PROcesses of Vertical Exchange in Shelf Seas (PROVESS)

MAST III Project # 96 1032

Cruise Report

Northern North Sea experiment cruise N-3
R.V. Pelagia 19-30 October, 1998
(Pelagia cruise 64PE125)

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(with contributions from participants)

27 November 1998

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0. Contents

Appendices

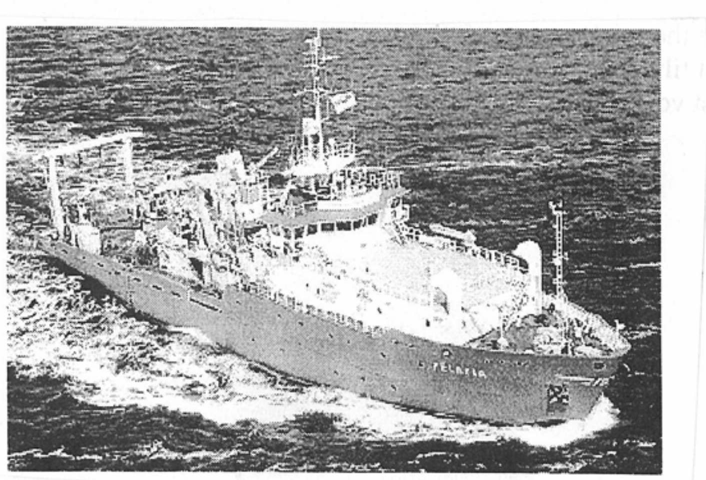
1. Summary of R.V. Pelagia cruise PROVESS N-3

The R.V. Pelagia (NIOZ, the Netherlands) cruise PROVESS N-3 started on Monday 19 October 1998 and ended on Friday 30 October 1998. The working area was located in the Northern North Sea, in a 100 x 50 km box around the central position 59° 20' N, 01° 00' E, where the majority of instrumentation was moored by the R.V. Valdivia (PROVESS N-1).

The purpose of cruise N-3 was to moor additional equipment to observe internal wave motions and to obtain an extensive set of turbulence, CTD, pelagic biological and optical measurements, in order to monitor (possible variations in) the vertical exchange in the water column. The emphasis of the study is on the exchange across the largest temperature variation with depth (the thermocline) during autumnal breakdown.

Despite the rather extreme weather conditions, with only occasional spells of calms in predominantly force 7-10 winds, we managed to complete most of the intentional programme. In total 42 CTD casts were taken, on 19 casts water samples were taken for biological and sedimentological sampling, some 200 profiles were obtained of turbulence dissipation rate and 14 times a sequence of optical profiling. Three surveys with the undulating CTD (Seasoar) were successfully completed, each lasting about 15 hours. With some difficulty the bottom lander mooring was deployed, whereafter, unfortunately, the major ADCP did not record data anymore. The drifting buoy holding a sediment trap did not provide data, because it was picked up by fishermen during its first deployment and damaged during the transfer back to us at sea.

A first preliminary analysis of the data showed some unexpected results, including very low turbulence dissipation rates in a 10-40 m thick layer immediately below the thermocline, a similar distribution of phytoplankton and a turbidity minimum at the depth of the thermocline, where one would expect a maximum. The depth of the thermocline varied between 40-60 m depth. Its thickness varied as well, albeit being rather thin (typically 5-10 m thick).


PELAGIA

2. PROVESS' general research summary and objectives.

Definition and aim.

PROVESS (PROcesses of Vertical Exchange in Shelf Seas) is an EC-MAST III project. The project is founded on the integration of experimental, theoretical and modelling studies of vertical exchanges in shelf seas, including the joint analysis and interpretation of measurements and model calculations. Innovative measurements of turbulence properties in continental shelf seas (dissipation rate throughout the water column and intensity over a wide frequency range) are the heart of the proposal.These, together with biological measurements concentrating on fluxes near the sea bed, will be made at two contrasting sites in the North Sea - one shallow, high energy, the other deeper, low energy.

This cruise plan is on the experiment at the deeper site, to study the vertical exchanges during the autumnal breakdown of the stabilizing density stratification.

Research summary and objectives.

Since turbulence directly affects the environment perceived by particles, including living biota, detritus and suspended sediment, studies will be made of aggregation, flocculation and sedimentation, and of trophic interactions. New hypotheses about turbulence effects on zooplankton grazing rates, diet selectivity, vertical distribution and patchiness will be tested against process oriented field and laboratory measurements.

Water column numerical models describing turbulent physics and integrated biology/physics will incorporate the understanding gained from the process studies and be rigorously tested against the turbulence and biological measurements, to establish the robustness of parameterisation and the domain of validity of the models.

The improved understanding will be applied to the exchange of nutrients across the stratification and to nutrient recycling in the benthic boundary layer. This fundamental research will contribute towards the long term goal of developing robust water column plankton models applicable in the full range of turbulence environments encountered in shelf seas.

Objectives.

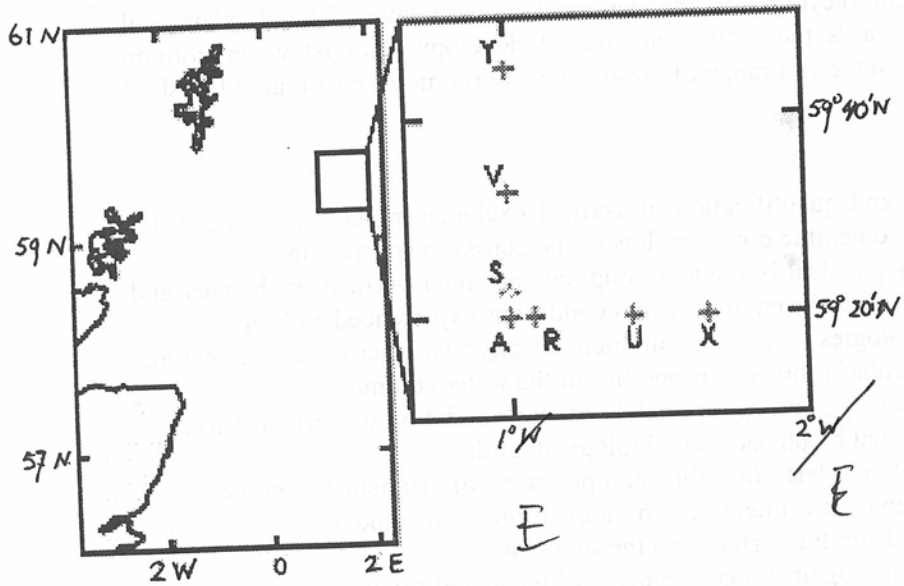
* Improve understanding and quantification of vertical exchange processes in the water column, in the surface and benthic boundary layers and across the pycnocline.
* Explore mechanisms of physical-biological coupling in which vertical exchanges and turbulence significantly affect the environmental conditions experienced by biota.
* Apply innovative technologies to the measurement of physical microstructure features and phenomena, in particular turbulence properties in the water column.
* Provide a new, comprehensive and synoptic data set for validation of vertical fluxes of energy and matter calculated by physical and biological models.
* Develop 1-D physical models for the computation of statistical moments of microstructure phenomena and integrated biological-physical models of the water column, including fluxes from the surface and the sediment.
* Test and validate the models against measurements of mean and fluctuating properties in the water column.
* Provide modules for vertical exchanges which can be implemented in state-of-the-art 3-D water quality and ecological models.

a. Northern North Sea experiment and site.

The observational study on the diapycnal exchange during the autumnal breakdown of stratification in the Northern North Sea took place between 5 September - 9 November, 1998. Four ships participated, each cruise lasting about two weeks. The R.V. Valdivia sailed between 5-18 September 1998 and basically deployed all of the mooring equipment, that remained on site for about two months. The R.V. Dana sailed between 14-26 October and the observations were focused on turbulence, video camera work on plankton movements and suspended sediment sampling.

The R.V. Pelagia cruise took place between 19-30 October, with the aim of extensive turbulence dissipation measurements and a comparison thereof during the brief overlap with the R.V. Dana cruise. From the Pelagia also a bottom lander was deployed with fast sampling ADCP's and thermistor strings. Furthermore, phytoplankton and optical measurements were obtained besides Seașoar undulating CTD surveys of the area. From the R.V. Challenger, sailing between 22 October and 9 November, additional biological and sedimentological measurements have been made prior to the final recovery of all moorings.

The central site is at 59°20' N, 1° E, where the water depth is about 100 m. Moored equipment has been deployed within 50 km from this position (see map). All other measurements are carried out within a range of about 50-100 km from the central site.



Mooring Positions

	Lat. N	Long. E
A	59 20'	1 00'
R	59 20'	1 05'
S	59 22.5'	1 00'
U	59 20'	1 25'
V	59 32.5'	1 00'
X	59 20'	1 40'
Y	59 45'	1 00'

3. Cruise PROVESS N-3.

a. Participants.

Institute	*Name*
NIOZ	Dr. Johannes J.M. van Haren (PI)
NIOZ	Dr. Johannes R. Gemmrich
NIOZ	M. Th. J. Hillebrand
NIOZ	Margriet A.Hiehle
NIOZ	Martin Laan
PAS	Dr. Slawomir Sagan
PAS	Ryszard Hapter
PAS	Piotr Kowalczuk
SOC	David Teare
SOC	David Jolly
NUE	Dr. Karin Ann Wild-Allen
UWB	Dr. Thomas Philip Rippeth
UWB	Raymond John Wilton
UWB	David Christopher Boon
UWB	Neil Robert Fischer

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NUE Dept. of Biological Science, Napier University, 10 Collinton Rd, Edinburgh EH10 5DT, UK
PAS Institute of Oceanology, Polish Academy of Sciences, 81712 Sopot, Poland
SOC RVS, Southampton Oceanographic Centre, Empress Dock, Southampton SO14 3ZH, UK
UWB School of Ocean Sciences, Menai Bridge, Gwynedd LL59 5EY, UK

b. Instrumentation.

