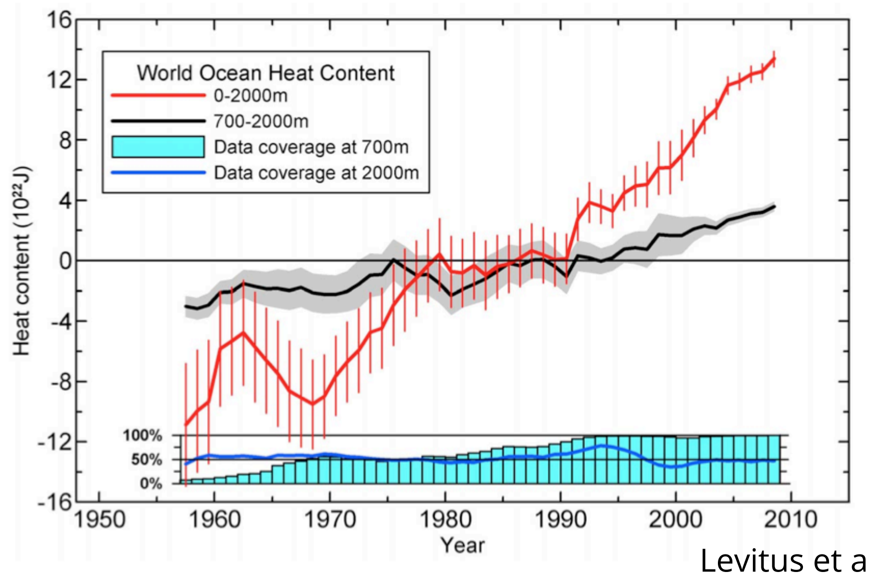
The main pycnocline of the Atlantic Ocean

Guillaume Maze, Herlé Mercier, Virginie Thierry

Euro-Argo meeting
Southampton, June 18-20 2013

Context

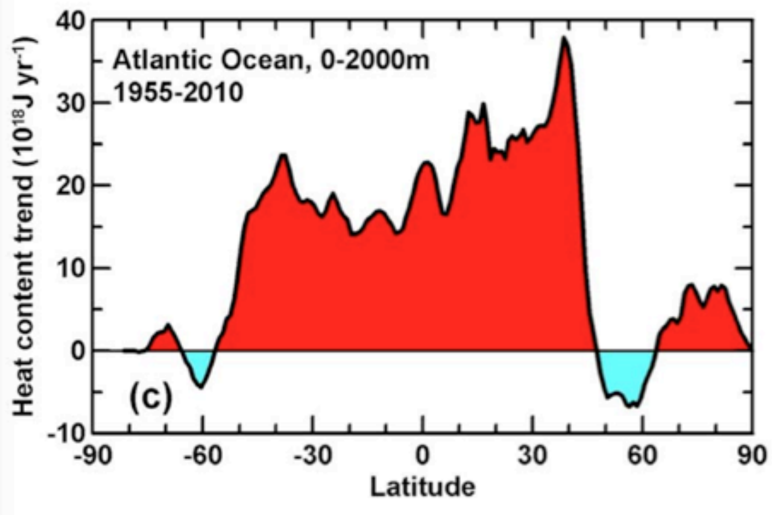
- **Oceans warm**



Levitus et al, 2012

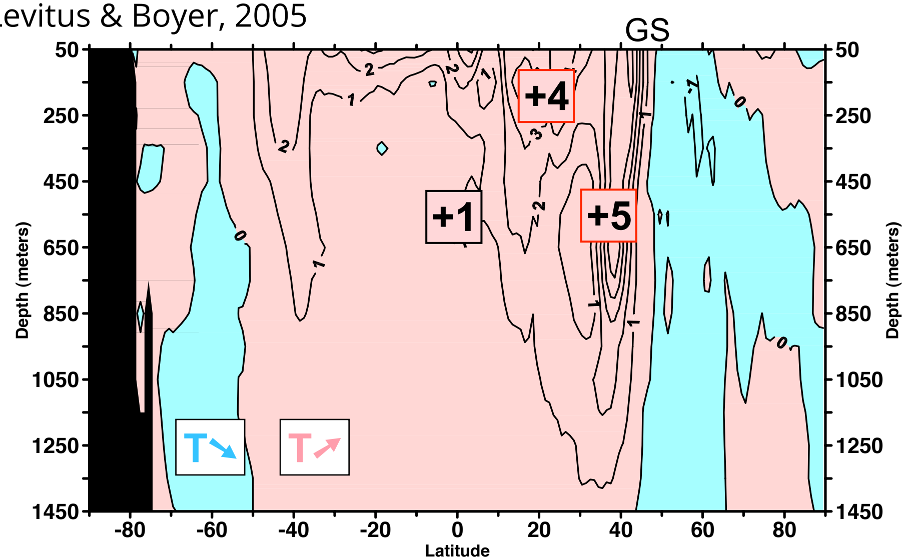
Observed trend in Oceanic heat content (0-2000m, zonal average)

Levitus et al, 2012

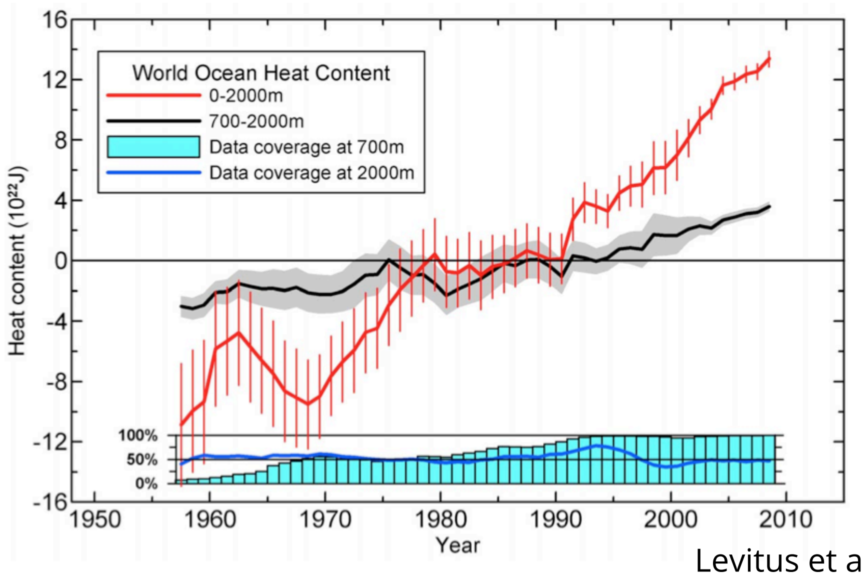


Observed trend in Oceanic heat content (Atlantic, 1955-2003)

Levitus & Boyer, 2005



- Oceans warm

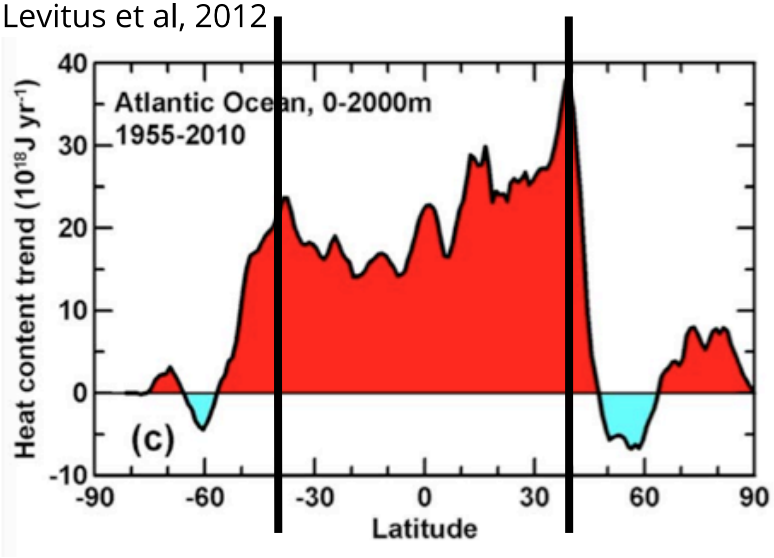


Levitus et al, 2012

Context

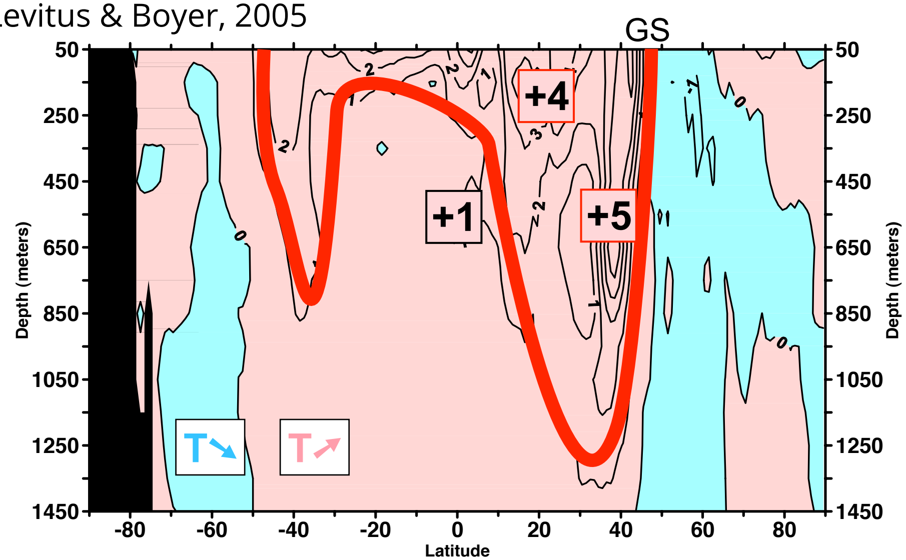
Observed trend in Oceanic heat content (0-2000m, zonal average)

Levitus et al, 2012



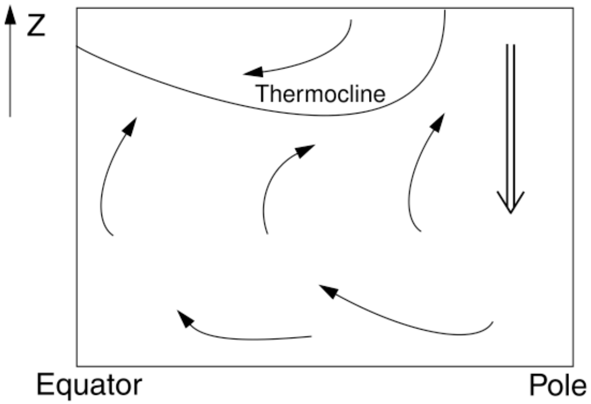
Observed trend in Oceanic heat content (Atlantic, 1955-2003)

Levitus & Boyer, 2005



- Constrained by main pycnocline structure

Due to the large scale water mass ventilation process



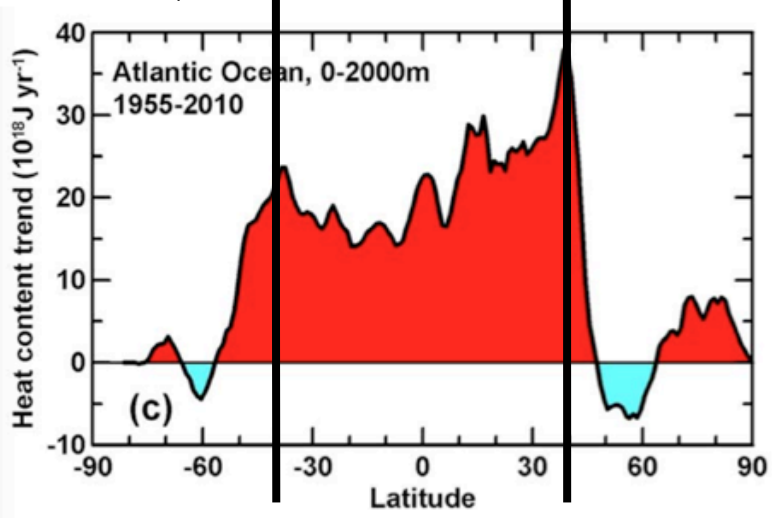
Vallis, 2005

- Oceans warm

Context

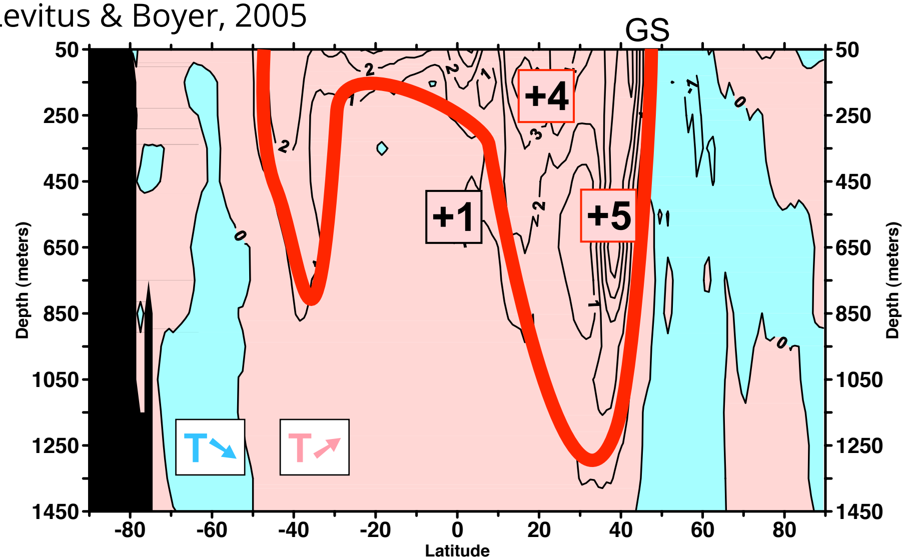
Observed trend in Oceanic heat content (0-2000m, zonal average)

Levitus et al, 2012



Observed trend in Oceanic heat content (Atlantic, 1955-2003)

Levitus & Boyer, 2005

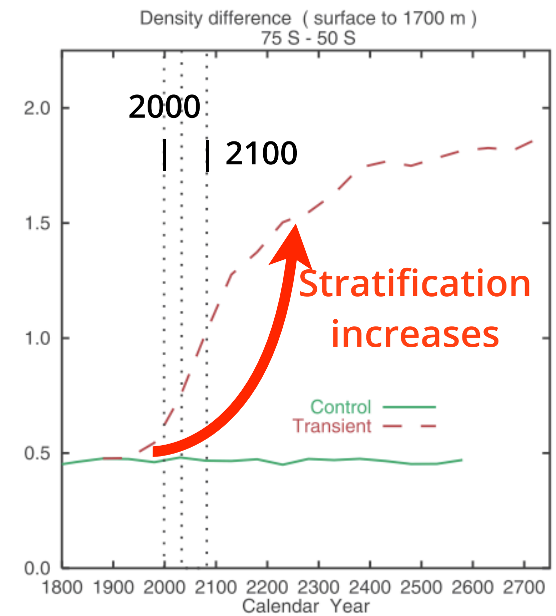


- Oceans *will* warm & main pycnocline structure *will* change

Climatic projection of the stratification

Matear et al, 2003

$CO_2(2100) = 3 \times CO_2(1900)$

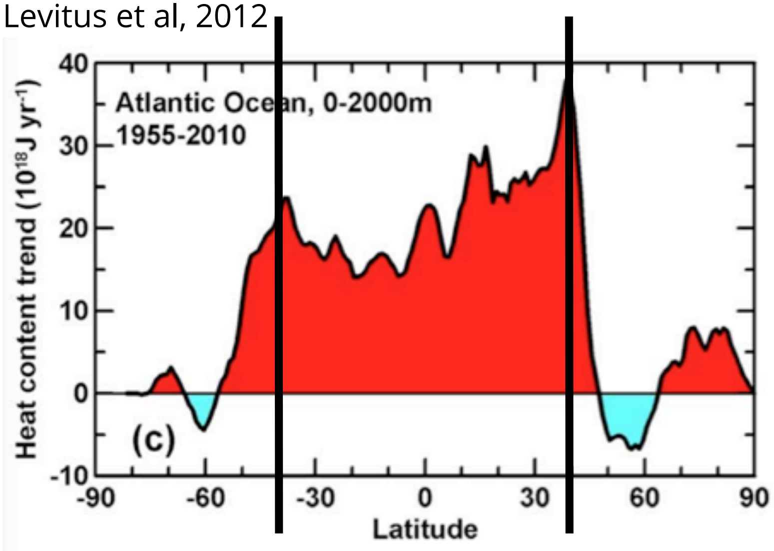


- Oceans warm
- Constrained by main pycnocline structure

Context

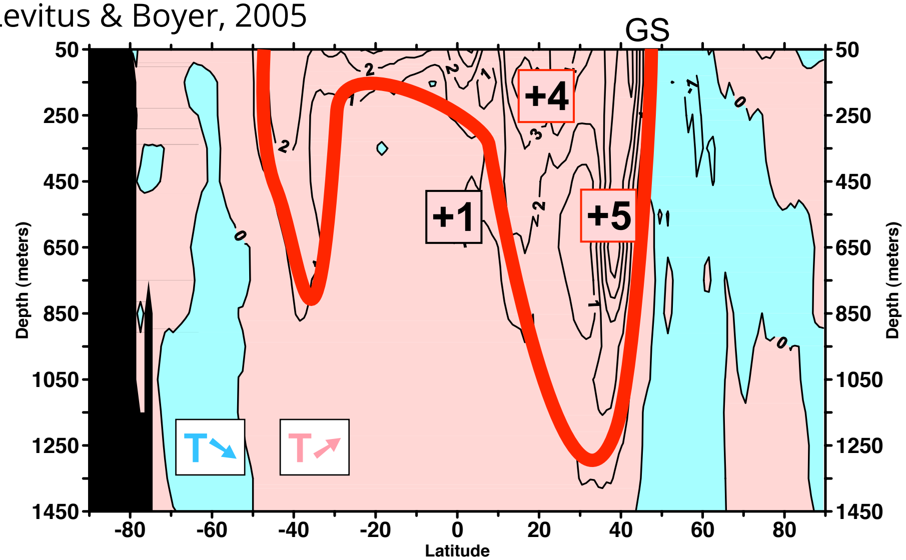
Observed trend in Oceanic heat content (0-2000m, zonal average)

Levitus et al, 2012



Observed trend in Oceanic heat content (Atlantic, 1955-2003)

Levitus & Boyer, 2005



- We need a state estimate of the main pycnocline today

but why do we care ?

