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CURRENT AND TEMPERATURE STRUCTURE OF RIHAND LAKE

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ABSTRACT

The environmental parameters such as wind, water and air temperatures, and currents were measured in Rihand lake during the hottest months, May-June of 1983. Rihand is an artificial lake having an area of 300 km^2 and situated in tropical arid zone. The winds are normally weak but highly variable. High surface temperature gradients are established near the shore. The discharge of warm water from a nearby super thermal power station does not appear to have major influence on the vertical as well as horizontal temperature structure of the lake. The surface currents are highly variable due to wind but mostly follow the depth contours. The bottom waters of the deepest area seem to be stagnant as seen from the current and temperature structure.

Key-words : Currents, temperature, wind, Rihand lake.

INTRODUCTION

Limnological studies describing the hydrodynamical aspects are sparse in India. But quite a large number of lakes are presently used for industrial purposes. Many coal-fired super thermal power stations are being established on the banks of Rihand lake in Uttar Pradesh, India, in addition to the existing Singrauli Thermal Power station. These plants draw coolant water from the lake and discharge it back after use. As the efficiency of the thermal power stations depends on the temperature of the intake water, the temperature changes in the reservoir due to the combined effect of natural and artificial processes need to be known. It was in this context the temperature structure and circulation pattern of Rihand lake were studied. Data were collected during the hottest months (May to June) of the year 1983. The surface heat budget over the Rihand reservoir has been reported earlier (Sadhuram, Vethamony, Suryanarayana, Swamy and Sastry, 1988).

This paper presents the current pattern and the variation of water temperature of the lake.

THE RIHAND LAKE ENVIRONMENT

The Rihand lake (reservoir) is located between $24^oN,83^oE$ and $24^o2'N,82^o38'E$, with a surface area of 30 km x 15 km having a maximum depth of 25 m (Fig.1); the average depth being 10 m. It is located in an arid zone. The conditions over the lake

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are hostile when dust storms and whirl winds occur during mid- afternoons. During local storms fairly high waves are formed. During dust storms the visibility is reduced to around 100 m or less and navigation becomes extremely difficult. The winds with intense gustiness increase rapidly by afternoon. The submerged hillocks and tree trunks, uneven bathymetry etc., add to the problems of navigation. The area experiences severe winter and summer. In summer, the air temperature crosses 45°C at times. By the end of June, thunder storms develop occasionally and the rains are copious and unpredictable. The water level in the lake is controlled at Rihand Dam (NIO Report, 1983).

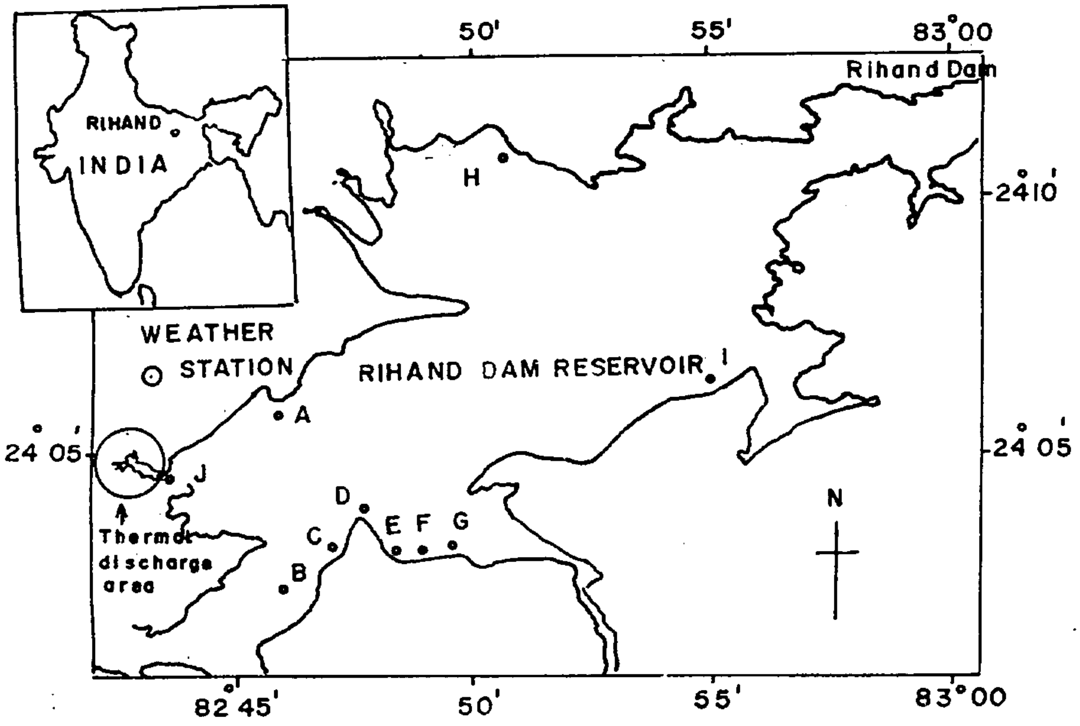

Fig. 1. Station and thermal plume location map.

INSTRUMENTS AND OBSERVATIONS

Aanderaa current meters were moored at stations A, B, C, D, E, F, G, H and I (Fig.1). These stations/locations were identified for the proposed water intake/discharge points for the thermal power stations. Being an artificial lake with a number of submerged obstructions, the current meter moorings were confined to specific sites of future thermal discharges. Sampling interval for the observations was set at 10 minutes. At station B (depth 20 m) two current meters, one 3 m above the lake bed and the other 3 m below the surface level were moored. The moorings at the remaining stations carried one current meter about 3 m above the lake bed uniformly. However, we could get reliable data only from the mooring stations B, E, H and I.

A surface drogue (1 m level) and a subsurface one (3 m level) designed in the form of vane-float assembly were released together at stations C, E, F and J several times for varying durations. These experiments were mostly performed under calm conditions (wind <5 m/s) to minimise the wind effect on the floats and also owing to position fixing limitations in choppy conditions.

Simultaneous observations of water temperature at different levels at stations B, D, H and I were made during the period of study using a temperature probe made at NIO. The accuracy (±0.5°C) and stability of this probe which had to cover unusually large range were repeatedly checked.

All meteorological parameters, including wind speed and direction were measured every 15 minutes at an elevation of about 8 m from the ground level by an automatic weather station (Aanderaa Instruments) at the top of a building about 1 km away from the reservoir bank during May-June, 1983 (Fig.1).

