WOCE

World Ocean Circulation Experiment

NEWSLETTER

Number 11 September 1991

FEATURES

NEWS FROM THE WOCE-IPO

During this summer, a number of staff changes took place at the WOCE International Project Office. The Director, Dr Peter Koltermann, returned to the Bundesamt für Seeschiffahrt und Hydrographie, Hamburg, Germany after almost five years at the WOCE-IPO in Wormley, UK. Dr Nicholas Fofonoff of the Woods Hole Oceanographic Institution, USA, will be the new Director of the IPO, arriving in early autumn 1991. In the interim period, Dr Bruce Taft is Acting Director of the IPO. He will return at the end of October to the Pacific Marine Environmental Laboratory/NOAA in Seattle, USA.

Also in the autumn, Dr Ilse Hamann will join the IPO. She has worked in Germany and presently is located at NOAA Fisheries Laboratory in Honolulu. While at IPO she will be on secondment from Germany.

Dr George Needler, who has been with WOCE since 1985, returned to the Bedford Institute of Oceanography in August 1991. He will continue as WOCE Chief Scientist at that location over the coming year.

Bruce Taft and Bert Thompson, together with Sheelagh Collyer and Penny Holliday, will help to provide a smooth transition.

Peter Koltermann remarked at a recent farewell gathering that he feels that it has been a very interesting personal opportunity to contribute to the development of one of the most fascinating oceanographic experiments. The early WOCE fathers in the beginning of the 80s had a clear perception of what was needed to obtain a better view of the role of the ocean in influencing climate. During the WOCE planning years, the public awareness to climate change issues, and the role of the ocean in the climate system, has found widespread recognition. He also noted that the continuous and active involvement of scientists all around the world had made life at the IPO challenging, and that he hoped the IPO had met that challenge. He also said that he is returning to Germany with a sense of loss, since working with his colleagues on the Marine Physics floor of the Institute of Oceanographic Sciences Deacon Laboratory and with the British oceanographic community had been very rewarding, and living in the beautiful countryside of Southern England had been a great compensation for a sometimes hectic job.

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“STARTING YEAR TWO OF WOCE” AN INTRODUCTORY TALK TO WOCE-16 BY R. ALLYN CLARKE

The World Ocean Circulation Experiment (WOCE) has been more than 10 years in the planning and is now just entering into the second year of its intensive field period. This may seem like a very long planning time frame; however, given the importance that satellites play in the global nature of this programme, a decade is the time it takes to get satellite systems funded and flying.

It seems appropriate that this meeting of the Scientific Steering Group takes a good look at what WOCE has accomplished so far as well as where we are not doing as well as we had hoped. This discussion will lead to a consideration of the actions we can take to ensure that WOCE meets as many of its scientific goals and objectives as possible. I will begin this process by giving my personal review on what we have accomplished and what we are not accomplishing.

We spend so much of our effort counting and evaluating national commitments and evaluating reports and messages from the IPO staff and the various scientific working groups and implementation committees, it is easy to forget that already there are a number of significant achievements. WOCE also is changing the way that many oceanographers will work in the future.

In the South Atlantic, the Deep Basin Experiment and the associated large-scale one-time survey hydrographic sections are well underway. In addition to hydrographic and tracer sections, several mooring arrays have been set and deep floats are about to be released. This complex experiment has brought together the efforts and resources of a number of countries and will be completed largely as originally planned.

In the north Atlantic and Pacific oceans, repeat hydrographic sections are being completed on a regular basis. In fact, on at least one section, more repeats are being carried out than were originally asked for and this will provide a better estimate of the temporal variability.

A new instrument, the ALACE float, has moved from initial design through working prototype to operational instrument. Of the first 10 prototype instruments launched in the Drake Passage, seven are still operating in the southern South Atlantic after more than a year. This instrument provides oceanographers with a tool to measure deep Lagrangian flows in remote ocean regions without the necessity of revisiting the area at frequent intervals to recover listening stations or to replace sound sources. The instrument also offers a possible platform for obtaining repeated temperature and salinity profiles from such remote locations should appropriate sensors be built.

WOCE has already completed one of its major mooring arrays, a three-year array on the east Greenland Slope which showed that the transport of the waters that overflow the Greenland-Scotland Ridge is remarkably steady over periods of a month to a few years. WOCE also has collected and published the eddy statistics of all the deep-ocean current meter records longer than nine months in the archives of the world’s oceanographic institutions.

We have been extremely fortunate that the US Navy Geosat altimetry data were made available to the scientific community. Scientists in many countries have started to work with that data to look at regional, basin-wide and global circulation in association with classical hydrographic data, SST features analysis and model output. As a result of this work we have a large number of experienced scientists who are waiting with models and significant analysis capabilities for the ERS-1 and TOPEX/POSEIDON altimetric data sets. We have had our spin-up period, we are ready for the real thing in WOCE.

It was the WOCE SSG who pressed CCCO and JSC to establish Klaus Hasselmann’s working group on air-sea fluxes in order that the ocean modelling community would have a global surface wind field of as uniform and high a quality as possible. This working group has worked hard with ECMWF in order to improve their model’s atmospheric boundary layer formulation. This development is already giving us better surface winds than we have gotten from an atmospheric model before. ECMWF also is fully prepared to assimilate the ERS-1 scatterometer data using both surface wave and atmospheric boundary layer models to provide the next generation global surface wind analysis. These developments also are being pursued by other weather services.

Building on TOGA arrays, we are expanding the surface velocity, sea level and XBT programmes into higher latitudes. In the surface velocity programme, we have developed and tested new drifters and are in the process of putting together the interests and the resources of a number of groups and countries to achieve a near-global coverage. Similar developments are taking place with sea level gauges and XBT sections.

The WOCE Data Information Unit has been operational for several years and its information banks are being accessed by an increasing number of interested people. The tracking of XBTs through the DIU allows us for the first time to identify where XBT data are being lost as it moves through the GTS and other data exchange mechanisms. Data assembly centres and special analysis centres are being slowly brought into operation and the first WOCE data sets are moving through their planned data quality control, validation and analysis pathways.

WOCE has spawned a new interest within the ocean modelling community for basin-wide and global-scale models. Observationalists have begun to analyze the outputs of the FRAM and North Atlantic Community Model simulations. We will hear about analyses of the FRAM model data at this meeting. The modelling community in turn has looked at ocean observations and there has been an active development of a whole family of different data assimilation/data inverse studies. We can certainly be confident that a modelling community is now prepared to analyze the expected WOCE global data sets. Most recently, we have seen the developing interest in coupled ocean/atmosphere models and operational ocean models. Both these developments are a necessary step toward the achievement of WOCE's scientific goals.

WOCE has accomplished much during its years of planning and its first year of operation. But many of these accomplishments have come about through the actions of a few scientists working together on particular problems and using a particular technique or instrument. It is fair to say that WOCE has not done as well as its planners might have hoped in creating a large group of scientists interested in combining a range of different data types into new global oceanic fields.

It is true that there are a large number of scientists ready to work with the ERS-1 altimetry data when it begins to flow early this summer, but how many of them will create basin-wide and global sea-surface elevation fields that others can use along with the surface velocity, hydrographic, tracer and deep float data to create models of the four-dimensional ocean velocity fields? Are we going to have a global WOCE sea-surface elevation field or simply a large number of scientific papers on various oceanographic applications of satellite altimetry? Of course we want both but we will have to work hard as WOCE planners to ensure the former comes to fruition.

It is not just in satellite altimetry that we need to work better as a global WOCE community. A number of questions need to be asked. Who are the data assimilators who will be creating global ocean transport fields? Must they all reside in the WHP Special Analysis Centre in Hamburg? How can we get tracer chemists to worry about collecting global tracer fields rather than just collecting and analyzing samples on their nation's or their institute's vessels and cruises? How do we get sensitivity analysis performed on global and regional ocean models when these models are so often developed by research groups who are more interested in moving to the next generation of such models? I don't expect that we can find answers to all these concerns in our discussions over the next three days; however, I hope that the SSG and its working groups will continue to highlight and emphasize that for WOCE to succeed it must be more than simply a checking off of which section, mooring, float, drifter or model has been occupied or deployed, or which model has been developed. WOCE needs to create a body of people working on the integration of these types of data to describe the global ocean circulation on a large scale.

Finally, I wish to address the question of the adequacy of the Implementation Plan itself. When the Implementation Plan was developed, the SSG believed that it would have to be reviewed regularly in the light of new ideas, new techniques and new information. It was for this reason that the Core Project Working Groups were established. One fundamental idea behind the WOCE design was that one could merge density, tracer, velocity and sea-surface elevation data collected over a period of up to five years to arrive at an estimate of the three dimensional global circulation field for that period. As WOCE has faced the reality of the available resources (money, ships and people), this five year period has gradually been allowed to expand. Both the Core Project 1 Working Group and the SSG have expressed concern that as data from longer and longer periods of time are merged together, the errors in the estimates of circulation are likely to increase. Unfortunately, having never oversampled an ocean basin in either time or space, we have no available data sets to quantify such an increase in error.

Some of these questions were to have been addressed by Core Project 3 within their recommended well-measured basin concept. The repeat hydrography of the North Atlantic (including the control-volume experiments) and the enhanced density of floats and drifters were to have provided estimates of the temporal variations of the full-depth gyre circulation within periods less than two years. The high-density XBT sections and the repeat hydrography of the North and Tropical Pacific would provide similar but sparser estimates of the wind-driven upper-ocean circulation. Neither of these approaches is fully funded or supported at this time; however, both have substantial resources committed to them.

The question now being asked is, with the available temporal information (altimetry, repeat hydrography, XBTs, floats and drifters), can one hope that four-dimensional data assimilation models can deal with temporal variability over periods up to 5 to 7 years or should one make a special and concentrated effort to complete all of the WOCE work in a given ocean within a much shorter time frame (1 to 2 years)? We do have the Atlantic data set collected over a five year period in the early 1980s (Long Lines, TTO/SAVE) to give us some idea of what can be learned from a hydrographic data set collected over five years. We can compute error estimates from the crossovers of the various sections; however, we have little data to suggest the time scale of the processes which cause these differences. We need to find data modellers as quickly as possible to look at this problem in order to decide whether we need to reschedule and focus WOCE resources on short intense campaigns on individual ocean basins during the later years of WOCE.

SR4/SCM7:
SUMMER WEDDELL GYRE STUDY 1990
<u>POLARSTERN</u> - CRUISE ANT IX/2

Punta Arenas - Cape Town, 17 November - 30 December 1990

The main operation area of the Summer Weddell Gyre Study 1990 was located in the Weddell Sea between the northern tip of the Antarctic Peninsula and Kapp Norvegia. The basic programme along the transect (SR4) consisted of 86 CTD-profiles with additional measurements of vertical profiles of temperature, salinity, oxygen, nutrients and natural as well as anthropogenic tracers. In addition, seven moorings with current meters were recovered and 21 deployed (SCM7). On two moorings, water level recorders were added. Six upward-looking sonars were installed to measure ice thickness.

The measurements aim to determine the circulation and the water mass distribution in the Weddell Gyre and to estimate the related volume, heat and salt transports. This will allow us to determine the contribution of the Weddell Sea to the deep circulation of the world ocean and its effect on climate. In this context the programme focuses on the rate of bottom water formation in the Weddell Sea which controls to a large extent vertical exchange and consequently the ability of the ocean to store heat and gas. Furthermore, knowledge of the physical conditions provides the base for biogeochemical and biological programmes which were carried out during the cruise and are to be viewed in the context of the Joint Global Ocean Flux Study (JGOFS).

The present cruise is part of a four-year programme (1989 to 1993) during which we plan to obtain two winter and two summer occupations of the transect and longer-term measurements with moored instruments to assess seasonal and interannual variability of the Weddell Gyre water masses and circulation.

