SECTION 1: CRUISE SUMMARY

WOCE AR11, RRS DARWIN CRUISE 73 IN THE N.E. ATLANTIC
SUBDUCTION 3 MOORING DEPLOYMENT AND RECOVERY CRUISE

Expedition Designation (EXPOCODE) 74AB73_1

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Ship: RRS Charles Darwin, owned by the Natural Environment Research Council UK, chartered by the Woods Hole Oceanographic Institution.

Ports of Call: Funchal, Madeira to Ponta Delgada, Azores.

Cruise Dates: 30 September 1992 to 26 October 1992.

CRUISE OVERVIEW

Cruise Track

The cruise track and station locatios are shown in an accompanying figure.

Number of Stations

A total of 59 CTD/Rosette stations were occupied employing a 12 place, 10 litre Niskin Bottle Rosette with a Neil Brown CTD.

Sampling

Water sample measurements were made for salinity, oxygen, Tritium and Helium. No nutrient samples were taken.

Floats and Drifters

One SIO Autonomous LAgrangian Circulation Explorers was deployed during Darwin cruise 73. It was deployed at position 25 19.36'N, 29 05.79'W on 14 October 1992 at 0508 UTC. No surface drifters were deployed.

XBTs

Two hundred and one T-7 XBTs were deployed during the cruise. The profiles were archived within the GTSPP program at US NODC, Washington, DC from which they may be retrieved.

Moorings

An array of five surface moorings carrying meteorological and oceanographic instrumentation were deployed for a period of two years beginning in June 1991 as part of an Office of Naval Research (ONR) funded Subduction experiment. Three eight month deployments were achieved. The moorings were deployed at nominal positions 18N 34W, 18N 22W, 25.5N 29W, 33N 22W, 33N 34W. During Darwin cruise 73 the second setting of the moorings were recovered and redeployed for a third eight month period. This was the principal task of the cruise and is not described any further here. For mooring data consult the records from the WOCE current meter Data Assembly Centre and the Technical Report WHOI-93-18 The Subduction Experiment, March 1993 from the Woods Hole Oceanographic Institution (hereinafter described as REF 1).

TABLE 1 CRUISE PERSONNEL & TASKS

Richard Trask	WHOI Chief Sci.	Moorings/XBTs PI
William Ostrom	WHOI	Moorings
Bryan Way	WHOI	Moorings
Neil McPhee	WHOI	Moorings
Nancy Galbraith	WHOI	Current Meter Processing
Richard Payne	WHOI	Met Measurements PI
Melora Samelson	WHOI	Current Meter Processing
Steve Abbott	SIO	Moorings
Glenn Pezzolli	SIO	Moorings
Jeff Sherman	SIO	Moorings
Marshall Swartz	WHOI	CTD
Peter Landry	WHOI	Tracers
William Jenkins	WHOI	Hydrography/Tracers PI
Dave Wellwood	WHOI	Oxygen/Salinity
Mike Davies	NERC RVS	Winches
Colin Woodley	NERC RVS	Winches
Adrian Fern	NERC RVS	Computing/Navigation

SECTION 2: SCIENTIFIC PROGRAM

Subduction is the mechanism by which water masses formed in the mixed layer and near surface of the ocean find their way into the upper thermocline. The subduction process and its underlying mechanisms were studied through a combination of Eulerian and Langrangian measurements of velocity, measurements of tracer distributions and hydrographic properties and modeling.

As described above five moorings were recovered/deployed at nominal positions 18N 34W, 18N 22W, 25.5N 29W, 33N 22W, 33N 34W. Each mooring was heavily instrumented between 10m and 750m. In all 34 Vector Measuring Current meters were deployed and 58 temperature data loggers (REF 1).

A Vector Averaging Wind Recorder (VAWR) and an Improved Meteorological Recorder (IMET) collected wind speed and wind direction, sea surface temperature, air temperature, short wave radiation, barometric pressure and relative humidity. The IMET also measured precipitation.

Expendable bathythermograph (XBT) data were collected and meteorological observations were made in transit between mooring locations. The principal concern here is with 59 CTD stations which were made and the water samples taken to be analyzed for Tritium, Helium, salinity and dissolved oxygen content.

SECTION 3:UNDERWAY MEASUREMENTS

A) EXPENDABLE BATHYTHERMOGRAPHS (XBT)

Two hundred XBTs were deployed during Darwin cruise 73. The T-7 probes were purchased from Spartan of Canada. XBT data was logged on a NEC APC IV with a Spartan data acquisition microprocessor card. The digital data was simultaneously logged in memory and plotted on the screen. Problems with a drifting calibration were encountered early on resulting in XBT surface temperatures which differed from those taken by the bucket thermometer. After numerous attempts to find the cause of this problem the cable on the ship's hand held launcher was replaced with a new shielded cable. With this change the calibration became stable and the surface temperatures agreed with the surface bucket temperatures. Once the cable was replaced there were very few probed that failed to produce reasonable data. Unfortunately the first 48 probes were used prior to correcting the calibration problem.

