CRUISE REPORT

HUDSON 92053

NORTH ATLANTIC

A Contribution to the North Atlantic Tracer Release Experiment - NATRE

APRIL 5 - MAY 14, 1993

A. CRUISE NARRATIVE

1. Highlights

Cruise Designation: 92053

Ship: C.S.S. Hudson

Agency: Bedford Institute of Oceanography
Box 1006
Dartmouth N.S. B2Y-4A2
Canada

Chief Scientist: Neil S. Oakey

Fax 902 426 3147
Omnet Bedford.inst
Internet neil@oakey.bio.dfo.ca

Ports of Call: Halifax, N.S. Canada; Las Palmos, Canary Islands; Halifax, N.S. Canada

Dates: 5 April, 1993 to 14 May, 1993

Survey Area: Canary Basin near (26^{o}N, 31^{o}W)

2. Cruise Summary Information

2.1Station Positions

The cruise track is shown in Figure 1.1. The positions of the observations, ie. CTD stations, CTD plus rosette water samples stations, biological stations etc. are shown in Figure 1.2. The biological sampling took place during the entire cruise.

2.2Sampling Accomplished

At the 46 Fast CTD tracer stations a Seabird CTD was used to obtain temperature, salinity and dissolved oxygen profiles to a depth of about 350 meters. Two rosette bottles were fired at each of these positions for analyses of salinity, dissolved oxygen, nutrients and total carbonate.

At the 65 Full CTD tracer stations a Seabird CTD was used to obtain temperature, salinity and dissolved oxygen profiles to a depth of about 500 to 700 meters. Twenty rosette bottles were fired at each of these positions for analyses of salinity, dissolved oxygen, nutrients and total carbonate.

45 Biology casts, both shallow and deep casts were performed.

66 ESPONDE profiler stations were occupied. Nearly 1000 profiles were obtained with the vertical microstructure profiler.

2 ALFOS floats were deployed. Floats #76 and #72 were deployed.

3 Cartesian diver deployments

3. List of Principal Investigators for All Measurements

Name	Responsibility	Affiliation
Neil S. Oakey neil@oakey.bio.dfo.ca	Chief Scientist, Microstructure Studies	BIO
James Ledwell ledwell@tracer.whoi.edu	Tracer Sampling	WHOI
Tim Duda timd@salsa.whoi.edu	Cartesian Diver Profiling	WHOI
Barry Ruddick barry@phys.ocean.dal.ca	Microstructure Studies	Dal U.
Rolf Lueck rolf@george.seaor.uvic.ca	TAMI	U. Vic
Glen Harrison g_harrison@bionet.bio.dfo.ca	Carbon, Nitrogen Uptake Kinetics	BIO
Edward Horne user@bodvax.bio.dfo.ca	Optical Measurements, Salinity	BIO
Paul Kepkay p_kepkay@bionet.bio.dfo.ca	Dissolved Organic Carbon	BIO
Brian Irwin b_irwin@bionet.bio.dfo.ca	Total Carbon Dioxide, Nutrients, Oxygen	BIO

Institute Abbreviations and Addresses

BIO	Bedford Institute of Oceanography Box 1006 Dartmouth, N.S., B2Y4A2, Canada
WHOI	Woods Hole Oceanographic Institute Woods Hole, MA, 02543 USA
Dal.U.	Dalhousie University Halifax, N.S., Canada
U. Vic	University of Victoria Victoria, B.C., Canada

4. Scientific Programme and Methods

4.1Purpose of Mission

The North Atlantic Tracer Release Experiment, NATRE, is a contribution to the core 3 WOCE study. The Hudson voyage to the eastern Atlantic Basin had as one primary purpose the measurement of vertical mixing processes from the study of the vertical spread of a purposeful tracer by J. Ledwell of WHOI. The second primary purpose was the physical estimates of mixing made using the vertical profiling instrument EPSONDE and other instruments including a free floating profiler called the Cartesian diver and a microstructure mooring. Secondary to the NATRE studies biological studies of carbon and nitrogen uptake, dissolved organic carbon, primary

production, total CO_2, and optical studies were carried out by scientists of Biological Sciences Division who continued their studies in a follow on experiment.

It should be noted that the current Hudson voyage was a continuation of the study started on the Woods Hole Vessel, the R/V Oceanus from 26 October to 19 November, 1992 on which Oakey was chief Scientist.

4.2Summary of Mission Along with Comparison with a Previous Cruise

The North Atlantic Tracer Release Experiment, NATRE, is a study of the rate of mixing in the eastern Atlantic carried out by a group of scientists from the United States, the United Kingdom and Canada as a part of the international WOCE Core Project 3 study. Diapycnal mixing is integral to the dynamics of ocean circulation; the temperature and salinity of water masses are altered by diapycnal mixing, and this affects the pole ward transport of heat by the circulation. Knowing the magnitude and the mechanisms causing mixing is important to developing better models of ocean circulation. NATRE was planned as part of WOCE Core Project 3 to be the first direct measurement of the diapycnal mixing rate in the main thermocline of any ocean basin. The essence of this experiment was to release a chemically inert, easily measurable tracer on a target isopycnal surface, and to measure the subsequent tracer dispersion over the following year.

Observations of turbulence and microstructure were part of the tracer experiment in order to understand the mixing processes that occur. This understanding is needed so that the results for the tracer can be applied appropriately and confidently to heat, salt, and density, and extrapolated from the experimental sites to the global ocean. NATRE provided an outstanding and unique opportunity to test the concepts, models and methodologies presently used to study mixing, and to refine them further, by comparison with direct measurements of diapycnal spreading rates of a tracer.

The NATRE experiment started in the spring of 1992 when Dr. Jim Ledwell and his group from WHOI on the R/V Oceanus injected 139 kg of sulpher hexafluoride at a depth of approximately 300 meters in an area of about 20x20 km in the Canary Basin. This patch of tracer diffused vertically and moved horizontally over the months to follow and various surveys explored this evolution, allowing us to deduce the rate of mixing or the vertical diffusivity in this region of the ocean. In the month after the injection Ledwell and Dr. Andy Watson from the UK explored the initial distribution from the UK ship the RRS Darwin. The patch had increased to about 50 km across and had thickened vertically consistent with a vertical diffusivity of order 10^{-5} m^2/s. In October through November, Ledwell and Watson explored the evolution of the dye patch during two cruises on the R/V Oceanus. They found about 35% of the original tracer in a narrow (10 to 20 km wide) band about 350 km long. Their measurements in the vertical yielded a vertical diffusivity of $1.1x10^{-5}$ m^2/s. During the second of these cruises Oakey and his group joined the R/V Oceanus and surveyed the area using EPSONDE, a vertically profiling microstructure instrument. A report of this experiment is included at the end of this report on the Hudson 92053 voyage.

The final surveys of the NATRE study were done in the spring of 1993 using the CSS Hudson (cruise 92053) and the RRS Darwin. Along with its other studies, the CSS Hudson gathered water samples using a CTD with a rosette sampler for analysis by Ledwell and his group from WHOI. About 115 CTD tracer stations were done to delineate the extent of the tracers horizontal dispersion including about 60 full profiles to examine the vertical diffusion of the tracer. The RRS Darwin, devoted only to the tracer studies obtained over 160 full tracer profiles. It is estimated that all of the tracer released in the spring of 1992 has been accounted in the survey a year later and that the tracer can be found spread over an area of about 500 km by 700 km and has increased in thickness due to vertical mixing from a few meters to about 30 meters. These measurements are consistent with the above estimates of vertical mixing but indicate that the rates

over the winter were higher than during the summer, about 1.8×10^{-5} m^2/s.

The largest program carried out on the April-May Hudson 92053 survey was an extensive set of microstructure and turbulence measurements. Nearly 1000 profiles to greater than 360 meters depth were obtained with the vertical microstructure profiler, EPSONDE. These measurements will be used along with the 825 profiles last November on the R/V Oceanus to estimate vertical mixing rates and explore the mechanisms which are important in the vertical dispersion of dye. These mixing studies are part of the WOCE NSERC collaboration between Oakey and Dr. B. Ruddick of Dalhousie. This is the largest set of data collected with this instrument and represents nearly 700 km of sampling of the fluctuations of temperature and velocity fluctuations in the ocean sampled at about 3 mm intervals, about 3 gigabytes of data! The challenge is whether we get the correct answer which has been obtained from the tracer studies. Preliminary results indicate that our results are consistent.

Other studies were done on Hudson 92053 as well. A group from the University of Victoria led by Dr. R. Lueck deployed and recovered a mooring designed to measure the intensity of mixing at a fixed site over a period of several weeks using a variety of microscale and larger scale sensors. Several deployments of an instrument called a Cartesian Diver were also carried out successfully. This instrument floated freely measuring vertical profiles of velocity and microstructure from which mixing processes can be explored.

To take advantage of the transit to the eastern Atlantic scientists from Biological Oceanography, BSB participated in the survey with extensive biological studies. They continued their experiment in the following experiment.

The ship left Halifax on Monday, 5 April, 1993 en route to the position 32°16'N, 34°08'W where a surface mooring buoy which had broken from a Scripps/WHOI mooring was recovered. Tracer surveys were started south from here to approximately 25°30'N, 34°08'W then east to near the site of a mooring central to the experiment at 25°30'N, 29°W. The ship track is shown in Figure 1. A mooring was placed in this region by the group from University of Victoria headed by Lueck, the first deployment of the Cartesian diver was done and coordinated tracer and EPSONDE surveys started. These continued until 18 April when the program was interrupted by a medical emergency that required taking the Chief Mate to Las Palmos. We returned to the site of the experiment on 23 April and continued sampling until the end of the study on 12 May allowing time for the transit to Las Palmos where the expedition terminated on May 14, 1993.

5. Major Problems and Goals Not Achieved

None

6. Other Incidents of Note

None

7. List of Cruise Participants

Name	Responsibility	Affiliation
Neil S. Oakey	Chief Scientist, Microstructure Studies	BIO
James Ledwell	PI, Tracer Sampling	WHOI
Gary Stanbrough	Technician, Tracers	WHOI
Brian Guest	Technician, Tracers	WHOI
Tim Duda	Cartesian Diver Profiling	WHOI
Barry Ruddick	Microstructure Studies	Dal U.
Dave Walsh	Post Doc, Microstructure	Dal U.
James Burke	Student, Microstructure	Dal U.
Nauzer Kalyaniwalla	Student, Microstructure	Dal U.
Rolf Lueck	PI, TAMI	U. Vic
Rick Hudson	Engineer, TAMI	U. Vic
Don Newman	Engineer, TAMI	U. Vic
Robert Ryan	Technician, Microstructure	BIO
Jennifer Hackett	Technician, Microstructure	BIO
Liam Petrie	Technician, Microstructure	BIO
Edward Verge	Technician, Microstructure	BIO
Glen Harrison	PI, Carbon/Nitrogen Uptake Kinetics	BIO
Edward Horne	PI, Optical Measurements	BIO
Brian Fraser	Technician, Optical Measurements	BIO
Paul Kepkay	PI, Dissolved Organic Carbon	BIO
Brian Irwin	PI, Total Carbon Dioxide	BIO

B. UNDERWAY MEASUREMENTS

1. Navigation

On the VAX, navigation was logged using *NMEA_NAV*. Information from the current navigation file was displayed on a VT220 terminal next to the logger PC using the *SUMMARY* command. Times and Positions were hand entered into the Seabird header from the *SUMMARY* display.

The *NMEA_NAV* logging was broken almost daily using Calendar Day as the station number.

2. Ship Meteorological Observations

Routine reporting of meteorological variables was carried out by the ship's crew.

C. HYDROGRAPHIC MEASUREMENTS - DESCRIPTIONS, TECHNIQUES AND CALIBRATIONS

In the sections to follow are outlined the specific projects of the study. A complete list of stations, times and positions is included in the event log for the experiment at the end of the report (Appendix 1).

