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TEMPERATURE EFFECT DETECTION OF TYPHOON ON THE SEA BY REMOTE SENSING USING SPLIT WINDOW DATA OF NOAA-7 AVHRR

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RESUMO

Para estudar a variação de temperatura da superfície do mar (SST) com a presença do furacão 8407 quando este deslocou-se ao sul do Japão, foi utilizado um sistema para produzir mapas de SST utilizando dados de satélites meteorológicos de órbita polar, considerando efeitos de atenuação atmosférica. Antes da tempestade, foram processadas duas imagens (25 e 26 de julho de 1984) e os resultados mostraram que próximo à rota do furacão existia uma larga banda de água com temperaturas de aproximadamente 29°C e 30°C. Após a passagem do furacão, duas imagens do NOAA-7 (31 de julho e 2 de agosto de 1984) foram processadas e verificou-se que SST diminuiu de aproximadamente 2°C a 3°C.

ABSTRACT

A system was utilized to produce maps of sea surface temperature (SST) using meteorological polar orbit satellite data, taking into account of the effects of atmospheric attenuation to study variation of the SST when typhoon 8407 moved across south of Japan. Before the storm, it was processed two images (25 and 26 July, 1984) and the results show that there was a wide band of water near typhoon tracks having temperatures at about 29°C to 30°C. After the passage of typhoon, two images of NOAA-7 (31, July and 2, August 1984) were processed. It was found that the SST decreased to an order of 2°C to 3°C.

INTRODUCTION

Variation of the sea surface temperature (SST) is difficult to estimate or measure by conventional methods in the presence of tropical cyclones. The role of satellites in monitoring conditions of the earth's atmosphere and ocean is an increasingly important one. The importance of accurate determinations of SST from satellite has long been recognized for the study of a variety of processes related to the interaction between oceans, air-sea, climatic and synoptic systems, and large areas of the oceans, since these areas cannot be sampled adequately by ships or other means. For example, SST plays a critical role in the formation, evolution, and dissipation of tropical cyclones. The SST of 26.5°C or greater is required for tropical cyclone formation over an area of anomalously warmer waters which are linked to intensification of tropical cyclones.

In this paper a system was utilized to produce maps of sea surface temperature using meteorological polar orbit satellite data, taking into account the effects of atmospheric attenuation to study variation of the SST when typhoon 8407 moved across south of Japan. The channel 4 (11μm) and 5 (12μm) data of Advanced Very High Resolution Radiometer (AVHRR) on board NOAA-7 received at the Japan Meteorological Satellite Center (JMSC) were processed at Meteorological Research Institute (MRI) in this study.

SST RETRIEVAL BY SATELLITE DATA

The theoretical basis of split-window SST retrievel techniques to correct infrared brightness temperatures for atmospheric attenuation was recently reviewed by McMillin and Crossby (1984). In this study the method of McClain et al., (1985) and the T_{11} and T_{12} brightness temperature measurements are used to obtain the SST calculations. The SST can be estimated as follows:

$$SSTS = 3.6139T_{11} - 2.5789T_{12} - 283.18,$$

where T_{11} and T_{12} are the brightness temperatures (in degrees Kelvin) measured by the AVHRR on the NOAA-7 operational spacecraft; SSTS is split-window multi-channel SST in degrees Celsius.

In this study four days raw AVHRR data sets in the form of digital counts, two images before and two after passage of a typhoon over western Pacific in Japan were selected in order to describe the variation in SST. It would be desirable to have a full observational picture of these waters before the storm to compare with that obtained afterwards.

The study area extended from 28N to 35N and 128E to 142E, shown in Figure 1 with the typhoon track. The satellite data are mapped onto the $0.1^{\circ} \times 0.1^{\circ}$ (lat. X long.) grid within the area analysed. Orbital parameters predicted routinely by the JMSC are used for the determination of the geographical location of each satellite observation. However, there are some displacements between the predicted sub-satellite points and those from the observed image. The correction of the displacement is manually determined by a simple translation using the coastline data.

