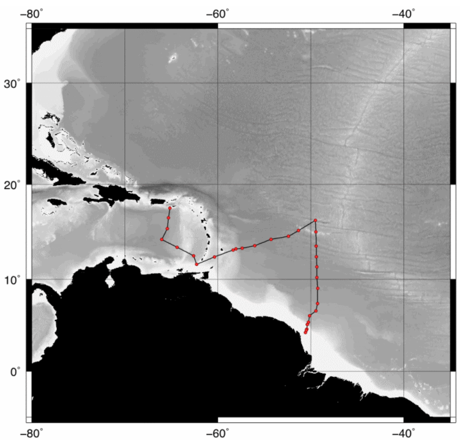
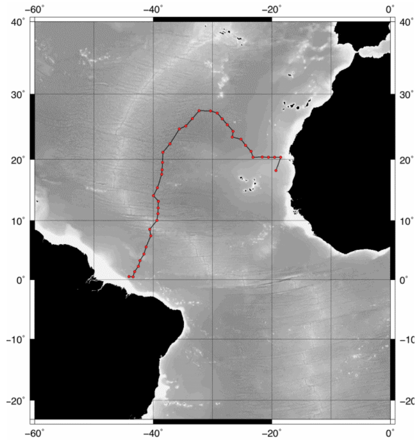
CRUISE REPORT: ATAS1-3

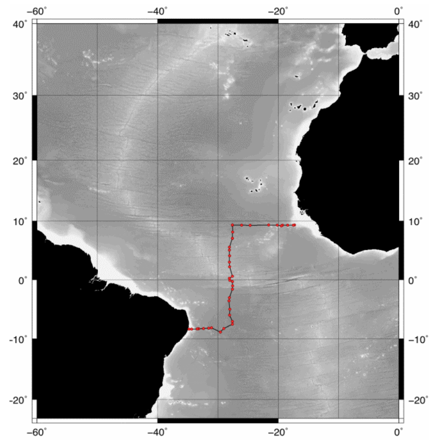
(Updated DEC 2011)



ATAS1



ATAS2



ATAS3

Highlights

Cruise Summary Information

WOCE Section Designation	**ATAS1**	**ATAS2**	**ATAS3**
Expedition designation	**316N198212_1**	**316N198212_2**	**316N198301**
Chief Scientists	**Jorge L. Sarmiento,** Princeton Univ.	**Claes G.H. Rooth,** Univ. of Miami	**Taro Takahashi,** LDGO
Dates	1982 DEC 01 - 1982 DEC 22	1982 DEC 29 - 1983 JAN 24	1983 JAN 30 - 1983 FEB 18
Ship	*R/V Knorr*		
Ports of call	San Juan, Puerto Rico - Belém, Brazil	Belém, Brazil - Dakar, Senegal	Dakar, Senegal - Recife, Brazil
Geographic Boundaries	27° 51.4' N 66° 2.1' W 17° 28.4' W 8° 38' S		
Stations	30	39	38
Floats and drifters deployed	0		
Moorings deployed or recovered	0		

Recent Contact Information:

Jorge L. Sarmiento
Princeton University
306A Sayre Hall • M44 Guyot Hall • Princeton • New Jersey • 08544
Phone: (609) 258-6585 • Email: jls at princeton.edu

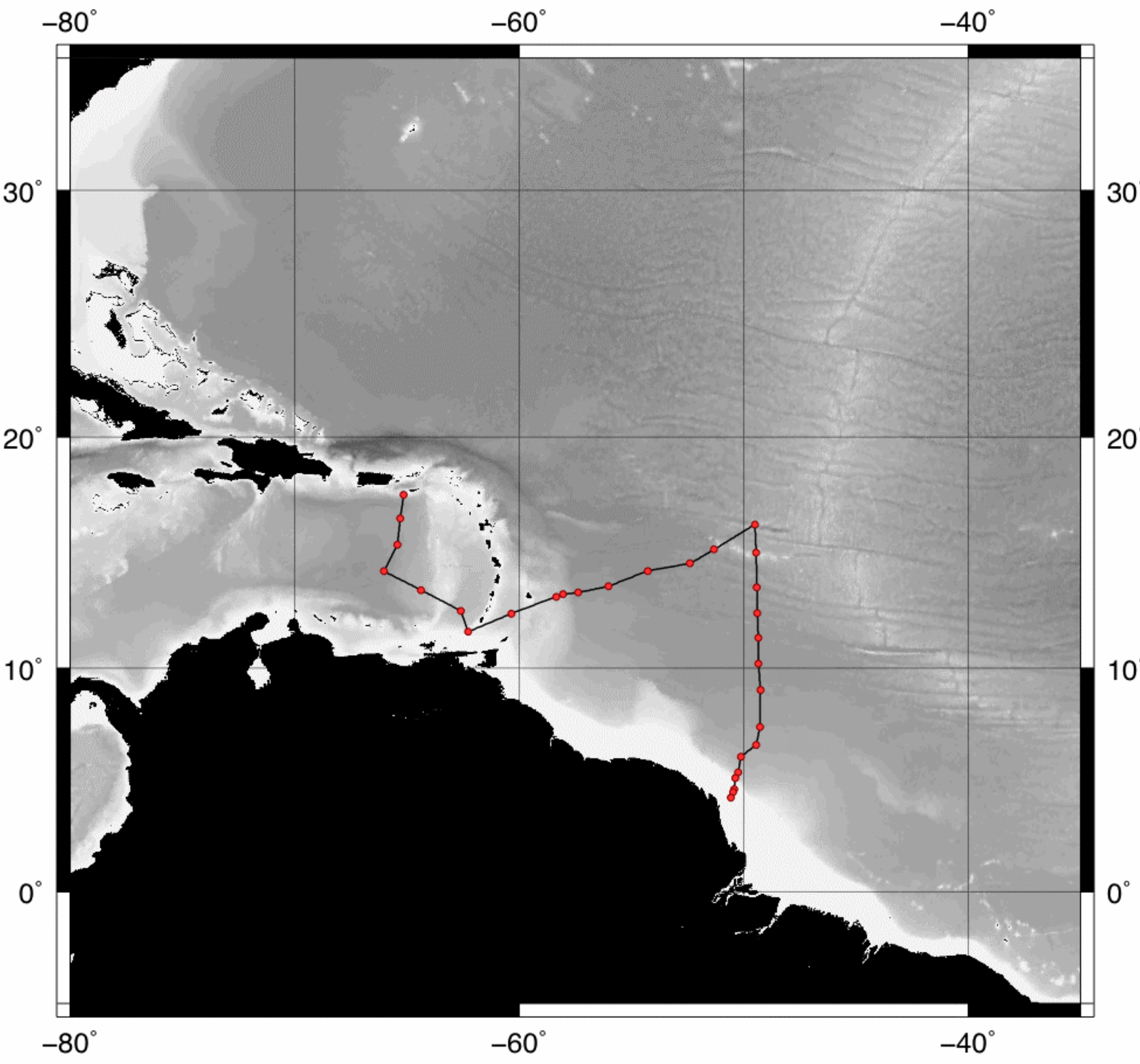
Claes G.H. Rooth
RSMAS/MPO • University of Miami
4600 Rickenbacker Causeway • Miami, FL 33149
Phone: 305-361-4162 • Fax: 305-361-4696 • Email: crooth@rsmas.miami.edu

Taro Takahashi
Lamont-Doherty Earth Observatory
101Comer • 61 Route 9W - PO Box 1000 • Palisades • NY • 10964-8000
Phone: 845-365-8537 • Fax: 845-365-8155 • Email: taka@ldeo.columbia.edu