Eg: A same amount of heat induces different temperature changes if distributed over different depth ranges

- Oceans warm
- Constrained by main pycnocline structure
- Oceans will warm & main pycnocline structure will change

Method

- Most methods to date were used in the tropical regions
- We need a bullet proof method

Yang et al, 2009

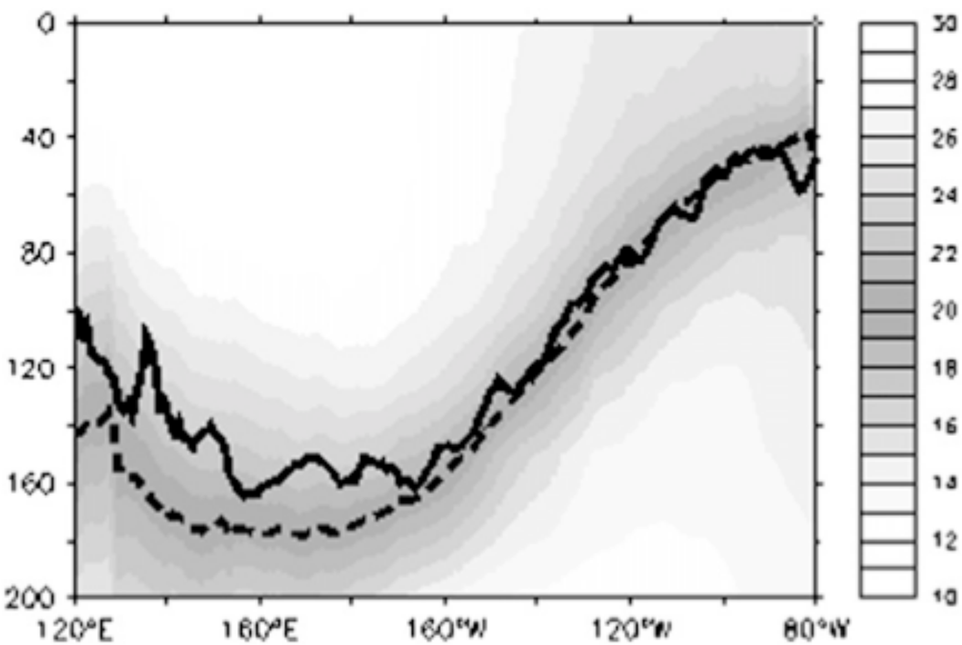
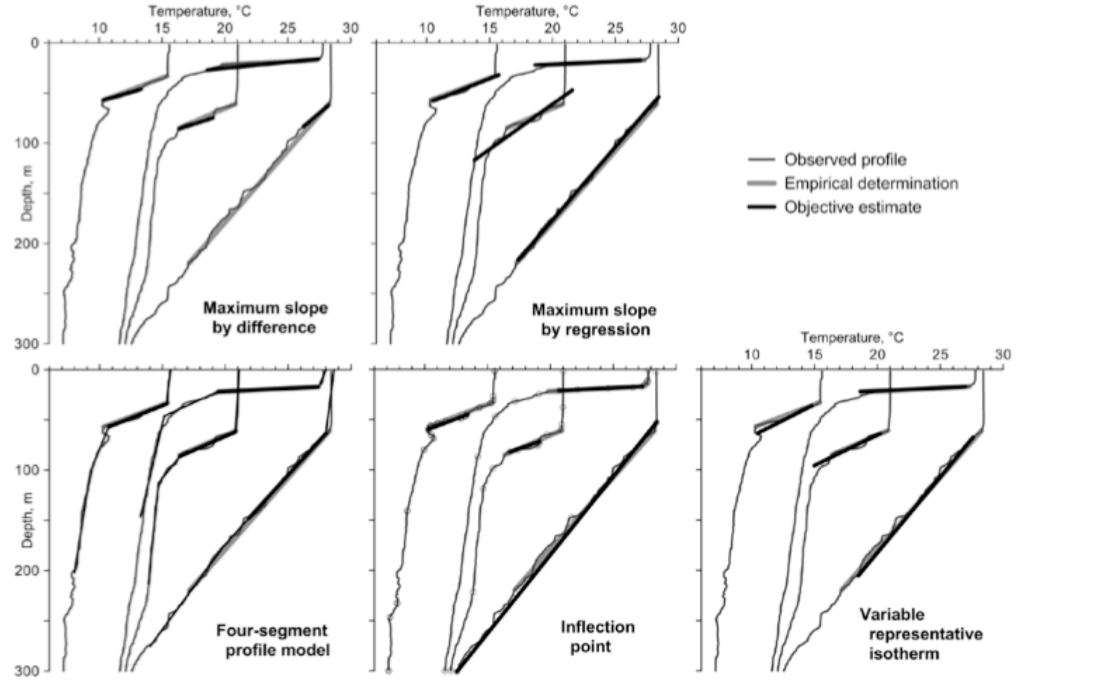


FIG. 1. Climatological annual mean upper-ocean temperature (°C) averaged between 5°S and 5°N from Levitus data (1955–2003). The dashed line shows the location of the 20°C isotherm (Z_{20}), and the solid line shows the location of the maximum vertical temperature gradient (Z_{tc}).



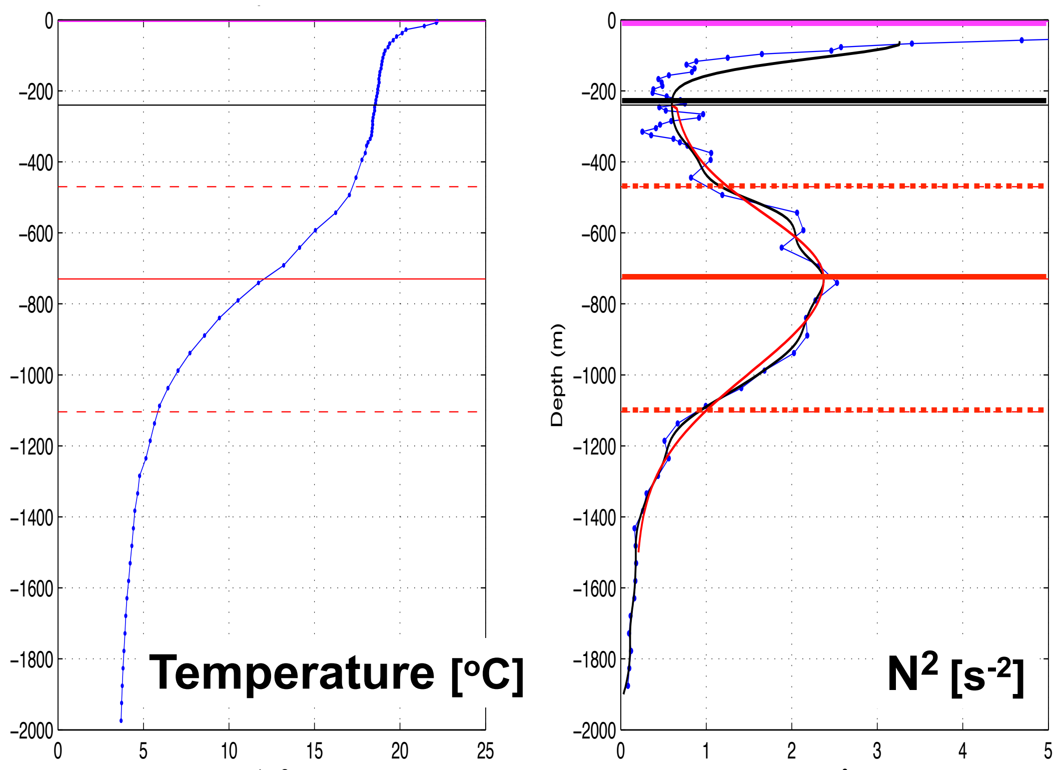
timated thermoclines from the five objective methods compared with empirically determined thermoclines (identical in each panel) for four erved profiles: from left to right in each panel, California Current, tropical, equatorial, subtropical. In the four-segment profile model panel, ments are plotted along with the thermocline segment. In the inflection point method panel, inflection points are plotted (circles).

Fiedler, 2010

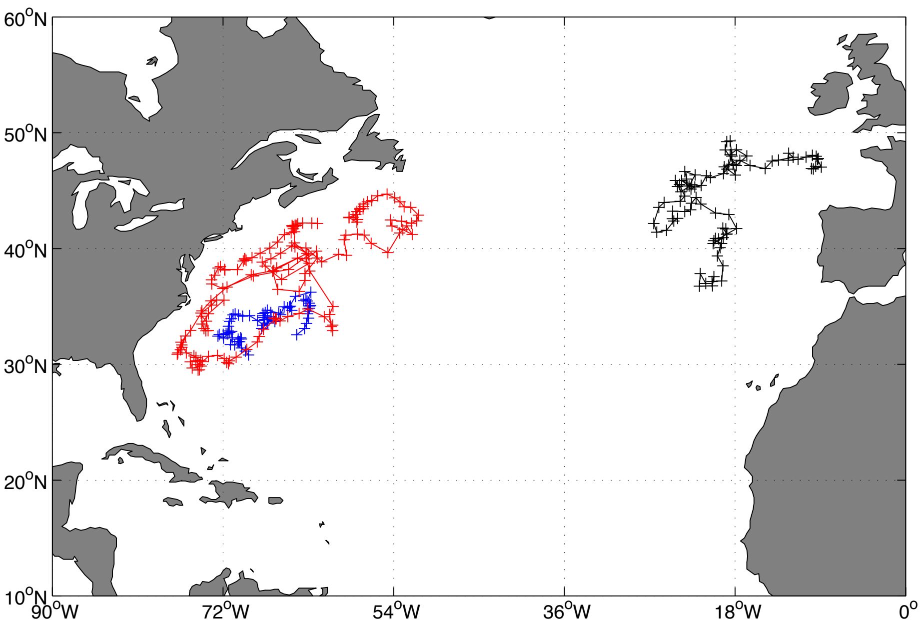
Method

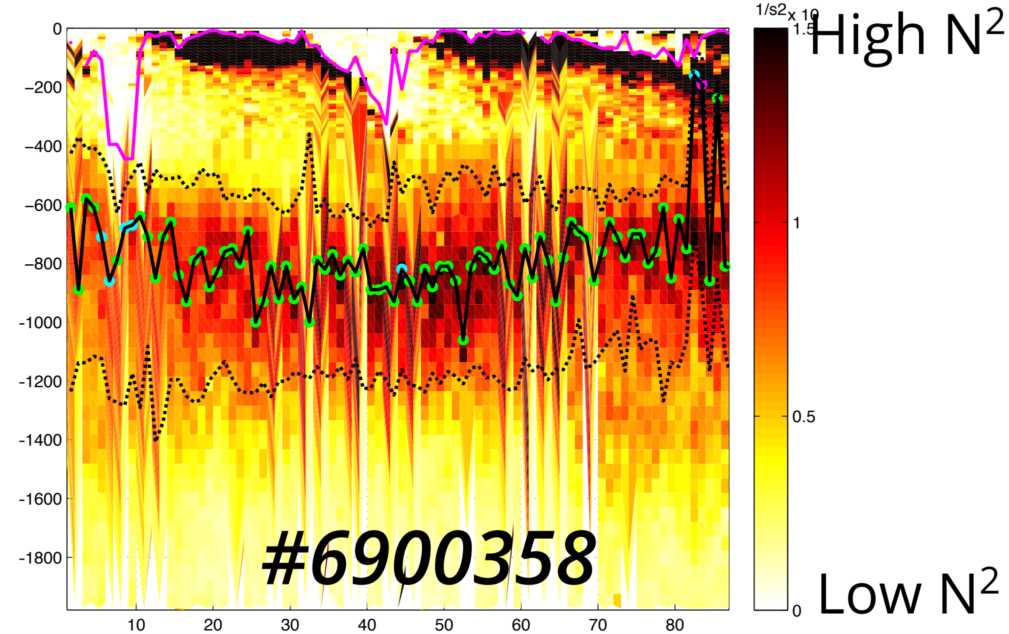
Standard set of parameters

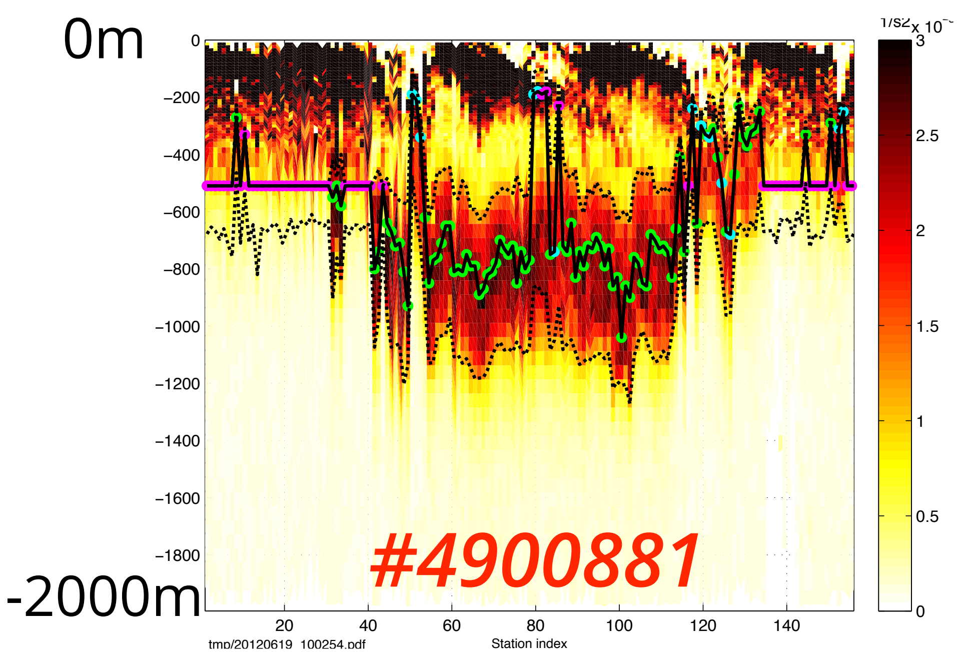
What we do:	What do we get:
Interpolate on a regular grid	
'Cut' profile below the mixed layer	Mixed Layer Depth
Smooth profile (scale>50m)	
Find N^2 minimum in the top 300 or 500m	Mode water' depth (1st inflection)
Find N^2 maximum below	Main thermocline depth
Fit 2 Gaussian curves above and below	Main thermocline thickness (asymmetric description)
Compute QC metrics	QC flag
Apply a decision tree	Adjusted set of parameters or Final results

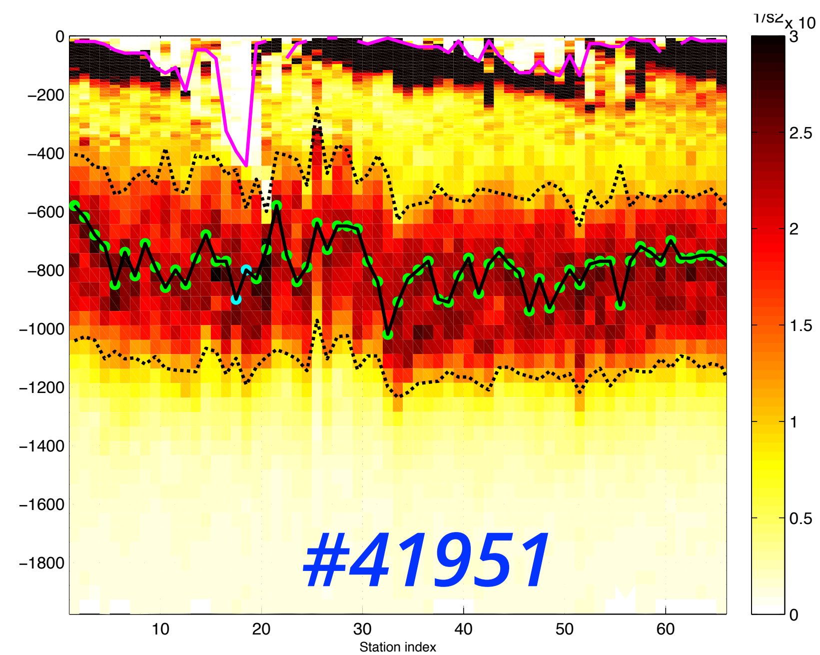


Method

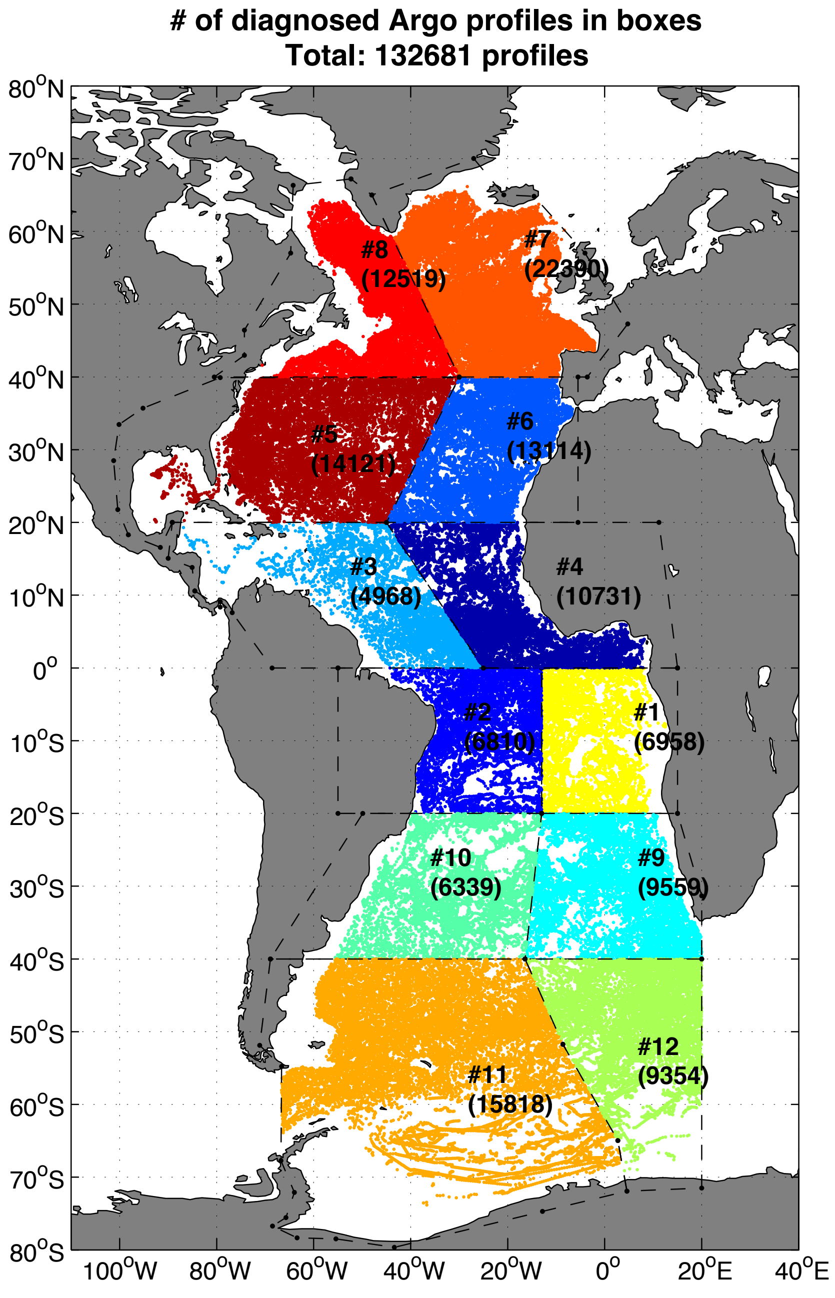

60°N
50°N
40°N
30°N
20°N
10°N
90°W
72°W
54°W
36°W
18°W
0°


#6900358
High N²
Low N²
1/s2 x 10
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
10
20
30
40
50
60
70
80
1.5
1
0.5
0

