Preliminary data Report
May 4, 1992

A. Cruise Narrative

A.1 Highlights

A.1.a WOCE designation: AR4E/AR4W/AR15

A.1.b EXPOCODE 06mt16/3

A.1.c Chief Scientist:

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A.1.d Ship name: R/V METEOR
A.1.e Ports of call: Belem, Brazio - Las Palmas, Canary Islands, Spain
A.1.f Cruise Dates: 23 May - 17 June 1991

A.2 Cruise Summary

A.2.a Geographic Boundaries

A.2.b Total number of stations Occupied

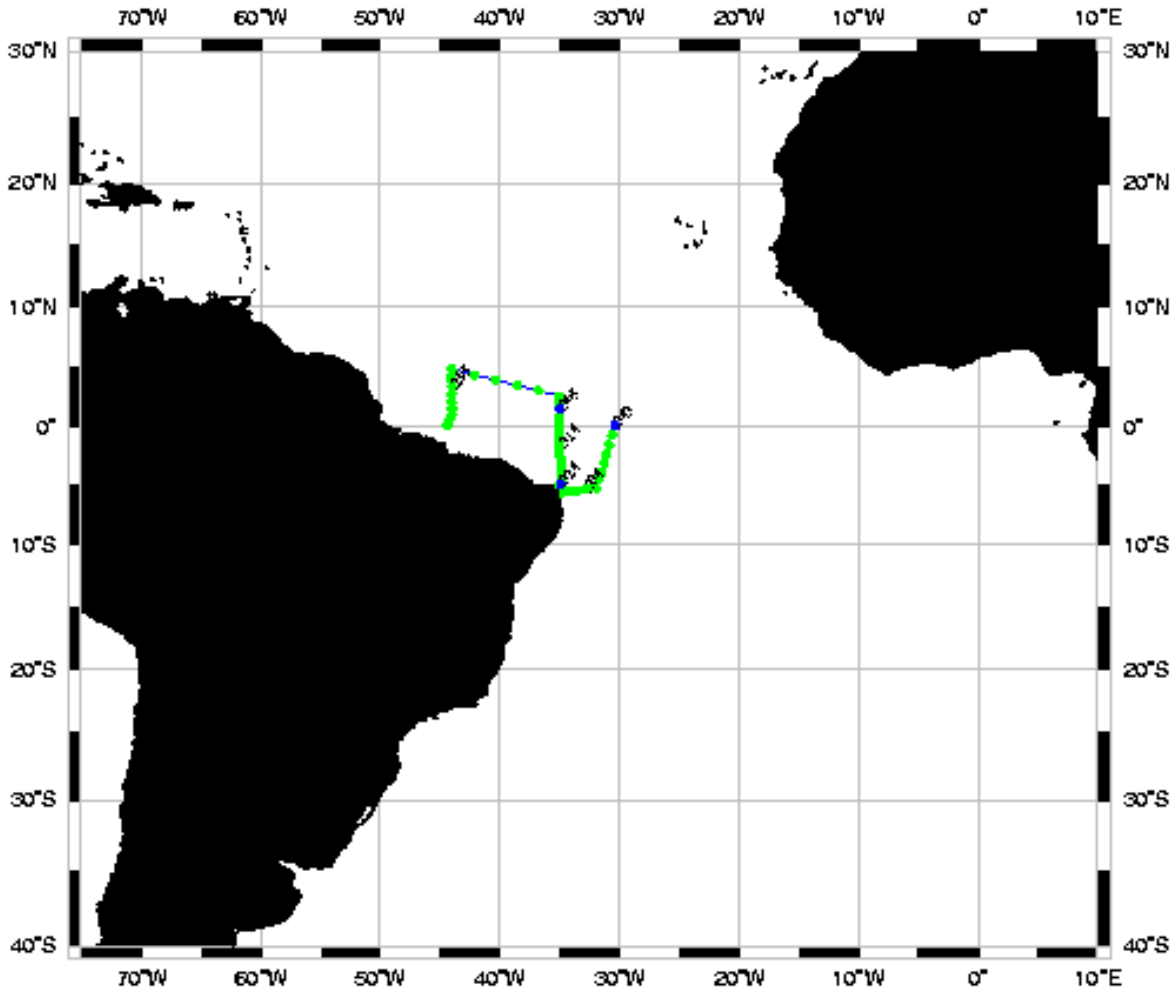
Total number of CTD stations: 60

Sampling equipment:

small volume sampling:	one 24-place rosette with 10-liter bottles
CTD system:	NBIS Mark III CTD, with ∞2 sensor and pinger
Salinometer:	2 Guildline Autosals
ADCP:	150 kHz ADCP manufactured by RDI, USA
Pegasus:	Benthos-Pegasus
Chlorofluorocarbons:	GC, Integrator: Shimadzu
Oxygen:	Winkler titration
XBT:	Sippican Deep Blue probes

Sampling: Water sampling on the cruise included measurements of salinity, both by CTD and water bottle samples, CTD and bottle sample oxygen determinations, CTD temperature. Tracer analysis were made for CFC-11 and CF-12.

