

Temperature, Salinity & Circulation in Saudi Coastal Waters (Arabian Gulf) during May 1985

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Temperature, salinity, and current measurements were made hourly at 6 stations in Saudi coastal waters during 19 to 29 May 1985. The surface temperature decreased from Ras Tanura to Manifa and the water mixing off Ras Tanura was higher than in any other region of the Saudi coastal water. Salinity increased from surface to bottom and from Manifa to Ras Tanura. T-S diagram showed 2 distinct water masses at most of the stations. The current measurements showed that the tide-induced current generally tends to flow south through southeastward on flood and west through northwestward on ebb tide. The survey suggests that the general trend of surface circulation pattern along the Saudi coastal waters of the Arabian Gulf is southeastward flow.

Review of hydrographic conditions in the western Arabian Gulf region confirms that there is insufficient data of physical parameters (temperature, salinity and currents) which can allow only superficial assessment of the physical processes contributing to the movement and dispersion of pollutants¹. The absence of current measurements makes it impossible to describe the circulation patterns in summer. Only recently, current measurements have been carried out at few stations in the coastal region of the northern area of the Arabian Gulf².

The present investigation pertains to the study of temperature, salinity and circulation in the coastal waters of the western Arabian Gulf from Ras Tanura to Safaniya-Zuluf-Marjan oil fields.

Materials and Methods

The Arabian Gulf is very shallow with an average depth of 35 m, and a maximum depth of 100 m near its narrow entrance. The elongate axis of the Arabian Gulf basin separates 2 major geological provinces—the stable Arabian foreland^{3,4} and the unstable Iranian Fold belt, which are reflected in the contrasting coastal and bathymetric morphologies of Arabia and Iran. Most of the Arabian Gulf area is very arid and little fresh water flows into the Gulf except at its northern end. There the Shatt al Arab, the confluence of the Tigris, Euphrates, and Karun, discharges. Rainfall into the Gulf is not more than 7 cm.y⁻¹.

Temperature, salinity, and current measurements were taken from 6 stations (Fig. 1). The

measurements were made during 19 to 29 May 1985 as given in Table 1.

Data were collected every hour at each station from several depths between surface and bottom layers. Current speed and direction were measured using an Endeco current meter type 110. Water samples were taken by Nansen reversing water bottles. Salinity was measured by a portable induction salinometer (model RS7-C), while the temperature was taken by the protected reversing thermometers. The average current speed and direction of each station at various depths over the tidal period were calculated using the statistical analysis system⁵. Meteorological data consisting of the air temperature and windspeed and direction were taken from the onshore and offshore stations of ARAMCO².

Results and Discussion

Temperature and salinity—Variations of water temperature at each station at different depths during 25 h are shown in Fig. 2. The mean temperature gradient between surface and bottom water is more appreciable at the offshore stations than at the onshore. The same pattern is shown

Table 1—Data Collection Details

St No.	Depth (m)	Date of sampling (May 1985)	Tidal range (m)	MSL-ISLW (cm)
1	23	19-20	41-91	85
2	34	21-22	46-102	85
3	18	22-23	50-145	92
4	23	25-26	70-163	108
5	33	27-28	64-111	88
6	13	28-29	47-115	92