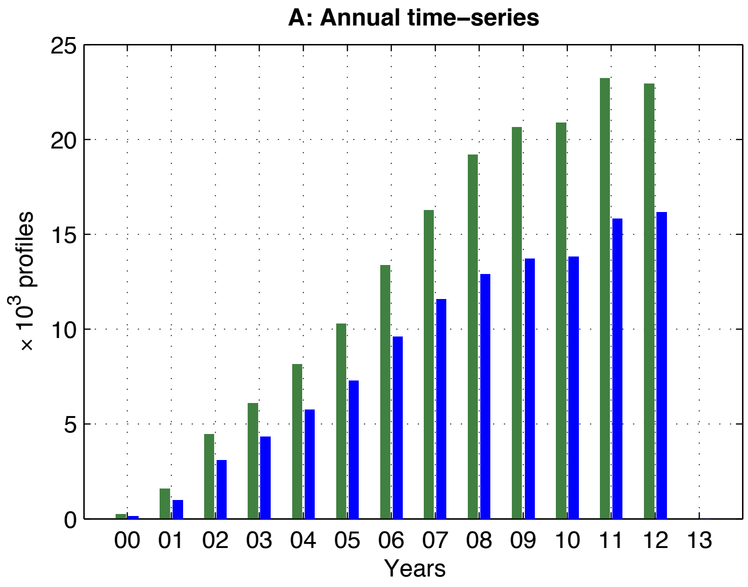

0m
-2000m
#4900881
1/s2 x 10
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
20
40
60
80
100
120
140
Station index
tmp/20120619_100254.pdf
3
2.5
2
1.5
1
0.5
0


#41951
1/s2 x 10
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
10
20
30
40
50
60
Station index
3
2.5
2
1.5
1
0.5
0

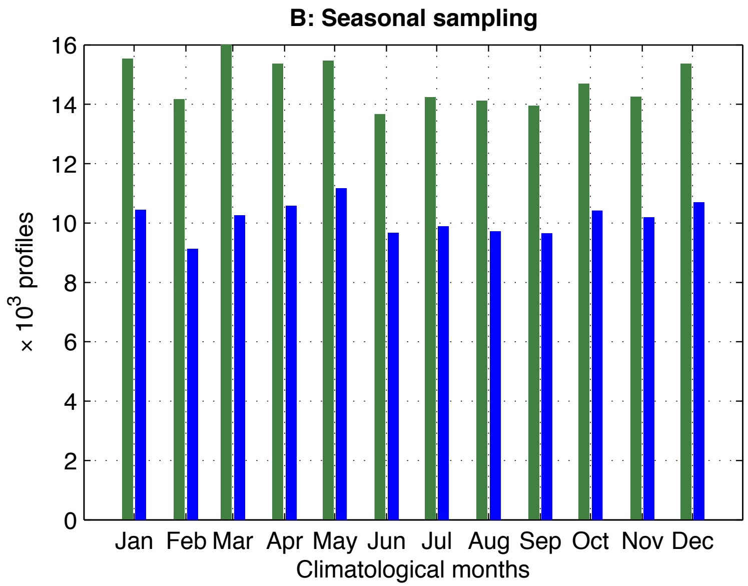
Method



# of diagnosed Argo profiles in boxes
Total: 132681 profiles
#8 (12519)
#7 (22390)
#5 (14121)
#6 (13114)
#3 (4968)
#4 (10731)
#2 (6810)
#1 (6958)
#10 (6339)
#9 (9559)
#11 (15818)
#12 (9354)
80°N
70°N
60°N
50°N
40°N
30°N
20°N
10°N
0°
10°S
20°S
30°S
40°S
50°S
60°S
70°S
80°S
100°W
80°W
60°W
40°W
20°W
0°
20°E
40°E



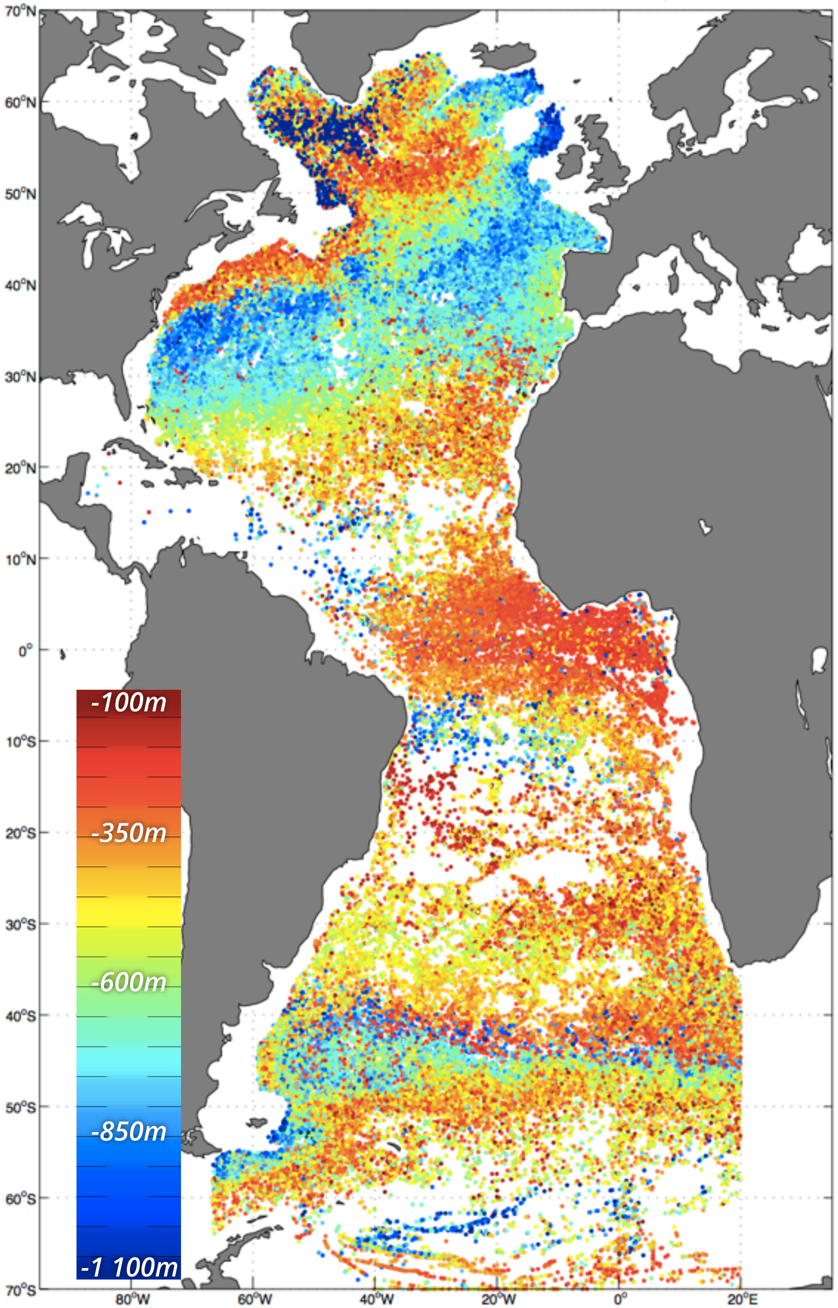
A: Annual time−series
× 10³ profiles
Years
00 01 02 03 04 05 06 07 08 09 10 11 12 13



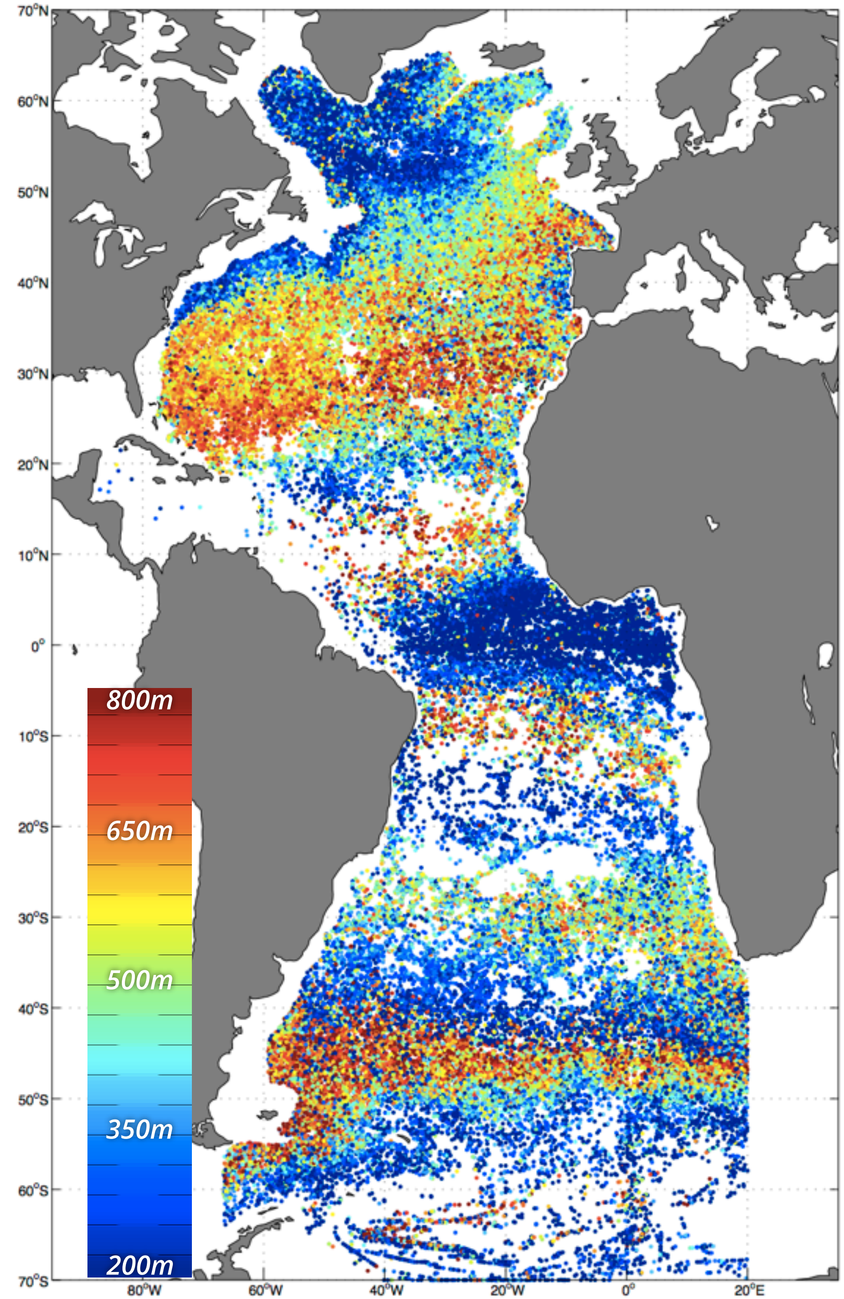
B: Seasonal sampling
× 10³ profiles
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Climatological months

