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Circulation and variability of the North Atlantic Current in the vicinity of the Mid-Atlantic Ridge

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ABSTRACT

Physical observations have been used to describe the circulation and water masses during a cruise whose primary objective was to study the effect of the Mid-Atlantic Ridge on benthic ecosystems at four sites along and across the Ridge between 49°N and 54°N. The cruise observations have been expanded using Argo floats and 16 years of satellite altimeter data to examine temporal variability over months to years. Water masses and transports are consistent with prior observations, showing subtropical water with large mesoscale eddy variability but weak mean eastward flow at the southern sites and cooler, subpolar water with low eddy variability and weak mean westward flow at the northern sites north of the Charlie Gibbs Fracture Zone. An interesting feature was high salinity bottom water at the southern sites, indicating a contribution of Iceland–Scotland Overflow Water mixed southwards through the central rift of the Mid-Atlantic Ridge. Another feature was that 27 Sv ($1\,Sv=10^6\,m^3\,s^{-1}$) eastward transport was mostly in the top 500 m of the water column except at the latitudes of the Charlie Gibbs Fracture Zone where two-thirds of the transport was deeper than 500 m. An intrusion of cold water extended 300 km southwards along a CTD section that paralleled the Mid-Atlantic Ridge, resulting in strong currents over the southern sites. The cold intrusion was flanked by a similar intrusion of warm water extending northwards. Each intrusion was present along the line of the section for about 6 months, controlling the pathway of 10 Sv of transport. Altimeter data reveal many similar intrusions, consisting of or spinning off mesoscale eddies which are slow moving and long lasting, often remaining identifiable near one vicinity for a year or more. Descriptions of the North Atlantic Current as a current with several branches which shift from time to time are a consequence of these long lasting, slowly changing eddies. Thus the North Atlantic Current is best described as a train of near-stationary eddies and meanders with the transport pathways and branching controlled by the slowly varying eddies.

1. Introduction

Mid-ocean ridge environments are some of the least studied areas of the world's ocean ecosystems. Their geographical remoteness and the difficulties associated with sampling rough terrain make them difficult to study. However, it is believed that they harbour unique habitat, species and ecosystems, and as part of the Census of Marine Life, an investigation into the fauna and flora of a section of the Mid-Atlantic Ridge was undertaken.

The ECOMAR project (Ecosystems of the Mid-Atlantic Ridge at the Sub-polar Front and Charlie Gibbs Fracture Zone) was designed to test the hypothesis that the presence of the Mid-Atlantic Ridge has two distinct effects leading to enhanced biodiversity and biomass of mid-ocean deep-sea communities:

(1) The ridge modifies deep-water exchange between the west and east halves of the ocean and in turn influences surface flow, so as to create an area of high primary production and elevated pelagic biomass. This results in enhanced export flux of organic matter to the sea floor and, therefore, greater biomass.
(2) The geomorphology has a direct effect in providing a wide variety of habitats at different depths.

To test the ECOMAR hypothesis, the project chose four sites to study (Fig. 1). Two of these were to the south of the Charlie Gibbs Fracture Zone, and the known influence of the North Atlantic Current (NAC). Two stations were located to the north in the subpolar gyre. Of the two pairs of stations, north and south, one of each pair was located to the west of the Mid-Atlantic Ridge, the