1. EPSONDE Microstructure Studies

Neil Oakey and Barry Ruddick

Microstructure measurements were made throughout the experiment using EPSONDE as shown in the track charts and as summarized in the eventlog for the experiment. The forward lab was used as the centre for this operation with computers for data logging and data analysis and display and a test bench set up for instrument maintenance and preparation. The winch and capstan were set up on the foredeck and the instrument was deployed from the starboard side. EPSONDE is a tethered free-fall instrument about 2.5 meters long with a self contained CTD and microstructure sensors on stings at the leading end of the instrument. It is deployed on a light tether line which is fed into the water using a capstan which is mounted on the rail of the ship. This tether is kept loose so that the instrument falls freely at a speed of about 1 meter per second until the required final depth of deployment is reached at which time the instrument is pulled back to the surface by the tether line. The operation is then repeated many times at each site to get a statistical picture of the mixing at that place and time. As many as twenty-five profiles were done at each site.

Data are transmitted to the ship via conductors in the tether cable and are recorded on board using a special interface card in a PC computer. The data were recorded on an XT computer and at the end of a series of profiles (or burst) data were transferred to a PC-486 computer for analysis and archiving. The operation was done with one person at the deck unit computer logging data and monitoring the progress of the EPSONDE profiler and another person on deck deploying the instrument and paying out the tether line with a person from the ship's crew operating the EPSONDE winch. This operation went on around the clock on a watch system of 4 hours on 8 off. Maintenance and instrument preparation were done by Neil Oakey as required so that there was always an instrument charged and ready for deployment. Data from this cruise were evaluated after acquisition and data from the previous cruise were analyzed by Jim Burke and Dave Walsh. Burke was responsible for data backups.

The computer set-up was the same as for the previous Oceanus experiment (described at the end of this report). It consisted of one XT-Computer used as a deck unit, two PC-486 computers used as data analysis and archiving computers and a PC-386 used for operations like keeping the event log up to date. All computers were linked using thin-line ethernet cards and a local net connecting all four computers. The were linked using the package NCSA. The system worked without fault throughout the experiment. Backup was accomplished using an exabyte tape unit attached to the PC-486. The two PC-486 computers were configured nearly identically, both with exabyte tapes, for operational redundancy. Logging redundancy was

accomplished by having extra deck unit cards that would work in any of the PC computers and in fact one was installed in one of the PC-486 computers so that it could be used during calibrations and instrument tests and setup.

Two profiling instruments were used, EPSONDE and ELITESONDE. The EPSONDE(2) is the 14 bit instrument which has been used for several experiments. It was tidied up and calibrated carefully prior to the experiment and during the study a fairly complete test bench was set up in the Hudson forward lab for repairs and calibrations as well as routine maintenance and sensor changes. ELITESONDE was rebuilt before the Oceanus cruise by building a new A/D card and rewiring the instrument. It was used inter-changeably with EPSONDE but was treated mainly as a spare instrument. Both instruments appeared to work well during the study but there is concern that there may be some noise problems with the forward sensor guard and with the calibration of the CTD sensors.

The cable handling system consisting of winch, cable, sheave block and capstan worked almost flawlessly during the cruise. Both the winch and capstan were fully reconditioned before the experiment because of minor problems near the end of the Oceanus study. New motors and drive belts were purchased for both winch and capstan. The drive motor for the winch was rebuilt and re-installed with the new motor prepared for replacement if necessary and stored in the main winch housing in that eventuality. A new motor was installed in the capstan and the old motor rebuilt as a spare. Extra spare belts and parts that had shown wear previously were purchased and put in the spares box. The sheave block which was built for the previous cruise caused no problems. Three cable lengths were prepared for the experiment by doing both a mechanical and electrical splice and installing them on the inter-changeable winch drums. A third older cable was prepared and placed on a wooden spool if required. No problems were experienced with the cables but the second cable was installed after about 500 profiles as a precaution since the breaking strength of Kevlar cables decreases with use.

A new data analysis package was completed near the beginning of the experiment. It included a package that did FFT spectral analysis, a program written by Oakey in Turbo Pascal. A subsequent package to do spectral corrections, noise and spike removal was finalized for use on a PC486 from the old program AUTOALL written by Oakey for the Cyber (in Fortran). A data editing program was written by Burke and the package was implemented on the PC-DOS environment using batch files and an hierarchical directory structure. It seemed to perform quite well allowing one to process a profile of data completely in about the same time as it took to gather the data.

Over the experiment 66 sites were occupied with EPSONDE microstructure profiles with many profiles at each site. As shown in the event log for the study at the end of the report about 975 profiles to a depth of over 350 meters was achieved. Only a portion of these data were analyzed on the cruise to confirm that the instrument was functioning properly. However, much of the data from the previous cruise was analyzed.

2. Tracer Sampling J. Ledwell

At the heart of the North Atlantic Tracer Release Experiment is the release and subsequent sampling of a patch of tracer in the pycnocline. Approximately 140 kg of sulphur hexaflouride had been released in May 1992 on an isopycnal surface about 310 meters deep at around 25°40'W, 28°15'W, in a region about 15 miles on a side. The initial distribution was sampled in May 1992, and again in the fall of 1992. The lateral distribution was extremely streaky for these cruises, but well measured, and yielded an accurate estimate of the amount of vertical mixing that had occurred over the summer of 1992.

Sampling during the present cruise was a 2-ship operation, involving the RRS Darwin as well as the CSS Hudson. The role of Hudson was to scout the patch as she arrived at the site, and then later to perform high resolution sampling. The Darwin, which arrived a little later, executed a large scale survey, guided by the information from Hudson.

James Ledwell, Gary Stanbrough, and Brian Guest, from Woods Hole Oceanographic Institution, were on board Hudson to analyze water samples for tracer concentration. A gas chromatograph, equipped with an electron capture detector, was set up in the Geochemistry Lab for this purpose. Water samples were taken in 500-ml bottles from the Rosette bottles in the CTD room and brought below for analysis.

The search for the tracer started in earnest at 27°08'W, 33°55'W on April 13, with a southward line of fast CTD casts to the target density surface, spaced every 7 miles. The track turned eastward at 25°30'N, 33°55'W, stopping at 29°00'W on 15 April. Most of these casts sampled only at the target surface, but on a few of them, a full cast of 20 bottles, spread over 190m. were tripped to yield a vertical profile.

The results of this L-shaped cast were very rewarding. Tracer was found on all but 4 of the casts, in concentrations ranging from 1 to 100 fM(1 fM = 10 mol/L), and averaging about 50 fM. Thus, although the distribution was still inhomogeneous, the edges of the streaks had apparently begun to merge with one another over a broad area. The lateral scale of the variations was about 10 miles - not much greater than the sampling spacing. The important practical result was that the tracer was far easier to sample than it had been the previous fall.

The area covered by the tracer patch could be estimated from the mean concentration and the vertical thickness found on this initial track. The resulting estimate was about 5 x 10 km, ie a region 400 mi on a side. The strategy adopted was to sample diverse parts of the patch well, rather than to try to sample the entire patch with a coarse grid. To that end, Hudson sampled at coarse spacing, with tracer profiling interspersed with EPSONDE profiling.

Six clusters of stations were occupied in the subsequent weeks, as shown on the chart, with around 10 vertical profiles taken in each cluster. Individual profiles within a cluster vary

considerably in shape and in mean concentration, yet most are peaked within 20 m of the target surface, and fall to background levels at 100 m above and below the target surface. The mean of each cluster produces a fairly smooth, simply peaked curve centred within a few meters of the target surface, with an rms width of around 30 m. This width, once properly calibrated and set within the context of the density gradient, will yield an estimate of the vertical mixing. Preliminary indication are that the vertical, or "diapycnal" diffusivity was greater during the winter of 1993 than the value of 0.11 cm /S inferred for the summer of 1992, but not by more than a factor of 2 or so.

3. CTD Computer Report

3.1 CTD Calibrations

The latest CTD calibration coefficients were entered into two *.CON* files after the cruise began. The files were *NATRE_1* for CTD System #1 and *NATRE_2* for CTD System #2. CTD System #1 was used during the whole cruise (165 stations).

On Station 16 a conductivity offset of 0.00050 was applied to correct the salinity and remained in effect till Station 165.

3.2 SEABIRD Logging

The CTD data logging and data processing were carried out using the Seabird Data Acquisition Software (Seasoft Version 4.001) on the main 486 (PC1). In general this was an easy system to run. It has only a few "windows of opportunity" for human error.

Here are the known problems for this cruise:

- Station 6 was a very small *.DAT* file. The data was only logged for every 36 scans. Processing produced a large number of null data values. It is uncertain how "the number of scans to be processed" became changed.

- Station 12 *.DAT* file had zero bytes in it at the end of logging. It is suspected that the CTD Deck Unit was not turned on prior to the beginning of logging and the logging programs did not store the data when the error message came up "<Instrument is not listening>".

- Station 92 has *.ROS* and *.BTL* files but the *.DAT* file was missing. It is uncertain if this file was deleted because the "<Instrument is not listening>", or if it happened during the aborted processing procedure. Logic might tell you that it was during the

latter.

Two types of stations were logged:

- Biological casts were logged using only the plots displayed on the PC screen. Plots were of Temperature, Fluorescence, and Absolute Light (PAR) vs. Pressure. No hard copy plots were printed.

- NATRE casts were logged using both: plots displayed on the PC screen, and real-time data logged to an XT100 terminal. Plots were of Temperature, Salinity, and Oxygen vs. Pressure. No hard copy plots were printed. The XT100 terminal was directly hooked to a serial port on the PC. The Seabird option to output real-time data to an external was used. Several variables were selected (including density). They were logged to the XT100 at a reduced sampling interval.

3.3 VAX Logging

On the VAX, navigation was logged using *NMEA_NAV*. Information from the current navigation file was displayed on a VT220 terminal next to the logger PC using the *SUMMARY* command. Times and Positions were hand entered into the Seabird header from the *SUMMARY* display.

The *NMEA_NAV* logging was broken almost daily using Calendar Day as the station number.

3.4 SEABIRD Processing

(**NOTE:** See Appendix 2 for a description of the reprocessing performed on this dataset.)

Processing of the data was done by invoking a batch file which ran two sets of routines. The two sets of routines consisted of the pre-packaged set of Seabird software and the "System's Group" software. The *PROCESS.BAT* file was run after logging each station. It took an average of 20 to 40 minutes to complete! It was curious that the processing took so long to complete. It is possible that the *FTP* connection with the VAX was responsible for the delay. A total of 8 files per station were created and *FTP*'d over to the VAX automatically.

The 8 files were:

- *.CON* file of configurations.

  [NOTE: Two basic configurations were used: *NATRE_1* with 13 channels for Physical Oceanography casts *EPWH_1* with 17 channels for Biological casts.]

- *.HDR* file (ASCII)
- *.DAT* file (ASCII header with BINARY data for DN and UP)
- *.ROS* file (rosette stops for UP only)
- *.BTL* file (processed *.ROS* for UP only)
- *.QAT* file (processed knowing blank rosettes for UP only)
- *.ODF* file (1 dbar data with ODF header for DN only)
- *.1DBAR* file (1 dbar for DN only)

There were a few hitches in processing when the wrong calibration file was used (*NATRE_1* or *EPWH_1*). There were 2 different symptoms:

1 - The PC processing would hang the system when the *ROSSUM* program was running and it would have to be rebooted.

Remedy : *DATCNV* had to be run interactively and the configuration file changed to the proper one.

2 - Other times the processing ran to completion, but the *DATCNV* would create huge *.ROS* files.

Remedy : Same as above

[In retrospect, I didn't take note whether these 2 symptoms were with the same configuration file or not.]

