Proposal

At the November 1986 Core Project 1 Workshop in Washington DC it appeared that certain regional groups were discounting the possibility of carrying out large volume sampling even though the results would be of value to their WOCE objectives, because of the long station times, the cost and/or the difficulty of using the existing system in their ships.

In the spirit of the RV WOCE programme (now the WHP) the MAFF Fisheries Laboratory, Lowestoft, offers the loan of its existing system to one or a succession of users worldwide during the WOCE observing period, since the tracer chemistry that we ourselves plan for our East Greenland programme will not involve large volume sampling.

Though some users will already be familiar with the IOS Wormley acoustic release system we are of course prepared to give tuition on our adapted large volume sampling system to any user who requests it. If the user or the WHP can assume responsibility for the cost of maintenance, round trip transport, loss or damage as part of its normal "ship expenses" all that would be needed would be a winch of sufficient cable capacity for the job in hand and some form of crane for moving full samplers (400 kg) into the rack. We can supply further details to any WOCE participating group who may be interested in borrowing this gear.

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TRANSPACIFIC SECTION AT 47°N

Introduction

Long hydrographic transects of the world's oceans with the aim of describing baroclinic flow, transports, properties and tracers on a global scale will be a basic ingredient of the WOCE Core Project 1 programme. Such sections have long been a staple of oceanographic description. Sampling philosophy has evolved in recent years to include relatively closely-spaced stations along the sections in order to minimize aliasing by mesoscale features and to adequately resolve boundary currents, sampling to the ocean bottom in order to describe flow at all levels, and employment of a CTD in addition to discrete bottles in order to fully describe the vertical temperature, salinity and oxygen structure. Inclusion of inorganic nutrient and tracer sampling at many or all stations is also a feature of many programmes. While individual transects are quite useful, a network of sections increases their value many-fold, allowing large-scale mapping and budgeting of transports and properties. Groups of sections have been occupied recently in the North and South Atlantic and in the North Pacific, with a greater or lesser degree of basin coverage: a number of these sections will be considered part of the WOCE survey.

The transect of the North Pacific subpolar gyre at 47°N in August, 1985, was one such section. The cruise track is shown in Figure 1. Both this section and a sister section at 24°N included the aspects mentioned above - relatively close station spacing, sampling to the bottom, use of a CTD, sampling for oxygen and nutrients, and a fairly large number of small-volume tracer programmes. Programmes conducted by other scientists included sampling for tritium, helium-3, chlorofluoromethanes, alkalinity, total CO_2 plutonium, carbon 14, chlorophyll, phytoplankton, and rare earth elements; an acoustic Doppler system was in operation throughout the cruise and a salt-bridge GEK was towed between stations.

