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SEASONAL AND INTERANNUAL VARIATIONS OF THE SEA SURFACE TEMPERATURES (SST) IN THE BANDA AND ARAFURA SEA AREA

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ABSTRACT

Satellite observations now make it possible to follow variations in sea surface temperatures (SST) over several consecutive seasons and years. A processing method of the GOSSTCOMPT charts has been perfected for Indonesian waters. This note presents weekly SST observations, averaged over a four-year period (1 July 1981 to July 1985) for 23 spots (squares) in the Banda and Arafura Seas. For 2 spots the weekly SST are given for the full four-year period, indicating the interannual variation. The data show a seasonal SST variation in all squares with lower temperatures from June till September and maximum temperatures from November till April. The amplitude of the seasonal SST variation increases from north to south and from west to east, ranging from 2-3°C to 5-6°C. In addition, significant interannual variations in SST were recorded, probably related to the El Niño-phenomenon.

RÉSUMÉ

L'observation des satellites permet maintenant de suivre l'évolution des températures de la mer en surface sur plusieurs saisons ou années consécutives. Une méthode de traitement des cartes GOSSTCOMPT vient d'être mise au point en Indonésie. L'article présente les températures moyennes hebdomadaires de surface en 23 points des mers d'Arafura et de Banda - moyenne sur quatre années de juillet 1981 - juillet 1985. De plus en deux points, cette note donne les températures hebdomadaires pendant toute cette période, montrant les variations interannuelles. En tout point, on observe une variation saisonnière de la température de surface avec un minimum de juin - septembre et un maximum de novembre - avril. L'amplitude des variations saisonnières croît du nord au sud et de l'ouest vers l'est, allant de 2-3°C à 5-6°C. A ceci s'ajoute une nette variation interannuelle, probablement reliée au phénomène 'El Niño'.

1. INTRODUCTION

Many fisheries, both in temperate and tropical seas, regularly show large variations from year to year, which may reflect the reaction of the species exploited to variations in their environment. Of the many physical and chemical parameters that characterize different environments, the temperature of the water is one of the easiest, if not the most important, to determine, and its analysis often provides a satisfactory description of the main features of the environmental situation.

Until quite recently the only means oceanographers had to describe the marine environment was to make *in situ* observations at sea from research vessels or collect regular records at coastal stations. Such observations were always discontinuous in time and space, but allowed a study of the movements of seawater masses and the detection of seasonal variations, as was the case in Indonesia (WYRTKI, 1957, 1961).

Today a new method for analysing a regional situation at any given moment is available to scientists in the form of remote sensing from satellites. Depending on their equipment, geostationary and scanning satellites can record certain marine physical parameters such as surface temperature, state and colour of the sea, wave height etc. over large areas and almost continuously. This technique has been used with great success in many parts of the world in the last fifteen years for instance by French (STRETTA & SLEPOUKHA, 1983; CITEAU *et al.*, 1984, 1985), American and Japanese scientists. In Indonesia, however, cloud cover is a severely limiting factor in remote sensing of for instance SST. Moreover, the absence of suitable software to process SST images from satellite made it impossible to compare them with our observations at sea (BOELY *et al.*, 1986, 1990) collected during the surveys of the R.V. 'Coriolis' off Irian Jaya (1983) and in the Java Sea (1985).