Profiles results

Pycnocline Depth



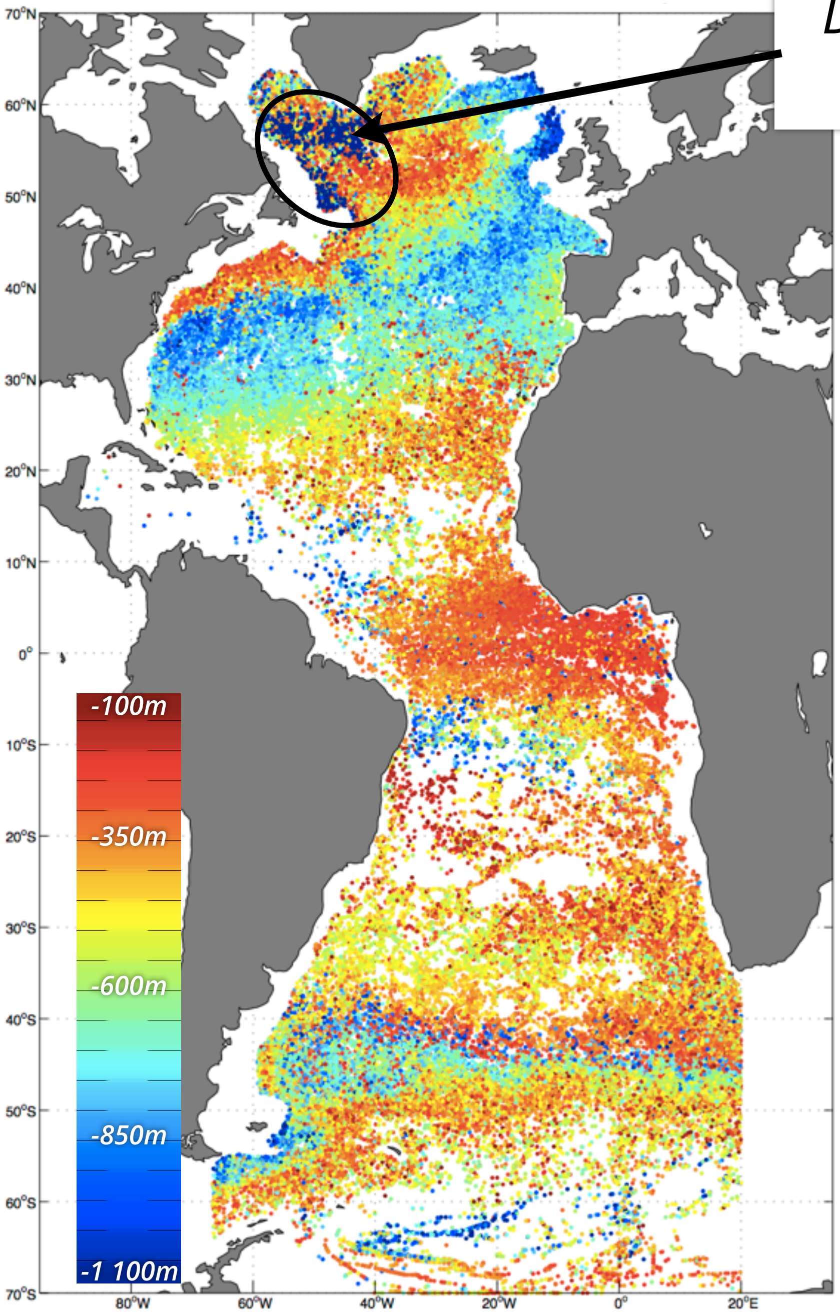
Pycnocline Thickness



92,799 profiles with QC=1

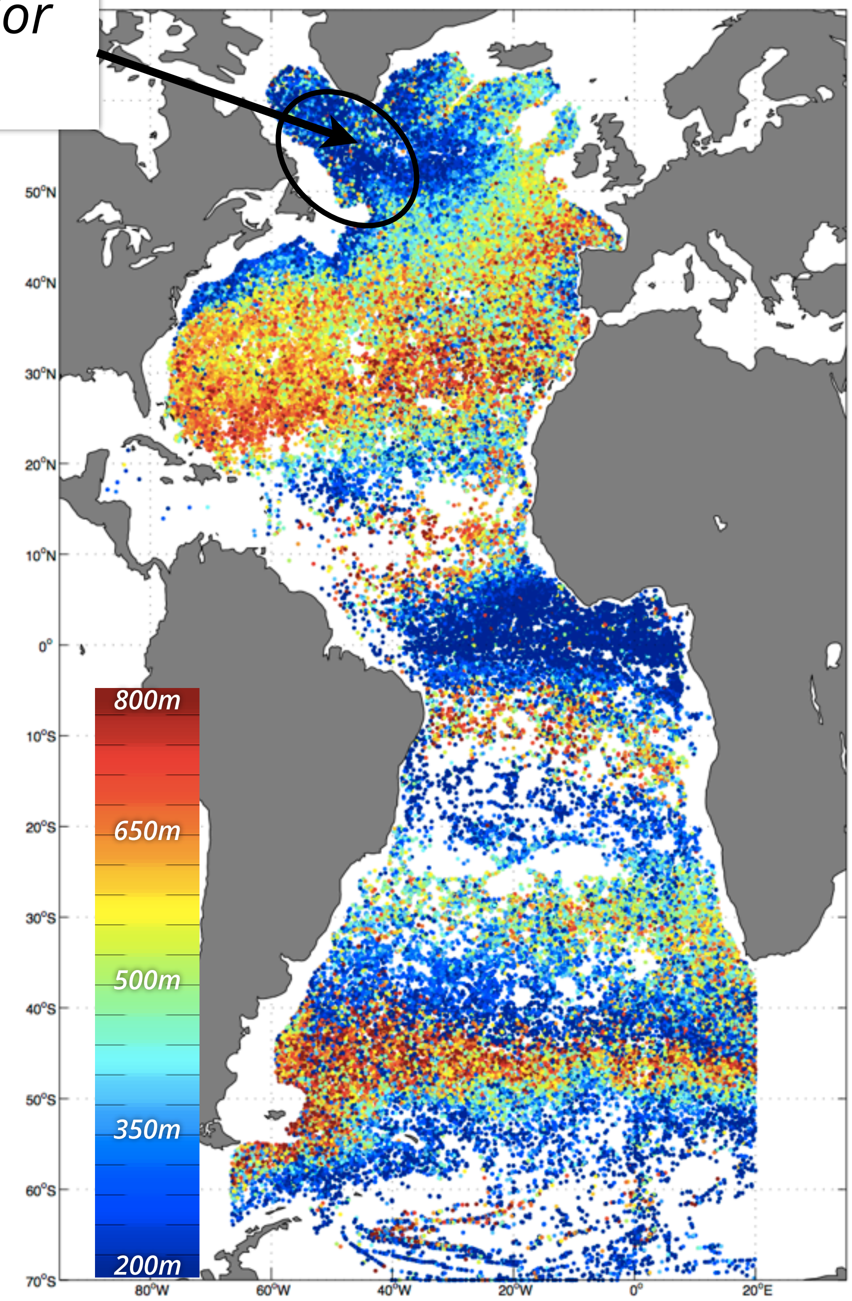
Profiles results

Pycnocline Depth



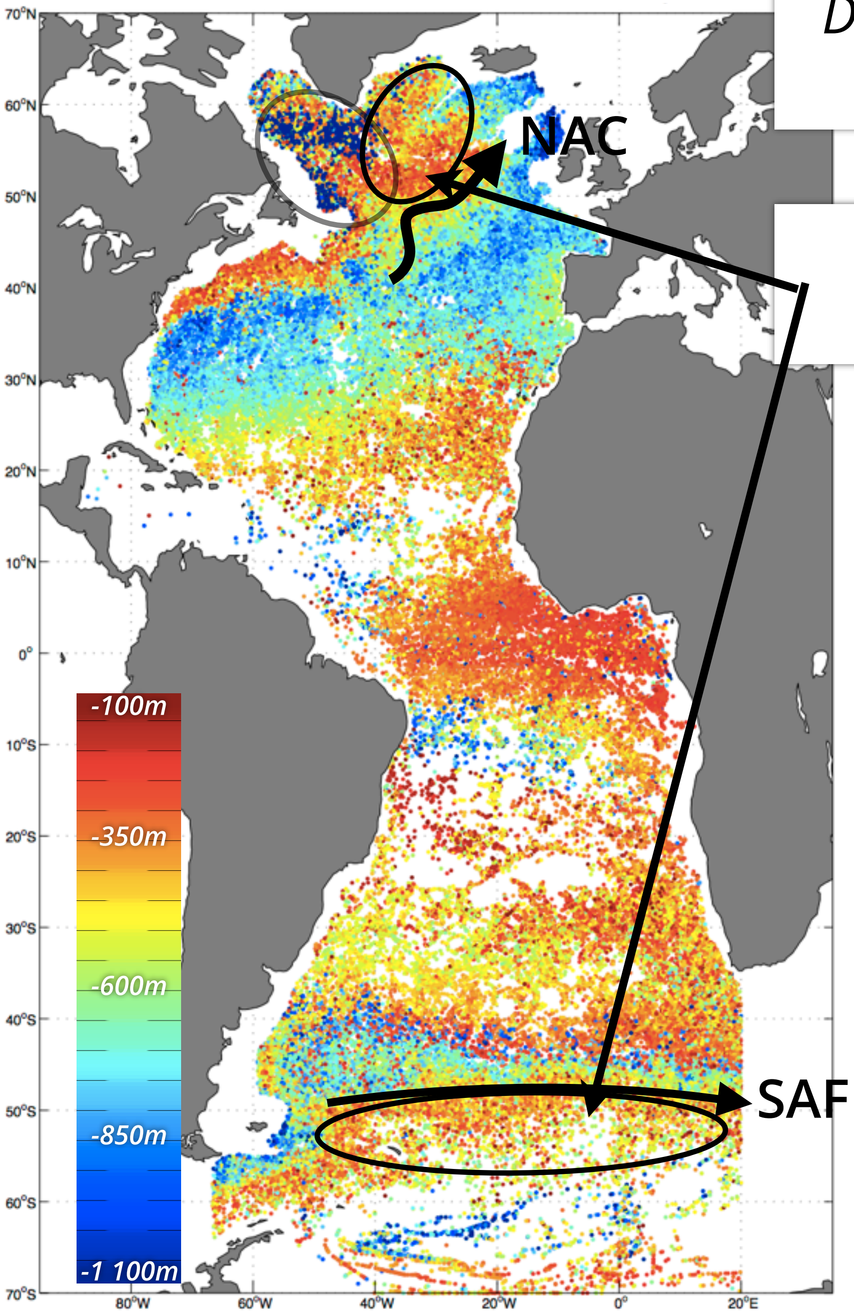
Deep, thin Labrador Sea features

Pycnocline Thickness



Profiles results

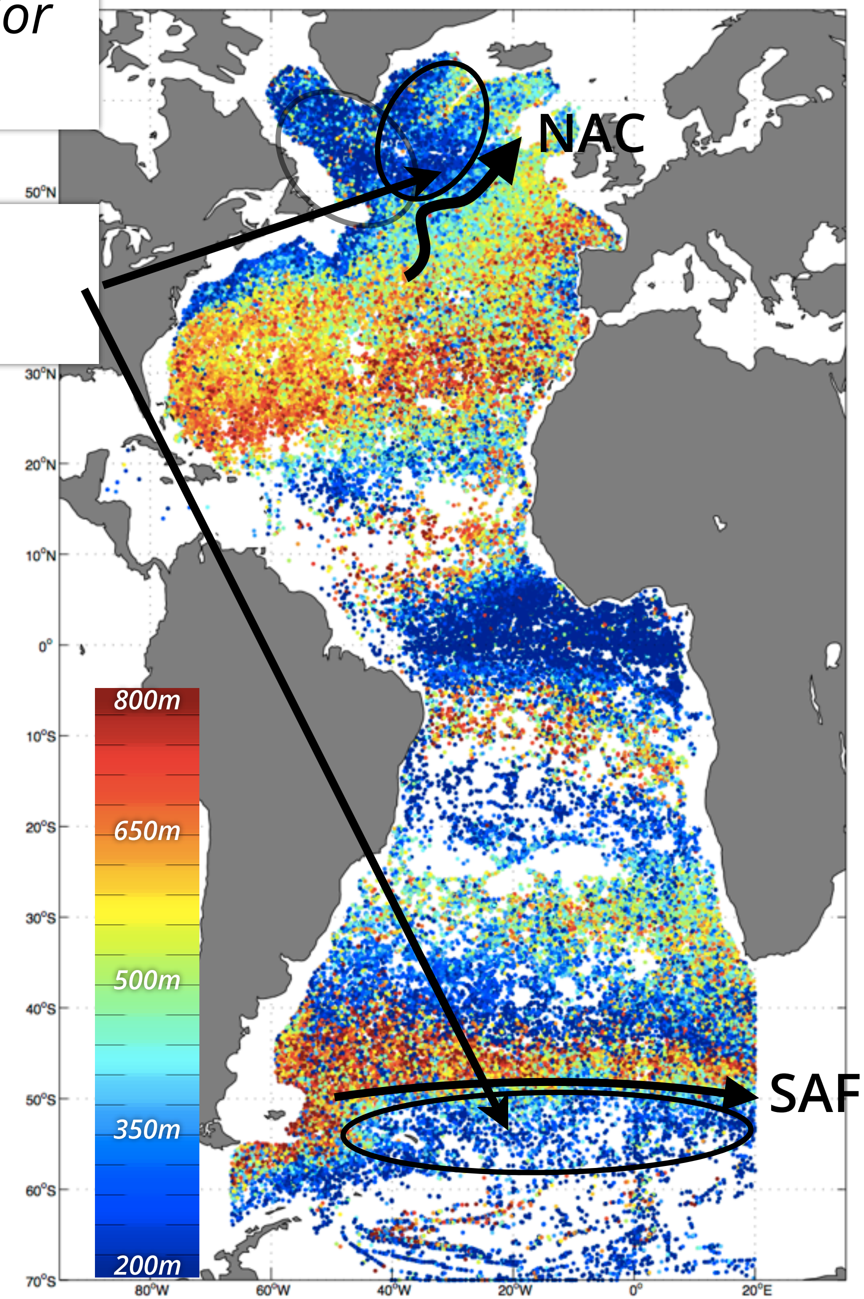
Pycnocline Depth



Deep, thin Labrador Sea features

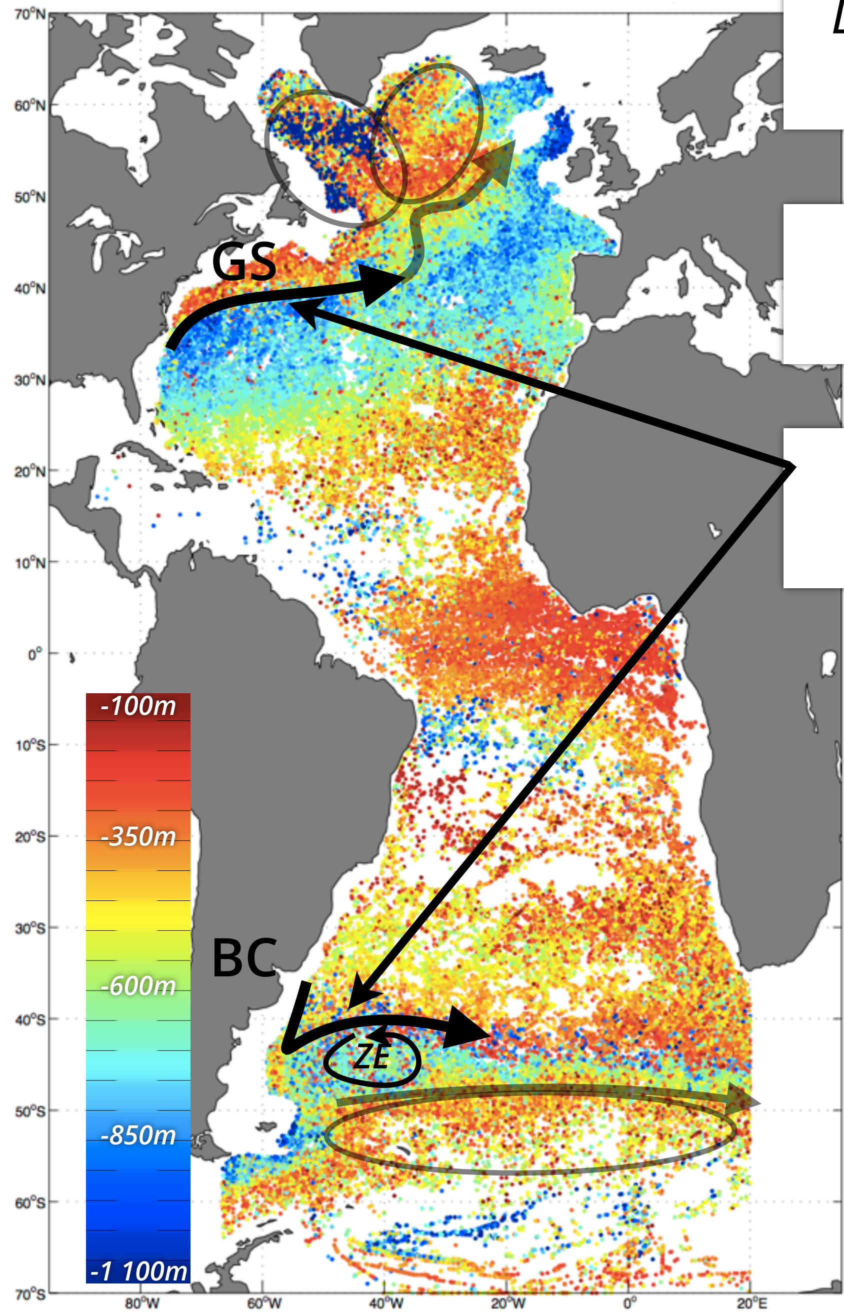
Shallow, thin at subpolar fronts

Pycnocline Thickness



Profiles results

Pycnocline Depth

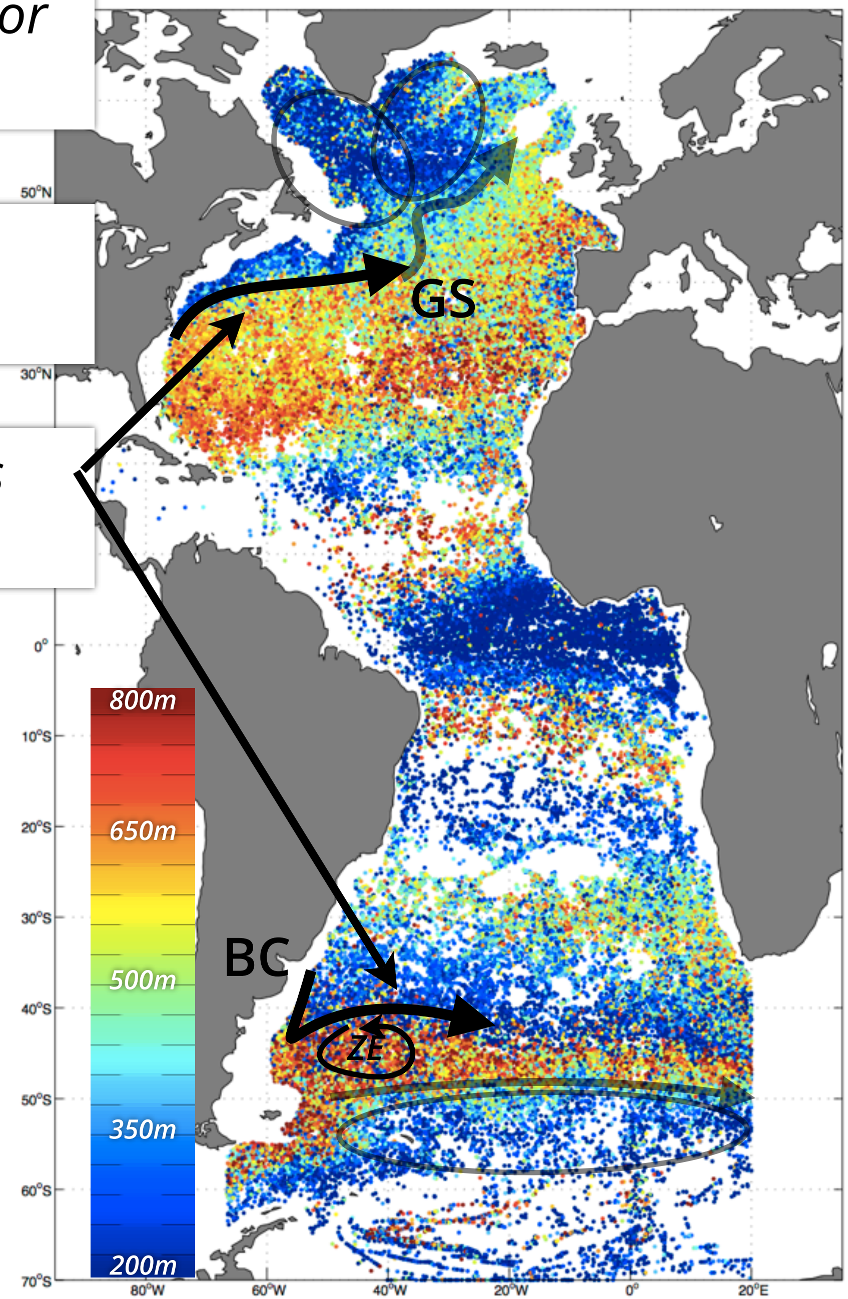


Deep, thin Labrador Sea features

Shallow, thin at polar fronts

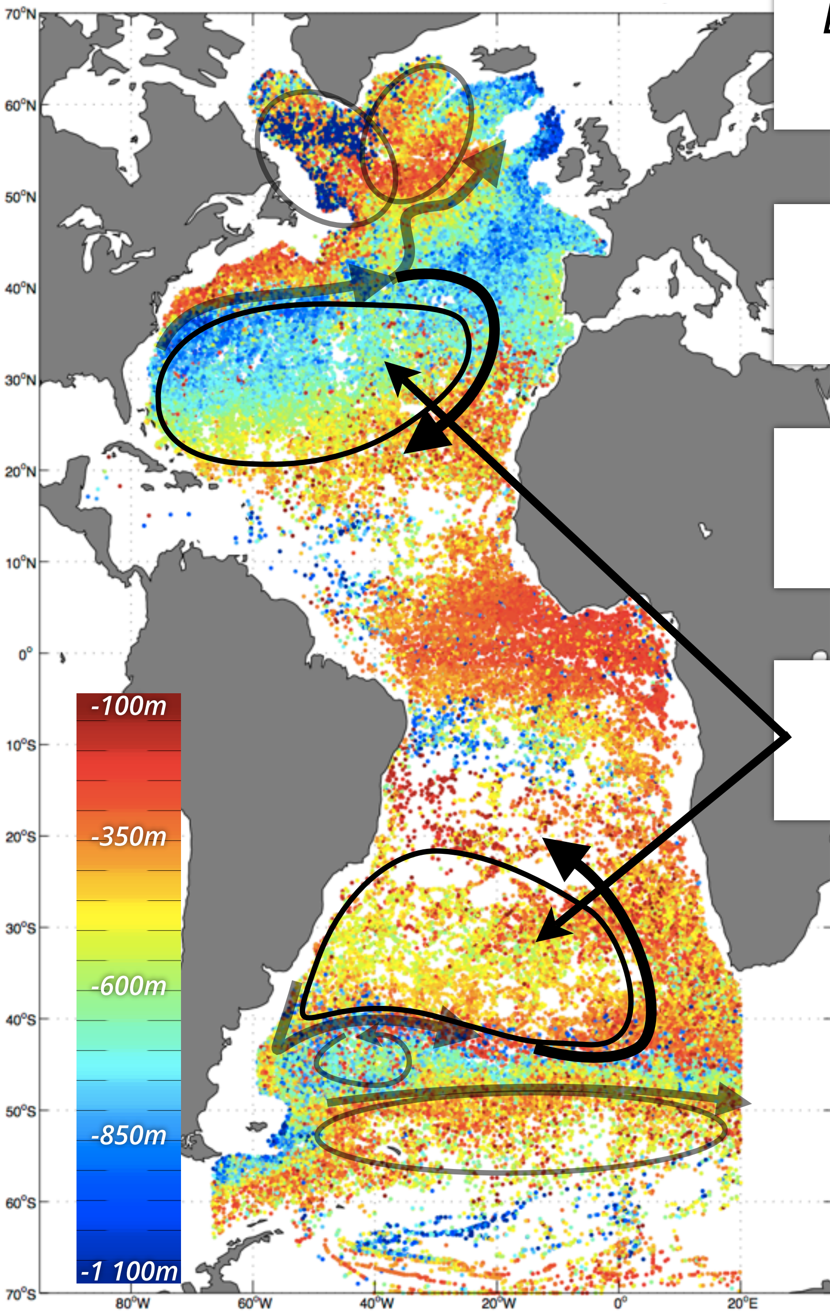
Strong gradients across WBC

Pycnocline Thickness



