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Observations of the Faroe Bank Channel overflow using bottom-following RAFOS floats

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Abstract

Overflows do not easily lend themselves to study by Lagrangian floats that remain on a constant isobaric (pressure) or isopycnal (density) surface, since the mixing, entrainment, and descent of an overflow plume result in an increase of the pressure and typically a decrease in the density of the overflow waters. A simple technique to maintain the float's altitude above the bottom was developed, and 12 "bottom-following" RAFOS floats were deployed at or downstream of the sill in the Faroe Bank Channel in the summer of 2000 from the R.S.S. *Discovery*. A technical problem resulted in the majority of the floats becoming stuck to the bottom; nevertheless several floats were able to traverse the Iceland Basin and surface near the southeastern slope of Iceland. These floats made a descent from the mouth of the Faroe Bank Channel, only to shoal along the southern slope of the Iceland-Faroe Ridge before descending again when passing through the northwest corner of the Iceland Basin. Typical current speeds through the Basin were 0.20–0.30 $m\,s^{-1}$, with peaks of 0.40–0.50 $m\,s^{-1}$. Although the floats that were stuck on the bottom provided no trajectory information, they were able to provide a time-series of bottom or near-bottom temperature. In addition, a crude estimate of the flow regime could be made by interpreting the pressure signals from these stuck floats as a response to strong or weak currents. Floats that were bottom stuck near the mouth of the Channel experienced large fluctuations in temperature (0–5 °C) and height of the bottom (and thus presumably speed) on scales from 1 to 4 days. Another float stuck 100 km downstream of the sill underwent temperature and speed excursions on similar time scales, albeit over a smaller range. The behavior of the floats is assumed to be the result of the mesoscale variability of the overflow plume downstream of the Faroe Bank Channel.

1. Introduction

The Faroe Bank Channel is the deepest passage connecting the Nordic Seas to the North Atlantic Ocean, and is 850 m deep at its shallowest, which occurs at a narrow constriction (of only 20 km at the 500 m isobath) between the Faroe Islands and the Faroe Bank (Fig. 1). It is a primary conduit for the equatorward flow of the convectively formed cold and very dense waters that will eventually form part of the Deep Western Boundary Current.

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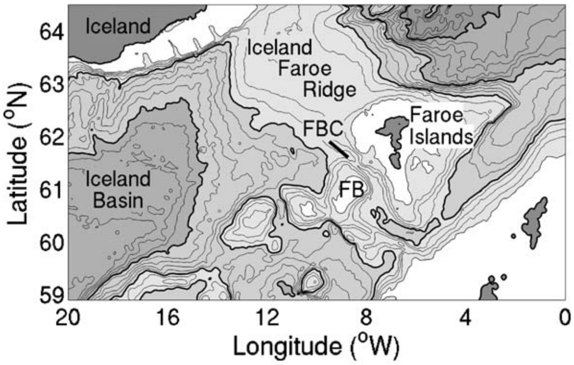

Fig. 1. The Faroe Bank Channel region. "FBC" denotes the Faroe Bank Channel and "FB" marks the Faroe Bank. Scotland and the Shetland Islands are in the lower right. Contours intervals are 200 m, with 1000 m intervals in bold.

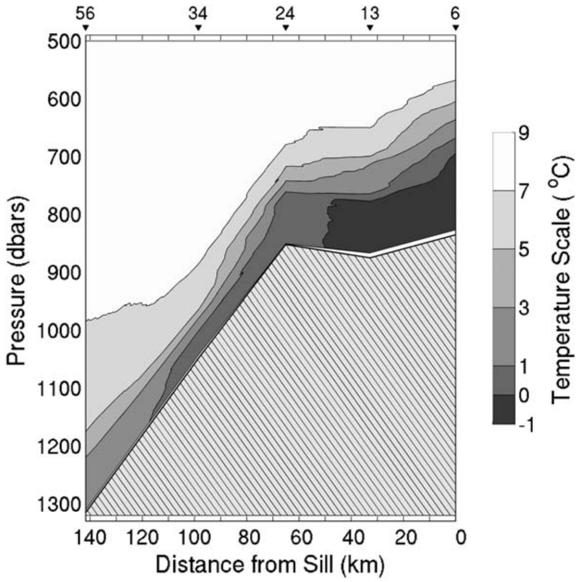

Fig. 2. Non-synoptic section of temperature approximately along the core of the Faroe Bank Channel overflow plume from CTD casts obtained during the June 2000 cruise on the R.R.S. *Discovery*. The stations used were from sections across the plume, and the casts that showed the thickest and coldest plume waters were used. The time interval between the first and last station shown was 5.5 days. (The thickening of the layer below 7 °C and the disappearance of the layer below 1 °C between CTD casts 34 and 56 might resemble the mixing and structure of a hydraulic jump, or could be an indication of the episodic entrainment that blends the waters of the overflow into those of the overlaying North Atlantic waters. We did not have enough observational evidence to validate either hypothesis).

These waters, commonly called Norwegian Sea Water (NSW), are found with salinities of 34.92 and temperatures in the range −0.8 to −0.5 °C (Borenäs and Lundberg, 1988). The channel is oriented (in the sense of the outflow from the Nordic Seas) from southeast to northwest. A transport of NSW of $1.1 \times 10^6\,m^3\,s^{-1}$ has been estimated by Dooley and Meincke (1981), and transports of $1.5–1.9 \times 10^6\,m^3\,s^{-1}$ have been given (Borenäs and Lundberg, 1988; Saunders, 1990) for waters colder than 3 °C. The core of the outflow at the sill is nearly 200 m thick (Fig. 2), and water properties are often homogeneous throughout the bottom 50 m. Core velocities exceed $1.0\,m\,s^{-1}$ (Crease, 1965; Østerhus et al., 1999) and thus water parcels can traverse the 100-km length of the channel in less than 28 h. Bottom stresses of 3.5 Pa have been estimated by Johnson and Sanford (1992). Due to the high velocities and the constraints of the channel and sill, intense mixing and entrainment occurs there and immediately downstream (Borenäs and Lundberg, 2004), changing the water properties of the outflow and blending in those of the overlaying North Atlantic waters.

Classic hydrographic studies on the region typically did not resolve the mesoscale variability of the outflow plume (e.g., Harvey and Theodorou, 1986), and those that did were unable to clearly distinguish waters originating from the Faroe Bank Channel from those of the Iceland-Faroe Ridge (Cooper, 1955; van Aken and de Boer, 1995). Nevertheless, more recent observations clearly indicate that the overflow does not smoothly descend as an idealized "stream-tube" (Smith, 1976; Price and Baringer, 1994; Killworth, 2001), but rather the current shows evidence of instability in the form of meanders and eddy shedding. Saunders (1990) noted that hydrographic sections separated by just days show only coarse agreement. Data from a line of near bottom current meters along 10.83°W were used by Høyer and Quadfasel (2001) to show a train of mesoscale eddies, with a dominating period of 3.5 days. Temperatures and currents varied by 3 °C and $0.50\,m\,s^{-1}$, respectively. The authors used satellite altimetry to show that this was also a region of increased eddy kinetic energy. Lake (2003) pre-