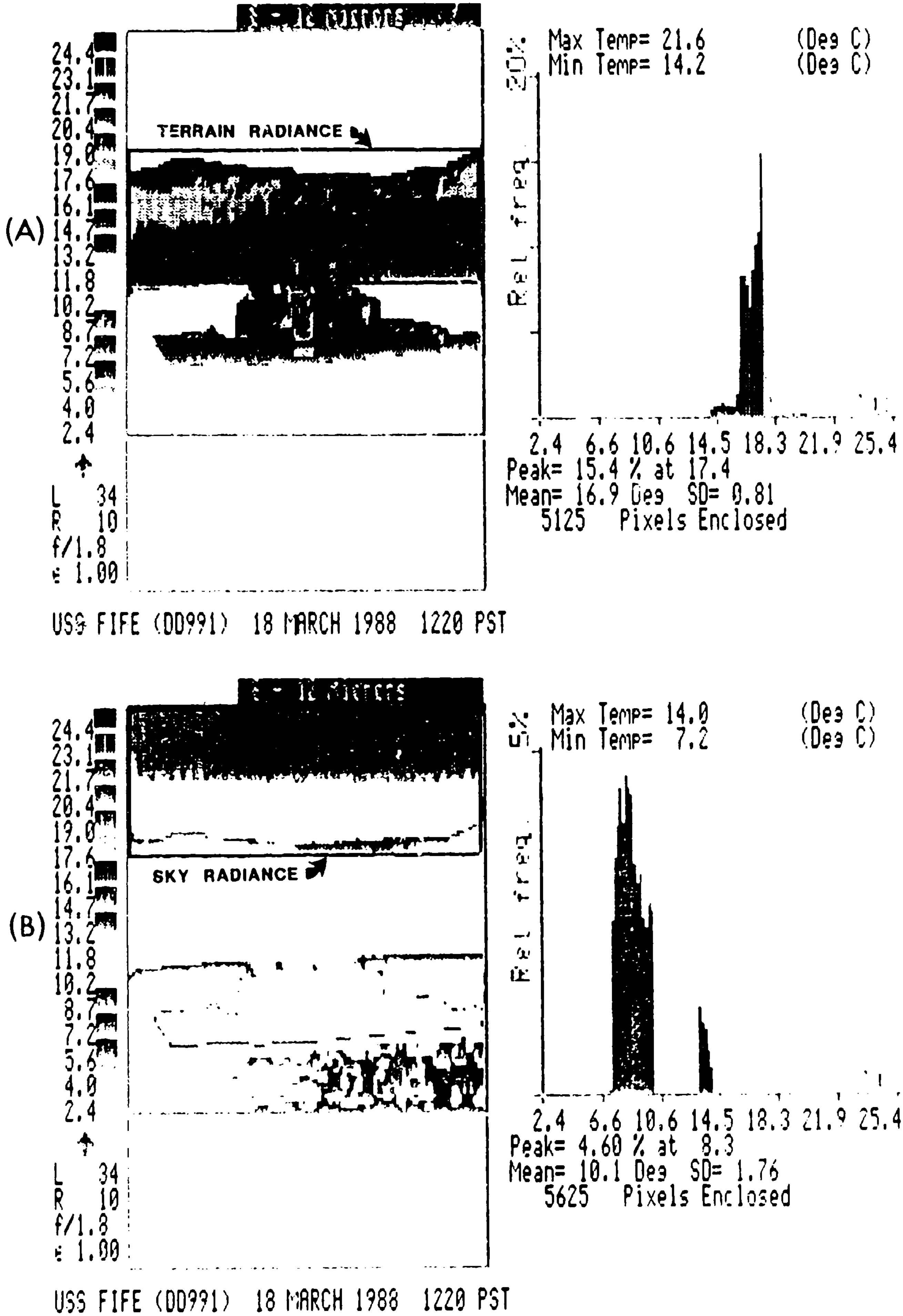
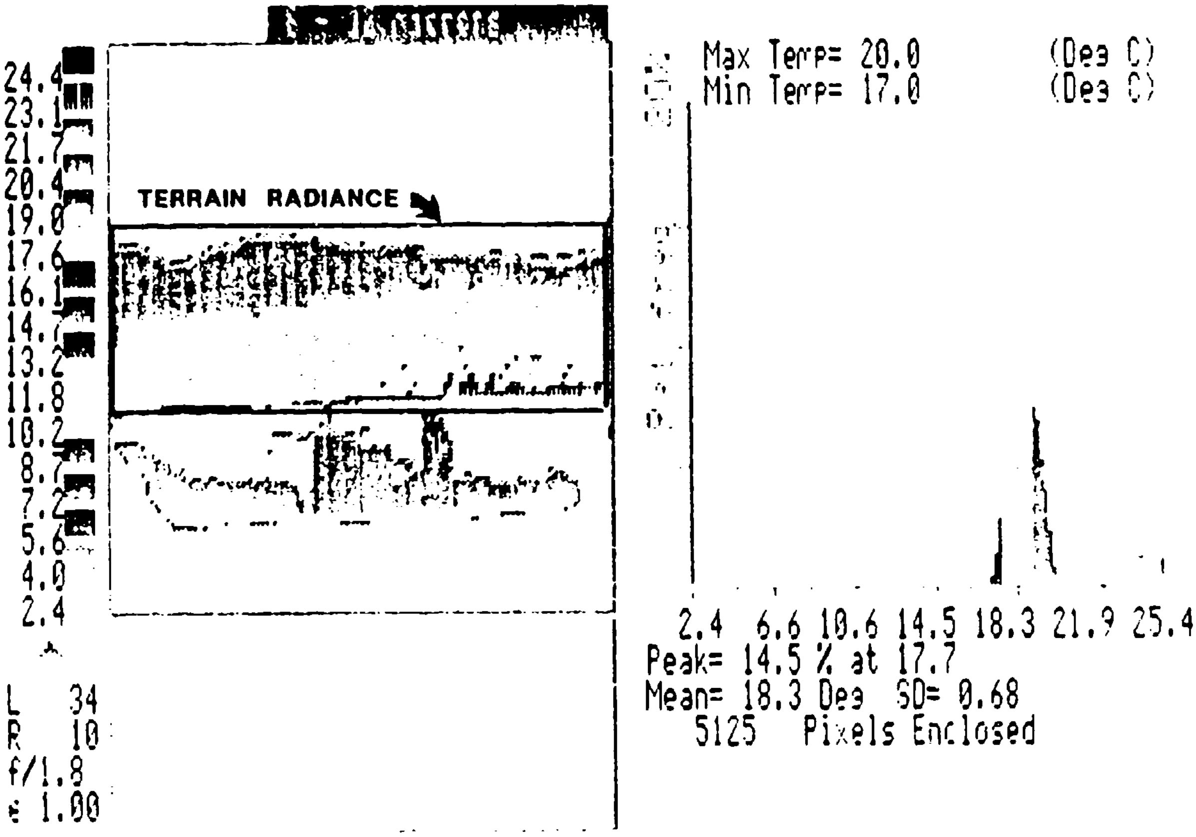