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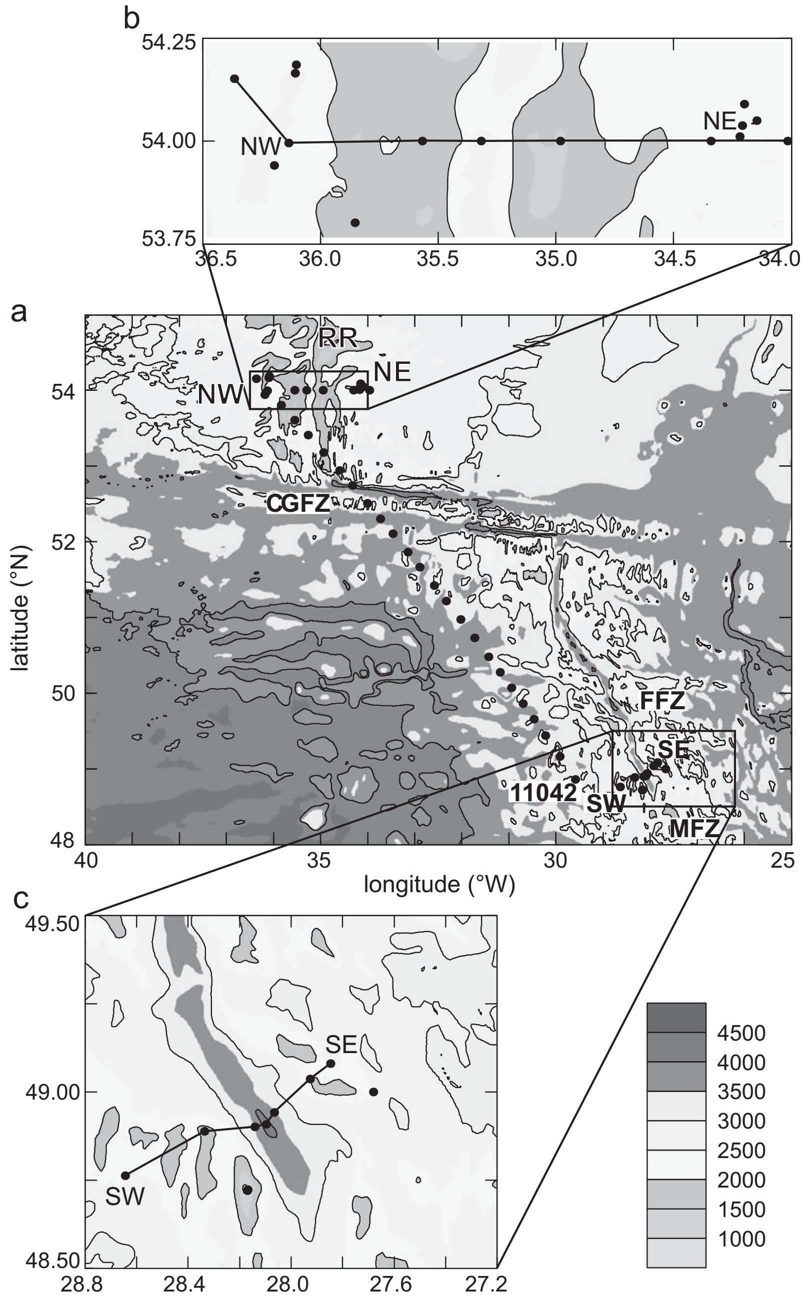

Fig. 1. CTD station positions (dots) during RRS *James Cook* cruise 11 (13 July–18 August 2007). Bathymetry contoured at 1000, 2000, 3000 and 4000 m with additional shading below 3500 m (dark) and above 2000 m (light colour): (a) full cruise survey, (b) enlargement of the two northern sites and (c) enlargement of the two southern sites. CTD profiles used to form sections in Fig. 4 are joined by lines. RR—Reykjanes Ridge, CGFZ—Charlie Gibbs Fracture Zone, FFZ—Faraday Fracture Zone, MFZ—Maxwell Fracture Zone. NW, NE, SW, SE—four study sites, 11042—southern end of western section.

other was situated to the east of the ridge. The exact locations were chosen as functions of depth and seabed topography as suitable locations were required for deep-ocean moorings, bottom trawling and benthic survey work. The target depth was 2500 m. The first investigations into the area took place between 13 July and 18 August 2007 on the RRS *James Cook* cruise 11.

Faunal distributions are significantly influenced by the deep-water circulation across seabed topography (Bullough et al., 1998) and deep-water circulation is connected to the upper ocean, therefore the investigation included studies of the water properties and circulation both at depth and throughout the water column. This paper describes the physical structure and circulation at the time of the cruise from CTD and Argo float data, compares it with previous studies and examines whether it is representative of long-term circulation by comparison with 16 years of satellite altimeter data.

1.1. Background

Between 48°N and 54°N, the Mid-Atlantic Ridge presents a major barrier to the eastward flowing NAC. The flow originates at the western oceanic boundary between 52°N and 54°N (Rossby, 1996). As it extends across the western North Atlantic, the current meanders and separates into several branches in a latitudinal band between 45°N and 53°N (Krauss, 1986). On approaching the Mid-Atlantic Ridge, the branches tend to be topographically steered. This is particularly noticeable with the northern branch,