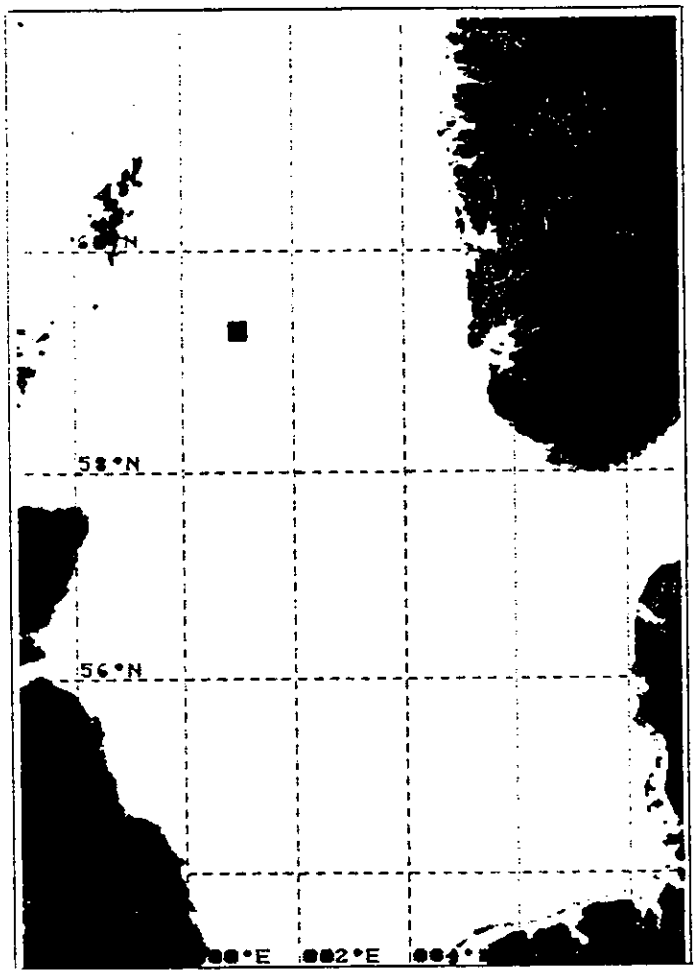
PROVESS

Processes of Vertical Exchange in Shelf Seas

MAST III Project No. 96 1032



The Northern North Sea Experiment

Cruise Report

"VALDIVIA" Cruise 174

"PROVESS N-1"

5.9. - 17.9.1998

Cruise Report

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"VALDIVIA" Cruise 174

"PROVESS N-1"

Bremerhaven - Northern North Sea - Bremerhaven
05.09. - 17.09.1998

Gunther Krause with contributions of the participants

1. Introduction

The EU project PROVESS aims at a better understanding of **PRO**cesses of **V**ertical **E**xchange in **S**helf **S**eas. An important aspect within the large variety of relevant mechanisms is the autumnal breakdown of the stratification as it occurs in large parts of the Northern North Sea between September and December. It involves heat loss to the atmosphere, wind mixing, exchanges across and deepening of the thermocline, and overturning in the surface mixed layer.

A specific experiment has been designed to study these processes in detail including biological consequences such as mixing of nutrient-rich deeper water into the photic zone creating favourable conditions for phytoplankton blooms in autumn.

The study area has been chosen in the Northern North Sea where tidal currents are weak, and water depths in the order of 100 m are large enough to clearly separate the surface mixed layer and the bottom boundary layer. Excluding effects by Atlantic inflows and by the Norwegian Costal Current a site centered at 59°20'N, 1°E has been selected for the experiment.

In view of the rather long period and the event-like character of transitions from stratified to mixed conditions the observations involve 4 ships from September to November and an array of 18 moorings for that time. This cruise report deals with the first expedition in this series with the general goal to provide the initial conditions prior to or during the onset of the cooling phase and stormy wind season.

2. Objectives

The scientific aims of the cruise were

- to assess the hydrographic conditions in the study area by means of CTD-surveys including the distributions of chlorophyll-fluorescence and turbidity.
- to perform biological and chemical sampling for phytoplankton, photosynthetic pigments, particulate organic matter and dissolved oxygen.
- to observe temporal changes of the stratification and of the nutrient situation during the first phase of the autumnal changes of the summer stratification.
- to study the turbulence regimes in the water column above, across and beneath the thermocline to derive turbulence parameters for modelling of the vertical mixing processes.

A further major task for this expedition was the deployment of numerous moorings to measure time series of meteorological, hydrographical and chemical quantities. The moorings will be recovered at the end of the experiment in November.

3. Narrative of the cruise

RV "Valdivia" left the port of Bremerhaven on September 5, 1998, about midday. Mooring work began in the early morning of September 7, and continued for 4 days during daylight hours. The nights in between were used for the planned CTD work on a box with sides of about 50 km around the main site. Except for one day of a bit rough conditions work was accompanied by moderate winds and wave heights.

In the late afternoon of September 10 the ship anchored on a water depth of about 100 m in the vicinity (1.5 km) of the central mooring array. Regular CTD-casts and turbulence measurements were carried out every 1.5 hours until September 14, about midday.

A second CTD survey followed, this time on two sections perpendicular to each other with the center at the main site. Making use of the favourable weather conditions on the next morning the survey was interrupted to recover moorings C and F. The last CTD station was perfomed on September 15 at midnight.

"Valdivia" arrived back in Bremerhaven on September 17 in the early afternoon, one day earlier than planned.

4. Work achieved

4.1 Moorings (J. Humphery)

A total of nineteen mooring-packages were deployed from the "Valdivia" during the above cruise. They included surface buoys, single-point (pop-up) sub-surface moorings and benthic landers (bed-frames) in waters which are generally a little over 100 m deep. A heavily-instrumented site centred close to 59° 20'N, 1° 00'E is complimented by secondary sites extending up to 40 km North and East. Unless stated otherwise, all the moorings are due for recovery in early November by RRS "Challenger".

Surface buoys:

Moorings E and F were deployed to measure near-surface currents, with two Inter Ocean S4 electromagnetic current meters suspended at 4m and 10m below the surface on each. Mooring E was a J-rig (so called because of the shape which the mooring takes up in the water); the current-meters should have enough endurance to last until November. Mooring F is an eta-rig (so called because it takes the shape of the Greek letter eta when in the water); this mooring is thought to have a better dynamic performance than the J-rig, but history has shown that it does not survive very well. It has been recovered at the end of the "Valdivia" cruise and carries two high-capacity Inter Ocean S4 current meters working in fast mode.

Mooring G carries a 2.6m toroidal buoy which supports a meteorological package supplied by NIOZ, Texel, Netherlands.

Mooring H is a Waverider buoy measuring heave only: the signal is processed into spectra which are transmitted to the ARGOS satellite system together with position-information.

Mooring I is a 1.9m toroid carrying a flourometer, a transmissometer and a nitrate analyser at a nominal depth of 1m to provide environmental data. Another fluorometer, supplied by NIOZ, Texel, Netherlands, is carried at a depth of about 14m.

Sub-surface mooring strings:

These moorings were of standard pop-up form with spherical sub-surface floats and 0.5 tonne chain anchors. In-line buoyancy (glass spheres) was fitted to protect the instruments and releases from trawling activity where necessary.

Moorings J1 and J2 are, respectively, midwater and near-bed environmental moorings, carrying fluorometers, current meters, transmissometers and nutrient analysers. J1 carries its array (with a standard nitrate analyser) at about 50 m (ie, in mid-water), and J2 carries its array at about 10m above the bed. J2 carries a double nutrient package: as well as a standard nitrate system, it also carries a prototype silicate analyser.

Mooring K was not deployed because a faulty SUV6 data logger could not be repaired in time for the cruise.

Moorings L, R and S all carried thermistor strings and miniature temperature loggers to investigate the breakdown of the thermocline with the approach of winter. Additionally, mooring L carried an INFLUX current meter for the Alfred Wegener Institute, Bremerhaven; this device combined a current meter with fluorometer and backscatter sensors.

