The subpolar Atlantic in numerical models at increasing spatial resolution

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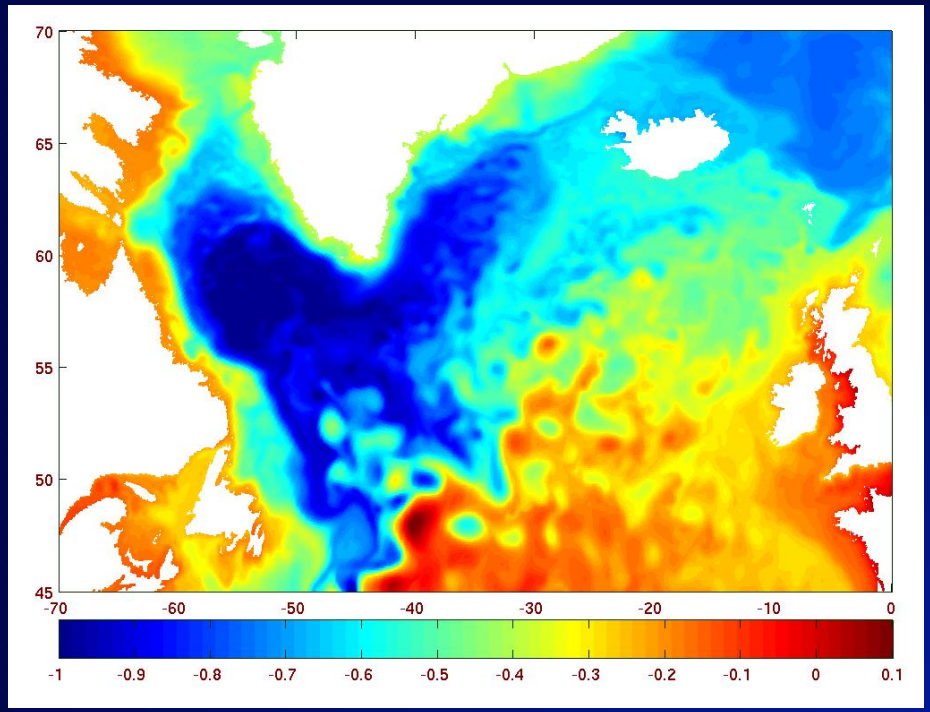
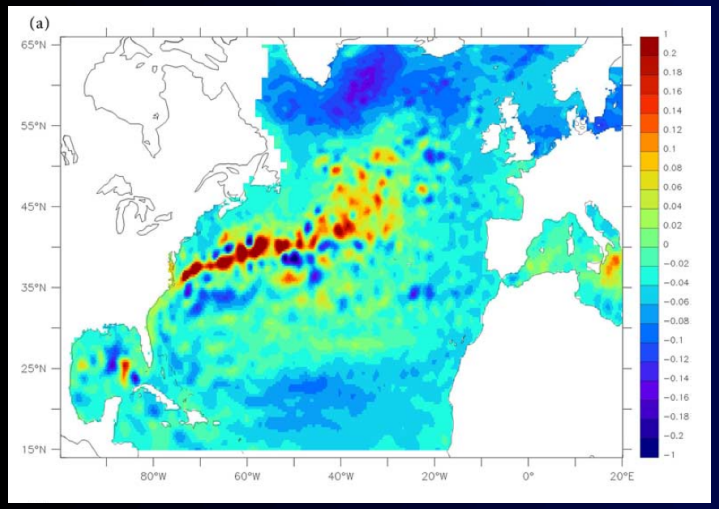


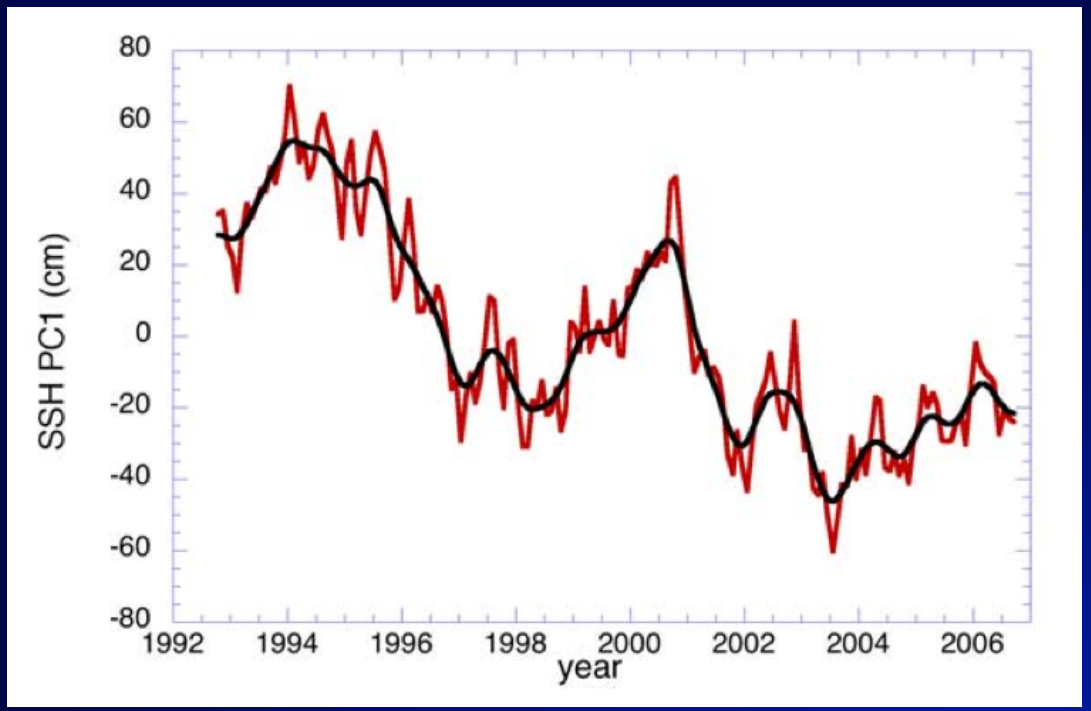
Instantaneous sea surface height anomaly, North Atlantic 1/12° model, DRAKKAR project www.drakkar-ocean.eu

