WP 3.4 Output to the North Atlantic and global circulation

E. Hansen[1], R. Gerdes[2], F. Hacker[2], K. Haines[3], C. Köberle[2], M. Marnela[4], R. Mugford, B. Rudels[4], G. Smith[3] and L. de Steur[1]

[1]Norwegian Polar Institute, [2]Alfred-Wegener-Institut für Polar- und Meeresforschung, [3]Reading University, [4]Finnish Institute of Marine Research

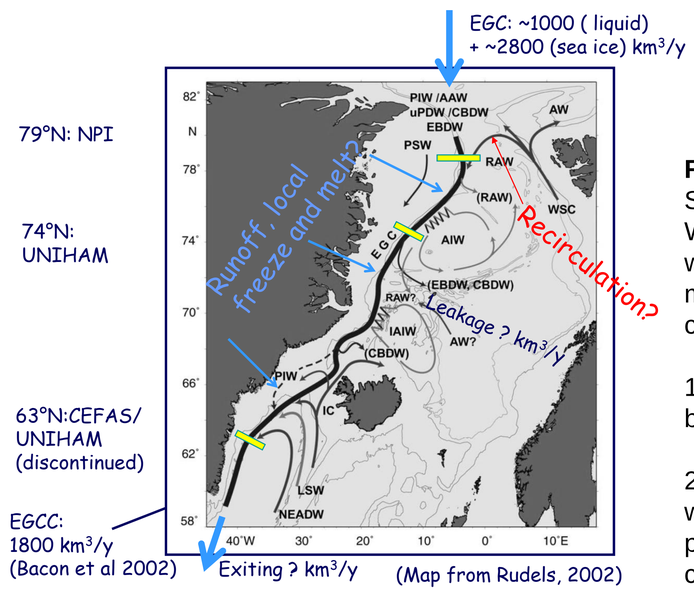
Introduction

WP 3.4 under Damocles is concerned with the output from the Arctic Ocean to the northern North Atlantic. The output has the potential to alter the stratification of the subpolar basins where processes controlling the northern limb of the meridional overturning circulation (MOC) are taking place. This is one of the main ways that the Arctic Ocean communicates with the global climate system. Two main questions are addressed under WP 3.4:

•*Is there a switchgear that determines whether Arctic freshwater will pass by directly to the the Atlantic conveyor or recurve eastward back into the Nordic Seas?*
•*What is the scale and extent of changes associated with ocean freshwater fluxes, and their impact on the MOC*?

The questions are addressed through a combination of a) direct observations, b) using historical data with geostrophic calculations, and c) numerical modelling and data assimilation.

Sites with direct observations are illustrated as yellow rectangles on the map. The 63°N array was discontinued in 2006 due to extensive instrument losses. Along with permanently deployed instruments, annual cruises to the region provides CTD, ADCP and tracer data that feed into the models.



(Map from Rudels, 2002)

Recirculation:
Some of the inflowing Atlantic Water recirculates in Fram Strait where our mooring array is maintained. This has two main complications:

1) The net inflow/outflow volume budget is difficult to close

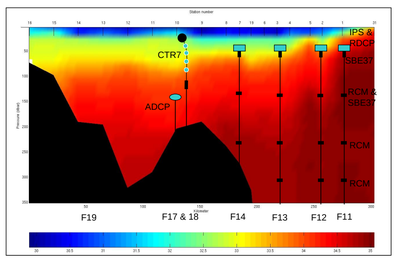
2) The recirculating inflow mixes with the outflow, blurring our picture of the outflow characteristics

Observations

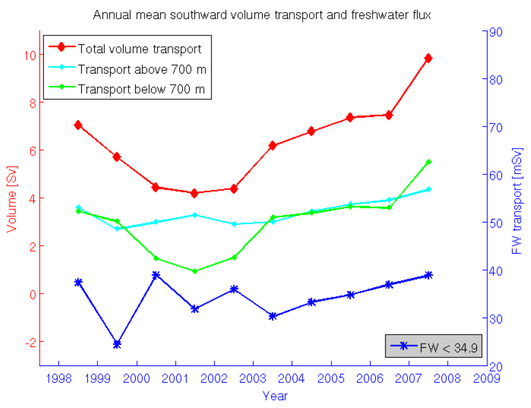
Direct observations (NPI – PI Hansen)

