Report of
Freshwater fluxes through Fram Strait
(preliminary results)

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Introduction

The transport of fresh and cold polar water southward through Fram Strait within the East Greenland Current (EGC) is a major, if not the main, oceanic pathway of freshwater entering the North Atlantic. A freshwater layer can close down deep convection in the sub polar gyres and hence influence the meridional overturning cell, also known as the Global Conveyer Belt. Rapid climate change can therefore be triggered by large freshwater anomalies. For the understanding of global climate knowledge of the magnitude and variability of the freshwater transport is therefore indispensable. The Norwegian Polar Institute (NPI) has been making regular measurements in Fram Strait using moorings and hydrography since 1990. Starting in 2003 within the ASOF program, the focus is now on freshwater flux. Here we present a first estimate of the liquid fresh water flux from these data. As transports in the EGC are mostly southward, we will use the notation of positive transports being towards the south.

Data

Since 1990 NPI has monitored the EGC at about 79°N using moored instruments. A continuous monitoring array of four moorings across the EGC have been in regular operation since fall 1997. During this years regular CTD surveys were also carried out. This report focuses on the most recent data (1999-2003), although the errors of the 2000 to 2002 period are larger due to instrument loss. Work is in progress to analyze the whole data set including estimates of ice transport, which are still not done, as the ice thickness data is still not fully processed.

Hydrography and geostrophic transports

An extensive hydrographic survey was carried out in Fram Strait in September 2003 (see insert in figure 4). The main section across Fram Strait shows (figure1) the cold and low salinity Polar Water on the East Greenland Shelf in the western part of the section. At the upper eastern part the warm and saline Atlantic Water flows northward into the Polar Ocean. After a journey through the Arctic, some of this water returns, transformed into colder and lower salinity Arctic Atlantic Water, which can be seen at the Greenland shelf break up to depths of about 1200m. The third water mass flowing south within the EGC is Atlantic Water which recirculates within Fram Strait, the rAW. Its characteristics are not as extreme as the inflowing AW, but is also characterized by high salinity and temperature, seen here at about 3°W and 250m depth.

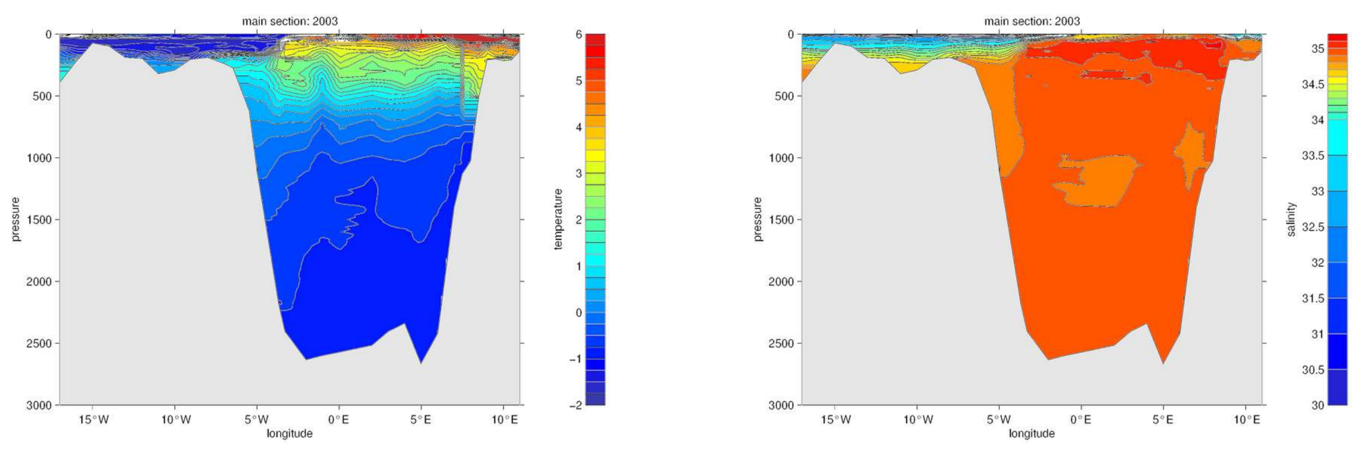
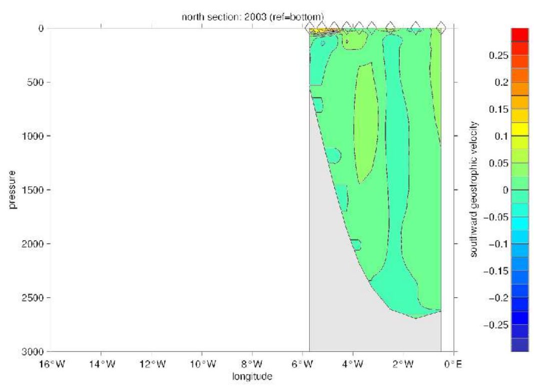