Shipborne equipment

On board the R.V. Pelagia the **NIOZ** CTD/Rosette system contains a Seabird 911 CTD, with additional electronic sensors on fluorescence (Chelsea Instruments Aquatracka MKIII), K-meter (PAR light attenuation) and a transmissometer (Seatech). The CTD samples at a 24 Hz rate. The Rosette holds 22 12 l and 2 6 l water bottles.

UWB brought two FLY-II microstructure profilers with winch and line pulling system. This system has been operated frequently to measure the turbulence dissipation in the water column and its temporal variations in relation to the variations in external and internal forcing.

PAS operated the optical sampling, several times a day, by water sampling, profiling irradiance meters, and by installing (permanently) a pyranometer and a solar radiometer on an unobscured deck.

NUE was responsible for the biological sampling (using the CTD-Rosette sampler) for analysis of pigment concentration, SPM spectral signature, C-N content and microplankton community composition.

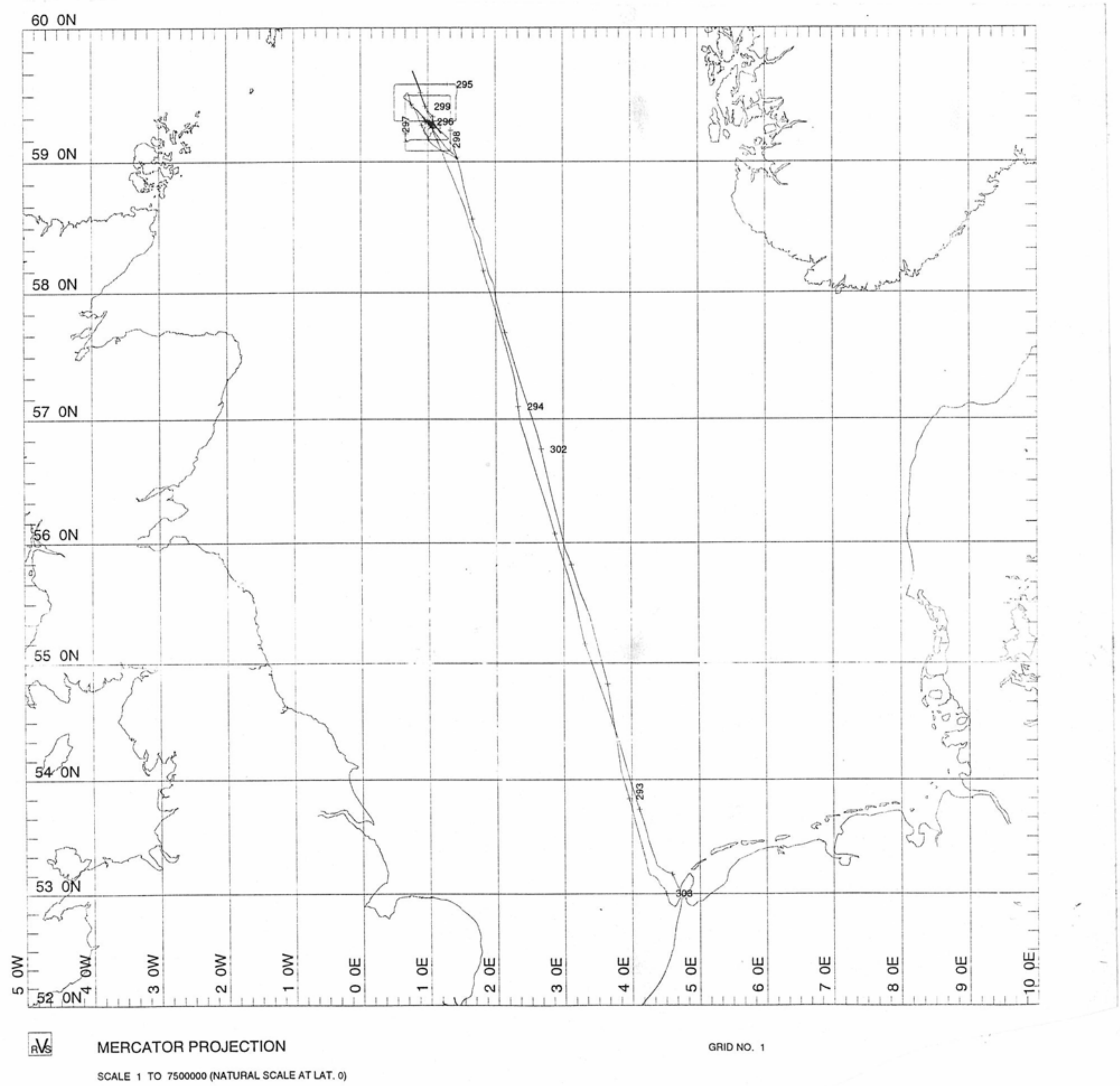
SOC operated an undulating CTD (Seasoar) that has been used during surveys in the vicinity of the moorings, at distances of about 50 km from the central position A.

Mooring equipment

Two types of non-shipborne equipment have been launched. Firstly, a **NIOZ** bottom lander containing two acoustic Doppler current profilers (ADCP's) and two thermistor strings have been moored for a period of about three weeks. This mooring has been recovered by the R.V. Challenger. The equipment samples at a fairly high temporal (30 s) and spatial (0.5- 1 m) resolution the water temperature as well as all three components of velocity. The purpose of the data analysis is to attempt to estimate directly internal wave band eddy fluxes, besides the overall flow and temperature field. In order to couple the temperature variations to density variations a proper estimate of the temperature-density relationship is required by sufficient CTD sampling.

Secondly, a sediment trap has been deployed as a drifter with the trap suspended at the bottom of the thermocline (**NUE**).

Cruise track



PROVESS N-3 19-30 October 1998_

4. Daily summary.

Monday 19 October

Loading starts at about 8.30 local time in the NIOZ harbour, Texel NL. Every participant on board the R.V. Pelagia. Departure for the PROVESS Nothern North Sea sites at 17.30 local time (15.30 UTC), NW winds Bf5-6, clear.

Ship time switch from local time to UTC.

Tuesday 20 October

NW 5-6, decreasing during the day, clear visibility. During the morning the ground speed increases from 7-10 knots. All day steaming, in the evening attempted contact with the Dana through FAX.

Wednesday 21 October

Arrival at the PROVESS mooring site A at 13 UTC. Contact with the R.V. Dana, so that we know the thermocline depth is around 60 m depth. The wind has subsided to about Bf 4 from the SE, but the waves are pretty high still. The first scientific activity concerns the deployment of the NIOZ bottomlander for internal wave band measurements. Unfortunately, the deployment is somewhat less smoothly than hoped for, as the lander breaks loose upon the passage of two high waves, thereby bashing against the side of the ship and breaking two buoyancy elements. After the delay, the lander is deployed at 59° 19.05' N, 01° 00.52' E, 110 m water depth. The remainder of the afternoon is filled with the first two CTD casts, showing a sharp pycnocline at about 40-50 m depth, surrounded by active mixing patches near its edges. The first biological and optical samplings were successful, like the first hour of (test) FLY measurements. The dissipation measurement intercomparison with the instrumentation on board the R.V. Dana is scheduled for tomorrow. The night is used for Seasoar survey I, comprising the sides of a rectangle bordered by 59° 18.5' N, 00° 30' E, 59° 18.5' N, 01° 25' E, 59° 35' N, 01° 25' E and 59° 35' N, 00° 30' E.

Thursday 22 October

Early in the morning the wind increases to about Bf 7, from the SSW. The Seasoar survey I finishes at 07.25 UTC. Contact with the R.V. Dana, and the 25 hour turbulence intercomparison starts at about 8 UTC. While talking to Andy Visser he notices that we are not just sampling with reference to UTC, but also live according to that standard time, whereas they are not. As a result the first batch of turbulence measurements have been done just consecutively between the ships, rather than simultaneously. For the remainder of the day this is synchronised. The day is continued with two batches of FLY measurements, preceded and followed by CTD casts and biological and optical sampling. At about 15.30 UTC the sediment trap is launched (SED I). The wind has dropped its force to Bf 4. From 18.00 UTC onward until the next morning, every two hours a CTD cast is taken followed by an hour of FLY drops.

Friday 23 October

A night of succesful FLY and CTD profiling (every 2 hours) ends at 08 UTC. Soon after, the wind speed increases. By noon we have SW 7-8. Nonetheless CTD (including a 1.5 hour yoyo) and (bio-)optics profiling continue. In the afternoon the search for the sediment trap causes a surprise. According to the ARGOS fixes it has moved about 5 miles in 2.5 hours in the morning. As it turns out somewhat later, this it the speed of a fisherman, PD203, who has picked up the float out of the water. After some deliberations they agree to set the instrument overboard, but not until 19 UTC. During the waiting time of about 4 hours, CTD, optical measurements and a sequence of FLY profiling are taken (at Bf 7). The sediment trap is picked up from the water easily, after the fisherman came alongside and had thrown it overboard. An impeller is missing on the current meter and the flash light is missing. Otherwise the system seems undamaged, but the data are no good. (Not until the following morning a large crap is seen in the hood of the surface float. It appears full of seawater, with most of the electronics exposed). From 19.30 onwards Seasoar survey II is started to cover an area south of the moorings. Meanwhile the spectrophotometer malfunctions, but this problem is solved by recalibrating it after a couple of hours. The westerly winds increase from Bf8 to Bf9.

Saturday 24 October

SW winds at Bf 7. Challenger calls around 03.30 UTC. The three ships are within 5 miles from each other. The Seasoar survey II, successful as ever before, is completed by 07.30 UTC. The day is devoted to CTD and bio-optical measurements, with an increased number of FLY profiling in between, at a rate of about once every 1.5 hours. With time, the wind increases. By about 15 UTC we are no longer able to operate FLY, wind speeds are up to about 16-18 m/s (Bf 8). By 16 UTC we are no longer able to operate the CTD. The observations are suspended, while the SW, backing SE winds increase to Bf 9-10. The Dana leaves for Hirtshals around 17 UTC.

Sunday 25 October

At 8 UTC CTD, optical and FLY measurements are resumed. We are in the center of a 960 mB depression. By 9.30 UTC we suspend measurements again, we have NW 9.