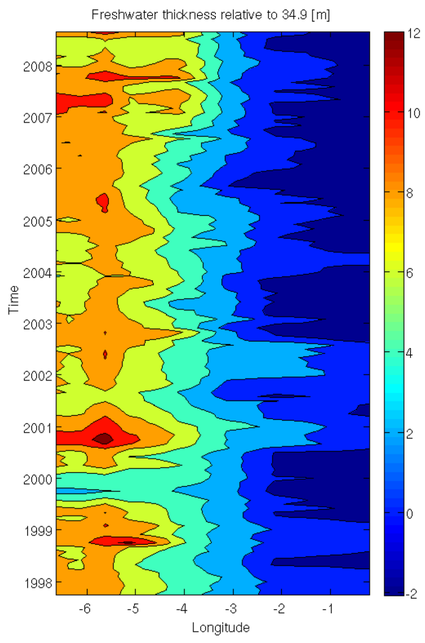
Method:
The 79° freshwater observation mooring array is schematically illustrated to the right. Monthly mean velocities are determined from daily means interpolated on terrain following coordinates. Missing values due to instrument loss or failure are replaced by monthly means from the total observational period. The same holds for T and S although due to a large lack of good salinity data below the mixed layer, a grid is constructed combining good S data from the moorings with spring and annual September CTD sections. The vertical stability is checked upon by correcting σ(T,S) in the vertical and recalculating S.

79° N mooring array



Results:
A Hovmöller plot of the freshwater thickness (below, right) shows no clear trend in time or space although in 2007-2008 it has increased by ~60% in the core of the EGC at ~4ºW. The annual mean southward volume transport shows an increase over the last 5 years due to a large increase in the layers below 700m while the southward freshwater flux remains fairly constant in time (below, left).

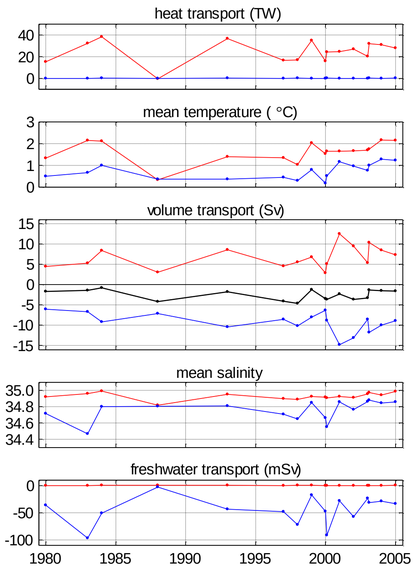


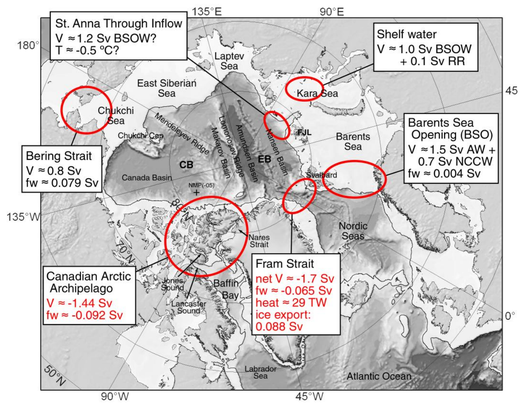


Geostrophic computations of transports of volume, heat and freshwater (FIMR – PI Rudels)

Based on 1980-2005 CTD sections. Reference velocity obtained by imposing constraints on the deep water exchanges ($\sigma_\theta \geq 28.06$). Prescribed inflow of 0.2 Sv with S=34.910 and an outflow of 0.6 Sv with S=34.925 . The mean outflow temperature and the mean inflow salinity on each section are used as reference temperature and reference salinity.

Balancing the geostrophic transports in Fram Strait with existing estimates for the other openings (map), it appears that we achieve freshwater balance but cannot close the volume budget. A net outflow of 1.1 Sv is found. The deficit is interpreted as an underestimate of the barotropic component of the West Spitbergen Current. 1.1 Sv of mean inflow characteristics is therefore added to the northward flow. This can be done without affecting the freshwater balance since the mean inflow salinity is used as reference and the added inflow does not carry any freshwater. It has, however, been assumed that a barotropic inflow is reasonably well represented by the mean inflow characteristics.





