

**Institut für Meereskunde
an der Universität Kiel**

Date: 03.04.2001

Cruise Report

Compiled by: O. Llinás

F.S.Poseidon

Cruise No.: P257

Dates of Cruise: 13.03.2000 - 21.03.2000

Areas of Research: Physical, chemical and biological oceanography

Port Calls: Las Palmas de Gran Canaria/ Spain 12.03.2000 - 14.03.2000
Las Palmas de Gran Canaria/ Spain 21.03.2000

Institute: Instituto Canario de Ciencias Marinas (ICCM), Telde de Gran Canaria

Chief Scientist: Dr. Octavio Llinas

Number of Scientists: 11

Projects: ESTOC

Cruise Report

This cruise report consists of 26 pages including cover:

1. Scientific crew
2. Research programme
3. Narrative of cruise with technical details
4. Scientific report and first results
5. Scientific equipment, instruments and moorings
6. Additional remarks
7. Appendix of maps with cruise tracks, list of stations, diagrammes etc.
 - A. Map with cruise track
 - B. Station list

1. Scientific crew

Name	Function	Institution	Discipline
Llinás, Octavio	Chief scientist	ICCM	Chemical Oceanography
Rueda, M^a José	Scientist	ICCM	Chemical Oceanography
Lenz, Bernd	Scientist	IFMK	Physical Oceanography
Barrera, Carlos	Scientist	ICCM	Chemical Oceanography
Cianca, Andrés	Scientist	ICCM	Chemical Oceanography
Maroto, Leire	Scientist	ICCM	Chemical Oceanography
Pérez, Javier	Scientist	ICCM	Chemical Oceanography
Villagarcía, Marimar	Scientist	ICCM	Chemical Oceanography
González-Dávila, Melchor	Scientist	ULPGC	Marine Chemistry
Rodríguez-Ucha, Iván	Student	ULPGC	Marine Chemistry
Siruella-Matos, Victor	Scientist	ULPGC	Marine Chemistry

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2. Research programme

ESTOC (European Station for Time-Series in the Ocean Canary Islands) is a cooperative project established by four research institutions: Institut für Meereskunde, Kiel (IFMK) and the Fachbereich Geowissenschaften der Universität Bremen (UBG) in Germany, and in Spain the Instituto Español de Oceanografía (IEO) and the Instituto Canario de Ciencias Marinas (ICCM). Observations started in 1994 (Linás et al., 1994; Neuer and Rueda., 1997) and the objectives are maintained until nowadays.

This observational project stated from the beginning the need to establish the meaning of the ESTOC position in relation to the area where it is located. Thus, many cruises have taken place to the north and east of the Canary Islands; among them it is worthy mentioning those made within the European project CANIGO. The analysis of the water masses made in the referred cruises has pointed out the appearance of water masses arriving from the south, probably Antarctic Intermediate Water (in the text we always refer it as AAIW). Presently the design of the samplings in the cruises is intended to establish the continuity towards the south of the water mass encountered at ESTOC; further, to progress in the classification of the origin and characteristics of the water masses from southern origin.

3. Narrative of cruise with technical details

Due to a last-minute injury of a crew member, the beginning of the cruise which was meant for the 13.03.2000 was delayed one day to wait for the plane arrival of the replacement of the crew member. On March 14, 2000 at 22:00 UTC, POSEIDON sailed from Las Palmas; in this moment the continuous recorder of CO₂ (pCO₂) and the PC-LOG were turned on. Course was set to north of Gran Canaria towards station ESTOC. Next day in the morning, a test station with CTD/rosette was performed at ESTOC going till 1000 m of water depth. Next, the thermosalinograph was set on and the ESTOC station (St. 1) was made according to the monthly routine sampling which started in 1994.

Several transects were then made according to the cruise planning; the sections were made using a CTD/rosette and sampling for oxygen, carbon dioxide, trace metals, nutrients, gelbstoff and chlorophyll and salinity was made in most of them (see Table B1 for station information and Table B2 for sampling information). Along the 15°15' W section, some of the stations were only made to deploy 4 XBT probes (Stations 2, 3, 5 and 6) and complete the usual XBT monthly sampling done between ESTOC and Gran Canaria.

Station work finished east of Fuerteventura (St. 23) where after sampling, the ICCM 12x2.5 l rosette was tested down to 1560 m.

POSEIDON called port of Las Palmas 21 March, 2000 at 08:00 UTC.

4. Scientific report and first results

4.1 Physical Oceanography

B. Lenz, A. Cianca and C. Barrera

4.1.1 Methods

Measurements with a Conductivity-Temperature-Depth (CTD) recording FSI were carried out on 19 of the 23 stations(#) during P257. Except 2 casts (test and #12/cast no.10) all casts were

performed to the bottom. The FSI-CTD was operated together with a General Oceanics rosette carrying 24x10 l Niskin bottles.

The FSI-CTD has a laboratory calibration for the temperature and pressure sensors according to the standards of the World Ocean Circulation Experiment (WOCE). A Beckman oxygen sensor recorded oxygen current and the temperature inside of the sensor. A Haardt Fluorometer was attached to the CTD at #1 (test) and #20 - #23. To check the correct closing of bottles 5 SIS tilting thermometers or pressure sensors, respectively, were fixed at the Niskin bottles and several salinity samples from the Niskin bottles were also taken.

Salinity samples from the deep ocean in low gradient zones were taken to calibrate in-situ conductivity and salinity of the CTD.

Salinity measurements with a Guildline AUTOSAL 8400 A were put through at the ICCM after the cruise. After processing, calibration and averaging to 2 dbar intervals, the accuracies of the FSI-CTD data are expected to be better than 1 ppt for pressure (e.g. 6 dbar for a pressure of 6000dbars), better 0.002 mK and better 0.003 in salinity.

XBT measurements are made using Shipican T6 probes, capable of measuring down to 460 m for ship speeds up to 20 knots. Following Walsh (1996) data in the upper 5 m are removed from the files because of the finite response time of the probe (0.63 s), generating unrealistic temperature values during the transition from air to water temperatures. A rate of fall of 6.5 m s^{-1} corresponds to a depth of 4.08 m.

The deployments were made during the way from ESTOC to the working area south of the Canary Islands along $15^\circ 15' \text{ W}$, with a nominal spacing between samples of 10 nautical miles (in total, 4 launches).

4.1.2 CTD Measurements

4.1.2.1 First results CTD

As a first result we present a T/S relation for selected stations and the distribution of potential temperature and salinity along three sections. The following water masses can be found at the ESTOC position (#1) and south of the Canary Islands. In the upper 200m the Surface Water (SF) shows a variability between 18.4°C and 19.7°C in temperature and $36.6 - 36.9$ in salinity, respectively. These values indicate that no significant upwelling area was touched during the cruise.

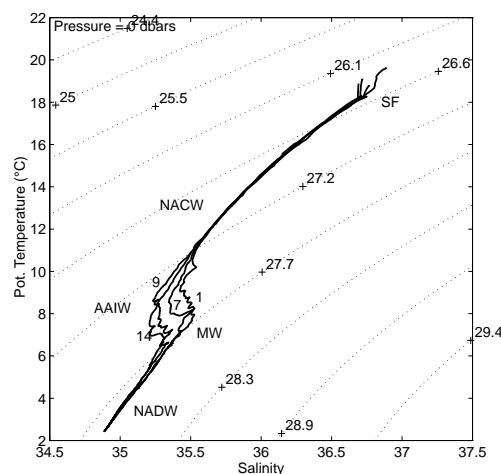


Figure 1. Potential Temperature/ Salinity relations for selected stations. The numbers in the plot indicate the station number.

Below the surface the North Atlantic Central Water (NACW) with its fixed temperature/salinity relationship is observed in the whole area of investigation (Figure 1). In the deep ocean below 1400-1500dbar with corresponding isotherm of 6°C and isohaline 35.25 down to the bottom the North Atlantic Deep Water (NADW) covers the whole region with only small temperature and salinity variations.