Figure 1: Temperature (left) and salinity (right) section across Fram Strait at about 79ºN in September 2003.

Mass transport in the ocean is mostly in form of pure water, which is the essence of the freshwater transport. More interesting is the net freshwater transport in or out of a bounded region, as this relates to evaporation, precipitation and river runoff and changes of the total salinity content (zero in the steady state case) of this region. To use this concept also for a single section, the freshwater transport across a section is defined as the net mass transport, after compensating the salt transport across the section with a transport of water with a certain reference salinity. We use a, in this region characteristic value of 34.9 as reference salinity. The geostrophic calculations are done using a level of no motion at the bottom, respective at the deepest common depth of each station pair. This should lead to an understimate of the southward transports in the western Fram Strait and an underestimate of the northward transports in the eastern part. In 2003 the southward geostrophic transports across the whole Fram Strait were 5.2 Tgs^{-1} for mass, -8.5 TW for heat, 180 Ggs^{-1} for salt and 1200 km^3/year for freshwater. In the following we will just consider only the transports in the western part of Fram Strait, where most of the freshwater transport takes place.

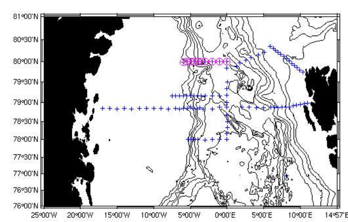
All zonal sections of 2003 seem to catch the main core of the EGC (figures 2,3,4,5), as the total transport relative to the bottom is very similar. The freshwater transport is larger at the wider sections, most probably due to the inclusion of larger portions of the shelf. Although the velocities west of the EGC core are not large, their direction is mainly southward and the salinity is very low, leading to a larger southward freshwater transport.

Figure 2: Geostrophic transports of the 2003 northern section at 80º00'N referenced to the bottom.



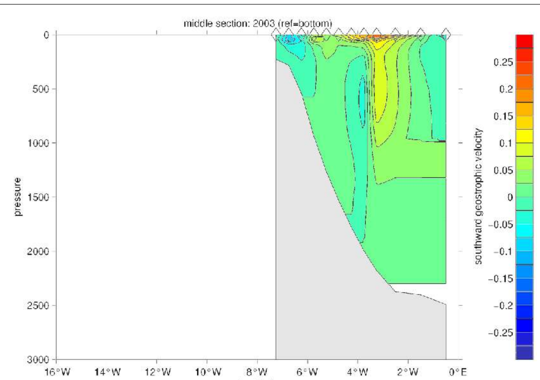
Section of southward geostrophic velocity relative to the bottom.

Variable	Transport
Mass	2,36 Tgs^{-1}
Salt	81,5 Ggs^{-1}
Freshwater	900 km^3/year



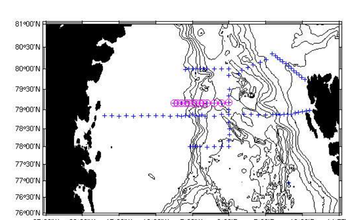
Map of the CTD station used.

Figure 3: Geostrophic transports of the 2003 north-mid section at 79º10'N referenced to the bottom.



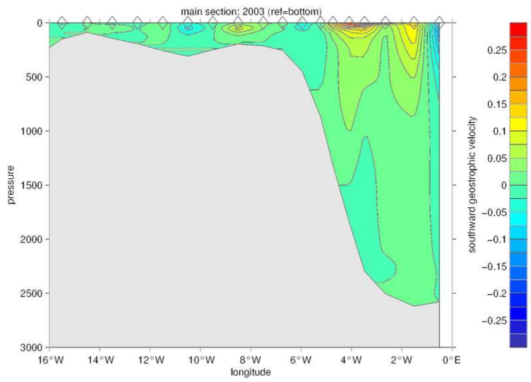
Section of southward geostrophic velocity relative to the bottom.