Variability of the subpolar Atlantic circulation

From Hakkinen and Rhines, 2009:
Decline of SSH after 1994, linked with NAO index

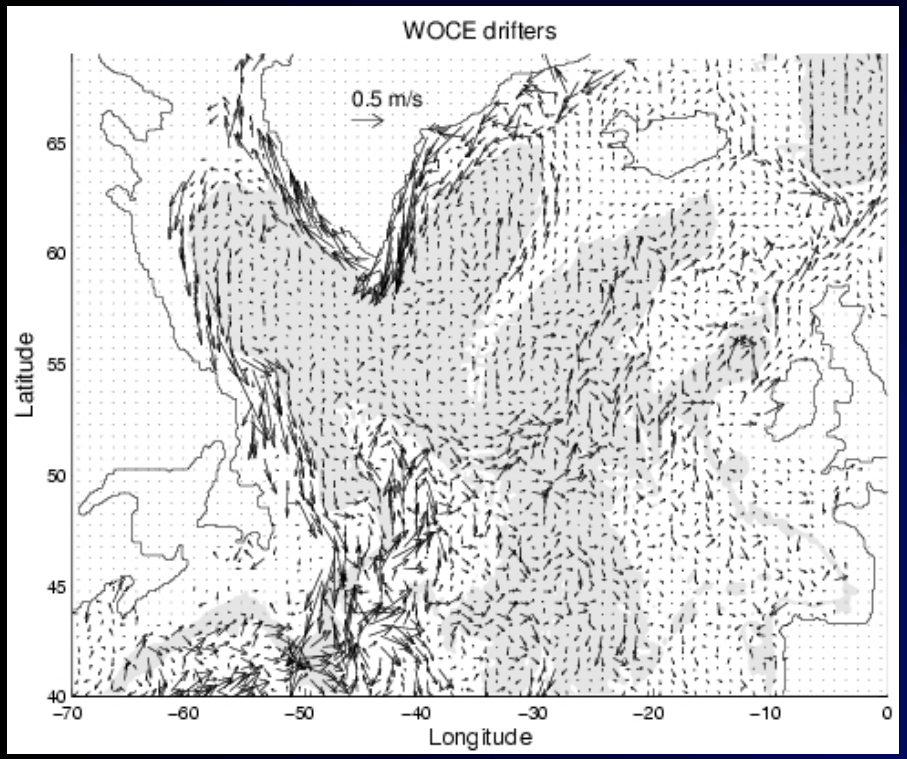


Spatial structure and
PC1 of SSH (Aviso data)

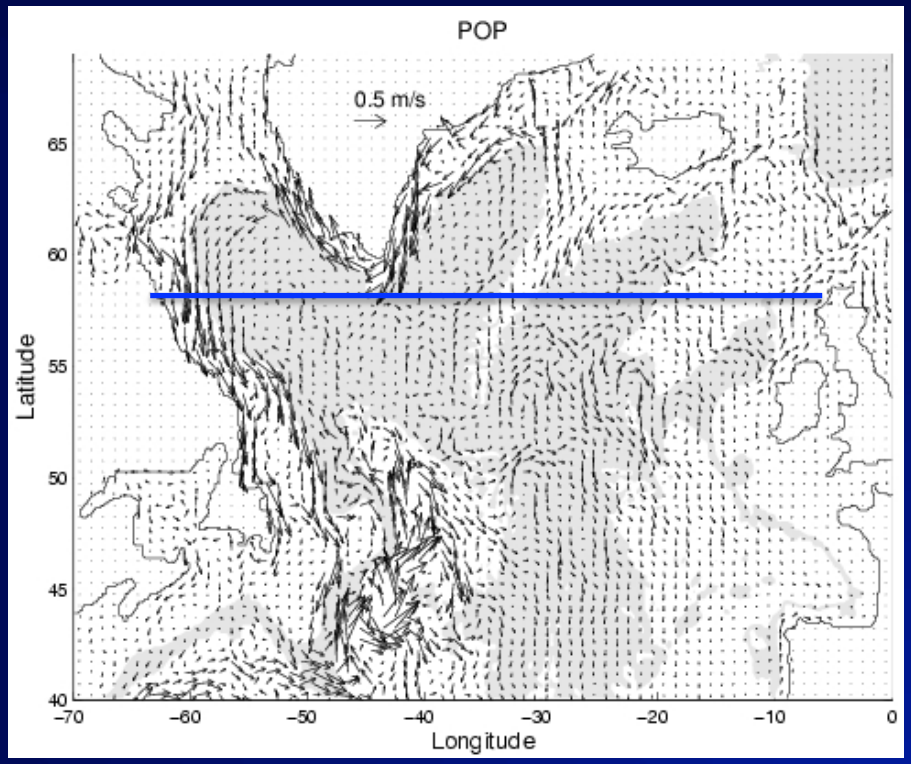


Modelling the subpolar circulation

Figures from Treguier et al, JPO 2005.

