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Impact of the NEMOv3.6 stochastic paramétrisation on the CNRM-CM6.1 coupled model

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CNRM CM

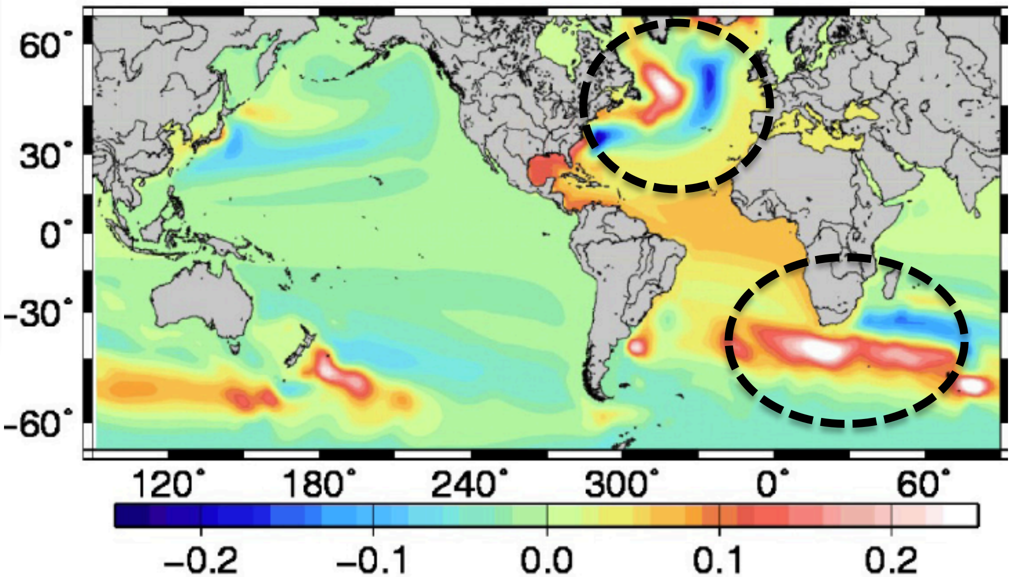
Using parameterisations to mimic unresolved scales

- The **coarse horizontal resolution in standard coupled models** (~100 km) does not allow mesoscale dynamics
- These **unresolved processes provide a great degree of uncertainty**
- **Parameterisation → simulating** the uncertainties associated **to sub-grid scale processes**

Stochastic parmeterisation on the equation of state: *Brankart et al. 2013*

$$\rho = \rho\,(T, S) \rightarrow \quad \rho = \rho\,(T + \Delta T, S + \Delta S)$$

SSH (m) standard − stochastic (ORCA2, forced)



STOchastic Parameterisation (STOP) of the equation of state

Brankart etal. 2013

$$\rho = \rho(T, S) \rightarrow \rho = \rho(T + \Delta T, S + \Delta S)$$

- **ΔT, ΔS proportional to the local gradient** : $\Delta T = \xi * \mathrm{grad}(T)$ $\Delta S = \xi * \mathrm{grad}(S)$

- **ξ_i, i=1,…, p random walks** (2p random walks centered over each grid point)
  $\xi_i \rightarrow$ **first order autoregressive process**

$$\begin{bmatrix} \xi_{i,x}(t_k) \\ \xi_{i,y}(t_k) \\ \xi_{i,z}(t_k) \end{bmatrix} = \varphi_i \begin{bmatrix} \xi_{i,x}(t_{k-1}) \\ \xi_{i,y}(t_{k-1}) \\ \xi_{i,z}(t_{k-1}) \end{bmatrix} + \sqrt{1-\varphi_i^2} \begin{bmatrix} w_{i,x} \\ w_{i,y} \\ w_{i,z} \end{bmatrix}$$

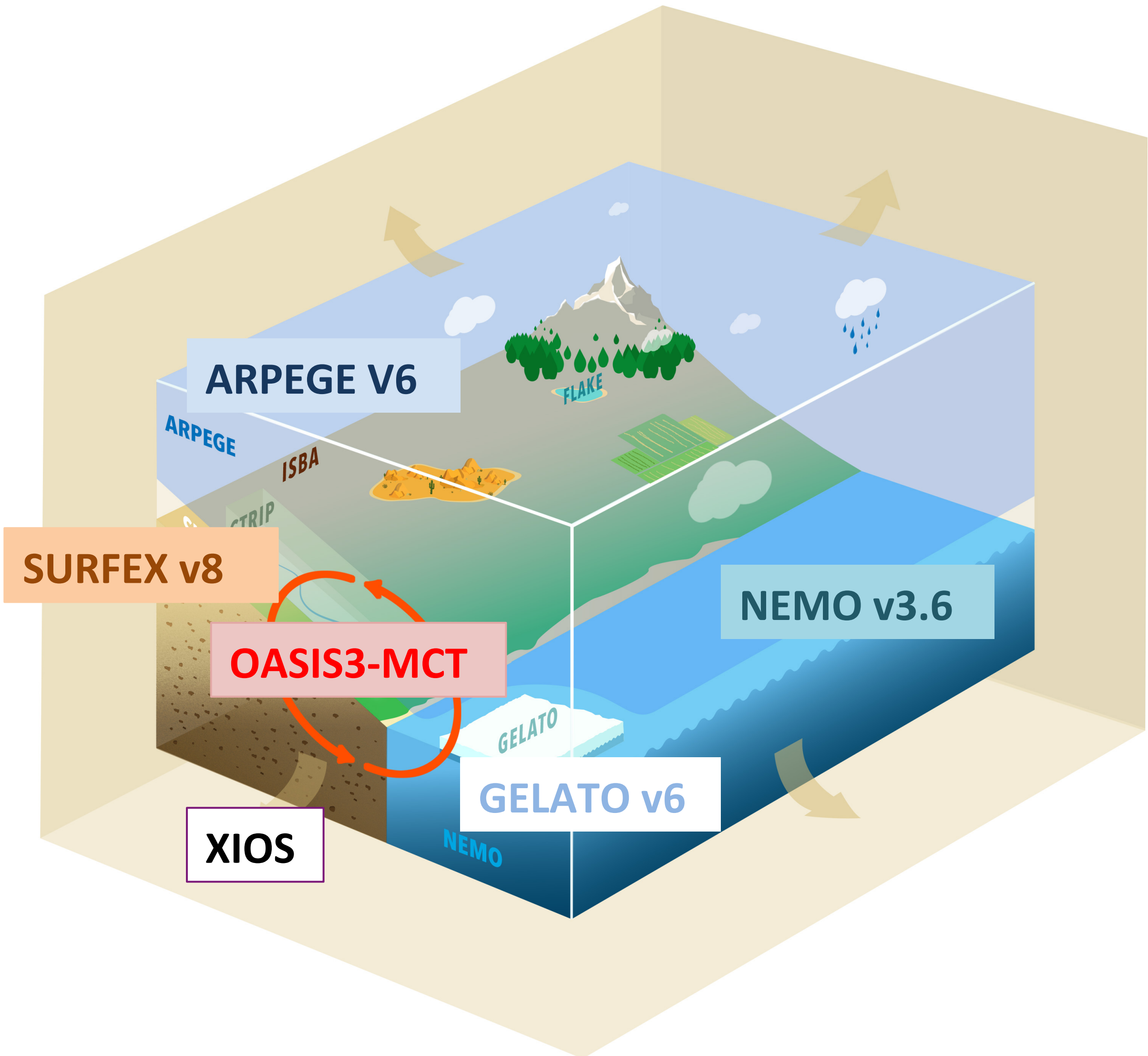
W -> gaussian noise *(zero mean) and standard deviation σ (x, y, z)*

Φ -> parameter of decorrelation time *for the random walk*

Statistical parameters defining the random walks (NEMO namelist)

Number of random walks	$p = 6$
Horizontal standard deviation ($i = 1, \ldots, p$)	$\ell_x = \ell_y = 4.2\lvert\sin\lambda\rvert$ grid points
Vertical standard deviation ($i = 1, \ldots, p$)	$\ell_z = \lvert\sin\lambda\rvert$ grid points
Correlation timescale ($i = 1, \ldots, p$)	$\tau = 180$ time steps