There were also a few hitches because the "System's Group" software was very unforgiving. There were two different problems:

1 - The *SEAODF* program would hang if the sounding had not been entered in the header, or if the sounding was entered as "4000M" with no space between the numeral and the "M". It would be advisable to not include the "M" in the field.

2 - The *SEAODF* program would run but did not create a *.QAT* file if the longitude was not entered in the header without the proper number of blanks. (IE. "N 56 35.500")

Remedy : The processing had to be split into two parts :

1) Processed up to *TRANS* which created the final ASCII data. Then the header in *.CNV* had to be edited.

2) Then the rest of the processing was completed.

3.5 VAX Processing

Temperature and Salinity Profiles and Temperature/Salinity curves were plotted on the LXY printer for each station.

An IGOSS file *[DATA.IGOSS]92050_IGOSS.DTA* was created for all 165 stations.

Two types of ASCII files were created using the PCSPIP software on the VAX and then transferred to floppies for various scientists:

- *D053A***.ASCII* files were created from *D053A***.ODF* files.
- *SMP4***.BOT* files were created from *053A***.BOT* files.

One problem had to be overcome in order to complete any of the VAX processing tasks:

1 - The *.ODF* files were not able to be read by the PCSPIP software. The number of characters in the PROCESS records of the *.ODF* files exceeded the limits of the program.

Remedy : To get *READ_ASCII_HEADERS.MPAS* to work properly, one line had to be edited in: Procedure_Read_ASCII_Headers_Reset

comment: %STRING[dm_test_len2]

and 2 lines had to be added in: *PCSPEN:ODF.MPID*

```
DM_TEXT_LEN3   =   8200      {* >105 lines of text *}
.
.
.
dm_text3   =   packed array [1..DM_TEXT_LEN3] of char;
```

And 1 line had to be changed in: *READ_ASCII_HEADERS.MPAS*

```
COMMENTS    =    [DM_TEXT_LEN3]
```

3.6 Chemistry Processing

Salinities

Conductivities were entered on the alternate 486 PC (PC2). 134 salinities were calculated using the Chemistry software *SALINITY.EXE* from Peter Strain. From these data the conductivity offset of 0.00050 was determined on Station 16 and applied.
[NOTE : The offset had to be applied to conductivity as Seabird does not have an option to apply one to salinity.]

Thermometers

Two digital thermometers were read by one person for stations 1,2,3,4,6,7,8,9,10 and 18 at the beginning of the cruise. None of this data was entered either on the PC or the VAX. Serial numbers used were 000T348 and 000T354.
From these data there was no offset necessary.

Oxygens

Oxygens from the *CYBER.DTA* file were compared with the oxygens in the *D053A00*.ASCII* files from the VAX *[.DATA.SEABIRD]* directory.
The difference was then plotted against pressure using *QUATTRO*. From these data there appeared to be a constant slope with pressure.

3.7 Backups

Double BACKUPS were created as follows :

044351	VHS	PCSLIB (USER BACKUP) Pre-Cruise 92053 (1)
044352	VHS	PCSLIB (USER BACKUP) Pre-Cruise 92053 (2)
044353	VHS	DUA1 (DATA BACKUP) 11 April 1993 (1)
044354	VHS	DUA1 (DATA BACKUP) 13 April 1993 (2)
044355	VHS	DUA1 (DATA BACKUP) 16 April 1993 (1)
044356	VHS	DUA1 (DATA BACKUP) 16 April 1993 (2)
044357	VHS	DUA1 (DATA BACKUP) 26 April 1993 (1)
044358	VHS	DUA1 (DATA BACKUP) 27 April 1993 (2)
044359	VHS	DUA0:PCSLIB (USER BACKUP) 27 April 1993 (1)
044360	VHS	DUA0:PCSLIB (USER BACKUP) 27 April 1993 (2)
044361	VHS	DUA1 (DATA BACKUP) 7 May 1993 (1)
044362	VHS	Bad Tape
044363	VHS	DUA1 (DATA BACKUP) 7 May 1993 (2)
044364	VHS	QIO Errors
044365	VHS	QIO Errors

044366	VHS	DUA1 (DATA BACKUP) 13 MAY 1993	(1)
044367	VHS	DUA1 (DATA BACKUP) 13 MAY 1993	(2)
044368	VHS	DUA0 (DATA BACKUP) 13 MAY 1993	(1)
044369	VHS	not used	
044370	VHS	not used	

There were some problems encountered during backups:

1 - Many times during backing up the data QIO errors resulted (Quota I/O). The only method which seemed to correct this was to delete a number of previously backed up files, thereby reducing the number of files being backed up. It is possible that this error could have been averted if the SYSTEM account had been used instead of the CRUISE account, but this was not tested.

2 - The EXABYTE tape drive hung during an INITIALIZE on the 15 April 1993. The VAX was rebooted and PCSLIB was reconfigured. However the background process RUN_TIME_STAMP which creates the TIME_STAMP.DAT file every 10 seconds was not restarted. SYNCTIME was run every week or so on the PC, it reset the PC time back to the reboot time. Subsequently the times and dates stored in the headers of Stations 76 through 131 are wrong.

4. Cartesian Diver Profiling

Timothy F. Duda

Collection of velocity, density, and microstructure profiles with the Cartesian Diver autonomous instrument was supported by NSF (USA), and ship time was graciously provided by Neil Oakey and Jim Ledwell. The instrument was prepared at Scripps Institution of Oceanography by my collaborators David Jacobs and Charles Cox. The Diver was launched and recovered three times at three separate locations.

The Diver is nearly neutrally buoyant and has a mechanism to actively control buoyancy. An electric motor drives a piston in a 400 ml chamber, providing 200 g of negative buoyancy when flooded and 200 g of buoyancy when flushed. A 200 ml exterior gas volume gives the Diver the compressibility it needs to have stable buoyancy and prevent isobaric float (Swallow float) behaviour.

Profiles of horizontal velocity are measured electromagnetically. The Diver essentially moves horizontally with the local water velocity, due to high drag on 4 wings, and records its motion with respect to the geomagnetic field. Vertical water velocity is deduced with a high gain, highpass filtered pressure gauge and an angular accelerometer. Temperature and conductivity are recorded at 4 Hz (roughly every 3.5 cm vertically), and high gain, highpass filtered conductivity is sampled at 64 Hz.

4.1Deployment C

The first launch was near the site of the Subduction program central mooring, and was also near where we deployed the U. Victoria microstructure buoy, approximately 25°12'N, 29°00'W. This is denoted C because Natre datasets A and B were collected from R/V Oceanus in November 1992. Launch was after lunch on April 17, and we were to sample with the Rosette, and make microstructure and CTD casts in the general vicinity, until Diver timed surfacing and recovery at 09:00 UTC April 19. This would yield about 36 hours of data, or 24 round trips (48 profiles). On the 18th we unexpectedly left the area for Las Palmos, and did not return to pick up the Diver until the 23rd. The instrument was tracked by Argos while at the surface, and we had no trouble locating and recovering it.

It could have made many more profiles while we were away, almost 5 days worth, but so could we all have been working during that period. As planned, 48 velocity, density, and micro-conductivity profiles were obtained between 100 meters and 450 meters depth at this site.

4.2Deployment D

After Diver recovery we moved to the second microstructure survey area, near 27°N, 31°W. The Diver was launched again in the afternoon on April 24, less than 24 hours after recovery. It was set to surface at 09:00 UTC on the 26th. After the morning CTD casts (26th) we moved toward the Diver location, heard the radio beacon, and recovered at 11:35 UTC.

The instrument did not sink immediately after launch at the profiling velocity of 14 cm/s, but remained near the surface. This can be caused by trapped air bubbles. After the initial delay, 28 round trips (56 profiles) were made in 1.67 days.

4.3Deployment E

The Diver was not deployed at the third microstructure site, 26°30'N, 33°00'W, but was checked out and recharged fully. It was deployed at the beginning of an SF transect and programmed to profile for 3 days. During launch on the afternoon of the 29th, the quick-release hook opened prematurely and the Diver fell 10 to 15 feet into the sea, breaking off one electromagnetic measurement wing. Since it was temporarily buoyant, we made two attempts to retrieve it before it degassed and began profiling, but failed to hook it. One of the 3 seals on the lower (buoyancy control) end of the Diver leaked slightly. The leak was detected and the instrument buoyed itself to the surface in the early morning of the 30th. It was recovered at 20:00 UTC, May 2, after a 4.5 hr search.

The platinum thermometer failed during the first profile. The seawater in the pressure case compromised low-signal-level connections to the single usable electromagnetic channel. It is likely that only the microconductivity, conductivity, pressure, and vertical velocity data are good.

Although the damage sustained was repairable, with the exception of one mechanical safeguard which was ruined, the cause of the leak was unknown and the instrument was not used again.

4.4Data

Vertical shear profiles and vertical wavenumber spectra of shear appear to be slightly more energetic than their November counterparts. Three of the four (A,B,C) Natre datasets are very good, and D has slight velocity noise due to an improper wing arrangement. The calibration of the Diver conductivity probe was in error, and was recalibrated during the trip by comparison with T/S diagrams from the ship's CTD.

Drop Locations

Description	Latitude	Longitude	Time
C Deployment	25°11.52'N	29°03.77'W	17 Apr 15:49
First C Argos Fix	25°14.16'N	29°04.20'W	19 Apr 09:17
D Deployment	26°59.14'N	31°13.24'W	24 Apr 14:45
D Recovery	26°57.60'N	31°11.00'W	26 Apr 11:35
E Deployment	25°30.16'N	33°26.93'W	29 Apr 15:00
E Recovery	25°27.30'N	33°24.78'W	2 May 20:00

5. Report on the deployment and recovery of the Tethered Autonomous Microstructure Instrument (TAMI)

Rolf G. Lueck, Rick D. Hudson, Don E. Newman
Ocean Turbulence Laboratory, Centre for Earth & Ocean Sciences, University of Victoria, BC.

5.1The System

The TAMI was conceived as a means to obtain time-series microstructure data, using a moored platform, rather than the more conventional towed- or vertical-profiling methods. The microstructure sensors comprise an array of four shear probes and two fast (FP-07) thermistors, mounted horizontally in the nose of a pressure case. See attached figure. A tri-axial accelerometer array, located close to the nose sensors, a flux-gate compass, and a pressure sensor are built into the same pressure case, which houses a low-powered data logger developed at WHOI, and modified for this application.

The electronics package is built around an IBM-XT data bus (62 pin) operating under DOS. Ten card slots are available, and are filled with analog conditioning circuit boards, a main CPU board, a memory board, an I/O board, a 1 Mbyte RAM board, a frequency counter board, a 16-bit analog-to-digital converter board, and two unique cards that are switched on and off depending on requirement. These two are both high power, off-the-shelf cards; one is an AT&T DSP chip running at 50 MHz, while the other is a SCSI controller card that interfaces to a single-sided, 470 Mbyte optical disk drive, located in the same pressure case. Since both these cards consume considerable power, but are used only intermittently, they are powered up only when needed.

A second pressure case houses sufficient batteries for up to a year's deployment.

The two pressure cases are horizontally mounted in a hydrodynamically shaped 'fish' measuring about 5 metres in length, through which a 3 metre long mast stands vertically. The mast serves several purposes:

in order to quantify the overall flow, shear and boundary conditions, three pairs of conductivity and temperature sensors are mounted at the top and bottom of the mast, and amidships of the fish. Two small flow meters (of the impeller design) are attached forward of the mast, 60 cm above and below the fish, to provide a measure of integrated forward flow. The top of the mast is also used to carry a DF radio beacon, a xenon flasher, and an ARGOS location-only PTT transmitter. The bottom of the mast has 25 kg of lead shot to ensure the fish floats near vertically when on the surface, and to provide some righting moment when moored from the base of the mast.