Seabed landers (bed-frames):

Wherever possible, seabed frames were used to house recording instruments: these are less susceptible to trawling-damage. They included acoustic doppler current profilers (at 150kHz and 1.2MHz), bottom-pressure recorders (BPRs) and the STABLE system. Submersible ARGOS beacons are fitted to the frames where possible.

Moorings A and U carried an RDI 150kHz broadband ADCP and pressure recorder on each frame (POL instruments). Moorings B and C carried RDI 1.2MHz (short-range) Workhorse ADCPs: that on mooring B is owned by UWB, is sampling slowly and will be recovered in November, while the POL instrument on mooring C is sampling quickly and has been recovered at the end of the "Valdivia" cruise.

Mooring D is the large benthic instrument called STABLE (Sediment Transport And Boundary Layer Equipment). This carries flow-sensors to measure turbulent and mean current strengths and directions, pressure recorders, acoustic backscatter sediment profilers, compass, pitch, roll and temperature sensors. Additionally, a new fast (8Hz) temperature and conductivity system is being used; the frame also carries three simple sediment traps.

Mooring V carries an RDI 150kHz narrow-band ADCP (RVS instrument).

Moorings X and Y are small frames which carry pressure recorders for water-depth and tidal signals. They are at the extreme ends of the experimental array, respectively at 40 km East and North of the main site.

Northern North Sea

Valdivia moorings - complete area

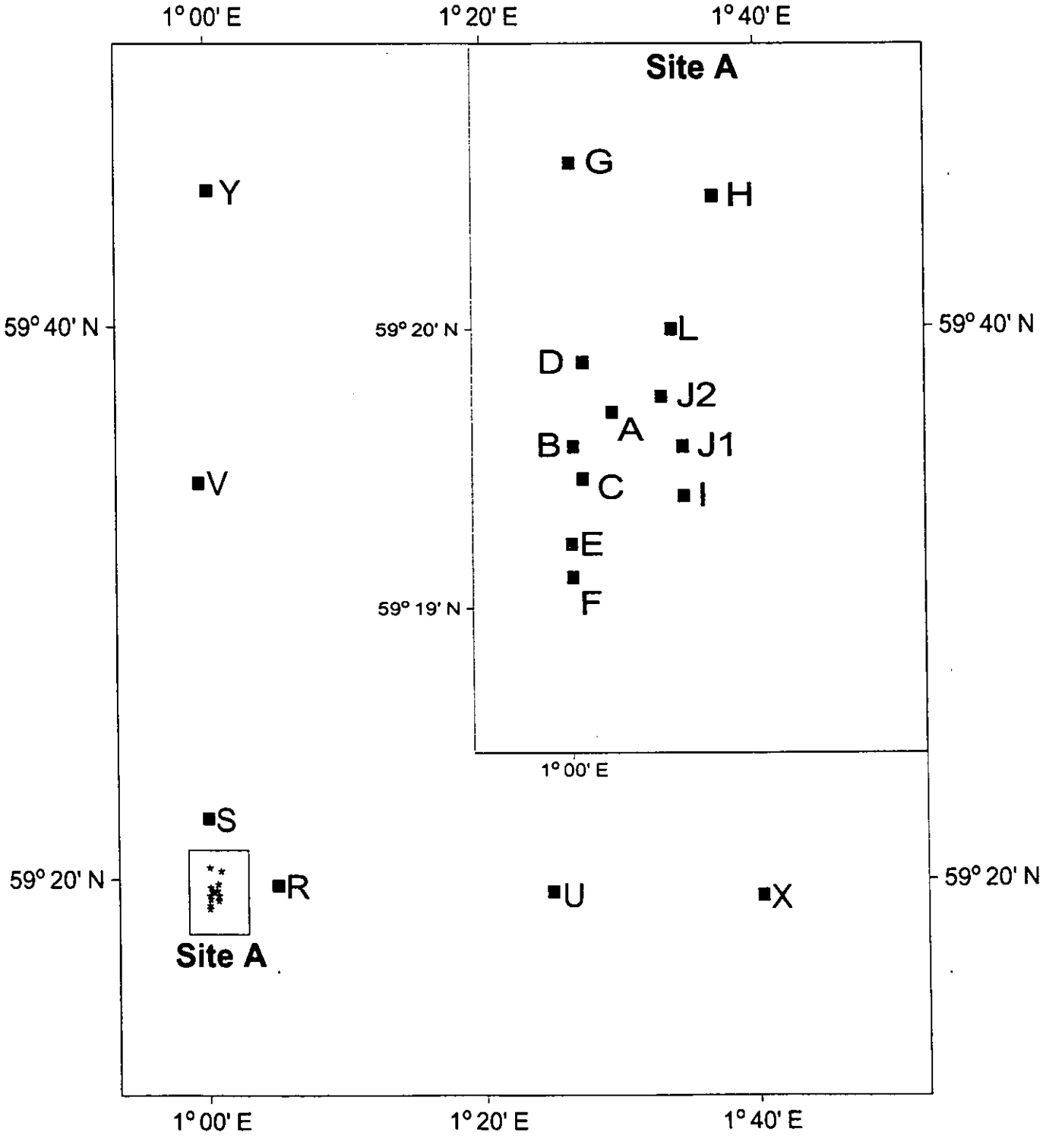


Table of Mooring Deployments Made During "Valdivia" Cruise 174,

5th - 18th September, 1998, for PROVESS.

Mooring designation	Event No.	Type of mooring (description)	Date	Time (UTC)	Position (lat/long)	Depth (metres)
A	50	POL 150kHz RDI ADCP	8/9/98	0856	59deg 19.70'N 01deg 00.22'E	-
B	53	UWB 1.2MHz W/horse	8/9/98	1125	59deg 19.54'N 00deg 59.99'E	105
C	53A	POL 1.2MHz W/horse	8/9/98	1217	59deg 19.42'N 01deg 00.08'E	107
D	48	STABLE	8/9/98	0658	59deg 19.87'N 01deg 00.06'E	-
E	70	Surface currents (J-rig)	9/9/98	0933	59deg 19.21'N 01deg 00.02'E	-
F	71	Surface currents (Eta-rig)	9/9/98	1226	59deg 19.10'N 00deg 59.99'E	-
G	49	Meteorological buoy	8/9/98	0800	59deg 20.61'N 00deg 59.73'E	-
H	52	Waverider	8/9/98	1046	59deg 20.46'N 01deg 00.87'E	105
I	68	Surface environment	9/9/98	0734	59deg 19.37'N 01deg 00.65'E	105
J1	93	Midwater environment	10/9/98	0935	59deg 19.57'N 01deg 00.67'E	105
J2	73	Nearbed environment	9/9/98	1758	59deg 19.75'N 01deg 00.53'E	-
K	-	U/V Nitrates - This mooring was not deployed - instrument failure.				
L	92	50m Therm. chain+INFLUX	10/9/98	0658	59deg 19.95'N 01deg 00.62'E	-
M, N	These moorings were not deployed from "Valdivia".					
R	95	50m Thermistor chain	10/9/98	1214	59deg 20.00'N 01deg 05.00'E	-

Table of mooring deployments from "Valdivia", (cont.):

S	96	40m Thermistor chain	10/9/98	1404	59deg 22.45'N 01deg 00.00'E	-
U	18	POL 150 kHz RDI ADCP	7/9/98	1135	59deg 19.98'N 01deg 25.07'E	-
V	72	RVS 150kHz n/band ADCP	9/9/98	1621	59deg 34.60'N 00deg 59.60'E	-
X	17	Seabed pressures (BPR)	7/9/98	1026	59deg 19.92'N 01deg 40.29'E	114
Y	53B	Seabed pressures (BPR)	8/9/98	1505	59deg 45.00'N 01deg 00.08'E	-

4.2 Hydrographic work

4.2.1 CTD and optical equipment

The basic instrument carrier to measure stratification and optical quantities in the water column was a Seabird Mini Rosette water sampler with 12 bottles, 2.5 litres each. This unit was modified to carry a Seabird 911 plus CTD, an optical instrument with sensors for the fluorescence of chlorophyll and yellow substance together with a sensor for Mie backscattering of light. The outputs of the optical sensors used the analogue channels of the CTD for digitizing and data transmission. Additionally a self-contained PAR instrument was fitted to the rosette frame.