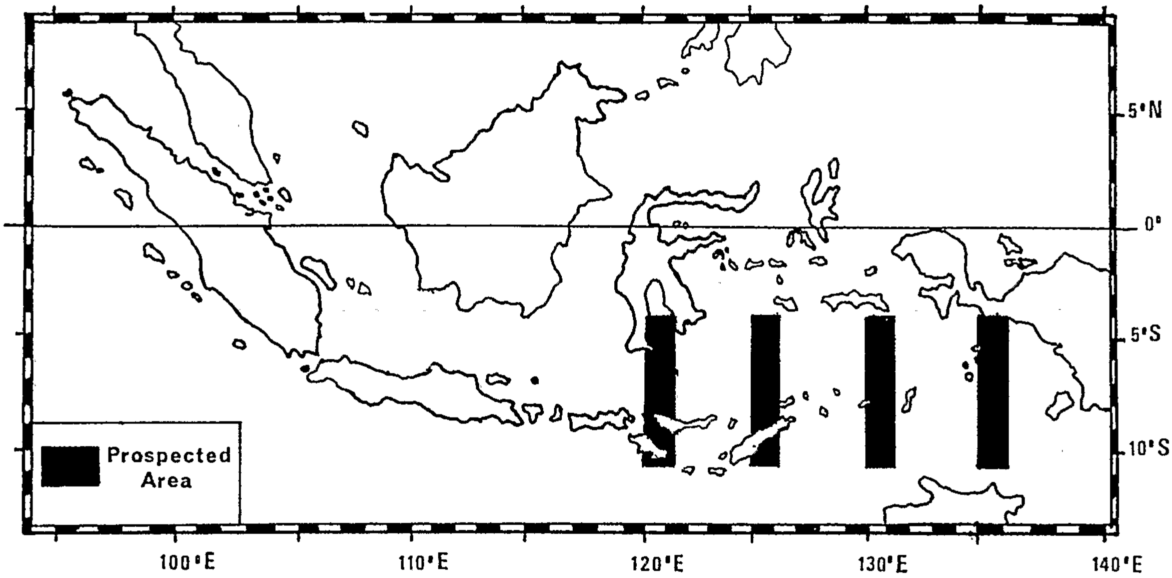

Fig. 1. The Indonesian archipelago and the four areas in the Banda and Arafura Seas chosen for processing of weekly SST charts.

Therefore the weekly sea surface temperature 1charts made by the NOAA were used for our analysis. In this paper we present results worked out for the Banda Sea and the Arafura Sea, regions for which oceanographic information is scarce. Our analysis covers the four-year period between 1981 and 1985, during which theme 3 of the Snellius-II Expedition collected sea surface temperatures in that area during August 1984 and February-March 1985, providing useful sea-truth data for our estimates. At the same time our data give some indication of the environmental variability in the area covered by the Snellius-II Expedition.

2. METHODOLOGY

The material at our disposal consists of 208 weekly GOSSTCOMPT charts, each covering the waters of the entire Indonesian archipelago and the adjacent oceans, *i.e.* between 90° and 140°E longitude and from 10°N to 15°S latitude (Fig. 1). The area is divided into statistical squares of 1°15′ longitude and latitude. Fig. 1 shows the series of squares considered in the Banda and Arafura Seas. First each square was numbered, followed by an iterative/interactive factorial analysis, combined with a 'parallepipedic' classification, enabling a comparison between each square and its neighbours. The method used is described in detail by GASTELLU-ETCHEGORRY & BOELY (1988). The work was done on an Apple-II computer, with a software conceived by J.P. Gastellu-Etchegorry. The precision of the results is of an order of 0.5°C.

3. RESULTS

The SST results presented here concern only the Banda Sea and part of the Arafura Sea. Fig. 2 presents the mean annual curves for the four series of six adjacent squares between 3°45′S and 11°15′S, situated due east of the longitudes 120°, 125°, 130° and 135°E averaged over the four years of observation. Fig. 3 shows the course of the sea surface temperatures in two squares situated at the same latitude—6°15′S—but at a distance of 300 nautical miles (125° and 130°E), from 1 July 1981 to 1 July 1985.

It is immediately evident that the annual temperature range is not large, with a maximum range of 7°C, between 24°C and 31°C. On the other hand, there is a clear seasonal variation, the lowest temperatures being found between June and September and the highest from November to April, thus distinguishing between a warm and a cold season. October and May are months of rapid transition. The amplitude of the variations increases towards the south and the east.

Along a north-south axis, latitude 8°45′ or 10°S seems to be a climatic limit. Towards the north, the warm season shows two temperature maxima. This phenomenon, particularly evident along the 125° and 130°E longitudes, is no longer present in the south where there is only one maximum in January and February. It is also absent along the 135°E longitude.

Along a west-east axis, the cold season, both in duration and amplitude, is most pronounced towards