5.2The Data Flow

Data are sampled for a period of 128 seconds every 5 minutes, with different sensors being recorded at varying rates from 1 Hz to 128 Hz, depending on requirement. The main CPU then hands approximately 500 Kbytes of data to the newly powered up DSP card, which performs a series of FFTs and cross-correlations, before handing back approximately 500 bytes of compressed data to the CPU, in about 11 seconds. These are stored in RAM, and the system powers down until the next 5-minute call.

Every 6 hours, the data in RAM are written to the optical disk, together with the latest block of unprocessed ('raw') data.

5.3The Mooring

In order to correlate with the NATRE experiment, it was decided to moor the TAMI at 300 metres WD, close to the central mooring. On the night of April 15th, a level area was surveyed at approximately 26N, 29W, and on the following morning, the fish was lowered into the water, connected via a 7m strop to a 56" diameter FTS syntactic foam mooring float which had a 1200 KHz RDI ADCP mounted vertically in it, looking upward; the plan being that the RDI would sample across the range 2 - 12 metres, thereby bracketing the TAMI above it. Sea state was 3 - 4.

Below the FTS float, a series of 500m lengths of 3/16" rubber-jacketed cable stretched approximately 5,300 metres to a Benthos deep-water pinger, a pair of Oceano acoustic releases, and an anchor. Eleven pairs of 17" glass floats in hardhats were deployed along the line, to ensure adequate lift in the event of the top floatation breaking free. Swivels were used, where necessary.

The 56" float had another use apart from (i) supplying low drag, high tension on the line, and (ii) housing the ADCP; there has been concern as to whether microturbulence measurements can be made successfully from a mooring, because of the noise likely to be introduced (line strumming, swivel and shackle chatter, upper mooring line surging and arc-sweeping). The FTS float, because of its effective mass, serves to de-couple the fish above from cable-induced vibration below.

The 1 tonne anchor was dropped using a BIO 3m x 3m drogue, and was logged at just under 2 m/s fall rate. Deployment began at 10:00 am, anchor drop was at 12:45pm, and the anchor was estimated to hit bottom at 13:35 pm (all times local ship time = GMT - 1 hour). A four-point ranging pattern determined the exact site as 25 26.95N, 29 07.17W, in 5,585 metres WD. Fall-back was 580 metres on a line of 5,320 metres.

5.4Recovery

The site was re-visited on May 9th, and one of the acoustic releases triggered at 8:30 am. Sea state was 1 - 2. Once on board, it was noted that the fish had suffered a number of heavy dents to its outside, although no sensors were damaged. Once the fish's side panels were removed, it was found that most of the 2" foam floats that packed the inner chamber, had imploded. That in itself was not a problem, as the fish has approximately 100 kg of positive buoyancy without the spare floats, and the additional lift is only a bonus. However, the jagged fiberglass edges of the broken floats had cut all but two of the internal cables running between remote sensors, batteries, and the main electronics case. Despite this, because of the unique redundant battery network, the system continued to operate using parallel systems.

Later inspection in the lab revealed that the optical disk cartridge had been ejected, due, almost certainly, to a heavy mechanical shock. Despite being isolated by no less than two separate rubber shock systems, plus an external foam buffer pad, the disk cartridge had released. By checking the contents of the disk, it was determined that this had occurred shortly after deployment, as the initial start-up data had logged successfully, but thereafter, there was nothing.

A small amount of water leaked into the main electronics case. Fortunately, it collected in a non-critical space, and did minimal damage, despite being there for almost a month. Inspection showed that it had penetrated a Seacon bulkhead connector and wicked up the wires, oozing out at the next connector in the line. What was surprising was that the connector was not in use (although powered up at times), and was capped with a well-greased dummy plug.

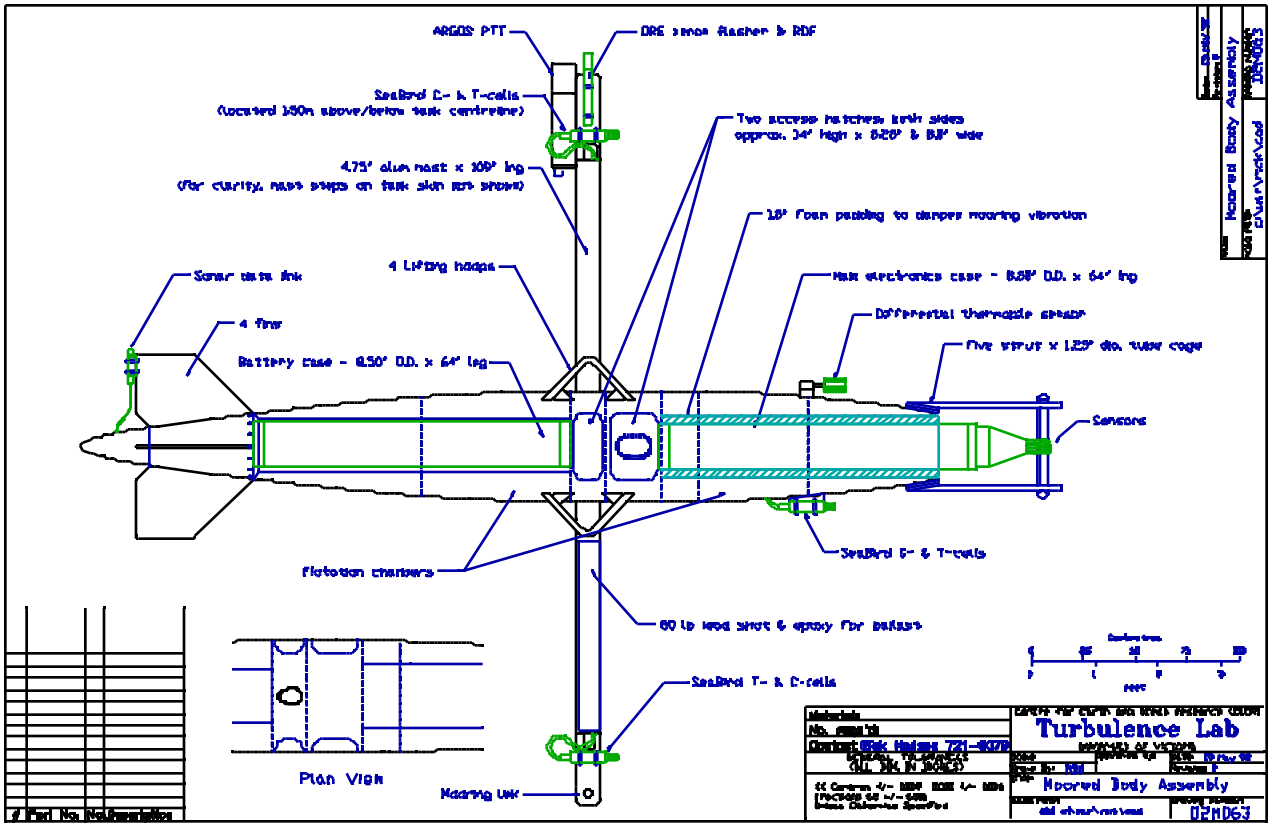
The modified shear probes developed for long-term deployment under pressure proved to have excellent durability. The three units used all retained resistances of over 300 G-ohms, when measured within 6 hours of recovery, while their capacities changed less than a few per cent from start to finish. In comparison, a conventional shear probe degraded from 250 G-ohm at the start, to 0.5 G-ohms on recovery.

5.5Conclusions

Modifications will be made to the method of mounting the pressure cases in the fish, to reduce shock and vibration effects (there are already 3 separate shock absorbing systems in place). The present 2" floats will be replaced with a more robust float which may offer less filling efficiency, but will not implode and cut cables. The mechanical release spring on the optical disk drive will be changed to a positive locking mechanism. The leaking cables and connector will be replaced.

5.6Acknowledgements

The financial support of Canada's NSERC and the United States' ONR and NSF are gratefully acknowledged. Field support for the CSS Hudson cruise is through DFO's Bedford Institute of Oceanography. In particular, the participation of the crew and staff of the CSS Hudson are sincerely appreciated.



6. Carbon and Nitrogen Uptake Kinetics G. Harrison

Stable isotope studies of carbon and nitrogen (nitrate and ammonium) utilization and nitrogen uptake kinetics were undertaken. The rate at which nitrate from the ocean interior is mixed into the euphotic zone is thought to be a principal regulator of 'new' primary production over vast areas of the world's oceans. The North Atlantic Tracer Release Experiment (NATRE) provided an excellent opportunity to investigate the link between small scale vertical mixing processes in the region of the nutricline and primary production (including phytoplankton nitrogen utilization rates) in the overlying waters. This work also represented a continuation of studies begun in 1989 and continued in 1990, 1991 and 1992 as one of the designated 'core measurements' of the

international Joint Global Ocean Flux Study (JGOFS). The objectives were to determine the concentrations of inorganic nitrogen (nitrate and ammonium) in the oceanic euphotic zone and nutricline and to quantify rates of nitrate and ammonium utilization by planktonic microorganisms. Additional experiments were performed to determine parameter values of the concentration -dependent uptake of nitrate and ammonium in the low nutrient environment of the open Atlantic.

This, to our knowledge, is among the first systematic attempts to measure uptake kinetics in nanomolar nutrient concentration waters. These parameter estimates should be of particular use to JGOFS modellers who, to date, have relied on out-dated parameter values of questionable relevance to open ocean conditions.

High resolution sampling (14 depths in the upper 200m) was used to characterize the inorganic nitrogen concentrations in the euphotic zone and upper nitricline; samples were also collected periodically in the 200-400m depth range to match the SF6 sampling. Nitrate concentrations were measured by two methods: the conventional colorimetric, automated method capable of measuring concentrations as low as ~100nM and the chemoluminescence method for 'low-level' nitrate determinations with detection limits of ~2nM. Ammonium was determined by manual colorimetric methods with detection limits of ~50nM. Low-level nitrate and ammonium concentrations were run on fresh samples; frozen samples were stored for conventional nutrient analyses which will be performed back at BIO. Carbon, nitrate and ammonium utilization rates from eight depths in the euphotic zone (to 130m) were determined using stable isotope tracer methods (13C and 15N). Isotopes were added near 'trace' concentrations (~10% of ambient levels down to 10 nM) and samples were incubated in on-deck ' simulated in situ' incubators. Concentration-dependent uptake kinetics for nitrate and ammonium and kinetics of ammonium inhibition of nitrate uptake were also determined from surface water samples. Nitrogen concentrations, utilization rates and kinetics were measured daily at the main study site and on the transits south from Halifax and east to Las Palmos. Periodically, measurements were also made of the light-dependence of nitrogen uptake. Stable isotope analyses could not be done onboard ship and will be carried later at BIO.

Mixed-layer ammonium concentrations were, with few exceptions, below the analytical limit of 50nM; actual concentrations were probably <10nM. Nitrate concentrations in the deep mixed layer at the main study site were in the nanomolar range and often at or below the lowest detection limit of the high sensitivity method (i.e. <2 Nm); these were the lowest values we have recorded in our studies to date. The top of the nitricline varied between ~110 and 150m and followed the density field.

7. DOC Transport to the Deep Ocean

P.E. Kepkay

Dissolved organic carbon (DOC) at the NATRE site is between 70 and 140 M C - similar to concentrations that are now being found in the oligotophic waters of the North Pacific Gyre.

This means that the high DOC concentrations measured in the Atlantic and Pacific from 1988 to 1992 are seriously in doubt. The opportunity to take part in Ledwell's intensive sampling of tracer gradients has allowed me to make the first direct and unequivocal estimates of DOC flux from shallow to deep water. Preliminary workups of the data suggest that vertical transport of DOC by diffusion is only 0.2 to 2.0% of primary production.

These results are important because they are based on direct determinations of DOC gradients and diffusivity. They are not the product of geochemical modelling and suggest that vertical diffusive flux is not a large component of DOC transport to the deep ocean. Instead, all signs point to subduction and Eckman transport as the primary mechanism of DOC transport. Luckily, these DOC gradients are from a region where diffusive and subductive transport are both the subjects of intense scrutiny.

