



INTERNAL DOCUMENT No. 5

SeaSoar data processing and calibration

**S A Cunningham, R T Pollard, M J Griffiths
S G Alderson & R Lowry**

1992



**Institute of
Oceanographic Sciences
Deacon Laboratory**

Natural Environment Research Council

**JAMES RENNELL CENTRE FOR
OCEAN CIRCULATION**

INTERNAL DOCUMENT No. 5

SeaSoar data processing and calibration

**S A Cunningham, R T Pollard, M J Griffiths
S G Alderson & R Lowry**

1992

Gamma House
Chilworth Research Park
Chilworth
Southampton SO1 7NS
Tel 0703 766184
Telefax 0703 767507

ABSTRACT

This manual arose because of a need to record the procedures for processing and calibrating SeaSoar conductivity, temperature and depth (CTD) data as existed within the Institute of Oceanographic Sciences (IOS) up to 1992.

During the early 1990's IOS made substantial investments in new technology and improved instruments for SeaSoar. This meant that many new procedures had to be developed to cope with the significant changes in the SeaSoar system.

A new winch with 750 meters of faired cable allowed SeaSoar to profile between the surface and 550 meters. This was a depth improvement of 100 meters over the old winch system.

A modified Neil Brown Mk III CTD, with an additional conductivity cell was mounted within SeaSoar. This was done to overcome the problems of fouling within the conductivity cell.

In addition a SeaBird Thermosalinograph was used for the first time, which was considered to have adequate conductivity accuracy and stability such that it could be used to calibrate the SeaSoar CTD data.

Here we document the new procedures which were adopted to process the data from the modified CTD and the new calibration techniques which make use of the TSG.

<u>CONTENTS</u>	PAGE
SEASOAR DATA PROCESSING MANUAL	7
INTRODUCTION	7
1. AN INTRODUCTION TO SEASOAR	8
1.1. The SeaSoar	8
2. SEASOAR DATA PROCESSING	10
2.1. An Introduction to Shipboard SeaSoar Processing	10
3. FOUR HOUR SEASOAR DATA PROCESSING	12
3.1. Four Hour Processing	12
3.1.1. ssexec0	12
3.1.2. ssexec1	12
3.1.3. ssexec2	13
3.2. Editing and Relative Calibration of SeaSoar CTD Data	13
3.2.1. Editing a four hour SeaSoar section	13
3.2.2. The double conductivity cell	13
3.2.3. The primary salinity channel	14
3.2.4. Relative calibration of the secondary salinity channel	14
3.2.5. T/S plots and their interpretation	14
3.2.6. Time series plots	15
3.3. Correcting Offsets in the Primary Salinity	16
3.3.1. Spotting the offsets	16
3.3.2. Identifying the data cycles	16
3.3.3. Swapping data cycles of shifting offsets	17
3.4. Examples of Interpretation of Real Data	17
3.4.1. Section ssl2083	17
3.4.2. Section ssl2070	18
3.4.3. Section ssl2024	18
3.5. Despiking SeaSoar Data	19
3.5.1. Causes of noise in SeaSoar CTD data	19
4. TWELVE HOUR SEASOAR DATA PROCESSING	21

4.1.	Twelve Hour Processing	21
4.4.1.	navexec0	21
4.4.2	ssl2exec1	21
4.4.3.	ssl2exec2	22
5.	ABSOLUTE CALIBRATION OF SEASOAR CTD DATA	23
5.1.	Introduction	23
5.2.	Calibration of SeaSoar CTD Data Against Vertical CTD Data	23
5.2.1.	Matching SeaSoar and CTD profiles	24
5.2.2.	Accuracy of the absolute SeaSoar data	24
5.3.	Calibration and Verification of SeaSoar CTD Data Against Underway Samples	25
5.3.1.	Comparing underway salinity samples against gridded SeaSoar data	25
5.3.2.	Comparing underway salinity samples against one second SeaSoar data	25
5.4.	Calibration of SeaSoar CTD Data Against a Thermosalinograph	26
5.4.1.	Calibration of the TSG against underway samples	26
5.4.2.	Calibration of SeaSoar against TSG data	26
6.	INSTRUMENTAL CALIBRATIONS	28
6.1.	Introduction	28
6.1.1.	Instruments and calibration data	28
6.1.2.	Applying the instrumental calibrations	30
	ACKNOWLEDGEMENTS	31
	REFERENCES	32
	TABLES	34
	FIGURES	35
	Appendix A:- RVS Commands	52
	Appendix B:- Problems Running C-shells	54
	Appendix C:- SeaBird Thermosalinograph Data Sheet	57
	Appendix D:- Calibration of a SeaBird Thermosalinograph	58
	Appendix E:- TSGEXEC0 - Comparison of TSG and SeaSoar CTD data	63
	Appendix F:- IOSDL Instrumentation Group Calibrations	70
	Appendix G:- Manual Page for CTDCAL (version 04)	73

SEASOAR DATA PROCESSING MANUAL

Introduction

Since 1978 staff of the Marine Physics Department at IOSDL have built up considerable experience and devised a particular methodology for SeaSoar data gathering, processing and calibration. This expertise however, has tended to reside with only a few people, particularly in the areas of data calibration and quality control. With the advent of WOCE and in particular the first trial of the seasonally repeated surveys, vivaldi, there is a pressing need to disseminate this knowledge because of the large volume of work required.

This report sets out to explain briefly how the data are gathered, the hardware set-up of the SeaSoar and the operational limits of the vehicle and what that implies for the data processing, with particular reference to the first use of a double conductivity cell Neil Brown MkIII CTD on vivaldi 1991.

The philosophy and method behind the cleaning up and despiking of SeaSoar data will be described with a view to establishing a consistent method between data processors. A uniform method helps greatly towards the internal consistency, accuracy and precision of the data during a cruise.

During the first vivaldi cruise the SeaSoar was recovered at 300 km intervals between full depth CTD's. These CTD stations together with hourly sampling for surface salinities and continuous monitoring of the surface salinity and temperature with the thermosalinograph (TSG) gave an unprecedented opportunity to have daily calibrations of the SeaSoar. In the past the TSG has only provided data of low quality. Now SeaBird sensors within the TSG have greatly improved the data quality. During the cruise calibration protocols were established, and these play a fundamental role in ensuring that the SeaSoar data are correct. These will be described and some example data from the cruise will be presented.

This report is aimed at people meeting SeaSoar processing for the first time, as a handbook for experienced SeaSoar processors and as a reminder to those who haven't been to sea for some time.

CHAPTER 1. AN INTRODUCTION TO SEASOAR

1.1. The SeaSoar

SeaSoar is a towed undulating vehicle, which carries instruments to measure water properties at high spatial and temporal resolution over the top 500m of the ocean.

Figure 1:- SeaSoar and winch as deployed during 1991

In 1990 IOSDL invested in a new winch to hold up to 750m of faired cable. This new winch with its extra cable capacity was designed to improve the depth penetration of the SeaSoar. As a rough guide the depth of penetration is given as 70% of the faired cable length. During vivaldi depth penetration regularly exceeded 500 m, an improvement of at least 100m over the old winch. (POLLARD, 1992) outline the latest operational characteristics of the SeaSoar and (GWILLIAM, 1990) reports on test hydrodynamic characteristics of the SeaSoar. (GRIFFITHS & POLLARD, 1991) have given an account of some of the most recent surveys to be carried out using SeaSoar.

SeaSoar is towed behind the ship at an operational speed of 9 knots. Its depth is changed by adjusting the pitch of the wings. These wings are driven by internal hydraulics powered by an impeller at the rear of the SeaSoar. This allows the SeaSoar to follow a saw tooth pattern through the water.

Figure 2:- Track profile followed by the SeaSoar

Generally the path followed by SeaSoar is automatically controlled by ship board hardware, however manual override is occasionally used. One limiting factor on the ascent/descent rate of the SeaSoar is the strain put onto the cable. This gives a cycling time of about 20 to 25 mins, for operation to 500m and a horizontal separation of around 4800 m to 6000 m.

Instruments are mounted within the body of SeaSoar to measure the required water properties. During vivaldi the SeaSoar carried a Neil Brown Mk III double conductivity cell CTD, a photosynthetically active radiation (PAR) meter to measure downwelling irradiance and a fluorometer, (CUNNINGHAM et al, 1992). The instruments are protected within the body of the SeaSoar while their sensors project from the body at suitable locations. The CTD sensors (double conductivity cells and Platinum resistance thermometer) are mounted on top of the SeaSoar close to the nose, giving an unobstructed flow of water around the sensor. The fluorometer is mounted low down beneath the nose and the PAR meter on the rear tail fin. (SMITHERS, 1991) describes the SeaSoar system, its development and current design performance. Comprehensive operational and maintenance notes are also given.

The cable used to tow the SeaSoar is a torque balanced load bearing armoured cable, with a seven strand conducting core, surrounded by a fairing to reduce drag. Data are transmitted from the instruments directly to the CTD deck unit where they are recorded to IBM cartridge (DC100)

tape. The data are then passed to Level A, which is the hardware interface between the instruments and storage of the raw data. At Level A the data are despiked and averaged to 1 Hz. Level A also converts the data to a ship specific data format. This format is known as message ship protocol (MSP), (VOSS, 1986), which hereafter will be referred to as RVS format. The data are then passed to Level B, stored on 9 track tape and logged to the magnetic disk of a Sun4 workstation. Level B is the critical level. If the data logger crashes then all data transmitted from Level A to Level B are lost.

Figure 3:- Schematic diagram of the data gathering path for SeaSoar data

This gives a brief introduction to the SeaSoar vehicle, its operational characteristics and the data path from instruments to the ship. The reader should consult the references for detailed explanations of the above.

CHAPTER 2. SEASOAR DATA PROCESSING

2.1 An Introduction To Shipboard SeaSoar Processing

Most of the shipboard SeaSoar data processing is done on computer workstations. Currently these are Sun4 workstations which run the UNIX operating system, see (POLLARD, LEACH & GRIFFITHS, 1991). The data are processed within c-shell scripts which call FORTRAN programs from the PEXEC program suite. The PEXEC program suite is an extensive FORTRAN software library which contains programs for manipulating data. PEXEC uses a data format known as PSTAR. This format uses a header for a particular data file, followed by the data. The header contains a unique data name for that file and a version code. The version code is incremented whenever a PEXEC program accesses and alters the data. In conjunction with data sheets this gives a complete record of what has happened to the data. The header also contains useful information such as the number of variables and datacycles and where and when the data were collected.

Figure 4:- SeaSoar Data Processing Path

Processing and calibration of SeaSoar data can be split into three main steps as shown in Figure 4. In step 1 data are processed as four hour segments through a series of execs. The instrumental calibrations are applied to the data in ssexec1 via the PEXEC program CTDCAL. The relative calibration of the twin conductivity measurements is determined and the data are despiked. This stage is repeated for a number of four hour sections as required.

At stage 2 a number of four hour sections from stage one are appended and merged with navigation data. Generally processing at stage 2 corresponds to a section of SeaSoar data between CTD stations.

Absolute calibration of the data is carried out at stage 3. It comprises of two parts. The absolute calibration of the SeaSoar data against CTD stations and the verification of the calibration. There are three possible paths for the verification, as shown in Figure 4. The preferred path is now route (iii) and for the sake of completeness the other possible paths are described. Route (iii) involves the intermediate calibration of a TSG against surface salinity bottle samples, and the comparison of the TSG data with the SeaSoar data.

Corresponding to the flow diagram of Figure 4 the manual will be split into the following chapters. Chapters 3 and 4 will describe four hour processing (stage 1) and twelve hour processing (stage 2) respectively. These chapters will only be concerned with guiding the data processor through the successful execution of each processing stage and a methodology for de-spiking the data is given.

Chapter 5 is more detailed, dealing with the absolute calibration of the SeaSoar data, and the TSG.

In Chapter 6 the instrumental calibrations (applied at stage 1) and their application will be described in detail. Chapters 5 and 6 are aimed at the person responsible for ensuring that the pre-cruise calibrations are obtained and applied correctly, and for the overall quality of the data on the cruise

CHAPTER 3. FOUR HOUR SEASOAR DATA PROCESSING

3.1. Four Hour Processing

This chapter deals with the processing outlined in stage 1 of Figure 4.

3.1.1. ssexec0

Figure 5 shows the flow chart of the data processing path for ssexec0. The first step is to read raw data from RVS format into PSTAR format. This is done by an RVS programme called DATAPUP (Appendix A), which is called from ssexec0. Each segment of data being processed must be assigned a unique file number identifier (eg 001, 002, 003 etc.). At the start of a section, when SeaSoar has been deployed it is necessary to identify the time at which RVS started logging data and similarly at the end of a section when logging ceased. There are RVS commands to do this and they will be explained in Appendix A.

The data route followed is;

DATAPUP - reads data from RVS data file and converts it to

PSTAR format

PCOPYA - resets data flags and deletes redundant

variables

PHEADR - adds in dataname, instrument, platform and

cruise number

3.1.2. ssexec1

This exec, Figure 6, performs simple editing on the raw SeaSoar data, removing gross pressure, temperature and conductivity spikes, then eliminating missing data values in pressure by interpolation. The instrumental calibrations are then applied to the data in CTDCAL which reads a sequential file of calibration constants.

The data route followed is;

PEDITA - sets datacycles to absent data for values outside a

given range

PINTRP - interpolates on pressure

CTDCAL - calibrates the data

3.1.3. ssexec2

Exec, ssexec2, Figure 7, produces plotcode for plotting on a hardcopy device. The user is prompted for which plots are required. PLOTPR oveplots four profiles with depth in different colours before offsetting for the next four. PLOTXY produces XY plots. The necessary plot description files can be created in the usual way (see PEXEC reference). It is worth spending time at the start of a cruise thinking carefully about the likely range of the variables in the region under measurement. For plotpr files it is usual to have the tick intervals set to 2 cm. eg 0.5 degrees = 2cm and 0.1 psu = 2 cm.

The data route followed is;

PLOTPR - produces offset plots, repeated four times.

PLOTXY - produces xy plots.

3 2. Editing And Relative Calibration Of SeaSoar CTD Data

3.2.1. Editing a four hour SeaSoar Section

Although much of the SeaSoar data processing is automated, there is a large part which has to be done manually. This is related to editing of spikes and correction of shifts within the data. Often the data processor is left to make qualitative judgements about deleting data. Because the data are processed in sections, sometimes errors occur in the relative calibration between sections. This chapter explains how we dealt with a double conductivity cell and gives examples of how the data processors should edit the data to try and achieve a consistency between each SeaSoar section.

3.2 2. The Double Conductivity Cell

When making conductivity measurements with a Neil Brown Mk III CTD within the SeaSoar, problems in the past have been encountered with fouling of the conductivity cell. In cross section the cell is only 4 mm square. Fouling occurs when biological material enters the cell and interferes with the conductivity measurements by changing the geometry of the cell. This leads to reduced conductivity measurement and hence a lower salinity measurement. Foulings occur as spikes when they are transient, or as shifts in the data when the foreign object is trapped in the cell. As the SeaSoar comes to the surface foulings are often cleared in the turbulent wave region and conductivity returns to its normal value.

To overcome the problems of fouling, the CTD unit was fitted with another conductivity cell. When one cell fouled the data could be replaced by data from the other cell. In this way the effects of fouling and degradation of the data could be reduced. A new system for processing SeaSoar data had to be established to deal with the twin conductivity cells. The basic philosophy that was established was that one of the conductivity cells would be designated as the primary conductivity cell and the other as the secondary. When foulings or spikes occurred in the primary the secondary would be used to correct these.

3.2.3. The Primary Salinity Channel

The conductivity measurements have only a nominal calibration applied to them (Chapter 6). Thus there is usually a relative difference in the conductivity measurements. To maintain continuity of the conductivity measurements the primary conductivity cell should be maintained as such, unless it is so badly fouled that there is no choice but to use the secondary conductivity. If one has to change to the secondary conductivity one has to ensure that the relative difference between the two cells is carefully removed, so that the primary and secondary measurements match.

3.2.4. Relative calibration of the secondary salinity channel

To determine the relative calibration of the secondary salinity, the difference of the two salinities is determined. The mean and standard deviation of this difference is then determined. Having calculated the mean and standard deviation of the salinity difference, recalculate the mean and standard deviation using only those values which lie within ± 2 standard deviations of the mean. This eliminates any outliers from the calibration, while maintaining the sample size. The mean determined from this second calculation can then be applied to the secondary salinity to bring it in line with the primary salinity. The second standard deviation calculated should be better than 0.004 psu. The PEXEC program PHISTO can be used to determine the means and standard deviations and PCALIB can be used to apply the calibration.

Foulings in the primary and secondary salinities complicate the above procedure. The relative calibration must be calculated for non-fouled and fouled sections separately. These different calibrations can then be applied to the secondary salinity by the PEXEC program FINCTD.

3.2.5. T/S plots and their interpretation

Each T/S curve in the T/S plots corresponds to an up or down cycle of SeaSoar. They are plotted in groups of four. Two up and two down, before offsetting the T/S curves by 0.1 psu. In the time series plot, one of the parameters plotted is pressure from the CTD. This is

the path followed by SeaSoar. Hence each down and up cycle corresponds to a T/S curve on the T/S plots. By looking to see whether the section starts on SeaSoar cycling down or up one can assign each cycle to its corresponding T/S curve, with the help of the colour coding used in the T/S plots. Black down, red up, green down and blue up. This can be seen in Fig 8a) and b).

Figure 8 :- Section ssl2083

- a) Time series plots
- b) Potential Temperature against Salin
- c) Potential Temperature against Salin2
- d) Potential Temperature against final Salinity

Figure 9 :- Section ssl2070

- a) Time series plot
- b) Potential Temperature against Salin
- c) Potential Temperature against Salin2
- d) Potential Temperature against final Salinity

Figure 10 :- Section ssl2024

- a) Time series plot
- b) Potential Temperature against Salin
- c) Potential Temperature against Salin2
- d) Potential Temperature against final Salinity

3.2.6. Time series plots

Looking now at Figs 8 a), 9 a) and 10 a). On these plots we see six parameters plotted. Only the variable `sall-2` needs some explanation. This variable is the difference between the primary and secondary salinities. Although it is a useful initial indicator of foulings and spikes in the section care has to be taken in its interpretation. If `sall-2` becomes smaller, then either the primary salinity is increasing or secondary decreasing. Over a long period, where the difference has remained constant then the most likely cause of a sudden decrease in `sall-2` is a fouling event in the primary. This however cannot always be assumed. An effect often seen is that one of either the primary or secondary fouls, followed shortly afterwards by a fouling in the other. This is seen first by a step in the difference one way closely followed by a step in the other direction. Situations like that are more difficult to correct, as a straight swap between the primary and secondary is not possible. Following on from this is a simultaneous fouling by the same amount. There is then no change in the difference and the fouling has not been identified. This could be identified by looking at the primary and secondary T/S plots. More use is made of the slope of the difference. If it is zero then it is likely that both cells are stable. It could of course be equal drift in both cells but experience has

shown that this is unlikely. One example of the usefulness of this was when the platinum electrodes on one cell started to break down and there was drift in conductivity with time. This showed up clearly in the difference between the two cells as the other cell remained stable. This type of problem is hard to spot from the T/S plots alone as it is indicated by a slight drift in the T/S curves to the left (lesser salinity). With variable water masses effects of this nature are difficult to interpret on a T/S plot.

3.3. Correcting Offsets In The Primary Salinity

At this point the secondary salinity should have been calibrated to match the primary salinity.

3.3.1. Spotting The Offsets

Now looking at a time series and T/S and T/S2 plots count out the T/S curves matching the SeaSoar cycling as mentioned in 3.2.5. Then go through the plots identifying foulings in the primary and secondary salinities marking on the plots where these occur. Be careful to check that each set of T/S curves only has four curves made up of black, red, green and blue, except at the start and finish of a section where there may be less than four. Occasionally a fouling can occur whereby the offset is about 0.1 psu. This is the same as the offset for each set of four T/S curves and hence T/S curves can be displaced to the wrong group. Then there are more than one colour of T/S curve in that group of four.

Having noted down all the offsets in the primary salinity a decision has to be made whether to swap data from the secondary salinity or to correct the offset with FINCTD. By looking at the difference between the two salinities on the time series plot it is often obvious if the fouling is a simple top hat shape or if there is a drift back to normal salinity. This can also be seen in the T/S plots. If a section of the T/S curve is displaced to low salinities, but maintains its shape compared to the other curves in the group, then it is just a straight offset. If shape and slope of the offset curve differ from those in its group then there is drift which can only be corrected by a swap with the secondary salinity.

3.3.2. Identifying The Data Cycles

Having identified visually all the offsets it is then necessary to identify the corresponding data cycles for those offsets. This can be done in two ways. You can use one of the interactive graphical editors to pinpoint and list data cycles from the time series or T/S plots, (PLXYED for the time series plots and PLPRED for the T/S plots), or by listing the data on the screen. Programs for

listing data are PLISTF and PLISTV. Each does something slightly different and details can be obtained under the PEXEC reference.

A combination of the graphical editors and the listing programs is most effective. To determine the correction for a fouling then the offset is given by the difference in salinity immediately before and after the fouling. This should be the same offset just before recovery.

3.3.3. Swapping Data Cycles Or Shifting The Offset

With all the start and end datacycles noted, then offsets can then be corrected by calibration or by swapping with the secondary salinity.

The PEXEC programs PCALIB or FINCTD can be used to correct offsets and PSWAP will replace data cycles from one variable with those of another.

3.4. Examples Of Interpretation Of Real Data

This section takes three examples of real SeaSoar data gathered during the vivaldi cruise. For each section the salient points of the data are explained and the reader is lead through a process of classifying and identifying shifts in the salinity data.