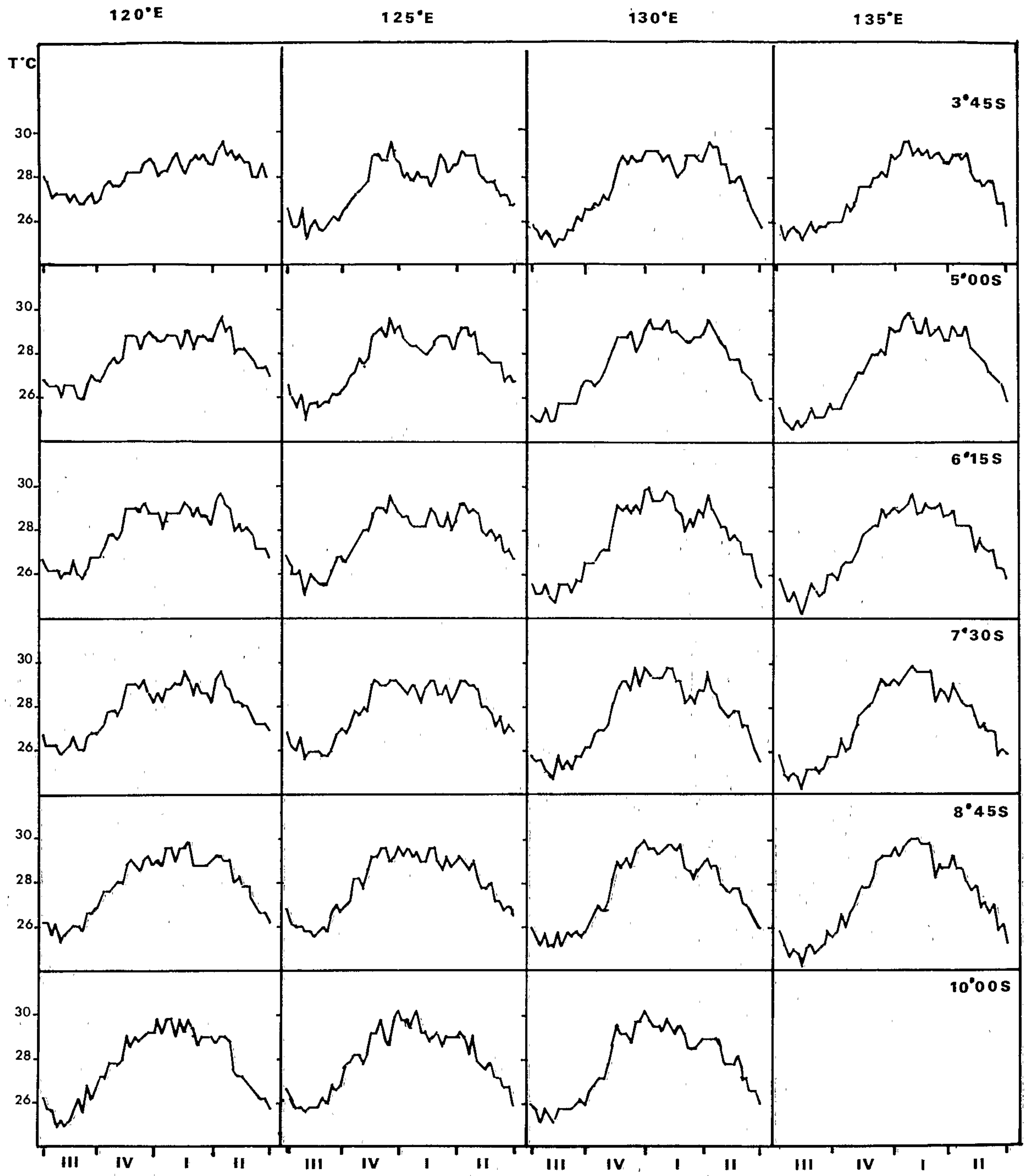

Fig. 2. Mean course of SST throughout the year, in each of 23 subareas. Weekly data averaged over July 1981 to June 1985. III: July-Sept.; IV: Oct.-Dec.; I: Jan.-March; II: April-June.