(A)
TERRAIN RADIANCE
Max Temp= 21.6 (Deg C)
Min Temp= 14.2 (Deg C)
20%
Rel freq
2.4 6.6 10.6 14.5 18.3 21.9 25.4
Peak= 15.4 % at 17.4
Mean= 16.9 Deg SD= 0.81
5125 Pixels Enclosed
24.4 23.1 21.7 20.4 19.0 17.6 16.1 14.7 13.2 11.8 10.2 8.7 7.2 5.6 4.0 2.4
L 34
R 10
f/1.8
ε 1.00
USS FIFE (DD991) 18 MARCH 1988 1220 PST
(B)
SKY RADIANCE
Max Temp= 14.0 (Deg C)
Min Temp= 7.2 (Deg C)
5%
Rel freq
2.4 6.6 10.6 14.5 18.3 21.9 25.4
Peak= 4.60 % at 8.3
Mean= 10.1 Deg SD= 1.76
5625 Pixels Enclosed
24.4 23.1 21.7 20.4 19.0 17.6 16.1 14.7 13.2 11.8 10.2 8.7 7.2 5.6 4.0 2.4
L 34
R 10
f/1.8
ε 1.00
USS FIFE (DD991) 18 MARCH 1988 1220 PST

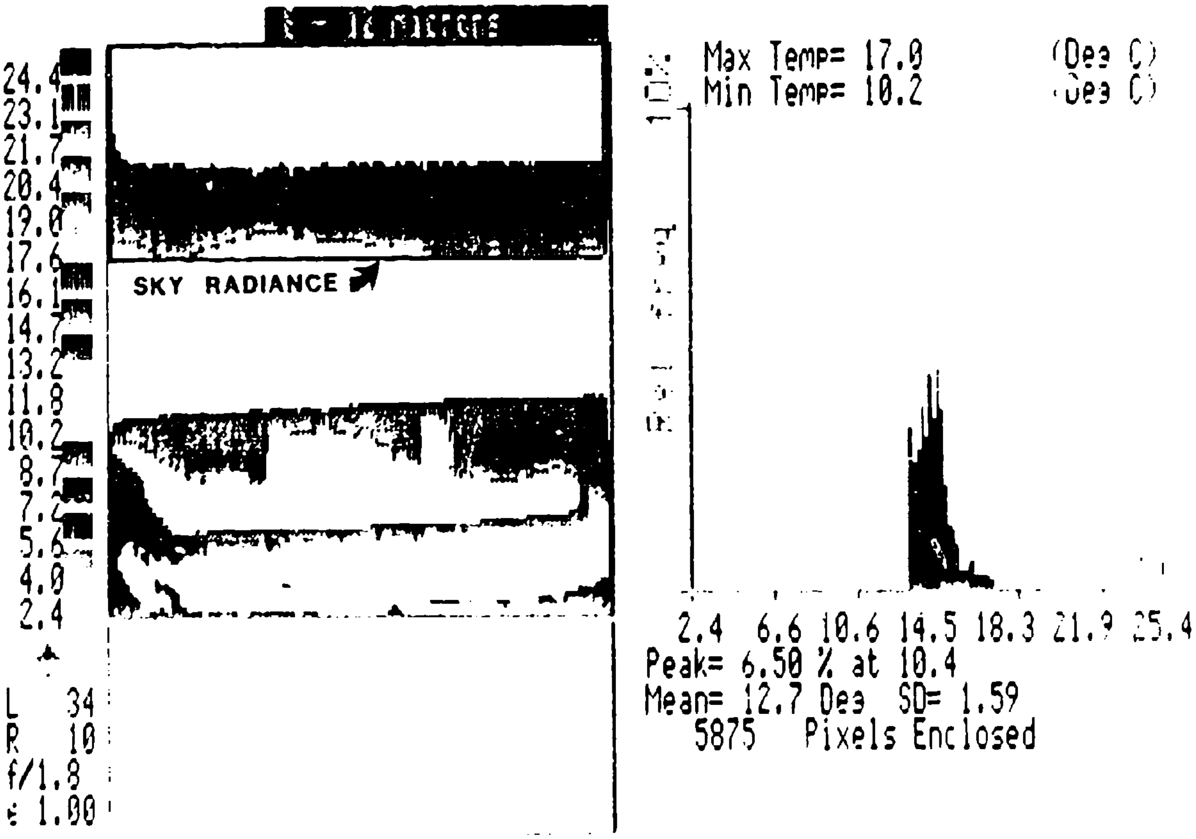
FIGURE 4

(A)



USS SCHENECTADY (LST1185) 18 MARCH 1988 1335 PST

(B)



