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INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION (of UNESCO)

WORLD METEOROLOGICAL ORGANIZATION

INTEGRATED GLOBAL OCEAN SERVICES SYSTEM (IGOSS)

Third Session of the Task Team on Quality Control Procedures for Automated Systems (TT/QCAS)

Ottawa, Canada, 23-25 October 1995

SUMMARY REPORT

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1. ORGANIZATION OF THE MEETING

1.1 OPENING OF THE MEETING

1 The Chairman of the IGOSS Task Team on Quality Control for Automated Systems, Mr Rick Bailey, opened the meeting at 9:00 hours on Monday 23 October 1995, at the facilities of the Marine Environmental Data Service (MEDS) in Ottawa, Canada. The Chairman gave a brief history of the Task Team and the evolution of its work *since* it was formed. He noted that the Task Team is not involved in certification or endorsement of instrumentation. However, it is involved in evaluating the performance of the instruments to provide guidance to the user community. He also noted that in order for reliable intercomparisons of data collected by different groups and with different instruments, it has been necessary to develop a-set-of standardized test procedures.

1.2 ADOPTION OF THE AGENDA

2 The Meeting reviewed the Provisional Agenda and approved it with the addition of a report of XCTD development by TSK (Tsurumi Seiki Company) under Agenda Item 4 and a discussion of thermosalinographs and problems in using XBTs in cold water to be discussed before Future Work. The Agenda, as adopted by the Meeting, is reproduced in Annex I.

3 The List of Participants is given in Annex II of this report.

1.3 WORKING ARRANGEMENTS

4 The Meeting adopted the work programme proposed by the local organizers and agreed to adjust it as necessary.

2. REVIEW OF SCIENTIFIC PAPER AND MODIFIED BATHY CODE

5 The discussion began with the Chairman informing the meeting of the status of the paper submitted for publication to Journal of Deep Sea Research. The paper was accepted at the end of 1994, and the Chairman has seen the galley proofs several months ago. However, no firm publication date has been given yet. Extended and abbreviated versions of the paper are available from other sources including UNESCO Technical Papers in Marine Science No.67, IOC Technical Series No.42, WOCE International Newsletter No.17 - November 1994, and TOGA Notes No.17 - October - 1994.

6 On the issue of the change in the BATHY code, a number of related issues were raised. First, the new code comes into effect on 8 November 1995. It was considered extremely important that users provide the necessary information about the probe and recorder type used so that this information is sent with the real-time data. It is also important that manufacturers of probes and software update their systems as soon as possible so that the same information is stored in the file with the data. Then when these data are processed on-shore and delivered to the archives, the information about the probe and recorder will be preserved in the archives.

7 RECOMMENDATION: Operators, manufacturers and software generators must use the old form of the fall rate equations-for the data submitted to the archives when no information is available on the probe type and recorder. If the information is available (whether it is using the old *or* new fall rate equation), this should accompany the data sent to the archives.

8 RECOMMENDATION : Manufacturers of XBTs change the fall-rate equation in their software.

9 *ACTION: The Chairman of TT/QCAS to send a letter to manufacturers formally requesting that they change the fall-rate equation in*

their software and include the probe, recorder type and fall rate coefficients into the headers of all their data files.

10 RECOMMENDATION: IODE-XV to advise national archives to store the information on fall rate, probe type and recorder now required to accompany XBT data.

11 Concern was expressed by the XBT vendors present, that they had not received notification of the requirement to include this information in the data logging and so could not meet an 8 November transition date. However, the Meeting agreed that it was important to avoid confusion during the transition rather than to rush manufacturers into changing their software to use the new fall rate equations. The Meeting suggested that major version numbers be used to identify when important changes such as these are implemented in their software. (For example, a change from version number 3 to 4 is more apparent to users than a change from 3.1 to 3.2).

12 The Meeting recommended that future Joint IOC-WMO Circular Letters -IGOSS (JCL) announcing important changes in procedures include manufacturers of relevant products in the distribution of the letter.

13 RECOMMENDATION: Joint Committee on IGOSS to recommend that each IGOSS National Representative provide information to the IGOSS Operations Co-ordinator concerning which national operators were notified about the new JJYY code form and when operators plan to implement the new code.

14 *ACTION : The IGOSS Operations Co-ordinator to place information about the BATHY code change including the JCL, an example of the new code form, and WMO code tables should be included on the IGOSS Home Page.*

15 *ACTION: Task Team Members to publish articles in their own agency and country newsletters publicizing the requirement for including probe and recorder type information.*

16 *ACTION : IGOSS Operations Co-ordinator to work with GTSPP to monitor the progress in converting to the new code form.*

17 It was noted that Sippican MK2 (strip chart) recorders still exist in the field. It will be impractical to implement the new fall rate equation in these units due to the different method of depth recording.

18 Other methods were discussed concerning how to notify operators of the requirements to include probe and recorder information for all probes used. Manufacturers were asked to provide information in each box of probes sold. This information could consist of a short article summarizing the findings to be published in Deep Sea Research, a copy of the JCL announcing the BATHY code change, including the WMO code tables 1770 and 4770, a covering letter by the TT/QCAS to give an overview of the information provided and identify the IGOSS Operations Co-ordinator as the point of contact for additional information and the URL of the IGOSS Home Page.

19 *ACTION : Mr Pierre Rual and Mr Rick Bailey to prepare the covering letter and the article for distribution by the manufacturers (including publication in their newsletters).*

20 Dr Savi Narayanan from Canada asked if the Task Team was contemplating an evaluation of other probes particularly the T-10, commonly used in shallow waters and in fisheries research. The ensuing discussion noted that work in coastal regions is becoming increasingly important and that such an evaluation would be desirable. The Team acknowledged the need for evaluations of other probe types but also needed volunteers to come forward to perform these. The Task Team suggested that Dr Narayanan join the Task Team and lead the evaluations of the T-10.

21 ACTION : *The Chairman to submit* a *list of* current *membership of the TT/QCAS to the Joint Committee on IGOSS for approval.*

22 In discussing how Task Team work on general probe performance evaluations could be better accomplished in future, the Chairman suggested the

need for a document containing standardized test procedures. He requested that the Task Team agree upon a set of standard test procedures and that the Team document them. The documentation should include information such as calibration of the CTD, test sample sizes to generate statistically significant results, field procedures, probe handling, and suggested statistical analysis techniques.

23 *ACTION: Mr Pierre Rual and Mr Darren Wright to prepare a set of standard test procedures for XBTs to be discussed at the next TT/QCAS meeting. This documentation to be provided to probe manufacturers for comment prior to the next meeting. Upon approval by the Task Team, this document will be submitted to IOC for publication as an IOC Guide.*

24 A result of the Upper Ocean Thermal Data Assembly Centre Workshop in May 1995 was a request to XBT manufacturers to provide information about storing and deploying XBTs which could be placed with the equipment on-board ship. The SOOP Meeting suggested that IGOSS be used to help spread this information as widely as possible. Manufacturers at this meeting agreed to provide the Chairman with a draft of these procedures by 14 November 1995. The Task Team will review these drafts and return comments to the manufacturers who will then distribute the final version. It is envisioned that this information will be laminated and placed near the probes and equipment on-board ship.

25 *ACTION: Sippican, TSK and Sparton to provide information about recommended XBT* storage *and deployment procedures to the Chairman by 14 November 1995.*

26 The software to determine accurate fall rate coefficients has evolved over the years on different computers and in different computer languages and has been modified by different scientists. This piecemeal software needs to be consolidated into a single streamlined programme for distribution to interested parties, including manufacturers. Because of his experience in past evaluations, the Meeting identified Mr Pierre Rual as the appropriate person to lead this effort. However, he noted a lack of funds to undertake this at this time. The Meeting agreed that a proposal to solicit funds for this effort was needed. The Team discussed the possibility of obtaining funding from XBT manufacturers. However, the manufacturers considered this funding to be the responsibility of an international organization.

27 *ACTION: Mr Pierre Rual to write* a *proposal detailing the work carried out to date to develop the software to determine accurate fall rate coefficients, and comparing the high costs of this development against the nominal funds needed "to deliver* a commercial *quality software package.*

28 *ACTION: Chairman to request Joint Committee on IGOSS to provide funds for consolidating the software to determine accurate fall rate coefficients.*

3. STATUS OF SIPPICAN T-5 AND FAST DEEP EVALUATIONS

29 The Meeting was polled to determine the status of evaluation of Sippican T-5 and Fast Deep probes. The Meeting learned that France, Japan and Germany all have data sets but that these have not yet been analyzed. A total of approximately 160 comparisons had been performed in the field. Dr Alexander Sy volunteered to lead the analysis effort. It was noted that, to carry this out, an area with sufficient temperature structure at 1000m was needed to intercompare XBT and CTD profiles. So far, intercomparisons have been performed in the northwest Pacific, and in the tropical and northwest Atlantic. Early T-5 results by Dr Kimio Hanawa showed Sippican T-5s fall slower than the manufacturers equation (about 30m depth error at 1000m depth).

30 *ACTION: Dr Alexander Sy to co-ordinate the analysis of T-5 and Fast Deep data collected to date once the consolidation of analysis software is completed.*

31 *ACTION: Mr Pierre Rual to determine if the Service Hydrographique et Oceanographique de la Marine (SHOM) has additional T-5 data.*

4. STATUS OF SIPPICAN AND TSK XCTD EVALUATIONS

32 Ms Randall Elgin of Sippican gave a presentation on the status of their XCTD development. She noted four modifications to improve the probe had been implemented in January 1994. These included a better system grounding, an improved data transmission, improved common mode rejection and improved signal processing through changed filtering parameters in software. The two outstanding problems are an incorrect fall rate equation and a conductivity start up problem due to bubble formation in the conductivity cell on launching. She noted that trials are underway to see if wetting agents might fix the conductivity start up problem. She concluded her presentation by summarizing the overall success rate in four sea trials of the XCTD conducted by Dr Sy, SHOM, UK Ministry of Defense and Sippican. However, other Team Members experienced 10-20% complete failure rates for VOS deployments and considered the conductivity errors in the upper 50-100m (which were found in some cases in up to 50% of the profiles) to seriously affect the use of the XCTD in the field. A copy of Dr Sy’s paper detailing his XCTD tests is given in Annex III.

33 Mr Rick Bailey presented the Australian preliminary results of comparisons of XCTDs and CTDs in the Southern Ocean. He noted that there is still a problem with the conductivity in the upper 50-100 meters depths but several of the earlier problems, such as spiking, have been minimized. The conductivity recorded by the XCTD is greater than that recorded by the CTD and so is unlikely to be caused by a bubble. Sippican speculated that thermal inertia of the probe might be the cause but needed to examine the data. Mr Bailey has provided these to Sippican and they undertook to look into the results. Mr Bailey pointed out the importance of measuring salinity in the upper 100m in the tropics.

34 Mr Hiroshi Iwamiya of TSK presented a brief overview of his company’s development of an XCTD. He noted that it was still an experimental version. In 1994, they switched development to an inductive measurement of the conductivity. He noted that this should allow for cheaper production costs and, faster response at start up. He stated that the signal sent up the wire was digital and that the shape of the probe nose was hydrodynamically determined in collaboration with the Japan Marine Science Technology Centre and differs from the XCTD produced by Sippican. He showed some intercomparisons which did not appear to have a fall rate problem but did show substantial conductivity offset from simultaneous CTD profiles. He noted that tests to date have been conducted from vessels traveling at only 10 knots and to 1000m depth.

35 The Meeting was pleased to learn of these many advances in the capabilities of XCTDs. The Meeting discussed the need for further evaluation of the fall rate equation for XCTDs. Although the conductivity is in error in the older version of Sippican XCTD probes, the probe body has not been changed. Therefore, the temperature profiles should still be valid to determine a revised fall rate equation. The Meeting agreed that Mr Rick Bailey would serve as the focal point for assembling data to accomplish this determination.

36 *ACTION: Mr Pierre Rual to contact SHOM to obtain their extensive XCTD data set.*

37 *ACTION: Dr Sy, Mr Wright, and Ms Elgin to send their XCTD data to Mr Bailey by 1 December, 1995. Mr Bailey to co-ordinate with Dr Dean Roemmich to perform the analysis once the consolidated analysis software becomes* available. *The data should include instrument types, calibration information, locations and speed of vessel and other relevant information.*

5. SPARTON XBT-7 PROBES

38 Mr Colin McCrae of Sparton of Canada gave a presentation on quality control in their manufacturing process. He reviewed procedures and

results of XBT-CTD intercomparisons performed for the US Navy. He showed that Sparton probes generally performed to the same level of precision and accuracy as those already in navy stocks.

39 The Task Team agreed that more data were required to verify the performance of the Sparton probes. Sparton agreed to look into the data that they hold and to provide usable data to the Task Team for evaluation.

40 Mr Pierre Rual informed the group that a paper evaluating a data set of the old Sparton XBT-7 probes was published in WOCE International Newsletter #19 - July - 1995. Mr Rual summarized results of analyzing the fall rates of old Sparton probes (manufactured prior to July, 1992) in different areas of the world. This included earlier work done by Dr Kimio Hanawa. The results from the older probes showed considerable variance with respect to the UNESCO standard.

41 However, in examining results from tests using the latest model of probe, good agreement was obtained by samples taken by ORSTOM in the tropical Atlantic and Pacific Oceans and by Germany's BSH in the North Atlantic Ocean. It was Mr Rual's opinion that there was no statistical difference between Sippican/TSK T-7s and those manufactured by Sparton for these data sets.

42 He noted that there remained unresolved questions about samples obtained by NOAA (National Oceanic and Atmospheric Administration) near Bermuda and more work needs to be done on the data set to explain the differences. The data provided by Sparton to date were insufficiently documented and not of adequate quality. Consequently, Mr Rual could not complete the analysis due to insufficient sample size.

43 *ACTION: Dr Sy to request usable probe test data from Germany's Polar Research Institution and inform the Chairman of his success.*

44 *ACTION : In the event that Dr Sy cannot obtain these data, Mr Bailey to co-ordinate with Sparton of Canada to perform tests in the Southern Ocean. Sparton volunteered to contribute probes for this test.*

45 *ACTION: Mr Rual to perform the analysis of remaining Sparton data and, upon review by the Task Team, to publish preliminary results in the WOCE International Newsletter.*

46 Once fall rate coefficients for Sparton probes are established by the Team, the new coefficients will need to be listed in the appropriate WMO code tables (1770 and 4770).