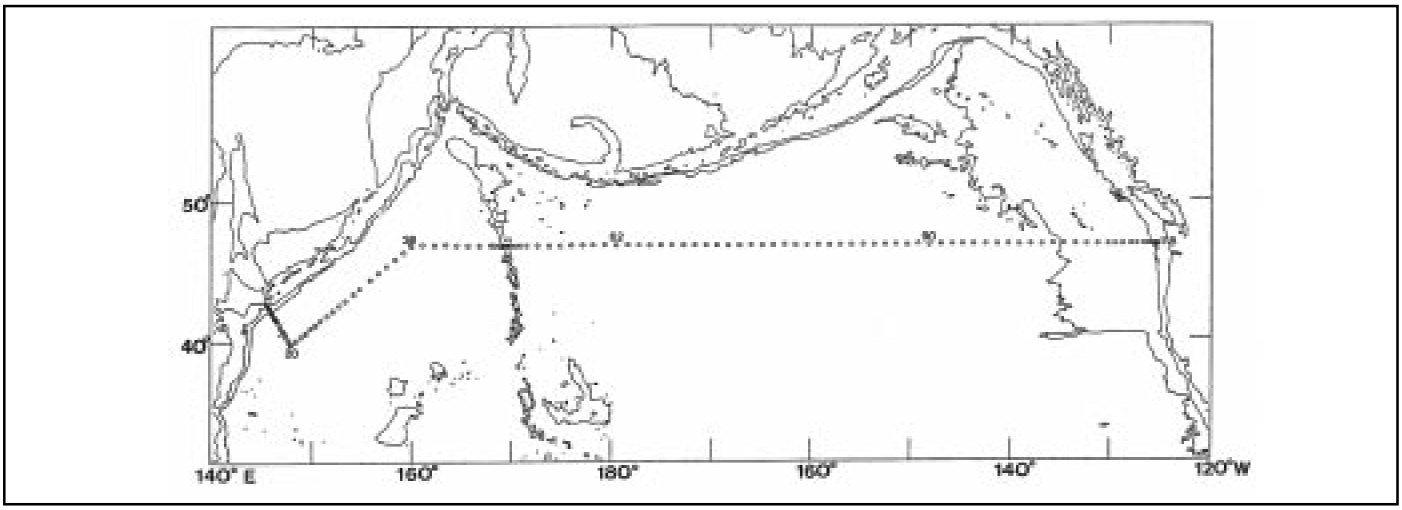

Figure 1. Stations occupied in August, 1985.

Observations

The 47°N section consisted of 115 stations to the ocean bottom; basic station spacing was 84 km with much closer spacing at the western boundary and over the Emperor Seamounts. Presented here is a sample of the observations including a description of the velocity field with simple estimates of mass and volume transports, strong evidence from CTD measurements for a basin-wide shift in curvature of the deep potential temperature/salinity relation, full confirmation of a double maximum in silicate in the eastern Pacific, and a striking zonal signal in oxygen at the oxygen minimum.

Velocities and Transports: The broad velocity pattern at the sea-surface shows northward flow over most of this subpolar section. Highest baroclinic velocities and variability are found at the western boundary, over the Emperor Seamounts, and at the eastern boundary. The western end of the section lies in the perturbed area between the Kuroshio and Oyashio; hence current and property patterns are fairly complicated there. Examination of the ten-day analyses of 100 meter temperatures produced by The Japan Meteorological Agency shows that a warm core ring was located in the centre of the westernmost leg of the transect for at least two months prior to the cruise. Water properties in the ring indicate that it was “transitional water” from the region between the Kuroshio and Oyashio. Relatively high southward velocities were found on either side of the ring, a common situation in the region: the western and eastern southwards flows have been called the first and second intrusions of the Oyashio (Kawai, 1972). Net transport in the upper waters on this westernmost leg was southward, relative to a deep reference level. For velocities at greater depths, choice of reference level or barotropic velocity is more crucial: relative to 1500 db, abyssal flow in the Japan Trench has the same sense as topographic waves, with the boundary on the right. Hence flow at the westernmost end is southward and flow on the east side in the Trench is northward. These are the same relative flow directions established using direct velocity measurements and water properties in the Aleutian Trench by Warren and Owens (1984). However, detailed examination of water properties in the Japan Trench indicated that the flow direction is actually the reverse of this. Vertical shear at all stations was of uniform sign from top to bottom, suggesting strong barotropic flow overwhelming weaker baroclinic flow which has the direction of topographic waves.

Velocity structure at the Emperor Seamounts is quite complicated: relative to 1500 db, there is northward flow on the west side and southward flow on the east side of the Seamounts. Oxygen patterns above the seamounts suggest relatively broad northward flow west and southward flow east of the Seamounts. Abyssal properties are not helpful in establishing flow direction - they merely suggest that the deepest water east of the Seamounts is older than that to the west. Abyssal properties on both sides of the Seamounts suggest much older water than that found at 35°N (Kenyon, 1983) or at the western boundary as far north as the entrance to the Bering Sea.