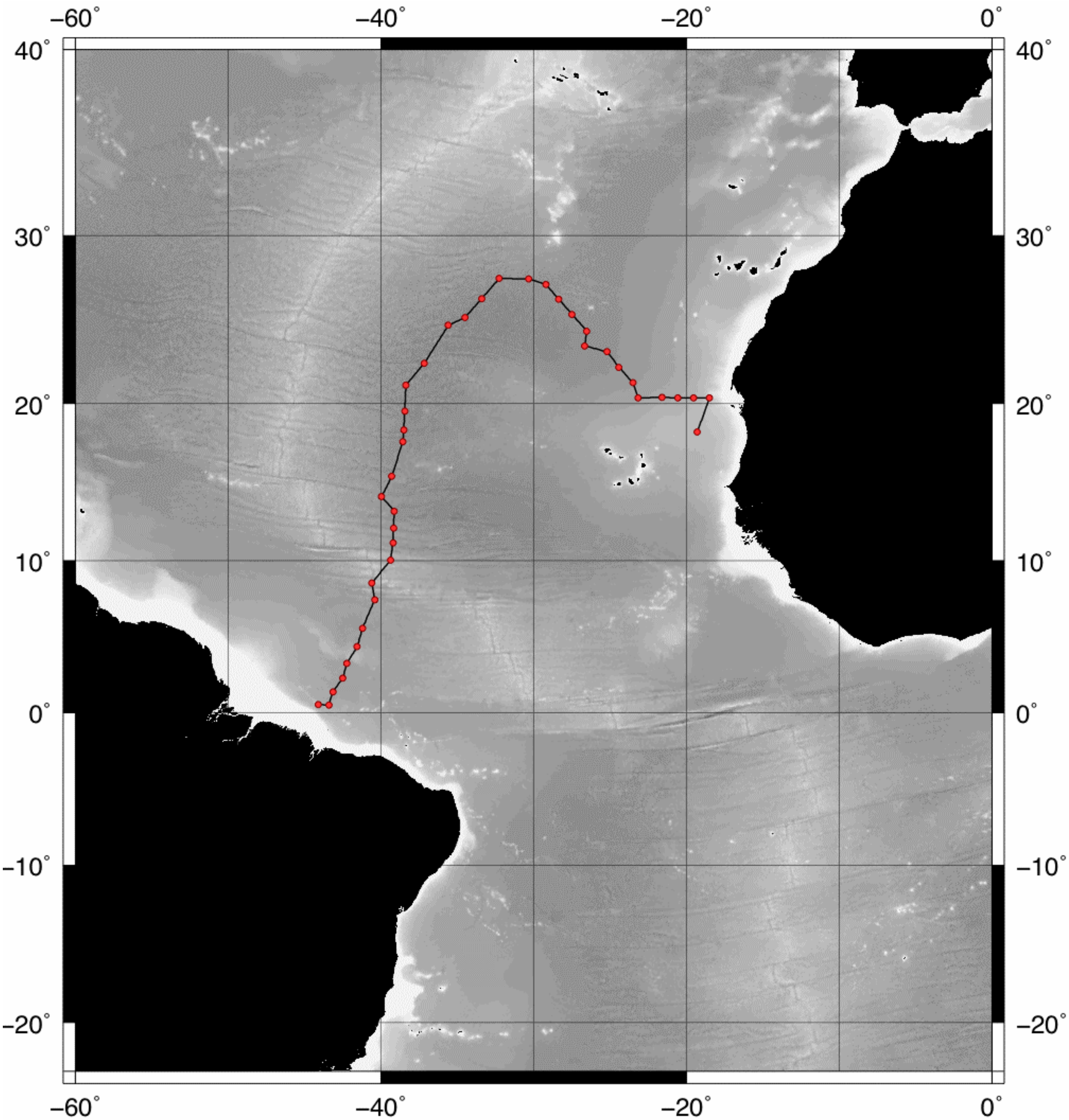
LINKS TO SELECT TOPICS

Shaded sections are not relevant to this cruise or were not available when this report was compiled.

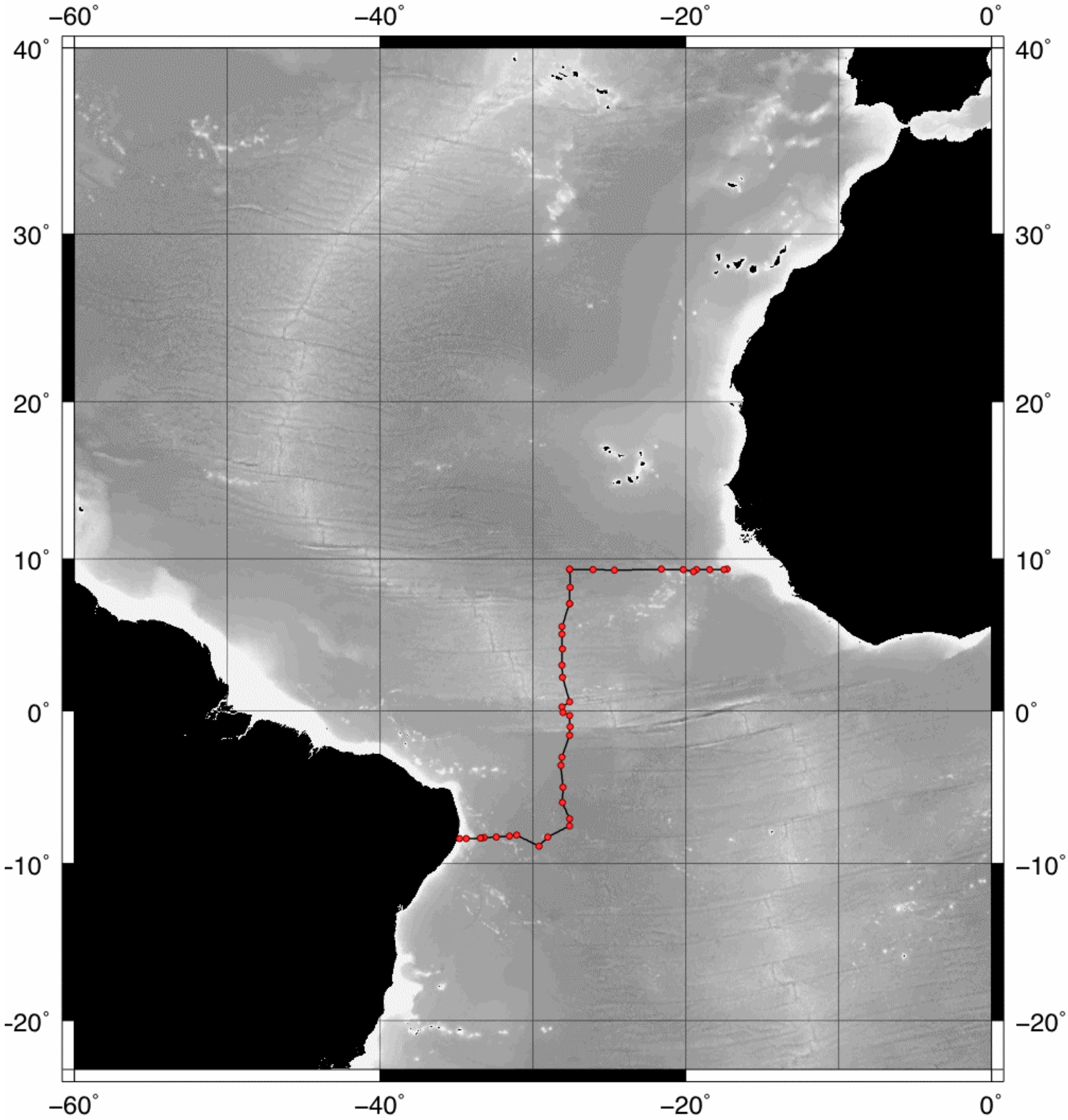
ATAS1 • 316N198212_1 • Sarmiento • *R/V Knorr* • 1982



ATAS2 • 316N198212_2 • Rooth • *R/V Knorr* • 1982



ATAS3 • 316N198301 • Takahashi • *R/V Knorr* • 1983



TRANSIENT TRACERS IN THE OCEAN

TROPICAL ATLANTIC STUDY

1 December 1982 - 18 February 1983

Shipboard Physical and Chemical Data Report

Data Report Prepared by

Physical & Chemical Oceanographic Data Facility
Scripps Institution of Oceanography
University of California, San Diego

