The Arctic Ocean Halocline variability over the past 20 years

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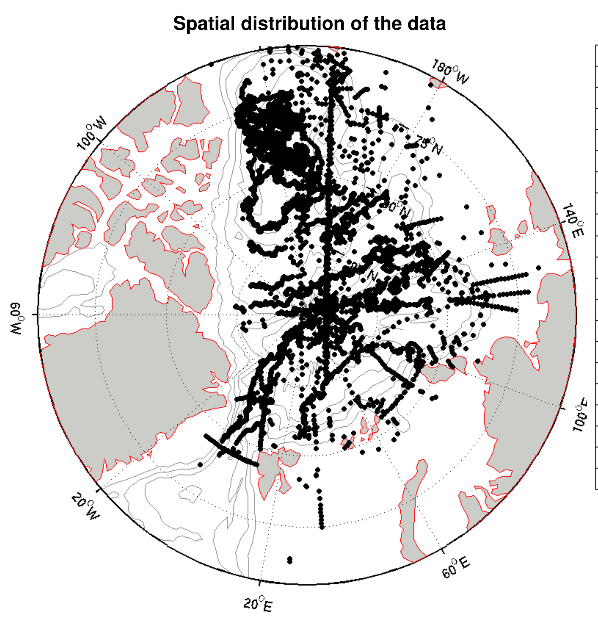
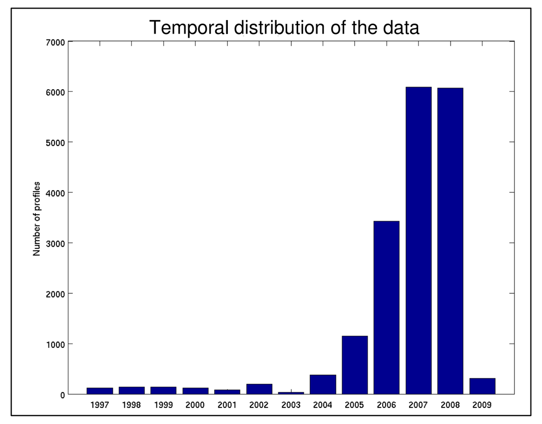
Abstract: The role of the Ocean on the sea-ice mass balance in the Arctic is still a matter of hot debates. The study of the cold and shallow halocline is essential to understand the mechanisms leading to the formation and/or disappearance of Arctic sea-ice. According to Steele and Boyd (1998), the cold halocline disappeared from the Eurasian basin during the early 90s due to a shift in the atmospheric wind forcing that would have changed the location where fresh Siberian shelf waters flow into the deep Arctic Ocean . Boyd (2002) and Björk (2002) signaled the recovery of the Arctic halocline in the late 90s. Is this kind of event unique or does it occur more or less regularly? Does this kind of event influence the surface layer heat content and consequently the sea-ice mass balance? What is the current situation in the context of a highly variable Arctic sea-ice cover during recent years? Based on a large data set collected in the central Arctic basin during the 4th IPY and the Damocles project, the main goal of this poster will be to address these questions and to provide some answers.

Tools

Data Set



Data Set	Time	Location
SCICEX	Autumns 1997-1998-2000	Central Basin
AMORE	Summer 2001	Gakkel Ridge
ODEN	Summer 2001	Eurasian Basin
Polar Observer	Spring 2002	Amundsen Basin
JWACS	Autumn 2002	Beaufort Sea
ARK XX2	Summer 2004	Fram Strait
BERINGIA	Summer 2005	Central Basin
POPS IPEV	2006-2007	Central Basin
LOMROG	Summer 2007	Fram Strait
ARK XXII2	Summer 2007	Eurasian and Makarov Basins
NABOS	Summers 2002 to 2007	Laptev Sea
Akademik Fedorov	Summer 2007	Laptev Sea and Canadian Basin
Akademik Fedorov	Summer 2008	Laptev Sea
NP 35	Autumn 2007 to Spring 2008	Nansen Basin
CHINARE	Summer 2008	Beaufort Sea
ARK XXIII3	Summer-Autumn 2008	Mendeleyev Ridge
NPEO Aerial Survey	Springs 2000 to 2008	Central Basin
TARA	Sep 2006 to Jan 2008	Central Basin
POPS JAMSTEC 9-11	Autumn 2008	Makarov Basin
ITPs 1 to 30	Aug 2004 to Jan 2009	Central Basin

