

## SEA SURFACE TEMPERATURE MAPPING USING A THERMAL INFRARED SCANNER

M.R. RAMESH KUMAR, R.M. PANDYA\*, K.M. MATHUR\*,  
R.J. KRISHNAMA CHARYULU AND L.V. GANGADHARA RAO

National Institute of Oceanography, Dona Paula, Goa 403004

### ABSTRACT

The sea surface temperature (SST) determined by remote sensing technique refers to the skin temperature of the sea surface, while the SST measured by conventional method employing a bucket thermometer gives the temperature of the water in the upper 1 metre water column below the sea surface. A thermal infrared scanner developed by the Space Applications Centre (ISRO), Ahmedabad was operated on board R V *Gaveshani* in April/May 1984 for mapping SST over the eastern Arabian Sea. SST values recorded by this device during the cruise are compared with those determined by conventional bucket thermometer and the results are discussed. The difference between the temperature values from the thermal scanner and those from the bucket thermometer varied from +1°K to -1°K in the present study.

Key-words: SST, skin temperature, thermal IR scanner.

### INTRODUCTION

Sea surface temperature (SST) is one of the important parameters required for various meteorological and oceanographic studies. Measurement of SST over a large area with an accuracy of 0.2°K is very much useful for air-sea interaction studies, long-range weather prediction, pollution monitoring etc. This can be achieved by remote sensing through infra-red scanners. The infra-red scanners on board satellites and aircrafts measure the skin temperature of the sea surface, whereas the conventional ship board measurements employing an insulated bucket thermometer give the temperature of the water in the upper 1 metre below the sea surface. The skin temperature of a water body is usually colder than the subsurface turbulent layers. This has been demonstrated by numerous authors (Paulson and Parker, 1972; Hill, 1972 and Katsaros, 1977) in the laboratory experiments as well as field observations (Nicholls, 1979; Ewing and McAlister, 1960; Schooley, 1977 and Simpson and Paulson, 1980) for various environmental conditions. In the present study an attempt has been made to compare the skin temperature of the sea surface, measured by a thermal infrared scanner with the SST obtained by conventional shipboard measurements.

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\* Address: Space Applications Centre (ISRO), Ahmedabad 380053.

## MATERIAL AND METHODS

**Description of the scanner and operation:** A thermal infrared scanner developed by the Space Applications Centre, Ahmedabad, was used for mapping sea surface temperature over the eastern Arabian Sea during the 136th cruise of R V *Gaveshani* from 25 April to 3 May, 1984. The scanner was mounted on a boom on the star-board side of the ship in such a way that it is located at a height of about 5 metres from the sea surface and 5 metres away from the ship's side in order to minimise the effects of sea spray and ship's radiation.

The scanner works in 10.5 to 12.5  $\mu\text{m}$  band. It has a large instantaneous field of view (IFOV) of 100 milliradians and its total field of view (FOV) is  $45^\circ$  with respect to nadir. A scan mirror of 5 cm in diameter, which can be rotated at a speed of 0.2 rps, is used. The scanner uses a pyroelectric detector for sensing the thermal infrared radiations. It has a temperature resolution of about  $0.2^\circ\text{K}$  at  $300^\circ\text{K}$ .