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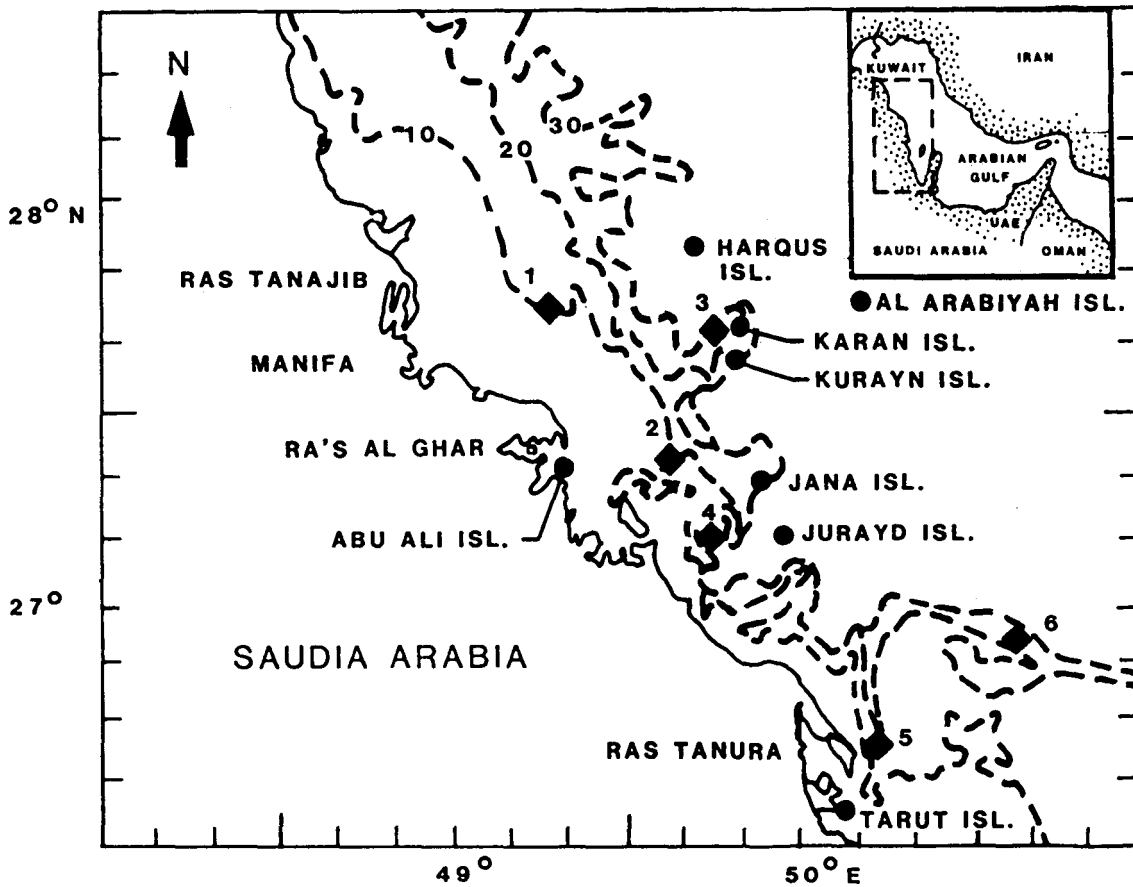


Fig. 1—Station locations in the Arabian Gulf

during a given tidal period. (Fig. 2). This is very clear at sts. 2 and 5. The mean temperature profiles over 25 h for the 6 stations show that the surface temperature decreases from Ras Tanura (st 4) to Manifa (st 2) (Fig. 1).

The mean temperature profiles also indicate that the water mixing in Ras Tanura area (st. 4) is higher than in any other region of Saudi coastal water. Variations of salinity during 25 h at different depths are shown in Fig. 3. Salinity increases from surface to bottom and from Manifa (st 2) to Ras Tanura (st 4). The mean salinity profiles indicate the same trend with the mean surface lowest value at st 1 and highest at st 4. From the small difference in mean salinity between surface and bottom, and the big differences in mean temperature at sts 2 and 5, it is clear that at the offshore stations in the Gulf, the summer pycnocline presents a barrier to vertical mixing, which precludes the dynamical treatment of summer conditions¹. The low value of surface salinity at st 1 may be as a result of the water discharge from Shatt al Arab, north of the Gulf, as it can be traced as far as 50°E and 28°N (ref. 6). Estimates⁷ of the annual influx from rivers to the Gulf, vary from 5 to 100 km.³ y⁻¹.

To identify the water masses which existed in the Saudi coastal area during summer, T-S diagram for each of the 6 stations were drawn (Fig. 4). At st 2, the T-S diagram show 2 water masses—an upper one of low salinity and high temperature (σ_t : 26.7 to 28.1) and lower one of high salinity and low temperature (σ_t : 28 to 28.5). At st. 2, at the Manifa offshore area, the T-S diagram shows 2 distinct water masses with bottom water of higher density than at st 1. At the shallow st 4, the wide variation in salinity and temperature existed at all depths. At st 6, where the water depth is not > 12 m, T-S diagram shows only 1 water mass with density 27 to 28.

At Ras Tanura, where the mixing is high, T-S diagram for st 4 shows 1 thermal water mass with salinity from $4.16\text{-}4.28 \times 10^{-3}$.

The general conclusion is that during the summer (May 1985) 2 distinct water masses were observed as indicated from previous surveys in the Gulf area¹.

General circulation—Earlier studies⁸⁻¹⁰ indicate a counterclockwise gyre within the Gulf resulting in southeasterly flowing current off Manifa. The same pattern is observed from the present short duration current survey at the 6 stations. From