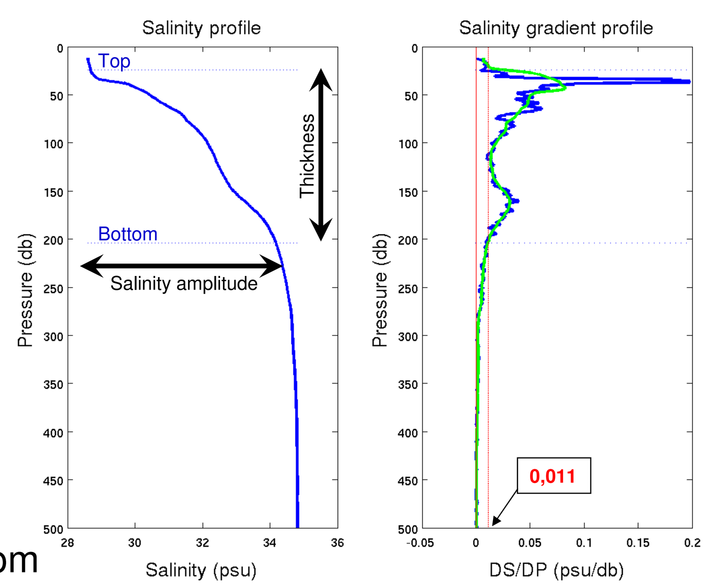


Thanks to a large cooperation among Arctic scientists from many countries, more than 18000 CTD vertical profiles have been collected in the central and deep part of the Arctic Ocean. It includes data from icebreakers campaigns, from drifting buoys and even from aerial survey and submarine cruises. They cover the period 1997-2009 and are distributed across the central Arctic basin. The histogram reveals that the 4th International Polar Year, in 2007-2008, has been highly valuable in terms of data collection in the Arctic Ocean. **About two third of the data set were collected during this 4th IPY.**

Haloclline Detection

Motivation:

Halocline = Salinity Gradient



- Halocline Top : Mixed layer bottom
- Halocline Bottom : fixed by a salinity gradient constant (=0,011 psu/db)
- Halocline stratification : Brunt Vaïsala's frequency averaged over the halocline thickness

