Cruise Report for Knorr 154-2

I. Cruise Narrative

I.1 Highlights

Ship: Knorr 154-2
WOCE designation: AR24
Dates: 5 October - 19 November 1997
Ports: Azores - Iceland - Woods Hole

I.2. Cruise Summary

163 CTD stations (30 stations were NOT full water column due to time)
43 PALACE floats
41 RAFOS floats
LADCP
Rosette Salts and Oxygens
Carbon sampling (Dissolved organic, Dissolved inorganic, Alkalinity)

I.3. List of Principal Investigators

Ms. Ruth G. Curry, WHOI, CTD/hydrography
Dr. Michael S. McCartney, WHOI, CTD/hydrography
Dr. Eric Firing, Univ. of Hawaii, ADCP/LADCP
Dr. W. Brechner Owens, WHOI, PALACE floats
Dr. Amy Bower, WHOI, RAFOS floats
Dr. Phil Richardson, WHOI, RAFOS floats
Dr. Catherine Goyet, WHOI, Carbon Chemistry

I.4 List of Cruise Participants

Master: A.D. Colburn III
Chief Scientist: Ruth Curry, WHOI
Science Crew:
Marshall Swartz, WHOI, Watch Leader
Shelley Ugsted, WHOI, Watch Leader
Gwyneth Hufford, WHOI, Watch Leader
Sarah Zimmermann, WHOI, CTD data processor
Alex Nimmo-Smith, UK, Watchstander
Tania Casal, Portugal, Watchstander
Helder Martins, Portugal, Watchstander
Heather Hunt, WHOI, Watchstander
Mike McCartney, WHOI, Watchstander
Marti Jeglinski, WHOI, Watchstander
George Knapp, WHOI, Oxygens
Pete Landry, WHOI, Salinity
Jules Hummon, U Hawaii, LADCP
Kathy Donoghue, U Hawaii, LADCP
Greg Eischeid, WHOI, CO2 tech
Erin Sweeney , WHOI, CO2 tech
Rick Healy, WHOI, CO2 tech
Cindy Moore, U Fla, CO2 tech
Greg Packard, WHOI, SSSG tech

I.5. Preliminary results

163 casts were made using a NBIS Mark III CTD measuring pressure, temperature, conductivity, oxygen current, and oxygen temperature. For each cast, water samples were collected at discrete intervals and analyzed for salinity and dissolved oxygen -- primarily for the purpose of calibrating the CTD sensors. Carbon chemistry measurements were also made for total organic carbon, total inorganic carbon, and alkalinity. Lowered Acoustic Doppler Current Profile (LADCP) measurements were acquired on each cast. Underway measurements include surface temperature and salinity, plus shipboard ADCP which profiled velocity in the upper 400 meters along track.

CTD casts

sta 1-27 Azores to Charlie Gibbs Fracture Zone (CGFZ)
sta 28-31 Southern trough CGFZ
sta 31-33 E-W section including break in ridge separating N/S channels
sta 33-37 Northern trough CGFZ
sta 38-62 section along crest of Reykjanes Ridge to Iceland
sta 63-65 1500m casts where PALACE floats were deployed (Iceland-Greenland)
sta 66-109 Angmagssalik - Ireland section
sta 110-115 eastern boundary, Porcupine Bank
sta 116-120 eastern boundary, Porcupine Bank
sta 121-127 eastern boundary, Porcupine Bank
sta 128-162 Goban Spur to Terceira, Azores

Most casts were full water column, EXCEPT the following stations where shorter casts were done in order to keep the 30 nm station spacing in the allotted cruise time:

SHORT casts: Sta 14,16,18,20,23,25,63,64,65,113,114,115,120,121,122, 123,124,135,137,139,141,143,145,147,149,151,153,155,157, 159

Problem stations:

Station 21 has bad CTD oxygen.
Stations 21 to 40 have troubled CTD oxygen, some stations worse than others.

Equipment/sensor changes:

New oxygen sensors put on for stations 902, 3, and 21.
CTD 8's oxygen assembly and sensor put on for station 41.

II. Finalized Description of Measurements.

II.1 CTD MEASUREMENTS

by Marshall Swartz and Sarah Zimmermann

II.1.a MAJOR DIFFICULTIES

There were problems with the CTD oxygen data for the first 40 stations. Three sensors were tried, and although most of the data was successfully fit to the bottle data, it was neccessary to fit almost every station individually. A new assembly, with a sensor only used once at the start of the cruise for a test station, was used beginning with station 41 and worked well for the remainder of the cruise. The results were more stable allowing for larger station groups for fitting to bottle oxygen. Stations that have not been successfully fit or have offsets, up to .3ml/l, over part of the station are stations 20, 21, 25, and 30 through 40.