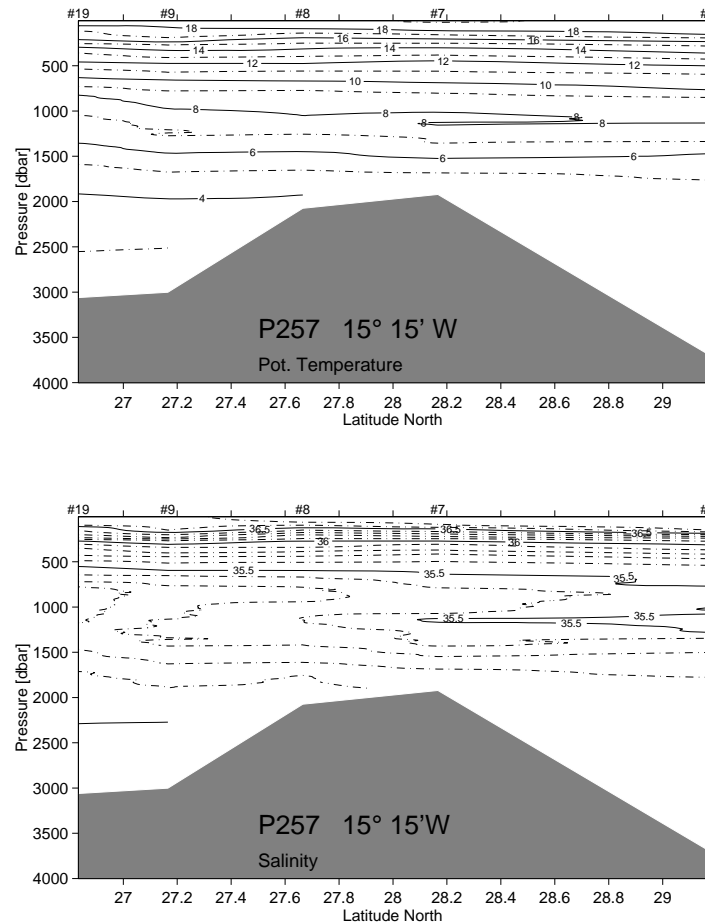


Figure 2. Potential Temperature and Salinity sections between ESTOC and the working Area south of the Canary Islands

Between NACW and NADW two water masses, Antarctic Intermediate Water (AAIW) and Mediterranean Water (MW) can be shown. The influence of AAIW is strong south of the Canary Islands, the influence of MW dominates the area around the ESTOC position. Plots in Figure 2 indicate the decreasing influence of MW from north to south. A tongue of salty and warm water (>35.5 , $\sim 8^{\circ}\text{C}$) spreads out from station 1 to station 7 with a core depth of 1200-1300dbar. South of the ridge between Gran Canaria and Fuerteventura salinity decreases rapidly to the values typical for the AAIW (35.2) with a core depth of 900-1000dbar. AAIW dominates the complete western part of the area under investigation (Figure 3) Between #20 and #21 (Figure 4) saltier water (> 35.3) can be found in a depth of 1200dbar. This value indicate a southward motion of MW passing the channel between the African shelf and Fuerteventura/Lanzarote. Further analysis combining the physical and chemical parameters and

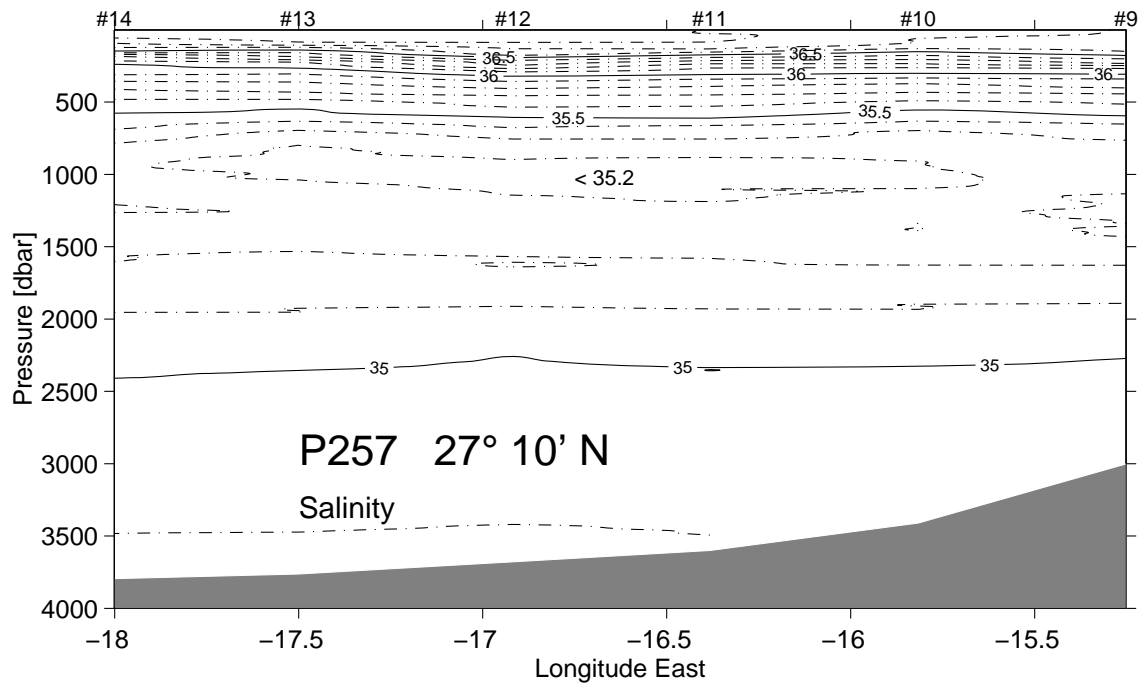
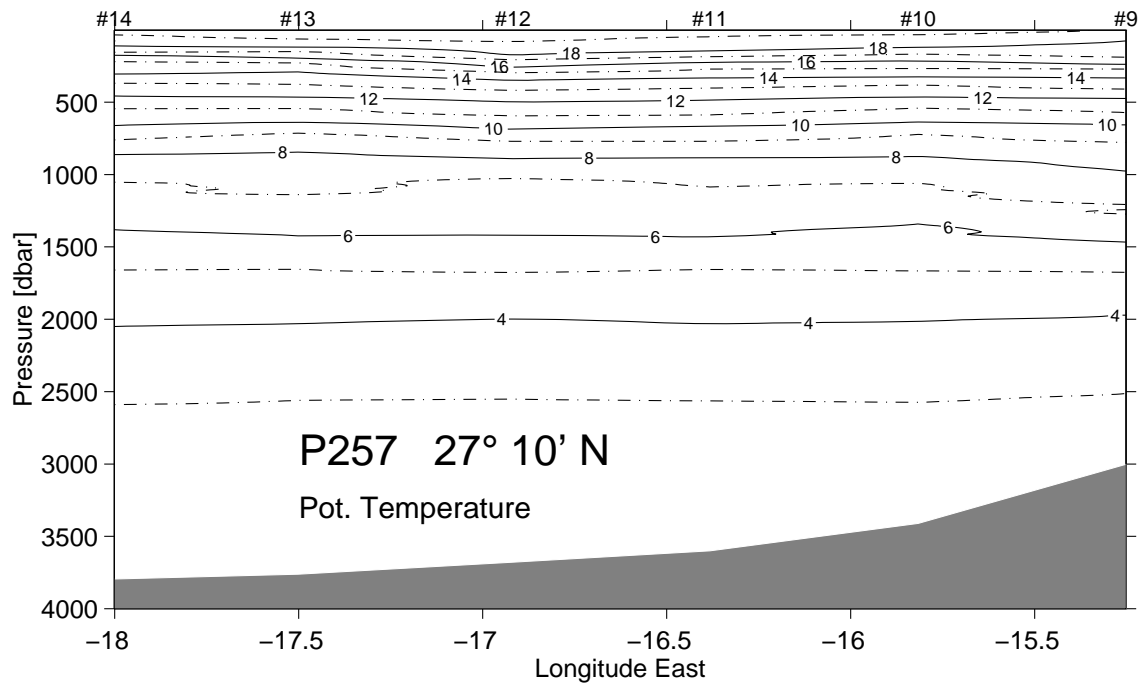


Figure 3. Potential Temperature and Salinity sections (West-East) south of the western Canary Islands, along 27° 10'N.

calculation of the volume transports for the different water masses will lead to a more detailed picture of the area under investigation.

