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PRELIMINARY RESULTS AND ANALYSIS OF THE MISSION SEREMAR III

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PRELIMINARY RESULTS AND ANALYSIS OF THE MISSION SEREMAR III

by

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Fernando de Mendonça
General Director

1.1 - SUMMARY

In proceeding the Phase D of the Brazilian Program of Remote Sensing Applications in Earth Resources Survey the Sea Resources Group planned for the period September 1972 the Mission SEREMAR III in the Cabo Frio Test Site 805. A PRT-5 Barnes Precision Radiation Thermometer (infrared radiometer) and a LN-3 Dual Channel Thermal Mapper (visible-infrared lines scanner) to measure sea surface temperature were installed in "Bandeirante" aircraft of this Institute. The aerial temperature surveys were supported by the ground truth data obtained with various temperature-measurement instruments installed in two Brazilian research vessels. The preliminary results have showed that the surface temperatures measured from PRT-5 coincided very much with those ground truth data, that the upwelling phenomena play an important role in the oceanographic characteristic of this region and that the IR Scanner is a valuable tool to mapping the sea surface thermal features.

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1.2 - INTRODUCTION

The INPE aircraft was used to fly over the Cabo Frio area for measuring sea surface temperature with the Precision Radiation Thermometer and the Dual Channel Thermal Mapper on September 18, 1972.

The flights were performed at an altitude of 300 meters and with an average speed of 150 knots. Such measurements were made for the purpose of studying the Test Site of Cabo Frio only from an oceanographic point of view.

The ground truth data support to these flights were provided by two Brazilian research vessels. These vessels were:

- The Brazilian Navy R/V "Almirante Saldanha" of the Brazilian Hydrographic Office
- The University of São Paulo R/V "Prof. W. Besnard" of the Oceanographic Institute

The R/V "Almirante Saldanha" sailed from Rio de Janeiro to the Cabo Frio along the 50 m - Depth line to measure sea surface and subsurface temperatures with a Bathythermograph on September 9, 1972, and remained in anchoring southwest of Cabo Frio during the period of September 9 to September 21, 1972, to measure oceanographic parameters by conventional

methods and with some special instrument, and then sailed 110 nautical miles east off the Cabo Frio to measure surface and subsurface temperature, and to take water samples from different levels of the sea.

The R/V"Prof. W. Besnard" started to sail from Santos on September 4, 1972. Unfortunately, a leak was found in the axle o-ring of the propeller while she arrived at Rio de Janeiro. The situation became worse so that the R/V "Prof. W. Besnard" had to leave the Mission for repairing on September 5, 1972. Accordingly many measurements that had been planned to be performed in this vessel during the Mission were forced to terminate.

PART 2 - COMMENTS ABOUT THE DATA COLLECTION AND ANALYSIS

2.1 - OBJECTIVES

The Mission SEREMAR III, coordinated by the Instituto de Pesquisas Espaciais (INPE) and supported by the Diretoria de Hidrografia e Navegação (DHN), the Instituto Oceanográfico da Universidade de São Paulo (IOUSP), and the Instituto de Pesquisas da Marinha (IPqM) has the following objectives:

a. To identify and locate sea surface thermal contrasts by means of the Remote Sensing methods.
b. To locate and define possible upwelling phenomenon in the Cabo Frio by means of studying oceanographic parameters.
c. To locate and define the boundary of the Brazil Current.
d. To develop correction methods for the radiometric data collected by the precision radiation thermometer at low altitude and obtain surface temperature values as close as possible of actual ones.

2.2 - DATA GATHERED BY REMOTE SENSOR

The flight lines performed by INPE aircraft are shown in Figure 1. The following data were obtained during performing PRT-5 on September 18, 1972.

Flight Line	Time (GMT) Start	Stop	Length (Nautical Mile)	Altitude (meter)	Speed (knot)
1	14:21'	14:50'	60	300	150
2	15:23'	15:47'15"	60	300	150
3	17:42'28"	18:06'28"	60	300	150
4	18:47'36"	19:09'52"	50	300	150
5	19:36'	19:39'45"	9*	300	150

Note*: Length calculated from flying time and speed

Five flight lines were performed in a total amount of 1.8 measuring hours and of 239.4 nautical miles. In addition to the radiometric sea surface temperature, other parameters, such as dry and wet bulb temperatures, wind direction and speed, weather conditions and cloud coverage, were measured during the flight. The radiometric sea surface temperature has been analysed and plotted as shown in Fig. 7. The detailed explanation and comparison of the radiometric thermal chart are referred to Section 2.4.

A general view of the INPE aircraft instrumented with remote sensors is shown in Fig. 2.

2.3 - GROUND TRUTH DATA COLLECTION

The position where the R/V "Almirante Saldanha" anchored from 19:00 GMT 9 September to 23:00 GMT 9 September 1972 is shown in Fig.1. Such position had the coordinates Lat.: 23°01'2S and Long.: 042°00'7W and had the depth of 79 meters.

During this period of time 93 oceanographic stations were performed at seven different levels every three hours. The data or samples that have been collected were the following:

- Surface and in-situ temperature measurements using reversing thermometers and the isoplet diagram was drawn.
- From the collected water samples the following chemical constituents were analysed:

  Salinity

  Oxygen

  Phosphate

  Silicate

  Nitrate

  Nitrite

- Bathythermograph was lowered into the sea to a depth of sixty meters each one hour and the isoplet diagram was also drawn.

- Current measurements were performed at 4 levels (2m, 5m, 20m and 50m) using current meters.
- Plankton samples were taken vertically from the bottom of the sea to the surface.
- Meteorological observations were continuously done with the following parameters:

  Wind direction and speed;

  Atmospheric pressure;

  Dry and wet bulb temperature;

  Sea surface temperature;

  Solar radiation.

- Radiosounds were performed at 00:00 and 12:00 GMT daily
- Water samples were taken for determination of primary productivity at the euphotic zone.

A new instrument from this Institute named STD (Salinity Temperature and depth continuous recorder) has been run once only for testing its ability. The results showed that it has functioned accurately and perfectly. It can continuously record salinity and temperature related to depth. This STD will be used by the R/V "Almirante Saldanha" in the next SEREMAR Mission. A general view of STD is shown in Figure 3.

Before the anchorage the R/V "Almirante Saldanha" performed ten BT stations on September 9, 1972 along a 50m depth line of the Western Cabo Frio. The temperature profile was herein drawn as shown in Fig. 4.

After the anchorage, the R/V "Almirante Saldanha" performed eight oceanographic stations. Many oceanographic parameters, such as surface and subsurface temperature, salinity,chemical constituents of the sea water, were measured. In Figure 1 shows the eight oceanographic sections, and Figures 5 and 6 show the temperature and salinity profiles after anchorage,

The characteristics of these Figures are explained in detail in the following section.

2.4 - PRELIMINARY ANALYSES

2.4.1 - REMOTE SENSING MEASUREMENTS

During the radiometric measurements performed by the INPE aircraft on 18 September, the prevailing wind over the flight area was from NEE (sixty degree from the north) with an average speed of 30 knots. The sky was totally overcast by cloud which was estimated about 900 to 1200 m high.

A radiometric thermal chart was drawn in accordance with PRT-5 data taken on September 18, 1972. From this chart as shown in Figure 7, we can see a cold front with sea surface temperature of 16.5°C occurred near the coast between Ponta Negra and Cabo Frio. Another cold front with sea surface temperature lower to 16°C took place in southeast off Cabo Frio*. These two cold fronts might be caused by upwelling phenomena, though there was no additional information to support them, An isothermal surface water with temperature 21.5°C existed between Lat. 23°05'S ~ 23°35'S and Long. 042°08'E ~ 042°36'E. Some other high thermal areas with sea surface temperature up to 23°C occurred far off the coasts. These high temperature areas could be influenced by the Brazilian current. A comparison between remote sensing and ground truth data is given in next section.

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* This feature seems to be related to the cold tongue reported in the Mission 96 Report.