Objective: impact of the STOP on the coupled model CNRM-CM6



NEMO 3.6
eORCA1 grid, L75

More details on the ocean component see Rym Msadek's talk

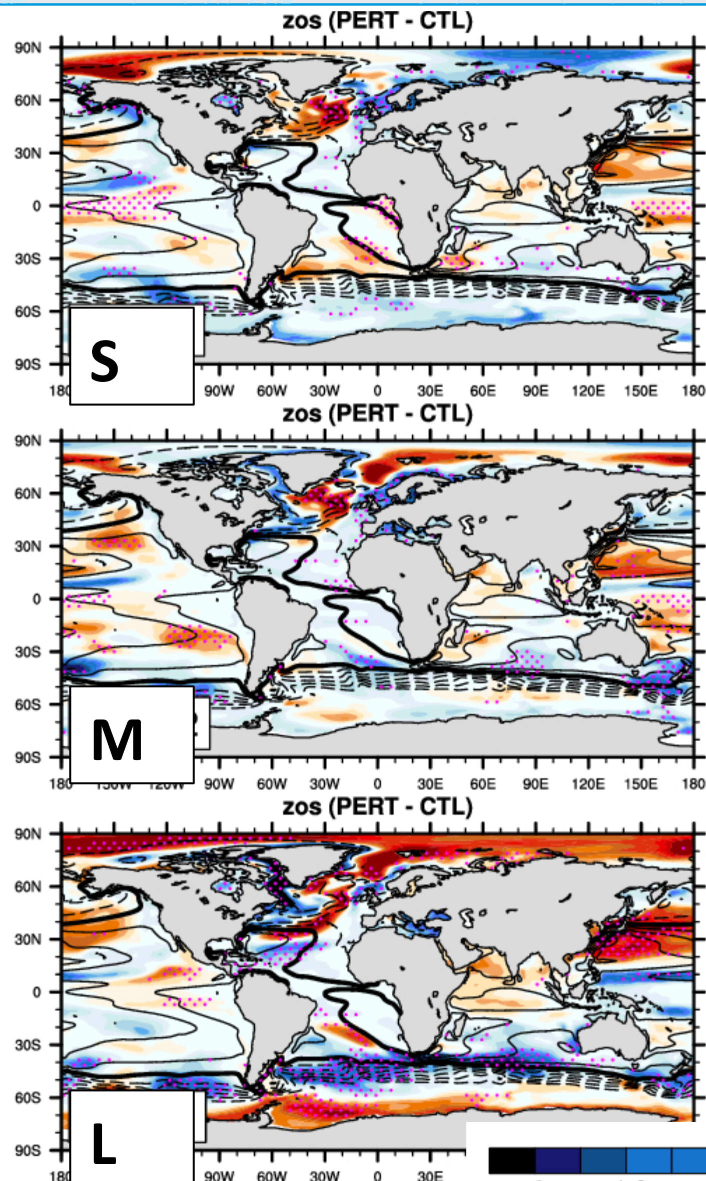
STOP Numerical experiments and methods

Parameter	Soft (S)	Medium (M)	Large (L)	Brankart et al
Nb random walks	4	4	6	6
Horizontal variance	0.7	1.4	2.1	4.2
Vertical variance	0.2	0.7	1.0	1.0
Decorrelation time	10 days	10 days	12 days	12 days

Ocean instabilities, model explosions

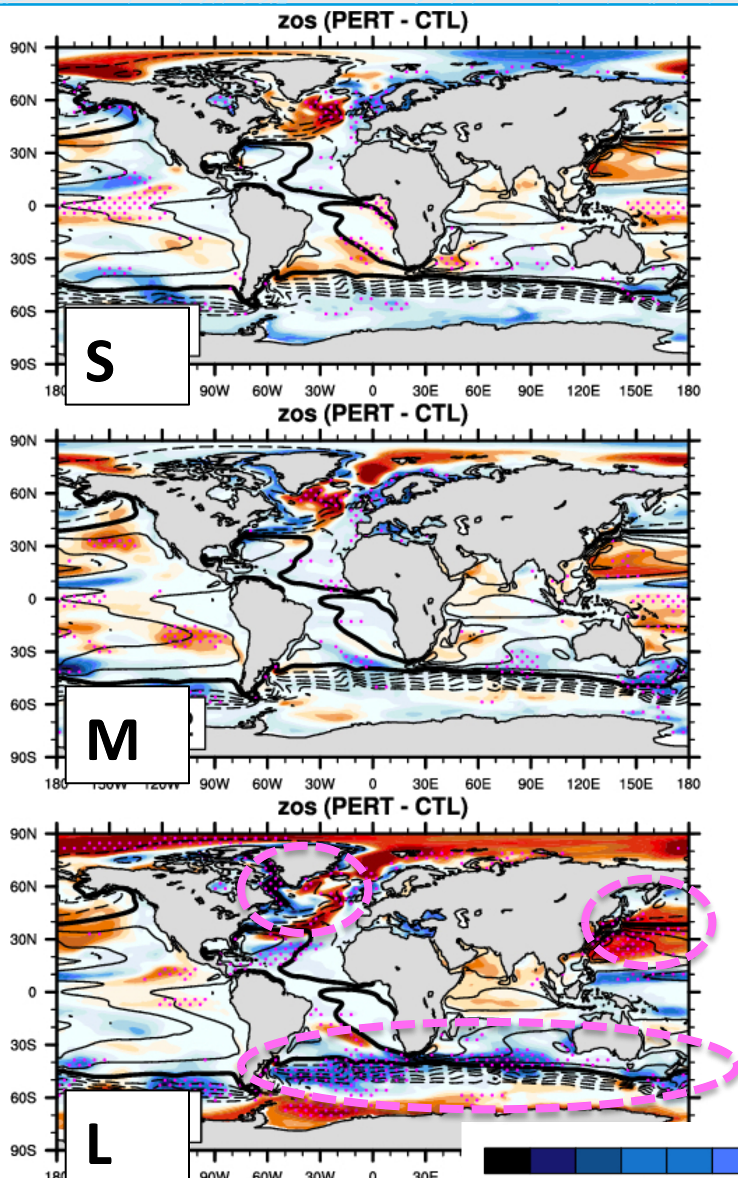
- ✓ **4 ensembles:**
  control → CTL (standard)
  perturbed → S, M, L
- ✓ **3 members of 30 years** (1970-2009) for each ensemble
- ✓ **same STOP for all members on one ensemble!!!!!**
- ✓ differences **PERTURBED – CTL (ensembles mean)**

STOP impact on Sea surface height



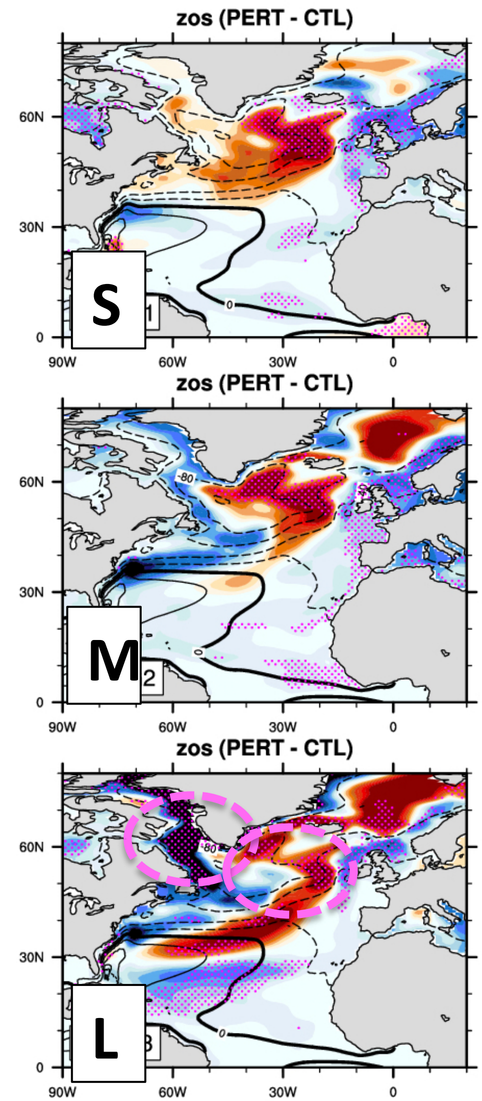
Contours:
CTL climatology

STOP impact on Sea surface height



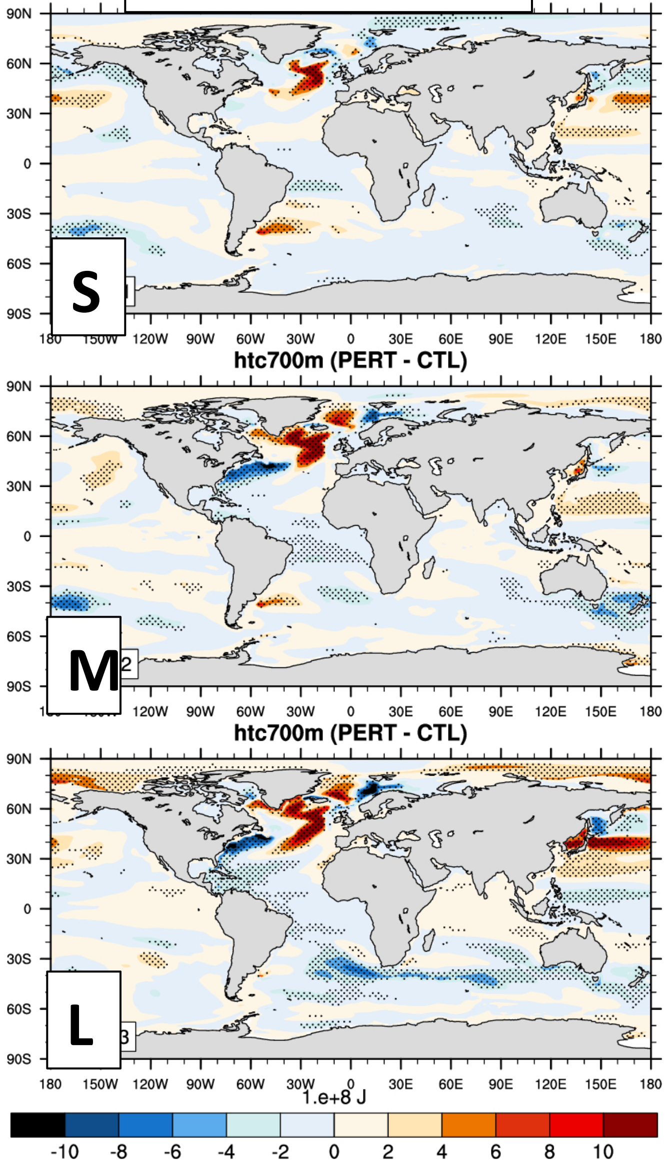
STOP impacts:
Similar as in Brankart et al. but lower magnitude