Seabird CTD

The sensors of the 911 plus unit had been calibrated at the factory prior to the cruise. As we have several years of experience with the sensors we are confident to rely on the calibration without further checks by water sampling.

The accuracies specified are

conductivity: ± 0.003 mS/cm pressure: ±0.35 dbar
temperature: ± 0.002°C

Optical sensors

The following 3 optical sensors are integrated in one housing. The unit is manufactured by Dr. Haardt, Optik Mikroelektronik, and the sensors have the following specifications within the ranges selected for this cruise:

Light source: 2 Xenon flash tubes

Filters for the detection of

Chlorophyll: Excitation: 380nm - 540 nm
Emission: Bandpass, peak 863 nm, half width 20 nm
Range: 0 to 10 mg/m^3

During the cruise signals were recorded in volts, and calibration will be done by a relationship established on the basis of actual chlorophyll determinations of water samples during the cruise.

Yellow substance:
Excitation: Bandpass, peak 340 nm, half width 50 nm
Emission: Bandpass, peak 430 nm, half width 30 nm

Mie backscattering:
Wavelength 520 nm, half width 20 nm

PAR spectrometer

This self-contained instrument is manufactured by Ingenieurbüro Marcel Kruse. It has a cosine diffusor and records radiation in a range of 400 - 700 nm using a diode array. Depending on light intensities integration time ranges between 15 ms to 16 s for one spectrum. Storage capacity is 90 spectra. Programming and readout is done by a laptop computer.

References

- Seabird Electronics INC., 1808, 136th Place NE, Bellevue, WA98005, USA
  CTD system, Operating and Instruction Manual

- Dr. Haardt Optik Mikroelektronik, Alter Kieler Weg 19, 24245 Kleinbarkau, Germany
  Back Scat Fluorometer Model 1302 Chla/Yell/Aut 2R/Mo, Instruction Manual

- Ingenieurbüro Marcel Kruse, Informationstechnik, Am Walde 12, 27616 Stubben, Germany
  Instrument pamphlet

4.2.2 Hydrographic surveys

The purpose of two CTD surveys was to assess the hydrographic situation at the beginning of the Northern Experiment. The first was done on sections forming a box of 76 x 51 km around the central position at 59°20'N, 001°00'E. Station spacing was about 5 km in the order of the tidal excursion in the area. As this work was carried out during the nights in between mooring laying, the interruptions have to be considered when assessing the respective sections.

The second survey formed a cross with its centre at the main site of the moorings. The positions and times of the CTD stations are listed in chapter 7. It also contains the series of profiles measured at the anchor station.

4.3 Anchor station 10.9. - 14.9.1998

The ship anchored at 59°19.2'N, 001°02.1'E on a water depth of 98 m for studying the temporal evolution of the thermocline and its microstructure.

At regular intervals of 1.5 hours one CTD cast and a series of 8 turbulence profiles were obtained. Biological and chemical samples were collected from time to time, and PAR spectra were also measured. Occasionally the CTD was placed in the thermocline to record internal waves.

4.3.1 Microstructure measurements with the MICSOS-probe (H. Baumert, J. Post)

Introduction

Vertical exchanges are controlled principally by the turbulence characteristics of the water column with three regions of special significance in the surface mixed layer, the pycnocline and the benthic boundary layer. For that reason one of the main targets of PROVESS is the determination of turbulence properties by means of innovative measurements at two locations in the North Sea. During the first cruise of the Northern North Sea Experimentî (PROVESS N-1) these measurements were made with the MICSOS- or MST-Probe.

The MICSOS Profiler

The MICSOS Profiler is a free sinking or rising multi-parameter probe equipped with high resolution microstructure (temperature) and turbulence (current shear) sensors and precision CTD sensors. To control disturbing vibrations of the profiler itself, an internal vibration sensor is incorporated. The turbulence is measured by an aerofoil-shaped shear probe with a time constant of 4 ms. The high resolution temperature probe is based on a thermocouple with a time constant of about 5 ms. Data resolution of all sensors is 16 bits. The sampling rate of the profiler is 1 kHz. The data are transmitted via a fast link to a computer on the mother ship. The descent rate of the profiler can be adjusted by removable weights.

The MICSOS-System consists of a profiler, a special neutrally-buoyant cable, a data and power supply interface and a logger. The system is completed by a data evaluation software package.

Field Work

During the VALDIVIA Cruise No. 174 the MICSOS profiler was used to collect data about the microscale water stratification and turbulence characteristics around the main pycnocline.

For that reason a series of about 50 sets of vertical profiles, each consisting of 8 casts, and therefore in toto about 400 casts, were measured from about ten meters below the sea surface down to a water depth of 80 to 90 meters. The uppermost ten meters cannot be evaluated due to the strong influence of the ship on the hydrodynamic fields of interest. The measurements were carried out while the ship was anchoring on a permanent position in the centre of the target area (59(20` N and 001( 00` E) within a water depth of about 100 meters. The main pycnocline was in a water depth of about 40 meters. When starting with the microstructure measurements the pycnocline was sharp. During the period of observations it changed it`s shape slightly with frequently occurring stair cases.

The MICSOS measurements were made between Thursday 10th at 16:00 UTC (18:00 local time) and Monday 14th of September 1998 at 13:00 UTC. The sets of profiles were made at 90 minute-intervals. Each set of casts took about 45 minutes. One cast produced about 4.2 MBytes of data so that for the whole MICSOS campaign about 2.5 Giga-Bytes of data were recorded. At the beginning of each set of microstructure measurements, a vertical CTD-profile was acquired with a SEABIRD probe, and so the MICSOS-CTD and SEABIRD data could be compared and correlated. Furthermore, the SEABIRD probe was used to carry out longer-term measurements (time series) at the centre of the pycnocline (at about 41 metres) to gain information on internal waves.

The series of MICSOS turbulence measurements was successful. At first glance it can be stated that:

a valuable set of microstructure and turbulence data have been collected;
the dynamic evolution of the pycnocline was recorded, and
the CTD time series sometimes revealed the occurrence of internal waves.

List of MICSOS Profiles
(Central Anchor-Station; Station No. 76; Lat.: 59° 20' N; Long.: 001° 02' E)

