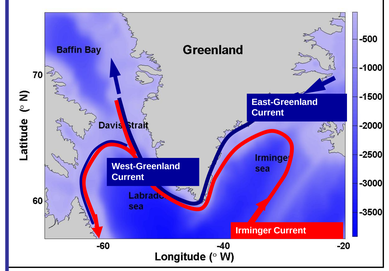
Hydrographic conditions and occurrence of new demersal and pelagic fishes on the Greenland shelf .

Anna Akimova (anna.akimova@vti.bund.de) and Heino Fock (Institute of Sea Fisheries (vTI), Hamburg, Germany)

1. Background.



The water circulation pattern off Greenland comprise three main currents: Irminger current, West and East Greenland currents. The East Greenland current transports the fresh and cold Surface Polar Water (SPW, shown in blue) to the south along the eastern coast of Greenland. The Irminger current is a branch of the North Atlantic current makes a cyclonic loop in the Irminger Sea and transports salty and warm Irminger Sea Water (ISW, shown in red) southward along the slope of the East Greenland. The West Greenland Current carries the water northward and consists of two components: a cold and fresh inshore component, which is a mixture of the SPW and melt water, and ISW offshore component.

Irminger and West Greenland currents are the northern currents in the Atlantic subpolar gyre (SPG) and therefore subject to hydrographic variations at different time scales, which go along with variability of the gyre. The SPG is known to be weakening since mid 1990s, that resulted in redistribution of the water masses and substantianal warming and salinification of the eastern North Atlantic (*Hatun et al, 2005*). There are several evidences about response of marine ecosystems to the ongoing changes in the North-Atlantic: redistribution of the whiting stock in the northeastern Atlantic (*Hatun et al, 2009*), appearance of southern fish species on the shelf of Iceland (*Astthorsson, OS. & Palsson, J. 2006*), increasing of cod recruitment and population in the Barents Sea and west off Greenland (*Drinkwater, 2009*).

In this study we concern on recent changes of the hydrological conditions on and off Greenland shelf and link them to the occurrence of new demersal and pelagic fish species, which appeared on the shelf of Greenland after 1996-1997.

2. Variability of Irminger Sea Water.

Data.

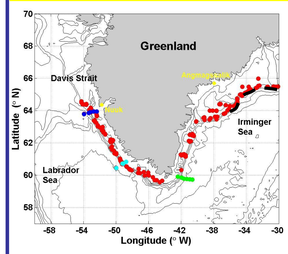


Figure 1. Map of the region and observations. Red dots – German groundfish survey; green dots – section AR07E (repeated WOCE section); cyan – Cap Desolation section; blue – Fyllas Bank section. Black dashed curve marks the section along the East Greenland shelf break. Annotated yellow dots are coastal meteorological station.

Table 1. Data used in this study.

Data	Years	Month	Source
AR07E (Ovide section 2002, 2006)	1991-2009 (not 1993, 1998, 2000)	Jun -- July	WODC, CLIVAR
Cape Desolation	1983- 2009 (not 1992, 1995)	Oct- Nov	Institute of Sea Fisheries
Fyllas Bank	1983-2009 (not 1992, 1995)	Oct- Nov	Institute of Sea Fisheries
German demersal survey	1981-2009	Oct- Nov	Institute of Sea Fisheries

Hydrographic section in East Greenland.

Both temperature (θ) and salinity (S) of the upper 500 m along the section over the East Greenland slope started to increase after 1996 due to larger volume and elevated temperature and salinity of ISW (θ > 3.5°C, S > 34.88).

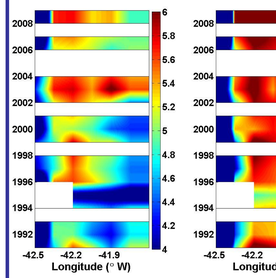


Figure 2. Mean temperature (θ) and salinity (S) in upper 100-500 m layer along A07E section (update from *Bersch 2002*).

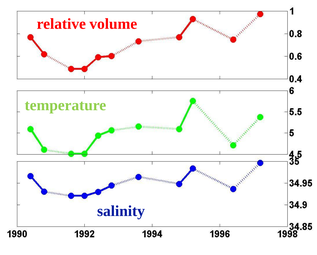


Figure 3. Mean characteristics of ISW.

Hydrographic sections in West Greenland.

Observations along two sections in West Greenland show an continuous increase of ISW temperature, salinity and volume since the late 1990s. This finding agrees with the previous studies of *Yashayaev (2007)* and *Myers et al (2007)* who used summer observations in West Greenland.

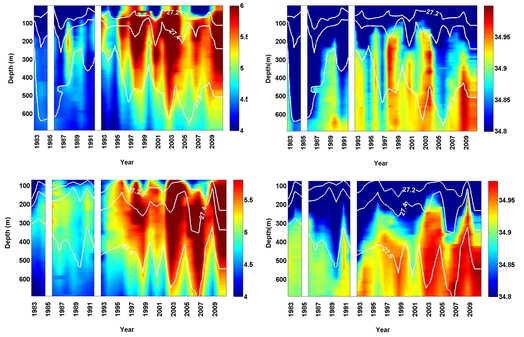
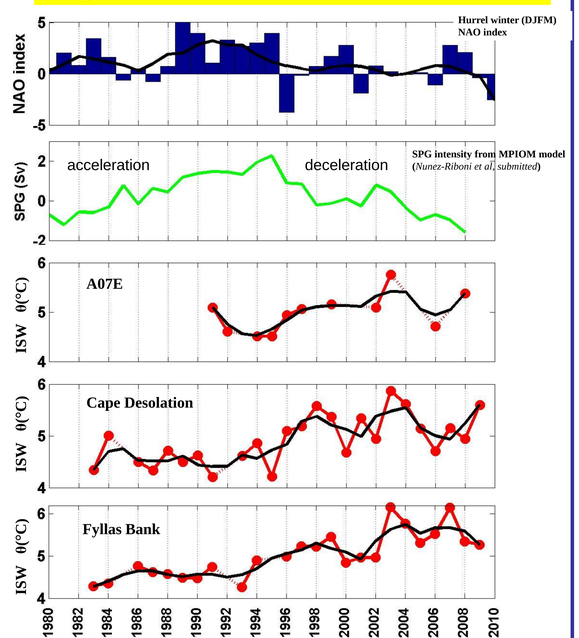


Figure 4. Mean over two offshore stations potential temperature (left) and salinity(right) at Cape Desolation (upper panel) and Fyllas Bank section (lower panel). White curves show the potential density.

