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Temperature distribution in the upper layers of the northern and eastern Arabian Sea during Indo-Soviet monsoon experiment

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ABSTRACT. Scientific cruises were carried out by the ships of the Indian Navy along one zonal section (along 20°N Lat.) and one meridional section (along 71°·30 E Long.) in the Arabian Sea during May, June and July 1973 under the Indo-Soviet Monsoon Experiment (ISMEX). Using the bathythermograph data collected in these cruises, vertical distribution of temperature in the upper 275 metres was studied. Along the zonal section, east of 67°E meridian, the depth of thermocline was found to increase gradually from about 20-30 m in May to 40-50 m in July. Significant fall (of about 1°C) in the temperature of the surface waters along the meridional section was observed from May to July. Along this section, in July the mixed layer developed well compared to May and the depth of thermocline increased from less than 40 m in the northern part to about 70 m in the southern part.

1. Introduction

Very few studies have been made on the thermal structure of the Arabian Sea during the southwest monsoon season. Among the earlier studies mention may be made of the work by Sastry and D'Souza (1970), wherein a few vertical sections and horizontal sections prepared with the data collected on board the U. S. Research Vessel '*Atlantis*' during August-September 1963 under International Indian Ocean Expedition (IIOE) were presented. Subsequent to IIOE, a vast amount of meteorological and oceanographic data was collected during May-July 1973 under the Indo-Soviet Monsoon Experiment to study the origin, structure and characteristics of the Indian Summer Monsoon and the associated oceanographic conditions. In this monsoon experiment, four research vessels of USSR Hydrometeorological Service and five ships of the Indian Navy took part. In this paper, a comparative study in the vertical distribution of temperatures in the upper layers of the Arabian Sea along 20°N zonal section and 71°30'E meridional section in the months of May, June and July is attempted using the bathythermograph (BT) data collected on board the Indian ships.

2. Collection and treatment of data

During May 20-24, the first Naval ship worked out 25 stations along the zonal section, while the second one occupied 27 stations along the meridional section. In June, only zonal section was covered. The third ship worked out 29 stations along this section during the period 10 to 14 June. The fourth ship occupied 9 stations along the zonal section and fifth one covered 8 stations along the meridional section during July 3-4. At all these stations bathythermograph was operated and data on some meteorological parameters were collected.

Using the processed BT data, vertical temperature profiles upto about 275 m depth along the zonal and meridional section were prepared for May, June and July. While analysing these vertical sections, the isotherms were drawn at 1°C interval. As the first ship worked out 4 stations along the zonal section in the Indian continental shelf in May twice at an interval of 4 days, this part of the section was analysed for studying short term variations in the vertical temperature distribution.

3. Results and discussion

In the following discussion, a vertical temperature gradient of 2°C/25 m is taken as the lowest limit to define thermocline after Schott (La Fond and Rao 1954) and the warm top layer of relatively low gradients of temperature lying above thermocline is referred to as mixed layer.

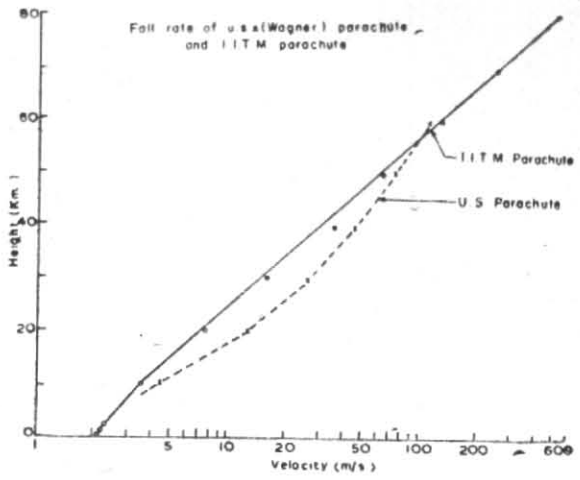

Fig. 1. Vertical distribution of temperature (°C) along the 20°N zonal section in May

