Rhine Outflow Region Studies (Challenger 72A and 72C)

The main aim of the Rhine outflow region study was to obtain time series data along the Dutch coast in order to investigate the variability of the water column stratification forced by the outflow and its influence on the conditions controlling primary production and sediment resuspension. An array of moorings was deployed around a central position (52°12.5'N, 4°09.5'E) near the source of the Rhine plume, which generally moves north-eastwards along the coast. The moorings were deployed on Challenger 72A and recovered on Challenger 72C.

Mooring configurations

At sites A, B, C and H rigs were deployed each comprising two instruments, an Acoustic Doppler Current Profiler (ADCP) and an Aanderaa WLR, and an IOS acoustic release. All were mounted on a low profile frame positioned on the sea bed. The instruments were located 0.8m above the sea floor. On recovery the release was triggered by sending acoustic signals from the ship so that the frame separated from the ballast weight. The frame, under its own buoyancy (glass spheres), then rose to the surface ready for picking up. The ADCP recorded vector averaged north and east components of current at set levels throughout the water column, backscatter strength and two components of tilt. The tilts gave an indication of mooring stability and were used to correct for uneven frame positions. The Aanderaa WLR measured pressure and temperature.

U-shaped moorings were deployed at sites A, B, C and D each with one InterOcean S4 current meter and three Aanderaa RCMs included in the line with the subsurface float, and a transmissometer, a fluorometer and an Aanderaa RCM measuring temperature and salinity only, attached just beneath the surface toroidal buoy. Moorings B and D did not include fluorometers.

A U-shaped mooring was deployed at site G containing an InterOcean S4 current meter 12m above the sea bed and an Aanderaa RCM current meter 7m above the sea bed.

An eta rig containing 2 near surface InterOcean S4 current meters (5m and 11m below the surface) was deployed at site E. At the same site a Waverider buoy and an Aanderaa Met. buoy were also deployed.

Acoustic Doppler Current Profiler (POL 1MHz version)

The ADCP (POL 1MHz version) sends out short acoustic pulses, typically lasting a few thousandths of a second, at a fixed frequency. The acoustic pulses are transmitted in two narrow beams at right angles to each other and 30 degrees to the vertical and are reflected back to the ADCP by small particles, such as plankton, which move with the water. The frequency of the reflected signal is changed by a small amount proportional to the current speed, the Doppler shift. By measuring the frequency change along the two beams the speed and direction of the currents are determined. The currents at different heights through the water are obtained by chopping the return signal into segments by time.

The 1MHz ADCP has a range of 30m and can measure up to 24 bins. However the technique has some limitations which reduce the amount of good data return. The closest bins to the transducers can give erroneous data due to the time taken for transients to decay and the far end bins can be affected by interference from side lobes reflected from the sea surface. Hence the good data return bins are usually between 15% of the depth from the surface and 10% of depth from the bottom.

ADCP specification

	Range	Accuracy
Speed	2 to 350 cm/s	+/- 4 cm/s
Direction	see below - ADCP angle correction	
Tilt	Two tilts measured at 90 degrees to each other	

ADCP set up details

Sample period	10 minutes
No. of bins (cells)	20
First bin height	3.9m
Bin separation	1.4m
Bin heights (1-20)	3.9m, 5.3m, 6.8m, 8.2m, 9.6m, 11.0m, 12.4m, 13.8m, 15.3m, 16.7m, 18.1m, 19.5m, 20.9m, 22.4m, 23.8m, 25.2m, 26.6m, 28.0m, 29.5m, 30.9m

ADCP angle correction

The compass, manufactured by Digicourse (no longer in production), measures the angle between magnetic north and the frame. The two beams can be converted into east and north components by using the angle obtained by the compass and trigonometry. During the North Sea Project the compass showed a tendency to return arbitrary zero directions thus giving directions of flow different from those predicted by tidal models and previous current meter records. Also the frame moved on the sea floor during some storm events. A correction was then required to the frame angle for each deployment.

The ADCP data were first processed through the software. The statistical analysis gave the angle of maximum variance, which was taken to represent the M_2 major axis tidal ellipse angle. The compass, although giving incorrect readings of frame angle, was recording direction to an unknown fixed position. The frame angle was adjusted by adding a correction angle.

The correction angle was calculated from the difference between the M_2 major axis tidal ellipse angle from a model and the angle of maximum variance calculated from the initial raw data analysis. The model gave a depth average value, so the angle of maximum variance obtained from the data bin closest to this depth was needed. The bin used was found by taking the bin nearest to a value z=0.4D, where D is the total depth of water and z is the height from the bottom (Prandle, 1982). There is an 180 degree ambiguity in the calculation of the angle of maximum variance which was resolved by study of the M_2 tidal phase given by the model and by other observations.