Event	Cast	Date	Time (UTC)	Filename
098	1 - 8	10.09.1998	16.50	E098C001 -8
101	1 - 8	10.09.1998	18.13	E100C001 - 8
103	1 - 8	10.09.1998	19.10	E103C001 - 8
105	1 - 8	10.09.1998	20.11	E105C001 - 8
107	1 - 8	10.09.1998	21.09	E107C001 - 8
109	1 - 8	10.09.1998	22.45	E109C001 - 8
111	1 - 8	11.09.1998	00.15	E111C001 - 8
113	1 - 8	11.09.1998	01.40	E113C001 - 8
115	1 - 8	11.09.1998	03.10	E115C001 - 8
117	1 - 8	11.09.1998	04.38	E117C001 - 8
119	1 - 8	11.09.1998	06.09	E119C001 - 8
121	1 - 8	11.09.1998	07.40	E121C001 - 8
124	1 - 8	11.09.1998	09.12	E124C001 - 8
127	1 - 8	11.09.1998	10.42	E127C001 - 8
130	1 - 8	11.09.1998	12.24	E130C001 - 8
133	1 - 8	11.09.1998	13.43	E133C001 - 8
135	1 - 8	11.09.1998	15.05	E135C001 - 8
137	1 - 8	11.09.1998	16.35	E137C001 - 8
139	1 - 3	11.09.1998	18.10	E139C001 - 3
141	1 - 8	11.09.1998	20.00	E141C001 - 8
143	1 - 8	11.09.1998	21.10	E143C001 - 8
145	1 - 8	11.09.1998	22.41	E145C001 - 8
147	1 - 8	12.09.1998	00.08	E147C001 - 8
149	1 - 8	12.09.1998	01.41	E149C001 - 8
151	1 - 8	12.09.1998	03.05	E151C001 - 8
153	1 - 8	12.09.1998	04.35	E153C001 - 8
155	1 - 8	12.09.1998	06.10	E155C001 - 8
158	1 - 8	12.09.1998	07.45	E158C001 - 8
161	1 - 8	12.09.1998	09.11	E161C001 - 8
164	1 - 8	12.09.1998	10.40	E164C001 - 8
166	1 - 8	12.09.1998	12.25	E166C001 - 8
169	1 - 8	12.09.1998	13.43	E169C001 - 8
172	1 - 8	12.09.1998	15.10	E172C001 - 8
175	1 - 8	12.09.1998	16.40	E175C001 - 8
178	1 - 8	12.09.1998	18.15	E178C001 - 8
181	1 - 8	12.09.1998	19.40	E181C001 - 8
184	1 - 8	12.09.1998	21.10	E184C001 - 8
186	1 - 7	12.09.1998	22.40	E186C001 - 7
188	1 - 8	13.09.1998	00.08	E188C001 - 8
190	1 - 8	13.09.1998	01.40	E190C001 - 8
192	1 - 8	13.09.1998	03.25	E192C001 - 8
194	1 - 8	13.09.1998	04.40	E194C001 - 8
196	1 - 8	13.09.1998	06.30	E196C001 - 8
199	1 - 8	13.09.1998	07.42	E199C001 - 8
202	1 - 6	13.09.1998	09.25	E202C001 - 6
205	1 - 8	13.09.1998	10.44	E205C001 - 8
207	1 - 8	13.09.1998	12.25	E207C001 - 8
210	1 - 8	13.09.1998	13.43	E210C001 - 8
212	1 - 8	13.09.1998	15.15	E212C001 - 8
214	1 - 8	13.09.1998	16.45	E214C001 - 8
216	1 - 8	13.09.1998	18.10	E216C001 - 8
218	1 - 8	13.09.1998	19.40	E218C001 - 8
220	1 - 8	13.09.1998	21.10	E220C001 - 8
222	1 - 8	13.09.1998	22.42	E222C001 - 8
224	1 - 7	14.09.1998	00.08	E224C001 - 7
226	1 - 8	14.09.1998	01.40	E226C001 - 8
228	1 - 8	14.09.1998	03.10	E228C001 - 8
230	1 - 8	14.09.1998	04.40	E230C001 - 8
232	1 - 8	14.09.1998	06.30	E232C001 - 8
234	1 - 8	14.09.1998	08.45	E234C001 - 8
236	1 - 8	14.09.1998	09.10	E236C001 - 8
240	1 - 7	14.09.1998	12.20	E240C001 - 7

5. Biological and chemical sampling (P. Tett)

Rosette bottles were used to take water samples for phytoplankton, photosynthetic pigments, particulate organic matter (POM), dissolved oxygen (DO) and dissolved nutrients. The 'main site' refers to samples taken at 59°19'-20'N, 01°01'-02'E, close to the moorings I, J1 and J2, which were equipped with fluorometers and nutrient analysers. The aims of this work were: (1) to obtain data for the calibration of these moored instruments, especially the fluorometers; and (2) to commence a time-series of biological observations at this study site.

Methods & Results

(1) Phytoplankton. Samples of about 200 ml were preserved with acid Lugol's iodine for microscopic analysis at Napier University.

date (Sep. 98)	CTD stn-event	depth(s), m	notes
7	1-15	6	SML at 59°20N, 1°42'E
9	49-69	5	SML at main site
10	73-94	30	DCM at main site
11	76-120	30	DCM at main site
13	76-206	6, 35	SML & DCM at main site
15	99-266	7, 35	SML & DCM at main site

(2) Photosynthetic pigments. About 2 litres were filtered through 47 mm GF/F filters, which were then extracted overnight in buffered 90% acetone. Optical densities were measured against a 90% acetone blank in a Shimadzu UV-1202 spectrophotometer using 50 mm pathlength sub-micro cells. Measurements were made at 750, 665, 664, 647, 630, 510 and 480 nm, and, after addition of 2 drops 1N HCl, at 750 and 665 nm. Concentrations of chlorophyll a and pheopigments were calculated by the Lorenzen method, of chlorophylls a, b and c by the Trichromatic equations (with coefficients of Jeffrey & Humphrey, 1975), and of total carotenoids from the o.d. at 510 and 480 nm.

Measurements suffered from high and somewhat variable blanks, and the s.d. of replicate chlorophyll a estimated by the Lorenzen method was too high (0.19 mg m^{-3}) for these values to be considered reliable. The standard deviations of replicate estimates of chlorophyll a by the Trichromatic method (0.05 mg m^{-3}) and of carotenoids (0.06 mg m^{-3}) were acceptable. A summary of results for the main site (all samples between 9 and 15 September) is given below. The s.d. values in the table are a measure of the spread of the observations, and in most cases exceed the measurement error deduced from replicates.

Depth (range), m	chloro-phyll a mean	mg m^{-3} s.d.	carotenoids mean	mg m^{-3} range	no. samples	comments
5 - 9	0.48	0.11	0.34	0.22	13	SML, surface fluorometers
28-36	0.76	0.16	0.50	0.09	9	DCM
50-54	0.12	0.06	0.04	0.04	11	50 m fluorometer
90-94	0.07	0.05	-0.02	0.07	11	BBL, 90 m fluorometer

Water samples were fractionated on 14 and 15 September, using 'Nucleopore'-type 5 mm pore-size filters, 47 mm diameter, placed on top of GF/F filters. About two-thirds of pigments in SML samples passed through the 5 mm pores and were retained by the GF/F filter. The proportion was closer to a half in the case of DCM samples.

(3) Particulate Organic Matter. About 1 litre of water was filtered through pre-baked 25 mm GF/F filters, which were then stored over desiccant in darkness for analysis at the Dunstaffnage Marine Laboratory.

date (Sep. 98)	CTD stn-event	depth(s), m	notes
9	53-74	5,50,90	main site
11	76-120	5,30,50,90	main site
13	76-206	6,35,53,93	main site

(4) Dissolved Oxygen. The micro-Winkler method was used. Glass bottles of about 160 ml were filled, via a silicone rubber tube, from the rosette bottles, and the contents fixed in the usual way with solutions of manganous sulphate and alkaline iodide. The contents were later acidified and titrated with a solution of sodium thiosulphate using the method of Bryan *et al.* with a Dosimat titrator and a photo-optical end-point detector; the thiosulphate was standardised against a known solution of potassium iodate. The standardisation s.e. was 0.4%.

Some problems were encountered with the sample titration end point, and some data were lost as a result of this. These difficulties were due to insufficient dissolution of the precipitate before titration. It was found that addition of 1.1 ml (rather than 1.0 ml as per recipe) of 5M sulphuric acid completely dissolved the precipitate in all cases, and resulted in a satisfactory end point. Disregarding samples which gave a poor end point (and for which data will not be reported), the s.d. of replicate oxygen measurements was 0.7 mM or 0.23% saturation.

date (Sep. 98)	CTD stn-event	depths, m (for good data)	notes
13	76-195	6,36,52,82,97	main site
13	76-213	5,20,31,50,80,97	main site
14	76-231	5,21,36,51,81	main site
14	76-237	58,63,82,87,95	main site
14	76-238	7,11,15,19,22,26,30,35,39,43,46,52	main site
15	99-265	11,23,32,42,52,63,72, 82,93	main site

(5) Dissolved Nutrients. GF/F filtered water was preserved with mercuric chloride for analysis for nitrate and silicate at the Dunstaffnage Marine Laboratory.

date (Sep 98)	CTD stn-event	depths, m	notes
9	53-074	4, 90	main site
15	99-266	93,52,36,7	main site

Discussion of results

Figure 1 shows the relationship between the voltage output of the chlorophyll channel of the 'Dr Haardt' BackScatter-Fluorometer, and water-sample chlorophyll as calculated using the Trichromatic equations.