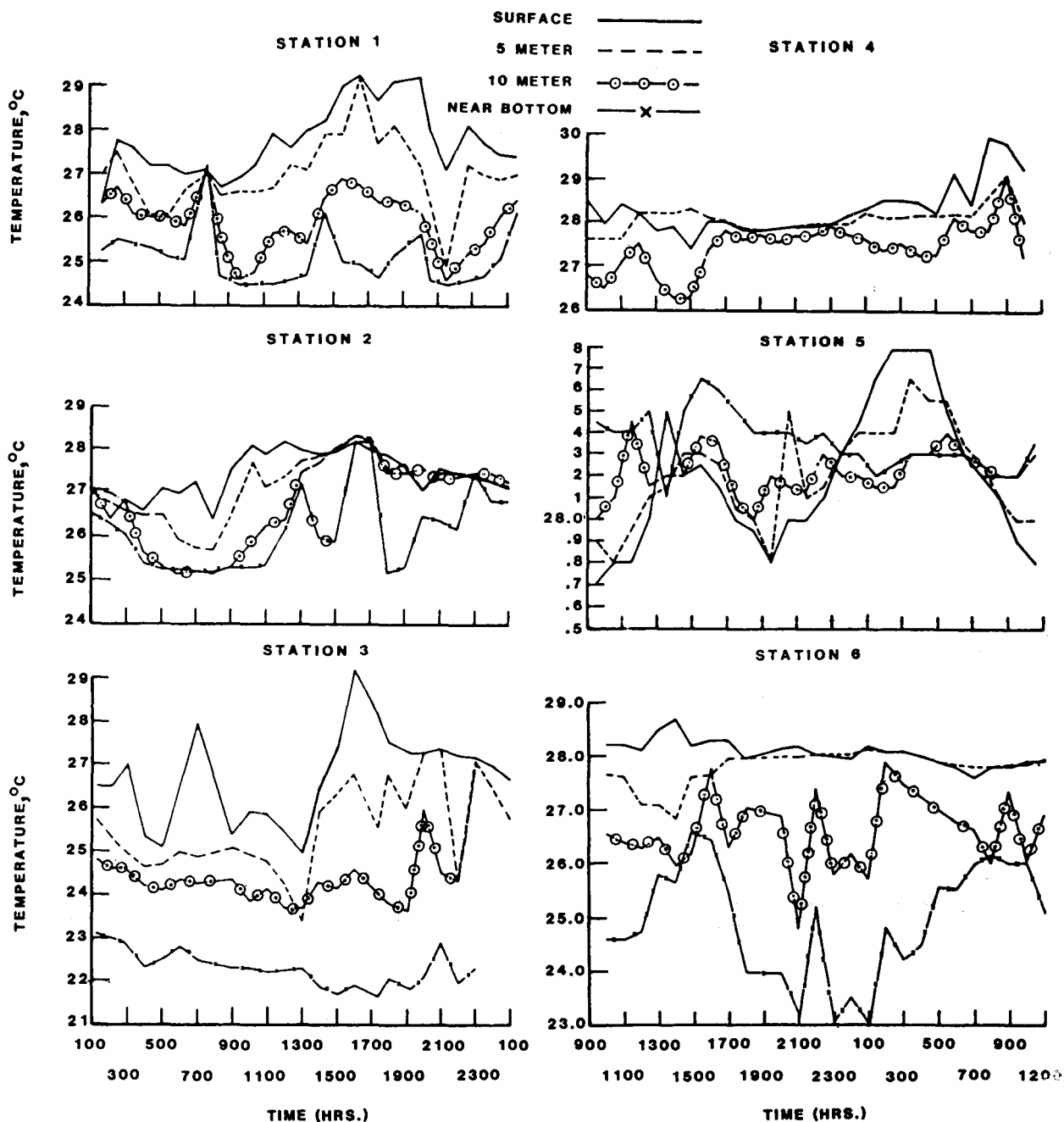


Fig. 2—Temperature variations with time at different depths

the rose diagrams over the tidal period at each station, it is seen that the southeasterly current is persistent at most of the stations at both surface and bottom (Figs 5 and 6). The current measurements show that the tide-induced currents generally tend to flow south through southeastward on flood and west through northward on ebb tide. This pattern is clearly illustrated at sts 2 and 3. At the other stations the tidal current changes from one station to another according to the type of tides as well as the coastal configuration. At Ras Tanura (st 4), the flood current is divided in-

to northern and a southern branch. This might be due to the presence of Bay of Salwa, south of Ras Tanura, which acts as a basin that will periodically be filled and emptied by the tidal movement. Similarly, the ebb current flowing southeastward along the coast north of Ras Tanura and that flowing northward out of the Bay of Salwa meet each other also at Ras Tanura. This pattern is shown by the progressive vector plot for surface current (Fig. 7) which is similar to previous¹¹ studies in that vicinity over a longer period in 1964.

