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THE DEEP STD STATION: TECHNIQUES FOR MAKING
SURFACE-TO-BOTTOM STD PROFILES AND
SOME EXAMPLES OF ABYSSAL MICROSTRUCTURE

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ABSTRACT

During the past few years we have made over 1000 STD profiles of the entire water column in all the world's oceans and in many major seas. Using Plessey Model 9006 and 9040 STDs, our main effort has been a study of the spreading and mixing of Antarctic Bottom Water in the Atlantic Ocean.

This paper describes the techniques we have evolved to accomplish this task and includes such topics as sea cables, slip rings, pingers, auxiliary sensors, command samplers, calibration, error evaluation, noise, data reduction and storage. Some examples of deep and abyssal microstructure found with the STD are briefly discussed.

INTRODUCTION

In the decade since its introduction, the STD (Salinity/Temperature/Depth) system has become one of the major tools in physical oceanography. It will eventually supersede the classical hydrographic cast as the standard method of measuring the physical properties of sea water.

The STD has been used very successfully to examine the microstructure of the upper water layers of the ocean. It is also capable of providing hydrographic data—with an accuracy comparable to that of the Nansen bottle cast—in the deep ocean from surface to bottom and, at the same time, delineate any microstructure that may occur in any part of the water column.

Since 1964 Lamont-Doherty Geological Observatory has taken 1250 STD stations, the vast majority of which are deep-ocean surface-to-bottom observations. These stations are located in the North and South Atlantic, North and South Pacific, Indian, Arctic and Antarctic Oceans, the Caribbean, Mediterranean, Tasman and Red Seas. Using Plessey Model 9006 and 9040 STDs and Model 8114 digital data loggers we have developed a system for collecting, recording, reducing and storing this data. Our main interest has been a study of bottom water processes and the bottom boundary layer. This paper describes the techniques we have evolved to take "the deep STD station" and gives some examples of microstructure we have discovered in the deep and abyssal waters that could only have been defined using an STD.

THE LAMONT STD SYSTEM

Our major systems are a Model 9006 with 6000 m depth sensors and a special 7000 m Model 9040 unit. The data is recorded on strip chart and on 7-track magnetic tape at 200 BPI density using Plessey Model 8114 digital data loggers. A back-up paper tape digital data acquisition system is frequently used. In situ calibration is provided using a surface-actuated multiple sampler (SAMS) attached to the body of the STD sensor

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(Gerard and Amos, 1968; Amos, Gerard and Blockburger, in prep.). We have also used a rosette sampler (Niskin, 1968) with the 9006 system. Additional equipment includes an electronic nephelometer (light scattering meter), a pinger, large-volume water bottles attached to the sea cable and, recently, a bottom-proximity sensor. Our shipboard computer facilities have been limited to processing calibration data and do not have magnetic tape-reading capabilities.

THE SEA CABLE AND WINCH

Perhaps the most critical pieces of equipment involved in making successful deep STDs are the sea cable and spooling apparatus.* Most of the STDs in use operate on a single electrical conductor of a double-armour type cable that carries both power down to the under-water sensors and a mixed signal up to the deck recording unit. The armour of the cable and the sea water itself are usually used to provide a ground to complete the circuit. The most frequent cause of cable breakdown occurs when the cable is crushed by bad level-winding under tension on the spooling equipment. Crushing causes breakdown of the electrical insulation and shorting of the center electrical conductor(s) to the cable armour. Sometimes this fault can be "cured" by paying out wire past the bad spot (when the tension appears to straighten out the crushed wire and eliminate the short), but this is a temporary cure at best. Open-circuit of the electrical conductor(s) seldom occurs as double-armour cable seems to have good "stretch" characteristics. With shallow casts, no matter how badly the wire is wound on the winch drum the cable is seldom damaged, but with more than about 2000 m of wire out the problem becomes increasingly serious as the wire tension increases. The problem is accentuated if the wire is not initially wound onto the drum under tension. Then, if all the cable is not payed out during a station, on hauling the STD in, the wire under tension bites deeply into the "soft" wire on the drum. This can easily cause loose wraps to form, which eventually get crushed by on-winding wire. The same thing can happen with improper level-winding, when the wire piles up unevenly on the drum and incoming wire forces a wrap to snap off a high spot and lay loosely on the drum. Two things then are essential for proper wire handling and long cable life: (1) the cable must originally be wound onto the drum under tension; (2) the cable must be level-wound.