RESULTS AND DISCUSSION

Winds and currents

Hourly mean wind vectors were grouped into eight sectors at intervals of 45° each and four speed classes and presented as histograms. Currents at stations B, E, H and I were analysed and presented in the same manner as that of winds. Sectors seven and eight were dominated by speeds 0 - 1 m/s and 3 to >4 m/s respectively. Wind speeds >4 m/s were less frequent in the remaining sectors and wind energy input was more evenly distributed. The frequency of the winds was very low in sector 2. The computed wind stress vary in the order of 10^{-2} to 10^{-5} N/m^2. The values of v-component (along Y-axis) of the wind stress are higher than that of u-component (along X-axis) (Fig.3.); both the components attaining maximum values in the afternoon hours (when the gusty winds prevail over the lake).

At station I (Fig. 2b), sector 2 and sector 3 were dominant, with currents mostly of speed 2.0 - 4.5 cm/s. The currents in the range of 9.5 - >12.0 cm/s are more pronounced in these two sectors than in any other sector. At this station, located near the eastern boundary of the lake, the currents were variable due to the effect of wind forcing.

At station H (Fig. 2c), which is far off from the main channel of the lake and also the northern most station, the currents were almost unidirectional (northerly, sector 1) and weak (<4 cm/s). It may be that the flow follows the alongshore component of the wind stress.

At the station E located in the southeastern region in a semi-enclosed area, the currents were of fluctuating type (Fig. 2d) and strong with speed exceeding 20 cm/s. Sectors 3 and 7, which are situated diametrically opposite are dominated with currents with a speed of more than 20 cm/s. The advection pattern (Fig. 6) showed the same trend with a meandering current because of the semi-enclosed nature of the

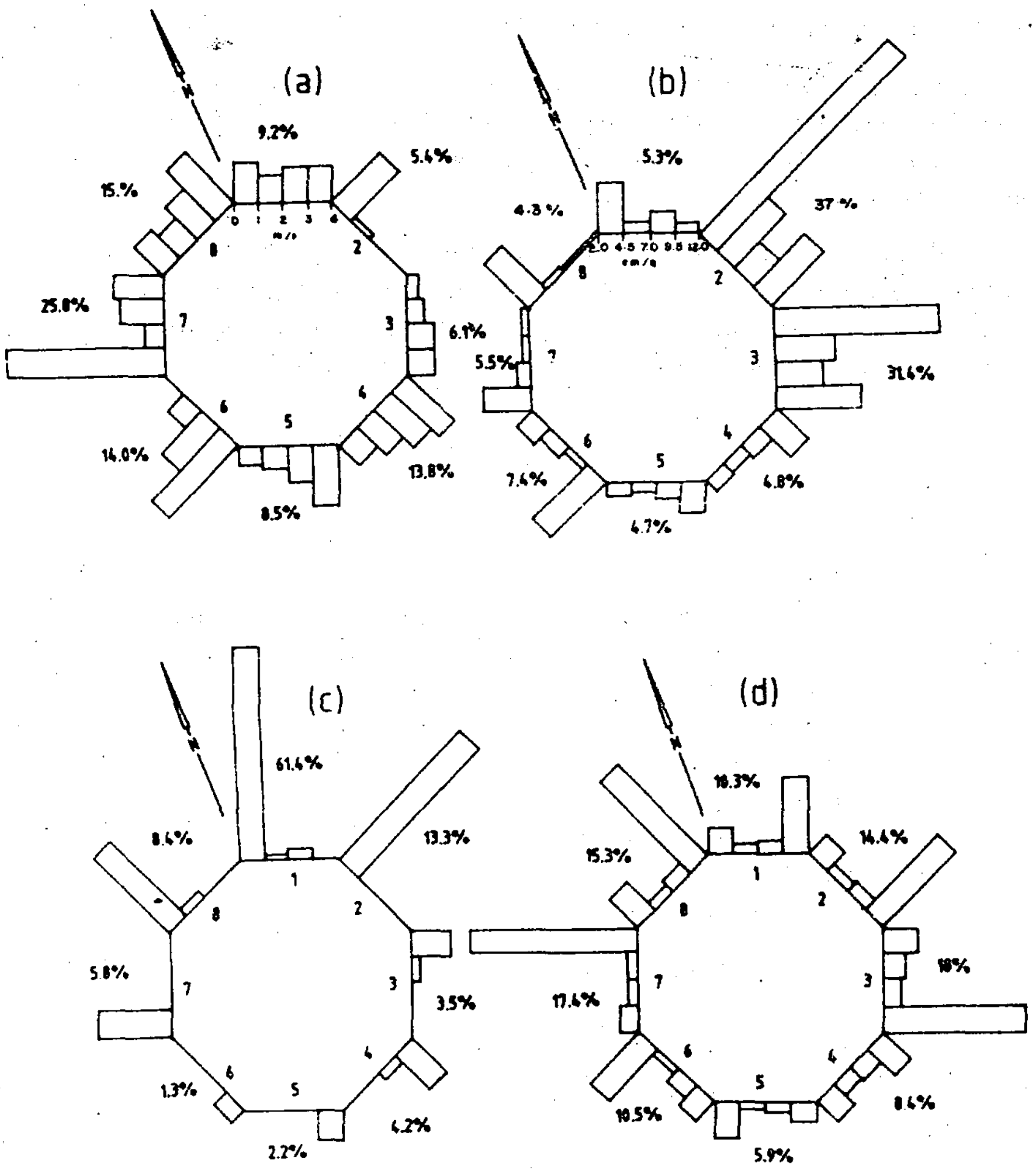

Fig. 2. Histogram of (a) wind vector and (b), (c) and (d) currents at stations I, H, and E respectively (The percentages indicate the occurrence of the direction of wind/current in the sector out of the total observations).

surroundings. The domination of westerly currents (sector 7) revealed the effect of wind on the surface at this station.

