Palaeoclimatology, oceanography and glaciology in the Helheim Glacier region

WORKSHOP
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Dynamic of tidewater glaciers in the Sermilik Fjord system and fjord-shelf interaction

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Hydrographic surveys accomplished in August 2008 and 2009 (CTD, surface T/S records, oxygen isotopes) over the southeast Greenland shelf and inside 80 km long Sermilik Fjord (SF) allow quantifying properties of water masses and their interannual variability. Fjord-shelf exchange is driven by brackish water outflow in the surface layer and local atmospheric circulation. Five layers structure can be detected in the SF from vertical profiles (fig.1): warm upper summer layer, two layers with negative temperature centered nearby 30 and 150m which are separated by warm interlayer. The lower temperature minimum layer transports cold and fresh water of Arctic origin. Below 200m the Atlantic Water (AW) with temperatures above zero occupies all deep parts of the SF.

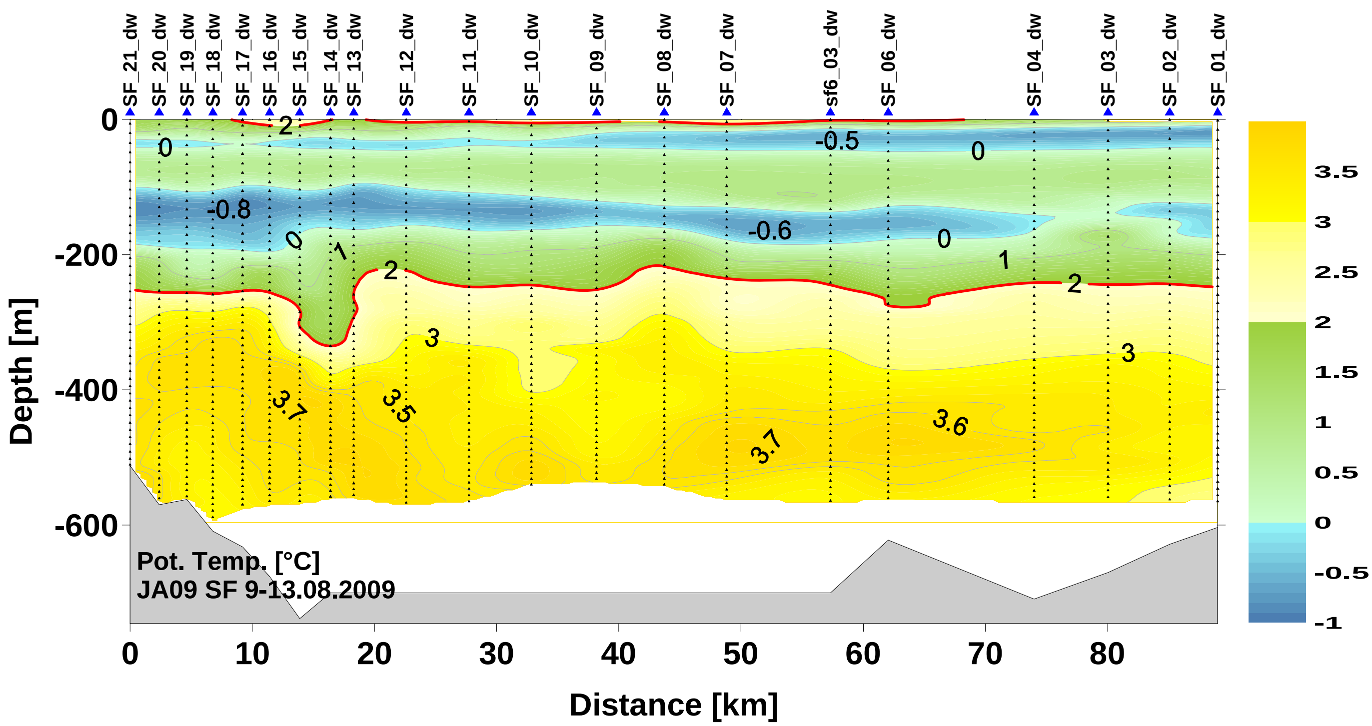

Fig.1 Potential temperature distribution along the Sermilik Fjord. Expedition on board ‘Jotun Arctic’ in August 2009

In August 2009, 155 CTD stations were completed along 11 sections inside the SF and over the adjacent Greenland shelf. Strong horizontal salinity gradients depict frontal zone which separates the fresh water plume discharged from the SF and shelf water carried by East Greenland Costal Current (fig.2, left). Oxygen isotope analysis allows quantify proportion of the AW, meteoric water and fresh water derived from sea ice melt. The meteoric water fraction on surface changed from 10 to ~80% over the study area (fig.2, right). Oxygen isotope samples taken from 50m show that more than 94% of water composes from the AW. Water mass properties in the mixing zone close to the SF mouth show considerable changes between 2008 and 2009. The AW core with temperature more than 7^{o}C was registered in 2008 close to the SF entrance, but was replaced by cold Arctic water in August 2009. It is unclear how far such pulses can penetrate into the fjord. Inside the SF the meteoric water fraction in 2009 increased by 25% in comparison with previous year, while it is unclear if it determined by seasonal or interannual variability. Findings that the SF is a deep fjord with AW circulated below 200m stimulated studying of connection between glaciers dynamic and variable oceanographic conditions.