USS SCHENECTADY (LST1185) 18 MARCH 1988 1335 PST

FIGURE 5

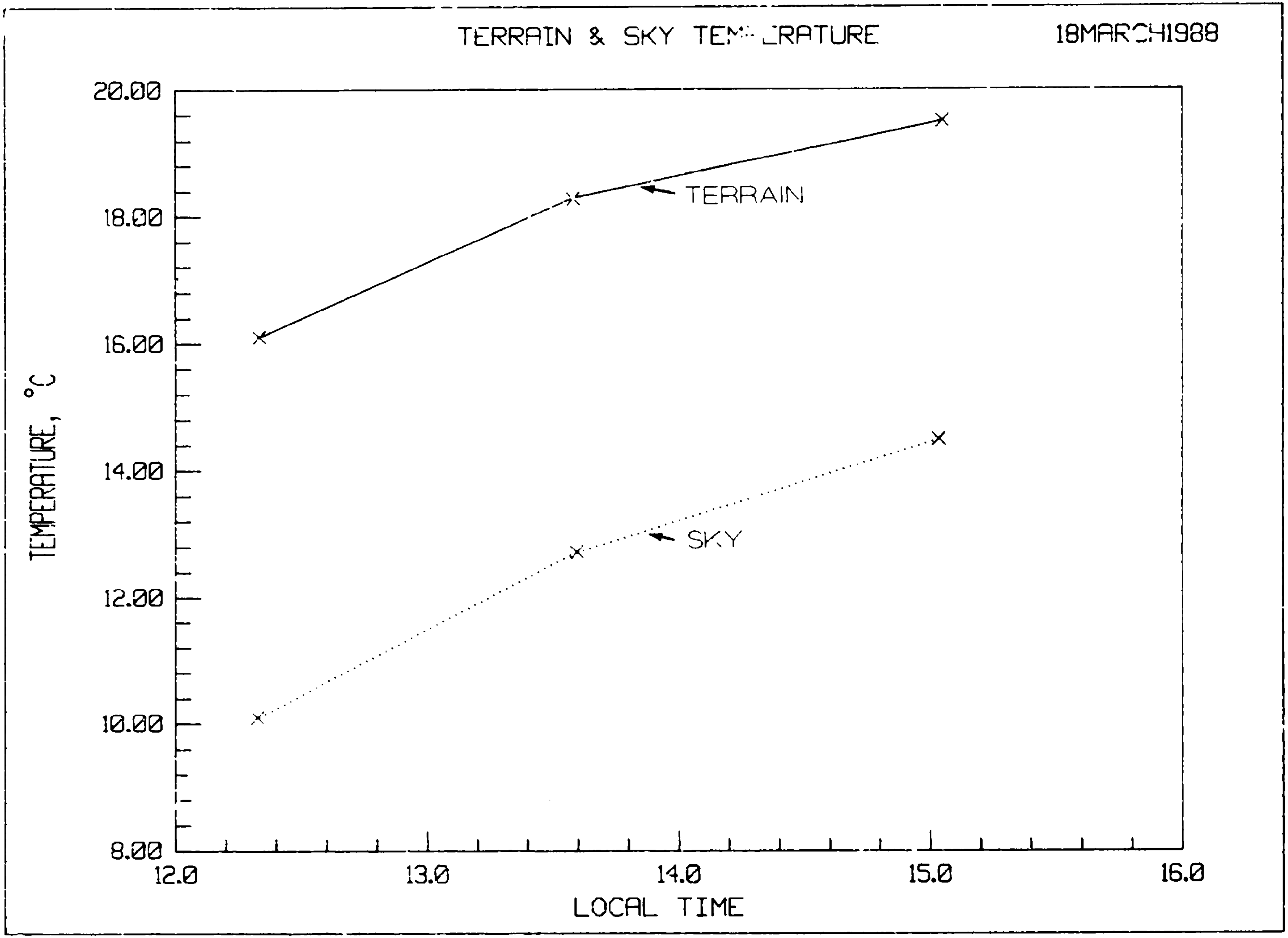

TERRAIN & SKY TEMPERATURE
18MARCH1988
TERRAIN
SKY
TEMPERATURE, °C
20.00
18.00
16.00
14.00
12.00
10.00
8.00
12.0
13.0
14.0
15.0
16.0
LOCAL TIME

