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INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
(of UNESCO)

IGOSS Task Team on Quality Control of Automated Systems
Geneva, 19-21 October 1992

SUMMARY REPORT

1. OPENING OF THE MEETING

The Meeting of the IGOSS Task Team on Quality Control of Automated Systems (TT/QCAS) was opened at 9:00 am on 19 October 1992 by Mr. R. Bailey and Mr. J. Withrow, Co-Chairmen of the Task Team. Mr. J. Rasmussen, World Meteorological Organization, welcomed the participants on behalf of the WMO and emphasized the importance of the agenda item on quality control.

2. ORGANIZATION OF THE MEETING

2.1 ADOPTION OF THE AGENDA

Mr. J. Withrow introduced the agenda. The Group decided to add as a separate agenda item the joint session with the TOGA-WOCE XBT-XCTD Programme Planning Committee. Also, a discussion of "Fast Deep" data was integrated into the agenda item reviewing T-5 Fall Rate Data. The agenda was adopted as shown in Annex I.

2.2 WORKING ARRANGEMENTS

The Group adopted the working arrangements for the meeting as presented by the Co-Chairmen and agreed to adjust them as necessary.

3. FINALIZATION OF THE SCIENTIFIC PAPER

The Task Team reviewed the Draft Scientific Paper on the fall rate of the Sippican T-7 Expendable Bathythermograph (XBT) prepared by Dr. K. Hanawa and Mr. R. Bailey and thanked the drafters for their effort in the preparation of the paper. Due to the recent similar results regarding the T-4/T-6 equation it was decided to modify the paper to include all three probe types (see para. 4). Assignments were made on the revision of the paper such that a new draft would be made available to the members of the Task Team by 1 December 1992. The Task Team would then have until 15 January 1992 to submit comments and agree on the paper before submission for publication. The *Journal of Deep Sea Research* would be contacted to see if the paper could be classified as a "rapid response" paper such that it would be published this summer or early fall.

SC-93/WS.26

4. IMPLEMENTATION OF THE FALL RATE EQUATION

The Task Team discussed the implementation of the new equations and made the following recommendations for further discussion at the TOGA/WOCE XBT/XCTD Programme Planning Committee Meeting:

Real Time Data:

The fall rate equation should not be changed until a new JJXX code is available. As soon as the new code is available then the process of transition should proceed as quickly as possible.

The new code should permit the encoding of the following information: Manufacturer, probe type, equation used, deck unit. The listings of the required information are contained in Annex III.

Delayed Mode Data:

The fall rate equation should be changed at an agreed future time to permit documentation of the change. Data sets should include as a minimum the Manufacturer, probe type, equation used, and deck unit used. In the meantime, the data centres must request of the data provider the depth equation used in the data submission, and this information must be recorded for implementation when appropriate new code formats are available.

5. FINALISATION OF THE T-4/T-6 EQUATION

The Task Team reviewed the results of the processing of the T-4/T-6 data by Dr. Hanawa. It concurred with his conclusion that there was now sufficient data to derive a new equation. The results of his study are contained in Annex IV. The study indicated that the fall rate equation approved for the T-7 probe was insignificantly different to that of to the T-4 and T-6 probes. The Task Team discussed whether it would be appropriate to reprocess all of the T-7, T-4 and T-6 data as a unified data set and publish one paper covering all of the probes. It was decided that one paper covering all these probes was more desirable than two separate papers in order to avoid confusion or a new universal equation, and the modifications could be made to include the new T-4/T-6 data with a minimum of delay. A schedule was developed and is presented under the agenda item on future work. It was decided to submit the paper to the *Journal of Deep Sea Research* in January 1993.

6. REVIEW OF T-5 AND "FAST DEEP" DATA

The Task Team reviewed the T-5 and "Fast Deep" data sets and concluded that further work was required to verify the manufacturers equation. It was noted that the two probes were very different and had different fall rate characteristics. Arrangements were made with Sippican, Inc. for the provision of additional probes to obtain a statistically significant data set. The Task Team accepted with appreciation the offer of Mr. M. Szabados to take responsibility for the processing of the data sets associated with both of these probes. The Task Team felt that barring unforeseen problems that another 50 good comparisons for each probe type should be sufficient to complete the data sets. Sippican, Inc. requested a copy of the fall rate evaluation software and Dr. Hanawa agreed to provide it to them.

7. EVALUATION OF SPARTON TEST RESULTS

Mr. Bruce Eidsvik presented the present state of development of the Sparton T-7 probe. He presented data from recent Navy qualification tests showing that the Sparton Probe had qualified for Navy use based on the fact that it conformed to the Sippican fall rate equation. The Task Team pointed out that there was insufficient data due to the way the tests were carried out to accurately determine if the new probe performed as the Sippican probe. In general, most XBTs were not dropped simultaneously with the CTD. Mr. Eidsvik pointed out that the navy's main requirement was that the probe have the same characteristics as the Sippican Probe which it did. The Task Team took into account existing data sets and decided that an additional two independent data sets were necessary to insure that the probe did indeed conform to the old Sippican fall rate equation in which case it would conform to the new universal equation. Sparton agreed to provide the probes for the additional tests. The Task Team felt that given it current resources that is should be possible to complete the evaluation by Spring/Summer 1993.

The Task Team also discussed the old Sparton probe which data indicated did not fall in accordance with the Sippican equation. The Task Team found that Sparton had sold approximately 12 000 of the old probes principally to navies. Sparton agreed to assist the IGOSS Operations Coordinator in notifying those agencies of the necessity of notifying the data archiving center that the data was collected with the old Sparton probe and should be handled accordingly. The Task Team noted that ORSTOM Brest had ordered several cases of the old probe and decided to approach ORSTOM to see if they would agree to conduct sufficient fall rate tests with the old probe to ascertain its fall rate equation.

8. EVALUATION OF XCTD PERFORMANCE DATA

Mr. Jim Hannon of Sippican presented the present state of development of the XCTD. Mr. Alex Sy made a presentation on his experience with the XCTD (Annex V). The conclusion of the Task Team after reviewing the data was that the probe still was not ready for use for the following reasons:

(i) many of the probes showed unaccepatable noise levels. This was attributed to the need for the instrument to be extremely well grounded and that the ship be relatively free of electrical noise. The Task Team was concerned that some Ships of Opportunity for various reasons may not be capable of providing such an environment.

(ii) nearly all of the probes showed an unacceptable offset at around 900 meters. This was attributed to a filter change.

(iii) some of the probes showed large unacceptable offsets from launch, apparently due to the way the XCTDs are wet-calibrated during production.

The Task Team noted that while problems still existed that significant progress had been made in the development of the XCTD. It urged Sippican to continue its development effort. Many of the Task Team members agreed to assist Sippican in its effort by providing test opportunities.

9. QUALITY CONTROL

At the Third Joint IOC-WMO Meeting for the Implementation of IGOSS XBT Ship-of-Opportunity Programme, Dr. A. Sy and Mr. P. Rual presented automatic quality control and filtering techniques to be used for processing XBT and CTD data prior to encoding for transmission. Concern was expressed by some participants that the data was being altered without the knowledge of the end user. The TTQCAS was asked to examine this problem and present a report to the GE/OTA. At the present TTQCAS meeting the group discussed the advantages and disadvantages of shipboard automated QC procedures. It was decided to review the current methods used and report the findings to the GE/OTA.

The task team did recommend that standard pre-GTS (shipboard) procedures need to be adopted.

10. FUTURE WORK

Assignments were made on the revision of the paper such that a new draft would be made available to the members of the Task Team by 1 December 1992. The Task Team would then have until 15 January 1992 to submit comments and agree on the paper before submission for publication. The *Journal of Deep Sea Research* would be contacted to see if the paper could be classified as a "rapid response" paper such that it would be published as soon as possible.

It wa s noted that the Task Team activities occupy a large percentage of the "voluntary" members time, and that insufficient resources to complete analyses remains as continued problem for the Task Team.

11. JOINT TOGA-WOCE XBT-XCTD PROGRAMME PLANNING COMMITTEE

The Task Team met jointly with the TOGA-WOCE XBT-XCTD Programme Planning Committee (report published separately).

Fall rate equation

The Committee considered that the new fall rate equation for Sippican and TSK T4,T6,T7 XBT's is now sufficiently documented to be adopted in the future. The Committee examined therefore the practical ways to implement these changes AND MAKE SURE THAT THEY ARE ACTUALLY SPOTTED both in real time transmission and in delayed mode archival of the data. The relevant additional information which are not yet transmitted and should be in the future have been identified and are listed in annex III.

The Committee recommended that these changes be fully implemented by January 1995, the end of TOGA.

The TT QCAS and the IGOSS operations coordinator will coordinate and track the progress of the technical implementation with the appropriate bodies. **Members of the committee are invited to report to them all the initiatives taken for action.**

In the mean time it is strongly recommended that the depth fall rate equation currently in use be maintained **in all the data exchanges** until the adequate procedures are in place.

Sparton probes

As preliminary findings show that there is a potential difference between SPARTON AND SIPPICAN T7 fall rate equations, the Committee recommends that:

1. The TT QCAS continues its evaluation of the revised T7 SPARTON XBT

2. Users of previous types of T7 SPARTON probes proceed to their own evaluation using the standardized procedures implemented by the TTQCAS, report their results to the TT QCAS for future tentative correction and keep track of the data sets created. The TT QCAS will provide the necessary technical help for these evaluations.

3. The identification of the data sets resulting from the probes already used be undertaken by the data Centres. The manufacturer and the IGOSS coordinator agreed to provide the data Centres with the necessary information.

Moreover the Committee recommended that, regardless of the manufacturer, fall rates for probes identified by identical type names should be the same. **This recommendation applies to all expendable devices under development.**

XCTD

The evaluation of the Sippican XCTD by the TTQCAS has shown that an improvement in the calibration and overall reliability of the CTD is still required, to meet the manufacturer's specifications (Annex V).

The Committee recommends that the TTQCAS monitor the progress of future developments and refinements of the XCTD, and to re-evaluate the XCTD once these or new develoments and refinements have been deemed to be completed.

THERMOSALINOGRAPH

The Committee was pleased to note the progress accomplished in the implementation of thermosalinographs on vessels operating along regular lines, the preliminary results reported, encouraged the members to maintain their efforts in view of a global coverage. The Committee .recommended that the TTQCAS document the accuracy and reliability of thermosalinographs and associated different sensors of sea surface temperature and salinity. The committee further recommended that codes used for data transmission, exchange and archival be able to identify the method of data collection.

It was recommended that a comparison of XBT controllers be made in the future. More information is required on the T5 probe, the Sippican Fast Deep probe, and the new and old Sparton probes. When this information is acquired, the task team will evaluate fall rate equations for each probe.

As resources allow, the team will standardize its procedures for evaluation of probes and publish the standardized procedures in a manual.

It was recommended that the fall rate equation should be examined for probes dropped with strip chart recorders as this data occupies a large percentage of the data bases and continues to be collected. Further errors may be apparent due to strip chart motor variations/reliability, chart paper differences, etc. It was noted, however that no resources were available to make such a study at this stage.

The task team will also discuss and draft a proposal for a TESAC algorithm for sending Temperature, Salinity and Current messages.

12. APPROVAL OF THE REPORT

The Meeting approved the Summary Report.

13. CLOSURE OF THE MEETING

The Co-Chairmen thanked the participants for their contributions and co-operation. They expressed their appreciation to the WMO for hosting the meeting. The meeting closed at 2200, 21 October 1992.

ANNEX I

AGENDA

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   2.1 ADOPTION OF THE MEETING
   2.2 WORKING ARRANGEMENTS
3. REVIEW OF THE SCIENTIFIC PAPER
4. IMPLEMENTATION OF THE FALL RATE EQUATION
5. FINALIZATION OF THE T-4 FALL RATE EQUATION
6. REVIEW OF THE T-5 FALL RATE DATA
7. REVIEW OF SPARTON PERFORMANCE DATA
8. REVIEW OF XCTD PERFORMANCE DATA
9. QUALITY CONTROL
10. FUTURE WORK
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12. APPROVAL OF THE REPORT
13. CLOSURE

ANNEX II

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ANNEX III

REQUESTED CODE CHANGE FROM TTQCAS AD HOC HOBART MEETING 24 MARCH 1993

I. INSTRUMENT TYPE

A. Expendable BATHY Probes

Sippican
T-4, T-5, FAST DEEP, T-6, T-7, DEEP BLUE, T-10, T-11

SPARTON
XBT-4, XBT-5, XBT-5DB, XBT-6, XBT-7, XBT-7DB, XBT-10, XBT-20, XBT-20DB

1. Depth Calculation - a subscript indicating the fall rate equation used.
   Example:
   a. 6.702a+8.2012b*b
   b. new equation
   c. etc.
   d. unknown

B. Mechanical Bathy Probes

C. Hydrocast

D. Other
Thermistor Chain
Mooring
Platforms
Anchored vessel

II. RECORDERS-CONTROLLERS (Expendable Probes, Thermistor Chain)

Sippican
MK2A/SSQ-61, MK9, AN/BHQ-7/MK8, MK12

Sparton
SOC BT/SV PROCESSOR MODEL 100

Bathy Systems
SA-810

Argos
XBT-CT

Scripps Metrobyte controller

TSK
Automatic launcher

Mooring

When these changes are approved by the CBS of WMO, we may consider disseminating a change to Manuals and Guides 3 "Guide to Operational procedures for the collection and exchange of IGOSS Data".

ANNEX IV

NEW DEPTH-TIME EQUATION OF XBT T-4 AND T-6 PROBES

by Kimio Hanawa
(Department of Geophysics, Tohoku University, Sendai 980, JAPAN)

13 subdatasets were collected to estimate a new equation for T-4 and T-6 probes. Table 1 shows summary of CTD-XBT comparison experiment. The number of probes thrown is 211.

The analytical procedures are same as those for T-7 probe except for skipping the iteration stages. Estimated depth-time equation for T-4 and T-6 probes is

$$z_X = 6.703t - 0.00236t^2. \qquad (1)$$

Table 2 shows summary of equations estimated for each subdataset and Figure 1 shows the scatter plot of coefficients a and b. Figure 2 shows distribution of the depth differences and standard deviations and Table 3 shows mean depth differences and standard deviations at 25m intervals against the equation provided by the XBT manufacturer.

Figure 3 shows the depth difference of Eq. (1) to the equation estimated for T-7 probe,

$$z_X = 6.733t - 0.00254t^2. \qquad (2)$$

The maximum difference between the two is 1.5m at 450m depth. This means that we can safely determine the unified equation for T-4, T-6 and T-7 probes.

Table 1. Summary of CTD-XBT comparison experiment for

T-4 and T-6 probes. Total number of probes is 211.

Institution	Data set name	Number of XBTs	XBT manufacturer	Experimental date	Cruise name
NOAA/NOS	N6A	7	Sippican	July 1988	STACS
	N6B	13	Sippican	July 1988	same as N6A
	N4A	7	Sippican	July 1988	same as N6A
	N4B	7	Sippican	July 1988	same as N6A
	N4C	21	Sippican	February 1992	?
ORSTOM	O6A	2	Sippican	December 1989	SURTROPAC
	O4A	16	Sippican	December 1989	same as O6A
	O4B	19	Sippican	August 1991	SURTROPAC
	O4C	26	Sippican	September 1991	COARE-1
	O4D	69	Sippican	February-March 1992	COARE-2
SIPPICAN	S4A	7	Sippican	June-July 1991	?
TOHOKU	T6A	9	TSK	June 1989	KT-89-9
	T6B	8	TSK	April 1992	KT-92-5

Data-set name	XBT data converter used	CTD used	Remarks
N6A	MK-9	Neil Brown III	
N6B	MK-9	Neil Brown III	
N4A	MK-9	Neil Brown III	
N4B	MK-9	Neil Brown III	
N4C	?	?	
O6A	?	SEABIRD model 9	
O4A	?	SEABIRD model 9	
O4B	?	SEABIRD model 9	
O4C	?	SEABIRD model 9	
O4D	?	SEABIRD model 9	
S4A	?	?	
T6A	Z-60-II	Neil Brown IIIb	
T6B	Z-60-II	Neil Brown IIIb	

Table 2. Summary of coefficients a and b of the equations for individual data sets of T-4 and T-6 probes.