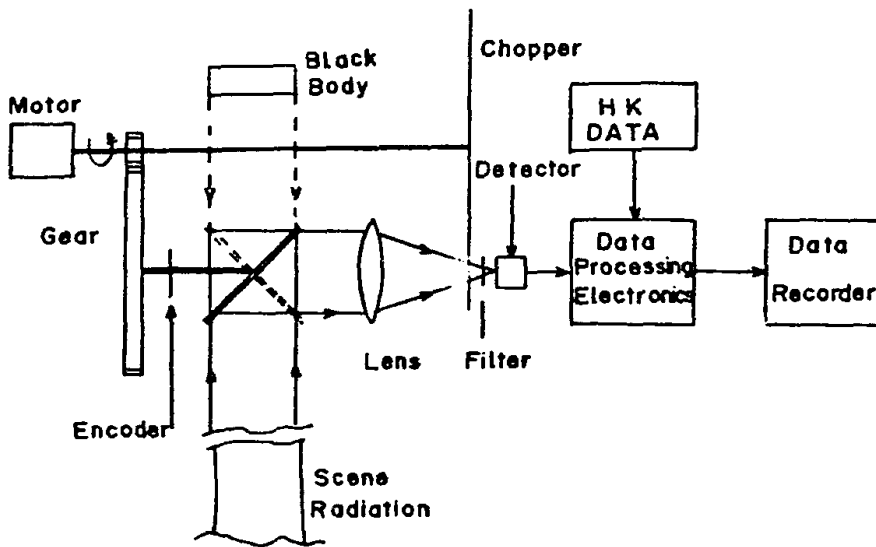


Fig.1. Schematic diagram of Slow Scan SST scanner

A schematic block diagram of the scanner is shown in Fig.1. A single synchronous motor is used to rotate the chopper and a scan mirror. The two are coupled through gears to get the proper rotation speed of 5 and 0.2 rps respectively. The gold plated mirror makes an angle of  $45^\circ$  with an optical axis of the lens. During its rotation it looks at the scene radiation as well as the two black body reference sources and housing. These radiations are collected by a germanium lens and focussed into pyroelectric detector. An interference filter is put before the pyroelectric detector to select only 10.5-12.5  $\mu\text{m}$  band. The scanner has two black bodies, one cold ( $C_{BB}$ ) maintained at  $15^\circ\text{C}$  and another a hot black body ( $H_{BB}$ ) maintained at  $40^\circ\text{C}$ . The chopper provides a very good S/N ratio at a frequency of 35 Hz.

The detector then converts these radiations into electrical signals which are then amplified, processed and digitized and recorded on a digital tape recorder.

The principle of operation of the scanner is similar to other scanning radiometers. When mounted on a moving platform like a ship, the scan mirror rotates in a plane perpendicular to the platform forward velocity. The scan direction of the mirror gives one dimension of the imagery, the other being obtained by the platform forward velocity.

**Calibration of the scanner:** The infrared scanner must be stable and well calibrated for accurate measurement of SST since a very small error in the absolute radiance can lead to very large temperature errors (Robinson, 1985). Pandya and Mathur (1984) have shown the following relationship between the final output and the scene temperature ( $T_{sc}$ ) as given below:

$$T_{sc} = \frac{C2/\lambda}{\ln \left[ 1 + \frac{C1}{\lambda^5} \left( \frac{1}{(D_{sc}/D_h) + (W_h - W_c) + W_c} \right) \right]} \quad \dots (1)$$

where  $T_{sc}$  – observed temperature of the scene,  $D_{sc}$  – digital counts referring to scene,  $D_h$  – digital counts referring to  $H_{BB}$ ,  $W_h$  – radiant emittance from the  $H_{BB}$ ,  $W_h = 0.00359715 \text{ W/cm}^2\mu$  at  $312.65^\circ\text{K}$ ,  $W_c$  – radiant emittance from  $C_{BB}$ ,  $W_c = 0.00251023 \text{ W/cm}^2\mu$  at  $288.20^\circ\text{K}$ ,  $C1 = 3.7415 \times 10^4 \text{ W/cm}^2\mu$ , and  $C2 = 1.43879 \times 10^4 \mu^\circ\text{K}$ .

The equation 1 was derived with the following assumptions: (a) That the atmosphere does not affect the radiation travelling from the scene to the scanner, (b) the radiation from a pixel at nadir and pixels at the extreme will travel along different paths and (c) the emissivity of  $C_{bb}$ ,  $H_{bb}$  and the scene (water) is unity.

## RESULTS AND DISCUSSION

The scanner was operated in 4 areas along the cruise track (Fig.2). Simultaneously, SST was measured by using an insulated bucket thermometer in order to prevent heat losses and cooling of the water due to evaporation and the data on environmental conditions were noted. The data recorded by the scanner on 1/2 inch CCT was further processed to derive the most probable temperature ( $T_{most}$ ) in each frame of 50 records (duration 250 sec) and its frequency of occurrence and standard deviation. Figs.3 to 6 show values of  $T_{most}$ , frequency and standard deviation for the areas 1 to 4. The maximum value of  $T_{most}$  was observed in area 1 ( $306^\circ\text{K}$ ) and the minimum value in area 4 ( $301^\circ\text{K}$ ). Maximum variation in the  $T_{most}$  values as well as in the standard deviation were observed in area 1. The standard deviations in other areas were very small showing the high repetitive nature of skin temperature measured.