At the eastern boundary, flow is relatively strong and southward nearest the shore with northward flow underlying it and surfacing about 100 km offshore. Velocities are relatively strong from the boundary to the edge of the Cascadia Basin.

Between these three regions of surface flows in excess of 10 cm sec^{-1}, flow reversal which could be labelled "eddy variability" occur regularly. The magnitude of variability is larger west of about 175°E then to the east. This is apparently a transition from a western subarctic regime to an eastern one, based on all water properties as well as baroclinic velocities.

Volume and heat transports were estimated from a number of different pressure reference levels, assuming an Ekman transport of 4.5 Sverdrups southward distributed over the top 10 meters and evenly across the section. No attempt was made in this simple calculation to correct volume transports to be nearly zero or 1 Sverdrup northward. Volume transports relative to 1500 din and 7000 db were 4 Sverdrups and 5.3 Sverdrups southward respectively with a larger range of transports if other reference levels were listed. Heat transports were less sensitive to choice of reference level and varied from 0. 1 to 0.2 x 10^{15} W southward, including 0.25 x 10^{15} W southward in the Ekman layer; sensitivity to the assumed depth of the Ekman layer was somewhat greater. This estimate of heat transport and its sign agrees quite well, but perhaps fortuitously, with Talley's (1984) estimates of heat transport at 40°N and 50°S. All indicate net heat gain north of 47°N, a somewhat counterintuitive result.

The vertical distribution of volume transport relative to 1500 db and to the bottom is shown in Figure 2. The Ekman transport is southward, off-scale, and not shown. Relative to 1500 db, there is net northward geostrophic transport above 4000 db and net southward transport below. The gross structure suggested by a breakdown of these transports across the section is of a cyclonic gyre above 1500 db and an anticyclonic gyre below 1500 db. The vertical structure relative to the ocean bottom is quite different, because large jumps in deep transport relative to 1500 db are eliminated. Relative to 7000 db, most transport occurs above 2700 db, with northward transport in the topmost layer (excluding the Ekman layer), and southward in an intermediate layer. The gross horizontal structure shows the usual cyclonic gyre above 1500 db; flow in the deep water is northward in a broad region around the Emperor Seamounts and southward otherwise.

Geothermal heating: Proceeding from west to east along the transect, the curvature of the abyssal potential temperature/salinity relation shifts from negative to positive, from colder to warmer temperature at a given salinity (Joyce, et al., 1986). The change is small enough that even an ambitious bottle sampling programme would not resolve it because of scatter in salinity measurements in an