- ACC
- Kuroshio extension
- North Atlantic drift and Gulf Stream
- Subpolar Gyre
- Labrador current

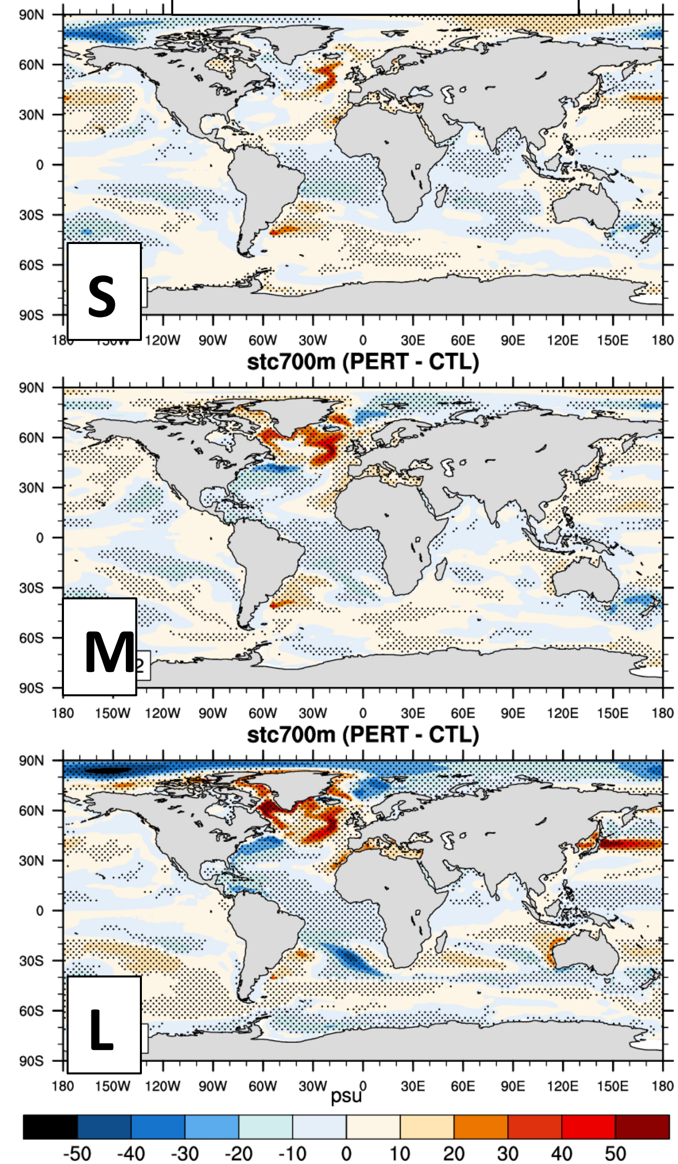


Ocean heat and salt content 700 m

Heat content

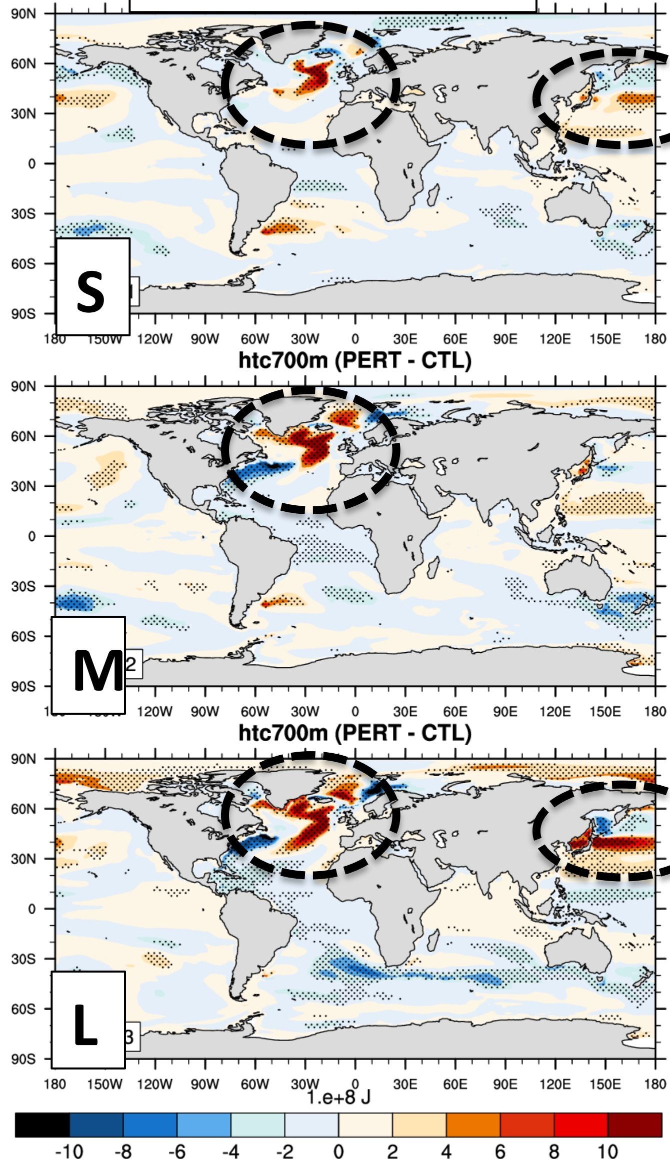


Salt content

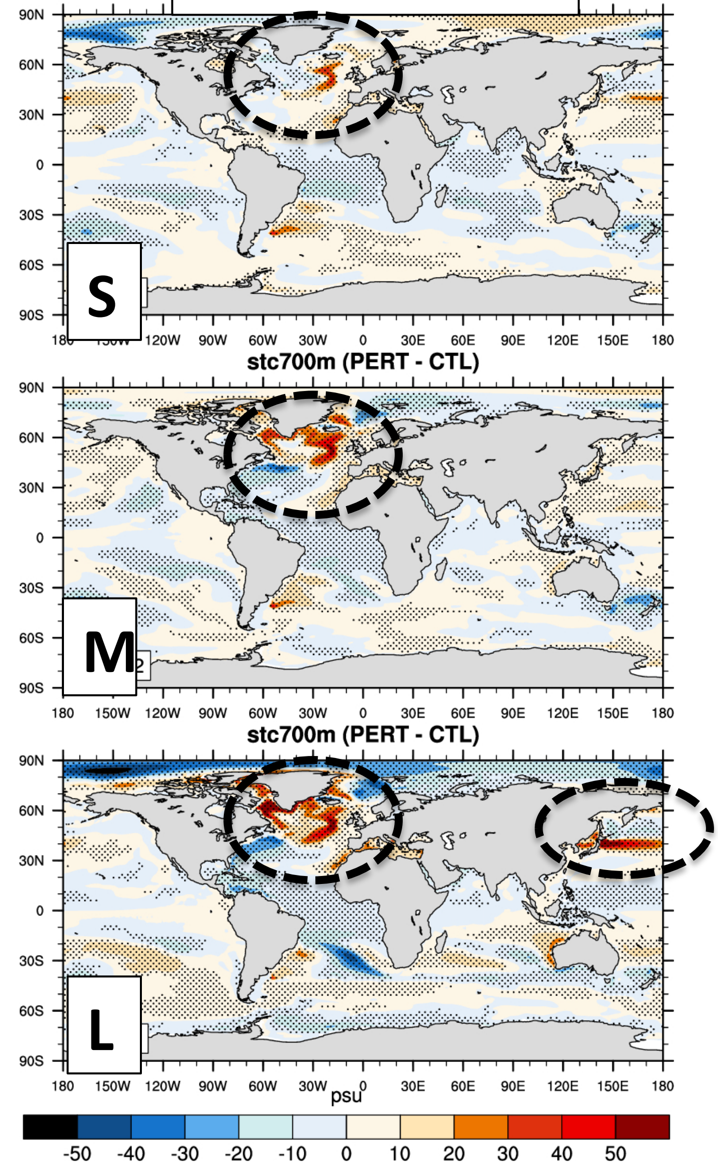


Ocean heat and salt content 700 m

Heat content

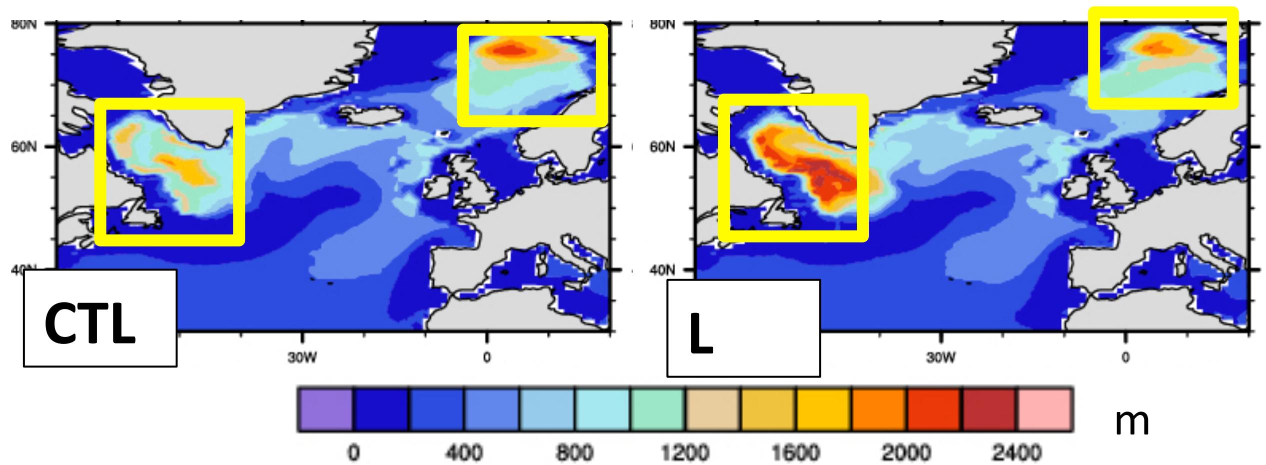


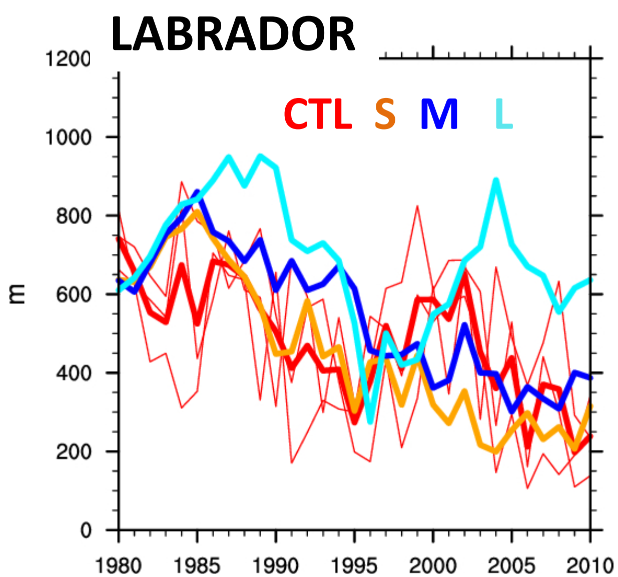
Salt content