Aanderaa Water Level Recorder (WLR) Model 5

The Aanderaa WLR Model 5 is a self-recording high precision instrument for recording water level by measurement of hydrostatic pressure. The standard range is 270m, corresponding to a sensor range of 0-400PSI. The effects due to waves are averaged over a 40 second integration time. Temperature is obtained from a thermistor fitted on the top plate of the meter and extending into the water.

WLR sensor specification

	Range	Accuracy
Pressure	0.0 to 27.2 bars (0 to 400 PSI)	+/- 0.01% of pressure
Temperature	0.0 to 30.0 degC	+/- 0.03 degC

InterOcean Systems Model S4 Current Meter

The InterOcean Systems Model S4 electromagnetic current meter is a self-contained 0.25m diameter sphere, with no protruding sensors. It measures current by creating a magnetic field and sensing the voltage induced in two orthogonal directions, by the movement of the sea water, an electrical conductor, through the field. This information is combined with instrument orientation, sensed by a flux-gate compass, and the north and east components of current computed. The S4s were used in vector average mode throughout the survey. They sampled every 0.5 seconds and averaged the vectors over the recording interval.

S4 specification

	Range	Accuracy
Speed	0 to 350 cm/s	+/- 2 cm/s
Direction	0 to 360 degrees	+/- 2 degrees

Aanderaa RCM4 Current Meters

The Aanderaa RCM4 current meter is a self-recording current meter. Temperature is measured by a thermistor fitted into a stud extending into the water. Conductivity is measured by an electrodeless induction conductivity cell and pressure is measured by a sensor consisting of a potentiometer driven by a Bourdon tube. A vane is attached to the meter in order to align the compass with current flow and keep the meter in an upright position. The RCM4 measures current speed with a savonius rotor situated on top of the meter and magnetically coupled to an electronic counter. The number of revolutions over the sampling interval gives the average speed over the interval.

RCM4 specification

	Range	Accuracy
Speed	2 to 250 cm/s	+/- 2 cm/s
Direction	0 to 360 degrees	+/- 5 degrees
Temperature	-2.46 to 21.4 degC	+/- 0.05 degC
Conductivity	21 to 51 mmho/cm	+/- 0.025 mmho/cm
Pressure	0 to 100 PSI or 0 to 200 PSI	+/- 1%

Fluorometer, transmissometer and temperature/salinity calibration

Fluorometers were calibrated by substituting them on the CTD and vertically profiling the chlorophyll fluorescence. The extracted simultaneous chlorophyll samples were used to calibrate the fluorometers for accurate determination of chlorophyll. The transmissometers and Aanderaa RCMs used for temperature and salinity were also attached to the CTD frame, allowing the transfer of calibration from the CTD sensors or, more usually, direct from the water samples.

Data Quality Control

These data have not yet been fully quality controlled by BODC. However, the start and end of the data, recorded before and after deployment has been deleted by BODC where necessary and some flagging has been carried out.

Please note: The rig at site A was recovered and redeployed on 8 Oct 1990 between 10:35 and 12:25. The rig at site C was recovered on 1 Oct 1990 and redeployed at site E. The data have been split into separate series for each section of the deployment.

In the table below each data file is identified by a mooring code (comprising the site name and deployment number), together with the instrument number, preceded by 'DP', 'WR', 'TR', 'FL', 'S', 'AA', 'TS' indicating ADCP, Aanderaa Water Level Recorder, transmissometer, fluorometer, InterOcean S4, Aanderaa RCM4 or Aanderaa RCM (measuring temperature and salinity only) respectively. The data file name is also given.

