The Deep Basin Experiment:
A Meeting Report

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1 Introduction

From Nov 15 to 17, 1999 a meeting of Deep Basin Experiment (DBE)Coles et al. (1996) participants was held at the Carriage House, Woods Hole Oceanographic Institution with 26 scientists from France, Germany, Great Britain and the United States attending. This is a particularly critical time for the DBE: most (but not all) of the field work has been completed. Investigators have been working singly or in small groups on various subsets of the data. The main purposes of this meeting were to make the group aware of what work is going on and what results have been achieved, and to stimulate research toward the overarching questions posed in the original DBE manifesto.

Reports summarizing data status and availability, publications completed and in process, and further studies contemplated were presented on the first morning. These were followed by short scientific reports grouped under the water mass themes appropriate to the DBE: Antarctic Intermediate Water (AAIW), North Atlantic Deep Water (NADW) and Antarctic Bottom Water (AABW). The meeting ended with a brief discussion about the future and how we might tackle an overall synthesis. It was agreed that the next meeting would take place in Brest, France in September of 2000. To supplement what is summarized below the interested reader is referred to a previously published description of the DBE given in Hogg et al. (1996) and a recent summary of circulation in the South Atlantic by Stramma and England (1999).

2 Summary of research

Although the meeting was structured around water mass themes it seems more appropriate for this report to repackage this under the headings of the original DBE objectives, namely[1]:

[1]Names in brackets indicate those who spoke on the topic of the preceeding sentence(s).

2.1 To observe and quantify the deep circulation within an abyssal basin.

The three water mass levels were instrumented with a large number of neutrally buoyant floats. French and German scientists have used a combination of cycling "Marvor" floats and one-shot "Rafos" floats to determine the circulation of AAIW. This has proven to be quite successful — the large–scale, subtropical gyre that feeds water westward at the southern boundary of the Brazil Basin (BB) with resulting bifurcation over the Santos Plateau at the western boundary has been well observed (O. Boebel, P. Richardson). The transports across WHP line A17 also exhibit a "Santos" bifurcation and many of the features of the circulation can be explained by a simple ventilated thermocline model (C. Schmid). Further north the interior flow is observed less well and appears to have smaller spatial scales. The complex system of zonal currents in the tropics and equatorial regions that has been described by other investigators is not apparent in the float data although there is some confirmation of the Southern Intermediate Counter Current (SICC). Just one of the floats at this level crossed the equator in the western boundary current but a number accomplished the task by taking interior, nearly zonal, routes near the equator. In the neighborhood of the Vitoria-Trindade Seamount Chain (VTSC) there is tantalizing evidence of a recirculating zonal flow but too few floats were in this feature to make it definitive (M. Ollitrault).

At the NADW level a well defined Deep Western Boundary Current (DWBC) exists, consistent with the classic Stommel-Arons (Stommel, 1958) picture but the interior flow appears to be zonally banded with small meridional length scales (W. B. Owens). A prominent eastward flow extends offshore from the VTSC between 20S and 25S. This is the region of the Namib-Col Current but on the basis of various computations combining direct current measures and simple box models from hydrographic data the offshore flow seems to carry 8–20Sv at least as far east as the Mid-Atlantic Ridge (G. Siedler, M. Vanicek, N. Hogg). What happens at the ridge is a puzzle: does it feed a northward flowing boundary current along the ridge flanks (K. Speer) or continue into the Angola Basin (M. Vanicek)? In addition to the 20S-25S eastward flow, the A17 transports suggest significant escapes from the boundary near 3 degrees on either side of the equator, at 10S, and at 30S-34S (M.Arhan).

Just north of the VTSC a moored array reveals a boundary current that carries a surprising 39 ± 20 Sv within the NADW toward the southeast and extends downward through the AABW layer. There is no evidence for a return recirculation to the north (G. Weatherly).

There were fewer floats put in the bottom water layer than in those above but the flow there seems to share the same zonal structure away from the western boundary. In addition, although the AABW does enter the basin from the south the flow north of the VTSC is generally southward closely resembling that within the NADW above (W. B. Owens, G. Weatherly, M. Arhan).

A large population of small vortices has been observed in the float trajectories, at all levels. They are of both signs of rotation with the direction of propagation generally consistent with theoretical arguments (P. Kassis). Several have also been found in the WOCE hydrographic surveys of the BB (G. Weatherly). Those within the NADW have property anomalies consistent with a source at the western boundary but they have been observed throughout the basin and generally travel westward (P. Kassis).

The WOCE hydrographic sections from the BB have been analyzed for regional aspects of the circulation with little, at this point, attempt to determine basin-wide circulation patterns. Given the dominance of zonal flows in the interior the meridional sections have been especially useful for giving support to the existence of flow away from the western boundary (M. Arhan) and extending eastward with CFCs playing an important role, especially near the equator (C. Andrié, M. Vanicek, W. Smethie).

