Impact of a freshwater release in the Mediterranean Sea on the North Atlantic climate

Poster T1-06

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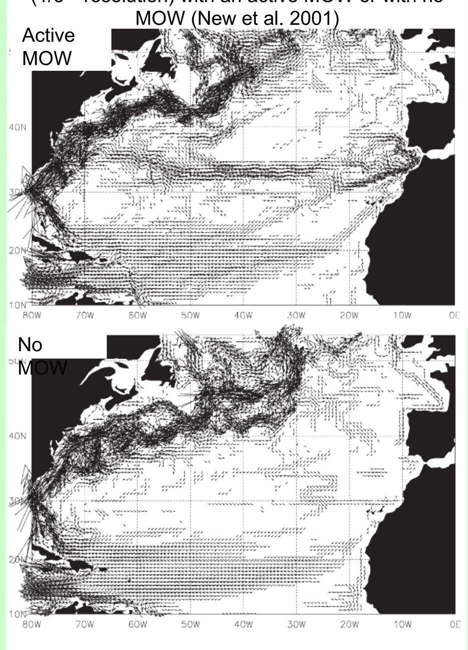
Background

Surface ocean velocity in OGCM simulations (1/3° resolution) with an active MOW or with no MOW (New et al. 2001)



➢ The climate of the Holocene is closer to present-day conditions than to the ones during Ice ages

➢ It is believed that substantial variations occur in the Atlantic Meridional Overturning Circulation (AMOC) during this time period (*e.g.* Kissel et al. 2013)

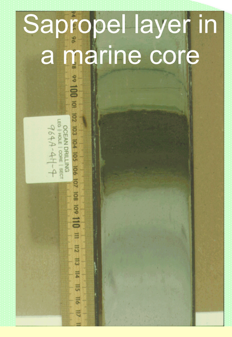
➢ Around 6000 kyrs BP and before, the Sahara was partially covered by vegetation (so-called "Green Sahara")

➢ Marine sediment cores from the Mediterranean indicate large sapropelic deposit during early Holocene (10-6 kyr BP, *e.g.* Rohling et al. 2015)

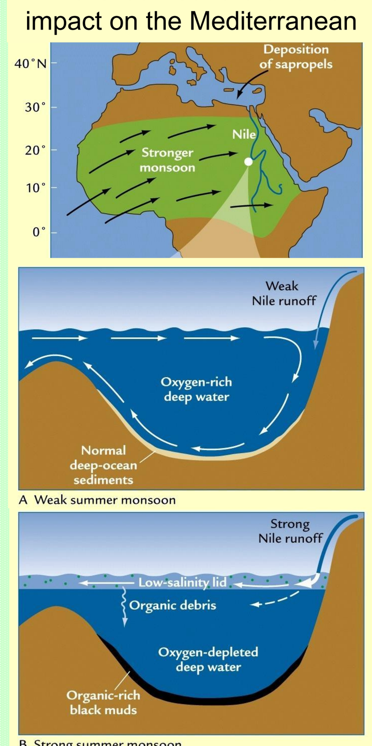
➢ Such Sapropelic deposit may be related with fresh surface water in the Mediterranean, related with large increase of River Nile flow, in link with Green Sahara at the same period, potentially impacting the Mediterranean Outflow (MOW).

➢ New et al. (2001) showed that the MOW intensity strongly impact of Azores current in high-resolution OGCM, while Ivanovitch (2014) showed that a reduced MOW may weaken the AMOC in a coarse AOGCM

Sapropel layer in a marine core



The Green Sahara and its impact on the Mediterranean



Aim of this work

1. Evaluate the impact of freshening of the Mediterranean on the Atlantic
2. Understand the key processes at play

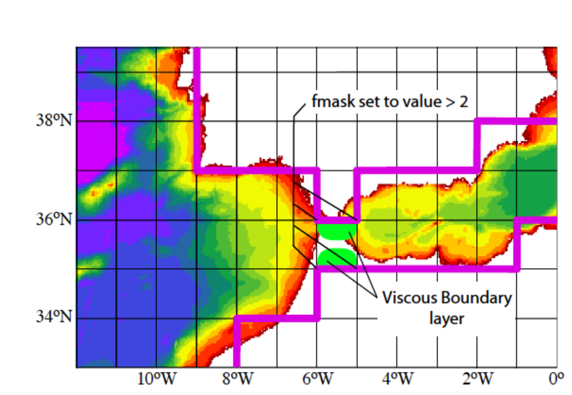
1) Model simulations

❖ We use the IPSL-CM5A-LR (Dufresne et al. 2013), a coupled AOGCM participating to the last CMIP5 database.