Profiles results

Pycnocline Depth



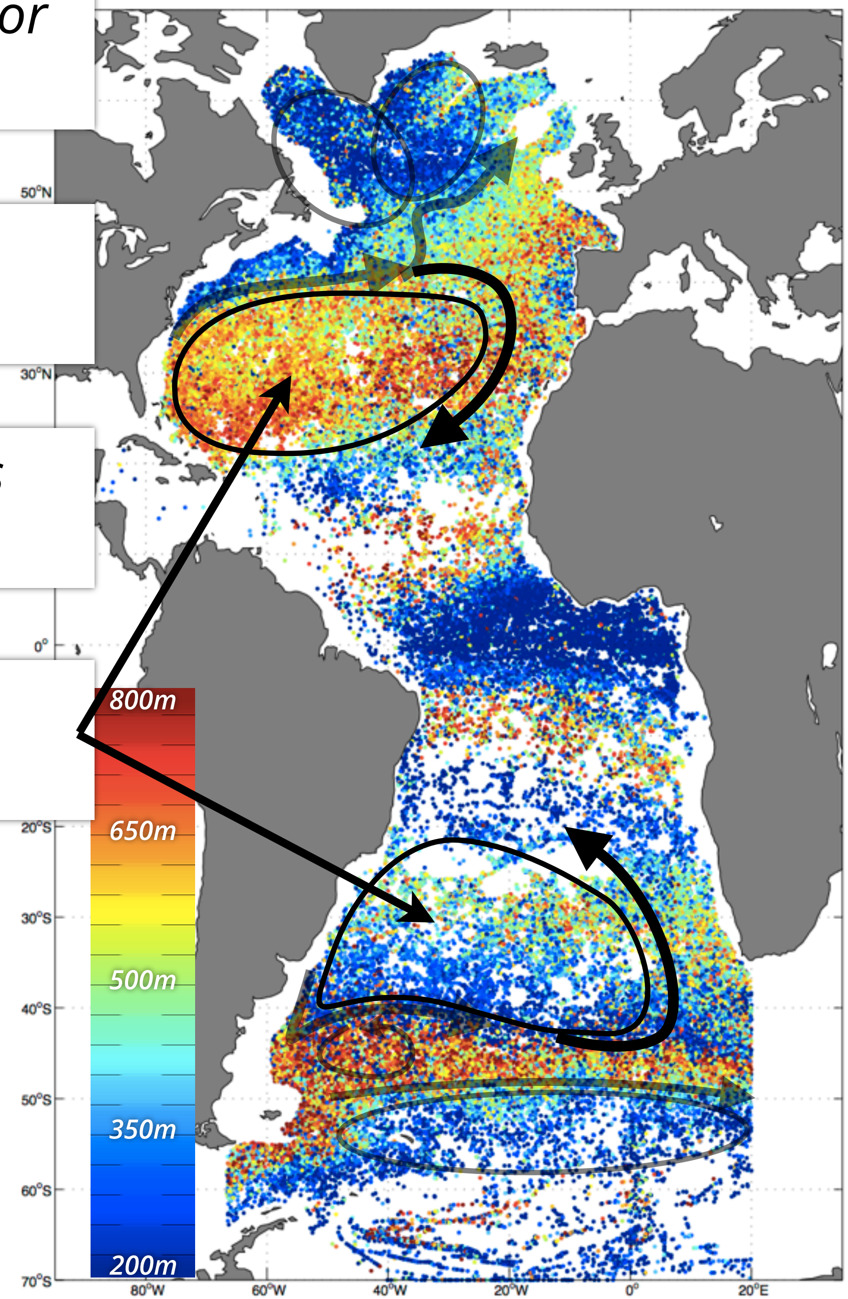
Deep, thin Labrador Sea features

Shallow, thin at polar fronts

Strong gradients across WBC

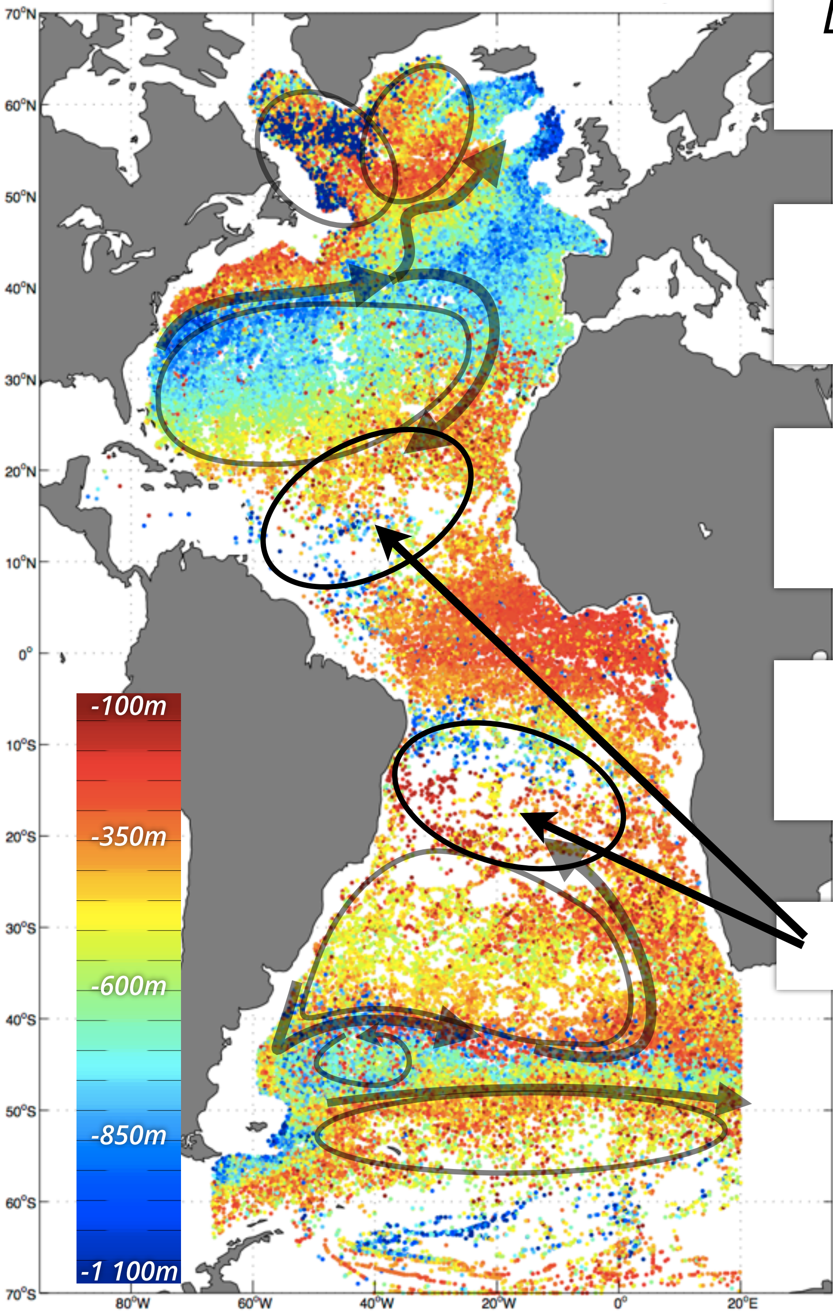
Deep, thick in subtp. gyres

Pycnocline Thickness



Profiles results

Pycnocline Depth



Deep, thin Labrador Sea features

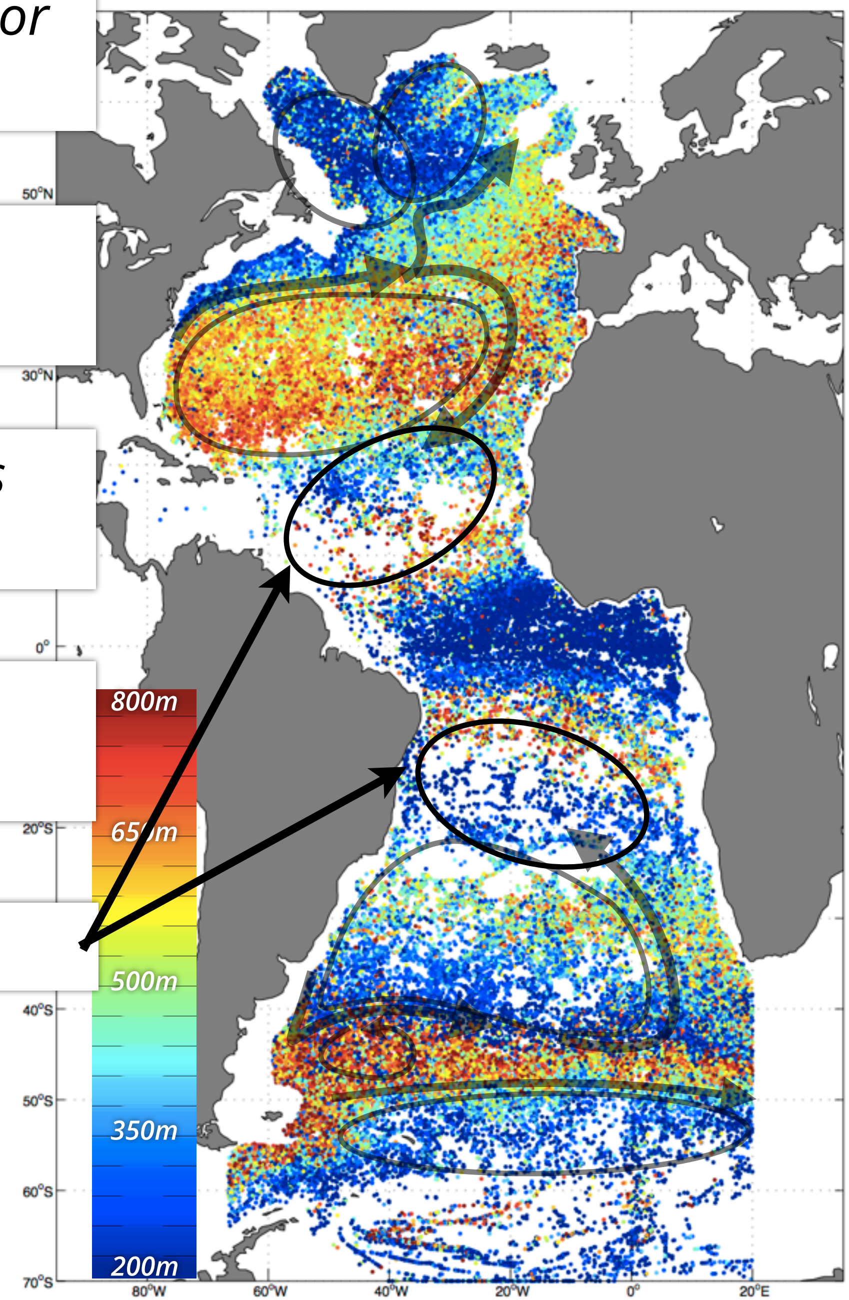
Shallow, thin at polar fronts

Strong gradients across WBC

Deep, thick in subtp. gyres

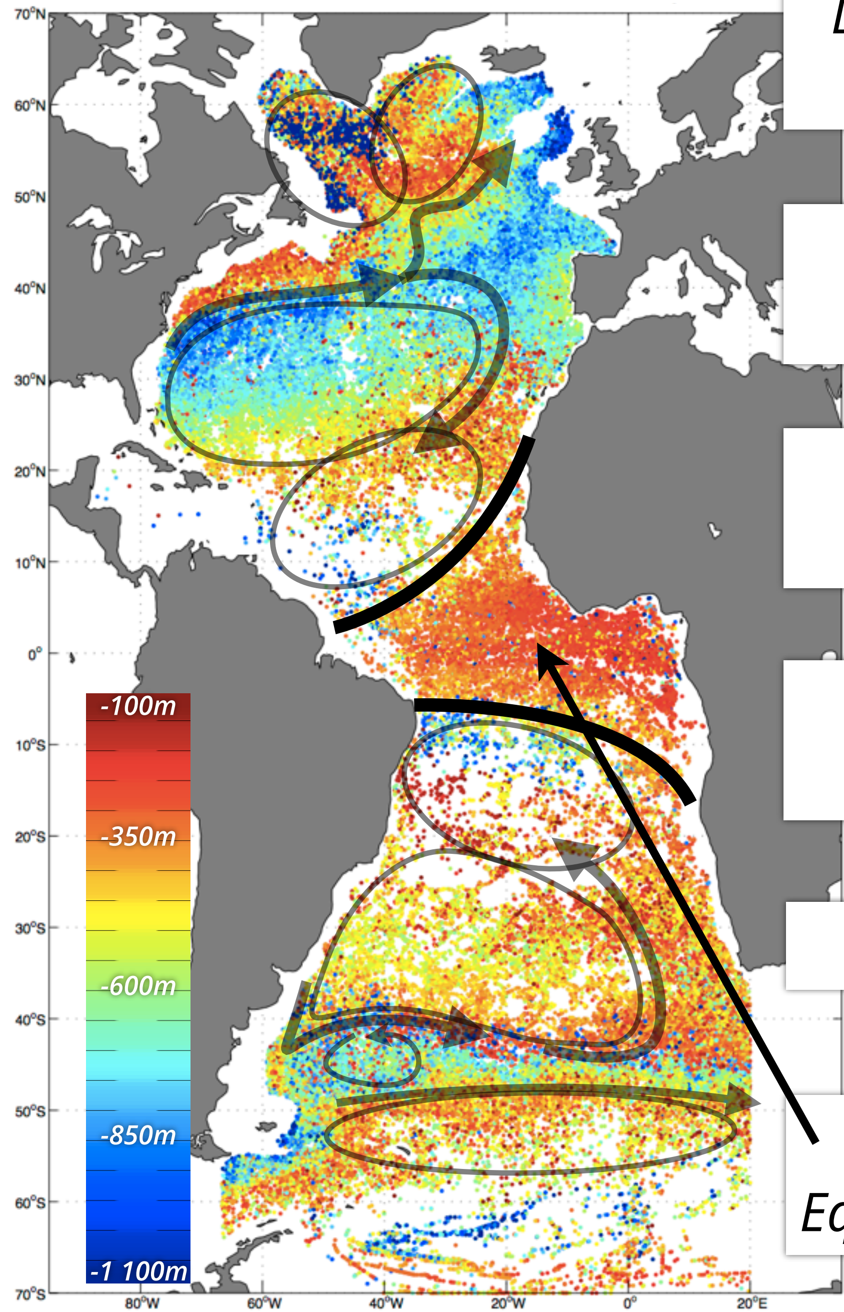
Transition zone

Pycnocline Thickness



Profiles results

Pycnocline Depth



Deep, thin Labrador Sea features

Shallow, thin at polar fronts

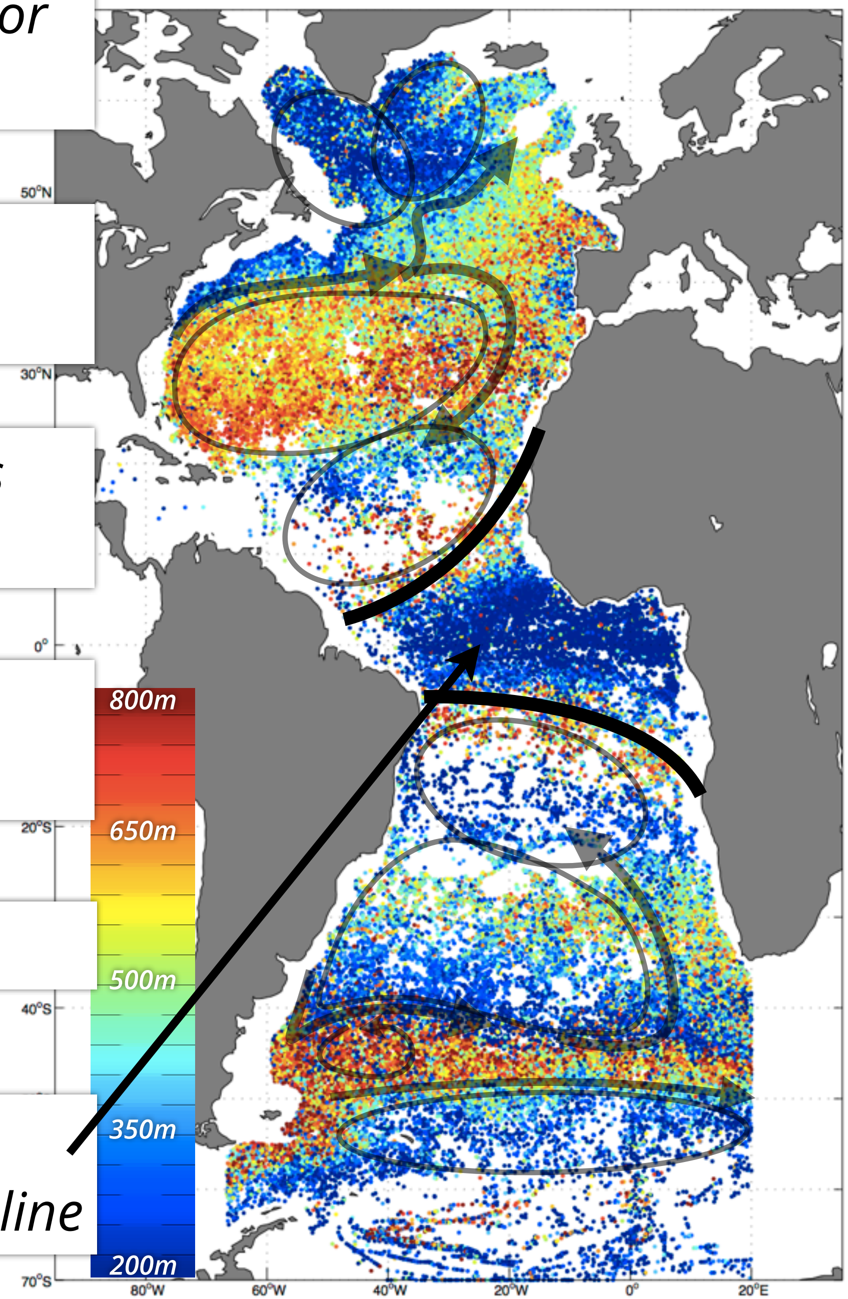
Strong gradients across WBC

Deep, thick in subtp. gyres

Transition zone

