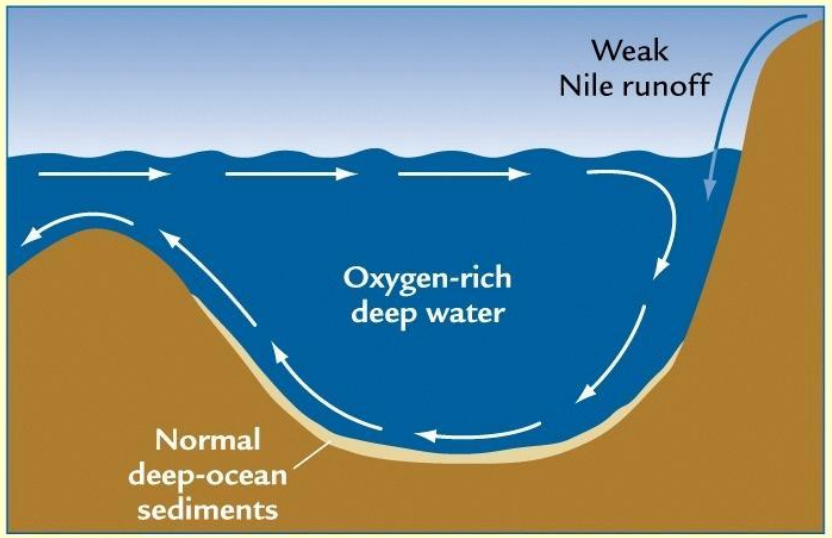
# Impact of a freshwater release in the Mediterranean Sea on the AMOC

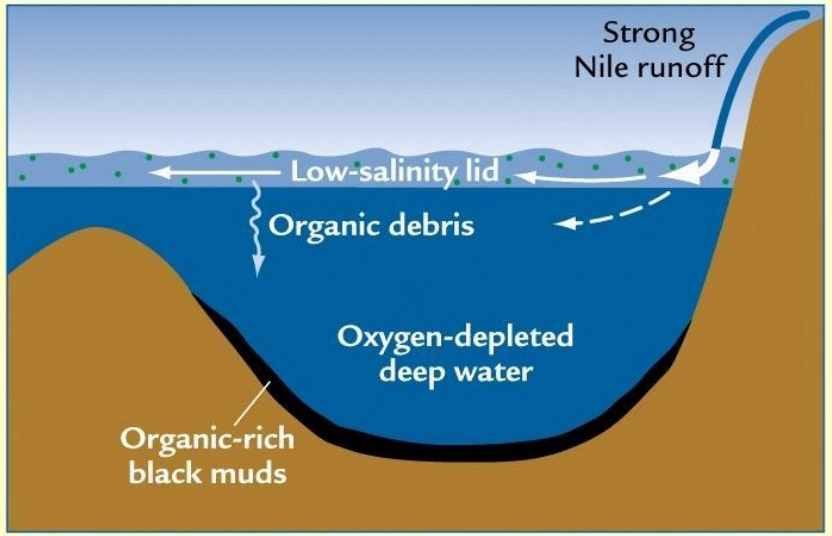
**Didier Swingedouw**

# Holocene Sapropel event

- Marine sediment cores from the Mediterranean indicate large **sapropelic deposit during early Holocene** (10-6 kyr BP) (Bethoux and Pierre 1999, Delange et al. 2008)
- Such Sapropelic deposit may be related with **fresh surface water in the Mediterranean**, potentially related with large increase of River Nile flow, in link with Green Sahara at the same period (remnant Fennoscandian melting as well)




A Weak summer monsoon

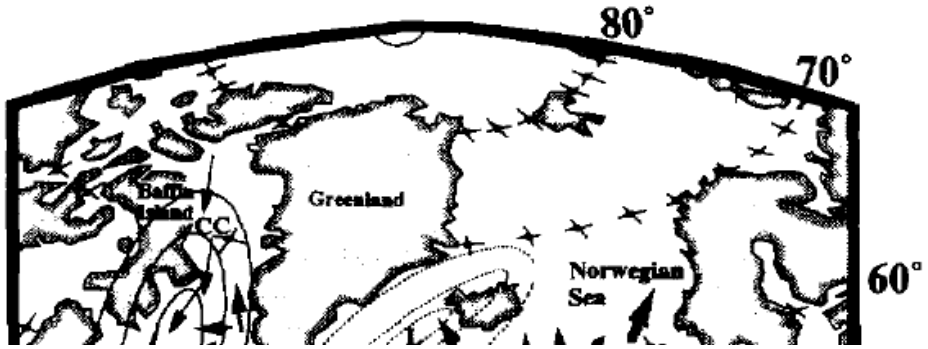



B Strong summer monsoon

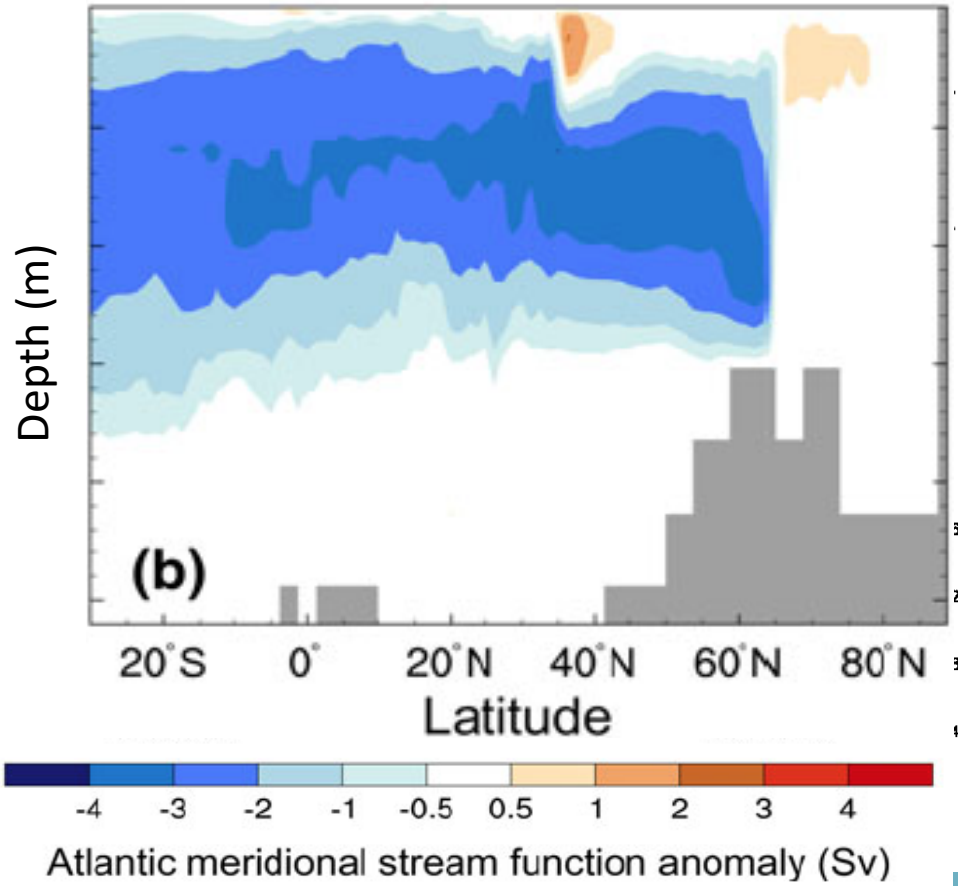
# MOW impact on the AMOC?

- Such changes in surface may strongly affect the Mediterranean outflow (MOW) and potentially the Atlantic Meridional Overturning Circulation (AMOC)
- Johnson (1997) using qualitative arguments: Aswan Dam ➔ reduced Nil flow ➔ increased MOW ➔ increased AMOC ➔ increased evaporation in Labrador ➔ new ice age!
- Rahmstorf (1998) using simple climate model: salty Med ➔ increased AMOC
- Ivanovitch et al. (2013) using HadCM3: decrease of AMOC when MOW ceases, except at the surface...