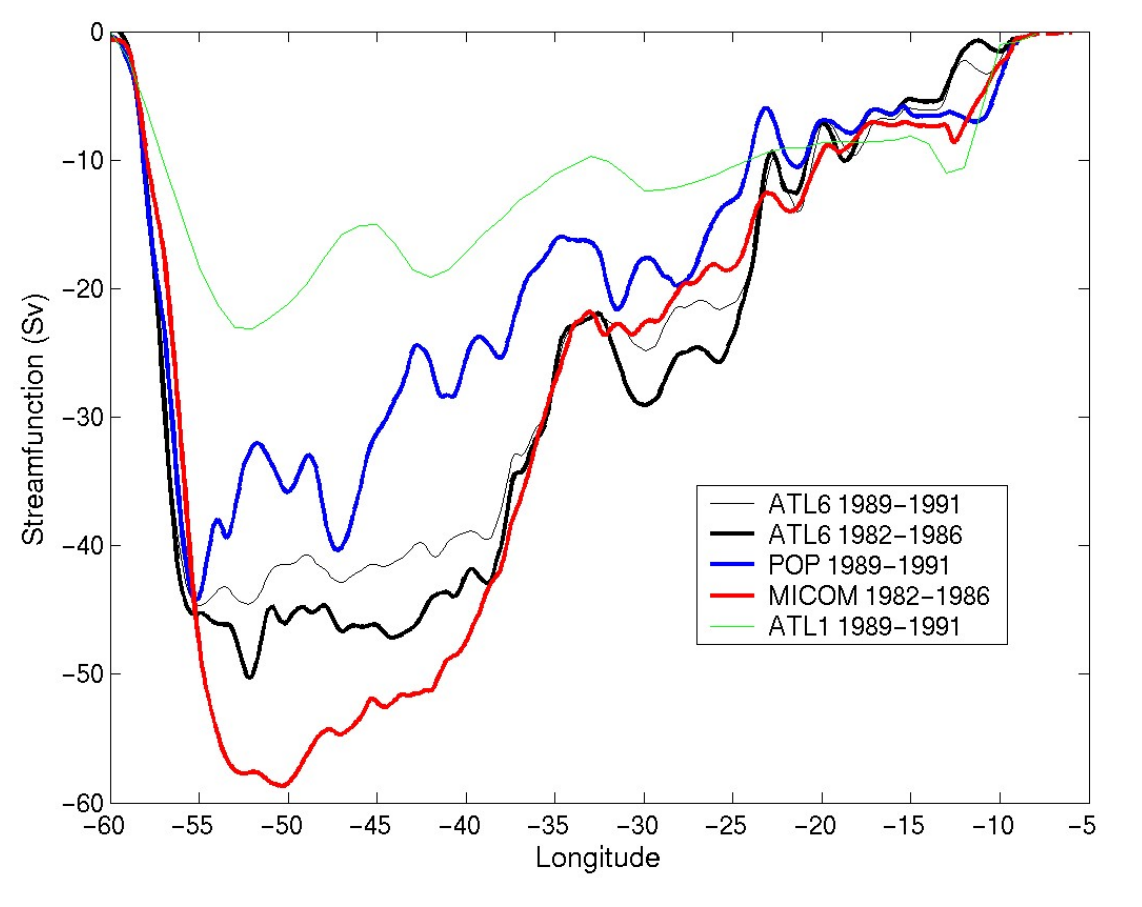


Woce drifters: Reverdin, Niiler, Valdimarsson, 2003



Surface currents in the Pop model of Smith et al, 2000.

Streamfunction at 57°N



Barotropic transport shows a strong dependency on model resolution (Treguier et al 2005)

Questions:

How do recent numerical models represent the circulation in the subpolar gyre and its variability?

What is the respective role of eddy fluxes and advection by the mean currents in meridional transports?