The first criterion is often difficult to meet as tension-winding equipment is not readily available, particularly in foreign ports. However, an initial winding under tension can be accomplished at sea by paying out the cable with a weight on the end all the way to the last layer and then rewinding. If the water depth is not sufficient for the length of wire, then the ship can steam ahead slowly to avoid snagging the wire on the ocean floor. Good level-winding is not as easily achieved. Level-winding on hydrographic winches is usually accomplished by a diamond lead-screw device that is geared into the drum drive and guides the wire through rollers onto the drum. The gearing of the lead-screw is such that it reverses direction when one complete layer of wire is on the drum to start the next layer in the opposite direction. Hydrographic winches are usually designed to accommodate more than one wire size using different gears to drive the level-wind mechanism

*This discussion is limited to STDs that record on-deck with data transmission via the center conductor(s) in "acoustical" cables.

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Figure 1. Lamont's 7000 m Model 9040 STD with SAMS bottles attached. Bottles at left are in the cocked position. Bottles are removed from frame for sampling.

Figure 2. Lamont's 6000 m Model 9006 STD shown with rosette sampler and pinger attached to cage. Rosette clamps directly to frame by removing three of the 12 available bottles. Pinger and rosette counter-balance each other making the package stable when lifted up from deck. Note sea cable mechanical end termination made by taking two turns around a large diameter thimble and securing loose end using partially crimped Nicopress fittings. Early Model 9006 STD is in background.

at the appropriate rate. The more common double-armour STD cable sizes (3/16", 7/32", 1/4" diameter) are frequently under or over nominal diameter and the gearing provided or the width between drum flanges causes poor level-winding. To attain any reasonable STD cable life with standard winches we have to constantly adjust the level-winder by hand when hauling the STD in—a time-consuming operation. Recently we have designed a grooved winch drum or Lebus spooling system for our 3/16" diameter cable, which will shortly be tested and which we hope will overcome the level-winding problems. The most successful diamond-screw system we have used is on a hydraulic winch designed and built by Gearhart-Owen Corporation with 4500 m of 3/16" cable which was used on the Arctic Pack Ice during the AIDJEX pilot program over 3800 m of water. Its success was primarily due to the small distance between drum flanges and between the rollers on the diamond-screw and the winch drum.

A further consideration is, of course, the length of wire and number of conductors required. Double-armour cable cannot be spliced at sea so once it is damaged it is a write-off. If a sufficiently long cable length is purchased to allow for some losses due to cutting off "bad" pieces this might increase the life of the cable. Quite frequently cable breakdown occurs in the middle or toward the drum-end of the cable, rendering it useless anyway. Also, long cable lengths introduce problems with signal loss and voltage drops, e.g., for a Plessey 9040 system, about the maximum length of 4-H-O cable (DC res. 24Ω/1000 ft) useable with the standard 150 V deck power supply would be 33,000 ft (10,000 m) due to voltage drop down the cable. Signal attenuation becomes critical at the higher frequencies of the depth and the fourth channel gives very low signal levels at the deck equipment end with such lengths of cable.

We have found that 20,000-25,000 ft (6100-7600 m) of type 1-H-O cable is the most suitable for our application. The wire is 3/16" diameter, allowing it to be used with most standard oceanographic winches, shieves and sampling bottles. It has a DC resistance of only 10Ω/1000 ft, adequate insulation around the conductor to protect against reasonable misuse and a breaking strain of 3600 lbs. With a reasonable wire angle this length of wire allows sampling down to the bottom in all the deep oceans (except in the trenches).