At the mid-channel station B, two current meters were moored one at 3 m below the surface and the other at 3 m above the bottom (station depth around 15 m). The

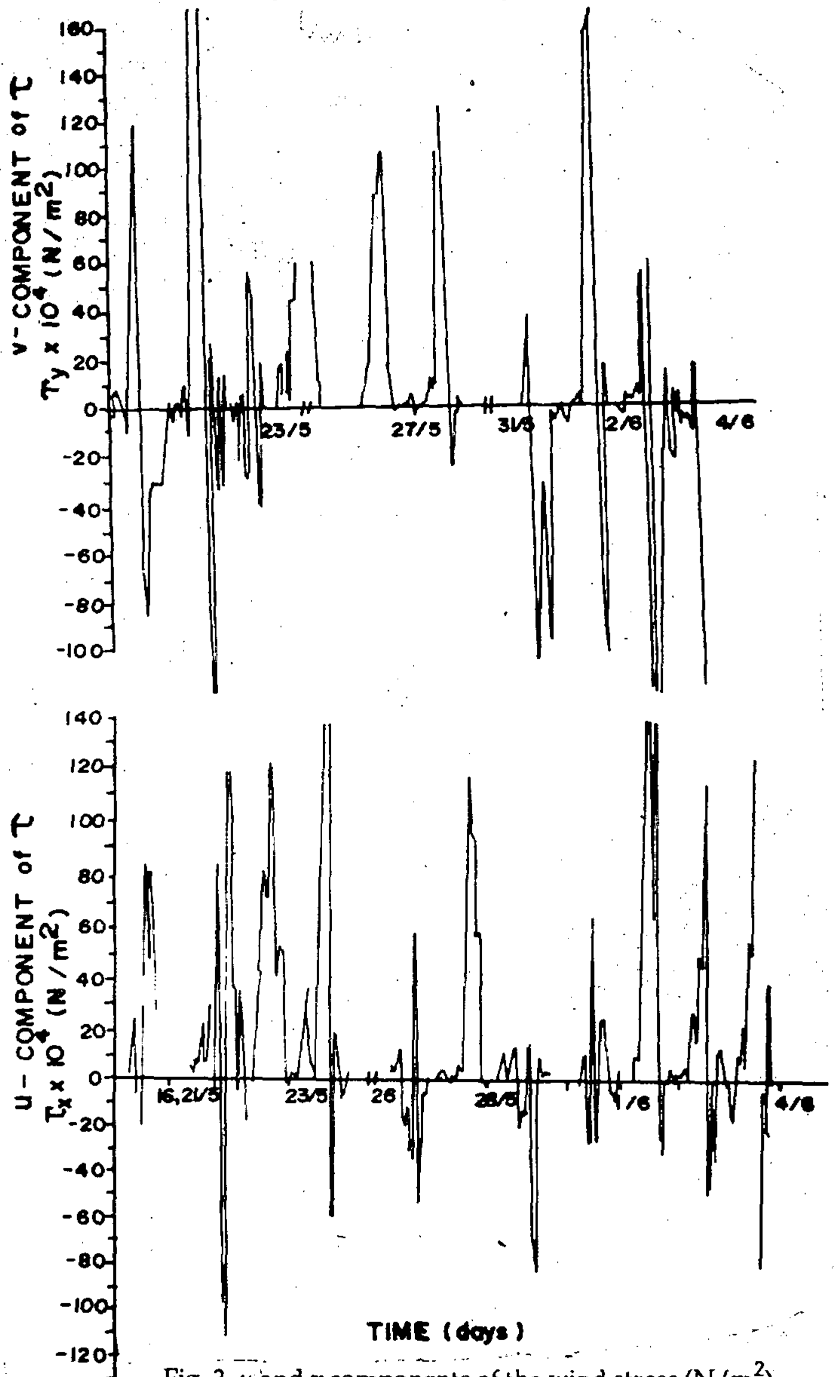

Fig. 3. *u* and *v* components of the wind stress (N/m^2).

surface currents (at 5 m depth, Fig. 4a) were weak and variable. The bottom currents (at 10 m depth, Fig. 4b) were weak (<4 cm/s) and unidirectional (southwest). As long as the lake was stratified, the hypolimnion remained shielded from the direct influence of wind and the structure of the bottom currents was controlled by the dynamics of the thermocline (Lammin and Imboden, 1987). They may then follow the bottom topography.

The simultaneous surface (continuous line) and sub-surface (dashed line) current trajectories at the stations C, E, F and J (Figs. 5-8) indicated vertical shear. At station C (Fig. 5) the drift was towards north (in the direction of general flow). The trajectories at station E (Fig. 6) mostly follow the topography. The flow at station F (Fig. 7) was in a meandering way which may be due to the submerged hillocks in that region. The trajectory of the float at station J (Fig. 8), where the thermal plume existed, was also in a meandering way due to shoals and eventually found its way towards the main channel.