May 1986

Sponsored by

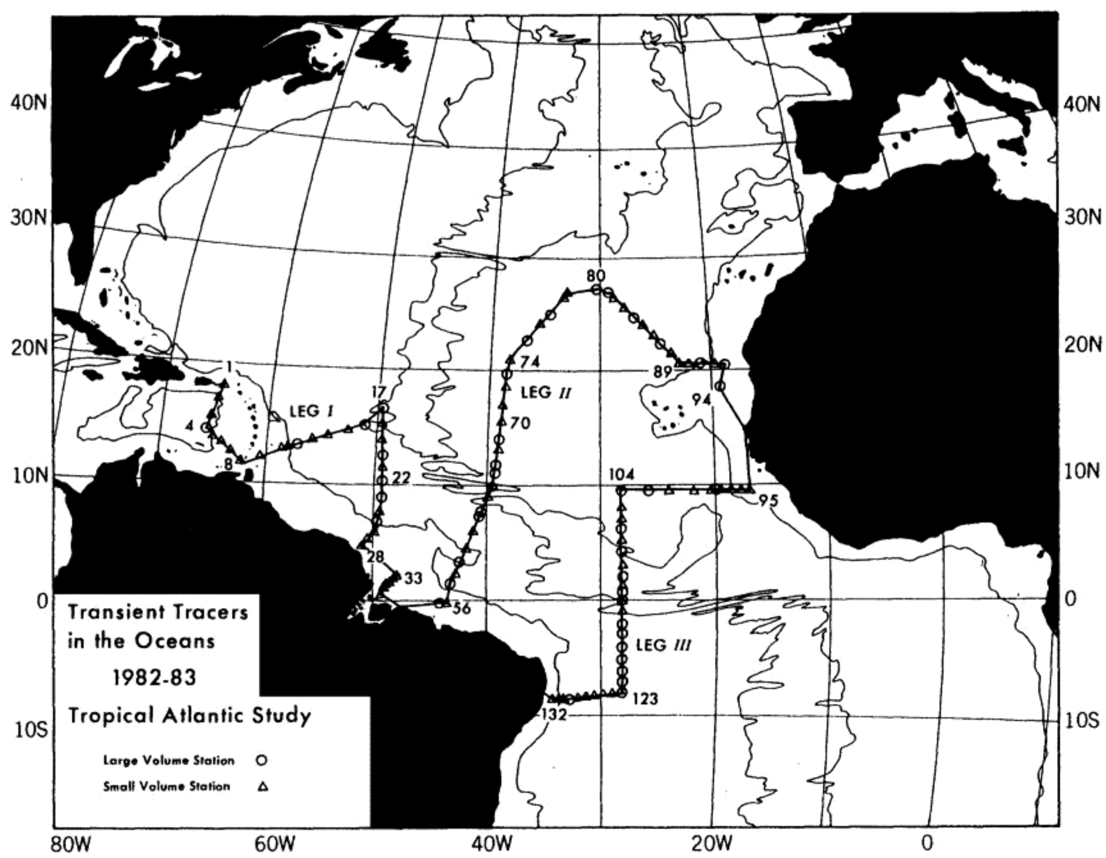
National Science Foundation
Grant OCE 81-17844

SIO Reference No. 86-16
PACODF Publication No. 222

Transient Tracers in the Ocean
Tropical Atlantic Studies

Itinerary of the *RV Knorr*

	Depart	Arrive
Leg I	San Juan, Puerto Rico 1 December 1982	Belém, Brazil 22 December 1982
Leg II	Belém, Brazil 29 December 1982	Dakar, Senegal 24 January 1983
Leg III	Dakar, Senegal 30 January 1983	Recife, Brazil 18 February 1983



Introduction

In this report are published the shipboard hydrographic and radon data taken during the Tropical Atlantic Study of the Transient Tracers in the Ocean program (TTO-TAS). Hydrographic data were taken by the Physical and Chemical Oceanographic Data Facility (PACODF) of Scripps Institution of Oceanography. The radon data included in the final section of this report were taken by William Smethie of Lamont-Doherty Geological Observatory.

The field work was carried out aboard *RV KNORR*, operated by Woods Hole Oceanographic Institution (WHOI), on an expedition of 3 legs. The expedition began at San Juan Puerto Rico, leaving port on 1 December 1982, and terminated on 18 February 1983, in Recife Brazil. During the expedition many of the Geochemical Ocean Section Study (GEOSECS) stations taken in 1972 were reoccupied, and many of the parameters measured during the GEOSECS program were sampled again, some by the same personnel, some even with the same equipment, and of course, on the same ship. The chief scientists, most of whom were heavily involved in the GEOSECS program, prepared brief narratives for each leg which were published as introductions to the preliminary leg reports, and which are reproduced in the following section of this final report.

Many of the potential users of this report are familiar with GEOSECS data reports, the GEOSECS Atlas series [1], and the units and parameters used therein. While the tabular data format appearing here is similar to that found in GEOSECS publications, potential temperature and density-related parameters (sigma theta, 2, 4) published in this report will not be directly comparable with the same GOSECS parameters. The specific gravity equations of Cox et al. [2] and compressibility of Ekman [3] were used throughout the GEOSECS program to calculate sigma theta and sigma 4. In the early stages of planning TTO, it was decided to use the new International Equation of State [4] from which absolute densities may be calculated rather than specific gravities. The sigma quantities in this report, as in the TTO North Atlantic Study report, are therefore potential densities in units of kilograms/cubic meter, from which 1000 has been subtracted.

Potential temperatures in the GEOSECS data were calculated according to Helland-Hansen [5]. In this report that parameter has been computed using Fofonoff's integration of Bryden's adiabatic temperature gradient equation [6]. The same routine is used to compute the temperature of water moved adiabatically to 2000 or 4000 decibars, for the subsequent calculations of sigma 2 or sigma 4.

A comparison of various calculations of sigmas, including the Knudsen equations [7], and potential temperatures for NAS Station 6 was published in Volume I, TTO-AS Preliminary Hydrographic Data Report. Typical differences are as follows:

P	T	S	POT T	SIG 0	SIG 2	SIG 4	Sources	
8	21.509	36.420	21.507	25.437	33.824	41.853	F-B	IES
			21.507	25.455	33.857	41.879	H-H	COX
				25.452	33.854	41.874		KNUD
2493	3.408	34.967	3.201	27.840	36.972	45.698	F-B	IES
			3.197	27.876	37.034	45.759	H-H	COX
				27.862	37.020	45.744		KNUD
5316	2.238	34.877	1.737	27.894	37.107	45.908	F-B	IES
			1.727	27.927	37.168	45.968	H-H	COX
				27.916	37.156	45.957		KNUD

Rosette cast **pressure** and **temperature** data given in this report were normally taken from the corrected CTD output at the time the bottles were tripped. Reversing thermometers provided pressure and temperature for Gerard and most shallow radon casts. **Salinity** has been calculated according to the equations of the Practical Salinity Scale of 1978 [8] from either CTD conductivity, temperature, and pressure, or conductivity ratio determined from bottle samples analyzed in duplicate with a Guildline Model 8400 laboratory salinometer. **Dissolved oxygen** was determined by a modified Winkler titration [9]. **Nutrients** (silicate, phosphate nitrate and nitrite) were analyzed using a modified Technicon AutoAnalyzer and the methodologies employed during GEOSECS [1]. Alkalinity and Total CO2 were determined by potentiometric acid titration with hardware developed for the GEOSECS Indian Ocean Expedition [10] and the equations of Bradshaw and Brewer [11].

Casts taken during the expedition can generally be categorized in two types, small and large volume. Small volume casts employed a PACODF-designed multisampler based on a General Oceanics rosette pylon. On the multisampler were mounted 24 PVC sampling bottles of 10 liters volume, a Neil. Brown Mark III CTD modified by PACODF, and a pinger. On occasional stations 30 liter Niskin bottles were deployed serially on the hydro wire for collection of surface radon samples.

Large volume stations included the normal small volume sample acquisition plus the collection of samples for shorebased analysis of **radiocarbon**, Ra–228, Kr 85, and infrequently, Ar–39. These samples were collected in 270 liter stainless steel Gerard barrels deployed on the ship's trawl wire. Usually, 9 barrels were used on each cast. A 10 liter Niskin bottle was mounted on the outside of each Gerard barrel and was linked to the Gerard closure mechanism so that the Gerard could not close without tripping the Niskin bottle as well.

The original intent of this system was to provide a verification of the Gerard tripping depths via the reversing thermometers mounted on the Niskin bottle, and by comparison of salinities taken from both samplers. For the TTO program a decision was made to draw the standard rosette samples from the Niskins used on large volume casts rather than interpolate property values from the rosette casts as was done during the GEOSECS program.