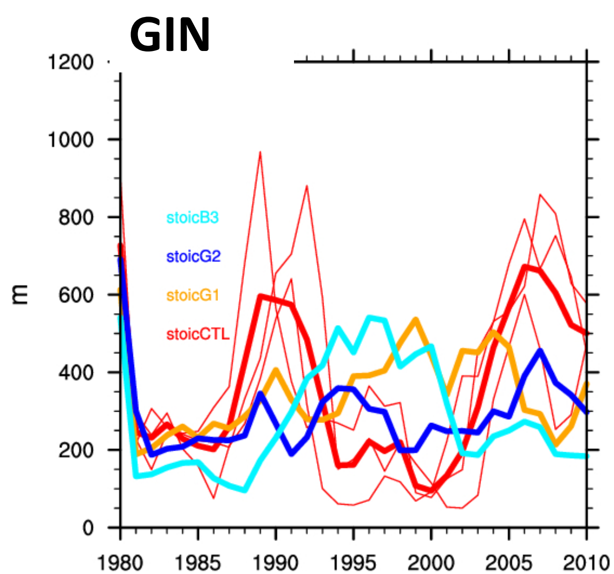


Deep convection North Atlantic

Maximum MLD JFMA





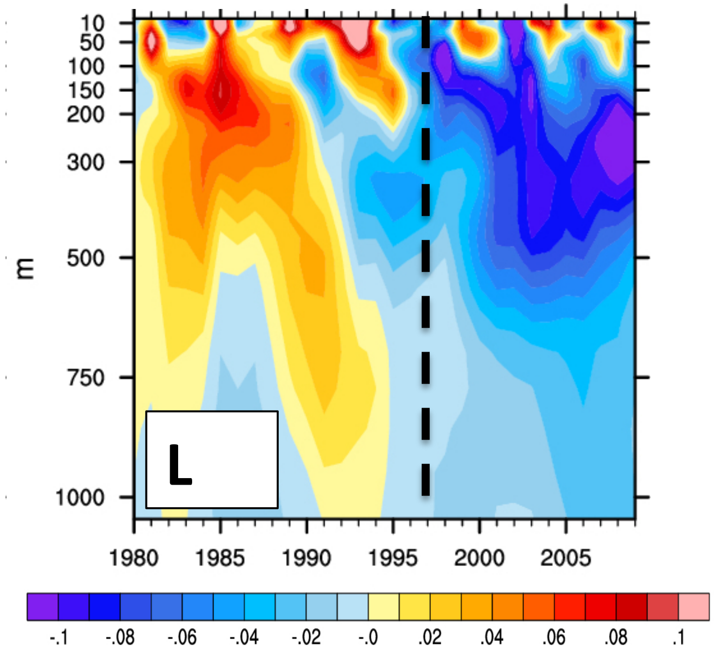


STOP enhances the deep convection in Labrador Sea

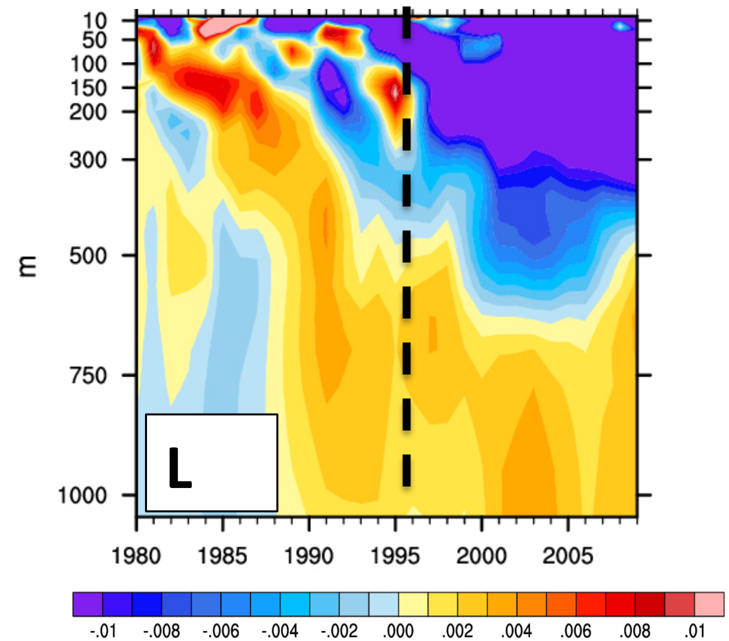
MLD time series

Timescales of the response to STOP

Temperature ATL

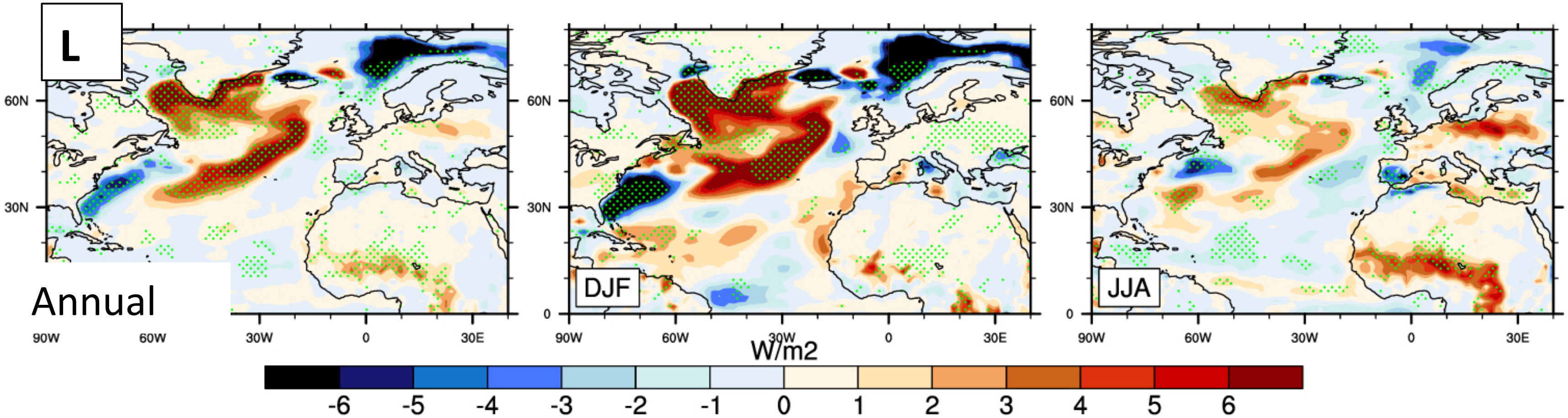


Salinity ATL



✓ **Drift in the response … need to extend experiments and to look at longer timescales**