Johnson (1997) process




Ivanovitch et al. 2013 (HadCM3, Halving Med salinity)

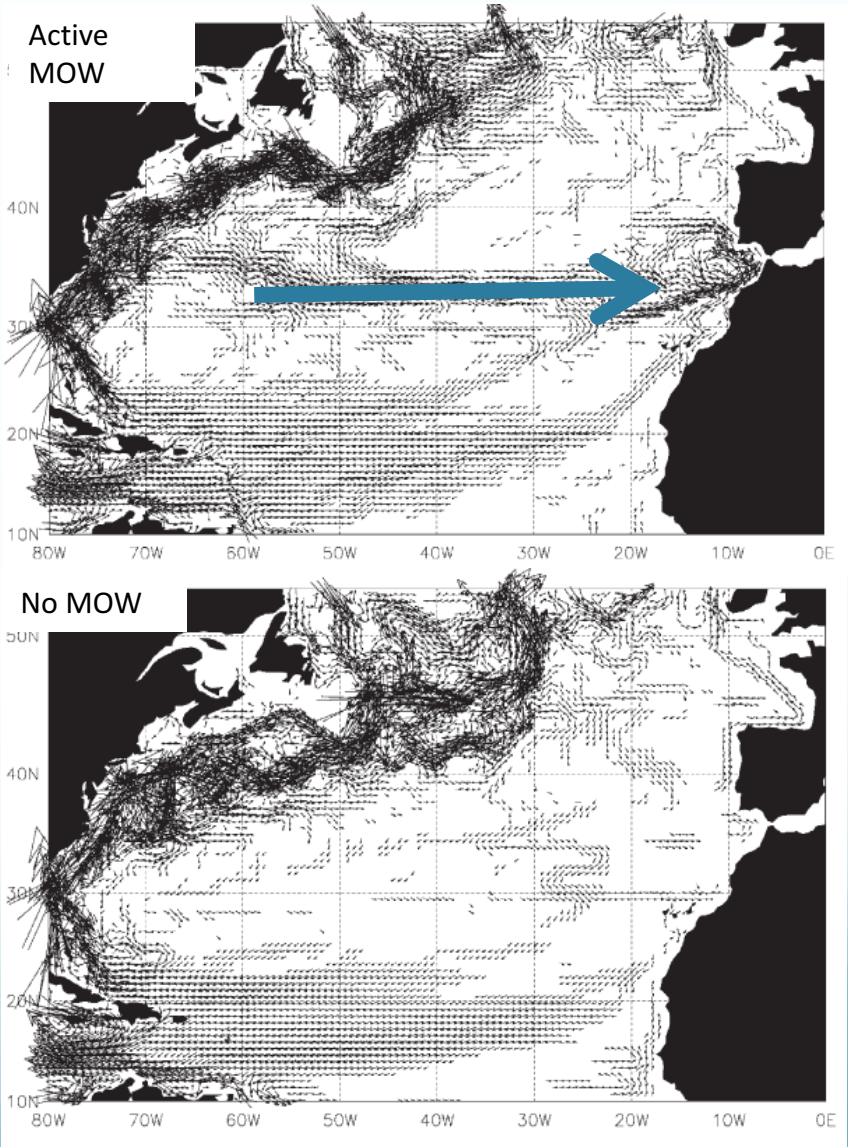



Depth

# Effect of MOW on surface ocean circulation

Jia (2000), New et al. (2001) using of high-resolution (<0.5) ocean GCMs, one with active MOW, the other without MOW

- With active MOW, there is clear branch of surface water going towards the Mediterranean
- Without any MOW, this branch disappears
- **What could the impact of these 3D large-scale circulation changes on tropical salinity transport, and then AMOC and climate?**




New et al. 2001

# Two opposing mechanisms for the AMOC

**1) No MOW: direct impact on density distribution in the ocean**

⇒ Lower zonal density gradient at depth (≈500-1500m)

⇒ Thermal wind relationship: **weakened AMOC at depth**

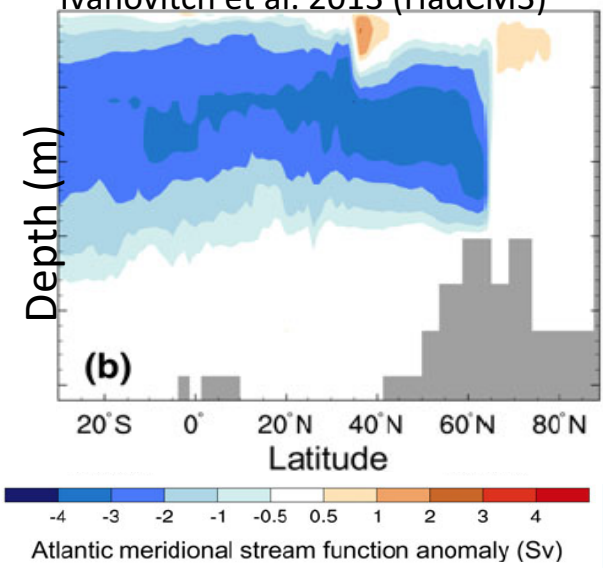
**2) No MOW: impact on subtropical gyre geometry**

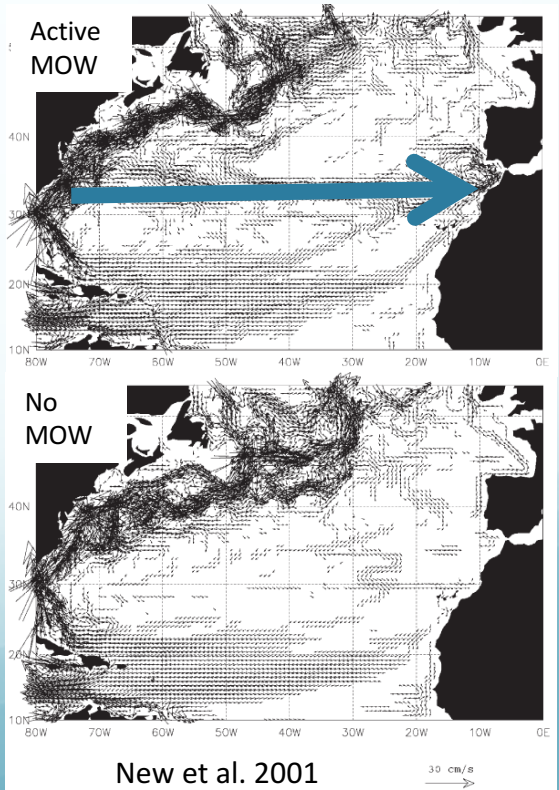
⇒ Increased subtropical surface water transport in the North Atlantic

⇒ Increased surface salinity and convection in the North Atlantic

⇒ **Increased AMOC and subpolar gyre**

Ivanovitch et al. 2013 (HadCM3)



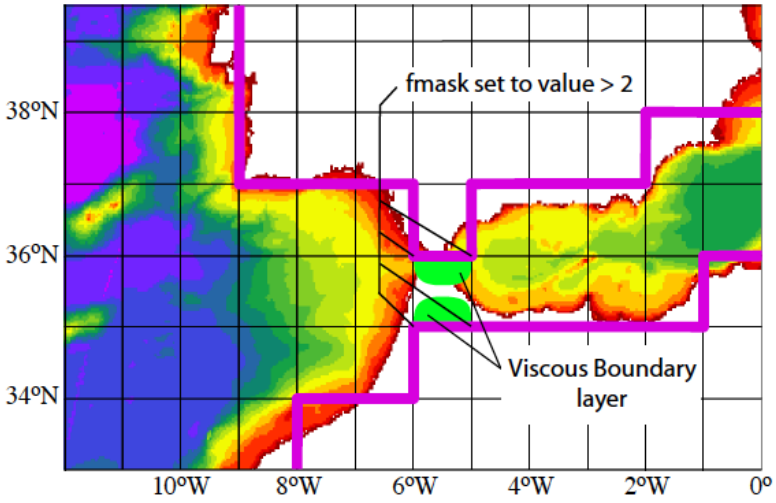

New et al. 2001

# Experimental design

**Objective**: *What is the impact of a MOW disappearance on large-scale ocean and climate in a state-of-the art climate model?*