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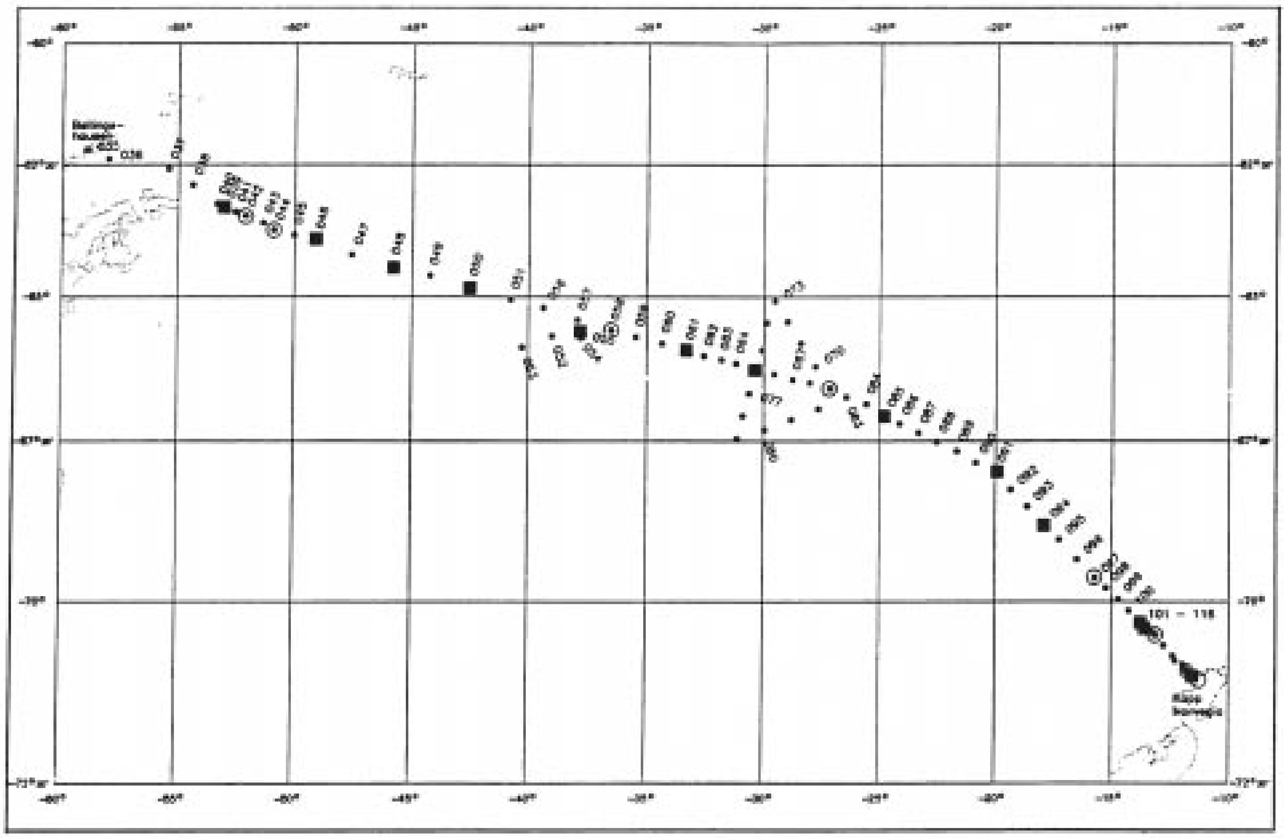

Figure 1. Oceanographic work carried out by <u>Polarstern</u> during ANT IX/2 from 17 November to 30 December 1990. Dots indicate CTD-stations, open circles recovered and redeployed current meter moorings. Newly deployed moorings are shown with squares.

AR7W:
LABRADOR SEA LINE - JULY 1990

The WOCE Labrador Sea line AR7W, Fig. 1, was completed for the first time between 29 June and 11 July 1990 from CSS Dawson. Our initial analyses indicate the temperature of the Denmark Strait Overflow Water (DSOW) has dropped back to the values observed between 1981 and 1985, while the chlorofluorocarbon values throughout the water column appear to be about the same as observed in 1986 except for an increase of 0.5 - 1.0 pmol kg^{-1} at σ_θ = 27.75 - 27.77 kg m^{-3}. Also measurements of carbon tetrachloride (CCl_4) were obtained for the first time in the region.

The DSOW flows along the bottom of the ocean from Denmark Strait, around Greenland and into the Labrador Sea (Fig. 1). It has its greatest influence at σ_2 values between 37.08 and 37.16 kg m^{-3} (27.88 < σ_θ < 27.92 kg m^{-3}; 3300 < p < 3500 db) and at the latter

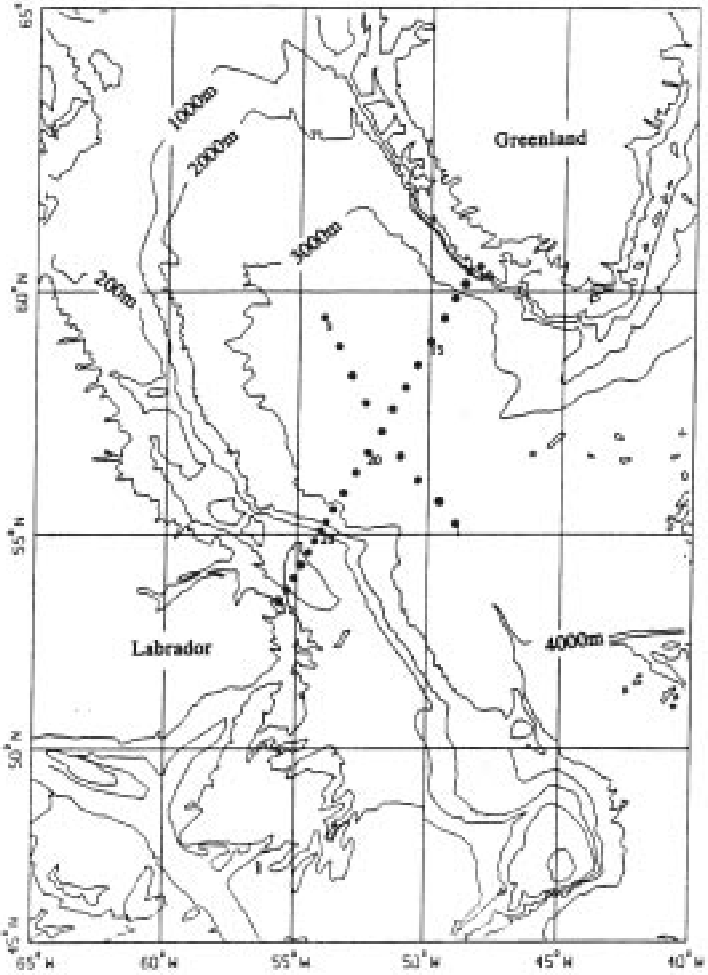

Figure 1. Positions of CTD stations occupied between 29 June and 11 July 1990. Stations 10 to 31 make up the WOCE AR7W line.

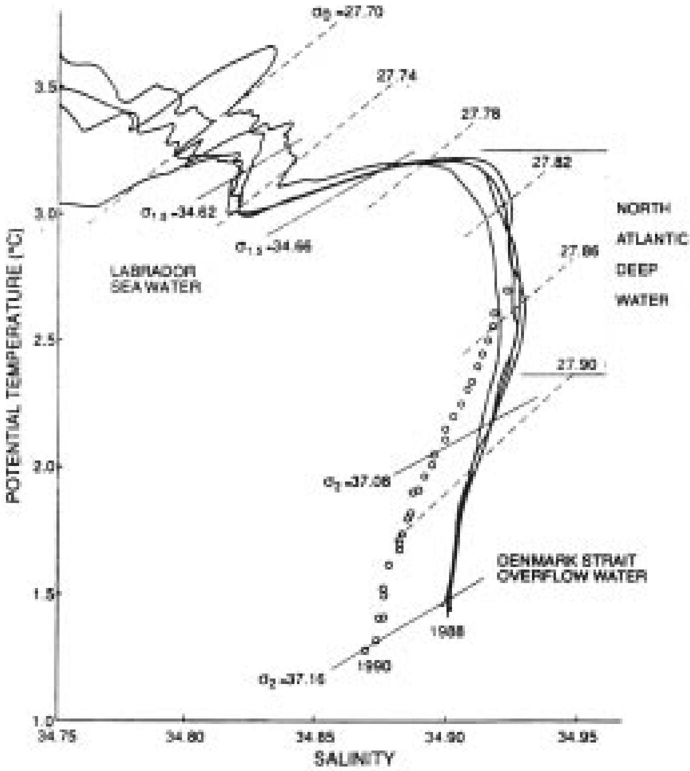

Figure 2. Potential temperature vs salinity curves from four stations obtained in the western Labrador Sea in 1988 (continuous lines) compared to some 1990 near-bottom observations (circles) showing decreases in temperature and salinity on surfaces of constant density.

density the temperature is now back to the 1981-85 value of ≈1.3°C, down 0.15°C from the 1986-89 value (Fig. 3). On the θ - S plane, Fig. 2, DSOW is distinguished from North Atlantic Deep Water (NADW), lying above, by lower temperatures and salinities. The available historical data in the western Labrador Sea indicates that the θ - S properties of these two water masses has changed over the 24 years between 1962 and 1986 but that the changes are much greater in the DSOW (Lazier, 1988). An extension of this analysis for the σ_2 = 37.16 kg m^{-3} surface (Fig. 3) begins in 1962 when the temperature was ≈1.5°C. It rose through the 1960s to between 1.6 and 1.7°C and then declined through the 1970s to its low of 1.32°C in 1981. This temperature remained more or less constant until 1985 when it suddenly rose to ≈1.45°C in 1986 where it remained until this year's drop.

The causes of these fluctuations are most likely to be found in the surface waters north of Denmark Strait where the DSOW originates. Recent contact with the atmosphere in this region is suggested by the high

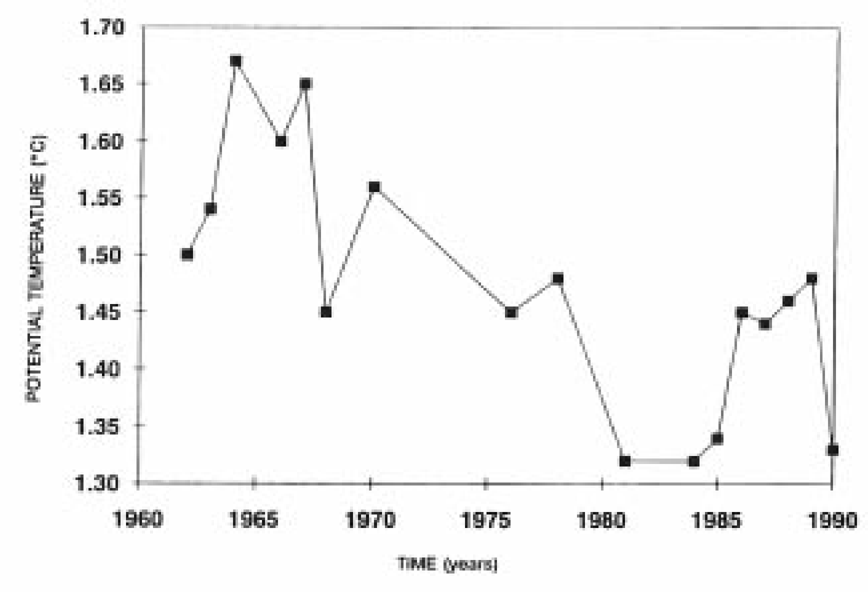

Figure 3. Potential temperature at $\sigma_2 = 37.16$ kg m^{-3} between 1962 and 1990. Data obtained in the western central Labrador Sea by various investigators with the final observation from the present cruise.

oxygen and CFC values ($O_2 > 6.2$ ml l^{-1}, $CCl_3F > 3.0$ pmol kg^{-1}) and by the relatively high speed of the overflow water (0.2 m s^{-1}), which moves water from Denmark Strait to the western Labrador Sea in ≈100 days.

The recent drop in temperature could reflect an increase in the heat loss in the Greenland or Norwegian Seas but because the density of the DSOW remains constant from year to year a decrease in temperature must be accompanied by a decrease in salinity. Salinity loss would result from an increase in the addition of fresh water through more precipitation or ice melt or by changes in the composition of the source waters caused by shifts in the wind patterns. If such connections can be established, variations in the properties of the DSOW at the bottom of the Labrador Sea may prove to be an easily measured indicator of the variations in the meteorological conditions over the Greenland and Norwegian Seas.

The Labrador Sea Water (LSW), one of the major intermediate water masses of the North Atlantic Ocean, is found between $\sigma_{1.5}$ values of 34.62 and 34.68 kg m^{-3} ($27.72 < \sigma_\theta < 27.76$ kg m^{-3}; $200 < p < 2000$ db). It is renewed in this region in winter through convectively driven vertical mixing and consequently exhibits relatively homogeneous temperature/salinity properties in the area, Fig. 2. The severity of the winter determines the depth limit of the convection (200 - 2000 m) and thus the ventilation of the various density surfaces. Monitoring the depth of this ventilation by measurement of the properties of the water mass is the principal aim of the programme. We hope that causes of any significant property changes can be identified and that sensible estimates of changes in the water mass at points downstream of the Labrador Sea can be made.