Variable	Transport
Mass	2,83 Tgs^{-1}
Salt	97,6 Ggs^{-1}
Freshwater	1200 km^3/year



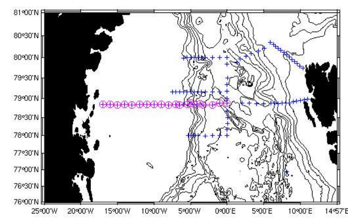
Map of the CTD station used.

Figure 4: Geostrophic transports of the 2003 main section at 78º50'N referenced o the bottom.



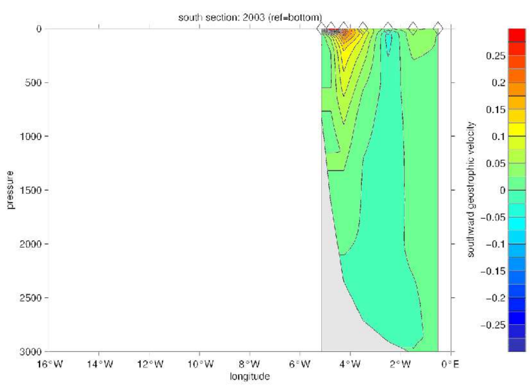
Section of southward geostrophic velocity relative to the bottom.

Variable	Transport
Mass	2,84 Tgs^{-1}
Salt	97,4Ggs^{-1}
Freshwater	1400 km^3/year



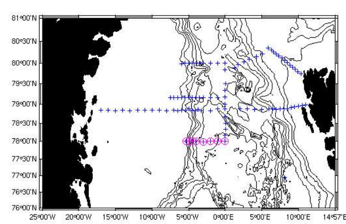
Map of the CTD station used.

Figure 5: Geostrophic transport of 2003 southern section at 78º00'N, referenced to the bottom.



Section of southward geostrophic velocity relative to the bottom.

Variable	Transport
Mass	3,15 Tgs^{-1}
Salt	109,3 Ggs^{-1}
Freshwater	500 km^3/year



Map of the CTD station used.

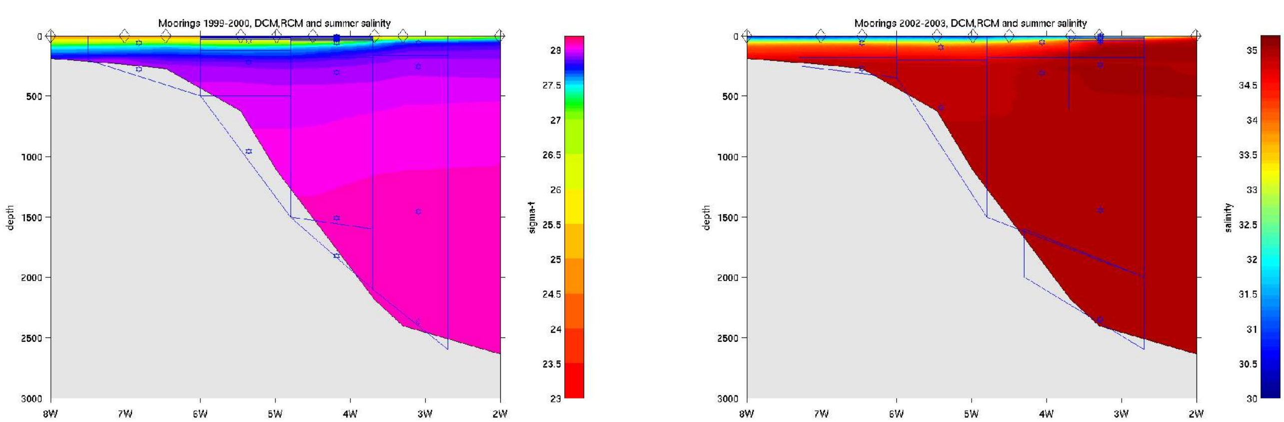


Figure 6: Sections of density (left) and salinity (right) from the 2003 CTD survey. Overlayed are the positions of the current meters (RCM and DCM) and the boxes representing the areas for the transport calculations (left for 1999-2000, right for 2002-2003).