6. EXAMINATION OF QC PROCEDURES USED PRIOR TO INSERTION ONTO THE GTS

47 Mr Pierre Rual made a presentation about on-board QC procedures long used by Australian and French ships and shortly to be adopted on NOS (National Ocean Service) operated ships. Only BATHY messages for temperature profiles that pass the on-board QC tests are sent to the satellite transmitter and the messages are computed only to the depth of the deepest "good" data point. The XBT profiles are despiked and low pass filtered prior to application of the data reduction method (broken stick) to determine significant data points. This is followed by a linear regression of the profile between the significant data points to reduce discrepancies between the BATHY message and the full profile. The QC software must be flexible enough to allow modification of the test parameters on a per-cruise basis should the ship transit to waters markedly different in temperature, such as the Arctic.

48 The Meeting noted that the first usable temperature measurement from an XBT occurred at approximately 0.5 seconds after entering the water. However, it also noted that IGOSS *Manuals and Guides* 3 - *Guide to Operational Procedures for the Collection and Exchange of IGOSS Data* was ambiguous in describing whether this should be encoded as a temperature at the surface (O m) or at the observed depth. In addition, it was evident that other parts of the same Manual are outdated. In particular, the section describing how to

extract a BATHY message from a full profile needed to reflect the procedures described by Mr Rual and to reflect changes in the new BATHY code.

49 RECOMMENDATION: The Chairman to request the Joint Committee on IGOSS to revise *Manuals and Guides 3* to bring its information up to date.

50 RECOMMENDATION: Operators to encode BATHY messages with temperatures at observed depths, not extrapolated to zero meters.

51 The Meeting decided that personnel installing the software take responsibility for entering quality control parameters into BATHY message construction software. These parameters reflect regional variations in ocean conditions. However, it is important that ship's crew be restricted from modifying these parameters to prevent errors.

52 *ACTION: Mr Wright and Mr Rual to prepare general guidelines for the quality control procedures discussed above for review by TT/QCAS.*

7. MODIFICATIONS TO THE TESAC CODE

53 The Meeting noted that IGOSS-VI, as a result of a previous TT/QCAS recommendation, instructed the Group of Experts on Operations and Technical Applications (GE/OTA) to modify both the BATHY and TESAC code forms to permit inclusion of information about the instrumentation used. The BATHY code changes have been acted on and will be implemented on the GTS shortly. However, no action has been taken on the TESAC code. This means it is still not possible to distinguish data collected using XCTDs from CTDs. The Meeting agreed that this was urgently needed and requested GE/OTA undertake this work as soon as possible. At the same time, it is clear that similar changes are required in the TRACKOB code form as well.

54 *ACTION: The Chairman to request GE/OTA prepare a new code form for TESACs that will contain the information on instrumentation.*

RECOMMENDATION: The Joint Committee on IGOSS to recommend changes be made in the TRACKOB code form to record information about instrumentation used.

55 The issue of whether to insert data on the GTS from XCTDs was discussed. The Meeting noted that there are still limitations *in* the use of salinity profiles due to uncertainty in data quality, salinities being uncalibrated, uncertainty in fall rates, and the inability to distinguish temperature and salinity measurements made by XCTDs, CTDs, PALACE floats, etc. in a TESAC message. The Meeting agreed that caution should be exercised before placing data from XCTDs on the GTS.

8. MISCELLANEOUS

56 The discussions covered issues common to all XBTs. Mr Rual noted that running the MK12 programme under Windows may cause timing errors depending upon computer speed. He cautioned that no apparent errors are detected but the results are unreliable. The Sippican documentation recommends the programme not be run under Windows.

57 Dr Sy discussed problems that he had encountered in launching probes in cold water (water temperatures less than 5 degrees C). Mr Bailey noted that, in his experience, it was more difficult to recover useful data in higher wind conditions associated with high latitudes, but not necessarily in cold water. He noted CSIRO had experienced and even higher failure rate with all the probes when used in cold waters, possibly due to exacerbated insulation cracking. Furthermore, temperature structures associated with water masses in higher latitudes are quite unusual and often difficult to distinguish subtle insulation problems which appear to be more common in colder waters. Mr Larry Hall noted that large differences between deck temperatures and surface water temperatures caused performance problems. In addition, Mr Jim Hannon noted that skim (frazil) ice can cause wire breaks due

to its sharp edges. He has launched probes using coring tubes to bypass the ice on the surface.

RECOMMENDATION: The Task Team recommends that whenever a questionable profile is obtained using an XBT, a second drop be made to verify the profile.

58 Mr Hall informed the Meeting that any damage to the fins on an XBT would alter the rate of fall of the instrument and so care was required in handling. He also stated that probe to probe variability was small based on multiple simultaneous drops in their experience. Mr Rual noted that variability in measurements at sea were due to a combination of factors including different types of probes, different waters in which they were deployed, and different CTDs used for comparisons. Consequently, probe to probe variability as measured in the field is higher than measured by manufacturers.

59 Mr Hall described Sippican's idea for determining the fall rate of probes by lowering acoustic transponders and measuring the travel time of a probe between the transponders based on the probes closest point of approach. The main benefit of this approach is that it permits higher accuracy in determining the fall rate to correct probe to probe variability. The Meeting supported this concept and encouraged all manufacturers to improve their products by devising new ways for quality control.

60 The discussion then moved to thermosalinographs (TSG). It was considered important for TT/QCAS to address QC issues related to TSGs given the expansion of the TSG network discussed at the SOOP meeting. Mr Rual informed the meeting that Mr Christian Henin is in charge of the TSG programme in ORSTOM-Noumea. Mr Rual reminded the group of the importance of salinity measurements in assessing the effects of rain on the surface salinity among other effects. The Meeting agreed that scientific bodies such as the GOOS-Ocean Observation Panel for Climate and the CLIVAR Upper Ocean Panel needed to decide what accuracy is required in the measurement of salinity. Mr Rual suggested that a document describing the installation of the TSG system used by ORSTOM be translated into English for wider distribution. The Meeting also noted that another document is needed containing guidelines on the operation of TSGs (their calibration, monitoring of data quality, trouble shooting, etc.) Finally, the Meeting also noted that a document describing quality control procedures to be applied to TSG data either as TRACKOB messages or in delayed mode form was also required. The Task Team suggested that Mr Henin become a member of the Team.

61 *ACTION: The Chairman to inform the GOOS-Ocean Observation Panel for Climate and the CLIVAR Upper Ocean Panel of the need to decide what accuracy is required in the measurement of salinity.*

62 *ACTION : The Chairman to request funding for translation from French to English of the ORSTOM TSG Installation Manual (approximately 50 pages) from the Joint Committee on IGOSS.*

63 *ACTION : Mr Rual to ask Mr Henin to prepare guidelines on the operation of TSGs.*

64 *ACTION : Mr Rual to ask Mr Henin to prepare another document describing quality control procedures to be applied to TSG data.*

9. FUTURE WORK

65 Future work for the Task Team is given both as a list of recommendations in Annex IV, and as a list of action items in Annex V. The Team agreed that future meetings should be held on alternate years to the SOOP meeting. This was workable because many of the members of the Task Team are also members of the SOOP. A tentative meeting date of August 1996 was agreed upon with no location decided.

10. CLOSURE OF THE MEETING

66 The Chairman thanked the vendors for attending the meeting. He noted that it was beneficial to have their participation. The Chairman thanked Mr Bob Keeley and MEDS for their excellent facilities, hospitality and Mr Keeley’s personal contribution in preparing the summary report. The Meeting closed on the afternoon of Wednesday 25 October 1995.

ANNEX I

AGENDA

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ANNEX II

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ANNEX III

IMPROVED MK-12/XCTD SYSTEM TESTED IN THE FIELD

Dr A. Sy, BSH, Germany

Introduction

An XCTD field evaluation on “Meteor” cruise no. 30/3 in the eastern North Atlantic in December 1994 and measurements under realistic ship-of-opportunity conditions in September/October 1995 have completed a series of field trials started in 1992. The first at-sea tests revealed significant deficiencies in the system’s performance (Sy, 1993). The urgent need to improve the reliability and accuracy of XCTD measurements led to the development of various modified devices by the system’s manufacturer, Sippican, Inc. The combined modifications result in a new configuration of the MK-12 hardware, firmware and software, and also include changes of the XCTD probe. After several field and laboratory tests carried out by the manufacturer (Elgin, 1994), the results were sufficiently promising to convince the customer of significant improvements of the overall system performance. The purpose of the last field evaluation was to check the manufacturer’s specification of the final product independently, i.e. from the customer’s point of view. The system’s accuracy for XCTD measurements is claimed by the manufacturer to be ± .03 °C for temperature, ± .03 mS/cm for conductivity, and ± 5 m or 2 % for depth (Sippican, 1992; 1994).

Operational details of the field test

12 XCTD probes were calibrated by Sippican, Inc. in September 1994 and made available for this test. The data acquisition system used a Compaq” LTE 4/33C laptop computer with extension unit, equipped with a Sippican MK-12 rev. J interface, firmware rev. 2.1 and software rev. 2.2.1. The “Meteor” cruise no. 30/3 was aimed at contributing to the WOCE Hydrographic Programme (WHP section Al). The XCTD test sites are located west of the British Isles (Fig. 1). This ocean area provides favorable conditions due to its well developed hydrographic stratification in both temperature and salinity.

Severe weather conditions forced a premature end of our regular research programme before we had the opportunity to carry out the planned XCTD field trial. Therefore, it was decided to use a combination of T-5 XBT and test XCTD probes en route home as a poor makeshift substitute to complete our hydrographic section in a rough-and-ready way (XCTD test part A). After successful and problem-free launching of 6 XCTDs at a ship’s speed of about 6 knots (Table 1), we were surprised by a sudden unpredicted favorable change of the weather situation. We returned to the break-off point of the hydrographic section to resume our field work including the originally planned XCTD versus CTD intercomparisons (XCTD test part B).

Field test part B was carried out with XCTD drops at 2 regular CTD stations (stat. # 542 and # 546) side by side with the down-profiling of a well calibrated NBIS MK-IIIB CTD. The protocol shown in Table 1 should clarify the procedure. The CTD data were processed according to WOCE standards (WHP, 1994). XCTD data processing included the conversion of raw data to physical units, editing of spikes and noise by 5-point-moving-median filtering (q = 5) of temperature and conductivity (S y, 1985), editing of start-up and profile end transients, and compaction to 2 dbar intervals. The accuracy of the reference CTD data was estimated as AT < $\pm$ 2 mK for temperature, AS < $\pm$ 0.002 for salinity and **Δp** < $\pm$ 2 dbar for pressure. The temporal stability of all parameters was extremely good.

Test results

All 12 probes launched gave traces from the sea surface to below 1000 m depth. In contrast to the previous 6 drops of test part A, which were carried out without any difficulties at all, the remaining 6 drops of test part B encountered problems. One drop failed, although good data were acquired, due to a software breakdown and data loss, for which a user mistake cannot be ruled out. One profile became very noisy below 730 m depth with unusable data, which may have indicated a signal wire problem. During one drop a wire jam was detected, which fortunately could be removed in time to prevent a premature wire break.

No erroneous profile is detectable in the T/S section of test part A (Fig. 2 b,c). The XCTD temperature section corresponds well to the XBT section (Fig. 2 a) as well as to the CTD section 30 nm south, which was carried out 3 days later (Fig. 2 d). The XCTD salinity section shows the usual eddy and stratification structures which correspond also quite well to those of the CTD section (Fig. 2 e). A significant discrepancy is revealed, low salinities, for the upper 50 m of drop # 6 caused by a slow start of the conductivity measurement. In test part B, XCTD drop # 7 showed the same start-up problem in the upper 60 m. Elgin (1994) provides the plausible explanation that air bubbles remaining in the conductivity cell cause too low a conductivity measurement until they eventually collapse by increasing pressure.

A first idea on the quality of all measurements of test part B is provided by Fig. 3. No calibration failures are detectable. The comparison of data from the homogeneous mixed layer provides a better estimate of the accuracy and the start-up problem. The range of temperature differences between XCTD and CTD traces does not exceed the $\pm$ 0.03 °C limit below 10 m depth (Fig. 4).

However, the conductivity differences of two profiles exceed the $\pm$ 0.03 mS/cm limit significantly (Fig. 5). Generally, the XCTD conductivity is low with respect to the reference CTD. This reduced overall accuracy and the start-up problem demonstrate the difficulty of controlling the conductivity parameter and consequently the computed salinity (Fig. 6). Increasing differences of some traces below 60 m are probably caused by temporal variability of the field (Fig. 4a, 5a, 6a).

The temperature data accuracy found in the mixed layer of the upper ocean remains stable also for the deeper ocean (Fig. 7). However, the conductivity difference becomes smaller with increasing probe depth and eventually falls inside the ± 0.03 mS/cm limit in the lower half of the traces (Fig. 8), This indicates that the data quality is positively influenced by increasing pressure, i.e. the bubble formation in the conductivity cell on launching is probably a more general problem. Ordinary air bubbles seem to be responsible for the slow start effect and micro bubbles for the reduced conductivity accuracy at the profile's upper part. Elgin (1994) reported on different resolution across the range of conductivity, with the poorest resolution at the high end. The measurements at the test sites, however, do not show these high conductivity values. As for conductivity, the salinity difference is also significantly reduced with greater depth (Fig. 9). It should also be noted that the 42.921 value previously used as standard conductivity was changed to the commonly recommended 42.914 value (R. Elgin, pers. comm.).

The hydrographic stratification allows an easy evaluation of the depth formula. As for XBT probes (Hanawa et al., 1994), the XCTDs fall faster than specified. The depth fall rate variability is small. The depth error is estimated to be about -30 m at 900 m depth (or about 3.3 %). That corresponds to previous findings (Sy, 1993) and shows that no change of the hydrodynamically effective underwater body design was carried out. Thus, for a more accurate re-calculation of the depth fall rate formula, all old and new XCTD versus CTD intercomparison data can be used.

With the improved system design, no increasing noise with depth is detectable (Fig. 10). The peak-to-peak noise was found to be in the range of the resolution of the MK-12 (± 0.01 °C, ± 0.01 mS/cm). Also, the system grounding problem and the data" offset at 900 m were obviously solved.

Measurements along a transoceanic section

A suitable opportunity to extend the test results by experiences obtained under realalistic ship-of-opportunity conditions was presented by CMS "Köln Express" (gross tonnage: 39,000 tons, length: 240 m, speed: 19 knots) from September 29 to October 2, 1995 when a complete section from the English Channel to the Grand Banks was carried out (Fig. 11). All measurements were carried out by a scientist from the vessel's stern (launch height: 10 m). For data acquisition the same equipment was used as 9 months before, except software rev. 3.03. From 60 probes, calibrated by Sippican, Inc. in August 1995, 4 probes failed due to probe malfunctioning (Fig. 12) and another 4 probes failed due to fatal software problems. Although the data processing is not yet finished a preliminary conductivity start-up failure rate is estimated as about 50 %.