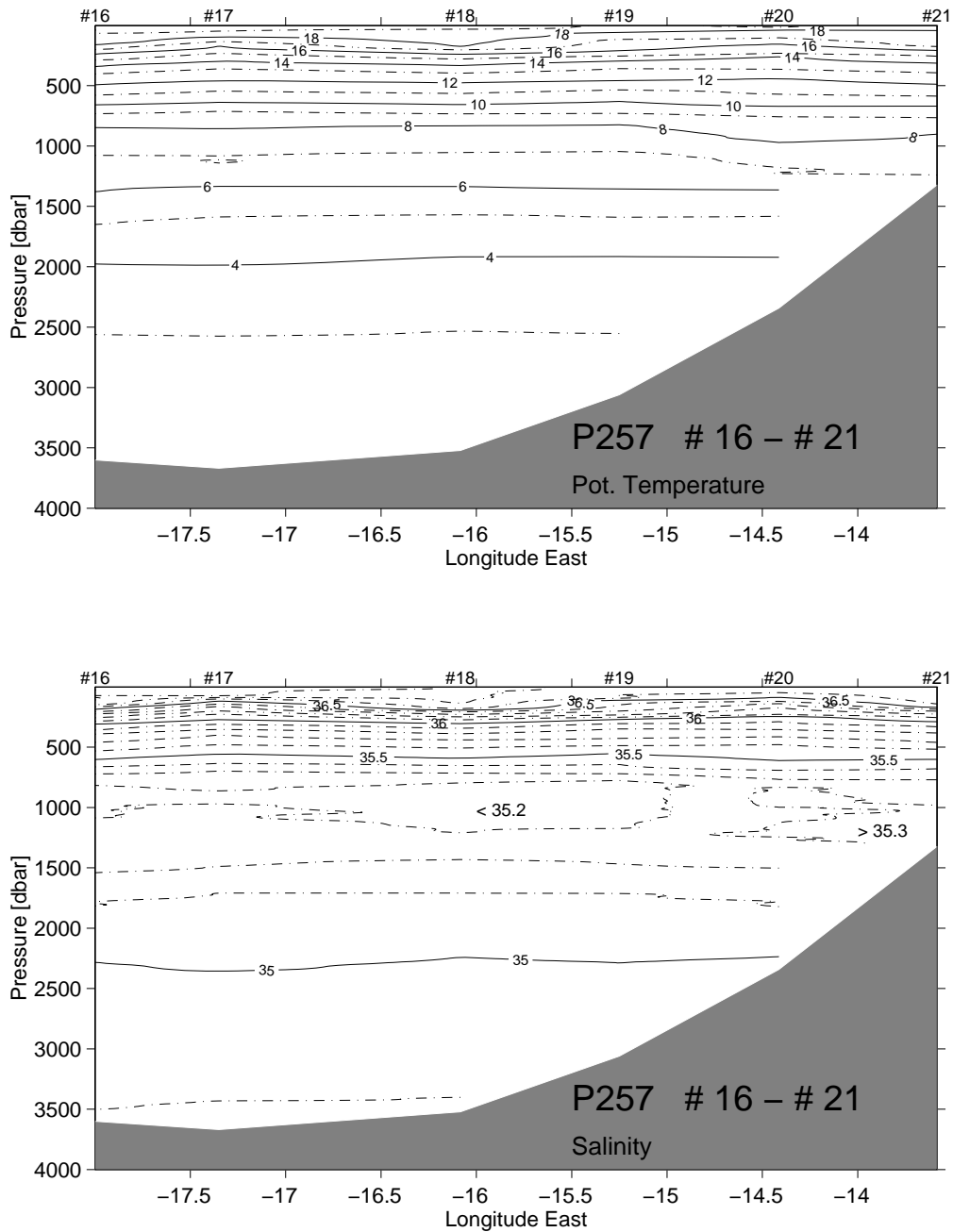


Figure 4. Potential Temperature and Salinity sections (West-East) south of the Canary Islands, stations #16 - #21.

4.1.3 Continuously registered data

With a cycle of 60 seconds the ship position with the GPS navigational system, meteorological data, data from the ship thermosalinograph and from the echosounders were recorded. Control and corrections of temperature and conductivity/salinity of the thermosalinograph were put through by comparison with CTD data, salinity samples from the near surface closed Niskin bottles and samples from the thermosalinograph itself. The

accuracy of temperature is expected to be better than 5mK and the accuracy of salinity is better than 0.008. The processing of the complete data set is ongoing.

4.1.4 Corresponding XBT line

The XBT line is part of the regular monthly sampling at ESTOC which started in 1994; it is intended that these measurements will allow the establishment of the seasonality in the zone comprising from the station until Gran Canaria Island. Thus, this work may contribute to distinguish whether the station is affected by the island nearness or it is representative of oceanic conditions. Winter conditions are depicted in Figure 5, showing a characteristic well-mixed layer down to 125 m of depth encountered frequently in this area.

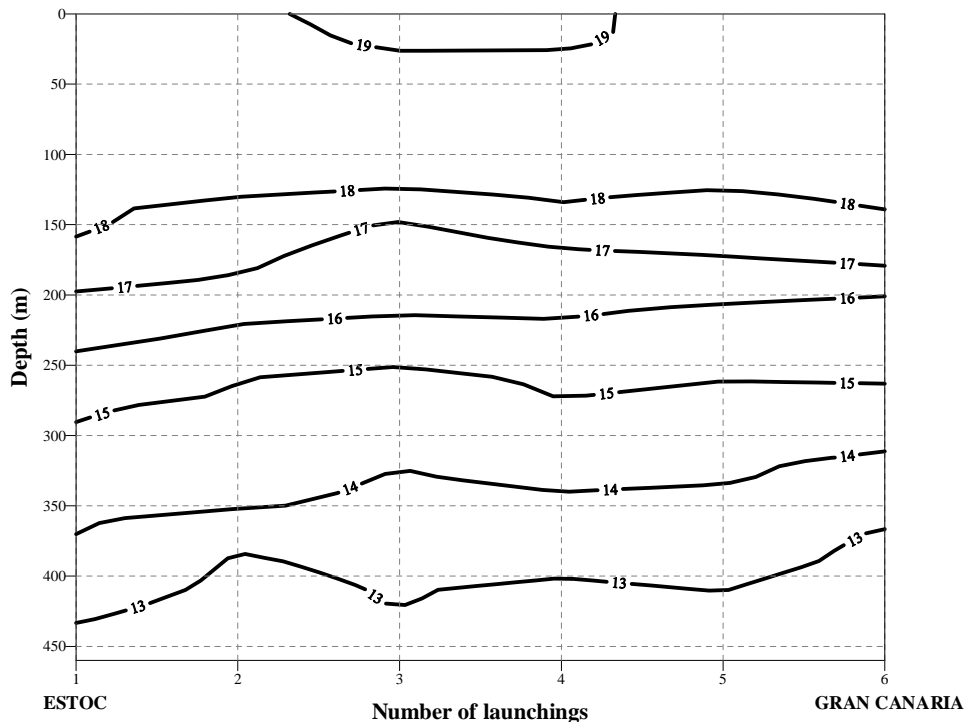


Figure 5. Temperature distribution derived from XBT launches in the transect Gran Canaria-ESTOC.

4.2 Chemical Oceanography

M.J.Rueda, M.Villagarcía, A.Cianca, L.Maroto, C.Barrera, J.P.Marrero and O.Llinás

4.2.1 Methods

4.2.1.1 Water Sampling

Samples were collected immediately after the bottles were on board from each depth. The sampling sequence was as follows:

- 1.) Oxygen: was taken in glass bottles of about 125 ml of volume which were previously cleaned and washed with HCl acid and was fixed at once; then it was kept for at least six hours according to WOCE regulations and finally it was analysed at the laboratory on board the ship.
- 2.) Nutrients: were taken in polypropylene bottles which were previously cleaned and washed with HCl acid and were completely dry. Samples were immediately frozen at -20°C , analysing them as soon as possible after arrival at the laboratory. Freezing the samples is a common practice; it does not or only in a non-significant way affect the nitrate+nitrite and the

phosphate values (by a slight decrease) and is not noticeable in the silicate values (Kremling and Wenck, 1986; McDonald and McLunghlin, 1982).

3.) Aluminium: the samples are kept in polypropylen bottles previously cleaned, washed with HCl and dried, and wrapped in plastic bags (each bottle individually) to avoid any contact with other ship materials. They are taken with gloves and each bottle is rinsed at least three times with water from the respective level, being subsequently frozen at -20°C to be transferred to the laboratory, where they are analysed according to the method following (Hernández-Brito et al., 1994a).

4.) Alkalinity and pH samples were taken in glass bottles, each bottle is rinsed with water from the respective level and the samples are fixed consequently.

5.) Gelbstoff: water was taken in dark glass bottles which were previously cleaned and washed with HCl acid. The samples were analysed within 3 hours of having taken them by spectrofluorometry.

6.) Salinity: samples were taken in dark glass bottles which were previously cleaned and washed with HCl acid. Then, they were kept in boxes to protect them from light till analysis on land.

6.) Chlorophyll: samples of one liter of water were taken. The chlorophyll samples were filtered immediately and the filters were frozen subsequently at -20°C . Their analyses takes place at the ICCM laboratory in land.

All samples were taken using the procedures established in the WOCE Operations Manual, WHP Office Report WHPO 91-1/WOCE Report No.68/91.

4.2.1.2 Analysis

Dissolved Oxygen :The samples were analysed using the method described in the WOCE Operations Manual, WHP Office Report No. 68/91; the final titration point was detected using a Metrohm 665 Dosimat Oxygen Auto-Titrator Analyser.

Nutrients

The nutrients determination was performed with a segmented continuous-flow autoanalyser, a Skalar® San Plus System (ICCM).

Nitrate+Nitrite: The automated procedure for the determination of nitrate and nitrite is based on the cadmium reduction method; the sample is passed through a column containing granulated copper-cadmium to reduce the nitrate to nitrite (Wood et al., 1967), using ammonium chloride as pH controller and complexer of the cadmium cations formed (Strickland and Parsons, 1972). The optimal column preparation conditions are described by several authors (Nydahl, 1976; Garside, 1993).

Phosphate: Orthophosphate concentration is understood as the concentration of reactive phosphate (Riley and Skirpow, 1975) and according to Koroleff (1983a) is a synonym of “dissolved inorganic phosphate”. The automated procedure for the determination of phosphate is based on the following reaction: ammonium molybdate and potassium antimony tartrate react in an acidic medium with diluted solution of phosphate to form an antimony-phospho-molybdate complex. This complex is reduced to an intensely blue-coloured complex, ascorbic acid. The complex is measured at 880nm. The basic methodology for this anion determination is given by Murphy and Riley (1962); the used methodology is the one adapted by Strickland and Parsons (1972).