Mooring transports

A first estimate of the transports from the mooring data was made assuming representative areas around each current measurement (see figure 6) and using only the velocity measurement from the moorings. The salinities from the moorings are not used, as these measurements did not cover the uppermost low salinity layer due to danger from ice. The mean salinity in these boxes were calculated using the monthly data from the World Ocean Atlas (¼º resolution), and, for comparison with the geostrophic transports, also with the summer 2003 salinities.

Table 1: Estimates of mass (in Tgs^{-1}), salt (in Ggs^{-1}) and freshwater (in km^3/year) transport from mooring data. The mean value (in parenthesis the median) is given for the respective calculations and days.

Year, instruments,salinity	***days***	***Mass***	***Salt***	***Freshwater***
1999-2000 RCM, WOA	325	3.4 (3.7)	118 (127)	515 (475)
1999-2000 RCM+DCM, WOA	325	3.4 (3.7)	119 (128)	555 (525)
1999-2000 RCM+DCM, summer	325	3.4 (3.7)	119 (127)	1135 (965)
2000-2002 RCM, WOA	753	3.4 (3.6)	117 (126)	350 (330)
2000-2002 RCM+DCM, WOA	653	3.6 (3.8)	125 (132)	575 (410)
2000-2002 RCM+DCM, summer	653	3.6 (3.8)	125 (131)	910 (945)
2002-2003 RCM, WOA	370	3.9 (3.6)	134 (126)	525 (460)
2002-2003 RCM+DCM, WOA	370	3.9 (3.7)	135 (128)	560 (490)
2002-2003 RCM+DCM, summer	370	3.9 (3.7)	145 (127)	910 (925)

The moorings also included some DCM current meters, which acoustically measure the velocity in 5 bins between deployment depth (usually less then 50m) and the surface. Including the available DCM data (one in 2002-2003, one in 2000-2002 and two in 1999-2000) the freshwater transport is larger then using only RCM data. The salinity decreases towards the surface, and the geostrophic velocity increases towards the surface in the current core (see figures). In the course of a year the core also reaches the mooring position. The higher near surface velocities together with the lower salinity at the surface are the reason for the higher freshwater transport.

The mean value over the 1763 days of available freshwater transport (figure 8) estimates are 433±590 km^3/year using WOA and RCM and 565±526 km^3/year including DCM data. Using the summer salinity and RCM the transport is 736±735 km^3/year and including DCM data is 964±693 km^3/year. The volume transport is larger than in the geostrophic calculations, demonstrating that the geostrophic calculations are missing (as expected) part of the southward barotropic flow. The summer freshwater transports however are comparable to the geostrophic calculations, although when including larger parts of the shelf the geostrophic transports are somewhat larger. From the water mass characteristics we expect a southward flow on the shelf, the mooring estimates are therefore probably biased low. For a better estimate moorings on the shelf are essential.