2.4.2 - GROUND TRUTH

From the temperature profile found before the anchorage as shown in Figure 4, we found an upwelling phenomenon was taking place around BT-8 station. The sea surface temperature dropped from above 21°C to 15.5°C, associated with a green to a blue color change in sea water. During this period a northeast wind was blowing with an average speed of 20 knots. We found once again the evidence that the upwelling phenomenon in Cabo Frio region would be generated by winds from N to E.

During the period from 19:00 GMT 9 September to 23:00 GMT 21 September 1972, the R/V "Almirante Saldanha" was anchored in south-western Cabo Frio and performed 93 oceanographic stations to measure conventional oceanographic parameters varying with time. Figure 8 shows those parameters varying with time.

During the period of anchorage, the meteorological conditions were described briefly as follows:

When the R/V "Almirante Saldanha" anchored at 19:00 GMT 9 September, there was still blowing a strong NE wind, with an average speed about 20 knots. From 22:00 GMT 9 September to 10:00 GMT 10 September the wind turned stronger to an average around 30 knots, and then it became moderate and gentle till 12:00 GMT 11 September. But during this period of time the prevailing wind was still from NE. After-

wards a calm period happened during 13:00 GMT to 21:00 GMT 11 September. From 12 September to 15 September the wind changed direction mostly from southeast, with an average speed around 10 knots. After 0:00 GMT 16 September the predominant wind was once again from NE with an average speed about 20 knots. This predominant wind kept on blowing until the last oceanographic station of the anchorage period, performed at 19:00 GMT 21 September 1972.

The atmospheric pressure began with 1012.3 mb at 19:00 GMT 9 September and dropped to a minimum value of 1007.8 mb at 19:00 GMT at 10 Sept. Then it increased gradually to a maximum value of 1024.7 mb at 13:00 GMT 15 September. The rest of the days the atmospheric pressure went down and up several times between values ranging from 1016.8 to 1023.8 mb.

The dry-bulb temperature started with 26^{o}C at 19:00 GMT 9 September, and dropped some 4^{o}C to 22^{o}C . It reached to a maximum temperature of 28.5^{o}C at 17:00 GMT 10 September. The rest of the days during the anchorage the dry-bulb temperature oscillated between 26.5^{o}C and 20^{o}C, mostly around 22^{o}C.

The sea state presented small wavelets or large wavelets. The current speed at the sea surface (2-5 m deep) was ranging from 0.15 to 2.7 knots. It got the maximum value at 05:45 GMT 16 September from the eastern direction. The direction of the surface current changed frequently before 10:00 GMT 13 September. Afterwards the current direction

at sea surface was ranging from SE to EEN, mostly from E. In general the current speed at sea surface turned high after 12:00 GMT 15 September. At 20-meter level the current direction also changed frequently before 14:00 GMT 13 September. After then the prevailing current was mostly from SE to EEN. The current depth came to a maximum value of 2.2 knots at 10:30 GMT 16 September. In general the current speed was smaller than one knot, mostly around 0.5 knot . For the current at 50-meter depth the direction changed frequently all the time. It also reached to a maximum value of 2.3 knots at 04:00 GMT 16 September with a direction from the east. General speaking,the current directions at the surface and at the 20-meter level coincided very well, while that at the 50-meter level was mostly different from the shallow ones. Sometimes the current direction at the 50-meter level was just even opposite to the shallow ones.

The detailed atmospheric pressure, dry-bulb and wet-bulb temperatures, dew-point temperature, current speed and direction at three levels and wind velocity and direction varying with time are shown in the upper part of the Figure 8.

After a combination study of various oceanographic parameters measured during the anchorage period, we found that upwelling phenomena did occur three times near by the R/V "Almirante Saldanha" anchorage point. The first time upwelling occurred soon after the R/V "Almirante Saldanha" was anchored at 12:00 GMT 9 September. The sea surface temperature decreased gradually to a minimum value of 14.94^{o}C

at Station Nº 2890, performed at 22:00 GMT 9 September. Then the sea surface temperature increased rapidly to 20.64°C at 01:00 GMT 10 September. Other oceanographic parameters changed very much. Salinity of the sea surface water also reached a minimum value of 35.50‰; relative abundance of the chemical constituents, such as phosphate, silicate, nitrate, nitrite, etc., were found; great amount of planktons were caught during this upwelling period. From the TS diagram shown in Figure 9, we found two water masses were identified. The first one was characterized by salinity between 35.37 and 35.65‰ and temperature between 13 and 17°C, which have been identified as the South Atlantic Central Water. The other was characterized by salinity between 35.75 and 35.9‰ and temperature between 18 and 20.5°C, which have not been identified before. This new water mass might possibly be caused by a mixing process. During the upwelling period, the predominant wind was from NE with an average velocity of 25 knots and the atmospheric temperature and pressure were around 23°C and 1013 mb, respectively.

The second upwelling phenomenon occurred from oceanographic stations Nº 2931 to Nº 2943. The sea surface temperature dropped gradually from higher than 21°C to 18.5°C at 05:00 GMT 16 September, and the 15°C isoplet line ascended from the bottom of the sea to a 20-meter level at 01:00 GMT 16 September. Salinity of the sea surface water once decreased to 35.50 ‰ and planty of chemical constituents and planktons were found at the same time. There were two water masses found during this period of time as shown in Figure 11. The one was charaeterized by salinity

between 35.25 and 35.75‰ and temperature between 13 and 17°C, which was, could be said, inside the range of the South Atlantic Central Water. The other was also a new water mass with salinity between 35.8 and 36.0‰ and temperature between 18.5 and 21°C. This new water mass was slightly different from that was found in the first convergence. During this period of convergence the predominant wind was from E with an average velocity of 15 knots; the atmospheric temperatue oscillated from 24.5 to 21°C, mostly around 22°C; the atmospheric pressure oscillated between 1024 and 1020.5 mb, with an average value around 1022 mb. From an observation of the 15°C isoplet line after station Nº 2940, we found the upwelled water did not descend so much and still remained in the 30 - meter level till another upwelling phenomenon occurred once again.

The third upwelling phenomenon was found pronouncedly after the oceanographic station Nº 2964 performed at 14:00 GMT 19 September. The 20°C isoplet line ascended just beneath the sea surface. The sea surface temperature then dropped gradually from above 20°C to 17.16°C at 17:00 GMT 20 Sept. At the same time the 15°C isoplet line ascended continuously to the 20-meter level at 18:00 GMT 20 September to the 10-meter level at 16:00 GMT 21 September The third upwelling phenomenon persisted in about 2 days. Until the last station of the anchorage period, performed at 19:00 GMT 21 September, the phenomenon was still very pronounced. During the period of third convergence, the prevailing wind was from NE all the time with an average speed of 20 knots. The atmospheric pressure oscillated between 1022 and 1016.8 mb, mostly around 1019 mb, and the atmospheric temperature also swang from 26.5 to 21°C, mainly around 22°C. The predominant current at the sea surface was

from E with a speed around 1 knot, while the predominant current at 20 meter depth was from EES with a speed around 0.6 knot and at 50 meter was from NW with a speed around 0.4 knot. From the TS diagram as shown in Figure 13 we can see only one water mass, which was identified salinity between 34.85 and 36.10‰ and temperature between 10 and 20.5^{o}C, existed during the period of upwelling phenomenon. This new water mass could be also mixed up well by many kinds of water masses. If the mixed-up time is long enough, a new kind of water mass with homogeneous characteristics, as we had then, will be formed.

In Figures 10 and 12 show the water masses appeared between 09:00 GMT September and 04:00 GMT 15 September and between 23:00 GMT 16 September and 11:00 GMT 19 September 1972.

The South Atlantic Central Water could be found all the anchorage period; but strongely enough, the coast water never appeared this time. The South Atlantic Central Water could be the chief cooling factor of the upwelling phenomena.

Refer to the isoplet diagram in Figure 8, we can see the cold water set down very fast after 09:00 GMT 11 September under a W or SW wind and S or SW current. After 21:00 GMT 12 September, the wind and surface current directions were changed from the SE. Consequently the cold water began to rise and the second upwelling phenomenon occurred.

Another interesting thing should be noted that the cold water still remained just under the sea surface after the second upwelling phenomenon. During this time the predominant wind was from NE and the prevailing surface current was from E. By assuming the upwelling phenomenon is induced chiefly by wind and current, we could explain the SE and NE wind as well as SE and E current will be in favor of the convergence condition in the region of Cabo Frio. Nevertheness the W and SW wind are not favorable for the upwelling condition in this area.