Silicate: The determination of the soluble silicon compounds in natural waters is based on the formation of the yellow coloured silicomolybdic acid; the sample is acidified and mixed with

an ammonium molybdate solution forming molybdosilicic acid. This acid is reduced with ascorbic acid to a blue dye, which is measured at 810nm. Oxalic acid is added to avoid phosphate interference. The used method is described in Koroleff (1983b).

Aluminium: The method of analysis is based on complexation of aluminum with 1,2-dihydroxyan-thraquinone-3-sulphonic acid (DASA) and measurement of the reduction current of this complex using high speed cathodic stripping voltametry (HSCSV). Samples were prepared in Teflon cups of polarographic cell, containing 10 ml of water, $2 \cdot 10^{-6}$ M DASA and 0.01 M BES. The adsorption potential (-0.9 V/Ag/AgCl) was applied to the working electrode, while the solution was stirred. After 40s accumulation time, the stirring was stopped and 5s were allowed for the solution to become quiescent. The scanning was started at -0.9 V and terminated at -1.4 V. The scanning is made using staircase modulation with a scan rate of 30 V/s and a pulse height of 5 mV. The DASA-Al peak appears at ca. -1.25 V. A standard addition procedure is used to quantify the aluminium concentration of the sample. The electrochemical system used has been designed to measure the instantaneous currents at short times with a low noise level (Hernandez-Brito et al., 1994b). Thus, the analytical time required for each sample is substantially reduced. A PAR-303A electrochemical cell with hanging mercury drop electrode (HMDE) was connected to a locally produced computer-controlled potentiostat.

Experimental pH: The pH in total scale (moles kg sol⁻¹) was measured following the spectrophotometric technique of Clayton and Byrne (1993) using the m-cresol purple indicator (DOE, 1994). The pH measures were done in a Hewlett Packard Diode Array spectrophotometer, in a 25°C-thermostated 1-cm flow-cell by using a Peltier system. Using a stopped-flow protocol, the seawater was analysed for a blank determination at 730 nm, 578 nm and 434 nm. The flow was restarted and the indicator injection valve switched on to inject 10 µl dye through a mixing coil (2 m). Three photometric measurements were carried out for each injection in order to remove any dye effect on the seawater pH measurement. Repeated seawater measurements of different CRMs samples (n = 54) gave a weighted standard deviation of ± 0.002 pH units.

Total alkalinity: Total alkalinity of seawater (A_T) was determined by titration with HCl until carbonic acid end point using two potentiometric systems (Mintrop et al., 2000). The titration systems consist of a titrator type Titrino 702SM (Metrohm, Herisau, Switzerland) and a Titrino 719S, respectively, both interfaced to personal computers. All measurements were made in thermostated plastic cells provided by Frank J. Millero (Rosenstiel School of Atmospheric and Marine Science (RSMAS), Miami, Florida, USA). The titration was performed by adding HCl to the seawater past the carbonic acid end point. A computer program was used to run the titration, record the volume of the acid added and the EMF readings of the electrodes. The HCl solution (25 l, 0.25 M) was made up from concentrated analytical grade HCl (Merck[®], Darmstadt, Germany) in 0.45 M NaCl, in order to yield an ionic strength similar to open ocean seawater. The acid was standardized by titrating weighed amounts of Na₂CO₃ dissolved in 0.7 M NaCl solutions. The total alkalinity of seawater was evaluated from the proton balance at the alkalinity equivalence point, $pH_{equiv} = 4.5$, according to the exact definition of total alkalinity (Dickson, 1981). The precision of the fit (s-value) is better than $0.4 \mu\text{mol kg}^{-1}$ for the samples analyzed. The performance of the titration systems ($\pm 2 \mu\text{mol kg}^{-1}$) has been monitored by titrating different batches of CRMs (#42) that have known C_T and A_T .

Fugacity of CO₂: Fugacity of carbon dioxide (fCO₂) in air and in surface seawater is determined with a flowing system similar to the one designed by Wanninkhof and Thoning (1993) and developed by Frank J. Millero's group at the University of Miami. The equilibrator used is based on the design described by Weiss (1981). The concentration of CO₂ in the air and in the equilibrated air sample is measured with a differential, non-dispersive, infrared gas analyser supplied by LI-COR (LI-6262 CO₂/H₂O Analyser). The samples are measured wet and the signal corrected for water vapour using the water channel of the LI-COR. The instrument is operated in the absolute mode and gathers CO₂ concentrations directly from the instrument. The LICOR analyses the concentration of CO₂ in the instrument every 6 s, averages these values over a 1-min interval, and records them. Atmospheric air is pumped at the bow of the ship and measured every hour. The system was calibrated by measuring two different standard gases with mixing ratios of 348.55 and 520.83 ppm CO₂ in air. These calibrated standards were provided by NOAA Institution and they are traceable to the WMO (World Meteorology Organisation) scale. Our system has a precision of less than 1 µatm and is thought to be accurate, relative to the standard gases to 2 µatm. Fugacity of CO₂ in the seawater was calculated from the measured x CO₂ (mole fraction of CO₂ gas corrected to dry air and to the pressure of 1 atm).

Yellow Substance: The values were obtained using the methodology described by Determan et al. (1994, 1996). The samples were measured with a spectrofluorometer SHIMADZU RF-1501 at an excitation wavelength of 341 nm and the intensities taken at emission wavelength between 350 and 500 nm. Gelbstoff fluorescence is derived from the emission spectra and obtained in Raman units.

Phytoplankton pigments: Pigments were measured using fluorimetric analysis, following the methodology described by Welschmeyer (1994). The determination was achieved using a fluorometer TURNER 10-AU-000.

Salinity: Samples were measured with a salinometer, model Autosal 8400a, whose measurement range was between 0.005-42 (psu), with an accuracy of ±0.003, according to the manufacturer. It was calibrated following the manufacturer's information and standardizing it with IAPSO Standard Seawater. Salinity values were calculated as practical salinity according to Unesco (1978, 1984).

4.2.2 Chemical Parameters

4.2.2.1 Nutrients and Oxygen distribution

The preliminary results of the nutrients analysed (nitrates+nitrites, phosphates and silicates, see Figure 6) point out the need to determine them in parallel to the temperature and salinity, in order to detect water masses in zones like the Canary Islands, where the presence of some of them is very low. In this area, the concentration of nitrates+ nitrites is a good indicator of the presence of AAIW, shown by maximum values of 30 µmol/l which point out clearly the distribution core. This nutrient depicts better this water mass than the relative maxima of silicates which has been widely used (Käse et al., 1986).

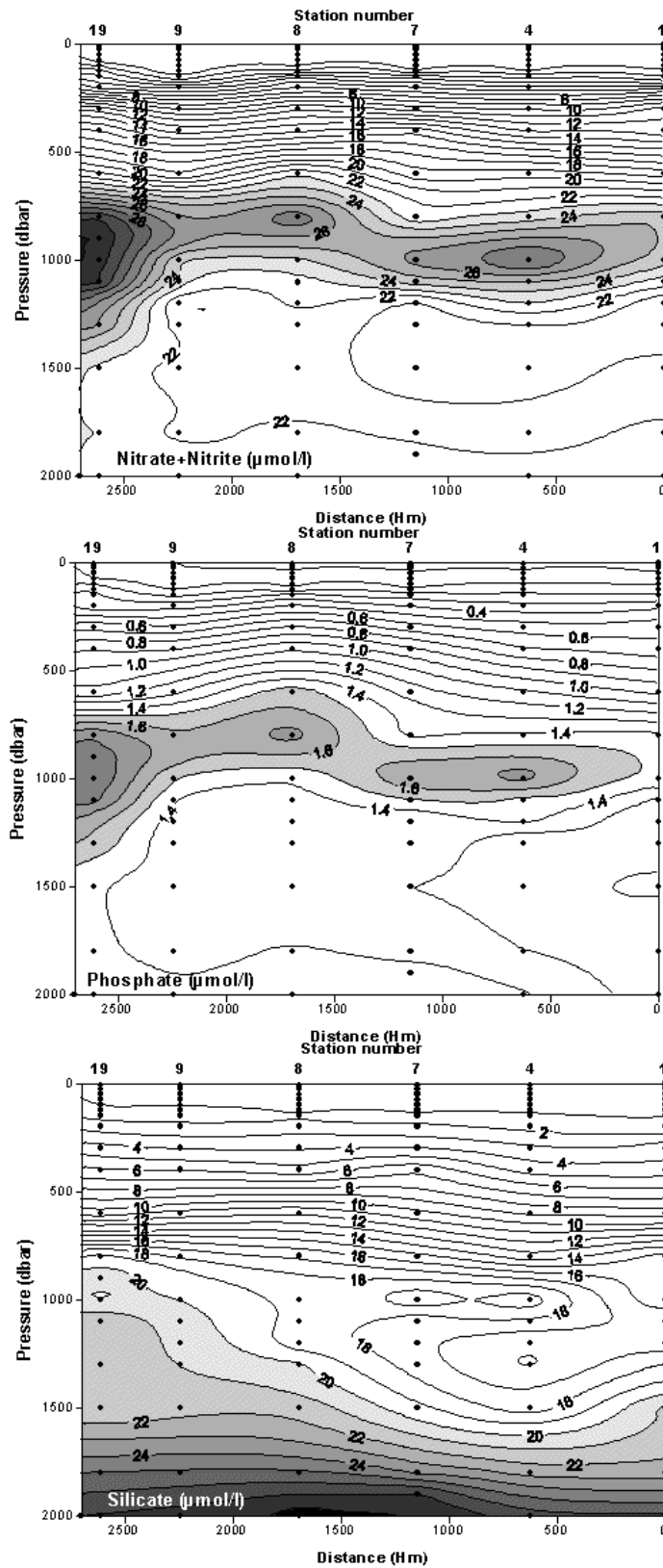


Figure 6. Nutrients distribution along a transect north-south starting from station ESTOC(# 1).