FIGURE 6

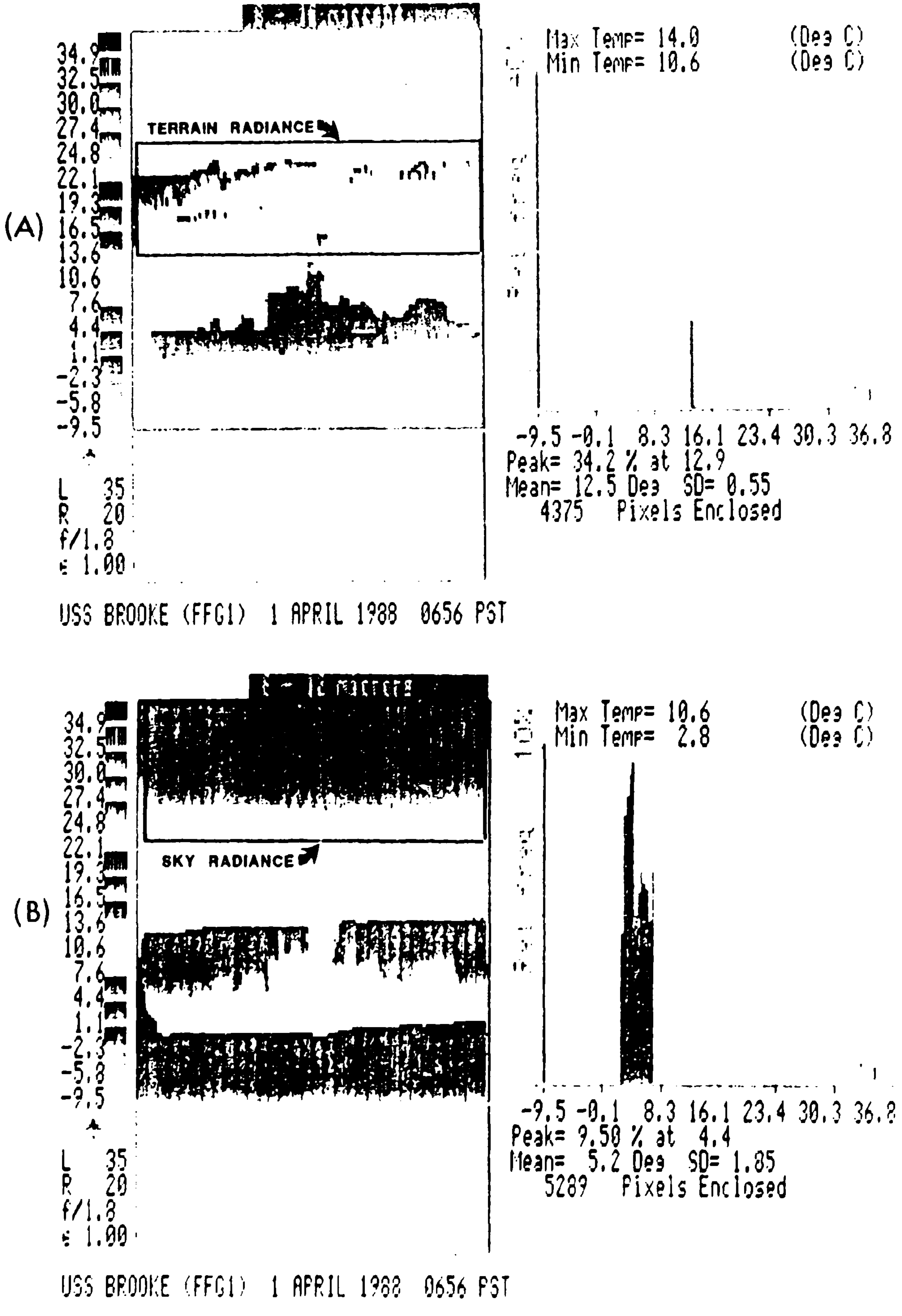

(A)
TERRAIN RADIANCE
Max Temp= 14.0 (Deg C)
Min Temp= 10.6 (Deg C)
-9.5 -0.1 8.3 16.1 23.4 30.3 36.8
Peak= 34.2 % at 12.9
Mean= 12.5 Deg SD= 0.55
4375 Pixels Enclosed
L 35
R 20
f/1.8
ε 1.00
USS BROOKE (FFG1) 1 APRIL 1988 0656 PST
(B)
SKY RADIANCE
Max Temp= 10.6 (Deg C)
Min Temp= 2.8 (Deg C)
-9.5 -0.1 8.3 16.1 23.4 30.3 36.8
Peak= 9.50 % at 4.4
Mean= 5.2 Deg SD= 1.85
5289 Pixels Enclosed
L 35
R 20
f/1.8
ε 1.00
USS BROOKE (FFG1) 1 APRIL 1988 0656 PST