Following the protocol established during the GEOSECS program, all samples were given a sample number which is equal to the cast X 100 plus the bottle number. For convenience, sampling bottles were numbered as follows:

1–24	10 liter rosette bottle
25–36	30 liter rosette bottle
40–47	10 liter bottle mounted on Gerard barrel
50–65	5 liter rosette bottle
70–78	30 liter bottle deployed on hydra wire
85–97	270 liter Gerard barrel

Throughout the data report alphabetic characters may be found in the tabular data. These characters have the following meaning.

D	A salinity value, normally from a bottle sample has been taken from CTD records.
H	A pressure or temperature value has been calculated from thermometric sources rather than from the CTD as is normally the case on rosette casts.
U	A data value is suspect, although no obvious reason has been found.

Listings of the subroutines used in the calculation of various parameters are included in Appendix I.

The hydrographic and CTD work was **supported by the National Science Foundation**, Division of Ocean Science Section, Grant #OCE 81−17844 to Physical and Chemical Oceanographic Data Facility, Scripps Institution of Oceanography.

Robert T. Williams
Acting Project Director
PACODF

References

[1] A.E. Bainbridge, GEOSECS Atlantic Expedition Volume 1, Hydrographic Data, National Science Foundation (1981) 038−000−00491−3.

A.E. Bainbridge, GEOSECS Atlantic Expedition Volume 2, Sections and Profiles, National Science Foundation (1980) 038−000−00435−2.

W.S. Broecker, D.W. Spencer, H. Craig, GEOSECS Pacific Expedition Volume 3, Hydrographic Data, National Science Foundation (1982) 038−000−00503−1.

H. Craig, W.S. Broecker, D.W. Spencer, GEOSECS Pacific Expedition Volume 4 Sections and Profiles, National Science Foundation (1981) 038−000−00496−4.

R.F. Weiss, W.S. Broecker, H. Craig D.W. Spencer GEOSECS Indian Ocean Expedition Volume 5, Hydrographic Data, National Science Foundation (1983) 03−000−00525−1.

D.W. Spencer W.S. Broecker, H. Craig, R.F. Weiss, GEOSECS Indian Ocean Expedition Volume 6, Sections and Profiles, National Science Foundation (1982) 038−000−00515−4.

H.G. Ostlund, H. Craig W.S. Broecker, D.W. Spencer, GEOSECS Atlantic Pacific, and Indian Oceans Expedition Volume 7, Shorebased Data, National Science Foundation (In press).

[2] R.A. Cox, N.J. McCartney, and F. Culkin, The specific gravity/salinity/temperature relationship in natural seawater, Deep Sea Research 17 (1970) 679−689.

[3] V.W. Ekman, Die Zusammendruckbarkeit des Meerwassers nebst einigen Werten fur Wasser und Quecksilber, Publications de Circonstance Conseil Permanent international pour l'exploration de la Mer 43 (1908) 1−47.

[4] F.J. Millero, C.T. Chen, A. Bradshaw, and K. Schleicher, A new high pressure equation of state for seawater, Deep Sea Research 2 (1980).

[5] B. Helland−Hansen, The Ocean Waters Intern. Rev. Gee. Hydrobiol. Hydrogr., Suppl. to Bd. III, Ser.1, H.2 (1912) 1−84.

[6] N.P. Fofonoff, Computation of potential temperature of seawater for an arbitrary reference pressure, Deep Sea Research 24 (1980) 489−491.

[7] N. Knudsen, C. Forch, and S.P.L. Sorensen, Berichte uber die Konstantenbestimmungen zur Auftellung der Hydrographischen Tabellen. Vgl. Danske Videnskab. Selskabe, Skrifter, Naturvidenskab. math, Afdel. XII 1 (1902) 2−151.

[8] E.L. Lewis, The Practical Salinity Scale 1978 and its antecedents, IEEE J. of Oceanic Eng. OE−5 (1980) 3−8.

[9] J.H. Carpenter, The Chesapeake Bay Institute technique for the Winkler dissolved oxygen method, Limnology and Oceanography 10 (1965) 141−143.

[10] D.L. Bos, R.T. Williams, History and development of the GEOSECS alkalinity titration system, Workshop on Oceanic CO2 Standardization, November 30–December 1, 1979, Carbon Dioxide Effects Research and Assessment Program, CONF–7911173, U.S. Department of Energy (1982) 42–59.

[11] ALL. Bradshaw, P.O. Brewer, DBK. Schaefer, R.T. Williams, Measurements of total carbon dioxide and alkalinity by potentiometric titration in the GEOSECS Program, Earth and Planetary Science Letters 55 (1981) 99–115.

Leg I

1 December – 22 December 1982

1. General Description

Leg 1 of the Tropical Atlantic Study was carried out during the period December 1, 1982 to December 22, 1982, between the ports of San Juan, Puerto Rico and Belém, Brazil. The leg consisted essentially of four sections. The first section took us southeast across the Caribbean Basin. The second section vent east–northeast across the deep western basin of the Atlantic up to the Mid–Ocean ridge. The third section went south across the North Equatorial Current salinity front. The fourth part of the leg took us onto the Brazilian continental shelf and then south and into the main channel of the Amazon estuary.

The *KNORR* departed San Juan on time after several days of sustained effort by the PACODF group and others to set the ship up for the expedition. Our Brazilian Navy observer, Lt. Jair Xavier da Silva arrived just in time for our departure.

We had been alerted to the fact that there had been a considerable spill of C–14 on the ship on the leg prior to ours. Gate Ostlund was able to complete a swab test while we were still in San Juan that showed that C–14 activities were high and that the contamination was far more extensive than we had been led to believe. As a consequence, we swabbed the entire laboratory area with dilute acid and took the C–14 extractors apart in order to bathe them in a dilute acid bath. The scientific crew did a superb job, particularly Tim Field, who had to strip down and reassemble the extractors and then do a series of blank runs to verify that we had achieved our goals. The blank runs and a subsequent swab test, carried out during a short stop in Barbados, showed that the contamination problem was apparently taken care of by our efforts. This experience demonstrated the great value and importance of the Ostlund swabbing procedure.

The first station was carried out on the day following our departure from San Juan. We had the misfortune to lose a sampling rosette during this station. The station was completed with a hydrocast while the spare rosette was assembled for the next station. All subsequent work was completed without any further technical problems. The PACODF group did an excellent job with able assistance from four people who had come along for the Amazon work from Harvard University, MIT and Princeton University. We were able to complete most of the work that had been planned except for some reduction of the track that had to be done due to the slow cruising speed against the winds and currents during the first part of the leg. The excellent support of the officers and crew of the *KNORR* is gratefully acknowledged, as is the generosity of the Brazilian Government in allowing us to work in their territorial waters. Lt. Jair Xavier da Silva made an excellent shipmate who showed a great deal of interest in all that was going on around him. Our results are going to be of far greater benefit because o the opportunity we had to carry our sections onto the Brazilian continental shelf and into the Amazon estuary.

2. Highlights of Preliminary Results

The fresh surface mixed layer waters of the Caribbean and East Atlantic were shown to have high silica content, consistent with a strong Amazon River component. We carried out extra nutrient sampling in this water in order to trace its distribution in greater detail. This work should prove of great interest, particularly as it was carried out in conjunction with a detailed study of the Amazon estuary.

The structure of the Subtropical Underwater salinity maximum and the Central Waters below that were consistent with previous studies of these water masses. The detailed sampling of our station configuration was supplemented by XBTs taken approximately every 30 to 50 kilometers. We observed multiple staircase structures at they bas of the Central Waters. The salinity front in the North Equatorial Current was successfully crossed on the third section of the leg. The freon measurements throughout this depth range showed the structure that one would expect from the tritium observations of the 1972 period. The greater detail of this survey will permit a far more careful study of the structure of the transient tracer fields.

The Antarctic Intermediate water was detected at a depth of 600–1000 meters. The freon signal in this water was at background. The core of the Antarctic Intermediate Water strengthened perceptibly as we vent towards the mouth. Just below this was the upper North Atlantic Deep Water. This water type had a strong freon signal, consistent with the maximum observed at the same depths in tritium on previous cruises. The freon at this depth was observed even as we neared the equator.