Institution	Data-set name	Number of XBTs	Number of depth difference data	The estimated equation: Coefficient a	Coefficient b
NOAA/NOS	N6A	7	98 (93%)*	6.803	0.00274
	N6B	13	190 (97%)	6.819	0.00308
	N4A	7	97 (92%)	6.855	0.00281
	N4B	7	103 (98%)	6.862	0.00231
	N4C	21	233 (74%)	6.509	0.00028
ORSTOM	O6A	2	15 (50%)	6.479	-0.00140
	O4A	16	184 (77%)	6.577	0.00048
	O4B	19	239 (84%)	6.624	0.00185
	O4C	26	205 (53%)	6.854	0.00456
	O4D	69	704 (68%)	6.696	0.00225
SIPPICAN	S4A	7	96 (60%)	6.862	0.00422
TOHOKU	T6A	9	135(100%)	6.554	0.00139
	T6B	8	119 (99%)	6.583	0.00184
		211	2418 (76%)	6.703	0.00236

* Percent good defined as the ratio of actually used depth-error data to data to be detected (27 x number of probe).

Table 3. Detected mean depth differences and standard deviations at 25m intervals against the equation provided by the XBT manufacturer.

Depth (m)	Number of data	Mean difference	Standard deviation
100	177	-2.45	3.37
125	180	-3.34	3.60
150	181	-4.21	3.76
175	173	-5.78	4.20
200	178	-6.76	4.41
225	174	-7.64	4.88
250	170	-8.34	5.52
275	167	-9.63	5.45
300	164	-10.32	5.83
325	158	-11.06	6.15
350	155	-11.87	6.40
375	151	-12.89	6.49
400	143	-13.79	6.55
425	141	-14.29	5.89
450	106	-15.47	6.40
Total	2418		

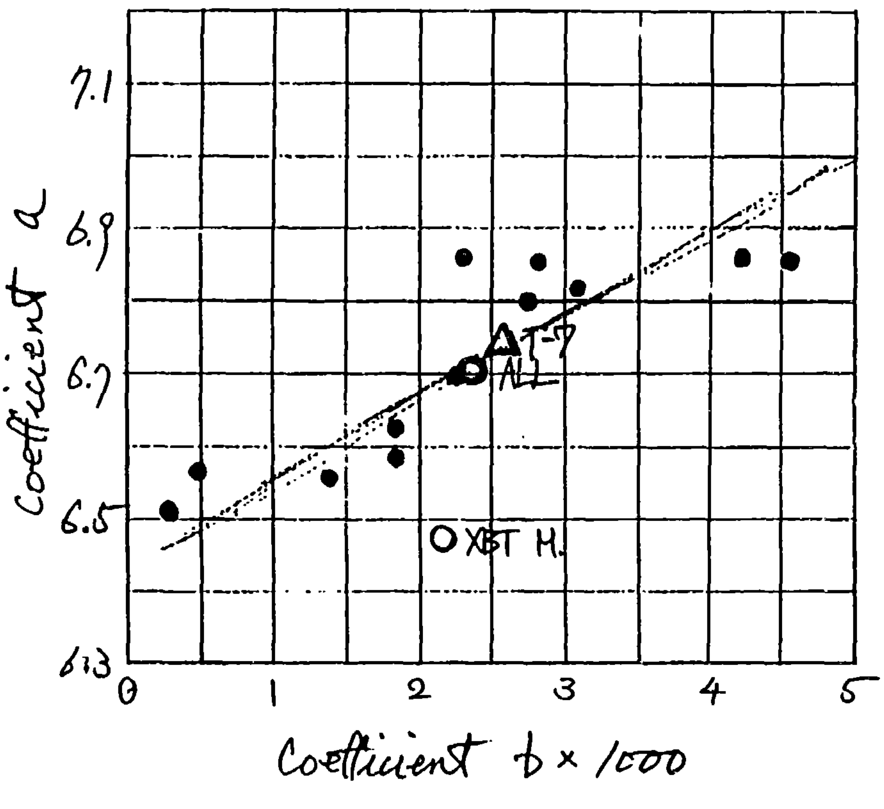

Fig. 1. Scatter plot of coefficients a and b of depth-time equations estimated for individual subdatasets. See Table 2.

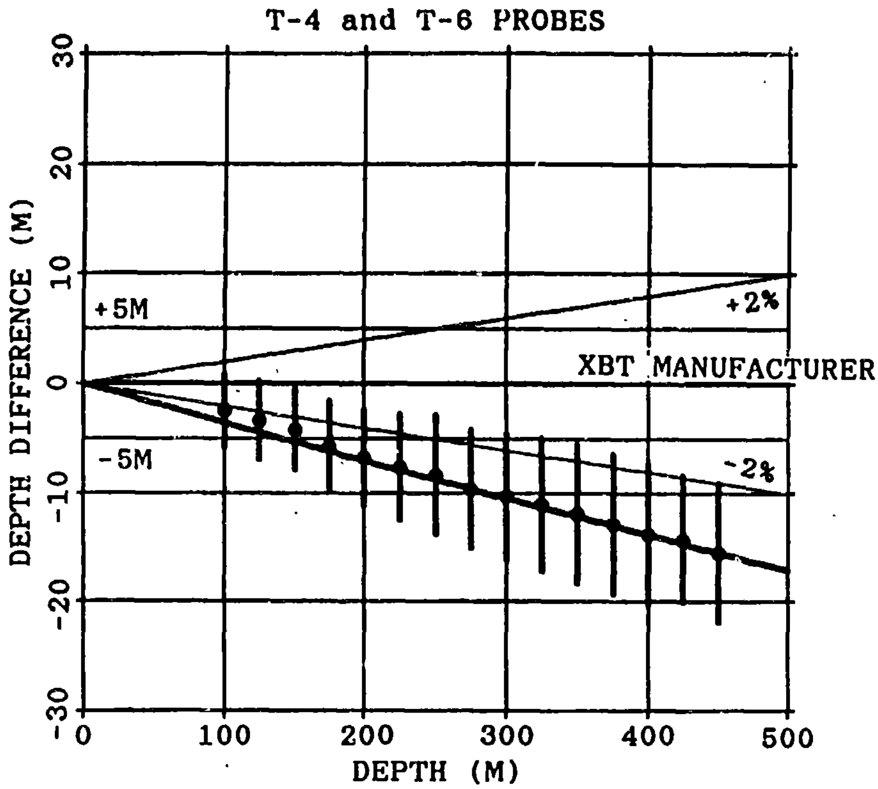

Fig. 2. Behaviour of mean depth differences and standard deviations estimeted for all T-4 and T-6 probes data against the equation provide by XBT manufacuturer. The heaviest line denotes that of Eq. (1) newly estimated in the present analysis.

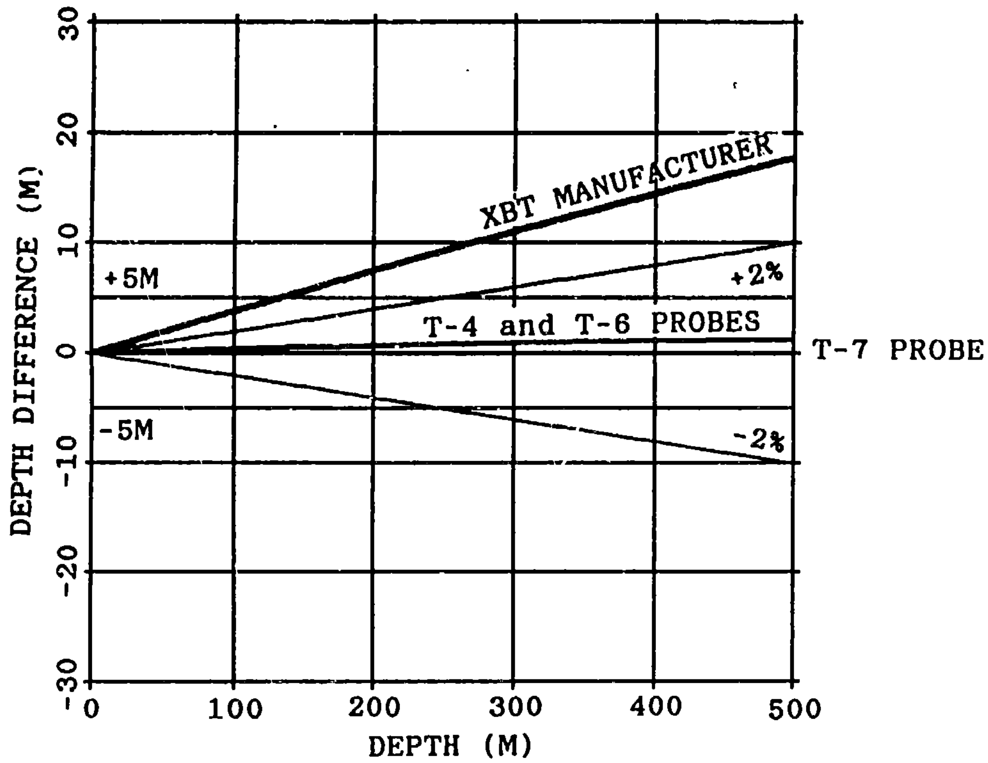

Fig. 3. Behaviour of depth differences of the equation for T-4 and T-6 probes, Eq. (1), from the equation for T-7 probe, Eq. (2). The maximum difference is about 1.5m at 450m depth.

ANNEX V

XCTD measurements in the North Atlantic:

Report on XCTD performance data

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Introduction

Since 1988 the Bundesamt für Seeschiffahrt und Hydrographie (BSH) has operated a ship of opportunity line between the English Channel and the US East Coast as part of WOCE (line AX-3). From the start XBT measurements have been carried out by CMS "Köln Atlantic" (call sign: DAKE) with a temporal resolution of about one month and a spatial resolution of 30 to 40 nautical miles.

Line AX-3 crosses the subarctic North Atlantic close to the endpoint/startpoint of the thermohaline-driven Conveyor Belt (Broecker, 1987). It covers areas of pronounced processes such as the region of Subarctic Mode Water production on its eastern and central section (McCartney and Talley, 1982), or features like the meanders and branches of the North Atlantic Current west of 30 °W (Sy, 1988; Sy et al., 1992), and the extreme frontal regime between the Labrador Current and the North Atlantic Current east of the Grand Banks (Clarke et al., 1980). The stability of the North Atlantic portion of the Conveyor Belt has recently been questioned on the basis of paleoclimatic investigations (e.g. Broecker et al., 1985) and results from numerical ocean models (e.g. Maier-Reimer and Mikolajewicz, 1989). All these features are candidates for global change indication.

Temperature measurements, if sampled frequently enough, can give an idea about space and time scales. But because of the variable T/S relationship in the western North Atlantic (Emery and Dewar, 1982), XBTs alone do not satisfactorily meet the requirements for investigation of changes in climate-relevant processes. This brief introduction shall emphasize the need for systematic T/S sampling, i.e. in terms of ship of opportunity programmes, there is an urgent need for the use of XCTD probes.

The first transoceanic XCTD section (February 1992)

The first ocean crossing XCTD section was probably carried out by CMS "Köln Atlantic" (gross tonnage: 39.000 tons, length: 240 m, speed: 19 knots) from Feb 22 to Feb 26, 1992 (Fig. 1). The section was repeated in July 1992. All XCTD measurements were carried out by a scientist from the vessel's stern (launch height: 10 m). For data acquisition, two

Compaq SLT/286 laptop computers equipped with Sippican MK-12 interface rev. E and software rev. 1.3 were used. During the February cruise, two versions of XCTD probes were launched, a 10 knt standard version having been purchased in October 1991 (calibrated by Sippican in Sept./Oct. 1991), and an 18 knt special version provided by Sippican for test purposes (calibrated in February 1992) was also launched. The manufacturer claimed that the special probes were capable covering the upper 1000 m at a ship's speed of 18 knots - an important requirement for most ship of opportunity programmes.

In the MK-12 user's manual (Sippican, 1991), it is noted that for most probe types a proper seawater ground is needed and that the actual resistance necessary depends on the type of probe being used. However, it was found that XCTD operation is extremely sensitive for a good sea water contact. We searched for a suitable seawater ground by drilling a hole in one of the vessel's frames, polishing the steel at the hole until it gleamed, and mounting a thick copper ground wire with a brass screw as tightly as possible to reduce the transition resistance to a minimum (Fig. 2). On the July cruise the grounding site had to be repolished carefully because even the smallest rust particles increased the transition resistance beyond a critical limit. Presumably, this grounding problem is not peculiar to "Köln Atlantic", because on R.V. "Valdivia" in September 1992 we were affected by the same problem when testing XCTDs in a bucket. Our experiences lead us to believe that for ship of opportunity purposes XCTD probes are too sensitive for a seawater ground. There are reasons for the assumption that insufficient seawater ground caused noisy test profiles collected by some investigators.

In February, 40 XCTD probes were launched - 4 probes failed. During the July cruise, 45 probes were launched - 5 probes failed. This failure rate is similar to that of XBT probes. The failure rate of the 18 knt probes was 4 of 24 used. Inspection of the probes or of what remained after a drop gave some indications of tangled wire spooling. It should thus be checked whether the calibration procedure affects wire spooling or even sometimes damages the signal wire. It will come as a relief to the worried user to know that Sippican has promised to replace its expensive probes in case of failure (Jim Hannon, pers. comm.).

18 knt XCTDs were launched side by side with 10 knt probes or with T-5 (Fast Deep) XBTs, respectively. A representative overview of the records acquired is shown in Fig. 3 a-c. To illustrate more details, an enlarged single measurement is given in Fig. 4. Depending on the ship's speed and the relative wind velocity, the 10 knt probes covered a depth range of only 600 to 650 m only. The 18 knt probes failed obviously (see Fig. 3). Their true depth fall rate was much slower than calculated and varied from probe to probe. It turned out that only a very few records were acceptable. A possible explanation might be hydrodynamic instability of the underwater body. The noise level in the 18 knt records is higher than in the 10 knt records, and for both probe types there is an increase of noise with depth (see Fig. 4). A staggering or a capsizing probe does not guarantee a regular (high and constant) flow rate through the conductivity cell. At low flow rates, circuit heat dissipation may heat the water near the sensor's surface.

All 10 knt records were processed completely. Processing, however, turned out to be a frustrating trial and error game due to several incorrect conversion formulas given in the

MK-12 user's manual (Appendix D). The vertical resolution of raw data is about 0.8 m. Unfortunately we needed to use some effective noise and spike rejecting procedures as median filtering (Sy, 1985), followed by smoothing filtering and interactive screen editing, which reduced the vertical data independency to about 10 m. In 5 profiles erroneous segments (signal disturbances) of up to 100 m had to be removed completely. After averaging in 10 m increments, some records contained a doubtful signal, which consists of more or less well developed wave- or step-like features (Fig. 5 a,b). Again, it is thought that these structures could be an indication of stability problems.