The measurements were carried out under severe weather conditions. The ship's speed of 12 to 19 knots and the strong head wind added up to relative windspeeds of up to 60 knots or Bf. 11 (Fig. 12). Frequency distributions of depth ranges and of prevailing windspeeds are displayed in Fig. 13 and Fig. 14. XCTD probes are. designed to cover the upper 1000 m at a maximum ship's speed of 10 knots. The depth range of XCTD profiles was found between 460 m and 764 m with a mean maximum depth of 606 m. For many ship-of-opportunity programmes this reduced depth range will not meet their requirements. No relationship between windspeed and depth range or windspeed and probe malfunctioning can be deduced from Figs. 13 and 14. The probe malfunctions occured at high and at low windspeeds and 'are thus more likely a manufacturing problem. One should expect to find a strong dependence of the depth range from both ship's speed and windspeed. In this case, however, both effects are superimposed (Figs. 15 and 16). The visible effect of windspeed on the depth range appears in terms of an increasing maximium depth variability, but without a decreasing mean maximum depth.

Conclusion

The results of the field evaluation of December 1994 and of the transoceanic section 9 months later conclusively reveal that modification efforts of the manufacturer during the last years have resulted in a significant MK-12/XCTD system performance improvement. Obviously most performance difficulties encountered at previous sea trials have been successfully solved. The system is at the point of meeting the claimed specification. Unsolved deficiencies are the slow conductivity start problem, the reduced conductivity accuracy at low pressure, and the inaccurate depth formula. Also the MK12 software, although easy to use, needs a careful revision. To review the XCTD depth fall rate should be one of the next actions to be taken by the IGOSS Task Team on Quality Control of Automated Systems (TT/QCAS).

References

Elgin, R. H. (1994): An Evaluation of XCTD Performance with Design Improvements. Sippican, Inc., Marion, Mass., USA, unpublished manuscript, 6 pp.

Hanawa, K., P. Rual, R. Bailey, A. Sy and MM. Szabados (1994): Calculation of new depth equation for Expendable Bathythermographs using a temperature-error-free method. UNESCO Technical Papers in Marine Science, 67,46 pp. and IOC Technical Series, 42,46 pp.

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Sy, A. (1993): Field Evaluation of XCTD Performance. WOCE Newsletter, No. 14, pp. 33-37.

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XCTD TEST Protocol, Cruise "Meteor" 30/3

Drop #	Date	Time (UTC)	Position Lat N	Position Long W	Depth m	SST °C	Wind m/s	R e m a r k s
TEST PART A								
1	9.12.94	18:00	53 00.9	22 47.6	4000	11.1	12.0	s/n 94090122, (XCTD/XBT section), XBT # 114
2	"	21:10	52 49.5	22 00.3	4000	11.1	13.0	s/n 94090119 " XBT # 116
3	10.12.	01:05	52 47.6	21 10.7	3711	10.9	23.0	s/n 94090110, (wrong pos in file), XBT # 120
4	"	03:55	52 50.3	20 21.7	2550	11.0	20.5	s/n 94090116, (XCTD/XBT section), XBT # 122
5	"	06:55	52 48.0	19 31.7	2600	11.1	16.0	s/n 94090121 " XBT # 124
6	"	10:05	52 47.1	18 40.0	3526	11.1	16.0	s/n 94090118, (end XCTD section), XBT # 126 slow conductivity start-up
TEST PART B								
fail	13.12.	12:55	52 20.0	18 52.0	4280	11.6	3.0	s/n 9409112, CTD # 542, run-time error M6101 data loss but good profile up to 1237m
7	"	13:06	"	"	"	"	"	s/n 9409115, CTD # 542 at 700 m slow conductivity start-up
8	"	13:14	"	"	"	"	"	s/n 9409114, CTD # 542 at 1200 m
9	"	13:25	"	"	"	"	"	s/n 9409113, CTD # 542 at 1700 m noisy below 730 m
10	14.12.	11:41	52 20.0	15 47.0	3255	10.9	11.0	s/n 9409117, CTD # 546 at 50 m
11	"	11:52	"	"	"	"	"	s/n 9409120, CTD # 546 at 500 m XCTD wire jam removed

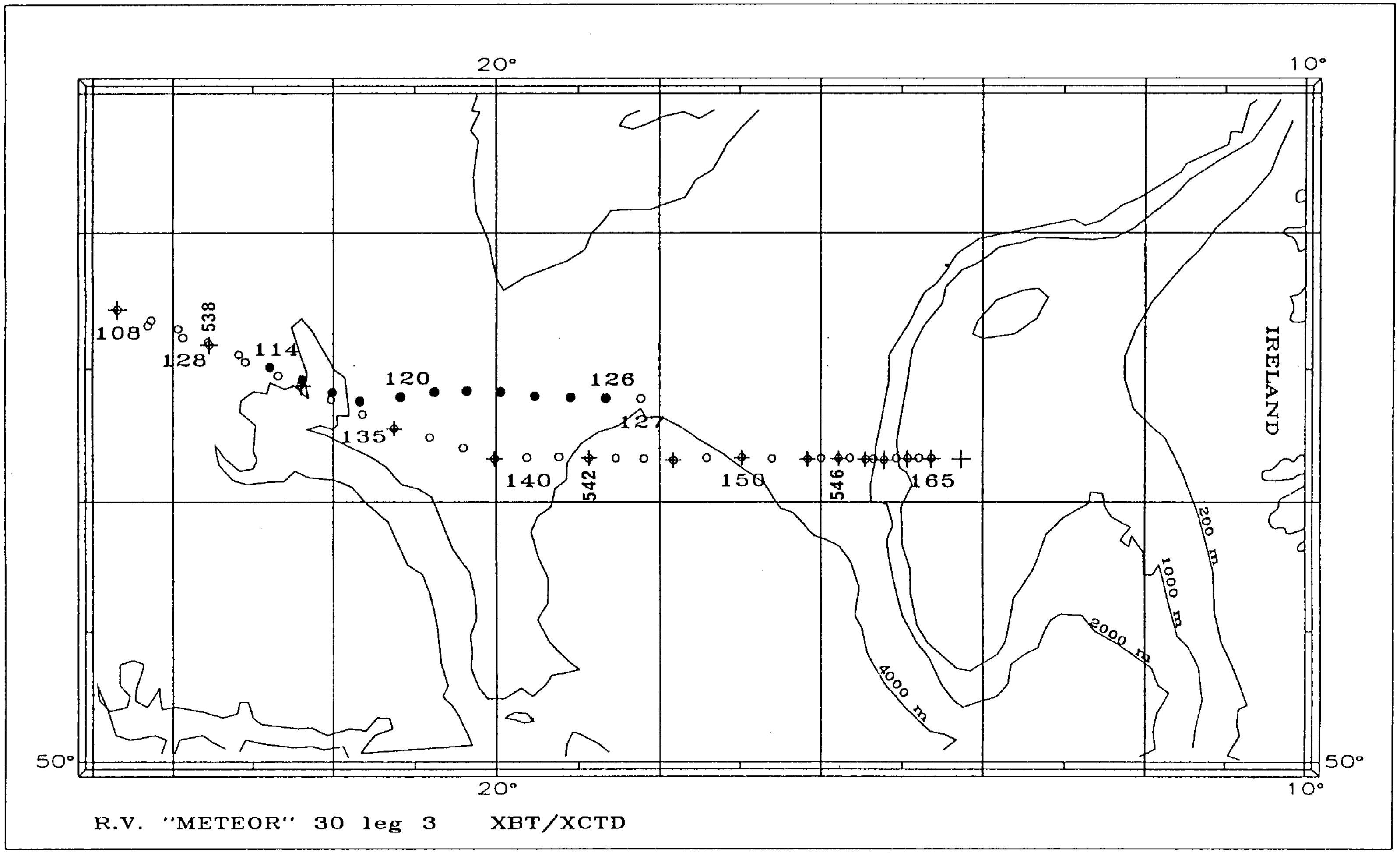
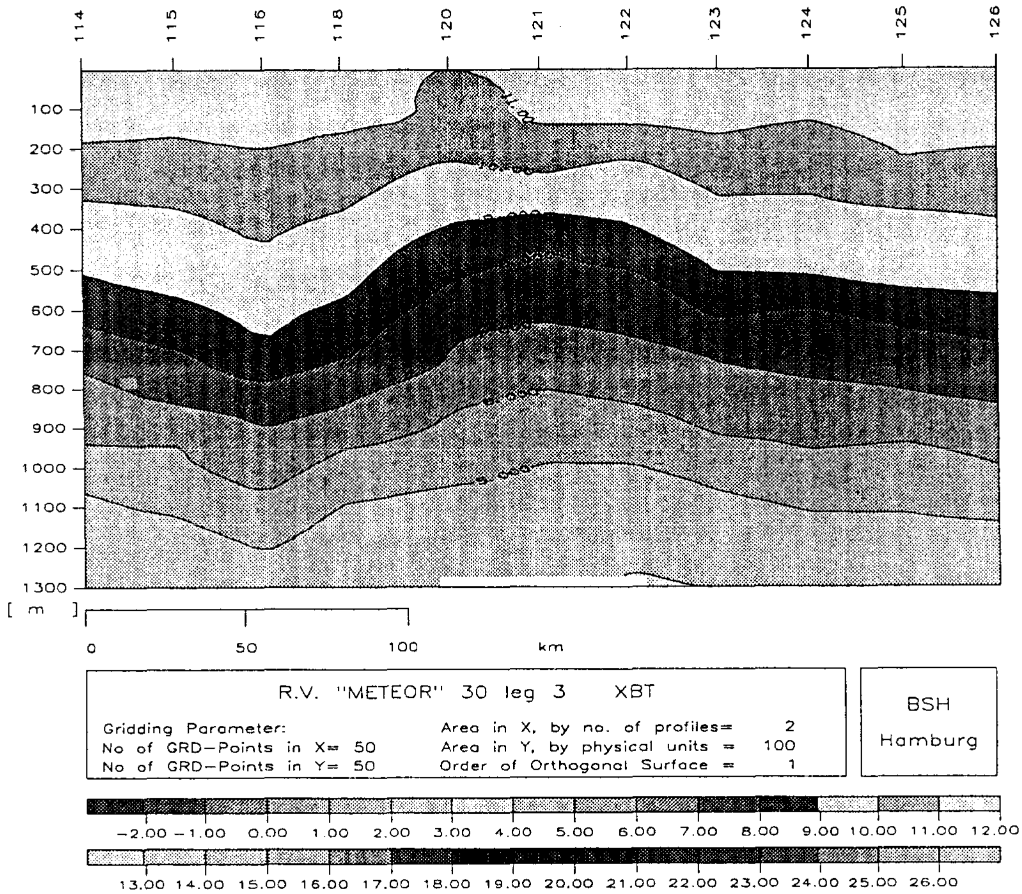


Fig. 1: XCTD test sites of WOCE-Nord cruise "Meteor" 30/3 (December 1994)

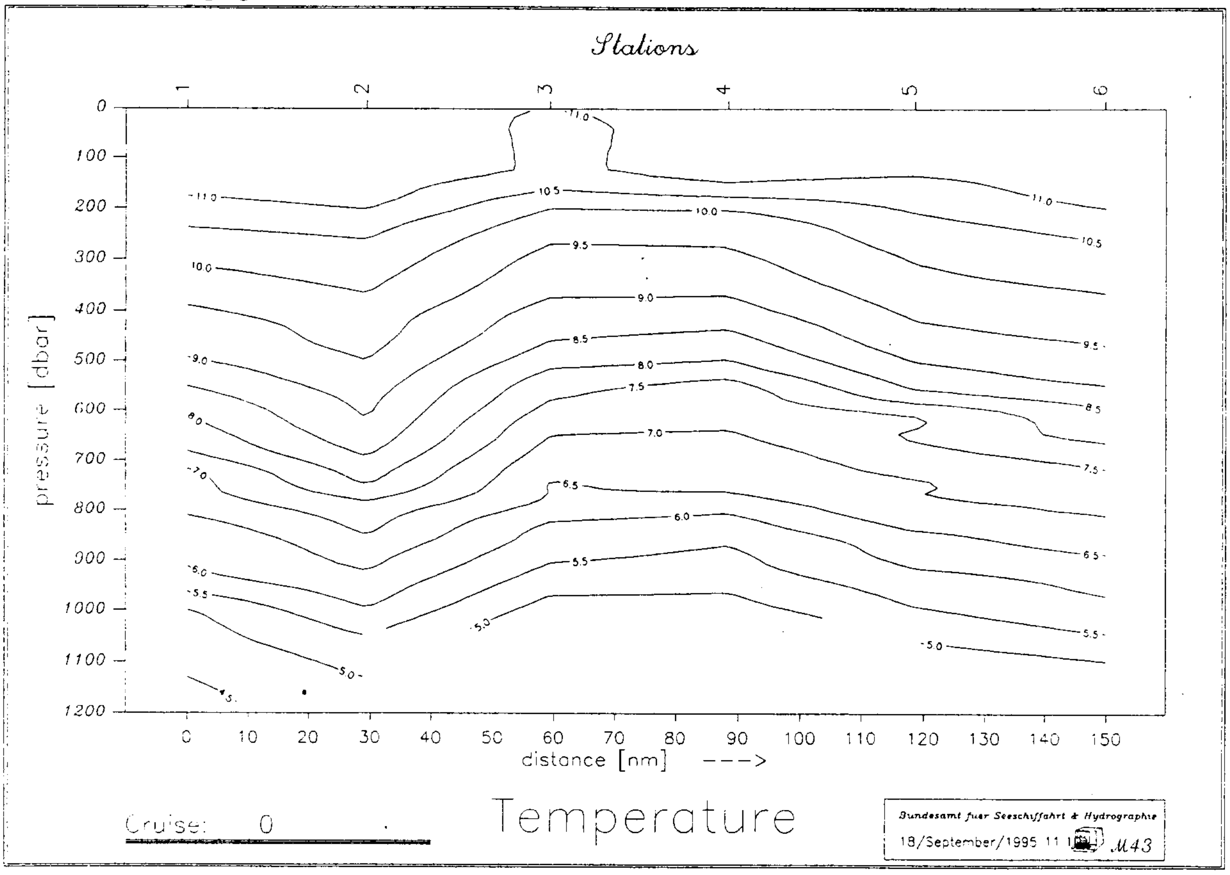
+	CTD stations along WHP section A1 (Sites of XCTD test part B are stat. # 542 and # 546)
o, ●	XBT drop locations
●	XBT/XCTD section with XCTD drops at every second XBT drop location (Sites of XCTD test part A)



