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RETRIEVAL OF SEA SURFACE TEMPERATURE FROM NOAA-AVHRR DATA – SOME RESULTS

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ABSTRACT

The NOAA-AVHRR data recorded at the Indian Earth Station are processed for the retrieval of Sea Surface Temperature (SST) by using thermal infra-red channels 4 and 5. The pseudo coloured SST weekly composited imagery for the 5 to 11 May, 1988 with 1°C interval are presented. The satellite derived SSTs fairly matched, with those of sea truth observations, with an RMS deviation of 0.57. It is found that the warmer temperatures were present over the western and central parts of the Arabian Sea. The application aspects of satellite derived SSTs are discussed.

Key-words: SST, infra-red, satellite, NOAA-AVHRR.

The Sea Surface Temperature (SST) is one of the most important parameters in the climatic changes and oceanographic studies. In the recent years, after realising the dependence of global climatic changes on bottom boundary heat source, considerable attention has been paid to link the Indian Summer Monsoonal activity with SST anomalies.

The SSTs over the Arabian Sea are significantly correlated with the Indian Summer monsoonal rainfall (Shukla 1975, Shukla and Mishra 1977, Anjaneyulu 1980, Joseph and Pillai 1984). Pisharoty (1981) has suggested the feasibility of medium range forecasting of the Indian monsoon from knowledge of the SST anomaly field in the Northern Indian Ocean. Satellite derived SSTs are found to be useful for monitoring of the areal distribution of waters encountered by the 27-28°C range, which appears to be critical for monsoon activity (Babu, Rao and Sadhuram 1985, Kumar, Nath, Viswambaran and Rao 1986).

The use of NOAA-AVHRR thermal imagery to locate oceanic fronts for direct application of commercial fisheries has been suggested by Breaker (1982), Turgeon (1986). Strong negative SST anomaly observed over an area is an indicator for the intense upwelling (Kumar, Nath, Viswambaran and Rao, 1986).

The measurement of SST by routine conventional means is not sufficient for the study of daily/weekly variations, related to various oceanographic applications as discussed earlier. While routine ship observations leave very wide gaps in the data coverage, the polar orbiting satellites technology has proven to be useful in providing spatial and temporal coverage desired for such investigations. The qualitative and absolute estimates of SST have been attempted since 1973 through satellite remote sensing. This paper presents some of the results of the ongoing studies on the retrieval of SST from NOAA-AVHRR data.

Processing of NOAA-AVHRR Data: The Advanced Very High Resolution Radiometer (AVHRR) is a scanning radiometer, flown onboard NOAA series of satellites operates primarily at five spectral regions (channels 4 and 5 are of same band). In the latter version of AVHRR (viz. NOAA-7, NOAA-9 and NOAA-10) an additional channel has been incorporated in place of earlier channel 5. The five channels are as follows: Channel 1: Visible 0.58-0.68 micrometers; Channel 2: Near infrared 0.725-1.1 micrometers; Channel 3: 3.55-3.93 micrometers; Channel 4: 10.3-11.3 micrometers, and Channel 5: 11.5-12.5 micrometers. Channels 3, 4 and 5 are in the thermal infrared region. Processing of AVHRR data for the retrieval of SST involves several steps viz. Radiometric Calibration, SST conversion, Systematic and Geometric correction, etc.

Radiometric calibration: Calibration of the thermal IR channels are performed through inflight calibration procedure using stable black body and space view data. In this approach, it is assumed that the output of each channel (in counts) is a linear function of the sensed radiance. The function is defined as N=GX+I, where N is the radiance of the target at count value X, G and I are channel gain and intercept respectively. The unknown G and I for each channel can be computed if the values of N and X are known at two points. The standard NOAA-NESDIS procedures were followed to compute these values (NESS, 1979).

Conversion of brightness value to SST: The simplest approach for atmospheric correction is to measure radiation from a given field of view at two or more window frequencies having different atmospheric absorptions. The SST (°C) can then be estimated as a linear combination of measured brightness temperatures at these frequencies:

$$SST = a_0 + a_i \sum_{i=1}^{N} T_i$$

where Ti is the brightness temperature at the i^{th} channel and N is the number of channels (usually two or three). The coefficients a_0 and a_i are determined by regression, either theoretically, by using a model, or empirically, by using satellite and *in situ* data. The empirical algorithm has the advantage of simplicity and under ideal conditions performs surprisingly well. For the present study, we have made use of the following empirical algorithm as derived by McClain (1982).

$$SST = 1.0351 \text{ TB ch4} + 3.046 \text{ (TB ch4 - TB ch5)} - 283.93$$

where TB ch4 and TB ch5 are Brightness Temperatures (°K) at channels 4 and 5 respectively.

Geometric corrections: Systematic corrections are applied on derived SST data and then registered with a reference image using an image to image tieup procedure, to bring the image to a standard map projection.

Multidate data images after applying the above geometric corrections can be overlayed one over the other as they are registered against a reference image and is a pre-requisite for time compositing.