Halocarbons (*e.g.* chlorofluorocarbons and carbon tetrachloride) are among the best conservative water mass tracers and were first measured in the region in 1986 (Wallace and Lazier, 1988). All the CFC-11 values obtained in 1986 and 1990 are plotted against σ_θ in Fig. 4. The LSW lying between values of 27.70 and 27.77 kg m^{-3} is distinguished by high CFC-11 values in both years. The 1990 values appear to be higher especially in the 27.75 - 27.77 kg m^{-3} range which may be an indication of deep convection during the intervening winters. The minimum in CFC-11 values centred at 27.85 kg m^{-3} is associated with the NADW while the higher values near the bottom are in the DSOW. Throughout these two deeper water masses there is no indication of significant changes in CFC-11 concentrations over the four years between the cruises. This constancy contrasts with the large θ - S changes in the DSOW shown in Fig. 2 and suggests that the changes in salinity and temperature in the formation region do not affect the rate of air-sea exchange of CFC-11. Continued examination of these data plus careful planning of our sampling strategies on future cruises will help to determine long term changes on the various density surfaces.

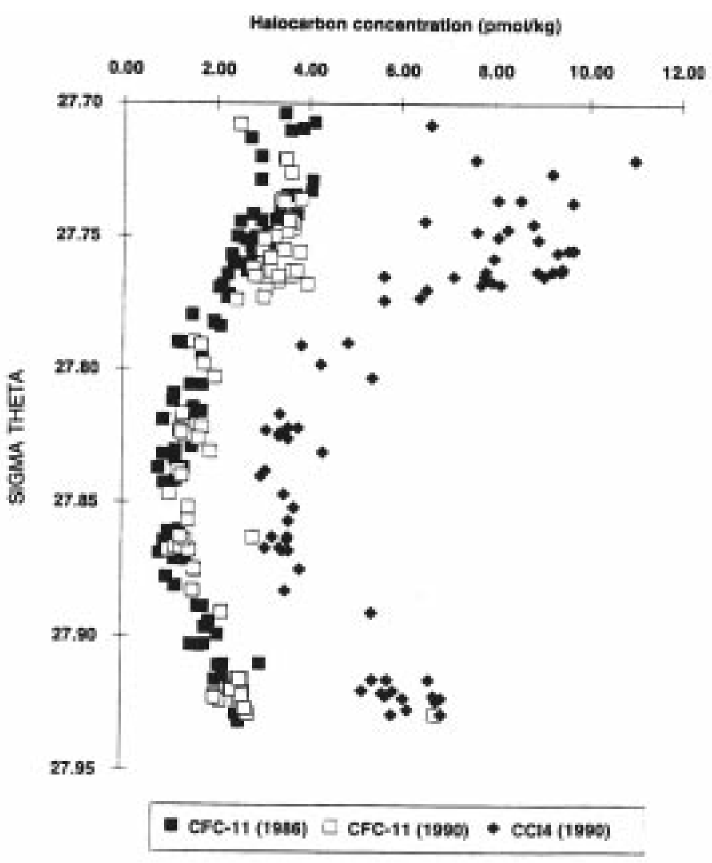

Figure 4. Observations of CFC-11 in 1986 and 1990 and CCl_4 in 1990 plotted against σ_θ.

The profile of CCl_4, Fig. 4, shows the same features as the CFC-11 profile, presumably for the same reasons, *i.e.* high values in the waters recently renewed at the surface (LSW and DSOW) and low values in the older waters (NADW). Information on the length of time the water has been submerged and isolated from the atmosphere's influence should be contained in the ratios CCl_4/CFC-11 and CFC-12/CFC-11. This is because the ratio of the atmospheric concentrations of these two have changed over the past four decades and the ratios in the water should reflect those of the atmosphere when the water sank away from the surface. Our profile of the ratio (not shown), however, shows almost constant values from top to bottom suggesting the ages of all the water masses are similar. Further analysis of the halocarbon data is needed as well as the collection of additional time-series data, including CFC-12 profiles, from the area.

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AR4: R/V METEOR CRUISE 14, LEG 2 MINDELO - RECIFE: 1 - 27 OCTOBER 1990

Leg 2 of Meteor cruise 14 focussed 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 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 800 m, and North Atlantic Deep Water (NADW) moving southward between 1200 and 4000 m. The details of this water mass exchange across the equator are not well understood, and were the main subject of this cruise.

Meteor left Mindelo (Cape Verde Islands) on 1 October 1990 at 18:00 local time, heading towards the North Brazilian coast. During this transit the instruments were set up and prepared. On 4 October a first CTD test-station was done. The same day the XBT-programme started (Fig. 1). The CTD-measurement programme began on 6 October at 7°30'N, 42°25'W (Fig. 2). From this location a hydrographic section with CTDs, XBTs and Pegasus-drops along 44°W was done until 8 October, when the 200-mile zone of Brazil was reached. One mooring (K329) just outside the 200-mile zone was recovered. From here the ship sailed to the Brazilian coast near Salinopolis, where the official Brazilian observer, who was not able to reach the ship on the Cape Verde Island in time, joined the cruise.

From Salinopolis the ship sailed to 0°05'N, 44°23'W to continue the measurements along 44°W. Two more moorings along this section (K327, K328) were recovered and three new moorings (K339-K341) were deployed. The work along 44°W was finished on 13 October at about 2°N. From here the ship sailed to 35°W, 2°30'N with XBT-drops as the only measurements.

A second hydrographic section with CTD, Pegasus and XBT-measurements was done along 35°W from 2°30'N to 5°S with deployment of seven surface drifters between 1°25'S

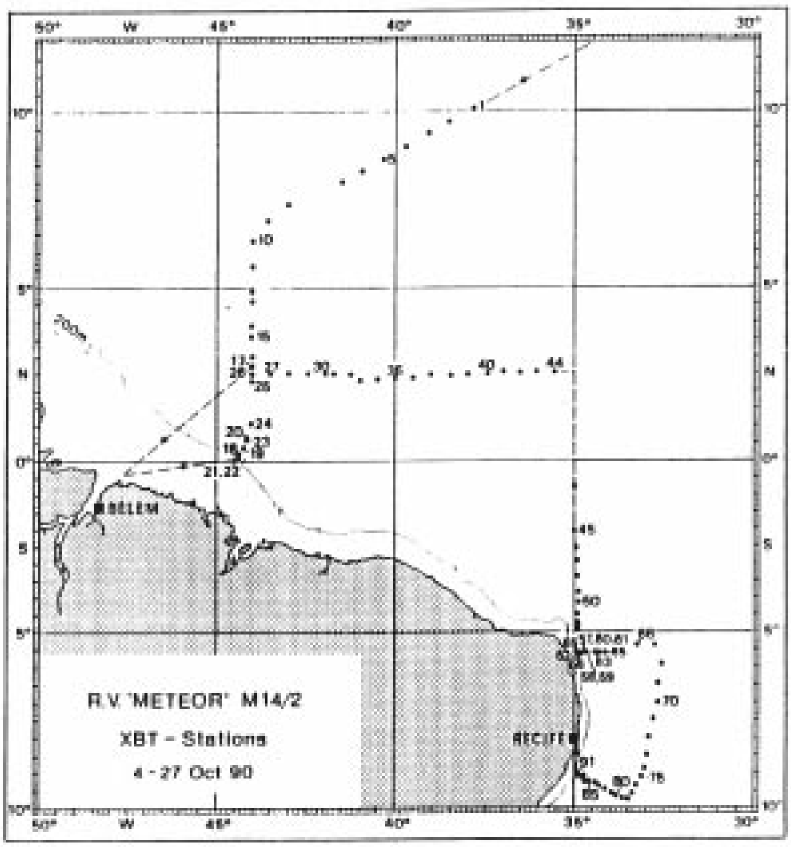

Figure 1. Locations of XBT stations on Meteor Cruise 14, leg 2.

and 4°S. This section was completed on 22 October. Another short hydrographic section was done along 5°30’S from the Brazilian shelf to 32°30’W, reaching the endpoint of the section on 25 October. The ship then sailed southward to 9°43’S, 33°40’W and then west to 9°05’S, 34°53’W. During this time only XBTs were dropped and 13 drifting buoys were put into the water. The location at 9°05’S was reached in the evening of 27 October and was the last station on which measurements were carried out. From here the ship sailed to Recife, where the cruise terminated on 27 October 1990 at 6:30 local time.

Processing of the data is in progress at the Institut für Meereskunde, Kiel. The data will be available by the end of September 1991 at the latest.

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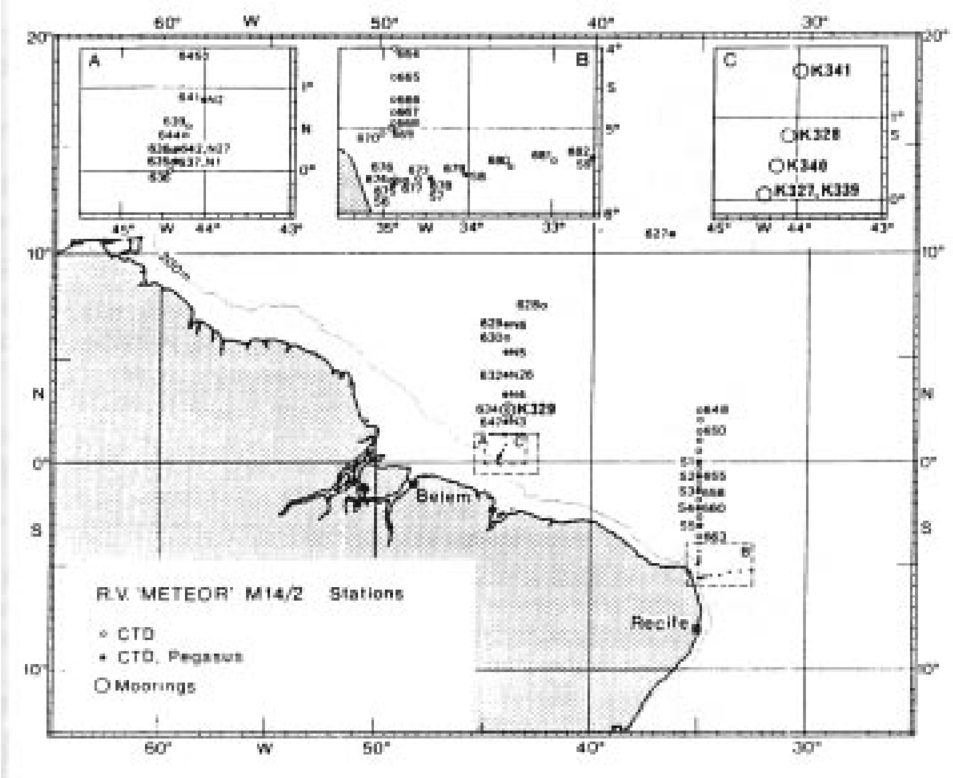

Figure 2. Locations of CTD stations, Pegasus current velocity profile stations and moorings recovered and deployed on Meteor Cruise 14, leg 2.

IR4: PRELIMINARY CRUISE REPORT R/V SONNE SO73

Figure 1. Cruise track Sonne cruise SO73 Goa - 6°S - Colombo.

Sonne cruise SO73 was carried out jointly by IfM Kiel (F. Schott) and IfM Hamburg (D. Quadfasel). The cruise departed Goa on 23 December 1990, began station work south of Sri Lanka along 80°30’E on 26 December, worked south to 6°S and back northward along that section. Station work was terminated south of Sri Lanka on 10 January 1991 and the cruise ended in Colombo on 11 January (Fig. 1). Two observers from the Sri Lanka National Aquatic Resources Agency (NARA) participated in the cruise.

Three moorings were deployed north of 4°15’N and a total of 41 CTD stations and 20 Pegasus profiles at 11 stations were taken (Fig. 2).

CTD station separation was generally 30 nm and was smaller near the northern border and near the equator. CTD stations were to the bottom at full degrees latitude, at all Pegasus stations and near the northern boundary. Oxygens were analyzed from 24 bottle samples at each station. Freons were measured by M. Rhein (IfM Kiel) on a subset of the stations.