Monday 26 October

At 8 UTC we restart CTD, optical and FLY measurements. Finally the storm has subsided, the number of migratory birds on board has rapidly increased, they are in the wheelhouse and some of us have to chase them off their computers in the labs. The rest of the day a tremendous number of CTD and FLY profiles is obtained. The storm has not done much to the stratification. It sharpened a little, but its features, including the turbulence dissipation rate minimum below it, do remain as before.

Tuesday 27 October

Quite unexpectedly we have to suspend briefly the FLY observations at 05.30 UTC. The SE 8-9 winds force us to skip one CTD cast. By 07 UTC we have resumed CTD, by 08.20 UTC FLY profiling. The 25 hour session ends at 11 UTC after optical measurements. From 14 UTC onwards Seasoar survey III is carried out along the 20 miles' long sides and one diagonal of a box with position A in its center, while winds are SW8.

Wednesday 28 October

Seasoar survey III ends with a CTD cast at 07 UTC. By now the thermocline finally seems to deepen, although it is noted that the CTD cast is taken some 15 miles from position A. As the WSW winds are still at Bf7-8 we end the data collection for PROVESS cruise N-3 here, and alter course to the direction 'Texel', *i.e.* we have a free roller-coaster ride home.

Thursday 29 October

We sail to Texel on schedule while the wind keeps up WNW 8-9. At midnight the clocks on board are switched from UTC to MET.

Friday 30 October

Arrival in Texel NL, NIOZ harbour at 08 MET.

5. Summary and first results of activities *(cf. Appendix A)*.

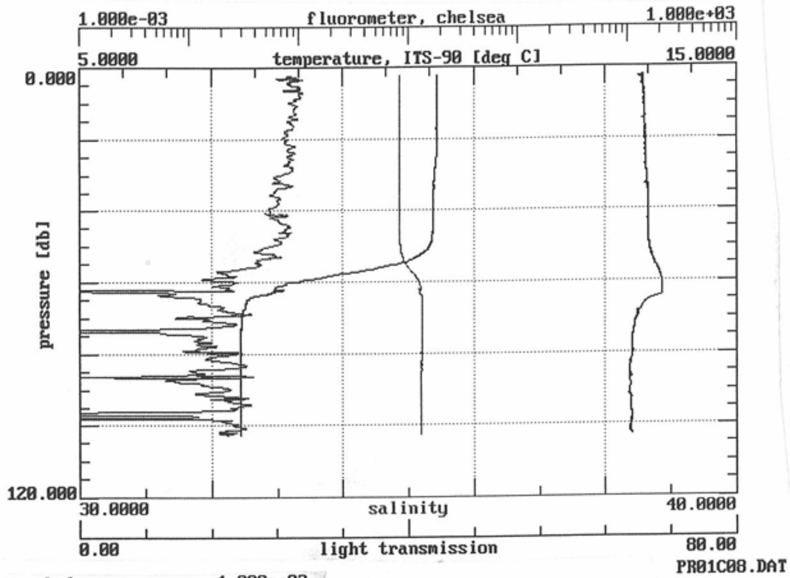
a. CTD.

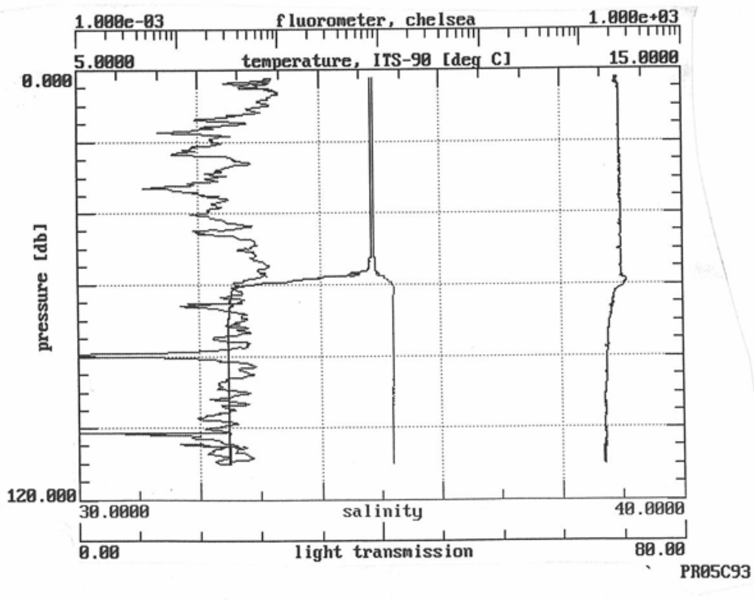
A total of 42 CTD casts has been taken. Apart from the study of variations in the hydrographic parameters in association with fluorescence, light transmission and PAR radiation, the CTD casts served two purposes. First of all, 19 times 4-13 bottles were closed at different depths (called '+biol. sampling' in App. A), for biological, suspended matter and optical properties. Secondly, each of the 32 FLY microstructure sessions was preceded by a CTD cast.

A 1.5 h CTD-yoyo between 30-80 m depth has been obtained to get a time series on internal wave activity with the full set of CTD sensors (**NIOZ**).

Two typical examples of CTD profiles are given in the figure below. It is seen that the thermocline rapidly thinned and that the temperature difference decreased in the week that the measurements were obtained. Thus, the atmospheric conditions are likely causing the rapid breakdown of the seasonal stratification. It is also seen that the fluorimeter indicates a vertically well-mixed phytoplankton distribution from the surface down to the top of the thermocline (see also Sub-section *d.*), and a rapid drop in magnitude below the first few meters of the thermocline, and remaining negligible down to the turbulent bottom boundary layer. Remarkable is the transmission maximum at the depth of the thermocline, perhaps an indication of active zooplankton grazing.

CTD stations 08 and 93





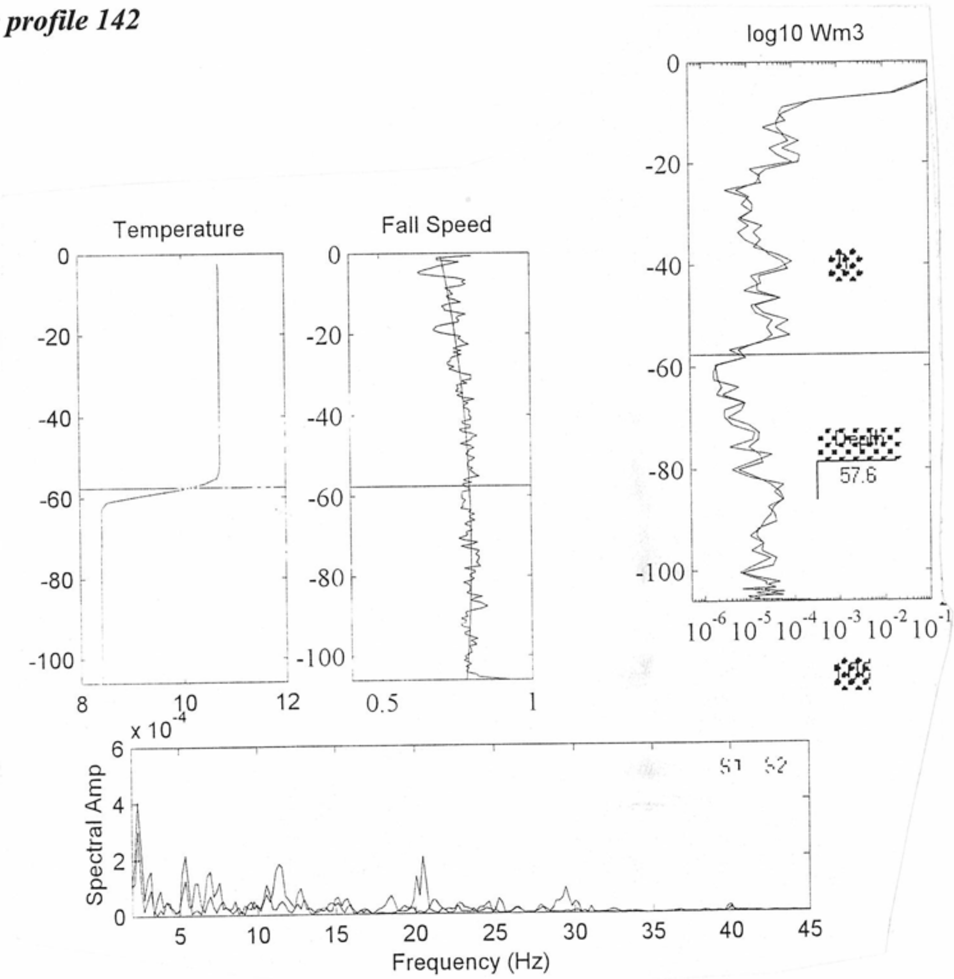
b. FLY microstructure profiling (Tom Rippeth, UWB).

Measurements of the rate of dissipation of turbulent kinetic energy were made during this cruise using a FLY freefall probe by the University of Wales Bangor, team. We think that, in terms of our previous measurements, we have probably broken two records with FLY use. The first was that, due to the skill of the ships' crew to hold the ship on course in very bad sea conditions, we successfully deployed FLY in force 7 and 8 winds.