The Mediterranean water (MW) is signed by relative minima values of the corresponding nutrients, that can appear quite modified by mixing with the AAIW. Similar minima values

are found for oxygen (Figure 7), which makes more difficult to discriminate between the two water masses. However, a good correspondence is obtained between the nitrates+nitrites, oxygen and silicates concentrations on one side and the thermohaline properties on the other; this is the case mainly in the more extreme positions where both water masses are present.

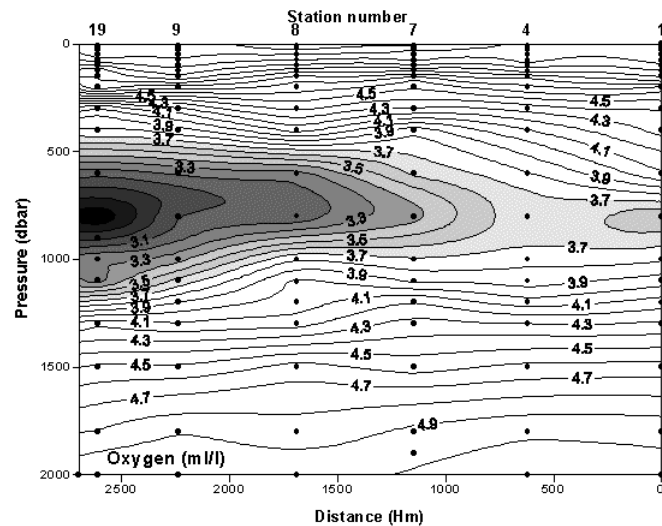


Figure 7. Oxygen distribution along the a transect north-south starting from station ESTOC.

The rate between nitrates+nitrites and phosphates is lower in the surface layer, increasing as the deepest samples are included (15.5 to 16.7). The nutrients gradients which are characteristic of the North Atlantic Central Water (NACW) appear very well defined between the surface layer and the intermediate water mass.

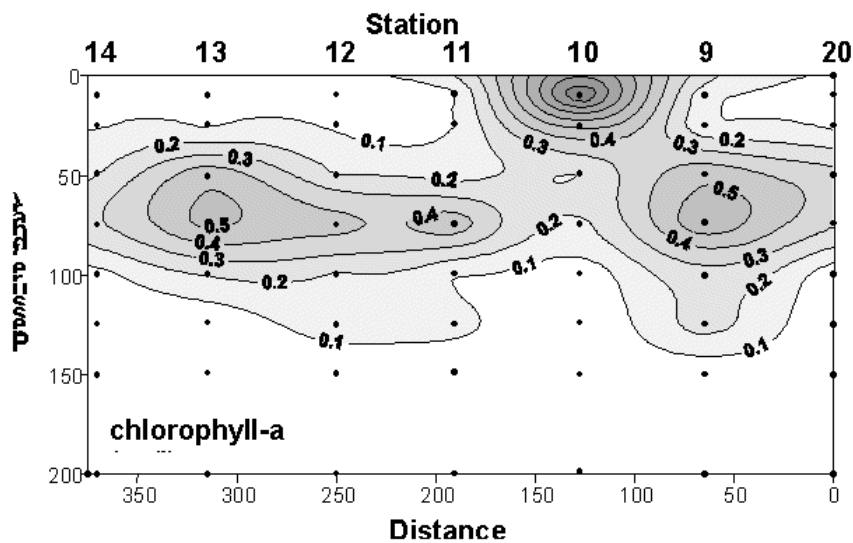


Figure 8. Chlorophyll „a“ distribution along a transect east-west (sta. # 20, 9-14). The distribution of chlorophyll “a” concentration is shown in Figure 8, which depicts the east-west transect located norther of the two lines sampled. The maxima are found between 50 and

75 m deep except in station no.10 where the maximum is nearly on the surface. This fact agrees well with the satellite observation which shows the station is under the area of influence where chlorophyll “a” is advected from the east. Intense chlorophyll “a” nuclei are found in the African coast due to the upwelling events encountered at those latitudes and this chlorophyll “a” moves west towards the open ocean.

4.2.2.2 Gelbstoff fluorescence samples

The observations of gelbstoff fluorescence along the cruise present distributions which show as a general trend an increase of this optical parameter from north to and from west to east in the Canary Islands surrounding waters. When other parameters show indications of AAIW presence, a characteristic isoline around 30×10^{-3} Raman units usually appears in intermediate waters at about 900 m in this area whereas it appears deeper when this water mass is not present (Villagarcía et al., in press). Further, the entrance of organic matter from African origin produces higher than normal values at shallower depths in the stations nearer to Africa.

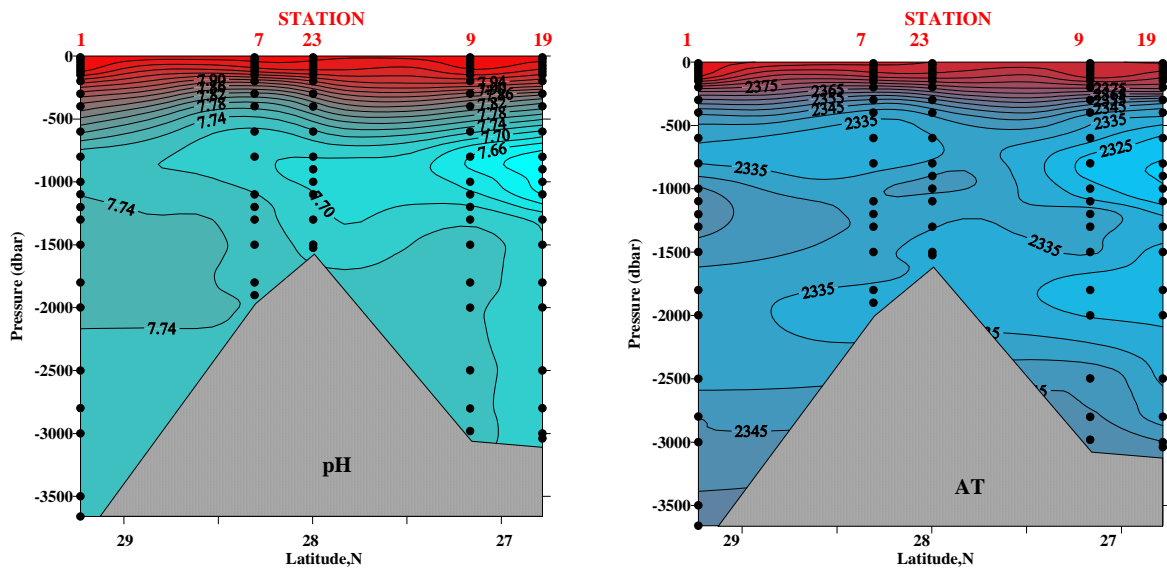
4.2.2.3 The CO₂ system in the Canary Region

M. González-Dávila, J. M. Santana-Casiano

The capacity of the oceans for uptaking CO₂ depends both on the inorganic carbon chemistry and also notably on many factors such as hydrography, circulation of water masses, mixed-layer dynamics, wind stresses and the biological processes in the same way. Determination of carbon system variables was carried out in the Canary Islands area including the ESTOC station (station 1) during cruise P257 on board F/S Poseidon. Total alkalinity and pH in the total scale at 25°C were obtained in 17 stations from surface to bottom. Total dissolved inorganic carbon (C_T) and fugacity of CO₂ (fCO₂) was computed from pH and alkalinity data using the corresponding thermodynamic constants. The fCO₂ in the atmosphere and surface seawater was measured