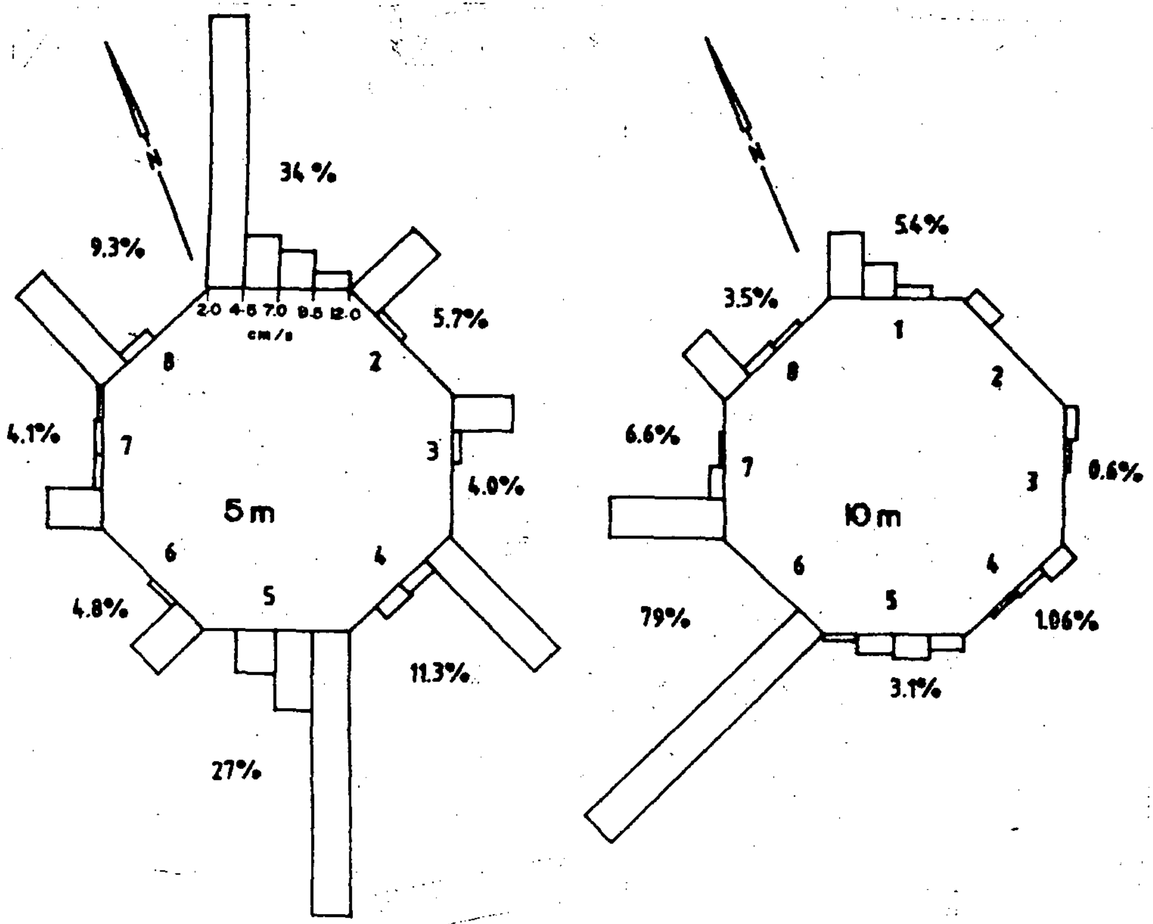

Fig. 4a.

Fig. 4b.

Fig. 4. Histogram of currents at (a) 5 m and (b) 10 m at station B (The percentages indicate the occurrence of the direction of wind/current in that sector out of the total observations).

Temperature

The temporal variations of temperature at different stations are shown in Figs. 9-12. The observations reveal that strong temperature gradients are established in the

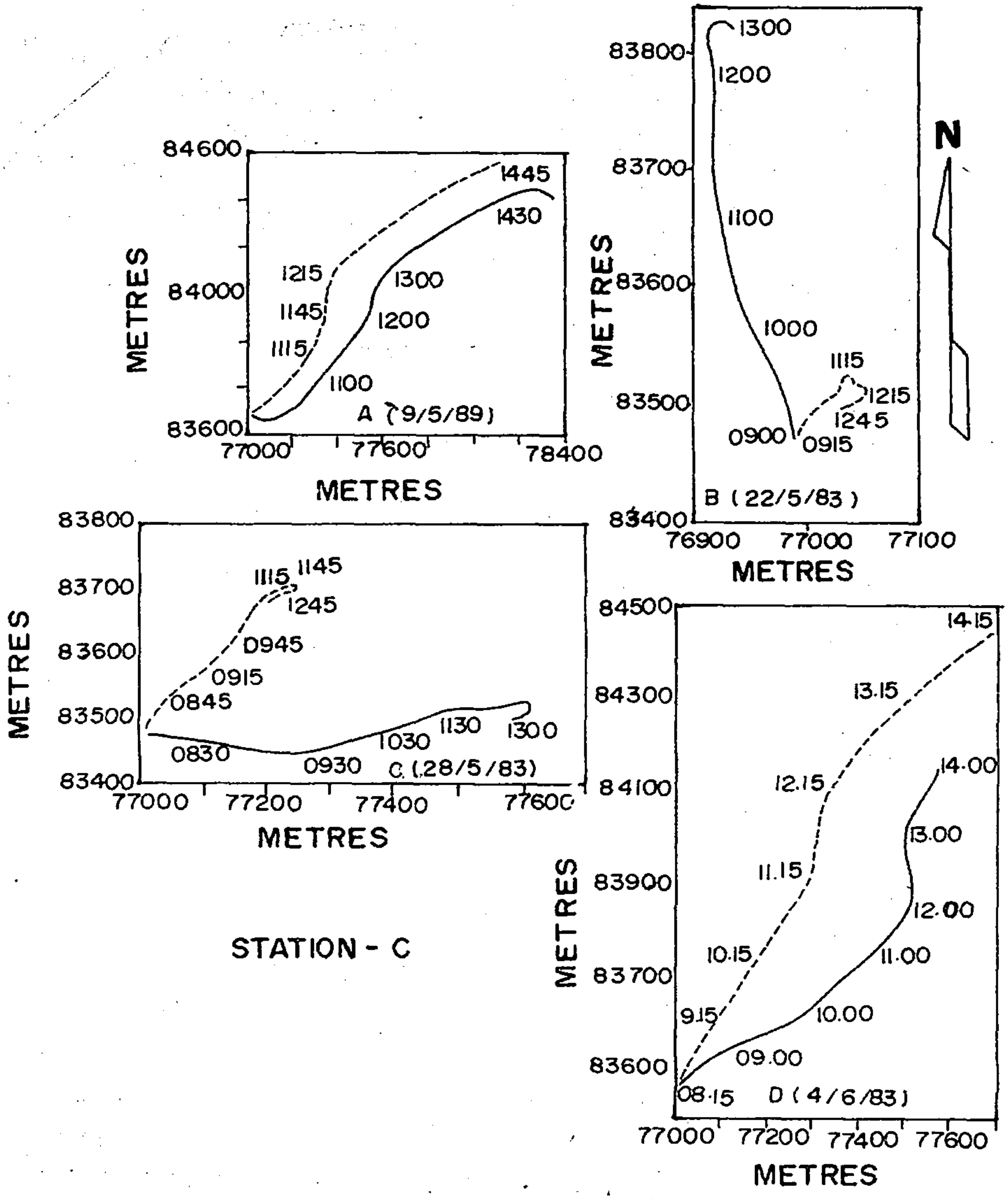

Fig. 5. Float trajectories on surface (continuous line) and subsurface (dashed line) at station C.