Station locations for AR04 SCHOTT



A.2.c Floats and drifters deployed

A.2.d Moorings deployed or recovered

A.3 List of Principal Investigators

Table 1: List of Principal Investigators

Measurements: Parameter	Sampling group	Responsible investigator
CTD O2 / Rosette	IfM Kiel	Lothar Stramma
Chlorofluorocarbons	IfM Kiel	Monika Rhein
ADCP	IfM Kiel	Jurgen Fischer
Pegasus	IfM Kiel	Uwe Send
Salinity	G.Britain	John Swallow
Oxygen	IfM Kiel	Joanna Waniek
XBTs	IfM Kiel	Lothar Stramma

IfM Kiel
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A.4 Scientific Programme and Methods

Leg 3 of METEOR cruise 16 focused on the investigation of the circulation and the water mass exchange in the western tropical Atlantic. This investigation was carried out in the context of the World Ocean Circulation Experiment(WOCE). The cruise was a follow-up study to the investigations done during METEOR cruise 14/2 in October 1990. The western tropical Atlantic plays an important role in the water mass exchange between the northern and the southern hemisphere. The meridional heat transport takes place by warm surface water and subpolar intermediate water from the southern hemisphere moving northward in the upper 1000 m, and North Atlantic Deep Water (NADW) moving southward between1200 and 4000 m. The details of this water mass exchange across the equator and the seasonal changes of the flow field are not well understood, and were the main subject of this cruise.

METEOR left Belem (Brazil) on May 23, 1991 at 6:00 local time, heading towards a location near 44∞W, where the first hydrographic section along 44∞W started. On May 24 at 10:00 UTC the first CTD station was done on the Brazilian shelf at 0∞00.54'N, 44∞24.49'W (station number 286, Flg.1; CTD-cast number 1, Fig.2). From this location a hydrographic section with CTDs and Pegasus-drops along 44∞W was done until the evening of May 27.As a new technique an ADCP connected to the CTD-rosette was lowered with the CTD. The 44∞W section was finished at 4∞43'N. From here the ship sailed to the northernmost location of the 35∞W section, with XBT-drops and 4 shallow CTD/ADCP stations along the way.

The second hydrographic section with CTD/ADCP and Pegasus measurements was carried out along 35∞W and started at 2∞30'N on May 30, 1991. This section was completed on May 6 on the Brazilian shelf at 5∞38.82'S, 34∞57.51'W. Another short hydrographic section was done along 5∞30'S from the Brazilian shelf to 32∞W. Along this section the CTD was used without the ADCP because of technical problems with the ADCP. From the endpoint of this section the ship headed NNE toward 30∞W and the equator, with 7 more shallow CTD stations south of the equator and one Pegasus-drop on the equator, on June 10. This was the termination of the measurement program. Then the ship headed north towards the Canary Islands with XBT-drops as the only measurements between the equator and 12∞30'N. The ship reached Las Palmas at 12:00 local time on June 17, where the cruise METEOR 16/3 terminated.

A.5 Major Problems and Goals not Achieved
A.6 Other Incidents of Note
A.7 List of Cruise Participants

B. Underway Measurements

B.1 Navigation and bathymetry
B.2 Acoustic Doppler Current Profiler (ADCP)
B.3 Thermosalinograph
B.4 XBT and XCTD
B.5 Meteorological observations
B.6 Atmospheric chemistry

C. Hydrographic Measurements

D. Acknowledgments

E. References

Unesco, 1983. International Oceanographic tables. Unesco Technical Papers in Marine Science, No. 44.

Unesco, 1991. Processing of Oceanographic Station Data, 1991. By JPOTS editorial panel.

F. WHPO Summary

Several data files are associated with this report. They are the metr16l3.sum, metr16l3.hyd, metr16l3.csl and *.wct files. The metr16l3.sum file contains a summary of the location, time, type of parameters sampled, and other pertinent information regarding each hydrographic station. The metr16l3.hyd file contains the bottle data. The *.wct files

are the ctd data for each station. The *.wct files are zipped into one file called metr16l3wct.zip. The metr16l3.csl file is a listing of ctd and calculated values at standard levels.

The following is a description of how the standard levels and calculated values were derived for the metr16l3.csl file:

Salinity, Temperature and Pressure: These three values were smoothed from the individual CTD files over the N uniformly increasing pressure levels using the following binomial filter-

$$t(j) = 0.25ti(j-1) + 0.5ti(j) + 0.25ti(j+1)\ j=2....N-1$$

When a pressure level is represented in the *.csl file that is not contained within the ctd values, the value was linearly interpolated to the desired level after applying the binomial filtering.

Sigma-theta (SIG-TH:KG/M3), Sigma-2 (SIG-2: KG/M3), and Sigma-4(SIG-4: KG/M3): These values are calculated using the practical salinity scale (PSS-78) and the international equation of state for seawater (EOS-80) as described in the Unesco publication 44 at reference pressures of the surface for SIG-TH; 2000 dbars for Sigma-2; and 4000 dbars for Sigma-4.