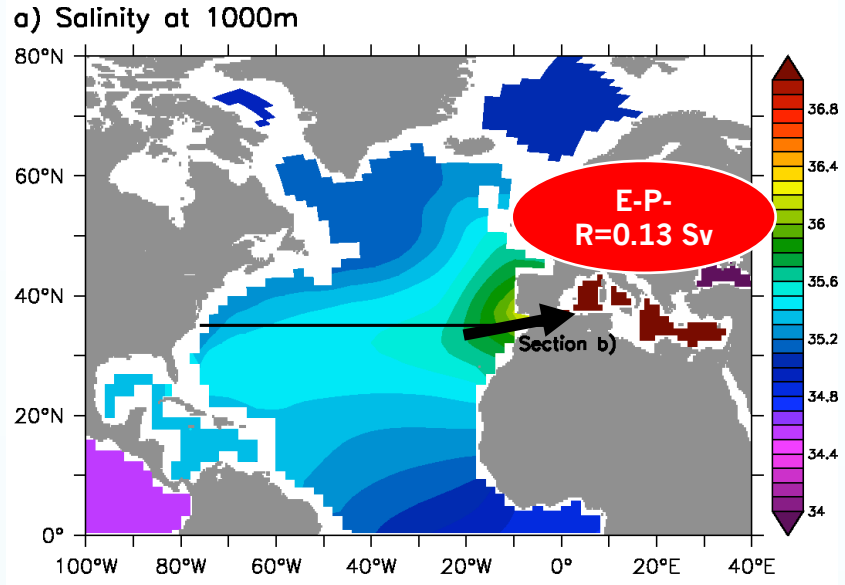
- IPSL-CM5A-LR:
  - Ocean-atmosphere GCM (≈2° )
  - Representation of Gibraltar by playing with viscosity for having realistic transport (modelled MOW=2.2 Sv, obs.≈1.8 Sv)
- **100 mSv** of freshwater put homogenously over the Mediterranean for **1000 years** (**HosMed**)

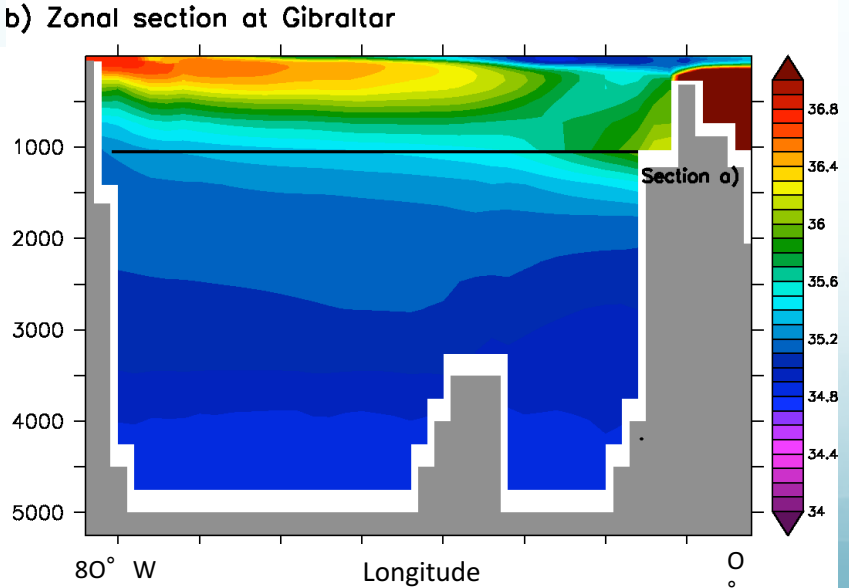
  (Nil ≈ 3 mSv; Amazon ≈ 200 mSv)
- Sensitivity test to the rate: **50 mSv, 200 mSv, 20 mSv**