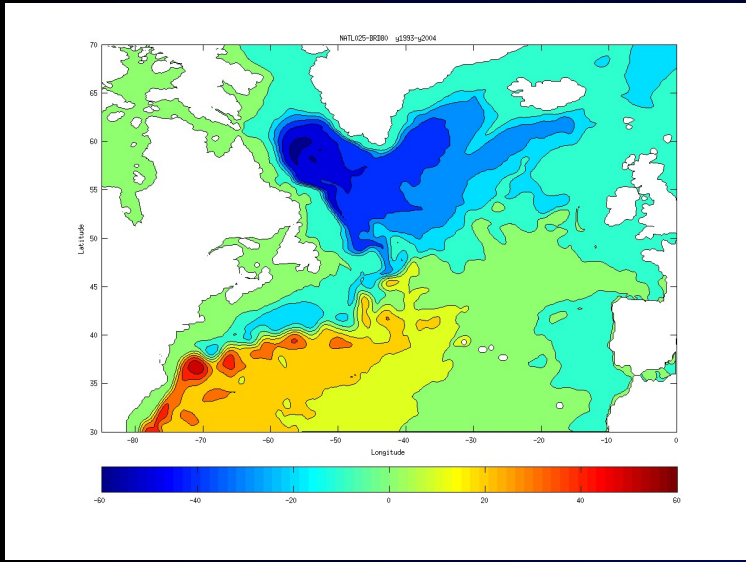
DRAKKAR numerical models

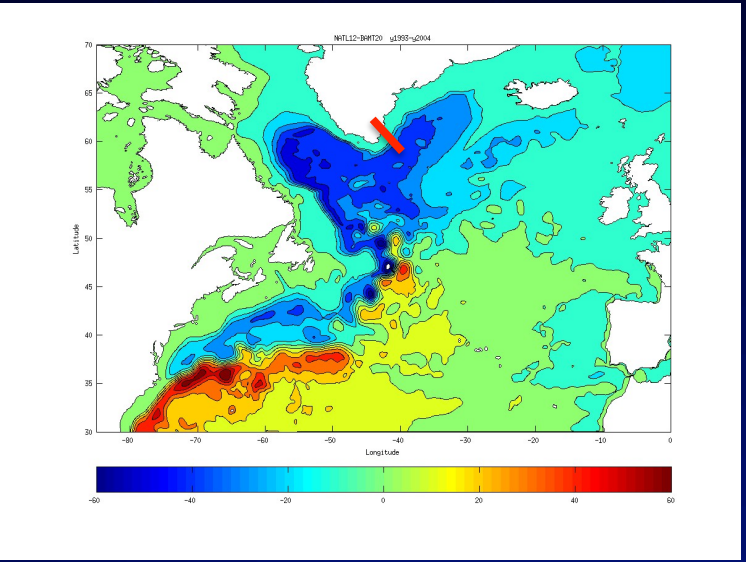
DRAKKAR: french group, LEGI Grenoble, LPO Brest, Mercator-Ocean, LOCEAN Paris; International collaborations NOCS, IFM-Geomar, …

- Based on the Nemo modelling platform www.nemo-ocean.eu , Madec 2008
- Progress in atmospheric/ice forcing: LIM2 sea ice model, ECMWF/satellite atmospheric forcings with CORE bulk formulae (Brodeau et al, ocean modelling, 2010)
- Global (ORCA) configurations: ¼° (Barnier et al, 2006) and 1/12°,
- simulations in NATL domain (20°S-80°N), 1980-2006.

Mean barotropic transport

Barotropic streamfunction, 1993-2004, NATL ¼° and 1/12°



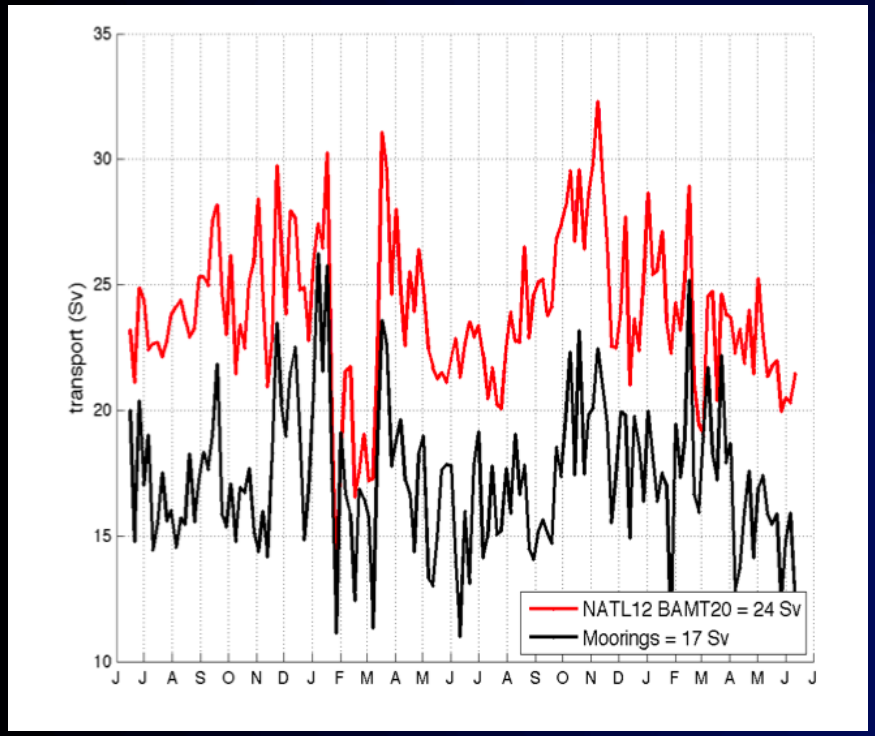


Subtropical gyre: Gulf Stream separation and Slope Water recirculation much improved at 1/12°.