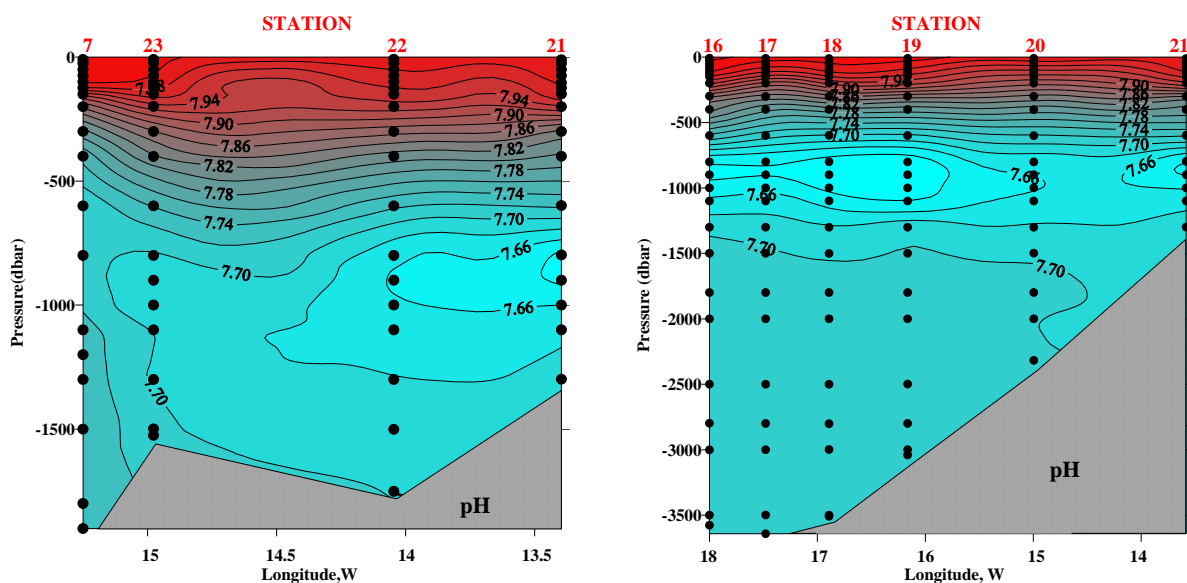
4.2.2.4.1 pH and alkalinity

Four different sections have been considered. Section 1 is a north-south transect and corresponds to stations 1, 7, 23, 9 and 19. Section 2 joins stations 7, 23, 22, 21 at 28° N. Section 3 joins stations 16 to 21, while section 4 corresponds with the west-east transect from stations 14 to 9 and stations 20 and 21 until the African coast. The most important features observed during this cruise for the carbon system parameters are presented in Figures 9 to 12. The distribution of pH on total scale at 25°C resembles the typical vertical profile. The pH reaches a maximum in surface waters (8.025 ± 0.005). pH values in surface waters decrease from north (8.020 at ESTOC) to south (8.011, station 19) and from West (8.025 at station 14) to East (7.998 at station 21). The pH then decreases due to the oxidation of plant material and exhibits a sharp decrease with depth to approximately 1000 m coincident with a minimum in O₂ and maximum in apparent oxygen utilization (AOU) (Llinás et al.) and fCO₂ (data not shown). The salinity minimum of 35.15 at 900 m in the southern section traces the northward advection of AAIW (Willenbrink, 1982) as a poleward undercurrent of the Canary Current.



Figures 9 and 10. Distribution of pH and alkalinity along transect north-south (Section 1).

This intermediate water reaches the Canary Islands as a seawater band centered at around 900 m between the African coast and at least 18° W (limit of the studied area). It is clearly traced by the lowest values of pH at around 900 m ($pH_t = 7.621$ at station 19). Figures 9, 11 and 12 show the pH distribution in this area. It is observed that the AAIW influence in the pH values are traced in all the stations except in station 1 (ESTOC). In section 2, the influence of AAIW is observed in stations 21 ($pH = 7.632$) and 22 ($pH = 7.645$) while in station 23 the pH increases reaching 7.68, with a lower influence and a much smaller influence in station 7 ($pH = 7.70$). Northern from this point, the pH increases until reaching a value of 7.726 at the ESTOC station. Following the distribution of pH it can be seen that during this time of the year the highest influence of the AAIW is found around the African shelf, where the values of pH are always lower than 7.63. Below 1000 m, an increase in pH is observed due to both the dissolution of calcium carbonate and the advection of water masses, which are more ventilated than the intermediate water masses.



Figures 11 and 12. pH distribution along Sections 2 and 3.

Values of A_T are shown for section 1 in Figure 10. At the ESTOC station a light signal of Mediterranean water is found around 1100 m, with the higher values of alkalinity ($2348.09 \mu\text{mol l}^{-1}$) at this depth.. The influence of AAIW is observed at stations 9 and 19 with low values of alkalinity ($2319.40 \text{ mequiv l}^{-1}$), well related with the lower salinity of this ancient intermediate seawater.

4.2.2.4.2 Fugacity of CO_2

The surface values of $f\text{CO}_2$ obtained for this time of year show clearly that this area is acting as a sinking of CO_2 . The atmosphere present a mean value of $f\text{CO}_2$ of $363.5 \pm 3 \mu\text{atm}$.

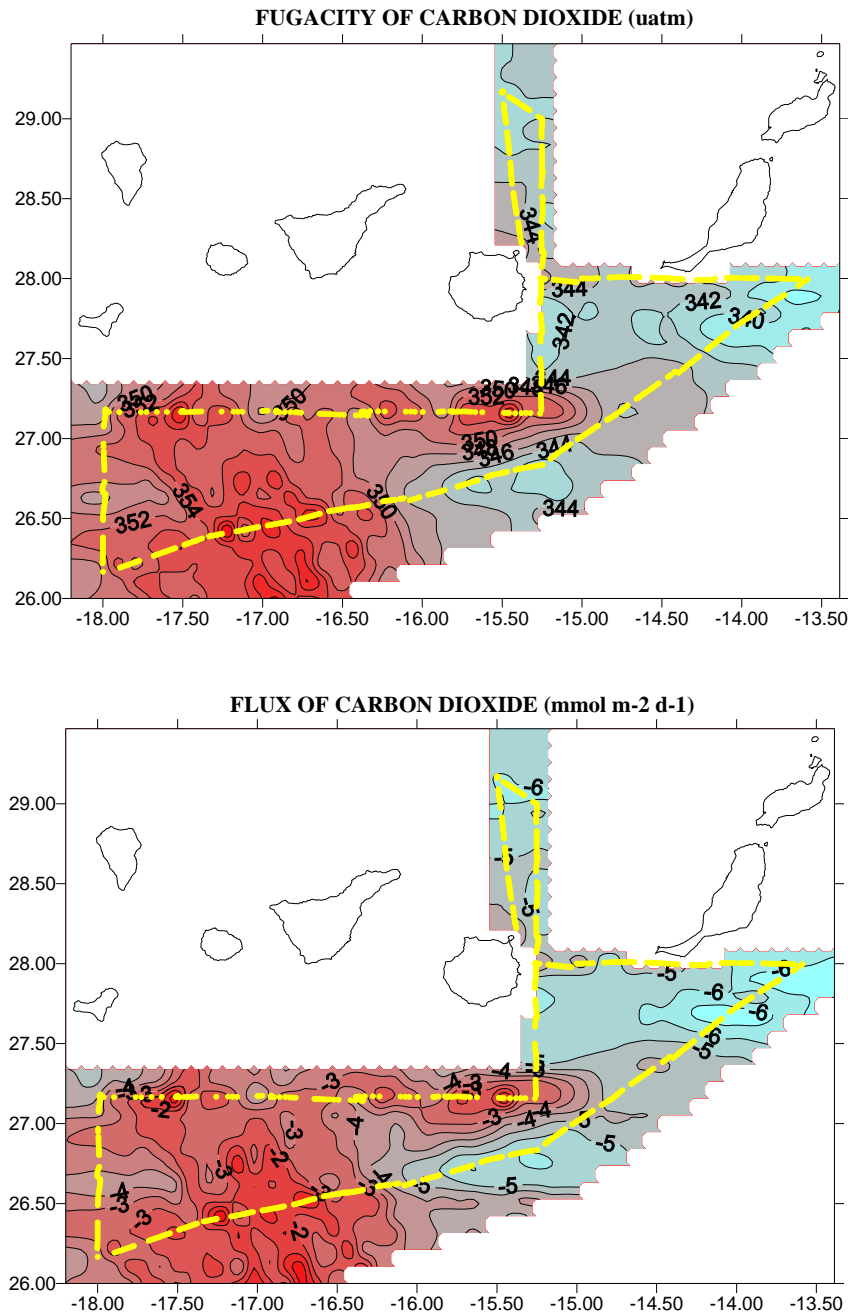


Figure 13. a) $f\text{CO}_2$ values for surface seawater and, b) air-sea flux considering a mean average wind of 10 m s^{-1} .

whereas the values of $f\text{CO}_2$ for surface seawater (Figure 13a) range from 338 μatm (East) to 362 μatm (West). The resulting air-sea flux determined by considering a mean average wind of 10 m s^{-1} is shown in Figure 13b. The maximum fluxes are observed in the area closed to African shelf ($-6 \text{ mmol m}^{-2}\text{d}^{-1}$) and in the ESTOC Station, decreasing from East to West. The lowest $f\text{CO}_2$ values (and highest flux) in the African coast may result from an important effect of the biological pump on the global CO_2 system, which decreases any effect coming from the upwelling of CO_2 present in richer and deeper seawater.

4.2.3 Remote sensing

In coincidence with the cruise, a search for AVHRR and SeaWiFS imagery was performed in the CREPAD archives of Maspalomas Satellite Acquisition Facility. A set of 8 images from each one of the sensors was obtained, covering from the 14th to 21st of March, 2000. The AVHRR daily images correspond to the noon overpasses of the NOAA-14 satellite, obtained from 14 to 16 hours UTC; the overpass of the Orbview satellite carrying the SeaWiFS sensor takes place between 13 and 14 hours UTC. In Figure 14 sea surface temperature and chlorophyll concentration are presented for the March, 19.