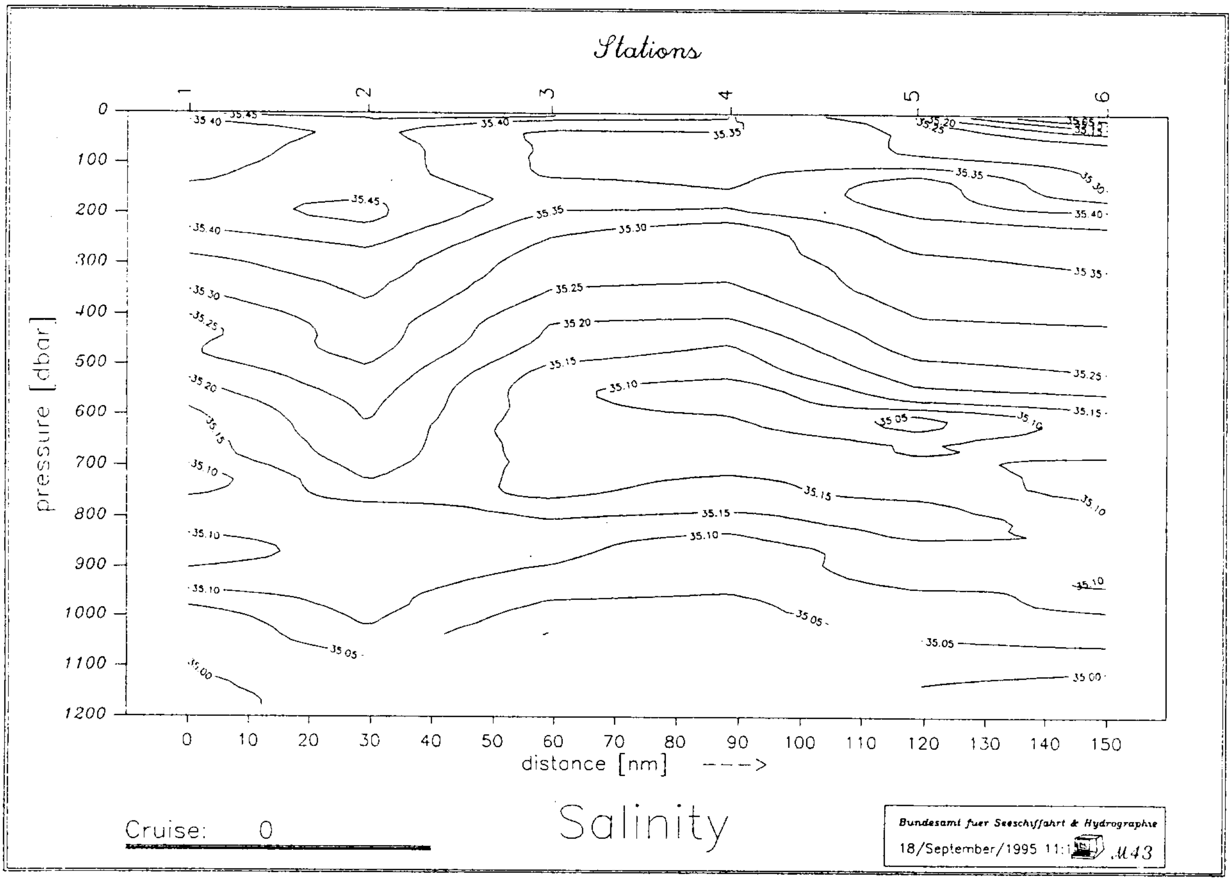
a)

Fig. 2: XCTD test part A

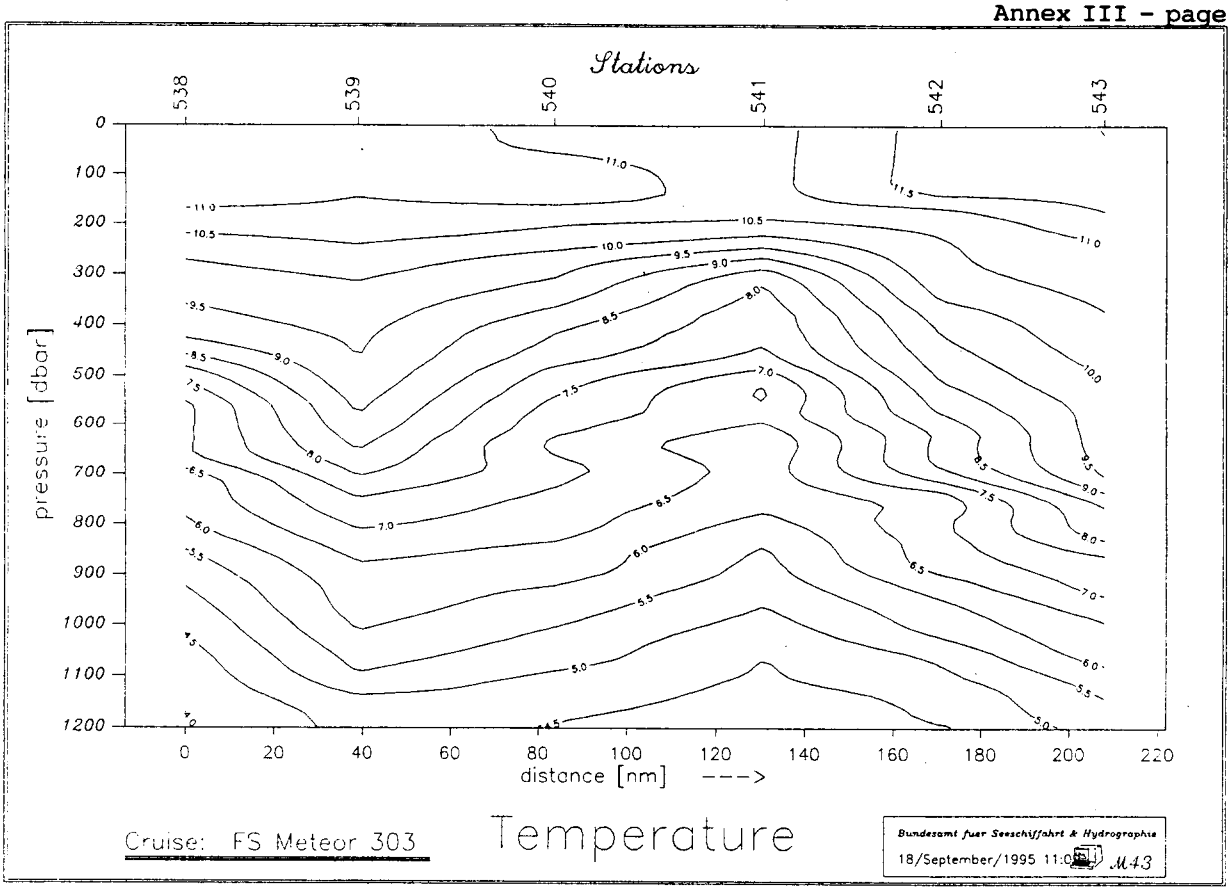
a) Temperature section of XBT (T-5) drop # 114 - # 126
b) Temperature section of XCTD drop # 1 - # 6
c) Salinity section of XCTD drop # 1 - # 6
d) Part of temperature section WHP A1 (CTD stat. # 538 - # 543)
e) Part of salinity section WHP A1 (CTD stat. # 538 - 543)


Stations
1
2
3
4
5
6
pressure [dbar]
distance [nm] --->
Cruise: 0
Temperature
Bundesamt fuer Seeschiffahrt & Hydrographie
18/September/1995
M43

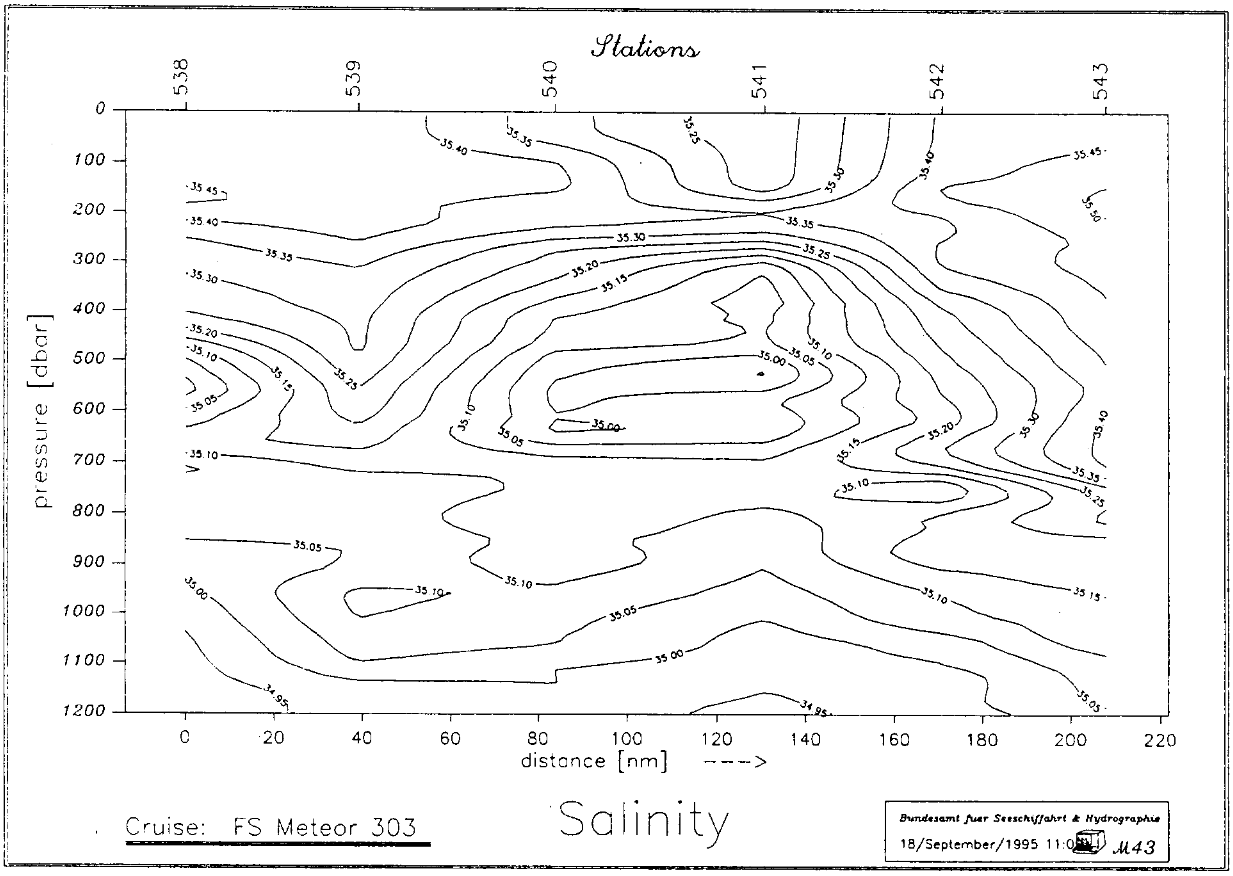
b)


Stations
1
2
3
4
5
6
pressure [dbar]
distance [nm] --->
Cruise: 0
Salinity
Bundesamt fuer Seeschiffahrt & Hydrographie
18/September/1995
M43

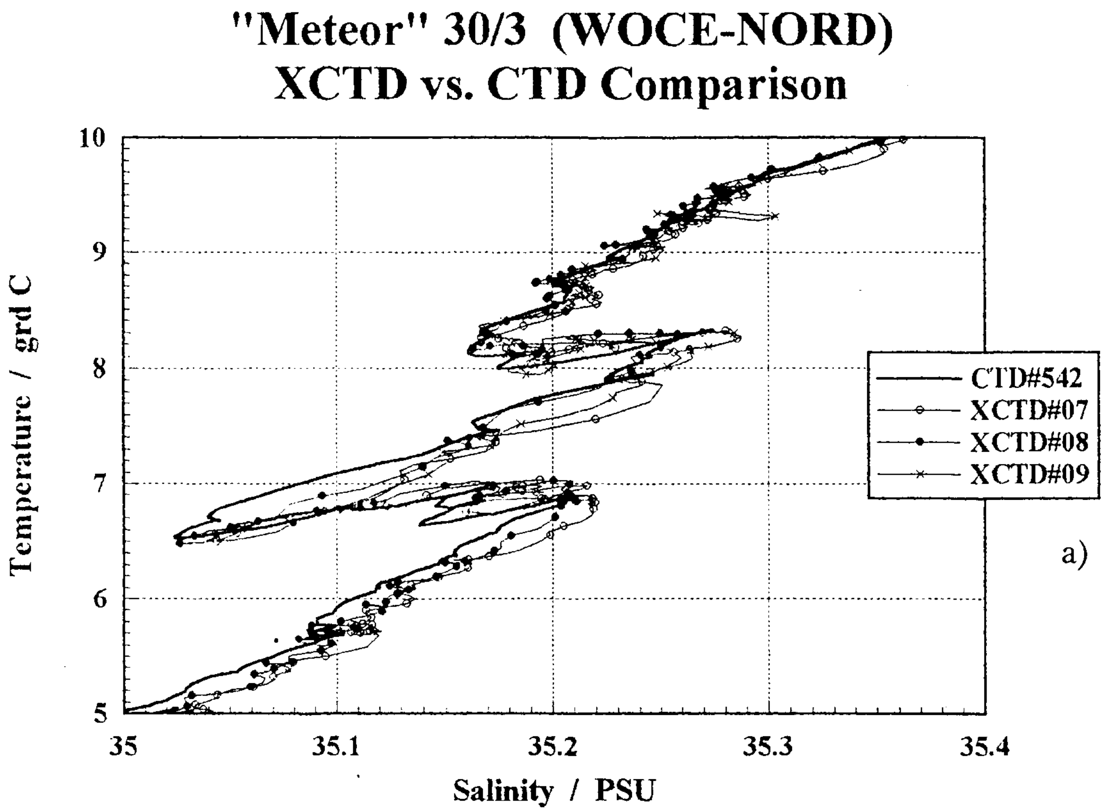
c)


Stations
538
539
540
541
542
543
pressure [dbar]
distance [nm] --->
Cruise: FS Meteor 303
Temperature
Bundesamt fuer Seeschiffahrt & Hydrographie
18/September/1995

d)


Stations
538
539
540
541
542
543
pressure [dbar]
distance [nm] --->
Cruise: FS Meteor 303
Salinity
Bundesamt fuer Seeschiffahrt & Hydrographie
18/September/1995

e)