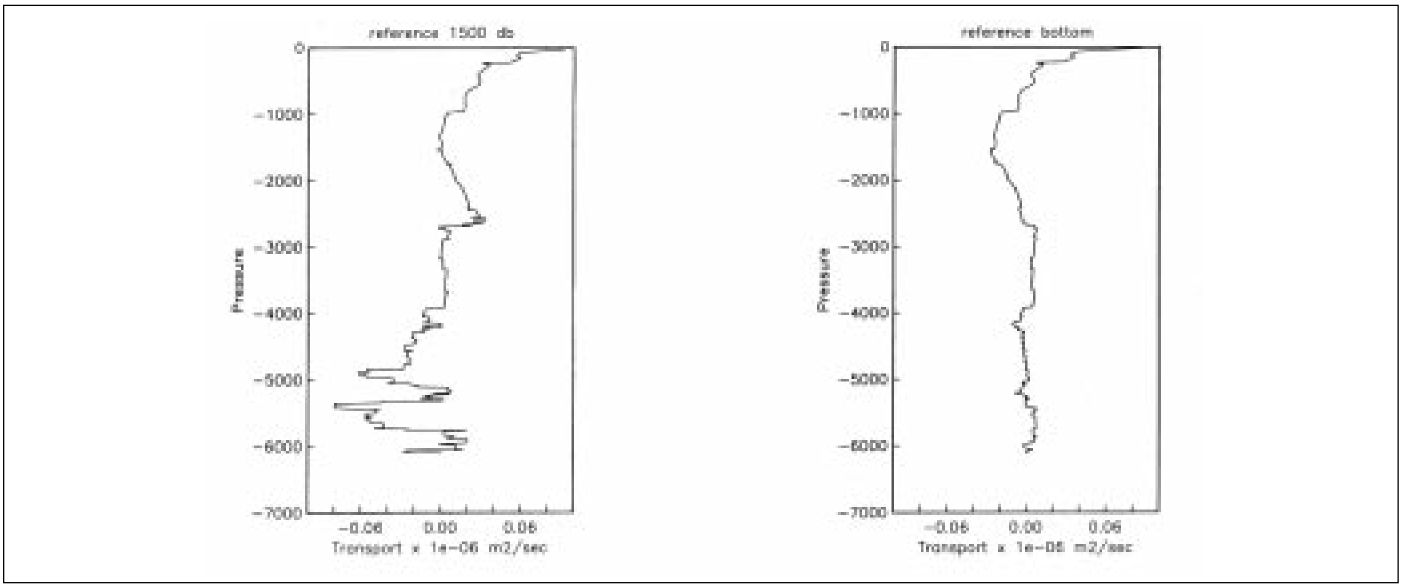

Figure 2. Vertical distribution of horizontally integrated velocities as function of pressure. Each layer 10 db thick. Total mass and heat transports are listed in the text.

environment where the maximum variation in salinity at 5000 meters is about 0.003 (ppt) along the portion of the section lying at 47°N. CTD casts however unequivocally resolve the shift in curvature, and moreover show that potential temperature increases to the east at a given salinity. Meridional sections which intersect the 47°N section indicate that the region of warmed water is isolated to latitudes between 40°N and 52°N. Because the warmed water is clearly associated with lower oxygen, hence older water, it was concluded that the potential temperature/salinity change is due to geothermal heating in the mid-ocean basins; heating rates, although low, are high enough to account for the observed change in potential temperature. A much larger change in potential temperature/salinity is observed on the 47°N section over the Cascadia Basin at the eastern end of the section, due to high geothermal activity associated with the Juan de Fuca ridge.

Silicate section: The vertical section of silicate shown in Figure 3 shows a remarkable double maxima which is highest in the east, reaching remarkable values greater than 200 (micromoles litre^{-1}) at the bottom on the deep ledge of the Cascadia Basin. It appears quite clear from this section and from maps of silicate at about 2500 meters (Reid, 1981) that the eastern boundary is the primary source of high silicate in the mid-depth maximum in the eastern Pacific. The Bering Sea is also a source of high silicate at about the same depth and density, and is probably the source of the isolated maximum centred at station 38.

The bottom maximum has not been as evident from previous data: the section at 47°N and a meridional section at 152°W indicate that bottom values increase dramatically to the east and that the maximum is coincided to latitudes between 40°N and 53°N. This region coincides with that in which older water was identified on the basis of deep potential temperature/salinity curvature and an hypothesis of geothermal heating. It is clear from the 47°N section that the source of high silicate is the ocean bottom in the east up to the Cascadia Basin. Because the bottom maximum crosses isopycnals to the west, it is not clear how much of the signal is advective and how much is local. Toward the Emperor Seamounts, the maximum does lift slightly off the bottom.

Other noteworthy features of the silicate section are the high values in the Japan Trench which, along with signals of all other water properties, indicate a southern source of abyssal waters. The dip in silicate from the surface to about 1500 meters between stations 7 and 18 is also mirrored in all other properties and indicates subtropical influence between the first and second Oyashio intrusion, as remarked in the section on velocities.