3.4.1. Section ssl2083

Figures 8a) and 8b) have fouling events marked 1. 2. and 3. The first fouling event occurs between the 4th and 5th set of T/S curves. Looking at the 4th group of T/S curves we can trace down black, up red, down green and then up blue. On the blue up, we see that at the point marked X the T/S curve disappears to lower salinities. Note that the blue does not appear higher up at all. The fouling however clears as the SeaSoar comes to the surface, at the point marked X1, and we see that the black T/S curve for the next downcycle starts at the correct position, offset on the plot by 0.1 psu (= 2cm). Although a fouling of this type would be corrected by swapping data from the secondary salinity, it is possible that the salinity profile measured by the cell is still correct, even though way off scale. This should always be kept in mind, especially in regions where simultaneous fouling of cells is likely and swapping data from the secondary salinity is not possible.

The second fouling of the primary salinity occurs between the 6th and 7th set of T/S curves. From the time series plot we see that it starts at the bottom of the 3rd T/S curve in group 6, that is green on the T/S plot and that the fouling again clears at the surface. On the T/S plot it is difficult to see the exact position of the fouling, but it is clear that the blue up is displaced to the left of the other curves.

The last and most obvious fouling of the primary salinity is on the last T/S curve of the section. It is a good example of a fouling with a drift recovery. The most appropriate solution of this would be to swap in the secondary salinity at this point. Figure 8c) shows the T/S curves for the secondary salinity.

Looking now at some more examples of foulings. There are two obvious foulings. One on blue of group 5, and another on black in group 6. The set of curves comprising group 7 looks complicated. On the time plot we see that there are two foulings of the secondary salinity in group 7. Tracing the curves we see that black fouls at X2. Red starts back up but then has a messy recovery and by X3 has recovered. On the down green there is a fouling at X4 which continues onto up blue, but soon after the start of the up blue it recovers. Of course as this is the secondary salinity we wouldn't sort a situation like this unless it was necessary to correct a worse situation in the primary salinity.

Once all the foulings have been identified the corresponding datacycles are identified by the methods mentioned in 3.3.3 and the foulings are corrected. Figure 8d) shows what the data should look like after the foulings have been removed. Note that this data has also been edited to remove spikes. This will be discussed in section 3.5.

3.4.2. Section ss12070

Looking now at the time series plot Figure 9a). At around 35 mins into the section there is a small fouling of the secondary salinity. This has a drift recovery as indicated by the slope in sall-2. At just after 100 mins the secondary salinity disappears completely, fouled off scale. At 210 mins it recovers to a level much lower than it had at the start of the section, as seen by the new level of sall-2. Having expanded the plot scale to look at the secondary salinity it was clear that the data was very noisy and variable due to the fouling of the cell. Therefore any foulings in the primary salinity would have to be corrected by removing the offsets and in the worst cases by deleting the data.

Figure 9b) at a first glance looks normal. A careful look reveals a few bad foulings. We can trace the T/S curves. The first group of four appear normal. The second group are the same, except that there appears to be an extra blue curve. What happens is that on the blue up of the third group there is a fouling marked X1 which shifts the blue curve to the left by 0.1 psu which is the offset spacing of the curves. Tracing this blue up to the top we see it steps to the next group of curves which should be set four, but because of the offset lands on group three. Group three now has two red and black curves. At the surface, at the top of the red curve, the primary salinity recovers the fouling (X2) so that green and blue for group four are in the correct position. In fact an initially complicated situation can be corrected rapidly by removing the offset at the appropriate datacycles between X1 and X2. Figure 9d) shows the final result.

3.4.3. Section ss12024

The previous two examples have been taken from regions where water properties were quiescent. The task of removing offsets from the data is more complicated in regions where water properties vary rapidly, eg in strong frontal regions. The third example is taken from a SeaSoar section through the North Atlantic Current into the sub-polar gyre. Looking at Figure 10a) we see that there are two small fouling events. One on the secondary salinity and one on the primary salinity. Unfortunately the T/S curves for salinity are heterogeneous (erratic) and do not form neat groups of curves. In Figure 10b) the fouling event is clear. However it can be imagined that if a similar fouling problem to that in the last example occurred, then correction would be more difficult. For the case of simultaneous fouling in the primary and secondary salinity, when the variable `sal1-2` does not change, spotting the offset would be hard. One possibility is to have an alternative method of checking the SeaSoar data. During *vivaldi* an alternative method was available and this will be discussed in section 5.4.2.

3.5. Despiking SeaSoar Data

Once the primary salinity channel has had all offsets removed, then the data can be despiked

3.5.1. Causes Of Noise In SeaSoar Data

There are several causes of noise in SeaSoar CTD data. The first is biological fouling of the conductivity cell. The second type of noise occurs when the SeaSoar is in the near surface region. If the SeaSoar broaches the surface, then the conductivity sensors will be in the air, hence causing spikes in the data. Both of the above cause asymmetrical spikes, in that conductivity is reduced leading to spikes to lower salinity. Spikes can also be caused by the response time mismatch between the platinum thermometer and the conductivity cells (see Chapter 6). This leads to hysteresis between the up and down profiles. The time constant correction factor has to be determined early in the cruise.

Figure 8b) is a good example of the typical noise to be seen in SeaSoar data. In the near surface region the data are contaminated by spikes all going to lower salinities. The first two T/S curves, black down and red up have a symmetrical type of spiking in the part of the profiles that corresponds to the top few meters of the water column. This is the type of noise seen soon after deployment of the SeaSoar. This can also be seen in Figure 8a) at the start of the section. The first few minutes of data while the SeaSoar was being deployed would be removed as the SeaSoar planes on the surface and is not actually in cycling mode.

Contrast Fig 8 b) & d) and Fig 9 b) & d) and Fig 10 b) & d) to see the extent of the despiking.

CHAPTER 4. TWELVE HOUR SEASOAR DATA PROCESSING

4.1. Twelve Hour Processing

Once all the four hour files for a section have been cleaned the first operation at the twelve hour processing stage is to produce an appended version of all the one second data for that section. The data are gridded on pressure and density and merged with Global Positioning System (GPS) navigation data to include latitude and longitude in the files. This is shown as stage 2 of figure 4.

4.4.1. navexec0

This exec, Figure 11, reads navigation data from an RVS data file and writes it to a PSTAR output file. The output file may or may not exist beforehand. If it does not a new file is created from the data read in. If it does exist then the latest section of navigation data are appended. It is up to the user to ensure that there is no overlap in the file.

The data route followed is;

DATAPUP - reads data from RVS data file GPSNAV and
converts it to PSTAR format

PCOPYA - resets data flags

PHEADR - change dataname if navigation file doesn't exist

PAPEND - appends data to existing file

4.4.2. ssl2exec1

This exec, Figure 12, appends together as many SeaSoar four hour files as required, and then merges with navigation data to add in distance run. A time correction is first made to allow for the position of the SeaSoar behind the ship. Density is then calculated in preparation for gridding. After gridding it is necessary to calculate density again to correspond with the gridded salinities and temperatures. The user is then asked for a unique identifier for the twelve hour file (up to three characters).

The data route followed is;

PHEADR - changes dataname of first SeaSoar four hour file

PAPEND - append SeaSoar files for that section

PCALIB - subtracts 190 seconds from time

PMERGE - merge on time with navigation file to add distrun

to twelve hour data

PEOS83 - calculate sigma0 in preparation for gridding

4.4.3. ssl2exec2

This exec, Figure 13, grids the twelve hour SeaSoar file on pressure and density. It requires the user to specify the interval for gridding in the distrun variable - the minimum and maximum from the twelve hour file header are written out for guidance. The normal interval in horizontal grid spacing for SeaSoar is 4 km, and the start and end values should be multiples of 4. Note that it is useful to choose these grid points at half way points between acoustic Doppler current profiler (ADCP) grid points so that geostrophic velocities then overlie ADCP velocities. (i.e. choose adcp grid points at even distrun values which are not multiples of 4). The data are also averaged over 12 km bins at 4 km intervals.

The data route followed is;

PGRIDS - grid data into 8m * 4 km bins for pressure and

0.02 kg/m³ for density

PHEADR - new dataname

PMERGE - add in latitude and longitude by merging on distance run

PEOS83 - recalculate sigma0 so it corresponds to the gridded T and S

PADPAV - averages data

The data are now ready to be contoured into section plots of temperature, salinity and density. This is done using UCONTR with a suitable contour description file (CDF) and a colours file.

Chapters 3 and 4 provided a description of the main processing path for SeaSoar data. We have described the data path in terms of the cshell execs the PEXEC FORTRAN programs and the RVS programs required. Appendix A describes some of the RVS programs to interrogate the data files, to obtain the information required to run the execs. Some common problems running the execs are noted in Appendix B.

CHAPTER 5. ABSOLUTE CALIBRATION OF SEASOAR CTD DATA

5.1. Introduction

Figure 4 part 3 shows the final stage of the data processing. SeaSoar CTD data can be calibrated against vertically profiled CTD data or by comparison to samples drawn from the sea surface. Accurate thermosalinographs (TSG) which continuously measure the sea surface salinity can also be used. Techniques for determining the absolute calibration of SeaSoar data have differed between cruises, related to the operational constraints of the measuring strategy and improvements in analytical equipment. In the past it has been common to tow SeaSoar for several days before recovery. (COLLINS, POLLARD & PU, 1983), (POLLARD, HOLFORD & SHERROCKS, 1985), (POLLARD, COLLINS, COTTERALL & SHERROCKS, 1988). This meant that vertical CTD profiles for the absolute calibration were along way apart in space and time. This would therefore be a poor method of calibrating the SeaSoar CTD data. To overcome these problems underway surface salinity samples were taken and analysed on a salinometer. These samples then had to be matched to near surface SeaSoar data. Several implementations of this technique have been tried and will be discussed below.

During vivaldi, SeaSoar was recovered at three hundred kilometer intervals, between full depth CTD stations. In conjunction with underway surface samples and a TSG with much improved salinity determination, stricter limits could be set on the absolute calibration of the SeaSoar salinity data. This method provides the preferred route for the calibration of the SeaSoar data. i.e. calibration against CTD stations and verification of the calibration via the TSG, route (iii) in part 4 of Figure 3.

5.2. Calibration Of SeaSoar CTD Data Against Vertical CTD Data

Vertical CTD profiles are taken at the start and end of any SeaSoar section. These can be calibrated absolutely against bottle samples drawn when the profile is being made. For duplicate salinity samples measured on a Guildline salinometer the mean difference between samples is about 0.0015 psu. The accuracy of the salinity profile is of the order 0.002 psu below 2500 dbars and of order 0.004 psu for the whole water column. (KING, ALDERSON, BACON & GWILLIAM, 1991a).

To obtain an offset to apply to the SeaSoar CTD data, the T/S profiles at the start and end of the section are compared, by eye, to the respective CTD profiles. If the SeaSoar CTD has maintained the relative calibration the offset at each end of the section should be the same. This offset can then be applied to the SeaSoar CTD data.

5.2.1. Matching SeaSoar CTD and CTD Profiles

Due to temporal and spatial changes between the profile measurements, there is not usually an exact match between T/S curves. The relationship is usually best in quiescent waters and the worst in frontal regions or where eddy activity is high.

The SeaSoar profile extends over the top 500 meters of the water column. Poor fits between the profiles are more likely in the near surface region than in the deeper water.

If different regions of the T/S curves match and suggest different offsets then the hydrography at that particular station has to be considered. By studying the SeaSoar CTD data it may be seen that one part of the water column is more variable than another. In that case the more homogeneous part of the T/S curves should be matched.

When the T/S curves, at each end, suggest different offsets then there are two possible causes. Either the SeaSoar CTD data has not maintained its relative calibration or that spatial and temporal differences between the measurements has lead to different water masses being measured. If a careful check does not reveal any errors in the relative calibration of the SeaSoar data, then it must be considered that the hydrography has changed between the SeaSoar CTD measurements and the CTD. One helpful technique is to prepare a composite T/S envelope for that section. This is done by tracing out the T/S curves by hand. An intuition about the water mass variability is built up. Relative calibration errors are revealed if the curves are translated to the right or left.

5.2.2. Accuracy Of The Absolute SeaSoar CTD Calibration

There are quantitative methods to determine the absolute accuracy of the SeaSoar CTD data but these will be discussed in section 5.4.2. An estimate of the accuracy of fitting the SeaSoar CTD and CTD data can be made.

Ignoring any errors due to water mass variability, then fitting by eye, ought to be accurate to ± 0.005 psu at each end of the section. At the currently used plot resolution of 0.1 psu per 20 mm, this is a measurement accuracy of ± 1 mm.

Sometimes it is not possible to resolve differences between the SeaSoar CTD and CTD data to the above accuracy. If no problem with the relative calibration can immediately be identified then another approach to the absolute calibration has to be adopted.

5.3. Calibration And Verification Of SeaSoar CTD Data Against Underway Samples.

When the experimental requirements do not allow the SeaSoar to be recovered frequently for deep CTD measurements, an alternative to the absolute calibration has to be attempted. One

such method is to use surface salinity samples drawn through the non toxic supply. These samples are then analysed on a Guildline salinometer, and hence their salinity is well known. The problem with all these methods is matching the surface sample to the SeaSoar data. Two techniques are outlined in section 5.3.1 and 5.3.2.

5.3.1. Comparing Underway Salinity Samples Against Gridded SeaSoar CTD Data

Underway samples are drawn through the non toxic supply every hour and the sampling time noted, or drawn to correspond to a SeaSoar surfacing. These samples are then analysed on a Guildline salinometer. The sample data are then merged, on time, with the gridded SeaSoar CTD data. A histogram of the differences between the gridded and sample data is then determined. This should give an offset value for the absolute calibration of the SeaSoar CTD data. However the relatively few comparison points rarely allow the identification of different populations which indicate varying shifts along the section.

There are several problems with this method. Because the SeaSoar is gridded into 4 km bins it is possible that a comparison is made between an underway sample and a surfacing event up to 4 km distant. Also the 4 km bin may be an average of two SeaSoar surfacing events. The average is also made up of 16 salinity values over 8 m depth, while the non toxic supply is drawn from a depth of 6 m. Hydrographic conditions can also be important. Strong spatial variability could lead to discrepancies between the sample and the gridded value. This method had been described by (POLLARD, HOLFORD & SHERROCKS, 1985) and the problems by (KING, ALDERSON, BACON & GWILLIAM, 1991b).

5.3.2. Comparing Underway Salinity Samples Against One Second SeaSoar CTD Data

For this method to work it is important to match the surfacing of the SeaSoar and the drawing of the salinity sample from the non toxic supply. Given that the SeaSoar surfaces some 700m behind the ship, and the time delay from the sample entering the non toxic intake to the sampling point is not well known the method is still susceptible to spatial variation of the salinity field.

As the samples have been matched in time, to a SeaSoar surfacing they can be compared. To reduce the noise in the near surface SeaSoar CTD data, all values between 1 dbar and 5 dbars are averaged. This method produces similar corrections to the SeaSoar CTD data as the method outlined in 5.3.1.

(KING, ALDERSON, BACON & GWILLIAM, 1991b). made a comparison of the two methods. For the gridded method 75% of samples were less than 0.005 psu different from the gridded SeaSoar values and 92% were less than 0.01 psu different. The standard deviation of the differences

was 0.006 psu. For the second method 91% of the samples were less than 0.005 psu different and 98% were less than 0.01 different, with a standard deviation of 0.003 psu. The estimation of the errors for the SeaSoar data were reduced though the offset calibrations determined remained the same.

(KING, ALDERSON, BACON & GWILLIAM, 1991b). made a further change to the procedure by applying a low pass filter to the salinity differences, which were then applied to the data as the final absolute calibration of the SeaSoar CTD data.

5.4. Calibration Of SeaSoar CTD Data Against The TSG

With the advent of a thermosalinograph with a high resolution conductivity cell, Appendix C, it became possible, for the first time, to consider using the TSG to calibrate SeaSoar data. The method first involves calibrating the TSG against surface salinity samples drawn from the non toxic supply, and then comparing the calibrated TSG data to the one second SeaSoar CTD data, route (iii) Figure 4..

5.4.1. Calibration Of The TSG Against Underway Samples.

Surface salinity samples were drawn from the non toxic supply at hourly intervals and the time of drawing noted. After analysis on a Guildline salinometer these samples were merged, on time, with the TSG data. The TSG gave spot salinity values every thirty seconds. Therefore errors due to spatial and temporal differences between the samples were reduced. For each SeaSoar section, an offset correction to the TSG salinity was calculated. This was done by taking the mean of the difference between the TSG and surface salinity samples. This offset was then applied to the TSG. See Appendix D for a full discussion of the calibration of the TSG.

5.4.2. Calibration of SeaSoar CTD Against TSG Data

Having calibrated the SeaSoar data against CTD stations and the TSG data against underway samples, the SeaSoar CTD and TSG data can be compared. Appendix E outlines a new exec that was written to facilitate the comparison of the data.

The major advantage of comparing the SeaSoar CTD data to the TSG is the greatly increased number of calibration points available over each section, compared to the methods outlined in sections 5.3.1 and 5.3.2. This is seen in Table 1, where there are around 20 TSG versus bottle comparisons over a section, but once the TSG is calibrated this allows around 200 comparison points with the SeaSoar data. The TSG gave spot salinity values every thirty seconds. As the SeaSoar

was in the near surface region (top 3 dbars) for a few minutes, several comparison points were obtained at each surfacing.

The SeaSoar CTD one second data and TSG data were merged on time. The difference between the SeaSoar CTD salinities and TSG salinities were calculated. Figure 14 shows the SeaSoar CTD, TSG salinities and the difference between them. This plot shows the advantages of using the high temporal resolution of the TSG data. Looking at the difference of the two salinities it is clear that there is a relative calibration error with the SeaSoar CTD data. For the first 400 mins of this section SeaSoar salinity is low by -0.013 psu with a standard deviation of 0.007 psu. The next section is low by -0.026 psu standard deviation of 0.005 psu, while the last section shows only a very low difference. From this file it is possible to identify the exact times when the jumps occur, go back to the SeaSoar one second data and immediately identify the problem. As well as relative calibration errors, this calibration method is able to identify fouling events that occur over only a few cycles of the SeaSoar. These can then be corrected and the calibration redone.

Having checked the SeaSoar CTD data and corrected sections that were in error, the differences between the TSG and SeaSoar salinities were recalculated. This difference then represented the residuals after the final absolute salinity calibrations had been applied, Figure 15.

For vivaldi these residuals are given in Table 1 and Figures 16a, 17a and 17b. We can summarise the data thus, for the sixteen sections in cruise 58, 100% of the mean residuals for each section are less than 0.005 and for the seventeen sections of cruise 59, 94% of the mean residuals are less than 0.005 and 100% less than 0.01; the mean standard deviation of the residuals for cruise 58 and 59 being 0.0088 and 0.009 respectively.

CHAPTER 6. INSTRUMENTAL CALIBRATIONS

6.1. Introduction

Data transmitted from the instruments on board the SeaSoar are in raw engineering units. It is necessary to apply calibrations to the raw data to convert to absolute or relative engineering units. Firstly the instruments being carried on the SeaSoar must be identified and the most recent laboratory calibrations of those instruments obtained. This is a most important step that must be carried out well before the cruise. Once the calibration data have been obtained, they can be included in a calibrations file for use at sea.

6.1.1. Instruments And Calibration Data

The modified Neil Brown Mk III CTD carried by the SeaSoar contains four sensors. Two conductivity cells, a platinum resistance thermometer and a stainless steel diaphragm strain gauge pressure sensor.

Sensors

1.Pressure

Paine Model;211-35-440;350 Ω bonded strain gauge
bridge

2.Temperature

Platinum thermometer; Rosemount Model 171 BJ 200 Ω @
20 °C (185.3 Ω @ 0 °C)

3.Conductivity

NBIS, Inc No. B10086 4 electrode cell 0.4 cm * 0.4 cm * 3cm.

Variables	Range	Accuracy	Resolution	Stability
Pressure	0-650	1.0	0.01	0.1%/month
Temperature	-32 to 32	0.005	0.0005	0.001 /month
Conductivity	1 to 65 mmho	0.005	0.001	0.003 /month

Conductivity cell flush time 30*10⁻³ seconds

The strain gauge is part of a 4 way bridge. As the resistance of the strain gauge changes with increase of pressure, the current in the bridge changes. The bridge is balanced to obtain null current through the centre of the bridge. From this the pressure is determined.

The temperature as determined by an unmodified CTD, is made up from the platinum thermometer and a fast response thermistor. The platinum thermometer while extremely accurate

and stable, has a significant thermal mass. This causes the measured temperature to lag behind the in-situ temperature. A fast response thermistor is used to counteract this effect. This gives better suppression of the thermal lag which reduces problems of spiking in the salinity profiles.

IOSDL has held the view that it is more important to minimise the hysteresis between up and down curves, POLLARD et al (in prep), than to minimise spiking in the salinity data. Therefore the CTD on the SeaSoar does not have a fast response thermistor. To determine the lag time, τ , T/S profiles are overplotted and the time lag is chosen to minimise the hysteresis between up and down profiles.

The temperature response may be written as follow;

$$dT/dt = 1/\tau (T' - T)$$

$$T' = T + \tau (dT/dt)$$

T = measured temperature

T' = true temperature

τ = time constant

dT/dt is estimated by taking the first and last good temperature values in the one second interval, and the time dt between them.