The observed volume, temperature and salinity increase of Irminger Sea Water off Greenland shelf coincide with the ongoing weakening of the North Atlantic subpolar gyre started in 1996.

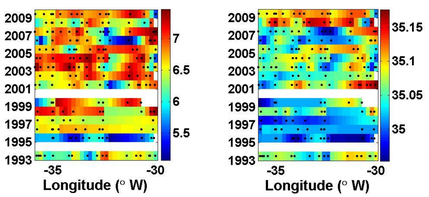
Irminger Sea Water off Greenland.



3. Influence of ISW on the shelf water conditions .

The increasing temperature and salinity of the Irminger Sea Water off Greenland shelf has an imprint on the hydrographic conditions over the eastern and western Greenland shelf, where stocks of many commercial demersal fishes exist.

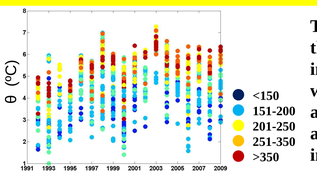
East Greenland shelf break.



The increase of the ISW temperature and salinity within the Irminger Current is seen also over the shelf break off East Greenland. The amount of ISW shows no clear trend and probably depends mainly on the wind induced Ekman transport .

Figure 6. Properties of ISW over the East Greenland shelf.

West Greenland shelf.



The temperature of the bottom water over the western shelf of Greenland has also increased since 1996 (Fig.7). Since the shelf water is the mixture of SPW and ISW, it is affected both by the warming of the ISW and an increase of the air temperature, observed in the area since late 90s.

Figure 7. Temperature of the bottom water over the Greenland shelf . Color shows the depth of the stations.

5. New pelagic and demersal fish species.

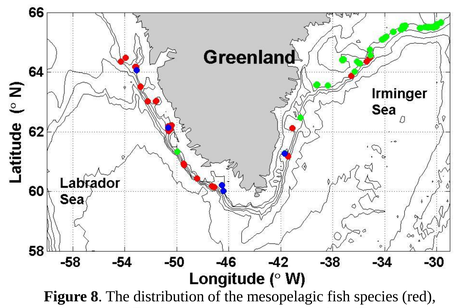


Figure 8. The distribution of the mesopelagic fish species (red), grey gurnard (*Eutrigla gurnadus*, blue) and saithe (*Polachius virens*, green)

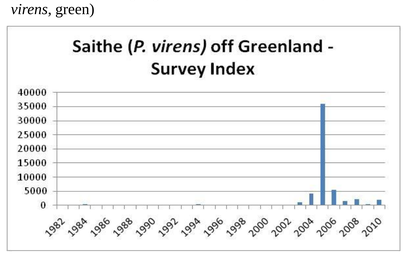


Figure 9. Time series of the survey index of saithe (*Polachius virens*) off Greenland.

Starting in the late 1990s a massive change in the demersal fish assemblages was observed, mainly indicated by increasing presence of species with a preference to warmer waters (*Fock, 2008*). Among them are typically pelagic fishes (Figure 8), many of them are typical for the eastern and southern Atlantic (Table 2). The pelagic fish are passively transported with the water masses and therefore might be used as passive tracers of the water masses from southern and south-eastern Atlantic. These species probably appeared off Greenland due to the subtraction of the SPG and redistribution of the water masses within the gyre, associated with its ongoing deceleration.

Family	Species	Typical distribution (www.fishbase.org)
Paralepididae	*NOTOLEPIS RISSOI*	Pelagic worldwide
Serrivomeridae	*SERRIVOMER BEANI*	Atlantic Ocean between 60°N and 20°S eastern Atlantic up to Iceland
Myctohidae	*LAMPANYCTUS MACDONALDI*	Southern and Eastern Atlantic
Stomiidae	*CHAULIODUS SLOANI*	Warm and temperate parts of all oceans
Nemichthyidae	*NEMICHTHYS SCOLOPACEUS*	Worldwide in tropical and temperate seas
Platytroctidae	*SAGAMICHTYS SCHNAKENBECKI*	Pelagic eastern Atlantic (eastern Greenland)
Sternoptychidae	*MAUROLICUS MUELLERI*	Eastern and southern Atlantic
Trachipteridae	*TRACHIPTERUS ARCTICUS*	Eastern Atlantic
Anotopteridae	*ANOTOPTERUS PHARAO*	North Atlantic

Table 2. Mesopelagic fish species found on the Greenland shelf from 1996 to 2010.

Another group of the fishes, found over the Greenland Shelf after 2000 are active swimmer that can migrate over a long distance searching for the favorable food and temperature conditions. Survey based index of saithe (*Polachius virens*) started to increase in 2002 (Fig. 9). Several individuals of other typically southern species, such as herring (*Clupea harengus*), sea lamprey (*Petromyzon marinus*) and grey gurnard (*Eutrigla gurnadus*, Fig 8) were found on the Greenland shelf after 2000. We suggest, that the migration of these species was caused by increase of the water temperature in the region.

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