II.1.b EQUIPMENT CONFIGURATION

A WHOI-modified EG&G Mk-III CTDs was used throughout the cruise (CTD #9). It was provided with an oxygen current and temperature channel, a platinum temperature probe, and a 3 cm conductivity cell. CTD9 was modified at WHOI to install a thermally-isolated titanium pressure transucer, with a separately digitized pressure temperature channel (Toole, Bond, Millard, 1991)(Toole et. al., 1993). Pressure, temperature and conductivity calibrations were performed at WHOI prior to the cruise. Calibrations will also be performed upon return to WHOI.

A Sensormedics oxygen sensor was installed for the test station prior to station 1. Not having worked well for three stations it was replaced before station 3. The sensor was replaced again before station 21. Over the next 20 stations the quality deteriated, and it was decided to change out the whole assembly, replacing it before station 41 with the assembly and sensor that were used for the test station of the backup CTD.

A redundant 400ms platinum thermometer (OTM Ocean Temperature Module #1326 produced by Falmouth Scientific Intruments) was connected to the CTD for the first four stations. It added noise to the CTD data so was removed for the remainder of the cruise.

Two FSI 24- position Sure Fire Water Samplers were provided for the cruise The pylon was controlled through a dedicated personal computer from which commands were issued and pylon responses displayed and logged.

An FSI Integrated CTD, ICTD#1338, recording data internally, was used to collect backup data for selected stations (48, 103, 104, and 136). ICTD 1338 data was downloaded directly to a computer, demodulated using FSI software.

Two rosette frames were provided for the cruise. Both frames held 24 4 liter bottles. Only one was used during the cruise. The bottles had been produced at WHOI. A Lowered Acoustic Doppler Current Profilers (LADCP), from University of Hawaii was mounted on the frame. Besides the CTD, the LADCP and the occasional FSI backup CTD, a 12-khz pinger was secured on the frame.

II.1.c AQUISITION AND PROCESSING METHODS

Data from CTD 9 was aquired at 23.8 hz and with a temperature lag of 150 ms. The temperature lag was checked by comparing density reversals in theta salininity (TS) plots (Giles and McDonald, 1986). It was found that 150 ms showed the least amount of looping or density reversals.

The CTD data was acquired by a FSI DT 1050WS deckunit providing demodulated data to two personal computers running EG&G version 5.2 CTD acquisition software (EG&G, Oceansoft acquisition manual, 1990), one providing graphical data to screen and plotter, and the other a running listing output. Bottom approach was controlled by following the pinger direct and bottom return signals on the ship-provided PDR trace.

After each station, the CTD data was forwarded to another set of personal computers running both EG&G CTD post-processing software and custom-built software from WHOI (Millard and Yang, 1993). The data was first-differenced, lag corrected, pressure sorted and centered into 2 decibar bins for final data quality control and analysis, including fitting to water sample salinity and oxygen results. This data was then forwarded to the PI for analysis, to compare to historical and water sample data.

II.1.d SUMMARY OF LABORATORY CTD CALIBRATIONS

The pressure, temperature, and conductivity sensors were calibrated by Marshall Swartz at the WHOI's Calibration Laboratory.

PRESSURE CALIBRATION

Method/Calibration Standards

The CTD pressure transducer was calibrated in a temperature controlled bath against the WHOI Ruska dead Weight Tester (DWT) as descibed by Millard and Yang (1993). The pressure temperature S1 and S2 terms were calculated from the results of the two temperature pressure calibrations. D0, the pressure temperature dynamic term, was determined from a temperature dunk test in the laboratory and also from pressure analyses at sea.

The pre-cruise calibration, performed Sept 19 to 24, 1997, consisted of pressure calibrations at two temperatures, 2.0øC and 30.4øC.

	BIAS	SLOPE	QUADRATIC
CTD9			
pre-cruise 2.0øC	-.128314E+02	0.999371E-01	0.150538E-09
STANDARD DEVIATION =	0.462988E+00		
pre-cruise 30.4øC	-.808852E+01	0.999495E-01	0.563499E-10
STANDARD DEVIATION =	0.330181E+00		

PRESSURE TEMPERATURE

CTD9	S1	S2	T0	D1
pre-cruise	2.3969e-007	0.1583	2.0	-290.15
adjusted at sea	-	-	-	-380.0

TEMPERATURE CALIBRATION

Method/Calibration Standards

The CTD's temperature, pressure temperature and oxygen temperature sensors were calibrated in the large temperature controlled bath against the F18/SPRT4070. The CTD is totaly immersed in the salt water bath for a full calibration of seven points from 30 to 1 deg C.

The pre-cruise temperature calibration was performed Sept 19 to 24,1997.