After the anchor was weighted alway, the R/V "Almirante Saldanha" sailed directly to east off the coast about 110 nautical miles. During the period time eight oceanographic stations were performed. The temperature and salinity profiles are shown in Figures 5 and 6, respectively. A high temperature core of 23^{o}C associated with high salinity of 36.8‰ existed at 30 meter level between stations Nº 2988 and 2989. This could possibly be affected by the Brazilian Current. After a combination study of these profiles as well as the chemical constituents , we could say an upwelling phenomenon was occurring at the oceanographic station Nº 2985, performed at 08:50 GMT 22 September 1972. The sea surface temperature dropped from 21.3^{o}C to 19.9^{o}C and the salinity of the sea surface water also decreased from 36.2 to 36.12 ‰ . There was observed a slight increase in chemical constituents during this period.

During this Mission the R/V "Prof. W. Besnard" of the IOUSP was still in trouble. Therefore we did not have enough ground truth data

to compare with the remote sensing ones, measured by PRT-5 radiometer.The better thing can be done here is to compare the ground truth data from the R/V "Almirante Saldanha" with the radiometric ones. The radiometric chart of the sea surface shown in Figure 7 shows that the flight line Nº 5 passed over the anchorage point of the R/V "Almirante Saldanha". This flight line was performed between 19:36' and 19:39'45" GMT 18 September 1972. The sea surface temperature was 20.2°C, measured at 19:00 GMT 18 September and 20.3°C, measured at 20:00 GMT 18 September, with the temperature about 20.25°C at 19:30 GMT 18 September by means of interpretation. However the radiometric thermal distribution curve passing the anchorage point was 20.2°C, showing a very good agreement between the measurements. Therefore, the IR scanner is a valuable and an accurate tool to mapping the sea surface thermal features.

PART 3 - CONCLUSION

3.1 - CONCLUSION

There were four objectives in this Mission SEREMAR III as mentioned in Section 2.1. Up to the present time, the first three objectives have been completely and sucessfully reached, while the last one has partially been completed. The following points are the conclusion of the Mission SEREMAR III:

1. The upwelling phenomena could be detected from the color difference of sea water, in addition to the conventional oceanographic parameters. From the R/V "Almirante Saldanha" we could identify clearly the spots and boundaries of the different color sea water
2. With the prevailing wind above 20 knots in the area we observed that the upwelled water could not reach the sea surface layer, remaining at some 15-meter layer under the sea surface and passing over with a warmer water and strong current.
3. Considering the prevailing meteorological conditions encountered in this area, we suppose the strongest upwelling region is located near by the Largo de Saquarema (Lat. $22^{o}57'S$ and Long. $042^{o}35'W$).
4. From a combination study of the sea temperature, either

from ground truth or radiometer, we could detect the Brazilian current flowing direction and boundaries.

5. Not only the strong wind from N to E, mainly NE, but also the strong wind from SE, mainly E could generate the upwelling phenomenon of the Cabo Frio region. However the strong wind from SW could generate the downwelling phenomenon of this region.
6. Under a strong mixing process, new water masses with the different characteristics each time will form in this region. The coastal water could be mixed up and loses its original characteristics.
7. The correction method for the PRT-5 has been studying so that the result might be obtained in near future.

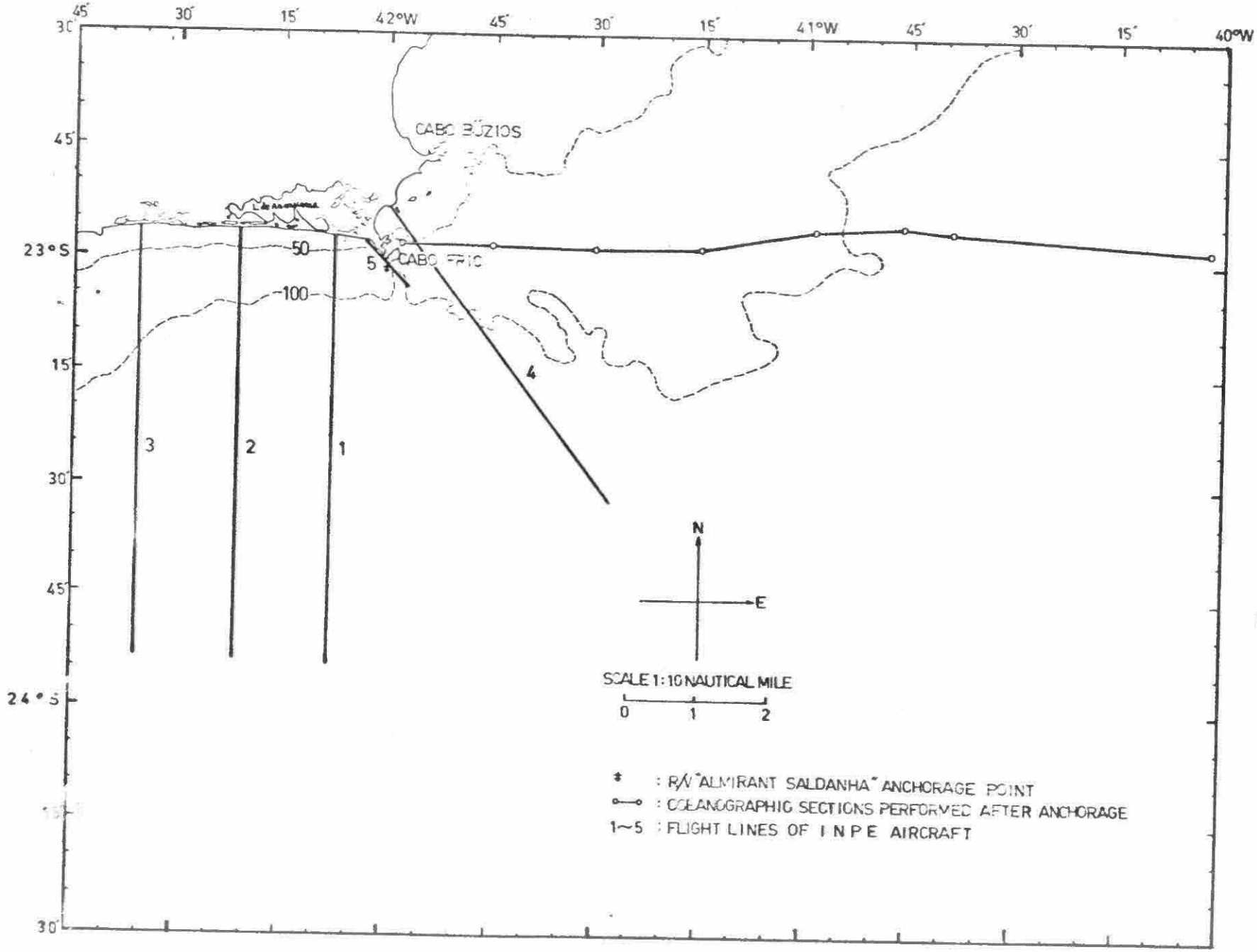


FIG. 1 – R/V "ALMIRANTE SALDANHA" ANCHORAGE POINT, OCEANOGRAPHIC SECTIONS PERFORMED AFTER ANCHORAGE, FROM 00:50 GMT 22 TO 05:00 GMT 23 SEPTEMBER 1972, AND THE FLIGHT LINES OF I N P E AIRCRAFT, MEASURED ON 18 SEPTEMBER 1972.

Fig. 2 - A general view of INPE aircraft instrumented with a PRT-5 Radiometer.

Fig. 3 - A general view of STD.