Compositing: The multidate data is composited to eliminate the cloud contaminated pixels. The maximum temperature values occurring during the week were considered while time compositing. The temperature less than 20°C has been selected as threshold temperature for cloud and is represented by gray colour in Fig.1. This temperature is very much less to be assigned as threshold value, since the 20°C temperature climatologically may not exist over the North Indian Ocean during May. But there are some pixels having less than 20°C value during 6-11 May, 1988. This is mainly due to the presence of residual cloud, even after time compositing for one week. It is assumed that the fully cloud contaminated pixels are of temperature less than 20°C. According to Hastenrath and Lamb (1979) the minimum mean temperature present over the North Indian Ocean during May is 28°C. Also it is assumed that the temperature anomaly could be of the order of 3°C for any year. Hence, the temperatures less than 25°C can be treated as artifacts and are chiefly due to the partial contamination of clouds. It is also seen from Fig.1 that these temperatures are associated with the residual cloud (gray colour) regions.

The NOAA-AVHRR data have been processed for the retrieval of SST for a period of one week (5th to 11th May, 1988) following the procedure discussed earlier. The pseudo coloured SST imageries have been prepared with 1°C interval. The data of 9th May have not been processed due to bad quality. A composited image has been prepared using all the 6 days SST data to eliminate cloud contaminated data as illustrated in Fig.1. The SSTs are mostly ranging from 27 to 32°C. An abnormal warming over the western and central parts of the Arabian Sea with a maximum value of 32°C can be seen from Fig.1. Anjaneyulu (1980) has shown the association of observed warm/cold SST anomalies during May over the western and central parts of the Arabian Sea with the following strong/weak monsoon activity. It can also be seen from Fig.1 that the presence of zonal SST gradient is obviously due to the poleward decrease of solar radiation. The presence of colder waters along the Mangalore, Orissa and Tamil Nadu coast may be related to upwelling. The composited image would show large scale persistent patterns over a week rather than small scale and dynamical features since the maximum temperature during the week has been presented.

In situ observations collected during research cruise and AVHRR derived SSTs of the same period (Table I) during the same period have been compared. The satellite derived SSTs match fairly with those measured by digital bathythermograph (DBT) with an rms deviation of 0.57, and an rms deviation of 1.52 when compared with the observations collected by bucket thermometer (Bkt). When considering this difference, it should be noted that SST as measured by a bucket thermometer refers to "Sub-surface" temperature (nearly one metre below the surface) while a satellite measures the skin temperature. Saunders (1967) reported that the former was generally about 0.6° higher than the latter. The digital bathythermograph (DBT) sensor is supposed to record the temperature as soon as it makes

Table I — Comparison of NOAA-AVHRR derived SSTs with those of sea truth observations

Sl. No.	Date	Lat N (deg & min)	Long E	Sea Surface Temperatures (°C) Bkt	DBT	AVHRR
1.	6.5.88	13 55	69 23	30.2	29.0	28.76
2.	6.5.88	13 34	68 30	30.4	29.2	27.82
3.	6.5.88	13 14	67 34	30.3	29.0	28.61
4.	6.5.88	12 53	66 34	30.4	29.0	28.99
5.	7.5.88	12 34	65 43	30.4	29.2	29.56
6.	7.5.88	12 13	64 45	30.4	30.2	29.81
7.	7.5.88	12 52	63 47	30.8	30.2	29.76
8.	7.5.88	11 30	62 49	30.4	29.3	28.96
9.	7.5.88	11 19	61 50	30.6	29.3	28.87
Average temperatures				30.43	29.38	29.02
Standard deviation				0.16	0.45	0.59

Bkt — Bucket thermometer; DBT — Digital bathythermograph.

Table II — Comparison of weekly composited NOAA-AVHRR derived SSTs with those of sea truth observations

Sl. No.	Date	Lat N (Deg & Min)	Long E	Sea Surface Temperatures (°C) Bkt	DBT	AVHRR comp.
1.	6.5.88	13 55	69 23	30.2	29.0	29.06
2.	6.5.88	13 34	68 30	30.4	29.2	28.87
3.	6.5.88	13 14	67 34	30.3	29.0	28.61
4.	6.5.88	12 53	66 34	30.4	29.0	29.78
5.	7.5.88	12 34	65 43	30.4	29.2	29.64
6.	7.5.88	12 13	64 45	30.4	30.2	29.94
7.	7.5.88	12 52	63 47	30.8	30.2	29.96
8.	7.5.88	11 30	62 49	30.4	29.3	29.78
9.	7.5.88	11 19	61 50	30.6	29.3	30.21
10.	8.5.88	11 51	60 27	30.4	29.1	29.00
11.	8.5.88	12 15	60 36	30.8	30.0	28.99
12.	8.5.88	13 00	60 03	31.4	29.1	29.50
13.	8.5.88	13 57	59 31	31.2	29.1	29.44
14.	8.5.88	14 41	59 00	30.8	28.2	28.51
15.	9.5.88	15 15	58 40	30.2	28.3	28.00
Average temperatures				30.58	29.21	29.27
Standard deviation				0.34	0.44	0.61

Bkt — Bucket thermometer; DBT — Digital bathythermograph.