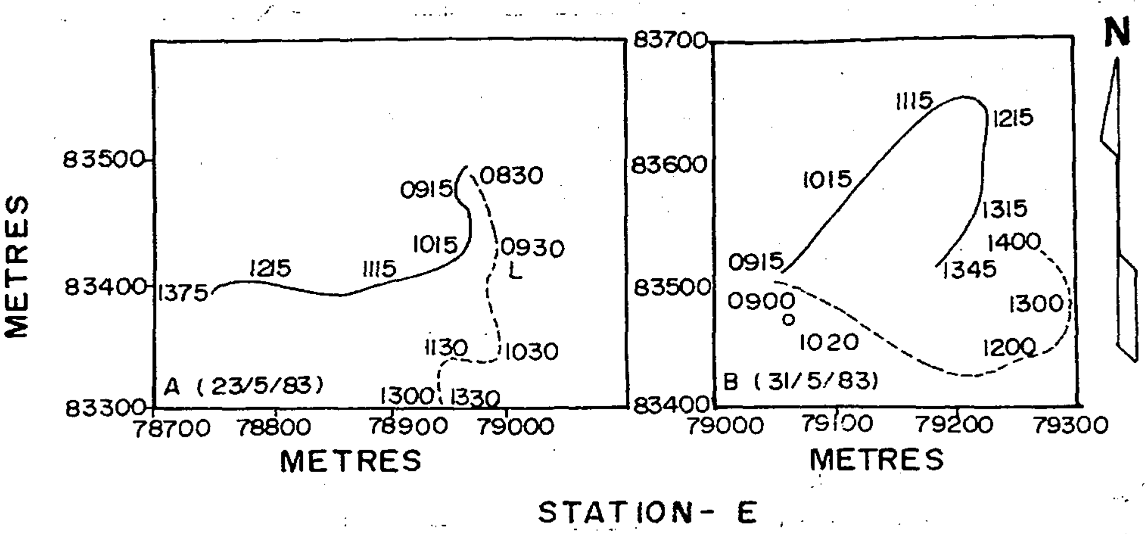

Fig. 6. Float trajectories on surface (continuous line) and subsurface (dashed line) at station E.

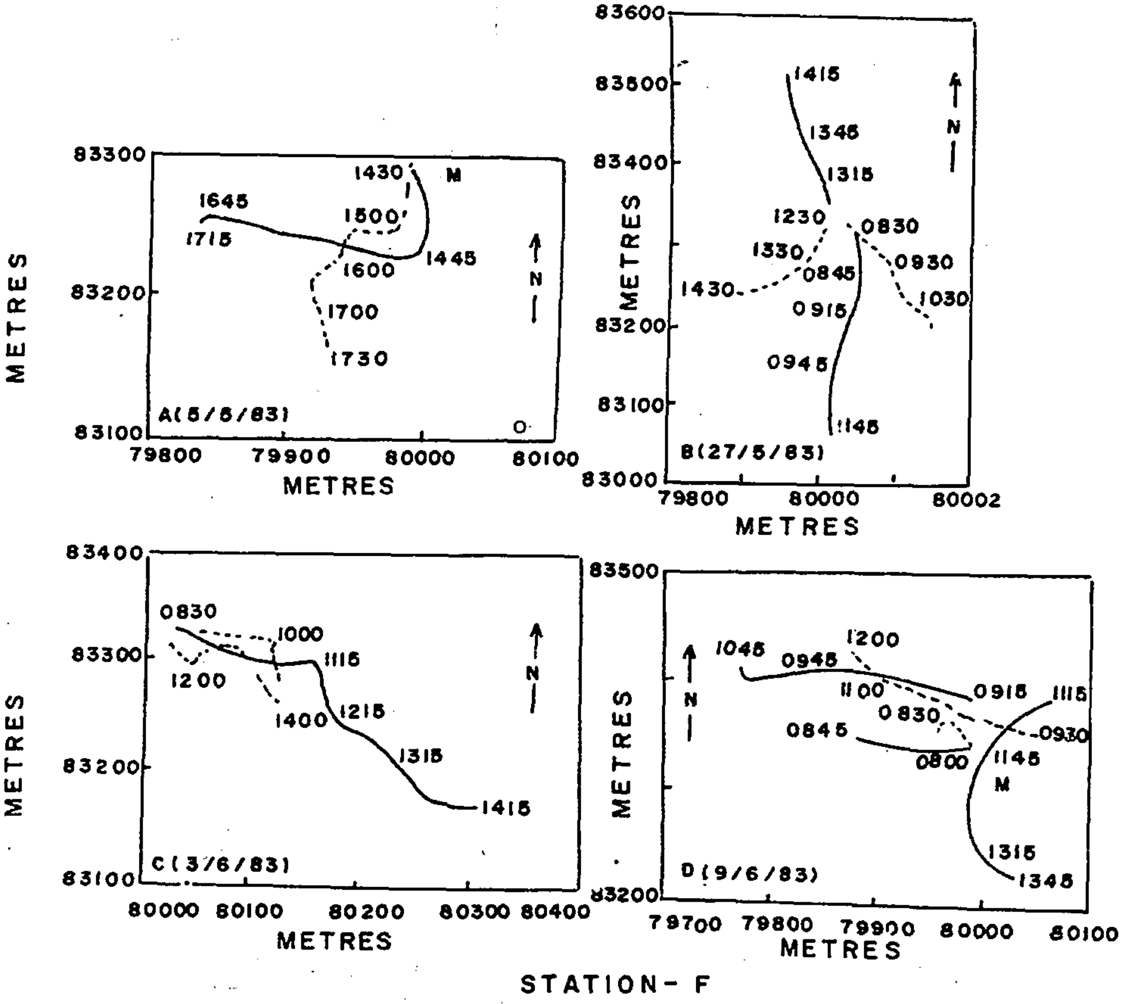

Fig. 7. Float trajectories on surface (continuous line) and subsurface (dashed line) at station F.

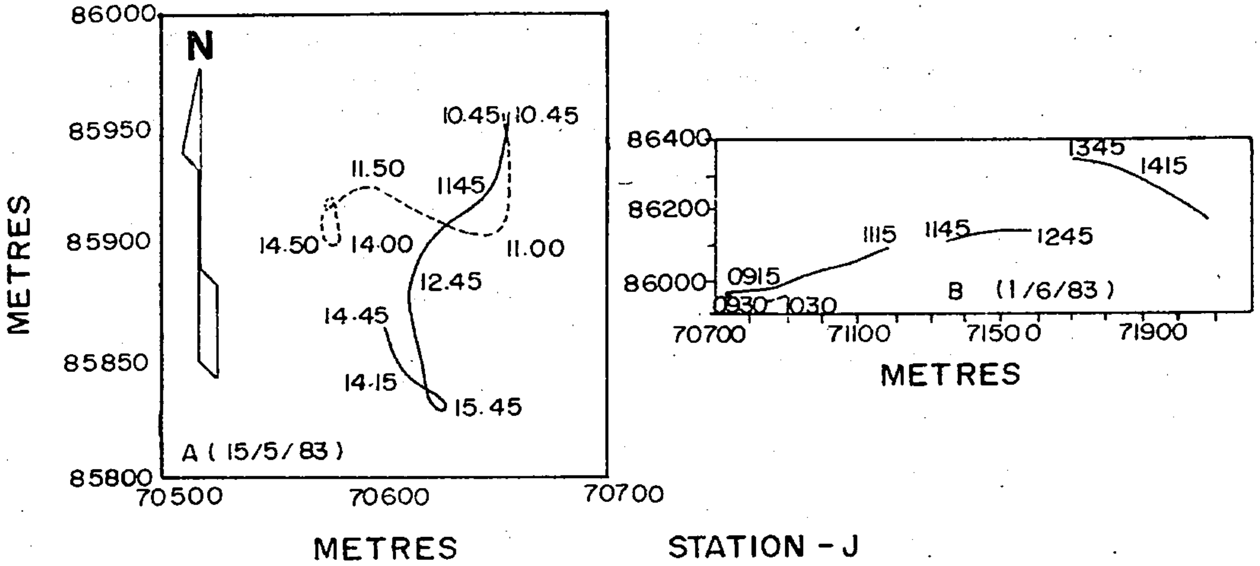

Fig. 8. Float trajectories on surface (continuous line) and subsurface (dashed line) at station J.