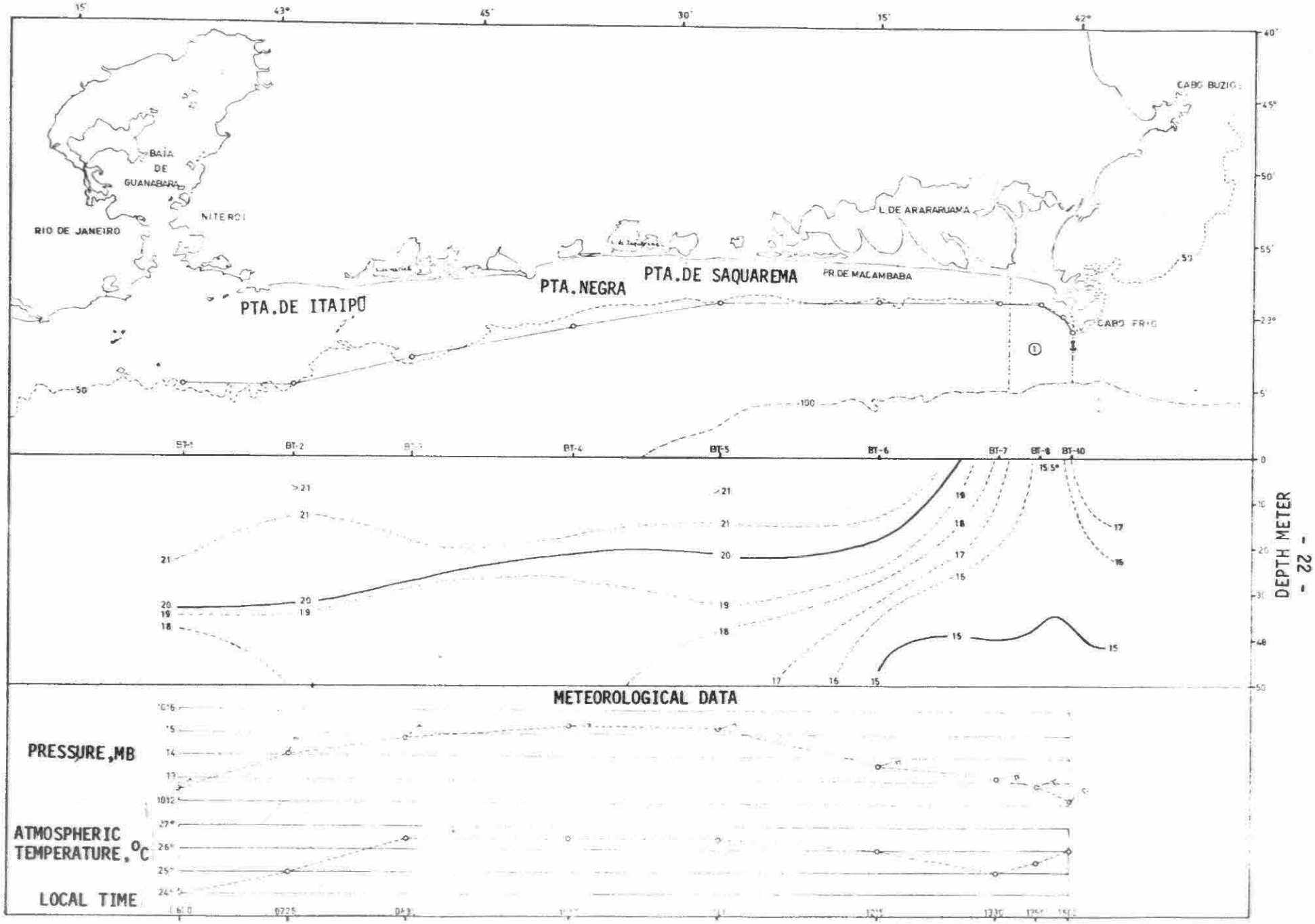


FIG.4 - BT STATIONS AND THE TEMPERATURE PERFILE BEFORE ANCHORAGE, MEASURED IN SEPTEMBER 9, 1972.

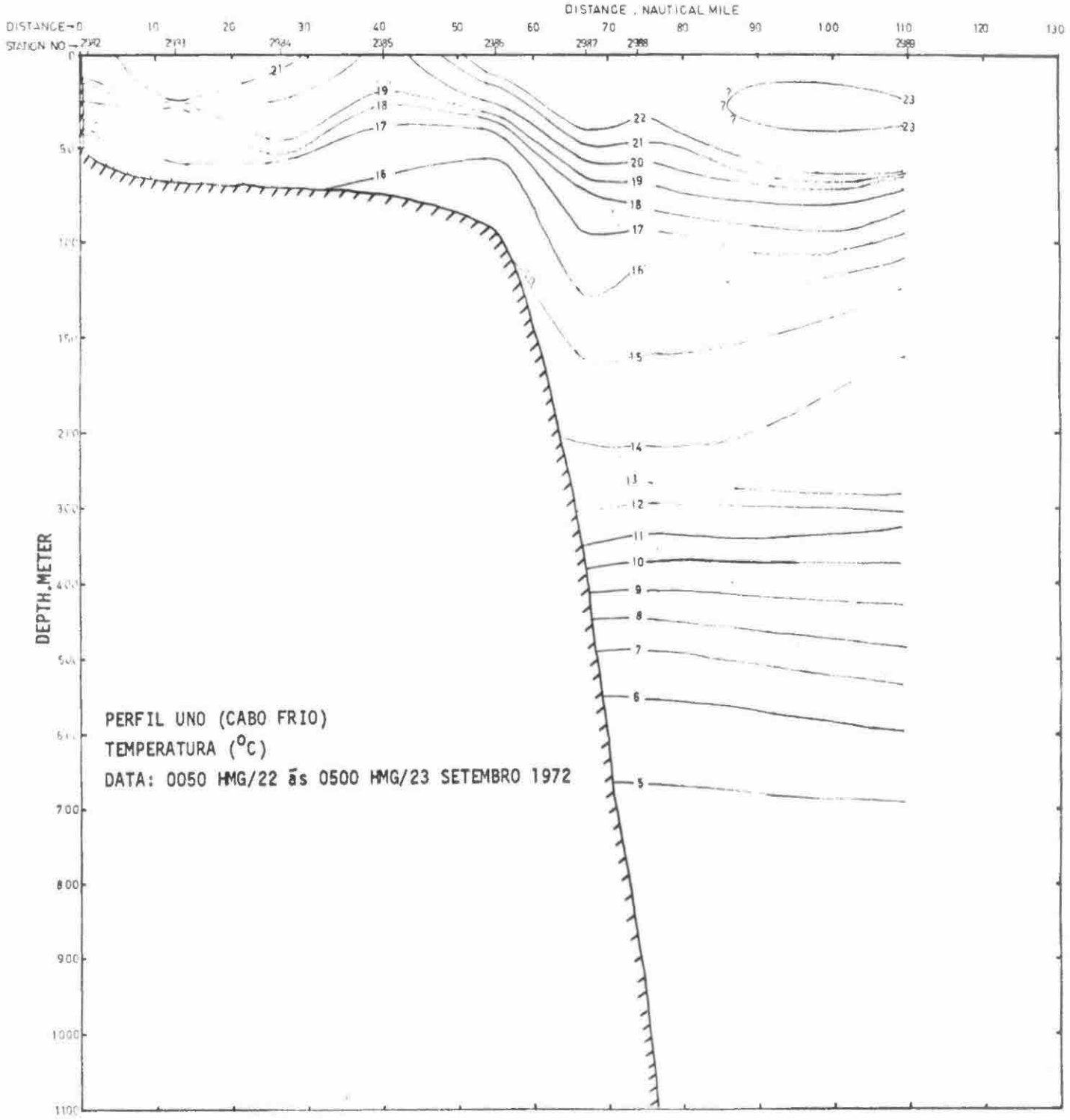


FIG.5 - TEMPERATURE PROFILE FROM 00:50 GMT 22 SEPTEMBER TO 05:00 GMT 23 SEPTEMBER 1972 (AFTER ANCHORAGE).