❖ The ocean (NEMO) has a horizontal resolution of 1-2° and 31 vertical levels; the atmosphere (LMDz) has a horizontal resolution of around 2° (96x95) and 39 vertical levels

❖ The model also includes sea ice (LIM2) and land surface (ORCHIDEE) models as well as biogechemical ocean module (PISCES)

❖ At Gibraltar Strait, the viscosity is increased in order to have a correct representation of volume export of MOW



Parametrisation of the Gibraltar Strait flow in ocean model NEMO

Table summarizing the simulations analysed

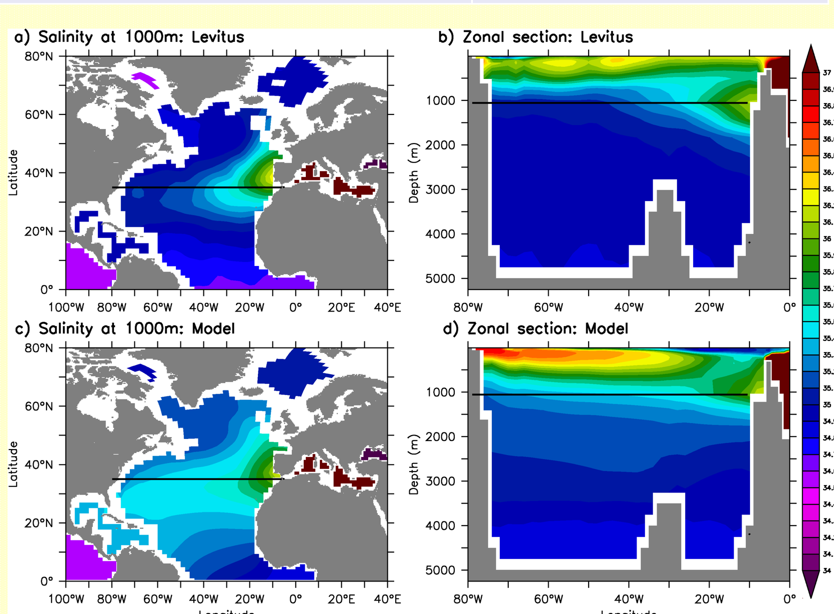
Name	Forcing	Hosing	Length
Control	Pre-industrial conditions	none	1000 years
HosMed2	Pre-industrial conditions	0.2 Sv in the Mediterranean	500 years
HosMed1	Pre-industrial conditions	0.1 Sv in the Mediterranean	1000 years
HosMed05	Pre-industrial conditions	0.05 Sv in the Mediterranean	1000 years
HosMed02	Pre-industrial conditions	0.02 Sv in the Mediterranean	1000 years

❖ When compared with Levitus data, the representation of the Mediterranean Outflow (MOW) has relatively correct temperature and salinity properties and depth location in the control simulation

❖ MOW is equal to around 0.7 Sv in the model, similar to what is observed

❖ The hosing of 0.1 Sv over the Mediterranean is large, but represents a Nile outflow of only around half present-day Amazon flow (present-day: Nil=3 mSv ; Amazon=200 mSv)