surface layers particularly at stations close to shore (*e.g.* station D) around noon (Fig.10). The deeper stations had weak thermoclines and the temperature drop with depth was fairly gradual (*e.g.* station B, Fig. 9). At stations B and I (Figs. 9b & 12b), there were well-defined mixed layers in the morning hours. The variation of surface water temperature at station B (28° to 31°C) was less compared to those at station I (27° to 34°C), station D (27.5° to 35°C) and station H (28.5° to 32.5°C). This is due to the proximity of stations to the land. The land would heat up by noon and simultaneously the temperature of the nearby waters would increase through conductivity substantially. The air temperature exceeded 38°C during the month of May and reached 40° during June. In a detailed study on heat fluxes at different locations over this reservoir, it was indicated that heat was also transferred from the atmosphere to the reservoir, resulting in high surface water temperatures in the afternoons (Sadhuram, Vethamony, Suryanarayana, Swamy and Sastry, 1988).

The near-bottom temperature at all these locations was nearly constant throughout the period of observation. At station B, the bottom temperature was 22°C, where the depth was more than 15 m. At station I it was about 25.5°C.

The discharge temperature of the existing Singrauli thermal power plant has been rated about 10°C above the lake water temperature (around 30°C at the surface). The warm water enters the lake through a natural drain. The distribution of temperature within the thermal plume is shown in Fig. 13. The source of the plume is at around 24°48′N and 82°44.5′E and extended eastwards (Fig. 1). The length of the plume is around 2 km and the average width 450 m. The variation of surface temperature is high within the plume. At the source region it is >34°C and decreased to 30°C within

3 km away. The warm water that enters the reservoir is first cooled by mixing. Beyond this, evaporation is the principal mechanism of heat transfer as the plume disperses as a surface layer (Coulter, Gurthrie, Kirkwood and Lamb, 1972). Since evaporation

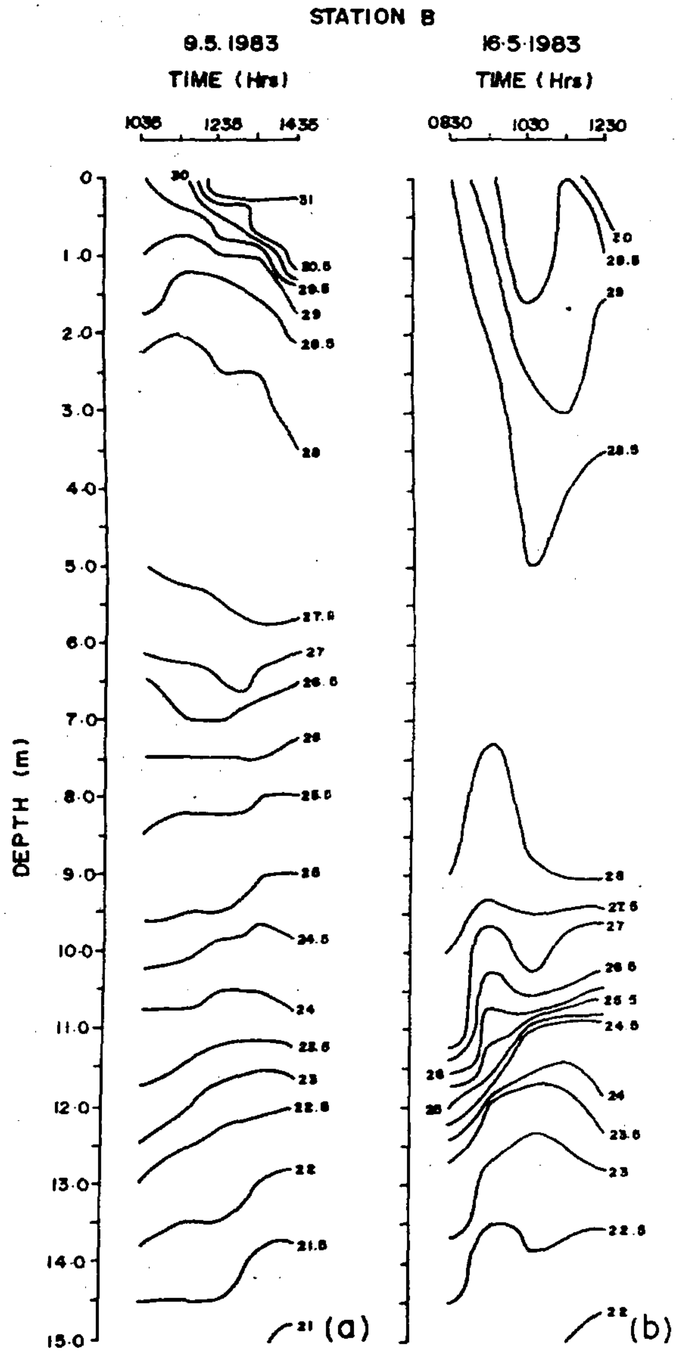

Fig. 9. Temporal variation of temperature (°C) at station B.

is low over the Rihand lake (Sadhuram, Vethamony, Suryanarayana, Swamy and Sastry, 1988) the cooling of the plume is achieved by mixing due to the variable winds.

The high surface temperature at stations D and B in the morning hours seems to be due to the influence of the thermal plume and in the afternoon due to the combined effect of the thermal plume and atmospheric heating. Since winds are highly variable and weak, the currents mostly follow the bottom topography. Apparently the behaviour of the thermal plume which forms at station J has no drastic influence on the temperature structure of the lake apparently.