Atmospheric response



- Impacts on LH over in the North Atlantic, some signals over the continents
- No detected impact in other variables (temperature 2m, atmospheric dynamics)
- Need to run more members to conclude

Conclusions

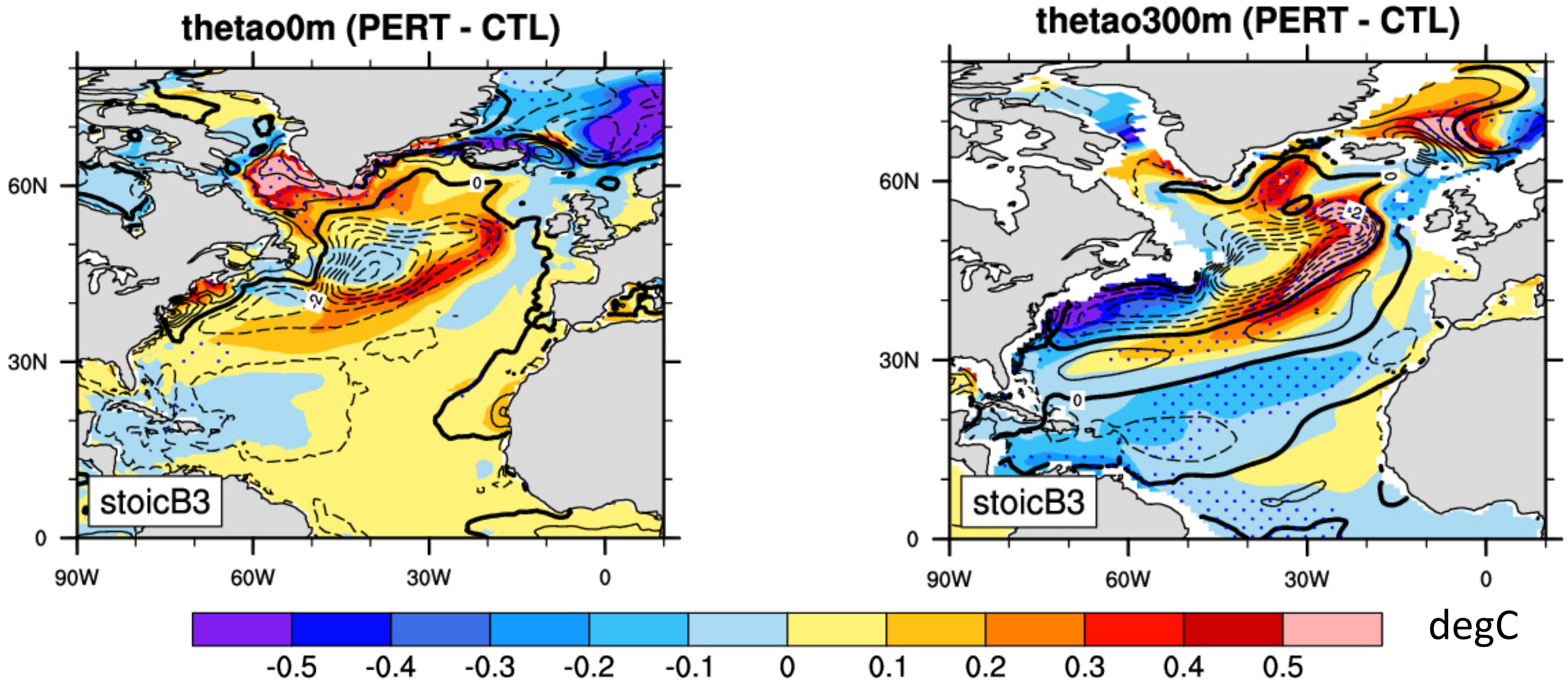
STOP impacts (similar to Brankart et al. 2013):

- ❑ North Atlantic Ocean is one of the regions the most affected
- ❑ **Modifications of the ocean circulation: strengthening of the Gulf Stream, North Atlantic drift and western boundary Labrador current**, not only at the surface but also at deeper levels.
- ❑ **Increase of the mixed layer depth and deep convection over the Labrador sea,** whereas there are not significant changes in the GIN area.
- ❑ **Impact on latent heat heat flux but moderate effect on the atmospheric fields**, in particular it is difficult to detect a significant effect over the midlatitudes areas.

Caveats :

- ❖ 30 years not enough for ocean adjustment : run extension is running
- ❖ 3 members not enough to detect atmospheric response : possibility of increasing ensembles size…