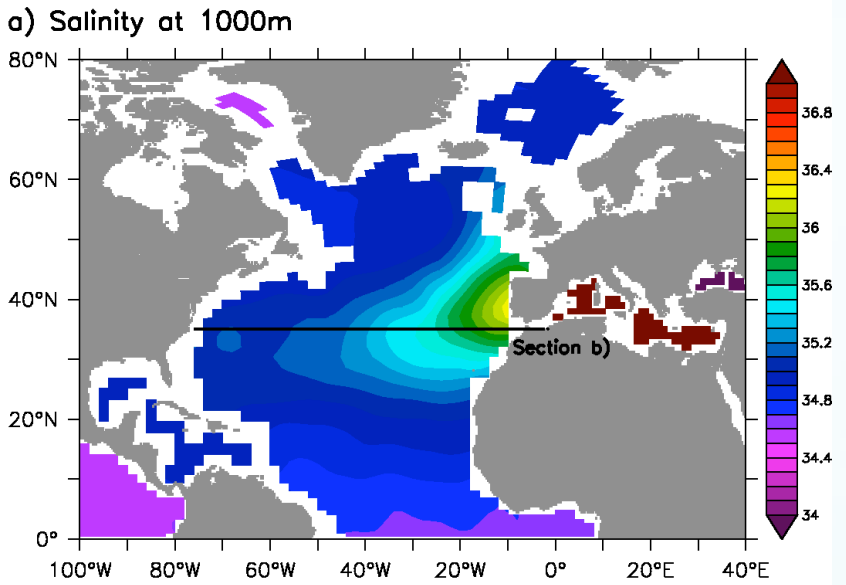
# MOW within IPSL-CM5A-LR

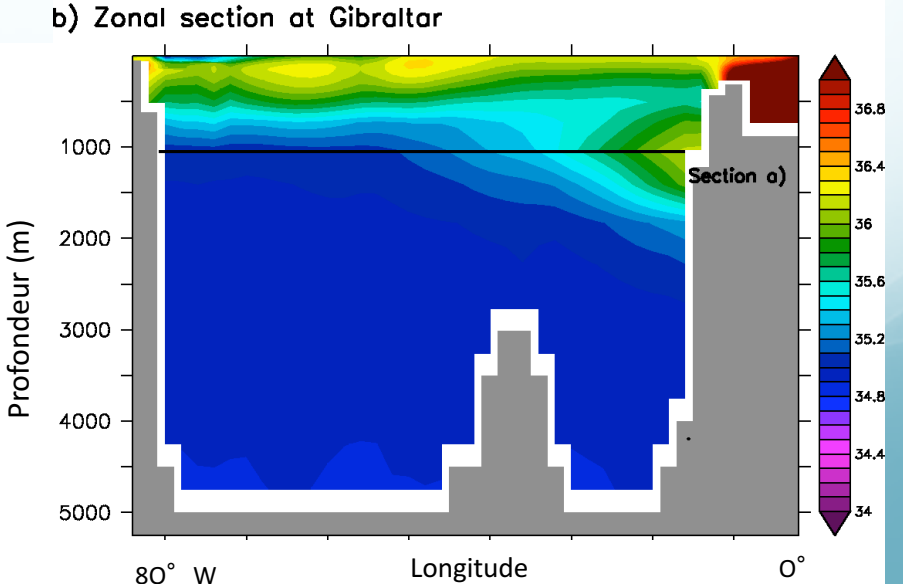
Control simulation IPSL-CM5A-LR



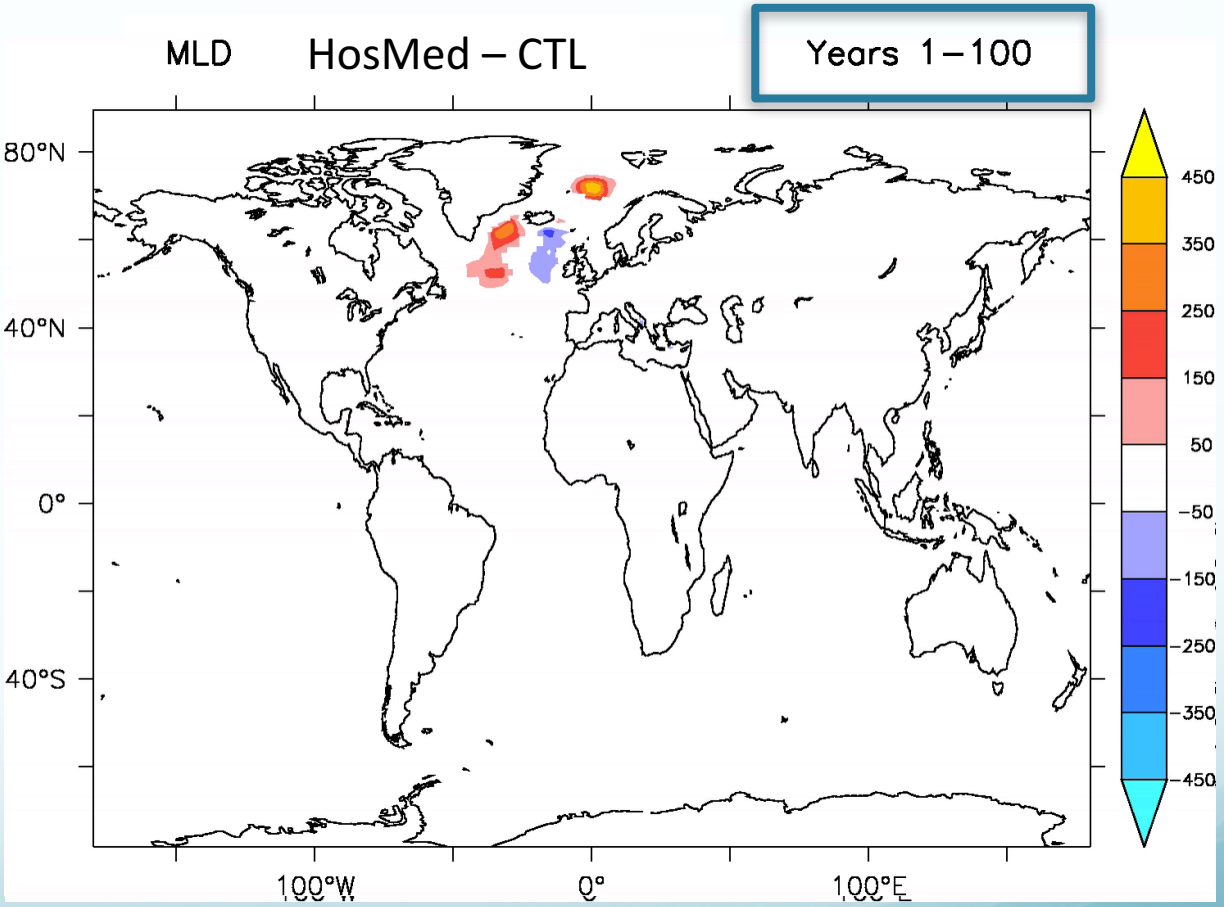

Levitus data



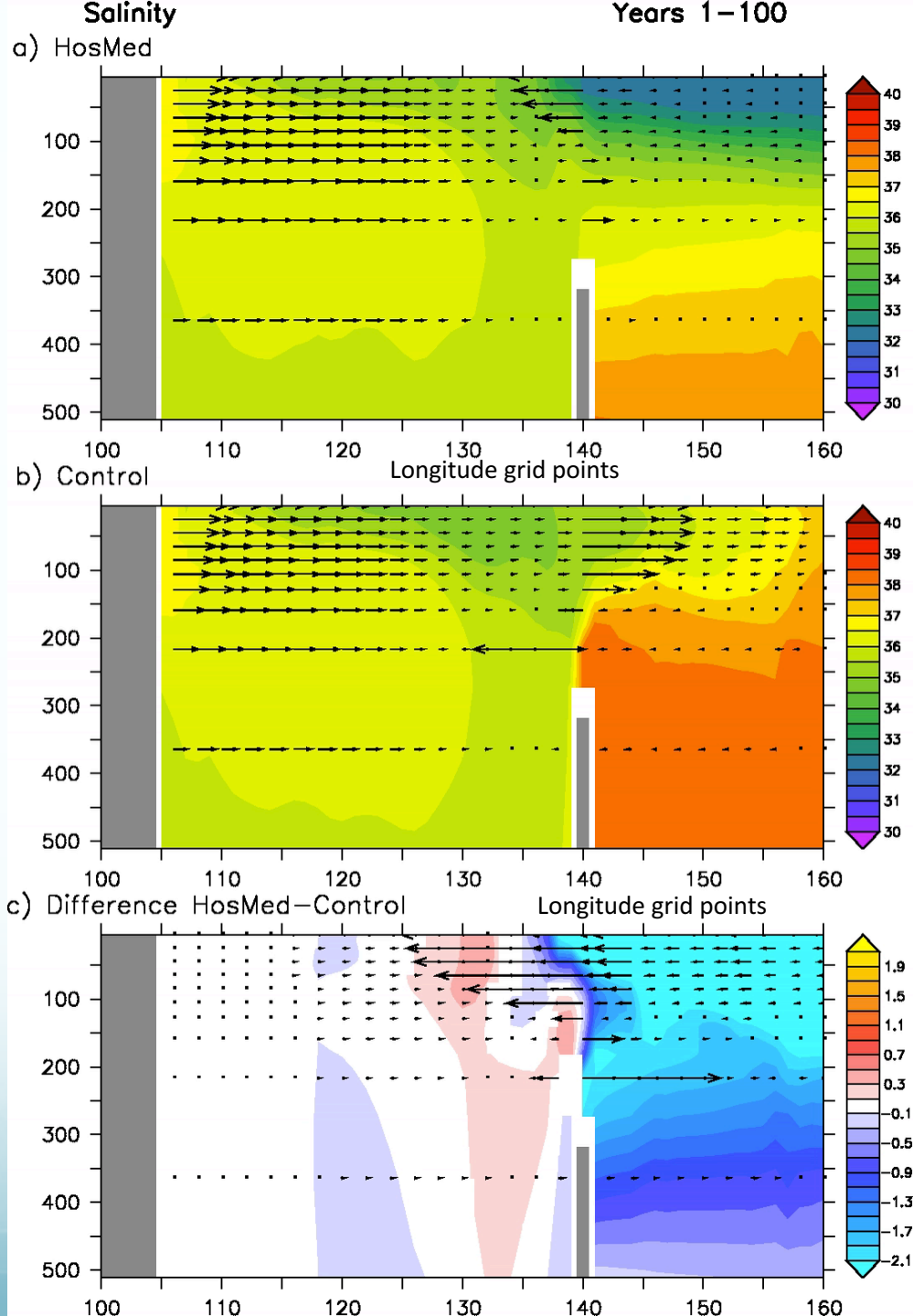
# Freshwater release in the Mediterranean

- Only a small proportion of the freshwater released leaves the Mediterranean at the surface
- Increase of SSS in the North Atlantic!
- And of convection