From the calibrated Channel 4 and Channel 5 data the T_{11} and T_{12} brightness temperatures are obtained in the two channels of AVHRR on board NOAA-7. They are used for retrievel the SST and cloud type classification. Clouds are presented to some degree in every image and they are identified because their signal is so large that it interferes with the SST analyses. Clouds are usually colder than the sea surface and their temperature variance an order of magnitude larger than for the ocean. It was used the variance of the values in a small subset of 2 X 2 pixels of the image to indicate a mixture of data type. The local variance of the brightness temperatures (T) in this subset is given by

$$\sigma^2 = 1/N \sum_{i=1}^{N} (T_i - \bar{T})^2,$$

where N represents the number of subset pixels, and $\bar{T}$ is averaged temperature. Low variance of subset with $\sigma^2 \leqslant 0.1$ is classified as being completely clear, i.e., classify SST with difference of temperature ΔT between neighbouring pixels less than 0.3° ($\Delta T \leqslant 0.3^{\circ}C$), and the variance $\sigma^2 > 0.1$ is classified as clouds non-ocean category. For cloud type classification it was used threshold technique proposed by Inoue (1987) for split window measurements.

CASE STUDY AND DISCUSSION

Between 25 July to 2 August 1984, typhoon 8407 moved northwestward across the northeastern south of Japan. In order to describe the effects of typhoon upon the waters of the sea of Japan before the storm, it was processed two images (25 and 26 July, 1984) of NOAA-7 polar orbiting satellite. Figures 2 and 3 show SST maps obtained by the present method over the area studied. Figure 2 shows that there were clouds near the typhoon tracks, to the left between 28N to 30N and 130E to 133E, and to the right 30N to 31N and 134E to 138E, there were

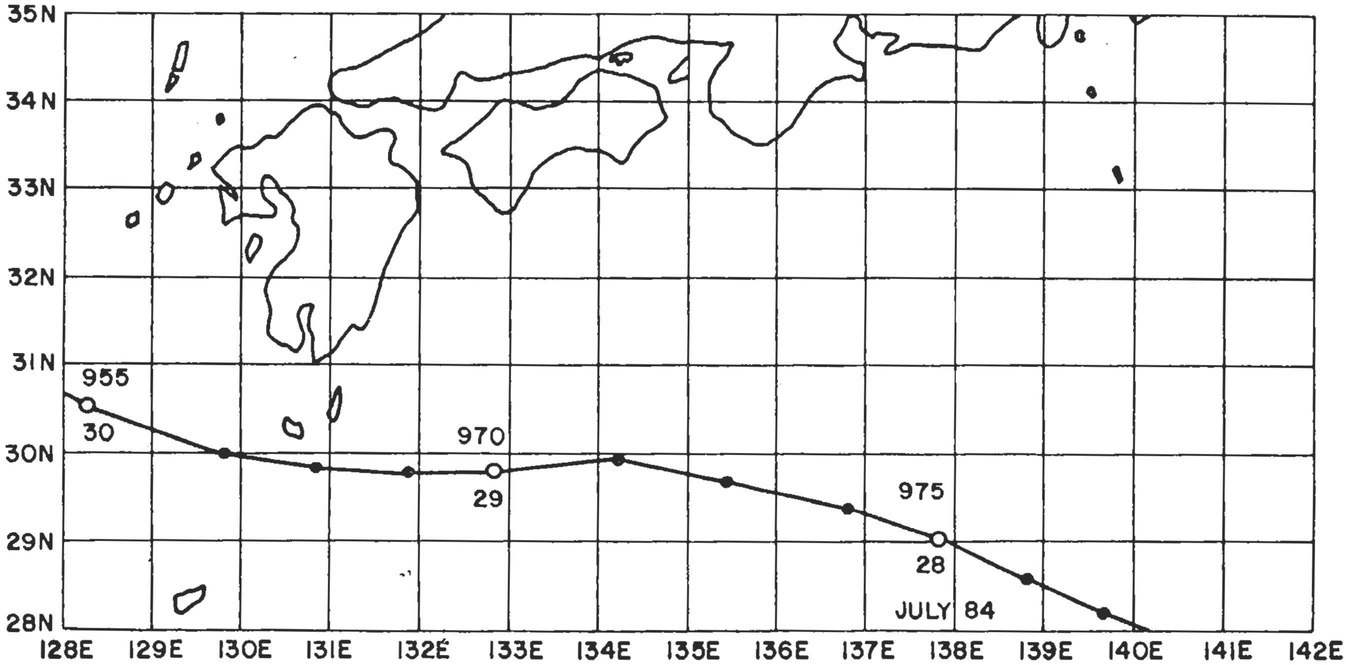

Figure 1 — Analysis area with the track of typhoon 8407.