Subpolar gyre: No large change in amplitude between ¼° and 1/12°

EGIC: comparison with OVIDE moorings

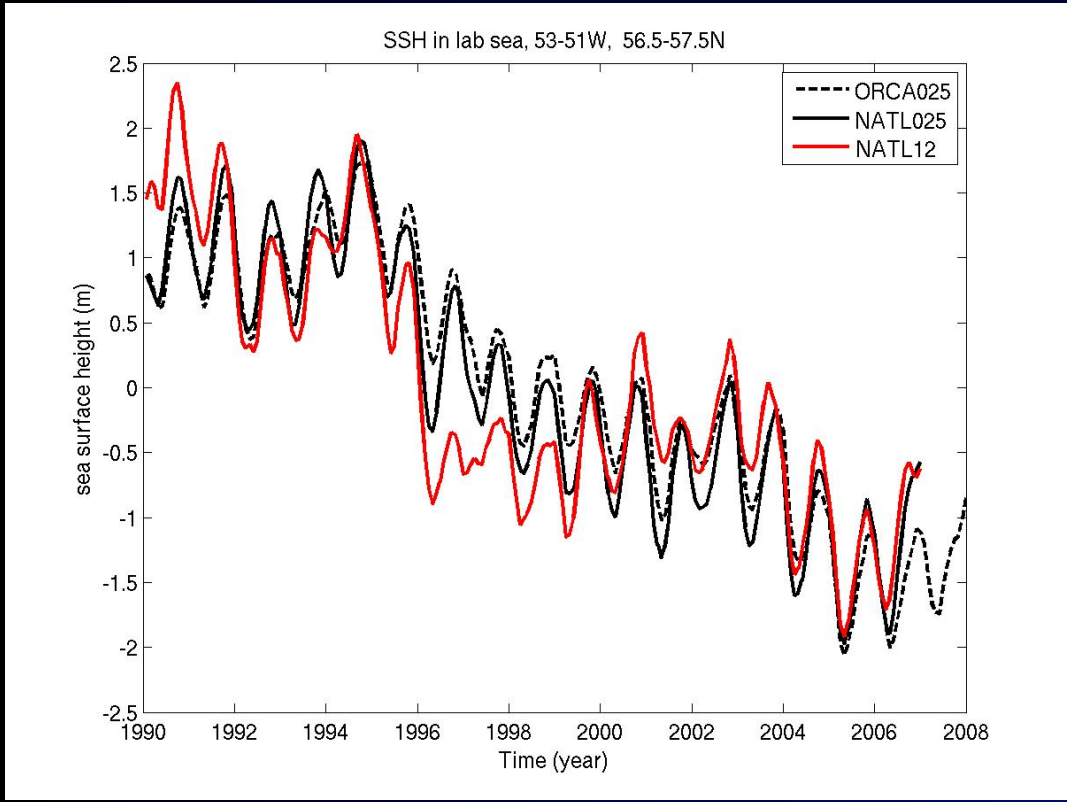
Transport above 2000m measured during two years,
OVIDE project, june 2004-june2006, Daniault et al, JPO 2011.



In NATL12, the mean transport is overestimated;

Correlations:
NATL12 5 days 66%
NATL12 monthly 54%
ORCA025 monthly 59 to 78%

Principal component analysis of Sea Surface Height

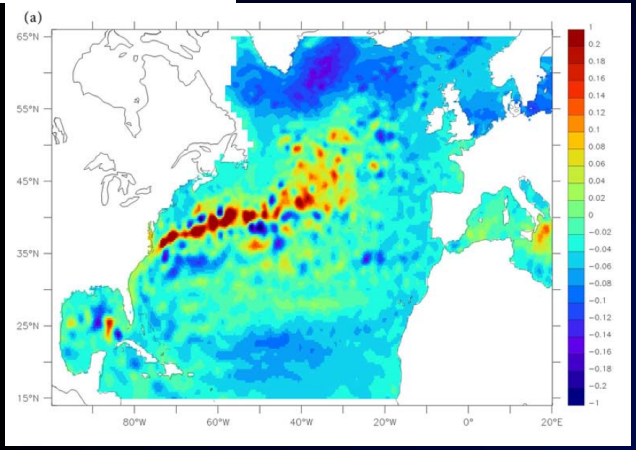


PC1: Good agreement between models for the time series.

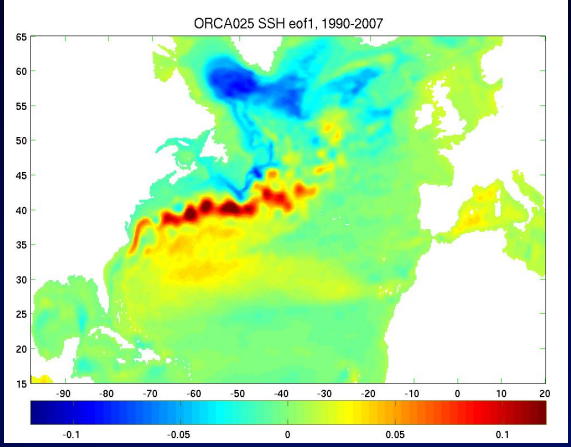
¼ global, ¼° NATL and 1/12° NATL reproduce the observed decline after 1994.