We were very impressed to find a weak freon signal in the deeper North Atlantic Deep Water Western Boundary Current even as far south as our section off Brazil at approximately 5 to 10 degree. north. This clearly demonstrates that the tracer signals which have been observed in the North American Basin off the Blake–Bahama Outer Ridge as well as north of the Greater Antilles have managed to advect out of the Basin and move quite far to the south.

There was no clear evidence of freon in the Antarctic Bottom Water during the preliminary shipboard analysis.

The Amazon estuary phase of the cruise wag completed without any major difficulties other than the usual navigational problems encountered when working in such a small area without any shorebased navigational aids. The conditions found during our study were quite different from those of an earlier study in that nutrient removal from river water was occurring at a much higher salinity than previously observed. This was apparently due to the high turbidity encountered on this expedition.

Jorge L. Sarmiento

Peter Rhines

William N. Smethie, Jr.

Leg II

29 December 1982 – 24 January 1983

1. General Description

The objectives for this leg of the TAS Expedition were:

[1] To fill in a major data gap in the upper water column tritium distribution in the central subtropical and tropical North Atlantic.

[2] To provide a first systematic set of freon concentration profiles in the same region.

[3] To illuminate abyssal circulation and exchange conditions by C–14 and Ra–228 distribution studies in the interhemispheric deep water passage in the West Atlantic, and along the eastern slope of the Mid–ocean ridge north of the Vema Passage.

[4] To provide two general chemical sections crossing the southerly boundary of the Central Atlantic salt tongue in the Central Waters and of the expected shadow zone edge for the wind driven circulation in the main thermocline.

[5] To reach into the region of influence of the NW African upwelling zone in order to help assess its significance as an input zone for trace substance contamination in the Atlantic main thermocline.

The *KNORR* departed Belém in fair weather on the assigned day, hurried on in fact, by the imminent docking of a giant bulk grain carrier at the silo dock where we had been tied up. Fairly strong head winds and adverse swell conditions during the first two weeks held our rate of steaming between stations to barely above eight knots, causing a decision to truncate the NW corner of the originally planned track. Time was later recovered under light wind conditions, allowing a track diversion in a more favorable direction perpendicular to a steep section of continental rise off Cape Blanc, and an enhanced station density there, compared to the original plan. Fortuitously, the data indicates that these track revisions probably lead to a significant enhancement of the value of the final leg segment in towards Africa.

A total of forty Rosette stations were occupied, fifteen of them accompanied by large volume samples from twenty–six Gerard casts. Thirteen radon casts were also made, in general at the large volume stations (see map).

Technically, the whole operation vent quite smoothly in spite of severe resource limitations both in personnel and in computer equipment in the CTD operations. This can be ascribed not only to the usual competent performance of the SIO–PACODF Group, but also, in a large degree, to the help rendered on the deck watches by the CalTech students, Don Piepgras and Mary Stordal. Without it the workload on the PACODF Group would have been quite excessive.

The value of the satellite communication link to home bases for the clearing up of minor technical problems was repeatedly demonstrated.

Finally, the excellent support of the officers and crew of the *KNORR* must be acknowledged as an essential element in the smooth progress of the scientific work.

2. Some Highlights of the Preliminary Results.

One can consider this leg as being composed of three sections, viz. the Western Basin transect, Stations 55–62; the Eastern Ridge Slope Transect, Stations 63–79 and the Shadow Zone Transect, Stations 80–94.

During the Western Basin transect, our attention was captured by the strong baroclinicity along the Continental Rise, even just at the equator. Water as cold as $\theta = 0.9°C$ was found between the equator and a latitude of about 4°N, in a depth range of 4300 to 4400m. A distinct reversal in baroclinicity was observed at $\theta = 1.6$ to 1.7°C, indicating that the maximum inflow velocity occurs in that temperature range.

The coldest potential temperature observed in the Eastern Basin Transect (just north of the Vema fracture zone) was 1.745°C. A slight rise in dissolved oxygen concentration below a depth of 4000m was observed all along the Rise section. It remains to be considered to what degree a westward intensified bottom circulation and leakage through the ridge may be contributing to this phenomenon. Comparison with the Eastern Basin GEOSECS data, as well. as with the final section of this leg, show that in the central and eastern parts of this Basin, the deepest layers show oxygen concentration decrease, rather than increase.

The freon data on the first two sections of this leg indicate a minimum concentration at the AAIW salinity minimum, with a distinct increase below it. The letter is associated with the relatively high salinity North Atlantic Central water. The deep freon signal was close to the detection limit everywhere except at the first few stations in the western boundary region. The intermediate freon minimum, on the other hand, gradually vanished along with the disappearance of the distinct AAIW signature.

A large anticyclonic thermocline eddy was encountered on the final section, at Station 84. Although it was impossible to devote the time required for a mesoscale survey, it was clear from the Station 84 data that this was an object comparable to the main eddy observed by Armi during Leg 2 of the TTO–NAS Expedition in 1981. The central density (Sigma 2) was almost identical, and the vertical extent comparable to that observed before. AOU values were slightly higher in the core bottle samples. Most exciting was the observation of an enormous **freon** signal, with a ratio of concentrations of F–11 and 12 suggestive of quite recent origin.

It is tempting, albeit impossible of proof, to speculate on the possible identity of the two eddies observed with an eighteen month time differential. The mean southward drift rate of about 1 cm/sec is certainly not unreasonable. More promising, however, is the prospect that between the various tracer signatures, we might discern a definite source for the eddy, and perhaps an approximate age.

The main points of interest in the final stations are two viz, the upwelling influence and the effect of bottom processes on the Cape Verde Plateau. As expected, we observed strong baroclinicity in the upper several hundred meters, as well as strong lateral intrusion signatures. A clear **pCO2** maximum generated in the bottom boundary layer on the plateau was found, and surprisingly, a pronounced freon signature as well. The latter was quite anomalous in its composition strongly dominated by F–11. The observation of this contamination both at stations 93 and 94, and at the latter both in the bottom sample, and at a level about 120m up suggests a substantial source. A special bottom boundary layer experiment on the Cape Verde Plateau, with freon and radon profile mapping along with physical turbulence observations, seems to offer very exciting prospects.

Claus G.H. Rooth

Robert M. Key

Leg III

30 January 1983 – 18 February 1983

The *RV KNORR* departed Dakar, Senegal at 1300 local time on January 31, 1983, for Leg 3 of Tropical Atlantic Study, the Transient Tracers in the Oceans Project. The major objectives of this leg were to collect the hydrographic and atmospheric chemistry data along the following three transects:

A) an E–W transect between the African coast and the 28 degree W meridian along the 9°30'N parallel in the eastern basin of the North Atlantic Oceans

B) a N–S transect between 9°30'N and 8°S latitudes along the 28 degree W meridian across the equator; and

C) an E–W transect between the 28 degree W meridian and the coast of Brazil along the 8 degree S parallel.

The first six stations (Stations 95 through 100) define the E–W transect across the Kane Gap (approx. 4660 meters deep), which is the major conduit for the deep waters of the Sierra Leone Basin to the south and the Gambia Abyssal Basin the north. No benthic boundary layer characteristic of fast water movements along the sea floor was observed.

The E–W transect of the eastern Basin is defined by Stations 100 through 104. German Meteor Stations 11–505, which was occupied in 1981, was reoccupied at Station 103 at 9°30'N and 26°00' W, and 9 samples each for C–14, Ra–228 and tritium were collected in addition to a standard 22–bottle rosette cast.

The N–S transect along the 28 degree W meridian across the equator is defined by Stations 104 through 123. Stations 104 through 111 are located in the eastern Basin, Stations 112 through 114 are located in the vicinity of St. Paul's fracture zone, and Stations 115 through 123 are located in the western basin. In the depth range of 60 to 100 meters, high salinity tongues of the Subtropical Underwater originating in the northern and southern temperate latitudes were observed. The potential temperature (θ)–salinity (S) relationships observed at these stations are shown in Figure 1. The salinity values for Station 123 are to be read according to the scale shown, and those for all other stations are offset by 0.05 ‰ salinity each in order of decreasing station number. At Station 106 a salinity inversion is observed at a depth of about 400 meters (θ = 9.5°C), and a weak salinity signal is also seen at Station 107 at a similar depth and temperature. These features are characteristic of the interleaving of South and North Atlantic Central Waters originating off Africa. At greater depths of about 800 meters and potential temperature of about 5°C, the Antarctic Intermediate Water (AAIW) is observed. The largest horizontal gradients in the AAIW are observed in the southward transect of the Eastern Basin (Figure 2). The temperature at the salinity minimum for AAIW decreases from about 5.9°C at 9°30'N (Station 104) to 4.6°C a 00°30'S (Station 113), and the salinity value at the minimum decreases from 34.7 ‰ to 34.5 ‰ in this same distance. This boundary is the result of intensification of AAIW toward its source region as well as recirculation of these waters in the North Atlantic. Between the salinity minimum for the AAIW and the underlying salinity maximum which identifies the Upper North Atlantic Deep Water (UNADW), the temperature stays more or less constant. However, beginning at Station 109 an increase in potential temperature with depth is observed. This is due to the fact that the intermediate waters have cooled so that they are colder than the underlying UNADW.