At the Level A the data are despiked and averaged. (POLLARD, READ & SMITHERS, 1986 b) has outlined the algorithms applied to CTD data at the Level A. Firstly the pressure data are despiked by looking for jumps greater than 2.5 dbars. Then data cycles collected within each one second period are despiked according to the following algorithm. Each variable is sorted into ascending order. Two median values are then used to calculate a mean M and difference D . If D is zero it is reset to a minimum value. Data outside the range $M \pm nD$ (where n depends on the sampling frequency) are omitted from the average.

Before taking the instrument to sea the sensors will have been calibrated by the Ocean Instrumentation Group at IOSDL. The calibration data contain a serial number which refers to a specific sensor and a date showing when the calibration was done. Appendix F contains the laboratory calibrations for the CTD used on vivaldi.

Temperature from the platinum thermometer is calibrated to the T90 ITS scale. The strain gauge pressure sensor and thermometer calibration should give absolute values of pressure and temperature. Calibrations applied to the conductivity data are only nominal as the data are calibrated against in-situ bottle samples analysed on a Guildline salinometer.

As well as the CTD, the SeaSoar carries other instruments which have to be calibrated. Calibrations for those instruments also have to be obtained and are applied at the same time as the CTD calibrations.

6.1.2. Applying The Instrumental Calibrations

Having obtained the instrumental calibrations they are included in a calibration file which is read by the PEXEC program CTDCAL. This program applies the calibrations to the raw data. This is done in exec ssexec1, see 3.1.2.

The sequential calibration file which is read by CTDCAL takes the following format (this is an example from the vivaldi cruise)

eg. 'shalctd.cal' calibration file for CTDCAL

:calibration file for shallow ctd

:comment field

press	.01	-2.2282	1.000287	0.0	0.0
temp	.0005	-0.1020392	.9990832	0.0	0.0
cond	.001	0.	0.99830	0.0	0.0
cond2	.001	0.	0.99830	0.0	0.0
fluor	.001	0.	1.3773	-1.2278	0.0
oxyc	.001	0.	1.05	0.0	0.0
oxyt	.128	0.	1.0	0.0	0.0
oxyfrac	-.022	0.000135	1.0	0.0	0.0
oxygen	.0	0.0	0.0	0.0	0.0
trans	.001	0.	1.0	0.0	0.0
deltat	.22	0.	0.0	0.0	0.0
uwirr	.001	2.3443	-4.975	0.0	0.0

In this case the pressure calibration would be;

$$\text{Pressure} = (1.000287 * (0.01 * P_{\text{raw}})) - 2.2282$$

The program performs the calibration, writing the calibration constants into the file header, lists the output file header and finishes.

The program CTDCAL has been extensively modified since the vivaldi cruise. This was done to make the data processing path for CTD data more consistent. The new PEXEC manual page has been included as Appendix G for the readers reference.

7. ACKNOWLEDGEMENTS

Many people have contributed their knowledge and experience to enable this manual to be completed. I would like to thank Raymond Pollard who gave me the full benefit of his experience during Vivaldi '91.

Figures 8 to 10 were prepared by Louise Fuger and Figure 2 was contributed by Mike Griffiths.

8. REFERENCES

- COLLINS, D. S., Pollard, R. T. and Pu, S. 1983 Long SeaSoar CTD sections in Northeast Atlantic Ocean collected during *RRS Discovery* Cruise 116.
Institute of Oceanographic Sciences, Report No.148, 77pp.
- CUNNINGHAM, S. A., Griffiths, M., Hemmings, J., Alderson, S. G., Griffiths, G., (1992) SeaSoar CTD, fluorescence and scalar irradiance data from *RRS Charles Darwin* Cruises 58 and 59 in the Northeast Atlantic as part of Vivaldi 1991
Institute of Oceanographic Sciences Deacon Laboratory, Internal Report (in preparation).
- GRIFFITHS, G., Cunningham, S. A., Griffiths, M. and Pollard, R. T. et al. 1992 CTD oxygen, tracer and nutrient data from *RRS Charles Darwin* Cruises 58 & 59 in the NE Atlantic as part of Vivaldi '91.
Institute of Oceanographic Sciences Deacon Laboratory, Report No. 296, 51pp.
- GRIFFITHS, G., Pollard, R. T. 1991 Modern tools of upper ocean surveys
Journal of Naval Science (Feb 1991 edition)
- GWILLIAM, P., 1990 IOS test hydrodynamic characteristics of the SeaSoar
SeaSoar News 199 No.1 p1
- KING, B. A., Alderson, S. G., Bacon, S., Gwilliam, T. J. P., Hirst, C., Paylor, R., Read, J. F. and Swallow, J. C. (a) 1991 CTDO station data from the north east Atlantic from *RRS Discovery* Cruise 189
Institute of Oceanographic Sciences Deacon Laboratory, Report No. 287 182pp.
- KING, B. A., Allison, S. A., Alderson, S. G., Bacon, S., Gwilliam, T. J. P., Paylor, R. and Read, J. F. (b) 1991 SeaSoar data from the Northeast Atlantic, collected on *RRS Discovery* Cruise 189, April 1990.
Institute of Oceanographic Sciences Deacon Laboratory, Report No. 289, 34pp.
- POLLARD, R. T. 1986 (a) Frontal surveys with a towed profiling conductivity/temperature/depth measurement package (SeaSoar).
Nature 323, 433-435.
- POLLARD, R. T., Read, J. F. and Smithers, J. 1986 (b) SeaSoar CTD surveys during FASINEX.
Institute of Oceanographic Sciences Deacon Laboratory, Report, No 230, 111 pp.
- POLLARD, R. T., Read, J. F., Smithers, J. and Stirling, M. W. 1987 SeaSoar sections from the Antarctic Circumpolar Current at 52°S, 32°E to the subtropical front at 37°S, 52°E.
Institute of Oceanographic Sciences Deacon Laboratory, Report No. 244, 55pp.
- POLLARD, R. T., Holford, D. and Sherrocks, K. 1985 SeaSoar CTD sections in the Northeast Atlantic ocean collected during *RRS Discovery* Cruise 132
Institute of Oceanographic Sciences Deacon Laboratory, Report No. 200, 61pp.
- POLLARD, R. T., Collins, D. S., Cotterall, T. C., Sherrocks, K. and Smithers, J. 1988 Long SeaSoar CTD Sections in the North east Atlantic ocean collected during *RRS Discovery* Cruise 114
Institute of Oceanographic Sciences Deacon Laboratory, Report No. 255, 99pp.

POLLARD, R. T. 1992 SeaSoar - an upper ocean survey system
(In preparation)

SMITHERS, J. 1991 SeaSoar the IOSDL towed undulating vehicle.
Institute of Oceanographic Sciences Deacon Laboratory, Internal Report
No. 301, 57pp

VOSS, A. J. R., Sherwood, J., Jackson, C. S. and Bilimoria, C. S. 1986 A standards based
distributed oceanographic computing system. IEEE Proceedings of The Fourth
Working Symposium on Oceanographic Data Systems; San Diego, CA.

TABLE 1

Section	CD58				TSG v's Bottles			
	SeaSoar v's TSG				Mean	Std. Dev	N	SE ₃ of mean
sal1001	0.004	0.007	273	0.0013	-0.020	0.004	13	0.0033
sal1002	0.000	0.005	242	0.0010	-0.018	0.005	12	0.0043
sal1003	-0.001	0.006	344	0.0010	-0.015	0.004	22	0.0026
sal1004	0.003	0.006	291	0.0011	-0.015	0.006	19	0.0041
sal1005	0.000	0.010	157	0.0024	-0.019	0.006	15	0.0046
sal1006	0.000	0.007	333	0.0012	-0.017	0.005	22	0.0032
sal1007	0.003	0.007	95	0.0022	-0.014	0.005	22	0.0032
sal1008	-0.002	0.008	145	0.0020	-0.018	0.004	24	0.0024
sal1009	0.001	0.012	209	0.0025	-0.014	0.004	20	0.0027
sal1010	0.005	0.007	204	0.0015	-0.018	0.006	20	0.0040
sal1011	0.000	0.013	268	0.0024	-0.020	0.005	21	0.0033
sal1012	0.002	0.012	253	0.0023	-0.019	0.004	20	0.0027
sal1013	-0.002	0.009	211	0.0019	-0.018	0.004	25	0.0024
sal1014	-0.002	0.009	192	0.0019	-0.016	0.004	20	0.0027
sal1015	0.000	0.009	247	0.0017	-0.013	0.006	17	0.0044
sal1016	0.001	0.013	296	0.0023	-0.008	0.006	18	0.0042
Mean =	0.0008	0.0088	Mean =		-0.0164	0.0049		
Std. Dev =	0.0021	0.0026	Std. Dev =		0.0031	0.0009		

Section	CD59				TSG v's Bottles			
	SeaSoar v's TSG				Mean	Std. Dev	N	SE ₃ of mean
sal2001	0.002	0.009	174	0.0020	0.003	0.011	20	0.0074
sal2002	0.000	0.008	73	0.0028	-0.003	0.008	22	0.0051
sal2003	0.004	0.011	179	0.0025	-0.011	0.006	21	0.0039
sal2004	0.003	0.010	156	0.0024	-0.017	0.005	21	0.0033
sal2005	0.003	0.008	106	0.0023	0.016	0.006	24	0.0037
sal2006	-0.001	0.007	132	0.0018	-0.021	0.003	19	0.0021
sal2007	0.005	0.008	194	0.0017	-0.012	0.010	23	0.0063
sal2008	-0.001	0.008	153	0.0019	-0.009	0.005	25	0.0030
sal2009	0.002	0.009	123	0.0024	-0.008	0.004	22	0.0026
sal2010	0.002	0.011	158	0.0026	-0.005	0.004	22	0.0026
sal2011	0.000	0.006	182	0.0013	-0.003	0.007	21	0.0046
sal2012	0.003	0.009	195	0.0019	-0.003	0.005	17	0.0036
sal2013	-0.009	0.018	128	0.0048	-0.002	0.010	21	0.0065
sal2014	0.000	0.011	76	0.0038	0.002	0.011	21	0.0072
sal2015	-0.001	0.005	70	0.0018	0.010	0.004	20	0.0027
sal2016	0.000	0.006	175	0.0014	0.011	0.006	22	0.0038
sal2017	0.001	0.009	118	0.0025	0.013	0.007	22	0.0045
Mean =	0.0008	0.0090	Mean =		-0.0042	0.0066		
Std. Dev =	0.0031	0.0029	Std. Dev =		0.0099	0.0026		

N = Number of Observations

$$SE_3 = 3 \times \frac{\text{standard deviation}}{\sqrt{N}}$$

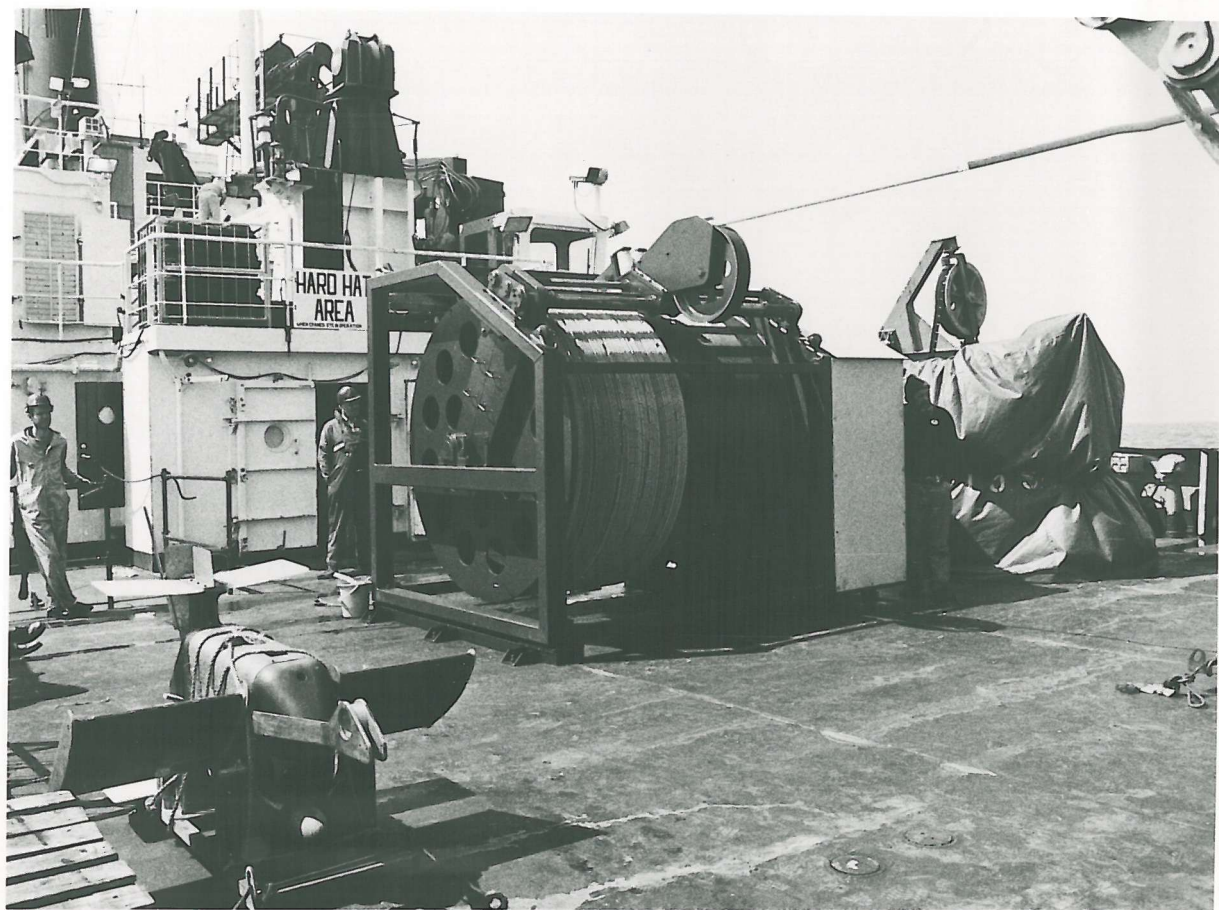


Figure 1:- SeaSoar and Winch as deployed during Vivaldi '91
 Top picture shows winch holding 750m of faired cable
 partially paid out.
 Lower picture shows SeaSoar hanging beneath the "A"
 frame prior to deployment

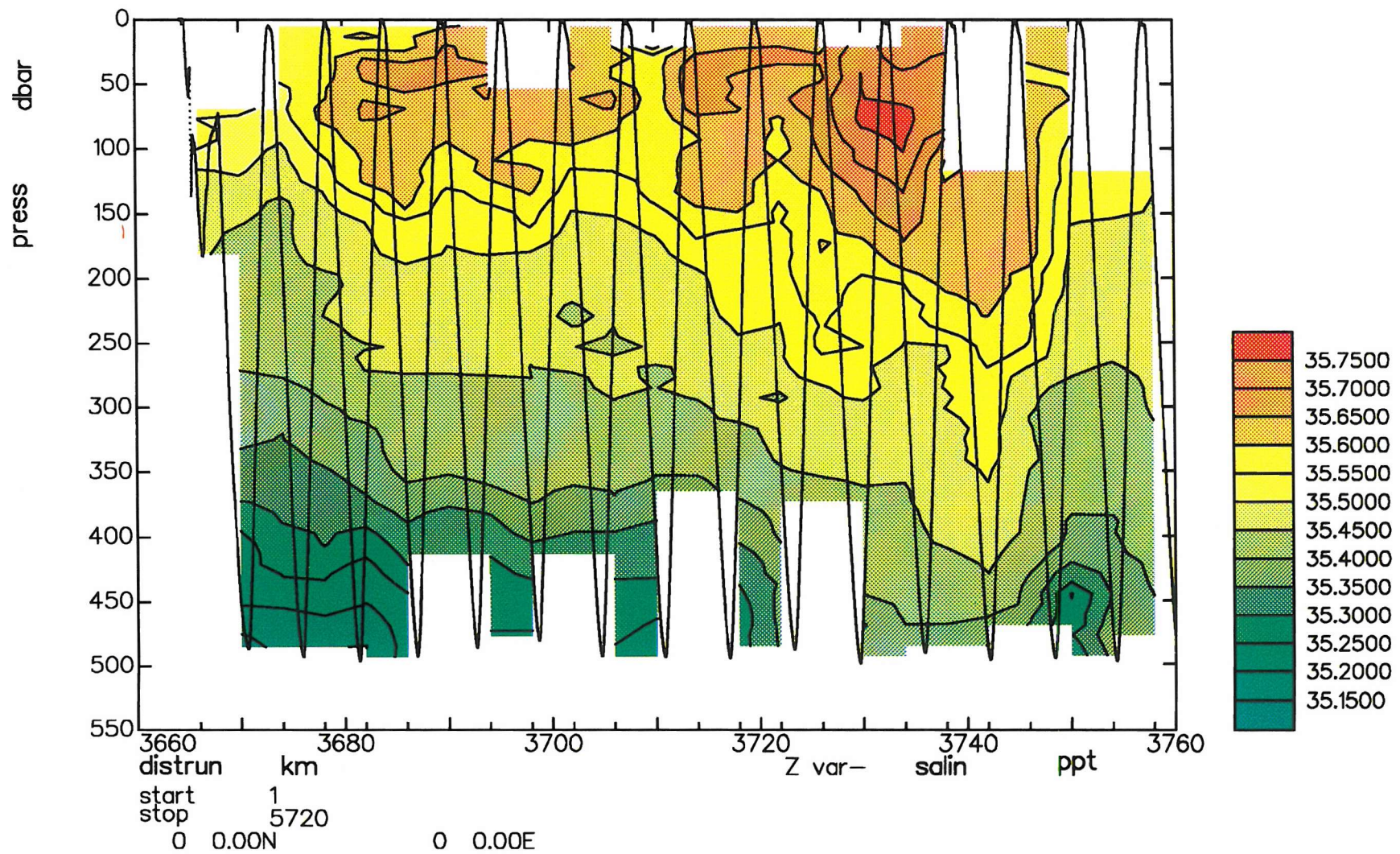


Figure 2:- Track profile followed by SeaSoar overlaid on a gridded salinity section, Vivaldi '91