Table I gives the comparison of temperature values from ship-borne infrared radiometer ( $T_{skin}$ ) and bucket thermometer ( $T_{sst}$ ). Air temperature ( $T_{air}$ ), time of observation, surface wind speed and

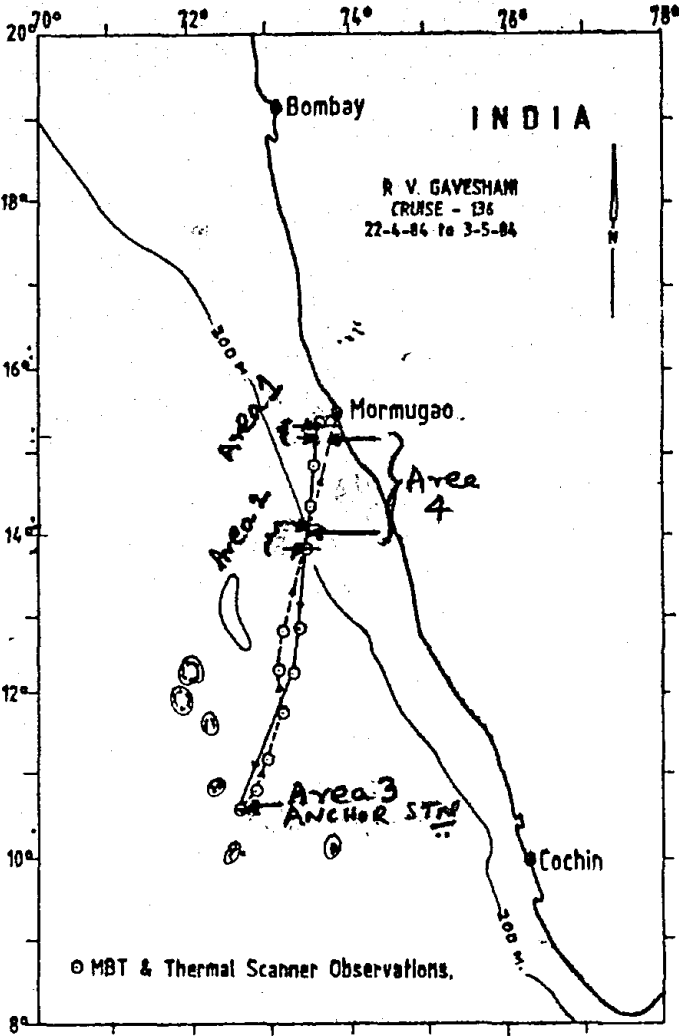


Fig.2. Map showing the cruise track.

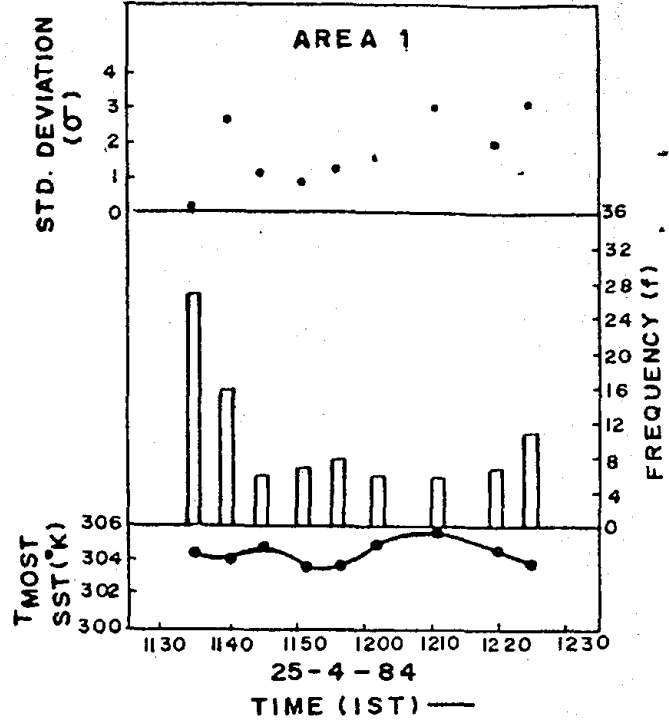


Fig.3.