COMMAND SAMPLERS

The STD, at the present time, does not provide data whose absolute accuracy is comparable to data obtained by Nansen bottles and reversing thermometers unless a constant check is kept on its calibration. Consequently we use our SAMS sampler with every station. The SAMS attaches to the outside of the STD and uses nine 1.7-liter Niskin bottles equipped with reversing thermometer frames (Fig. 1). The bottles can be triggered on command from the deck control in any order—an advantage over the rosette sampler (Fig. 2) which triggers bottles in sequence—in that it allows for less critical placement of thermometers with respect to their range. We collect samples with the SAMS on the downtrace only, attempting to cover the salinity, temperature and depth range encountered as evenly as possible to provide a good calibration curve. Due to high gradients making it difficult to hold the STD in the thermocline without getting large variations in the sensors' output frequencies, we tend to get most calibration data in the high and low ends of the salinity and temperature ranges.

LAMONT-DOHERTY GEOLOGICAL OBSERVATORY

STD LOG SHEET #1

SHIP LYNCH CRUISE 47 STATION 189 DATE 09-V-71 TIME (GMT) 0909 = SHIP'S TIME +3 HRS.

SENSOR DATA	
MODEL	9006 9030 9040
SALINITY#	2519 RANGE 30-40
TEMP#	3683 RANGE -2 +35
DEPTH#	3557 RANGE 6000m
SOUND VEL#	— RANGE

RECORDING DATA		
MAG. TAPE# <u>3</u> PAPER TAPE# <u>—</u>		
ANALOG SCALES		
DEPTH	TEMPERATURE	SALINITY
1	3, 4, 3, 2	3, 4
2	2	4
3	2	4

BOTTOM DEPTH DATA				
MATTHEWS AREA <u>9</u>				
TIME	UNCORR. FMS.	CORR.	CORR. FMS.	CORR. METERS
0925	2538	77	2615	4782
1050	2539	77	2616	4784

ADDITIONAL EQUIPMENT	
FINGER ☒	TYPE <u>BENTHOS</u>
COMMAND SAMPLER ☒	TYPE <u>ROSETTE</u>
LIGHT SCATTERING	—
OTHER	—

DATA	SHIP	CRUISE	STATION	MODE	DAY	MONTH	YEAR	GMT	LATITUDE	LONGITUDE
	LY	047	0189	1	009	05	71	0909	41° 44.5' N	57° 17.7' W
COLUMN	1	2	3	4	5	6	7	8	9	10

DATA	MARSDEN	CORR. DEPTH	MAX. SAMPLE DPTH.	DIST. FROM BOTTOM	WIND DIR.	FRCE.	SEA DIR.	ST.	AIR TEMP.	DEW POINT	NO. OF SAMPLES
	150	4784	4782	002	00	06	00	4	0083	0061	09
COLUMN	41	42	43	44	45	46	47	48	49	50	51

DATA	BAROMETER	SAL. SENSOR	TEMP. SENSOR	DEPTH SENSOR	MODEL NO.	DEPTH PERIOD AT SURFACE	NO. OF CHANNELS
	10280	02519	03683	03557	9006	102970	004
COLUMN	1	2	3	4	5	6	7

DATA	TMAX	TMIN	SMAX	SMIN
	105	021	359	340
COLUMN	41	42	43	44

Figure 3. Lamont STD log sheet for LYNCH STA. 189. Information is keypunched directly from this log to provide header information entered into our STD computer programs.

DEPTH SENSOR
PERIOD FOR
CORRECTED SONIC
DEPTH

STATION # LY-47-189

STD. BOTTLE NO. 91186

DATE 03-V-71

TIME 0912

- 1 T ✓
- 2 T ✓
- 3 T ✓
- 4 T ✓
- 5 T ✓
- 6 T ✓
- 7 T ✓
- 8 T ✓
- 9 T ✓

CHECK LIST
FOR BOTTLE
TRIPPING
(T=Thermometer)