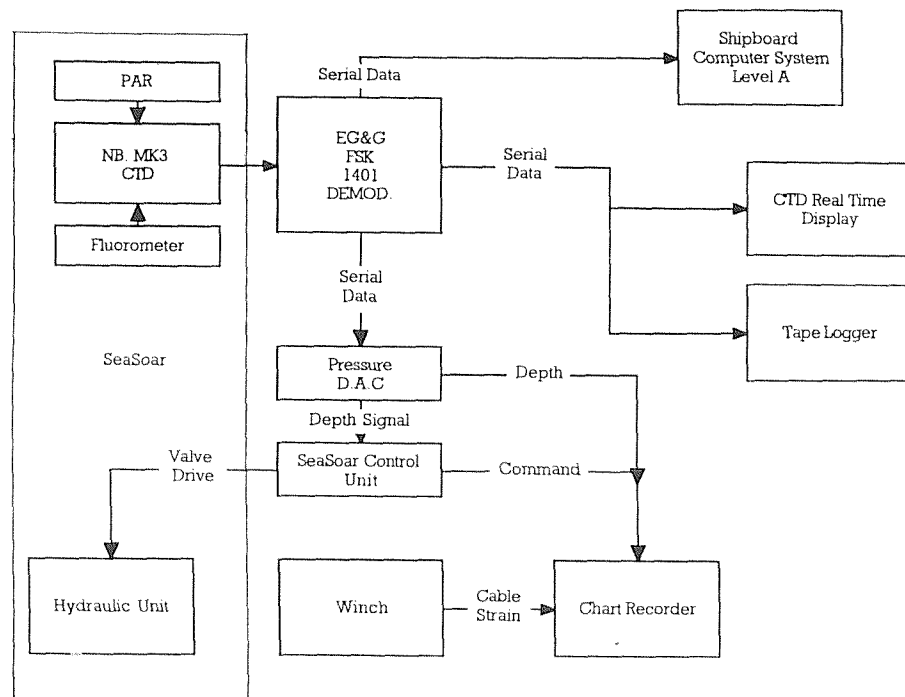


Figure 3:- SeaSoar System & Data Acquisition Path

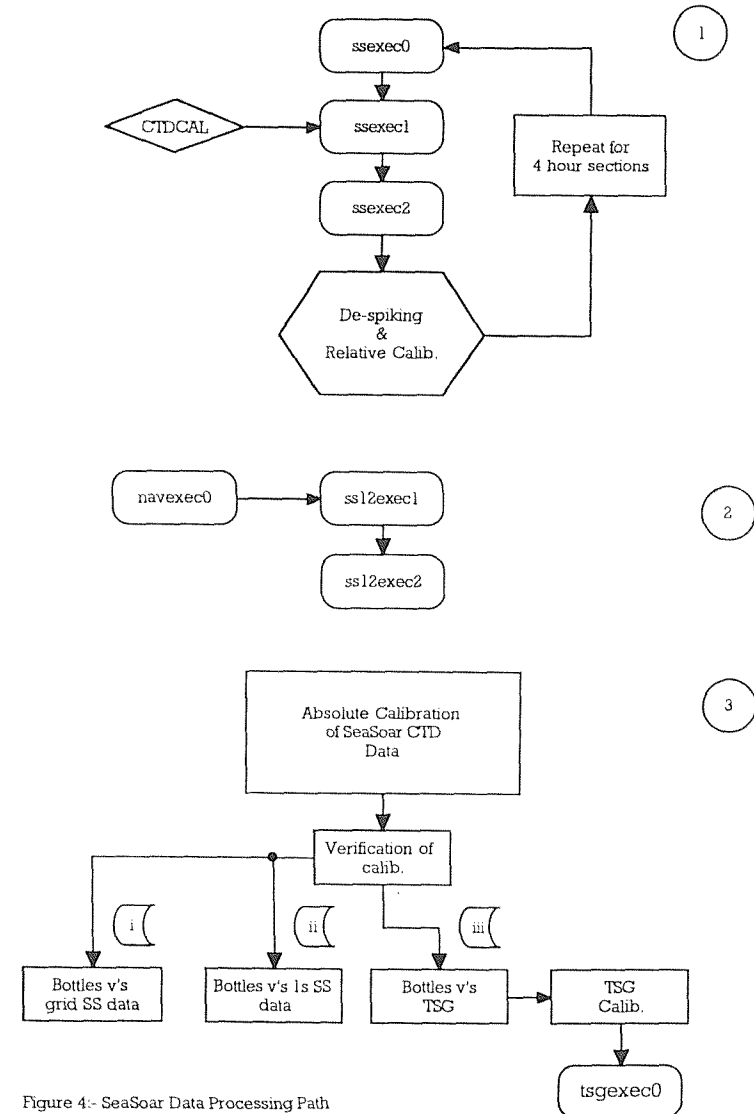


Figure 4:- SeaSoar Data Processing Path

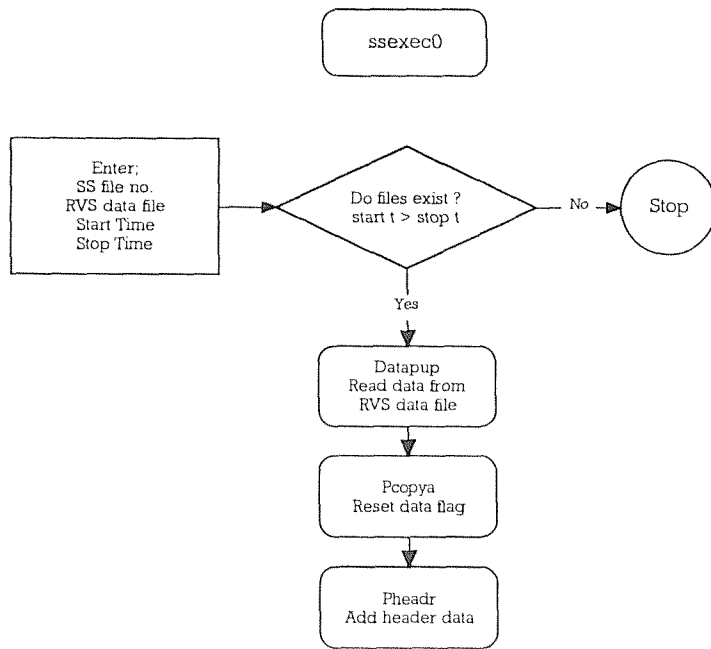


Figure 5:- Flow Chart for ssexec0

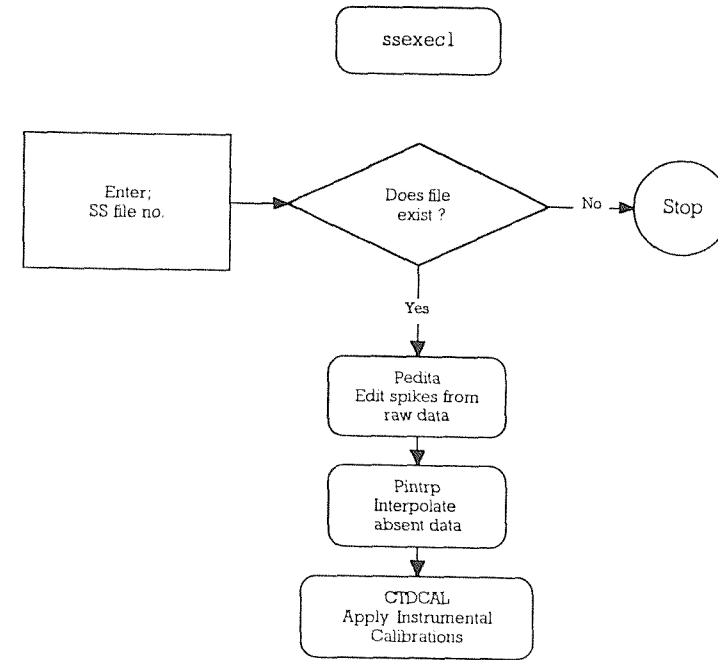


Figure 6:- Flow Chart for ssexec1

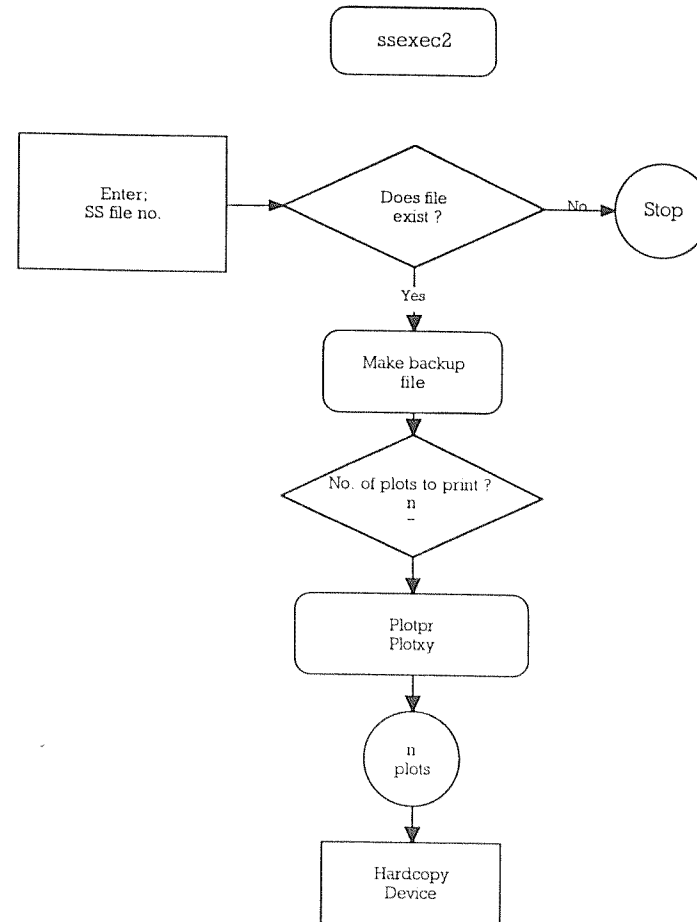


Figure 7:- Flow Chart for ssexec2

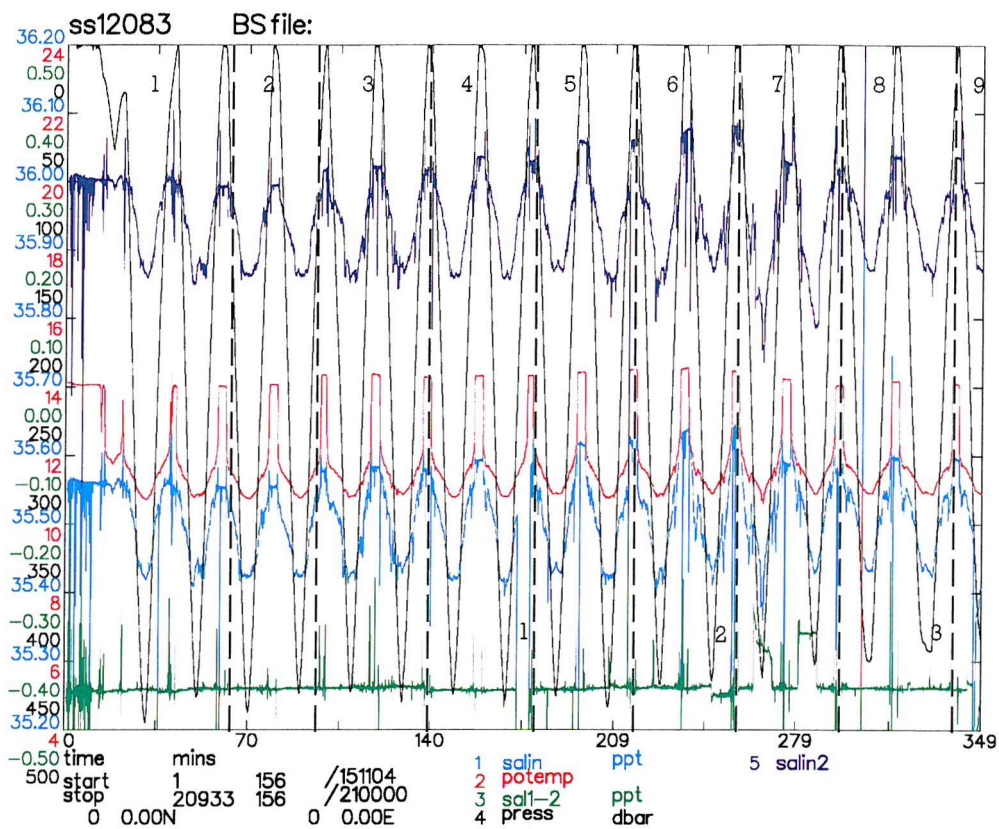


Figure 8a:- SS12083 Time Series Plot

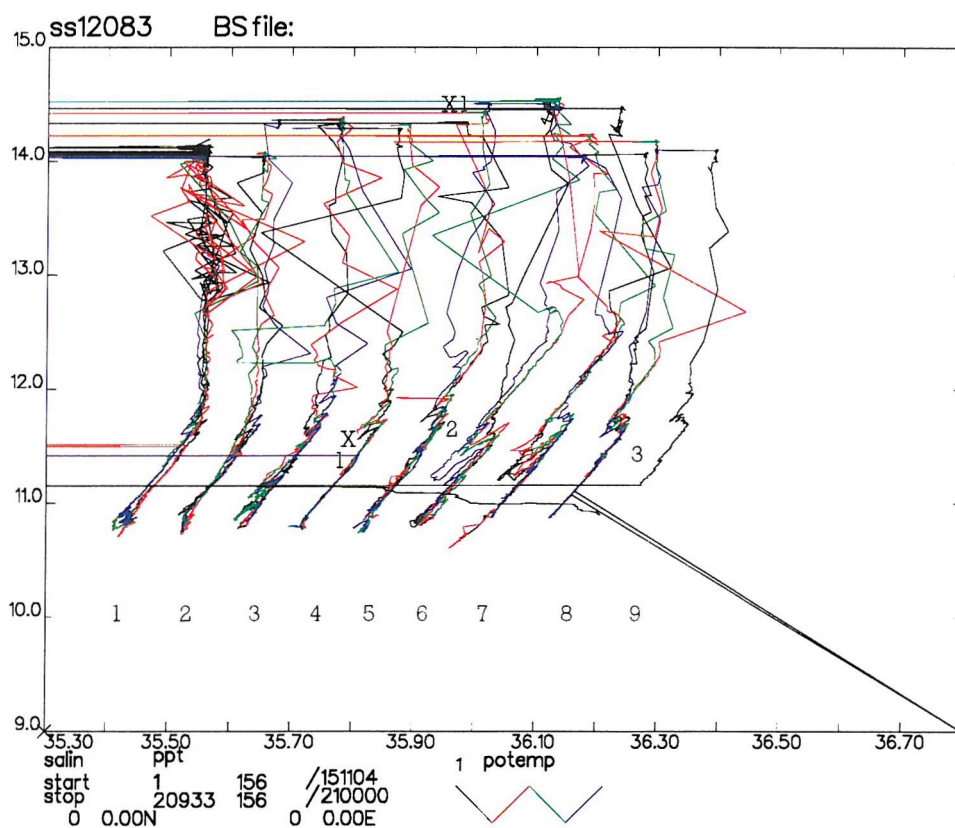


Figure 8b:- SS12083 Potential Temperature against Salin

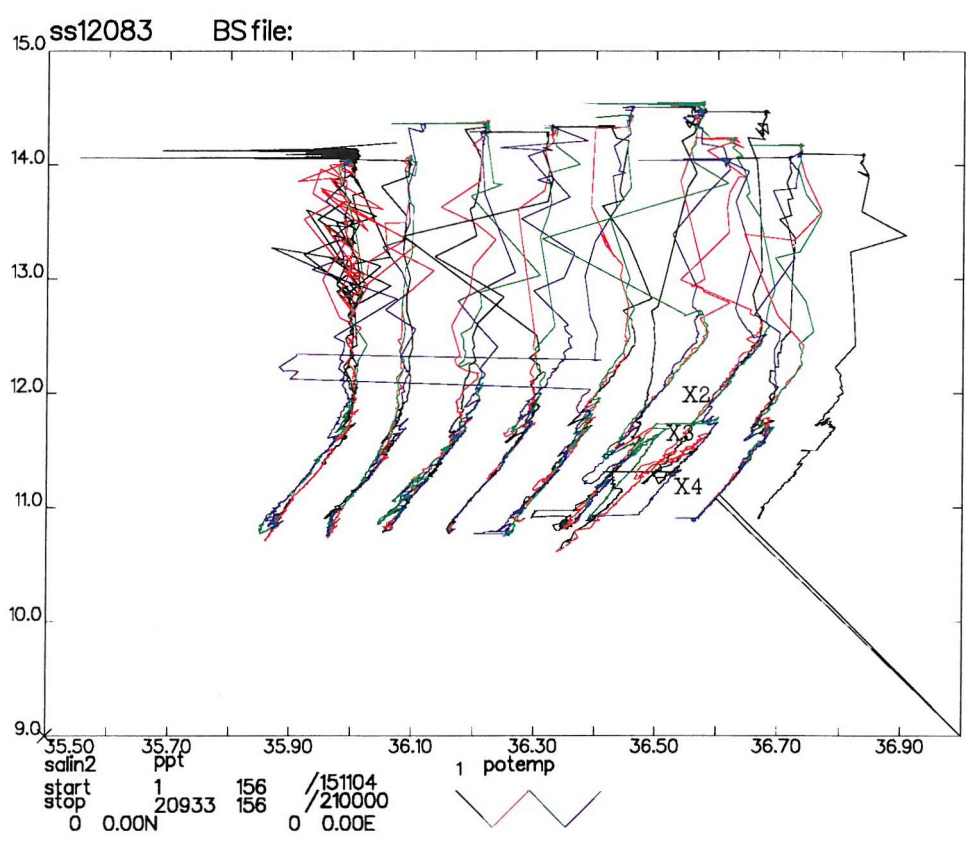


Figure 8c:- SS12083 Potential Temperature against Salin2

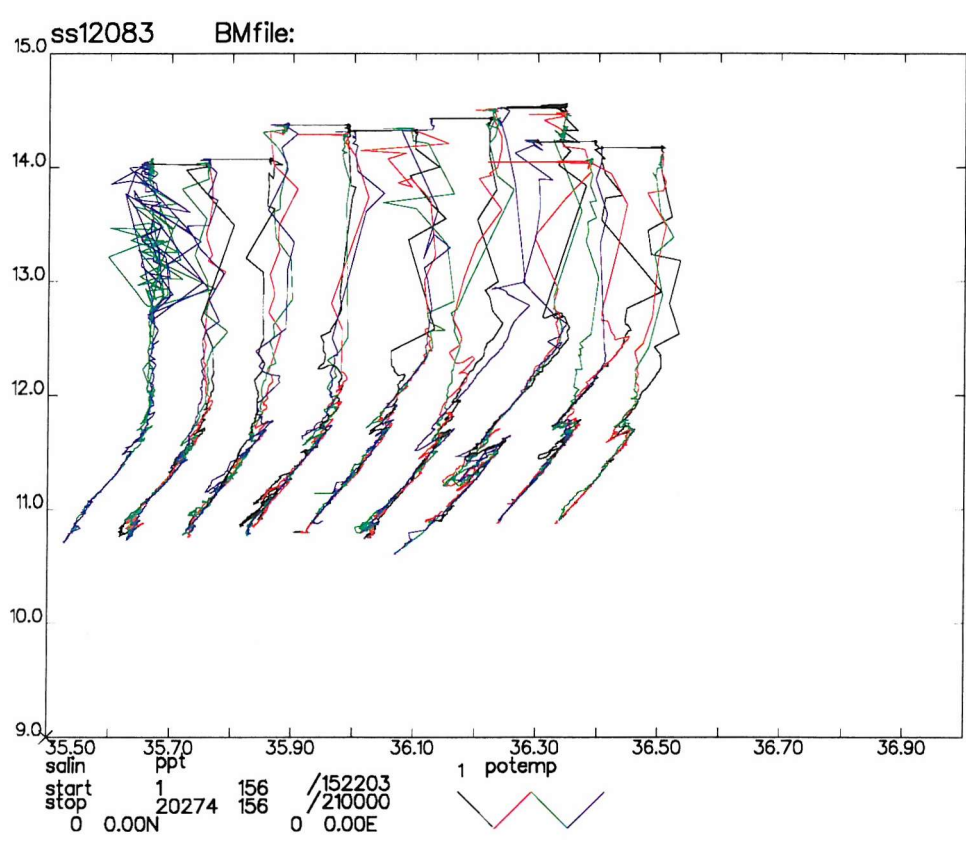


Figure 8d:- SS12083 Potential Temperature against final Salinity

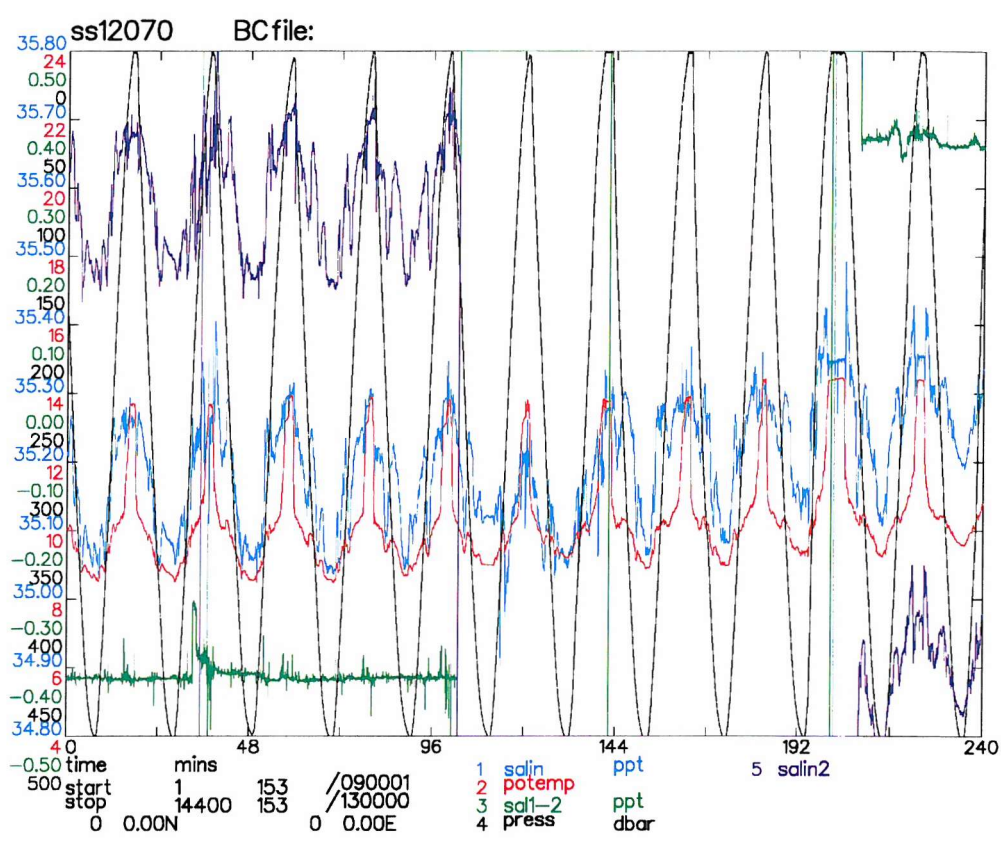