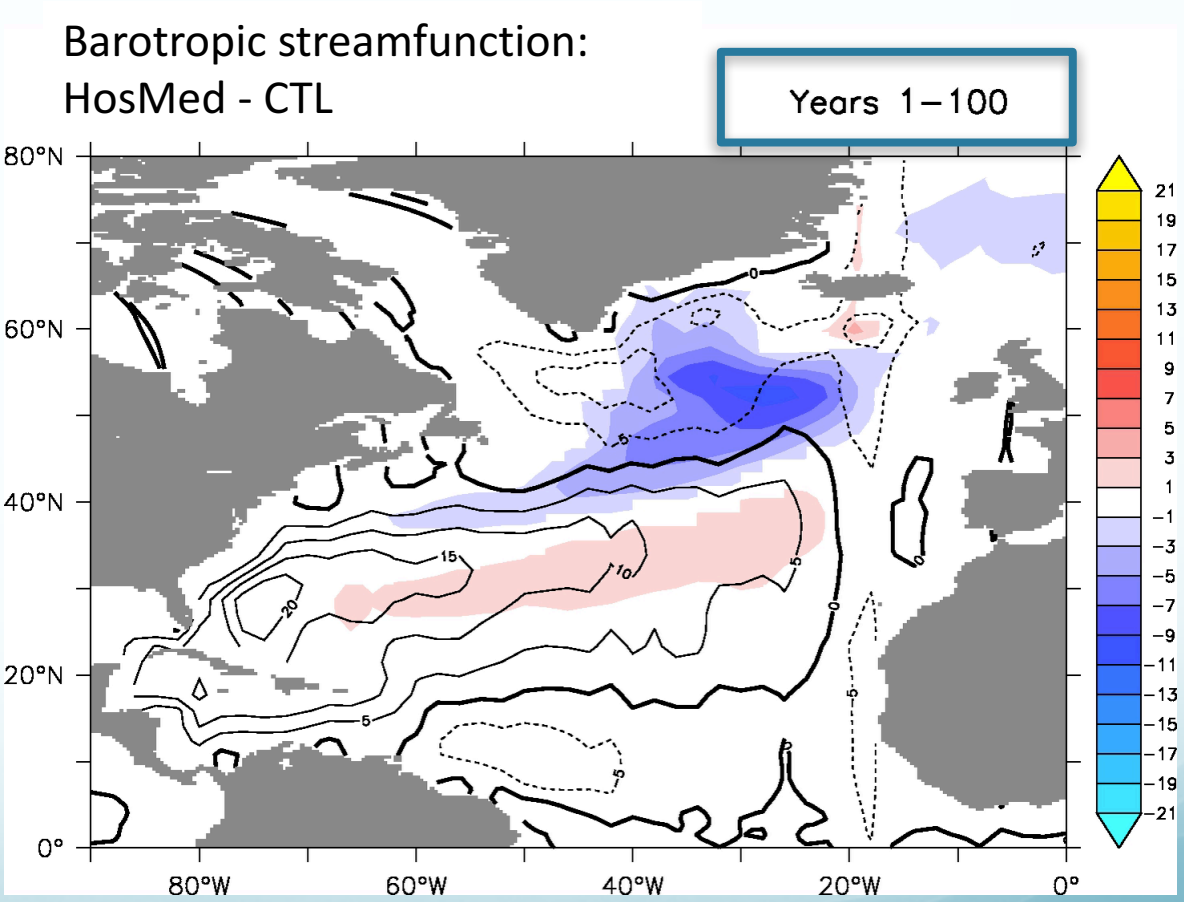
# Change at Gibraltar Strait

- The flow is reversed at Gibraltar, there is no more MOW, and the Mediterranean export in the Atlantic of surface surface (fresh) waters
- This is participating to the freshening in the Atlantic: **A third process at play!**



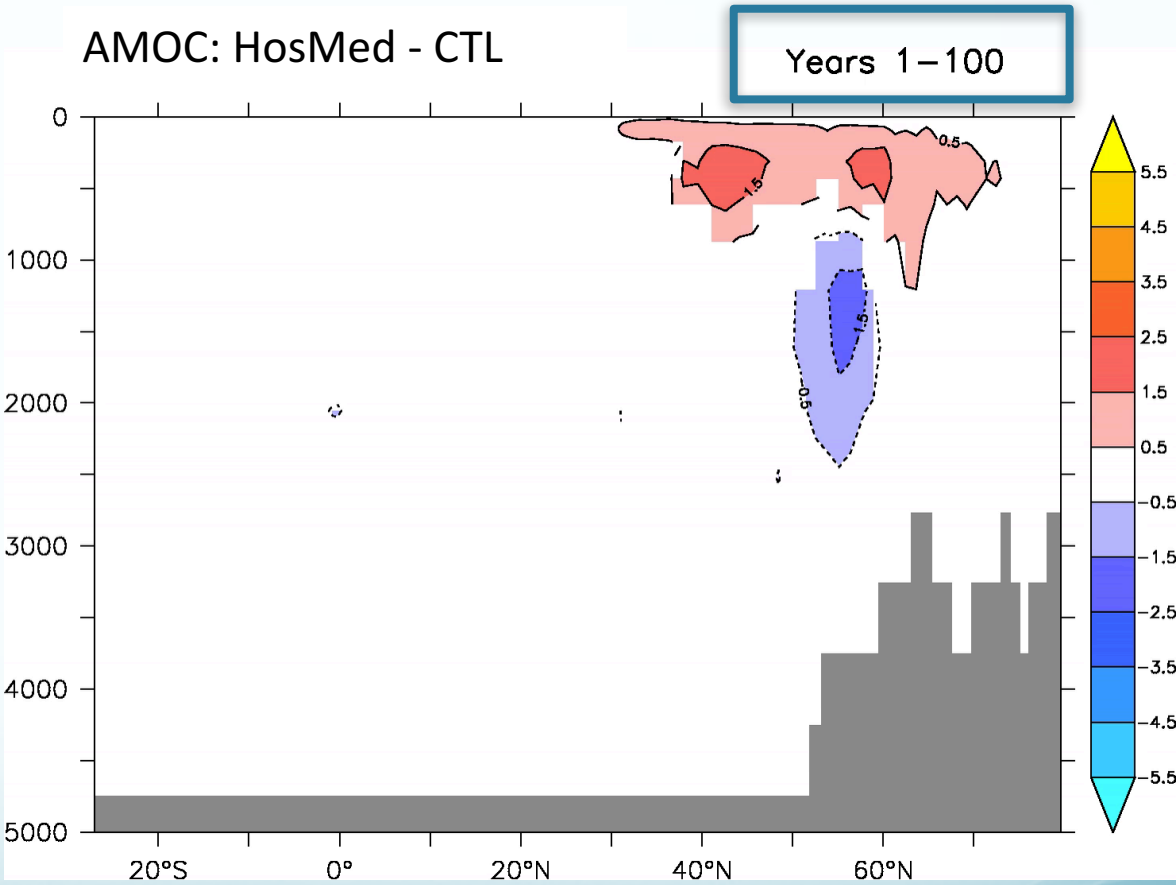
# Impact on barotropic circulation

- Increase of the eastern subtropical gyre in line with a weakening of the Azores current.
- Increase in the eastern subpolar gyre at the beginning
- Both impact decrease with time