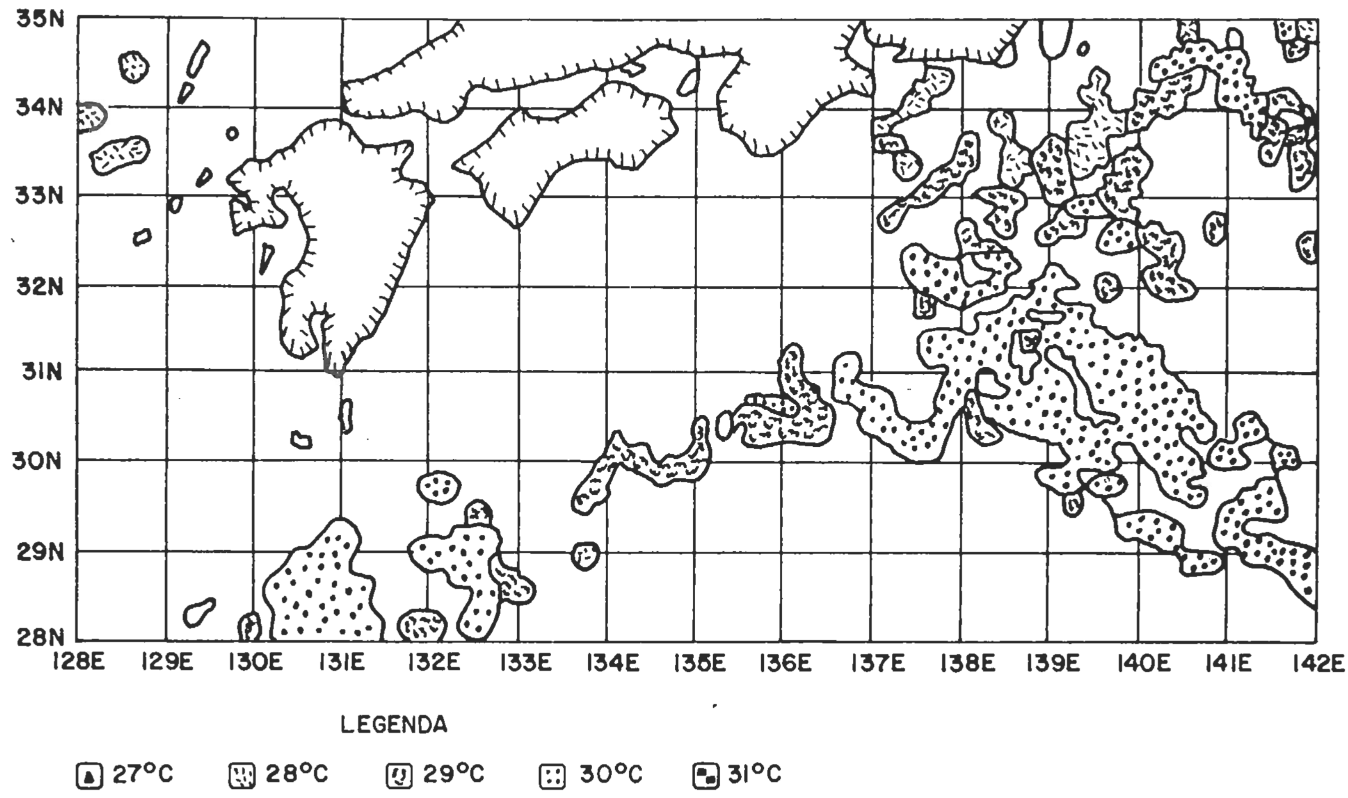

Figure 2 — Satellite derived sea surface temperature on July 25, 1984.