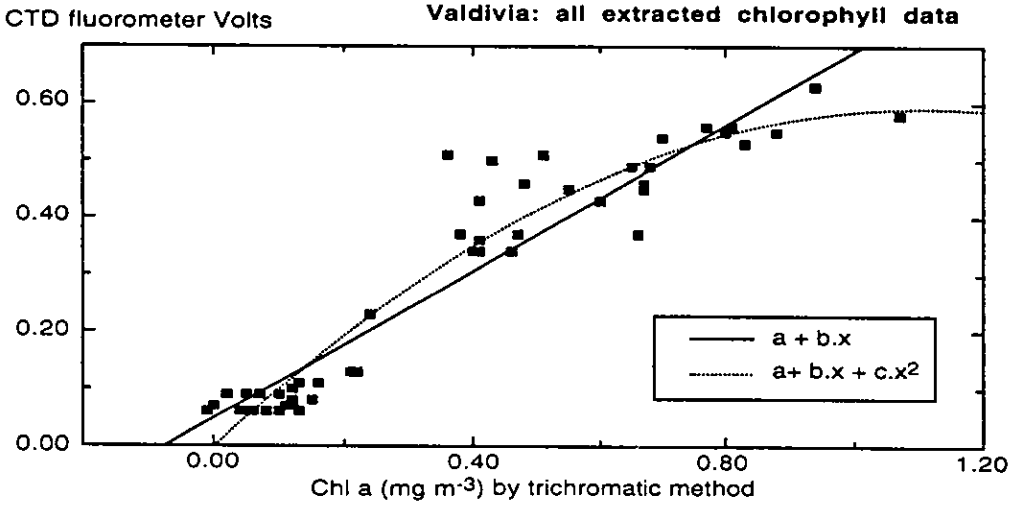


Fig. 1. Preliminary calibration for the 'Dr Haardt' (chlorophyll) fluorometer on the CTD: plot of fluorescence voltage obtained when sampling bottle closed, against Trichromatic estimate of chlorophyll a. The quadratic provided a slightly better fit, but may be less appropriate (for theoretical reasons) than the linear regression.

Although a quadratic equation fitted somewhat better, a linear regression of voltage (V) on chlorophyll concentration (X, in mg m^{-3}) provides a preliminary calibration for this fluorometer:

$$V = a + b.X \implies X = (V - a)/b$$

where the coefficients were:

a = 0.05, s.e.= 0.02 Volts
b = 0.64, s.e.= 0.03 Volts (mg chl a m^{-3})$^{-1}$

Profiles showed well developed boundary layers and thermocline, as exemplified in Fig 2. for 14 September at the main site.

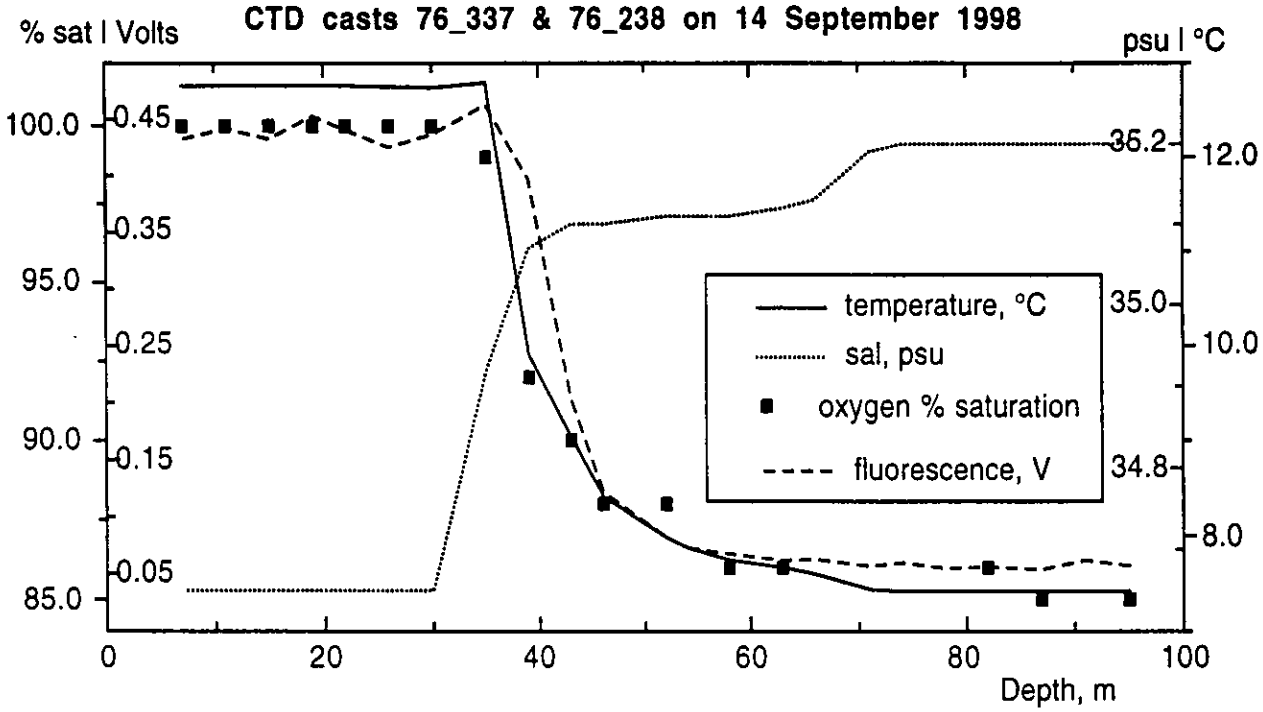


Fig. 2. Typical profile (from 76-237 and 76-238, at the anchor station at main site on 14 September 1998) of dissolved oxygen, and bottle data only from CTD casts for temperature, salinity and fluorescence. Oxygen % saturation = 100% * (actual_oxygen_concentration) / (saturation_concentration). The saturation_concentration was that calculated for temperature and salinity at the depth from which the sample was taken.

During the 7 days (September 8-15) of intensive sampling, chlorophyll averaged about 0.5 mg m^{-3} in the Surface Mixed Layer. Some (but not all) profiles showed a Deep Chlorophyll Maximum in the upper thermocline with concentrations sometimes exceeding 0.75 mg m^{-3}. In the lower thermocline and in the Bottom (or Benthic) Boundary Layer, chlorophyll concentrations did not exceed 0.25 mg m^{-3}. The pigment size fractionation measurements showed that most chlorophyll-containing particles in the SML were less than 5 mm in diameter. This suggests that the phytoplankton here was a Summer association of small cells supported by recycled nitrogen. (Had an Autumn bloom of diatoms already commenced, it is likely that most chlorophyll would have been retained on a 5 mm pore size filter).

The profile of oxygen % saturation in Fig. 2 shows that there has been consumption of oxygen below the SML during the period when the sub-surface water was (as it continues) isolated from the atmosphere. When Apparent Oxygen Utilisation (AOU) was plotted against water temperature, a straight line was obtained (Fig. 3), implying that the oxygen profile was dominated by the effects of physical mixing and boundary exchange. That is, most remineralisation, and concommitant use of oxygen, probably occurred in or on the sea-bed, or in the BBL, rather than in the thermocline.

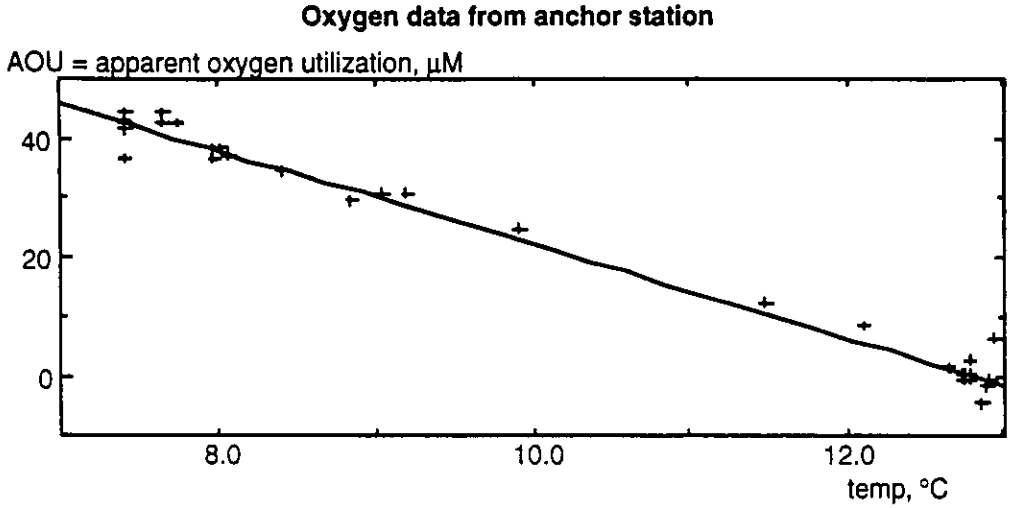


Fig. 3. Regression of AOU on water temperature. AOU = (saturation_concentration) - (actual_oxygen_concentration), and is the Apparent Oxygen Utilisation since the (presumed) last occasion when the sampled water was in contact with the surface, and hence at 100% saturation. Water is assumed to retain its pre-stratification temperature when trapped in or below the thermocline.

