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Liquid freshwater transport and Polar Surface Water characteristics in the East Greenland Current during the AO-02 *Oden* expedition

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ABSTRACT

Dynamical features of the East Greenland Current (EGC) are synthesized from a survey conducted by the Swedish icebreaker *Oden* during the International Arctic Ocean – 02 expedition (AO-02) in May 2002 with emphasis on the liquid freshwater transport and Polar Surface Water. The data include hydrography and lowered acoustic doppler current profiler (LADCP) velocities in eight transects along the EGC, from the Fram Strait in the north to the Denmark Strait in the south. The survey reveals a strong confinement of the low-salinity polar water in the EGC to the continental slope/shelf—a feature of relevance for the stability of the thermohaline circulation in the Arctic Mediterranean. The southward transport of liquid freshwater in the EGC was found to vary considerably between the sections, ranging between 0.01 and 0.1 Sverdrup. Computations based on geostrophic as well as LADCP velocities give a section-averaged southward freshwater transport of 0.06 Sverdrup in the EGC during May 2002. Furthermore, *Oden* data suggest that the liquid freshwater transport was as large north of the Fram Strait as it was south of the Denmark Strait.

1. Introduction

Some 5–8 Sverdrup (Sv; 1 Sv = 1×10^6 m^3 s^{-1}) of warm Atlantic water enter the Arctic Mediterranean over the Greenland–Scotland Ridge (Hansen and Østerhus, 2000). As the Atlantic water circulates through the Arctic Mediterranean, it loses heat to the atmosphere and becomes less saline due to freshwater input. The action of these two transformation processes separates the Atlantic water into two circulation loops (cf. Rudels, 1995; Mauritzen, 1996). The major deep loop is determined mainly by the cooling occurring in the Norwegian Sea and the Barents Sea, which increases the density of the Atlantic water. This loop creates the dense deep waters of the Arctic Mediterranean and supplies the overflow water to the North Atlantic. The second weaker surface loop is dominated by the river runoff to and the melting of sea ice in the Arctic Ocean, forming the low salinity, less dense Polar Surface Water. After following several and different circulation paths in the Arctic Mediterranean the waters of the two loops join the East Greenland Current in and north of Fram Strait. The less dense surface loop, augmented with Pacific Water from the Bering Strait (Jones et al., 1998), forms a low-salinity wedge near the coast above the denser water masses of the deep loop. The interaction between the two loops is limited but not absent. Ice formation in lee polynyas on the Arctic Ocean shelves may, through brine rejection, create waters saline and dense enough to supply the deeper loop, and the open ocean convection in the Greenland and Iceland Sea can bring low-salinity surface water, detached from the East Greenland Current, into the deep.

The Arctic Mediterranean receives a freshwater input of about 0.28 Sv, which originates from river runoff (0.13 Sv), net precipitation (0.06 Sv), and inflow of low-salinity Pacific water through the Bering Strait (0.09 Sv) (see Aagaard and Carmack, 1989; Dickson et al., 2007, and references therein). The freshwater supplied to the Arctic Mediterranean is exported to the North Atlantic west and east of Greenland, through the Canadian Arctic Archipelago and across the Greenland–Scotland Ridge, respectively. The freshwater transport east of Greenland is about 0.19 Sv of which 0.05 Sv is carried by the dense overflow waters (Dickson et al., 2007).

The freshwater in the EGC—should it enter the central Greenland Sea—has the potential to decrease the surface density and thus reduce the convective activity and the associated deep-water production, hereby curtailing or disrupting the thermohaline exchange over the Greenland–Scotland Ridge (Stigebrandt, 1985). Thus, the transport and horizontal mixing of freshwater in the EGC are important for the operation and stability of the thermohaline circulation in the Arctic Mediterranean and the Nordic Seas

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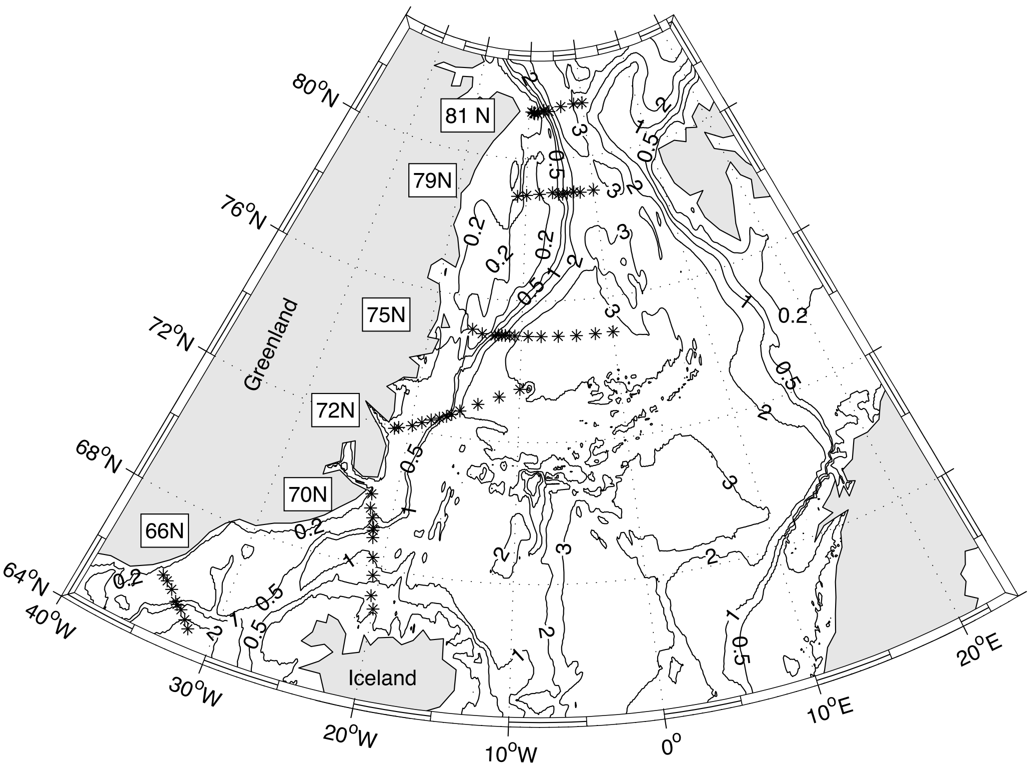