Map of PC1 of SSH in three models

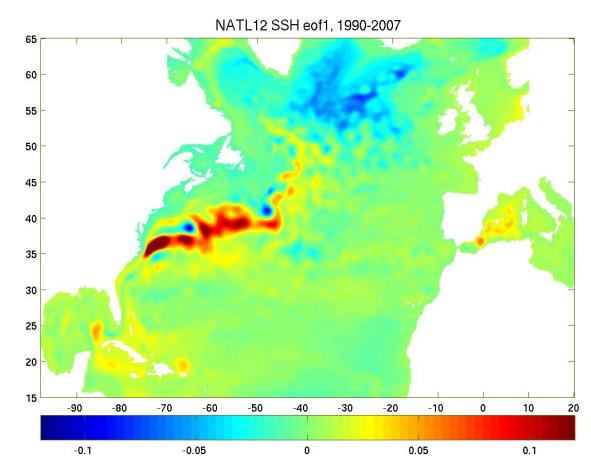
Obs (H&R)



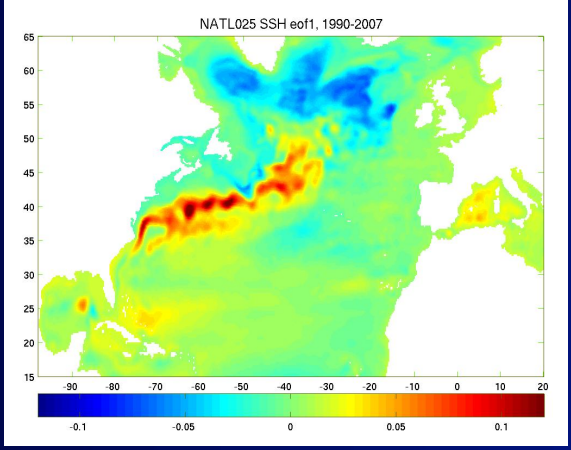
Global ¼°



NATL 1/12°

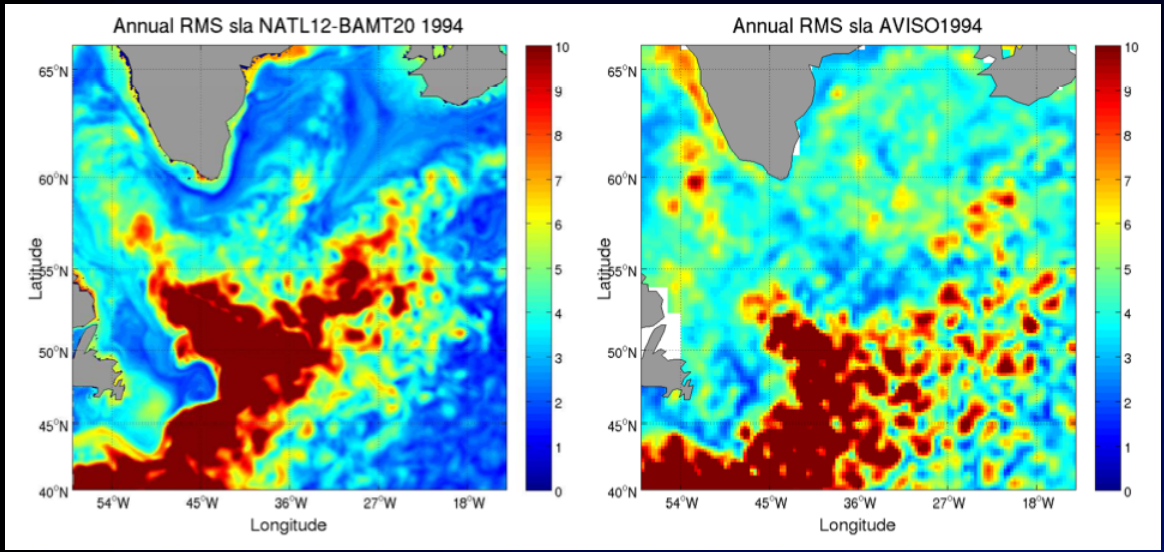


NATL ¼°

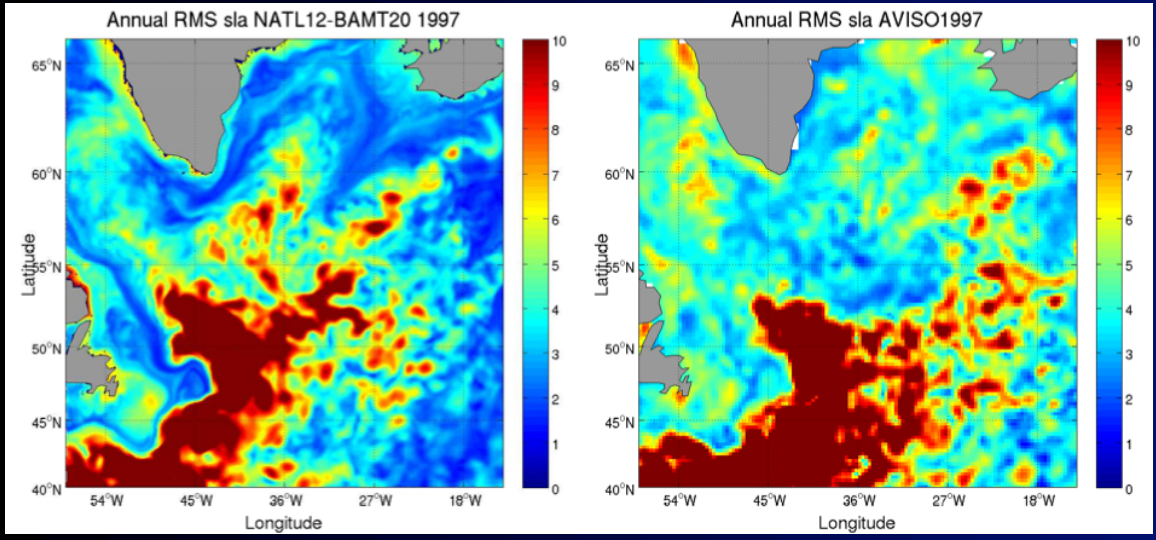


Overall picture is similar in obs and models at ¼° and 1/12°

Irminger sea: spurious variability at 1/12°



NATL12- AVISO data comparison



Irminger branch does not appear in ¼° NATL.