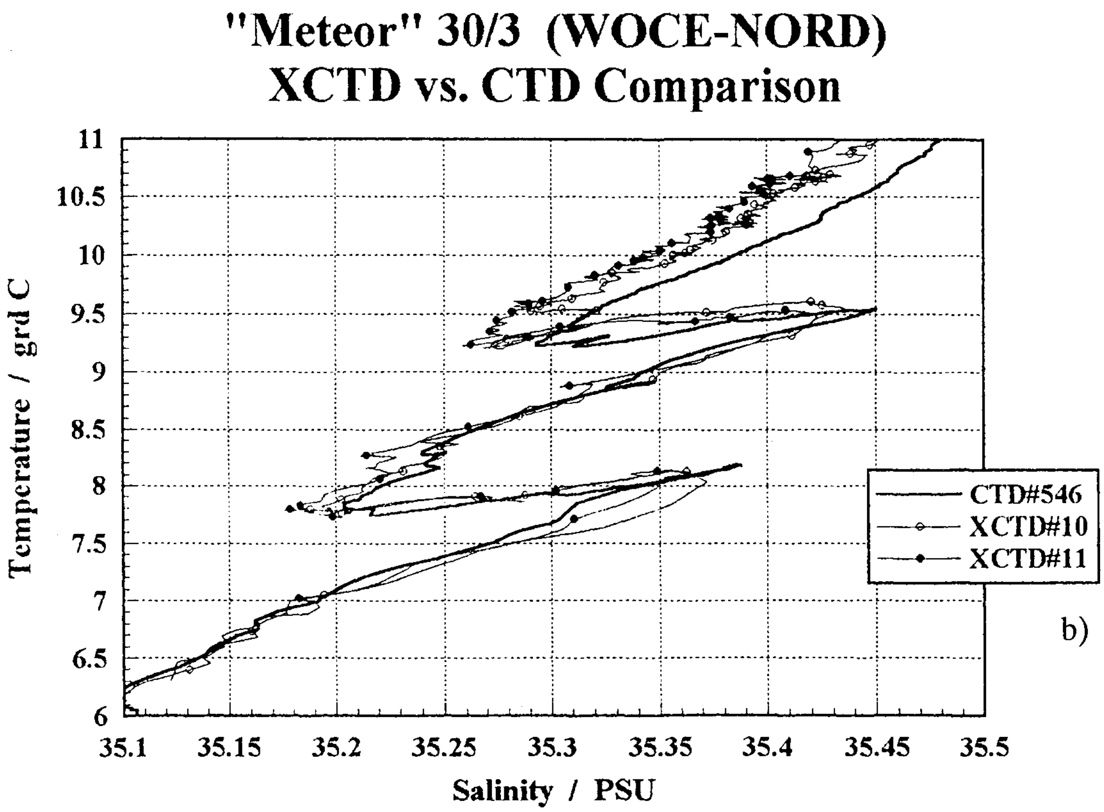
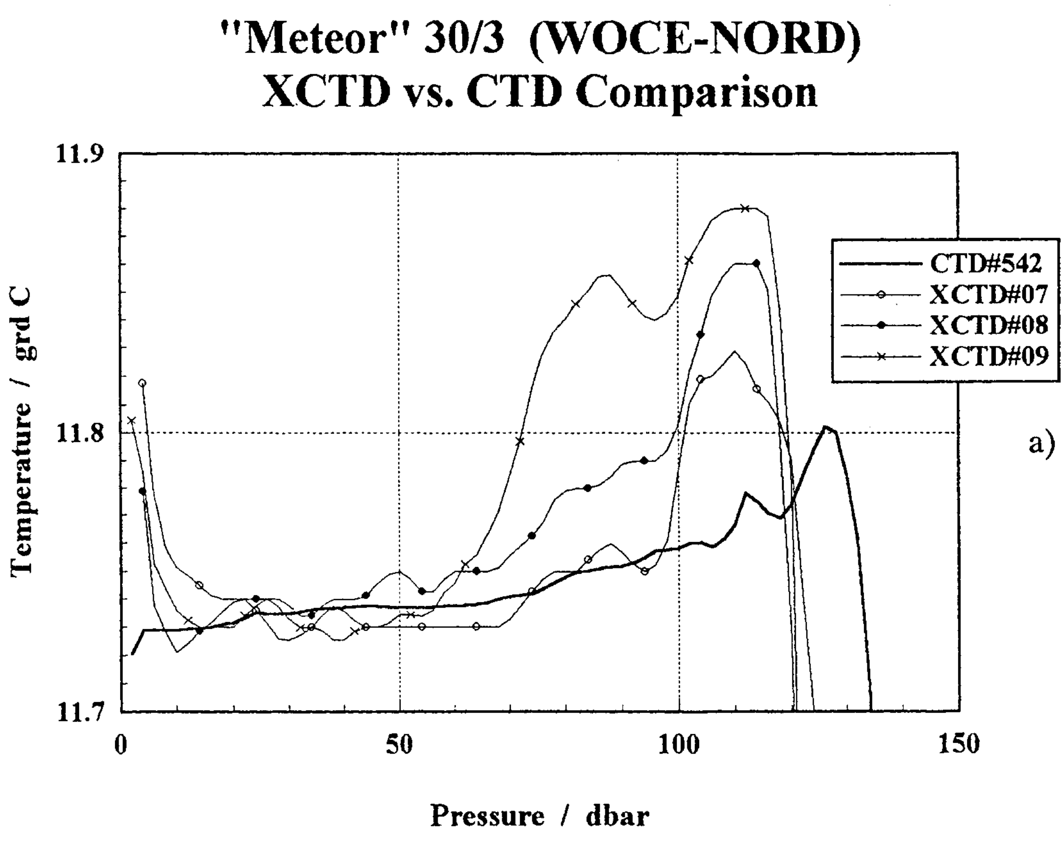


Fig. 3: Enlarged cut of the T/S diagram of CTD and XCTD data
a) at stat. # 542 b) at stat. # 546



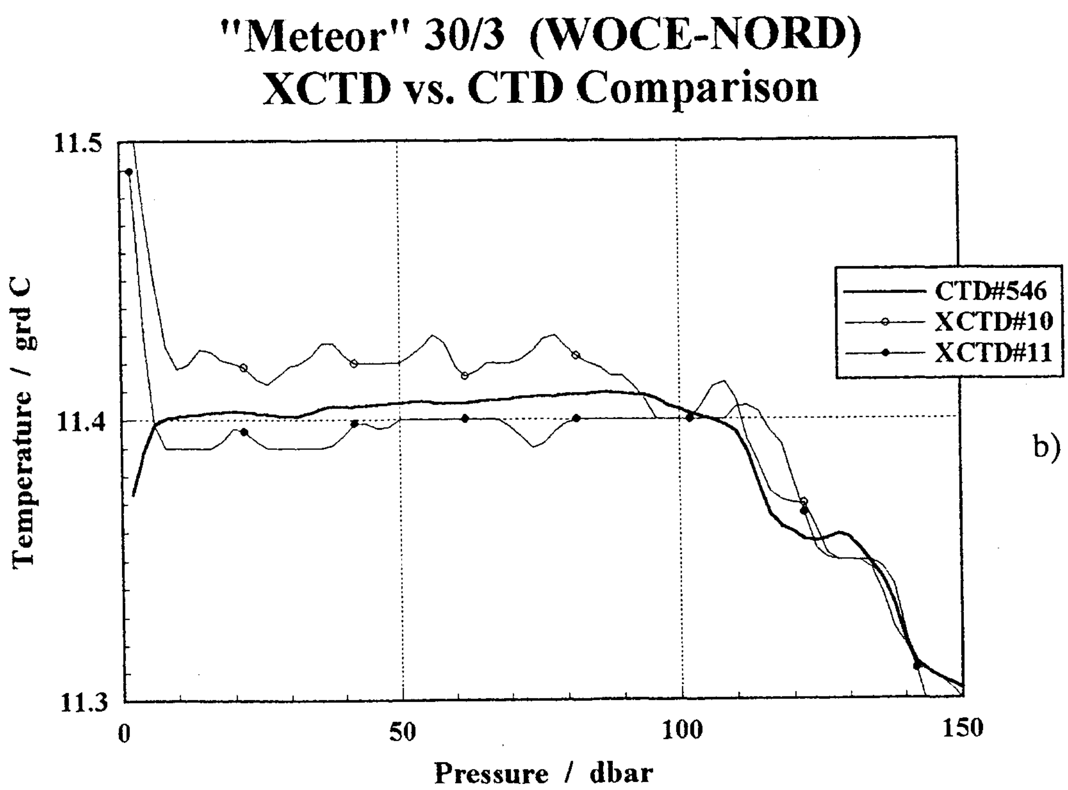
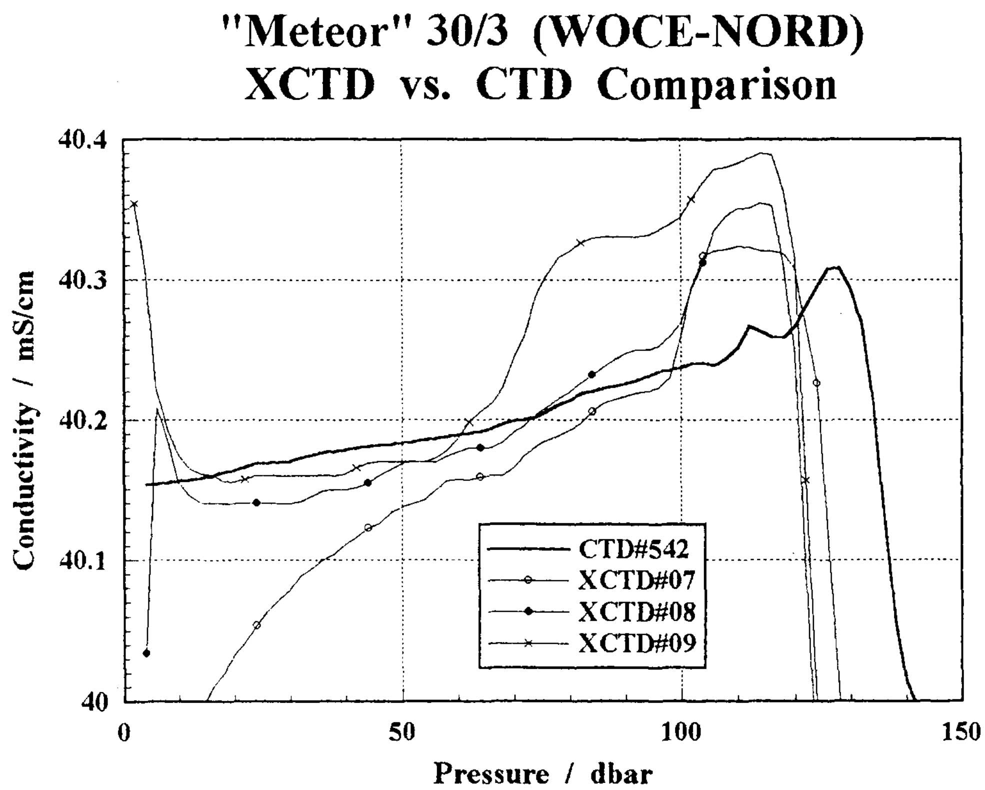
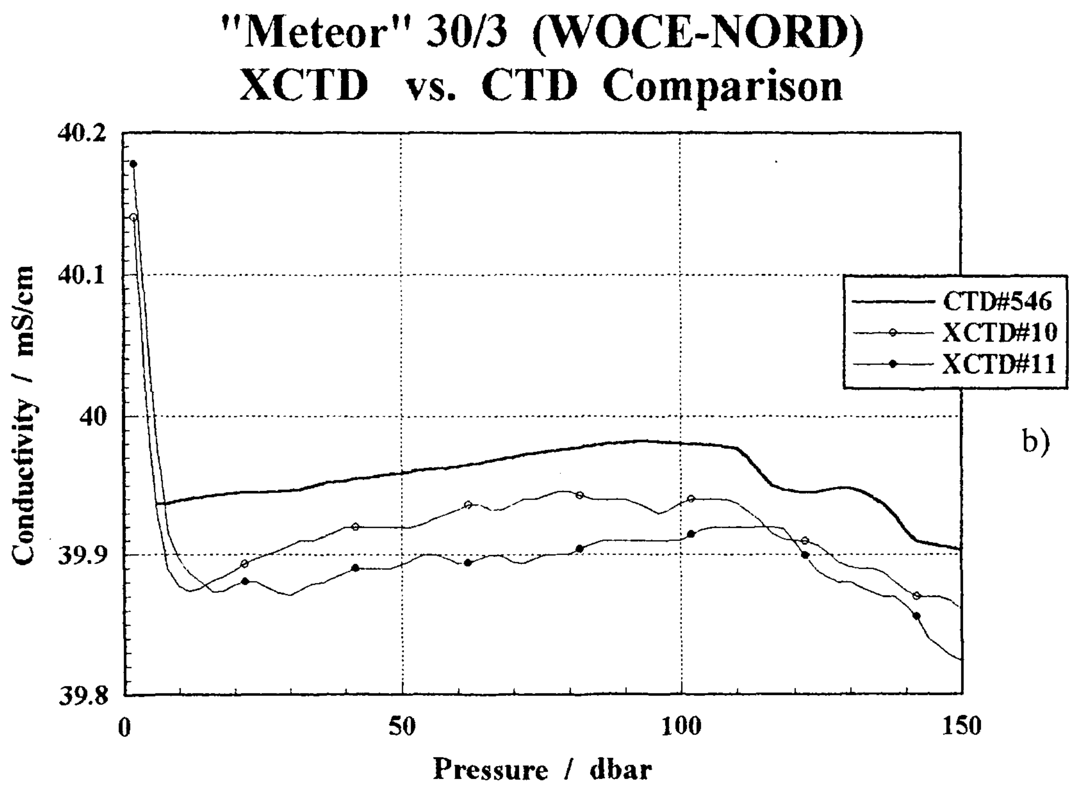


Fig. 4: CTD and XCTD temperature profiles of the upper 150 dbar
a) at stat. # 542 b) at stat. # 546



