The East Greenland Current South of Denmark Strait

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1 Introduction

Along the East Greenland Shelf Break to the south of Denmark Strait there exists a sharp hydrographic front separating cold and fresh Arctic-origin water from warm and salty Atlantic-origin water (Figure 1). This front and its associated jet - known as the East Greenland Irminger Current - is one of the main routes by which fresh water and intermediate density Arctic water is advected southwards into the North Atlantic.

It has been long established that the front and its jet are both highly variable in time and unstable, with lenses of Irminger Water being observed on the inshore side of the front as early as 1930 (Defant). Such cross-frontal exchange with the open Atlantic may be driven either by strong down-front barrier winds adjacent to the Greenland Plateau, or by baroclinic instability of the boundary current.

In the period 2001-2007, four high resolution hydrographic/velocity sections were made during summer across the shelf and continental slope close to 66°N (Figure 2). These were designed to resolve the detailed cross-stream structure of the boundary current for the first time and to determine the shelf-basin exchange processes taking place.

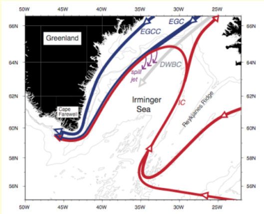

Figure 1: Boundary currents of the Irminger Sea. IC = Irminger Current; EGC = East Greenland Current; DWBC = Deep Western Boundary Current, along with the Spill Jet.

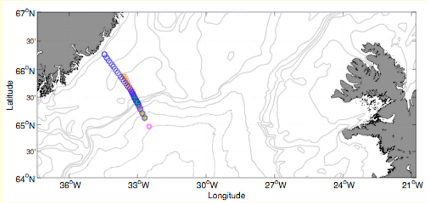

Figure 2: Positions of the hydrographic stations occupied during the four crossings of the boundary current: 2001 (red triangles), 2003 (purple squares), 2004 (blue circles), 2007 (green crosses).

2 Structure of the Boundary Current System

From the four occupations, mean sections of potential temperature, salinity and absolute geostrophic velocity were constructed. The EGC/IC can be identified as a strong surface intensified current flowing equatorward close to the shelf break, whilst the DWBC is seen near the base of the continental slope. A third component of the boundary current system, first identified in a single section by Pickart et al. (2005), is a bottom-intensified velocity maximum in the vicinity of the shelf break and upper slope. This "Spill Jet" (Figure 3) is thought to formed by dense water on the outer shelf cascading over the shelf break onto the upper slope, providing a route by which Arctic-origin water can enter the interior of the basin. The cross-shelf exchange process appears to be two way, with warm and salty lenses of Irminger Water observed shoreward of the main front in all four years. The Spill Jet itself also appears to be a persistent feature, being observed in all four occupations with a volume transport as large or larger than the DWBC at this latitude (Table 1).

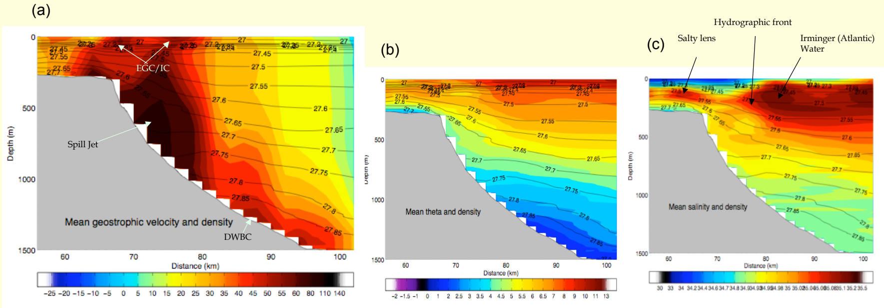

Figure 3: Mean vertical sections of (a) absolute geostrophic velocity (cm/s), referenced to vessel-mounted ADCP and overlain by potential density (kg/m³), (b) potential temperature (°C) overlain by potential density and (c) salinity overlain by potential density.

3 Transports and Variability

Substantial variability occurs in both the position of the boundary current components and their transport between the individual section occupations (Table 1). For instance, in 2003 the hydrographic front was located far onshore allowing warm subtropical-origin water to penetrate onto the shelf and shifting the Spill Jet onto the outer shelf (Figure 4a). By contrast, in 2004 the hydrographic front resided much further offshore (Figures 4b/c) and the extremely steep isopycnal slope at the shelf break leads to a very strong Spill Jet (peak velocities exceed 150 cm/s). Nevertheless, the feature is very narrow (<20 km).