ANALOG RECORDER
DEPTH SCALE
CHANGE

CLOSEST APPROACH
TO BOTTOM; NOTE
DISTANCE OFF BOTTOM;
SONIC DEPTH

TIME	SALINITY PERIOD	TEMPERATURE PERIOD	DEPTH PERIOD	CHANNEL & LIGHT SCAT	WIRE OUT	REMARKS
0825	—	393365	102966	—	—	on deck: loop in my hand
0909	161961	260458	102966	—	2	hold at surf
0912	161949	260191	102959	—	2	trip #1
0912	start down	80m/min	—	—	—	—
0918	150609	237483	102577	—	159	hold
0920	150606	237478	102575	—	157	trip #2
0925	—	—	—	—	~ 1000	1/2 50m/min
0953	154419	406849	98843	—	1533	hold: mark chart change scale
—	154432	406814	98844	—	1533	mark left scale #1
1001	154418	409501	97782	—	2890	hold: trip #3
1014	154620	416858	95724	—	3054	hold: mark chart
1016	154626	416852	95728	—	3054	mark depth in #3
1028	154907	421975	95604	—	3750	trip #4
1120	155096	422888	91691	—	4600	hold: trip #5
1041	155101	422920	91688	—	4600	trip #6
1044	155121	422955	91246	—	4799	hold: trip #7 (22m off)
1047	155151	422930	91112	—	4856	hold: 1-2 fm. off
1048	stop end	may tape record down time	—	—	4856	mark chart: change chart paper
1049	155146	422929	911	—	4856	trip #8: 15m off
1050	start may tape record	up time	—	—	—	trip #8: 25m off
1119	154665	416824	95752	—	3095	hold: mark chart change to A side 2
—	154610	416800	95753	—	3095	mark chart
1126	154578	414832	95840	—	2800	hold: trip #9
1156	154404	406374	98960	—	1541	hold: mark chart change to A side 1
1157	154410	406305	98959	—	1541	mark chart
1226	160877	353611	102966	—	2	hold at surface
1226-70	may tape record	off	—	—	—	—
1220	—	378460	102965	—	—	on deck: loop in hand

(1)

(2)

(5)

(4)

(3)

(5)

(1)

Figure 4. Lamont STD station record log for LYNCH STA 189. Numbers in parentheses refer to numbered paragraphs in the text.

Another peculiarity of this type of sampling is that the surface sample, after being collected, is carried all the way down to the bottom of the ocean and back again. We have not yet found evidence of contamination but the sampling bottles have to be in good condition to prevent this from happening.

PROCEDURE FOR MAKING THE DEEP STD STATION

Two essential items required for taking any successful STD stations are (1) An electronic counter, or better still, one counter per STD channel, to constantly monitor the frequency output of each sensor. We also provide ourselves with tables for converting frequency (period) to parameter values at every 0.001°/oo, 0.01°C, and 1 m interval, based on the linear frequency/parameter value relationship provided by the manufacturer.

Table 1. Sample of Conversion Table for Temperature Sensor
Temperature (°C) to Period (µsec)

TEMPERATURE V/S PERIOD. PAGE 5 4.00 DEG C TO 5.99 DEG C							
TEMP.	PERIOD	TEMP.	PERIOD	TEMP.	PERIOD	TEMP.	PERIOD
4.00	406169	4.50	401615	5.00	397162	5.50	392806
4.01	406 77	4.51	401525	5.01	397 74	5.51	392720
4.02	405985	4.52	401435	5.02	396986	5.52	392634
4.03	405893	4.53	401345	5.03	396898	5.53	392548
4.04	405801	4.54	401255	5.04	396810	5.54	392462
4.05	405709	4.55	401165	5.05	396722	5.55	392376
4.06	405617	4.56	401 75	5.06	396634	5.56	392290
4.07	405526	4.57	400986	5.07	396546	5.57	392204
4.08	405434	4.58	400896	5.08	396459	5.58	392118
4.09	405342	4.59	400806	5.09	396371	5.59	392 32
4.10	405250	4.60	400717	5.10	396283	5.60	391947
4.11	405159	4.61	400627	5.11	396195	5.61	391861
4.12	405 67	4.62	400537	5.12	396108	5.62	391775
4.13	404975	4.63	400448	5.13	396 20	5.63	391689

A step better than this would be real-time processing using a shipboard computer or a digital display using "engineering" units. (2) Adequate logging of all events occurring during the station. I cannot overstress the importance of this often overlooked aspect of STD operation, particularly if people other than the shipboard personnel are going to do the data reduction. Also, if your STD data are going to be used by other institutions with any degree of confidence, adequate documentation of all stages of collecting and processing of the data are essential. Figures 3 and 4 show examples of the shipboard log sheets that we use at Lamont.