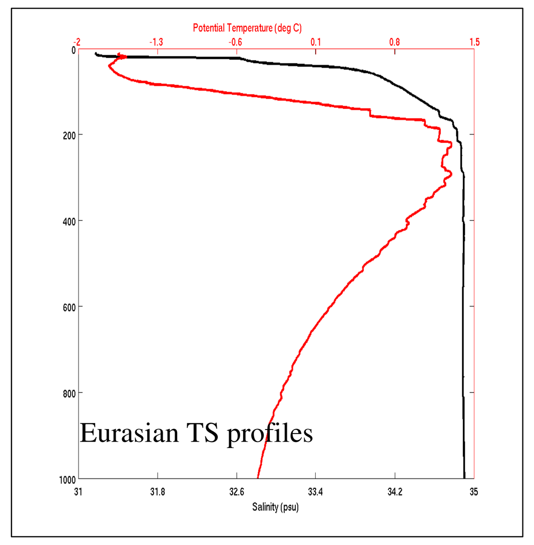
Interpolation

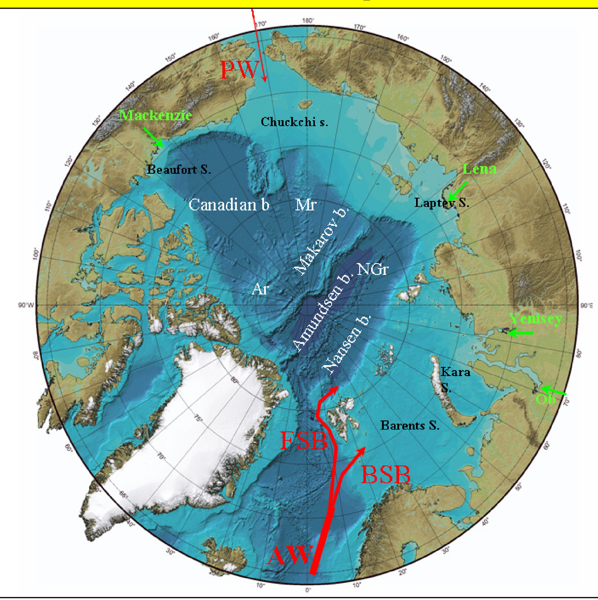
Spatiotemporal maps were obtained through the Kriging method. It is a geostatistical technique to interpolate the value of a random field at any location from observations at nearby locations.

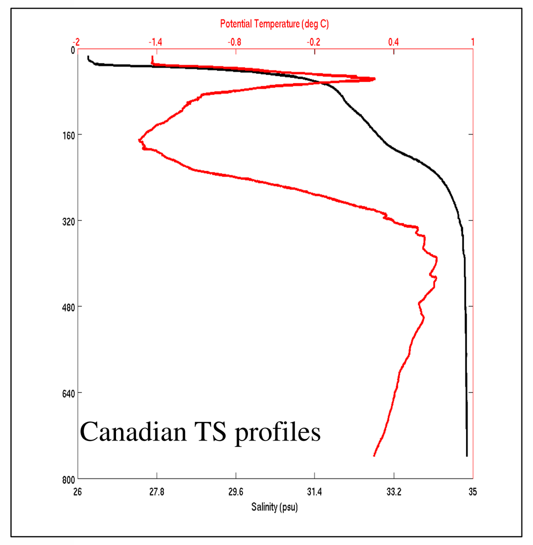
General situation (1997-2009)

In the Eurasian basin, the halocline is called « Cold Halocline » (CHL) because the temperature profile stays at the freezing point all over the halocline thickness. This halocline is strongly influenced by the Siberian river runoff at surface and the Atlantic layer at depth (around 300m).

Using the mean salinity of the depth 40-60m as a CHL's tracer, Steele & Boyd (1998) saw a retreat of the CHL during the early 1990's and Boyd (2002) and Bjork (2002) observed a partial recovery in the late 1990's. Our results do not show such a fluctuation.