FIGURE 7

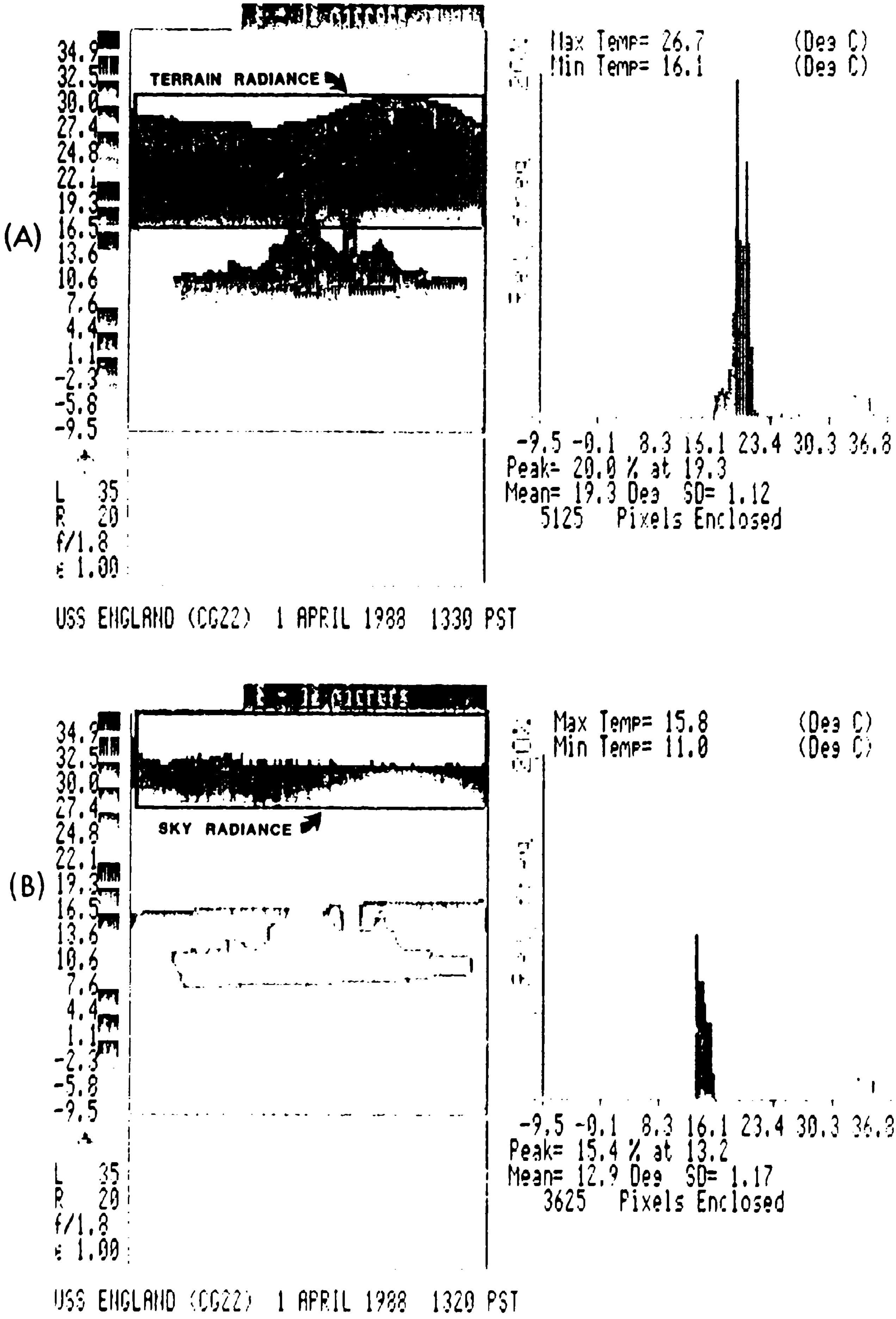