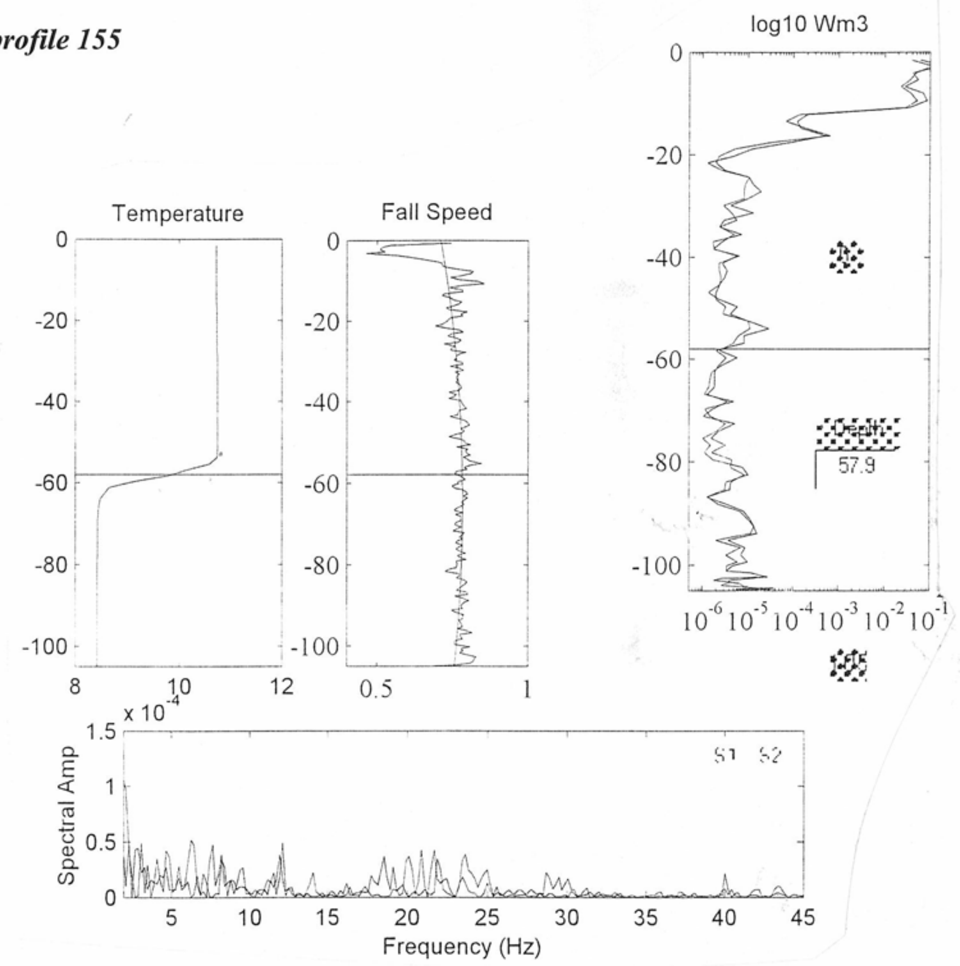
The second record we may have set is that we consistantly measured dissipation rates at the instruments' low dissipation threshold ($< 10^{-6}$ Wm^{-3}). The water column structure was two layer with a very thin thermocline,and little thermocline displacement, indicating the lack of internal wave activity. The dissipation profiles show two distinctive layers, above the thermocline there were relatively high levels of dissipation with a maximum often evident at the top of the thermocline. Below the thermocline turbulence levels were generally low with a tidal boundary layer which extended the whole depth of the thermocline at maximum ebb and flood of the tide. At other times of the tide a layer of very low dissipation (perhaps at the instruments' low dissipation threshold) was evident between the top of the tidal boundary layer and the thermocline bottom. At times this layer reached a depth of 30 m.

Examples of the profiles collected are provided. In total 220 profiles were taken mainly centred around two 24 hour periods. In terms of both quantity and quality of data collected, and particularly considering the poor weather conditions sustained, we would regard the cruise as having been a great success.

Fly profile 142



Fly profile 155



c. Biological & sediment observations sampling (Karen Wild-Allen, NUE).

Water samples were taken from the Flow-Through CTD with fluorometer and from water bottles attached to the profiling CTD with fluorometer, transmissometer and PAR light meter. A total of 173 samples were taken. Analysis for pigments and particulate absorption were completed onboard, the remaining samples were prepared and stored for subsequent analysis in the laboratory. Pigment sample data will be used to calibrate the Flow-Through, Profiling and Sea-Soar fluorometers.

Analysis	**No. Samples**
pigments (inc. chlorophyll)	120
SPM carbon, nitrogen ratio	17
microscope	10
particulate absorption	14
total SPM organic/inorganic mass	12

CTD casts showed that the water column structure was divided into 3 distinct layers:

The surface layer was well mixed down to ~60 m with reduced transmission (enhanced SPM), and relatively high fluorescence which corresponds with chlorophyll concentrations of ~ 1.0 mg m^{-3}. The chlorophyll was mostly ~80% from the small size fraction <5 μm of SPM.

The bottom mixed layer extended from the bed (100m) to ~65 m and had the lowest transmission (highest SPM), and low fluorescence which corresponded to ~0.1mg m^{-3} of chlorophyll.

The thermocline layer varied in thickness from ~1-10 m. Transmission in this layer was high (low SPM) and fluorescence and chlorophyll were low < 0.2 mg m^{-3} of chlorophyll. A possible explanation for this enhanced transmission is intense zooplankton feeding in the thermocline and a few copepods were occasionally found on the filters. Further evidence of zooplankton activity was recorded on the Simrad echo sounder with clear vertical migrations seen at sunrise and sunset. A detailed analysis of the zooplankton community has been taking place simultaneously on the Danish research ship the R.V. Dana in the same area and their results will be very interesting to see.

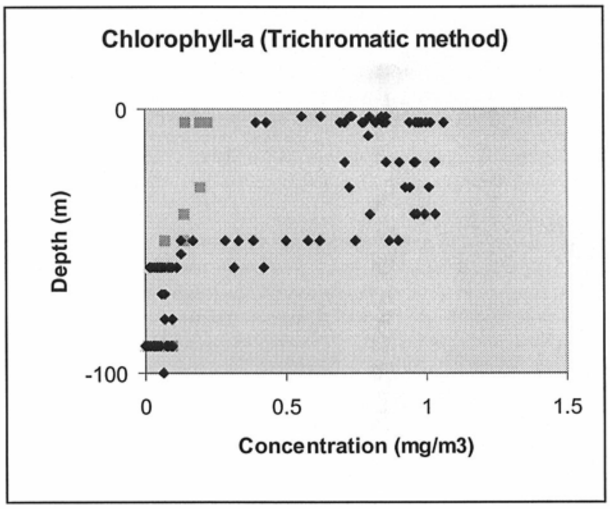


Figure 1: Chlorophyll-a concentrations: diamonds = GFF filter; squares = >5 µm; triangles = <5 µm.

To investigate sedimentation of material out of the surface layer a drifting buoy with a sediment trap and current meter suspended at ~60 m was deployed. The buoy was tracked by satellite overnight but fished out by trawler men the following morning. Unfortunately during re-acquisition the buoy was damaged and much of the data lost. The satellite track of the buoy however will be useful for comparison with moored current meters in the area.

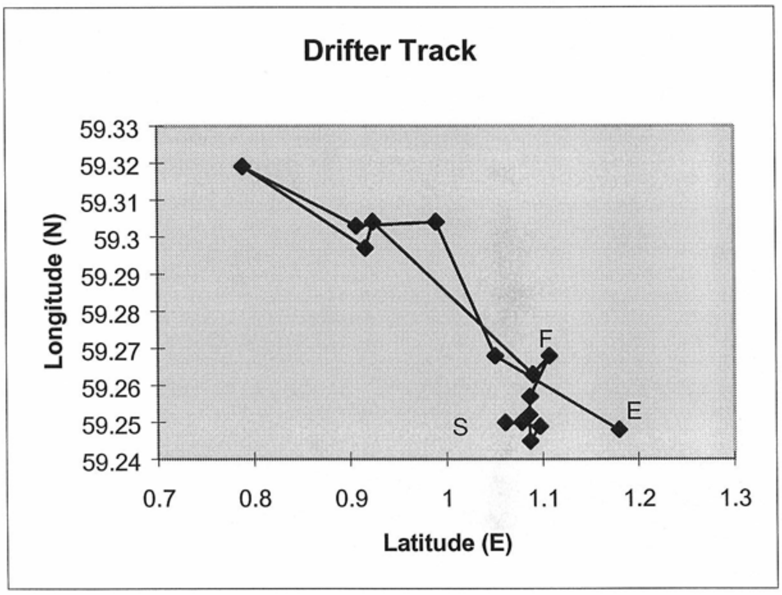


Figure 2: Argos satellite track of the drifting buoy; S = start, F= buoy fished, E = end.

d. Optical measurements (Slawomir Sagan, PAS).

The equipment was loaded on the ship promptly after arrival on Monday morning, 19th of Oct. Computers and registering devices were securely installed in the lab, as well as laboratory spectrophotometer and a filtering gear. First problem: it has turned out that ship has a pressure filtering system, while the gear we brought is a vacuum type. As a result we used the pump borrowed form Karen Wild-Allen, and she in turn asked us to use our spectrophotometer for chlorophyll spectra.

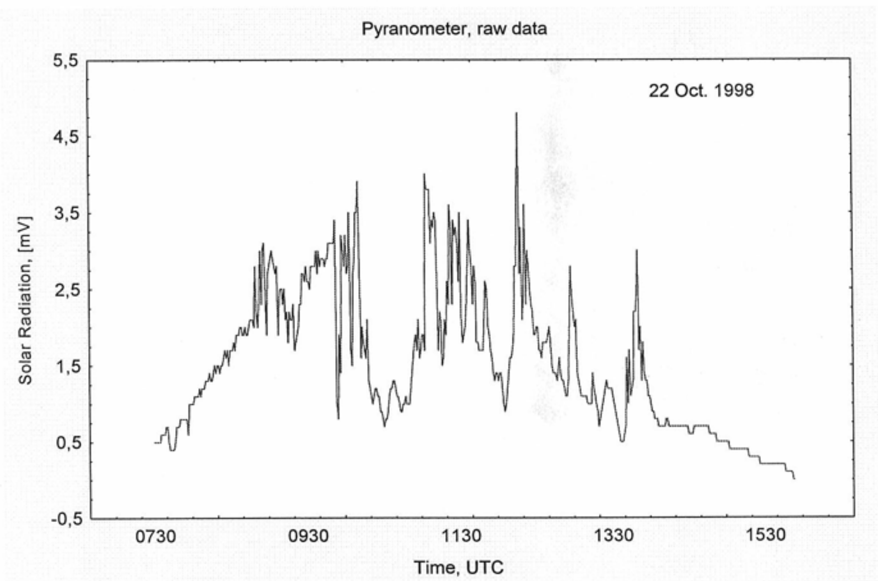
Before the departure the pyranometer, solar irradiance meter and a reference device for Multispectral Underwater Meter were installed on the upper deck.
After the mooring deployment instruments and cabling were set up next to the CTD sampler. Problem: there was no other way to lead the cables to the lab as through the door, the purpose hole was to small, so we had to be prepared to quick action of disconnecting the cables shall the door had to be closed in case of a rough weather.