PLATINUM THERMOMETER

	BIAS	SLOPE	QUADRATIC
CTD 9			
pre-cruise	-.179154E+01	0.496266E-03	0.483534E-11
STANDARD DEVIATION =	0.276514E-03		

PRESSURE TEMPERATURE

CTD9	BIAS	SLOPE
pre-cruise	0.374454E+02	-.918590E-02
STANDARD DEVIATION =	0.704427E-01	

OXYGEN TEMPERATURE

	BIAS	SLOPE	QUADRATIC
CTD 9			
pre-cruise	0.140770E+00	0.122493E+00	0.522138E-05
(Used for stations 1 to 40)			
STANDARD DEVIATION =	0.151450E+00		

CONDUCTIVITY CALIBRATION
Method/Calibration Standards
Bottle salinities were drawn during the temperature calibration, four bottles at each temperature. The salinties were then converted to conductivity and compared to the values read by the CTD at the each temperatures point (Millard and Yang, 1993).

	BIAS	SLOPE
CTD9		
pre-cruise	-.152394E-01	0.996828E-03

STANDARD DEVIATION = 0.119487E-02

II.1.e SUMMARY OF AT-SEA CTD CALIBRATIONS
PRESSURE CALIBRATION
The pressure bias of CTD9 at the sea surface was monitored at the beginning of each station to make sure there was no signifigant drift in the calibration. The pressure bias was found looking at the calculated pressure prior to the CTD entering the water. The bias varied from 0 to 1db over the 163 stations. The bias did not vary enough to warrant a change in the pressure calibration.

CONDUCTIVITY CALIBRATION
Basic fitting procedure
The CTD conductivity sensor data was fit to the water sample conductivity as described in Millard and Yang 1993. All the stations were fit as one large group, and divided into sections where there was a noticible shift in the sensor. These groups were fit for both slope and bias.

Data Quality
The overall drift of the sensor during the cruise was .006 psu fresh. Calibrated, the overall standard deviation of the CTD and water sample differences was .0105. Reducing the number of observations from 3343 to 3337 by removing the outliers greater than +/- .1 psu the standard deviation dropped to .0055 with a mean of -9.78e-05. Looking at the data deeper than 1000db, and removing the 6 outliers less than +/- .1 but greater than +/- .02 leaves a standard deviation of .0019.

After being fit to the water sample salinities, the CTD data below 3000db still trends saltier than water samples for a maximum offset of .001psu at 5000db. If this needs to be corrected, changing beta from 1.5e-8 to .75e-8, and then refitting the groups' slope should work.

OXYGEN CALIBRATION
Basic Fitting procedure
The CTD oxygen sensor variables were fit to water sample oxygen data to determine the six parameters of the oxygen algorithm (Millard and Yang, 1993). As with conductivity, the stations were fit after being broken into groups where there was a shift in the response of the sensor.

Data Quality
Before being fit, the difference between water sample and CTD oxygen varied greatly from -2 to 2 ml/l. Calibrated, the overall standard deviation of the CTD and water sample differences was .157. Removing differences greater than .5 ml/l, reducing the number of observations from 3351 to 3287 leaves a standard deviation of .089 and a mean of

-.0026. Looking at the deep data, below 1000db, and removing the outliers greater than +/- .2 ml/l leaves a standard deviation of .0428.

As mentioned earlier, there were problems with the CTD oxygen data for the first 40 stations. Three sensors were tried, and although most of the data was successfully fit to the bottle data, it was neccessary to fit almost every station individually. A new assembly, with a sensor only used once at the start of the cruise for a test station, was used beginning with station 41 and worked well for the remainder of the cruise. The results were more stable, allowing larger station groups to be used in the fits. Stations that have not been successfully fit or have partial offsets, up to .3ml/l, are stations 20, 21, 25, and 30 through 40. Quite a few stations required spikes or sections to be removed using interpolation. The stations requiring interpolation and the pressure bounds interpolated over are listed further down.

II.1.f OTHER NOTEABLE DATA ACQUISTION/PROCESSING ISSUES

The CTD hit bottom on station 102. There was no resulting shift in the conductivity calibration. The backup CTD, ICTD 1338, was put on for stations 103 and 104 for comparison. The ealier station 48 needs to be compared to determine if there was any shift between the CTDs before and after station 102.

At-sea logs were kept for both CTD data acquistion and processing. They include anything of note regarding each station: equipment changes, instrument behavior, equipment or operational problems, how data noise was delt with, where it occured. KN54ACQ.DOC contains the data acquistion descriptions. KN54PROC.DOC contains the data processing descriptions and pressure bounds of bad data removed through interpolation.