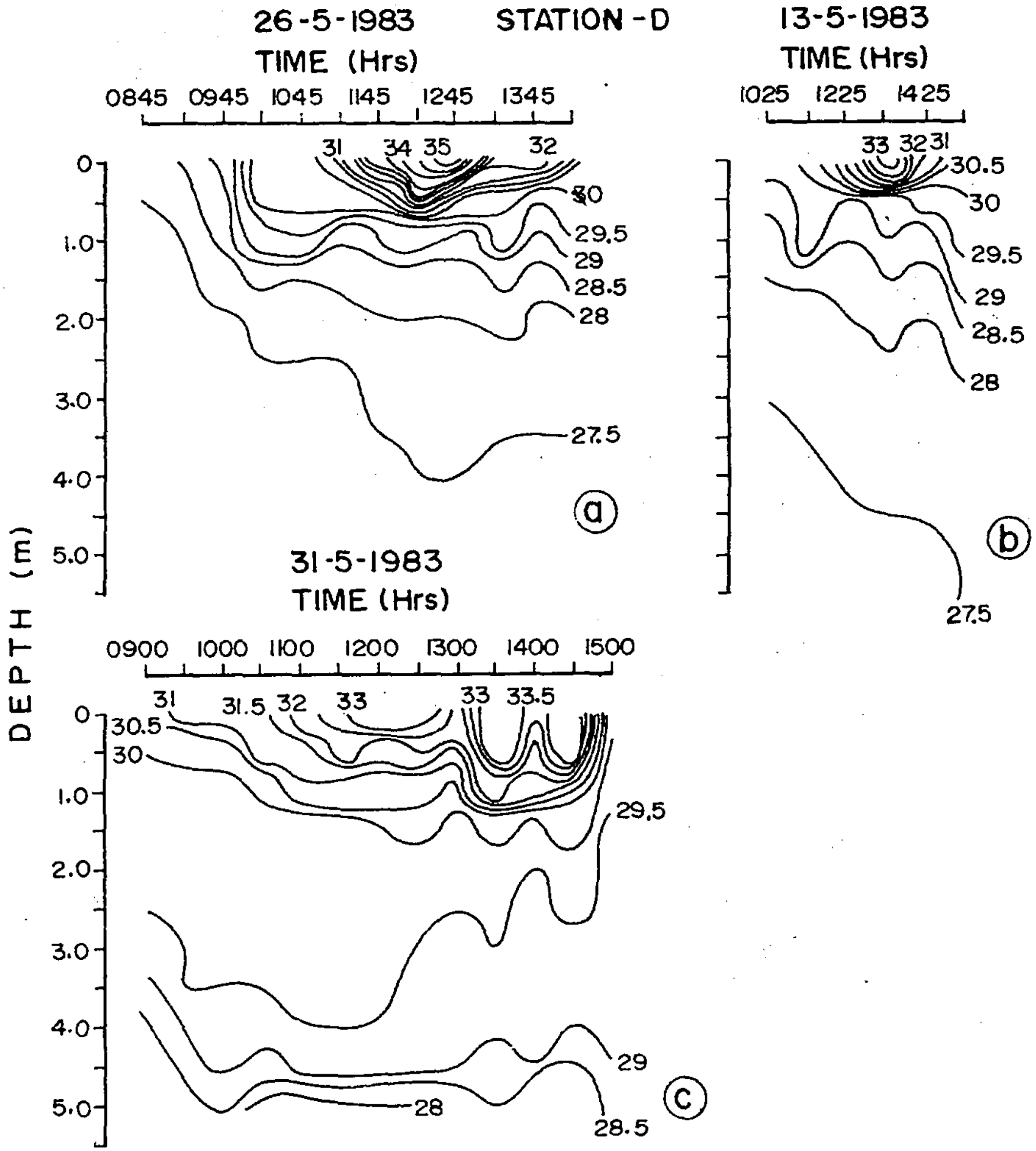

Fig. 10. Temporal variation of temperature (°C) at station D.