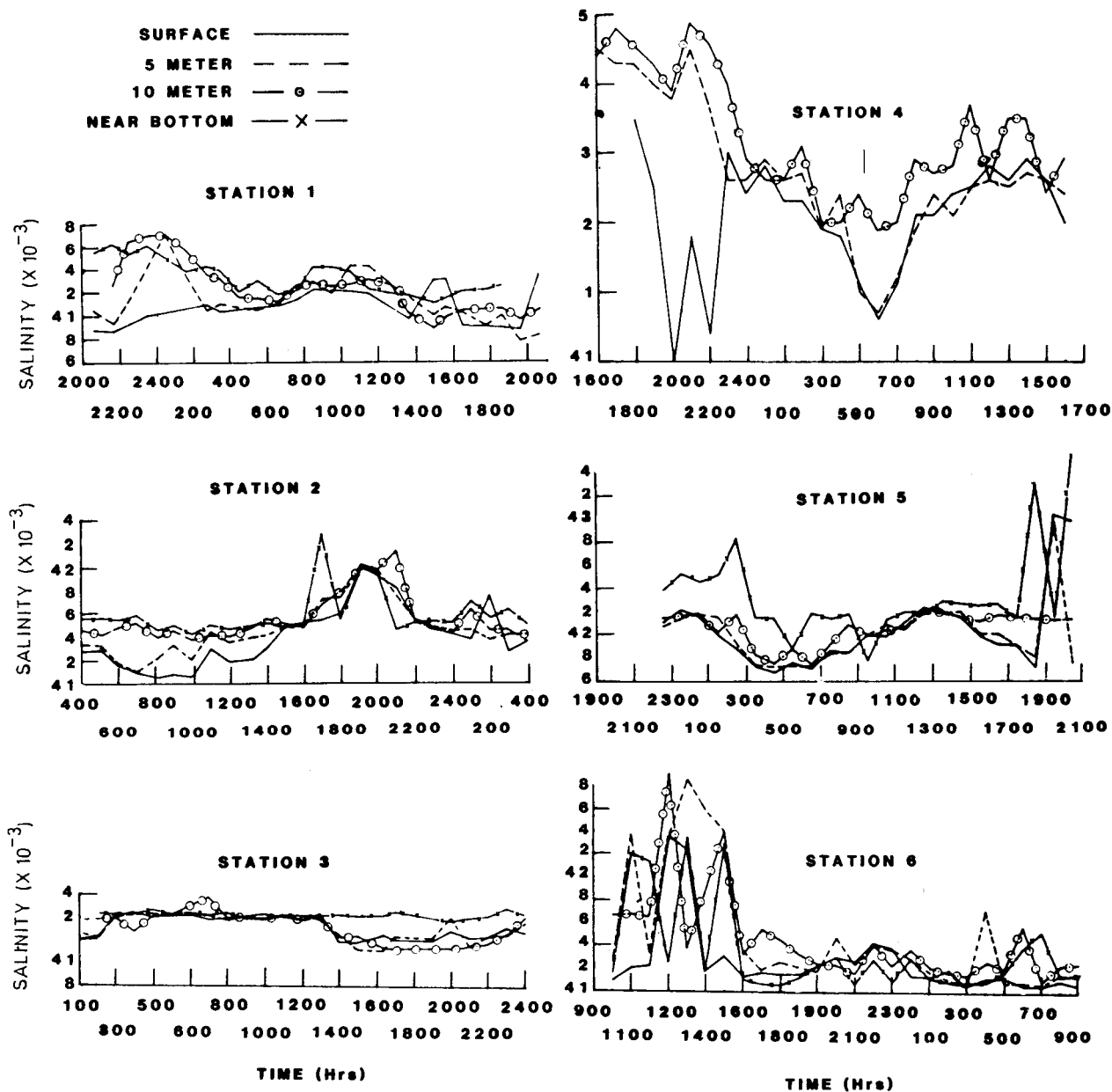


Fig. 3—Salinity variations with time at different depths

At Manifa coastal area (st 1), the tidal regime can be classified as mixed dominantly semi-diurnal, producing 2 unequal highs and lows daily. From the progressive vector plot (Fig. 7), it is seen that the tide induced current tends to flow northwest through the southeastward on flood and northeast through southeastward on ebb, with max. flood current 30.9 cm. sec⁻¹ towards 340° and max. ebb one of 46.31 cm. sec⁻¹ towards 315°. The current direction is most frequently NW or SE, which coincides with the orientation of the major axis of the tidal ellipse. At st 6, the progressive vector plot for the surface current (Fig. 7) indicates that the current is directed to the

south through southeastward of the tidal cycle with a max. current of 77.2 cm sec⁻¹ on the flood at direction of 140°. This might be due to the effect of the configuration of Abu Ali Island as well as the type of tides at that time.

At Abu Safah Gosp (st 5), where the tides are mainly semi diurnal with 2 unequal highs and lows daily, the tidal cycle is mainly in the southeast direction.