Subpolar gyre circulation in the Drakkar models

- At ¼° and 1/12°, good representation of wind-forced variability of the boundary currents.

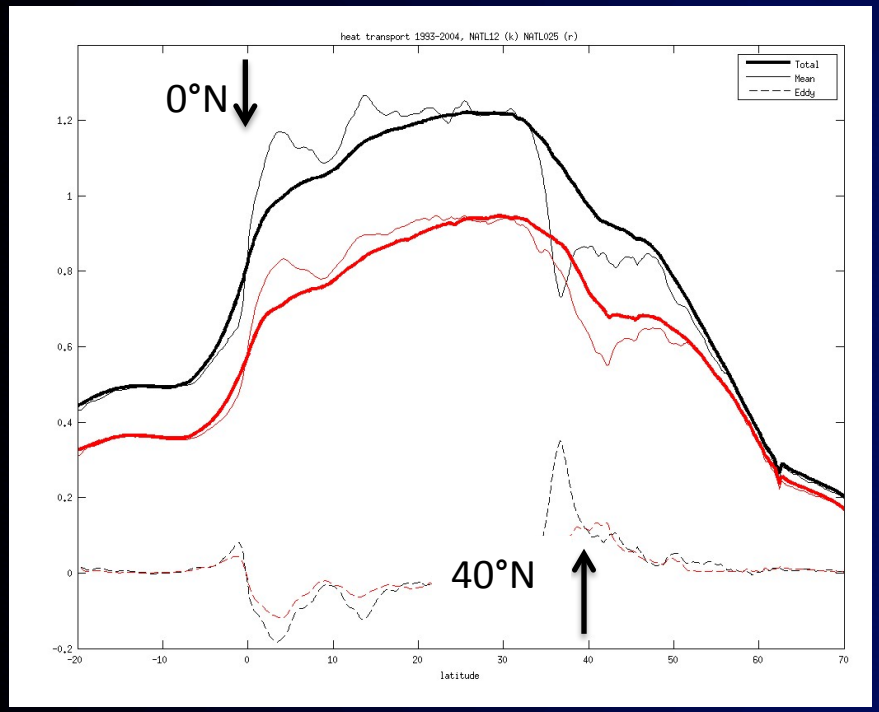
- Large scale overview of the variability (PC1 of SSH) coherent with observations and robust between simulations.

- At smaller scales (individual current branches) strong difference between 1/12° and ¼°, and differences with observations: this indicates a **very nonlinear behavior of the North Atlantic current** at 1/12°.

Meridional eddy heat transport

$$\int \overline{vT} = \int \overline{v}\,\overline{T} + \int \overline{v'T'}$$

Average for years 1993-2004
Eddies flux heat out of the subtropical gyre.
Northward eddy heat transport across the Gulf Stream and NAC (40-45N): 0.2 PW
Southward eddy heat tranport in the tropics (5-10°N): 0.25 PW



Comparison between ¼° NATL025 (red) and 1/12° NATL12.

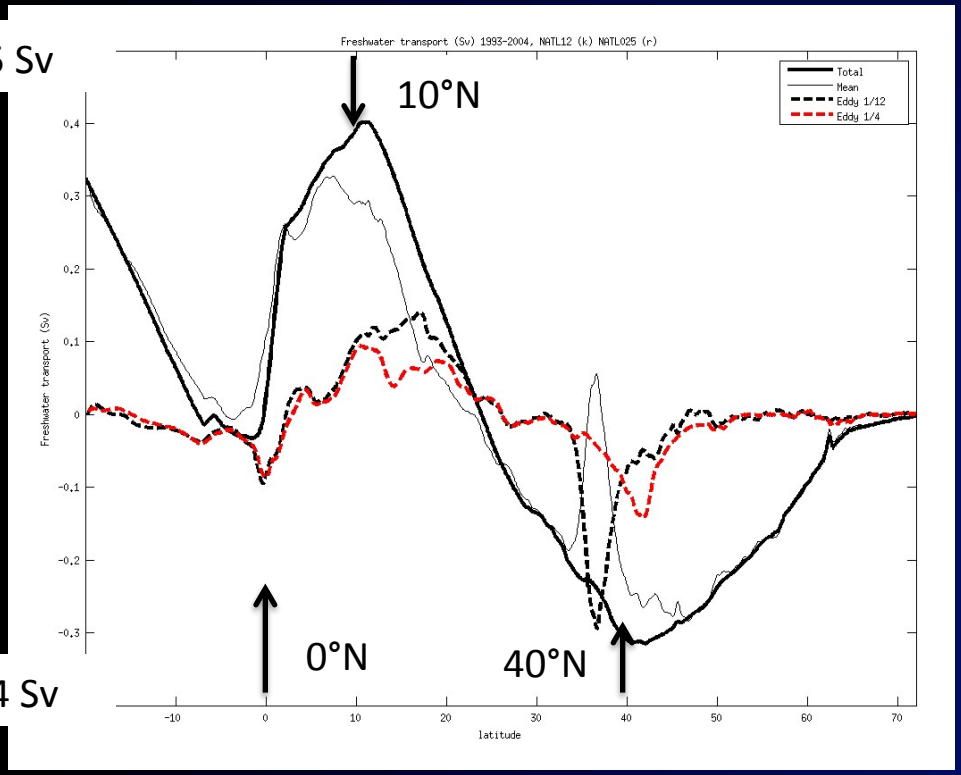
Large change in the mean, Stronger compensation between mean and eddy fluxes at 1/12°