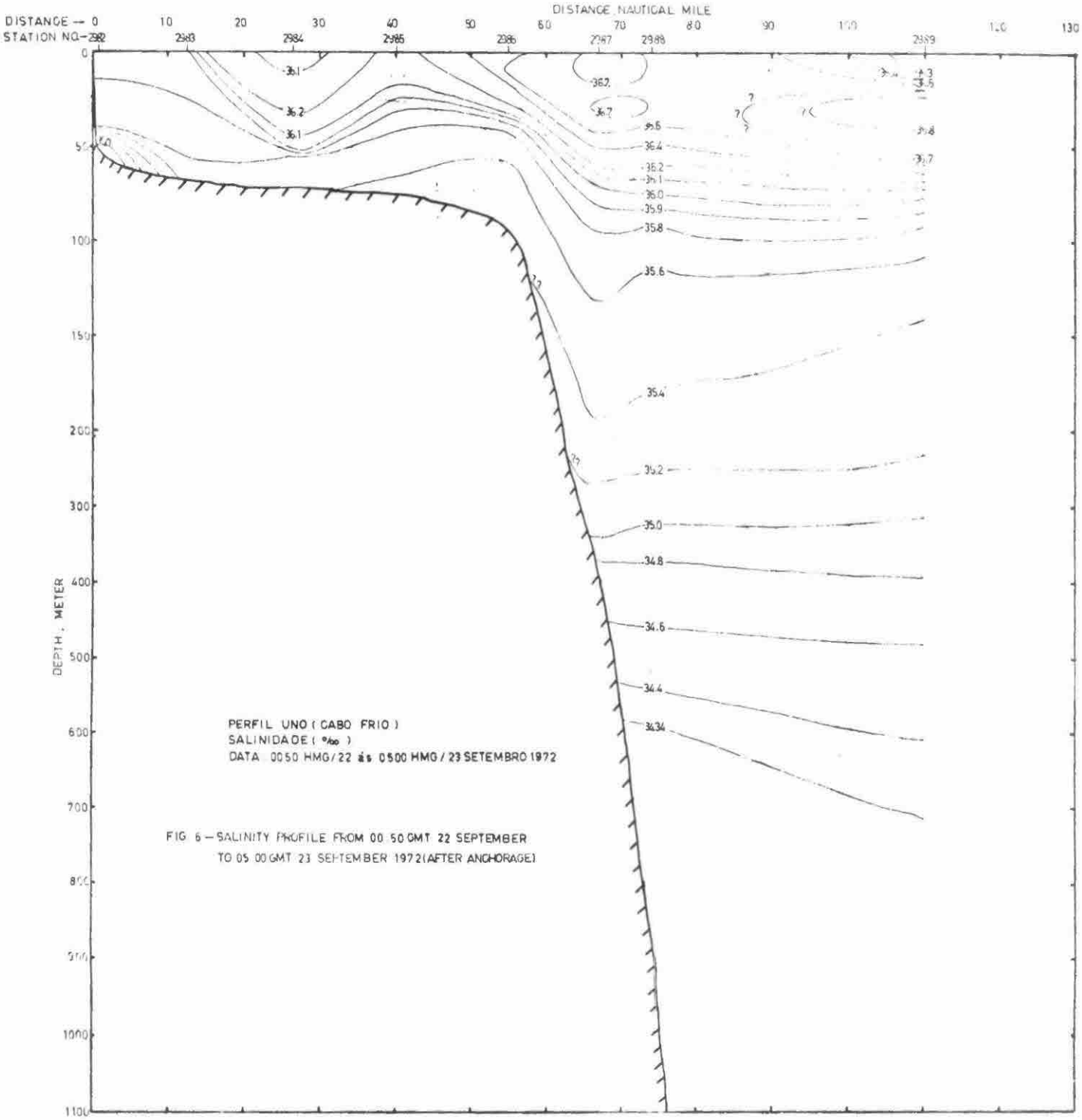


FIG 6 — SALINITY PROFILE FROM 00 50 GMT 22 SEPTEMBER TO 05 00 GMT 23 SEPTEMBER 1972 (AFTER ANCHORAGE)