2.2 To distinguish between boundary and internal mixing processes.

There are 4 major passages connecting the Brazil Basin to neighboring basins and all were instrumented with current meter arrays during the DBE so as to better constrain the mass and heat budgets for the bottom water relative to that done previously (Hogg et al., 1982). At the exits for bottom water in the north the Romanche-Chain Fracture Zones allow 1.22 Sv (H. Mercier) and the equatorial passage near 35W about 2.0 Sv (M. Hall) to leave. At the south the Vema Channel and the Hunter Channel both contribute significant amounts of bottom water to the Brazil Basin with the former estimated at 4.0 Sv and the latter at 2.9 Sv (W. Zenk) with little net transport of AABW coming over the Santos Plateau to the west. The Hunter array was the least well equipped to determine the transport with any accuracy.

These refined passage transports have been used to recompute the basin averaged diapycnal diffusivity of between 3 and 5 $cm^2 s^{-1}$, not significantly different from the earlier values (M. Hall). The real question for the DBE is how uniform this mixing process actually is. The original concept was to coarsely subdivide the basin with hydrographic surveys and make use of direct velocity measurements to constrain box inversion so as to be able to distinguish between regions that were over smooth (i.e. central basin) and rough (i.e. western boundary, Mid-Atlantic Ridge) areas. The work based on inverse techniques is still in its infancy but the Brazil Basin Tracer Release Experiment (BBTRE) has somewhat finessed the outcome. The release of a small quantity of sulphur hexafluoride close to the 1.6C (potential temperature) surface and subsequent sampling at periods of 12 and 22 months has permitted the direct estimation of diapycnal diffusivity. Rates are between 2 and 10 $cm^2 s^{-1}$ depending on how close to the (rough) bottom one is (J. Ledwell). A reasonable candidate for the source of the mixing is the conversion of barotropic tidal energy into internal tides by interaction with small scale bathymetry and subsequent breaking through intensified shears (K. Polzin). Horizontal spreading is consistent with a lateral diffusivity of order 100 $cm^2 s^{-1}$ (J. Ledwell). The combination of direct estimates of mixing from microstructure observations with regional distribution of water properties has permitted estimation of the local 3-dimensional flow regime (L. St. Laurent). This inverse model predicts upwelling where density surfaces intersect the western flanks of the ridge (within canyons formed by the fracture zones) whose strength is sufficient to account for virtually all that demanded by the basin averaged budgets (if extrapolated along the length of the ridge). Such mixing will drive flow away from the ridge that is very different from that of the old Stommel–Arons scheme (M. Spall).

2.3 To understand how passages affect the water flowing through them.

As well as being important tactical locations to measure the mass and heat flux of bottom water passages are likely places for water modification through mixing in the accelerated flows. Two modeling studies are underway, one centered on the Romanche Fracture Zone at the equator (B. Ferron) and the other on the Vema Channel (T. Müller). By way of contrast a density current flows downhill some hundreds of meters at the exit of the Romanche and results in intense mixing ($> 300 cm^2 s^{-1}$) while the Vema Channel and its northward extension has a much gentler exit which, along with the geostrophic tendency to force flow to follow depth contours, results in little mixing. A concentration of hydrographic sections near the Vema Channel has permitted a special focus on this region (E. McDonagh). Its outflow has been traced to about 13S with little change but thereafter seems to split into 2 cores, one goes to deeper depth contours toward the Romanche and the other to the 35W equatorial exit to the western North Atlantic (G. Weatherly).

2.4 To study the means by which deep water flows across the equator.

This topic has been mostly dealt with by other groups outside the DBE and was, by no means, fully covered at the meeting although some examples of floats within the AAIW traversing the equator were given (M. Ollitrault) and the zonally banded structure implied by the CFCs was presented (C. Andrié). Once again the reader is referred to the recent summary of Stramma and England (1999).

3 The future

Much of the research effort is now turning toward analysis of the collected data and synthesis of the various data sets so that the regional circulation will be better defined and the above objectives more completely addressed. Overlapping groups of investigators will pursue a variety of subjects during this WOCE AIMS phase. Virtually all of the DBE data sets will be made public by the end of this year. Exceptions are the A14 meridional line in the Angola Basin, promised for summer of 2000, and the last half of the Marvor float data from the AAIW layer for which tracking has not been completed. The preliminary results have already provoked new measurement programs aimed at quantifying the long period changes in the Vema Channel (T. Müller) and the 35W equatorial passage (R. Limburner) and following up on questions related to enhanced mixing over rough topography (J. Toole). The possibility of a zonal connection between the NADW DWBC near the Vitoria-Trindade Seamounts and the Angola Basin stimulated the interest of a number of participants and seems likely to lead to future field programs.

References

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