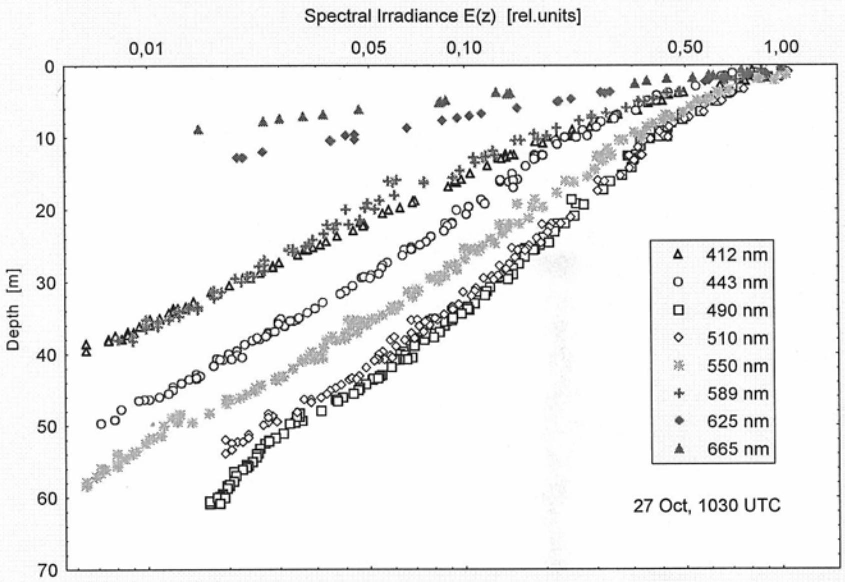
First and only that day deployment, 21st of Oct, all went well, but ac-9 gave suspicious readings. Tested in air later, gives normal results. On the 22nd: the pump for ac-9 does not work properly, preventing from proper data acquisition. This coincided with the next day HvH proposition to streamline optical measurements due to tight schedule to 3 basic instruments casts (MER, MOS and pump-probe fluorometer), what meant any add-ons as ac-9 and ATF had to be skipped anyway. The decision was agreed, as it did not compromise the main task to fulfil. For the rest of the cruise all subsequent casts went successfully, also thanks to professional work of the deck crew, and the fact they picked up some polish on the way only helped.

Every day filtered water samples were stored in the liquid nitrogen container, preserved water samples in the refrigerator. Spectrophotometric analyses for phytoplankton pigments and yellow substances absorption were being done every second day.

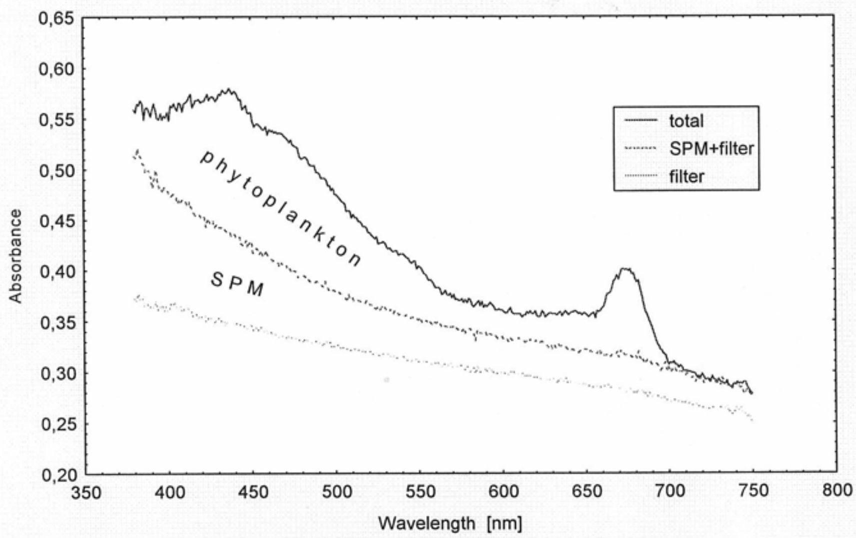
Solar spectral radiometer finally have not been employed, since there was no recommended weather conditions met: minimal cloud cover (2/8), distant Cu at most, no As or Cs.

Sample figures:

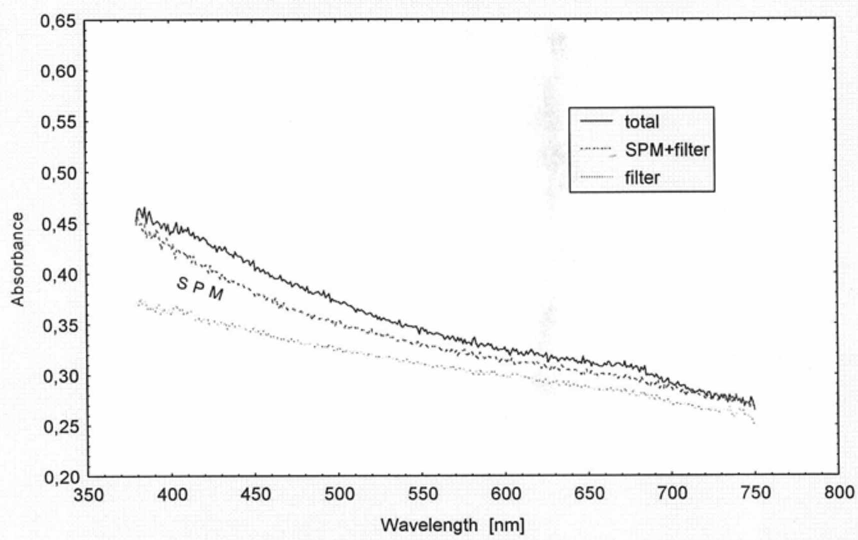


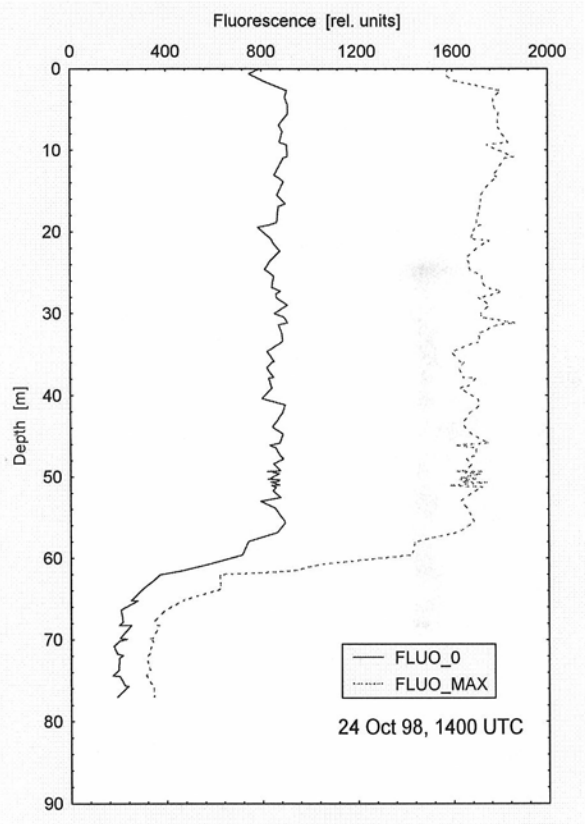


Phytoplankton Spectra *in vivo*, 24 Oct, depth 5 m



Phytoplankton Spectra *in vivo*, 24 Oct, depth 60 m





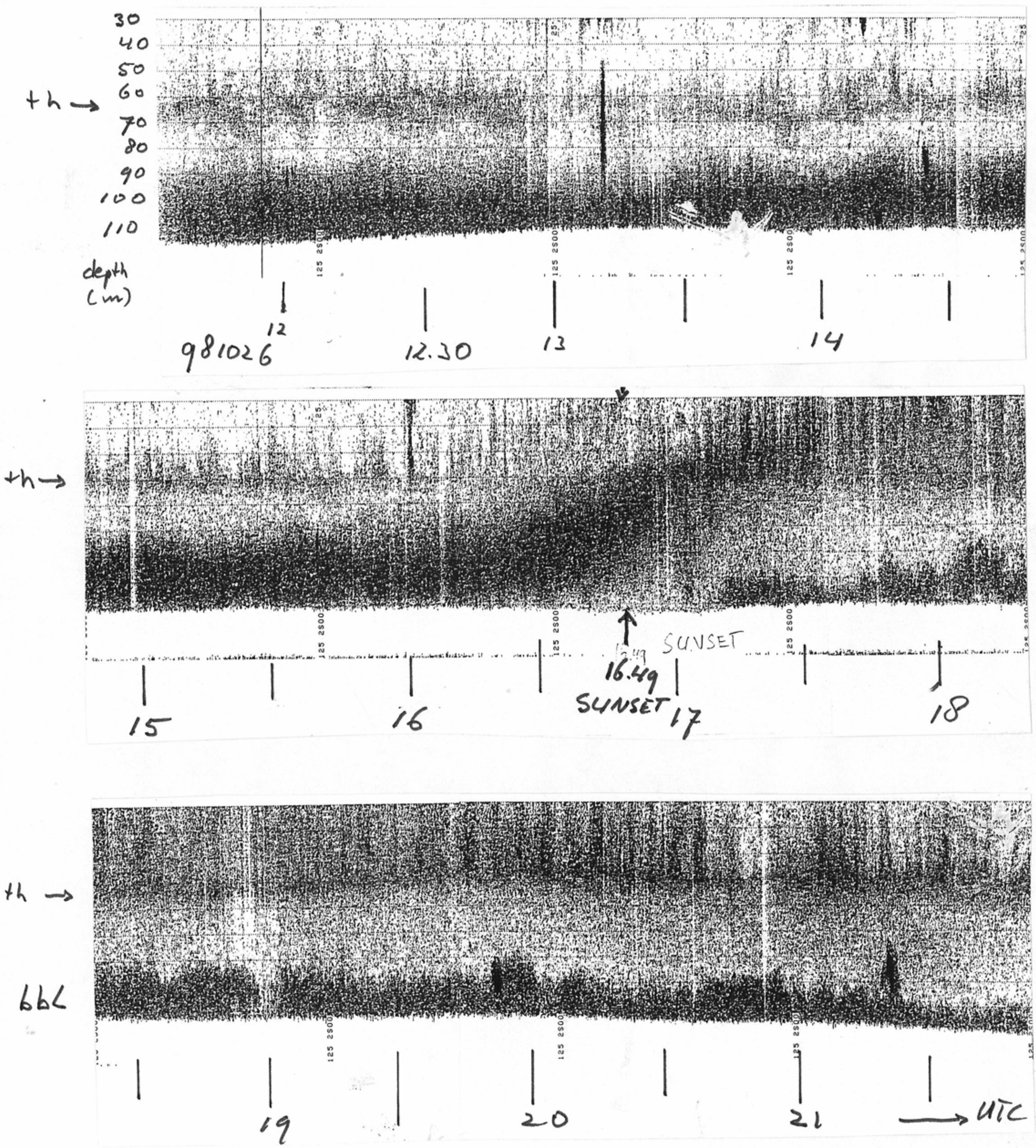
e. Continuous recording.