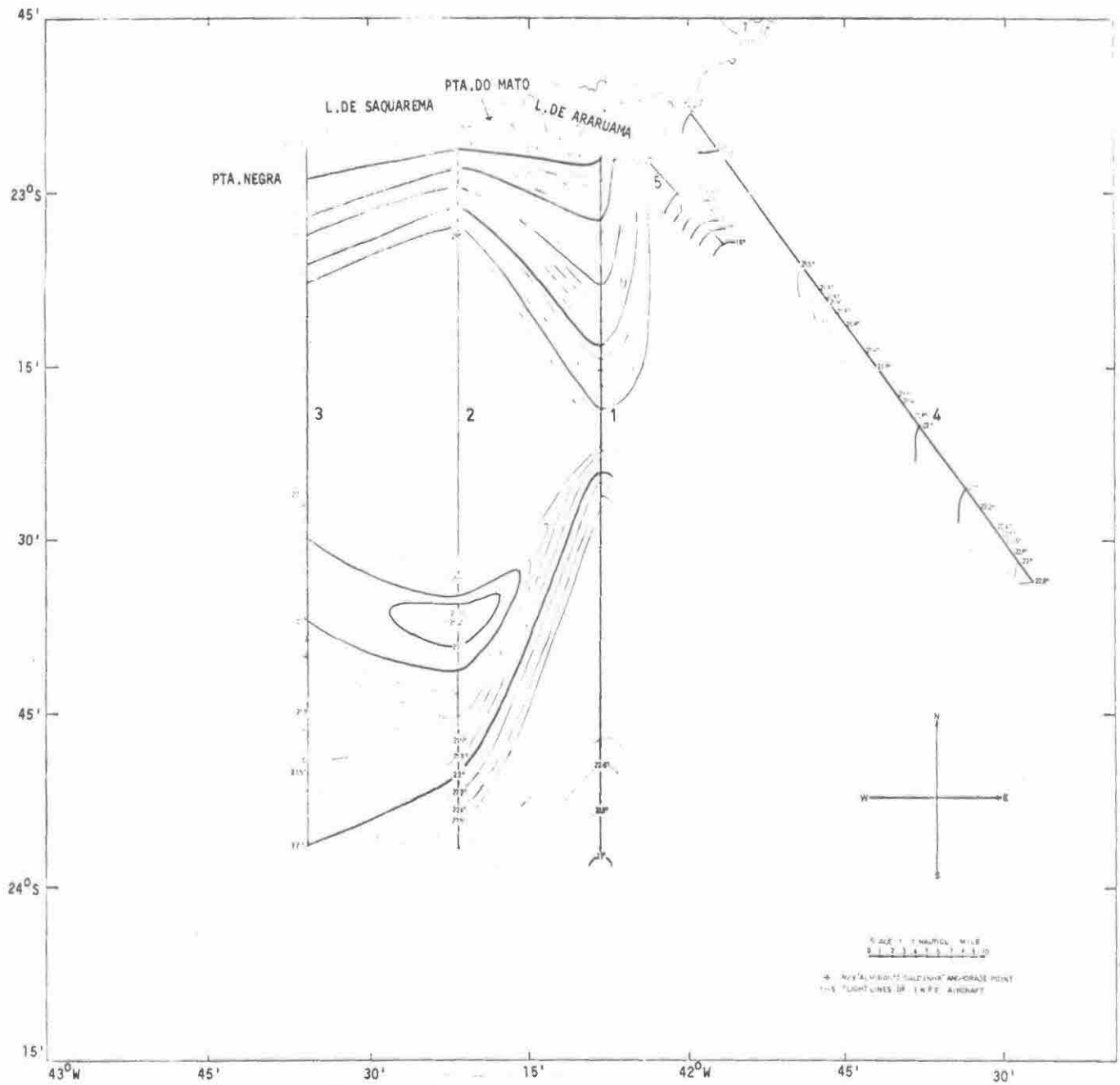


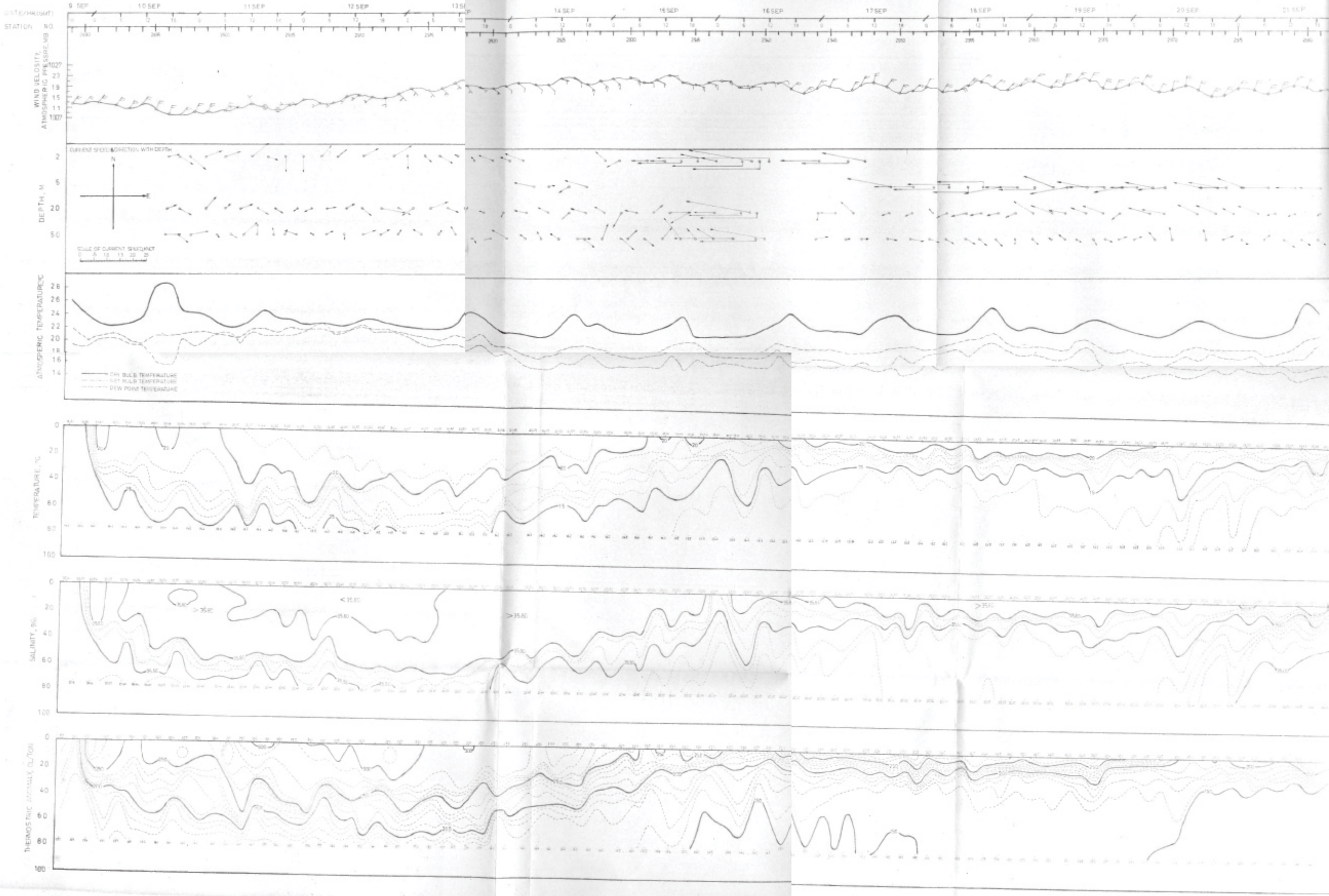
FIG. 7 - THE RADIOMETRIC THERMAL CHART OF THE SEA SURFACE IN THE EASTERN, WESTERN & SOUTHERN COATS OF CABO FRIO OBTAINED IN 18 SEPT. 1972.

NOC ALMIRANTE SALDANHA

OPERATION SEREMAR III SEPTEMBER 1972

ANCHORAGE POSITION LAT 23°07'12"S LONG 042°02'12"W DEPTH 79 M

T S & δ_T VARIATION WITH TIME



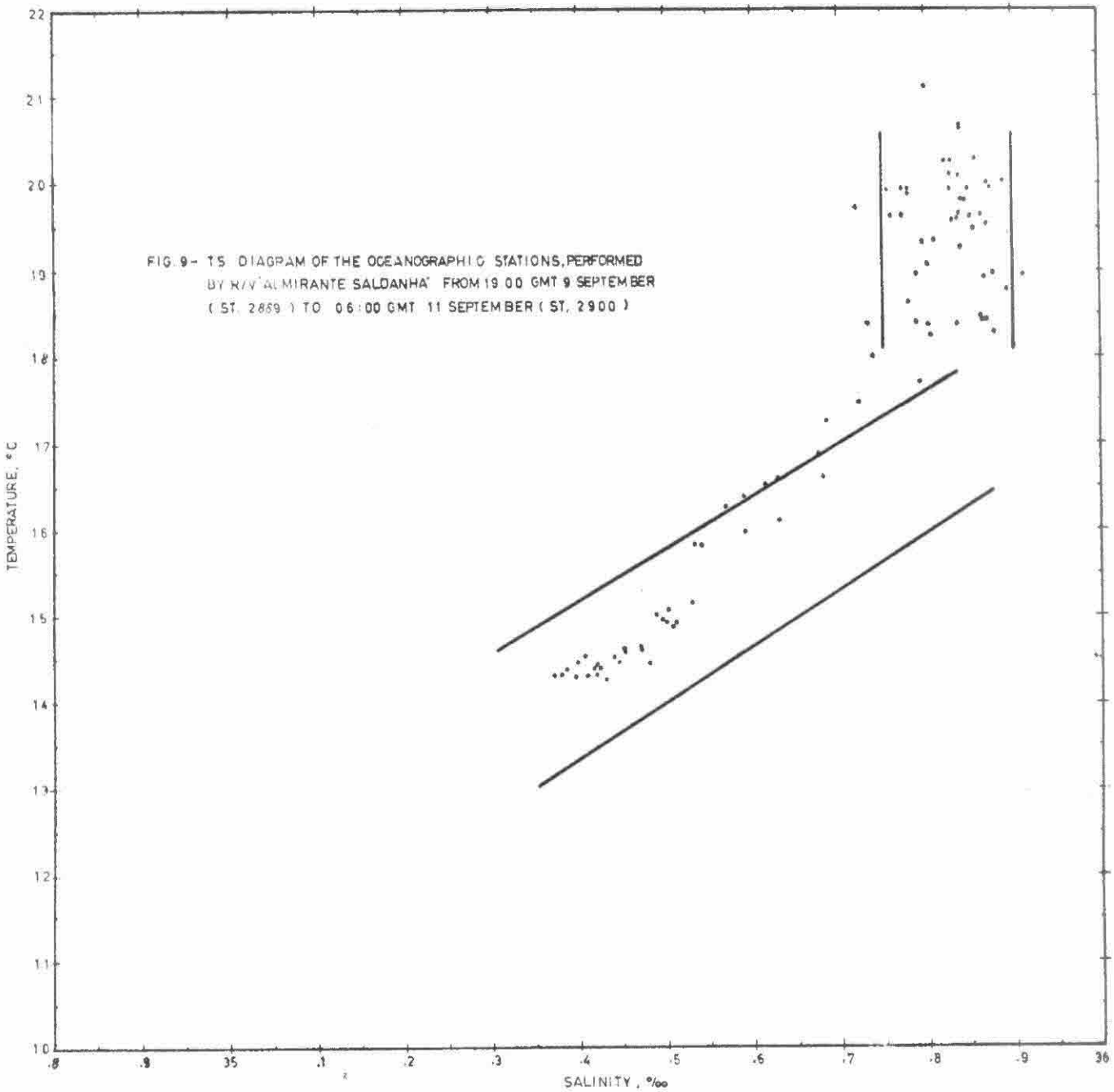


FIG. 9 - TS DIAGRAM OF THE OCEANOGRAPHIC STATIONS, PERFORMED BY R/V "ALMIRANTE SALDANHA" FROM 19 00 GMT 9 SEPTEMBER (ST. 2869) TO 06:00 GMT 11 SEPTEMBER (ST. 2900)