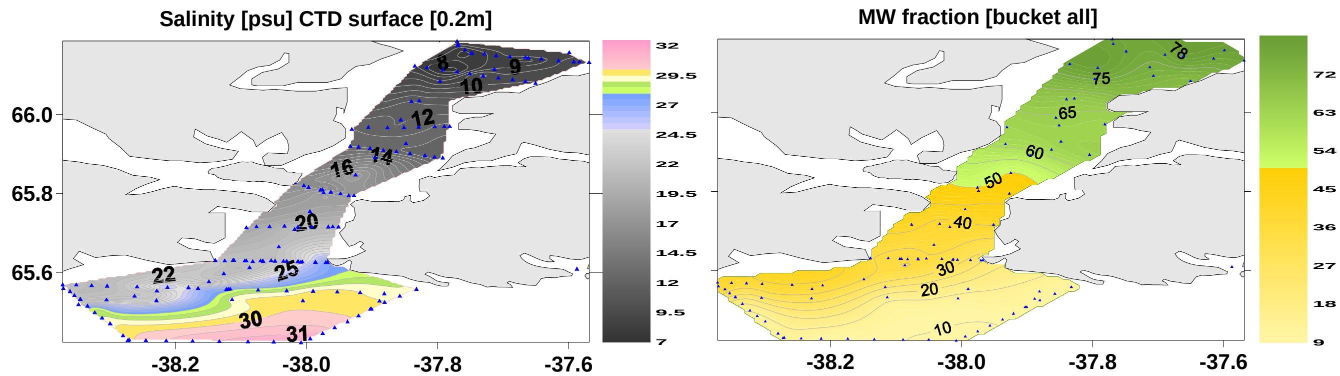

Fig.2 Surface salinity [psu] from CTD (left) and meteoric water fraction [%] derived from oxygen isotope analysis (right). Expedition on board 'Jotun Arctic' in August 2009. Blue rectangles – position of CTD stations and oxygen isotope samples.

Several glaciers in the SF contribute to the total discharge into the sub-polar North Atlantic in the form of melt water and icebergs including the third biggest in Greenland the Helheim glacier (HG). During the stable period (prior 2001) the HG calving front was grounded above the 550 m depth sill in the Helheim fjord *(Joughin et al., 2008)*. It means that considerable part of the subsurface ice front was in direct contact with the AW. Submarine melting depends on AW temperature and intensity of the buoyancy convection along the ice front driven by sub-glacial discharge *(Motyka et al., 2003)*. The first factor is controlled by the AW properties advected from source region that can be traced back to the Irminger Sea. The second factor is governed by influx of water that infiltrates to the base from the glacier surface and therefore depends on surface air temperature (SAT). To find explanation of the HG rapid retreat that started in 2002, we analyzed the upstream AW properties in the Irminger Sea. Results show that since the end of the 1990s warm and low density anomaly prevailed in the upper 500-800m layer. The anomaly picked during 2005-2008 with 0.5^{o}C excess over long-term mean. Advection of the anomaly into the SF is the most probable mechanism that could trigger rapid retreat of the HG ice front, its thinning and acceleration. Tasiilaq SAT records also reveal positive anomalies since the late 1990s, peaked in 2003 with more than 2^{o}C excess. Therefore both factors reinforced submarine melting of the HG ice front and triggered amplified calving front retreat over the seal to the bottom depression. Although, some studies show that submarine melting is much more efficient than surface melting *(e.g. Mayer et al., 2000)*. Total retreat of the HG ice front for 2001-2005 exceeded 7 km. Retreat acceleration after 2002 can be connected with increase of ice area exposed to submarine melting above the bottom depression. After the re-advance in 2006 all three main glaciers in the SF (Helheim, Fenris, Midgard) reveal unstable advance/retreat behavior.

We conclude that glaciers dynamics in the SF during the 2000s is a non-linear constrained equilibrium among the long-lived AW/SAT anomalies which drive forced convection along the ice front and fjord bed topography. Similar climate conditions and glaciers response were observed in the 1930s, while during the late 1960s the main contribution was from the increased AW temperature. The AW anomaly found in the Irminger Sea in 2000s is not unique. Reported process of the Greenland' tidewater glaciers 'retreat/acceleration/thinning' propagation to the north *(Howat 2008, Hanna 2009, Nick, 2009)* can be linked to the similar anomaly circulated in Norwegian, Return Atlantic and East Greenland currents system.

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