The three moorings, focussing on the Monsoon Current regime, are part of WOCE array ICM8. Two of them (K1, K3) carry upward-looking ADCPs at 250 m depth to measure the near-surface currents. A total of 14

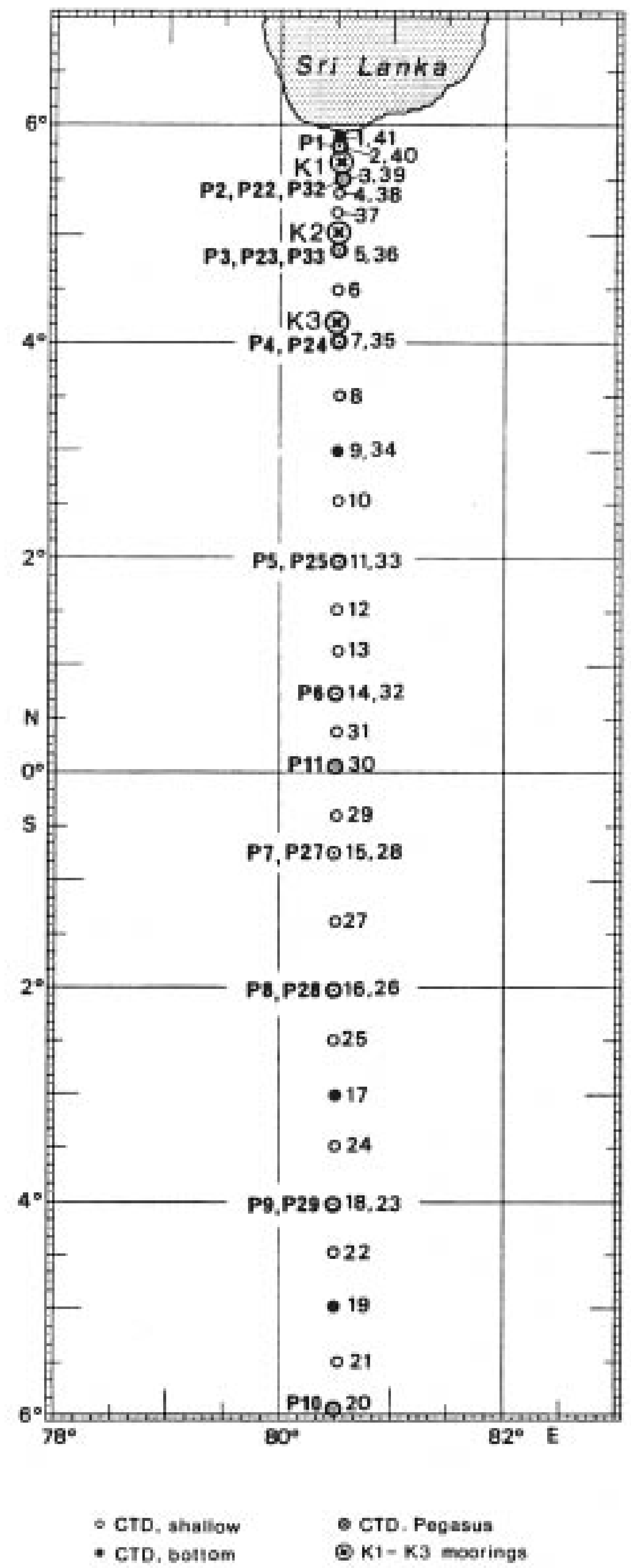

Figure 2. Station map showing positions of moorings K1 - K3 (K1 and K3 with upward-looking ADCP), CTD stations (full depth and shallow) and of Pegasus stations P1 - P11 (profile repetitions on the return leg are indicated by additions of 20 and 30, respectively, to station number).

Aanderaa current meters were deployed, most of them above the 1000 m level; some were equipped with conductivity sensors.

Underway Doppler current measurements were carried out with shipboard ADCP down to about 180 m, and at some CTD stations current profiles down to 1500 m were obtained by attaching a self-contained ADCP to the rosette.

The Monsoon Current was found to be confined to the area north of about 4°N, carrying low-salinity Bay of Bengal water westward with near-surface velocities exceeding 1 m s^{-1}. South of that regime, currents were quite variable but with a persistent westward undercurrent in the depth range 50-150 m in the equatorial band.

Since R/V Sonne is not returning to the Indian Ocean in time for mooring retrieval we are looking for a vessel in the timeframe December 1991 - April 1992. One possibility explored at present is a charter of a Sri Lanka fishing vessel; another one is the Indian R/V Sagar Kanya passing by there in late 1991. We are also trying to arrange Pegasus measurements on a smaller vessel out of Sri Lanka. Any other suggestions we could pursue would be welcome.

Funding requests to extend array ICM8 southward and to repeat the section work will be submitted shortly to the German WOCE programme.

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A9 AND DBE: JOINT GERMAN/US WORK ABOARD FS METEOR

Following an earlier pilot phase involving a year-long current meter deployment in the Brazil Current off Rio de Janeiro, more intensive investigations from Meteor started in late December 1990. The programme is internationally co-ordinated in the framework of the World Ocean Circulation Experiment in the subtropical South Atlantic. The physical and chemical work of Meteor cruise No. 15 had two aims. The first was to determine the transports in the Brazil Current and the deep western boundary currents, including the inflow from the Argentine to the Brazil Basin. These measurements also form a part of the Deep Basin Experiment (DBE), a component of WOCE Core Project 3. The second aim was to obtain a high resolution (30 nm) hydrographic section at 19°S. These observations were a part of the WOCE Hydrographic Programme (WHP), a Core Project 1 activity.

The long trans-Atlantic section (A9) was completed when the ship reached the Republic of Congo on 24 March 1991 and the first two legs were successfully terminated in Vitoria, Brazil on 8 February. Gerold Siedler is co-ordinator of the whole expedition and was the Chief Scientist of Leg 3. Legs 1 and 2 were led by Walter Zenk.

The departure of the Meteor from Rio de Janeiro on 30 December 1990 also marked the start of the Deep Basin Experiment. From the DBE perspective, principal objectives of cruise Legs 1 and 2 included:

- The deployment of a joint German-US moored array between the continental slope and the Rio Grande Rise.
- A bathymetric survey of both the Vema and the Hunter Channels.
- The taking of a detailed hydrographic section along the line from the slope to the Hunter Channel with denser spacings in both channel areas.

The cruise tracks for the two legs are shown in Figure 1.

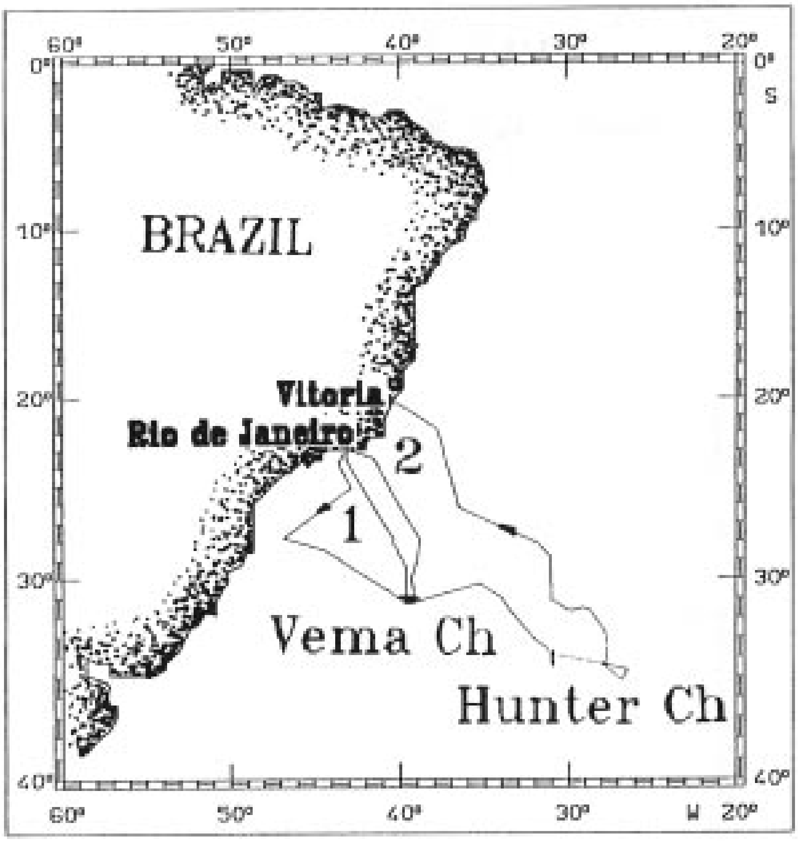

Figure 1. Track of Meteor cruise No. 15, legs 1 and 2. After crossing the shelf the ship headed towards the quasi-zonal CTD section shown in Figure 2. The western part of this section includes 13 current meter moorings between the shelf break and the Vema Channel. After an intermediate stop in Rio the ship returned to the Vema Channel to continue its work across the Rio Grande Rise towards the Hunter Channel. More work was done by geologists on the eastern flank of the Ridge before calling at Vitoria, Brazil.

The moored array, superimposed on a potential temperature section in Figure 2, contains 13 moorings with nearly 60 instruments and has several objectives. Three German moorings, at the western end, are focussed on the Brazil current and include upward looking ADCPs. The next 5 moorings, moving eastward, are US moorings designed to measure the exchange across the Santos Plateau from the Argentine Basil to the Brazil Basin and contain a concentration of current meters in the bottom and deep water masses. The next three span the Vema Channel and the last two the eastern flank of the channel and the western slope of the Rio Grande Rise. We benefitted in the deployment of the moorings from the availability of "Hydrosweep", a German version of the older Seabeam depth sounding system which produces a swath of bottom contours of width equal to twice the local bottom depth. This was most revealing in the Vema Channel (Figure 5) where we were able to fine tune the deployments to cross the sill near 30°12'S, 39°24'W.

It is usual practice to bring spares of most mooring equipment. Because the planned deployments went so well we were able to use the spare gear to set a 13th mooring at the eastern end of the planned array. This completed the section to the flanks of the Rio Grande

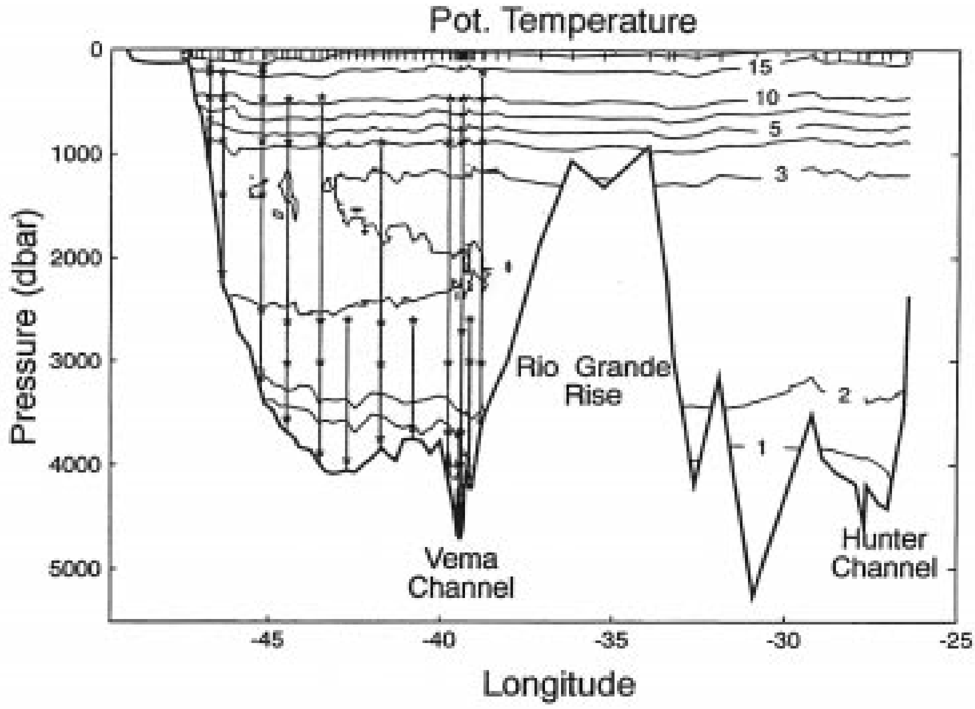

Figure 2. Section of potential temperature with selected isotherms (in °C) connecting the Brazilian shelf at 27°40'S with the Hunter Channel area. CTD stations are indicated by ticks at the surface line. Note the close separation in the Vema Channel (order 4 km). The bottom topography of the section is reproduced only roughly by the maximum pressure values of the CTD whose greatest pressure was determined by a bottom switch device and a pinger. Note the warm deep water in the western part at about 2000 dbar. Sloping near-bottom isotherms indicate northward bottom water flow in the western boundary region off the continental slope and in the deep channels. Superimposed are locations of moored current meters indicated by asterisks. Due to the projection only 12 out of 13 moorings could be displayed in the series.

Rise where previous hydrographic surveys suggest a boundary current carrying deep water out of the Brazil Basin. The combined array has comparable horizontal resolution to the original Meteor section that was completed across nearly the same track line in 1925. A total of 59 current meters (including 2 ADCPs) were deployed on 13 moorings.

It is presently planned to recover the moored array in early 1993, again aboard the Meteor. Many of the taller moorings contain ARGOS transmitters which will give warning and position information should the mooring fail and come to the surface prematurely.

Moorings were set at the beginning of each day and were usually completed by noon. The remainder of the 24 hour period was occupied with carrying out a very highly resolved CTD section and with a subsidiary biological sampling programme. Horizontal resolution was especially high in the Vema Channel where station spacing was of order of the local water depth (4 km). Water samples were taken for instrument calibration of salinity and oxygen.