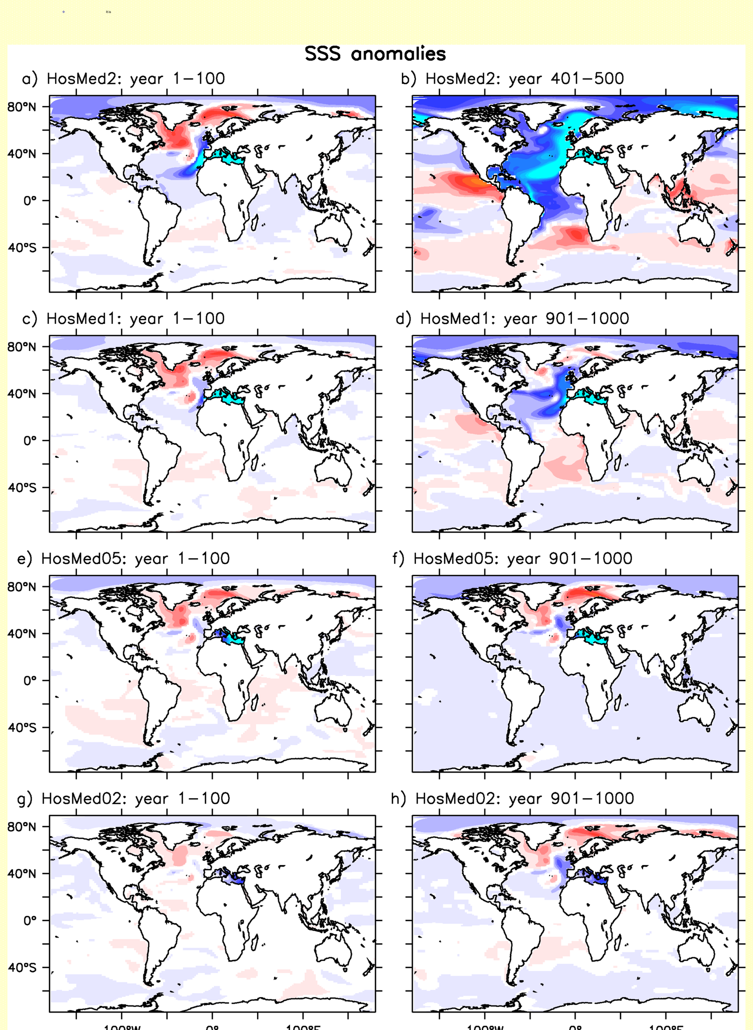
❖ Recent simulation only for the Mediterranean (Grimm et al. 2015) rather used a flux of around 0.02 Sv to represent last Sapropel event



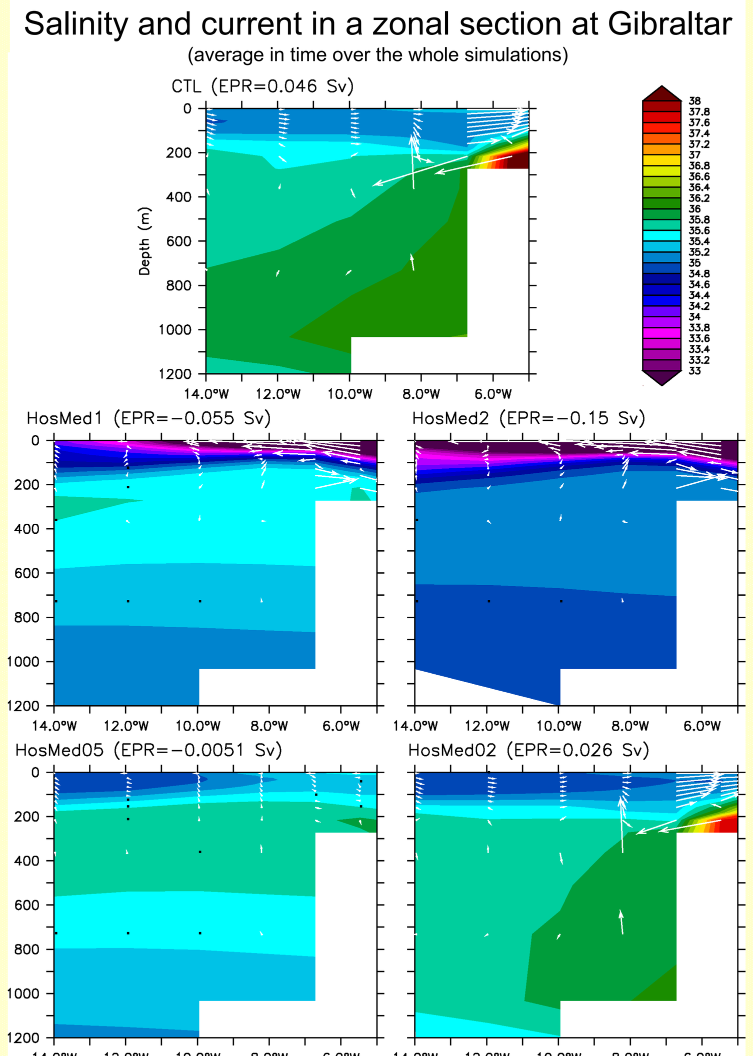
2) Response in the Mediterranean and Atlantic