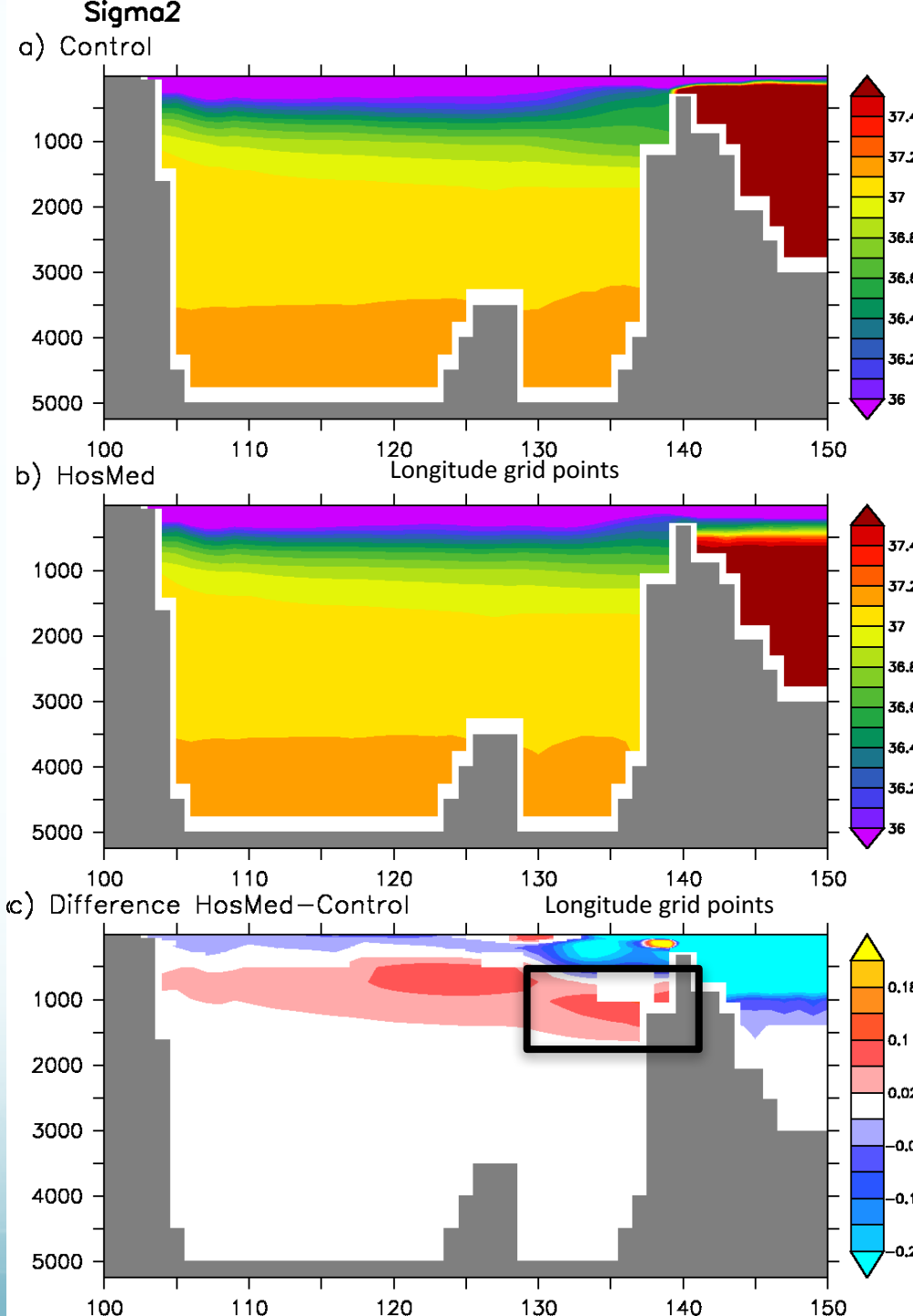
# Who wins in the long term?

- First effect wins (thermal wind changes at depth) over the second (Azores current changes) after a few centuries
- Or/and release of freshwater at Gibraltar
- The AMOC globally weakens by up to 5 Sv at the end of the 1000 years of hosing in the Mediterranean



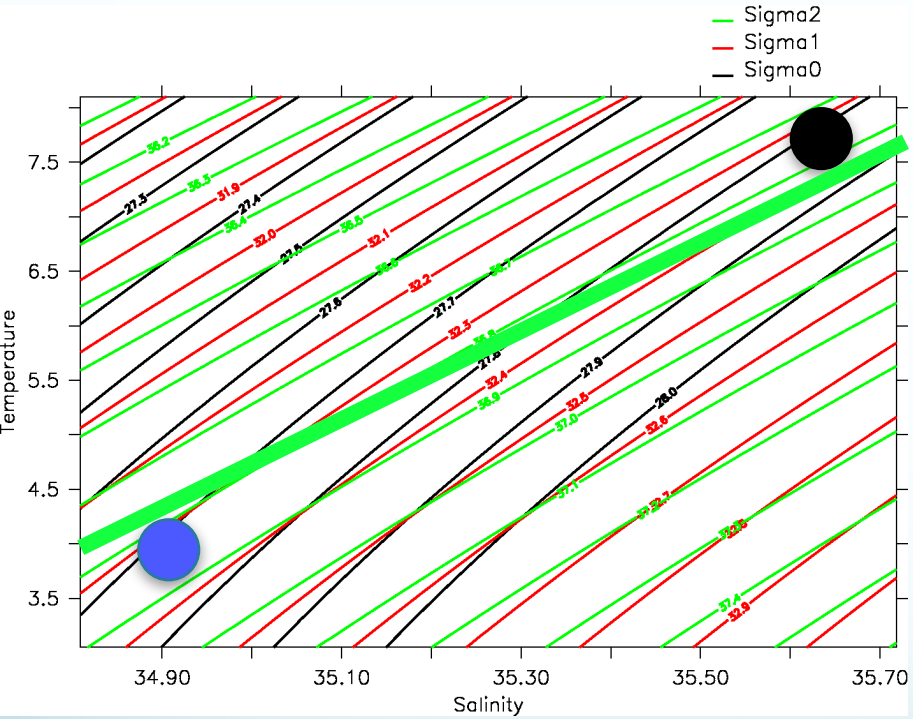
# Understanding the thermal wind changes

- Is the density along the Iberian margin increasing or decreasing when the MOW ceases?
- If it decreases below 1000m, then the lower limb of the AMOC should increase...
- But it increases in sigma2