On returning to Rio on 16 January the US group left Meteor and their bunks were taken by geologists from Bremen University. Two days later the ship sailed back south east and the Kiel group finished the "Hydrosweep" work in the Vema Channel with two final track lines. The hydrographic survey was continued across the eastern part of the Rio Grande Rise towards the Hunter Channel or, more accurately, towards what is labelled as Hunter Channel/Gap on bathymetric charts. With a less dense sequence of CTD stations we approached the Hunter area. The region appears to be much more complex than what we had experienced before in the Vema Channel. We surveyed a deep zonal fracture segmented by at least two meridional gaps. Unfortunately

Figure 3. An Aanderaa current meter from the Institut für Meereskunde is attached to the mooring line. Above the instrument three glass balls from the Woods Hole Oceanographic Institution provide the necessary buoyancy.

weather conditions allowed only limited “Hydrosweep” surveys. Nevertheless, our new hydrographic data from the area document a significant northward flow of bottom water, which could be traced along the eastern flank of the Rio Grande Rise.

When we ran out of time and had to leave the region all of us, hydrographers and geologists, were convinced that we had investigated only a minor fraction of the Hunter area and we definitely have the desire to return. We would like to know if and where there are further outlets for bottom water flow and where they might have existed in previous geological time periods.

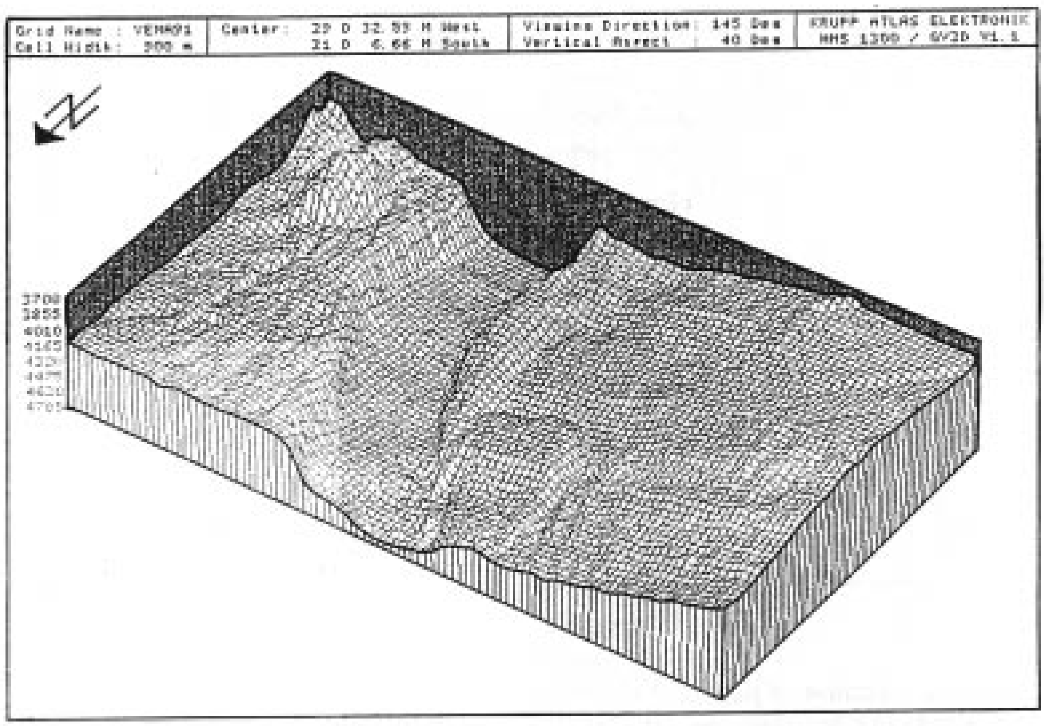

Figure 5. A three-dimensional view of the centre part of the Vema Channel seen from the Brazil Basin. The horizontal cell width is about 0.9 km. The diagram is centred at 31°07’S, 39°33’W. Data were obtained by the computer supported echo sounding system “Hydrosweep” of the Meteor. Postprocessing was done during the cruise on board the ship.

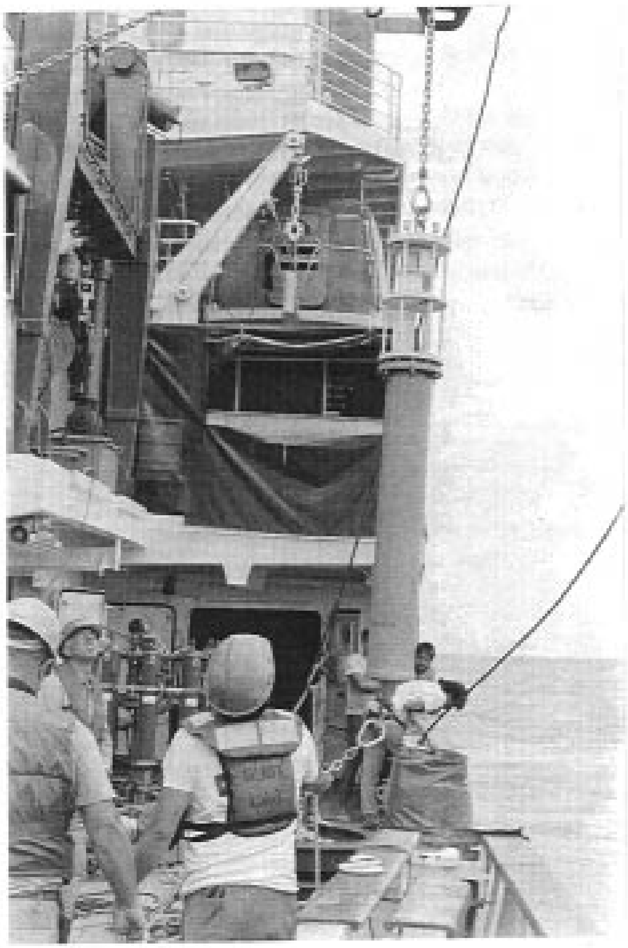

Figure 4. A vector averaging current meter (VACM) is launched over the side.

On the return leg Meteor took (as before) the opportunity for another cross section through the Brazil Current. These CTD observations were finished only hours before Meteor entered the harbour of Vitoria.

This work has been made possible by funding from the Deutsche Forschungsgemeinschaft and the Bundesministerium für Forschung und Technologie, both in Bonn, and the National Science Foundation of the US. The success of the voyage was immensely aided by the friendly and professional assistance of Kapitän Bruns, his officers and crew, and the technical support groups from IfM-Kiel and WHOI. The generous hospitality of the University of Rio de Janeiro in providing space and assistance for the Woods Hole group for instrument preparation prior to the departure of the Meteor also is gratefully acknowledged.

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PCM9 DEEP WESTERN BOUNDARY CURRENT ARRAY DEPLOYED

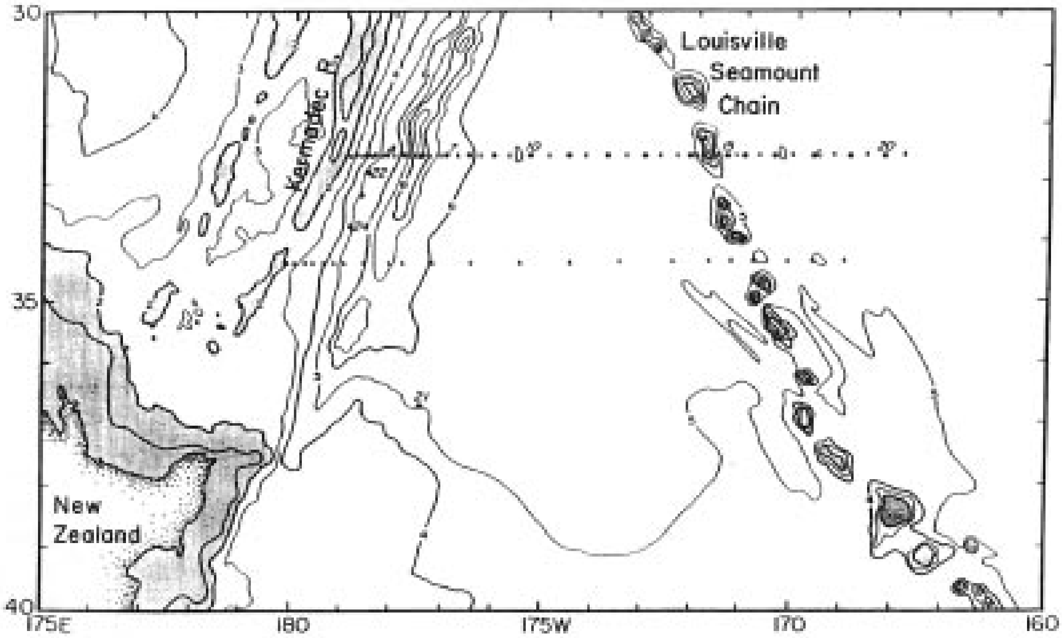

Figure 1. Locations of PCM9 moorings (•) and hydrographic stations (×) during cruise MAPKIWI-I aboard R/V Rapuhia *in February-March 1991.*

The R/V Rapuhia, operated by the New Zealand Oceanographic Institute, departed Lyttleton, New Zealand, on 1 February 1991 to conduct the initial field phase of a two-year study of the Deep Western Boundary Current in the South Pacific. Thirty-six days at sea were required to deploy the PCM9 array and to survey the regional hydrography on a second leg of the cruise (Figure 1).

This study, dubbed MAPKIWI for reasons too complicated to explain, is a joint US-New Zealand effort co-directed by Worth Nowlin and Tom Whitworth (Texas A&M), Dale Pillsbury (Oregon State), Bruce Warren (WHOI), and Mike Moore (NZOI).

The PCM9 array consists of 59 current meters (with temperature and pressure sensors) on 20 moorings (Figure 2). The array extends from the flank of the Kermadec Ridge at the western boundary of the South Pacific some 1000 km east along 32.5°S. The moorings are closely-spaced east of the Kermadec Ridge and east of the Louisville Seamount Chain (172°W), both areas where previous tracer studies suggest an intensified northward flow of waters of Antarctic origin. Four additional moorings were deployed south of PCM9 along the 5000 m isobath (Figure 1) to sample the along-isobath variability upstream of the main line of moorings.

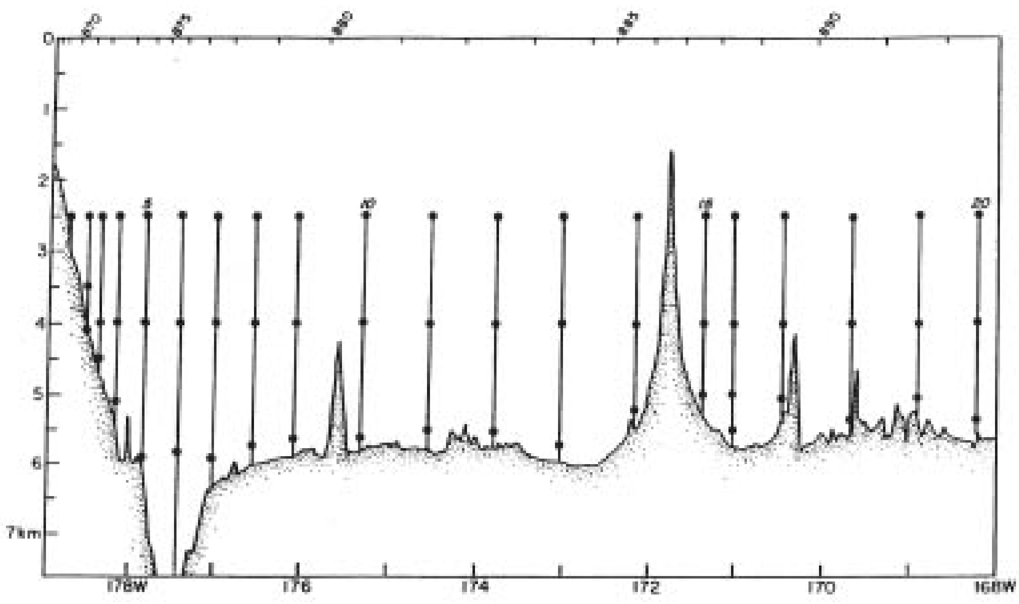

Figure 2. Configurations of recording instruments in vertical section along main mooring line (32.5°S). Mooring 6 is anchored at a depth greater than 9000 m. The Louisville Seamount Chain is evident between 171° and 172°W.

The hydrographic survey (crosses in Figure 1) consisted of CTD profiles supplemented with rosette samples for analysis of salinity, dissolved oxygen, and nutrients. Measurements were made along PCM9 and on a parallel section farther south. A short section was also made across the sill between the Southwest Pacific and South Fiji Basins near 35°S, 178°E.

The array is scheduled for recovery in early 1993.