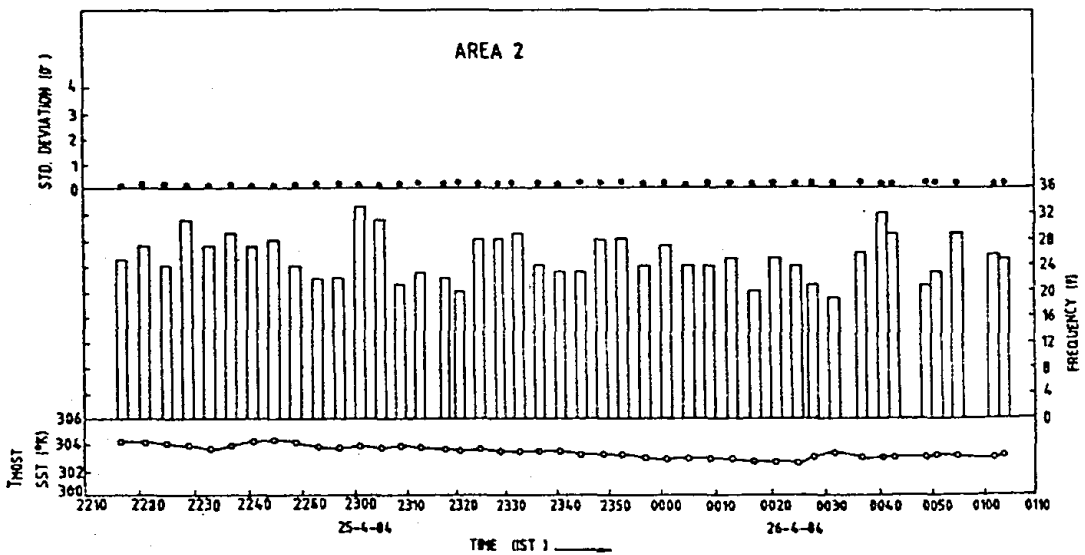
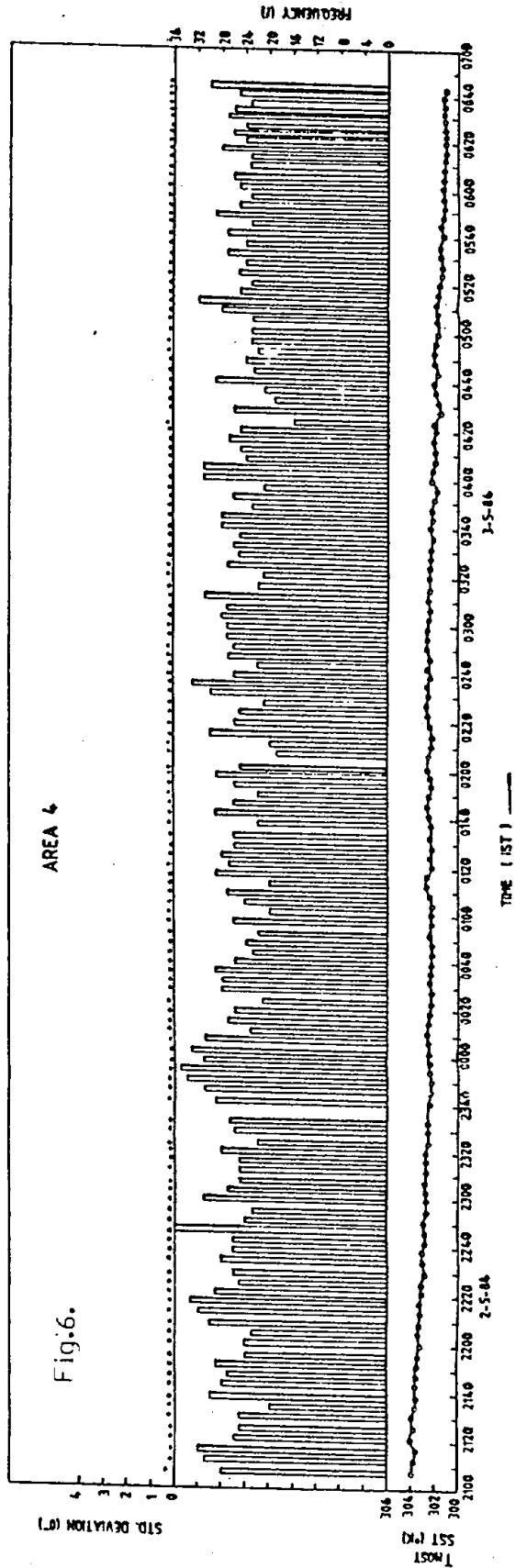