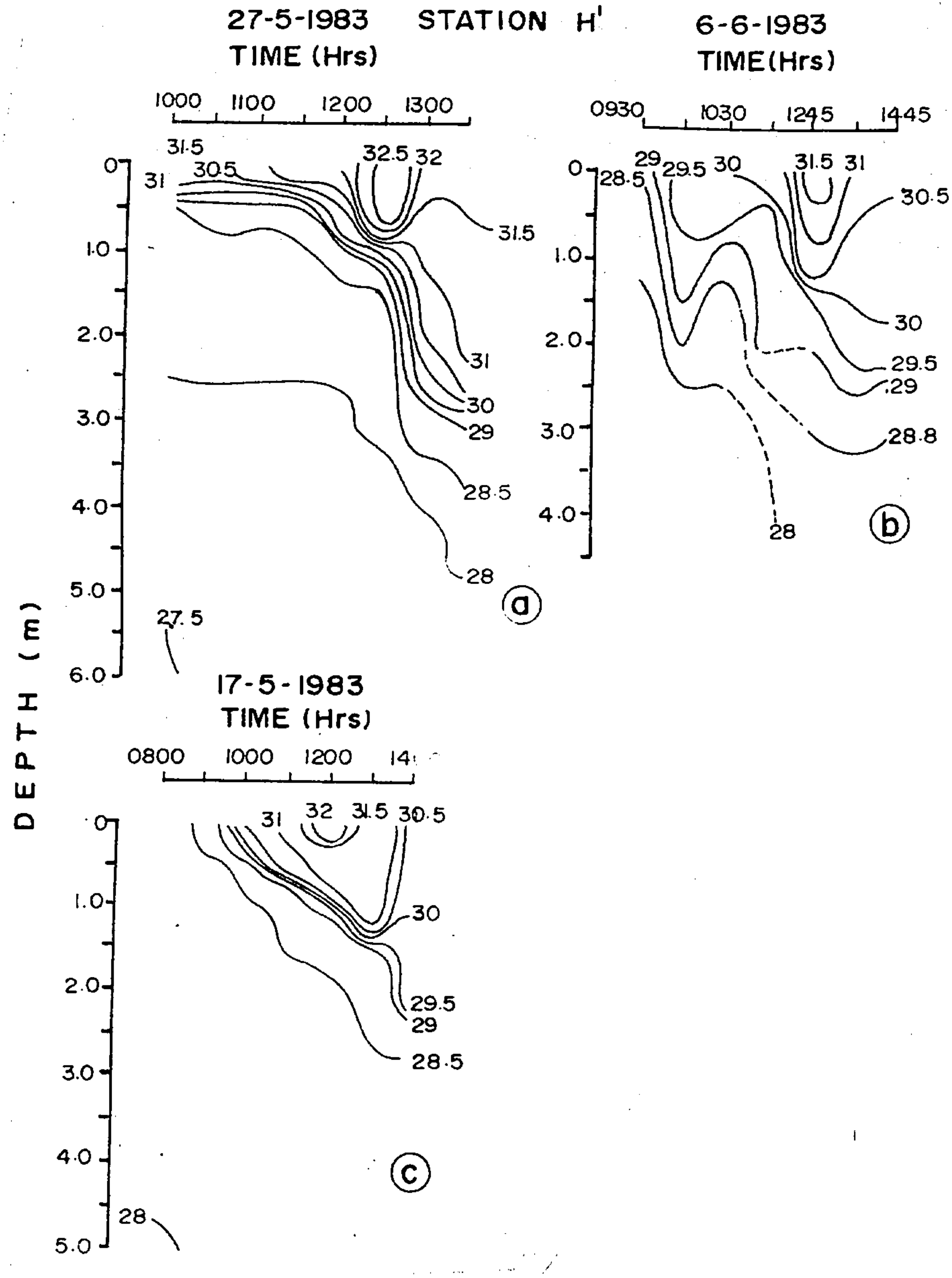

Fig. 11. Temporal variation of temperature (°C) at station H.

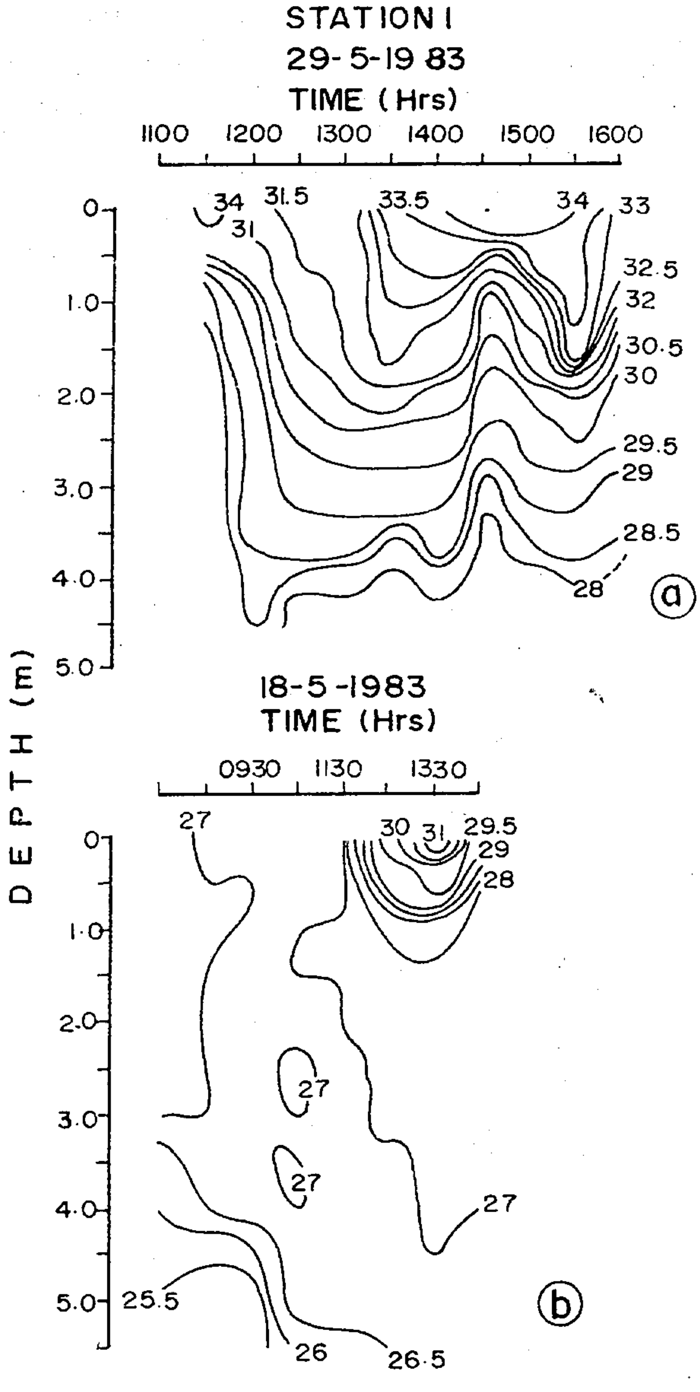

Fig. 12. Temporal variation of temperature (°C) at station I.

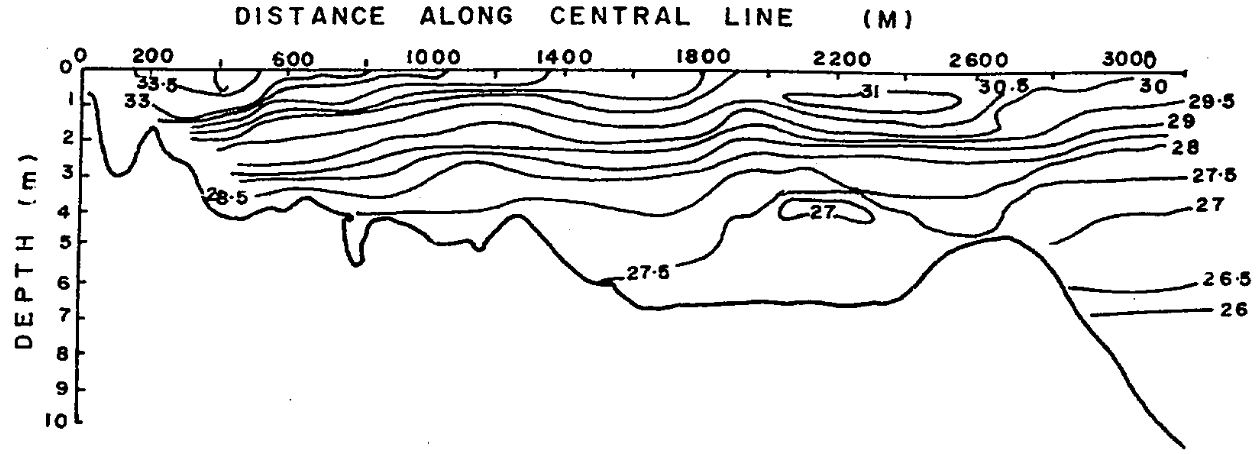

Fig. 13. The distribution of temperature (°C) within the thermal plume.

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