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AKADEMIK VERNADSKY CRUISE 43, LEG 1: WOCE COMPARISON/TRAINING

A comparison/training exercise was carried out under the banner of the WOCE Hydrographic Programme aboard the research vessel Akademik Vernadsky from 27 June to 8 July 1991. The goals of the exercise were fourfold: shorebased lectures and practicum on high precision measurements of salinity, and at sea comparisons of salinity, oxygen and CTDs. The cruise was supported by a donation of shiptime by the Marine Hydrophysics Institute in Sevastopol, support for the US water sampling equipment and personnel came from the National Science Foundation in the US, partial support for the shorebased salinity course was provided by the Secretariat of the IOC, and partial support for port fees in Funchal, Madeira came from the Director of the Woods Hole Oceanographic Institution. Travel and expenses for the UK and Spanish participants were provided by their host countries.

F. Culkin and P. Ridout of Ocean Scientific International (OSI), producer and distributor of IAPSO Standard Seawater presented a one day lecture and practicum on 27 June on standard seawater and the operation of Guildline Autosals, the generally-regarded standard for high precision salinometers. The lecture was attended by all of the scientific personnel taking part in the comparison/training cruise. A smaller group of about seven joined Ridout and Culkin in the practicum which included hands-on training in the salinity calculation algorithms and use and maintenance of the Guildline Autosal. OSI provided ampoules of standard seawater with salinities of 10, 30, 38, in addition to the normal 35 reference salinity. The MHI group provided a number of ampoules of Soviet standard seawater with a salinity of 35, in use as a secondary standard throughout the USSR. In addition, several ampoules of Soviet standard seawater were provided as check samples with salinities of 10, 20, 30 and 40. The ship departed Funchal in the early evening of 27 June following the shorebased activity and steamed to the west for the first comparison station on the evening of 28 June.

In all, 35 ampoules of Soviet standard seawater (with a salinity near 35) from three different production runs were analysed on the Autosal during the cruise. This was one of the most extensive comparisons of the two standard seawaters in recent years. The IAPSO standard waters were used by the US/UK groups and the MHI group to evaluate the linearity of the calibration of two different shipboard salinometers over a wide range of known salinities. Finally, the IAPSO standard water was employed on both salinometers (Autosal and SOKOL) by the US/UK groups and the MHI group to compare salinities from water samples drawn from the Rosette system during the oxygen comparison.

A Mark IIIb Neil Brown CTD was modified to include a second platinum temperature sensor, dissolved oxygen sensor with aspirating pump, and a 12 place, 10 litre General Oceanics Rosette. Water from the sampling bottles was used for extensive comparisons of oxygen and salinity sampling in the waters to the west of Madeira. A total of eight stations were occupied during the comparison: all except the first station were dual casts. We typically occupied one station per day with periods in between taken up by other ship programmes, usually done while underway. The last station was done on 7 July after which the vessel returned to Funchal to debark the non-Soviet scientific party.

In all, five groups participated in the oxygen comparison: US (WHOI), UK (IOSDL), Spain (IEO, Tenerife), and the USSR (MHI and the State Oceanographic Institute, GOIN). Each station usually consisted of two casts: one deep cast to 3000 m (limited by available cable and large wire angles), and a shallow cast to 1000 m. All groups sampled the Rosette in such a way that each collected one water sample from every bottle with replicate samples from four bottles on each cast. The replicates were used to provide an estimate of experimental precision while the inter-lab comparisons were used to indicate the systematic errors. On one of the eight stations, another replicate experiment was conducted in which each group repeatedly sampled the same bottle six times. In general, these replicate errors were slightly less than those from normal replicates. Finally, one cast was devoted to a sparging experiment. In this, the sample bottles were all tripped at the surface and brought on deck where nitrogen gas was bubbled through each of the bottles for different lengths of time. In this experiment, very low oxygen concentrations were obtained, thus enabling a comparison of different measurement systems over a sampling range of 0.5-6.5 ml/l, nearly twice that possible with natural seawater in the region of the North Atlantic to the west of Madeira.

Because of the electrical cross-talk in the conducting cable, both the WHOI and the MHI (ISTOK-7) CTDs could not be lowered simultaneously from a single winch. The data will be compared from separate casts from different winches made throughout the cruise and from a simultaneous cast to 500 m on different winches during the last day of work at sea. The ISTOK-7 is the principal CTD to be used on the Subduction cruise of the Vernadsky on the leg immediately following the comparison/training cruise.

Two reports will be written on the results of the cruise: one dealing with salinity/oxygen comparison and one on CTDs. The former will be drafted by the US/UK groups using data already available from the shipboard water sampling and standard water work. The latter will be drafted by the Soviet group using final CTD data from the US and Soviet groups.

In addition to the above financial support, we would like to gratefully acknowledge the assistance of Captain Malinovsky, Chief Scientist Panteleyev, as well as the scientists and crew aboard the Vernadsky for all of their help and encouragement during the cruise.

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OCEANOGRAPHIC DATA ARCHAEOLOGY WORKSHOP

Data archaeology, defined as the recovery and scientific use of "buried" datasets, is potentially of considerable value to research into climate change.

An international workshop on the subject was hosted by the U.S. National Oceanographic Data Center (NODC) in September 1990 and funded by the NOAA Climate and Global Change Program. It included scientists and data managers from seven countries (USSR, Japan, Korea, Chile, Australia, Denmark, and the USA) who had an understanding of the needs of the research community and a broad knowledge of the availability of historical data and possible methods for finding and acquiring that data. The participants collectively provided coverage of most regions of the globe.

Climate and global change research depends on the availability of global oceanographic data covering long time periods. Programs such as WOCE will provide critically needed global data, but researchers dealing with long-term changes in the ocean will have to wait many years (even decades) for long enough data sets to accumulate. Our only recourse, therefore, is to take full advantage of data that have been collected over the past decades. Unfortunately, perhaps half of all historical global ocean data may not presently reside in any of the maintained data archives around the world and thus are not available to climate and global change researchers. Many of these data are at risk of being lost forever.

Our main workshop objective was to obtain enough information from the participants to design an integrated data archaeology approach for the efficient and extensive acquisition of historical global oceanographic data for use by the climate and global change research community. A secondary one was to gain an initial sense of priorities - specifically determine the areas where data are most needed, and decide which aspects of data archaeology are most important to pursue.

An integrated approach to oceanographic data archaeology will include activities such as:

- setting priorities based on geographic and temporal needs of the research community, and the need to "rescue" data at risk;
- summarizing existing archived digital data sets in the world's data centres and data gathering institutions;
- summarizing known manuscript and analog data that should be digitized;
- discovering the existence of historical data;
- convincing institutions to provide the newly discovered historical data (preferably in digitized form) and the necessary documentation;
- digitization (optical or manual) of manuscript and analog data;
- performing quality control activities;
- making the data accessible to the scientists who need it; and
- increasing communication among international scientists and data managers about oceanographic data sets and data archaeology efforts.

Participants gave examples of interesting and useful datasets not in computer compatible form.

S. Levitus (NODC) mentioned that there are approximately 158,000 mechanical bathythermograph (MBT) profiles at the Scripps Institution of Oceanography, dating back as far as 1942. WDC-A for Oceanography (collocated at NODC) has a large collection of valuable historical data in manuscript form.

While preparing for the workshop Harry Dooley (Hydrographer of ICES) discovered 200,000 cards of hydrographic data in the cellar of ICES. These cards were all originally thought to be included in the ICES computer database, but that database included only data from the Bulletin Hydrographique (which ICES published from 1902 to 1956) and these cards were found to contain considerably more data, including data from the Rapport Atlantique, which the ICES Atlantic Slope Committee published from 1921 to 1935. At least 5000 of these cards contained deep-water data from the eastern North Atlantic, an area where historical data have been scarce. Additionally, in the basement of Charlottenlund Castle (the former ICES headquarters), another 20,000 cards of geographically sorted Danish data turned up that were also not in the computer database. Some of these cards contained data from the 1896 Ingulf Expedition in the Norwegian Sea.

We agreed that initially the archaeology effort should concentrate on hydrographic profile data, including nutrient data.

As a start, the U.S. NODC and WDC-A will begin producing data distribution maps of its hydrographic data holdings on a country-by-country basis for decadal, pentadal, or interannual time periods (to assure that individual cruise tracklines will be visible). Appropriate maps will be sent to data centres and data gathering institutions in every country. From these maps, those institutions will be able to tell whether all their data are in the U.S. NODC/WDC-A archive (and what data may be in that archive that they don't have). WDC-A will also help other countries produce data distribution maps of their holdings, if such help is required.

We will compile an inventory of manuscript and analog data sets that the workshop participants are aware of now. With this information priorities for expending resources to digitize data can be decided on. By distributing this list to various data centres it can also be determined if any of these data may have already been digitized. This inventory will be continually updated as new historical data sets are discovered.

We felt that an Ocean Data Archaeology Newsletter would not only help to make the scientific and data management communities aware of data archaeology efforts and but more importantly would provide the kinds of information that would stimulate the discovery of unarchived historical data sets, such as: data distribution maps, lists of known manuscript and analog data, updates on newly discovered data, rumours and leads that need substantiation, articles about research and archaeology projects at various institutions, and even interesting historical articles dealing with cruises and data. In addition, a telemail bulletin board (or mailbox) would allow for rapid communication on archaeology issues and potential data sets.

These techniques will play an important role in discovering and acquiring historical data sets. Others proposed included: visiting scientist programs and joint research projects using historical data, monetary and ADP support of "regional archaeology centres" and institutions with historical data in need of digitization and quality control; use of an automated ROSCOP/cruise report system to point to data collected but never archived; bibliographic searches of published and grey literature to discover additional historical data sets; use of the WDC-A Catalogue of Data and Catalogue of Accessioned Publications; compilation of an inventory of researchers and data managers working with particular data types; the development of a PC program for quality-controlled data entry and format conversion to aid manual digitization efforts at some institutions; and the compilation of instrumentation and quality control methods used over the years for particular data types.

For a copy of the Workshop Report send a request via telemail to NODC.WDCA, or call 1-202-673-5571.

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COLLABORATION BETWEEN WOCE AND JGOFS ON THE BIO-OPTICAL PROPERTIES OF THE OCEAN

Introduction

Large-scale ocean surveys such as Geosecs, Transient Tracers in the Ocean, and the International Indian Ocean Expedition, and compilations of data into atlases (*e.g.*, Wyrtki, 1971; Levitus, 1982) have contributed significantly to the development of physical and chemical oceanography. Without these influential contributions, our understanding of ocean processes would be at a primitive state. No comparable surveys exist of biological parameters or optical properties. It could be argued that ocean satellite imagery will suffice for global coverage of these quantities; however, sea-truth is required for interpretation of the satellite signals. As stated by Gordon and Morel (1983, p. 14), the interpretation of satellite signals rests entirely on the "...data bank generated by ship-bound oceanographers." Improvements in algorithms for the estimation of chlorophyll from satellite data does not depend on a satellite aloft.

Delineation of the optical properties in the global ocean is important for another reason. Recent advances in bio-optics allow daily primary production to be estimated from optical properties (Bidigare *et al.*, 1987; Marra *et al.*, 1990). Thus, in addition to observing the distribution of bio-optical properties of the ocean, an important component of the global carbon cycle can be estimated as well.

One objective of JGOFS is to participate in large-scale surveys of ocean processes and properties important to the global carbon cycle. For the immediate future, the best means to accomplish this is in league with WOCE in the WOCE Hydrographic Programme (WHP). A problem in interpreting any data from the upper ocean is its seasonality and spatial variability. Biological and optical properties are changeable, and akin to dissolved CO_2 (dCO_2) measurments which already have been implemented on WHP transects. The U.S. National Oceanographic Data Center (NODC) is in the process of preparing a global data base for pigments and primary production. The measurements made on WOCE ships will add significantly to this data base.

Optics Data for the World Ocean

Jerlov, in 1951, was the first to compile optical data for the world ocean (Jerlov, 1976). He used his own data from the North Sea, North Atlantic and Mediterranean (and later with Chinese and Japanese data from the certain areas of the Pacific) to arrive at an optical classification of ocean waters. This was a semi-quantitative way to classify waters according to their color and attenuation, and has endured and proved useful over the years to many investigators (for example, see Simonot and Le Treut, 1986).

The other data set on optical properties in the ocean is based on the Secchi disk depth, and these have been recently compiled by the U.S. NODC (Lewis *et al.*, 1988). The Secchi depth has proved useful, but has shortcomings. As discussed by Preisendorfer (1986), interpretation of Secchi disk data requires corrections for the physiological state of the observer and corrections between observers. Furthermore, the Secchi depth is inversely proportional to a compound optical property, the sum of beam attenuation (an inherent optical property) and the diffuse attenuation coefficient (an apparent property). It is not necessarily true that these will co-vary, and the only way to learn about the behavior of either is to use an irradiance meter of some kind. As pointed out by Preisendorfer (1986), the use of an irradiance meter then obviates the need for the Secchi disk depth measurement.