Finally, some brief remarks on time-lag issues. Usually the temperature sensor has a slower response than the conductivity cell. For that reason the specific sampling sequence (temperature prior to conductivity, 4 cycles per second) shall compensate the time-lag error (D. Kaiser, pers. comm.), provided that the flow through the cell is constant. Theoretically this condition should be fulfilled for free-falling probes, because they are unaffected by ship's movements. Fig. 6 is intended to show that the time-lag has presumably been overcompensated by the manufacturer. In this case a significant noise reduction of salinity occurred by slowing down the temperature by 80 ms. On the other hand we were not able to reduce the time-lag-induced noise generally, i.e. for all profiles in the same way. We assume that the flow rate varies (depending on the probe's stability). We did not, however, systematize the time-lag problem further.

Admittedly, the results obtained are not quite yet the scientific data base we had hoped for, and it must be regarded as preliminary as long as the data quality in terms of accuracy and reliability isn't completely known. Nevertheless, we conclude that the result should not be discouraging because

1. comparison of the XCTD temperature section vs. the XBT temperature section shows good agreement (Fig. 7 a,b);
2. the detection of signal errors is much easier for T/S data than for temperature data alone which, incidentally, has led to the decision to delete XBT drop # 6 in Fig. 7 b;
3. the spatial range of salinities between their minimum in the Labrador Current regime and their maximum in waters west of the English Channel differs by more than 2 PSU, and the temporal variability in the upper ocean can be expected in the order of several tenths of PSU (Levitus, 1989).

XCTD vs. CTD intercomparison (September 1992)

Fortunately we were able to carry out XCTD versus CTD comparisons during a WOCE cruise onboard R.V. "Valdivia" in September 1992. The test area is located west of the British Isles, which is a good test site for expendable probes due to well developed structures in both temperature and salinity. The XCTD data acquisition system was the same as that in February. For this comparison 12 XCTDs were launched, 3 of which remained from the batch used in February and 9 came from a batch purchased in July 1992 and calibrated by Sippican in June 1992. The comparisons were carried out at 3 regular CTD stations, side by side with a well calibrated NBIS MK-III CTD. The log shown in Fig. 8 should clarify the procedure. 2 drops failed due to broken wire (no signal, Oct. 91 batch) and 1 probe had no contact with MK-12 (June 92 batch). The system's accuracy for XCTD measurements is given by Sippican as ± .03 °C for temperature, ± .03 mS/cm for conductivity, and ± 5 m or 2 % for depth. The records of the remaining 9 successfully launched probes are shown by way of examples (Fig. 9 - 11). The results are summarized as follows.

- Two measurents revealed calibration failures. One temperature record has an offset of about + .2 °C (Fig. 10a) and one conductivity record has an offset of about - .3 mS/cm (Fig. 11b). On the other extreme the result from the remaining probe from the Oct 91 batch (XCTD # 1) corresponds well for temperature, conductivity (as far as 650 m), and depth with the CTD data (Figs. 9 a-c) so that Sippican's specs are met in this case.

- As an overall result the range of temperature difference between CTD and XCTD was found to be about ± .06 °C, and the range of conductivity difference was found to be about ± .05 mS/cm.

- As for XBT probes the XCTDs (except XCTD # 1) fall faster than specified (Figs. 9c, 10b, 11a). The error was estimated between 3 % and 4 %.

- Probably due to compensation effects, the salinity deviation was found to be not larger than .05 PSU (for 7 records). Salinity deviation, however, increases with depth due to the depth underestimating fall rate formula (Fig. 11c). On the other hand, this salinity difference is underestimated because Sippican uses a standard conductivity C(15,35,0) = 92.921 whereas we use the value 92.914 (Figs. 9d, e). Finally, it should be noted that the numerical precision of XCTD salinity data we used (after transformation from binary in ASCII code, i.e. *.SIP to *.EXP) was only .01 (Figs. 9d, e). Thus salinity accuracy is affected by truncation errors.

- Increasing data noise with increasing depth is apparent in several records (Figs. 9g, 10c, 11d), which confirms the results from "Köln Atlantic". Another effect appeared which was not observed before. At 900 m depth there is a significant offset in salinity and density (Figs. 10c, 11d), which is caused by a shift in conductivity. The profiles collected at CTD # 24 show the same offset, however, at 550 m depth (Figs 9f, g).

Conclusion

As is usual for new oceanographic devices, it is not surprising that the field evaluation of XCTD performance reveals some discrepancies between theory and reality. The test results conclusively show that XCTD probes do not meet the manufacturer's specification. Furthermore, some problems occurred which need to be solved urgently. First of all, however, the manufacturer should improve the reliability of XCTD measurements. On the other hand, the scientific community should not shy from taking action and should co-operate in this enterprise.

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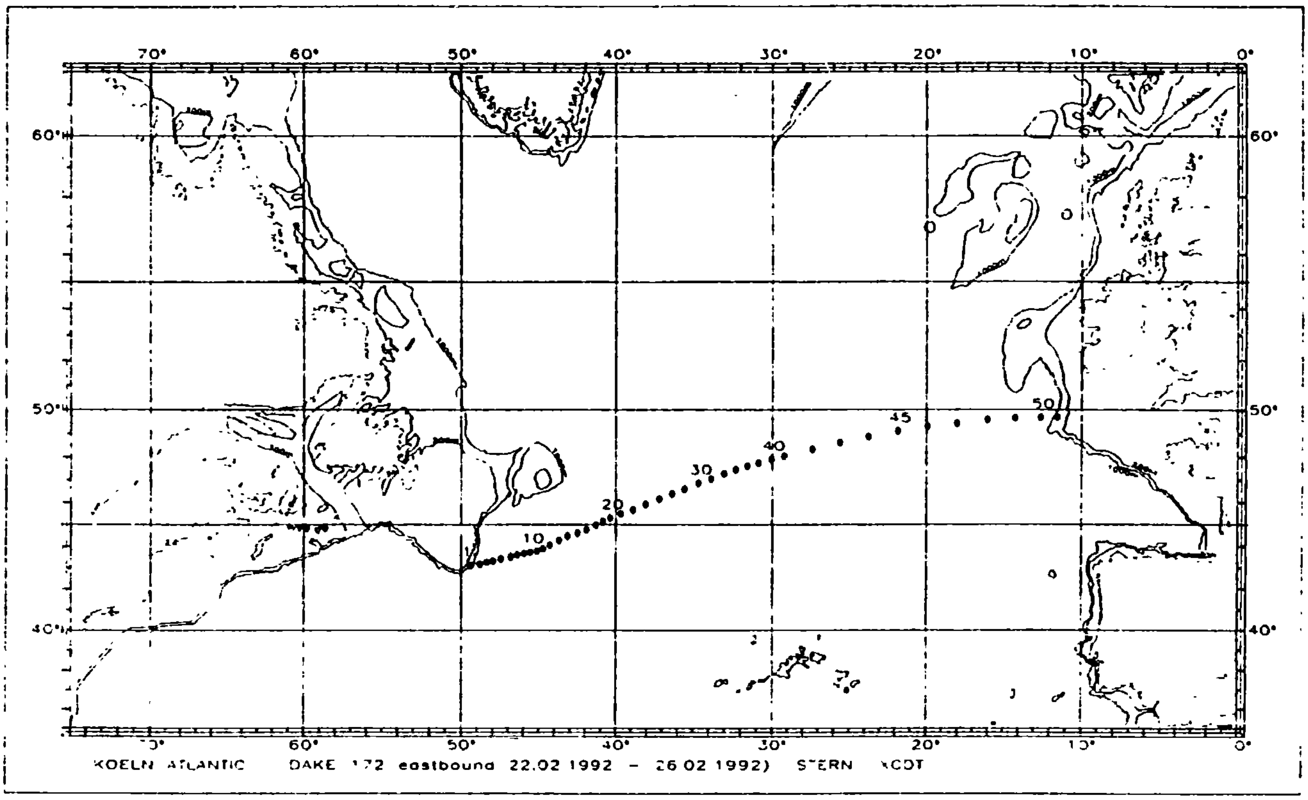


Fig. 1 Track plot of XCTD profiles collected in February 1992 onboard CMS "Köln Atlantic".

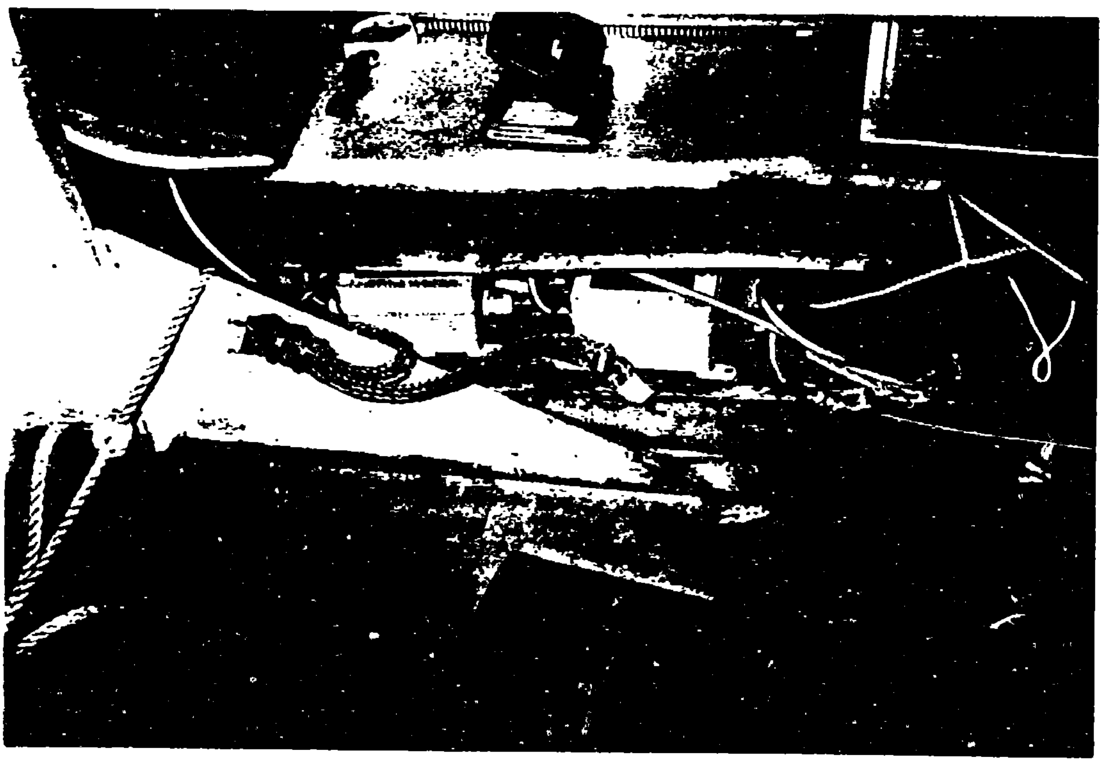


Fig. 2 Grounding of MK-12 Connector Boxes on CMS "Köln Atlantic"

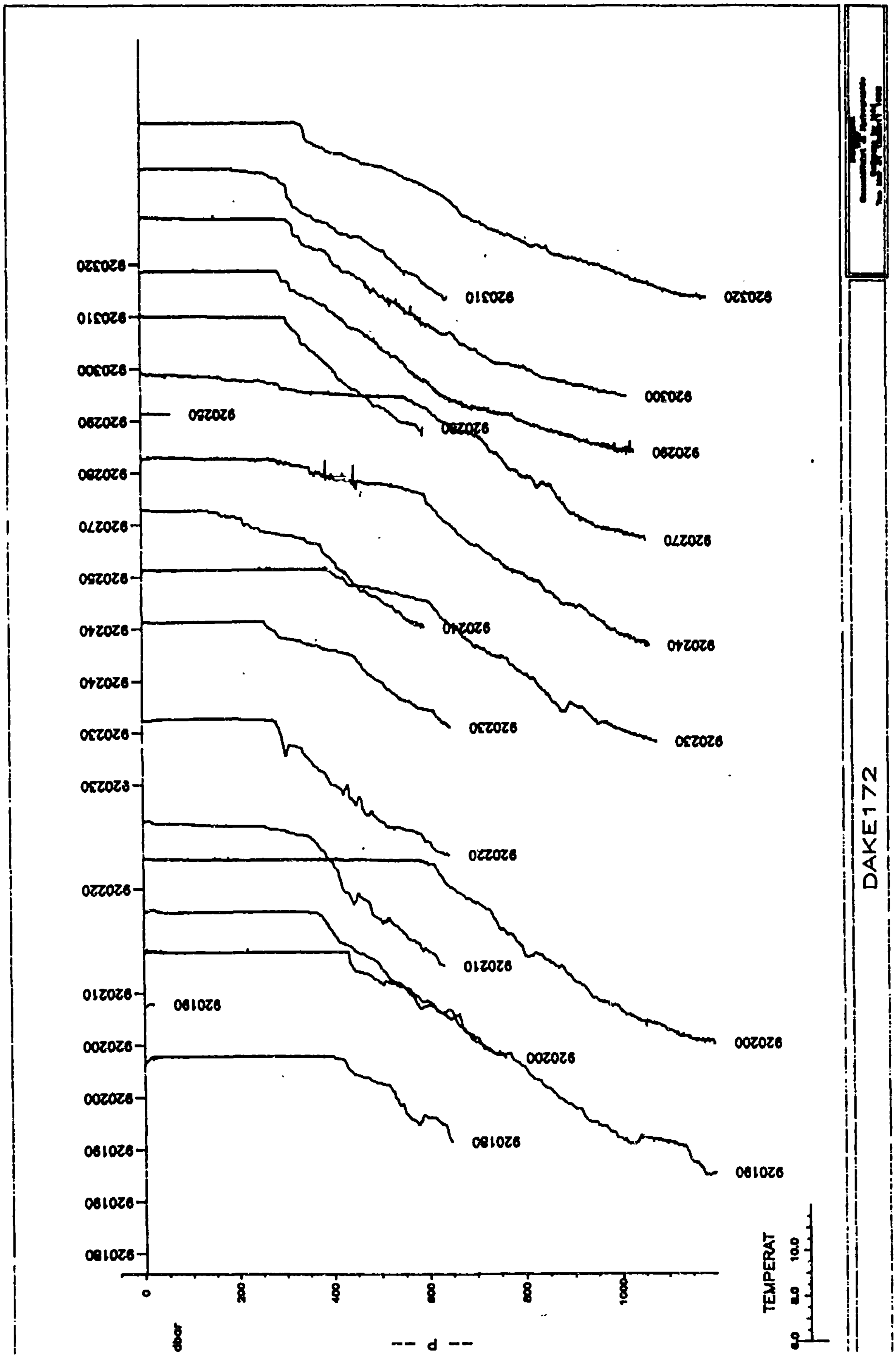


Fig. 3a Temperature profiles (raw data) at drop location n°s 18 to 32. The same drop n°s shown at two different profiles indicate a side by side drop of a 10 knt probe (first profile) and a 18 knt probe (second profile). Drop sequence from n°s 18 to 32 took a total time of 21 hours. Wind changed from westerly (Bf5) to southwesterly (Bf9) direction. Ship's speed was 15 to 16