The wind forces were light to moderate over the Saudi coast of the Arabian Gulf varying from calm to max. wind force of about 17 knot. During the current measurements at each station the wind forces did not exceed 12 knot, indicating

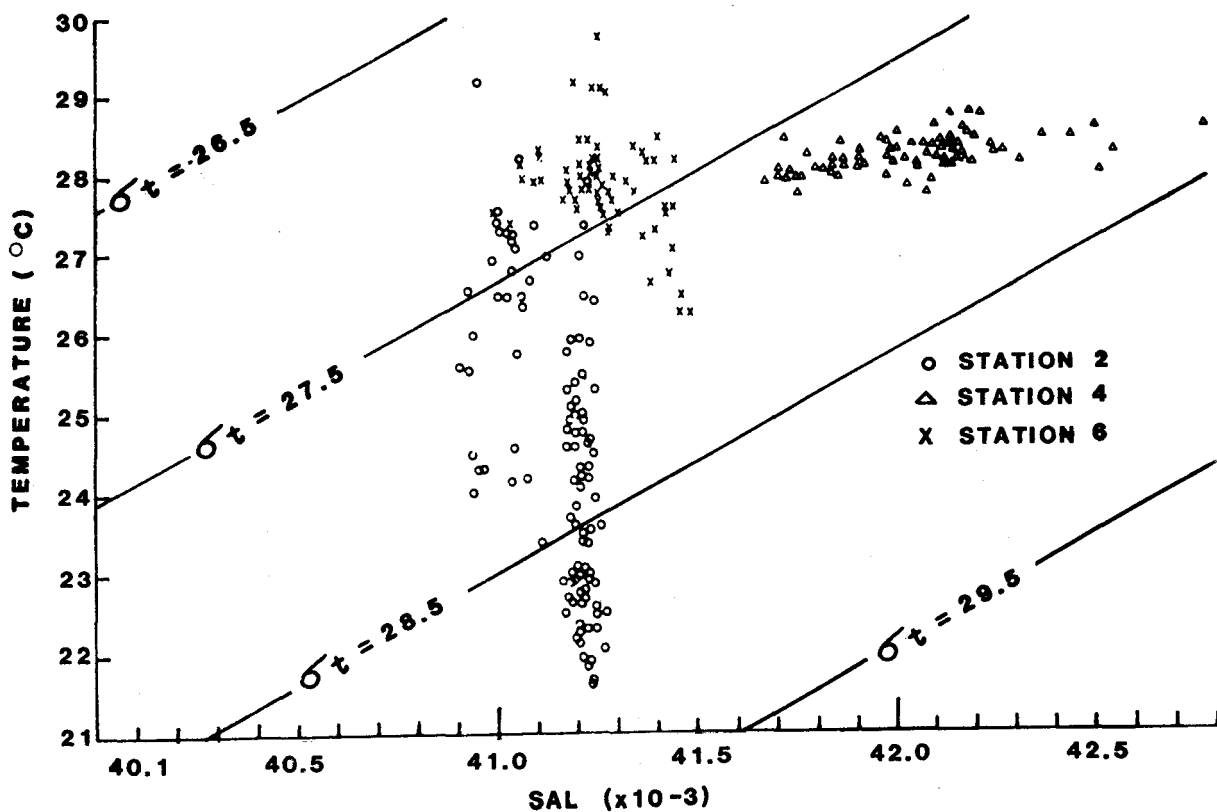
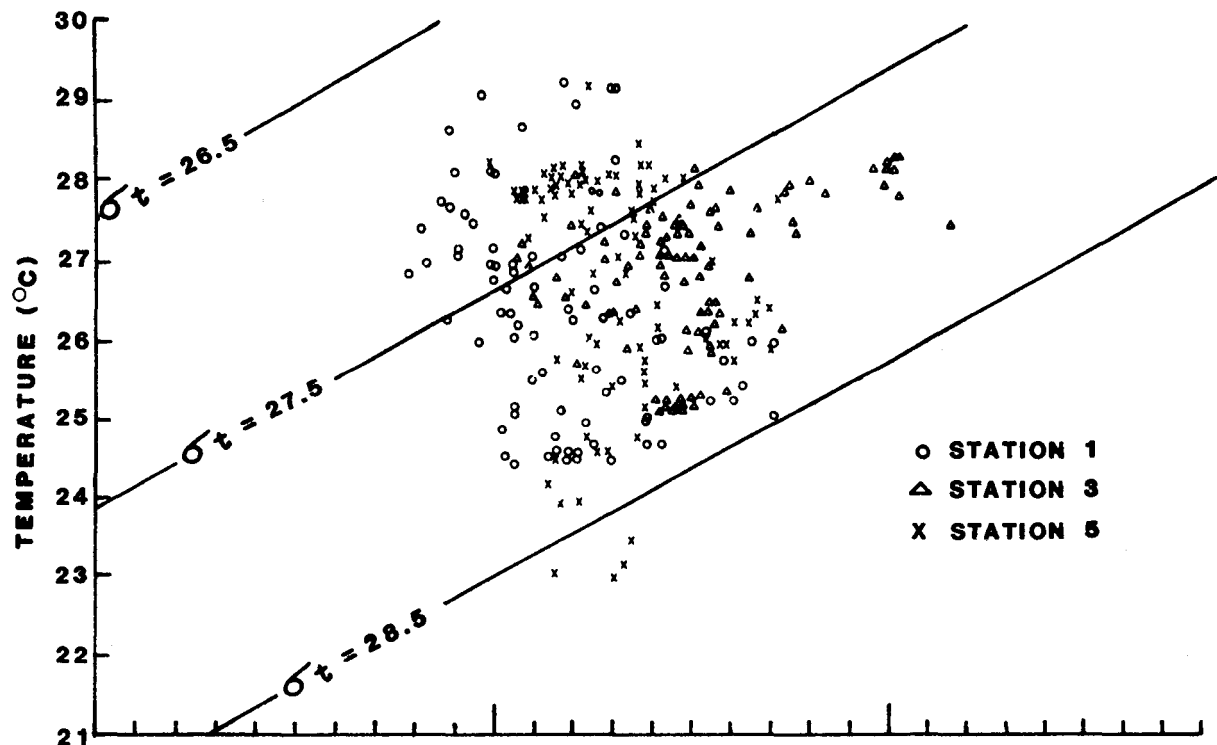