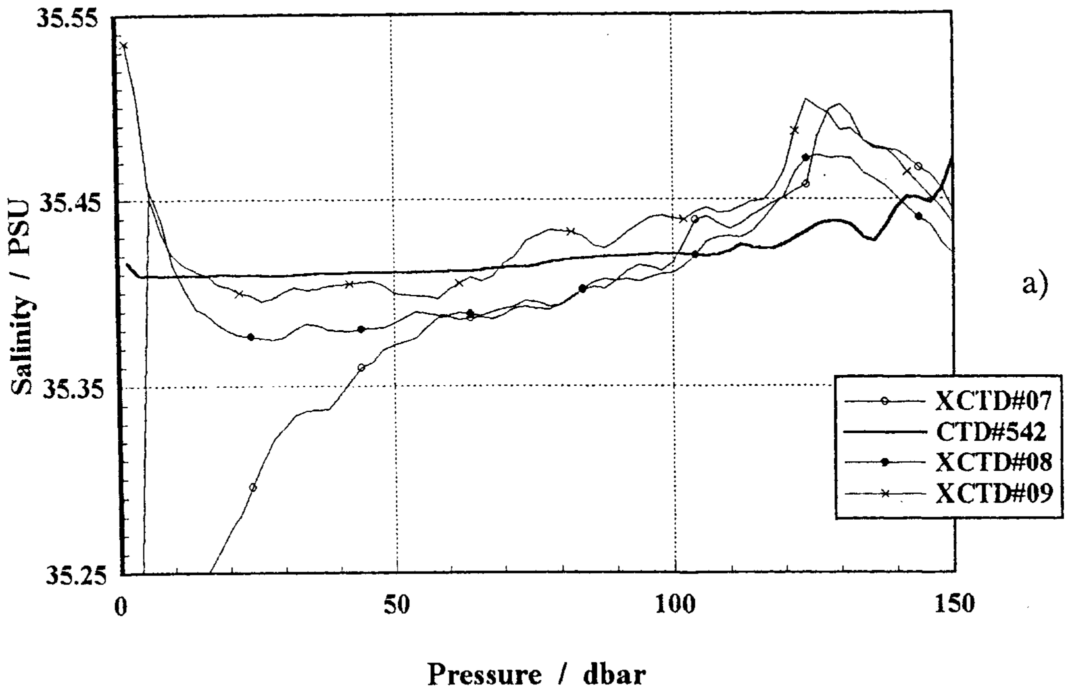
a)



b)

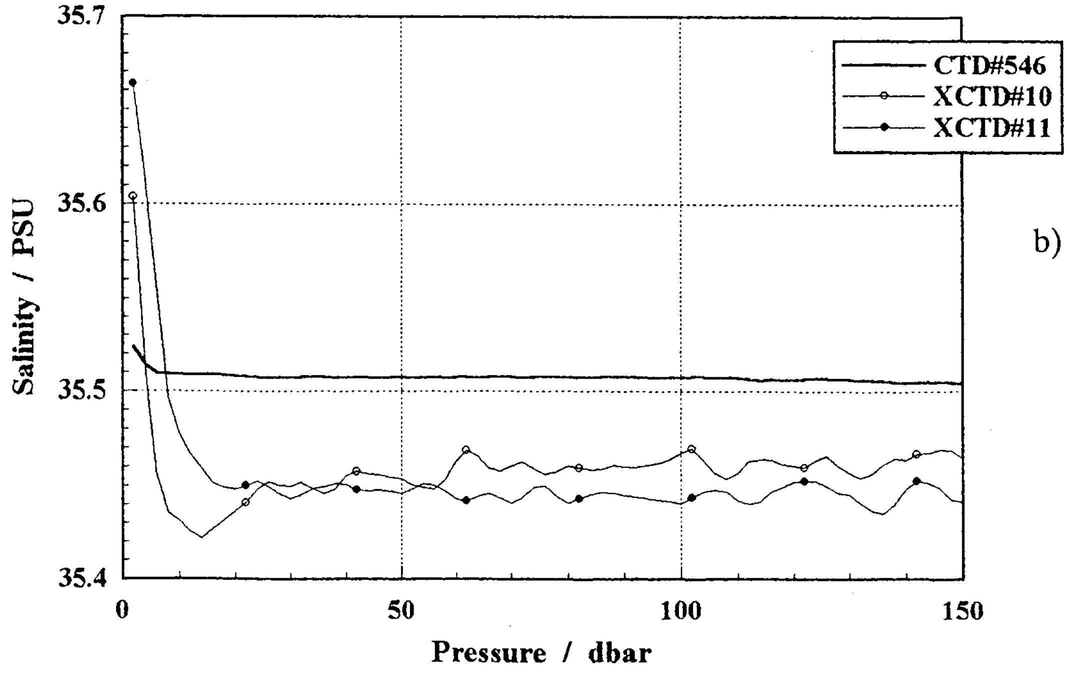
Fig. 5: CTD and XCTD conductivity profiles of the upper 150 dbar
a) at stat. # 542 b) at stat. # 546

**"Meteor" 30/3 (WOCE-NORD)
XCTD vs. CTD Comparison**



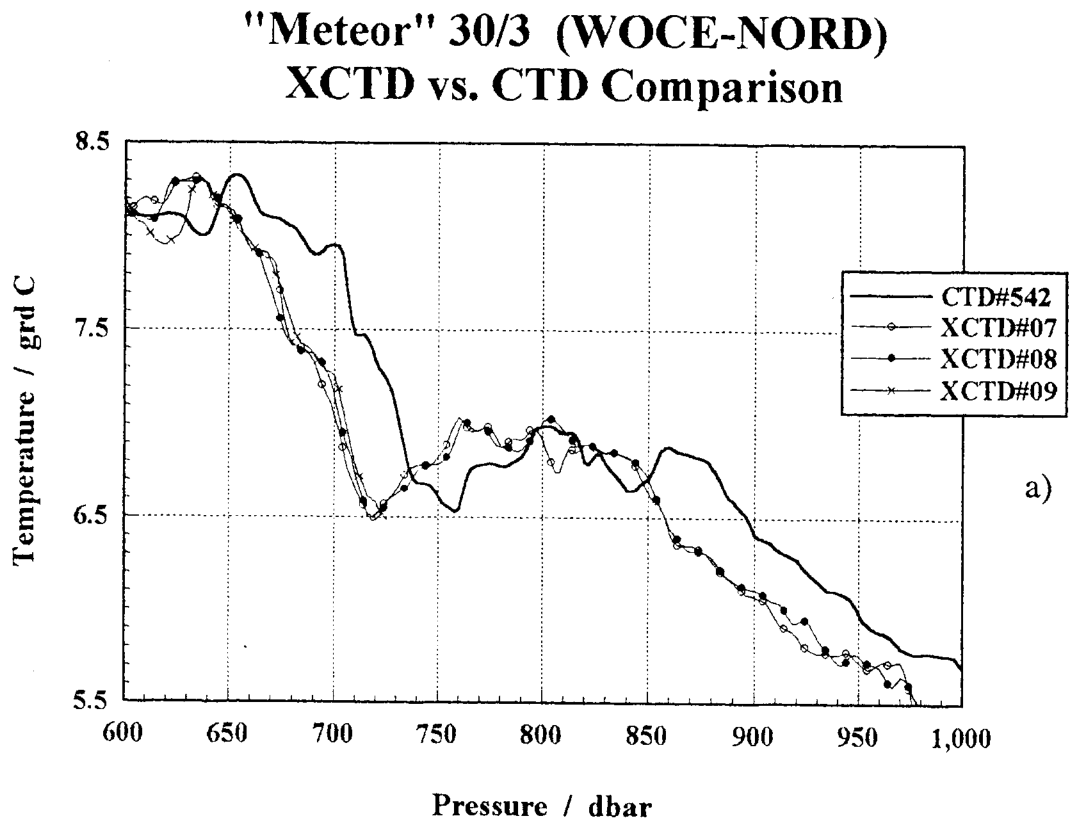
a)

**"Meteor" 30/3 (WOCE-NORD)
XCTD vs. CTD Comparison**

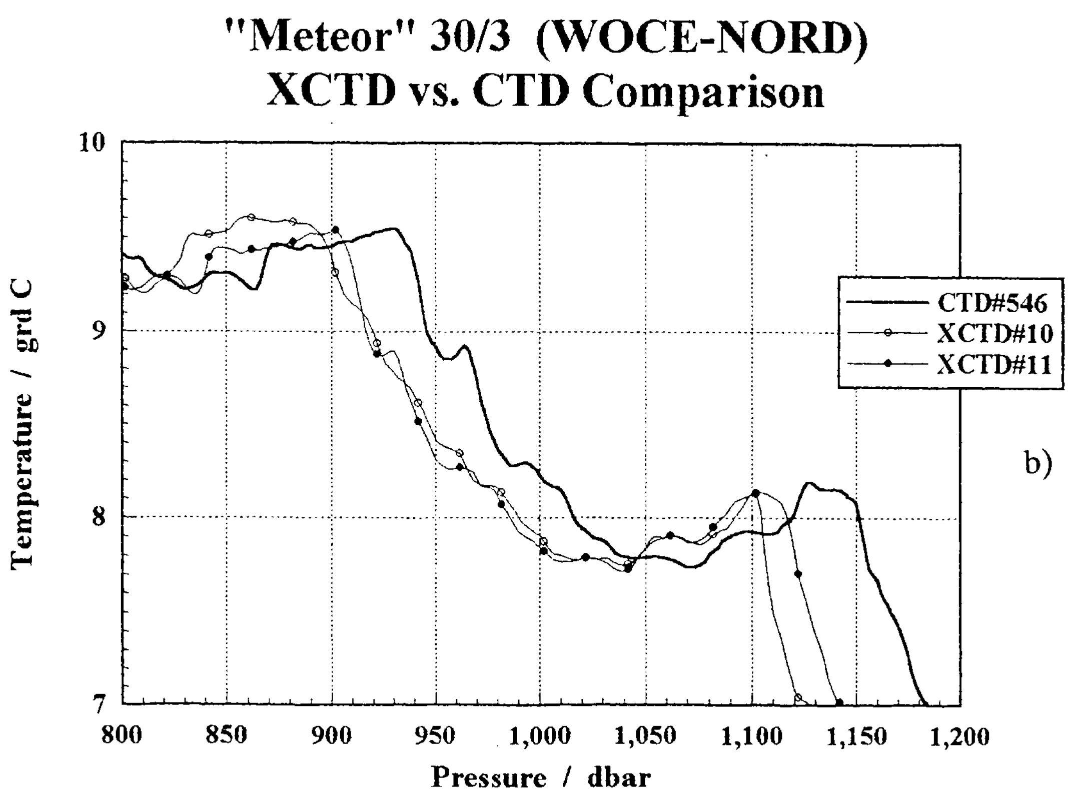


b)

Fig. 6: CTD and XCTD salinity profiles of the upper 150 dbar
a) at stat. # 542 b) at stat. # 546

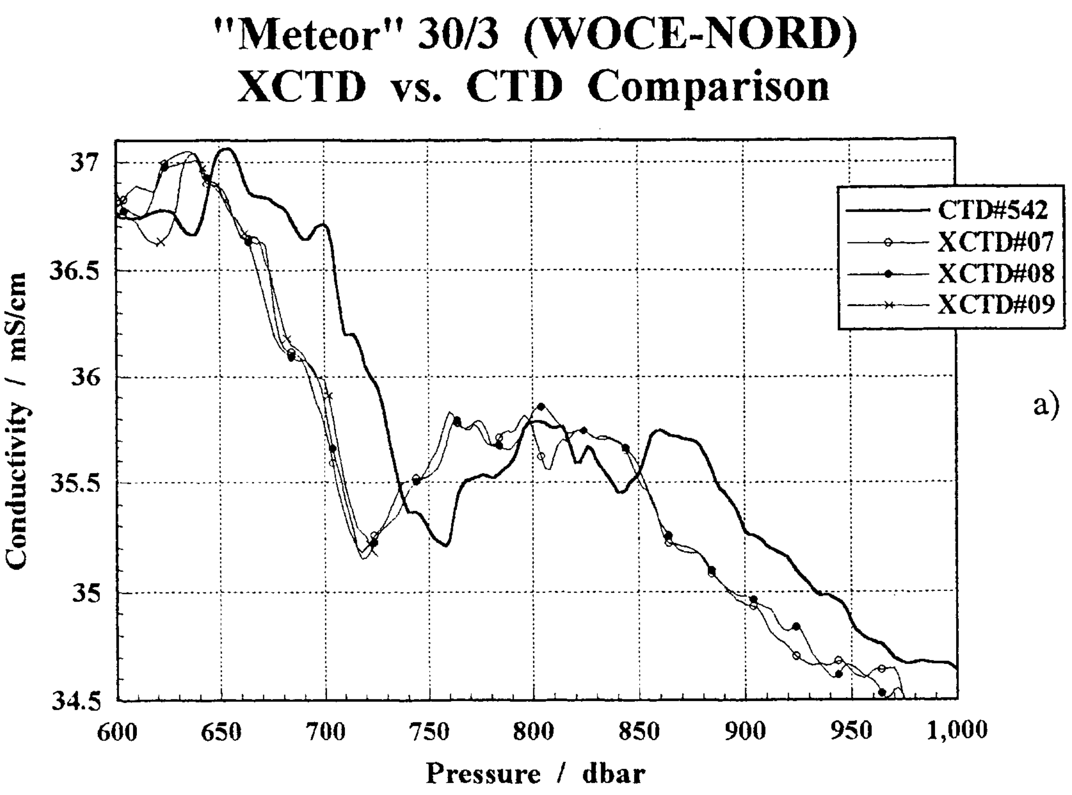


a)



b)

Fig. 7: CTD and XCTD temperature profiles of deeper layers
a) at stat. # 542 b) at stat. # 546