II.2 Salinity and Dissolved Oxygen Measurements for Knorr 154/leg 2

by George Knapp

II.2.a Summary

Water samples were collected from virtually every bottle during this cruise for the determination of salinity and dissolved oxygen. The primary purpose of these measurements is to accurately calibrate the sensors on the CTD.

II.2.b Salinity

Water was collected in 8 ounce glass bottles. The bottles are rinsed twice, and then filled to the neck. After the samples reached the lab temperature of 22 degrees , they were analyzed for salinity using a Guildline Autosal Model 8400B (WHOI #11) salinometer. The salinometer was standardized once a day using IAPSO Standard Seawater Batch P-132 (dated 09-APR-97). The Autosal worked flawlessly and showed virtually no drift for the entire cruise. Conductivity readings are logged automatically to a computer, salinity is calculated and merged with the CTD data, and finally used to update the CTD calibrations. Accuracy of salinity measurements are +/- 0.002.

II.2.c Dissolved Oxygen

Measurements are made using a modified Winkler technique similar to that described by Strickland and Parsons (1972). Each seawater sample is collected in a 150 ml brown glass Tincture bottle. When reagents are added to this sample, iodine is liberated which is proportional to the dissolved oxygen in the sample. A carefully measured aliquot is collected from the prepared oxygen sample and titrated for total iodine content. Titration is automated, using a PC controller and a Metrohm Model 665 Dosimat buret. The titration endpoint is determined amperometrically using a dual plate platinum electrode, with a resolution better than 0.001 ml. Accuracy is about 0.02 ml/l, with a standard deviation of replicate samples of 0.005. This technique is described more thoroughly by Knapp et al (1990). Calculated oxygen is merged with the CTD data, and used to update the CTD calibrations.

Standardization of the thiosulphate titrant was performed daily. The titration apparatus worked flawlessly, and no unusual problems were noted.

II.3 Shipboard ADCP

contributed by Dr. Jules Hummon, University of Hawaii

Upper ocean current measurements were made throughout the cruise using the hull-mounted acoustic Doppler current profiler (ADCP) system that is permanently installed on the R/V Knorr. The system includes five components:

1) an incoherent (narrow bandwidth, uncoded pulse) 4-beam Doppler sonar operating at 153 kHz (model VM-150 made by RD Instruments), mounted with beams pointing 30 degrees from the vertical and 45 degrees azimuth from the the keel;

2) the ship's main gyro compass, continuously providing ship's heading measurements to the ADCP via a 1:1 synchro;

3) a Global Positioning System (GPS) attitude sensor (Ashtech model 3DF), which uses a 4-antenna array to provide interferometric measurements of ship's pitch, roll, and heading;

4) a GPS navigation receiver (Trimble Tasman) providing position fixes using both GPS frequency bands (L1 and L2) and the P and Y codes (military "Precision Positioning Service", or PPS);

5) an IBM-compatible personal computer running the Data Acquisition Software (DAS) version 2.48 from RD Instruments, augmented by Firing's software interrupt handler ("user exit") program "ue4", C. Flagg's user exit "agcave", and Flagg's TSR watchdog timer program.

The ADCP was configured for 16-m pulse length, 8-m processing bin, and a 4-m blanking interval (all distances being projections on the vertical and based on a nominal sound speed of 1470 m/s). The transducer depth was 5 m; 60 velocity measurements were made at 8-m intervals starting 21 m below the surface. About 240 pings were sent in each 5-minute averaging interval. For each ping, velocities relative to the transducer were rotated to a geographical coordinate system using the gyro compass heading, but assuming pitch and roll to be zero. The single-ping velocities were then vector-averaged over the 5-minute ensemble. The ensemble-averaging was done separately for the vertical average from bins 2 through 10 and for the deviation of each bin from this vertical subset; the two parts were then added back together and stored. The conversion from Doppler shift to velocity was done using soundspeed calculated from the temperature measured by a sensor in the transducer, assuming a constant salinity of 35 psu. When a velocity estimate in one of the four beams was missing, velocity was calculated from the remaining three beams.

In regions of shallow water, the ADCP was configured to track the bottom with one bottom-tracking ping for each water-tracking ping. This was effective to depths of 600 m or more. From the time the ship left Woods Hole to the last station of the present cruise, approximately 60 hours of underway bottom tracking data were collected. This is significant for the calibration calculations discussed below.

The user exit program integrated the GPS position and attitude information into the ADCP data stream. Position fixes were recorded at the start and end of each ADCP averaging interval (5-minute ensemble). Attitude from the 3DF was sampled at each ping and edited within each ensemble. The mean, standard deviation, minimum, and maximum values of pitch, roll, and compass heading error were calculated and recorded. The compass error is the quantity of primary interest: for each ping, the compass reading used by the ADCP was subtracted from the most recent 3DF heading (updated once per second), and this difference was taken as the time-variable compass error plus some constant misalignment of the 3DF antenna array. The 3DF attitude information was not used for the real-time vector-averaging of velocity because it is not quite reliable enough; dropouts and outliers do occur.