Fig. 4—Temperature/salinity (T-S) diagrams for different stations

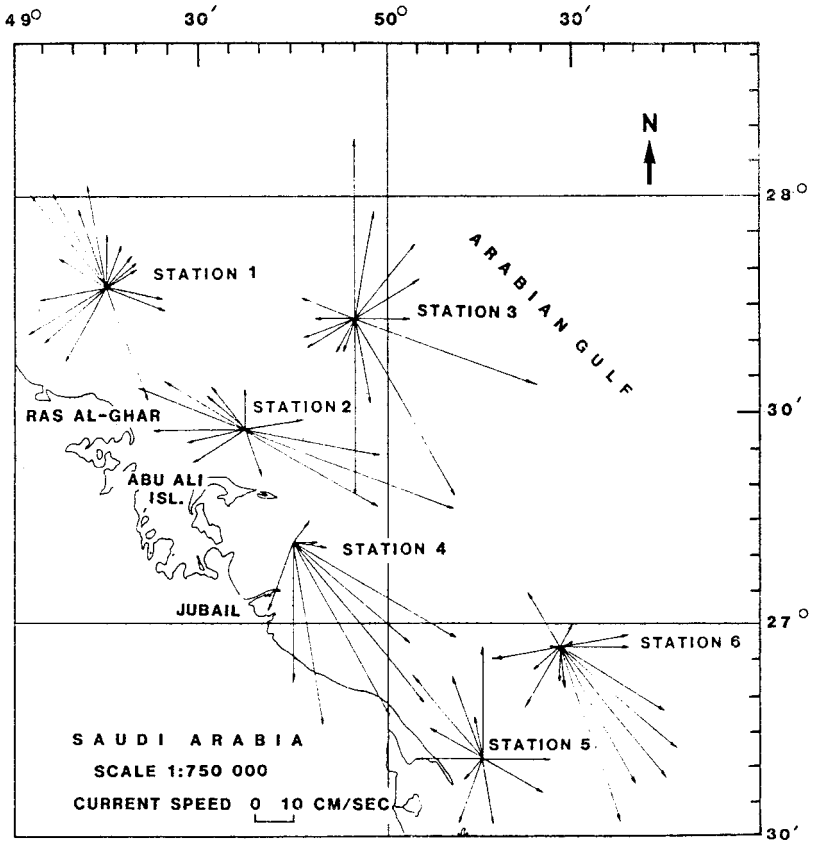


Fig. 5—Current velocity distribution at the surface in Saudi coastal waters

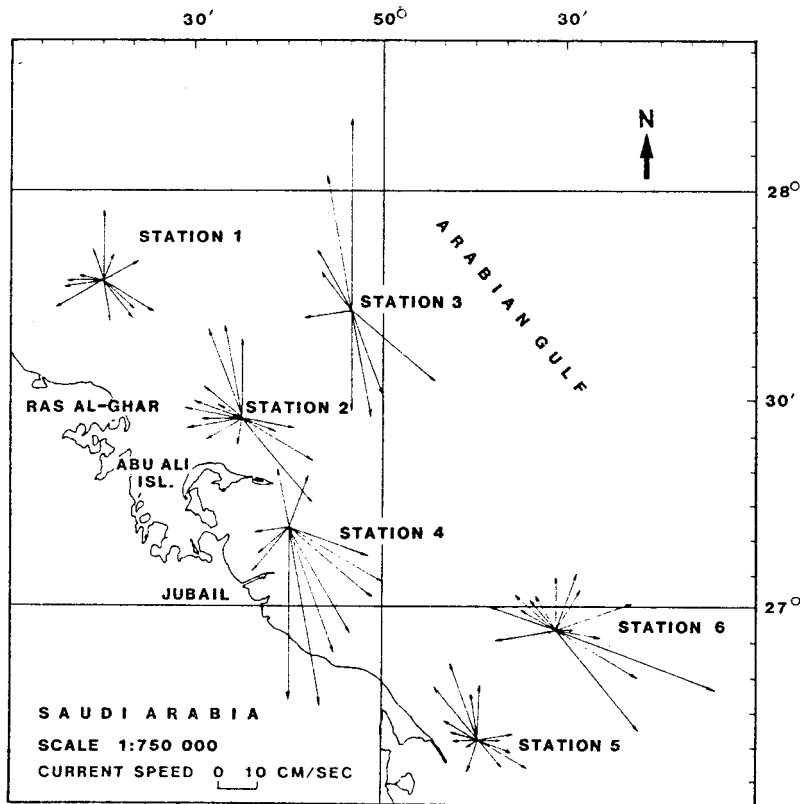


Fig. 6—Current velocity distribution at the bottom in Saudi coastal waters

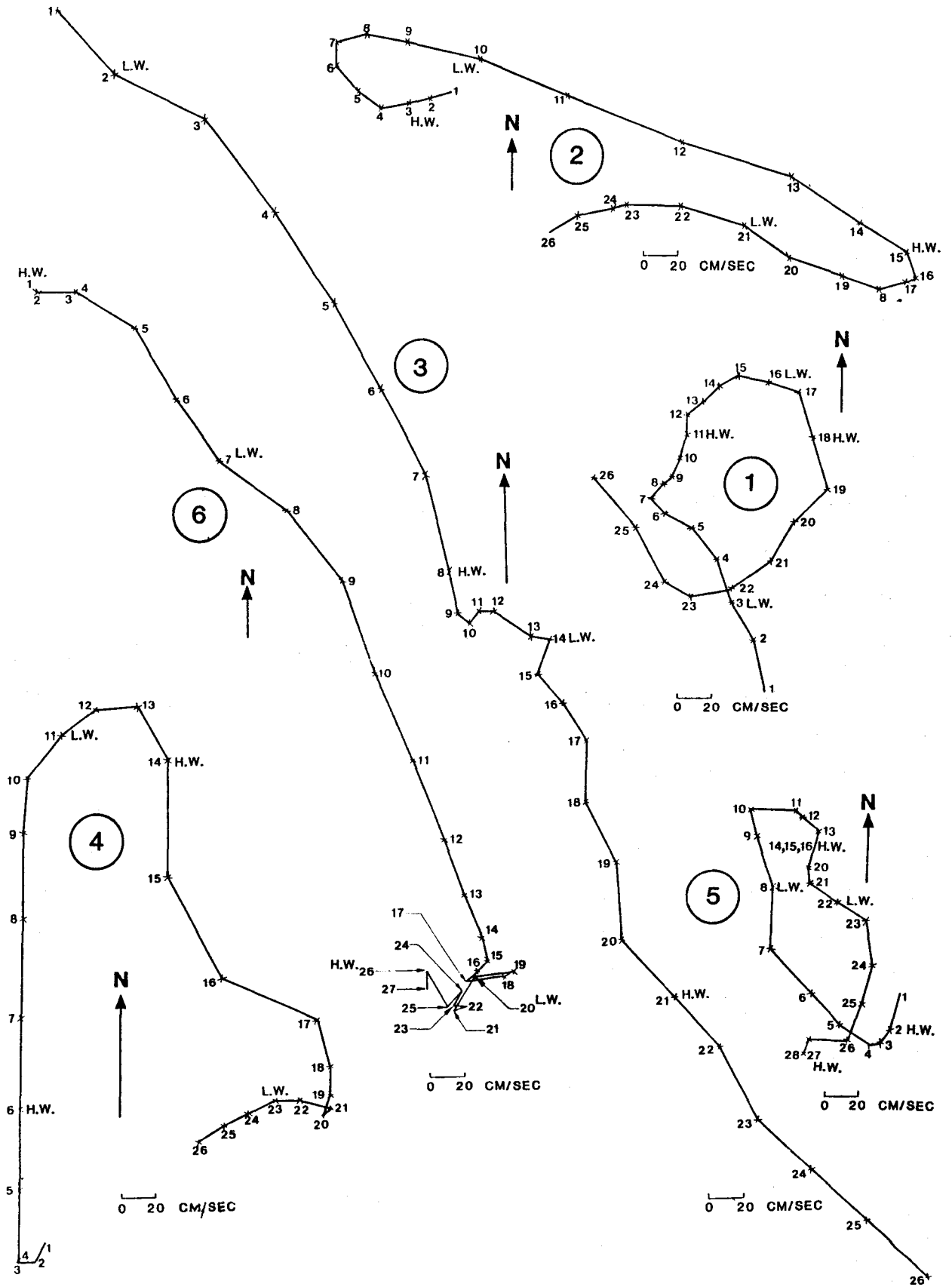


Fig. 7—Progressive vector plots for surface currents at different stations (Numbers indicate observational time in hours from the start to the end of measurement)

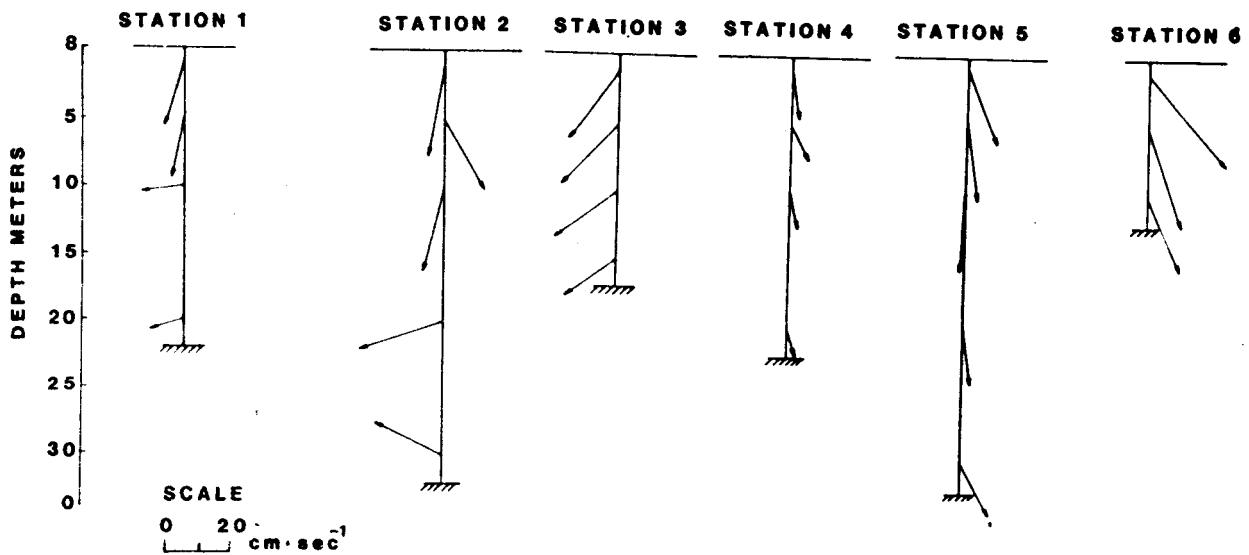


Fig. 8—Mean current profiles over 25 h for different stations

that the surface current was mainly affected by tides during that time. The mean current over 25 h at different depths at 6 stations is shown in Fig. 8. The mean current at most of the depths at sts 4-6 was directed southeastward, while