8. Primary Production Experiments

Brian Irwin

Samples for Primary Production experiments were collected from the rosette sampler on the transect to the tracer station and at the tracer station. Water was collected from 1, 20 and 40 m. Additional samples were collected at 1,10, 20,40,60,70,80,90,100,120,130,140,150 and 200 m for chlorophyll estimation and inorganic nutrient concentrations. A total of 7 stations were sampled on the transect out, 19 stations at the tracer site and 2 stations on the way into Las Palmas. In addition surface water was collected from the sampling pump in the forward lab during the period 19 to 23 April.

In general, chlorophyll biomass was extremely low at the tracer station with the maximum concentrations never exceeding 0.2 micrograms per liter and surface values in the range of 0.02 to 0.04 micrograms per liter. Assimilation numbers were quite high (range 8 to 12) and compensation light levels were as high as 10 to 15 watts m^2.

9. Total Carbon Dioxide

Brian Irwin

Water samples for Total Carbon Dioxide estimates were collected from the rosette sampler on alternate days. Depths sampled were 1,20,40,70,100,150 and 200m. Carbon dioxide was estimated by the coulometric method. Aliquots of water were acidified with phosphoric acid and the released carbon dioxide gas was trapped in monoethonalamine and dimethyl sulphoxide. This solution was then titrated to give carbon estimates. Carbon dioxide concentrations did not vary much over large geographical areas but did show a trend to higher values in the most easterly stations.

10.Optical Measurements

E.P.W. Horne

After a slow start great strides were made in the optical instrumentation during this cruise. In Bedford Basin during tests one track on a circuit board in the endcap of BUD shorted to the endcap and blew out the A/D converter, two UART's and several other chips. This took a week of work to trace down and repair. The spectral irradiance meter with the new Tektronics CCd was successfully deployed for the first time. Several timing problems in the readout of the CCD were identified and solved by burning new timing control EPROMS. The cooler turning on and off, to maintain a constant chip temperature was shown to cause noise (since it draws 3 amps when running). This was solved by successfully ac coupling the CCD to the output electronics and then the cooler could be left on all the time (since the DC level of the dark current no longer mattered). Wavelength resolution was found to be better than ever ~3nm. We were not successful in linking the lightmeter to BUD's datastream. It works for a while but eventually the microprocessor in BUD does not have time to service an interrupt from the CTD as well as read spectral irradiance data and once it gets out of step it cannot recover. Seimac are working on a fix which should be ready for the next leg of the cruise. Several successful drops were obtained and there positions are noted in the event log.

The BUD winch is still a problem as it can't lift BUD on deck. The problem was got around by lifting it over the side with the crane. During the latter part of the cruise our effort was concentrated on building a second copy of the irradiance meter to be used on BUD during the next leg.

D. ACKNOWLEDGMENTS

Funding provided through a cooperative research initiative of NSERC (National Science and Engineering Research Council) of Canada and DFO (Department of Fisheries and Oceans).

F. APPENDICES

APPENDIX 1: Cruise Summary

APPENDIX 2: Post Cruise Data Processing

APPENDIX 3: Duplicate Water Samples

APPENDIX 1: Cruise Summary

EVENT SUMMARY: ALL INSTRUMENTS AND EVENTS(CRUISE 92-053) APR. 5 to May 13 1993

No	Instrum	Stn	Cast	Date	Start	Stop	Lat	Long	Comments
1	CTD	TEST		096	13:25	13:51	43 17.16	59 01.05	FAILED-CABLES
2	CTD	TEST		096	14:08	14:17	43 17.07	59 01.24	FAILED-CABLES
3	CTD	TEST		097	11:38	11:44	41 27.22	53 38.54	BAD NEPHEL. CABLE
4	CTD	1	1	097	12:50	13:30	41 23.31	53 26.10	BIOLOGY
5	CTD	2	1	097	14:12	14:42	41 23.13	53 24.02	BIOLOGY
6	CTD	3	1	098	10:32	10:58	39 27.92	48 33.71	BIOLOGY
7	CTD	4	1	099	10:30	11:10	36 50.67	42 53.71	BIOLOGY
8	CTD	5	1	099	11:48	12:27	36 50.59	42 53.50	BIOLOGY
9	CTD	6	1	100	10:30	11:15	34 37.63	38 16.62	BIOLOGY
10	CTD	7	1	100	11:45	12:20	34 37.80	38 16.44	BIOLOGY
11	BUOY			101	10:30	11:10	32 16.10	34 07.84	SIO/WHOI
12	CTD	8	1	101	11:50	12:22	32 16.99	34 08.79	BIOLOGY
13	DSR			101	12:30	13:20	32 17.31	34 09.23	WHOI DEPLOY
14	LISTEN			101	16:57	22:36	31 43.80	33 55.10	WHOI LISTENING
15	CTD	9	1	102	09:54	10:45	29 38.55	33 55.63	BIOLOGY
16	CTD	10	1	102	11:11	11:45	29 38.64	33 56.04	BIOLOGY
17	EPSONDE	1	10	102	15:07	17:00	28 55.61	33 54.82	TESTING
18	CTD	11	1	103	02:05	02:23	27 08.36	33 54.83	FAST TRACER CAST
19	CTD	12	1	103	03:33	03:49	27 00.73	33 54.90	FAST TRACER CAST
20	CTD	13	1	103	04:33	04:52	26 53.80	33 54.91	FAST TRACER CAST
21	CTD	14	1	103	05:50	06:09	26 46.78	33 55.00	FAST TRACER CAST
22	CTD	15	1	103	07:18	07:33	26 39.75	33 54.95	FAST TRACER CAST
23	CTD	16	1	103	08:14	08:33	26 32.61	33 54.99	FAST TRACER CAST
24	CTD	17	1	103	09:12	09:28	26 25.99	33 55.30	FAST TRACER CAST
25	CTD	18	1	103	09:43	10:12	26 25.59	33 55.35	BIOLOGY
26	CTD	19	1	103	10:59	11:13	26 18.75	33 55.07	FAST TRACER CAST
27	CTD	20	1	103	12:12	12:26	26 11.68	33 54.79	FAST TRACER CAST
28	CTD	21	1	103	13:05	13:21	26 04.99	33 55.13	FAST TRACER CAST
29	CTD	22	1	103	13:58	14:15	25 57.96	33 55.05	FAST TRACER CAST
30	CTD	23	1	103	14:55	15:12	25 51.05	33 55.04	FAST TRACER CAST
31	CTD	24	1	103	15:51	16:33	25 43.84	33 55.04	FULL TRACER CAST
32	CTD	25	1	103	17:11	17:27	25 36.74	33 54.95	FAST TRACER CAST
33	ALFOS	1	1	103	17:35	17:36	25 36.60	33 55.06	#76 DEPLOYED
34	CTD	26	1	103	18:18	18:33	25 29.83	33 55.13	FAST TRACER CAST
35	CTD	27	1	103	19:24	19:41	25 30.23	33 47.42	FAST TRACER CAST
36	CTD	28	1	103	20:25	20:41	25 30.43	33 39.90	FAST TRACER CAST
37	CTD	29	1	103	21:27	21:42	25 30.18	33 32.33	FAST TRACER CAST
38	CTD	30	1	103	22:28	23:01	25 30.45	33 24.82	FULL TRACER CAST
39	CTD	31	1	103	23:49	00:03	25 30.53	33 17.29	FAST TRACER CAST
40	CTD	32	1	104	00:47	01:01	25 30.55	33 09.73	FAST TRACER CAST
41	CTD	33	1	104	01:42	01:59	25 30.99	33 02.05	FAST TRACER CAST
42	CTD	34	1	104	02:38	02:54	25 30.82	32 54.30	FAST TRACER CAST
43	CTD	35	1	104	03:30	03:48	25 30.85	32 46.94	FAST TRACER CAST
44	CTD	36	1	104	04:30	04:45	25 30.93	32 39.42	FAST TRACER CAST
45	CTD	37	1	104	05:33	05:50	25 31.19	32 31.85	FAST TRACER CAST
46	CTD	38	1	104	06:36	06:51	25 30.39	32 24.31	FAST TRACER CAST
47	CTD	39	1	104	07:37	07:52	25 31.27	32 16.66	FAST TRACER CAST
48	CTD	40	1	104	08:35	08:56	25 31.26	32 09.13	FAST TRACER CAST
49	CTD	41	1	104	09:09	09:50	25 31.71	32 09.43	BIOLOGY DEEP
50	CTD	42	1	104	10:13	10:33	25 32.23	32 10.21	BIOLOGY SHALLOW
51	CTD	43	1	104	11:35	12:06	25 31.35	32 01.68	FULL TRACER CAST
52	CTD	44	1	104	14:28	14:50	25 31.21	31 54.00	FAST TRACER CAST
53	CTD	45	1	104	15:34	15:50	25 31.31	31 46.36	FAST TRACER CAST
54	CTD	46	1	104	16:33	16:49	25 31.22	31 38.84	FAST TRACER CAST
55	CTD	47	1	104	17:37	17:53	25 31.36	31 31.24	FAST TRACER CAST
56	CTD	48	1	104	18:42	18:59	25 30.91	31 23.78	FAST TRACER CAST
57	CTD	49	1	104	19:44	20:03	25 31.34	31 16.34	FAST TRACER CAST
58	CTD	50	1	104	20:51	21:07	25 31.39	31 08.63	FAST TRACER CAST
59	CTD	51	1	104	21:54	22:12	25 30.98	31 01.14	FAST TRACER CAST
60	CTD	52	1	104	22:54	23:08	25 31.19	30 53.78	FAST TRACER CAST
61	CTD	53	1	104	23:52	00:16	25 30.85	30 45.98	FAST TRACER CAST
62	CTD	54	1	105	01:00	01:16	25 31.05	30 38.43	FAST TRACER CAST
63	CTD	55	1	105	02:03	02:40	25 30.98	30 30.85	FULL TRACER CAST
64	CTD	56	1	105	03:28	03:45	25 30.94	30 23.39	FAST TRACER CAST
65	CTD	57	1	105	04:34	04:50	25 31.03	30 15.79	FAST TRACER CAST
66	CTD	58	1	105	05:40	05:55	25 30.98	30 08.31	FAST TRACER CAST
67	CTD	59	1	105	06:45	07:00	25 30.98	30 00.55	FAST TRACER CAST
68	CTD	60	1	105	07:50	08:07	25 30.13	29 52.85	FAST TRACER CAST
69	CTD	61	1	105	08:57	09:20	25 30.93	29 45.40	FAST TRACER CAST
70	CTD	62	1	105	09:28	09:49	25 30.67	29 45.60	BIOLOGY SHALLOW
71	CTD	63	1	105	10:41	10:59	25 30.48	29 37.81	FAST TRACER CAST
72	CTD	64	1	105	11:56	12:28	25 30.49	29 30.21	FULL TRACER CAST

