ENDEAVOR 223 CRUISE SUMMARY

FORMATION AND SPREADING OF THE SHALLOW COMPONENT OF THE NORTH ATLANTIC DEEP WESTERN BOUNDARY CURRENT

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In March-April 1991 a 34 day hydrographic cruise was undertaken aboard R/V ENDEAVOR to investigate the formation of the shallow component of the Deep Western Boundary Current (DWBC). West of the Grand Banks this component of the DWBC is in the depth range 700-1200 m with potential temperature 4-6 degrees C; its core density is sigma theta ~ 27.68 kg/m^3. This water mass is characterized most readily by a core of high Chlorofluorocarbons (CFCs) and anomalously fresh salinity relative to the interior water. The CFC signal is evident all the way to the equator where it splits into two cores, one progressing eastward along the equator and the other further southward along the western boundary. The precise origin of this water mass is still under question; the purpose of this cruise was to determine the geographical area of formation, investigate the dynamics of formation, and quantify the downstream entrainment and spreading as the water progresses equatorward in the shallow DWBC. It was also our intent to study the downstream evolution of the two deeper components of the DWBC, the Labrador Sea water and Norwegian-Greenland Sea overflow water.

To investigate water mass formation it was necessary to perform the field experiment in late winter. Thus, working conditions during the cruise were often harsh and as a result we were unable to complete all planned sections. The cruise was quite successful, however, and a total of 47 stations were occupied.

In all, 4 crossings of the DWBC were completed and two additional stations were occupied in the central part of the Labrador Sea. In Figure 1, open squares denote CTD stations and crosses denote XBT drops. Sections 2 and 3 extended just far enough to cross into the North Atlantic Current, but to save time Section 1 was started to the north of the Gulf Stream front (the approximate location of the Gulf Stream / North Atlantic Current was known from satellite maps which proved quite accurate). The region of a detailed XBT/CTD survey around a lense of newly ventilated water is indicated by the large square in Figure 1.

All CTD casts (except those comprising the small scale survey) were occupied to the bottom. Water sample measurements included oxygen, nutrients, CFCs, and tritium/helium (the latter were collected through collaboration with William Jenkins of WHOI). Because there were two freon systems aboard, both CFC-11 and CFC-12 were measured at all 24 levels (CFC-113 was measured during the second half of the cruise); tritium/helium was measured at most stations (typically 6-12 levels). At the end of each CTD cast an acoustic transport (POGO) float was dropped to measure the upper layer transport. These data were processed aboard ship and will be used for referencing the geostrophic velocities. Figure 2 shows the POGO vectors for the entire cruise (typically to ~1000 m).

Our plan was to occupy a pre-determined set of sections, and if while doing so we encountered evidence of recently formed water then perform a smaller scale regional survey. It was thus necessary to process both the water sample and CTD data quickly to look for evidence of formation. For each station we routinely plotted salinity, oxygen, CFC-11, silicate, and potential vorticity, all versus depth, potential temperature and potential density. For salinity and oxygen we overlayed the bottle values on the CTD profiles. The CTD calibration coefficients were updated whenever necessary during the cruise based on the bottle comparisons. In addition to these graphs, after each transect was completed we made vertical sections of potential temperature, salinity, potential density, oxygen, CFC-11 and silicate (using the digitized bathymetry from the line scan recorder).

An example of the vertical sections computed during the cruise appears in Figure 3. One can see the striking nature of station 15, which in fact is a lense of newly formed shallow DWBC water (with a very high CFC content) extending to greater than 1000 m. The temperature of the lense is less than 3.2 degrees C and its salinity is less than 34.82 psu, revealing how drastically different this water is upon formation versus a short distance downstream where its properties have moderated to 4-5 degreesC / 34.92-34.94 psu (at a comparable density). This feature is not nearly as striking when viewed as an isolated vertical profile; in fact we did not recognize its significance until the vertical sections were made after completing the transect. Consequently we were too far away to turn the ship around and go back to the feature. However, having learned what to look for we were better prepared when we encountered a similar lense during the next section. This time we performed a detailed XBT survey to define the dimensions of the feature, and then occupied CTD stations within it. A lateral map of temperature at 500 m from the XBT survey is shown in Figure 4. The feature is best described as a chimney-like remnant of recent convection (whose core is only 10-15 km wide) which is being intruded by strong lateral mixing. The chimney is capped, but below the surface it is characterized by almost vertically uniform density.

After completing section 3 we steamed into the central Labrador Sea (continually dropping XBTs to look for evidence of more lenses) where we occupied two CTD stations. The purpose of this was to sample ``classical" Labrador Sea water so as to compare it to the shallow DWBC water observed further south. We did indeed encounter newly ventilated Labrador Sea water with uniform properties to nearly 2000 m (i.e. deep convection). During the steam to port (Reykjavik) we had a lucky break in the weather and were able to occupy a short section across the DWBC south of Cape Farewell.