Our technique for making deep STD stations is as follows (refer to Fig. 4):

- 1 - The on-deck depth sensor output is logged just prior to taking the station (using a resistive loop through the conductivity head to give a simulated salinity output).
- 2 - As soon as the ship is stopped on station, the STD is lowered to just below the sea surface (to a depth of 1-5 m, depending on sea state), the analog and digital recorders are turned on, all parameter outputs are logged and a surface sample collected.
- 3 - Although the analog record is not our prime data source,

due to frequent breakdowns of our DDL, we make the analog records with as much care as possible so that they can be digitized if necessary. This means keeping the recorder calibrated at all times and marking the top and bottom of each trace while logging the output frequency of each sensor to aid in accurate digitization.

4 - The STD is lowered at a speed of 20-30 m/min through the upper water layers where gradients are high, it often being necessary to lower at this speed to a depth in excess of 1500 m.

5 - Each time a SAMS bottle is tripped the sensor output frequencies are logged as soon as the STD is stopped in the water and at the moment the bottle is tripped. This is done because the STD frequently drifts up or down during the time it takes for the thermometers to come to equilibrium. The analog records are also marked.

6 - Although the accuracy of the STD is not impaired by large wire angles, we attempt to maintain as small a wire angle as possible. This is essential when trying to hold the sensors in a narrow lamina of homogeneous water in a thermocline and when trying to approach within a meter or two of the ocean floor.

7 - We increase the lowering speed to a maximum of 80 m/min in the deep and abyssal waters. Any greater speed causes the rather hydrodynamically unstable package to "kite up" and tie knots in the sea cable.

8 - On approaching the ocean bottom with the STD package we usually reduce the lowering speed a couple of hundred meters from the bottom. This may be necessary anyway in some parts of the ocean where gradients increase again near the bottom. Using a pinger, we can usually get to within 5 meters of the ocean floor. It is essential not to hit the bottom with the STD: the salinity head and temperature probes are particularly vulnerable to mechanical damage. We have recently used a bottom-finding device in conjunction with the pinger to enable us to get safely close to the bottom and also collect a small gravity core. The device was designed by Neil Brown of Woods Hole Oceanographic Institution and is simply a trigger weight on a known length of wire, hanging below the STD and coupled by a magnetic reed switch to a 12 KHz oscillator which in turn is inductively coupled to the sea cable. When the trigger weight touches the ocean floor the 12 KHz signal is superimposed on the STD FM signals and activates a buzzer on the deck console equipment. A slave buzzer sounds in the winch house and in this way the winch operator can keep the STD at a known distance off the ocean bottom while bottles are tripped, scales changed and records marked.

9 - The uptrace is recorded on both analog and digital recorders and as much care is taken with it as with the downtrace. Due to time considerations though, the STD is frequently raised to the surface at a higher speed than it was lowered.

10 - The average time for a complete STD station to a depth of 5000 m, from the time the ship stops to when it is underway again is 4.5 hours.

AUXILIARY SENSORS AND SAMPLING

In order to utilize ship's time to the fullest while making a 4-1/2 hour STD station, we augment the STD with additional sampling programs. Among these are an electronic light-scattering meter (nephelometer) which attaches to the sea cable just above the STD and whose signal utilizes the fourth channel available in our STD system. A number of water sampling programs have been carried out using the STD cable, including large-volume sampling bottles for radon, dry-weight particulate matter, organic carbon/nitrogen determinations and dissolved nutrients.