73	CTD	65	1	105	13:40	14:20	25 30.42	29 19.98	FULL TRACER CAST
74	CTD	66	1	105	15:35	16:28	25 30.00	29 10.16	FULL TRACER CAST
75	DSR			105	16:30	17:00	25 29.48	29 11.64	APPROX LOCATION
76	CTD	67	1	105	18:51	19:35	25 30.13	29 00.21	FULL TRACER CAST
77	CTD	68	1	106	01:37	01:57	25 29.64	29 00.03	MOORING SURVEY
78	LUECK			106	11:29	13:46	25 26.64	29 07.42	MOORING POSITION
79	ACOUST			106	16:48	16:49	25 26.95	29 ??.??	LISTEN ABOVE MOORING
80	CTD	69	1	106	17:00	17:51	25 29.14	29 07.50	FULL TRACER CAST
81	BUOY			106	19:03	:	25 19.77	29 09 18	SONABUOY
82	CTD	70	1	106	19:46	20:16	25 20.20	29 10.31	FULL TRACER CAST
83	EPSONDE	2	17	106	20:32	00:10	25 20.20	29 10.80	XT TIME NOT UTC
84	CTD	71	1	107	02:39	03:25	25 20.00	29 00.01	FULL TRACER CAST
85	EPSONDE	3	15	107	03:41	07:50	25 19.94	29 00.51	
86	CTD	72	1	107	09:27	10:01	25 10.15	28 59.95	FULL TRACER CAST
87	CTD	73	1	107	10:31	11:11	25 09.90	29 00.50	BIOLOGY (11 BOTTLE)
88	CTD	74	1	107	11:42	12:00	25 09.50	29 01.00	BIOLOGY (7 BOTTLE)
89	EPSONDE	4	15	107	12:20	15:34	25 10.15	29 00.12	
90	DIVER	1	1	107	15:48	15:53	25 11.51	29 03.70	CARTESIAN DIVER
91	CTD	75	1	107	17:14	17:51	24 59.94	28 59.82	FULL TRACER CAST
92	EPSONDE	5	15	107	18:09	22:00	25 00.48	28 59.79	
93	CTD	76	1	107	23:24	00:01	24 50.10	29 00.80	FULL TRACER CAST
94	EPSONDE	6	15	108	00:07	03:35	24 50.10	29 01.10	
95	CTD	77	1	108	05:08	05:44	24 39.97	29 10.35	FULL TRACER CAST
96	EPSONDE	7	15	108	05:58	09:20	24 39.97	29 10.35	
97	CTD	78	1	108	09:26	09:47	24 41.30	29 12.30	BIOLOGY
98	CTD	79	1	108	10:56	11:35	24 50.04	29 10.01	BIOL/TRACER CAST
99	EPSONDE	8	15	108	11:39	15:05	24 50.20	29 10.30	
				108	15:20		MED-EVAC C/MATE TO LOS PALMOS		
100	DIVER	1	1	113	14:10	14:15	25 17.12	29 20.87	C/DIVER RECOVERED
101	CTD	80	1	113	14:20	15:25	25 17.05	29 21.02	FULL TRACER CAST
102	EPSONDE	9	5	113	15:30	16:45	25 16.33	29 20.99	
103	CTD	81	1	114	04:00	04:55	27 00.14	31 00.17	FULL TRACER CAST
104	EPSONDE	10	15	114	05:02	08:28	26 59.58	31 00.60	
105	CTD	82	1	114	08:58	09:40	26 59.53	31 05.94	FULL TRACER CAST
106	CTD	83	1	114	10:13	10:53	26 58.64	31 07.10	BIOLOGY DEEP
107	CTD	84	1	114	11:19	11:38	26 58.28	31 07.90	BIOLOGY SHALLOW
108	EPSONDE	11	12	114	11:47	14:35	26 58.21	31 08.65	25 KNOT WIND
109	DIVER	2	1	114	14:45	14:45	26 59.36	31 13.50	C/DIVER DEPLOYED
110	CTD	85	1	114	15:15	16:00	26 59.20	31 14.08	FULL TRACER CAST
111	EPSONDE	12	15	114	16:11	19:35	26 58.70	31 11.70	
112	CTD	86	1	114	20:09	20:57	26 59.73	31 21.78	FULL TRACER CAST
113	EPSONDE	13	15	114	21:07	00:30	26 59.36	31 22.04	
114	CTD	87	1	115	00:47	01:34	27 01.73	31 28.16	FULL TRACER CAST
115	EPSONDE	14	12	115	01:48	04:27	27 01.75	31 28.36	
116	CTD	88	1	115	04:35	05:28	27 02.59	31 32.09	FULL TRACER CAST
117	EPSONDE	15	9	115	05:40	07:40	27 01.92	31 32.42	
118	CTD	89	1	115	09:20	09:46	27 00.17	31 20.33	BIOLOGY SHALLOW
119	CTD	90	1	115	11:41	12:33	26 49.67	31 00.41	FULL TRACER CAST
120	EPSONDE	16	15	115	13:06	16:10	26 49.17	31 01.07	
121	ALFOS	2		115	16:25	16:29	26 49.58	31 06.91	# 72 DEPLOYED
122	CTD	91	1	115	16:35	17:23	26 49.59	31 07.06	FULL TRACER CAST
123	EPSONDE	17		115	17:30	20:45	26 49.15	31 07.68	
124	CTD	92	1	115	21:02	21:39	26 50.34	31 13.39	FULL TRACER CAST
125	EPSONDE	18		115	21:45	01:15	26 50.26	31 13.94	
126	CTD	93	1	116	01:25	02:04	26 51.89	31 18.63	FULL TRACER CAST
127	EPSONDE	19	10	116	02:10	04:22	26 51.84	31 18.76	
128	CTD	94	1	116	04:35	05:30	26 52.40	31 22.43	FULL TRACER CAST
129	EPSONDE	20	10	116	05:35	07:52	26 52.09	31 22.90	
130	DIVER	2		116	11:35	11:50	26 57.60	31 11.00	C/DIVER RECOVERED
131	CTD	95	1	116	09:15	10:00	26 54.66	31 15.13	BIOLOGY DEEP
132	CTD	96	1	116	10:18	10:40	26 54.39	31 15.24	BIOLOGY SHALLOW
133	CTD	97	1	116	13:33	14:20	26 39.85	31 15.24	FULL TRACER CAST
134	EPSONDE	21		116	14:25	17:40	26 39.69	31 15.99	
135	CTD	98	1	116	18:02	18:45	26 40.19	31 22.79	FULL TRACER CAST
136	EPSONDE	22	21	116	18:55	23:50	26 40.20	31 22.79	H-DISK FULL
137	CTD	99	1	117	07:18	08:06	26 29.59	33 00.16	FULL TRACER CAST
138	CTD	100	1	117	08:47	09:45	26 29.15	33 00.70	BIOLOGY DEEP
139	CTD	101	1	117	10:05	10:28	26 29.12	33 01.82	BIOLOGY SHALLOW
140	EPSONDE	23	15	117	10:42	13:45	26 29.10	33 01.82	
141	CTD	102	1	117	13:50	15:47	26 29.63	33 04.14	FULL TRACER CAST
142	EPSONDE	24	15	117	15:52	19:00	26 30.03	33 05.22	
143	CTD	103	1	117	19:20	20:07	26 30.15	33 07.71	FULL TRACER CAST
144	ELTSONDE	25	15	117	20:16	23:27	26 30.26	33 08.35	
145	CTD	104	1	118	00:00	00:35	26 30.52	33 11.38	FULL TRACER CAST
146	ELTSONDE	26	15	118	00:41	03:39	26 30.50	33 12.18	
147	CTD	105	1	118	03:50	04:24	26 31.35	33 14.21	FULL TRACER CAST
148	ELTSONDE	27	15	118	04:30	07:26	26 31.86	33 14.66	
149	CTD	106	1	118	07:47	08:39	26 32.53	33 15.68	FULL TRACER CAST
150	CTD	107	1	118	09:44	:	26 32.50	33 16.00	BIOLOGY SHALLOW
151	EPSONDE	28	15	118	09:15	13:10	26 32.50	33 16.20	
152	CTD	108	1	118	13:31	14:03	26 32.58	33 17.37	FULL TRACER CAST

153	EPSONDE	29	15	118	14:11	17:00	26 32.68	33 17.37	
154	BUD	1	1	118	17:00	17:54	26 33.50	33 18.10	
155	CTD	109	1	118	18:06	18:57	26 33.54	33 17.94	FULL TRACER CAST
156	LISTEN	2	1	118	19:36	21:55	26 33.69	33 17.81	WHOI LISTENING
157	ELTSONDE	30	23	118	22:42	03:30	26 33.74	33 16.88	
158	CTD	110	1	119	11:37	12:25	25 30.16	33 29.60	BIOLOGY DEEP
159	CTD	111	1	119	12:55	13:22	25 30.45	33 29.14	BIOLOGY SHALLOW
160	CTD	112	1	119	13:54	14:30	25 30.02	33 28.09	FULL TRACER CAST
161	DIVER	3		119	15:01	15:15	25 30.16	33 26.93	DEPLOYED-1 WING
162	ELTSONDE	31	15	119	15:55	19:09	25 30.13	33 26.17	
163	CTD	113	1	119	20:46	21:25	25 30.19	33 38.02	FULL TRACER CAST
164	CTD	114	1	119	22:55	23:37	25 30.02	33 46.16	FULL TRACER CAST
165	CTD	115	1	120	00:35	01:21	25 29.94	33 54.00	FULL TRACER CAST
166	CTD	116	1	120	02:15	02:48	25 29.92	34 02.02	FULL TRACER CAST
167	CTD	117	1	120	03:45	04:25	25 30.03	34 10.03	FULL TRACER CAST
168	LISTEN	3	1	120	05:30	10:00	25 30.00	34 18.00	SOFAR FLOAT LISTEN
169	CTD	118	1	120	10:51	11:15	25 30.00	34 18.00	BIOLOGY SHALLOW
170	CTD	119	1	120	11:43	12:31	25 29.44	34 17.67	FULL TRACER CAST
171	EPSONDE	32	21	120	12:34	16:40	25 28.80	34 17.40	
172	CTD	120	1	120	17:45	18:34	25 29.90	34 25.90	FULL TRACER CAST
173	ELTSONDE	33	27	120	18:43	00:13	25 29.57	34 26.19	
174	CTD	121	1	121	01:08	01:45	25 29.96	34 34.07	FULL TRACER CAST
175	EPSONDE	34	15	121	02:00	07:30	25 29.33	34 34.13	
176	CTD	122	1	121	08:19	08:58	25 30.13	34 42.09	FULL TRACER CAST
177	CTD	123	1	121	09:29	10:11	25 29.62	34 41.74	BIOLOGY DEEP
178	CTD	124	1	121	10:41	11:00	25 29.02	34 41.88	BIOLOGY SHALLOW
179	ELTSONDE	35	0	121	11:09	12:00	25 28.70	34 42.10	BAD BATTERY
180	CTD	125	1	121	12:46	13:23	25 30.00	34 50.10	
181	CTD	126	1	121	14:21	14:57	25 30.13	35 00.03	
182	ELTSONDE	36	13	121	15:51	18:53	25 29.10	35 00.90	
183	LISTEN	5	1	121	19:00	21:52	25 27.57	35 03.00	HYDROPHONE
184	CTD	127	1	121	22:33	23:37	25 29.90	35 08.18	FULL TRACER CAST
185	ELTSONDE	37	18	121	23:46	03:24	25 28.90	35 09.00	
186	LISTEN	6	1	122	08:28	09:51	25 29.14	34 01.90	HYDROPHONE
187	CTD	128	1	122	10:13	10:33	25 29.51	34 03.80	BIOLOGY SHALLOW
188	EPSONDE	38	7	122	13:40	15:05	25 29.90	33 25.30	
189	DIVER	3	1	122	15:15	20:10	25 29.51	34 03.80	POOR RDF RANGE
190	CTD	129	1	122	22:51	23:33	24 59.90	33 10.08	FULL TRACER CAST
191	ELTSONDE	39	2	122	23:45	00:24	24 59.50	33 10.30	BATTERY FAILURE
192	EPSONDE	40	25	123	00:24	05:44	24 59.50	33 11.10	
193	CTD	130	1	123	06:04	07:00	25 00.19	33 19.01	FULL TRACER CAST
194	ELTSONDE	41	6	123	07:04	08:24	24 59.58	33 19.36	
195	LISTEN	7	1	123	08:38	09:55	24 59.64	33 22.39	HYDROPHONE
196	CTD	131	1	123	10:14	10:57	24 59.79	33 24.64	BIOLOGY DEEP
197	CTD	132	1	123	11:30	11:53	24 59.30	33 24.60	BIOLOGY SHALLOW
198	BUD	2	0	123	12:10	12:55	24 59.20	33 25.00	DISFUNCTIONAL
199	CTD	133	1	123	12:39	13:13	24 59.10	33 25.48	FULL TRACER CAST
200	ELTSONDE	42	25	123	13:24	19:00	24 57.75	33 26.09	
201	CTD	134	1	123	19:16	20:02	25 00.00	33 34.20	FULL TRACER CAST
202	ELTSONDE	43	5	123	20:28	21:30	25 00.03	33 34.63	INST. PROBLEMS
203	EPSONDE	44	13	123	21:40	00:28	25 00.41	33 36.24	INST. PROBLEMS
204	CTD	135	1	124	00:38	01:20	25 00.48	33 39.92	FULL TRACER CAST
205	ELTSONDE	45	1	124	01:28	01:53	24 59.90	33 40.30	
206	EPSONDE	46	26	124	02:07	07:30	24 59.70	33 40.98	
207	CTD	136	1	124	07:58	08:45	24 59.10	33 47.59	BIOLOGY SHALLOW
208	CTD	137	1	124	09:09	09:32	24 58.20	33 47.90	FULL TRACER CAST
209	EPSONDE	47	24	124	09:50	15:00	24 57.60	33 48.00	
210	CTD	138	1	124	15:18	16:00	24 56.75	33 53.37	FULL TRACER CAST
211	EPSONDE	48	26	124	16:10	21:32	24 56.40	33 53.82	
212	CTD	139	1	124	21:43	22:19	24 57.00	33 58.80	FULL TRACER CAST
213	EPSONDE	49	8	124	22:26	00:13	24 56.66	33 58.79	BATTERIES LOW
214	ELTSONDE	50	15	125	00:17	03:30	24 56.83	34 00.50	
215	CTD	140	1	125	03:36	04:20	24 57.21	34 03.90	FULL TRACER CAST
216	EPSONDE	51	12	125	04:30	06:59	24 56.85	34 04.43	
217	CTD	141	1	125	07:22	08:15	24 57.44	34 07.31	BIOLOGY DEEP
218	CTD	142	1	125	08:35	08:56	24 57.08	34 07.62	BIOLOGY SHALLOW
219	CTD	143	1	125	21:52	21:30	25 00.00	31 00.00	FULL TRACER CAST
220	EPSONDE	52	23	125	22:35	03:17	25 00.00	31 00.00	
221	CTD	144	1	126	03:21	04:25	25 00.00	31 05.02	FULL TRACER CAST
222	EPSONDE	53	27	126	04:39	09:51	24 59.62	31 04.81	
223	CTD	145	1	126	09:59	10:21	24 58.44	31 07.00	BIOLOGY SHALLOW
224	CTD	146	1	126	10:52	11:15	24 58.50	31 07.00	FULL TRACER CAST
225	EPSONDE	54	15	126	11:33	14:31	24 58.70	31 07.30	
226	CTD	147	1	126	15:29	16:06	25 00.00	31 11.10	FULL TRACER CAST
227	ELTSONDE	55	1	126	16:15	16:35	24 59.80	31 10.90	INST. PROBLEMS
228	HYDRPHN	1	1	127	20:35	21:47	26 09.08	29 13.95	LISTEN FOR RINO
229	LISTEN	8	1	127	22:00	:	26 08.00	29 36.00	LISTEN FOR RINO
230	CTD	148	1	127	22:12	22:53	26 07.88	29 13.42	AT RINO SITE?
231	CTD	149	1	128	07:47	08:36	26 12.63	29 21.07	BIOLOGY DEEP
232	CTD	150	1	128	09:02	09:25	26 12.40	29 20.73	BIOLOGY SHALLOW
233	CTD	151	1	128	10:06	10:45	26 11.96	29 20.42	FULL TRACER CAST