Velocity, position, and attitude measurements were post-processed using the University of Hawaii CODAS software package, generally as described by Firing in WHP Office Report WHPO 91-1, WOCE report 68/91. The essential modification since then is the rotation of the velocity measurements relative to the ship to correct for the gyro compass error as measured by the 3DF. After this correction, and a small but varying sound speed correction, standard water and bottom tracking calibration methods (Joyce, 1989; Pollard and Read, 1989) yield two constants: a velocity scale factor, and a horizontal angular offset between the transducer and the 3DF antenna array. The angular offset is particularly important; an error of 0.1 degree leads to a cross-track bias of 1 cm/s for a ship speed of 11 kts. Bottom track data were primarily obtained leaving from and returning to Woods Hole, off the coast of Iceland and Greenland, and off the coast of Ireland. Water track calibration calculations based on the entire cruise (all stations--water track calibration requires ship accelerations, such as stops for stations). Bottom and water track final calibration values indicated an angle offset of -.51 degrees. Closer inspection of all available calibration information indicates that the "constant" factors are measurably not constant. The angle offset factor may vary within a range of up to plus or minus 0.2 degrees. A possible cause is under investigation; it is not clear whether it will be possible to reduce this uncertainty in the present or future data sets.

The quality of the shipboard ADCP data set from this cruise is reasonably good. No instrument problems were detected and there was an abundance of acoustic targets on the entire cruise track. There were no known compass failures and no long dropouts of 3DF data. During the first two-thirds of the cruise, data were typically obtained to 400-450m. During the last third of the cruise, bad weather reduced the penetration to 350m in places. The transit from the Azores back to Woods Hole had sufficiently bad weather to cause data loss to as shallow as 250m in places.

The upper ocean velocity field during the cruise is summarized in a map of shipboard ADCP velocity vectors averaged from 100 to 300 m (adcp Figure); vertical shear was weak on most of the cruise track, so this layer average is representative. Many characteristics of the velocity field in this figure are similar to the previous two cruises. The overall impression is of weak currents--usually under 50 cm/s, and mostly in the form of ubiquitous small-scale squirts and eddies. The East Greenland Current stands out as a narrow jet flowing southwestward along the Greenland coast. The eddy field was relatively strong in the Rockall Trough and in the Iceland and Irminger basins on the section from Greenland to Ireland. One deep barotropic eddy found in the Iceland basin was present in each of the three cruises. Currents were moderately weak and quite varied between the Azores and Ireland.

II.4 Lowered ADCP

contributed by Dr. Jules Hummon, University of Hawaii

To measure velocity throughout the water column at each station, a self-contained ADCP was mounted on the rosette; this is referred to as the lowered ADCP (LADCP). The LADCP includes a magnetic compass and a tilt sensor, so the velocity profiles can be rotated into the local east-north-up coordinate system. Because the motion of the rosette over the ground is not measured, the LADCP measurements of current relative to the instrument cannot be used directly to infer the current over the ground. Instead, the single-ping velocity profiles are differentiated vertically to remove the package motion (which changes only slightly between the time a ping is transmitted and the time the backscattered return is received). The vertical shear estimates from all pings are then interpolated and averaged on a single uniform depth grid covering the whole water column. This full-depth shear profile is integrated vertically to yield a velocity profile with an unknown constant of integration; and the constant is calculated from the known displacement of the instrument between beginning and end of the cast, together with the shape of the relative velocity profile and the measured current past the instrument as a function of time during the cast. The method is explained in detail by Fischer and Visbeck (1993).

The instrument used on this cruise was a new 150-kHz coded-pulse ("Broadband") profiler made by RD Instruments (a specially modified Phase-III DR-BBADCP), with four beams angled 30 degrees from the vertical.

All 161 profiles were made with the following instrument parameters: blanking interval, pulse length, and processing bin length were all set to 16 m (projected on the vertical). Sixteen depth bins were recorded. Pings were transmitted alternately at 1 and 1.5 or 1.6 second intervals. Data from each ping was recorded individually, with no averaging. Ambiguity resolution mode 1 (no automatic resolution) was used, with an ambiguity intervals of 3 m/s, 3.5 m/s or 4 m/s--the smallest value was used when weather was exceptionally calm. Medium bandwidth was selected. Three-beam velocity solutions were not used, and solutions with an error velocity exceeding 15 cm/s were rejected. Bin-mapping based on tilt was selected.