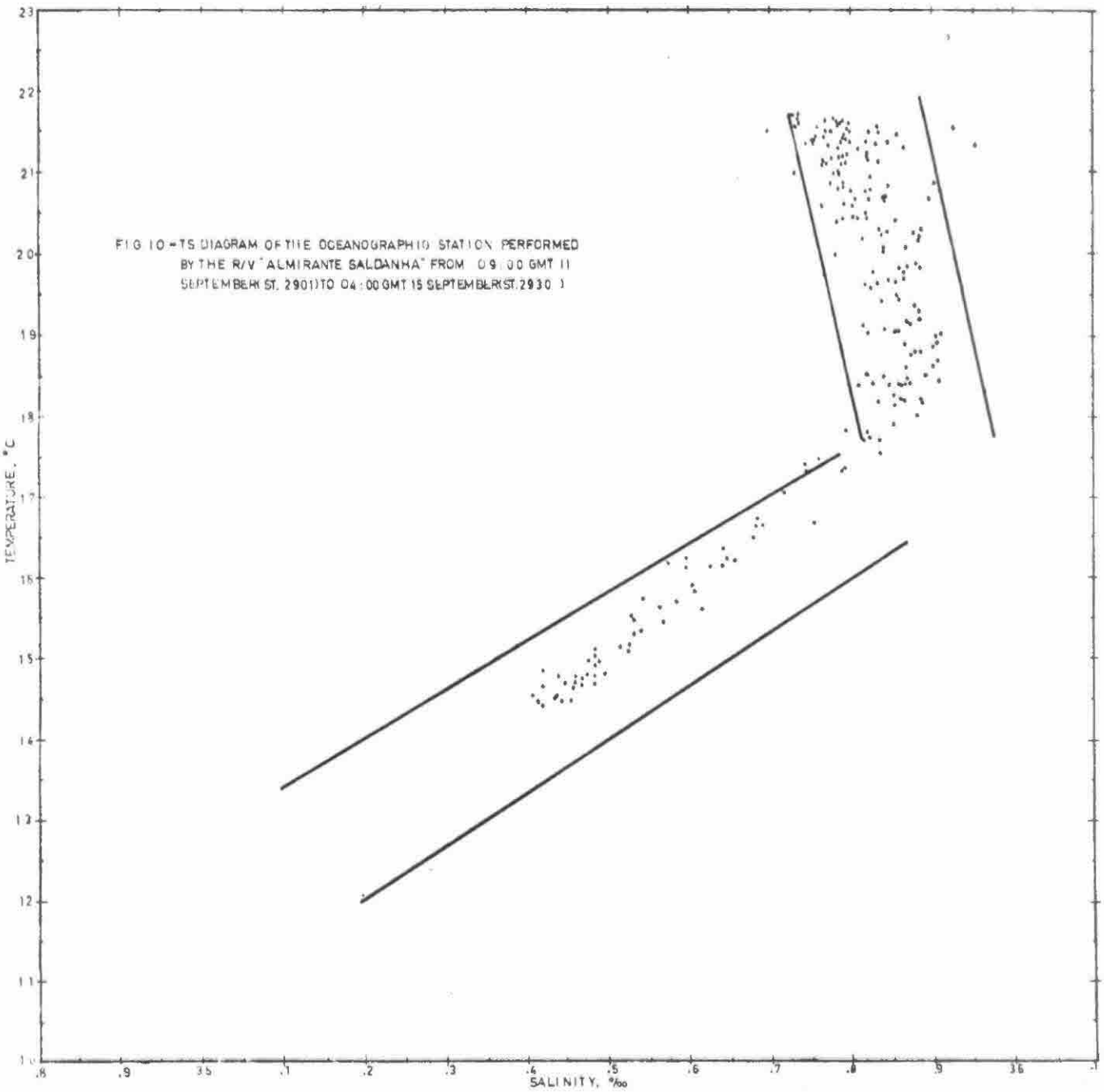


FIG 10 - TS DIAGRAM OF THE OCEANOGRAPHIC STATION PERFORMED BY THE R/V "ALMIRANTE SALDANHA" FROM 09:00 GMT 11 SEPTEMBER ST. 2901) TO 04:00 GMT 15 SEPTEMBER ST. 2930)

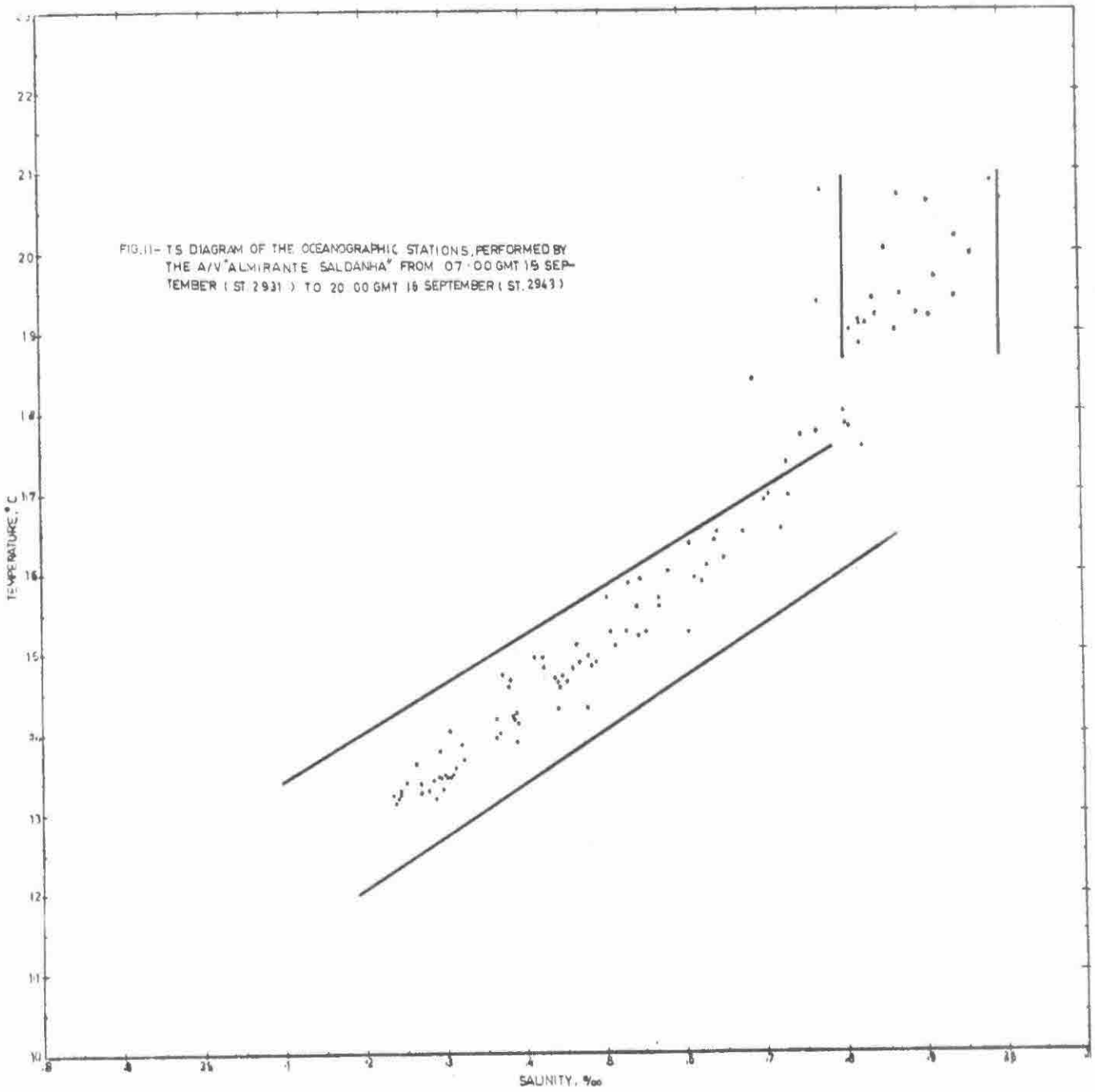


FIG. 11 - T S DIAGRAM OF THE OCEANOGRAPHIC STATIONS, PERFORMED BY THE A/V "ALMIRANTE SALDANHA" FROM 07 · 00 GMT 15 SEPTEMBER (ST. 2931) TO 20 00 GMT 16 SEPTEMBER (ST. 2943)