Figure 9a:- SS12070 Time Series Plot

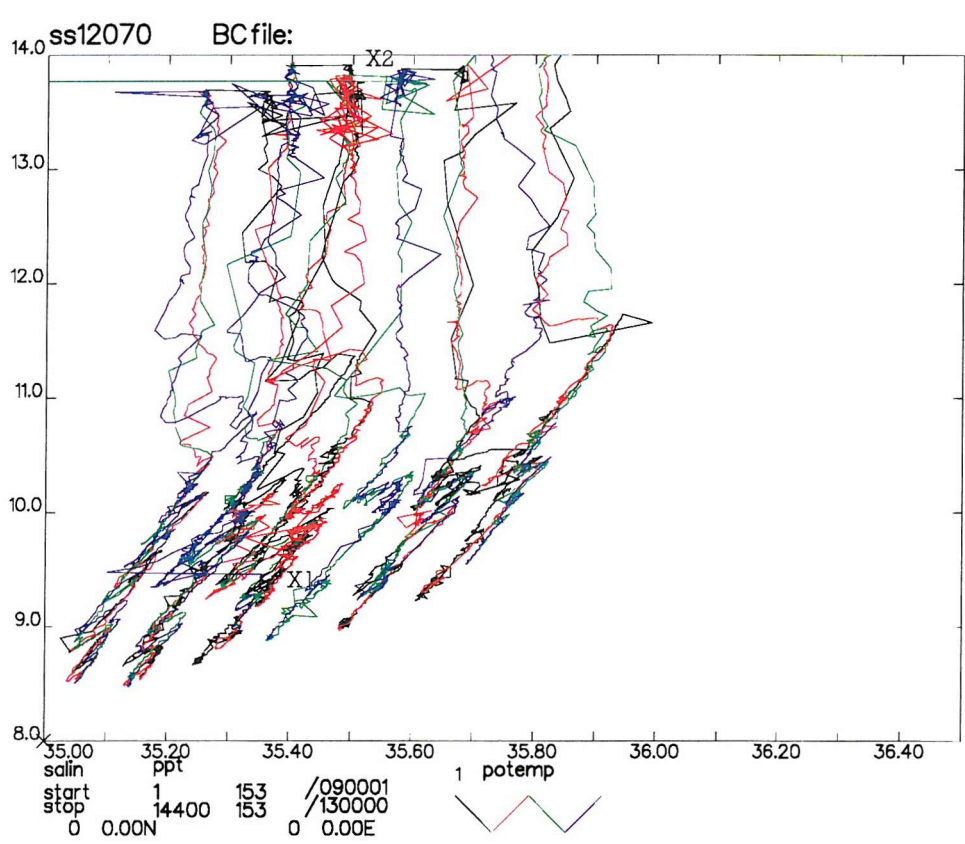


Figure 9b:- SS12070 Potential Temperature against Salin

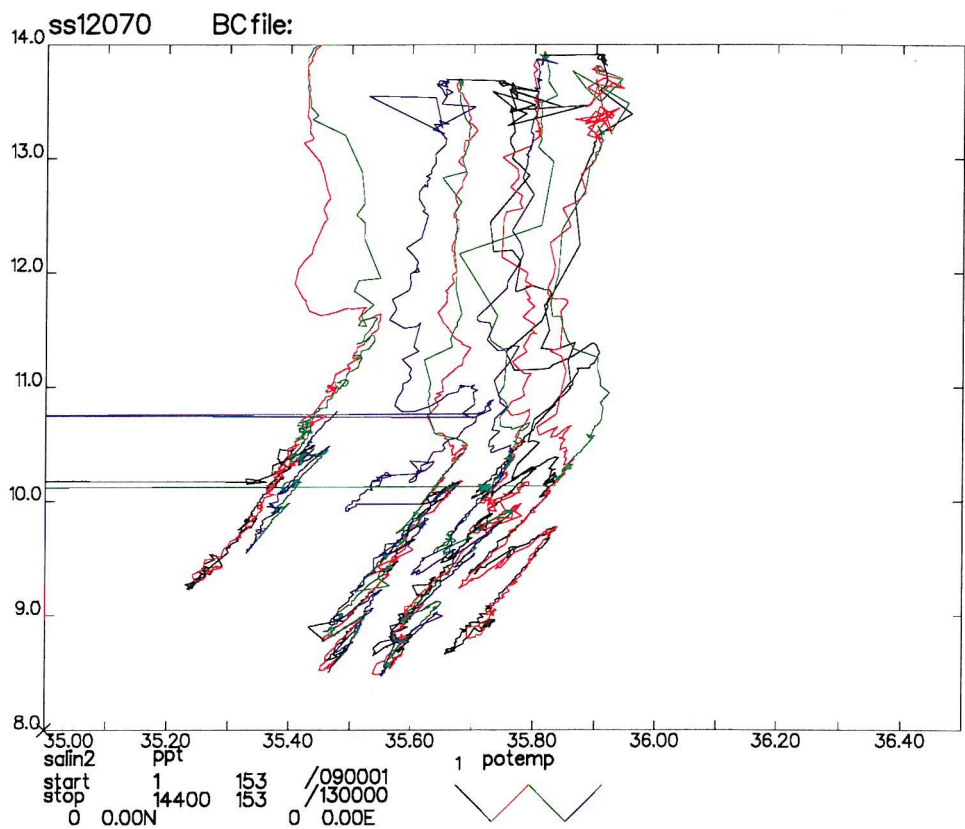


Figure 9c:- SS12070 Potential Temperature against Salin2

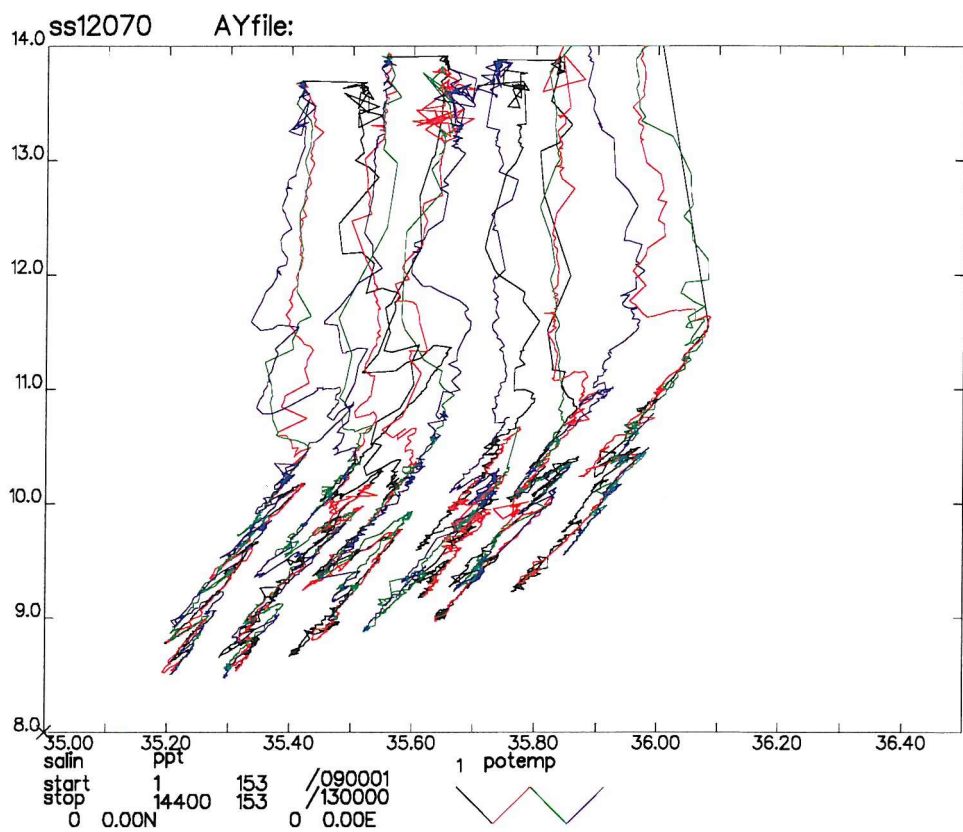


Figure 9d:- SS12070 Potential Temperature against final Salinity

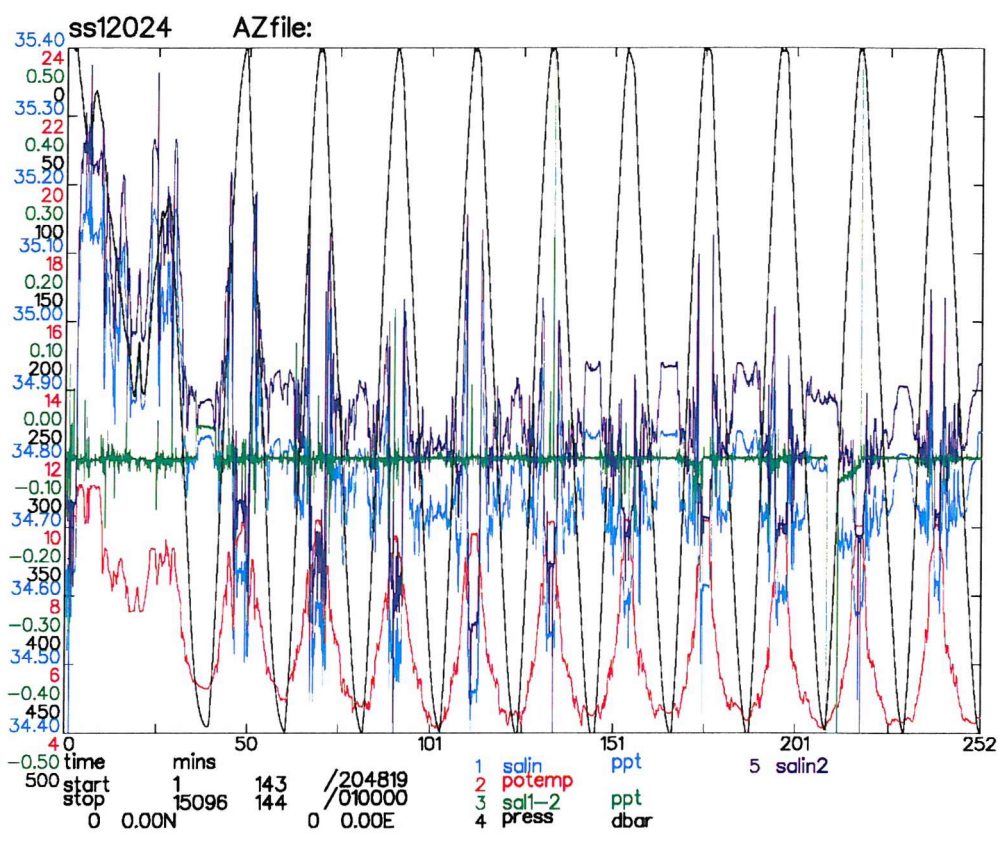


Figure 10a:- SS12024 Time Series Plot

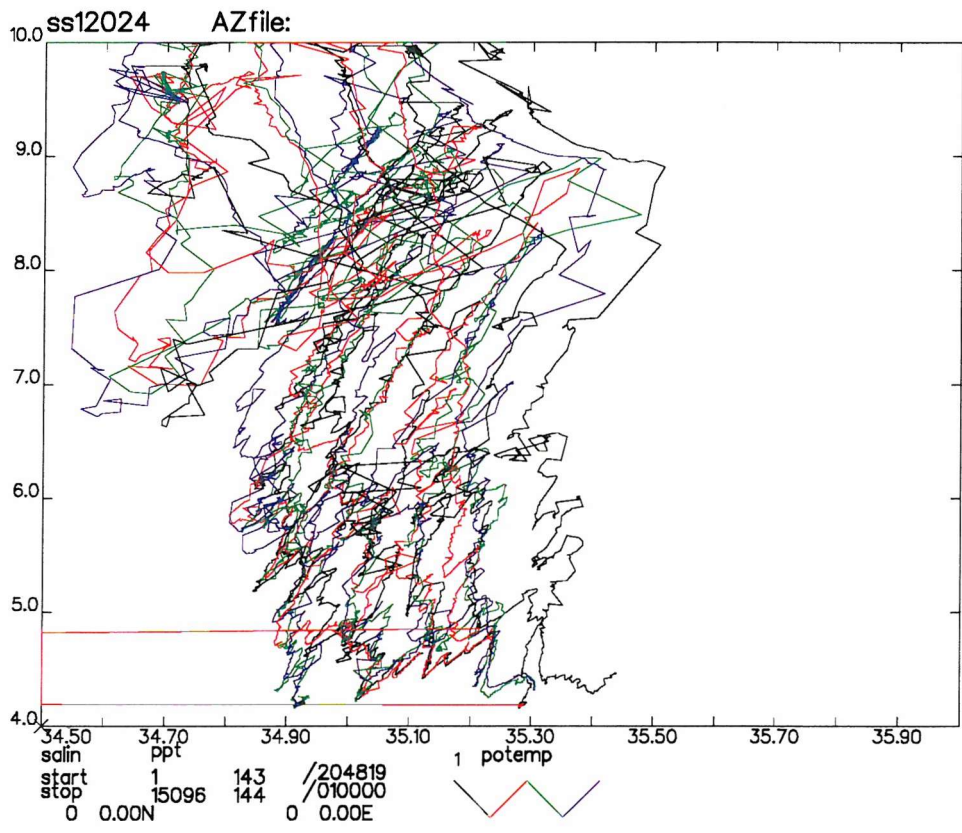


Figure 10b:- SS12024 Potential Temperature against Salin

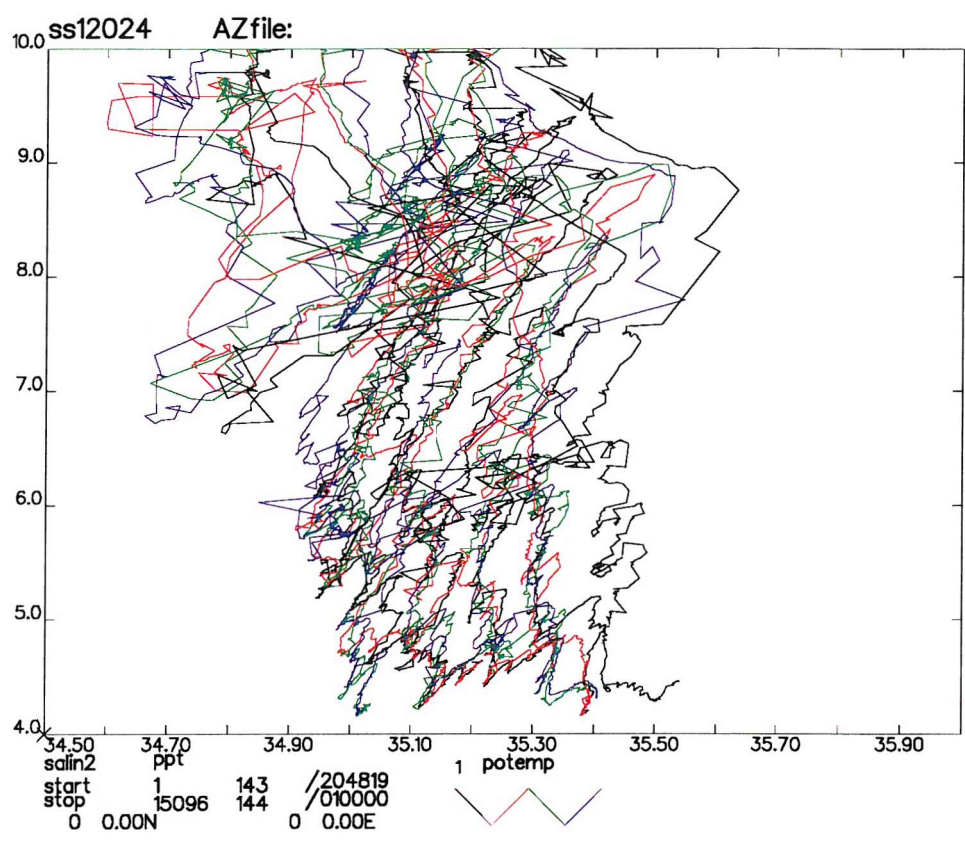


Figure 10c:- SS12024 Potential Temperature against Salin2

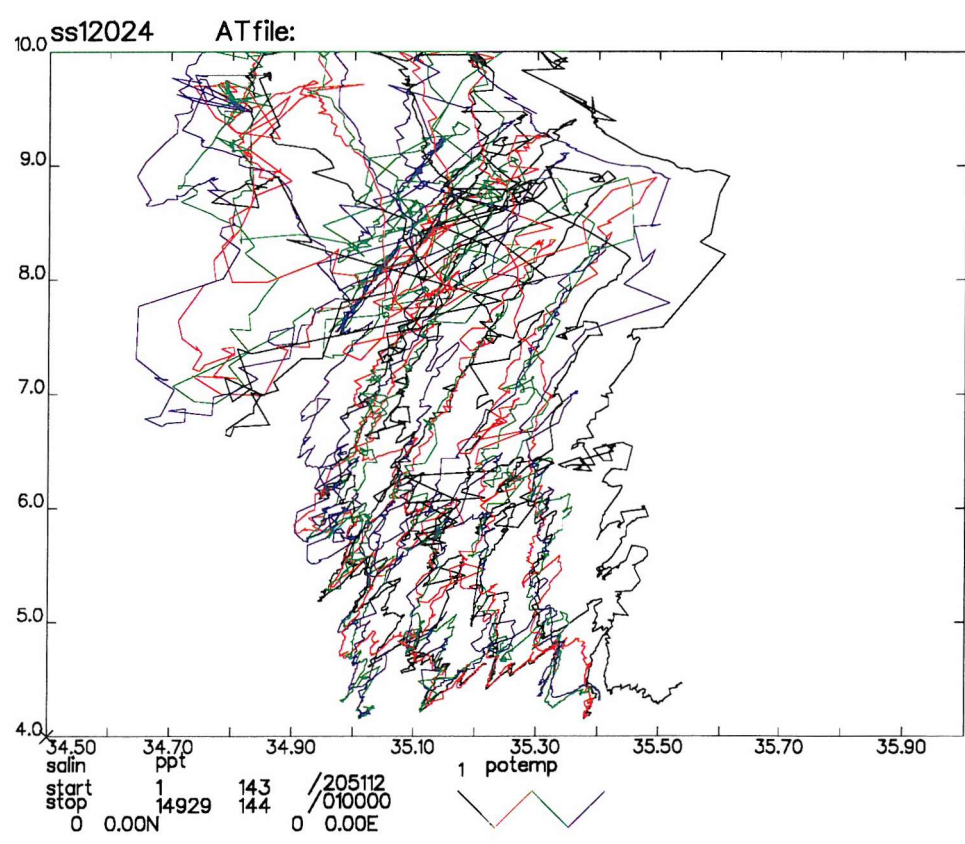


Figure 10d:- SS12024 Potential Temperature against final Salinity

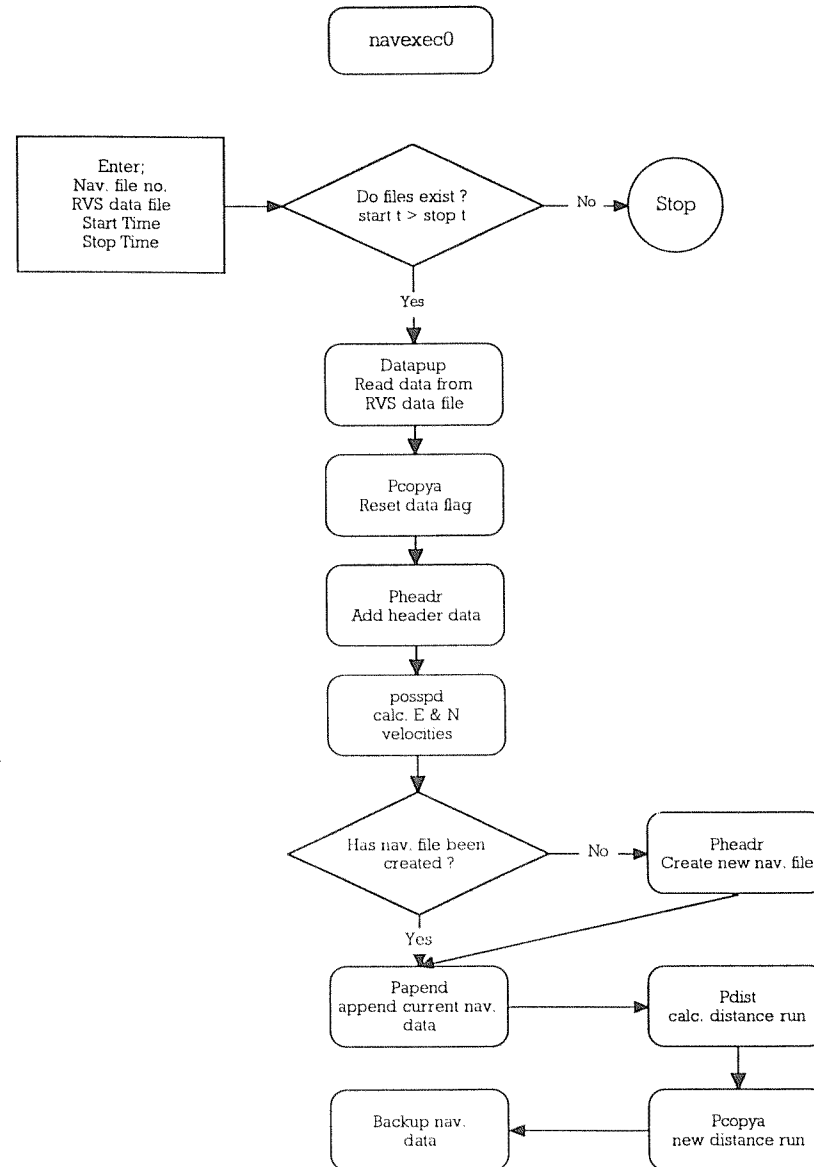


Figure 11.- Flow Chart for navexec0

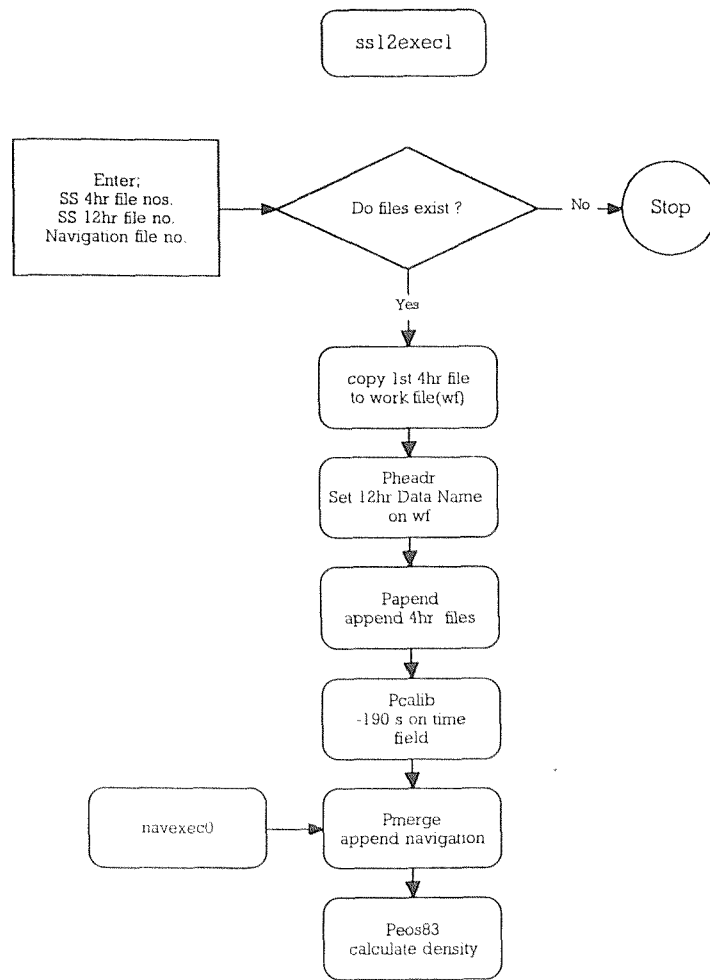