Immediately after each station the data were dumped from the LADCP to a PC via a serial line (RS-422), and transferred to a Sun workstation for archiving and processing. The profile was processed using the University of Hawaii system, a mixture of C, Matlab, and Perl programs. Velocity and shear data are automatically edited based on several criteria including correlation magnitude (typically 70-count minimum), error velocity (10 cm/s maximum), deviation of vertical velocity in a given bin from its vertical average (5 cm/s maximum), and deviation of individual shear estimates from a mean shear profile (3.5 standard deviations). Additional editing is done on the upcast: the top two depth bins are rejected if the current, profiler vertical velocity, and profiler orientation are such that one beam may be intersecting the profiler's wake. Depth bins subject to contamination from the sidelobe return from the bottom, or from the return of the previous ping from the bottom, are also automatically rejected. Critical to this part of the editing is accurate knowledge of the depth of the bottom and the depth of the profiler. Therefore we have an automated routine for matching the time series of vertical velocity measured by the LADCP with the time series of vertical velocity calculated from the CTD pressure record, and then assigning the corresponding CTD-derived depths to the LADCP. With these instrument depths in the LADCP database, another program scans the LADCP backscatter amplitude profiles in the near-bottom region; the LADCP depth plus the vertical range to the amplitude maximum is the bottom depth.

Accurate position fixes at the start and end of the LADCP profile are essential to the calculation of absolute velocities. We log the PPS GPS fixes at the full 1 Hz sampling rate. The processing software accesses these files and extracts the subsets needed for each profile. Magnetic variation is needed to calculate true direction from the compass readings; we calculate the variation from a standard model of the earth's magnetic field.

An unfortunate problem appeared to develop in the LADCP after about 50 casts: the LADCP velocity data became increasingly unrealistic both in physical terms and in comparison with the shipboard ADCP data. It was determined that the problem lay in the magnetic heading recorded by the instrument. The compass used by this instrument was a TCM2 magnetic flux gate compass. This compass is strapped down to the chassis and measures three orthogonal components of the magnetic field: under ideal conditions, the measured magnetic field vector would be the earth's magnetic field. The LADCP uses the horizontal component of this vector to transform the velocities from instrument coordinates to geographic coordinates. It is this horizontal component that we determined to be in error. A total of 74 casts were taken with the first compass. A spare TCM2 compass was mounted during station 76. This compass ultimately appeared to have the same problem and was swapped out between casts 127 and 128. A total of 50 casts were taken with the second compass. The new components (provided by Terry Joyce) included a KVH compass, compass circuitry, tilt sensors, and transducer driver boards. The KVH compass differs from the TCM2 compass because it is fluid-gimbaled and measures only the horizontal components of the magnetic field. The data from the last compass system (36 casts) appeared to be reasonable.

The LADCP compass headings were corrected by finding the heading-dependent error which minimized the magnitude of the vector difference between a given LADCP profile and the overlapping region of shipboard data during that cast. The heading-dependent correction was modeled as a sinusoidal function of measured heading. The following table shows the improvement in the comparison between LADCP and shipboard adcp values after the correction was applied:

Comparison of (LADCP-shipboard adcp) values for all stations with each of the three compasses.

		MEAN ladcp-adcp values (cm/s) u	v	mag
(TCM2 compass #1)	(n=74)			
orig		-10.80	-3.17	12.85
rotated		-0.21	-0.67	2.76
(TCM2 compass #2)	(n=50)			
orig		-8.11	-2.74	10.48
rotated		-0.42	-0.19	2.80
(KVH compass)	(n=36)			
orig		-0.46	-1.65	3.59
rotated		-0.07	-0.57	3.15
summary (orig)	(n=160)	-7.63	-2.70	10.03
summary (rotated)	(n=160)	-0.24	-0.50	2.86

The correction in LADCP heading brought the magnitude of the vector difference between LADCP and shipboard ADCP down to 2.9 cm/s from 10cm/s (dominated by errors from the first two compasses). For comparison, the average magnitude of the vector difference between LADCP and shipboard ADCP velocities from the cruise 6 months previous (which had an extremely good LADCP-adcp comparison) was 2.6 cm/s. The mean differences in u and v were reduced from -7.6 cm/s and -2.7 cm/s (original u and v) to -0.2 cm/s and -0.5 cm/s (for rotated u and v). Again, for comparison, the mean differences in u and v for data collected 6 months earlier were 0.04 cm/s and 0.03 cm/s. These corrections have clearly done a relatively good job of correcting for the failing TCM2 compasses.