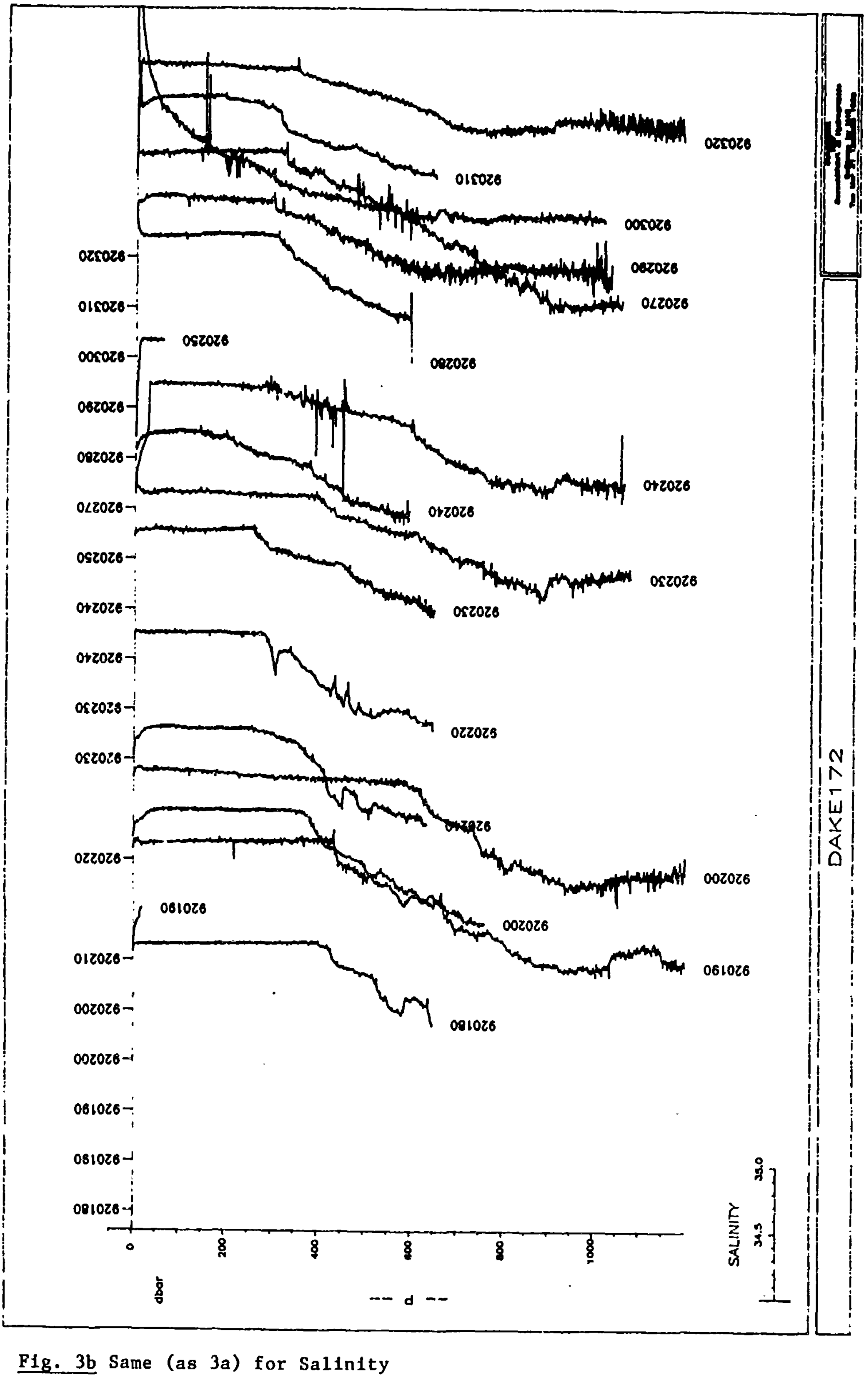


Fig. 3b Same (as 3a) for Salinity

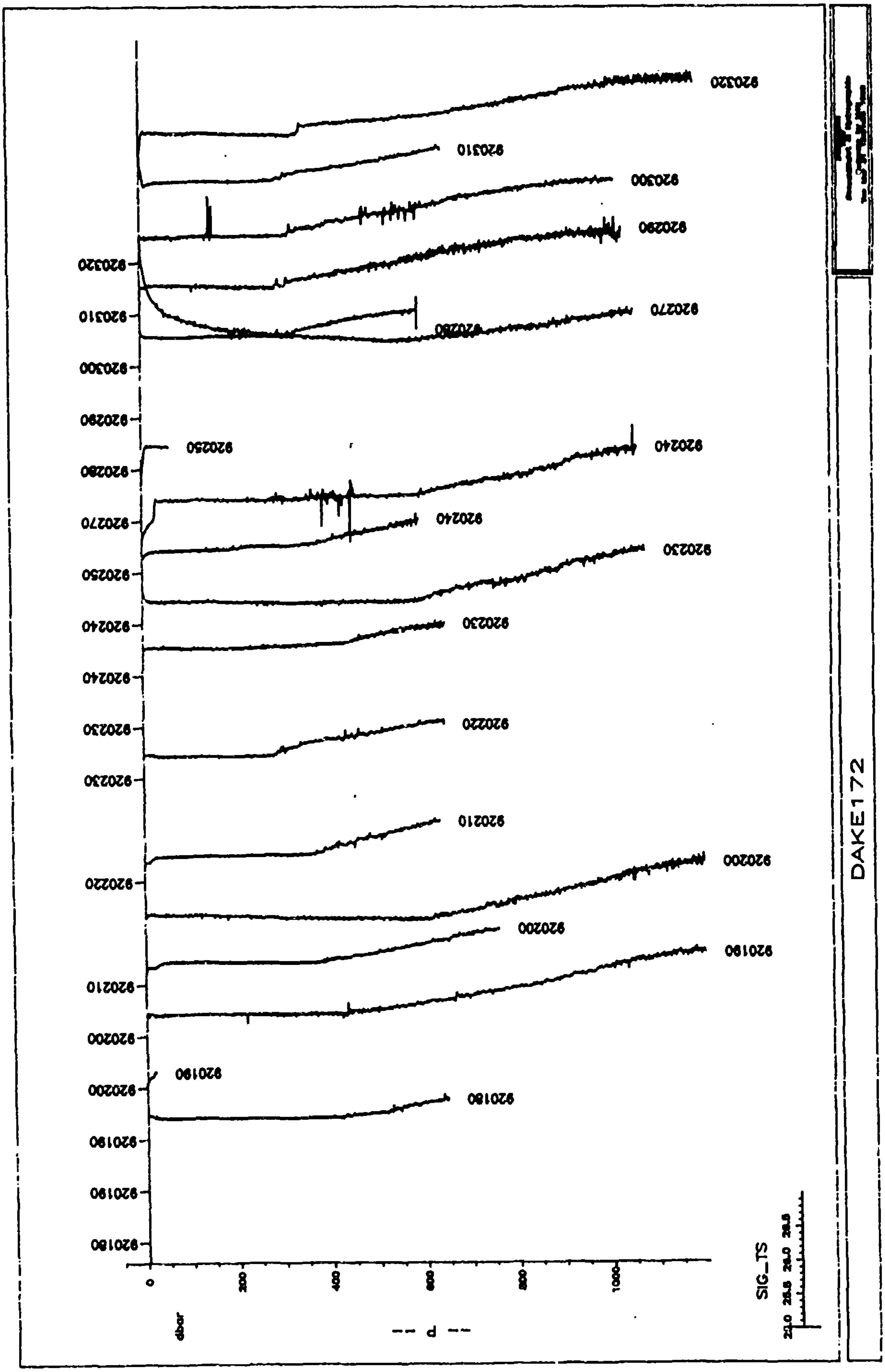


Fig. 3c Same (as 3a) for Density

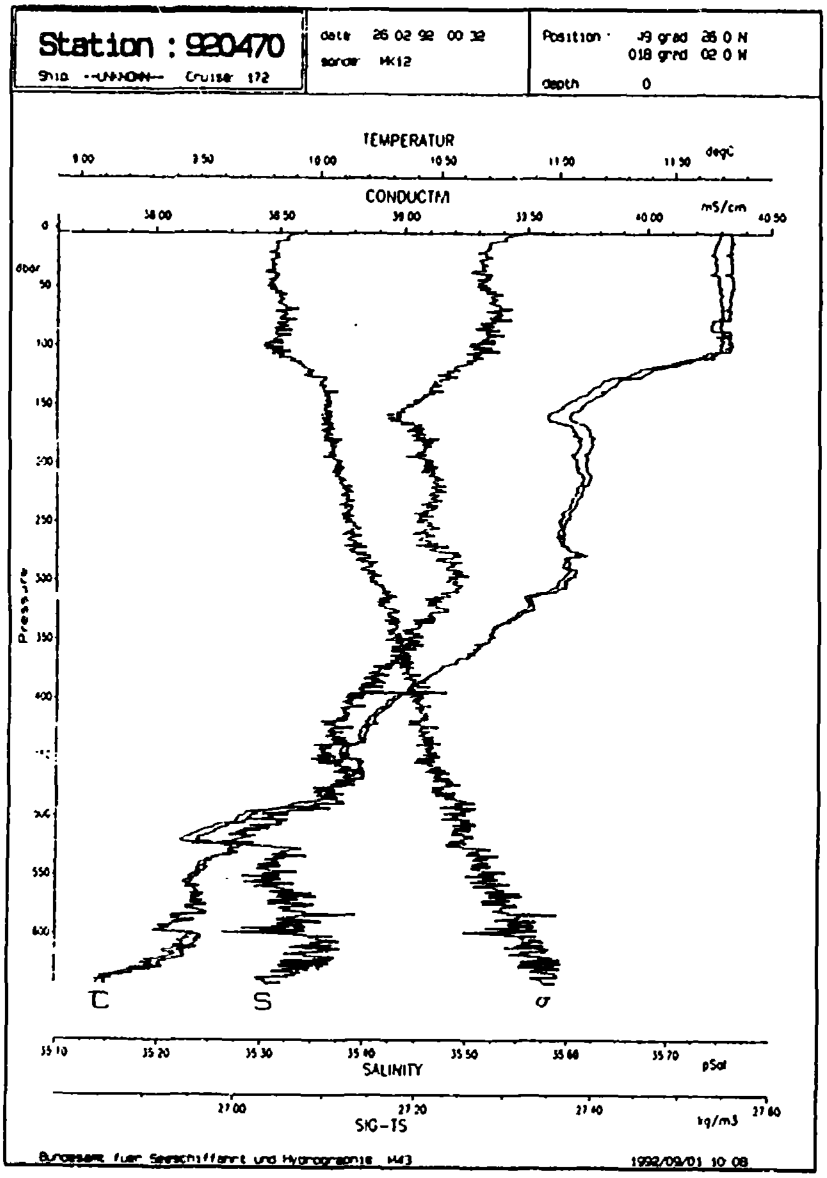
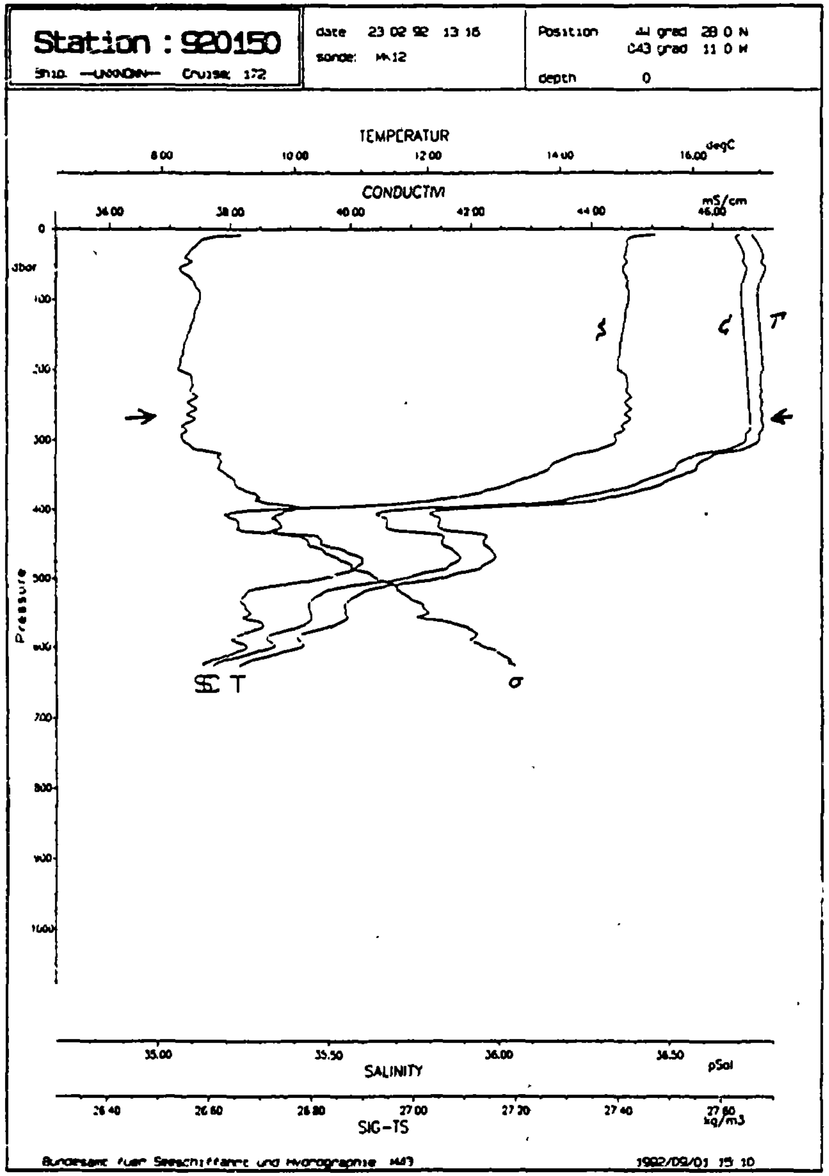
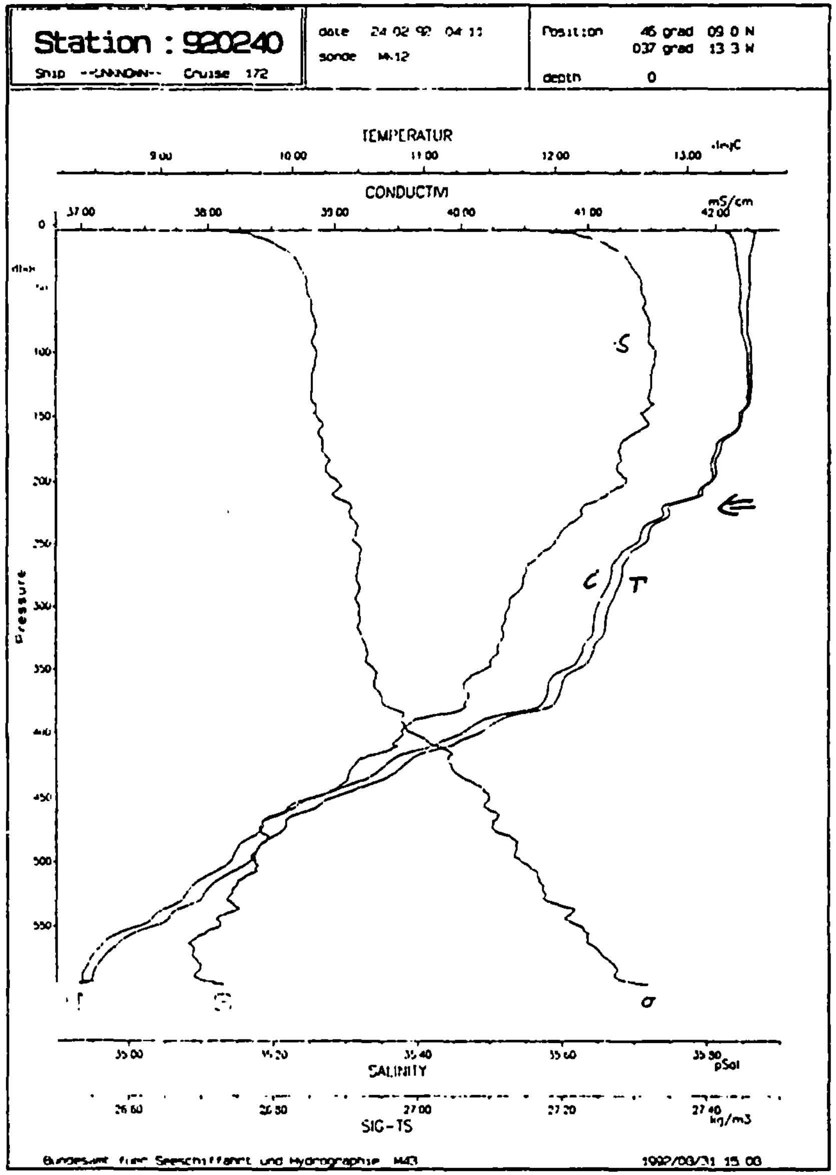