Properties of UNADW were found to have the greatest variability in the Eastern Basin (Figure 3) with temperature and salinity increasing from 3.4 to 3.9°C and 34.95 to 34.97 ‰, respectively, along 9°30'N from the African coast to 28 degrees W. The most saline UNADW, 34.98 ‰, was observed at Station 114 and corresponded to minimum silicate (17.4 µM/kg) and maximum oxygen (248 µM/kg) . UNADW properties approaching these values were also observed at Station 130 near Brazil.

Beneath the UNADW, oxygen maximum associated with Middle and Lower North Atlantic Deep Waters were observed. These features were better developed in the Western Basin than the Eastern Basin and appeared most clearly at Stations 120–123. Here the oxygen content of the MNADW and LNADW was 252 and 257 µM/kg respectively, and the oxygen minimum separating these waters was 243 salinity for this depth zone (2400 to 3000 meters) and temperature range (2.0 to 2.7°C) is nearly constant, and a small salinity inversion develops at stations 120–123 between the oxygen minimum and the LNAW. This salinity feature occurs at a depth of about 2700 meters and a potential temperature of 2.6°. It is probably due to differing flow paths and rates of the over and underlying water masses. Below 2°C, the θ - S relationship is linear, representing a mixing line between the Antarctic Deep Water (AADW) with the overlying NADW. The highest silica concentration observed in the near bottom samples at these stations is about 120 µM/kg, indicating a strong influence of the AADW.

The atmospheric chemistry was also investigated during the N-S transect across the equator. It has been observed that the atmospheric concentration of CO2 and freons both decrease dramatically south of the Intertropical Convergence Zone (ITCZ) located between 5°30'N and 2°30'S. Atmospheric krypton samples were also collected during this transect. The air-sea gas exchange rate was investigated using Rn-222, a natural radioactive gas produced by decay of Ra-226 present in seawater. Within the equatorial doldrum zone, where the sea surface was like a mirror due to little or no wind, an extremely low gas exchange rate of 0.6 meters/day (compared to the global mean of 2.8 ± 0.3 meters/ day) was observed.

The E-W transect along the 8°S parallel is defined by Stations 123 through 132 located between 28 degrees W and the coast of Brazil. The observed θ - S relationship at these stations are shown in Figure 4. It is observed that the AAIW freshens westward to the Brazilian coast, and that the 0 - S curve between the NADW salinity maximum and the AABW becomes increasingly smooth to the Brazilian coast. The constant salinity zone located at temperatures between 2.0 and 2.7°C is observed only at the easternmost stations (Station 123, 126 and 127 in Figure 2). At three stations located over the continental slope of Brazil (Stations 129 through 131), strong freon signals were observed at a depth range of 1600 to 1900 meters (θ = 3.8 C and salinity 34.97 ‰ oxygen 240 µM/kg and silica = 18.1 µM/kg). The observed high freon concentrations indicate the this water is young (i.e. formed within the last 25 years or less), and the silica data indicate that this water is of the northern origin. The high oxygen concentration also supports a young age of this water. Thus, it is speculated that this water may represent a continuation of the southward flowing Western Boundary Undercurrent of the northern origin.

The expedition was completed on February 18, 1982 at Recife, Brazil.

Taro Takahashi

Curtis Collins

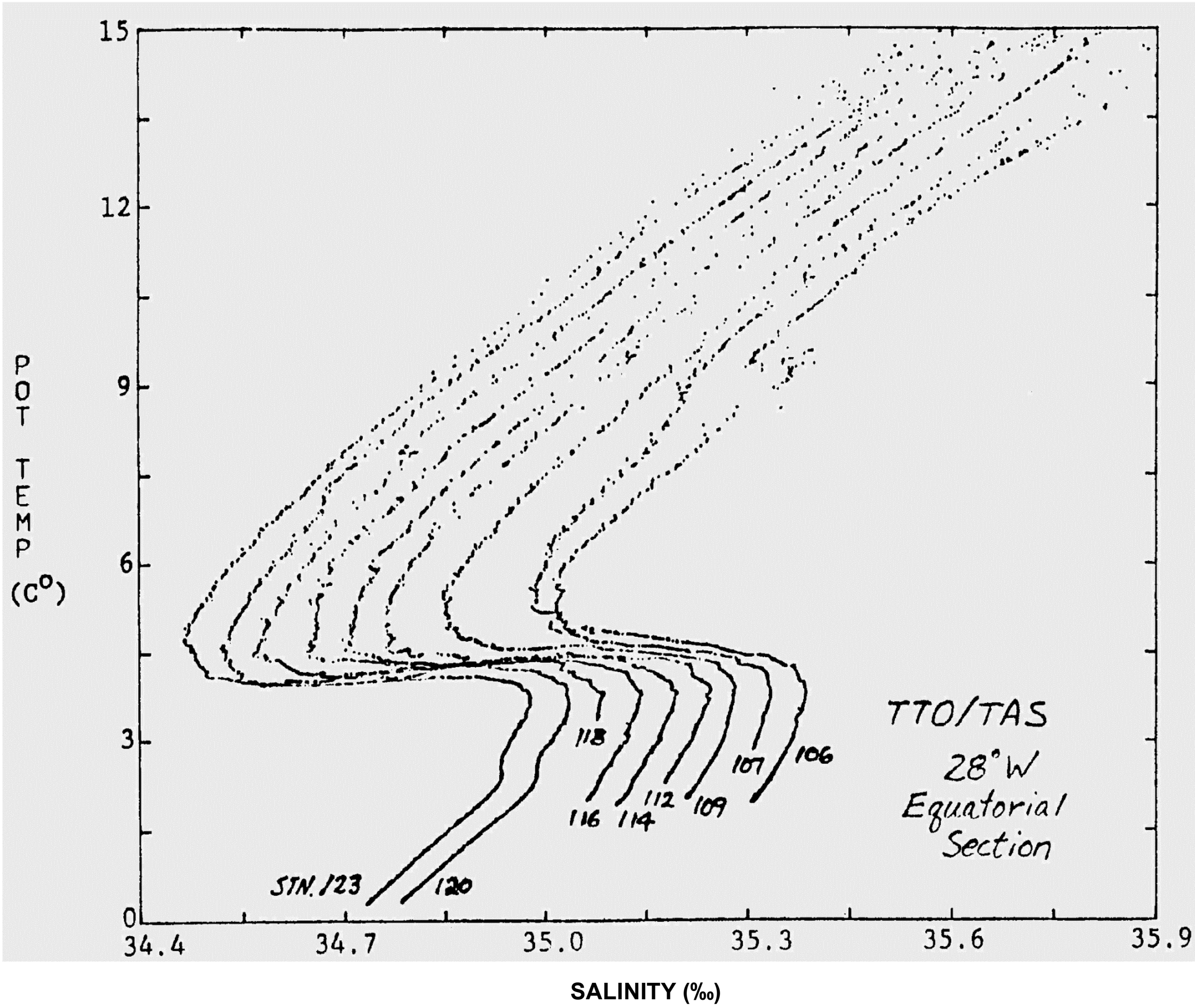


Figure 1: *The potential temperature-salinity relationships observed at Stations 106 through 123 along the 28°W meridian. Stations 106 through 111 are located in the eastern Basin, and Stations 112 through 123 are in the western Basin. Note that the salinity scale indicated applies only to Station 123, and the earlier stations are offset by 0.05 ‰ each in order of the decreasing station number.*