A map of corrected LADCP current vectors averaged over the full depth range of the profile (ladcp Figure) shows some characteristics of the currents as observed on this cruise. As in the shipboard ADCP data, the East Greenland Current stands out as a prominent feature amid the welter of eddies. The barotropic component of the eddy field is weakest on the Ireland-Azores section and strongest on the Greenland-Ireland section, where vertically averaged velocities of 10 cm/s or more are common. The eddy in the Iceland Basin is captured by the LADCP data. In general the eddy field is not well resolved by the station spacing; the velocity profiles typically change radically from one station to the next.

II.5 Expendable Current Profilers

A total of 19 expendable current profilers (XCP; Sanford et al., 1982, 1993) were deployed during this cruise. Each probe was launched while the CTD was descending, typically passing the CTD at about 1000 m. Data from 18 XCPs (at stations 17, 21, and 23-38) were good. The XCP measures currents relative to an unknown depth-independent constant, with 2-m vertical resolution and 0.5 cm/s rms uncertainty. Profiles extend from the surface to 1600 m, but approximately the top 250 m is contaminated by the electromagnetic signal of the ship, and a region of about 200 m extent near the CTD was contaminated by the electric field of the CTD on some stations.

II.6 Carbonate Chemistry

contribute by Greg Eischeid/WHOI, Chipboard Leader of CO2 team
Principal Investigator: Catherine Goyet/WHOI
Crew Members: Healy/Sweeney/WHOI, Moore/RSMAS

A number of instruments were used aboard the R/V Knorr to measure carbonate chemistry continuously in surface sea water and discretely in the water column. Underway measurements include continuous analysis of total inorganic carbon, partial pressure of CO_2, and chlorophyll concentration. Discrete samples werealso taken from the underway sea water supply for total alkalinity and total organic carbon analysis. These discrete samples were taken on the average every 2 hours when transitting and at every station position for an average spacing of 30 nautical miles.
Discrete samples were taken from CTD casts and analyzed for total inorganic carbon, total alkalinity, and total organic carbon. A total of 44 stations were sampled, 472 samples for total organic carbon and 786 samples each for total inorganic carbon and total alkalinity. All total inorganic carbon and alkalinity analysis were performed at sea, approximately 75 percent of total organic carbon analysis will be done post-cruise in the labs at WHOI.

II.7 RAFOS floats

A RAFOS float is a freely drifting subsurface acoustic float which determines its position from moored sound sources and measures temperature and pressure along its trajectory. After a year the float surfaces and telemeters its accumulated data to a satellite. These floats were ballasted to drift a the 27.5 sigma-t density surface.

These and other RAFOS float data are archived and accessible via the website:
http://wfdac.whoi.edu

'KN154RAFOS_flttable.txt' gives an overview of all the floats launched on KN154, November-December 1997.
There are two files per float, the rfb-file contains the raw float data, the rfc-file contains the final edited temperature, pressure, track data, and velocities.

ACCE KN154 RAFOS Float Summary (PIs: Bower, Richardson):
Float ID, Target Density, LAUNCH {Date Time(GMT) Lat Lon}, ...
SURFACE {Date Time(GMT) ARGOS Fix-time(GMT) Lat Lon}, Status Code