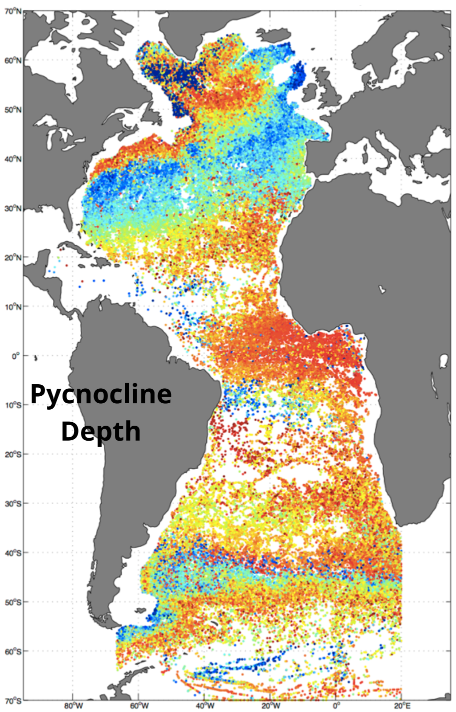
Shallow, thin Equatorial thermocline

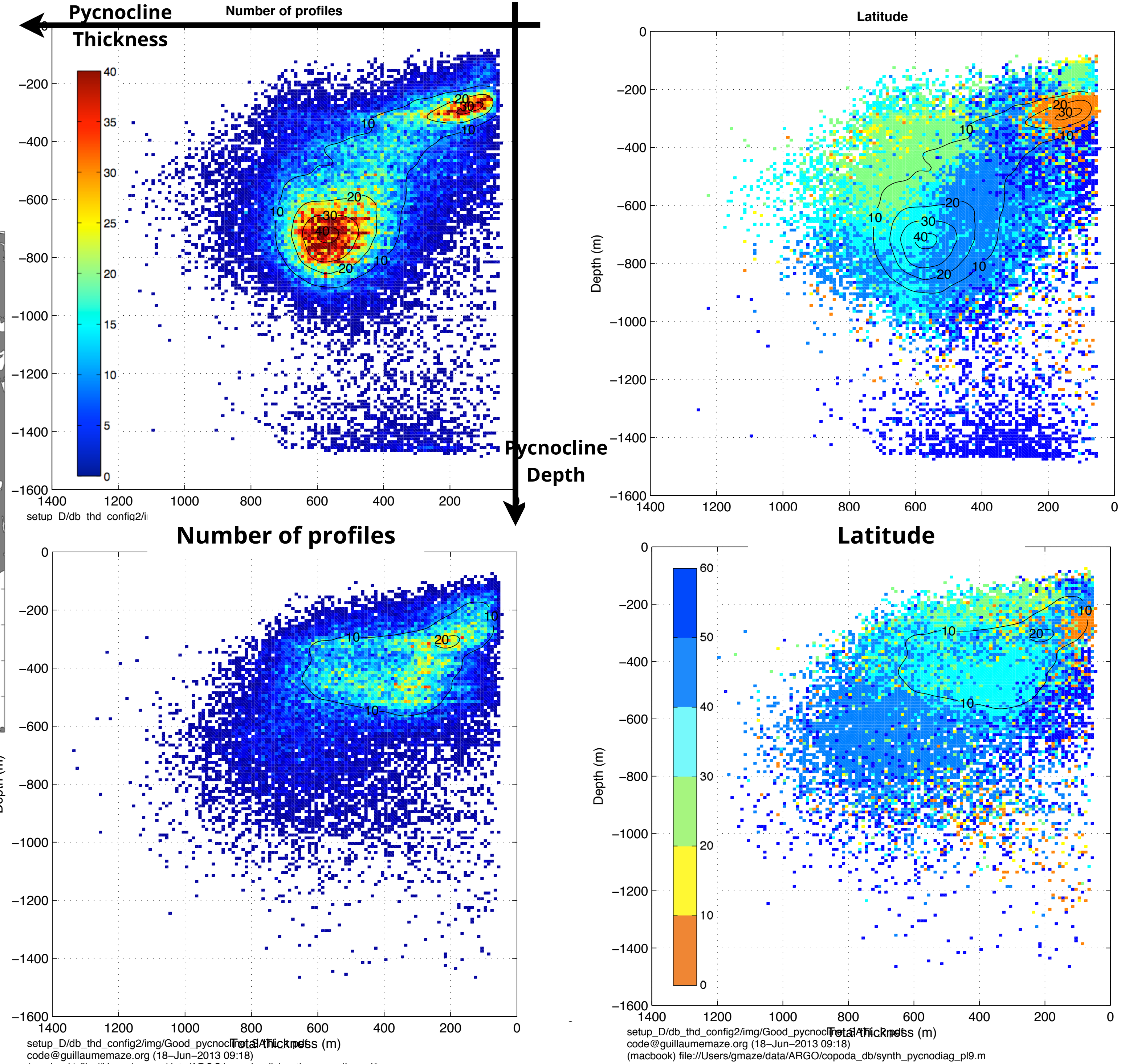
Pycnocline Thickness



Coherence

Northern hemisphere



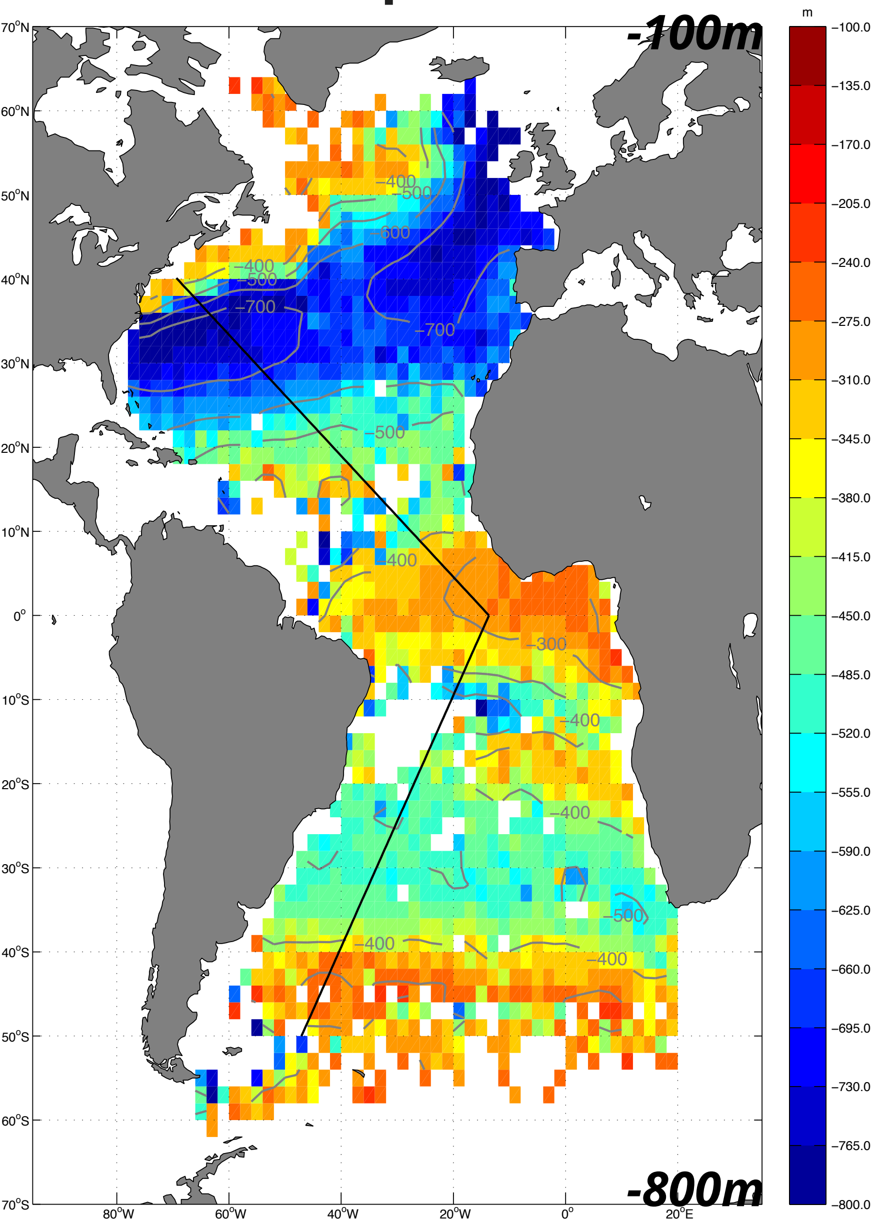


Southern hemisphere

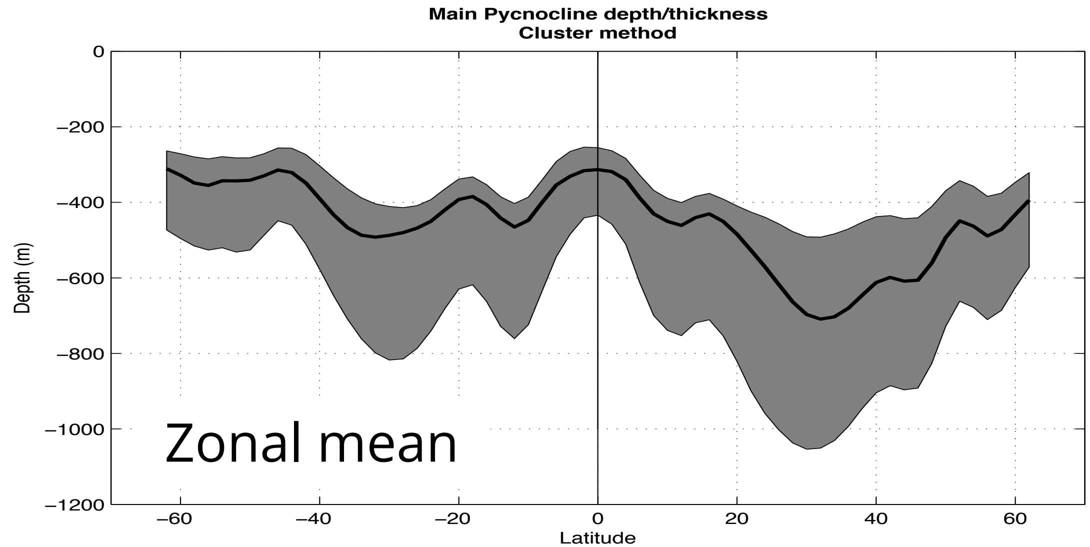
Mapped properties

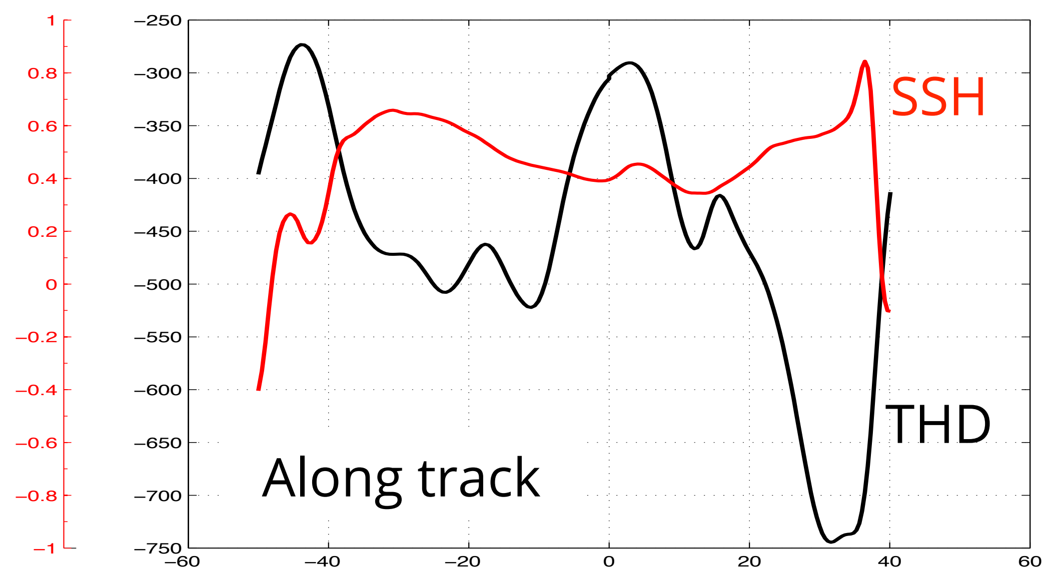
- **Northern hemisphere much deeper**
- **Topographic effect**

Depth



setup_D/db_thd_config2/img/Good_pycnocline_depth_binned_with_maskID7_overlayID0.pdf
code@guillaumemaze.org (19–Jun–2013 01:15)

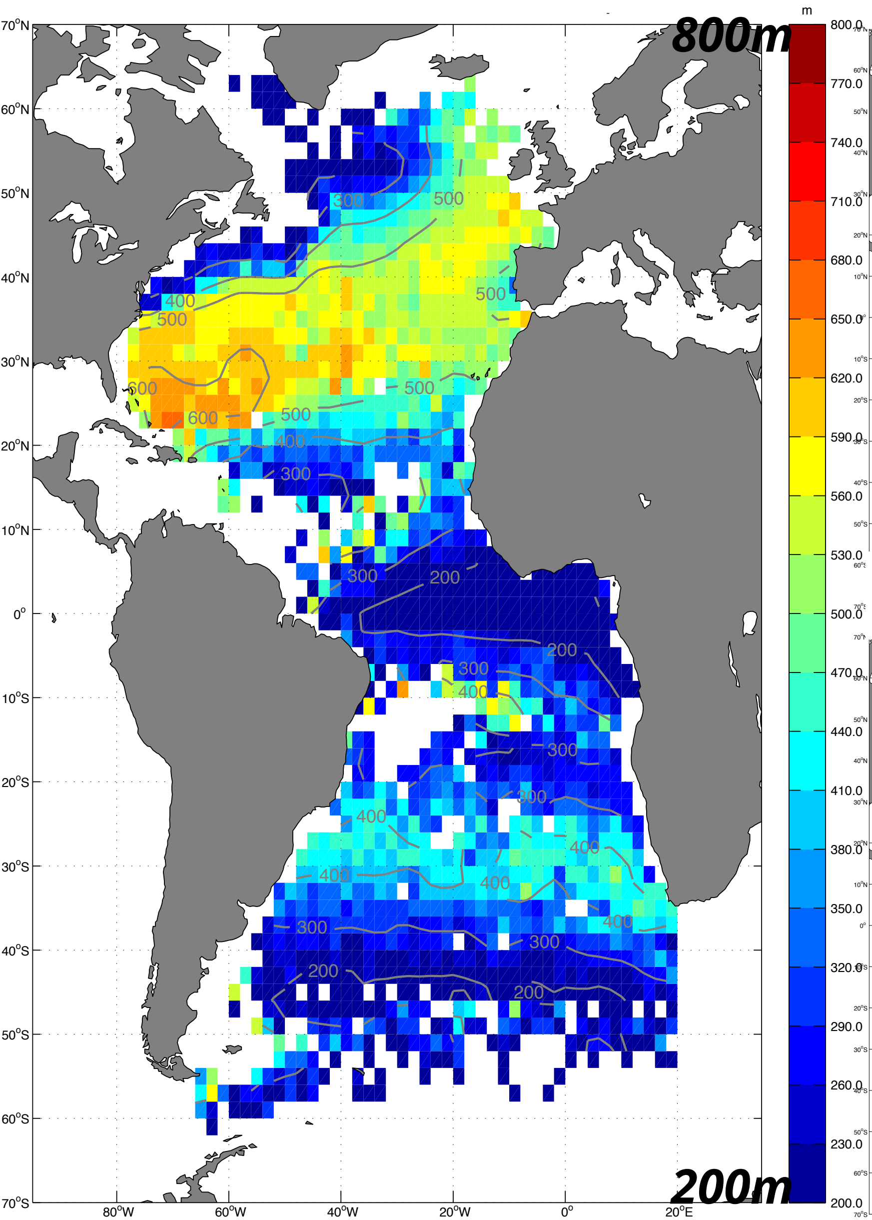




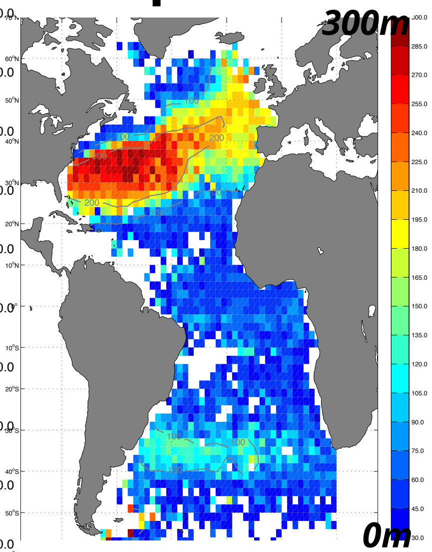
tmp/20130619_011243.pdf
code@guillaumemaze.org (19–Jun–2013 01:12)
(macbook) file://Users/gmaze/data/ARGO/copoda_db/synth_pycnodiag_pl5.m