❖ In response to the different freshwater release rates, the outflow at Gibraltar is strongly modified:
  - ❖ It is reversed in HosMed1 and HosMed2
  - ❖ It is weakened in HosMed02 and HosMed05

❖ The MOW vanishes in HosMed1 and HosMed2, while it remains to 0.6 Sv in HosMed02 and 0.1 Sv in HosMed05



Salinity and current in a zonal section at Gibraltar (average in time over the whole simulations)



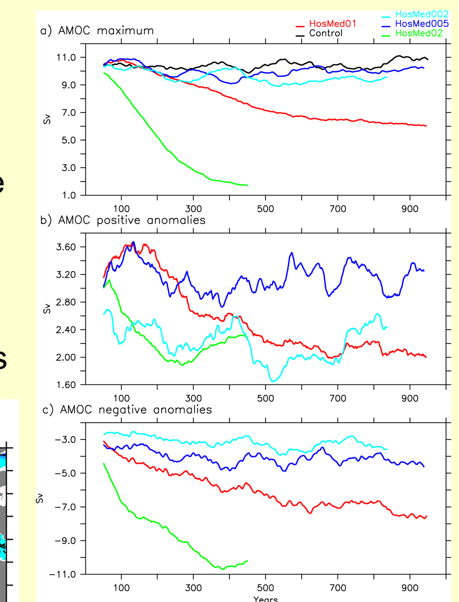
❖ In response to freshwater release in the Mediterranean, the surface salinity in the North Atlantic is changing:
  - ❖ A negative salinity anomaly is spreading from Gibraltar
  - ❖ A positive anomaly is found in the subpolar North Atlantic

3) Ocean circulation changes

❖ The surface currents are strongly modified in the Atlantic

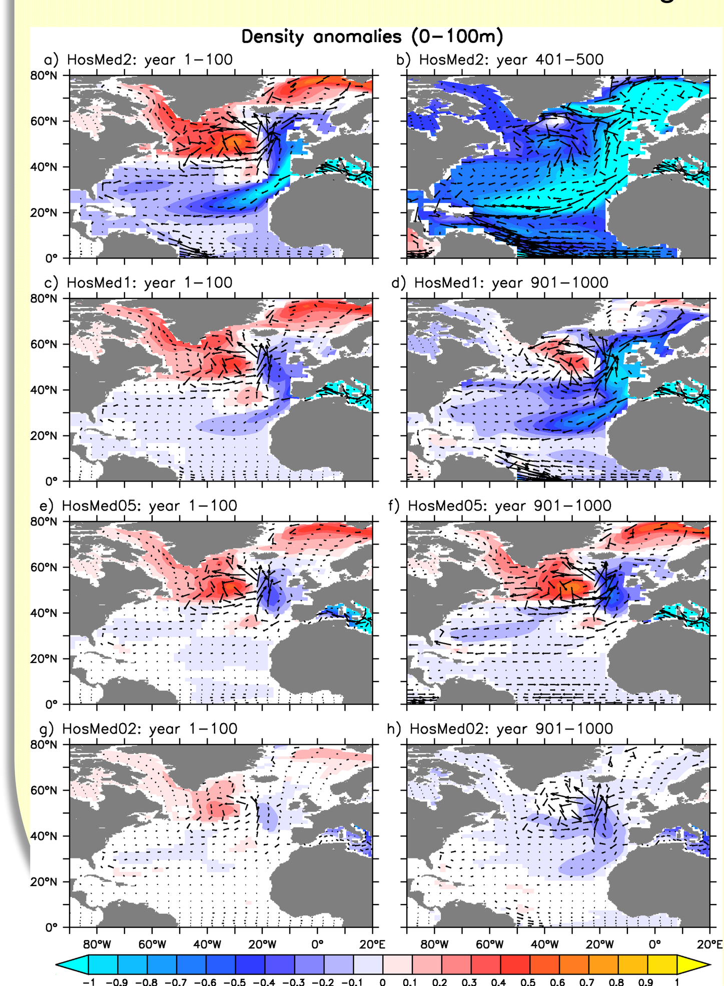
❖ The Azores current is reduced and we notice a strong increase of northflow on the east

