THE FRESHWATER TRANSPORT WITHIN THE EAST GREENLAND CURRENT

J. Holfort and E. Hansen
Norwegian Polar Institute (holfort@npolar.no)

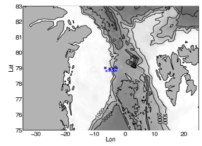
Introduction

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.

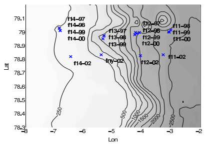
The Norwegian Polar Institute (NPI) has been making regular measurements in Fram Strait using moorings and hydrography since 1990. Starting in 2003 within the ASOF program, the focus is now on freshwater flux. In this poster we present an estimate of the liquid fresh water flux from these data.

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 poster 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.

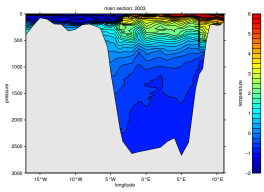


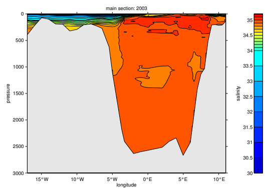
Study area and mooring positions (crosses). The numbers in mooring names indicate the year of deployment. All moorings have several instruments to measure currents, temperature and salinity. In addition many moorings also have an upward looking sonar to measure ice thickness.

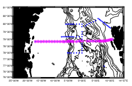


Hydrography and geostrophic transports

An extensive hydrographic survey was carried out in Fram Strait in September 2003. The main section across Fram Strait shows 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.



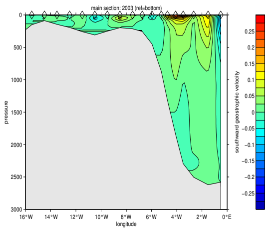


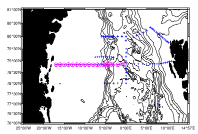


Temperature (left) and salinity (right) section across the Fram Strait. Positions of the used CTDs are marked as magenta circles in the map. The table gives the total geostrophic transports relative to the bottom. The mass compensated heat transport is 8.5TW into the Arctic ocean. Using only the Bering Strait salt inflow (0.8Sv*34.5) to close the Arctic Freshwater Budget, the net outflow through Fram Strait amounts to 380 $km^3 year^{-1}$.

Variable	Transports ²
Mass	5.19
Salt	179.8
Freshwater¹	1200

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.
All sections seem to catch the main core of the EGC, 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.



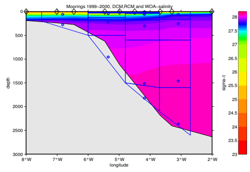


Section of the geostrophic velocity relative to the bottom at about 78º50'N (see map) and a table of the associated transports of different sections across the EGC (from the westernmost station to approximately 0°W).

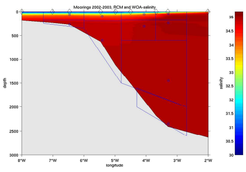
Hydrographic Section	Transports ²		
	Volume	Salt	Freshwater
80°00'N section 2003	2,36	81,5	900
79°10'N section 2003	2,83	97,6	1200
78°50'N section 2003	2,84	97,4	1400
78°00'N section 2003	3,15	109,3	500

Mooring transports

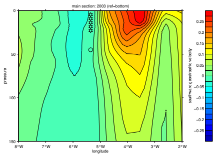
A first estimate of the transports from the mooring data was made assuming representative areas around each current measurement (see figures) and using only the velocity measurement from the moorings. The salinities from the moorings are not used, as these measurements did not cover the uppermost low 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 summer 2003 salinities.

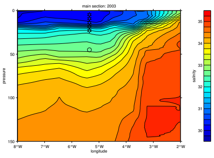


Sections of density (upper) and salinity (lower) from the CTD survey in September 2003. Overlayed are the positions of the current meters and the boxes representing the areas for the transport calculations. On the left the 1999-2000 deployment period, on the right the 2002-2003 period.

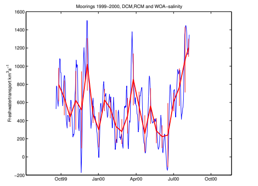


Sections of the near surface geostrophic velocity (left) and salinity (right) from the September 2003 cruise along the mooring line. Hexagons shows the mean depth of the DCM current measurements, the circle shows the RCM position for the 1999-2000 period (mooring F13).

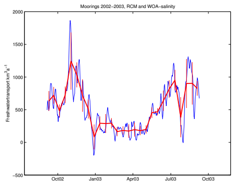




The moorings also included some DCM current meters, which acoustically measure the velocity in 5 bins between deployment depth (usually less then 50m) and the surface. Including the available DCM data (1 in 2002, 2 in 2000) the freshwater transport is larger then using only RCM data. The salinity decreases 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 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 transport however is 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.



Time series of the freshwater transport including DCM measurements in 1999-2000 (left) and 2002-2003 (right). The blue curve are daily values, the red curve is a smoothed version. The lower winter values are mostly due to higher salinity in the uppermost water column..

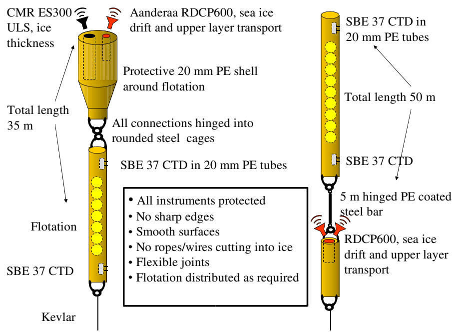


Mooring line	Transports ²		
	Volume	Salt	Freshwater
1999-2000 only RCM, summer salinity	3.4 (3.7)	120 (130)	780 (1260)
1999-2000 only RCM, WOA salinity	3.4 (3.7)	120 (130)	510 (470)
1999-2000 RCM+DCM, WOA salinity	3.6 (3.7)	120 (130)	550 (520)
2000-2002 RCM+DCM, WOA salinity	3.6 (3.8)	120 (130)	600 (420)
2002-2003 only RCM, summer salinity	3.8 (3.6)	130 (120)	700 (800)
2002-2003 only RCM, WOA salinity	3.8 (3.6)	140 (120)	530 (460)

Further work

1- instead of using fixed boxes we will map the mooring velocities onto the geostrophic velocity field for the transport integration
2- include the time dependent temperature and salinity information in a similar fashion
3- better resolve the structure in the upper 100m, starting in 2003 we incorporated “tube moorings” in the mooring array.
4- extend the measurements onto the shelf, which was also started in 2003.
5- for a better mapping of hydrographic information with the moorings a winter section is planned, hopefully in early 2005.

Schematic diagram of “tube moorings”, which are designed for deployment in regions with the possibility of contact with drifting ice and smaller icebergs. The first of such moorings were deployed in 2000 at 63°N and 74°N from the IfM Hamburg and proved to be reliable.



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 $km^3 year^{-1}$.

1) Freshwater transports are relative to a salinity of 34.9
2) Positive transports are to the south. Volume transports are given in Sv ($10^6 m^3 s^{-1}$), mass transports in Tgs^{-1}, salt transports in Ggs^{-1} and freshwater transports in $km^3 year^{-1}$. If two values are given the first is the temporal mean and the second in parenthesis is the temporal median.

This research was supported by the Norwegian Polar Institute and the European Commissions Fifth Framework Program, project ASOF-N .