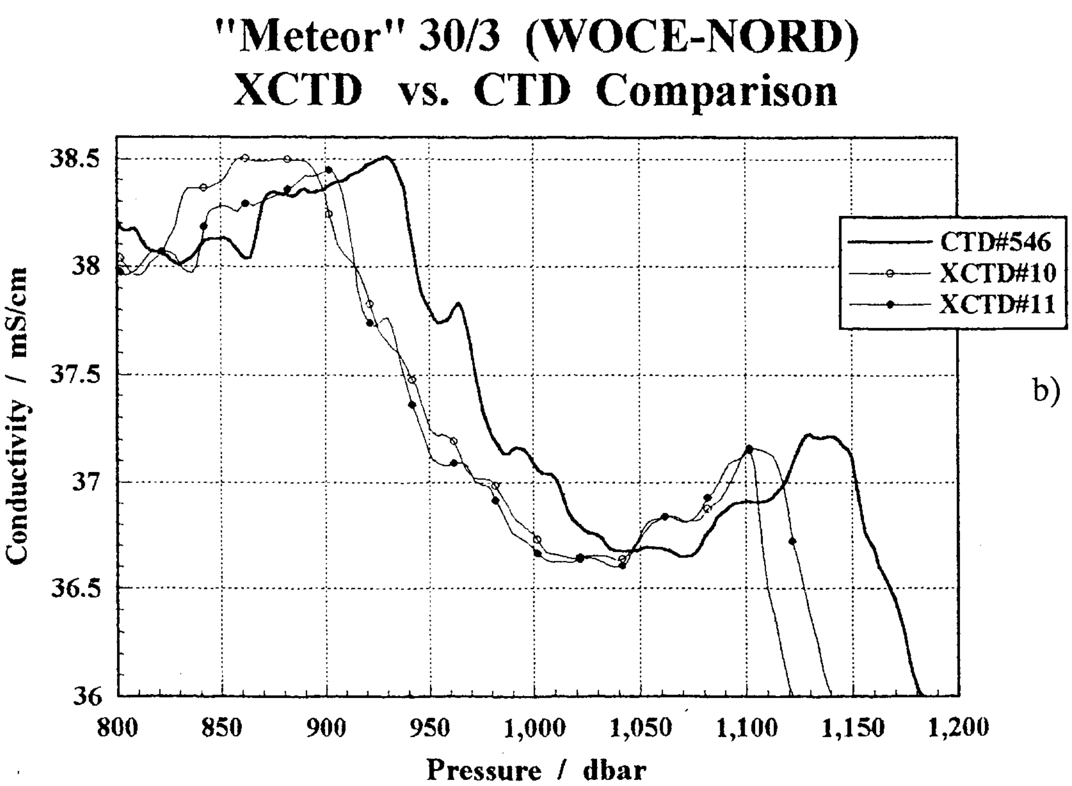
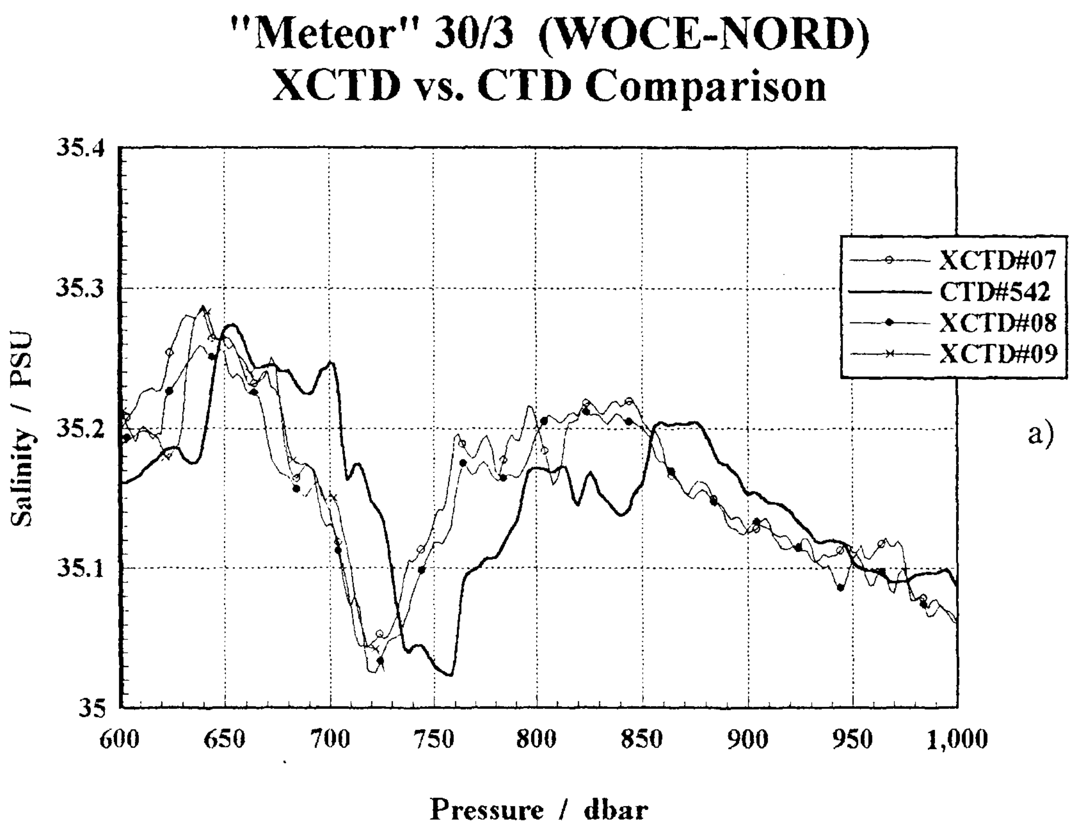


Fig. 8: CTD and XCTD conductivity profiles of deeper layers
a) at stat. # 542 b) at stat. # 546



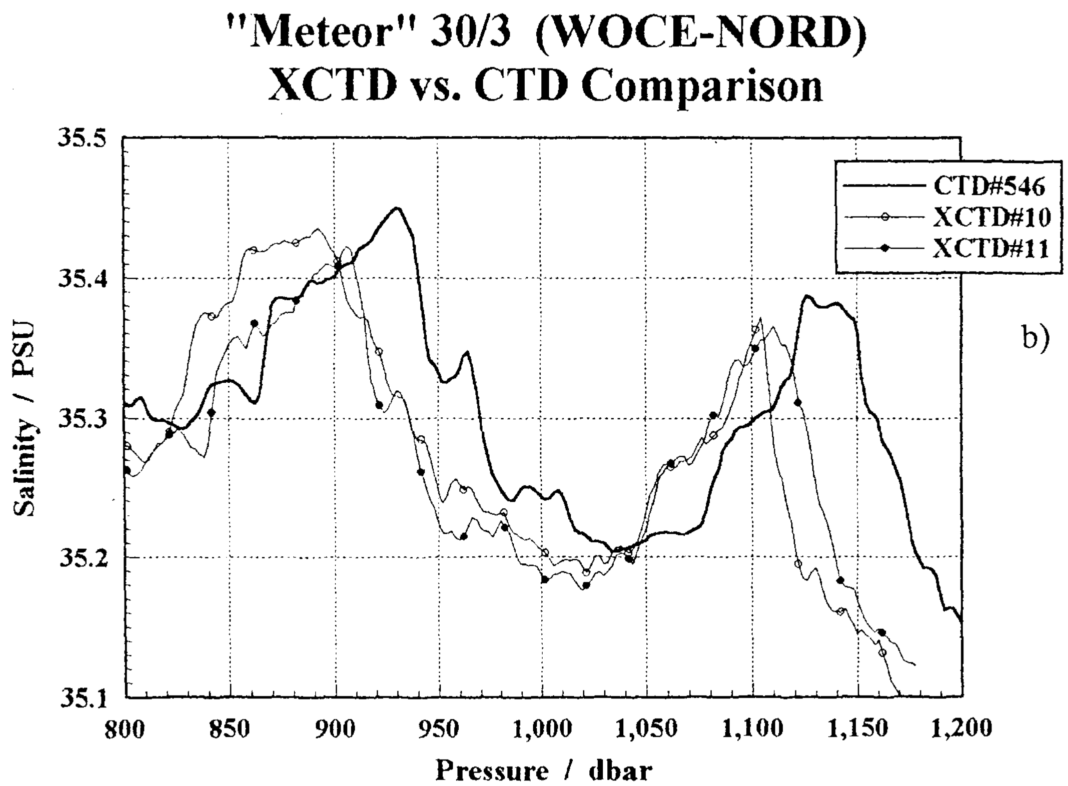


Fig. 9: CTD and XCTD salinity profiles of deeper layers
a) at stat. # 542 b) at stat. # 546

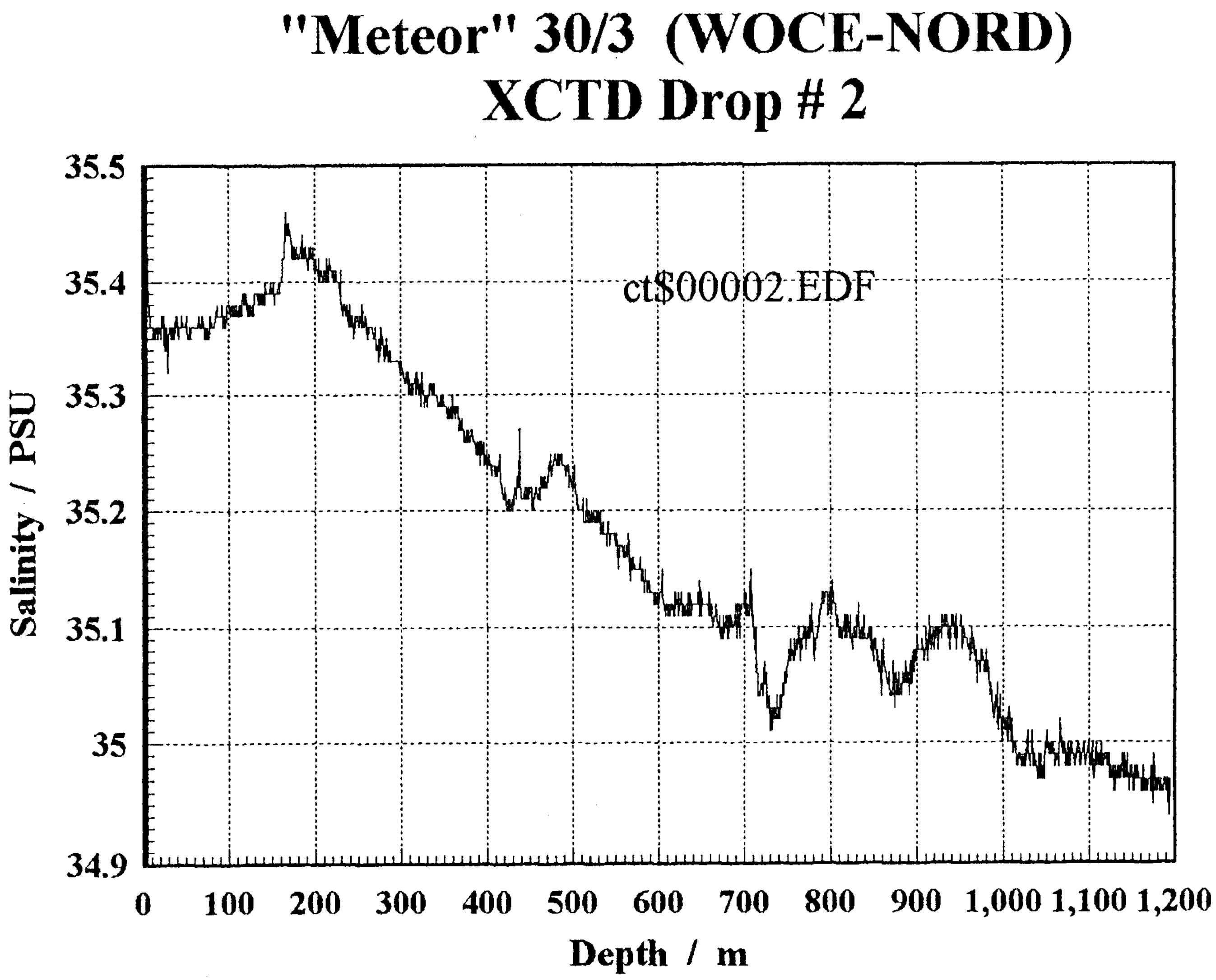


Fig. 10: A typical unprocessed salinity profile (EDF file of XCTD drop # 2)

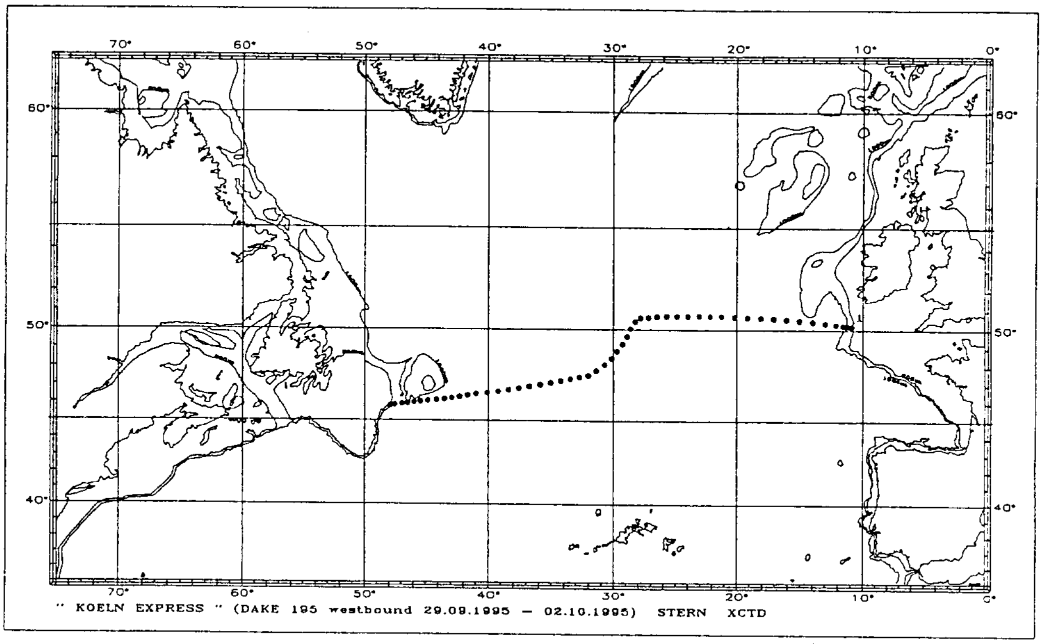


Fig. 11: Transoceanic XCTD section carried out by CMS "Köln Express"

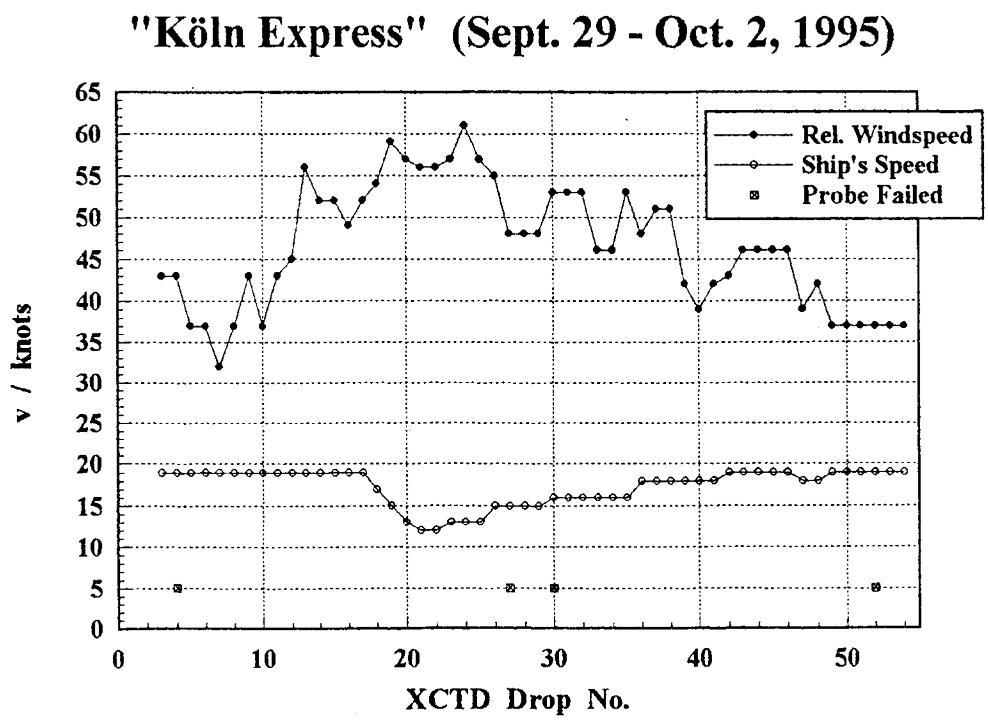


Fig. 12: Relative windspeed and ship's speed during XCTD drops

"Köln Express" (Sept. 29 - Oct. 2, 1995)