	IC/EGC	SPILL JET	DSOW
2001*	11.7	1.9	6.0
2003	12.3	1.9	6.0
2004	7.0	8.9	5.6
2007	3.3	4.6	1.6
Mean±standard error	8.6±2.1	4.3±1.7	4.8±1.1

*Figures from Pickart et al. (2005)

Table 1: Volume transports by year (Sv).

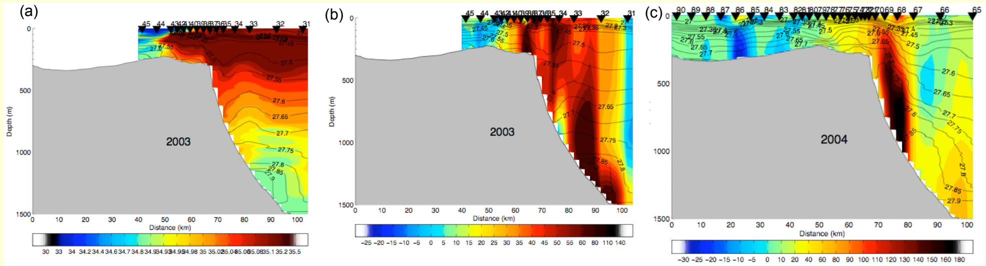

Figure 4: (a) Salinity for 2003 with potential density contours overlain (kg/m³); (b) absolute geostrophic velocity (cm/s) for 2003 with potential density contours (kg/m³) overlain; (c) absolute geostrophic velocity (cm/s) for 2004 with potential density contours (kg/m³) overlain.

4 Vorticity and Mixing

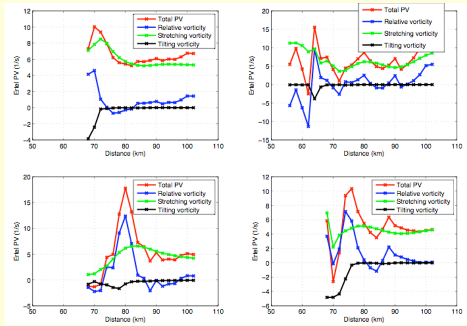

Figure 5: Total potential vorticity (red) and its components in the depth range of the Spill Jet for 2001 (top left), 2003 (top right), 2004 (bottom left) and 2007 (bottom right).

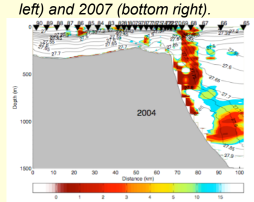

Figure 6: Gradient Richardson Number for the 2004 occupation. Dark red areas denote regions where Ri <1.

The Ertel potential vorticity was determined for the boundary current system:

$$\Pi = -f/\rho_0\, \partial\sigma_\theta/\partial z \;+\; 1/\rho_0\, \partial u/\partial y\, \partial\sigma_\theta/\partial z \;-\; g/\rho_0^2 f\, (\partial\sigma_\theta/\partial y)^2$$

stretching term   relative vorticity   tilting term

In each of the four occupations, the total PV changes significantly in the vicinity of the Spill Jet. In 2004, where the Spill Jet is particularly narrow and strong, the strong anticyclonic and cyclonic vorticity associated with the feature means that the relative vorticity dominates the total PV (its magnitude is 2.5 times that of the stretching term). In addition, the Charney-Stern requirement for baroclinic instability - that there is a change in the sign of the total PV gradient within the domain - is met in all four years, implying that the cross-frontal exchange may be driven by baroclinic instability.

As the cold and fresh Arctic-origin water spills over the shelf at this location, there is evidence that it mixes vigorously with the warm and salty Atlantic-origin water. In 2004, the gradient Richardson number was less than 1 over almost the entire water column within the Spill Jet. This mixing is thought to alter the density structure of the East Greenland Current as it flows towards Cape Farewell.

In September 2007, an array of profiling CTDs with ADCPs were deployed along this section. The instruments were successfully recovered in October 2008 and the data they have collected will help to determine the seasonal variability of the Spill Jet, the role of wind forcing in driving dense water off the shelf and the nature of the mixing (including double diffusion) which sets the density structure of the downstream flow.

References and Acknowledgements

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