Mooring/ Meter No.	Start Date dd-Mon-yy	Data Length (days)	Comment
A/TR3	08-Sep-90	8.0	Good record obtained (ASEP9005.TR)
A442/DP006A	23-Sep-90		
A442/WL444	23-Sep-90	0.0	No data recorded.
A443/TR3	23-Sep-90	23.0	Good record obtained (AOCT9020.TR)
A443/TS8240	23-Sep-90	23.0	Larger temperature spikes flagged, but the record still contains some noise. All conductivity values giving rise to salinities greater than 34.1 PSU flagged and all conductivity values on 5 Oct 1990 flagged. Rig was recovered and redeployed on 8 Oct 1990, data collected while the instrument was out of the water has been flagged out. (AOCT9020.AA)
A443/FL113	23-Sep-90	15.0	Good record obtained; spike at start of record flagged. (AOCT9020.FL)
A443/S1262	23-Sep-90		
A443/AA3257	23-Sep-90	0.0	No data recorded.
A443/AA3261	23-Sep-90	23.0	Speed and direction record noisy in places; not flagged. Pressure record indicates that the rig was not re-laid at exactly the same site. (AOCT9008.AA)
A443/AA9652	23-Sep-90	23.0	Section of record flagged out when mooring recovered and re-laid. (AOCT9004.AA)
B444/DP002A	23-Sep-90		
B444/WL500	23-Sep-90	23.0	Good record obtained (BOCT9001.PR).
B445/TR4	23-Sep-90	23.0	Good record obtained (BOCT9020.TR)
B445/TS5228	23-Sep-90	10.0	Good record obtained, a few spikes flagged. (BOCT9020.AA)
B445/S1264	23-Sep-90	12.0	Good record obtained (BOCT9020.S4).
B445/AA9680	23-Sep-90	23.0	Good record obtained (BOCT9011.AA).
B445/AA9634	23-Sep-90	23.0	Good record obtained (BOCT9007.AA).
B445/AA3308	23-Sep-90	18.0	Good record obtained until 00:55 13 Oct 1990, record truncated at this time as no further good data were recorded. All direction values of zero flagged (as they had caused spikes). However, one or two valid zero direction values may also have been flagged. (BOCT9003.AA)

C446/DP004A	22-Sep-90	23.8	Good record obtained for the eleven bins nearest the sea bed (i.e. up to and including 18.1m). Data from the remaining bins have been deleted since they are not in the water. (COCT9001.DP).
C446/WL915	22-Sep-90	22.0	Good record obtained (COCT9001.PR).
C447/TR1	22-Sep-90	8.0	Good record obtained (COCT9020.TR).
C447/TS6275	22-Sep-90	8.0	Good record obtained (CSEP9020.AA).
C447/FL109	22-Sep-90	0.0	No data recorded.
C447/S1117	22-Sep-90		
C447/AA6749	22-Sep-90	8.0	Good record obtained, one temperature and conductivity spike flagged (CSEP9011.AA).
C447/AA5913	22-Sep-90	5.0	Noisy record, much flagging. Many spikes occur on 26 and 27 Sep 1990. (CSEP9007.AA).
C447/AA9643	22-Sep-90	24.0	Good record obtained (CSEP9003.AA).
E447/TR1	01-Oct-90	12.0	Good record obtained (EOCT9020.TR).
E447/TS6275	01-Oct-90	16.0	Temperature and conductivity spikes flagged, salinity calculated from conductivity noisy after 11 Oct 1990. (EOCT9020.AA).
E447/FL109	01-Oct-90	0.0	No data recorded.
E447/S1117	01-Oct-90		
E447/AA6749	01-Oct-90	16.0	Good record obtained (EOCT9011.AA).
E447/AA5913	01-Oct-90	0.0	No data recorded.
E447/AA9643	01-Oct-90	16.0	Good record obtained (EOCT9003.AA).
D448/TR2	22-Sep-90	23.0	Good record obtained (DOCT9017.TR).
D448/TS6941	22-Sep-90	0.0	No data recorded.
D448/S1263	22-Sep-90	12.0	Good record obtained (DOCT9017.S4).
D448/AA9650	22-Sep-90	23.0	Good record obtained (DOCT9009.AA).
D448/AA9632	22-Sep-90	23.0	Good record obtained (DOCT9006.AA).
D448/AA7063	22-Sep-90	23.0	Good record obtained, two direction spikes and a pressure and temperature spike flagged (DOCT9003.AA).
E/Met. buoy	23-Sep-90		
E/Waverider	23-Sep-90	31.0	Good record obtained (EOCT9022.WV).
E/S1306	23-Sep-90	0.0	Rig lost.
E/S1308	23-Sep-90	0.0	Rig lost.
G/S1196	22-Sep-90		
G/AA9631	22-Sep-90		
H/DP0007	26-Sep-90		
H/A9959	26-Sep-90		

References

Howarth, M.J. 1990. Atlas of tidal elevations and currents around the British Isles. Department of Energy, Offshore Technology Report, OTH 89 293, 16pp

Prandle, D. 1982. The vertical structure of tidal currents and other oscillatory flows. Continental Shelf Research, 1(2), 191-207