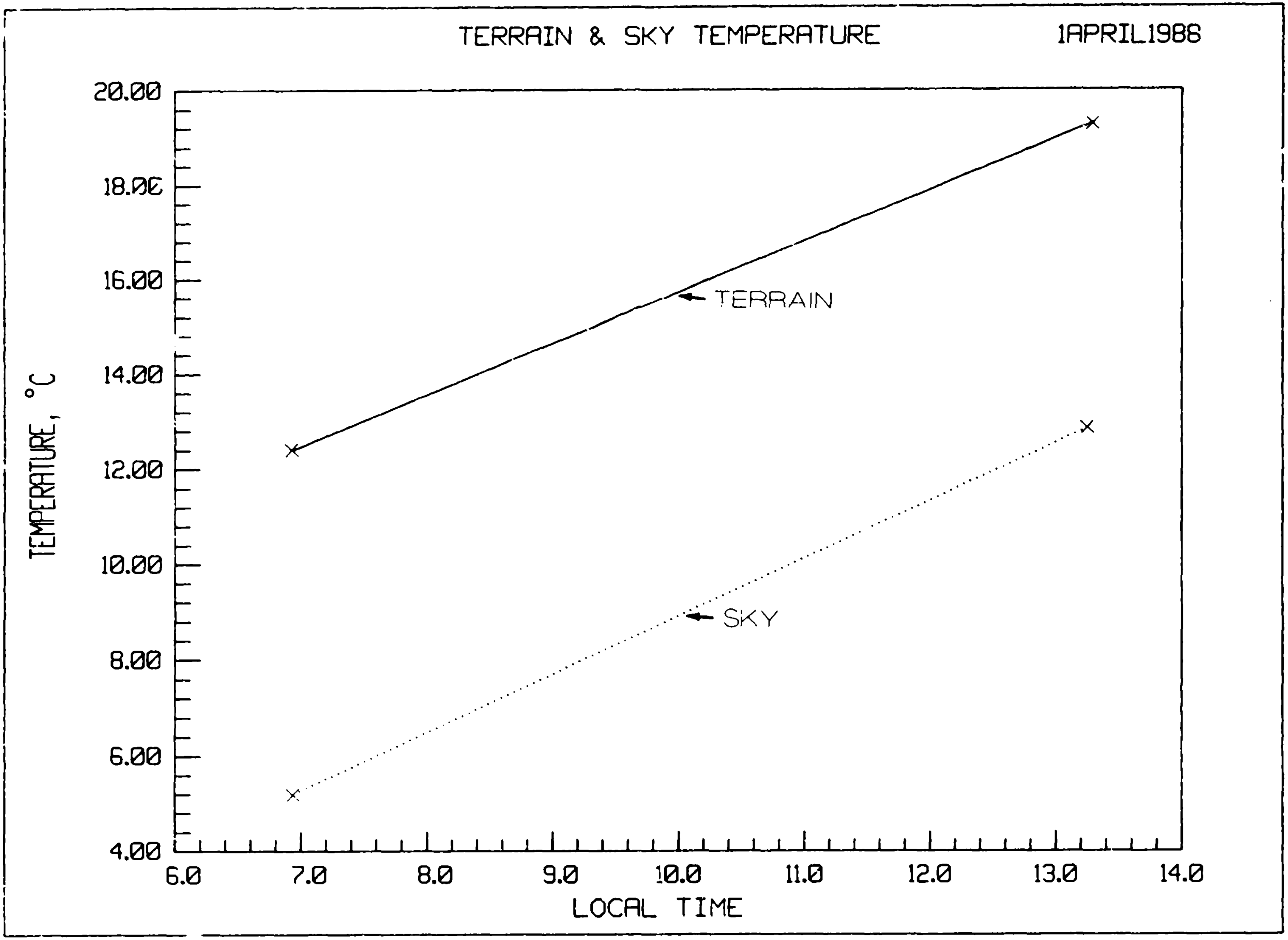