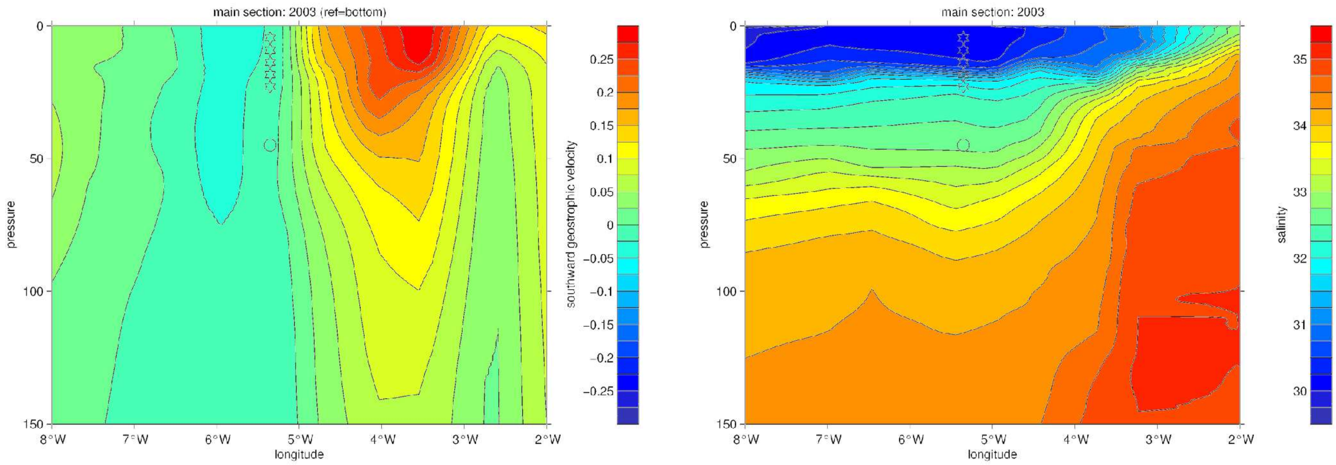


Figure 7: Sections of near surface velocity (left) and salinity (right) from the September 2003 cruise along the mooring line. Hexagons show the mean depth of the DCM current measurements and the circle the mean depth of the RCM (all for 1999-2000 period and mooring F13).

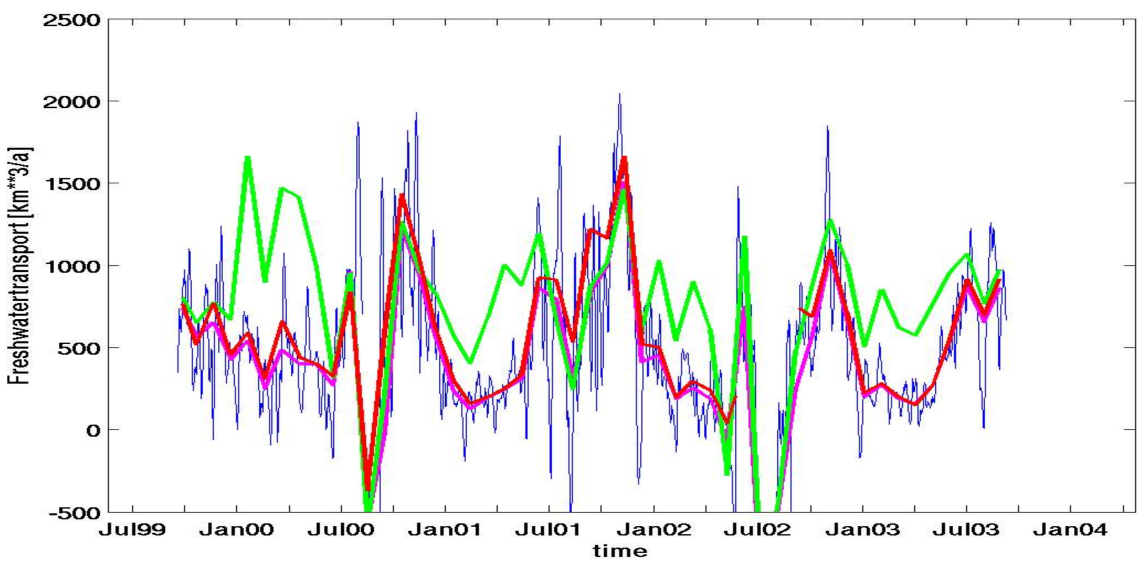


*Figure 8: F*reshwatertransport as a function of time. The blue line gives the daily values using WOA salinities and only RCM data. The magenta line is a mean over 30 days of this data. The red line is the 30 days mean including DCM data and the green line is the transport using summer salinities and only RCM data.

Conclusion

The calculations presented here have large uncertainties. The geostrophic freshwater transport values are biased high since we are using the low near surface salinity values from summer and are biased low because they miss part of the barotropic velocity component . The mooring calculations are biased low because they are still missing the shelf region and some of the stronger currents near the surface. As this is ongoing work, the transport estimates will get more reliable in near future. For the moment we can hope that the low and high biases cancel out. Our best estimate, with a large error bound, of the liquid southward freshwater transport of the EGC in Fram Strait is therefore 1000 $km^{3/}$year or 0.0317 Sv.