Oxygen, phosphate and nitrate: These vertical sections are not shown, but have well-known extrema at about 1000 meters. Examination of these three properties along their extrema (minimum in oxygen and maxima in phosphate and nitrate) and along isopycnals which intersect the extrema shows a zonal pattern which must reflect the gyre circulation and sources of the nutrients. Referring only to oxygen since all three show similar patterns, oxygen is highest in the very west where subtropical influence is strong and in a wide region east of 170°W. Between stations

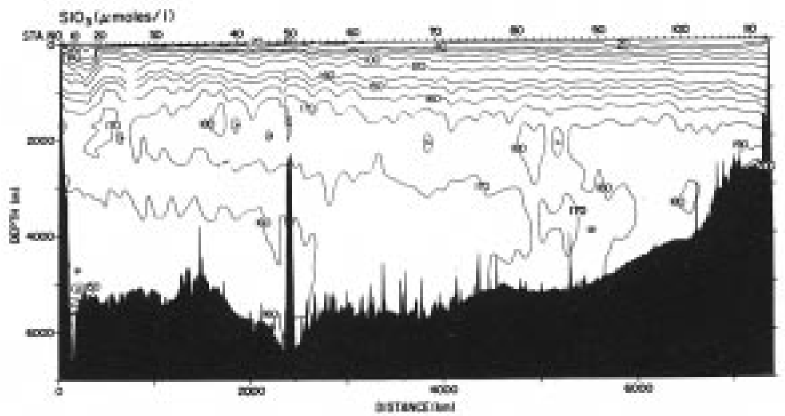

Figure 3. Vertical section of silicates

25 and 70, oxygen is 0.2 to 0.3 (micromoles litre^{-1}) lower at the minimum. The conclusion is that subtropical influence is stronger in the east than in the west whether due to a northward swing of the windstress pattern, hence closer proximity to the subtropical gyre, to the east, or due to a greater admixture of subtropical waters in the east.

Within this broad pattern, a finer pattern near the Emperors shows higher oxygen west of the Seamounts and lower oxygen east of the Seamounts, perhaps indicating northward and southward flow respectively.

Conclusions

The relatively fine-scale survey at 47°N show a number of new features, some of which would have been barely detectable without a CTD and others of which simply required a good survey of water properties in the region. Use of other high-quality sections in conjunction with this subpolar transect should allow basin-wide budgets of heat and mass and basin-wide mapping of properties and circulation. Such studies are currently being pursued by a number of investigators associated with these sections.

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DRIFTING BUOY DATA FOR MARINE RESEARCH

Introduction

With the advent during the early 1970s of the ability to track by satellite the movements of radio transmitters on or above the earth’s surface, many limitations imposed by traditional tracking techniques on the use of drifting buoys to study ocean currents were eliminated. With subsequent improvements in buoy system capabilities, buoys are not providing a cost-effective means of obtaining long-term, in-situ measurement of environmental parameters from vast and remote ocean areas. A comprehensive archive of past and present drifting buoy data is needed to improve their availability and usefulness for studies of large-scale circulation and climatology such as WOCE and TOGA. Unfortunately, opportunities to preserve these data are being lost.

The purposes of this article are to note the potential importance of these data to present and future research efforts, to describe the coordinated efforts of the Canadian Marine Environmental Data Service (MEDS) and the US National Oceanographic Data Center (NODC) to assemble a comprehensive archive of these data, and to stimulate increased flow of data to the archives. Furthermore, it is hoped that this article will promote a more vigorous dialogue between WOCE researchers and archive centres, so that data management issues will be addressed in a way that will help ensure a successful WOCE.

The Value of Data from Drifting Buoys

Surface drifting buoys have been most frequently used to measure surface currents, sea surface temperature, and sea level pressure. Surface currents (or, if the buoy is drogued, currents at drogue depth) are inferred from the buoy trajectory. Other parameters which have occasionally been measured with varying degrees of success include air temperature, wind velocity, air pressure variation, wave characteristics, subsurface temperatures, subsurface relative currents, and ambient noise (to infer wind speed and precipitation). Possible future sensors include those for atmospheric humidity,