Fig. 4 Enlarged display of single XCTD record



<u>Fig. 5a</u> Example for a doubtful wave-like signal in the temperature record



<u>Fig. 5b</u> Example for doubtful step-like signal in the temperature and conductivity record

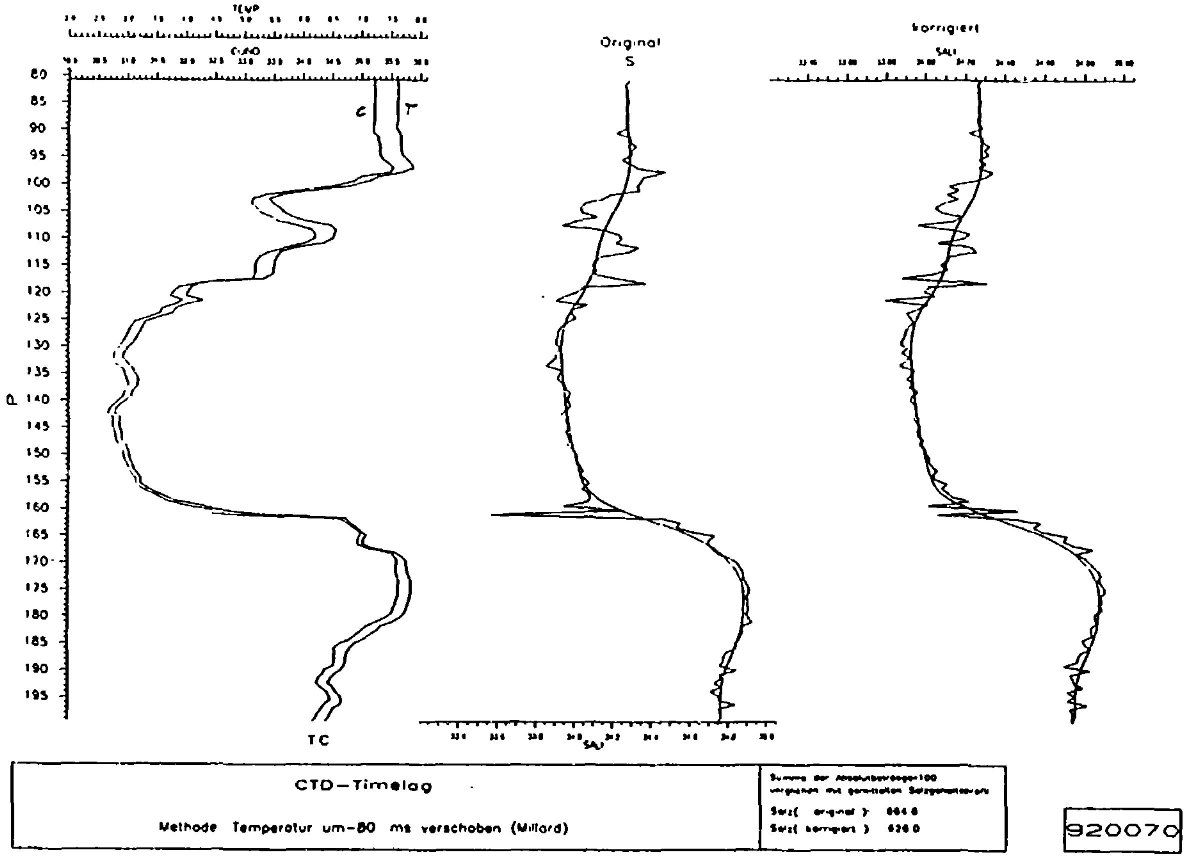
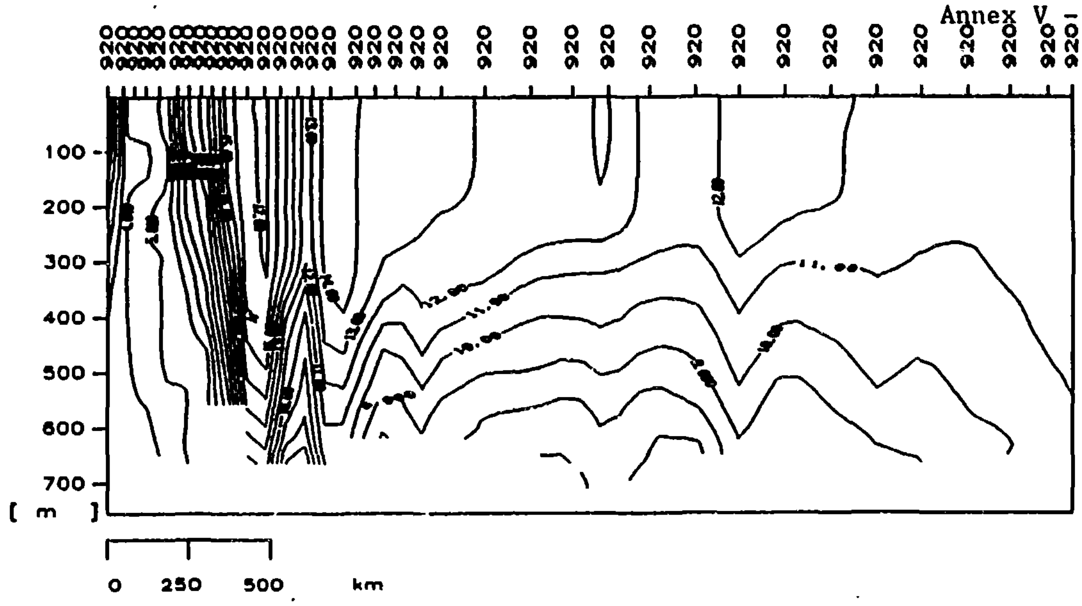


Fig. 6 Example for XCTD time-lag. Left and middle panel shows raw data of temperature, conductivity and salinity, respectively. The right panel shows recalculated salinity after a time shift of - 80 ms for temperature. Time-lag correction was performed by a recursive filter technique as proposed by Millard (Unesco, 1988). The smooth curve is calculated mean salinity.

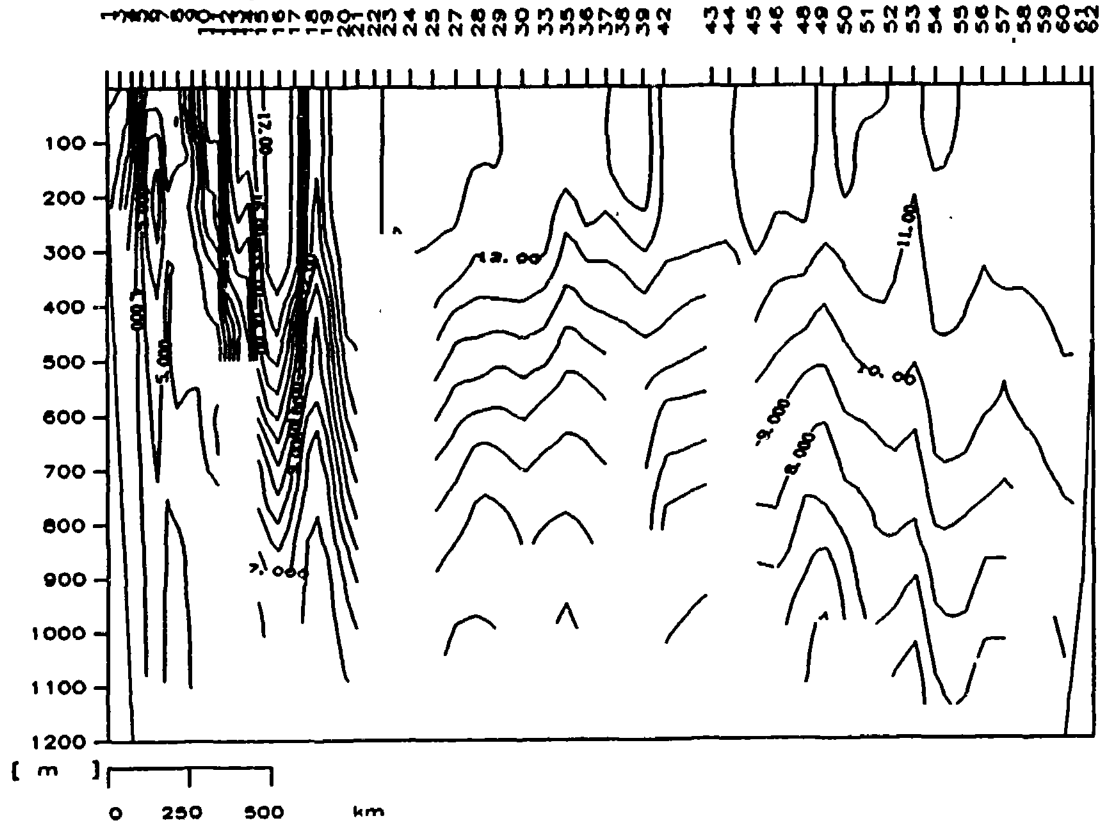


SOOP 172 TEMPERATUR/ degC

Gridding Parameter:	Area in X, by no. of profiles =	2
No of GRD-Points in X= 50	Area in Y, by physical units =	100
No of GRD-Points in Y= 50	Order of Orthogonal Surface =	1

BSH
Hamburg

Fig. 7a Section plots of "Köln Atlantic" measurements in February 1992 - XCTD temperature

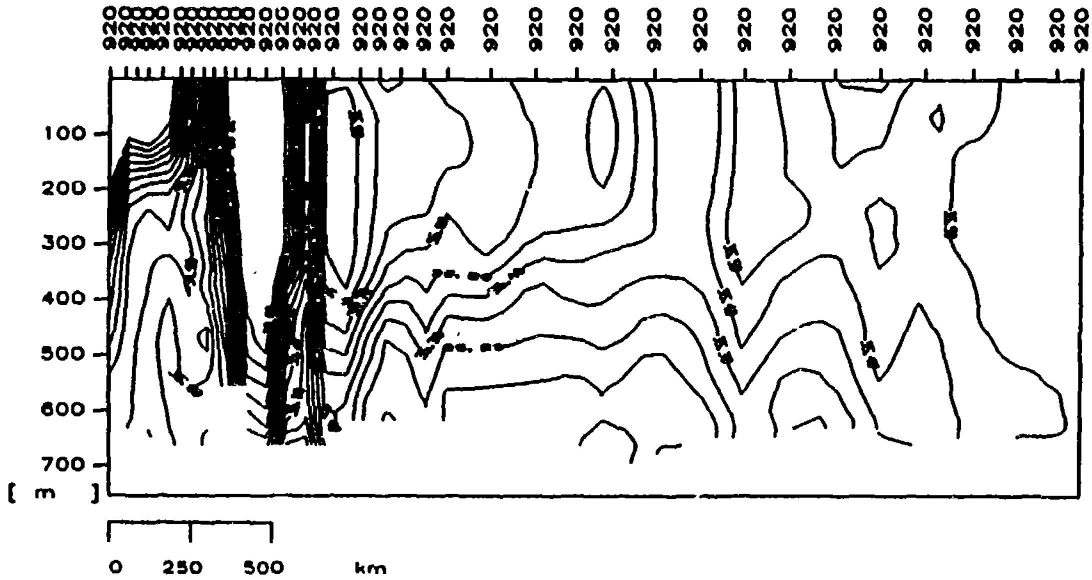


Orthogonal Surface Analysis: DAKE 172 N-ATL.east

Gridding Parameter:	Area in X, by no. of profiles =	2
No of GRD-Points in X=100	Area in Y, by physical units =	100
No of GRD-Points in Y=100	Order of Orthogonal Surface =	1

BSH
Hamburg

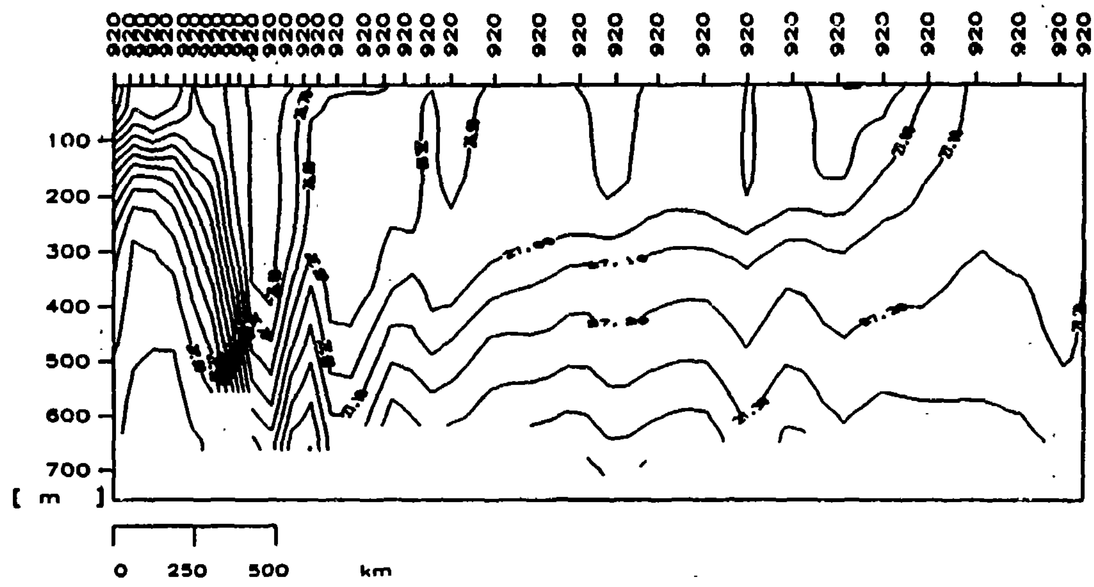
Fig. 7b Section plots of "Köln Atlantic" measurements in February 1992
XBT (T-5 "Fast Deep) temperature XBTs were launched from the bridge's wing



SOOP 172 SALINITY/ pSal

Gridding Parameter:			BSH
No of GRD-Points in X= 50	Area in X, by no. of profiles=	2	Hamburg
No of GRD-Points in Y= 50	Area in Y, by physical units =	100	
	Order of Orthogonal Surface =	1	

Fig. 7c Section plots of "Köln Atlantic" measurements in February 1992 - XCTD salinity



SOOP 172 SIG-TS/ kg/m3

Gridding Parameter:			BSH
No of GRD-Points in X= 50	Area in X, by no. of profiles=	2	Hamburg
No of GRD-Points in Y= 50	Area in Y, by physical units =	100	
	Order of Orthogonal Surface =	1	