(similar to POP results, Smith et al, 2000; Hecht et al, 2008)

Meridional freshwater transport

$$\int \overline{v\frac{(S_0 - S)}{S_0}} = \int \overline{v} - \int \frac{\overline{v}\,\overline{S}}{S_0} - \int \frac{\overline{v'S'}}{S_0}$$

$S_0 = 34.8$



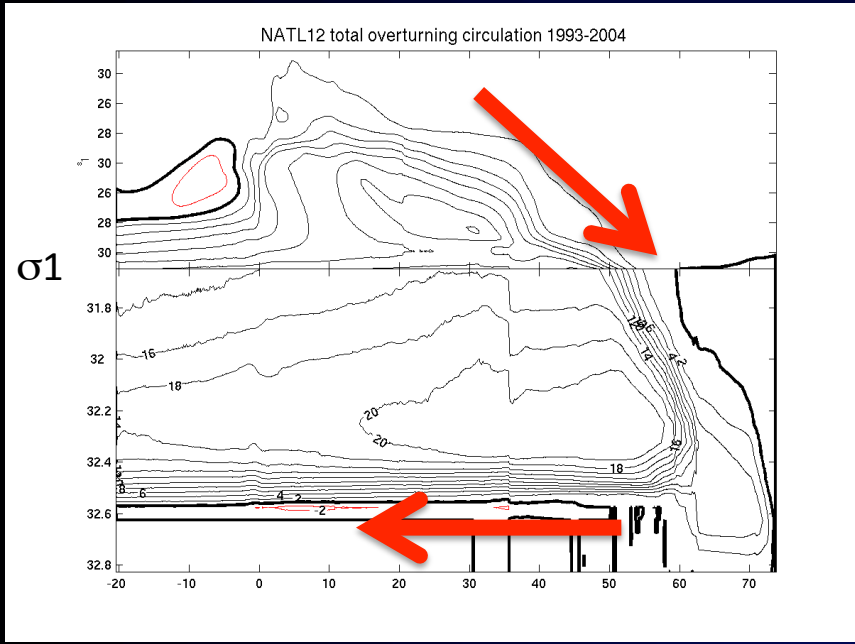
Mean and total/relative to transport at 80°N (1.5 Sv Southward)

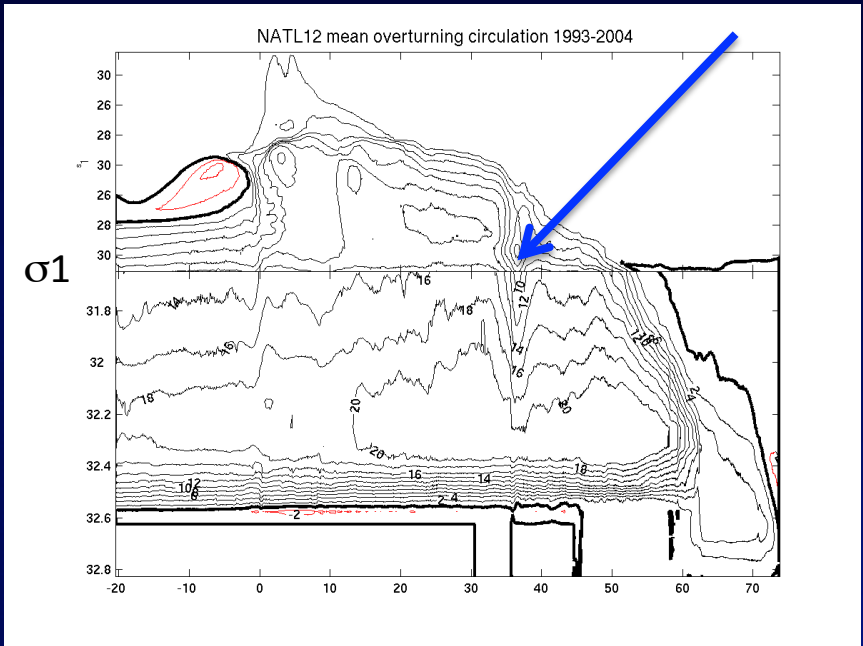
Eddy contribution large at 15°N (0.15 Sv) and 36°N (0.3Sv)

Eddies flux freshwater into the high salinity subtropical gyre.

Eddy contribution to the meridional overturning in density coordinates

In sigma coordinates: total and overturning from mean





The difference is the eddy contribution (8 Sv at 36°N).

Conclusions

- Eddy contributions to meridional transports cannot be ignored in the subtropical gyre,

- The variability of the North Atlantic subpolar gyre remains a challenge for numerical models, even at 1/12°;

- Importance of boundary conditions: from NATL to a global 1/12° model (ORCA12)