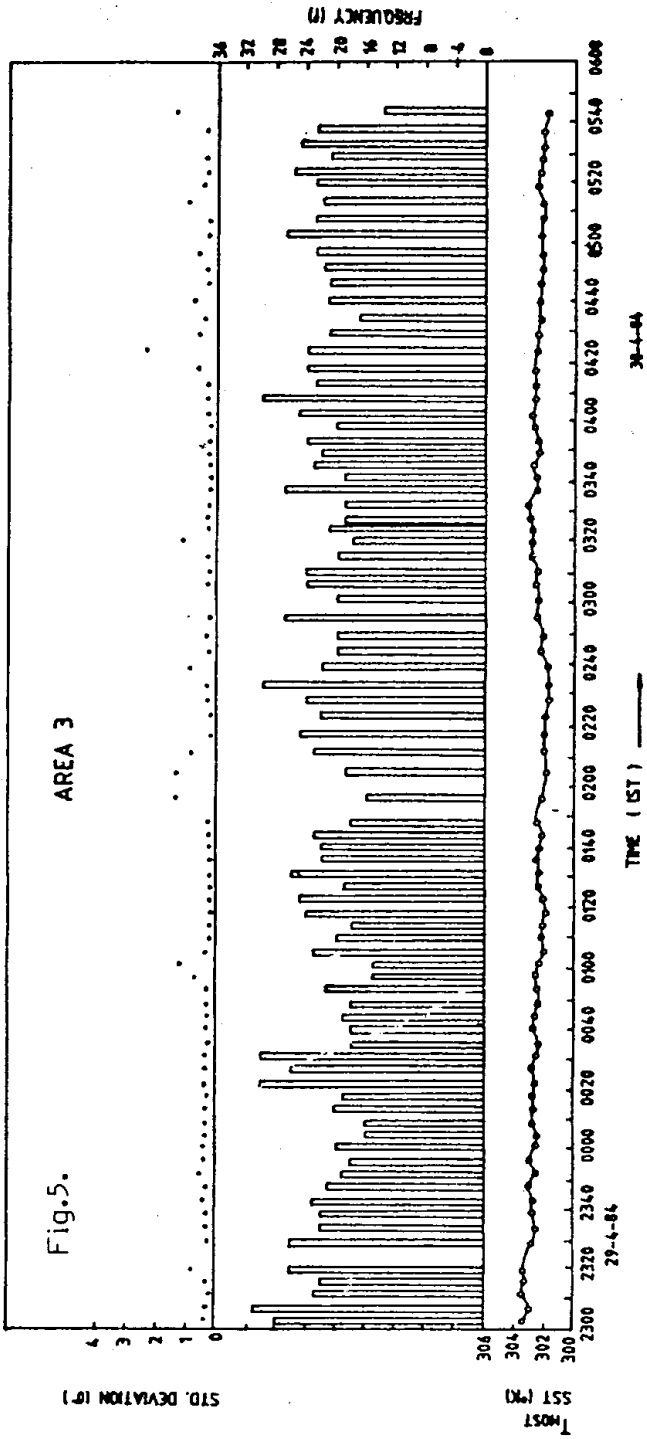