Mapped properties

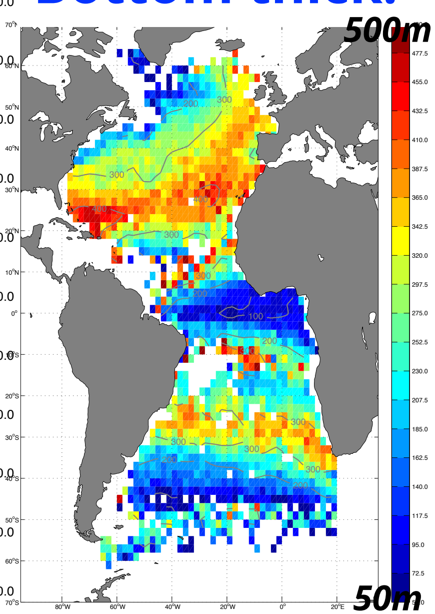
Total thickness



Top thick.

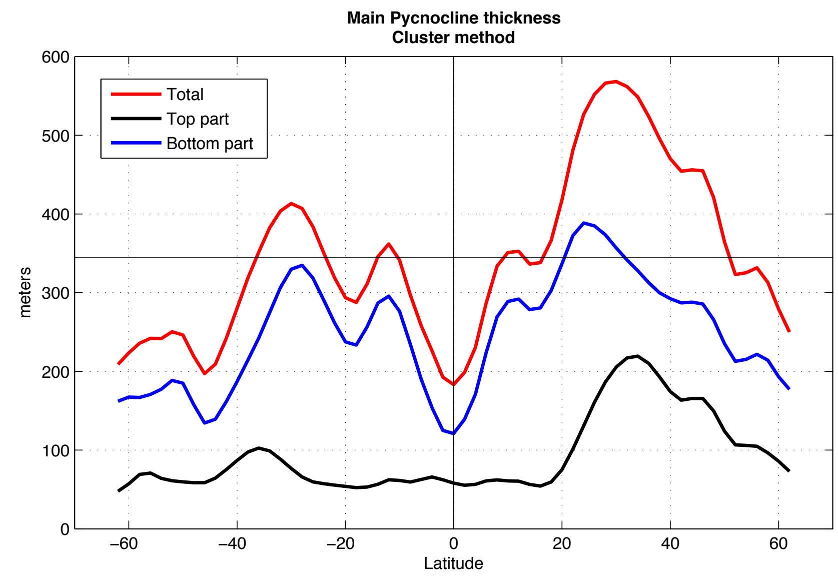


Bottom thick.



setup_D/db_thd_config2/img/Good_pycnocline_thickness_bottom_binned_with_maskID7_overlayID0.pdf
code@guillaumemaze.org (18–Jun–2013 23:51)
(macbook) file://Users/gmaze/data/ARGO/copoda_db/synth_pycnodiag_pl5.m

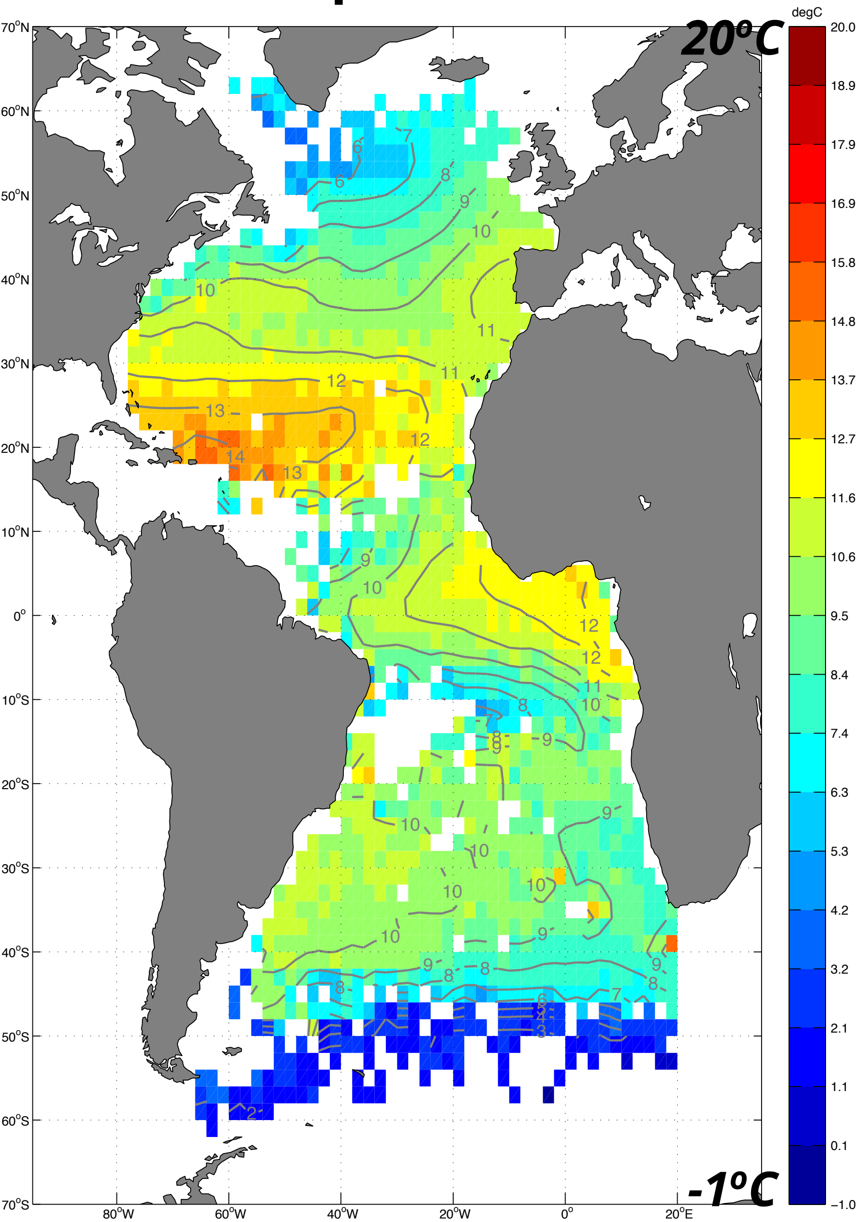
- Northern hemisphere thicker
- Vertical asymmetric description reveals large differences in the geo. structure



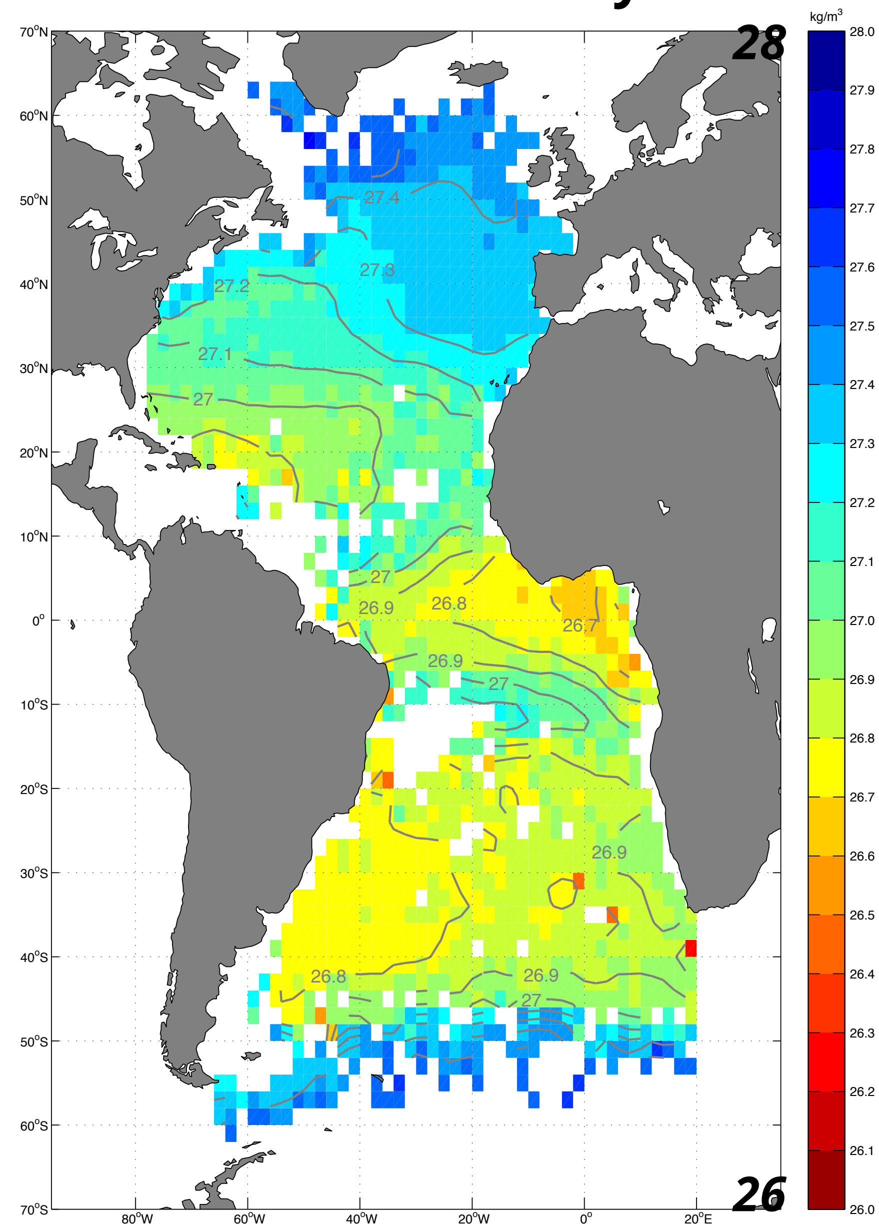
Zonal mean

setup_D/db_thd_config2/img/Good_pycnocline_thickness_binned_with_maskID7_overlayID0.pdf
code@guillaumemaze.org (18–Jun–2013 23:38)

Temperature



Potential Density



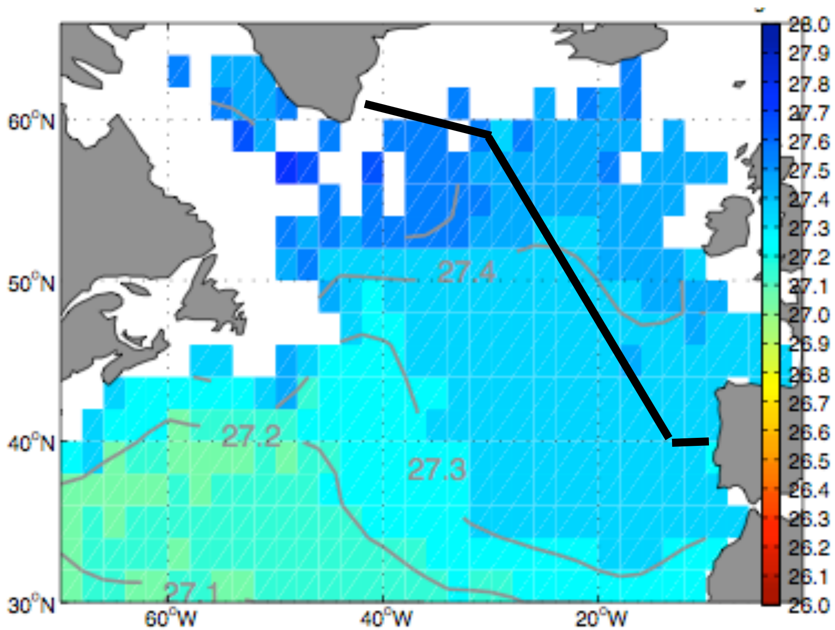
- **Core subtropical thermoclines have similar temperature of 10-11°C**
- **Only small areas are isopycnal surfaces**

setup_D/db_thd_config2/img/Good_pycnocline_temperature_binned_with_maskID7_overlayID0.pdf
code@guillaumemaze.org (18–Jun–2013 23:39)

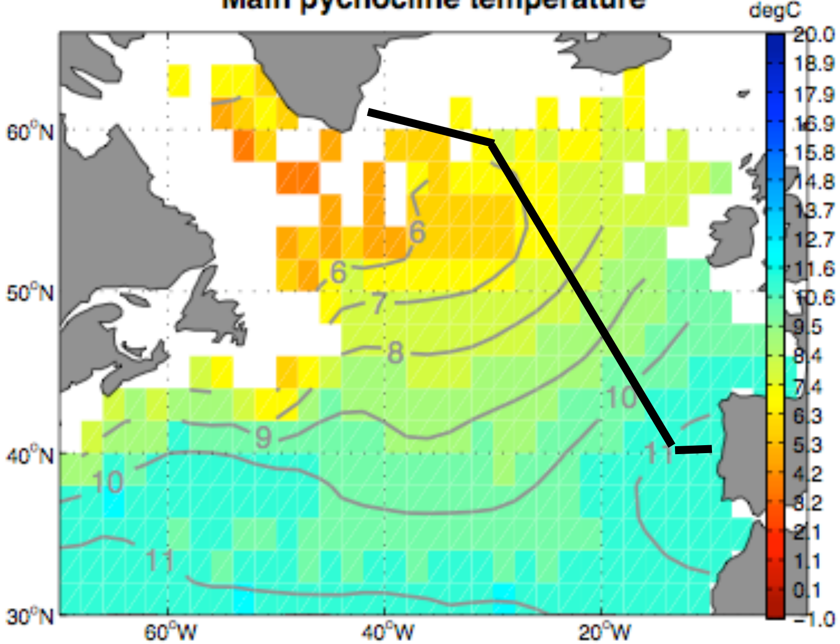
setup_D/db_thd_config2/img/Good_pycnocline_potential_density_binned_with_maskID7_overlayID0.pdf
code@guillaumemaze.org (18–Jun–2013 23:39)