Figure 12:- Flow Chart for `ss12exec1`

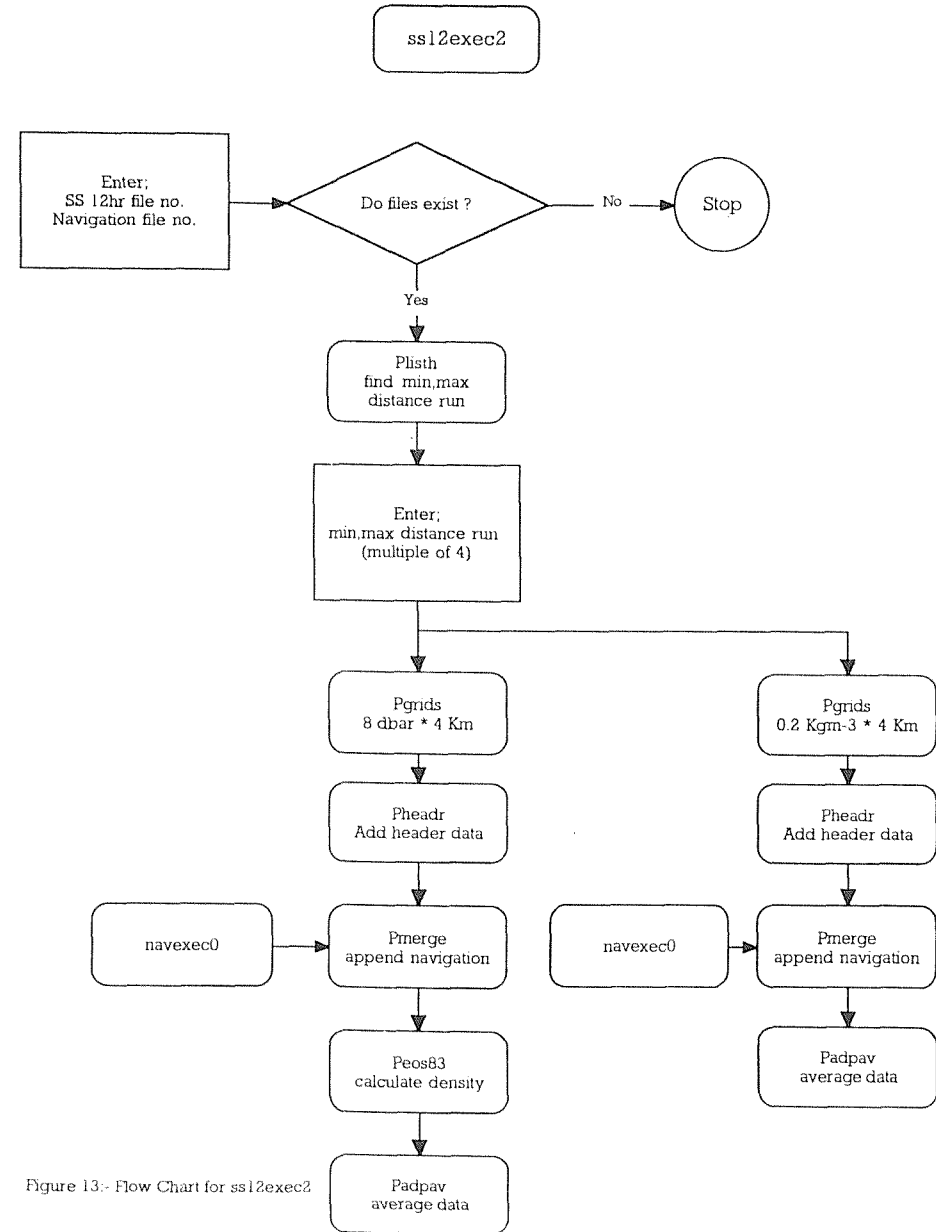
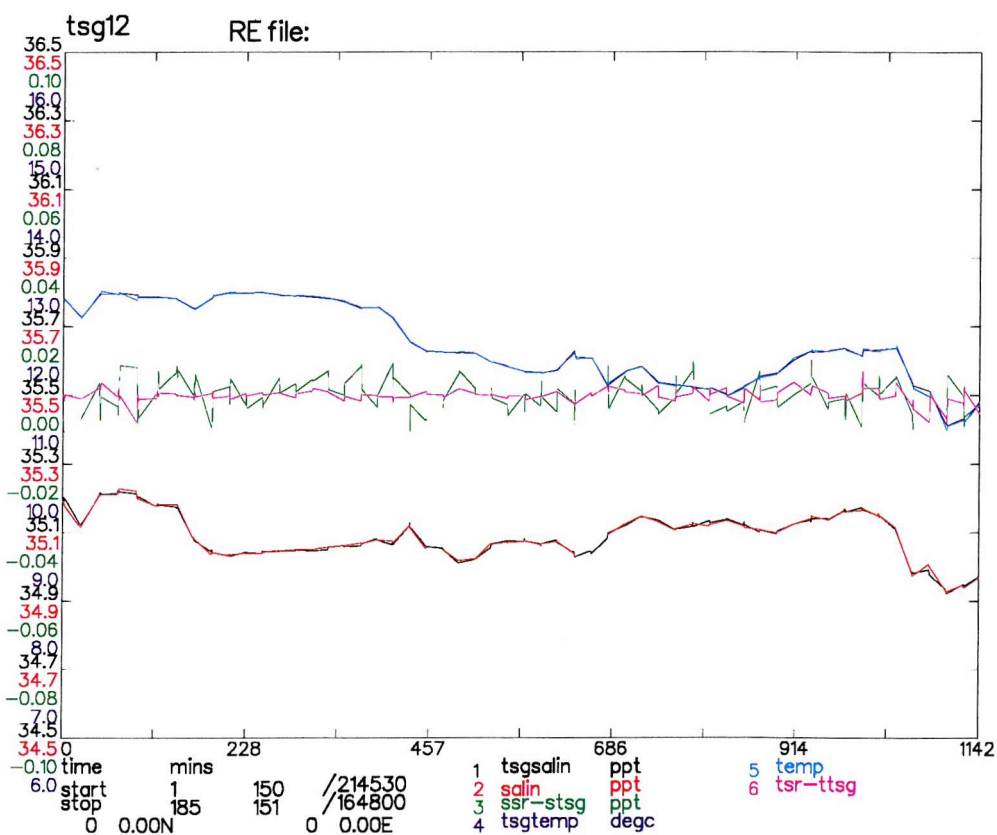
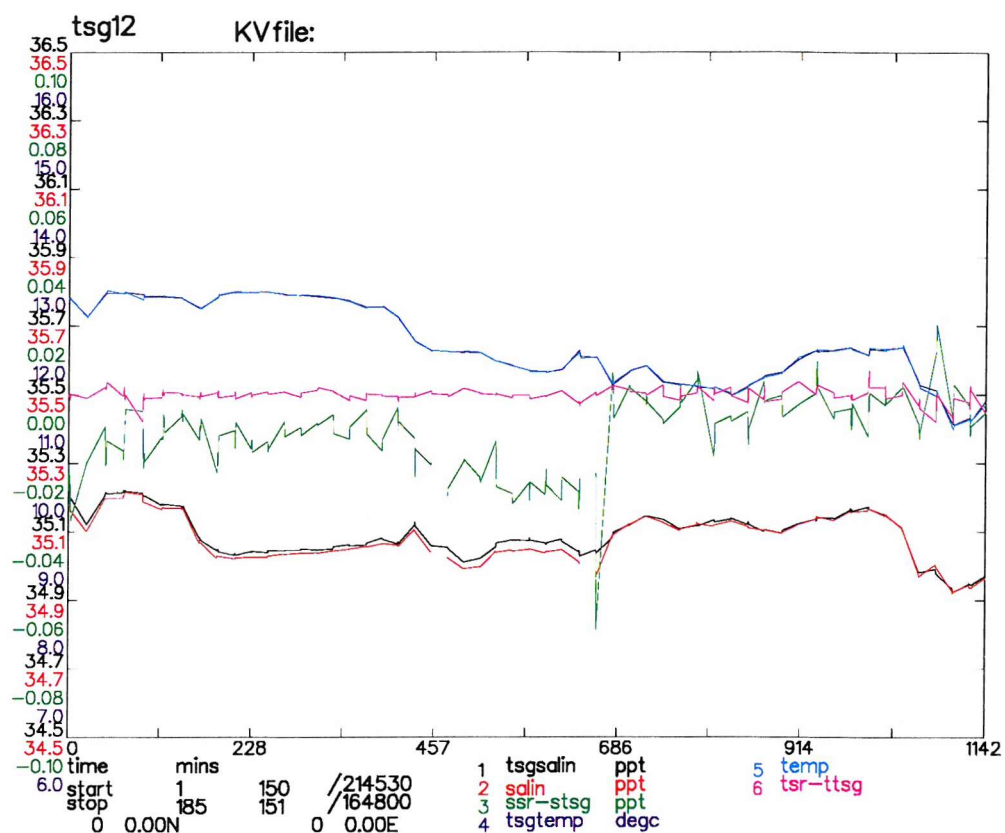


Figure 13:- Flow Chart for `ss12exec2`



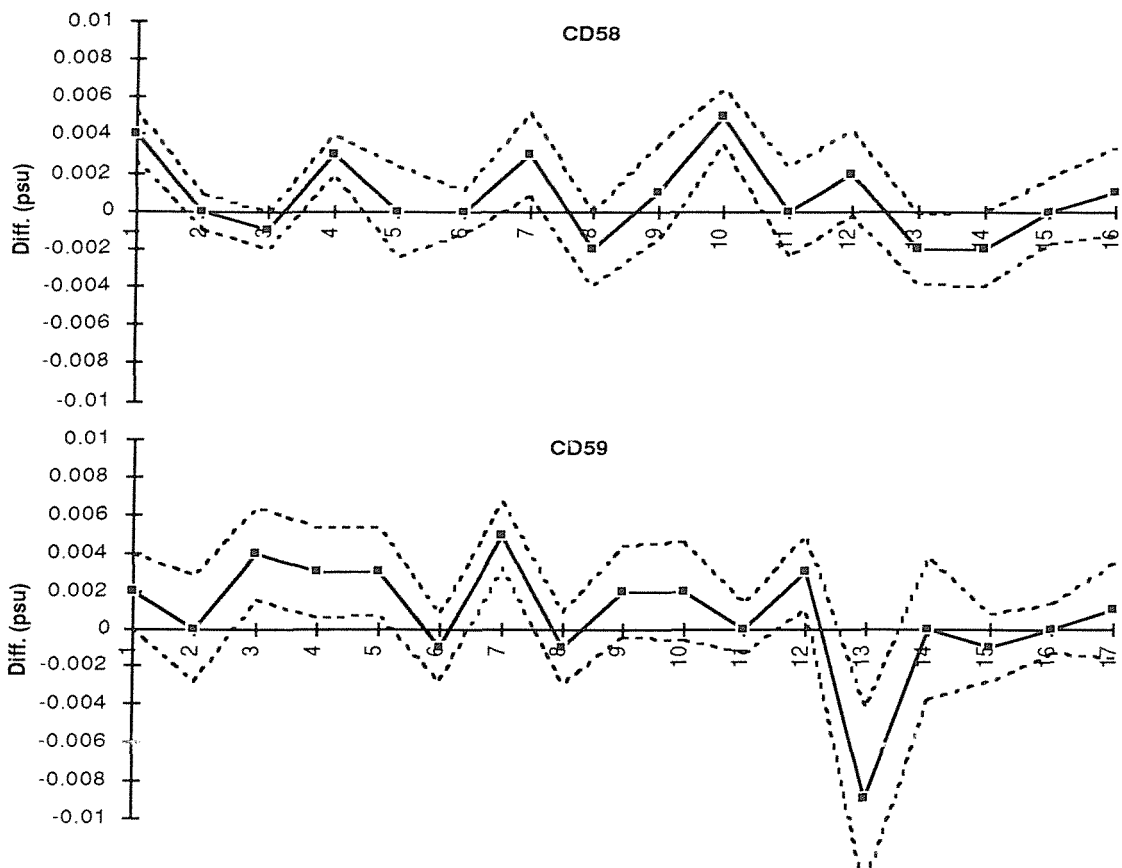


Figure 16a:- Residual salinities between the SeaSoar and the TSG.

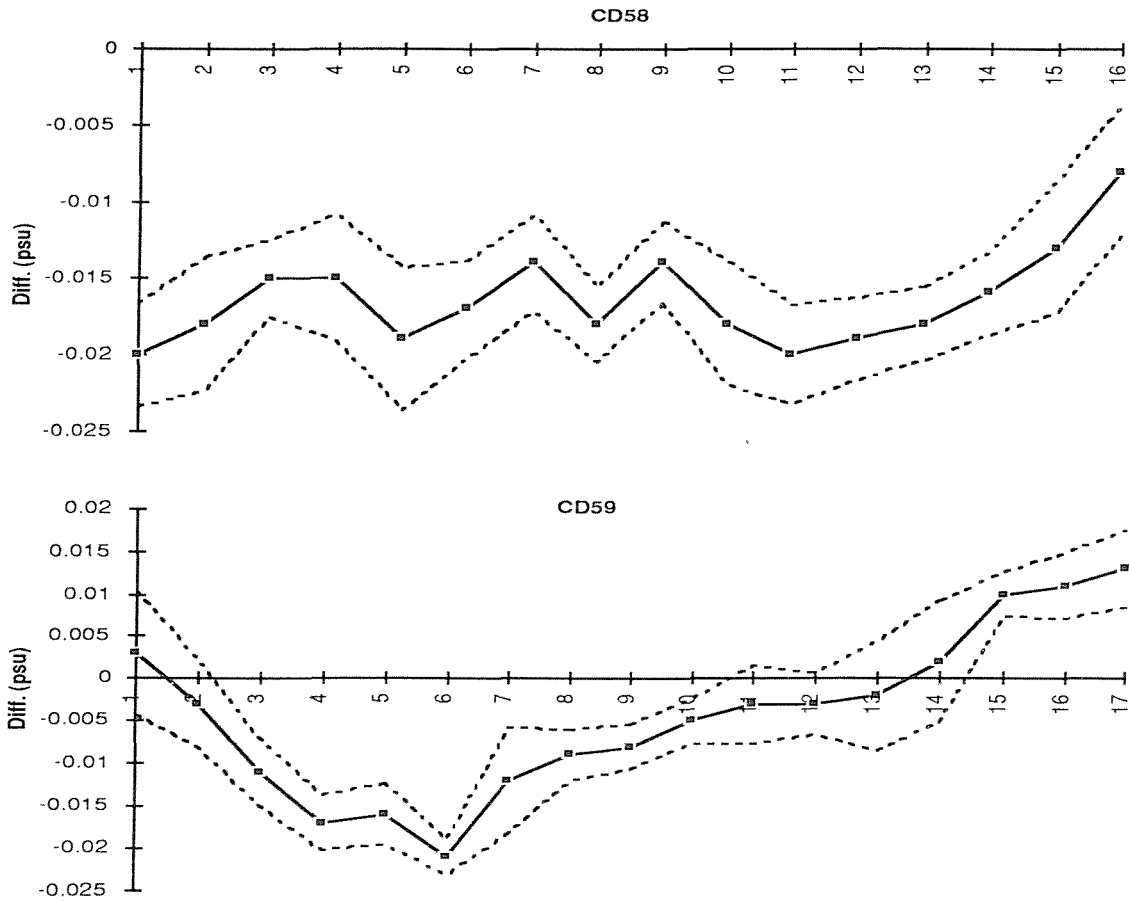


Figure 16b:- Residual salinities between bottle samples and the TSG.

x-axis: Section Number
 Error Bars: Three Standard Errors of the Mean

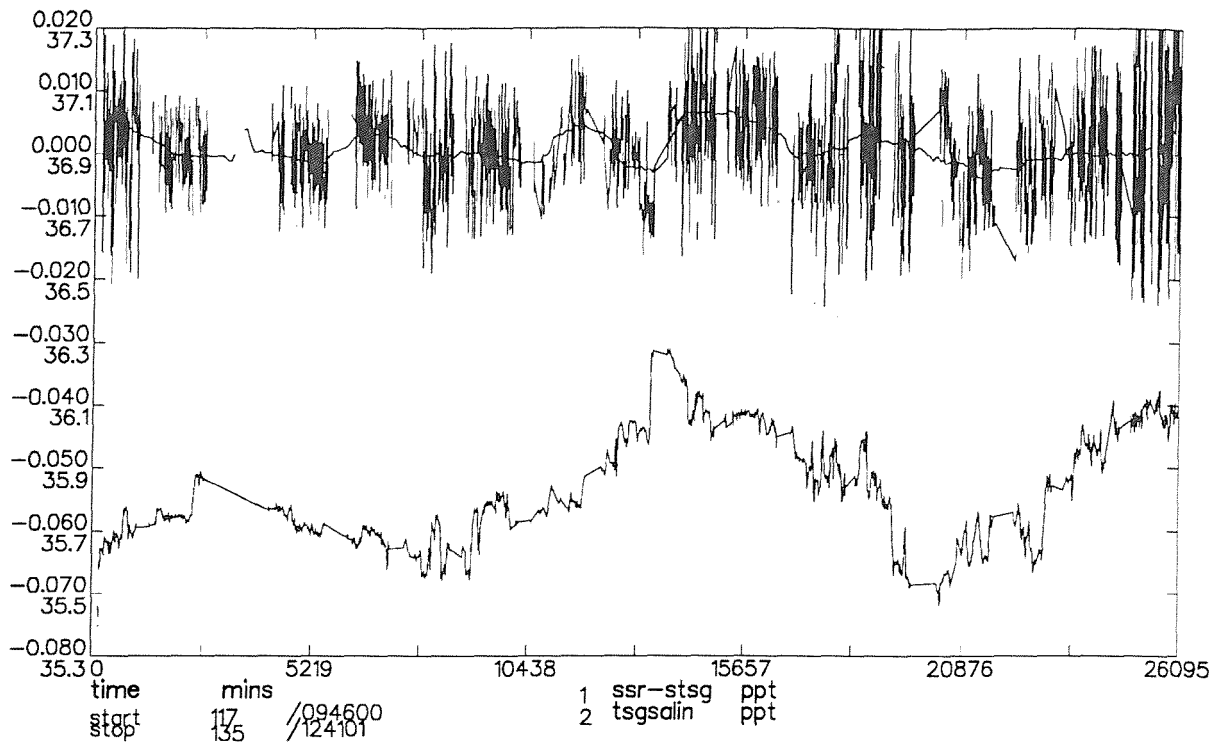


Figure 17a:- CD58 1. SeaSoar salinity minus TSG salinity.
2. Low pass filtered SeaSoar/TSG salinity differences.
3. TSG surface salinities.

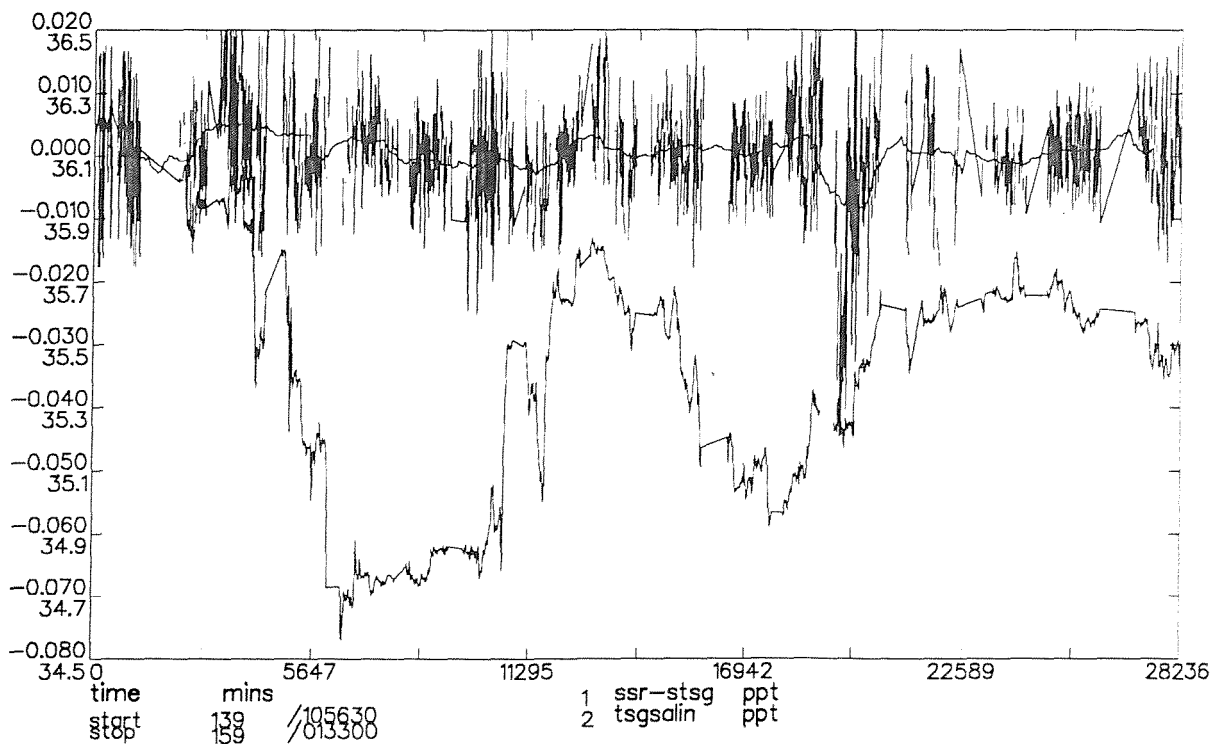


Figure 17b:- CD59 1. SeaSoar salinity minus TSG salinity.
2. Low pass filtered SeaSoar/TSG salinity differences.
3. TSG surface salinities.