234	BUD	3	1	128	11:53	12:34	26 11.64	29 20.05	
235	DSR	3		128	16:18	16:56	25 26.91	28 51.72	RECOVERY
236	CTD	152	1	128	18:50	19:32	25 41.96	28 54.14	FULL TRACER CAST
237	EPSONDE	56	27	128	19:38	01:33	25 41.69	28 53.99	
238	CTD	153	1	129	02:55	03:35	25 37.93	29 06.18	FULL TRACER CAST
239	ELTSONDE	57	19	129	03:45	07:42	25 37.49	29 06.14	
240	CTD	154	1	129	08:30	08:55	25 29.04	29 07.74	BIOLOGY SHALLOW
241	LUECK	1	1	129	10:00	13:00	25 26.00	29 07.24	RECOVERED
242	CTD	155	1	129	13:10	13:35	25 25.90	29 07.24	500m. 1 BTL.
243	EPSONDE	58	25	129	13:50	18:48	25 25.74	29 07.15	
244	CTD	156	1	129	22:15	22:45	25 40.04	28 40.00	FULL TRACER CAST
245	EPSONDE	59	21	129	23:10	03:35	25 37.79	28 40.30	
246	CTD	157	1	130	06:03	06:50	25 50.16	28 20.04	FULL TRACER CAST
247	EPSONDE	60	10	130	07:06	09:09	25 49.20	28 19.87	
248	CTD	158	1	130	09:12	09:55	25 47.08	28 20.14	BIOLOGY DEEP
249	CTD	159	1	130	10:20	10:42	25 46.60	28 19.90	BIOLOGY SHALLOW
250	EPSONDE	61	1	130	10:47	11:03	25 46.30	28 19.78	
251	BUD	4	3	130	14:00	15:10	25 59.86	28 00.15	
252	CTD	160	1	130	15:17	15:54	25 59.06	28 00.54	FULL TRACER CAST
253	EPSONDE	62	18	130	16:05	20:40	25 59.00	28 00.55	
254	ELTSONDE	63	2	130	20:40	21:06	25 55.23	28 03.30	
255	CTD	161	1	130	23:38	00:21	26 00.00	27 30.00	FULL TRACER CAST
256	EPSONDE	64	29	131	00:28	07:07	25 59.60	27 29.98	
257	CTD	162	1	131	09:51	10:14	25 59.90	27 00.00	BIOLOGY SHALLOW
258	CTD	163	1	131	10:44	11:23	25 59.36	26 59.90	FULL TRACER CAST
259	EPSONDE	65	4	131	11:37	12:35	25 58.70	27 00.00	
260	BUD	5		131	12:45	13:55	25 58.10	26 59.74	
261	EPSONDE	66	1	131	14:00	14:20	25 57.54	26 59.68	TOO CALM
262	BUD	6	1	131	15:10	15:29	25 56.99	26 59.83	
263	CTD	164	1	132	08:17	08:44	26 38.86	23 06.25	BIOLOGY DEEP
264	CTD	165	1	133	07:09	07:47	27 22.80	18 43.15	BIOLOGY SHALLOW

APPENDIX 2: Post Cruise Data Processing

Anthony W. Isenor

CTD Temperature and Salinity

After returning to shore, examination of the 1 dbar CTD dataset showed various inconsistent features that included density inversions and salinity spiking. Also, the conductivity offset of 0.0050 was not consistently applied for stations after 16. Due to these problems, a detailed reexamination of the dataset was initiated. The objective was to modify CTD processing coefficients to minimize salinity spiking and density inversions and then to reprocess the dataset using the modified coefficients.

The reexamination looked in detail at two aspects of the processing: i) the time alignment of the conductivity and temperature signals, and ii) the Lueck filter coefficients used to compensate for the thermal mass of the conductivity cell. The initial work concentrated on stations 35 and 140 and determined optimal coefficients for these two profiles. Next, the validity of this coefficient set was tested by application to stations 21, 50, 90 and 160. These stations are temporally and spatially scattered throughout the cruise. Using the 24 Hz data, profile plots were produced using the new coefficients and compared to plots produced using slightly different coefficients as well as the standard onboard processing coefficients.

Based on visual comparison, the examination indicated that the coefficients chosen based on station 35 and 140 were indeed appropriate for the entire cruise dataset. The values were:

-0.055 seconds9 time shift of conductivity relative to temperature
0.02 9 Lueck filter amplitude (alpha)

The application of a conductivity time offset of -0.055 s is in addition to any offset applied within the deck unit.

After verification of the coefficients, a complete reprocessing of the CTD dataset was performed. This procedure was altered slightly from the onboard processing, to produce averaged data on intervals of 0.25 dbar and 2 dbar. Also, this processing used Seasoft Version 4.201. The processing steps were as follows:

DATCNV Converts the raw data to physical parameters.

SPLIT Splits the data into DOWN and UP cast.

WILDEDIT For every block of 12 scans, flags all scans whose pressure, temperature, conductivity and oxygen values differ from the mean by more than 2 standard deviations. Recomputes mean and standard deviation from unflagged data then marks as bad all scans exceeding 4 standard deviations from these new values.

FILTER Low pass filter pressure and conductivity channels to time match parameters for salinity computation. Time constant used for conductivity is 0.045 seconds, for pressure 0.150 seconds.

LOOPEDIT Marks as bad, all cycles on the down trace for which the vertical velocity of the CTD unit is less than 0.1 metres/sec.

ALIGNCTD Aligns the temperature, conductivity and oxygen values relative to the pressure values accounting for the time delays in the system. Time offsets of -0.055 secs for conductivity, 0.000 secs for temperature and 3.000 secs for oxygen are used.

CELLTM A recursive Lueck filter used to remove the thermal mass effects from the conductivity data. Thermal anomaly amplitude and time constants of 0.02 and 9.0 secs were used.

DERIVE Computes oxygen values.

BINAVG Averages the down cast into 0.25 and 2 dbar pressure bins.

DERIVE Computes salinity, potential temperature and $sigma_{theta}$.

The CTD used throughout the entire cruise was BIO Syytem #1, serial number 9P5676-0248. The CTD sensor calibrations (except for the conductivity offset) used during the processing of this dataset were supplied by Seabird Electronics and are as follows:

Conductivity Sensor 040954 (All stations)

$$\text{Conductivity} = (af^m + bf^2 + c + dt)/[10(1-9.57(10^{-8})p)]$$

where f is the frequency
m = 4.4
p is pressure in dbars
t is the temperature
$a = 1.01513041 \times 10^{-5}$
$b = 5.69078601 \times 10^{-1}$
c = -4.20143902
$d = -2.42081062 \times 10^{-4}$
offset = 0.0050

Temperature Sensor 031247 (All stations)

$$T = 1/\{a + b[\ln(f_o/f)] + c[\ln^2[f_o/f] + d[\ln^3(f_o/f)]\} - 273.15$$

where ln indicates a natural logarithm
f is the frequency
$a = 3.68701496 \times 10^{-3}$
$b = 6.01256466 \times 10^{-4}$
$c = 1.63681774 \times 10^{-5}$
$d = 2.54555248 \times 10^{-6}$
$f_o = 6590.790$

Pressure Sensor 48361 (All stations)

$$\text{pressure} = c\,(1 - T_o^2/T^2)\,(1 - d[1 - T_o^2/T^2])$$

where T is the pressure period
$c = c_1 + c_2\,U + c_3\,U^2$
$d = d_1 + d_2\,U$
$T_o = T_1 + T_2\,U + T_3\,U^2 + T_4\,U^3 + T_5\,U^4$

U is the temperature
c_1 = -2.651490 X 10^{+4} psia
c_2 = 1.537220 X 10^{-1} psia/deg C
c_3 = 8.182160 X 10^{-3} psia/deg C^2
d_1 = 3.319500 X 10^{-2}
d_2 = 0.0
T_1 = 3.05779 X 10^{+1} micro sec
T_2 = -2.025480 X 10^{-4} micro sec/deg C
T_3 = 4.254880 X 10^{-6} micro sec/deg C^2
T_4 = 1.79002 X 10^{-9} micro sec/deg C^3
T_5 = 0.0

Referring to the original objectives, results of the reprocessing showed substantial reduction in salinity spiking and the small scale density inversions. However, larger scale density inversions (many dbars in extent) remained in the data. This is thought to be a near-surface phenomenon due to the fact that about 90% of the inversions occur within the upper 20 dbars. The larger scale density inversions will be used to identify and flag the CTD data before delivery to the WOCE data centre. Density inversions will be flagged as bad.