at sts 1-3 it was in southwest direction. Although the period from the current survey was short, the same pattern of circulation in the Gulf along the Saudi coastal water was deduced.

One of the most important features of the circulation of the Arabian Gulf is the counterclockwise gyre within the Gulf resulting in a southeasterly current during the summer and winter seasons. This conclusion is based on oceanographic data¹ taken in the Gulf, mainly in the Iranian water, and at very few stations in the offshore Saudi water. The present survey, which includes onshore and offshore stations, support the same pattern of circulation in the Gulf along the Saudi coastal water. It also gives the salinity and temperature variations in the horizontal and vertical directions during the tidal period. The T-S diagrams are shown as an evidence for the existence of 2 water masses in the Saudi coastal water of the Arabian Gulf. The low salinity at st 1 (Safinaya) may be a direct result of the water discharge from Shatt El Arab.

The present data indicate that the surface temperature decreased from Ras Tanura (st 4) to Manifa (st 2). Also they show that the water mixing in Ras Tanura is higher than any other region in the Saudi coastal water of Arabian Gulf. The salinity variation gives general trend of increase from surface to bottom and from Manifa to Ras Tanura. The appreciable difference in tempera-

ture between surface and bottom at the offshore stations during the tidal period indicates that the temperature above the thermocline is very high and hence the density contrast between the top and bottom layers.

Acknowledgement

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