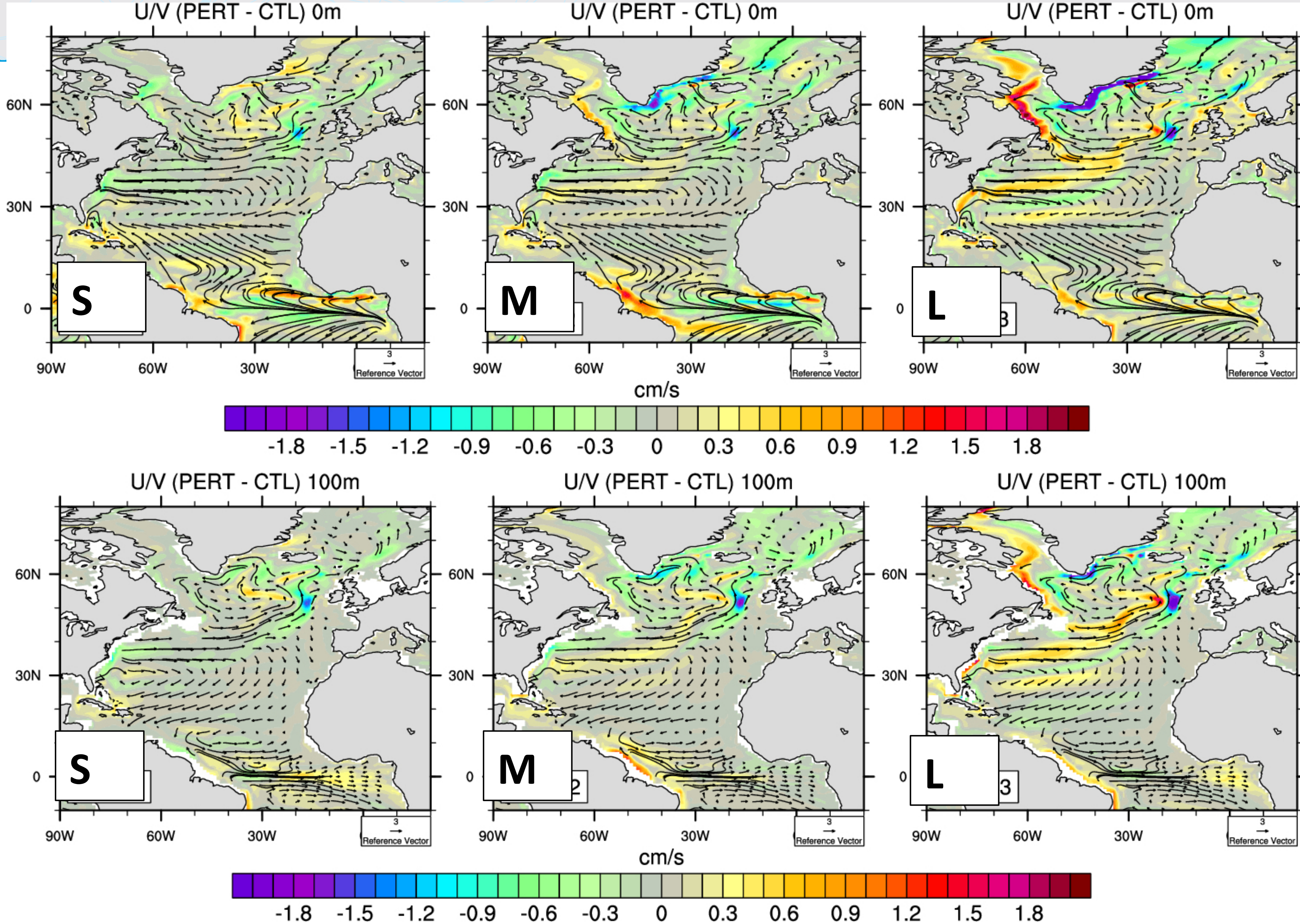
Impact of STOP on T and S biases



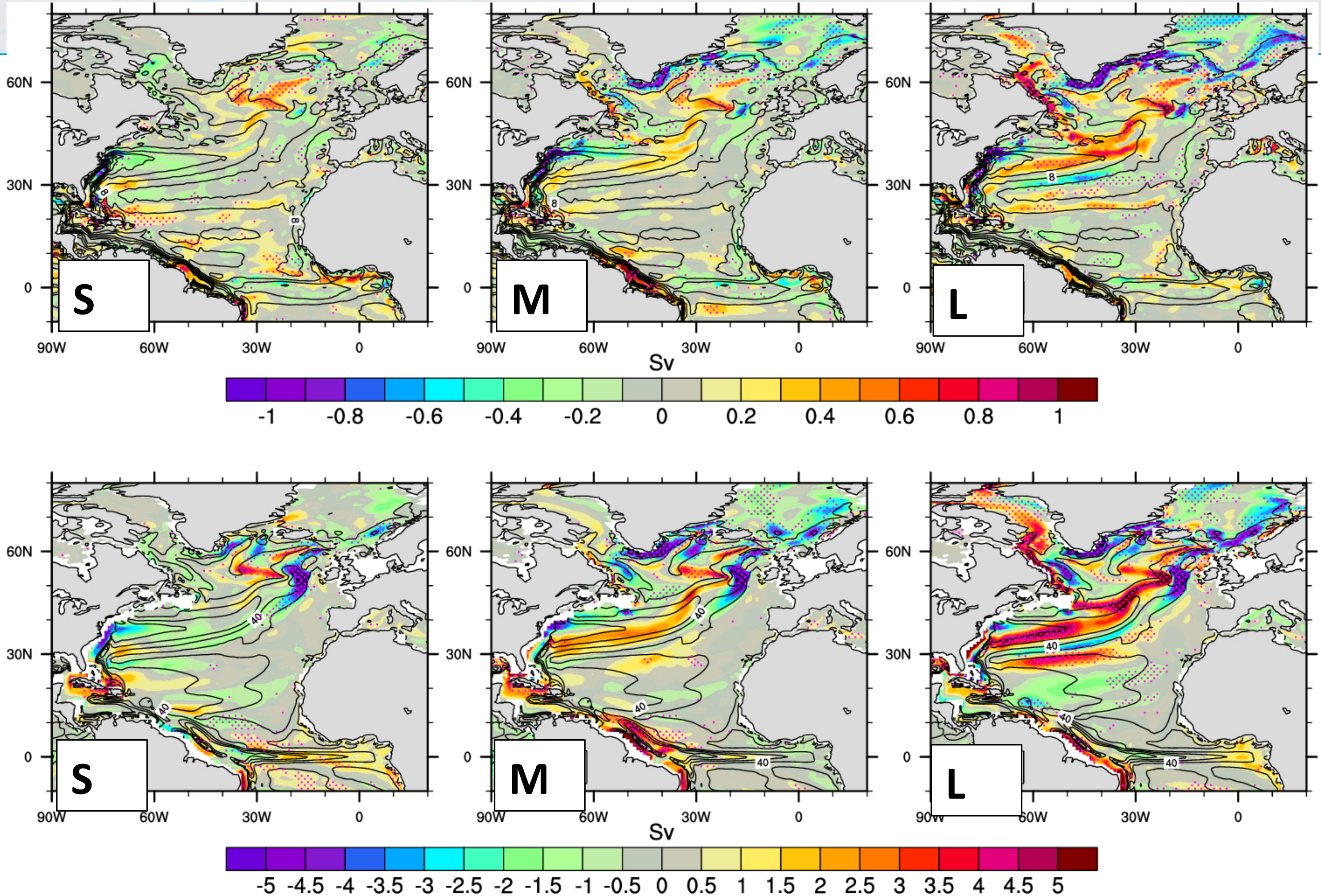
Contours = model bias respec to to WOA13
Shading : ML- CTL

✓ **STOP leads to improvements over the eastern flacnk of the « blue spot » (cold bias reduction)**