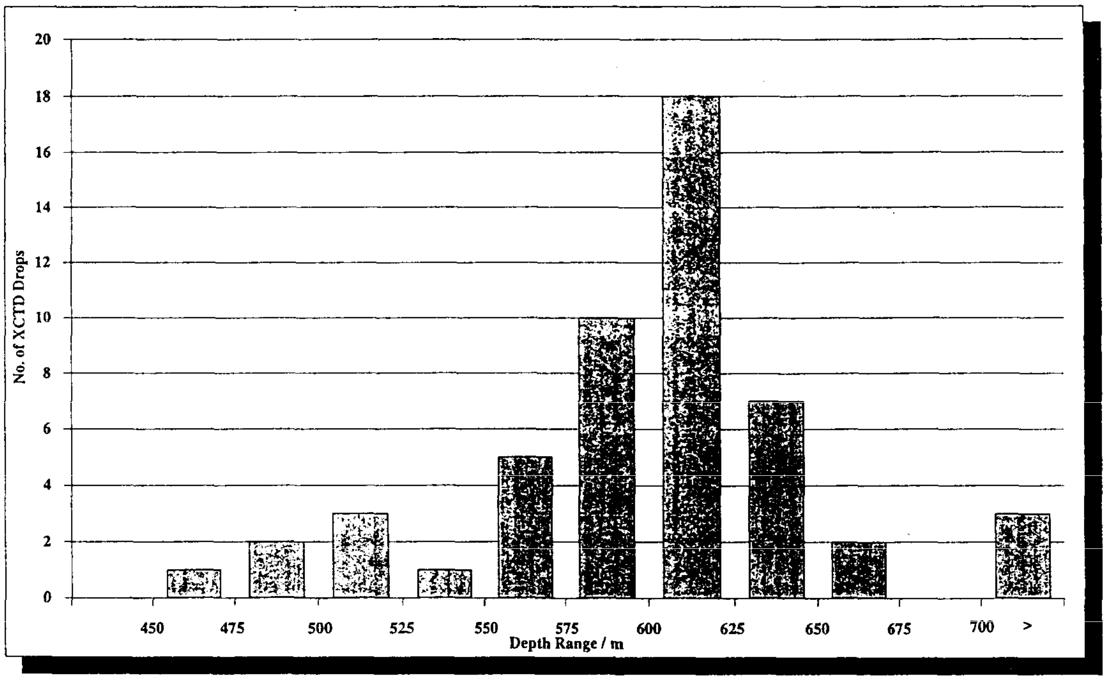


Fig. 13: Depth range of XCTD drops

"Köln Express"(Sept. 29 - Oct. 2, 1995)

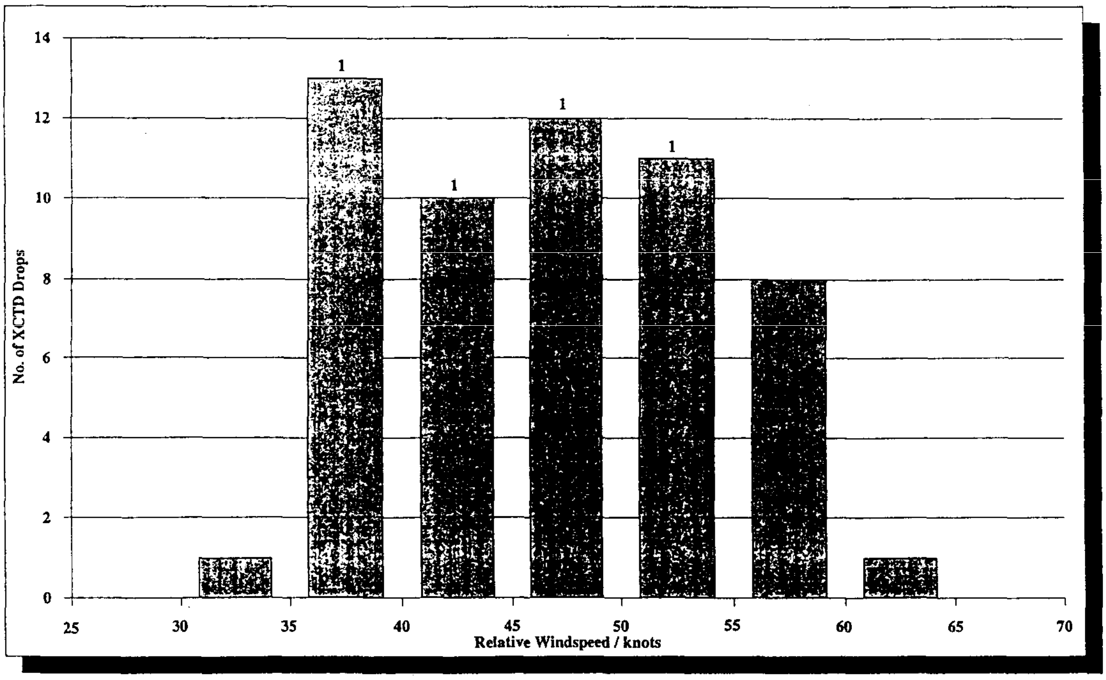


Fig. 14: Relative windspeeds during XCTD drops (1 - probe failed)

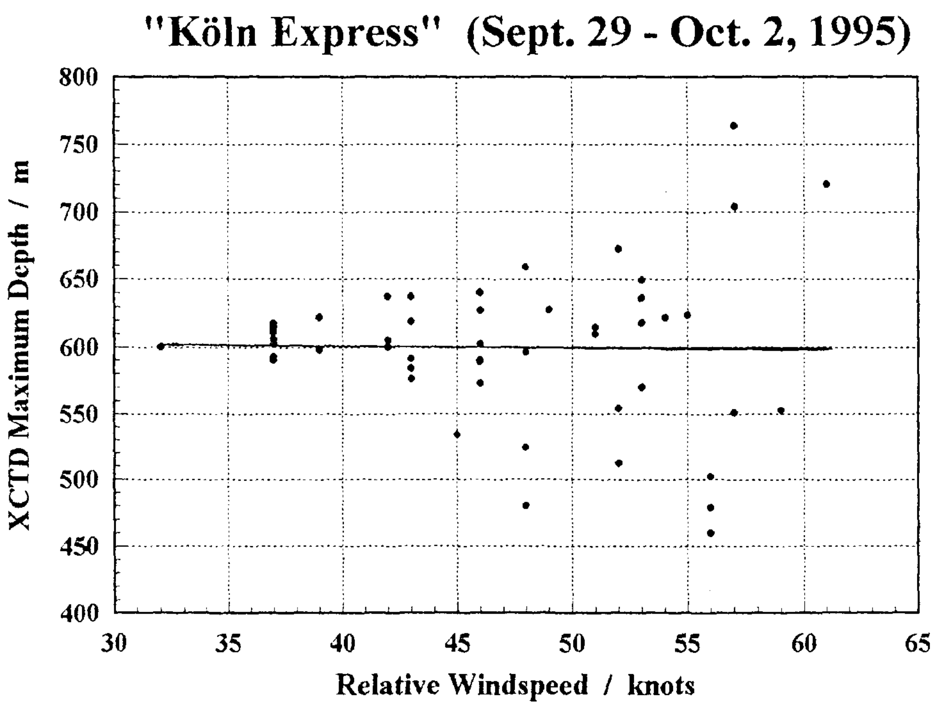


Fig. 15: XCTD depth versus relative windspeed

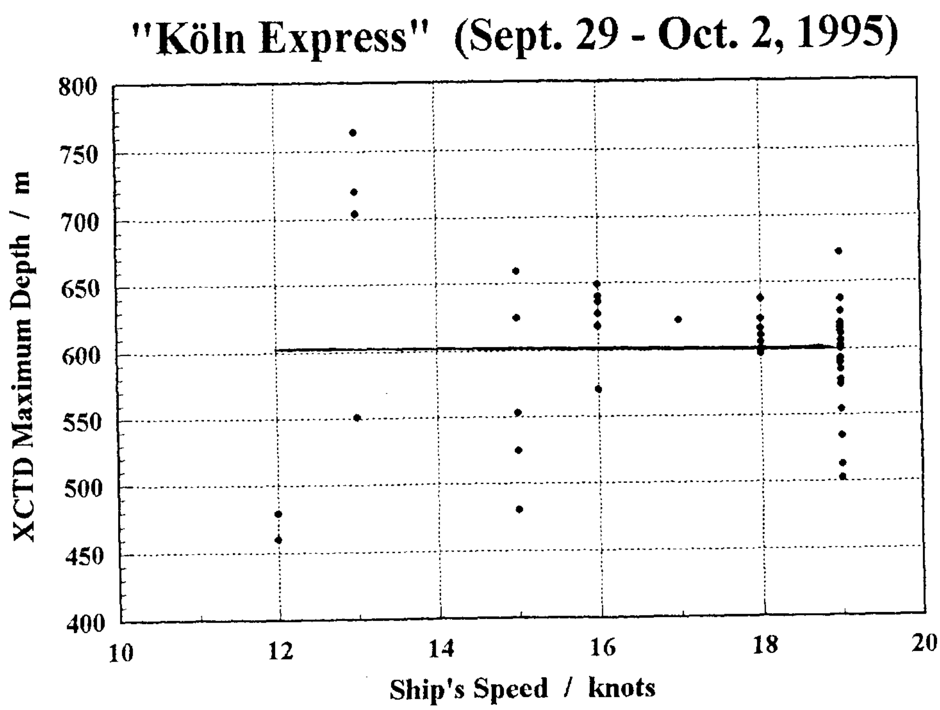


Fig. 16: XCTD depth versus ship's speed

ANNEX IV

LIST OF RECOMMENDATIONS

1. Operators, manufacturers and software generators must use the old form of the fall rate equations for the data submitted to the archives when no information is available on the probe type and recorder. If the information is available (whether it is using the old or new fall rate equation), this should accompany the data sent to the archives.

2. Manufacturers of XBTs change the fall-rate equation in their software.

3. IODE-XV to advise national archives to store the information on fall rate, probe type and recorder now required to accompany XBT data.

4. Joint Committee on IGOSS to recommend that each IGOSS National Representative provide information to the IGOSS Operations Coordinator concerning which national operators were notified about the new JJYY code form and when operators plan to implement the new code.

5. The Chairman to request the Joint Committee on IGOSS to revise *Manuals and Guides 3* to bring its information up to date.

6. Operators to encode BATHY messages with temperatures at observed depths, not extrapolated to zero meters.

7. The Joint Committee on IGOSS to recommend changes be made in the TRACKOB code form to record information about instrumentation used.

8. The Task Team recommends that whenever a questionable profile is obtained using an XBT, a second drop be made to verify the profile.

ANNEX V

LIST OF ACTION ITEMS

1. The Chairman of TT/QCAS to send a letter to manufacturers formally requesting that they change the fall-rate equation in their software and include the probe, recorder type and fall rate coefficients into the headers of all their data files.

2. The IGOSS Operations Coordinator to place information about the BATHY code change including the JCL, an example of the new code form, and WMO code tables should be included on the IGOSS Home Page.

3. Task Team members to publish articles in their own agency and country newsletters publicizing the requirement for including probe and recorder type information.

4. IGOSS Operations Co-ordinator to work with GTSPP to monitor the progress in converting to the new code form.

5. Mr Pierre Rual and Mr Rick Bailey to prepare the covering letter and the article for distribution by the manufacturers (including publication in their newsletters).

6. The Chairman to submit a list of current membership of the TT/QCAS to the Joint Committee on IGOSS for approval.

7. Mr Pierre Rual and Mr Darren Wright to prepare a set of standard test procedures for XBTs to be discussed at the next TT/QCAS meeting. This documentation to be provided to probe manufacturers for comment prior to the next meeting. Upon approval by the Task Team, this document will be submitted to IOC for publication as an IOC Guide.

8. Sippican, TSK and Sparton to provide information about recommended XBT storage and deployment procedures to the Chairman by 14 November, 1995.

9. Mr Pierre Rual to write a proposal detailing the work carried out to date to develop the software to determine accurate fall rate coefficients, and comparing the high costs of this development against the nominal funds needed to deliver a commercial quality software package.

10. Chairman to request Joint Committee on IGOSS to provide funds for consolidating the software to determine accurate fall rate coefficients.

11. Dr Alexander Sy to co-ordinate the analysis of T-5 and Fast Deep data collected to date once the consolidation of analysis software is completed.

12. Mr Pierre Rual to determine if the Service Hydrographique et Océanographique de la Marine (SHOM) has additional T-5 data.

13. Mr Pierre Rual to contact SHOM to obtain their extensive XCTD data set.

14. Dr Sy, Mr Wright, and Ms Elgin to send their XCTD data to Mr Bailey by 1 December, 1995. Mr Bailey to co-ordinate with Dr Dean Roemmich to perform the analysis once the consolidated analysis software becomes available. The data should include instrument types, calibration information, locations and speed of vessel and other relevant information.

15. Dr Sy to request usable probe test data from Germany's Polar Research Institution and inform the Chairman of his success.

16. In the event that Dr Sy cannot obtain these data, Mr Bailey to co-ordinate with Sparton of Canada to perform tests in the Southern Ocean. Sparton volunteered to contribute probes for this test.

17. Mr Rual to perform the analysis of remaining Sparton data and, upon review by the Task Team, to publish preliminary results in the WOCE International Newsletter.

18. The Chairman to inform the GOOS-Ocean Observation Panel for Climate and the CLIVAR Upper Ocean Panel of the need to decide what accuracy is required in the measurement of salinity.

19. The Chairman to request funding for translation from French to English of the ORSTOM TSG Installation Manual (approximately 50 pages) from the Joint Committee on IGOSS.

20. Mr Rual to ask Mr Henin to prepare guidelines on the operation of TSGs.

21. Mr Rual to ask Mr Henin to prepare another document describing quality control procedures to be applied to TSG data.

22. Mr Wright and Mr Rual to prepare general guidelines for the quality control procedures discussed above for review by TT/QCAS.

23. The Chairman to request GE/OTA prepare a new code form for TESACs that will contain the information on instrumentation.