Gradient Potential Temperature (GRD-PT: C/DB 10-3) is calculated as the least squares slope between two levels, where the standard level is the center of the interval. The interval being the smallest of the two differences between the standard level and the two closest values. The slope is first determined using CTD temperature and then the adiabatic lapse rate is subtracted to obtain the Gradient potential temperature. Equations and Fortran routines are described in Unesco publication 44.

Gradient Salinity (GRD-S: 1/DB 10-3) is calculated as the least squares slope between two levels, where the standard level is the center of the standard level and the two closes values. Equations and Fortran routines are described in Unesco publication 44.

Potential Vorticity (POT-V: 1/ms 10-11) is calculated as the vertical component ignoring contributions due to relative vorticity, i.e.pv=fN2/g, where f is the coriolius parameter, N is the bouyancy frequency (data expressed as radius/sec), and g is the local acceleration of gravity.

Bouyancy Frequency (B-V: cph) is calculated using the adiabatic leveling method, Fofonoff (1985) and Millard, Owens and Fofonoff (1990). Equations and Fortran routines are described in Unesco publication 44.

Potential Energy (PE: J/M2: 10-5) and Dynamic Height (DYN-HT: M) are calculated by integrating from 0 to the level of interest. Equations and Fortran routines are described in Unesco publication, Processing of Oceanographic station data. Neutral Density (GAMMA-

N: KG/M3) is calculated with the program GAMMA-N (Jackett and McDougall) version 1.3 Nov. 94.

G. Data Quality Evaluation

Hydro (Affonso Mascarenhas)

The data, I was asked for to evaluate, comprise CTD and bottle data (salinity and oxygen) collected on two cruises from AR15/ar4. The first one, leg 2 of Meteor cruise 14, was from Cape Verde Island to Salinopolis and Recife, Brazil. No CTD oxygen was reported for this cruise due to problems with the titration of dissolved oxygen and he calibration of the CTD oxygen sensors, according to an additional note of the cruise report.

A figure showed the histogram for the differences (Bottle-CTD) salinity, for leg 2 Meteor cruise 14. The standard deviation is 0.0024, that is the expected accuracy attained with altosal salinometers, in spite of the WOCE requirement of 0.001. Also 66 percent of the differences are within this range definition the sample as a reasonable data set since the distribution is no Gaussian. Many plots were performed in order to evaluate their quality and in all of then the distribution of the points indicate the data set as a good quality one. As an example a figure showed (bottle-CTD) salinity versus station number and a figured showed (bottle-CTD) salinity verses salinity. Another figured showed an intriguin distribution of points in the trace, that was also observed in others stations. I checked the data set and replotted the TS on difference scale range, and it is hard to affirm if they are real or caused by shed wakes, pressure reversals or ship heave.

The only data flagged as questionable in this set were:

Station	sample	bottle	pressure	salinity
630	10	17	698	34.5490
632	11	16	21	36.0320

The second data set was from leg 3 of Meteor cruise 16 from Belem, Brazil to Las Palmas, Canary Island. In this case we have CTD and bottle salinities and oxygen, being both parameters not observed in some depths as indicated in files *.hy2. A figure shows the histogram from the differences (bottle-CTD) salinity, the distribution has a positive skewness and a standard deviation of 0.0019 that is the accuracy of Autosal salinometers, even though as stated before an accuracy of 0.001 could be attained.

On the other hand, 56 percent of the differences are within this range, meaning that statistically there is a poor agreement between the set of differences with their mean. In spite of this, both salinities fits very well as well as with the TS relationships of the area.

Other figures display a cluster of data between +/- 0.005 which is a guarantee of the goodness of the data set. The additional information to the data report refers to an offset that would result by using the upcast bottle data for the calibrations of the meteor 14 and

16 salinity profiles. The salinity data set could be considered good even with the offset caused by the used of the upcast bottle data.

A histogram for the differences (Bottle-CTD) Oxygen was done. The comparison of the Oxygen Bottles and CTD is impressive. The standard deviation of the differences is 16.39, and most of the data fell within it (80%). In the dissolved oxygen data set the differences shows a bias being the titration values less than the CTDOXY values most of the times. The Oxygen values agree with the historical values of the region the systematic low values (below the mean for the region) between 200 and 350 m in the station 339 to 343 seems to be real (I probably need a better oxygen data bank for the region). How the CTDOXY values should be calibrated it is left to WHP Office.

Notes by T.J. Joyce

The water sample -CTD differences are expected to exceed WHP specifications as both quantities have error. One expects deep values to show little difference. However, there is a persistent differences for pressures greater than 1500 dbar for groups of stations on both cruises (289-297 and 307-316 Meteor 16 and 627- 634 on Meteor 14). That suggests that the CTD data could be better 'calibrated'.