During the entire cruise the following information has been continuously sampled and stored through the ship's RVS-ABC system: time, ship's position lat/lon, depth, meteorological data, aquaflow (T,S,flc from 4 m below surface). Water samples have been taken for salinity calibration purposes (**NIOZ**), and chlorophyll (phytoplankton) determinations (**NUE**).

PAS has installed a pyranometer and a solar irradiance meter on the upper deck for continuous radiation measurements (see Section *d*).

A few time series (lasting about 12 hours) of 120 kHz SIMRAD echosounder have been stored in graphical form (see Figure). Clearly, near the thermocline scattering is larger than anywhere else in the water column. The majority of reflections comes from (daily migrating) zooplankton, as may be inferred from the uprising band near sunset. Remarkable is their straight crossing through the thermocline, where, as seen in the previous sections, no phytoplankton maximum is found (see figure next page)

SIMRAD 120 kHz echosounder sample



→ thermocline

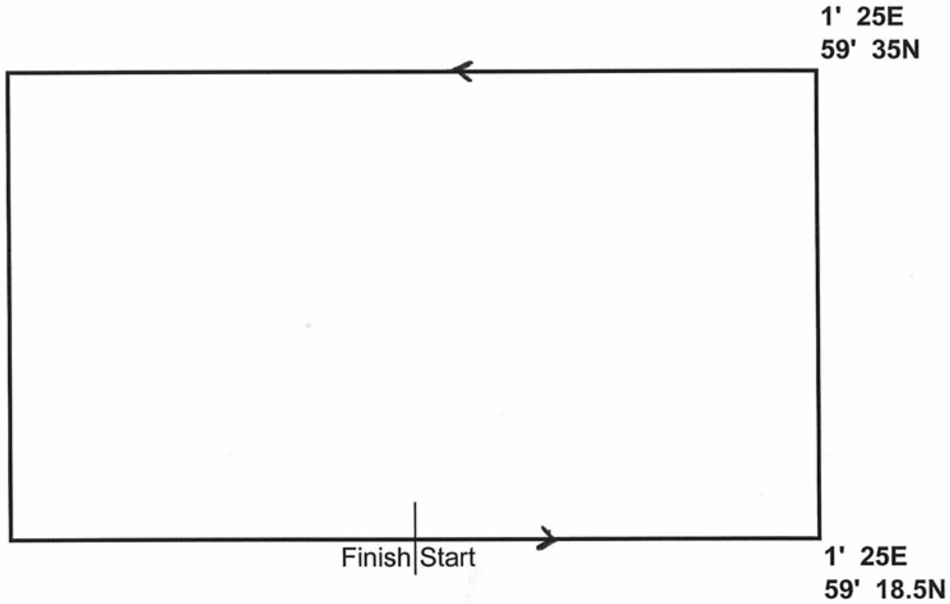
f. Seasoar surveys (David Teare, SOC).

Three surveys were completed. Survey 1 21-22/10/98 (12 hrs), Survey 2 23-24/10/98 (12 hrs), Survey 3 27-28/10/98 (16 hrs), see the seasoar log sheets for survey co-ordinates. The Seasoar was equipped with a Neil Brown MkIIIB C.T.D. which measured conductivity, temperature, depth and oxygen and a Chelsea Instruments MkIII fluorometer to measure chlorophyll-a. All sensors appeared to work without problem. Salinity samples were taken at the beginning and end of each survey from the ships aqua flow system, with the Seasoar at approx. 4 metres depth (also the depth of the aqua flow intake). Samples were also taken during the surveys at approx. 4 hourly intervals. A C.T.D. was done prior to and after survey 3 to collect water samples for calibration of chlorophyll. A post cruise calibration will be done for temperature, and the measured salinity will be corrected for instrument offset using the samples taken during the survey.

Most of the surveys were done with Seasoar on 200 metres of tow cable, this gave a depth range of surface to approx. 80 metres. Attempts to increase the max. depth by paying out more wire proved problematic, as the speed through the water was insufficient to bring the Seasoar to the surface.

Seasoar tracks

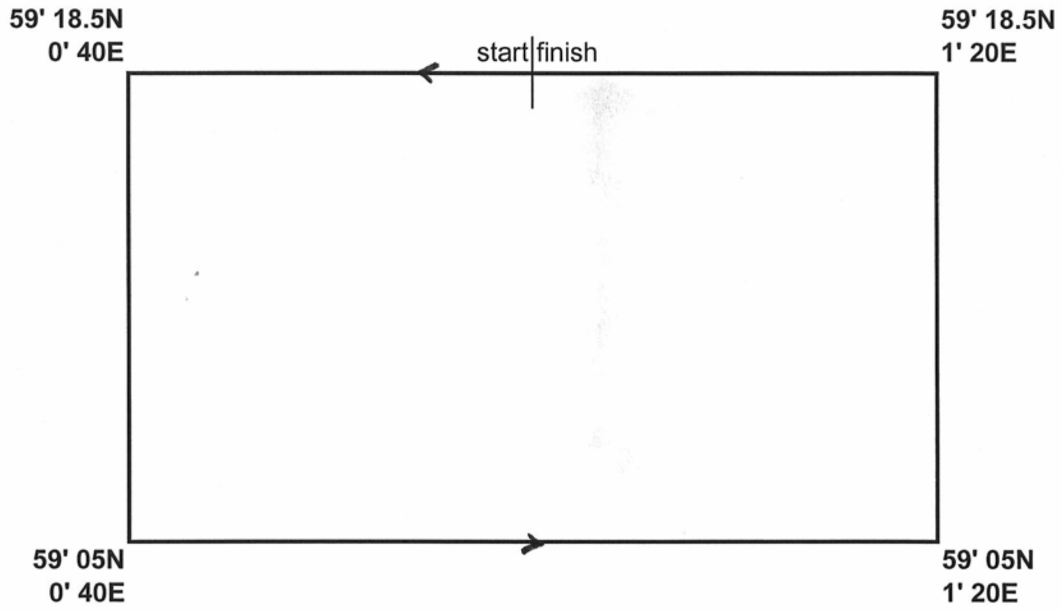
Seasoar survey 1



19:00 seasoar in water,pay out 150m of cable, move to start of line
19:49 start of line
20:26 seasoar brought to surface. only going to 70m. with poor response cable let out 50m to 200m out, good response to max depth of 80m
21:25 surface for course change to 360' / 0'
21:32 back to undulation
23:31 surface for course change to 270'
23:37 back to undulation
02:44 surface for course change to 180'
02:54 back to undulation
05:25 surface for course change to 90'
05:30 back to undulation
07:15 approx. end of survey, seasoar at suface
07:40 seasoar on deck

SURVEY SPEED 7.5 TO 8 KNTS

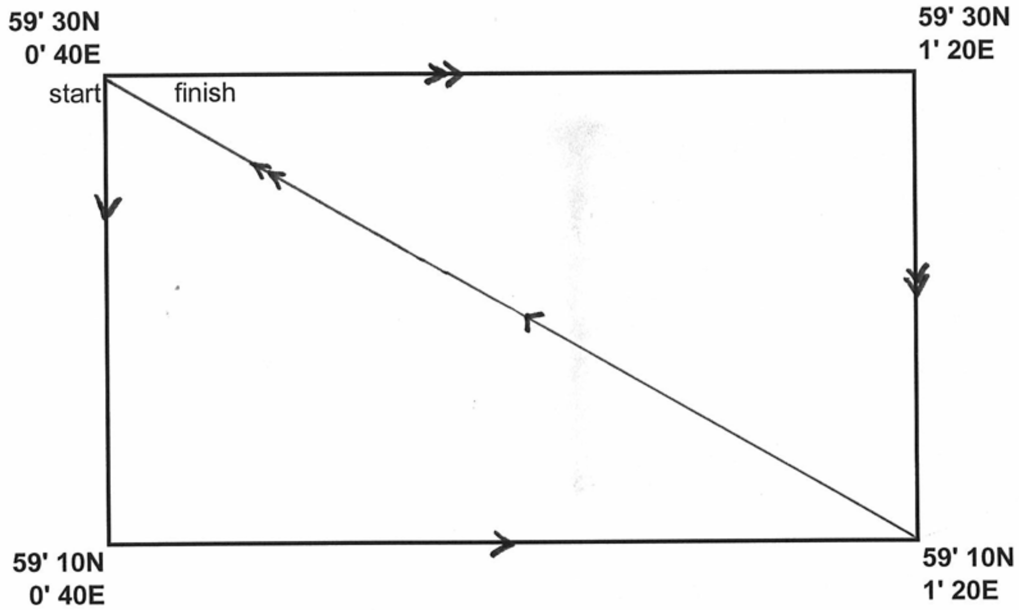
SEASOAR SURVEY 2



1) 20:00 seasoar in water. 250m of cable out to try and increase max depth attainable. With 250m out unable to keep seasoar on surface in 'override' , reduce wire out to 200m.
2) 22:29 start turn to 180'
3) 22:33 finish turn.
4) 00:35 start turn to 270'
5) 00:44 finish turn
6) 03:39 start turn to 0'
7) 03:45 finish turn
8) 04:45 start turn to 270'
9) 04:53 finish turn
10) 07:25 surface seasoar
11) 07:45 seasoar on board

Average speed 6 knts

SEASOAR SURVEY 3



1) 14:00 seasoar in water
2) 14:42 250m of cable out, starting to undulate
3) 15:00 (approx) surface seasoar for turn to 180'
4) 15:32 end of turn start to undulate
5) 18:21 surface for turn to 90' , shorten cable to 200m
6) 18:41 turn completed start to undulate
7) 21:00 surface for turn to 305'
8) 21:08 start to undulate
9) 00:36 surface for turn to 90'
10) 00:47 start to undulate
11) 00:50 start/ finsh point
12) 03:37 surface for turn to 180'
13) 03:47 start to undulate
14) 06:35 surface for end of survey
15) 07:00 seasoar on deck

Average speed 7 knts

g. Deployment of bottom-lander "mix-BB".