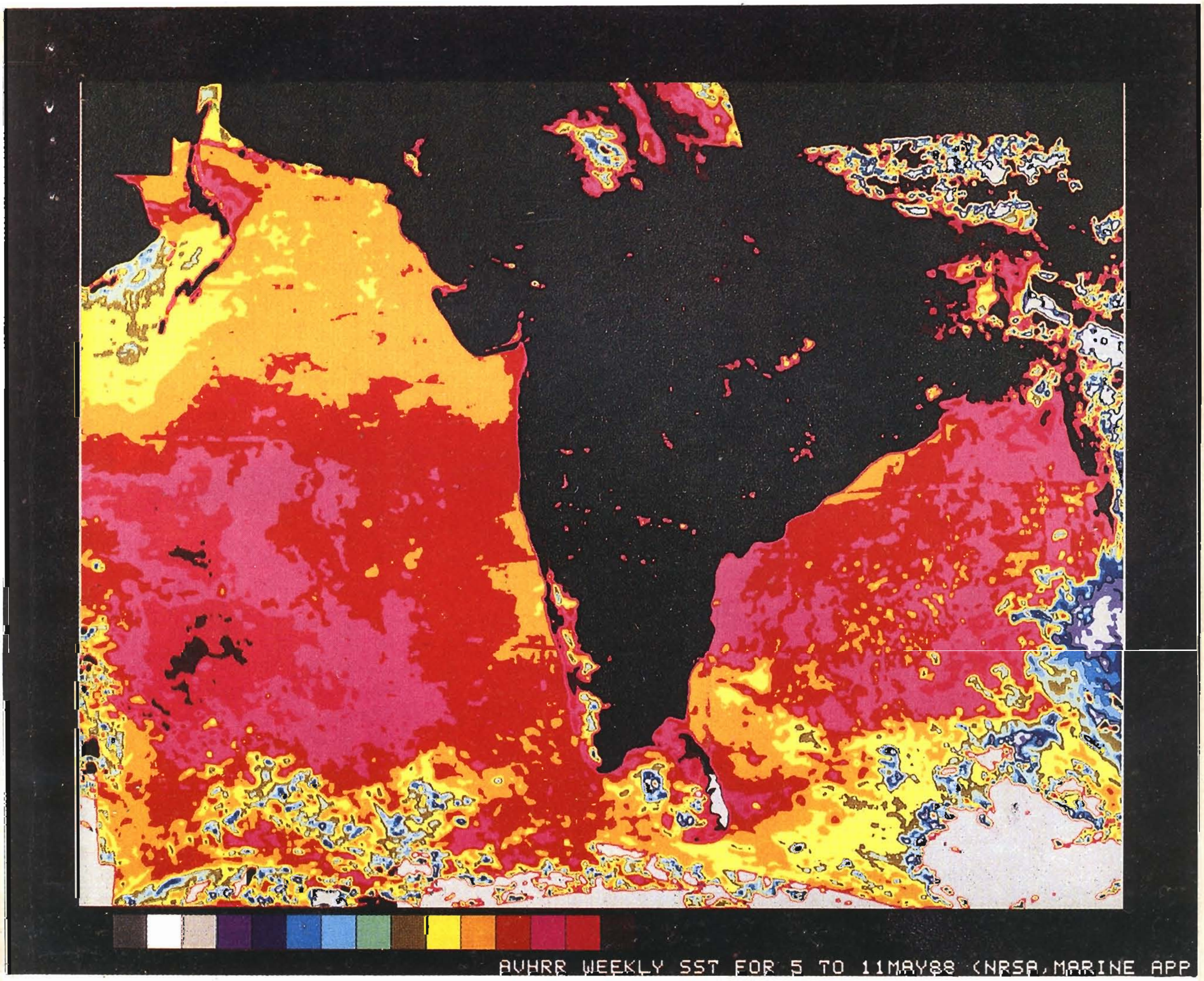

Fig.1. Composited pseudo coloured Sea Surface Temperature (°C) image during 5-11 May, 1988 with 1 °C interval (Grey: <20 - Cloud, Mauve: 20 - 20.75, Blue: 21 - 21.75, Sky Blue: 22 - 22.75, Cyan: 23 - 23.75, Green: 24 - 24.75, Olive: 25.75, Yellow: 26 - 26.75, Orange: 27 - 27.75, Red 28 - 28.75, Magenta: 29 - 29.75, Pink: 30 - 30.75, Chocolate: 31 - 31.75, Dark Green: >32 Land).

contact with the surface and is considered closer to the skin temperature. The ship measured SST (DBT) has a mean value of 29.38°C and a standard deviation of 0.45. While the AVHRR SST has a mean value of 29.02°C with a standard deviation of 0.59. Thus on an average, the AVHRR SST is found to be lower than the DBT SST by about 0.36°C. The SSTs derived from satellite data were reported to be lower by 1.5°C when compared to Ship's SST (Legeckis, Legg and Limeburner 1980, Pathak 1982 and Rao, Babu, Rao and Sastry 1986). The ship SST values are also compared with those of weekly composited SST values making an assumption that SSTs will not vary much within a week (Table II) and are found to be in good agreement with those of observed DBT surface temperatures with an rms deviation of 0.50.

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