❖ These changes mainly follow density changes, indicating geostrophic balance and could be associated with SSS changes



❖ The classical AMOC index is indicating a weakening, but the upper AMOC is increasing by up to 3.5 Sv

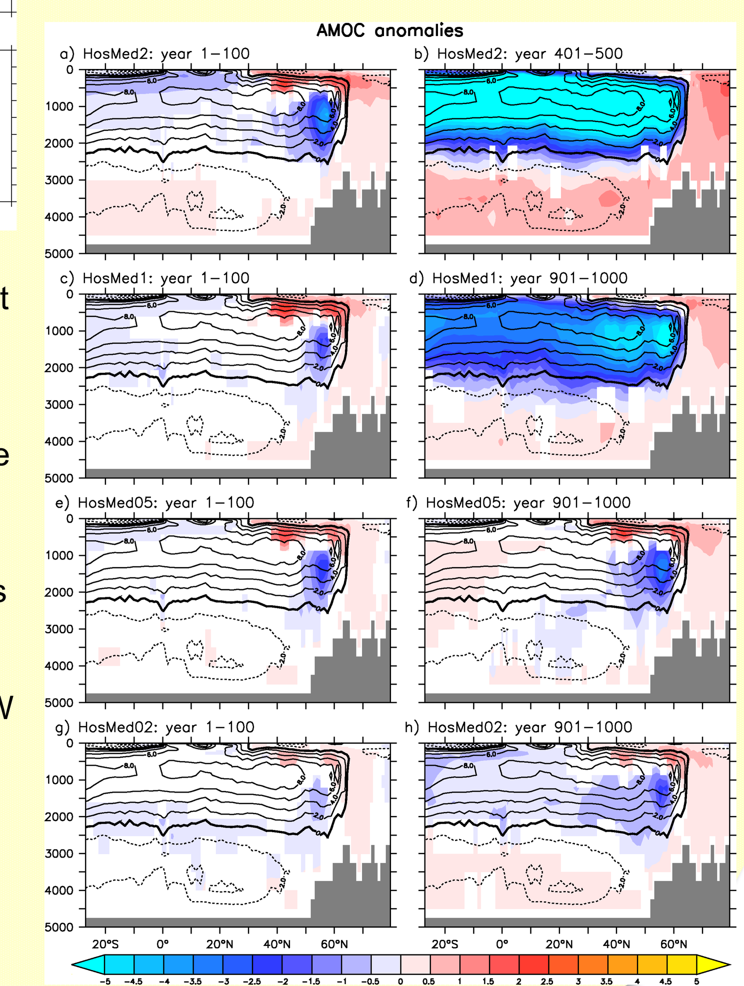
❖ The impact on heat transport is therefore depending on opposite influences:
  - ❖ Changes in AMOC, depending on the depth of the change
  - ❖ Change in the gyres transport



❖ The AMOC weakening at depth is in agreement with a collapsed MOW leading to lower zonal gradient of density in the Atlantic (cf. Ivanovitch et al. 2014)

❖ Nevertheless this implies a decrease in density at depth on the east: the water replacing the MOW is denser (mainly due to the effect of pressure on density, not shown)