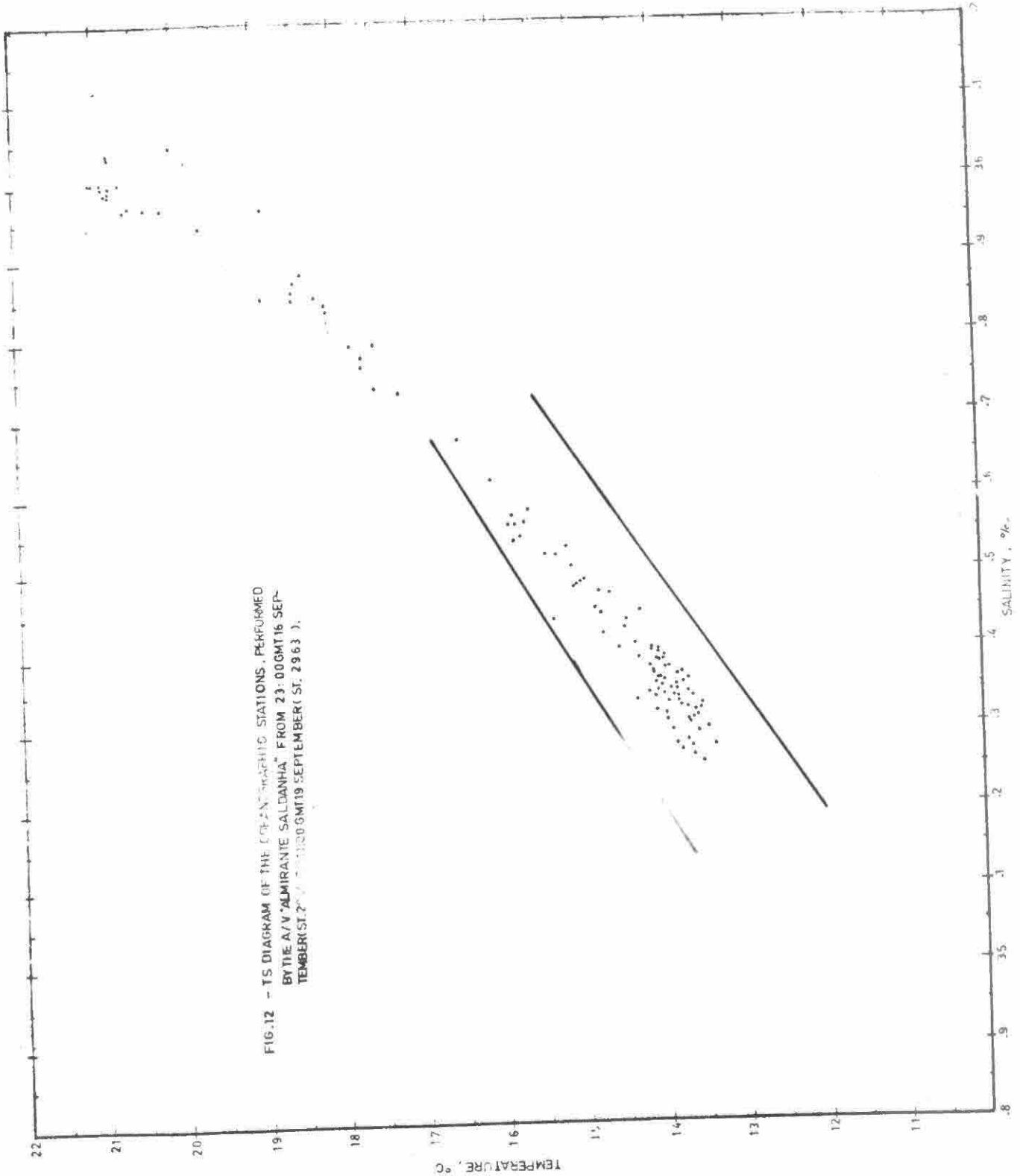


FIG.12 – TS DIAGRAM OF THE OCEANOGRAPHIC STATIONS, PERFORMED BY THE A/V "ALMIRANTE SALDANHA" FROM 23:00GMT16 SEPTEMBER(ST. 2963) TO 11:00GMT19 SEPTEMBER(ST. 2963).

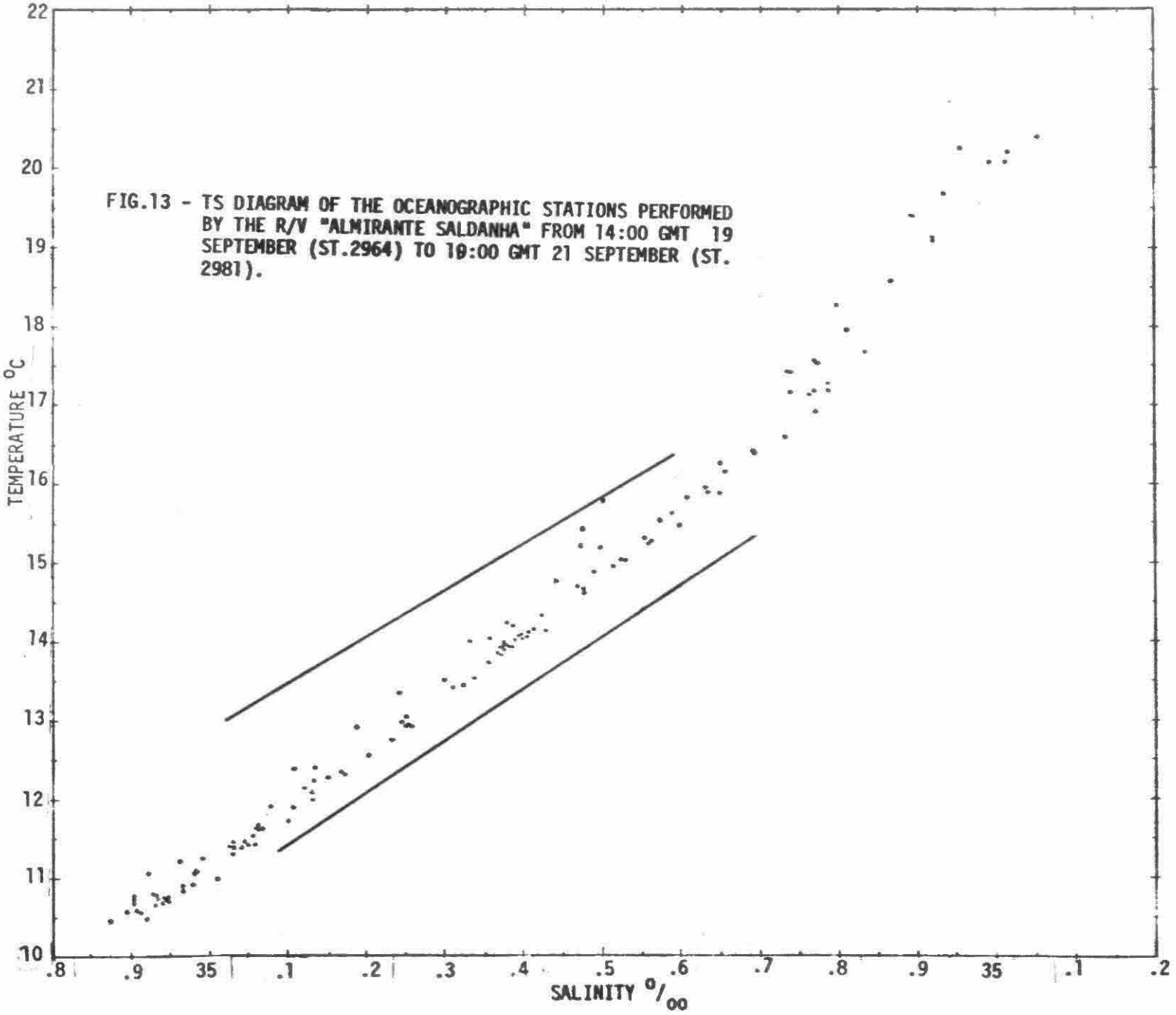


FIG.13 - TS DIAGRAM OF THE OCEANOGRAPHIC STATIONS PERFORMED BY THE R/V "ALMIRANTE SALDANHA" FROM 14:00 GMT 19 SEPTEMBER (ST.2964) TO 19:00 GMT 21 SEPTEMBER (ST. 2981).

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