Zoom North Atlantic: ocean currents 0 and 100 m

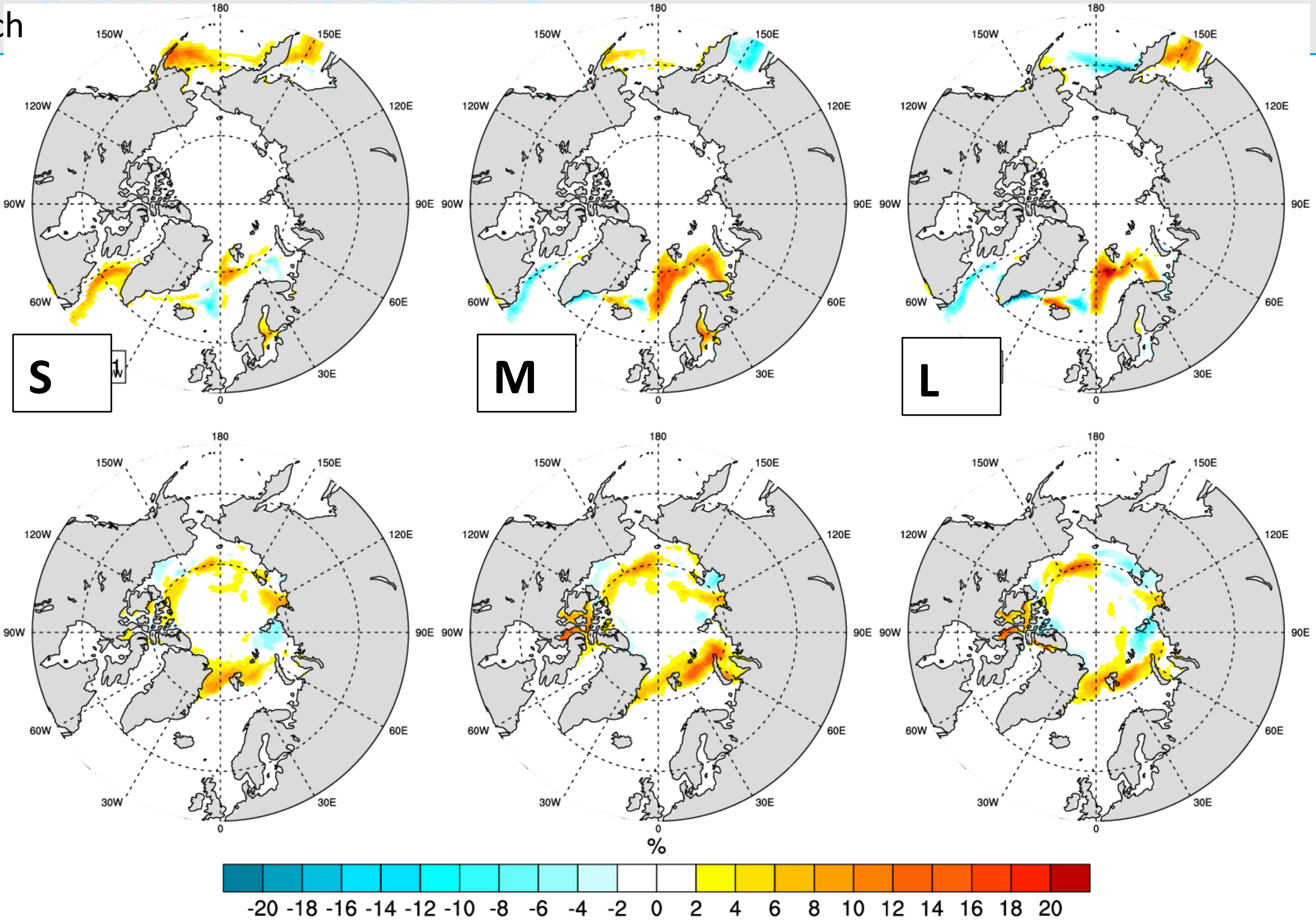


Zoom North Atlantic: mass transport 0 and 100m



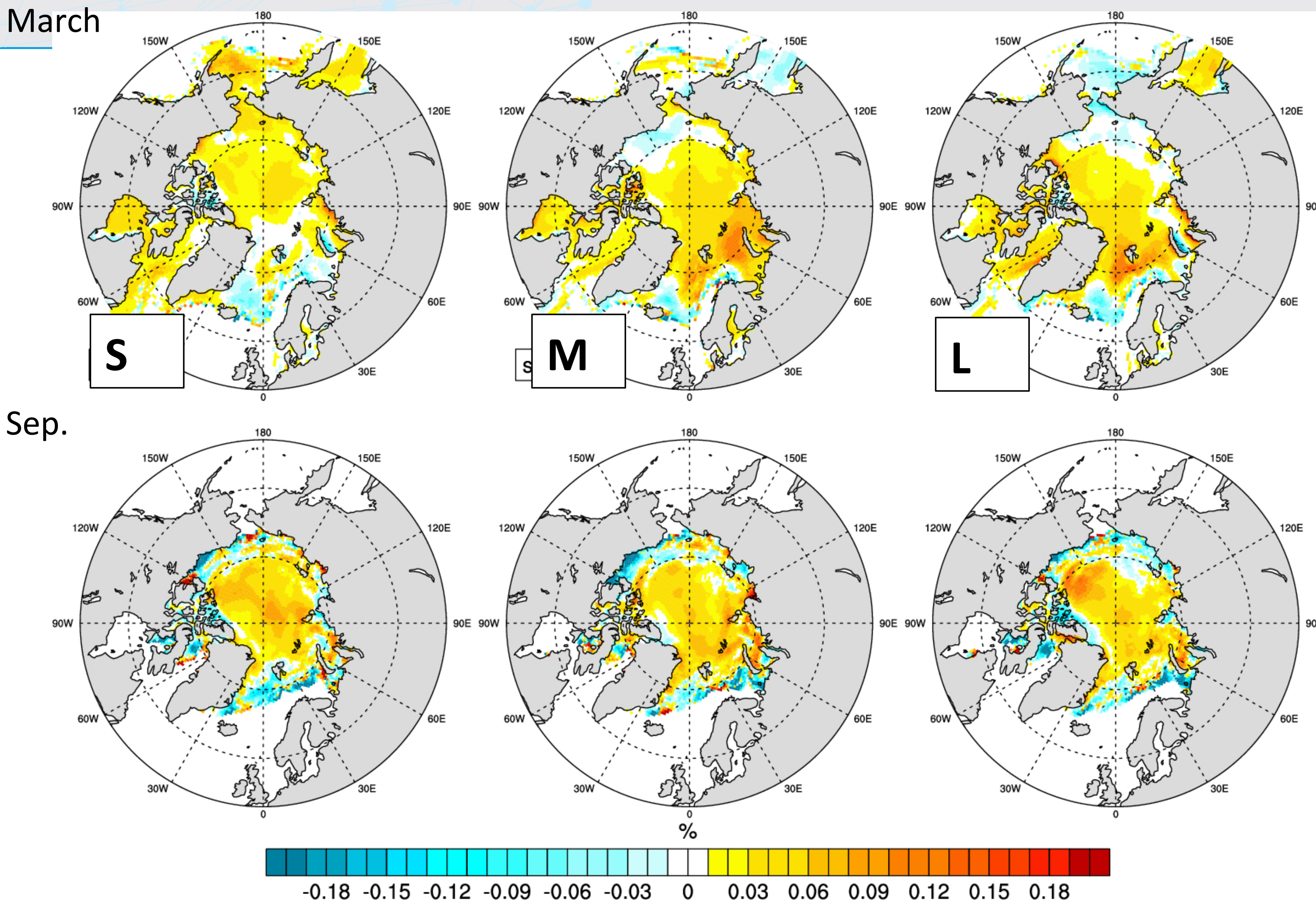
Sea ice concentration

March

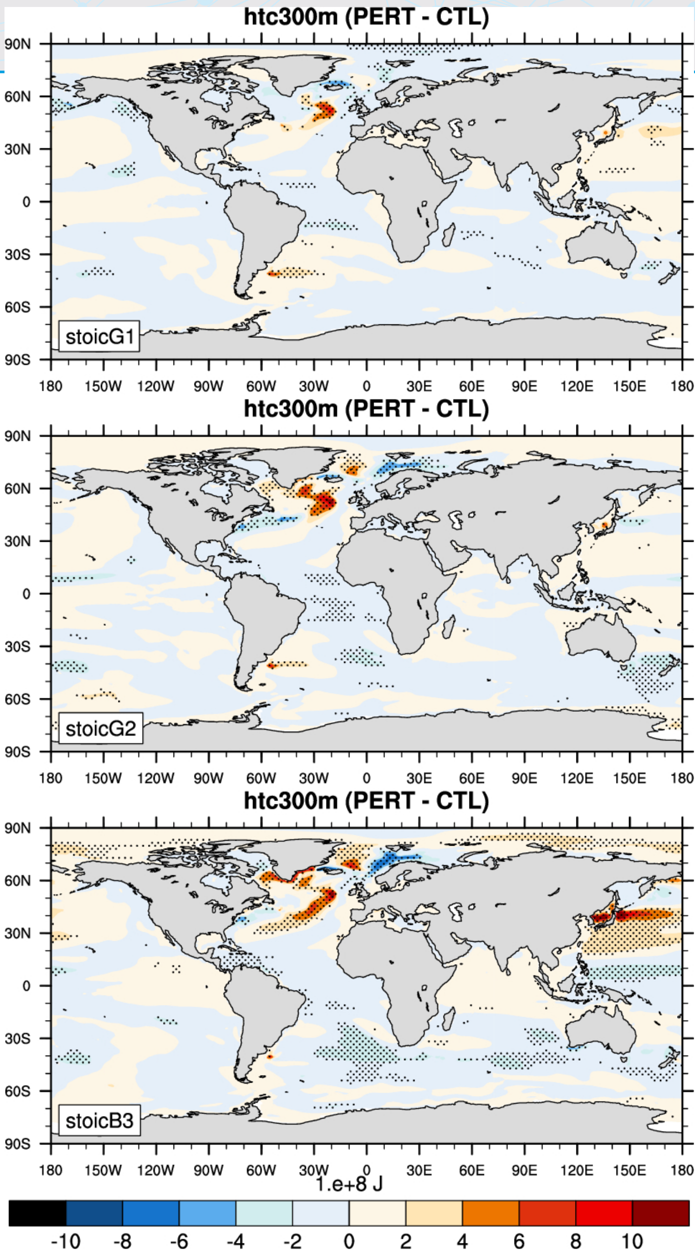


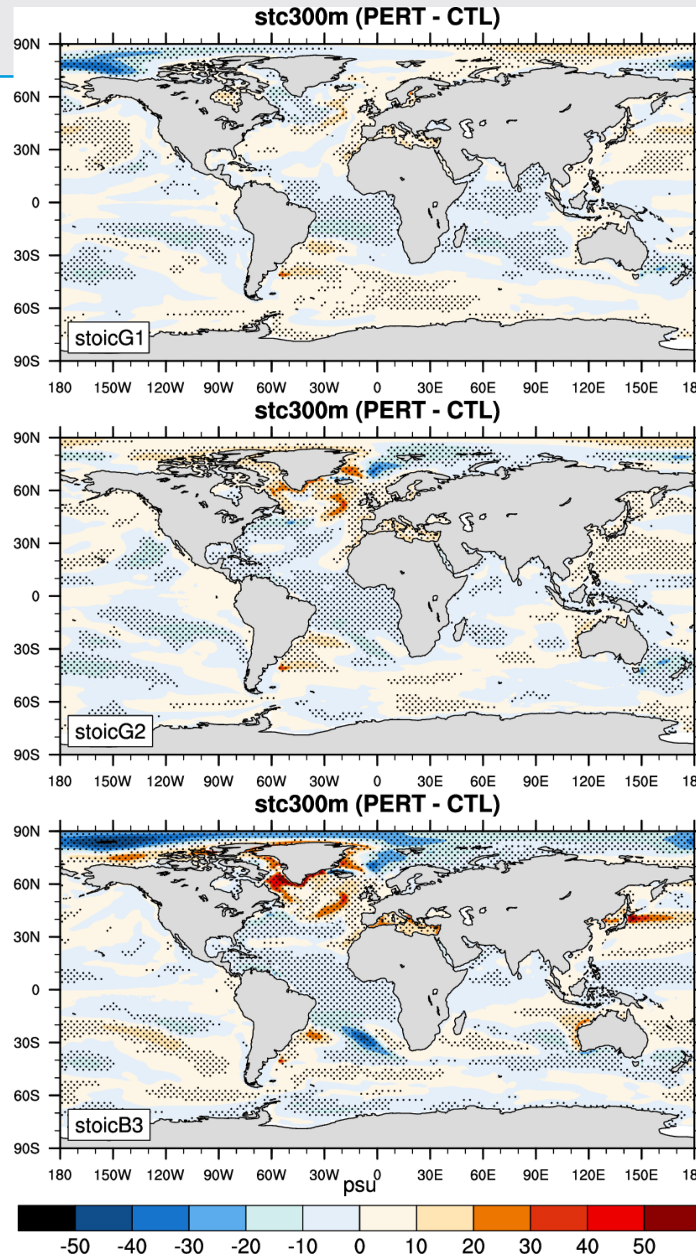
Sep.