Reference:
Rudels B, Marnela M, Eriksson P (2008) Constraints on Estimating Mass, Heat and Freshwater Transport in the Arctic Ocean: An Exercise. In: RR Dickson, J Meincke, P Rhines (eds) Arctic-Subarctic Ocean Fluxes, pp. 315-341. Springer, Dordrecht.

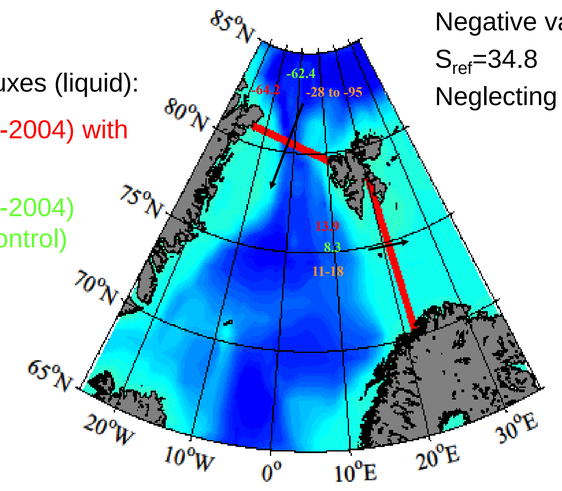
Numerical modelling

NEMO modelling framework - OPA9 ocean model, LIM2 ice model (U. Reading – PI Haines)
Global 1/4° resolution tripolar grid (ORCA025)

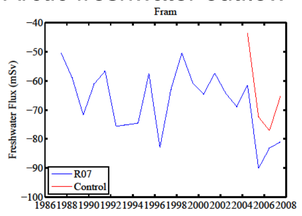
- Control run: 1958-2004 (B. Barnier et al.) extended to 2005-7 (UoR)
- Reanalysis 1987-2007 (UoR)
- Warning: Some changes to Met data post 2002 need further checks

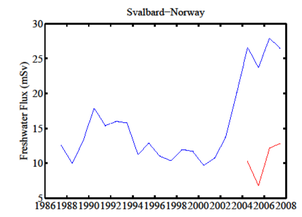
Mean freshwater fluxes (liquid):

- ORCA025 (1987-2004) with assim (R07)
- ORCA025 (1958-2004) without assim (control)
- Observations



Negative values = Arctic freshwater outflow
S_{ref}=34.8
Neglecting Ice



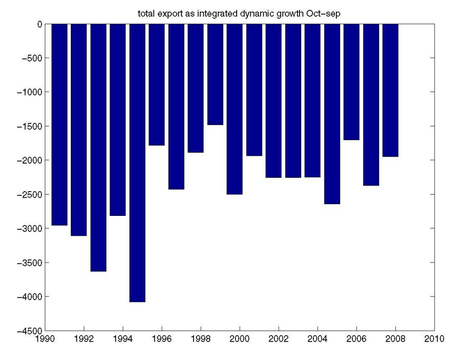


Reanalysis Results

- Fram Strait: freshwater outflow & volume flux inflow: Increasing trend for FW outflow 1987-2007
- Svalbard-Norway: freshwater inflow & volume flux inflow: Increased FW inflow post 2003

Freshwater components in 2007 and 2008 as simulated by NAOSIM (AWI – PI Gerdes)
- 1/12 degree resolution on rotated grid (=9km)
- NCEP forcing
- January 1990 until October 2008

The area integral of the dynamic ice export over the Arctic Ocean yields the total ice export from the Arctic Ocean. The time series shows for instance the large export in the winter of 1994/95. The winters 2006/07 and 2007/2008 do no stand out exceptional ice export winters. However, it seems that large ice exports occured in the second half of 2008 (not influencing the integral Oct – Sep much).



Liquid fresh water (below) at the end of summer 2008 was more concentrated in the interior of the Beaufort Gyre while fresh water content is reduced at its periphery. Changes in the Nordic Seas and in Baffin Bay seem rather insignificant and of small scale structure. Changes in the interior Arctic freshwater content seem to be related to wind forcing, not to thermodynamic ice growth (which is rather similar in 2007 and 2008).