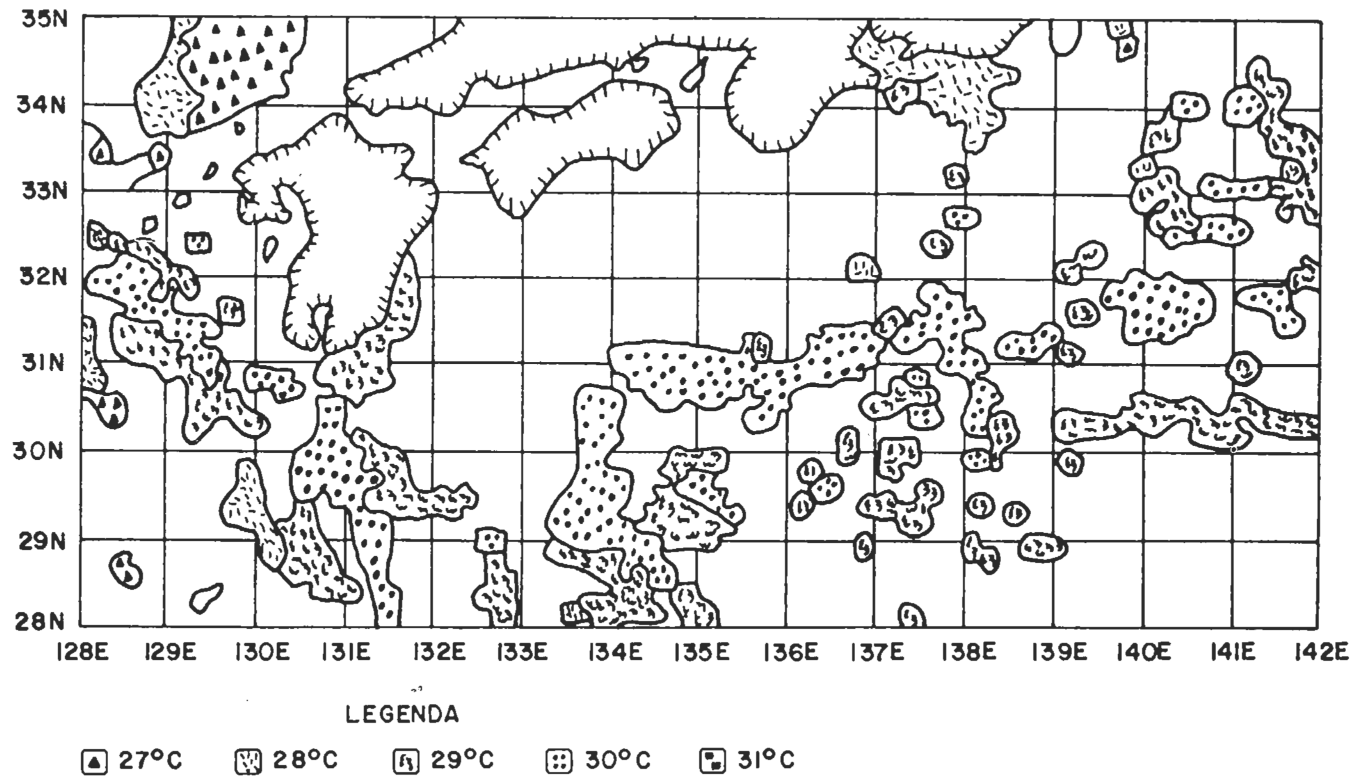

Figure 3 — Satellite derived sea surface temperature on July 26, 1984.

waters having temperatures at about 29°C to 30°C. Figure 3 shows that there was a wide band of water near typhoon tracks having temperatures at about 29°C to 30°C.

The general character of the SST distribution are based on the ship data. This data were used to obtain the averaging values over ten day period (July 21-31, 1984) by the Japan Meteorological Agency and they are presented in Figure 4. These data show that there was a wide band of water having temperatures at about 29°C in the typhoon tracks. After the passage of typhoon, two images of NOAA-7 (31, July and 2, August, 1984) were processed and they are shown in Figures 5 and 6. Figure 5 shows that the cold areas were found mainly to the right of the storm track. The SST decreased to an order of 2°C to 3°C after the passage of the typhoon. The observed low temperature near the storm center may be due to the divergence of surface water caused by the wind-stress. This divergence produces upwelling and mixing with subsurface layer. The ocean surface becomes anomalously cool along the storm track. The systematic study of Leiper (1967) for an intense hurricane shows that the upwelled water decreased by more than 5°C. It is probable that, 3 days after passages of maximum intensify of typhoon the upwelled waters gradually sunk bank to its normal position and warm surface waters outside the upwelling are moved back horizontally toward the typhoon path. This is shown in Figure 6. From this figure it is also observed that between 30N to 31N and 134E to 135E the temperature remains about 27°C.