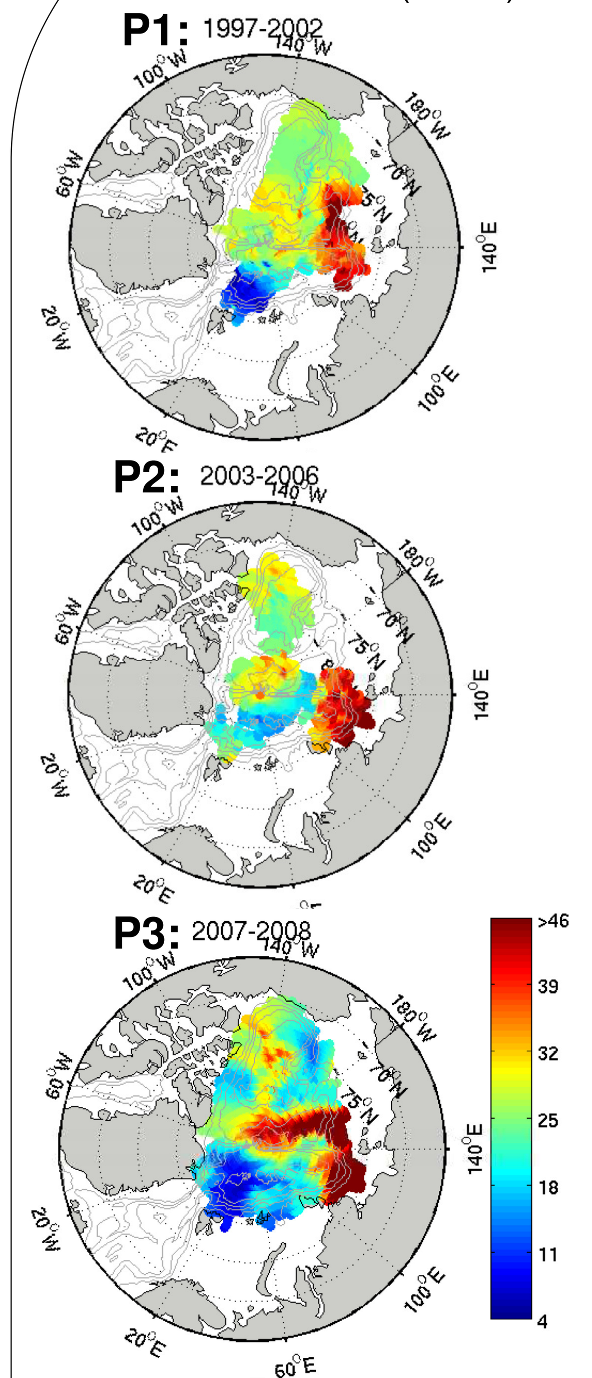




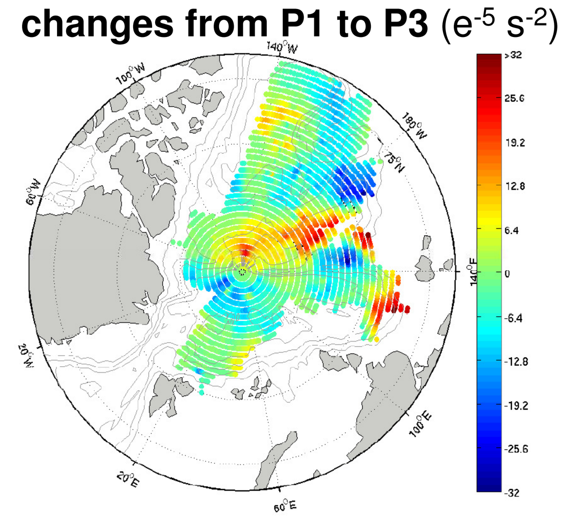
The Canadian halocline is special. In addition to the Atlantic layer influence, it is also influenced by the Pacific water input that enter the Arctic Ocean by Bering Strait. These Pacific waters are warm and relatively fresh, they penetrate the water column at various depths according to the season (Woodgate, 2005) and weaken the halocline stratification at mid depths. They are responsible for this typical salinity profile characterised by an inflexion point at mid depths.

How did the halocline evolve during the last 12 years?

Halocline stratification evolution (e^{-5} s^{-2})



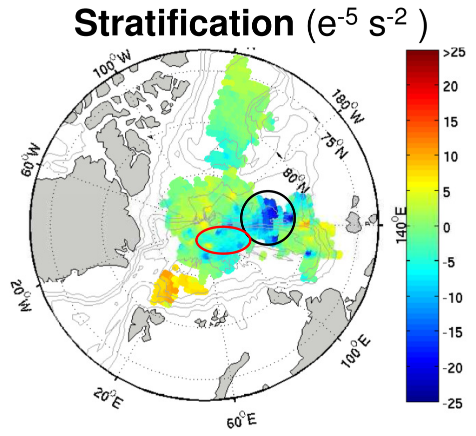
Halocline stratification changes from P1 to P3 (e^{-5} s^{-2})



The halocline is less and less stratified in the Western Amundsen basin and above the Lomonosov ridge from the late 1990's to the IPY and is especially well stratified in the Makarov basin during the IPY.