Fig.4.

Figs.3 & 4. Showing value of  $T_{most}$ , frequency and standard deviations for areas 1 & 2.



Figs. 5 & 6. Showing value of  $T_{\text{most}}$ , frequency and standard deviations for areas 3 & 4.

Table I—Comparison of temperature values ( $^{\circ}\text{K}$ ) from IR scanner and bucket thermometer.

Location	$T_{\text{skin}}$	$T_{\text{SST}}$	$\Delta T$	$T_{\text{AIR}}$	Time (IST)	Surface wind speed (m/sec)	Cloud type & amount
15 $^{\circ}$ 22'N 73 $^{\circ}$ 40'E	304.93	303.96	0.97	303.16	1145	7.2	-
13 $^{\circ}$ 52'N 73 $^{\circ}$ 30'E	303.20	303.16	0.04	301.96	2345	7.7	-
10 $^{\circ}$ 32'N 72 $^{\circ}$ 36.5'E	304.09	303.36	0.73	303.46	1800	9.3	St & Cu; 3/8
—	303.44	303.36	0.08	303.06	1900	3.1	St & Cu; 3/8
—	302.35	303.16	-0.81	302.96	2000	9.8	-
—	302.64	303.21	-0.57	302.96	2030	8.5	-
—	302.93	303.26	-0.33	302.96	2100	7.2	-
—	303.03	303.26	-0.23	302.66	2200	7.2	-
—	303.39	303.06	0.33	302.56	2300	7.2	-
—	302.90	303.21	-0.42	302.66	2330	7.0	-
—	302.55	303.16	-0.61	302.66	0000	6.7	-
—	302.45	303.26	-0.81	302.66	0100	5.2	-
—	302.11	303.26	-1.05	302.16	0200	6.2	-
—	302.44	303.16	-0.72	302.46	0300	6.2	-
—	302.88	303.16	-0.28	302.66	0400	7.7	-
—	302.28	303.16	-0.88	301.66	0500	6.7	-

Table II—Values of  $\Delta T$  deduced by various authors (adapted from Robinson, 1985).

Authors	$\Delta T$ ( $^{\circ}\text{C}$ )	Location	Conditions during observations
Nicholls (1979)	-0.5 to +0.3	At Sea	Low to moderate wind and waves
Paulson & Parker (1972)	-1.14 to -1.81	Laboratory	No Waves
Ewing & McAlister (1962)	-0.6	At Sea	Low winds, night time
Hill (1972)	1) -0.1 2) -0.2 3) -0.1	Laboratory	Low wind, no surface film Low wind, surface film present Higher wind conditions
Katsaros (1977)	1) -0.4 to -2.4 2) Upto -3.4	Laboratory Reservoir	No wind No waves
Kropotkin (1978)	1) 5.0 2) -1.0	At Sea At Sea	Calm, 1mm oil slick. Sea state 3, 1 $\mu\text{m}$ oil slick
Schooley (1977)	1) -0.2 2) 0.0	At Sea At Sea	2.5m/sec wind, no cloud. Under cloud shadow,
Simpson and Paulson (1980)	-0.15 to -0.30	At Sea	Winds: 5 to 9 m/sec.
Grassl (1976)	-0.17 to -0.21	At Sea	Winds: 1 to 10 m/sec.
Woodcock & Stommel (1947)	-0.50 to -1.00	Reservoir	Calm, night time
Present study	-0.23 to -1.00	At Sea	Winds: 7 to 9 m/sec, night time.

clouds (type & amount) are also given. The  $\Delta T$  values ( $T_{\text{skin}} - T_{\text{sst}}$ ) varied from +1 to -1°K. The results obtained agree with the study of Saunders (1967) who stated that the  $\Delta T$  values were independent of wind speed for small values of infrared flux. The  $\Delta T$  values obtained in the present study are also compared with those obtained by other authors under various environmental conditions (Table II).

From this study it is observed that the thermal infrared scanner can be used to map the SST with fairly good accuracy. The values of skin sea surface temperature given by the infrared scanner are lower than conventionally measured SST values by 0.2 to 1.0°K under moderate winds during night time.

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