The characteristics of Polar Water on the East Greenland shelf as viewed in measurements, climatology and a numerical model

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Introduction

Fresh and cold Polar Water (PW) is carried southward from the Arctic Ocean into the North Atlantic by the East Greenland Current. PW is found at and near the surface across the East Greenland Shelf and above the shelf break. The flow of PW and Sea ice transport constitutes a major part of the freshwater transport into the North Atlantic.

We present the first multi year long time series of the PW characteristics at three latitudes, look for seasonal and longer term signals and compare the measurements against a state of the art numerical model.

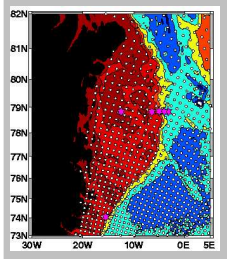
The Data

Near surface time series in ice covered regions are difficult to obtain due to the possibility of damage or total mooring lost due to ice bergs and ridges.
Starting in 2000 we deployed moorings where the upper part was protected from damage due to ice by a 40m long plastic tube. At nominal depths of 20m and 60m temperature and salinity was measured using Microcats inside the tube. The first 2 deployments sides were on the shelf, but near the shelf break, at 63ºN and 74ºN. In 2003 a tube mooring was also deployed on the inner shelf at 79ºN. Starting before 2000 conventional moorings measured T/S at a minimum depth of about 50m across the shelf break at 79ºN. All mooring sites are still active in 2005.

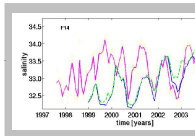
Mooring name	Latitude	Longitude
63N tube	63º00.2N	40º43.7W
74N tube	74º01.7N	15º31.3W
79N tube	78º49.8N	12º29.9W
F14	78º49.2N	06º27.5W
F13	78º50.7N	05º01.0W
F12	78º49.6N	04º03.6W
F11	78º49.9N	03º16.1W

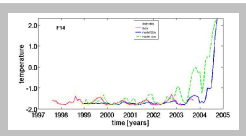
The mooring positions can also be seen in the two maps in the model and 63ºN paragraph.
All data around defined depths were averaged into daily means, which again were used to calculate monthly means. Anomalies were calculated from the monthly means by subtracting the corresponding long term monthly mean from all data.

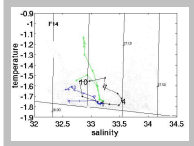
The Model

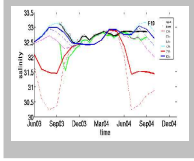


The model used for the numerical experiment is the coupled ocean-ice model NAOSIM (North Atlantic/Arctic Sea-Ice Ocean Model). The ocean part derives from the GFDL modular ocean model MOM-2 and is coupled to a dynamic-thermodynamic sea ice model. The model domain encloses the northern North Atlantic, the Nordic Seas and the Arctic Ocean. The horizontal resolution is approximately 28 km on a rotated spherical grid (white dots in map). In the vertical, the model has 30 unevenly spaced levels. The current model experiment is forced with atmospheric data from the NCEP reanalysis and covers a period from 1948 to 2004. The surface salinity is restored to PHC climatology on a timescale of 180 days.





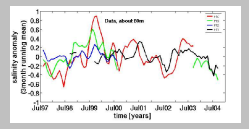


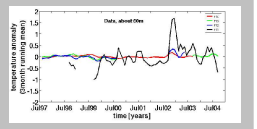


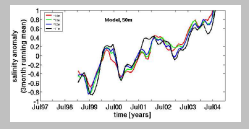
79ºN

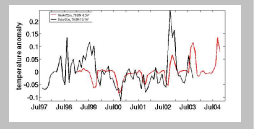
At F14 data and model correspond very well from autumn 2002 to the end of 2003. But otherwise the model shows a trend towards higher salinities and from 2003 on also to higher temperatures which is not seen in the data. In the TS diagram we see, that the model has much to low winter salinity values.
On the inner shelf the expected summer drop in salinity is missing in the 2004 data. During the measurement year model and data salinity correspond quite well at 60m. But clearly longer measurements are needed.

Anomalies along 79ºN are highly correlated in the model, but do not resemble the data. Although the temperature anomaly on the inner shelf in the model resembles closely the anomalies in the data at F14.
The correlation between the different moorings is not a striking, but the broad signals are the same. The salinity anomalies are in general larger at F14 then at F11 and the temperature anomalies viceversa. This can be a hint, that the salinity changes are triggered in the west and the temperature anomalies in the east.

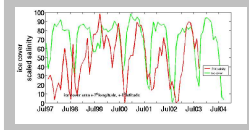


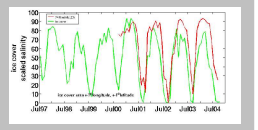




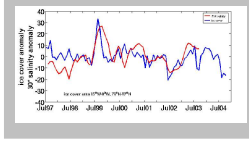


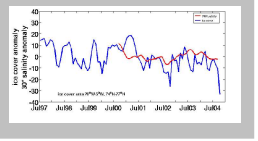
Ice Cover

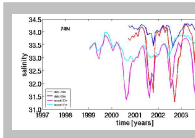


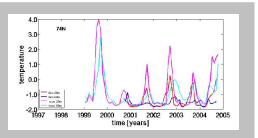


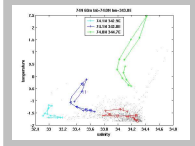
The seasonal cycle at 74ºN and 79ºN is determined to a large part by ice melting (summer drop in salinity) and formation (salinity increase in late autumn) in a region near the moorings {↑Figures}.
Similarly the longer term salinity anomalies are related to the larger scale change in ice cover. Positive anomalies in ice cover (e.g.1999) are associated with positive salinity anomalies{↓Figures}.