Halocline Changes from P1 (1997-2002) to P2 (2003-2006)

Stratification (e^{-5} s^{-2})

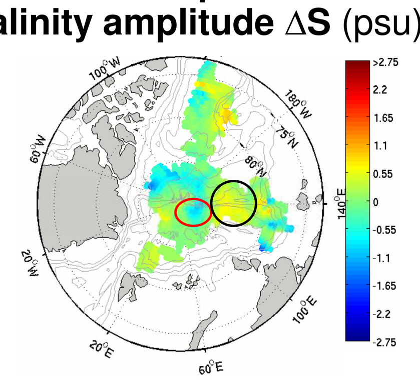


Destratified halocline above the Lomonosov ridge (LR)

Destratified halocline in the Amundsen basin center (AC)

The halocline thickness is as important as the salinity amplitude for the stratification

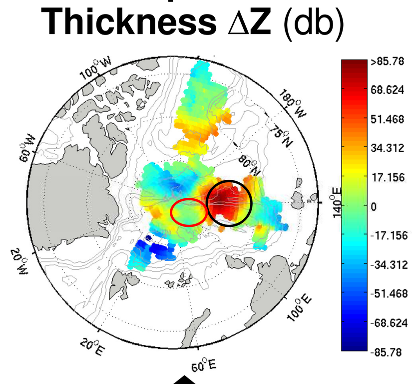
Salinity amplitude ΔS (psu)



Slight increase of ΔS above LR

Decrease of ΔS in theAC

Thickness ΔZ (db)

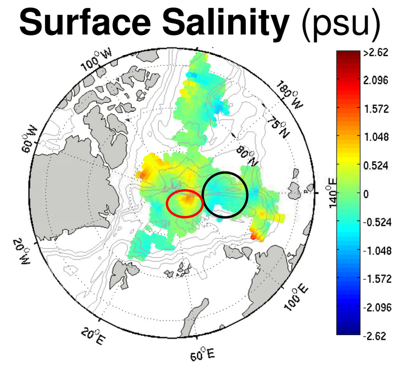


Much thicker above LR

No change of ΔZ in the AC

The halocline bottom salinity is very stable. (S~34,1 psu)

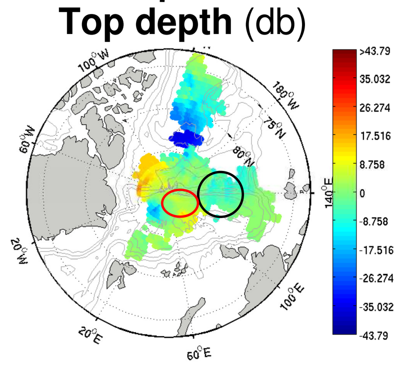
Surface Salinity (psu)



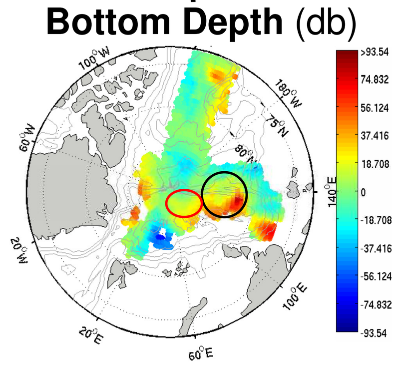
Slightly fresher surface waters above LR

Saltier surface waters in the AC

Top depth (db)



Bottom Depth (db)