Hourly XBTs were taken on the hour while the ship was underway. If a scheduled XBT occurred within a half hour of a CTD station then the XBT was not taken. XBTs were also suspended when the ship was within 10 miles of a surface mooring.

B) METEOROLOGICAL MEASUREMENTS

The primary source of high quality meteorological data on Darwin 73 was a Multimet system installed by Peter Taylor's group from Rennell Centre, Southampton. The Multimet sensors were installed on a foremast about 4 meters aft of the peak of the bow with most of the sensors located at a height of about 15 meters above the water line. Sensors on the foremast included an R.M.Young AQ anemometer, an Eppley pyrgeometer, two aspirated wet/dry bulb aspirated temperature units, and two Kipp and Zonen short wave pyranometers were located about 2 meters to port and starboard from the mast. The larger value was selected in the processing with the assumption that the larger had not been affected by the mast's shadow. The barometric pressure sensor was in the top lab with the processing and recording electronics package. The output of the ship's gyro was also recorder.

All parameters were averaged over the first 50 seconds of each minute. The time assigned to these values was that of the beginning of the minute. These one minute values of undecoded data were recorded on EPROM within the electronics package and on the ship's Sun-based data logging system.

All appropriated sensors were calibrated before and after the cruise. The calibrations were applied to the raw data in off line processing using a set of programs developed by the Taylor group. The processing used the navigation data recorded by the ship's logging system to correct the measured wind speed and direction for ship movement. The logged outputs of the ship's thermosalinography were added to the final data files.

Manual meteorological observations were taken hourly on the half hour. The manual observations consisted of recording the time, position, ship's speed, ship's heading, wind speed and wind direction from the bridge readout, barometric pressure using an AIR hand held barometer, air temperature and relative humidity using a hand held Vaisala sensor, sea surface temperature and salinity as measured by the thermosalinography (pumped from 5 meters depth), cloud type and cloud coverage in octas and bucket temperature. In addition the corresponding Multimet data was also recorded by hand.

Hourly on the hour in conjunction with XBTs the time, position, sea surface temperature and salinity from the thermosalinography and bucket temperature were recorded.

SECTION 4: THE TRACER/HYDROGRAPHY PROGRAM

A. INTRODUCTION AND PURPOSE

The purpose of this part of the cruise was to obtain a large scale mapping of the distribution of tritium-helium age, oxygen, salinity and temperature over the area of study. The tritium-helium age, deduced from the distributions of both tritium (the heaviest isotope of hydrogen) and its stable daughter product helium-3, can be regarded as a measure of elapsed time since water was at the ocean surface, and hence is a direct measure of subduction rates of different water masses. By subduction, we mean the process by which water resident at the ocean surface enters the subsurface circulation of the great, subtropical ocean gyres. Subduction apparently takes place in several ways. The first is called Ekman Pumping, whereby water is forced downward by wind driven convergence of surface waters. The second is a form of "thermodynamic underthrusting", where southward flowing water at the base of the previous winter's mixing layer is buried under warmer, less deeply convecting surface layers. The third, associated with secondary vertical processes and mixing at current fronts (in particular, the Azores Front), we refer to as "frontal subduction". The first is computable from the large scale wind fields, coupled with more-or-less well understood upper ocean physics. The limitation of this calculation is the quality and availability of good wind observations over the ocean (hence the need for the meteorological mooring in the Subduction Experiment). The second has only recently been recognized as an important process, and has been estimated by a combination of upper ocean circulation fields and the topography of the winter mixed layer depths. The third is by far the most difficult to assess and predict, and is probably only addressable from tracer and tritium-helium age measurements. We suspect that all three processes play an important role in subduction. Indeed, this is supported by observation of tracer distributions and the tritium-helium age fields. The goal of the Tracer/Hydrography component of the Subduction Experiment is evaluate the relative contributions of these mechanisms and to characterize the subsurface circulation and mixing.