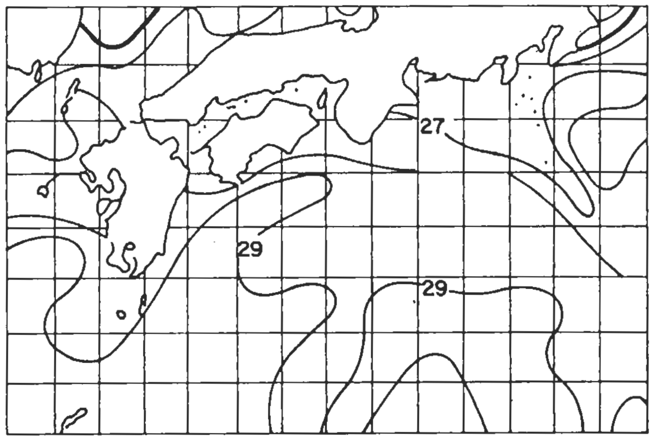

Figure 4 — Ten day marine report by JMA. Mean sea surface temperature (July 21-31, 1984).

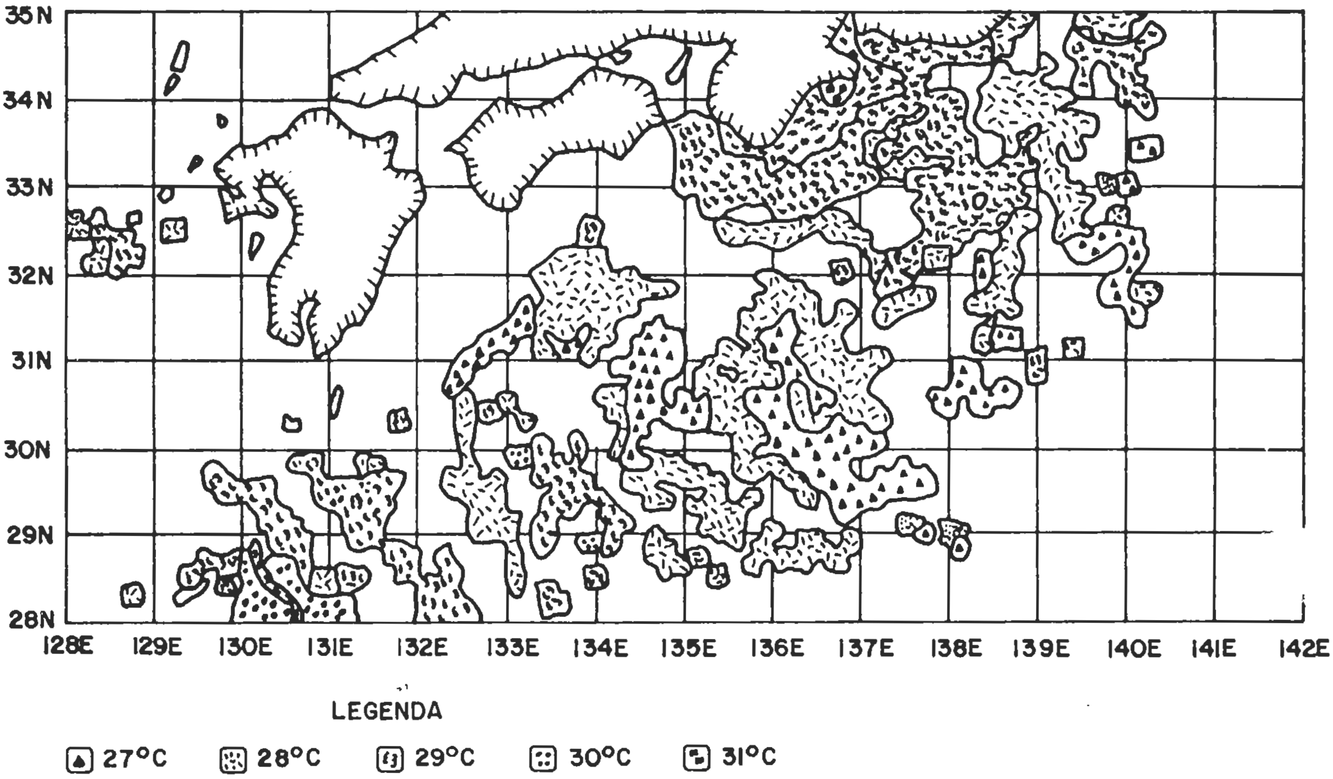

Figure 5 — Satellite derived sea surface temperature on July 31, 1984.