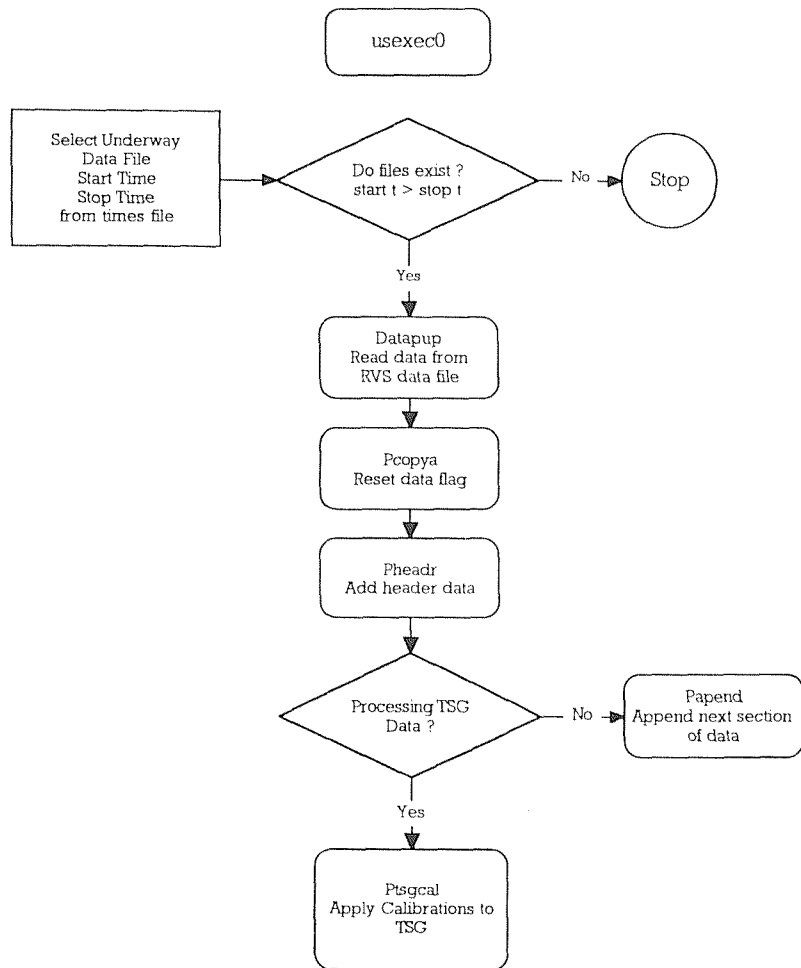


Figure 18:- Flow Chart for usexec0

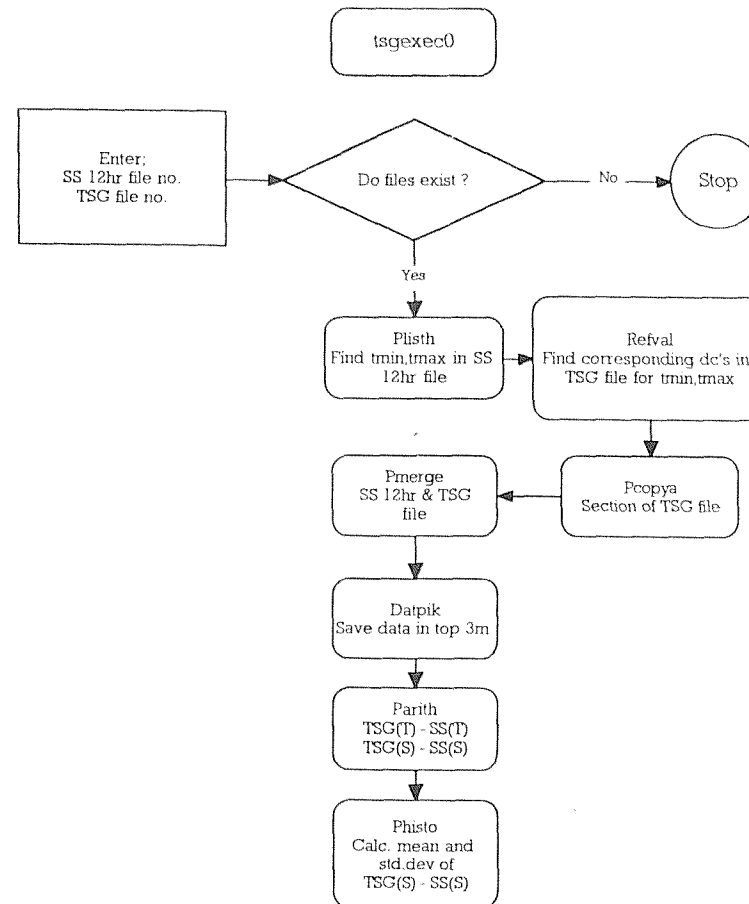


Figure 19:- Flow Chart for tsgexec0

11. APPENDICES

Appendix A

RVS Commands

To interrogate the RVS data files a knowledge of the available RVS commands is useful.

i) DATAPUP Usage:- datapup reads data from an RVS datafile and converts it to PSTAR format.

Format:- datapup [-syydddhhmmss] [-eyydddhmmss] [RVS data file] [output PSTAR file]
[RVS variables to read; '-' indicates all variables]

Note:-Care has to be taken to know what RVS variables are required, their order and their naming convention which is different to that in PSTAR.

ii) GAPS

Usage:- gaps provides a list of data logging start and stop times for the required RVS data file.

Format:- gaps [-syydddhhmmss] [-eyydddhmmss] [RVS data file]

Note:-The use of the -s and -e start and stop specifiers is optional. One problem with gaps is that after a long period of data recording the memory blocks on computer allocated for data storage are cycled and early data gets overwritten. The GAPS command is unable to cope with this and hangs.

iii) DFINFO

Usage:- dfinfo provides a list of the earliest and latest times on tape.

Format:- dfinfo [RVS data file]

Note:-

iv) LISTIT

Usage:- listit allows you to list out values from the RVS data files.

Format:- listit [-syydddhhmmss] [-eyydddhmmss] [RVS data file] [variables]

Note:- A list of the variables in each RVS data file can be obtained by use of the following command.

v) VARIABLES

Usage:- variables lists the variables in any RVS data file.

Format:- variables [RVS data file]

Note:-

vi) USAGE

Usage:- usage gives the format, usage and delimiters of a given RVS command

Format:- usage [RVS data file]

Note:- This is a particularly useful command to find out delimiters for commands such as listit, which for instance would allow you to list data in 60s intervals.

Appendix B

Some Common Data Processing Problems

(i) Problems running C-SHELLS

Invariably problems will be encountered when data processing. In nearly all instances the problems will be due to human error. Usually the problems are easily rectified. The trick is spotting what has gone wrong. The following will give a few of the common mistakes and the fix it quick solutions.

(ii) Directories

Underlying all of the data processing is an assumed directory structure. This enables the data processing to be organised and simplifies the archival of data. Certain stages of the data processing require access to other files for example to the sequential files of calibration data. At the start of the cruise when the data processing packages are installed these paths are set. If a c-shell is run in the wrong directory it may not be able to access a required file. The program will crash and either the files can be deleted and the processing started in the correct directory or the files moved to that directory and the processing started from the last stage. Note that some of the c-shell execs have been updated, and they automatically set the absolute path to the directory where they are supposed to run from. In the future this should limit the above problem.

(iii) Input to programs and files

Although the c-shell execs automate a large part of the data processing they still require input from the user. Common problems include inputting nonsensical start and stop times, or stop times earlier than the start time.

If a file looks wrong then check carefully the start and stop times of that file - is it sequential to the previous file and does it have approximately the correct number of data cycles for that particular stage of processing. Look also at the header of the file and check the variables present and their order - are the minimum and maximum values in the header sensible. Unless the problems are small it is usually better to start processing at the stage previous to the one that has gone wrong, rather than trying to sort the data by hand.

(iv) Corrupted files

It is possible for files to become corrupted. Commonly the user may have entered the wrong variable number to one of the editing programs and deleted some data cycles. This is particularly important if the time variable has been edited as some of the programs rely on merging data using the time variable. The PEXEC program suite has search programs, PLISTV, PLISTF and REFVAL, which allow data values to be searched for, including absent data. Again it is best to go back to the

last data processing stage where the data are good. In doubt make a backup of the file before processing it.

(v) Errors in navigation files

The integrity of the navigation files is one of the most important aspects of the data processing. It is the navigation data which locate the other data in time and space and hence is important for the quality of the oceanographic data. If a serious problem is ever suspected with the navigation files it should be referred to the most experienced person available. If the navigation file has not been updated before the data processing of SeaSoar data has started then the start and stop times of the navigation file may not span the start and stop times of the SeaSoar data file. When the navigation data and SeaSoar data are merged on time the program will crash. The solution is to update the navigation file and start again.

One serious problem that has been encountered was when the Level B data logger crashed. On restart of the Level B the origin of the distance run variable from the GPS file was reset. Unfortunately it did not reset to the value at the start of the cruise. The next time the current navigation file was updated then time and distance run were not monotonic increasing, as the time and distance run variable from before and after the Level B crash overlapped. This problem can only be sorted by an RVS computer operator resetting the GPS file to a previous known values and then updating the navigation files once this has been done.

(vi) C-shells, Unix Environment variables and PEXEC programs

When PEXEC is mounted at sea, and the c-shells are made ready for use, a set directory structure has to be established and the paths to each directory set. Certain environment variables also have to be set. The order of the variables in the raw data files established, and the c-shell execs suitable adjusted, as these execs pass the variable order to the PEXEC processing programs. These programs are dependant on specific data order and hence must be passed correctly from raw data files, through the c-shell to the PEXEC program.

Problems of this nature are the responsibility of the PEXEC operator and must be dealt with by them only. Usually these problems will be limited to just after the system has been set up.

(vii) Printer problems at sea

On board ship there are usually three types of printer. A colour rasterscan Tektronix printer, a flatbed and a drum Nicolet printer. Very few problems were encountered with the first two, although the flatbed is slow. The Nicolet printer however is temperamental and often hangs. The solution to this is usually to switch the plotter off, and to clear the plotter ports. This is done in the following manner from any of the Sun stations on board:

```
type> telnet sport1 2048      [return]
```

- user is prompted for the RVS System Administration password. See RVS for this.

```
type> password               [return]
```

- takes you into administration mode

type> sp [return]

- this shows the ports on the system. Nicolet is port 7

type> ki 7 [return]

- this kills port 7

type> q [return]

- to exit administration mode

Having switched off the plotter it is necessary to reset the pen pressures. These are different for different plotting mediums, but for the standard grade paper it is 34. To set this; Put printer offline, green LED is illuminated. Select 'E' + 'pause' LED flashes. Using 'pen select' illuminate pen LED 3 and press return. All pen LED's bar one are now illuminated. Using 'pen select' switch off pen LED 4 and press return. The printer can now be put back on line by a double press of return. LED stops flashing and is off.

Other problems should be referred to RVS. Eg Changing pen pressures and plotter speeds for tracing paper or Mylar.

In the future Hewlett Packard ink jet plotters will be taken to sea. These are fast, and have proved very reliable.

Appendix C

SeaBird Thermosalinograph Data

Sea-Bird Electronics, INC

Conductivity Meter Model SBE 4

FEATURES

Absolute Accuracy and/or Long Term Stability:

0.001 S/m* per month guaranteed

0.003 S/m per year typical

Usable Resolution:

better than 5×10^{-5} S/m at 12 samples per second

better than 1×10^{-5} S/m at 3 samples per second

Conductivity Sensing Element:

2-terminal platinum electrode cell, flow-through type

cell guard is treated with tributyltin anti-fouling

Response Time:

depends on the flushing rate (less than 170 ms when towed at 4 knots)

70 ms when pumped at 15 ml/s and towed at 1 m/s

Warmup Time:

less than 2 seconds to be within 5×10^{-4} S/m of final state

Output:

0.7 volt rms sine wave, short-circuit proof

approximately 2.8 to 11 kHz for 0 to 6 S/m, respectively

Power Required:

10 to 20 volts dc at 8 ma (internally regulated)

Pressure Housing:

anodized 6060_T6 aluminium, 4.83 cm (1.9 inch) diameter

zinc anode protected

5000 psi pressure capability standard, 10000 psi optional

Connector:

3-pin Advanced cable and assembly A303/ 3/4-16

(Aluminium body)

connectors from Kintec, Impulse or Envirocon are available as options

Weight:

in air - 735 grams (26 oz.)

in water - 340 grams (12 oz.)

* Siemens per meter. Multiply S/m by 10 to obtain mmho/cm

Appendix D

Calibration of a SeaBird Thermosalinograph

Underway data such as TSG data are processed via `exec usexec0`. This `exec` is shown in Figure 18. The underway data to be processed are selected and read from the appropriate RVS data file, using `datapup`. If the data being processed are TSG data the instrumental calibrations are applied via `PTSGCAL`. Note that the times of the data being processed are read from a `times` file.

The data route followed is;

`DATAPUP` - reads data from RVS data file and converts it to `PSTAR` format

`PCOPYA` - resets data flags and deletes redundant variables

`PHEADR` - adds header information

`PTSGCAL` - applies the instrumental calibrations to the TSG data

The data can then be plotted using `usexec1`, and spikes deleted using `PEDITA`, `PEDITB` or `PLXYED`. The data are then ready to be calibrated.

An `exec` to perform the absolute calibration of the TSG data has not yet been written. However an `exec`, `tsgexec0`, (Appendix E) was written to allow the comparison of TSG and SeaSoar data. As the procedures carried out are close to those required to calibrate the TSG it could form the basis of a calibration `exec`. The manual procedure used on `vivaldi` is outlined below.

Salinity Calibration

Each underway segment needs to be calibrated against the salinity samples taken at hourly intervals from the non toxic supply.

For each segment merge the underway salinity bottle samples with the TSG data over the required data cycles. Then determine the difference between the bottle and TSG salinities. Calculate a mean difference using data within ± 2 standard deviations and apply this mean as an offset calibration to the TSG salinity.

Temperature Calibration

The temperature calibration is carried out after the salinity calibration.

The method to be used for the temperature calibration is to assume that the SeaSoar temperature channel is correct and use this to calibrate the TSG. Because the SeaSoar surfaces some

700m behind the ship and the delay of the surface sample reaching the TSG via the non toxic intake is not known it is necessary to assume that the sea surface is homogeneous over 700m for most of the time and reject data from the calibration where this is not the case.

Using PMERG2 the TSG data and the relevant one second SeaSoar file are merged. Copy time, pressure, temperature and salinity from the SeaSoar file.

This file takes no account of the depth of the SeaSoar. This problem may be overcome by using DATPIK to eliminate datacycles where pressure lies outside the range -1.0 to 3.0 dbars.

Again, determine the difference between the SeaSoar and TSG temperatures. Calculate a mean using data within ± 2 standard deviations, and apply this mean as an offset calibration to the TSG temperature.

The SeaBird TSG Calibration Equations

Although the SeaBird calibration equations used on the vivaldi cruise are explained here, it should be noted that they are specific to this instrument and the Level A configuration used. It is still useful to include them as an example of how to investigate how the equations are calibrating the data.

The calibration equations supplied by RVS for the TSG are as follows,

1. Housing Temperature

$$\begin{aligned} \text{HTEMP} = & -63.6289 + 7.441474\text{E-}3 * \text{FH} - 2.067987\text{E-}7 * \text{FH}^2 \\ & + 2.880193\text{E-}12 * \text{FH}^3 \end{aligned}$$

where FH is typically around 16000 and the level A value = (FH - 12000)

FH	constant	linear	quadratic	cubic	HTEMP
15000	-63.629	111.622	-46.530	9.721	11.184
16000	-63.629	119.064	-52.940	11.797	14.292
Difference	0.000	7.442	-6.410	2.076	3.108
16332	-63.629	121.5341	-55.1603	12.5470	15.2919
16333	-63.629	121.5416	-55.1670	12.5493	15.2950
Difference	0.000	0.0075	-0.0067	0.0023	0.0031

Therefore all terms are significant and none can be omitted.

2. Remote Temperature

$$\begin{aligned} \text{RTEMP} = & -12.43502 + 3.137205\text{E-}3 * \text{FR} - 8.350152\text{E-}8 * \text{FR}^2 \\ & + 1.532481 * \text{FR}^3 \end{aligned}$$

where FR is typically around 11000 and level A value = (FR - 2000)/2

FR	constant	linear	quadratic	cubic	RTEMP
11000	-12.435	34.509	-10.10368	2.0397	14.0103
12000	-12.435	37.646	-10.10552	2.04029	14.0122
difference	0.000	0.0147	0.00056	0.00056	0.0019
11000	-12.435	34.509	-10.10368	2.0397	14.0103
11001	-12.435	34.5124	-10.10552	2.04029	14.0122
difference	0.000	0.0147	0.00184	.00056	0.0019

Again all terms are significant. The level A conversion has reduced the resolution by a factor of two from 0.0018 C to 0.0036 C.

3. TSG Conductivity

$$\text{HCOND} = 8.80739112\text{E-}7 * \text{FC5.1} + 4.30906377\text{E-}1 * \text{FC2} \\ - 4.38268295 - 2.25947132\text{E-}4 * \text{HTEMP}$$

where FC = (SeaBird count)/2000 and level A value = (SeaBird count)/2 - 3000.

HTEMP only plays a minor correction role in the HCOND equation. A 1 C change in HTEMP only changes HCOND by 0.0002 mmho/cm and a 10 C change by 0.002 mmho/cm. Thus HTEMP must only be a minor residual correction for the effects of housing temperature on conductivity and not the direct effect of temperature. HTEMP could be replaced by a constant value of 15 C, change the constant term by -0.003389 to -4.38607, and the error in HCOND would be no more than 0.001 mmho/cm for housing temperatures in the range 10 to 20 C.

Level A	FC	FC5.1	quadratic	constant	HCOND
7500	21000	0.142204	47.50743	-4.38607	43.2636
7501	21002	0.142272	47.51648	-4.38607	43.2727
difference	2	0.00007	0.00905	0.0000	0.0091

Hence the Level A output resolution is only 0.01 mmho/cm, whereas SeaBird was half that. Averaging over N samples should reduce that by (N)^{0.5}. So for N = 9 the resolution is approximately 0.003 mmho/cm.

It is also possible to linearise the FC5.1 term, to $(1 + x)^{5.1} \approx 1 + 5.1 * x + O(x^2)$ where x is small. Choosing 21250 counts as the number to linearise (i.e. Level A output of 7625). The equations become,

$$\text{DFC} = (\text{Level A})/1000 - 7.625$$

$$\text{HCOND} = 44.41027 + \text{DFC} * 9.2292645 + \text{DFC}^2 * 0.430906377$$

The equation is exactly the same as the given calibration for Level A value of 7625, giving HCOND = 44.410. If Level A value = 7500, it yields HCOND = 43.2633, which is 0.0003 different from that given above. Since surface conductivity is unlikely to change by more than 10 mmho/cm, the errors are likely to be less than 0.003, the resolution of the instrument.

Discussion

The usable resolution of the TSG is dependant on the sampling frequency. The sampling frequency has to be chosen in consideration with the response time and hence the flushing rate. During vivaldi spot samples were taken every thirty seconds with a resolution of 0.01 psu. The response of the conductivity cell depends on the flushing rate. At 4 knots the response time is 0.2s (See appendix C). Hence it would be possible to sample at up to 5 Hz. If a one second average was then taken the accuracy would be $0.01/5^{0.5} = 0.005$ psu. It would also not be unrealistic to take an average over thirty seconds to reduce the effects of spatial inhomogeneity. This would eliminate some of the noise when matching SeaSoar and TSG salinity data.

Table 1 shows the mean and deviations for each SeaSoar section during vivaldi. The standard mean standard deviation of the TSG-bottle salinities is 0.0049 psu for CD58 and 0.0066 psu for CD59. Thus we can say that on average for both legs of the cruise the TSG was calibrated to 0.0058 psu. It is clear from Table 1 that some sections have a rather high standard deviation. This may be due to drift in the SeaBird TSG conductivity cell, over a period of a day. Figures 16b, 17a and 17b show the mean and standard deviation of the TSG-bottle salinities as well as the actual surface salinities. Comparing 16b(CD58) and 17a and 16b(CD59) and 17b there appears to be a correlation between the variation of the mean salinity difference and the surface salinity variation. For CD58 the surface salinity variation is much less than in CD59. If the mean salinity difference is related to the surface salinity this may explain the better results obtained for the TSG calibration on CD58.

Given that there appears to be significant changes in the TSG salinity on time scales of a day, it may have been inappropriate to use an offset calibration from the bottle data. A linear fit to the data may have improved the calibration and hence reduced the standard deviation of the TSG-bottle salinities.