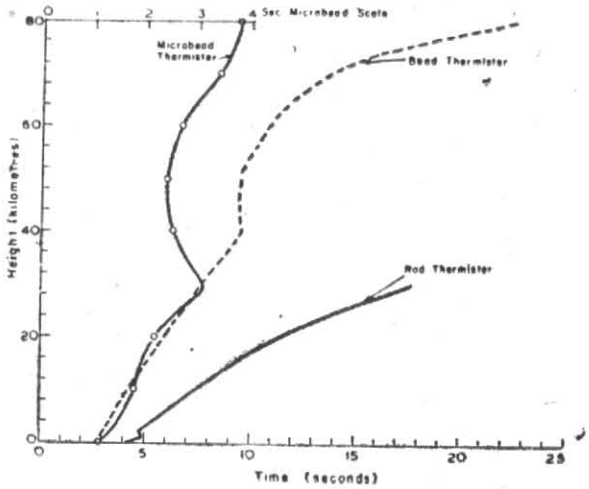

Fig. 2. Vertical distribution of temperature (°C) along the 20°N zonal section in June

3.1. *Zonal Section*

Figs. 1 and 2 show the vertical distribution of temperature along the 20°N zonal section in May and June respectively.

In May, the surface temperature generally varied between 29°C and 28.5°C along this section. The upward tilting of isotherms in association with the presence of relatively cold waters with temperature of the order of 27°C in the upper 25 metres around 62°E meridian suggests the divergence of currents in this region. The top of thermocline was generally found at a depth of 20-35 m along this section, except in the western part (off the Arabian coast) where it was pushed down to about 45 m depth. The presence of remarkably weak thermal gradients between 50 m and 200 m depth levels in the middle and western part of this section is very conspicuous and it appears to be the result of considerable mixing of water masses in this layer.

In June, the surface temperature, in general ranged from 29°C to 29·6°C. The depth of the top of thermocline varied between 20 m and 40 m along this section. The presence of relatively colder water (temp.<29°C) in the upper 30 m around 63°E meridian may be due to the spreading of upwelled water off the Arabian coast into this region. The presence of internal waves could be inferred from the large wavy pattern exhibited by the isotherms along this section. Weak thermal gradients observed along this section, between 50 m and 150 m depth levels around 63°E appear to indicate mixing caused by internal waves.

In July, the section was covered upto 67°30'E from the Indian coast. The surface temperature showed slight variation (28·5°C to 28·9 C) along this section. Relatively thick mixed layer was observed along the entire section. This may be the result of strong winds associated with

the monsoon. The effect of clouding and monsoon rains is seen in the relatively low temperature of the surface layer. Thermocline occurred at 40–50 m depth, in general, along this section. Similar feature in the same region was reported by Sastry and D'Souza (1970) in their studies on the oceanography of Arabian Sea during the monsoon season. The region between 60 m and 150 m depth levels outside the shelf was found to be characterised by significantly low gradients of temperature probably associated with considerable mixing of waters.

3.2. *Meridional Section*

A close study of the vertical distribution of temperatue along 71°30′E meridional section in May and July revealed the following features :

In May, the surface temperature varied between 30·9°C and 30°C along this section except in the northern part located in the Indian shelf region, where it decreased to less than 29°C around Lat. 19° 40′N. Thermocline occurred, in general, at 30–45 m depth along this section. Just below its top, thermocline exhibited remarkable spreading along the entire section suggesting considerable mixing at these in depths.

In July, the meridional section was covered only upto 13°48′N. The surface temperature, in general, varied between 29°C and 28°C. The depth of thermocline increased southwards from about 35 m in the northern part over the shelf to about 70 m around Lat. 14°N. This remarkable increase in the thickness of mixed layer in a north-south direction suggested the intense monsoon activity in the southern part. It may be mentioned here that significant increase in the wind force from less than 10 kt in the northern part upto 30 kt in the southern part (south of 16°N) was observed. An interesting feature observed was the presence of nearly homogeneous water of relatively low temperature in the thick mixed layer at Lat. 15°16°N. This feature may be related to the possible sinking in this region of upwelled water off the Indian coast.

3.3. *Short term variations in the vertical temperature structure of the Indian shelf water along 20°N Lat.*

A close study of vertical temperature distribution in the Indian continental shelf along Lat. 20°N on 20 May and 24 May respectively reveals some interesting features. Within this period of 4 days the temperature of the surface waters in the upper 25 m, was found to increase in the shelf region by 0·1° to 0·7°C, while beyond the shelf it decreased slightly. Even though there was no appreciable change in the depth of thermocline, the temperature gradients in the thermocline outside the shelf were found to decrease during this period. These features may be related to the diurnal and temporal variations in the environmental parameters which affect vertical temperature structure in the upper layers of the sea (La Fond 1954).

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