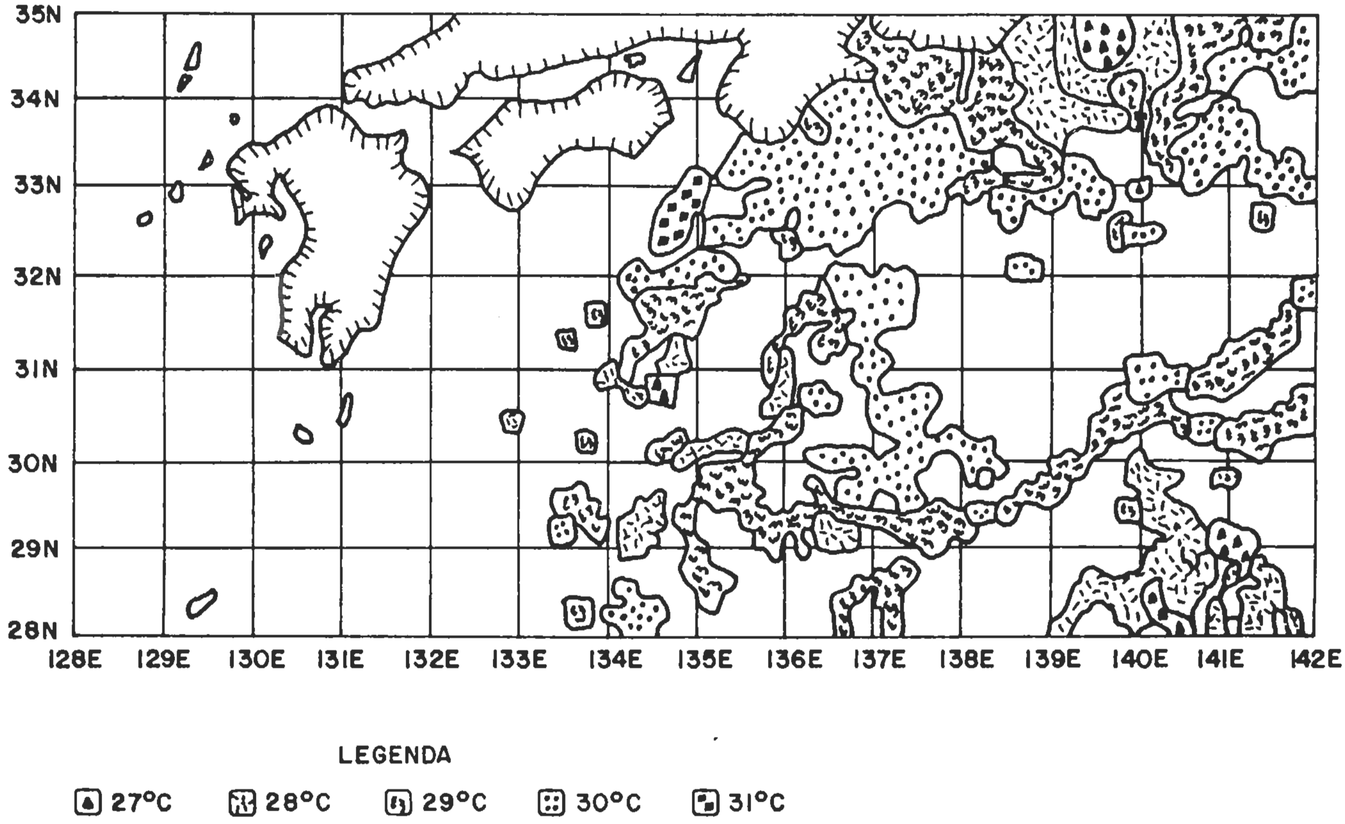

Figure 6 — Satellite derived sea surface temperature on August 2, 1984.

CONCLUSIONS

In this paper we have investigated the possibility of using accurate AVHRR measurements of infrared brightness temperature for retrievel the SST and cloud type classification. We have shown that it is possible to gain information about SST and also to study variation of the SST by satellite when typhoon moved across the sea.

The satellite SST areas show good agreement with ten day mean SST obtained by the conventional method before passage of the typhoon. These data show that there was a wide band of water having temperatures at about 29°C in the typhoon tracks. Further, after the passage of typhoon the SST obtained by satellite show that a decrease of an order to 2°C – 3°C. This may be due to the divergence of surface water caused by the wind-stress.

Although this study has been done by passage of one typhoon, the method presented may be useful in planning future surveys of similar situations with more passages of typhoons and to provide assumptions for theoretical developments.

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