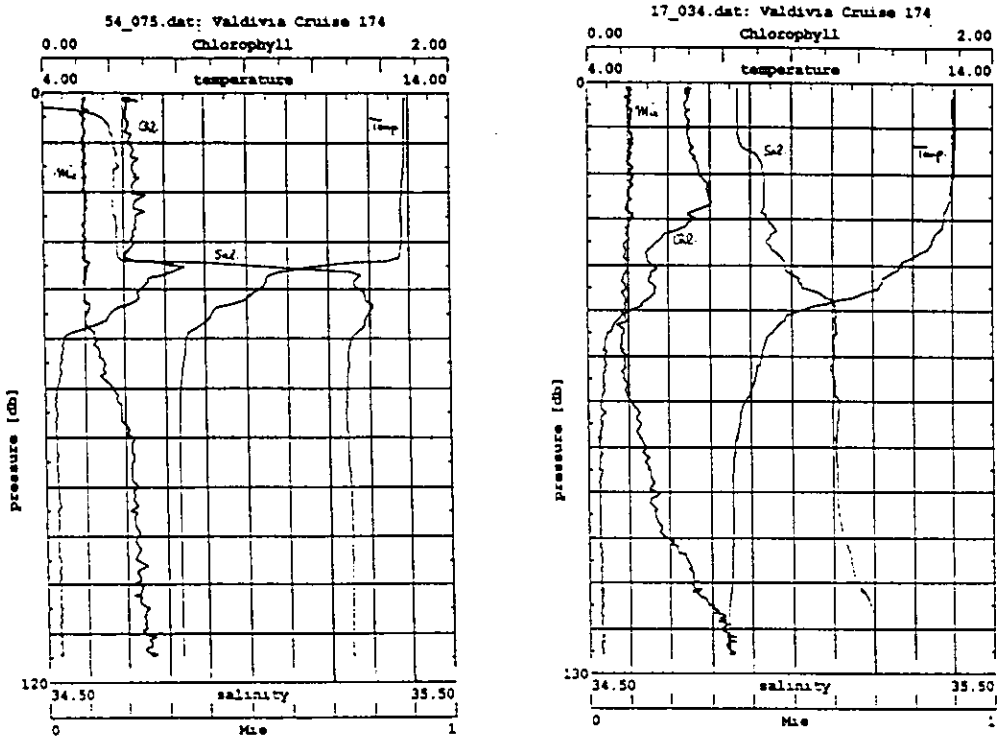
It may be presumed that the AOU in deep water corresponds to nutrient enrichment: the maximum AOU of 40 mM implies the release in deep water of 4 - 5 mM of nitrate since stratification began. Dissolved silica might also be expected to have increased during this time. Thus, future deepening of the SML will entrain water containing nutrients, including dissolved silica. This may give rise to an Autumn bloom of diatoms if other conditions (especially, mean irradiance in the SML) allow.

Other points

PAR spectra were collected on most days at about (local) noon, from depths of 30, 25, 20, 15, 10, 5 and 2 m. These spectra will be analysed to give spectra of the diffuse attenuation coefficient, for use with numerical simulations of phytoplankton growth.

It is possible that some of the chlorophyll-containing organisms in the pycnocline, were capable of some vertical migration. It will thus be interesting to examine the time-series of CTD-fluorescence profiles made at the anchor station (CTD 76), in order to find midwater peaks in fluorescence and to ascertain if they move vertically according to a diel cycle. Because of variability in pynocline depth due to internal waves, it will be best to plot fluorescence against density: vertical migration will be evidenced by shifts in the position of peaks relative to density.

6. Preliminary results



The stratification found at the Northern Site still exhibits the typical characteristics of summer conditions. This is also true for the phytoplankton association found in the area. From considerations based on oxygen measurements it is concluded that future deepening of the surface mixed layer will entrain water containing nutrients. This is one of the necessary conditions for an autumn bloom of diatoms.

There was a considerable variability of the stratification of temperature and salinity in space as well as in time. The above profiles display the range of shapes of the thermocline found in the area. The causes for the more or less steep gradients are not yet known. They have occured on neighbouring stations 5 km apart or at the same station in the course of time. Based on the large data sets of CTD and turbulence measurements collected on this and the future cruises - and together with the mooring data - it will be an exciting analysis to find the solution.

CTD RECORD

Ship: RV Valdivia

Cruise: PROVESS 1-1

17. September 1998

event	*date*	*time UTC*	*Lat. N*	*Long. E*	*file name*	*remarks*	*additional measurements*	*wind deg./bf*
6	7/9/98	06:00	59° 20.5'	001° 40.4'	1_006	CTD test station	PAR	147° / 3
15	7/9/98	08:02	59° 20.30'	001° 42.29'	1_015	water cast	PAR, water bottles	150° / 3-4
19	7/9/98	11:50	59° 20'	001° 25'	2_019	box	PAR	137° / 4
20	7/9/98	12:44	59° 17.5'	001° 40'	3_020	box		130° / 4
21	7/9/98	13:12	59° 15'	001° 40'	4_021	box		140° / 4
22	7/9/98	13:37	59° 12.5'	001° 40'	5_022	box		140° / 4
23	7/9/98	13:45	59° 12.5'	001° 40'	5_023	repetition of 22		140° / 4
24	7/9/98	14:10	59° 10'	001° 40'	6_024	box		132° / 4
25	7/9/98	14:18	59° 10'	001° 40	6_025	repetition of 24		132° / 4
26	7/9/98	14:47	59° 07.5'	001° 40'	7_026	box		132° / 4
27	7/9/98	15:15	59° 05'	001° 40'	8_027	box		132° / 5
28	7/9/98	15:47	59° 02.5'	001° 40'	9_028	box		135° / 4
29	7/9/98	16:35	59° 00'	001° 40'	10_029	box		135° / 4
30	7/9/98	17:07	59° 00'	001° 35'	11_030	box		150° / 5
31	7/9/98	17:36	59° 00'	001° 30'	14_031	box		150° / 5-6
32	7/9/98	18:03	59° 00'	001° 25'	15_032	box		155° / 6
33	7/9/98	18:38	59° 00'	001° 20'	16_033	box		155° / 6
34	7/9/98	19:09	59° 00'	001° 15'	17_034	box		155° / 6
35	7/9/98	19:40	59° 00'	001° 10'	18_035	box		130° / 6
36	7/9/98	20:10	59° 00'	001° 05'	19_036	box		130° / 6
37	7/9/98	20:40	59° 00'	001° 00'	20_037	box		130° / 6
38	7/9/98	21:11	59° 00'	000° 55'	21_038	box		130° / 5-6
39	7/9/98	21:41	59° 00'	000° 50'	22_039	box		130° / 6
40	7/9/98	22:14	59° 00'	000° 45'	23_040	box		137° / 5-6
41	7/9/98	22:58	59° 00'	000° 40'	24_041	box		137° / 5-6
42	7/9/98	23:30	59° 00'	000° 35'	25_042	box		137° / 5-6
43	8/9/98	00:05	59° 00'	000° 30'	26_043	box		136° / 5-6
44	8/9/98	00:36	59° 00'	000° 25'	27_044	box		136° / 5-6
45	8/9/98	01:10	59° 00'	000° 20'	28_045	box		136° / 5