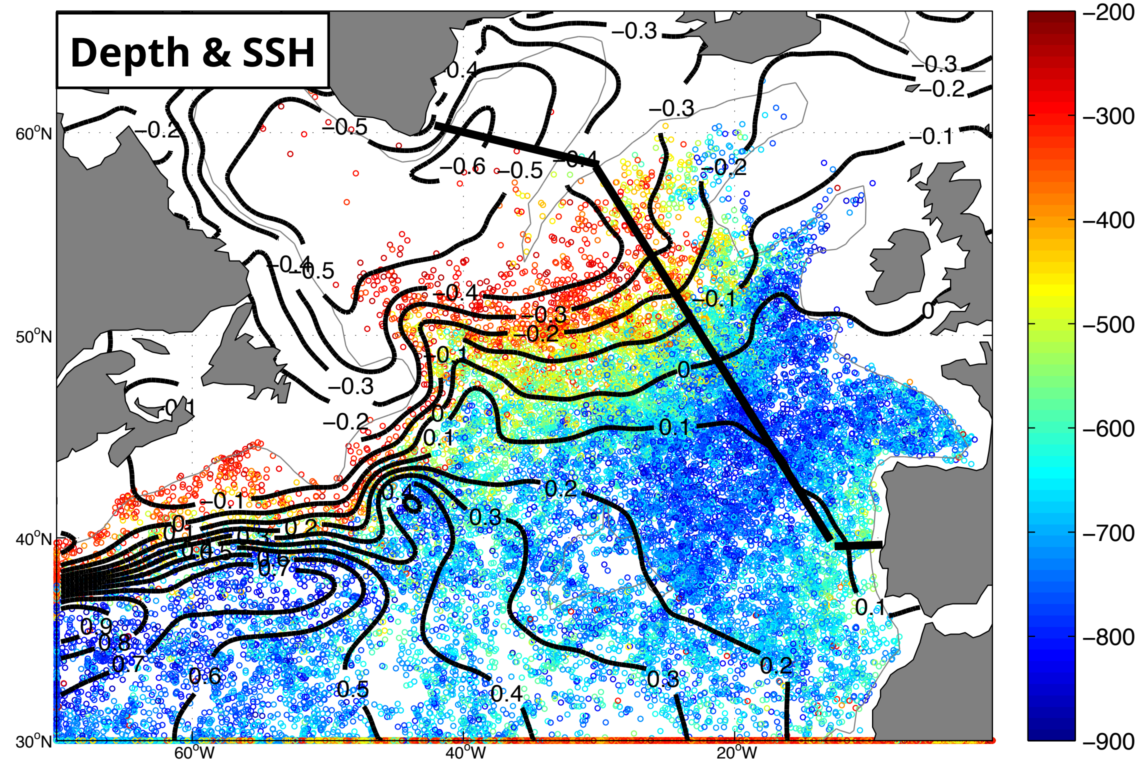
NE zoom

Potential density

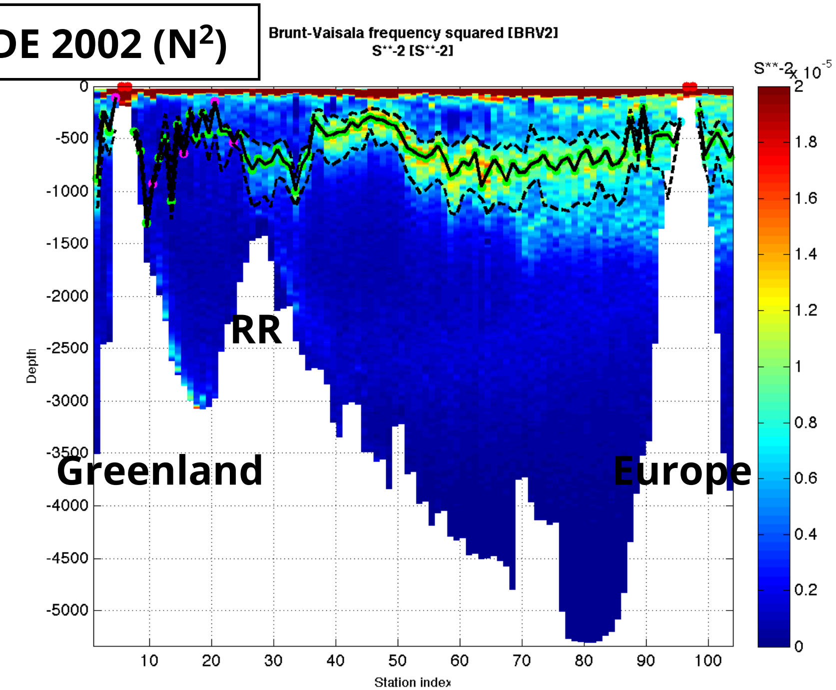


Main pycnocline temperature

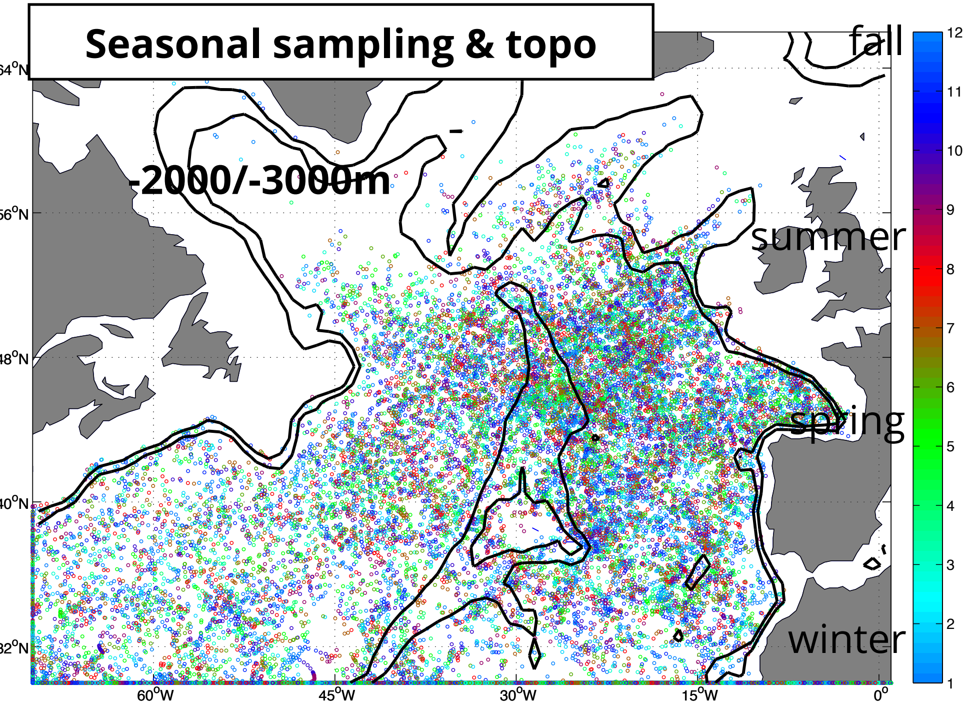


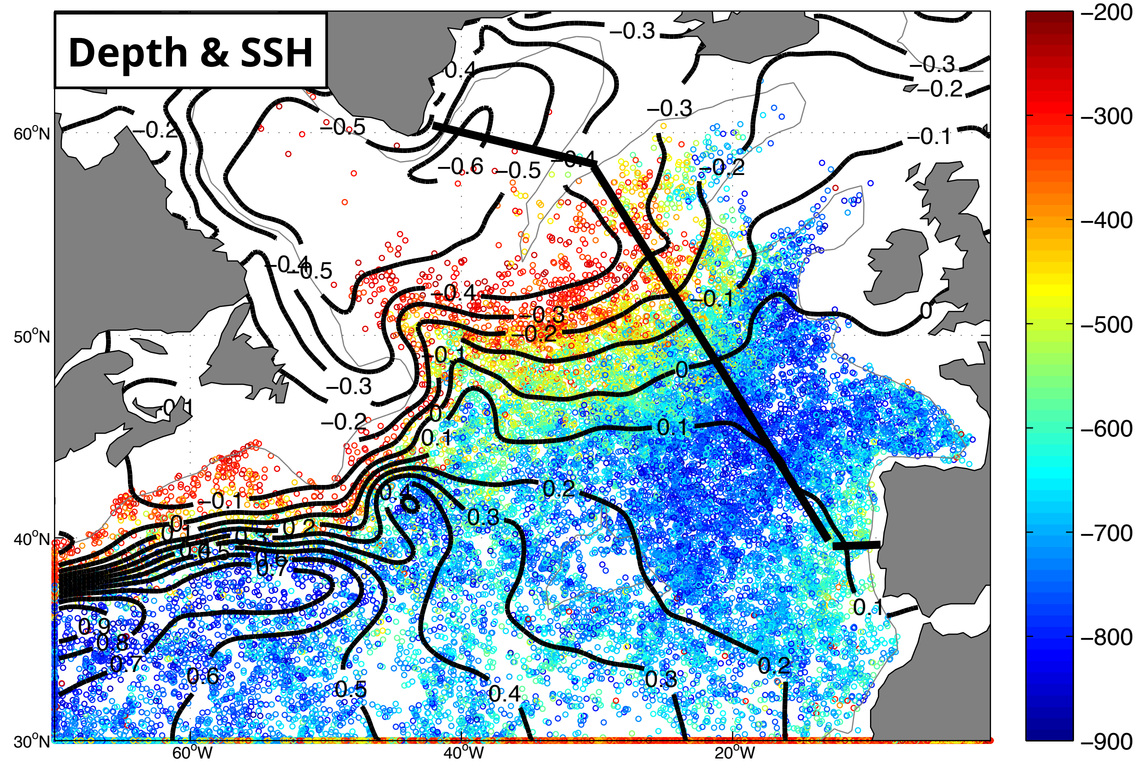


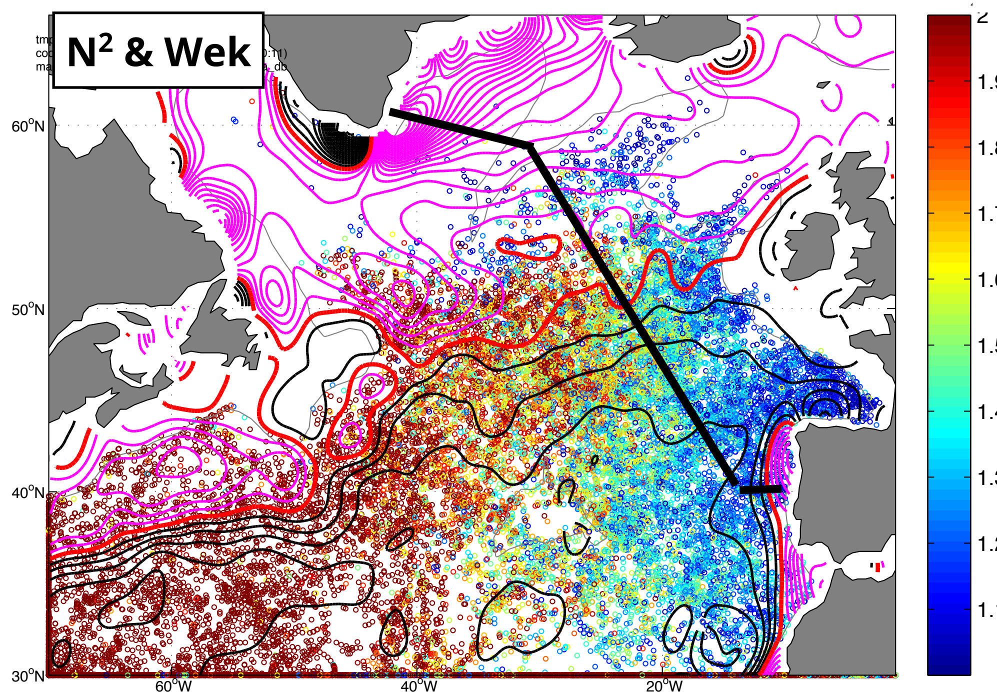
OVIDE 2002 (N^2)

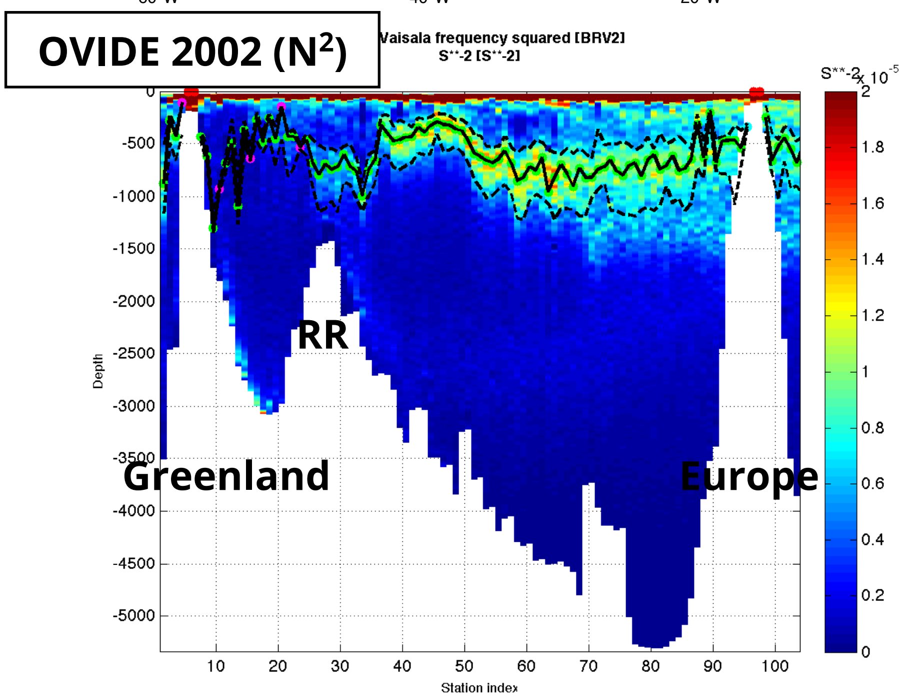


NE zoom


Seasonal sampling & topo
-2000/-3000m
fall
summer
spring
winter
60°W
45°W
30°W
15°W
0°

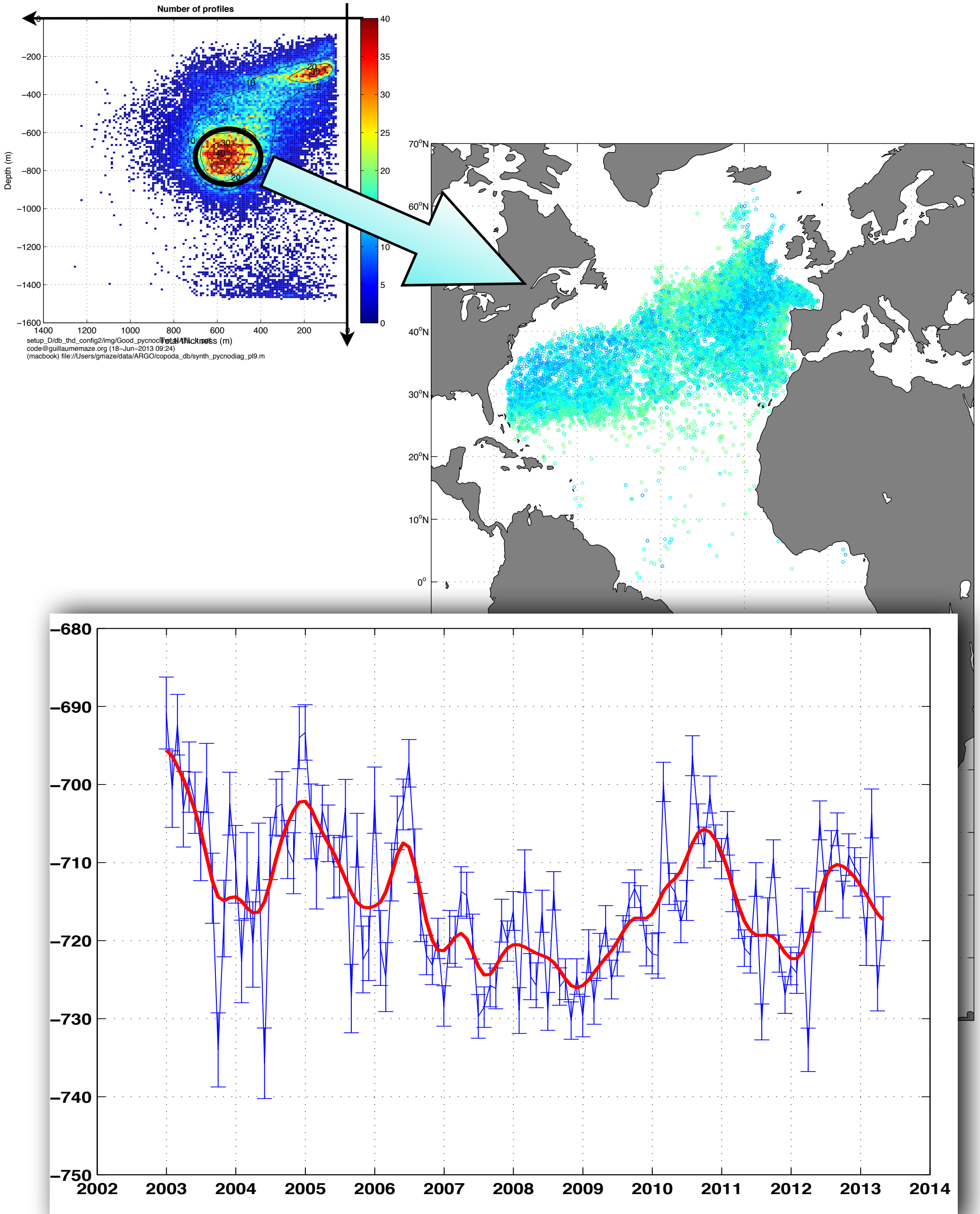

Depth & SSH
60°N
50°N
40°N
30°N
60°W
40°W
20°W
−200
−300
−400
−500
−600
−700
−800
−900


N^2 & Wek
60°N
50°N
40°N
30°N
60°W
40°W
20°W

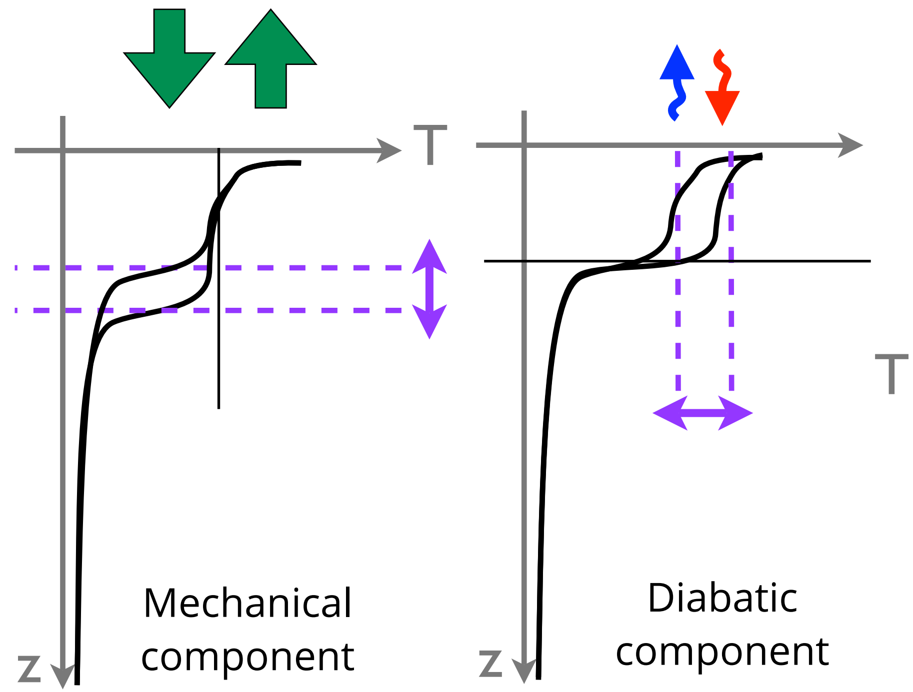

OVIDE 2002 (N^2)
Vaisala frequency squared [BRV2]
S**-2 [S**-2]
RR
Greenland
Europe
Depth
Station index

and now ...

- **Analyze time series**



- **Analyze the OHC variability**



What is the influence of the wind ?

Water mass properties ?

- **Go global !**