Max Temp= 26.7 (Deg C)
Min Temp= 16.1 (Deg C)
TERRAIN RADIANCE
(A)
34.9
32.5
30.0
27.4
24.8
22.1
19.3
16.5
13.6
10.6
7.6
4.4
1.1
-2.3
-5.8
-9.5
L 35
R 20
f/1.8
ε 1.00
-9.5 -0.1 8.3 16.1 23.4 30.3 36.8
Peak= 20.0 % at 19.3
Mean= 19.3 Deg SD= 1.12
5125 Pixels Enclosed
USS ENGLAND (CG22) 1 APRIL 1988 1330 PST
Max Temp= 15.8 (Deg C)
Min Temp= 11.0 (Deg C)
SKY RADIANCE
(B)
34.9
32.5
30.0
27.4
24.8
22.1
19.3
16.5
13.6
10.6
7.6
4.4
1.1
-2.3
-5.8
-9.5
L 35
R 20
f/1.8
ε 1.00
-9.5 -0.1 8.3 16.1 23.4 30.3 36.8
Peak= 15.4 % at 13.2
Mean= 12.9 Deg SD= 1.17
3625 Pixels Enclosed
USS ENGLAND (CG22) 1 APRIL 1988 1320 PST

FIGURE 8



TERRAIN & SKY TEMPERATURE
1APRIL1986
TEMPERATURE, °C
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
LOCAL TIME
TERRAIN
SKY

FIGURE 9