46	8/9/98	01:42	59° 02.5'	000° 20'	29_046	box		136° / 5
51	8/9/98	09:00	59° 20'	(001° 05')!	30_051	CTD after mooring A	probably meant as 0.5'	130° / 6-7
54	8/9/98	17:54	59° 27.56'	000° 45.11'	35_054	CTD after mooring Y		150° / 7
55	8/9/98	21:12	59° 05'	000° 20'	36_055	box		150° / 6
56	8/9/98	21:44	59° 07.5'	000° 20'	37_056	box		150° / 6
57	8/9/98	22:18	59° 10'	000° 20'	38_057	box		160° / 5
58	8/9/98	22:49	59° 12.5'	000° 20'	39_058	box		160° / 5
59	8/9/98	23:20	59° 15'	000° 20'	40_059	box		160° / 5
60	8/9/98	23:52	59° 17.5'	000° 20'	41_060	box		160° / 5
61	9/9/98	00:26	59° 20'	000° 20'	42_061	box		160° / 5
62	9/9/98	00:58	59° 22.5'	000° 20'	43_062	box		155° / 4-5
63	9/9/98	01:31	59° 25'	000° 20'	44_063	box		158° / 4
64	9/9/98	02:04	59° 27.5'	000° 20'	45_064	box		158° / 4
65	9/9/98	02:35	59° 27.5'	000° 25'	46_065	box		158° / 4
66	9/9/98	03:10	59° 27.5'	000° 30'	47_066	box		158° / 4
67	9/9/98	03:38	59° 27.5'	000° 35'	48_067	box		151° / 4
69	9/9/98	07:48	59° 19.36'	001° 00.68'	49_069	CTD after mooring I	PAR, water bottles	140° / 4
74	9/9/98	18:12	59° 19.68'	000° 59.85'	53_074	CTD after mooring J2	water bottles	120° / 2
75	9/9/98	19:45	59° 27'	000° 35'	54_075	same position as 67		140° / 2
76	9/9/98	20:12	59° 27.5'	000° 40'	55_076	box		140° / 2
77	9/9/98	20:40	59° 27.5'	000° 45'	56_077	box		140° / 2
78	9/9/98	21:05	59° 27.5'	000° 50'	57_078	box		160° / 2
79	9/9/98	21:32	59° 27.5'	000° 55'	58_079	box		160° / 2
80	9/9/98	21:55	59° 27.5'	001° 00'	59_080	box		160° / 2
81	9/9/98	22:25	59° 27.5'	001° 05'	60_081	box		180° / 2
82	9/9/98	22:51	59° 27.5'	001° 10'	61_082	box		180° / 2
83	9/9/98	23:26	59° 27.5'	001° 15'	62_083	box		180° / 2
84	9/9/98	23:51	59° 27.5'	001° 20'	63_084	box, bottom contact removed		180° / 2
85	10/9/98	00:19	59° 27.5'	001° 25'	64_085	box		180° / 2
86	10/9/98	00:53	59° 27.5'	001° 30'	65_086	box		var / 1

87	10/9/98	01:18	59° 27.5'	001° 35'	66_087	box		var / 1
88	10/9/98	01:47	59° 27.5'	001° 40'	67_088	box		var / 1-2
89	10/9/98	02:17	59° 25'	001° 40'	68_089	box		var / 1-2
90	10/9/98	02:49	59° 22.5'	001° 40'	69_090	box		0
91	10/9/98	03:18	59° 20'	001° 40'	70_091	box		0
94	10/9/98	10:17	59° 19.29'	001° 02.08'	73_094	CTD after mooring J1	PAR, water bottles	var / 1
99	10/9/98	17:39	59° 20'	001° 02'	76_099	begin anchoring station 76		250° / 4
100	10/9/98	18:00	59° 20'	001° 02'	76_100			250° / 4
102	10/9/98	19:00	59° 20'	001° 02'	76_102			240° / 3
104	10/9/98	20:00	59° 20'	001° 02'	76_104			240° / 3
106	10/9/98	21:00	59° 20'	001° 02'	76_106			240° / 3
108	10/9/98	22:30	59° 20'	001° 02'	76_108			240° / 3
110	11/9/98	00:00	59° 20'	001° 02'	76_110			229° / 2-3
112	11/9/98	01:30	59° 20'	001° 02'	76_112			240° / 3
114	11/9/98	03:00	59° 20'	001° 02'	76_114			240° / 3-4
116	11/9/98	04:30	59° 20'	001° 02'	76_116			270° / 3-4
118	11/9/98	06:00	59° 20'	001° 02'	76_118			280° / 3
120	11/9/98	07:30	59° 20'	001° 02'	76_120		water bottles	270° / 3
122	11/9/98	09:00	59° 20'	001° 02'	76_122			270° / 3
123	11/9/98	09:07	59° 20'	001° 02'	76_123	time series		
125	11/9/98	10:32	59° 20'	001° 02'	76_125			270° / 3
126	11/9/98	10:41	59° 20'	001° 02'	76_126	time series		
128	11/9/98	12:02	59° 20'	001° 02'	76_128		PAR	280° / 4
129	11/9/98	12:20	59° 20'	001° 02'	76_129	time series		294° / 4
131	11/9/98	13:35	59° 20'	001° 02'	76_131			280° / 6
132	11/9/98	13:40	59° 20'	001° 02'	76_132	time series		
134	11/9/98	15:00	59° 20'	001° 02'	76_134			270° / 5
136	11/9/98	16:30	59° 20'	001° 02'	76_136			280° / 5-6
138	11/9/98	18:08	59° 20'	001° 02'	76_138			290° / 4-5
140	11/9/98	19:30	59° 20'	001° 02'	76_140			290° / 4-5

142	11/9/98	21:00	59° 20'	001° 02'	76_142			290° / 4-5
144	11/9/98	22:30	59° 20'	001° 02'	76_144			310° / 3
146	12/9/98	00:00	59° 20'	001° 02'	76_146			302° / 2
148	12/9/98	01:30	59° 20'	001° 02'	76_148			280° / 3
150	12/9/98	03:00	59° 20'	001° 02'	76_150			307° / 2
152	12/9/98	04:30	59° 20'	001° 02'	76_152			var / 2
154	12/9/98	06:00	59° 20'	001° 02'	76_154			var / 2
156	12/9/98	07:30	59° 20'	001° 02'	76_156			var / 2
157	12/9/98	07:40	59° 20'	001° 02'	76_157	time series		var / 2
159	12/9/98	09:00	59° 20'	001° 02'	76_159			var / 2
160	12/9/98	09:10	59° 20'	001° 02'	76_160	time series		var / 2
162	12/9/98	10:30	59° 20'	001° 02'	76_162			358° / 3
163	12/9/98	10:40	59° 20'	001° 02'	76_163	time series		
165	12/9/98	12:00	59° 20'	001° 02'	76_165			358° / 3
167	12/9/98	01:30	59° 20'	001° 02'	76_167		PAR, water bottles	358° / 3
168	12/9/98	01:35	59° 20'	001° 02'	76_168	time series		
170	12/9/98	15:00	59° 20'	001° 02'	76_170			360° / 4
171	12/9/98	15:10	59° 20'	001° 02'	76_171	time series		
173	12/9/98	16:30	59° 20'	001° 02'	76_173			10° / 4-5
174	12/9/98	16:40	59° 20'	001° 02'	76_174	time series		10° / 4-5
176	12/9/98	18:00	59° 20'	001° 02'	76_176			
177	12/9/98	18:05	59° 20'	001° 02'	76_177	time series		
179	12/9/98	19:30	59° 20'	001° 02'	76_179			330° / 4-5
180	12/9/98	19:35	59° 20'	001° 02'	76_180	time series		
182	12/9/98	21:00	59° 20'	001° 02'	76_182			330° / 4-5
183	12/9/98	21:05	59° 20'	001° 02'	76_183	time series		
185	12/9/98	22:33	59° 20'	001° 02'	76_185			318° / 5
187	13/9/98	00:02	59° 20'	001° 02'	76_187			318° / 5
189	13/9/98	01:30	59° 20'	001° 02'	76_189			
191	13/9/98	03:00	59° 20'	001° 02'	76_191			318° / 4