One mooring has been deployed near position A at 59° 19.05' N, 01° 00.52' E, 110 m water depth. This **NIOZ**-ADCP/thermistorstring bottom lander "mix-BB" samples at 30 s intervals high resolution temperature and current profiles, with the aim to monitor the internal wave activity ('turbulence intensity'). The deployment of this mooring was problematic, despite the spell of fair weather at the time. After the sub-surface buoyancy elements and the thermistor string has been lowered to the sea surface and were drifting away from the ship, the bottom lander attached to it broke loose from its coupling to the acoustic releases during the hoisting overboard. During the intended repair, immediately thereafter, with the thermistor strings still overboard, two crew members became lightly injured as the bottom lander swung suddenly upon two large waves and bashed against the side of the ship.

This mooring has been recovered successfully by the Challenger on 3 November. It appears that all instruments have worked, except the upward looking 600 kHz ADCP, which has stored data until the deployment accident. In fact, both ADCP's show severe recorder problems now, and are still under repair currently. However, with difficulty good data have been extracted from the downward looking 1200 kHz ADCP. For the first time, the improved NIOZ fast-response thermistor string provided good in-situ data, meaning that a unique temperature data set has been obtained at a resolution and relative accuracy down to 50 μK, thereby in principle enabling the inference of internal wave activity in terms of temperature variance.

6. Concluding remarks.

This cruise has been successful, and we have managed to do nearly all the measurements we planned. This is remarkable, considering the extremely rough weather conditions (Appendix B). This success could only be achieved by the good cooperation between the different scientific groups on board, and, not in the least, by the very pleasant and cooperative attitude of the crew of the R.V. Pelagia.

thank you all
hvh

Appendix A Summary of stations (activities).

CTD=CTD, **OPT**=optics, **FLY**=FLY **MOR**=mooring, **SED**=sediment trap, **SES**=Seasoar

station	activ	date time (UTC)	latitude	longitude	depth (m)	remarks (# indiv. activity)
1	MOR	981021,14.05	59° 19.05' N	01° 00.52' E	110	NIOZ bottom lander, 2 glass spheres damaged
2	CTD	981021,14.25	59° 18.79' N	01° 00.36' E	111	1+ biol. samples
3	OPT	981021,14.41	59° 18.80' N	01° 00.32' E	111	1 instument A
4	OPT	981021,14.53	59° 18.80' N	01° 00.32' E	111	instrument B
5	OPT	981021,15.02	59° 18.77' N	01° 00.29' E	111	instrument C+D
6	FLY	981021,15.49	59° 18.76' N	01° 00.48' E	110	1 launch
7	FLY	981021,16.37	59° 18.28' N	01° 01.09' E	109	recover
8	CTD	981021,16.43	59° 18.28' N	01° 01.16' E	108	2+ biol. samples
9	SES	981021,19.47	59° 18.50' N	00° 59.70' E	110	Seasoar leg I start
		981021,21.25	59° 18.50' N	01° 25.00' E	104	alt. course to 000
		981021,23.30	59° 35.00' N	01° 25.00' E	115	alt. course to 270
		981022,02.44	59° 35.02' N	00° 31.24' E	127	alt. course to 180
		981022,05.24	59° 18.50' N	00° 30.90' E	134	alt. course to 090
		981022,07.12	59° 18.50' N	00° 59.70' E	110	Seasoar leg I end
10	CTD	981022,08.20	59° 17.69' N	01° 00.88' E	110	3+biol. sampling
11	FLY	981022,08.50	59° 17.50' N	01° 01.00' E	110	2 launch
		981022,10.30	59° 16.25' N	01° 02.90' E	110	recover
12	CTD	981022,10.38	59° 16.25' N	01° 02.92' E	113	4+biol sampling
13	OPT	981022,11.04	59° 15.99' N	01° 03.47' E	113	2 optics in
		981022,11.56	59° 15.47' N	01° 04.34' E	111	optics out
14	CTD	981022,13.20	59° 16.52' N	01° 05.40' E	105	5
15	FLY	981022,13.38	59° 16.56' N	01° 05.67' E	104	3 in
		981022,14.51	59° 15.45' N	01° 04.53' E	111	out
16	MOR	981022,15.24	59° 15.15' N	01° 03.88' E	111	sediment trap deploy I
17	CTD	981022,15.36	59° 15.13' N	01° 04.14' E	111	6+biol sampling

CTD=CTD, **OPT**=optics, **FLY**=FLY **MOR**=mooring, **SED**=sediment trap, **SES**=Seasoar

station	activ.	date time (UTC)	latitude	longitude	depth (m)	remarks
18	OPT	981022,15.56	59° 15.45' N	01° 04.23' E	110	3 in A
19	OPT	981022,16.06	59° 15.52' N	01° 04.19' E	110	in B
20	OPT	981022,16.13	59° 15.46' N	01° 04.16' E	110	in C
21	OPT	981022,16.30	59° 15.51' N	01° 04.17' E	110	in D
22	FLY	981022,16.50	59° 15.67' N	01° 03.95' E	112	4 in
		981022,17.24	59° 15.41' N	01° 02.61' E	112	out
23	CTD	981022,18.06	59° 18.11' N	01° 00.20' E	110	7
24	FLY	981022,18.22	59° 18.19' N	00° 59.81' E	110	5 in
		981022,18.55	59° 18.09' N	00° 58.80' E	110	out
25	CTD	981022,20.03	59° 18.65' N	00° 58.01' E	114	8
26	FLY	981022,20.15	59° 18.60' N	00° 58.08' E	114	6 in
		981022,20.50	59° 18.23' N	00° 58.41' E	114	out
27	CTD	981022,22.01	59° 18.51' N	00° 57.43' E	116	9
28	FLY	981022,22.15	59° 18.57' N	00° 57.58' E	116	7 in
		981022,22.57	59° 17.97' N	00° 58.31' E	116	out
29	CTD	981023,00.01	59° 18.26' N	00° 59.91' E	111	10
30	FLY	981023,00.18	59° 18.20' N	01° 00.35' E	111	8 in
		981023,00.54	59° 17.26' N	01° 01.22' E	110	out
31	CTD	981023,02.00	59° 16.75' N	01° 02.29' E	112	11
32	FLY	981023,02.25	59° 16.36' N	01° 02.36' E	111	9 in
		981023,02.59	59° 15.54' N	01° 01.89' E	114	out
33	CTD	981023,04.00	59° 15.69' N	01° 02.45' E	112	12
34	FLY	981023,04.13	59° 15.55' N	01° 02.08' E	113	10 in
		981023,04.50	59° 14.84' N	01° 00.55' E	114	out
35	CTD	981023,06.00	59° 16.97' N	01° 04.52' E	106	13
36	FLY	981023,06.10	59° 16.89' N	01° 04.46' E	106	11 in
		981023,06.48	59° 17.11' N	01° 03.11' E	110	out

CTD=CTD, **OPT**=optics, **FLY**=FLY **MOR**=mooring, **SED**=sediment trap, **SES**=Seasoar

station	activ.	date time (UTC)	latitude	longitude	depth (m)	remarks
37	CTD	981023,07.58	59° 18.08' N	01° 03.33' E	106	14+biol samples
38	OPT	981023,08.18	59° 18.19' N	01° 03.04' E	106	4 in A
		981023,09.05	59° 18.08' N	01° 02.19' E	106	out D
39	CTD	981023,09.19	59° 18.00' N	01° 02.43' E	111	15 yoyo in
		981023,10.45	59° 17.20' N	01° 01.00' E	111	yoyo out
40	CTD	981023,11.04	59° 17.14' N	01° 00.23' E	103	16+biol. samples
41	OPT	981023,11.25	59° 16.85' N	01° 00.34' E	103	5 in A
		981023,12.15	59° 16.18' N	01° 03.44' E	103	out D
search	for	sediment	trap.	Found at	PD203	fisherman
42	CTD	981023,14.40	59° 18.27' N	00° 55.17' E	120	17+biol. samples
		981023,15.30	59° 17.60' N	00° 56.64' E	120	out D
44	FLY	981023,16.58	59° 15.72' N	01° 03.97' E	110	12 in
		981023,17.35	59° 15.71' N	01° 02.90' E	110	out
45	SED	981023,19.00	59° 13.50' N	01° 11.00' E	110	recovery, rendez-vous with PD203
46	SES	981023,19.50	59° 18.50' N	01° 11.00' E	120	Seasoar leg II start
		981023,22.30	59° 18.50' N	00° 40.00' E	120	alt. course to 180
		981024,00.44	59° 05.01' N	00° 40.78' E	120	alt. course to 090
		981024,03.37	59° 05.01' N	01° 19.35' E	120	alt. course to 000
		981024,05.47	59° 18.50' N	01° 19.40' E	120	alt. course to 270
		981024,07.21	59° 18.50' N	00° 59.70' E	110	Seasoar leg II end
47	CTD	981024,08.16	59° 18.28' N	00° 57.54' E	114	18+biol. samples
48	OPT	981024,08.30	59° 18.32' N	00° 57.63' E	114	6 in A
		981024,09.08	59° 18.50' N	00° 58.53' E	114	out D
49	FLY	981024,09.14	59° 18.52' N	00° 58.54' E	114	13 in
		981024,10.08	59° 18.55' N	00° 57.94' E	114	out
50	CTD	981024,10.48	59° 18.39' N	00° 57.02' E	117	19+biol. samples
51	OPT	981024,11.03	59° 18.37' N	00° 57.13' E	117	7 in A