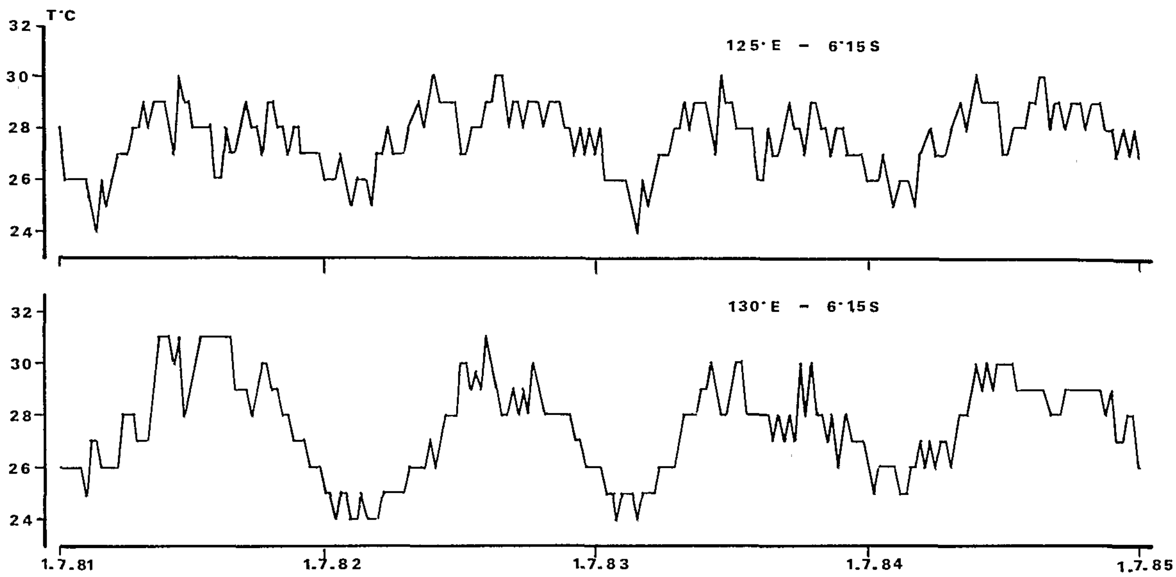

Fig. 3. Records of SST in two subareas from July 1981 to June 1985. Lines connect weekly data.

the east, where the minimum temperatures descend well below 25°C. In general, maximum temperatures during the warm season show little variation in the area surveyed, in contrast to the minima reached during the cold season, which decline from west to east and from north to south. The annual temperature range increases from about 2-3°C in the northwest to 5-6°C in the southeast.

A comparison between weekly temperatures in two regions over the full four-years period (Fig. 3) indicates a considerable interannual variability, some years being cooler than others. This variability concerns two factors: the length of the warm and cold seasons and the maximum and minimum temperature levels. Thus, the year 1984-1985, during which the Snellius-II Expedition took place, seems to have been warmer than the two preceding ones, while the annual temperature range was reduced to about 4°C as compared to 6-7°C in the preceding years.

4. DISCUSSION

The surface temperature recordings attained by satellite observations show a good agreement with sea-truth data published by ZIJLSTRA & BAARS (1987), ZIJLSTRA *et al.*, (1990) and ILAHUDE *et al.* (1990) for the Banda Sea and Arafura Sea in August 1984 and February 1985, taking into account the precision of 0.5°C. Both satellite observations and ground-truth data indicated SST's to be about 26°C in August 1984 and 29-30°C in February 1985.

The seasonal SST variation is only weakly represented in the northwest of the area considered, in the Flores Sea, due south of Sulawesi, but increases both towards the south and the east. The increase to the south, with in particular lower temperatures during the southern winter period may simply reflect a climatic change and a reduction in incoming radiation. The larger SST amplitudes towards the east, which are mainly caused by a lower SST during the June-September period, could, however, be related to upwelling processes in the eastern part of the area during that period, when the southeast monsoon is pushing surface waters of the whole area westwards (WYRTKI, 1957; ZIJLSTRA *et al.*, 1990). The rapid change in surface temperatures during the months of transition between the cold and warm season reflects the importance of the wind factor in the occurrence of this phenomenon.

If upwelling is responsible for the mid-year decline in SST, the surface covered by this process is extensive and it increases in intensity eastwards. It reaches a maximum towards the edge of the continental shelf at the boundary between the Banda and Arafura Seas. The presence in this sector of a number of islands makes the upwelling process more complicated to evaluate. However its intensity remains relatively low, as shown both by the slight ranges in temperature and the observations reported by ZIJLSTRA *et al.* (1990). Nevertheless ZIJLSTRA & BAARS (1987) observed important biological differences between the two seasons in the eastern part of the Banda Sea with twice as much plankton in August 1984 as in February 1985 and two to four times as many fish traces as shown by acoustic methods.

The warm season corresponds to a complete climatic change owing to the impact of the northwest monsoon (WYRTKI, 1957). There is a complete reversal of the surface currents and the monsoon brings waters from the Makassar Straits and the Java Sea into the area. The upwelling apparently disappears entirely and the maximum temperatures regularly recorded at the beginning and end of the warm season correspond to periods of calms with slight winds.

Variations in SST are not only seasonal but also interannual, as shown in Fig. 3 for two locations in the Banda Sea. Between-year variations were particularly strong in the easternmost area at 130°E 6°15′S, with SST amplitudes ranging from about 7°C between July 1981 and July 1982 to about 4°C between July 1984 and July 1985. As shown by NICHOLLS (1984), such changes are probably related to the southern oscillation phenomenon, the high SST amplitude in 1981-1982 preceding a strong El Niño year (1982-1983). If the SST variation within a full monsoonal cycle reflects the intensity of upwelling, the Snellius-II study in the Banda and Arafura Seas did not encounter a particularly strong upwelling situation.

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