Fig. 7d Section plots of "Køln measurements in February 1992 - XCTD density

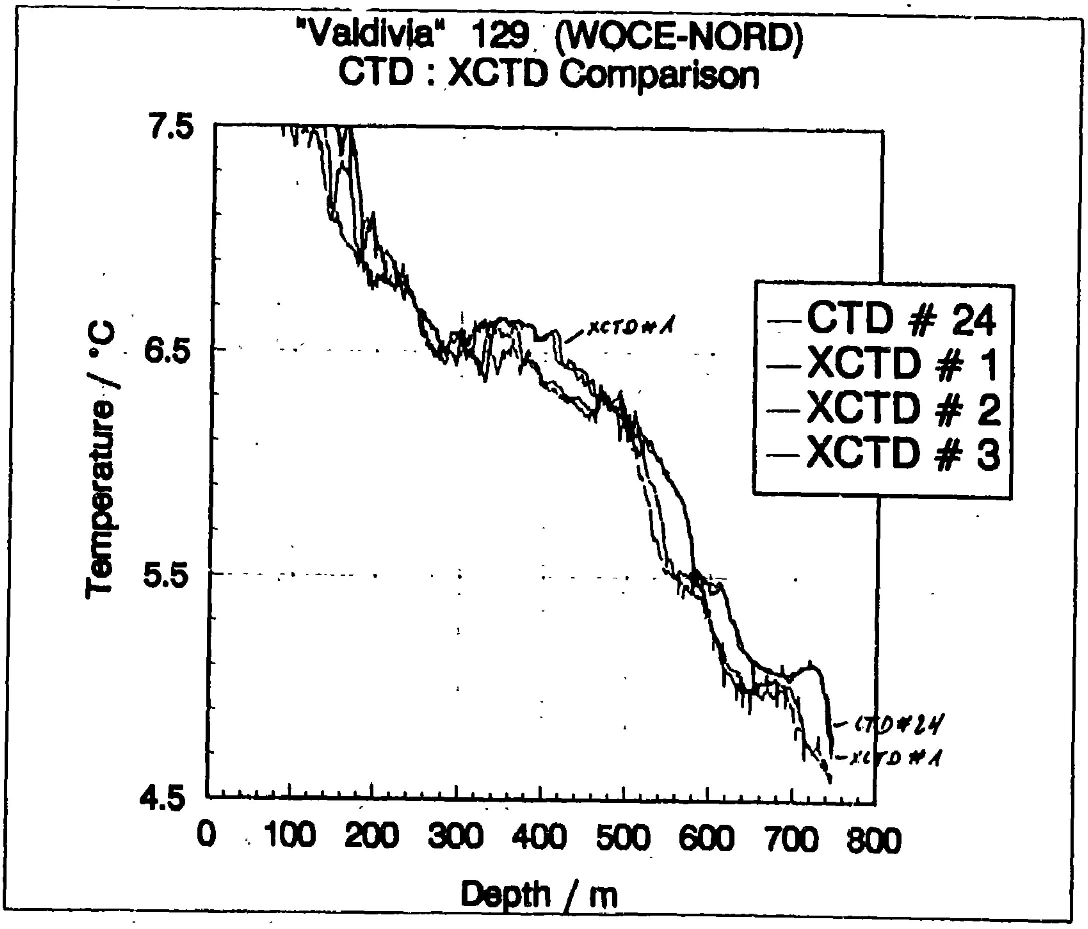
XBT-Protokoll

XCTD Test SIPPICAN

Schiff: Valdivia Reise: V 129
Rufz.: DESI ~~Kapitän~~ Wissenschaftler A. Sy
HK-12 Vers. 1.3

Abwurf (Nr.)	Sonde (Typ)	Datum	Uhrzeit (UTC)	Position (Breite)	(Länge)	Datendiskette (Name,Nr.)	File (Name)	W.-tiefe (m)	W.-temp. Oberfl.	Wind Richt/Stärke	Bemerkungen
CTD #24		21.9.92		58°04'N	29°22.5'W			2200 m	9.92°C	S 6	
1	XCTD		10:49			91100117.SIP					CTD=110m
2	-"-		10:56			92060025.SIP					CTD=610m
3	-"-		11:02			92070005.SIP					CTD=910m
											S/n 91100114 failed } wire
											S/n 91100113 failed } defect
CTD #35		23.9.92		53°59'N	22°30'W			3570 m	11.08	W 6	
4	XCTD		11:10			92060062.SIP					CTD=30m
5	-"-		11:18			92060064.SIP					CTD=400m
6	-"-		11:27			92060060.SIP					CTD=900m
											S/n 92060056 failed
											(no contact)
CTD #43		25.9.92		53°00'N	22°45'W			4000 m	11.09	calm	
7	XCTD		10:54			92060028.SIP					CTD=35m
8	-"-		11:02			92060093.SIP					CTD=400m
9	-"-		11:10			92060096.SIP					CTD=880m

Fig. 8 CTD versus XCTD intercomparison log



Figs 9 Selection of SCTD records at CTD n° 24. Please note that due to an operating error all XCTD launches at this satation are terminated at 750 m depth.

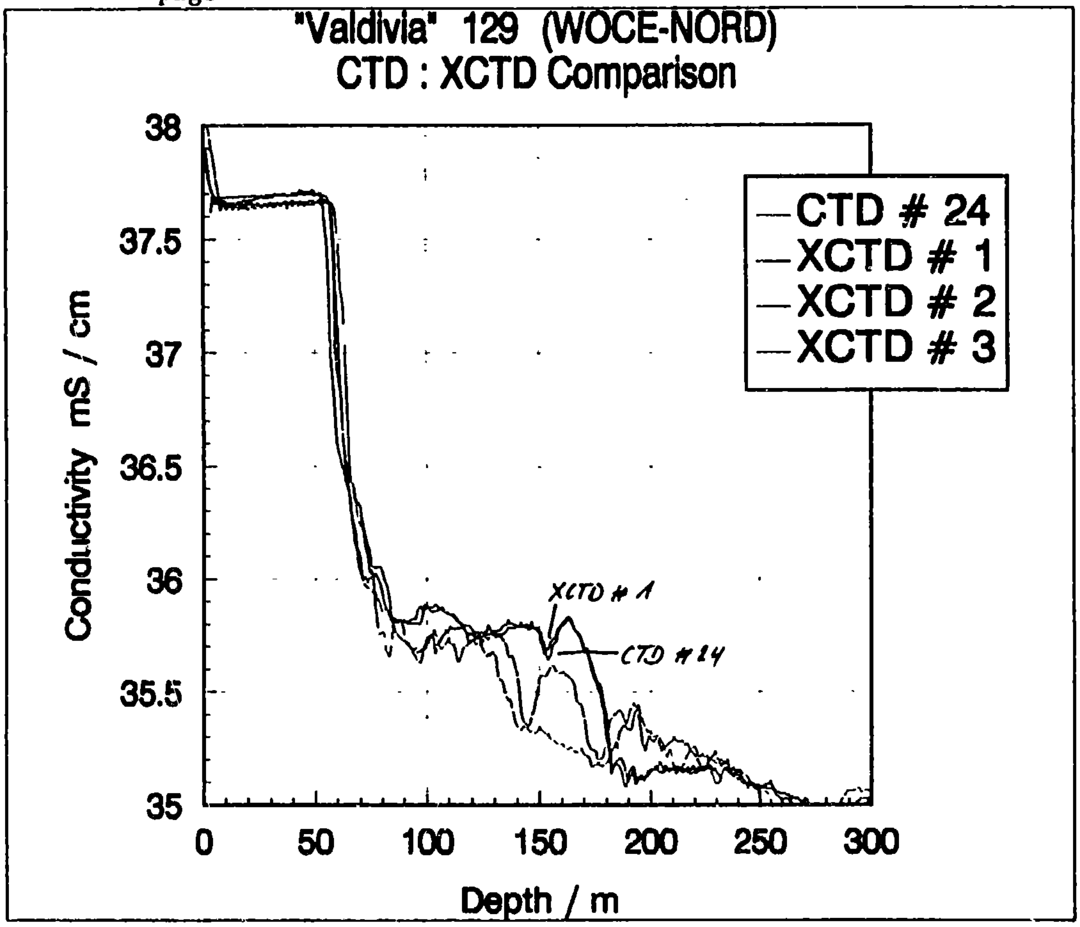
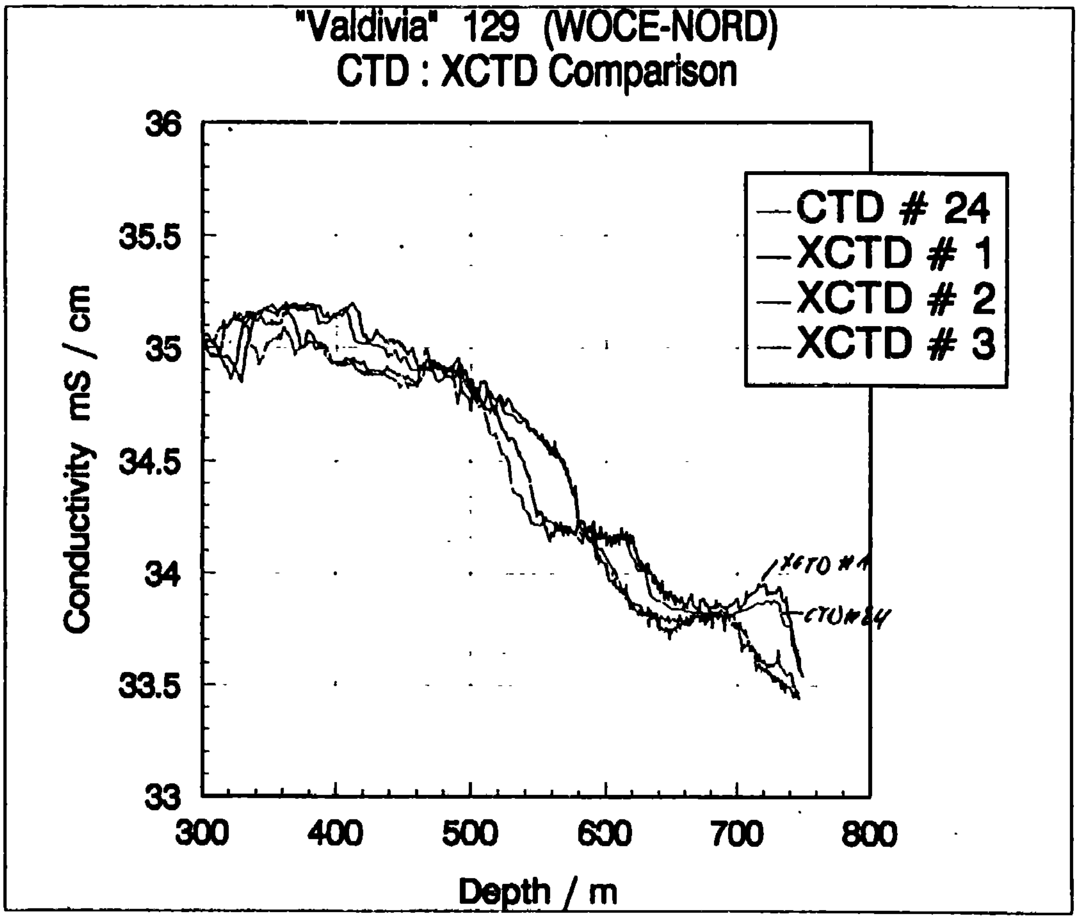


Fig. 9b Conductivity between 0m and 300m



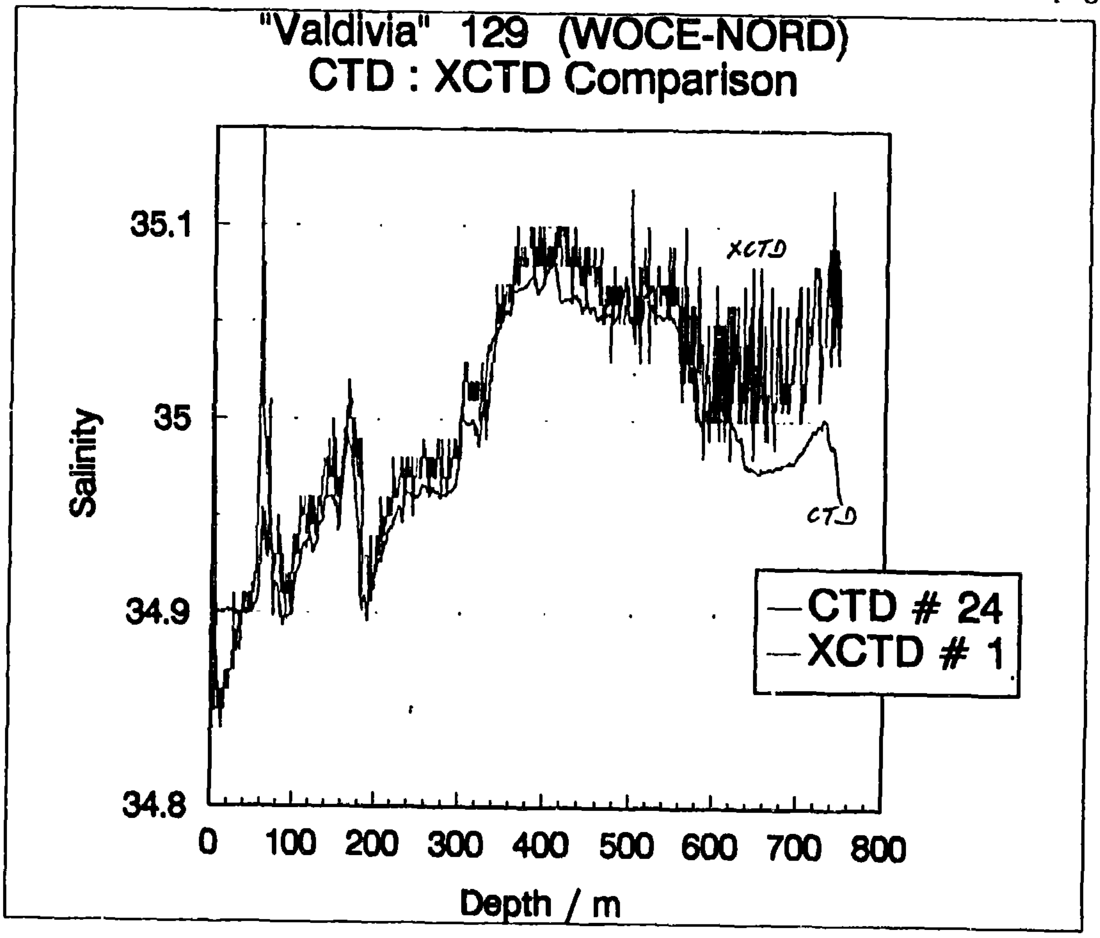


Fig. 9d Salinity of XCTD n° 1

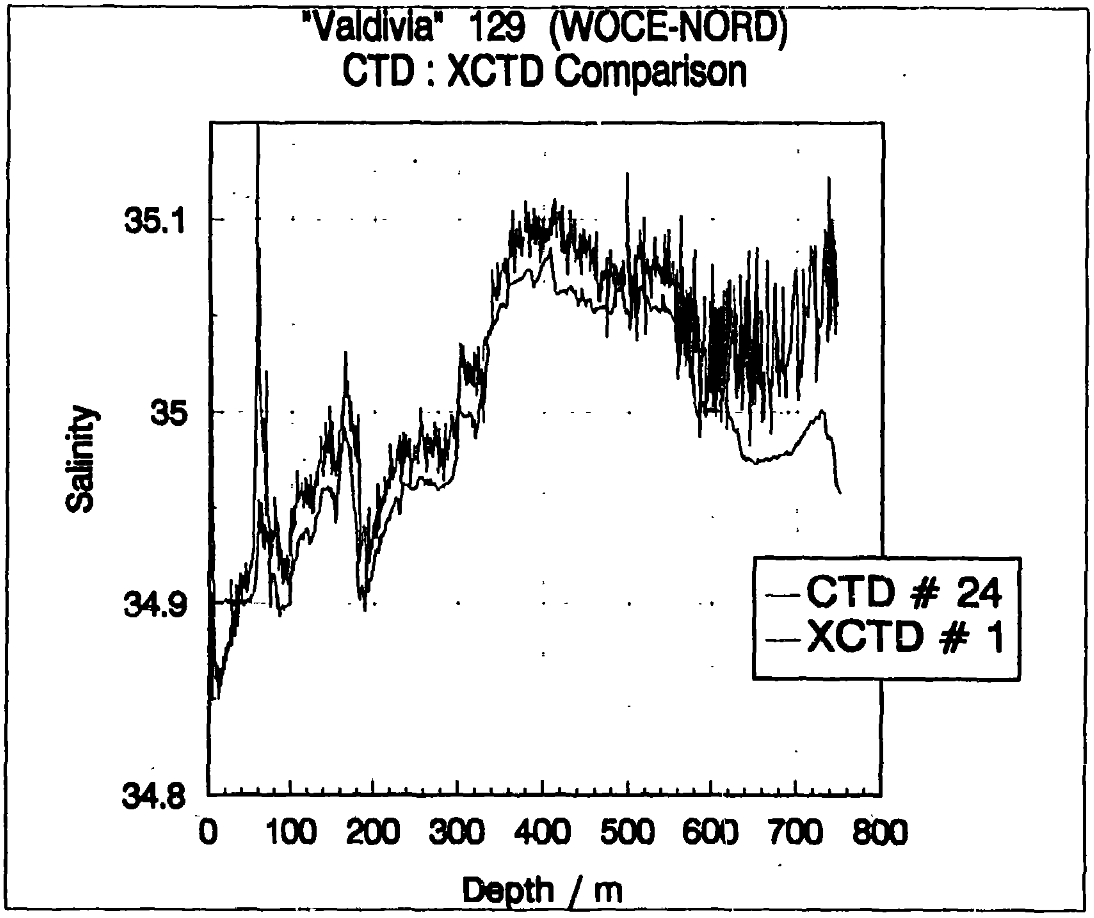


Fig. 9e As Fig. 9d) but recalculated with numerical precision of.001 and C(15,35.0) = 42.914