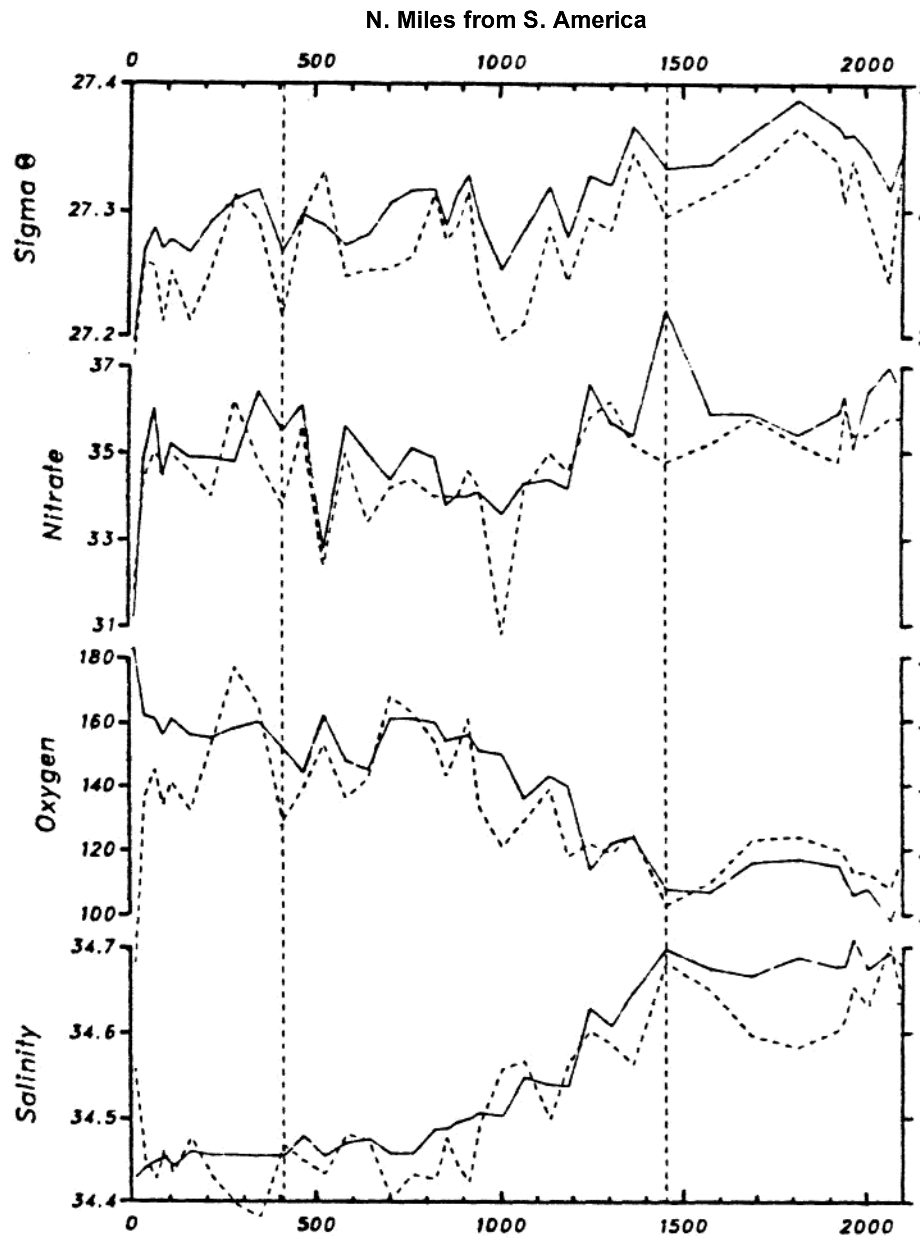


Figure 2: *Observed Properties of AAIW (quantities on right are plotted as dashed lines)*

N. Miles from S. America

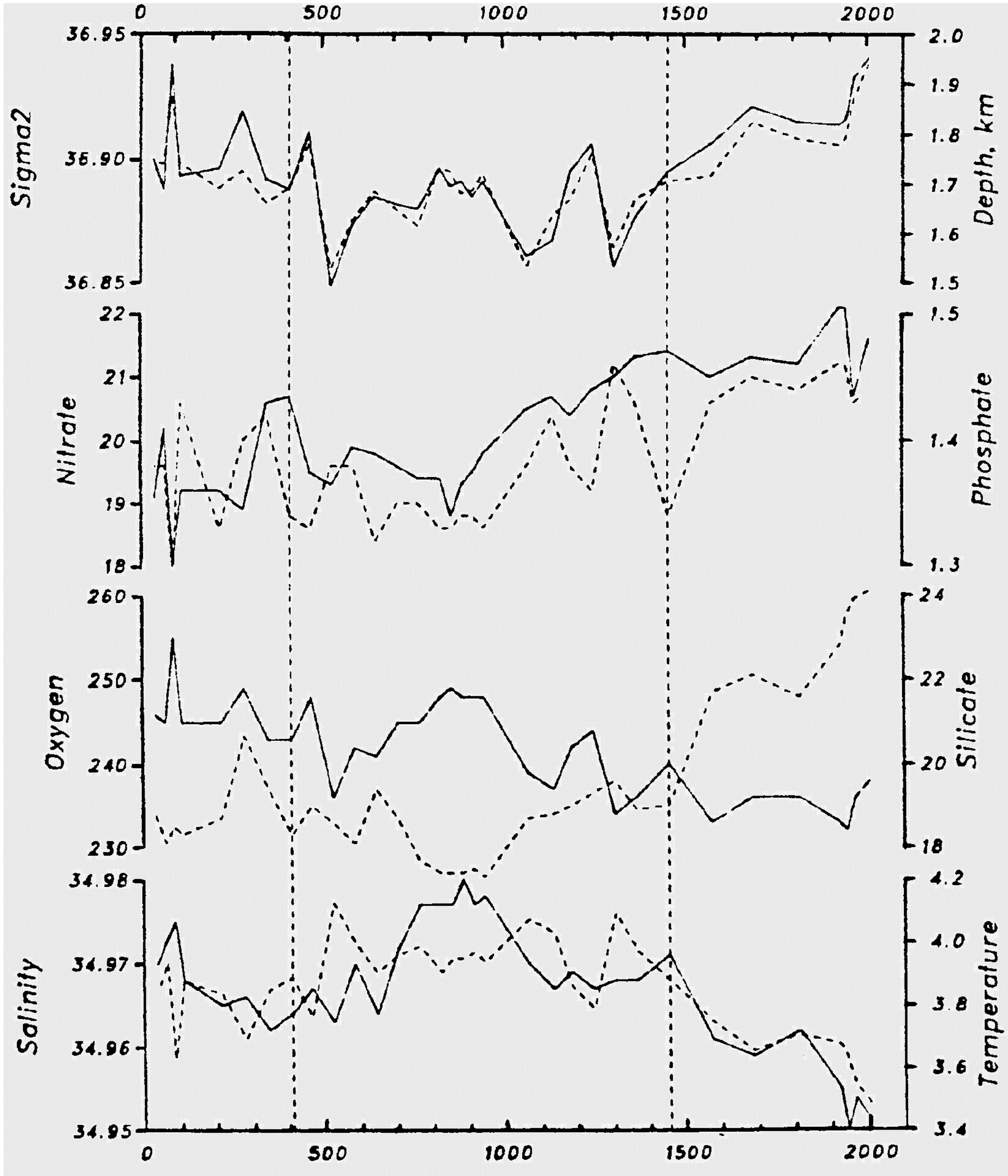


Figure 3: *Observed Properties of UNADW (quantities on right ore plotted as dashed lines)*