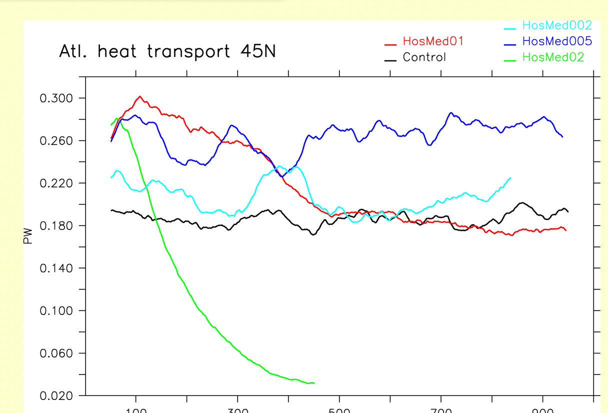
❖ In the upper ocean, the AMOC is enhanced



4) Climatic implications

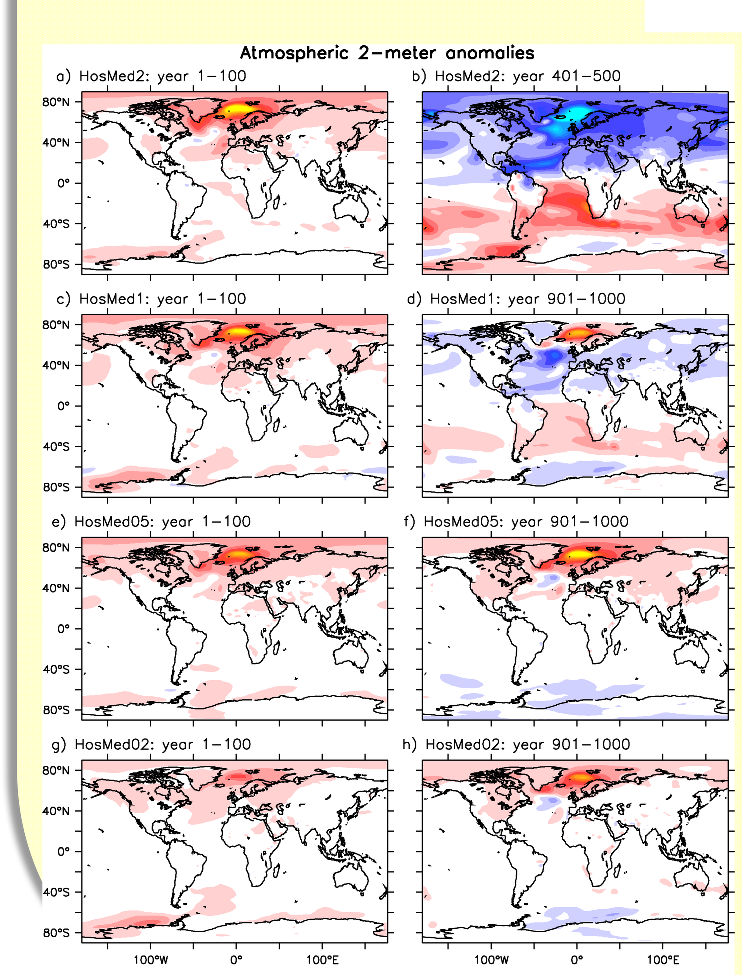
❖ In the Nordic Seas, the classical sea ice feedback (albedo and insulation effect) is clearly enhancing the warming

❖ At the end of HosMed2 and 1, a clear signal of cooling is superimposed, reminiscent of AMOC collapse fingerprint



❖ The heat transport at 45° N is increased at the beginning of all experiments

❖ It strongly decreases in HosMed2 and moderatly in HosMed1, indicative of large AMOC changes