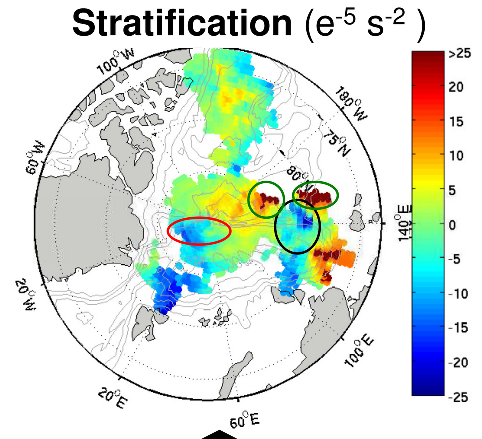


Lifting of the top and deepening of the bottom above the LR

Identical deepening of the top and bottom in the AC

Halocline Changes from P2 (2003-2006) to IPY (2007-2009)

Stratification (e^{-5} s^{-2})

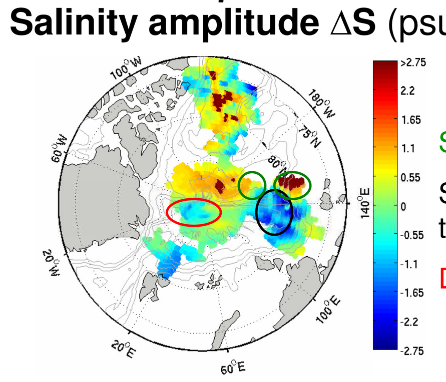


Strong stratification of the halocline in the Makarov basin (MB)

Destratified halocline above the LR

Destratified halocline in the Western (WA) Amundsen basin

Salinity amplitude ΔS (psu)

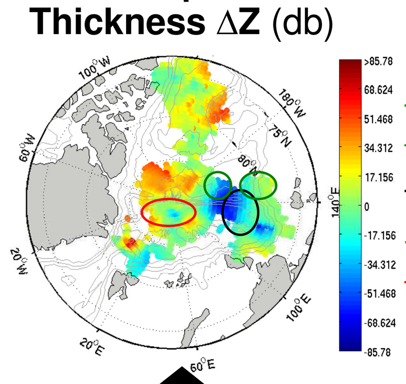


Strong increase of ΔS in MB

Strong decrease of ΔS above the LR

Decrease of ΔS in the WA

Thickness ΔZ (db)

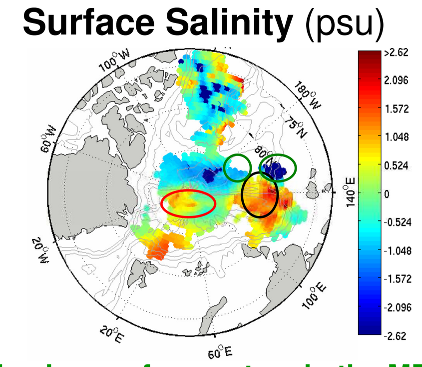


Thinning or slight thickening in MB

Thinning above the LR

Variable change of ΔZ in the WA

Surface Salinity (psu)

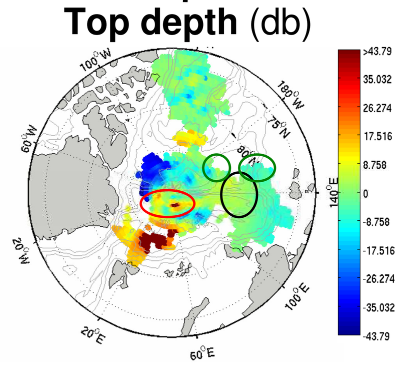


Fresher surface waters in the MB

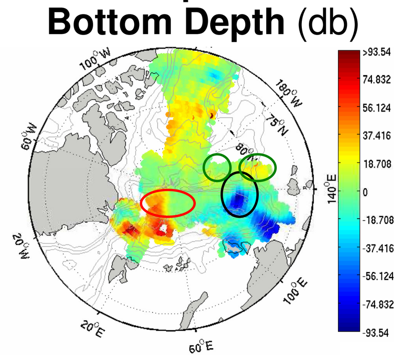
Saltier surface waters above the LR

Saltier surface waters in the WA

Top depth (db)