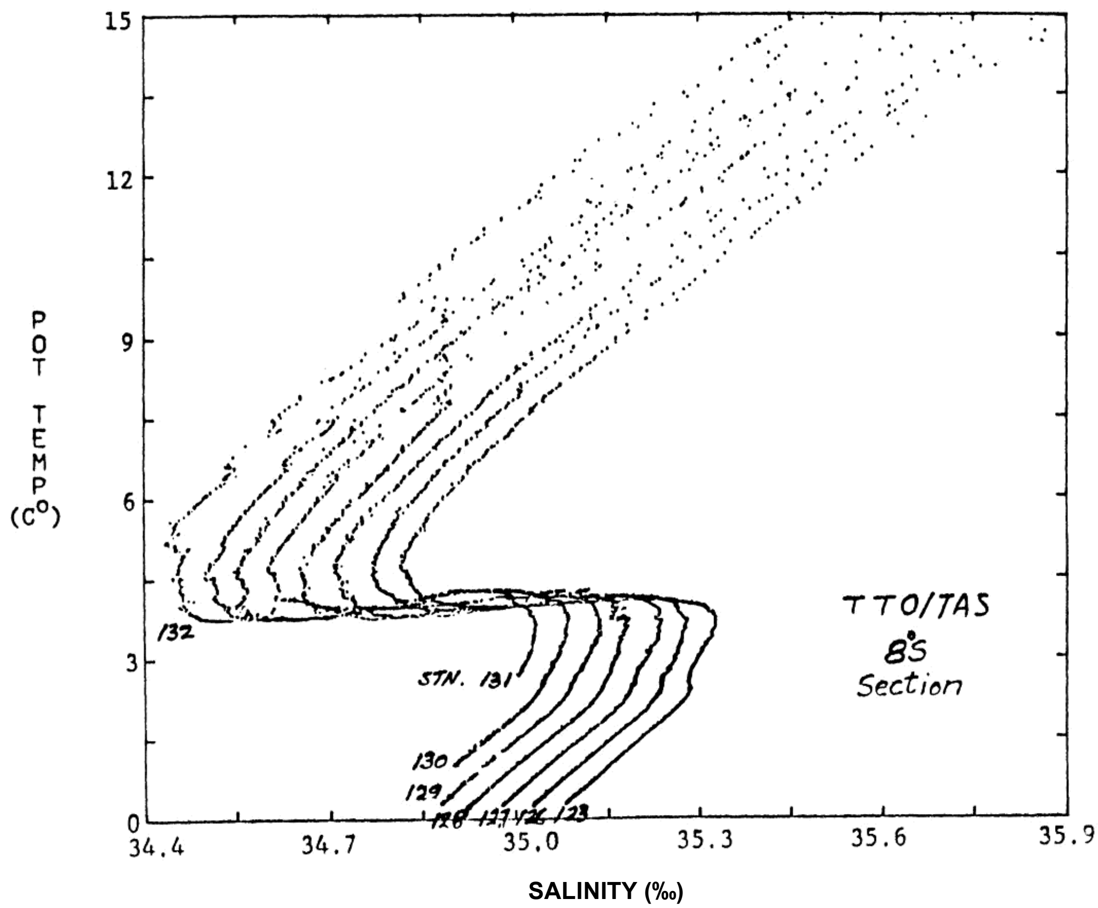


Figure 4: *The potential temperature–salinity relationships observed at Stations 123 through 132 along the 8°S parallel in the western Basin. Note that the salinity scale indicated applies only to Station 132, and the earlier stations are offset by 0.05 ‰ each in order o the decreasing station number.*

Scientific Programs

Participating Institutions	Principal Investigators	Scientific Programs	Total Samples Collected
Lamont–Doherty Geological Observatory of Columbia University	W.S. Broecker,	^{222}Rn	381
	T.–H. Pen g and	^{85}Kr	134
	W.M. Smethie, Jr.	and Modeling	
	T. Takahashi	pCO_2	1178
		and carbonate chemistry	603
Princeton University	J.L. Sarmiento	Modeling of tracers	
	J. L. Sarmiento,	^{228}Ra	437
	R.M. Key	^{226}Ra	485
	R.F. Stallard	Amazon River Chemistry	
Scripps Institution of Oceanography	R. F. Weiss	Chlorofluorocarbons	2282
	C.D. Keeling	Total CO_2	184
Physical & Chemical Oceanographic Data Facility	R.T. Williams	CTD	
		Salinity	3723
		Oxygen	2934
		Nutrients	2833
		Alkalinity and Total CO_2	1765
		Large volume sampling	
		^{14}C extractions	
University of Bern	J.H. Oeschger	^{39}Ar	54
University of Miami	H.G. Ostlund	^{3}H	1950
		^{14}C	436
Woods Hole Oceanographic Institution	W.J. Jenkins	^{3}H	1950
		^{3}He	476
	C. Measures	Be/Se	51
California Technological Institute	D. Piepgras	Nd	39
Harvard University	S. Wotsy	N_2O and CH_4	78

List of Participants

Leg I

Ship's Captain	Emerson Hiller
Scientists–in–Charge	Jorge L. Sarmiento, Chief Scientist, Princeton University William M. Smethie, Jr., Lamont–Doherty Geological Observatory Peter Rhines, Woods Hole Oceanographic Institution Lt. Jair Xavier Da Silva, Brazilian Observer
Harvard University	Warren A. Kaplan Richard G. Porter
Lamont–Doherty Geological Observatory	Owen W. Anderson David W. Chipman Andrew L. Herczeg
Massachusetts Institute of Technology	Barry C. Grant
Princeton University	Frank O. Bryan Robert P. Stallard
Scripps Institution of Oceanography	John L. Bullister Frederick A. Van Woy
Scripps Institution of Oceanography Physical & Chemical Oceanographic Data Facility	Marie C. Beaupre David L. Bos Carol B. Conway James P. Costello Timothy J. Field Walter A. Richter Edward J. Slater James A. Wells Robert T. Williams

Leg II

Ship's Captain	Emerson Hiller
Scientists–in–Charge	Claes G.H. Rooth, Chief Scientist, University of Miami Robert M. Key, Princeton University Lt. Jair Xavier Da Silva, Brazilian Observer
California Institute of Technology	Donald J. Piepgras Mary C. Stordal
Lamont –Doherty Geological Observatory	Owen W. Anderson Susan E. Trumbore Richard H. Wanninkhof
Princeton University	Mitsuhiro Kawase

Scripps Institution of Oceanography	John L. Bullister Mark J. Warner
Scripps Institution of Oceanography Physical & Chemical Oceanographic Data Facility	Marie C. Beaupre David L. Bos Carol B. Conway Timothy J. Field Mary C. Johnson Douglas M. Masten Carl W. Mattson David A. Muus James A. Wells

Leg III

Ship's Captain	Emerson Hiller
Scientists–in–Charge	Taro Takahashi, Chief Scientist, Lamont–Doherty Geological Observatory Curtis Collins, Woods Hole Oceanographic Institution Lt. Jair Xavier Da Silva, Brazilian Observer
California Institute of Technology	Mary C. Stordal
Lament –Doherty Geological Observatory	John G. Goddard Guy G. Mathieu Susan E. Trumbore Richard H. Wanninkhof Steven D. Warren
New York University	Tyler Volk
National Oceanic & Atmospheric Administration	Richard H. Gammon
Princeton University	Sallye Gorlick G.W. Kent Moore
Scripps Institution of Oceanography	Frederick A. Van Woy
Scripps Institution of Oceanography Physical & Chemical Oceanographic Data Facility	Carol B. Conway James P. Costello Timothy J. Field Douglas M. Masten Carl W. Mattson David A. Muus Ronald G. Patrick Paul R. Sweet James A. Wells

CCHDO Data Processing Notes

Event Date	Person	Date Type	Summary
2006-04-12	*Muus, Dave*	CTD/BTL	temp/sal/oxy/nuts/co2/trit/ ctd (some bad sals eliminated)

Notes on reformatting TTO TAS
Leg 1 Rosette Bottle and CTD data.
TTO - Transient Tracers in the Ocean
TAS - Tropical Atlantic Study
Leg 1 RV KNORR Dec 1-22, 1982
EXPOCODE 316N198212_1

1. Basic bottle data (Temperature, Salinity, Oxygen, Nutrients) from Kristin Sanborn odf@ucsd.edu:/spc/1/odf0-archive/235_TTO-TAS/tto-tas

   See file: whprptas

   CO2 and tritium data from Sarilee Anderson/Joe Reid: tas.c14.orig.Z were merged into the ODF data.

   No LVS (Gerard Barrel) data were included at this time.
2. CTD data downloaded from NODC Jan 10, 2006.

   ocldb1136925012.19600.CTD.csv.gz

   Many CTD salinity values were obviously bad and were deleted. Joe Reid's CTD data has the same salinity problem. No CTD is available from ODF. I do not know if the bad salinity data was in the final PACODF data.