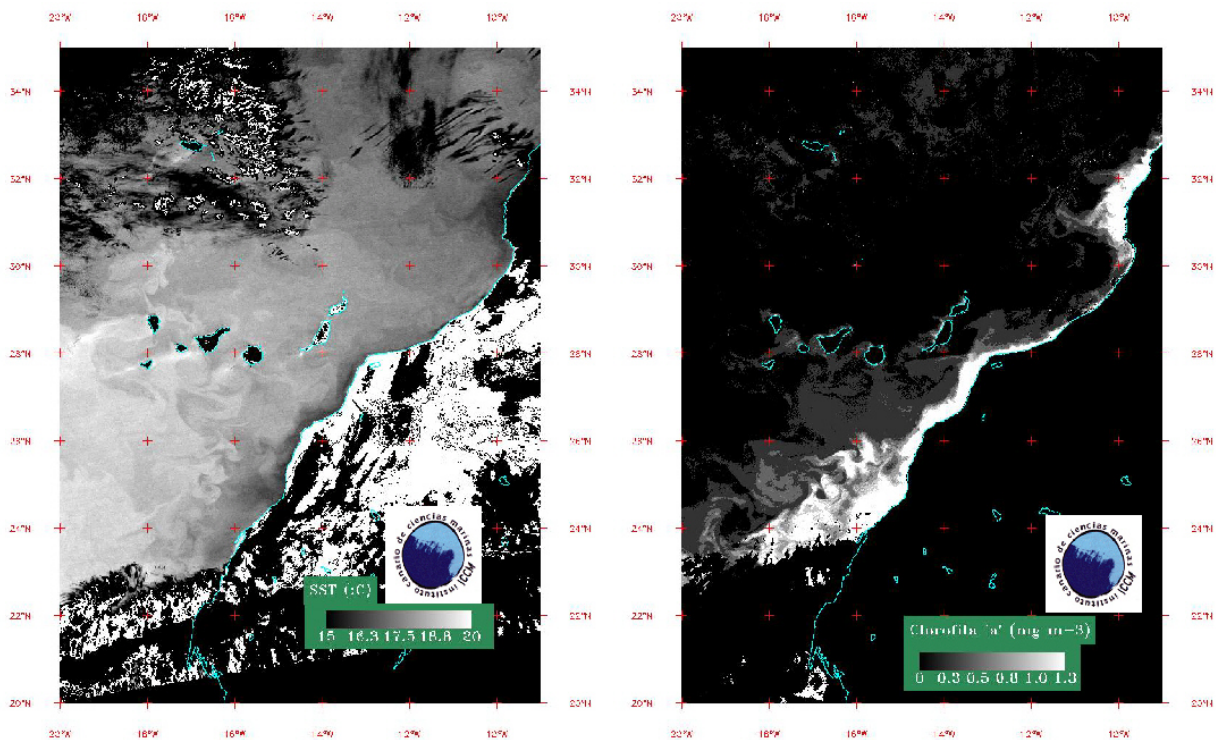


Figure 14. Sea surface temperature and chlorophyll concentration from March 19, 2000. Images derived from AVHRR and SeaWiFS respectively.

They were derived from AVHRR and SeaWiFS respectively using standard algorithms. Other geophysical parameters derived from satellites include: aerosol optical thickness, Amström exponent and diffuse attenuation coefficient at 490nm. The most salient feature appearing in these images is the strong upwelling off the coast of Africa that approaches towards the Canarian Archipelago in the form of cold and productive water meandering filaments. As soon as the analyses of the water constituents are ready, the satellite data are recalculated using this ground truth as a reference by means of statistical methods.

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5. Scientific equipment, instruments and moorings

- FSI-CTD equipped with a polarographic oxygen sensor (Beckman) and an in-situ fluorometer (down to 3000 m inly; Haardt)
- GO rosette including 24x10 l Niskin bottles
- Methrom 682 Titoprocessor
- Spectrofluorometer Shimadzu RF-1501
- CO₂ system using a non-dispersive infrared detector (LICOR 6262)
- Idronaut Rosette (12 bottles x 2.5 l) and CTD

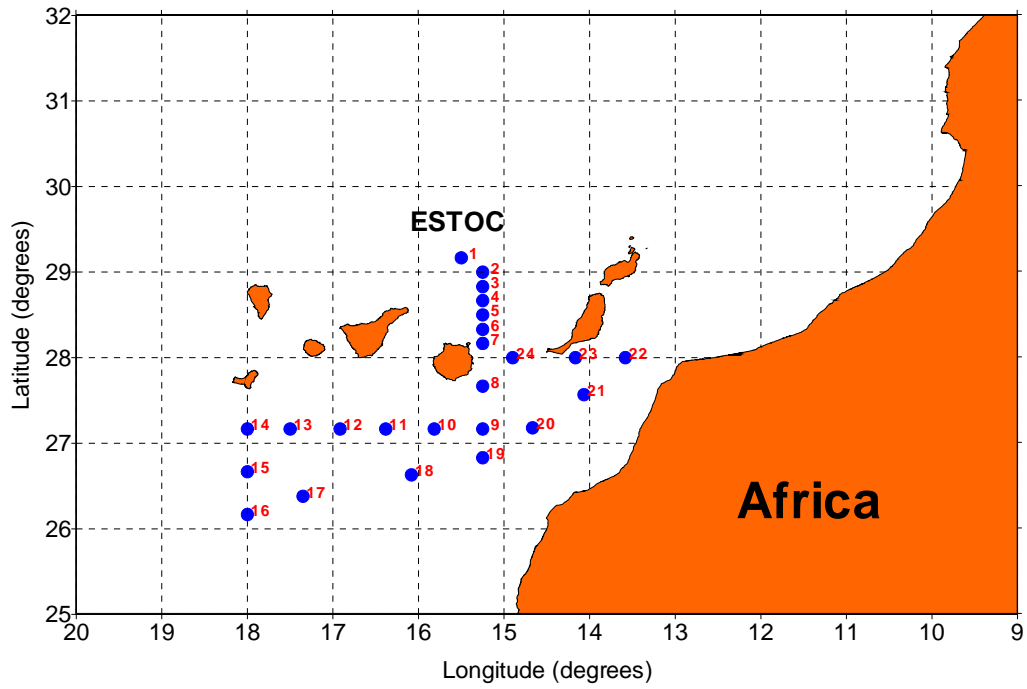
6. Additional remarks

We want to thank the crew of the FS POSEIDON with captain W. Klaassen for their excellent help in gathering these data sets.

7. Appendix

Appendix A

POSEIDON P257



Appendix B.

Table B1: Station List P257

POSEIDON 257 station and sample log.

Status: 01 February 2001

List of abbreviations:

St	: Station no.
Ca	: CTD cast no., monotonically increasing during the cruise; all casts to near bottom if not indicated else
Wd	: Water Depth
Instr	: Type of instrumentation or equipment
FSI	: Falmouth Scientific Instrument CTD; IFMK code FSI_1 with 24x10 l General Oceanics bottle rosette
PC-LOG	: on-line log of GPS date, time, position, pitch & roll; near-surface T, S; meteorological data; echosounder
pCO2	: continuous underway pCO2 measurement system
NOAA	: National Oceanic and Atmospheric Administration surface buoy
XBT	: Sippican Ocean Industries Expendable Bathythermograph (XBT, Type T6)

Additional sensors on and samples taken from CTD/rosette:

1	F	Fluorometer attached to CTD
2	O	oxygen
3	CO2	alcalinity and pH
4	Tr	trace metals
5	N	nutrients
6	Chl	chlorophyll_a
7	S	salinity
8	Y	yellow substance