This was the first time the SeaBird TSG had been used with the new deep CTD sensors. Hence little is known about its stability within the TSG unit. Further investigation within the vivaldi data set would shed light on this and on how to improve the TSG calibration from bottle data.

The calibration of the TSG has not been optimised. To improve its accuracy the following should be done for the next cruise;

- i. Change the TSG software to give a 5 reading average value of conductivity every second.
- ii. Measure conductivity continuously, not a spot value every thirty seconds, and then average to a thirty second value.
- iii. Try to ensure that the Level A conversions do not degrade the resolution of the measurements.

- iv. Investigate the stability of the conductivity cell within the SeaBird TSG to ascertain whether an offset, linear or more complicated calibration function is appropriate.
- v. Insist on accurate logging of the time when the surface samples are taken.

Appendix E

tsgexec0

Comparison of SeaSoar CTD and TSG data using tsgexec0

Figure 19 shows the flow chart for this exec. Firstly from the minimum and maximum times in the SeaSoar file, the appropriate section of the TSG file is copied. These two files are then merged. DATPIK is used to eliminate SeaSoar data not in the top 3m of the water column. Differences between the TSG and SeaSoar salinities are calculated. PHISTO then determines the mean and deviation of the difference.

Although it was written to enable SeaSoar and TSG salinity data to be compared sections could be included in a new exec which would merge TSG with salinity bottle data and separately with SeaSoar data. PARITH would determine the temperature and salinity differences in each file and PHISTO would give the offset calibrations.

```
#!/bin/csh
#tsgexec0 by S.A. Cunningham
# This exec takes TSG salinity and temperature data that have been
# calibrated against underway salinity bottles and SeaSoar surface
# temperature data, and compares TSG salinity against SeaSoar
# surface salinities
# NB:- The environment variable CRUISE is used in this exec
echo ">This exec will require the following information"
echo ">SeaSoar 12 hour file number eg 001"
echo ">A TSG file"
echo -n ">Continue (y/n) ?"
set ans = $<
if ($ans != "y") then
    exit
endif

echo -n ">Enter SeaSoar 12 hour file number "
set ssnum = $<
if (! -e ../../tmpraw/sa$CRUISE$ssnum)then
    echo ">sa$CRUISE$ssnum does not exist"
    exit
endif

if (! -e tsg$CRUISE)then
    echo ">tsg$CRUISE does not exist"
    exit
```

```
endif

# Remove any .glist files
/bin/rm -f .glist*

# Run PLISTH to get header output
echo ">Now running PLISTH to obtain sa start and stop times "
plsth>.glist<<!
../../tmpraw/sa$CRUISE$ssnum
!
if ($status != 0)then
  echo " *** Problem running PLISTH *** "
  exit
endif

# Use awk to search for min and max times in header of sa file
set satime_min = `grep l.time .glist | awk '{print $(NF-5)}'`
set satime_max = `grep l.time .glist | awk '{print $(NF-3)}'`

# Remove any .glist2 files
/bin/rm -f .glist2

# Use REFVAL to locate dc's in TSG from times of SA file
echo ">Now running REFVAL "
refval>.glist2<<!
tsg$CRUISE
l
$satime_min
$satime_max
-999
!
if ($status != 0)then
  echo " *** Problem running REFVAL *** "
  exit
endif

# Now extract the relevant dc's from .glist2
set datacycles = `grep found .glist2 | awk '{print $8}'`
set dcstart = $datacycles[1]
set dcstop = $datacycles[2]
```



```
set tsgtime_min = `grep 1.time .glist2 | awk '{print $(NF-5)}'`
set tsgtime_max = `grep 1.time .glist2 | awk '{print $(NF-3)}'`

echo ">TSG dc start = $dcstart ..... stop = $dcstop "
echo ">TSG start time = $tsgtime_min .... SS start time =
$stime_min "
echo ">TSG stop time = $tsgtime_max .... SS stop time =
$stime_max"

# Remove .glist2
/bin/rm -f .glist2

# Now run PCOPYA to extract dc's of TSG
echo ">Now running PCOPYA"
pcopya>/dev/null<<!
tsg$CRUISE
n
tsg$CRUISE.tmp
/
$dcstart,$dcstop
/
!
if ($status != 0)then
  echo " *** Problem running PCOPYA ***"
  exit
endif

# Now run PMERG2 to merge SeaSoar and TSG data
# Merging variable time. Variables being copied from SeaSoar file
# pressure, temperature and salinity

echo ">Now running PMERG2"
pmerg2>/dev/null<<!
tsg$CRUISE.tmp2
tsg$CRUISE.tmp
/
../../tmpraw/sa$CRUISE$ssnum
1,3,4,13/
!
if ($status != 0)then
```

```
echo " *** Problem running PMERG2 ***"  
exit  
endif
```

```
# Now run DATPIK to eliminate unwanted pressure data
```

```
echo ">Now running DATPIK"  
datapik>/dev/null<<!  
tsg$CRUISE.tmp2  
tsg$CRUISE.tmp3  
1/  
6,-1,3  
0/  
/  
!  
if ($status != 0)then  
  echo "*** Problem running DATPIK ***"  
  exit  
endif
```

```
# Now run PARITH to calculate TSG and SeaSoar salinity and  
temperature  
# differences
```

```
echo ">Now running PARITH"  
parith>/dev/null<<!  
tsg$CRUISE.tmp3  
tsg${CRUISE}sa$ssnum  
/  
2,7,4  
2,8,5  
0/  
tsr-ttsg  
degc  
ssr-stsg  
ppt  
!  
if ($status != 0)then  
  echo "*** Problem running PARITH ***"  
  exit  
endif
```

```
# Remind user of final file name and version code for the log
print_datnam tsg${CRUISE}sa$ssnum new

# Remove intermediate temporary files
/bin/rm -f tsg$CRUISE.tmp
/bin/rm -f tsg$CRUISE.tmp2
/bin/rm -f tsg$CRUISE.tmp3
/bin/rm -f .glist3

# Now run PHISTO to obtain initial values of mean and deviation
echo "> Now running 1st PHISTO "
phisto>.glist3<<!
tsg${CRUISE}sa$ssnum
1
n
10/
/
/
!
if ($status != 0)then
  echo "*** Problem running PHISTO ***"
  exit
endif

# Extract mean and deviation from .glist3
set mean = `grep standard .glist3 | awk '{print $(NF-5)}'`
set sdev = `grep standard .glist3 | awk '{print $(NF)}'`

set limit_min = `echo $mean $sdev | awk '{print $1-(2*$2)}'`
set limit_max = `echo $mean $sdev | awk '{print $1+(2*$2)}'`

# Remove .glist files
/bin/rm -f .glist4

# Now calculate the mean salinity difference within
# two standard deviations of the original mean
echo "> Now running 2nd PHISTO "
phisto>.glist4<<!
tsg${CRUISE}sa$ssnum
```

```
l
n
l0,$limit_min,$limit_max,0.001
/
/
!
if ($status != 0)then
    echo "*** Problem running PHISTO ***"
    exit
endif

# Extract new mean and deviation
set mean_2sig = `grep standard .glist4 | awk '{print $(NF-5)}'`
set sdev_2sig = `grep standard .glist4 | awk '{print $(NF)}'`

set mean_new = $mean_2sig[2]
set sdev_new = $sdev_2sig[2]

# Now give user options for outputing results
echo -n ">Do you want to list the results to screen or lineprinter
(s/l)"
set ans = $<
if ($ans == "s")then
    more .glist3
    more .glist4
else
if ($ans == "l")then
    lpr .glist3
    lpr .glist4
else
    echo ">$ans is not an option "
    exit
endif

# Output to screen means and deviations

echo "> Mean and deviation for the whole population is : "
echo "> Mean = $mean "
echo "> Standard Deviation = $sdev "
```

```
echo "> Mean and deviation for +/- 2 standard deviations is : "
```

```
echo "> Mean = $mean_new "
```

```
echo "> Standard Deviation = $sdev_new "
```

```
echo "> *** End of tsgeexec0 *** "
```

Appendix F

IOSDL Ocean Instrumentation Group Calibrations

1.

Pressure		; DIGIQUARTZ
Standard pressure S/N		;
Pressure temperature sensor S/N		;
Cal file	ctddata\NS22290.prs	;
Data last standard calibration		;
Pressure sensor S/N		;
Pressure sensor interface S/N		;
Data last pressure calibration		; 05-04-91
	A	; 0
	B	; 0
	C	; 0
	D	; 0.01000287
	E	; -2.2282
	LAG	; 25
	LAG'	; 0
	ACQLAG	; 0.225

Digiquartz refers to the laboratory standard instrument. Parameter D is the slope of the linear calibration line and E is the deck pressure offset in dbars. The given values for the linear calibration include the basic scaling factors to convert raw data to engineering units.

ie Full scale raw pressure = 65535 units

$$\begin{aligned} \text{Pressure (full scale)} &= (65535 * 0.01000287) - 2.2282 \\ &= 653.31 \text{ dbars} \end{aligned}$$

The coefficients A, B, C, LAG, LAG' and ACQLAG are coefficients for a non-linear calibration or are lag coefficients to correct the effects of lag.

2.

Platinum Temperature		;
Standard Temperature S/N (NBIS CT-2)		; 03-2009-01
Cal File	CTDDATANS9290F.DAT	;
Sprt Sensor S/N		; 3366
Date last standard calibration		; 27-04-91
Platinum temperature sensor S/N		;
Platinum temperature interface S/N		;
Date last temperature calibration		; 08-04-91

A ; 0
B ; 0
C ; 0
D ; 4.995416D-04
E ; -.1020392
LAG ; 200
LAG' ; 25
ACQLAG ; 0

3.

Conductivity

Conductivity standard S/N (NBIS CT-2) ;
Conductivity interface S/N ;
Conductivity sensor S/N ;
Date last standard calibration ;
Conductivity sensor S/N ;
Conductivity interface S/N ;
Date of last conductivity calibration ; 12-04-91

A ; 0
B ; 0
C ; 0
D ; 1.0D-03
E ; 0
LAG ; 25
LAG' ; 0.225
AQLAG ; 0.225

4.

Conductivity ;
Conductivity standard S/N (NBIS CT-2) ;
Conductivity interface S/N ;
Conductivity sensor S/N ;
Date last standard calibration ;
Conductivity sensor S/N ;
Conductivity interface S/N ;
Date of last conductivity calibration ; 12-04-91

A ; 0
B ; 0

B ; 0

C	; 0
D	; 1.001D-03
E	; 0
LAG	; 25
LAG'	; 0.225
AQULAG	; 0.225
ALPHA	; -6.5E-6
BETA	; 1.5E-8
TO	; 15.0
PO	; 0

Appendix G

Manual page for CTDCAL

SYNOPSIS

This program calibrates CTD data. Version CTDCAL04 offers, by means of switchable options, a variety of new functions that were previously available in other programs such as recal2. By disabling the new options, the functionality of CTDCAL03 can be recovered. CTDCAL04 can be used with Mk III or Mk V CTD data.

The program requires input and output PSTAR filenames, which must be different. Calibration constants are read in from a sequential file in a format similar to that used by RVS. Sample calibration files for MkIII and MkV data are appended at the end of this document. The calibration file will normally contain entries for most of the input variables and some of the derived output variables. This is not a requirement, however; default values are used when variables are omitted from the calibration file.

The list of variables in the output file includes all input variables, plus a number of other derived variables. Some derived variables are automatically included whenever the appropriate input variables are available, others are controlled by questions to the user.

Various subtle corrections may be applied to the CTD data. These are controlled by flags in the program, set by the user at the start of execution.

The questions and possible responses are described below. The response to the first question should be 3 or 5. Later responses should mainly be Y/y or N/n, or numerical data where appropriate.

DESCRIPTION

The user is prompted for input and output file names and the name of the calibration file. This is followed by questions about a number of options for more subtle CTD corrections. If any option is selected, there may be further questions about coefficients to be used or other data to be written out.

The program requests:

1) What kind of CTD ?

Reply 3 if the data are from a MkIII, 5 if from a MkV. The only use currently made of this flag is that you won't be offered a press_t correction unless you are a MkV user.

2) Should pressure be corrected for Temperature ?

If yes, a lagged CTD temperature will be used for MkIII data and a choice of lagged T or press_t for MkV data. Three constants are required for the lagged temp correction, PTSLOP, PTORG

and PTTIME. The use of PTSLOP and PTORG is defined in the algorithms section. PTTIME is the time constant for the temperature lagging in seconds. 400 is believed to be appropriate for the MkIII. These coefficients can be entered at run time or stored in another ASCII file. The lagged temperature, called PTLAG is written out on request.

3)Up/down pressure hysteresis ?

If yes, the data for the pressure correction must be in a table in an ASCII file. The file name is prompted for. The format required is described below.

4)Should conductivity be corrected for P and T ?

If yes, four coefficients are required. Default values are offered and may be accepted by replying Y/y. Otherwise they may be typed in or obtained from a file.

5)Should trans be corrected for deck air cal ?

Note that this is not the same as applying an offset because the deck reading is not zero when the light path is blocked. That effect is corrected using the cal2 entry for trans in the main cal file. This refers to the fact that the clear air voltage (typically around 4.3 volts) is not the same as when the manufacturer performed a water calibration.

If the answer to this question is Y/y, the program looks for a non-zero entry in the cal1 position of the potran line of the main cal file. If found, that value is used. If the entry is zero, the user is prompted for the clear air deck voltage. Also, if this option is selected, the option of computing potran and atten is offered.

6)If a lagged temperature is required for pressure or oxygen, an initial value is computed after the first buffer of temperature data have been calibrated. This value is the median of the first eleven non-absent temperatures. This is offered to the user for checking, with a request for an alternative starting value if first value is rejected.

ALGORITHMS

Where applicable, calibrated values of variables are calculated in the following order, using the algorithms indicated. The numerical entries for each line in the cal file will be referred to as cal1 to cal6.

1)time - assumed to be in seconds past PSTAR file header origin

2)jday - computed from time in seconds and start time of PSTAR input file.

4)temp - first add a fraction of raw deltata, controlled by the cal1 entry on the deltata line
temp -> temp + deltata_{raw} * cal then use a polynomial expression.

3)deltata - for output, this is scaled using the linear scaling from temp.

4)fast_t - (Mk V sensor) polynomial

5)press_t - (Mk V sensor) A correction for addition to raw press counts is given by,

$$\text{press_t} = (\text{press_traw} - \text{cal5}) * (\text{cal4} + \text{pressraw} * \text{cal3} / \text{cal2})$$
 where pressraw is raw press counts. For output values, this is scaled using the linear correction for press, so that the values are equivalent to the correction to press in db.

6)press - polynomial. Corrections for temperature are made at user request. If MkIII, a lagged temperature is constructed and used. The time constant and coefficients for the correction are requested at run time. Lagged temp is constructed in the same way as for oxyfrac (qv), using a time constant supplied at run time. The CTD gives a lower pressure reading when it is colder. The correction is

$$\text{press} \rightarrow \text{press} - \text{PTSLOP} * (\text{lagtemp} - \text{PTORG})$$

If MkV, either use lagged temp as above, or the press_t correction may be used.

If requested, the upcast portion of the file (defined to be all data cycles occurring after the maximum raw pressure) will have a correction for differences between the upcast pressure calibration and the downcast calibration (eg hysteresis). The procedure for calculating the amount of this correction is described in the section on user options.

7)cond - polynomial. Corrections for T and P at user request. The correction coefficients may be taken as default values, entered at run time, or found in a file. The revised cond is

$$C * (1 + \text{CPSLOP} * (\text{press} - \text{CPORG}) + \text{CTSLOP} * (\text{temp} - \text{CTORG}))$$

8)salin - derived from press, temp and cond.

9)potemp - derived from press, temp, and salin

9)cond2 and salin2 - cond2 may exist if the CTD has dual conductivity sensors. cond2 and salin2 are treated in the same way as cond and salin. There is no potemp2. If cond is corrected for T and P, then so is cond2.

10) oxyc - polynomial

11) oxyt - polynomial

12) oxyfrac - computed from oxyc, press and a temperature (T) which may be a combination of oxyt, temp and a lagged temp.

$$\text{oxyfrac} = \text{oxyc} * \exp(\text{cal1} * T + \text{cal2} * \text{press})$$

If required a lagged temperature (OTLAG) will be constructed using a time constant of cal4 seconds. Then

$$T = (\text{cal3} * \text{temp}) + (\text{cal5} * \text{OLAGT}) + ((1 - \text{cal3} - \text{cal5}) * \text{oxyt})$$

The lagged temperature, OLAGT, is constructed by updating

each data cycle as follows:

$OTWT = [\exp(-1 / cal4)] ** \text{time interval}$

$OLAGT = OLAGT * OTWT + \text{temp} * (1 - OTWT)$

If time is absent, OLAGT is unchanged; if temp is absent, the last non absent temperature is used.

13) oxygen - computed from oxyfrac and subroutine OXYSAT. There is no need for an oxygen line in the cal file.

14) fluor/fvolts - the input variable fluor is calibrated using the polynomial coefficients for variable fvolts, and output to fvolts. If fvolts is missing from the cal file, the data will be unchanged. Output fluor is then calculated from fvolts using the following exponential calibration, where the cal values are the fluor coefficients in the cal file:

$\text{fluor} = \exp(cal1 * cal3 * \text{fvolts} + cal2) + cal4$

15) trans - firstly, a polynomial calibration.

Note that the raw deck offset needs to be appropriately scaled to give a value for cal2. For example, on the MkIII, the appropriate scaling is 0.02.

Next, if the user has requested it, the values are corrected for the ageing of the light source by comparing the maximum clear air deck volts with the manufacturer's calibration. For convenience, these coefficients are read in from the potran line of the cal file. Thus:

$\text{trans} \rightarrow \text{trans} * cal3 * cal2 / cal1$

Here, cal3 is the manufacturers water correction and cal2 is the voltage a water cal in air at the time the manufacturer's cal was performed (eg of 1.0032 when the air cal was 4.355 volts); cal1 is the observed deck value on the ship (eg 4.34 volts) and will be requested at run time if set to zero in the cal file.

Finally, if potential transmittance and attenuation have been requested, these are computed. Note that these latter calculations include a correction for the refractive index of seawater, but that the output trans data have not had the correction made.

16) light - polynomial calibration

17) bottle - this is a flag that is supposed to indicate rosette bottle closure. It can safely be omitted from the cal file. The values will be copied across unchanged.

THE CALIBRATION FILE

The calibration file consists of a series of entries, one line per variable. Comments or blank lines have a colon ':' in the first column. The variable name forms the first eight characters of the line. The remainder of the line contains six blank delimited numbers, which are used as calibration coefficients; the default values for all variable names except potran are 1,0,1,0,0,0; potran and deltat default to all zeros. In general, the first number is a scaling used to convert raw

data to approximate engineering values (eg 0.0005 converts MkIII raw temperature to degrees), and the remaining numbers are coefficients in a polynomial calibration equation, starting with the offset, followed by the linear coefficient. Variables with, for example, exponential calibrations, are described individually below. The contents of the calibration file are written into the comment field of the data header, for future reference. Sample cal files

Sample cal files are given for MkIII and MkV CTDs. At present, no variables take values other than zero in position cal6, and that column may be safely omitted. The entries in the cal file are copied into the comment field of the PSTAR header. The comment field will be more readable if zeros are entered in the :sample cal file : this one is for Mk III CTD

```
temp      .0005  -0.01177  0.998595  0.  0.  0.
deltat    .15    0.      0.      0.  0.  0.
press     .1     -3.5     0.998977  0.  0.  0.
cond      .001   0.      0.99262  0.  0  0.
oxyc      .001   0.      1.2      0.  0.  0.
oxyt      .128   0.      1.       0.  0.  0.
:oxyfrac  -.046   0.000159  0.4     300. 0.6 0.
oxyfrac   -.046   0.000159  0.4     0.  0.  0.
fvolts    .001   0.      1.       0.  0.  0.
fluor     1.     -3.7     4.14    0.  0.  0.
trans     .001   -0.34    20.0000  0.  0.  0.
potran    4.33    4.355    1.0032  0.  0.  0.
```

:sample MkV calibration file

```
temp      .000001  -3.815946  38.15206  0.85310 0.      0.
deltat    .22     0.      0.      0.      0.      0.
fast_t    .000001  -6.883215  41.28104  -9.12208 6.735865 0.
press_t   1.      984624.83  0.027450  0.011658 3160.939 0.
press     .000001  -335.0183  7360.261  -0.56341 2.327870 0.
cond      .000001  0.019362  75.13750  0.03896 0.      0.
oxyc      .0001   -0.975    3.65    -0.02513 0.      0.
oxyt      .1     -7.096787  1.916104 -0.01596 0.      0.
:oxyfrac  -.022    0.000135  0.4     300.    0.6  0.
oxyfrac   -.022    0.000135  0.4     0.      0.      0.
trans     .0001   -10.14838  12.46214 -0.10487 0.      0.
potran    4.33    4.355    1.0032  0.      0.      0.
```

PRESSURE HYSTERESIS CORRECTION FILE.

A sample file is as follows:

0	0
500	6.3
1000	6.0
1500	5.6
2000	4.8
2500	3.4
3000	3.0
3500	2.4
4000	1.8
4500	1.2
5000	1.0
5500	0.0

The first line (12 in this example) is the number of lines in the rest of the file. The remaining lines consist of (pressure correction) pairs, read in in free format, giving the amount to be subtracted from the pressure on the upcast. Linear interpolation is used between levels defined in the table. Also, the correction is automatically adjusted so that it is zero at maximum pressure for casts to less than 5500 dbar. For example, on a 3000m cast, the correction at 1250 dbar would be:

$$5.8 - 3.0 * 1250/3000$$

and

$$p \rightarrow p - 4.55$$