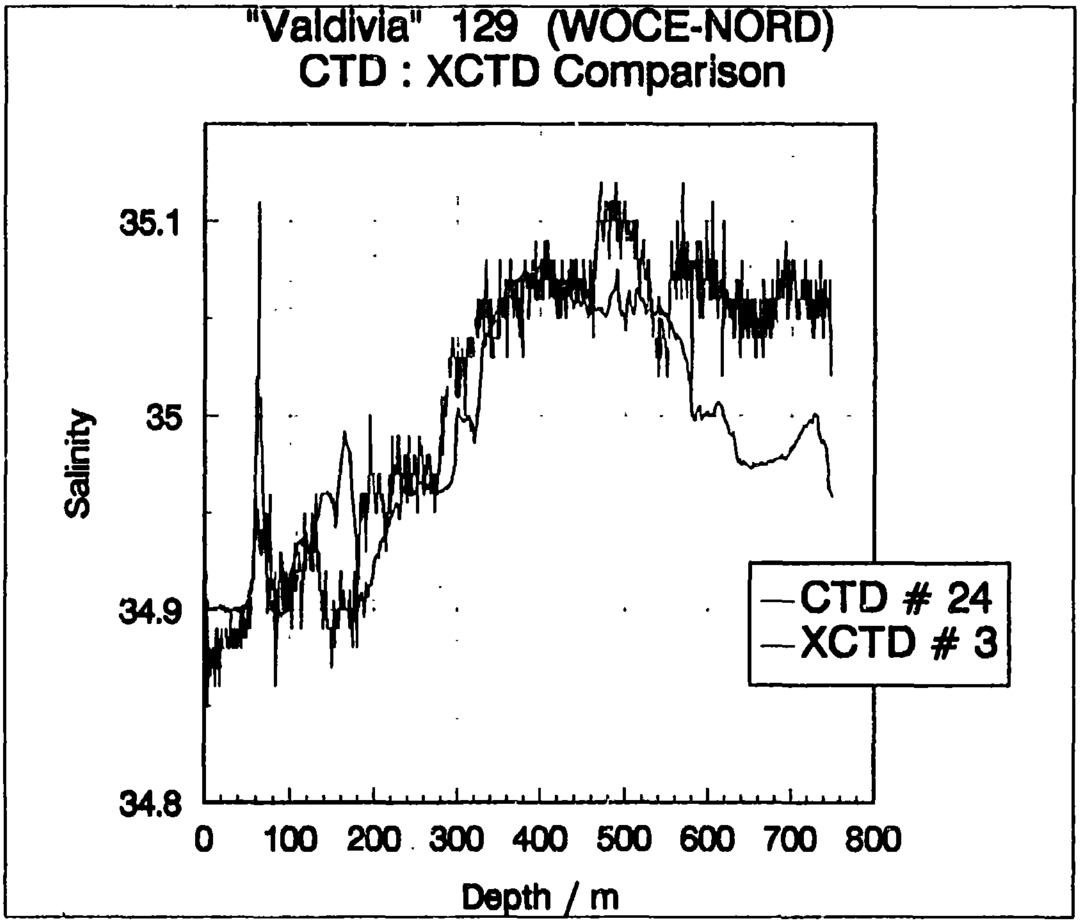


Fig. 9f Salinity fo XCTD n° 3

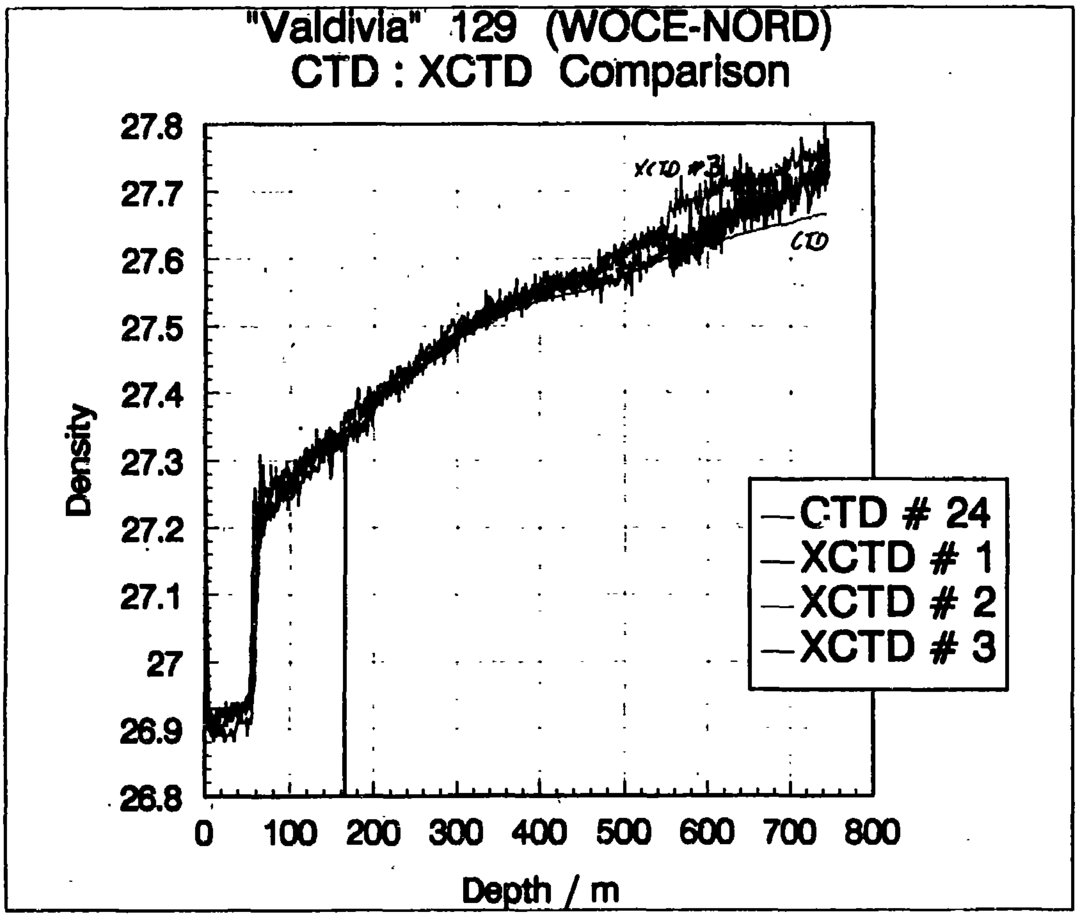


Fig. 9g Density with offset at 550m

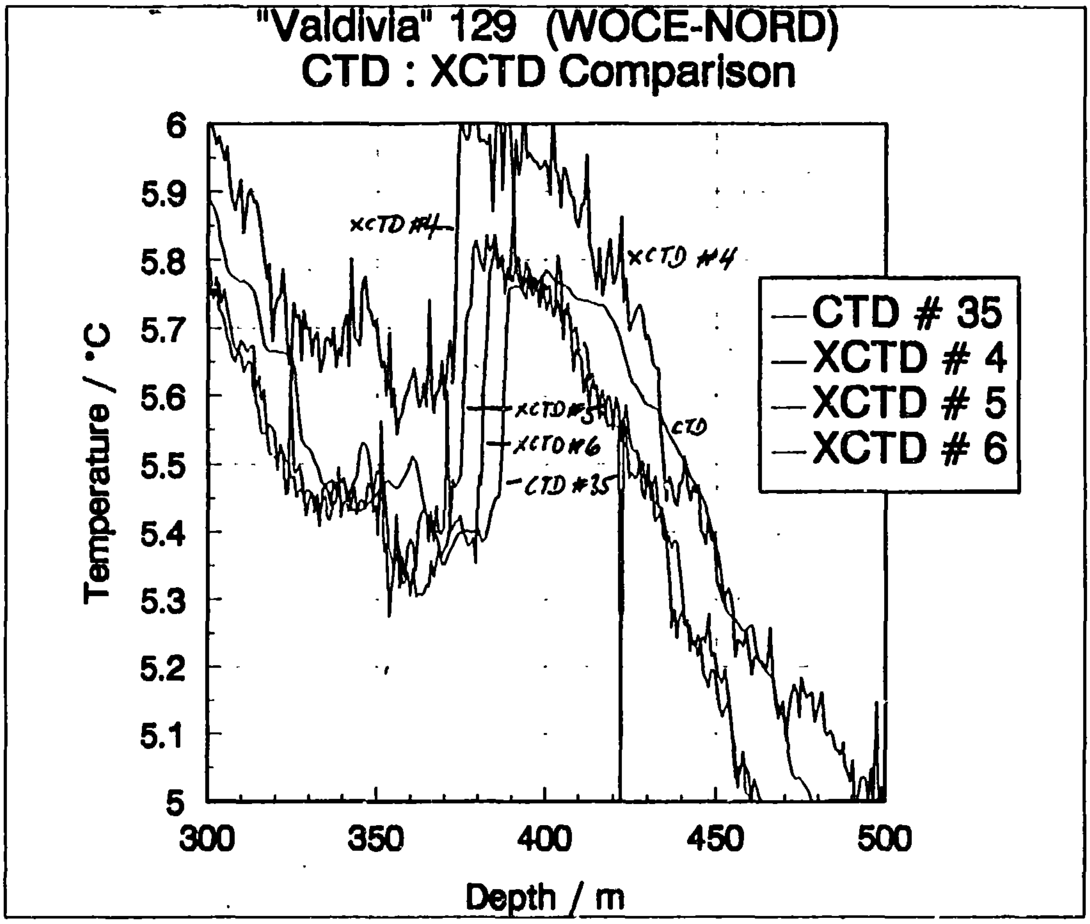


Fig. 10a Enlarged temperature records at CTD n° 35. One record (XCTD n°4 has an offset of + .2°C