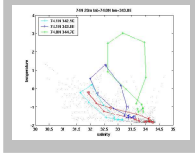






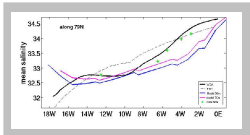


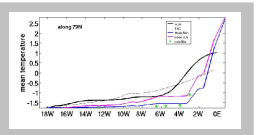




74ºN

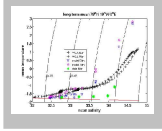
In data and model we see a pronounced seasonal cycle, saline and cold winters and short summer with low salinity and higher temperatures. The amplitude is larger near the surface but the seasonal signal also reaches a depth of 60m.
The TS diagrams show clearly, that the model salinity is to low. Also at model stations further east the specific very cold, medium salinity water found in the measurements is not found.

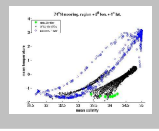


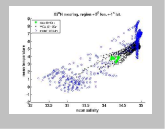


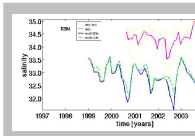
Long term means and climatology

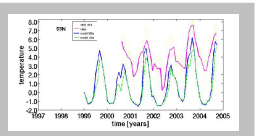
As historical data is scarce in the ice covered region of the EGC, the climatologies can differ considerably from the measurements. At 79ºN the annual mean salinities are quite well captured, but the climatologies show much to high temperatures {↑Figures}. The model captures very well the temperature distribution, but has to low salinities. Model and climatologies are missing the low temperature, medium salinity waters of the data. At 74ºN the climatology captures this water better then the model.

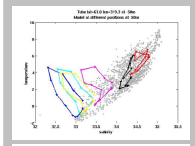


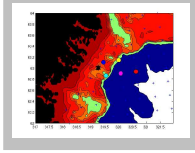






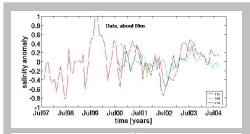


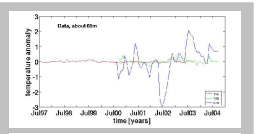


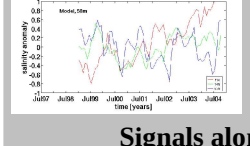


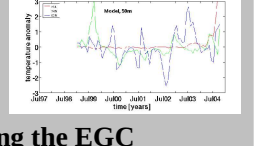
63ºN

In general the vertical gradient in model and observations is small. The model shows much too low salinity and temperature at the same geographical location. The mean TS characteristics of the data are found only much further east in the model.
Only the temperature shows a clear seasonal cycle, which is quite well captured in the model.
The general impression is that the model shows a more pronounced PW signal in a larger region then the data. This may be results of broader boundary current in the model.









Signals along the EGC

In the data coordinated changes at all 3 latitudes are seen in salinity, summer 2002 is fresher and summer 2003 is more saline then average. But as these occur at almost the same time or even earlier at 63ºN then at 79ºN these are not signals propagating with the EGC. The same holds for the model data at 63ºN and 74ºN, where also the salinity in summer 2003 is larger than a year before. A signal propagating from 79ºN to 74ºN in the end of 2002 can be assumed to occur in temperature. Temperature anomalies are very similar in model and data at 63ºN.

Conclusions

No final conclusions can be drawn since this is a work still in progress. Still some key features can be listed:

There is a strong seasonal cycle in the PW with a short, fresh and warm summer and a long, cold and saline winter. The seasonal cycle is coupled to the ice cover.

On the long term salinity anomalies at 74ºN and 79ºN are coupled with the ice cover extent in the region north of the respective latitudes.

Only one small anomaly could be seen propagating along the EGC from 79ºN to 74ºN but not further to 63ºN.

Salinity anomalies (2002 fresher, 2003 more saline) tend to appear simultaneously at all 3 latitudes

At 63ºN the PW is very diluted.

For the comparison with the model, only first steps have been made. Therefore caution has to be exercised since it is not yet clear, if data from model and observations are captured from the same hydrographic regimes when comparing at given geographical locations.

The model captures the main features of the seasonal cycle and some of the interanual variability.

The salinity of the PW in the model is to low, probably due to a restoring to the too fresh climatology.

The correspondence between data and model temperature anomalies at 63ºN is good.

Further information:

The work was funded by the European Commission 5º framework programs ASOF-N and ASOF-W as well as by the DFG project SFB512.

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The long term monthly means for the 79N model output were calculated excluding data after 2003 due to the strong temperature trend afterwards.

A detailed description of the model can be found in: Karcher, M. J., R. Gerdes, F.Kauker, C.Koeberle (2003): Arctic warming - Evolution and Spreading of the 1990s warm event in the Nordic Seas and the Arctic Ocean, J. Geophys. Res., Vol. 108 ,No. C2, doi:10.1029/2001JC001265.