After the reprocessing of the CTD data, a comparison between the CTD and the water sample salinities was conducted. The comparison indicated that an additional + 0.006 increase in CTD salinity was required for agreement with the water sample salinities. This additional offset was then applied to all CTD salinities.

The final comparison of difference between the water sample salinities - CTD salinities has the following statistics:

Number of Points = 126
Median = 0.0000
Mean = 0.0027
Minimum = -0.0193
Maximum = 0.0667
Standard Deviation = 0.0123

The comparison between the temperatures obtained from the digital thermometers and the CTD has the following statistics (Thermometer - CTD temperature):

Number of Points = 50
Median = 0.001%C
Mean = 0.048%C
Minimum = -0.376%C
Maximum = 1.024%C
Standard Deviation = 0.215%C

Based on the median temperature difference of 0.001%C and the interthermometer median difference of 0.005%C, we will not apply any temperature calibration to the CTD temperature data.

CTD Fluorescence

The voltage channel from the fluorometer was converted to chlorophyll-a concentration using the following conversion

$$\text{chlorophyll-a} = -68.13 + 138.8v - 94.4v^2 + 21.51v^3$$

where v is the fluorometer voltage signal. The chlorophyll-a concentrations are reported in units of mg/m^3. This calibration is based on 339 water samples collected and analyzed for chlorophyll concentrations during this and the following cruise (BIO Cruise Number 93002, May-June 1993) in the same area.

CTD Oxygen Data

CTD oxygen data was collected during this cruise but was not processed. Incomplete record keeping caused an inability to determine which oxygen sensor was used and thus an inability to assign appropriate processing coefficients to the oxygen computation. For this reason, CTD oxygen values were not processed and are therefore not reported.

Salinity

a. Description of Equipment and Technique

Salinity samples were analyzed on a Guildline Autosal model 8400 salinometer, BIO System 3. Samples are drawn in 150 ml medicine bottles.

The salinometer cell is filled and rinsed several times with sample water before readings are recorded. The rinsing procedure and readings are repeated until a stable reading is obtained for every sample and standardization. The last reading is then entered into the water sample database as the conductivity of the water sample.

b. Sampling Procedure and Data Processing Technique

Salinity samples are drawn into 150 ml medicine bottles after three rinses. The bottles are filled up to the shoulders and then capped.

Several conductivity files are then prepared based on cases of water samples. The files consist of a sample ID number, sample conductivity ratio and sample temperature. A PC based program computes the salinity using the conductivity ratio and the standard IAPSO formula. Any changes in the salinometer readings between successive standardizations is assumed to have occurred as a linear drift of the instrument. Thus, the program applies a correction to the ratios, which varies linearly with the samples analyzed.

c. Laboratory and Sample Temperatures

Full cases of samples are taken from the winch room to the GP lab where they are left for a period of at least 10 hours to equilibrate to laboratory temperature before being analyzed.

The bath in the salinometer was kept at 27%C.

d. Replicate Analysis

Duplicate salinity samples were periodically drawn from one of the rosette bottles.

A total of 63 duplicate salinity samples were drawn and statistically analyzed. The statistics of the differences between the duplicates are as follows:

Number of Points = 63
Median = 0.0010
Mean = 0.0027
Minimum = 0
Maximum = 0.0490
Standard Deviation = 0.0065

e. Standards Used

The salinometer was standardized on April 11, 1993 using IAPSO standard water, Batch P117, prepared on July 10, 1991. A check on the standardization using a new ampoule was carried out at the beginning and end of every 32 bottle case and at intermediate points during a case if instrument drift was suspected.

Reversing Thermometers

a. Description of Equipment and Technique

Sensoren-Instrumente-Systeme digital reversing thermometers model RTM 4002 were used to verify CTD thermistor readings on some stations. The thermometers have a depth range of up to 10000 m. The pressure housing is made of a glass tube closed at the ends by metal stoppers. One end contains the platinum sensor and the other end is the battery compartment.
The thermometers are placed in standard reversing thermometer racks on the Niskin bottles. Before deployment, a magnet is passed over the thermometers to clear the display and place the thermometer in sample mode. A new temperature will then be recorded upon reversal of the thermometer.

b. Sampling Procedure and Data Processing Technique

The digital thermometers indicate the temperature reading via a digital display. The temperature is read and noted on log sheets. The readings are later digitized and corrections applied using the water sample database system.

The following table lists the number of readings from each thermometer.

Thermometer Ser. No.	Number of Readings
000T348	25
000T354	25

c. Calibration Data

Data from the reversing digital thermometers were corrected using the March 1994 calibration data.

d. Replicate Analysis

Statistics on the differences of all duplicate temperatures from the digital reversing thermometers are as follows:

Number of Points = 25
Median = 0.005%C
Mean = 0.018%C
Minimum = 0.001%C
Maximum = 0.109%C
Standard Deviation = 0.027%C

Using the median difference as a measure of the inter-thermometer comparison (the mean is influenced equally by all points, including outliers), we note that the estimated thermometer difference is 0.005%C.

Leaking Bottle Investigation

Leaking bottles were identified using water salinity samples and CTD data. Using the *difference*, $Salinity_{Water\ sample} - Salinity_{CTD}$, the interquartile range (IQR) for the *differences* was determined. The IQR is defined using the *differences* at the 25 and 75 percentile, Q_1 and Q_3 respectively (note that Q_2 would be the 50 percentile, or the median). Bottles were flagged as leaking when all of the salinity samples taken from a particular bottle had *differences* outside the range,

$$difference < Q_1 - 1.5 * (Q_3 - Q_1) \text{ and}$$
$$difference > Q_3 + 1.5 * (Q_3 - Q_1)$$

Only one sample id number, 121020, came under this category. Two other sample id numbers, 122207 and 122378, had one of their duplicates outside of the defined range. In this case the individual salinity sample was flagged bad; but the bottle was not flagged as leaking.

Other bottle flags were assigned the WOCE bottle quality flag "1", indicating the scarcity of information pertaining to each bottle's performance.

APPENDIX 3: Duplicate Water Samples

Oxygen Duplicate Measurements

Sample ID Number	Oxygen (mol/kg)
121001	196.4
121001	196.9
121001	204.4
121002	189.0
121002	190.1
121002	192.4
121003	154.7
121003	156.6
121003	157.9
121004	119.5
121004	121.6
121004	123.2
121005	142.2
121005	148.7
121005	153.2
121006	148.2
121006	152.2
121006	164.0
121010	142.9
121010	154.8
121010	160.9
121018	179.4
121018	179.5
121018	182.6
121020	153.7
121020	159.8
121020	160.1
121024	158.9
121024	172.2
121024	175.1
121036	158.5
121036	169.1
121036	171.1
121055	125.0
121056	131.9
121056	133.4
121057	167.4
121057	178.6
121058	171.2
121058	175.2
121058	178.9
121059	152.7
121059	167.4
121059	172.3
121060	139.6
121060	148.2
121061	118.6
121061	138.0

121061	141.4
121062	155.1
121062	155.6
121062	159.0
121063	175.8
121063	184.1
121063	184.8
121081	207.8
121081	210.0
121084	217.9
121096	224.9
122001	178.1
122001	186.3
122001	196.8
122002	177.2
122002	178.2
122002	178.9
122003	84.6
122003	98.8
122003	205.7
122004	187.9
122004	201.4
122004	211.9
122005	73.5
122005	158.6
122005	212.0
122026	193.7
122026	201.1
122026	204.2
122031	133.6
122031	222.9
122031	234.7
122042	32.2
122042	196.3
122042	217.6
122042	229.0
122043	171.7
122043	173.5
122043	177.0
122044	68.3
122044	120.2
122044	164.0
122045	157.4
122045	177.9
122045	178.7
122046	184.8
122046	193.8
122046	201.7
122047	180.0
122047	188.3
122047	203.1
122071	188.9
122071	191.4
122071	197.1

122076	214.6
122076	219.6
122076	232.2
122087	75.2
122087	133.6
122087	179.3
122088	138.8
122088	143.5
122088	144.2
122089	114.9
122089	123.4
122089	125.3
122090	128.1
122090	138.7
122090	142.1
122091	171.8
122091	184.2
122091	196.0
122092	83.4
122092	137.9
122092	184.3

Salinity Duplicate Measurements

Sample ID Number	Salinity
121020	36.448
121020	36.449
121054	35.139
121054	35.152
121055	35.313
121055	35.315
121056	35.904
121056	35.908
121057	36.471
121057	36.472
121058	36.486
121058	36.488
121059	35.215
121059	35.215
121060	35.175
121060	35.176
121061	35.508
121061	35.509
121062	36.058
121062	36.056
121063	36.257
121063	36.258
121081	36.451
121081	36.453
122001	35.407
122001	35.407

122002	35.457
122002	35.457
122003	35.654
122003	35.655
122004	36.001
122004	36.001
122005	36.245
122005	36.246
122026	36.573
122026	36.573
122043	35.269
122043	35.269
122044	35.420
122044	35.421
122045	35.607
122045	35.608
122046	36.006
122046	36.007
122047	36.312
122047	36.313
122071	36.659
122071	36.662
122088	35.152
122088	35.153
122089	35.314
122089	35.315
122090	35.652
122090	35.652
122091	36.181
122091	36.182
122092	36.444
122092	36.445
122116	36.602
122116	36.604
122153	35.274
122153	35.275
122154	35.426
122154	35.430
122155	35.646
122155	35.648
122156	36.093
122156	36.102
122157	36.359
122157	36.360
122177	36.543
122177	36.544
122204	35.253
122204	35.253
122205	35.388
122205	35.388
122206	35.630
122206	35.631
122207	36.022
122207	36.071

122208	36.293
122208	36.294
122251	35.261
122251	35.262
122252	35.402
122252	35.403
122253	35.626
122253	35.627
122254	36.036
122254	36.037
122255	36.378
122255	36.378
122302	35.158
122302	35.159
122303	35.373
122303	35.375
122304	35.600
122304	35.605
122305	35.946
122305	35.946
122306	36.246
122306	36.247
122340	36.708
122340	36.708
122377	35.207
122377	35.208
122378	35.399
122378	35.410
122379	35.632
122379	35.636
122380	36.061
122380	36.067
122381	36.354
122381	36.360
122405	36.623
122405	36.625
122432	35.141
122432	35.150
122433	35.324
122433	35.325
122434	35.569
122434	35.569
122435	35.947
122435	35.947
122436	36.210
122436	36.211

Reversing Thermometer Temperature Duplicate Measurements

Sample ID Number	Reversing Therm. Temp.
121001	4.447
121001	4.450

121006	11.952
121006	11.949
121020	17.250
121020	17.272
121037	17.719
121037	17.727
121059	6.344
121059	6.454
121064	16.678
121064	16.686
121081	17.604
121081	17.588
121101	7.412
121101	7.414
121129	19.150
121129	19.071
121146	7.617
121146	7.619
122001	8.248
122001	8.251
122009	17.476
122009	17.479
122026	18.142
122026	18.151
122043	7.797
122043	7.804
122054	18.261
122054	18.216
122071	18.293
122071	18.302
122088	7.325
122088	7.329
122153	7.932
122153	7.908
122177	17.890
122177	17.902
122204	7.675
122204	7.670
122251	7.758
122251	7.747
122302	6.919
122302	6.921
122377	7.566
122377	7.519
122432	6.849
122432	6.834
122443	18.838
122443	18.815