w321	27.5	971104	0257	52.251N	16.407W	no show					
w325	27.5	971021	2119	54.902N	34.996W	990810	0300	0716	54.994N	48.767W	66?
w341	27.5	971017	1520	46.154N	30.967W	991017	0300	0615	48.785N	26.871W	00?
w342	27.5	971019	0924	50.595N	33.489W	991019	0300	0407	53.325N	18.240W	00
w343	27.5	971018	1412	48.512N	32.285W	991018	0300	0600	54.915N	18.756W	00
w344	27.5	971103	0026	53.157N	14.999W	991102	0300	0450	58.661N	30.413W	00
w345	27.5	971023	0128	58.150N	31.900W	no show					
w346	27.5	971018	0922	48.037N	32.012W	991018	0300	0421	49.627N	12.739W	00
w347	27.5	971019	1203	50.832N	33.611W	991019	0300	0548	60.785N	27.380W	00
w348	27.5	971018	0058	47.097N	31.501W	991017	0300	0609	62.555N	22.046W	00
w350	27.5	971103	2314	52.245N	15.703W	991103	0300	0617	62.014N	25.806W	00
w351	27.5	971106	0330	48.715N	12.347W	980414	0300	0906	48.820N	11.730W	80
w352	27.5	971106	0531	48.585N	12.434W	991105	0300	0418	45.672N	6.568W	00
w353	27.5	971103	2009	52.252N	15.318W	no show					
w354	27.5	971104	1515	50.998N	16.014W	991104	0300	2018	46.894N	9.019W	00
w355	27.5	971017	2036	46.615N	31.202W	991017	0300	0749	60.193N	28.391W	00
w357	27.5	971106	1223	48.175N	12.987W	991105	0300	1011	50.184N	11.715W	00?
w358	27.5	971106	0831	48.404N	12.632W	991105	0300	0705	47.787N	16.894W	00
w360	27.5	971020	1603	52.538N	35.338W	991019	0300	0728	58.392N	23.913W	00
w361	27.5	971104	2201	51.222N	15.258W	991104	0300	0609	54.826N	10.737W	00
w362	27.5	971103	0556	53.167N	15.834W	991102	0300	1116	57.004N	17.829W	00
w363	27.5	971103	0837	53.174N	16.245W	991102	0300	0950	62.078N	23.396W	00
w364	27.5	971104	1109	50.865N	16.525W	991104	0300	1034	50.296N	21.474W	00
w389	27.5	971019	0758	50.364N	33.344W	991018	0300	0558	61.235N	33.690W	00
w400	27.5	971019	0421	50.129N	33.217W	991018	0300	0600	54.647N	27.527W	00
w413	27.5	971018	2222	49.453N	32.805W	991018	0300	0704	60.667N	21.995W	00
w414	27.5	971018	0550	47.594N	31.752W	991018	0300	0830	57.549N	20.564W	00
w415	27.5	971020	0505	52.304N	34.170W	991019	0300	0731	57.390N	39.197W	00
w416	27.5	971018	1847	48.998N	32.545W	991018	0300	0557	62.750N	22.499W	00
w418	27.5	971018	2336	49.660N	32.939W	990616	0300	0556	47.939N	36.222W	66
w419	27.5	971105	0000	51.266N	15.061W	991104	0300	1033	46.347N	18.179W	00?
w420	27.5	971019	0306	49.913N	33.078W	991018	0300	0741	52.544N	33.255W	00
w421	27.5	971022	0715	56.110N	34.249W	991021	0300	0847	63.016N	53.656W	00
w422	27.5	971021	1328	54.001N	35.502W	991018	0300	0846	60.979N	17.608W	00
w423	27.5	971017	1118	45.687N	30.747W	991017	0241	0613	42.752N	24.555W	00
w424	27.5	971017	0548	45.216N	30.473W	991016	0300	0624	46.200N	24.811W	00?

w425	27.5	971022	1741	57.326N	32.958W	991022	0300	1016	63.771N	55.439W	00
w426	27.5	971023	1235	59.389N	30.262W	991023	0300	0649	43.242N	52.165W	00
w427	27.5	971021	0507	52.867N	35.384W	991020	0300	0536	64.467N	30.141W	00
w428	27.5	971019	1658	51.309N	33.888W	991019	0300	0642	57.755N	21.639W	00
w429	27.5	971019	2136	51.781N	34.144W	991019	0300	0549	55.248N	34.145W	00

Status codes at end of float mission: 0, 00: normal mission, 66: low battery, 80: over pressure, 83: lost weight.
If '?', then first message not received, and status code is assumed.

II.8 PALACE floats

III. References

Fischer, J., and M. Visbeck, 1993. Deep velocity profiling with self-contained ADCPs. J. Atmos. Oceanic Technol., 10, 764-773.

Giles, Alan B. and Trevor J. McDonald. 1986. Two methods for the reduction of Slalinity Spiking of CTDs. Deep Sea Research. vol 33, no 9. 1253-1274.

Joyce, T. M., 1989. On in situ "calibration" of shipboard ADCPs. J. Atmos. Oceanic Technol., 6, 169-172.

Knapp, G.P., M. Stalcup and R.J. Stanley (1990), Automated Oxygen Titration and Salinity Determination,. WHOI Technical Report, WHOI-90-35, 25 pp.

Magnum, B.W. and G.T. Furukawa.1990. Guidelines for Realizing the International Temperature Scale of 1990 (ITS-90). Nist Technical Notes 1265.

Millard, R. C. and K. Yang.1993. CTD Calibration and Processing Methods used at Woods Hole Oceanographic Insitute. Technical Report No. 93-44, 96 pages.

Oceansoft MKIII/SCTD Aquisition Software Manual. 1990. P/N Manual 10239. EG&G Marine Instruments.

Owens, Brechner W. and Robert C. Millard, Jr.1985. A New Algorithm for CTD Oxygen Calibrations. J. Phys. Oc. vol 15.621-631.

Pollard, R., and J. Read, 1989. A method for calibrating shipmounted Acoustic Doppler Profilers, and the limitations of gyro compasses. J. Atmos. Oceanic Technol., 6, 859-865

Strickland, J.D.H. and T.R. Parsons (1972) The Practical Handbook of Seawater Analysis. Bulletin 167, Fisheries Research Board of Canada, 310 pp.