B. SAMPLING SCHEME

The stations sampled are shown in an accompanying figure. A total of 59 stations were taken. Logistically, we were constrained to sample largely on the cruise tracks between the mooring sites, but a central "Z" shaped excursion was included to obtain mapping across important tritium-helium age gradients and flow lines. Because the overall goals and subject study of the mooring programme are the same as the tracer/hydrography programme, the cruise track is close to optimal for our purposes. The track may be divided into four major sections:

- a meridional section along 22 W (stations 4-17) cutting through the large scale flow stagnation point and penetrating into the confluence between southward flowing subtropical and northward flowing tropical waters

- diagonal section (stations 23-34) extending "upstream" into the tongue of subducting waters

- two sections (stations 34-42, and stations 45-59) transecting the southward veering subtropical gyre circulation

The last of these sections is perhaps the most critical, in that it provides the only means or directly assessing the frontal subduction component. The means by which this can be done is by determining the directional rotation of tritium-helium age isochrons relative to the mean streamlines.

C. SAMPLING PROCEDURES AND TECHNIQUES

Water samples were obtained from a 12 place, 10 litre Niskin Bottle rosette sampler with a Neil Brown CTD. Typical stations were to 500 metres depth, with occasional sampling to 1000 or 2000 metres. Sampling was primarily done over the potential density anomaly range of 26.0 to 26.9 kg/m3, with "supporting sampling" done above and below these levels. Salinity, oxygen, helium and tritium samples were drawn from the Niskins on deck. Salinity samples were measured using a Guildline AutoSalinometer bridge calibrated with IAPSO standard water ampoules. Oxygen measurements were by high precision Modified Winkler titrations using an automated dosimat with electrode end point determination. The helium and tritium samples were drawn into 90 cc stainless steel sample cylinders with O-ring sealed plug valves on either end. The helium was extracted into 25 cc glass ampoules (Corning type 1724, low He-permeability aluminosilicate glass) using a hot-extraction technique in an all metal UHV vacuum system. Tritium samples were degassed in 200 cc glass flasks (again Corning type 1724 glass) on a separate UHV system. Both UHV systems were cryo- and diffusion pumped, instrumented with convectron and ion vacuum gauges, and operated with computer controlled solenoid/pneumatic valves. The subsequently obtained samples are being returned to WHOI for shore-based mass spectrometric analysis of helium and tritium. The tritium will be determined by helium-3 regrowth techniques, after an incubation period of one year.

D. PRELIMINARY HYDROGRAPHIC RESULTS

Since they require shore-based analytical procedures, the tritium-helium data are currently unavailable. We do, however, have some preliminary hydrographic (temperature, salinity and dissolved oxygen) data. The isotherms, particularly warmer than 18 degrees, show the dominant southward deepening associated with subduction. Surface waters show a banded structure, with front-like southward increases in temperature at about the 1600 and 200 km positions. At the extreme southward end, the deep isotherms turn upward, characterizing the westward flowing limb of the subtropical gyre circulation.

The zonal banding is even more evident in the salinity distribution. Aside from the 100-200 km oscillation, the shallow salinity is domes upward in the middle of the section due to the high salinity cell created by the high Northeasterly trade winds. A subtle subsurface bulge in the salinity surface (most evident at about 100-150 metres in the southern end of the section) is an imprint of the subducting waters, known further west as the Subtropical Underwater. Deeper down, the influence of Antarctic Intermediate water can be seen in the southern end of the section at 500 metres.

The southern water influence is also seen in the oxygen distribution, where the deep oxygen concentrations dip to about 2 ml/l. This is an artifact of the large tongues of low oxygen water protruding from the coast of Africa. A striking feature of the oxygen distribution found here is the subsurface photosynthetic oxygen maximum at about 60-100 metres. This feature attenuates southward and eastward, reflecting geographic variations in new primary production, which result from changing patterns of nutrient recycling.

ACKNOWLEDGEMENTS

We are grateful for the skill of Captain McDermott and the assistance provided by all the crew members of the RRS Charles Darwin. The work was supported by the Office of Naval Research Grant

No. N00014-90-J-1490.

Cruise 74AB73_1 Darwin73 Subduction cruise with W. Jenkins as PS.

Notes- provided by pms (woceipo). 17 October 2000.

1.
The expocode has been changed in all files from 74AB73/1 to 74AB73_1

2.
Please note that ALL temperatures are specified on this cruise on the International Practical Temperature Scale 1968 IPTS-68
They can be converted to ITS-90 by multiplying by 0.99976

3.
No attempt has been made to reconcile CTDSAL and bottle salinity in detail, but they look reasonably in agreement over the full range of 34.8-37.6

4.
The agreement is not so good for the oxygens.
The CTDOXY values on average are about 5% lower than bottle oxygens.
NO CORRECTIONS HAVE BEEN MADE.

5.
You will note that the data includes tritium, helium and delhe3 measurements and their errors.