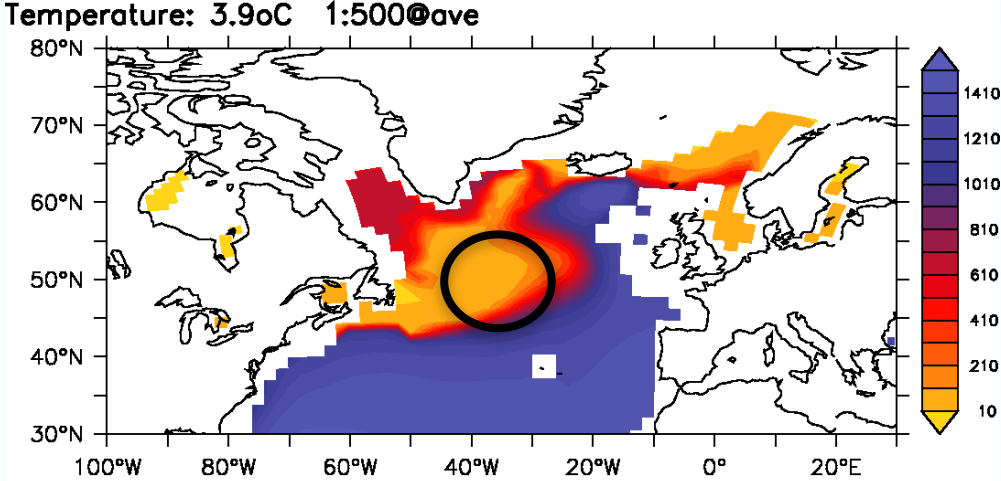


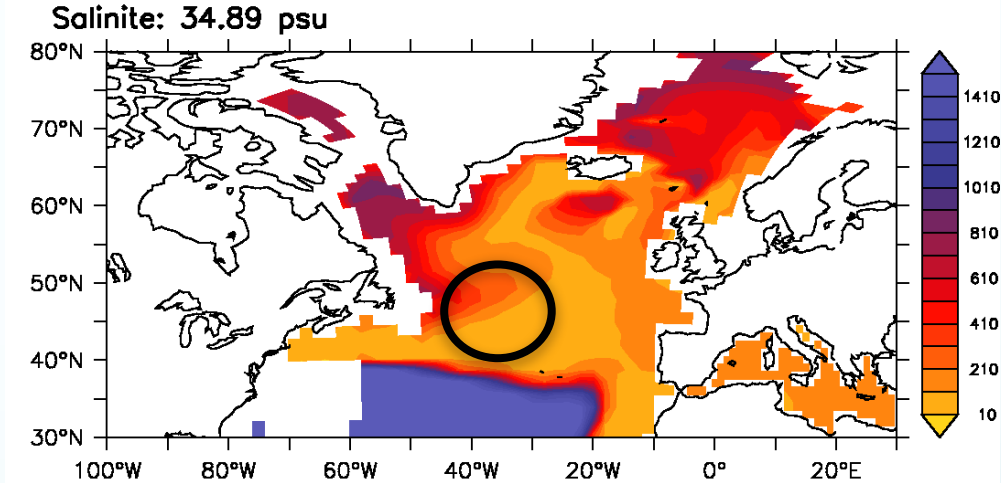
# Effect of the depth

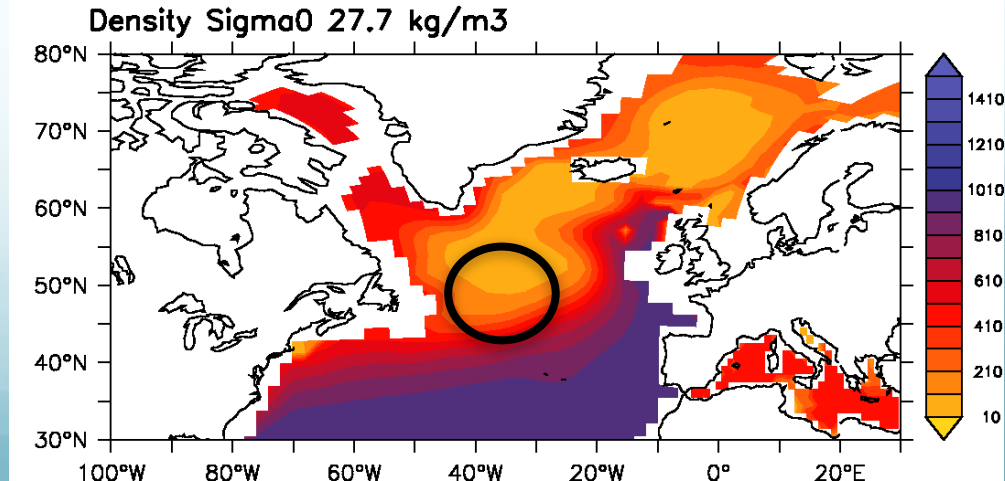
- Origin of the water mass replacing the MOW?
  [35.6, 7.5] => [34.9, 3.9]



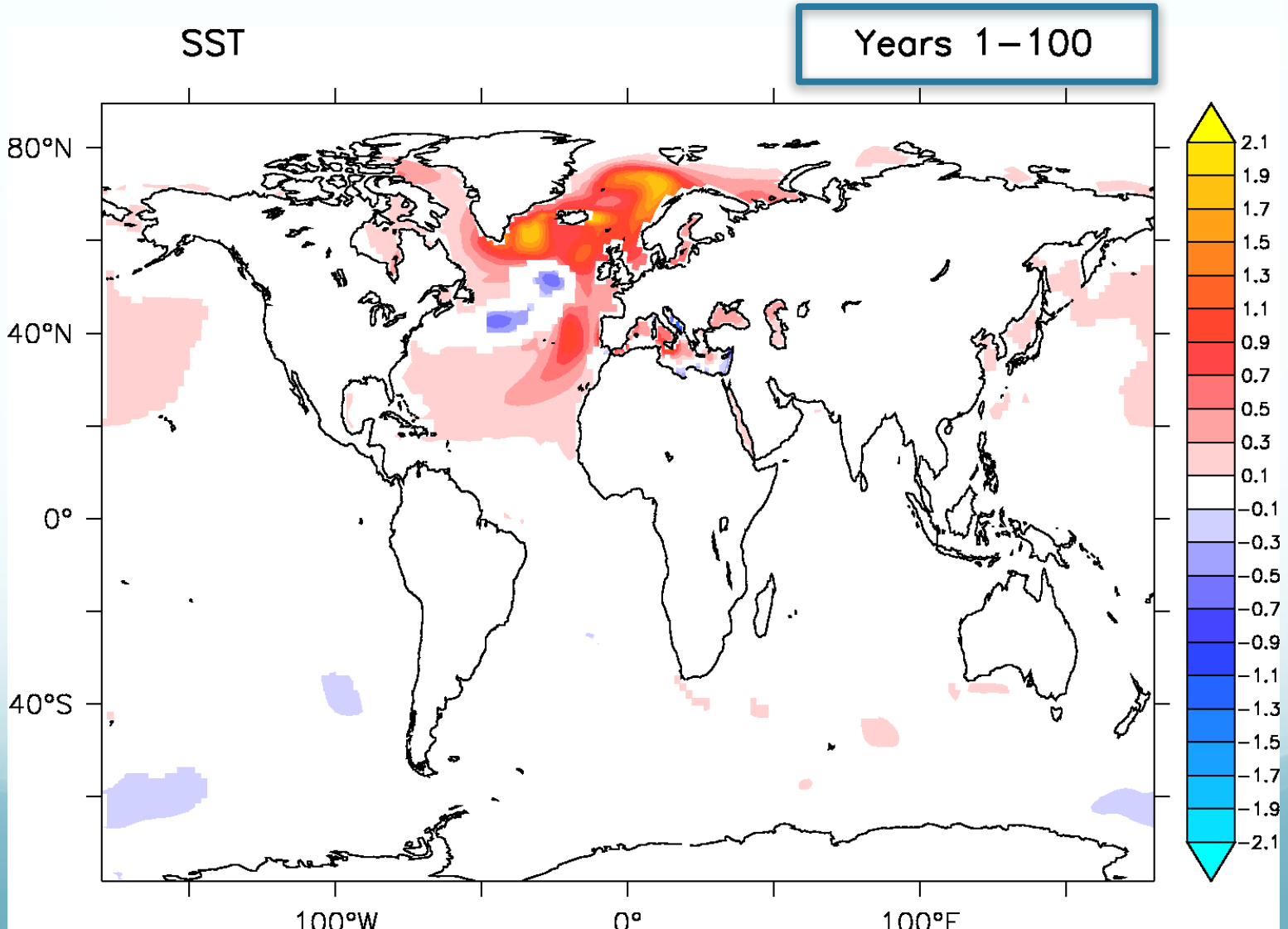

- Density changes with depth
- It has a strong impact here!