There are other data sources for optical properties (Austin and Petzold, 1984; Morel, 1988); however, the database is still unacceptably small.

Large-Scale Surveys of Phytoplankton Pigments

One conclusion we can make regarding the above mentioned data is that, in the open ocean, optical properties are closely tied to the pigment and biogenic particles suspended in the water. Relationships between spectral irradiance and pigment, though inexact, have proved useful for remote sensing of chlorophyll (Gordon and Morel, 1983). Several relationshiops need to be understood: (1) the relationship between chlorophyll-a and optical properties in the water column is needed to improve algorithms for the interpretation of satellite color images; (2) the vertical distribution of chlorophyll-a in the water column is needed in order to evaluate what the satellite senses; and (3) the effect of distribution of plant pigment and particles on the variation in optical properties and their relationship with primary production must be determined (Morel, 1988).

Global Ocean Primary Production

Better understanding of phytoplankton physiology and better data for submarine irradiance and photosynthetic rates have led to improved models of primary production in the ocean (Laws *et al.*, 1987; Marra and Heinemann, 1987; Marra *et al.*, 1990; Cullen, 1990). These are based on the quantity of irradiance incident on a phytoplankton cell, and two efficiencies: the efficiency with which irradiance is absorbed and the efficiency with which the absorbed irradiance is converted into biomass. A further way in which primary production can be estimated optically is by measuring the upwelling radiance at 683 nm (Lu683). The source of this light is phytoplankton fluorescence, a by-product of photosynthesis, and recent data suggest a predictive relationship exists between Lu683 and phytoplankton photosynthesis (Chamberlin *et al.*, 1991).

Protocols

In the U.S., we have made progress in defining the protocols for the JGOFS-WOCE collaboration for bio-optics. I would like to detail these arrangements, knowing that they may not not apply to all the international participants in WOCE.

Wiretime on the WOCE transects will be at a premium, producing two major sampling design considerations. First, the bio-optics casts must be done separately from the WOCE CTD so that the optical sensors do not interfere with the CTD operation, such as descent through the water, electronic power supply, etc. Second, the casts must be of short duration (less than 30 minutes).

These two design considerations have implications for the design of the JGOFS bio-optics program. They are: (1) measurements will rely on sensors rather than water-bottle sampling, to a large degree; (2) a ship-launched bio-optical system will be used; (3) there will be one cast per day, with a two-wire operation; and (4) that the bio-optical system must be relatively light-weight, operable by one person, and flexible enough to work on a variety of ships.

Sensors. An ideal system for this work would be a set of sensors to measure spectral absorption and scattering directly. The advantages of this arrangement is that inherent properties of the water are measured, from which the apparent properties can be calculated. Measuring the inherent optical properties (which aren't dependent upon the sun) means that data could be collected day or night. The measurements would be more complete, and the spatial resolution would be much improved. Unfortunately, this ideal is several years in the future. For now, the best prospect would seem to be measurements of spectral, solar irradiance underwater, from which reflectance and diffuse attenuation coefficients can be calculated directly. Also, sensors for measuring chlorophyll fluorescence and particle abundance are required to help interpret the irradiance profiles and for pigment measurements.

Unlike calibrations for dCO_2, which are absolute, optics calibrations usually require a standard, such as a U.S. National Bureau of Standards calibrated light source. Progress is being made on using the quantum yield of photochemical reactions as a means of calibrating sensors; see Matheson *et al*. (1984). So while dCO_2 data can be collected using a variety of instrumentation, optics standardization remains important. Also, a variety of optical parameters can be measured, depending on the bandwidth of the irradiance and the geometry of the sensor. International standards for measurements will have to be established in terms of these two considerations. The measurement of chlorophyll fluorescence in si*tu* has similar instrument and calibration considerations.

Ship-Launched Sensors. Presence of the launching platform has always been an interference to submarine optics systems currently available. Provided that casts are made facing the sun this problem can be minimized. The only solution is to configure sensing packages to operate independently of the ship. Although a few systems have been so-configured, they are not able to measure the full suite of bio-optical properties, nor have they become routine.

Sampling Resolution. Given the limitation of one optical cast per day, the optical data on these cruises will exist at a station spacing of about 100 km. A ship-board flow-through system for surface seawater, to measure such variables as temperature, conductivity, fluorescence, and dissolved oxygen could help determine spatial variability at the surface, and help to interpret the station data. Temporal variability is in the form of seasonality (whether tropical or temperate). Seasonal coverage for the global ocean is a desirable goal, but one which will take many years to accomplish. Being influenced by biology, optical properties are akin to other properties, such as nutrients and dCO_2, which have proved to be particularly valuable recently in modeling studies (Glover and Brewer, 1988; Wroblewski *et al*., 1989) and to studies of the global carbon cycle (*e.g*. Kawase and Sarmiento, 1985). Even if we are not able to sample at the appropriate spatial scale (which is probably unknown), the collection of data will further the study of the relationship between optical properties and the factors that cause their variability (Morel, 1988).

A workshop was held 21-22 March 1991 at the Lamont Doherty Geological Observatory for the participating countries in JGOFS with the objective of establishing a set of protocols for the collection of bio-optical data in global surveys. Copies of the meeting report are available from the author.

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DORIS SYSTEM AND MEAN SEA LEVEL

The DORIS system was designed for an accurate determination of orbits of satellites equipped with onboard altimeters. Based upon uplink two frequency Doppler measurements transmitted from a dense worldwide network of automated ground beacons, the system will aim at achieving a subdecimeter radial accuracy of the orbit. Coverage will allow a non-geographically correlated error and a better determination of the acting forces.

The first DORIS receiver was launched on SPOT-2 on 22 January 1990, and has been operational since March 1990. The network (40 beacons so far) will be augmented to achieve the baseline of 50 stations in the future: for TOPEX/POSEIDON, a coverage of 75-80% is expected.

The design of the network emphasized areas of interest for oceanographic studies and the southern hemisphere; advantage was taken of automated beacons. Special efforts were made to link the beacons to IERS stations (International Earth Reference System): laser, VLBI and WOCE sea-level gauges. At the present time, 12 stations are geodetically linked to IERS and 14 to sea-level gauges. Figure 1 shows the present status of the various networks.

The measurement noise level is 0.3-0.5 10^{-3} m s^{-1} on the relative velocity between beacon and satellite, measured every 10 s. A global gravity field was computed, based upon 3 months of DORIS data. There has been a clear improvement of orbit quality resulting from the implementation of DORIS, especially for polar satellites. Precise orbits are computed on a routine basis. The present accuracy is ±2 m along-track, and a few 10^{-1} m in the radial direction (satellite altitude); even for SPOT-2, an improvement of the orbit radial accuracy (to 10 cm) can be expected. On the other hand, DORIS is also used to determine beacon positions: present accuracy is 10-15 cm for absolute positioning and 1-4 cm in relative position.

Further improvement with TOPEX/POSEIDON is expected. For this mission, simultaneous use of DORIS, laser data and sea-level gauge and altimeter data will result in the computation of mean sea level and associated statistics. To reach centimetric accuracy, emphasis was put on the homogeneity of reference systems, standards and dense coverage. Note that use of sea-level gauges is not limited to the calibration of the altimetric system, but may also help to overcome problems due to aliasing arising from discrete sampling, *i.e.* sea-level gauges are not used as single point data, but assimilated into hydrodynamical models which compute a sea-level field.

DORIS will continue to work for a ten-year period: on SPOT-2, (and then TOPEX/POSEIDON, SPOT-3, SPOT-4, ...) and beacon positioning will also continue, either for a routine determination of the network, or in support of dedicated experiments. For the application to mean sea-level monitoring, positioning is especially important for beacons colocated with IERS sites or sea-level gauges.

More details on the status of DORIS are found in publications which may be obtained from M. Dorrer, CNES, Centre Spatial de Toulouse, 18 Avenue Edouard Belin, 31055 Toulouse Cedex (Fax: 33.61.28.14.08).

M. Lefebvre, GRGS, 31055 Toulouse, France

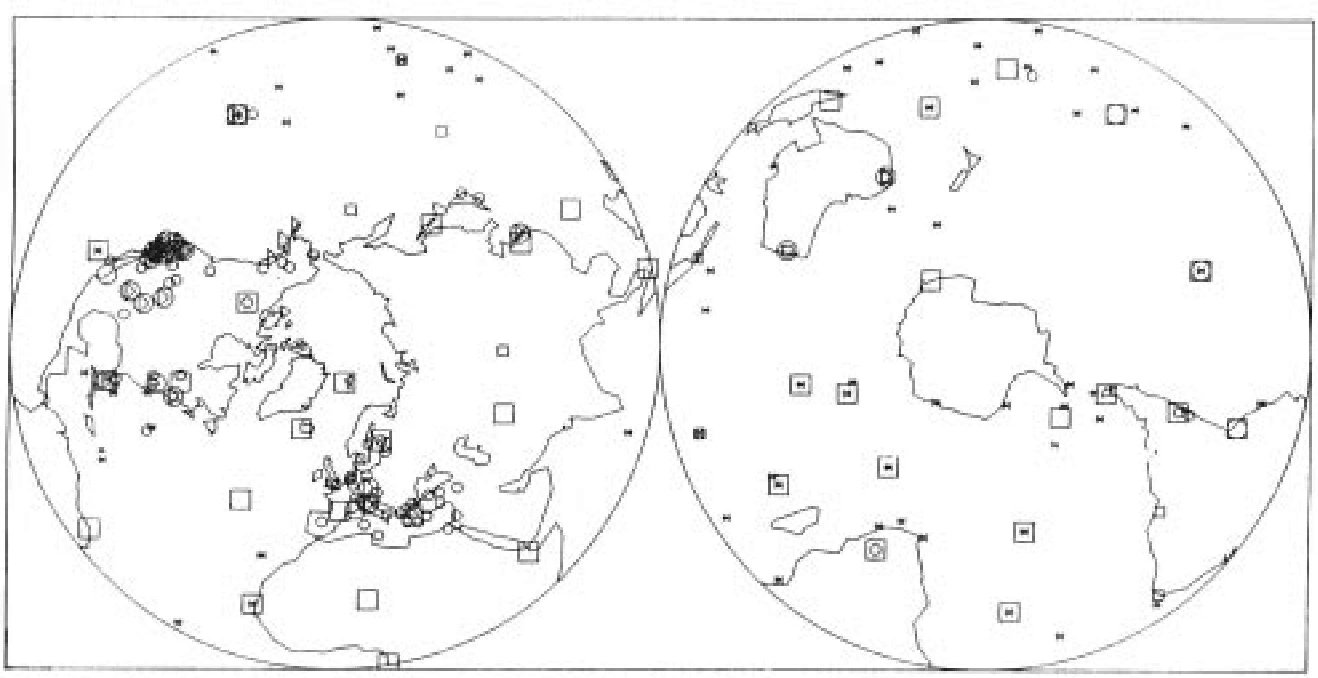


Figure 1. IERS primary network (large circles, VLBI), secondary network (small circles), DORIS network (squares) and WOCE sea-level gauges (asterisks)