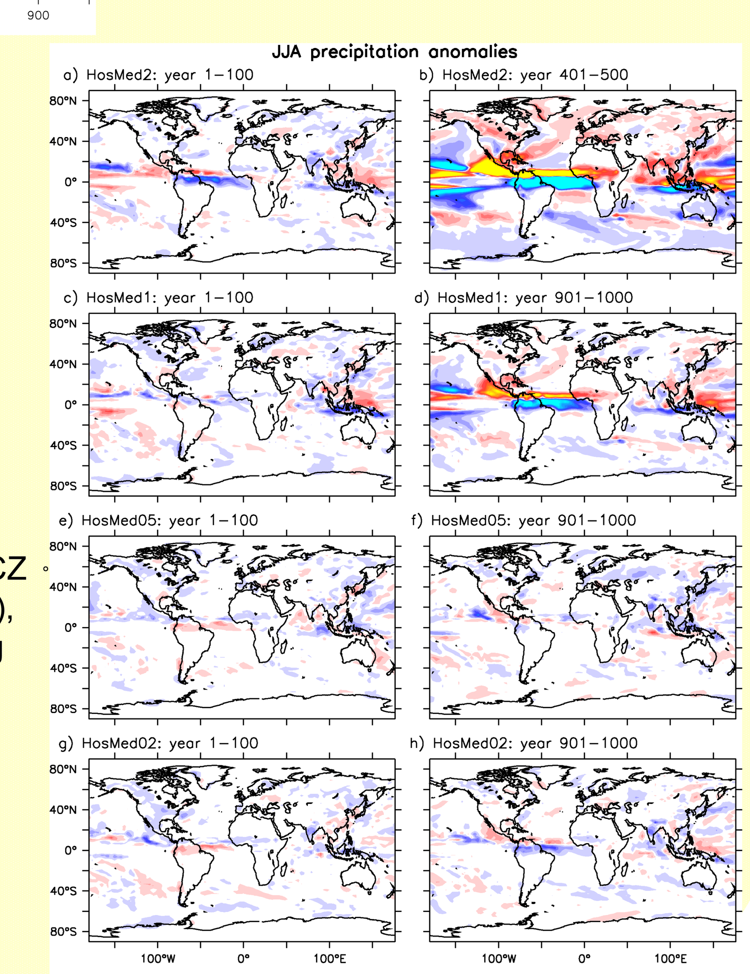


❖ As a consequence, the precipitations are also affected

❖ There is a southward ITCZ migration in HosMed2 and 1, in accordance with their AMOC changes

❖ In HosMed02 and 05, the migration of the ITCZ is northward (but weak), in link with the warming signal

❖ This may constitute a (weak) **positive feedback for Sahara greening**



Discussions and conclusions

➢ Freshwater release in the Mediterranean can strongly impact the Atlantic circulation and climate

➢ Depending on the rate of the release, the impact can be very different: for rates lower than around 0.05 Sv, it is warming the North Atlantic, while it is cooling most of it for rates larger

➢ This is related with AMOC changes as well as barotropic changes in the gyre

➢ **Three processes** are impacting the AMOC:

1. One is related with geostrophy due to the collapse of MOW and **weakens** the AMOC at depth
2. The other is due to the change in surface current, which **enhances** SSS in the subpolar, deep water formation and therefore the whole AMOC.
3. The last is associated with the slow spread of freshwater anomalies from the Mediterranean, which **decreases** SSS in the subpolar after some time, as well as deep water formation and the AMOC

➢ These results lead to a potential new explanation for variations of AMOC over the Holocene : **the Green Sahara can have participated to an increase in the AMOC**, and its cessation to a decrease

➢ We find a positive feedback (albeit week) from greening Sahara for freshwater release lower than 0.05 Sv in the Mediterranean.

References:
- Dufresne, J.-L. et al. (2013) Climate change projections using the IPSL-CM5 Earth System Model: from CMIP3 to CMIP5. Clim. Dyn. 40, 2123–2165.
- Grimm, R. et al., 2015. Late glacial initiation of Holocene eastern Mediterranean sapropel formation. *Nature Communications*, 6, p.7099.
- Ivanovic RF et al., (2014) Sensitivity of modern climate to the presence, strength and salinity of Mediterranean-Atlantic exchange in a global general circulation model. *Climate Dynamics*, 42(3–4), pp.859–877.
- Kissel C et al. (2013) Variations in the strength of the North Atlantic bottom water during Holocene, Earth Planet. Sc. Lett., 369–370, 248–259.
- New AL et al. (2001) On the role of the Azores Current in the ventilation of the North Atlantic Ocean. *Progress in Oceanography*, 48, (2-3), 163-194.
- Rohling EJ et al. (2015) Mediterranean climate and oceanography, and the periodic development of anoxic events (sapropels). Earth-Sci. Rev. 143, 62–97.