Date	Time	St	Ca	Latitude		Longitude		Wd	Inst
2000	UTC			North		West			
MMDD	hhmm			DD	MM.MM	DDD	MM.MM	[m]	
0314	2200			28	08.45	015	25.49	-9	sail from Las Palmas begin of P257
0314	2200								start PC-LOG
0314	2200								start pCO2
0315	0558	1	1	29	10.00	015	30.00	3609	FSI F, test station, 1000dbar
0315	0805								start Thermosalinograph
0315	0817	1	2	29	10.02	015	29.96	3610	FSI ESTOC March/2000
0315	1315	1	-9	29	10.03	015	29.54	3610	NOAA launch drifter No.20312
0315	1505	2	-9	29	00.05	015	15.12	3589	XBT 460m
0315	1612	3	-9	28	50.00	015	15.00	3588	XBT 460m
0315	1720	4	3	28	39.99	015	14.94	3577	FSI O,N,Chl,S,Y
0315	2140	5	-9	28	29.67	015	14.67	3454	XBT 460m
0315	2236	6	-9	28	20.10	015	15.22	2900	XBT 460m
0315	2338	7	4	28	09.99	015	14.99	1837	FSI O,CO2,Tr,N,Chl,S,Y
0316	0452	8	5	27	39.93	015	15.01	2004	FSI O,Tr,N,Chl,S,Y
0316	1009	9	6	27	09.93	015	15.11	2951	FSI O,CO2,Tr,N,Chl
0316	1655	10	7	27	10.03	015	48.63	3350	FSI O,CO2,Tr,N,Chl,S,Y
0316	2217	11	8	27	09.97	016	22.95	3535	FSI O,CO2,N,Chl,S
0317	0453	12	9	27	10.04	016	55.04	3612	FSI O,N,S,Y
0317	0835	12	10	27	10.35	016	54.86	3606	FSI 200 dbar, CO2,Tr,N,Chl,S,Y
0317	1331	13	11	27	09.78	017	30.10	3689	FSI O,CO2,N,Chl,S
0317	1917	14	12	27	10.04	018	00.01	3724	FSI O,CO2,Tr,N,Chl,S,Y
0318	0130	15	13	26	39.99	018	00.01	3690	FSI O,CO2,Tr,N,Chl,S
0318	0738	16	14	26	09.98	017	59.97	3532	FSI O,CO2,Tr,N,Chl,S,Y
0318	1515	17	15	26	23.02	017	21.02	3600	FSI O,CO2,Tr,N,Chl,S
0319	0317	18	16	26	37.97	016	05.08	3459	FSI O,CO2,Tr,N,Chl,S
0319	1228	19	17	26	50.02	015	15.04	3014	FSI O,CO2,Tr,N,Chl,S,Y
0319	2058	20	18	27	25.05	014	24.82	2298	FSI F,O,CO2,Tr,N,Chl,S,Y
0320	0510	21	19	28	00.00	013	35.04	1307	FSI F,O,CO2,Tr,N,Chl,S,Y
0320	0946	22	20	27	59.95	014	09.96	1742	FSI F,O,CO2,N,Chl,S,Y
0320	1537	23	21	28	00.00	015	00.00	1511	FSI F,O,CO2,N,Tr.Chl,S,Y
0320	1720	23	-9	27	59.10	014	59.91	1560	test ICCM CTD
0320	2035	-9	-9	28	00.08	015	15.53		stop PC-LOG stop Thermosalinograph stop pCO2
0321	0800								port of Las Palmas; end of P257

Table B2: Sampling levels for each station P257**P257: Sampling levels for each station (IfM Kiel Rosette, Station/Cast)**

1 Oxygen 2 CO₂ 3 Trace metals 4 Nutrients 5 Chlorophyll_a 6 Salinity
 7 Yellow substance

Pressure [dbar]	1/1	1/2 (ESTOC)	4/3	7/4	8/5	9/6	10/7
10		1234567	1—4567	1234567	1-34567	12345--	1234567
25		1234567	1—45-7	12345-7	1-345-7	12345--	
50		1234567	1—45-7	12345-7	1-345-7	12345--	1234567
75		1234567	1—45-7	12345-7	1-345-7	12345--	1234567
100		1234567	1—45-7	12345-7	1-345-7	12345--	1234567
125		1234567	1—45-7	12345-7	1-345-7	12345--	1234567
150		1234567	1—45-7	12345-7	1-345-7	12345--	1234567
200		1234567	1—45-7	12345-7	1-345-7	12345--	1234567
300		1234-67	1—4—7	1234—7	1-34—7	1234---	1234-67
400		1234-67	1—4—7	1234—7	1-34—7	1234---	1234-67
600		1234-67	1—4—7	1234—7	1-34—7	1234---	1234-67
800		1234-67	1—4—7	1234—7	1-34—7	1234---	1234-67
900							
1000		1234-67	1—4—7	1234—7	1-34—7	1234---	1234-67
1100		1234-67	1—4—7	1234—7	1-34—7	1234---	1234-67
1200		1234-67	1—4—7	1234—7	1-34—7	1234---	1234-67
1300		1234-67	1—4—7	1234—7	1-34—7	1234---	1234-67
1500		1234-67	1—4—7	1234—7	1-34—7	1234---	1234-67
1800		1234-67	1—4—7	1234—7	1-34—7	1234---	1234-67
2000		1234-67	1—4—7		1-34—7	1234---	1234-67
2500		1234-67	1—4—7			1234---	1234-67
2800		1234-67	1—4—7			1234---	1234-67
3000		1234-67	1—4-67				
3500		1234-67	1—4-67				
Bottom		1234-67 (3660 dbar)	1—4-67 (3636dbar)	1234-67 (1899dbar)	1-34-67 (2060dbar)	1234--- (2978dbar)	1234-67 (3396dbar)

P257: Sampling levels for each station (IfM Kiel Rosette, Station/Cast)

1 Oxygen **2** CO2 **3** Trace metals **4** Nutrients **5** Chlorophyll_a **6** Salinity
7 Yellow substance

Pressure [dbar]	11/8	12/9	12/10	13/11	14/12	15/13	16/14
10	12-456-	-----6-	1234567	12-456-	1234567	123456-	1234567
25	12-45--	Open	12345-7	1—45--	12345-7	12345--	12345-7
50	12-45--	Open	12345-7	1—45--	12345-7	12345--	12345-7
75	12-45--	Open	12345-7	1—45--	12345-7	12345--	12345-7
100	12-45--	Open	12345-7	1—45--	12345-7	12345--	12345-7
125	Open	Open	12345-7	1—45--	12345-7	12345--	12345-7
150	12-45--	Open	12345-7	1—45--	12345-7	12345--	12345-7
200	12-45--	Open	1234567	12-45--	12345-7	12345--	12345-7
300	12-45--	1—4—7		1—4---	1234—7	1234---	1234—7
400	12-4---	1—4—7		12-4---	1234—7	1234---	1234—7
600	12-4---	1—4—7		12-4---	1234—7	1234---	1234—7
800	12-4---	1—4—7		12-4---	1234—7	1234---	1234—7
900				12-4---	1234—7	1234---	1234—7
1000	12-4---	1—4—7		12-4---	1234—7	1234---	1234—7
1100	12-4---	1—4—7		12-4---	1234—7	1234---	1234—7
1200	12-4---	1—4—7					
1300	12-4---	1—4—7		12-4---	Open	1234---	1234—7
1500	12-4---	1—4—7		12-4---	1234—7	1234---	1234—7
1800	12-4---	1—4—7		12-4---	1234—7	1234---	1234—7
2000	12-4---	1—4—7		12-4---	1234—7	1234---	1234—7
2500	12-4---	1—4—7		1—4---	1234—7	1234---	1234—7
2800	12-4---	1—4—7		1—4---	1234—7	1234---	1234—7
3000	12-4---	1—4—7		1—4-6-	1234-67	1234-6-	1234—7
3500	12-4---	1—4—7		12-4-6-	1234-67	1234-6-	1234—7
bottom	12-4-6- (3587dbar)	1—4-67 (3664dbar)		12-4-6- (3670dbar)	1234-67 (3769dbar)	1234-6- (3739dbar)	1234—7 (3575dbar)

P257: Sampling levels for each station (IfM Kiel Rosette, Station/Cast)

1 Oxygen **2** CO2 **3** Trace metals **4** Nutrients **5** Chlorophyll_a **6** Salinity
7 Yellow substance

Pressure [dbar]	17/15	18/16	19/17	20/18	21/19	22/20	23/21
10	123456-	1234567	12345-7	12345-7	1234567	12-4567	1234567
25	12345--	12345-7	12345-7	12345-7	12345—7	12-45-7	12345-7
50	12345--	12345-7	12345-7	12345-7	12345-7	12-45-7	12345-7
75	12345--	12345-7	12345-7	12345-7	12345-7	12-45-7	12345-7
100	12345--	12345-7	12345-7	12345-7	12345-7	12-45-7	12345-7
125	12345--	12345-7	12345-7	12345-7	12345-7	12-45-7	12345-7
150	12345--	12345-7	12345-7	12345-7	12345—7	12-45-7	12345-7
200	12345--	12345-7	12345-7	12345-7	12345-7	12-45-7	12345-7
300	1234---	1234—7	1234—7	1234—7	1234—7	12-4—7	1234—7
400	1234---	1234—7	1234—7	1234—7	1234—7	12-4—7	1234—7
600	1234---	1234—7	1234—7	1234—7	1234—7	12-4—7	1234—7
800	1234---	1234—7	1234—7	1234—7	1234—7	12-4—7	1234—7
900	1234---	1234—7	1234—7	1234—7	1234—7	12-4—7	1234—7
1000	1234---	1234—7	1234—7	1234—7	1234—7	12-4—7	1234—7
1100	1234---	1234—7	1234—7	1234—7	1234—7	12-4—7	1234—7
1200							
1300	1234---	1234—7	1234—7	1234—7		12-4—7	1234—7
1500	1234---	1234—7	1234—7	1234—7		12-4--7	1234—7
1800	1234---	1234—7	1234—7	1234—7			
2000	1234---	1234—7	1234—7	1234—7			
2500	1234---	1234—7	1234—7				
2800	1234---	1234—7	1234—7				
3000	1234-6-	1234-67	1234—7				
3500	1234-6-	1234-67					
Bottom	1234-6- (3652dbar)	1234-67 (3509dbar)	1234567 (3040dbar)	1234567 (2327dbar)	1234-67 (1299dbar)	12-4-67 (1751dbar)	1234-67 (1525dbar)