We have also deployed pop-up current meters whenever possible at the same location as the STD station and collected small gravity cores as mentioned above. In this way our deep STD program is telling us a great deal about the physical, chemical and biological structure of the water overlying the deep ocean basins.

CALIBRATION

During each station, the actual frequency output of each sensor is logged at the instant the SAMS bottle is tripped. These frequencies are converted to oceanographic units using the manufacturer's linear relationship between frequency and parameter value, and then compared to the values obtained independently from the SAMS samples and reversing thermometers. The differences obtained (ΔS , ΔT and ΔD) are treated as follows:

ΔT is plotted as a function of temperature and the resulting error curve is usually insignificant, but does sometimes show a small offset and/or a slope error. The depth sensor is the only one that has an absolute reference point for calibration, i.e., we know the on-deck pressure is 0 PSIG. However, it is not necessary to adjust the oscillator to give the correct baseline frequency output on-deck. This frequency does seem to vary somewhat with temperature and so the depth sensor output is normalized to zero using the on-deck frequency reading. When ΔD is plotted as a function of depth, a second-order error curve is obtained (Figure 5a). Despite the rather unreliable reputation of unprotected reversing thermometers, by prudent selection and pairing of thermometers in a frame, the standard deviation of the calibration points can be remarkably small.

The depth error is probably due to our incomplete knowledge of the relationship between geometric depth and pressure in the oceans. Several people report their "depths" as pressure, which seems reasonable, as that is what the depth sensor senses.

The salinity errors are the most difficult to comprehend. Figure 6 shows ΔS at the surface for a series of stations taken on the USNS LYNCH in the North Atlantic. The shifts and drifts that occur in the salinity sensor output are reflected at all depths because ΔS plotted as a function of time at any other depth would give the same shaped curve. These changes can sometimes be traced to a particular event occurring, such as the STD hitting the bottom of the ocean or the side of the ship, or the STD not being used for a period of time, but frequently there is no logical explanation for their occurrence. If the salinity sensor output is corrected by subtracting the surface offset shown in Figure 6 for each station, we are still left with a salinity error that appears to be a function of pressure. Figure 5(b) shows ΔS plotted against depth (not corrected for surface offset) for 40 stations taken in 1972 during R/V ATLANTIS II, Cruise 68. The shape of this curve is typical for many different salinity sensors and types we have used for deep STD work: the error, after adjusting the surface to zero, increases to a maximum anywhere from 500 to 2000 m, then decreases, crossing the zero axis somewhere between 2000 and 4500 m, and starts to increase again for the rest of the depth range covered. The degree of curvature varies from sensor to sensor and cruise to cruise. Most puzzling is that the sign of the error is not always the same (c.f., Amos, Gordon and Schneider, 1971, Fig. 2; and Jacobs and Amos, 1967, Fig. 7). The amount of surface offset shown in Figure 5(b) (approx. $-0.4^{\circ}/\text{oo}$) is large, but we frequently encounter such deviations from calibration. It has

Figure 5. STD calibration data from 40 stations taken on R/V ATLANTIS II Cruise 68, 1972. (a) Difference between thermometric depth from SAMS thermometers and STD depth from manufacturer's linear depth/frequency relationship (ΔD) plotted as a function of thermometric depth. (b) Difference between SAMS salinities (determined with lab salinometer) and STD salinity from manufacturer's linear salinity/frequency relationship (ΔS), plotted as a function of STD depth.

Figure 6. Changes in surface ΔS for salinity sensor No. 2708 during LYNCH Cruise 40, 1970. Events that might affect the output frequency of this salinity sensor are indicated.

become our policy not to make any adjustments to any of our sensors at sea to compensate for errors like these - we let the computer adjust the data later.

The magnitude and curvature of this salinity error curve is such that we cannot ignore it; the curvature at depth may well mask some of the subtle changes in salinity gradient that indicate boundaries between water masses, and an absolute error of more than $\pm 0.01^\circ/\text{oo}$ is not acceptable when dealing with deep and abyssal water-mass identification. The source of the error has been traced to the equations used in the STD analog circuitry to compensate the sensed conductivity for pressure and temperature to give an output that is a function of salinity alone. The reason for the apparently random shifts and drifts in output is unknown to me and is a disturbing facet of the present STD systems.