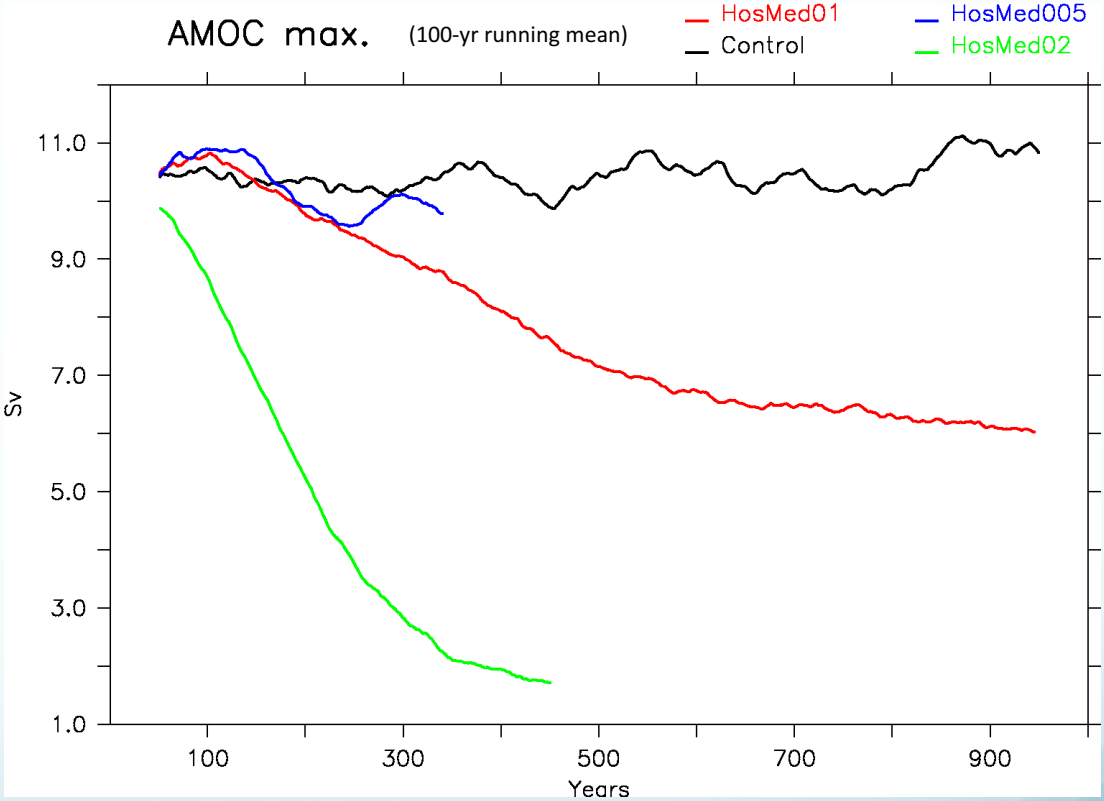



# SST impact


SST
Years 1–100
80°N
40°N
0°
40°S
100°W
0°
100°E
2.1
1.9
1.7
1.5
1.3
1.1
0.9
0.7
0.5
0.3
0.1
−0.1
−0.3
−0.5
−0.7
−0.9
−1.1
−1.3
−1.5
−1.7
−1.9
−2.1

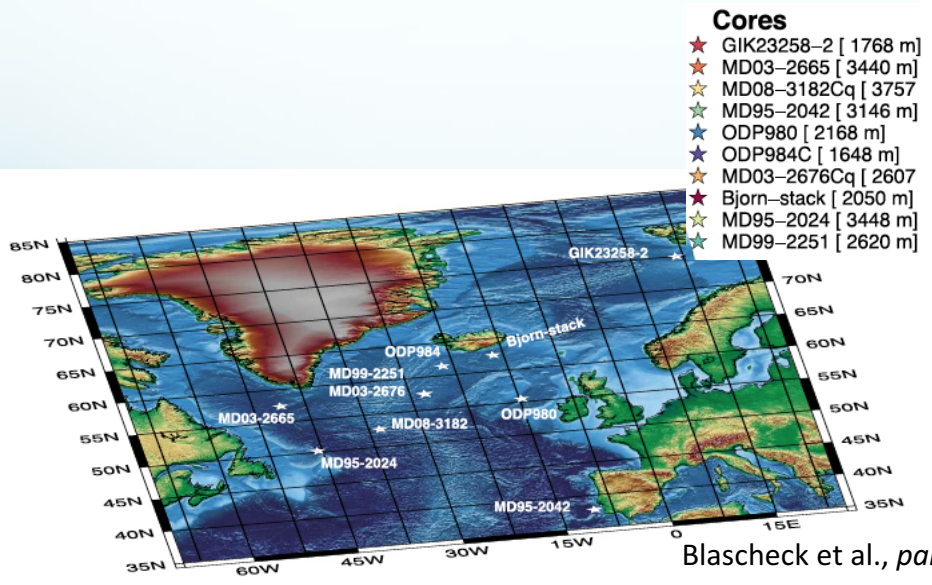
# Influence of the rate

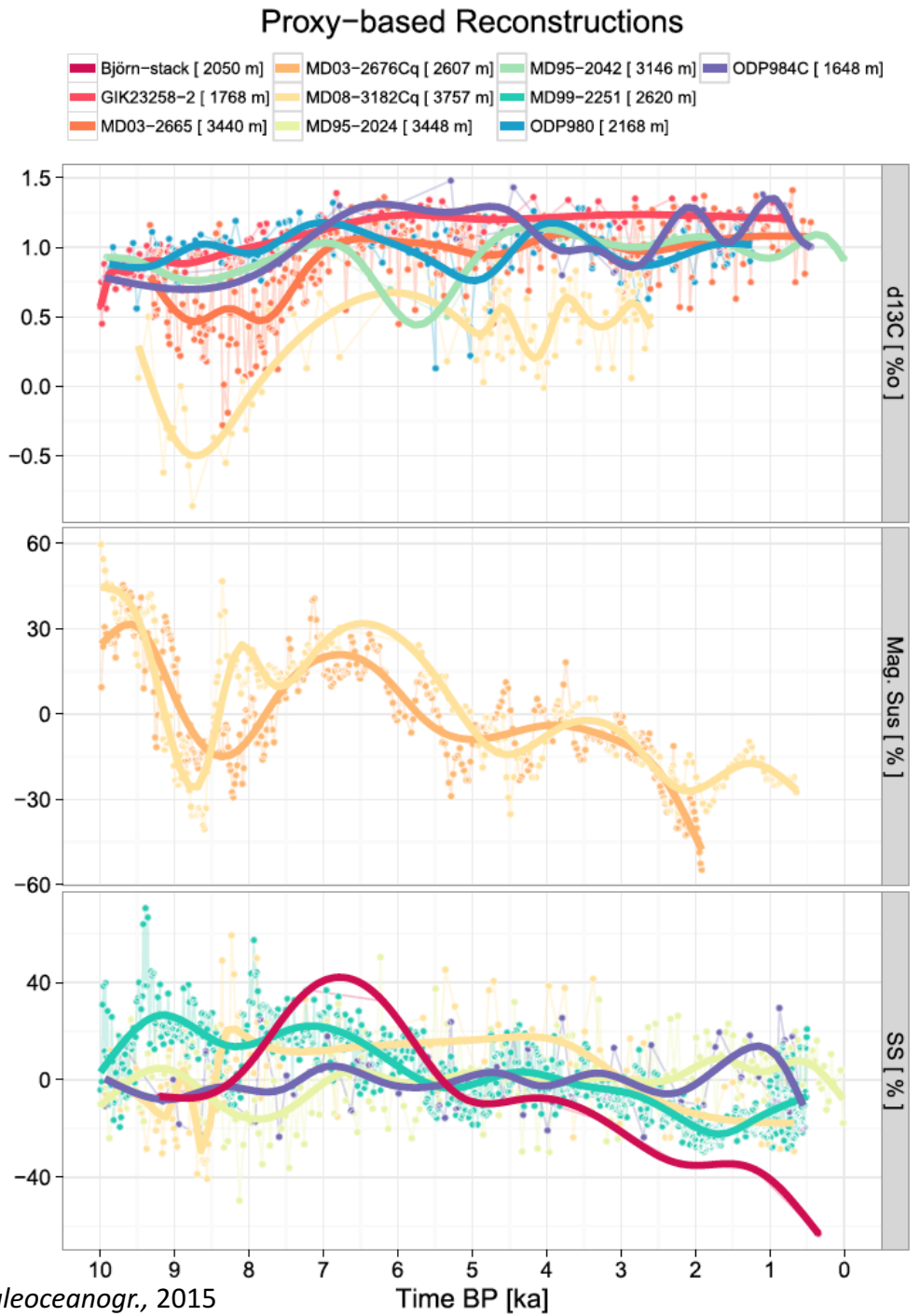
- What about lower rate than 0.1 Sv? 0.05Sv and 0.02 Sv in the machine
- From our results, the rate of the additionnal freshwater release could be key for the AMOC and SST response
- For lower rate than 0.1 Sv, decrease MOW could imply a warming in the North Atlantic



# Implications

- AMOC variability over the Holocene
- Poster from Mohamed Ayache: AMOC reconstruction over the Holocene
- Can Sapropel event have played a role in the variability?




Blascheck et al., *paleoceanogr.,* 2015

# Thank you!