193	13/9/98	04:30	59° 20'	001° 02'	76_193			320° / 4
195	13/9/98	06:00	59° 20'	001° 02'	76_195		water bottles	350° / 4
197	13/9/98	07:30	59° 20'	001° 02'	76_197			340° / 4
198	13/9/98	07:40	59° 20'	001° 02'	76_198	time series		
200	13/9/98	09:10	59° 20'	001° 02'	76_200			10° / 3
201	13/9/98	09:20	59° 20'	001° 02'	76_201	time series		
203	13/9/98	10:30	59° 20'	001° 02'	76_203			336° / 5
204	13/9/98	10:40	59° 20'	001° 02'	76_204	time series		336° / 5
206	13/9/98	12:03	59° 20'	001° 02'	76_206		PAR, water bottles	336° / 5
208	13/9/98	13:15	59° 20'	001° 02'	76_208		PAR	330° / 5
209	13/9/98	13:32	59° 20'	001° 02'	76_209			330° / 5
211	13/9/98	15:00	59° 20'	001° 02'	76_211			320° / 5
213	13/9/98	16:30	59° 20'	001° 02'	76_213		water bottles	320° / 5
215	13/9/98	18:00	59° 20'	001° 02'	76_215			320° / 6
217	13/9/98	19:30	59° 20'	001° 02'	76_217			320° / 6
219	13/9/98	21:00	59° 20'	001° 02'	76_219			320° / 6
221	13/9/98	22:30	59° 20'	001° 02'	76_221			345
223	14/9/98	00:00	59° 20'	001° 02'	76_223			336° / 5-6
225	14/9/98	01:30	59° 20'	001° 02'	76_225			341° / 5
227	14/9/98	03:00	59° 20'	001° 02'	76_227			338° / 5
229	14/9/98	04:30	59° 20'	001° 02'	76_229			340° / 5
231	14/9/98	06:10	59° 20'	001° 02'	76_231		water bottles	340° / 6
233	14/9/98	07:30	59° 20'	001° 02'	76_233			340° / 5-6
235	14/9/98	09:00	59° 20'	001° 02'	76_235			340° / 5-6
237	14/9/98	10:33	59° 20'	001° 02'	76_237		water bottles 92-52m	343° / 6
238	14/9/98	10:56	59° 20'	001° 02'	76_238		water bottles 48-4m	343° / 6
239	14/9/98	12:00	59° 20'	001° 02'	76_239		PAR(not OK), water bottles	343° / 6
241	14/9/98	13:30	59° 20'	001° 02'	76_241			330° / 6
242	14/9/98	14:30	59° 20'	001° 02'	76_242	last CTD on anchor station		330° / 6
243	14/9/98	18:00	59° 34.90'	001° 01.89'	77_243	cross S-N		330° / 6

244	14/9/98	18:27	59° 32.47'	001° 01.87'	78_244	cross S-N		330° / 6
245	14/9/98	18:57	59° 29.95'	001° 01.96'	79_245	cross S-N		320° / 5-6
246	14/9/98	19:32	59° 27.36'	001° 01.87'	80_246	cross S-N		320° / 5-6
247	14/9/98	19:54	59° 27.39'	001° 02.09'	81_247	cross S-N		330° / 6
248	14/9/98	20:25	59° 22.43'	001° 01.88'	82_248	cross S-N		330° / 5-6
249	14/9/98	20:53	59° 19.84'	001° 02.05'	83_249	cross S-N		320° / 5-6
250	14/9/98	21:19	59° 17.50'	001° 01.77'	84_250	cross S-N		320° / 5-6
251	14/9/98	21:50	59° 14.97'	001° 01.78'	85_251	cross S-N		320° / 6
252	14/9/98	22:25	59° 12.52'	001° 01.92'	86_252	cross S-N		311° / 6
253	14/9/98	22:56	59° 09.97'	001° 02.05'	87_253	cross S-N		310° / 7
254	14/9/98	23:28	59° 07.46'	001° 02.03'	88_254	cross S-N		310° / 6
255	15/9/98	00:03	59° 04.98'	001° 01.89'	89_255	cross S-N		310° / 6
256	15/9/98	00:43	59° 02.44'	001° 02.24'	90_256	cross S-N		310° / 6
257	15/9/98	01:19	59° 00.50'	001° 02.31'	91_257	cross S-N		317° / 6
258	15/9/98	04:30	59° 18.52'	000° 19.76'	92_258	cross W-E		320° / 6
259	15/9/98	05:00	59° 18.48'	000° 24.71'	93_259	cross W-E		290° / 5
260	15/9/98	05:30	59° 18.50'	000° 29.96'	94_260	cross W-E		290° / 5
261	15/9/98	06:00	59° 19.00'	000° 35.00'	95_261	cross W-E		290° / 5
265	15/9/98	12:35	59° 19.64'	001° 02.28'	99_265	pos. of station 76	water samples for Oxygen	263° / 5
266	15/9/98	12:48	59° 19.64'	001° 02.28'	99_266	pos. of station 76	PAR, water samp. Chl.	263° / 5
267	15/9/98	15:30	59° 18.48'	000° 35.11'	100_267	cross W-E		250° / 5-6
268	15/9/98	16:10	59° 18.51'	000° 39.89'	101_268	cross W-E		270° / 5-6
269	15/9/98	16:40	59° 19.44'	000° 45.04'	102_269	cross W-E		270° / 5-6
270	15/9/98	17:10	59° 18.38'	000° 49.98'	103_270	cross W-E		270° / 5-6
271	15/9/98	17:35	59° 18.38'	000° 55.02'	104_271	cross W-E		260° / 6
272	15/9/98	18:00	59° 18.47'	001° 00.04'	105_272	cross W-E		260° / 6
273	15/9/98	18:26	59° 18.43'	001° 05.03'	106_273	cross W-E		260° / 6
274	15/9/98	18:43	59° 18.36'	001° 09.01'	107_274	cross W-E		250° / 6
275	15/9/98	19:15	59° 18.38'	001° 15.07'	108_275	cross W-E		240° / 6
276	15/9/98	19:40	59° 18.38'	001° 20.00'	109_276	cross W-E		230° / 6

CTD RECORD

Ship: RV Valdivia
Cruise: PROVESS 1-1

17. September 1998

277	15/9/98	20:11	59° 18.31'	001° 25.03'	110_277	cross W-E		240° / 5
278	15/9/98	20:34	59° 18.50'	001° 30.02'	111_278	cross W-E		240° / 5
279	15/9/98	20:59	59° 18.41'	001° 35.03'	112_279	cross W-E		240° / 5
280	15/9/98	21:23	59° 18.27'	001° 39.94'	113_280	cross W-E		240° / 5
281	15/9/98	21:52	59° 18.43'	001° 45.00'	114_281	cross W-E		240° / 5

185 CTD cast total
11 with PAR
13 with water samples
16 time series

Rule for file name: station number, underscore, event number

8. Participants

NAME	INSTITUTION	Address
Ballard, Norman Charles G.	Proudman Oceanographic Laboratory	Bidton Observatory, Birkenhead Merseyside, L43 7 RA United Kingdom
Banaszek, Anthony	"	"
Dr. Baumert, Helmut	Hydromod Sci. Cons.	Bahnhofstraße 52 22880 Wedel/Holstein Germany
Boyd, Joyce	Southampton Oceanographic Centre	Empress Dock Southampton SO14 3ZH UK.
Damm, Michael	Alfred-Wegener-Institut	Columbusstraße 27568 Bremerhaven, Germany
Dr. Holtsch, Kurt	Sea and Sun Technology GmbH	Erfurter Str. 2 24610 Trappenkamp
Humphery, John Douglas	Proudman Oceanographic Laboratory	Bidton Observatory, Birkenhead Merseyside, L43 7 RA United Kingdom
Prof. Dr. Krause, Gunther Chief Scientist	Alfred-Wegener-Institut	Columbusstraße 27568 Bremerhaven, Germany
Ohm, Klaus	Alfred-Wegener-Institut	Columbusstraße 27568 Bremerhaven, Germany
Post, Johannes	Hydromod Service GmbH	Lister Meile 27 30161 Hannover
Dr. Tett, Paul	Napier University Dept. of Biol. Sciences	10 Colinton Road Edinburgh EH10 5DT Scotland. UK.
Wynar, John	RVS, Southampton Oceanographic Centre	European Way Empress Dock Southampton SO14 3ZH UK.