COMMITMENT TO ONE-TIME SURVEY SECTIONS

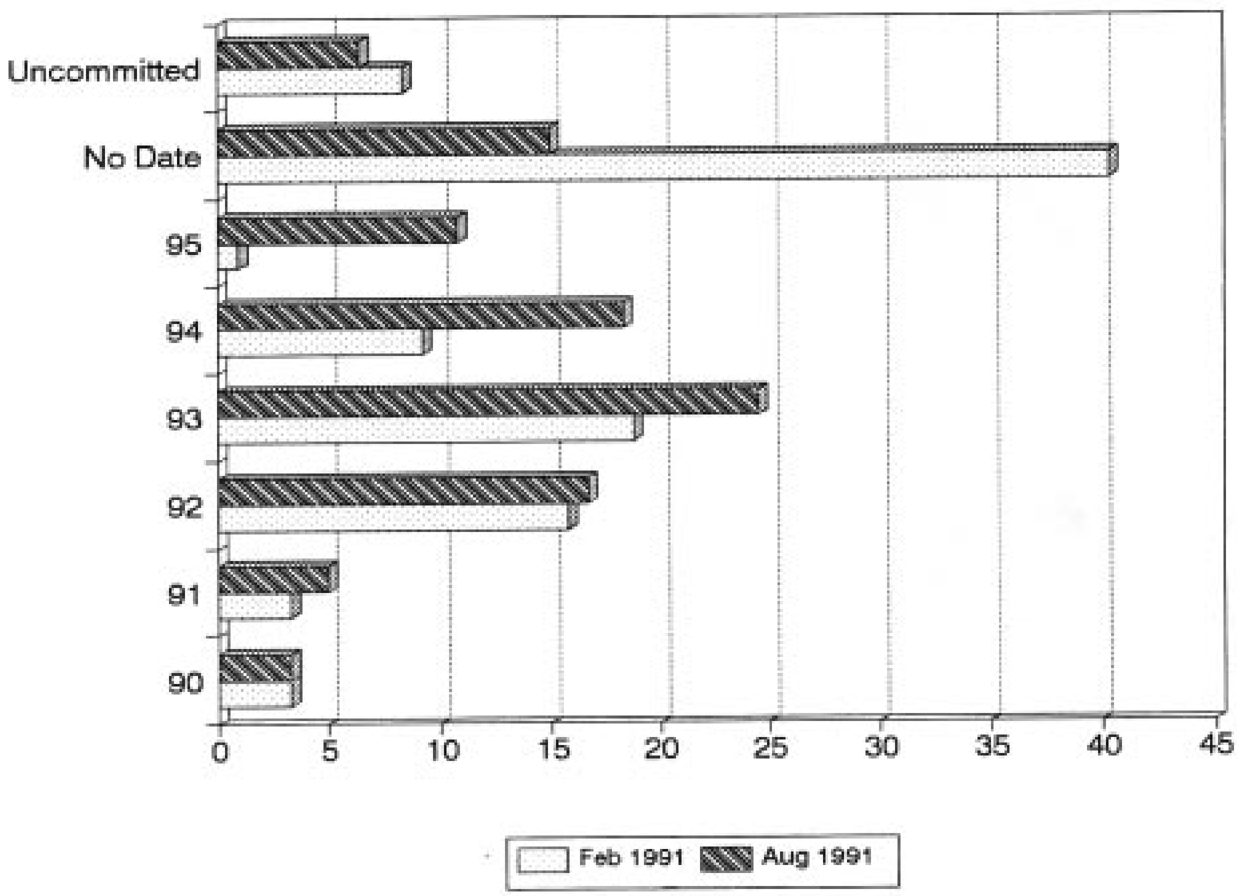
30/8/91

Commitments to the WOCE one-time survey sections have clarified considerably in the last six months. In February 1991, 40% of the commitments were in the “no-date” category. As of this writing, only 15% remain so. This change, and the few additional commitments that have been received, are certainly encouraging and will help the scheduling of other WOCE components as well *e.g.* subsurface float deployment. These changes do not, however, eliminate the concerns that a good number of lines are not coast to coast, will be completed by two or more parties in different years, and that several countries responsible for the sections lack the capability to carry out the tracer programmes.

The status of commitment to the one-time survey in August 1991 is compared to February 1991 below and the commitments of each country as of August 1991 are given on Page 21.

The word “commitment” as used here covers programmes which are executed, funded, proposed with funding under consideration and those that are included in a national WOCE plan.

Commitment to One-Time Survey Sections by Year (Number of Lines)



Commitment to One-Time Survey Sections by Year and Country

30/8/91

Pre-WOCE Sections are indicated by an asterisk (*).
Note that A21$^+$ = S1, A12$^+$ = S2, P12$^+$ = S3

1990/ PreWOCE

A12$^+$	GER
A21$^+$	GER
I5*	1987
P3*	1985
P4*	1989

1991

A1E	GER
A9	GER
P16N	USA (20N - 58N)
P16C	USA (40S - 20N)
P17C	USA (35S - 35N)
P21W	AA (W of 180)

1992

A5	SPAIN
A7	F
A10	GER
A11	UK
A15	USA
P6	USA
P13	USA
P14C	USA (17S - 37S)
P16S	USA (S of 45S)
P17S	USA (S of 40S)
P19S	USA (S of 50S)
P31	USA
S4 (PAC)	SU/USA

1993

A3	SU
A6	F
A17	F
I4	F
I6	F
P2	J
P8	PRC
P10	USA
P11S	AA (S of 5S)
P14N	USA (N of 17S)
P17N	USA (N of 35N)
P19N	USA (N of 50S)
P25	PRC
P27	ROC
P28	PRC
P29	PRC
P30	PRC

1994

A4	SU
A8	GER
A13	F
A14	F
A23	UK
I7S	F (S of 10S)
P1	SU
P9	J
P12$^+$	AA
P15N	CAN (N of 10S)
P24	J
P26	ROC

1995

P11N	SU (N of 35N)
I1	USA
I2	USA
I3	USA
I7N	USA (N of 10S)
I8	USA
I9N	USA (N of 35S)
I10	USA
S4 (IND)	AA

No Date

A1W	CAN
A2	UK
A16	USA
A18	USA
A19	F
A20	USA
A22	USA
I9S	AA (S of 35S)
P11C	PRC (35N - 5S)
P18	USA
P21E	USA (E of 180)
S4 (ATL)	SU

Uncommitted

P5
P7
P14S (S of 45S)
P15S (S of 10S)
P20

The status of planning of the WOCE one-time hydrographic survey is summarized in the above table. This is based on a survey conducted by the WOCE-IPO. Further details on the status of the individual cruises can be obtained from the WOCE Hydrographic Programme Office in Woods Hole (WHP Office). Regular updates of the status of the WOCE programme can be obtained from the WOCE Data Information Unit (DIU) by accessing OCEANIC through telemail or the SPAN and INTERNET networks.

TOGA DATA ON CD-ROM

A compact disk containing oceanographic and meteorological data has been produced by the Jet Propulsion Laboratory/NASA Ocean DataSystem and is available, free of charge, from the International TOGA Project Office (ITPO) (see below).

Designated as the CD-ROM JPL_TOGA_0001, this disk is the first in a planned series of TOGA data and World Climate Research Programme data.

This CD-ROM includes both selected observations and selected numerical model results for 1985 and 1986.

Observations:

- tropical ship surface data
- tropical ship subsurface data
- global drifting buoy data
- tropical Pacific moored current meter and temperature data
- tropical Pacific sea level data
- tropical Pacific island meteorological data

Fields:

- global surface meteorological fields (analyzed parameters and model-derived flux fields)
- global sea-surface temperature monthly analyzed and climatology fields
- surface pseudo-stress fields over tropical Indian, Pacific and Atlantic oceans.

Software for Data access and Data display

The TOGA CD-ROM is accompanied by data access and data display software provided on three high density (1.2 MB) floppy disks. The CD-ROM and companion software were developed as experimental prototypes and therefore the ITPO is looking for comments and feedback from researchers who have the opportunity to test this data package.

Minimum System Requirements

The equipment necessary to use this compact disk with the accompanying software is:

- IBM PC or compatible with 640K RAM
- hard disk drive (3 MB available)
- CD-ROM reader capable of assessing compact disks with the ISO 9660 standard
- Microsoft MS-DOS Extensions for CD-ROM (version 2.0 or higher).

In addition a color monitor with EGA (128 KB) graphics driver enables full use to be made of the graphics display system.

Extraction of the data from the CD-ROM is possible with Apple Macintosh equipment.

Availability

Users who have access to a system meeting these specifications are eligible to receive a free copy of the TOGA_0001 CD-ROM and its companion software. Please send your request to the International TOGA Project Office, World Meteorological Organization, C.P. 2300, CH-1211 Geneva 2, Switzerland, tel 44 22 730 8430.

Annex:

Following is a list of the data stored on the TOGA CD-ROM:

Tropical ship surface data
U and V component wind, Air temperature,
Dewpoint, Air pressure, Sea-surface temperature

Tropical ship subsurface data
Sea-surface temperature, Temperature profiles
Surface salinity

Global drifting buoy data
Daily averaged data:
Air pressure, Air temperature, Sea-surface temperature
U and V component wind

Tropical Pacific sea-level data
Daily averaged data from 72 stations

Tropical Pacific moored current meter and temperature data
Daily averaged data:
Air temperature, Sea-surface temperature
U and V component wind
U and V component current at certain depths
Water temperatures at certain depths

Tropical Pacific island meteorological data
Daily averaged data from three stations:
Air pressure, Air temperature
U and V component wind

Global surface meteorological fields (2.5 x 2.5° grid)
Twice daily fields:
Surface temperature
Sensible heat flux (integrated over six hours)
Latent heat flux (integrated over six hours)
Sea level pressure
U and V component wind at 10 m
Temperature and Dewpoint at 2 m
U and V component wind stress (integrated over six hours)

Global sea-surface temperature (2 x 2° grid)

Surface pseudo stress fields
Indian Ocean: 1° x 1° grid
Pacific Ocean: 2° x 2° grid
Atlantic Ocean: 2° x 5° grid

WOCE CALENDAR

Subject: Sixth WOCE Numerical Experimentation Group Meeting, NEG-6
Date/Place: 9-10 September 1991, Princeton, USA
Contact: WOCE.IPO/IOS.WORMLEY (D.J. Webb)

Subject: WOCE-ISS2 Indian Ocean Working Group
Date/Place: 24-26 September 1991, Wormley, UK
Contact: WOCE.IPO

Subject: First TOGA/WOCE XBT/XCTD Programme Planning Committee Meeting, XBT-1
Date/Place: 7-10 October 1991, Washington, DC, USA
Contact: WOCE.IPO/G.MEYERS

Subject: Joint Meeting of JSC/CCCO Working Group on Air-Sea Fluxes and WOCE Surface Layer Scientific Panel
Date/Place 21-24 October 1991, Reading, UK
Contact: WOCE.IPO/R.POLLARD/CCCO.PARIS

Subject: First WOCE Surface Layer Scientific Panel Meeting, SLSP-1
Date/Place: 25 October 1991, Reading, UK
Contact: WOCE.IPO/R.POLLARD

Subject: Ninth WOCE Hydrographic Programme Planning Committee Meeting, WHP-9
Date/Place: 21-25 October 1991, La Jolla, USA
Contact: WOCE.IPO/IOS.WORMLEY (P.M. Saunders)

Subject: Fourth WOCE Data Management Committee Meeting, DMC-4
Date/Place: 28-31 October 1991, Tokyo, Japan
Contact: WOCE.IPO/J.CREASE

Subject: Seventeenth WOCE SSG Meeting, WOCE-17
Date/Place: 20-22 November 1991, Wormley, UK
Contact: WOCE.IPO

Subject: Fifth WOCE SSG Executive Meeting, EXEC-5
Date/Place: 2 March 1992, Paris, France
Contact: WOCE.IPO

Subject: Second Intergovernmental WOCE Panel Meeting, IWP-2
Date/Place: 3-4 March 1992, Paris, France
Contact: WOCE.IPO/IOC.SECRETARIAT

Subject: Fifth WOCE Core Project 3 Working Group Meeting, CP3-5
Date/Place: March 1992, Europe
Contact: WOCE.IPO/IOS.WORMLEY (W.J. Gould)

Subject: Tenth WOCE Hydrographic Programme Planning Committee Meeting, WHP-10
Date/Place: April 1992, Europe
Contact: WOCE.IPO

Subject: Fifth WOCE/TOGA Surface Velocity Programme Planning Committee Meeting, SVP-5
Date/Place: April 1992, Bermuda
Contact: WOCE.IPO/P.NIILER

Subject: WOCE North Pacific Workshop
Date/Place: 27-28 April 1992, Vancouver, Canada
Contact: WOCE.IPO/P.LEBLOND

Subject: Fifth WOCE Core Project 1 Working Group Meeting, CP1-5
Date/Place: 29 April-1 May 1992, Vancouver, Canada
Contact: WOCE.IPO/L.TALLEY/P.LEBLOND

Subject: Fifth WOCE Core Project 2 Working Group Meeting, CP2-5
Date/Place: May 1992, La Jolla, USA
Contact: WOCE.IPO/A.GORDON

Subject: Eighteenth WOCE SSG Meeting, WOCE-18
Date/Place: 12-14 May 1992, Galveston, USA
Contact: WOCE.IPO

WOCE is a component of the World Climate Research Programme (WCRP), which was established by WMO and ICSU, and is carried out in association with IOC and SCOR. The scientific planning and development of WOCE is under the guidance of the JSC/CCCO Scientific Steering Group for WOCE, assisted by the WOCE International Project Office. JSC and CCCO are the main bodies of WMO-ICSU and IOC-SCOR, respectively, formulating overall WCRP scientific concepts.

The WOCE Newsletter is edited at the WOCE-IPO at IOSDL, Wormley, Godalming, Surrey, UK. Financial support is provided by the Natural Environment Research Council, UK.

We hope that colleagues will see this Newsletter as a means of reporting work in progress related to the Goals of WOCE as described in the Scientific Plan. The SSG will use it also to report progress of working groups, and of experiment design and of models.

The editor will be pleased to send copies of the Newsletter to institutes and research scientists with an interest in WOCE or related research.