Bottom Depth (db)



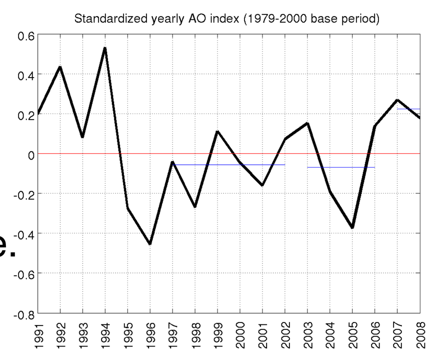
Lifting of the top and bottom unchanged or deeper in MB

Lifting of the bottom and top unchanged above the LR

Variable deepening of the top and bottom in the W A

➢ Why is the surface salinity changing ?

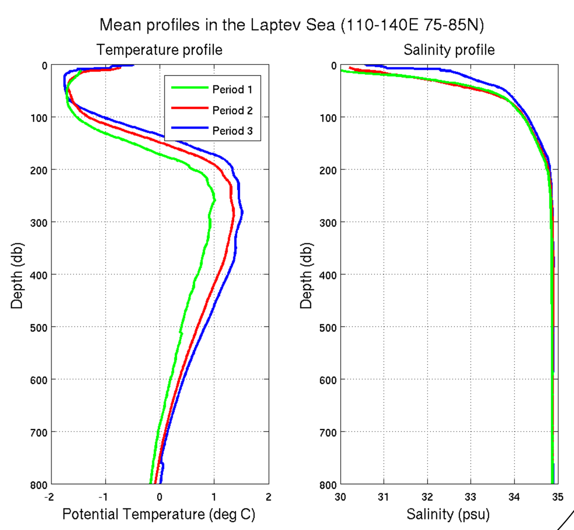
Last decade changes in the Arctic were partly attributed to the Arctic Oscillation (AO). For instance, a peculiarly high AO index induced an eastward component of the winds over the Laptev Sea. Therefore, waters in the East Siberian seas were fresher and waters in the Eurasian basin were saltier (Steele and Boyd 1998, Dickson 1999). So, the high AO of the early 1990's was responsible for the "CHL retreat". Another period of high positive AO just happened, during the IPY. This is concomitant with a strong freshening of the mixed layer salinity in the East Siberian Seas and a salinification at the junction between the Laptev Sea and the Lomonosov ridge. Therefore, it is possible the AO played a role in the recent surface salinity changes.



➢ Why is the halocline bottom depth changing ?

Around the Laptev Sea, the halocline base is particularly deep during 2003-2006. This induces a smaller salt content than during the other years. This deep salt content change can come either from below the halocline (less salt diffusion from the Atlantic water), or from the surface (less brines rejection). This last hypothesis is reinforced by the fact that the halocline bottom temperature is the warmest during period 2. It is possible that small scale processes play a bigger role in the halocline variability than previously thought.

	T_{bottom}	Z_{bottom}
1997-2002	-1,64℃	82 db
2003-2006	-1, 34℃	93 db
IPY	-1,5℃	76 db



Conclusions:

The halocline is documented here by a tracer that is based on the salinity gradient structure, taking into account both the salinity amplitude and the halocline thickness. Our tracer reveals that less stratified haloclines are gradually expanding the Amundsen basin from P1 to P3 (from the center to the Western side), mostly due to saltier surface waters. The Makarov basin becomes very stratified during the IPY because of the surface waters freshening, and the Lomonosov ridge is less stratified due to changes both in thickness and surface salinity. Changes in surface salinity might be linked to the AO as previously observed in the early 1990's. Changes in thickness play also an important role in the halocline stratification variability. Small scale processes, especially brines rejection, might be more involved in the halocline stratification than previously thought.