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The East Greenland Current studied with CFCs and released sulphur hexafluoride

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Abstract

The distribution and evolution of water masses along the East Greenland Current (EGC) from south of the Fram Strait to the Denmark Strait were investigated using chlorofluorocarbons (CFCs) and the released tracer sulphur hexafluoride (SF_6) together with hydrographic data. Water masses contributing to the Denmark Strait overflow, and to some extent also contributions to the Iceland–Scotland overflow, are discussed from observations in 1999. Special emphasis is put on the advection and mixing of Greenland Sea Arctic Intermediate Water (GSAIW), which could be effectively traced thanks to the release of sulphur hexafluoride in the Greenland Sea Gyre in 1996. By means of the dispersion of the tracer, Greenland Sea Arctic Intermediate Water was followed down to the Denmark Strait Sill as well as close to the Faroe–Shetland Channel. The results indicate that this water mass can contribute to both overflows within 3 years from leaving the Greenland Sea. The transformation of Greenland Sea Arctic Intermediate Water was dominated by water from the Arctic Ocean, especially by isopycnal mixing with upper Polar Deep Water (uPDW) but, to a less extent, also by Canadian Basin Deep Water. A mixture of Greenland Sea Arctic Intermediate Water and upper Polar Deep Water was lifted 500 m on its way through southwestern Iceland Sea, to a depth shallow enough to let it reach the sill of the Denmark Strait from where it can be incorporated in the densest layer of the overflow. The observations show contributions to the Denmark Strait overflow from both the East Greenland Current and the Iceland Sea.

Keywords: Tracers; Overflow; Intermediate water masses; Deep-water masses; Chlorofluorocarbons; Sulphur hexafluoride; Nordic Seas; East Greenland Current; Greenland Sea; Denmark strait

1. Introduction

The Nordic Seas, the generic term for the Greenland, Iceland and Norwegian seas, are important in the global thermohaline circulation, as they are a region

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where the ocean loses heat to the atmosphere and surface water loses enough buoyancy to convect away from the surface. The less dense portion of the descended water can flow south and across the Greenland–Scotland Ridge into the North Atlantic, where it makes up a considerable part of North Atlantic Deep Water. The importance of this process for the global thermohaline circulation has drawn large attention to the Nordic Seas and to the water masses and mechanisms that create the overflow water. Different sources of the overflow are reported (Swift et al., 1980; Smethie and Swift, 1989; Strass et al., 1993; Buch et al., 1996; Mauritzen, 1996; Jónsson, 1999; Rudels et al., 1999a, 2002; Fogelqvist et al., 2003) and there is still debate on the importance of different regions, water masses and processes. These divergent opinions can partly be explained by a variable composition of the overflow and recent reports on ongoing decadal changes (Dickson et al., 2002; Rudels et al., 2003).

Our investigations took part in summer 1999, mainly in the East Greenland Current (EGC) from 77°N to south of the Denmark Strait (Fig. 1). A major task was to map the compound sulphur hexafluoride (SF_6), which was released in the central Greenland Sea 3 years earlier (Fig. 1) as part of the EU/MAST III project European Subpolar Ocean Programme, phase 2 (ESOP-2), dedicated to investigate the thermohaline circulation in the Greenland Sea (Messias et al., 1999). Additional results from the tracer experiment are presented by Watson et al. (1999) and Gascard et al. (2002). Sulphur hexafluoride has been utilised as a deliberately released tracer in a range of studies (see the review by Watson and Ledwell, 2000). In addition to this, SF_6 has recently been used as a transient tracer (Law and Watson, 2001; Tanhua et al., 2004) in the

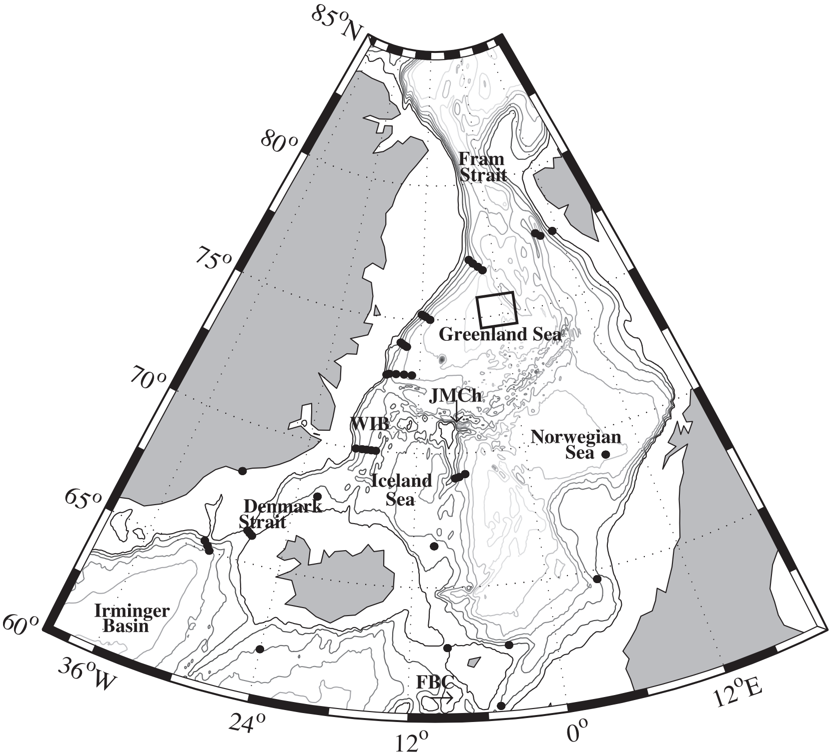

Fig. 1. Bathymetric map of the Nordic Seas with every 500 m represented by an isoline. The dots mark the locations of the stations sampled during the cruise with R/V Marion Dufresne in 1999. The black rectangle marks the area where 320 kg of SF_6 was injected in 1996. The compound was injected at a defined density level, σ_θ 28.049 kg m^{-3}, with an average depth of 330 m. (Abbreviations: JMCh—Jan Mayen Channel, WIB—West Iceland Basin, FBC—Faroe Bank Channel).