Fig. 1. Map of the hydrographic stations of the AO-02 expedition that are analyzed in the present study; see Rudels et al. (2005) for a detailed description of the AO-02 hydrography measurements. The latitude labels refer to the latitude of the westernmost station of the sections. Depth contours are given in km.

(Aagaard and Carmack, 1989; Strass et al., 1993; Marotzke, 2000; Rahmstorf, 2000; Curry and Mauritzen, 2005).

It should be underlined that the freshwater budget of the Arctic Mediterranean remains relatively poorly known. To some extent, this reflects the difficulty to monitor the freshwater transport in the EGC, where severe ice conditions makes it difficult to conduct direct measurements. Thus, a key aim of the present work is to investigate the freshwater transport in the EGC on the basis of hydrographic and LADCP data collected during the Swedish Arctic Ocean Expedition 2002 (AO-02); see Rudels et al. (2005) for an overview of the physical oceanography of the AO-02. The measurements in the EGC were taken onboard the icebreaker *Oden* in May 2002. During the first half of May 2002, cold and clear weather conditions prevailed: despite the presence of the midnight sun, daily-mean air temperatures were below −10 °C and new ice was forming over the open leads. During the latter part of May, the temperatures were less harsh but the ice conditions remained severe in the EGC even south of the Denmark Strait. Thus, the present data set provides a unique picture of the late-winter conditions in the EGC all the way from north of the Fram Strait to south of the Denmark Strait; see Fig. 1.

2. Data and methods

The CTD system used during the AO-02 expedition was a Sea Bird 911+ instrument mounted on a 24-bottle rosette. For calibration purpose, salinities were measured onboard with a Guidline 8400B Autosal. Currents were measured by an acoustic doppler current profiler (LADCP), which was attached to the rosette sampler and equipped with dual (upward and downward looking) 300-kHz RDI Workhorse ADCPs.

The raw LADCP data were processed using an inverse technique described in Visbeck (2002) and de-tided by subtracting the barotropic tidal velocity as computed by a high-resolution (5 km) barotropic inverse tidal model (Padman and Erofeeva, 2004). The errors associated with the tidal model are primarily related to the errors of the input bathymetry. In the two northernmost sections the relative difference between the tidal-model bathymetry and measured depth was as high as 70% at a few stations; in the more southerly sections the relative differences did not exceed 25% and were generally on the order of 10%. We estimate that relative error of the tidal-model velocities are roughly proportional to the relative error of the tidal-model bathymetry. The maximum tidal amplitudes in the sections range between 4 and 8 cm s^{-1}, except for in 70 °N section where the tidal amplitude reaches 15 cm s^{-1}. Except for in the two northernmost sections (where the errors are larger), we estimate the tidal-model errors to be less than 3 cm s^{-1} on the shelf, decreasing to 1–2 cm s^{-1} offshore of the shelfbreak.

To analyze the freshwater transport, it is instructive to compute how the volume transport in the EGC are distributed between different salinities. For this purpose, we define a cumulative volume transport function with respect to salinity (Walin, 1977, 1982)

$$M(S) = -v(x,y,z)H[S - S_0(x,y,z)]\,\mathrm{d}x\,\mathrm{d}z, \tag{1}$$

where $v(x,y,z)$ is the velocity component normal to the section (counted positive when directed towards the Arctic), $S_0(x,y,z)$ the measured salinity, and H a unit step function; the integral covers a given section. As defined here, $M(S)$ gives the net southward transport of waters having salinities less than S in a chosen section of the EGC. Further, we define a cumulative area function $A(S)$ according to

$$A(S) = H[S - S_0(x,y,z)]\,\mathrm{d}x\,\mathrm{d}z, \tag{2}$$

which represents the area occupied, on a given section, by water having a salinity less than S. We also introduce a mean-velocity measure defined as

$$\bar{v}(S) = M(S)/A(S), \tag{3}$$

which is the mean velocity of the water having a salinity less than S.