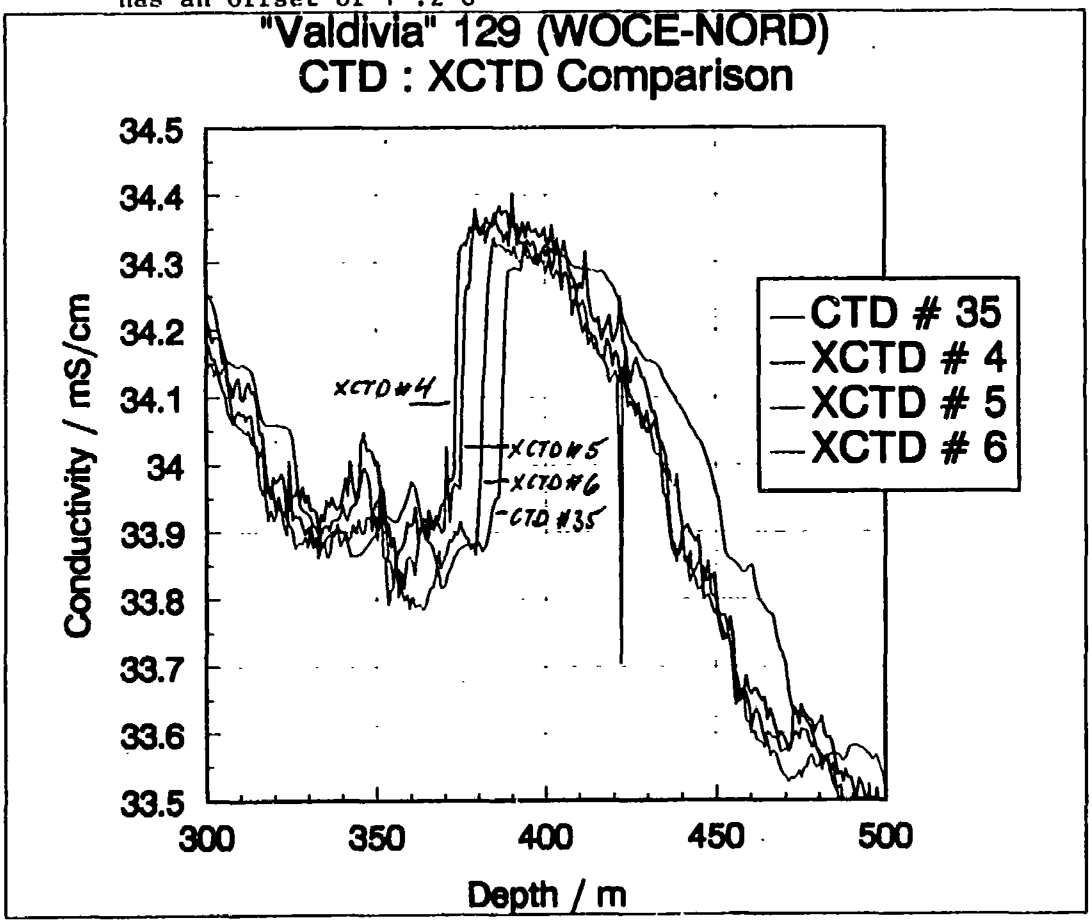


Fig. 10b Enlarged conductivity records at CTD n° 35

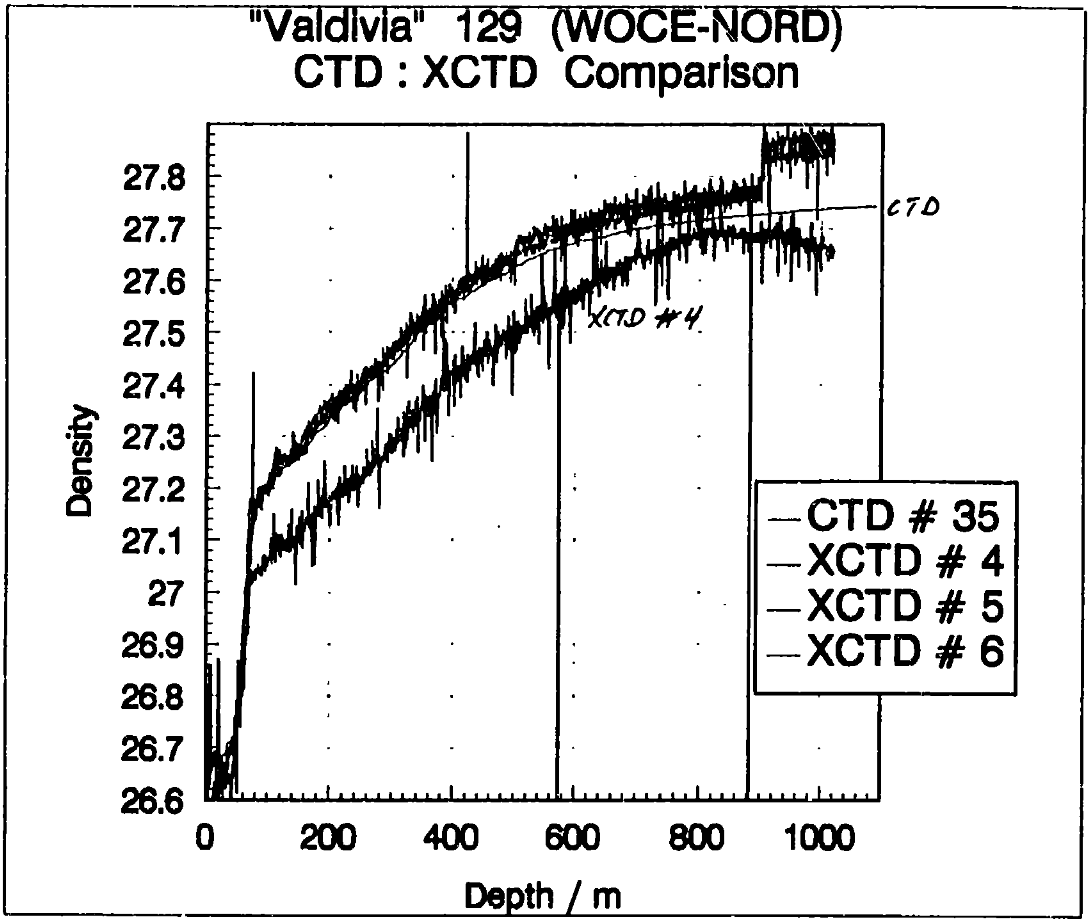


Fig. 10c Density with offset at about 900m

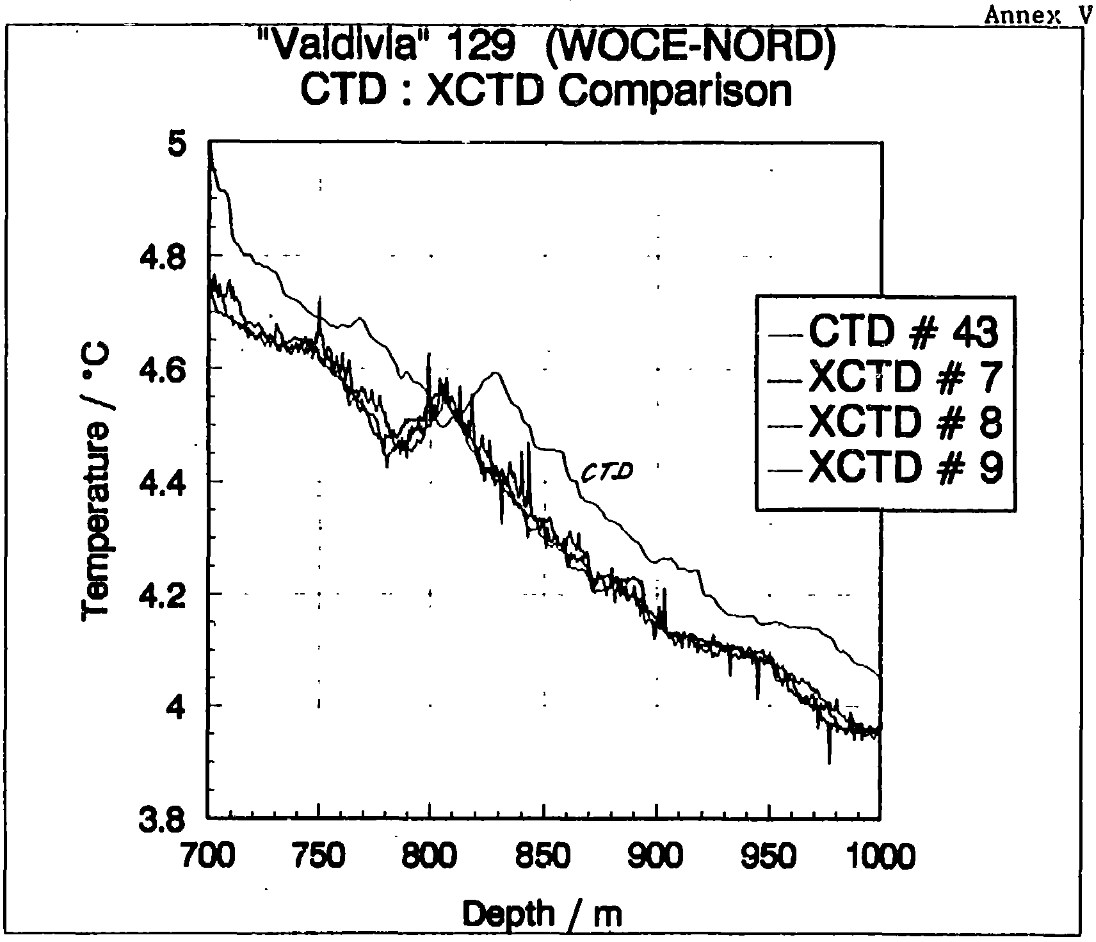


Fig. 11a Temperature between 700m and 1000m

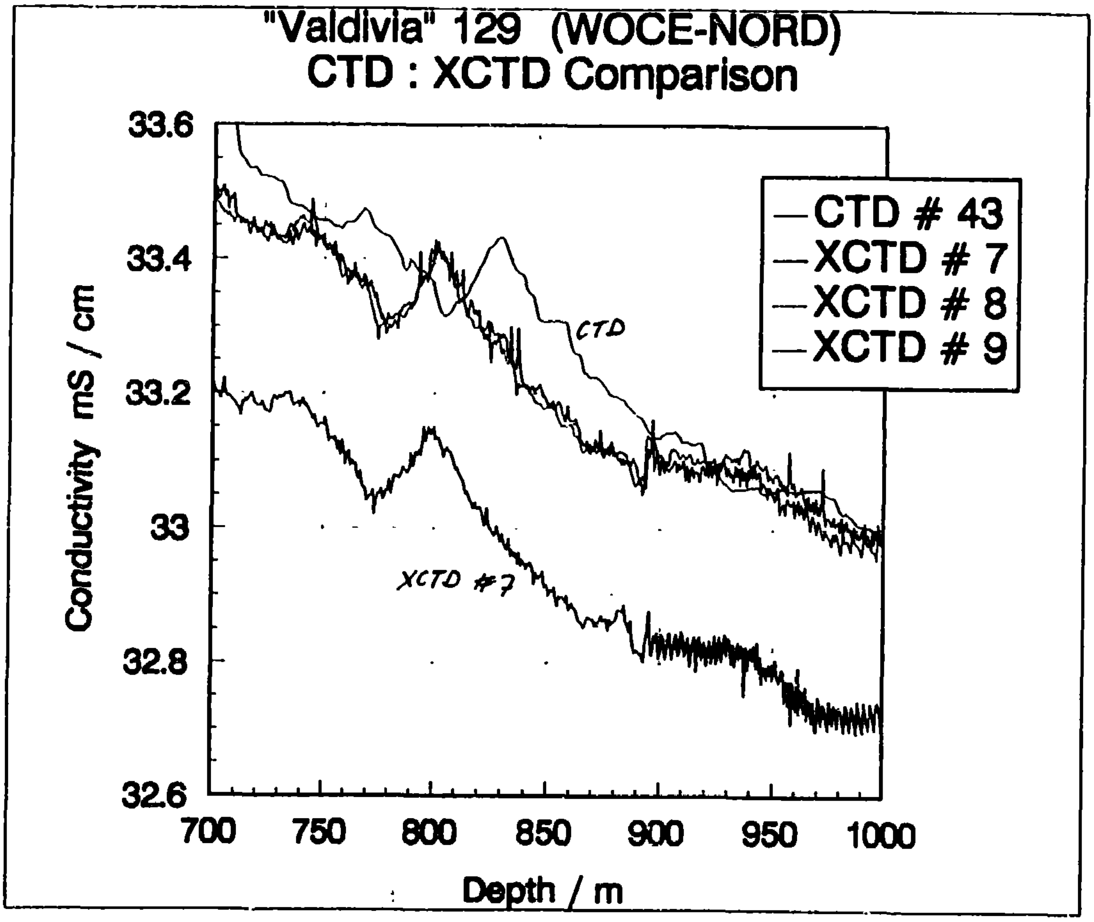


Fig. 11b Conductivity between 7000 and 1000m. Note the signal step and increasing noise at about 890m. One record (XCTD N°7) has an offset of increasing noise at about 890m. One record (XCTD n°7)

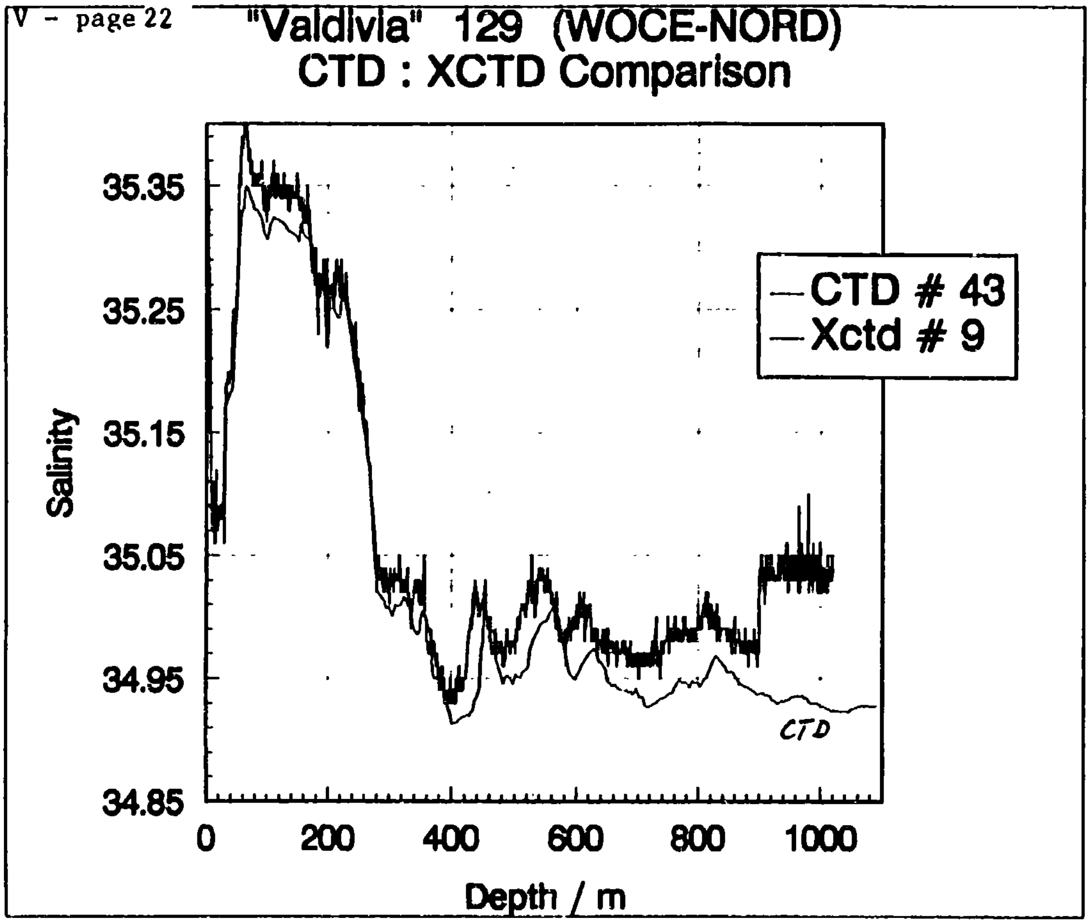


Fig. 11c Salinity of XCTD n°9. Note both the increasing depth error and salinity error

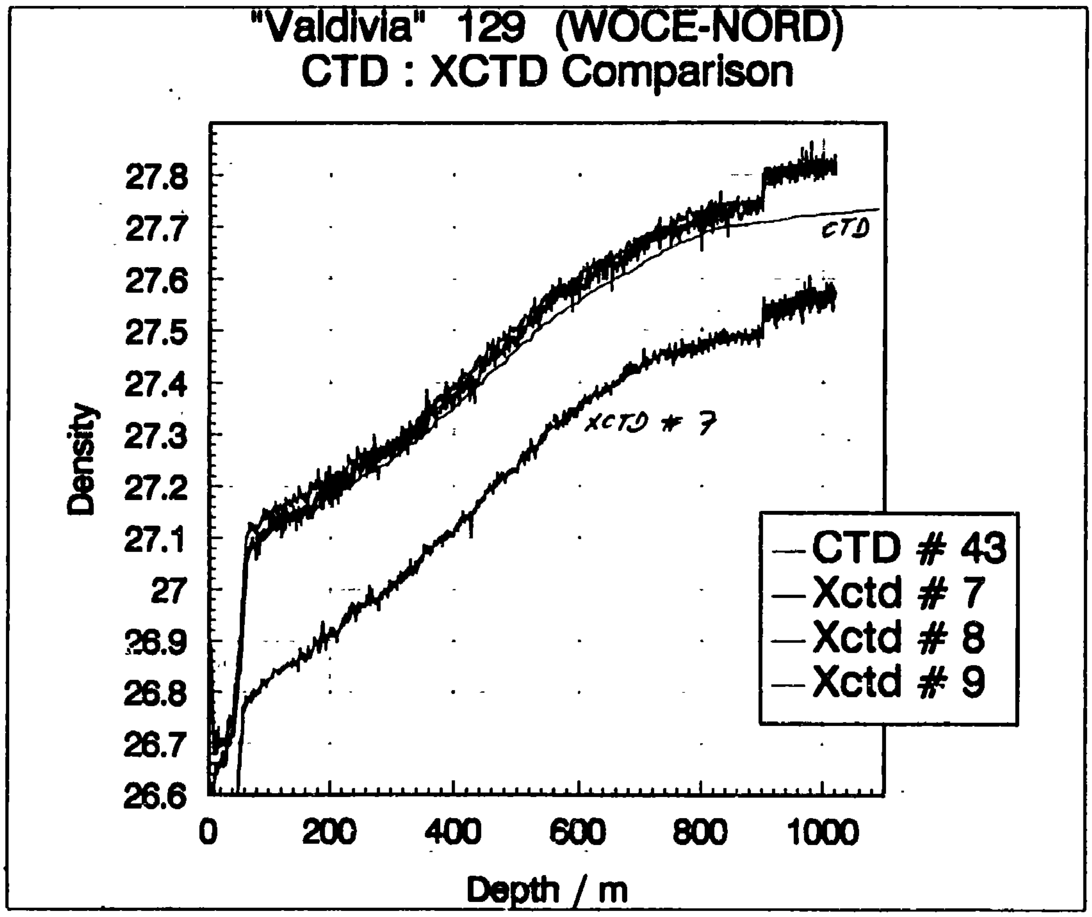


Fig. 11d Density with offset at about 900