CTD=CTD, **OPT**=optics, **FLY**=FLY **MOR**=mooring, **SED**=sediment trap, **SES**=Seasoar

station	activ.	date time (UTC)	latitude	longitude	depth (m)	remarks
	OPT	981024,11.33	59° 18.43' N	00° 57.66' E	117	out C (!)
52	FLY	981024,11.38	59° 18.44' N	00° 58.62' E	116	14 in
		981024,12.22	59° 17.54' N	00° 57.83' E	115	out
53	CTD	981024,13.08	59° 16.52' N	00° 58.02' E	114	20
54	FLY	981024,13.22	59° 16.31' N	00° 57.81' E	113	15 in
		981024,13.59	59° 15.37' N	00° 57.47' E	113	out
55	FLY	981024,14.49	59° 15.02' N	00° 56.95' E	114	16 in
		981024,15.25	59° 14.19' N	00° 56.17' E	115	out
56	CTD	981024,15.33	59° 14.13' N	00° 55.98' E	115	21+biol. samples
57	OPT	981024,15.46	59° 14.11' N	00° 55.69' E	115	8 in A
		981024,15.50	59° 14.09' N	00° 55.67' E	116	out A (!)
		observations	stopped	SE 8-10		
58	CTD	981025,08.12	59° 14.80' N	01° 06.04' E	108	22+biol. samples
59	OPT	981025,08.31	59° 15.10' N	01° 05.96' E	108	9 in A
		981025,09.05	59° 15.44' N	01° 05.56' E	108	out C
60	FLY	981025,09.20	59° 15.36' N	01° 05.98' E	108	17 in
		981025,09.37	59° 15.28' N	01° 06.63' E	115	out, stopped because of NW 8-9
61	CTD	981026,08.02	59° 18.68' N	01° 00.46' E	109	23+biol. samples
62	OPT	981026,08.24	59° 18.43' N	00° 59.73' E	109	10 in A
		981026,08.57	59° 18.38' N	01° 01.35' E	108	out C
63	FLY	981026,09.05	59° 18.43' N	01° 01.52' E	108	18 in
		981026,09.43	59° 18.69' N	01° 00.75' E	115	out
64	CTD	981026,10.18	59° 18.27' N	00° 59.27' E	112	24+biol. samples
65	OPT	981026,10.32	59° 18.40' N	00° 58.96' E	111	11 in A
		981026,11.06	59° 18.38' N	01° 00.19' E	111	out C
66	FLY	981026,11.07	59° 18.40' N	01° 00.13' E	111	19 in
		981026,11.44	59° 18.33' N	00° 59.21' E	110	out

CTD=CTD, **OPT**=optics, **FLY**=FLY **MOR**=mooring, **SED**=sediment trap, **SES**=Seasoar

station	activ.	date time (UTC)	latitude	longitude	depth (m)	remarks
67	CTD	981026,13.19	59° 18.31' N	01° 02.51' E	107	25
68	FLY	981026,13.23	59° 18.28' N	01° 02.71' E	107	20 in
		981026,13.55	59° 18.33' N	01° 02.91' E	107	out
69	CTD	981026,14.04	59° 17.53' N	01° 03.22' E	107	26+biol. samples
70	OPT	981026,14.07	59° 17.56' N	01° 03.48' E	107	12 in A
		981026,14.53	59° 16.99' N	01° 04.57' E	106	out C
71	FLY	981026,15.01	59° 16.94' N	01° 04.64' E	106	21 in
		981026,15.40	59° 17.51' N	01° 04.00' E	106	out
72	CTD	981026,15.58	59° 18.02' N	01° 03.61' E	106	27
73	FLY	981026,16.21	59° 18.13' N	01° 03.10' E	107	22 in
		981026,16.50	59° 17.40' N	01° 03.73' E	106	out
74	CTD	981026,18.01	59° 16.99' N	01° 04.34' E	104	28
75	FLY	981026,18.12	59° 16.95' N	01° 04.35' E	106	23 in
		981026,18.47	59° 17.01' N	01° 03.84' E	106	out
76	CTD	981026,18.59	59° 17.05' N	01° 03.46' E	108	29
77	FLY	981026,19.19	59° 17.19' N	01° 02.90' E	108	24 in
		981026,19.56	59° 17.40' N	01° 02.10' E	108	out
78	CTD	981026,20.02	59° 17.63' N	01° 01.53' E	108	30
79	FLY	981026,20.16	59° 17.76' N	01° 01.18' E	108	25 in
		981026,20.48	59° 18.10' N	00° 59.89' E	108	out
80	CTD	981026,20.59	59° 18.16' N	00° 59.80' E	110	31
81	FLY	981026,21.16	59° 18.29' N	00° 59.45' E	110	26 in
		981026,21.49	59° 18.72' N	00° 58.02' E	112	out
82	CTD	981026,22.01	59° 18.84' N	00° 58.03' E	114	32
83	FLY	981026,22.15	59° 18.56' N	00° 57.95' E	113	27 in
		981026,22.47	59° 19.37' N	00° 56.99' E	112	out

CTD=CTD, **OPT**=optics, **FLY**=FLY **MOR**=mooring, **SED**=sediment trap, **SES**=Seasoar

station	activ.	date time (UTC)	latitude	longitude	depth (m)	remarks
84	CTD	981026,23.59	59° 17.78' N	01° 01.83' E	107	33
86	FLY	981027,00.20	59° 17.72' N	01° 01.65' E	108	28 in
		981027,00.51	59° 17.88' N	01° 00.44' E	105	out
87	CTD	981027,02.00	59° 18.07' N	01° 01.03' E	109	34
88	FLY	981027,02.15	59° 18.03' N	01° 01.15' E	110	29 in
		981027,02.45	59° 17.90' N	01° 00.90' E	111	out
89	CTD	981027,04.06	59° 17.62' N	00° 58.78' E	113	35
90	FLY	981027,04.21	59° 17.55' N	00° 59.14' E	113	30 in
		981027,05.04	59° 17.21' N	01° 01.32' E	111	out
		stopped	SE 8-9			
91	CTD	981027,07.07	59° 14.93' N	01° 04.50' E	110	36+biol. samples
92	CTD	981027,08.06	59° 13.71' N	01° 04.59' E	116	37
93	FLY	981027,08.21	59° 13.44' N	01° 04.54' E	115	31 in
		981027,08.56	59° 13.45' N	01° 03.62' E	115	out
94	CTD	981027,09.09	59° 13.39' N	01° 03.22' E	116	38
95	FLY	981027,09.25	59° 13.16' N	01° 03.03' E	115	32 in
		981027,10.09	59° 12.58' N	01° 02.47' E	115	out
96	CTD	981027,10.18	59° 12.49' N	01° 02.39' E	115	39+biol. samples
97	OPT	981027,10.33	59° 12.28' N	01° 02.31' E	115	13 in A
		981027,11.00	59° 11.76' N	01° 02.23' E	115	out C
98A	CTD	981027,13.13	59° 24.72' N	00° 42.42' E	125	40(no bottles closed)
98B	CTD	981027,13.35	59° 24.49' N	00° 47.16' E	129	41+biol. samples
99	SES	981027,14.30	59° 28.01' N	00° 42.01' E	129	Seasoar leg III start
		981027,15.29	59° 30.01' N	00° 40.00' E	129	alt. course to 180
		981027,18.15	59° 10.00' N	00° 40.00' E	120	alt. course to 090
		981027,21.20	59° 10.00' N	01° 19.35' E	120	alt. course to 315
		981028,00.48	59° 29.97' N	00° 40.00' E	129	alt. course to 090

CTD=CTD, **OPT**=optics, **FLY**=FLY **MOR**=mooring, **SED**=sediment trap, **SES**=Seasoar

station	activ.	date time (UTC)	latitude	longitude	depth (m)	remarks
		981028,00.48	59° 29.97' N	00° 40.00' E	129	alt. course to 090
		981028,03.42	59° 29.66' N	01° 19.97' E	106	alt. course to 180
		981028,06.37	59° 10.00' N	01° 20.00' E	120	Seasoar leg III end
100	CTD	981028,07.14	59° 08.86' N	01° 19.83' E	118	42+biol. samples
		981028,08.00	departure	for Texel		
		981030,06.00	arrival	at Texel	NIOZ	harbour

Appendix B Wind (direction,force Bf)

date\time(UTC)	**04**	**08**	**12**	**16**	**20**	**24**
981019					NW5-6	NW6
981020	NW6	NW6	NW4-6	NW4	SSW3-4	SSE5-7
981021	SSW7	SSW6-7	W5-6	SW4	SSW4-5	SSW4-5
981022	SSW7	SW6-7	SW6-7	SSW5-7	SSW5	SW5
981023	SW4	W5	W6-7	W7	W7-8	W8-9
981024	W7	SW6	S7	SSE8-9	SSE9-10	SE8-9
981025	var4-5	var4	NNW9	NW9	NW8-9	NW8
981026	NW7	NW5-6	NW3-6	NW5	W5-6	SW6
981027	S6-7	WSW7-8	WSW8	WSW7	SW7	SW8
981028	SW8	WSW8	W8-9	WSW7-8	WNW7-8	WNW8-9
981029	W8-9	WNW8	WNW8-9	WNW8-9	WNW8-9	WNW8
981030	WNW8	WNW6				