We usually end up by applying an individual salinity correction curve to each STD station which includes the surface offset, so long as we have sufficient data points to adequately describe the curve. The standard deviation is often quite low ($\pm 0.003^\circ/\text{oo}$) hence we have some degree of confidence in our final accuracy.

DATA REDUCTION

We have developed a data reduction system that reads the DDL tapes, converts to engineering units, corrects for calibration data as described above, de-spikes the records and records final data on tape at one observed level per 0.7 meters. We do not perform any corrections for salinity transients caused by the lag in compensation in high temperature gradients, but are looking into the problem at the moment. The deep water structure has very few gradients steep enough to cause excursions of any serious magnitude. Far more troublesome are spikes caused by extraneous noise (see next section). Additional programs have been written to perform dynamic computations, plot vertical and horizontal profiles and handle time-series STD data.

NOISE

One of the most persistent problems with STD records is the appearance of noise on the records. The deep STD station, with its necessarily long cable length, seems particularly vulnerable to this annoying problem. We have found several sources of this noise, which appears as narrow spikes on one or more parameter traces regardless of the natural gradients or microstructure encountered. These sources are: low signal levels due to long cable lengths; magnetization of the conductivity head; dirty slip-ring contacts; momentary breakdown of sea cable conductor insulation when the wire snaps onto the drum or is crushed as described earlier; leaky underwater cable connectors and vibration sensitivity of the STD salinity sensor circuitry. This last fault seems to be a problem with two transformers in the salinity card and sometimes we have been able to minimize it by mechanically decoupling the STD sensor from sea cable vibrations using shock cord and elastic bands.

RESULTS

It is obvious that the present state of the art could use some improvement in reliability, and the STD is not an instrument one can just throw in the ocean and get instant and continuous data of Nansen-bottle accuracy. We feel that with the

necessary care the STD is an extremely valuable tool and has revealed structure that the Nansen cast cannot begin to resolve. The deep ocean is no exception: we have used the STD to compute geostrophic currents and volume transports in the North Atlantic (Amos, Gordon and Schneider, 1971) and we have discovered structure in the deep ocean impossible to detect with any other method. We are using the continuous nature of the STD records to show exactly where changes in gradients delineate water masses.

One of the most interesting things we have found is a thin, homogeneous layer (sometimes only 15 m thick) overlying the bottom of much of the western North Atlantic Basin (Fig. 7). This feature was particularly striking in the South Atlantic at 16°S (R/V ATLANTIS II, Cruise 68) where a strong temperature and salinity discontinuity was found a few tens of meters above the ocean floor. This is such a persistent feature that it leads us to believe it represents a bottom turbulent boundary layer which, of course, would only be revealed by the STD in an area where there is some gradient in the bottom waters—e.g., in the Antarctic bottom water whose temperature and salinity decrease rapidly towards the ocean floor. Our electronic nephelometer records have shown that a corresponding increase in suspended material occurs in many places, showing a similar homogeneity within the bottom mixed layer.

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REFERENCES

- Amos, A.F., A.L. Gordon and E.D. Schneider (1971). Water masses and circulation patterns in the region of the Blake-Bahama Outer Ridge. Deep-Sea Res. 18(2), 145-165.
- Amos, A.F., R.D. Gerard and J. Blockburger (in prep.) An improved surface-actuated multiple sampler.
- Gerard, R.D. and A.F. Amos (1968). A surface-actuated multiple sampler. Mar. Sci. Instrument. 4, 682-686, Plenum Press.
- Jacobs, S.S. and A.F. Amos (1967). Physical and chemical hydrographic observations in the southern oceans. USNS ELTANIN Cruises 22-27, Tech. Rep. Lamont Geol. Observ. CU-2663-38, 287 pp. (unpubl. manuscript).
- Niskin, S. (1968). A deck command multiple water sampler. Mar. Sci. Instrument. 4, 19-24, Plenum Press.