Sea ice thickness

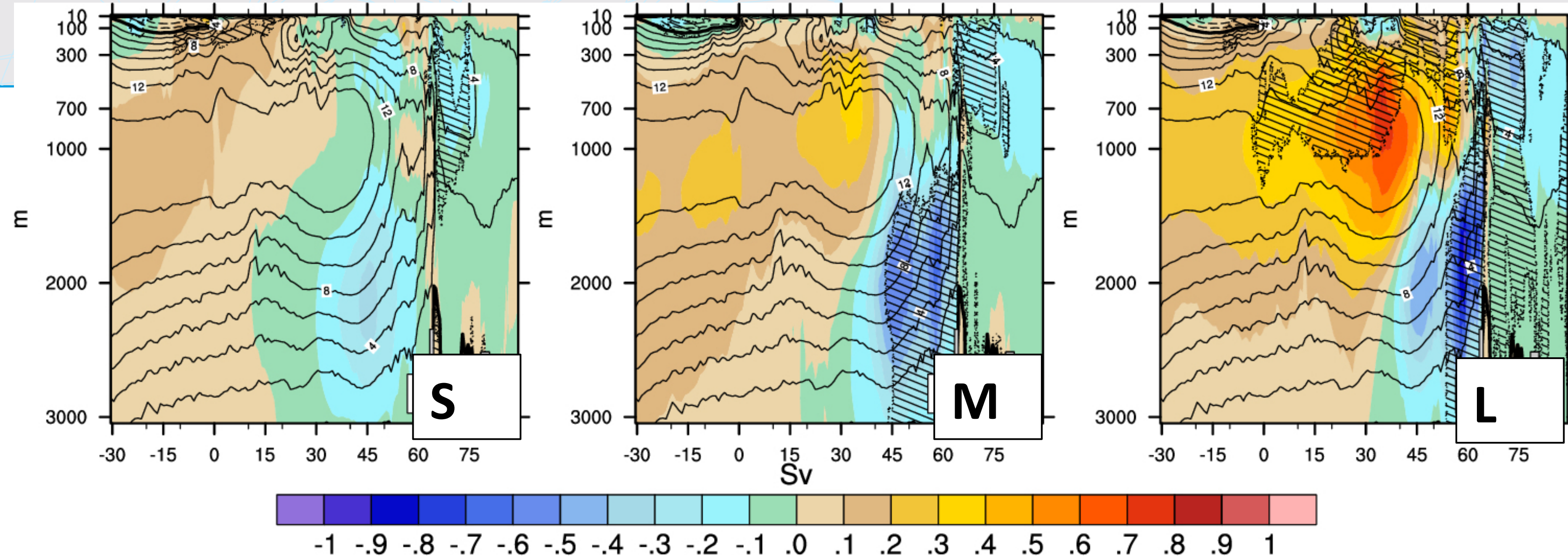


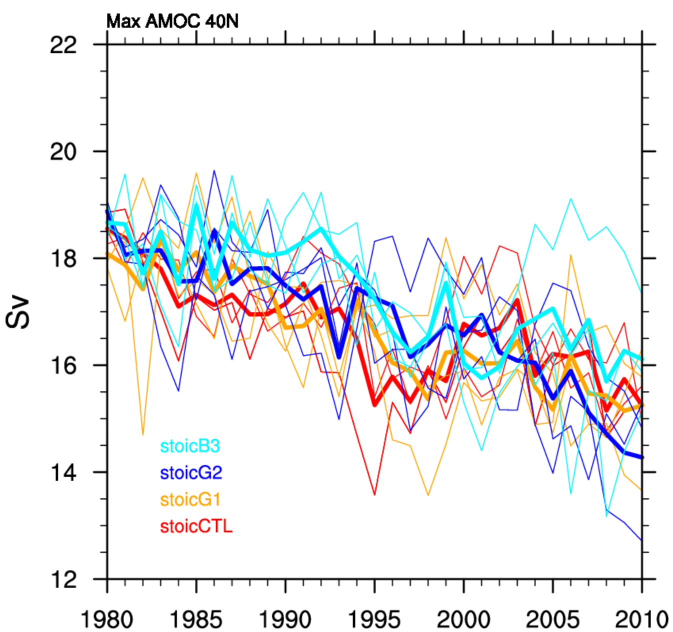
Heat and salt content 0-300 m

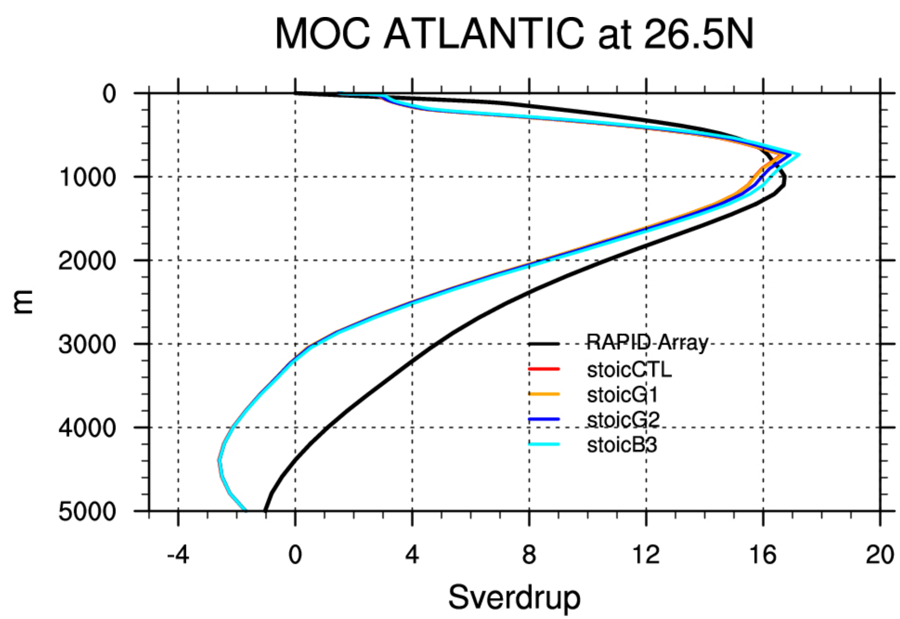




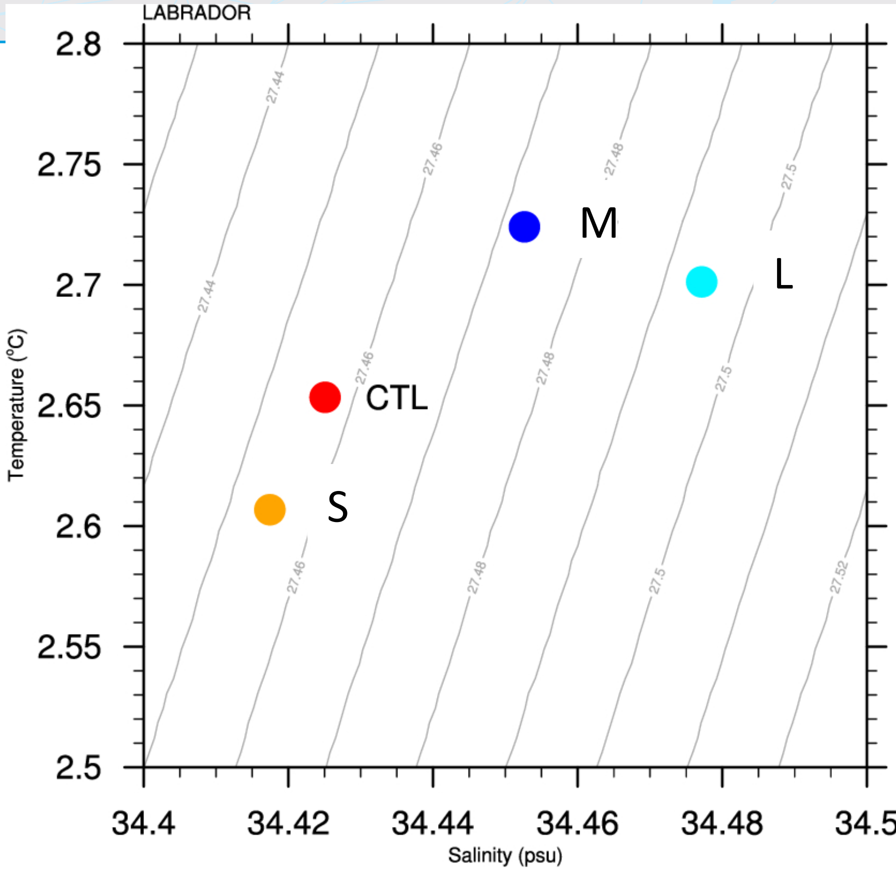
Zoom North Atlantic: AMOC

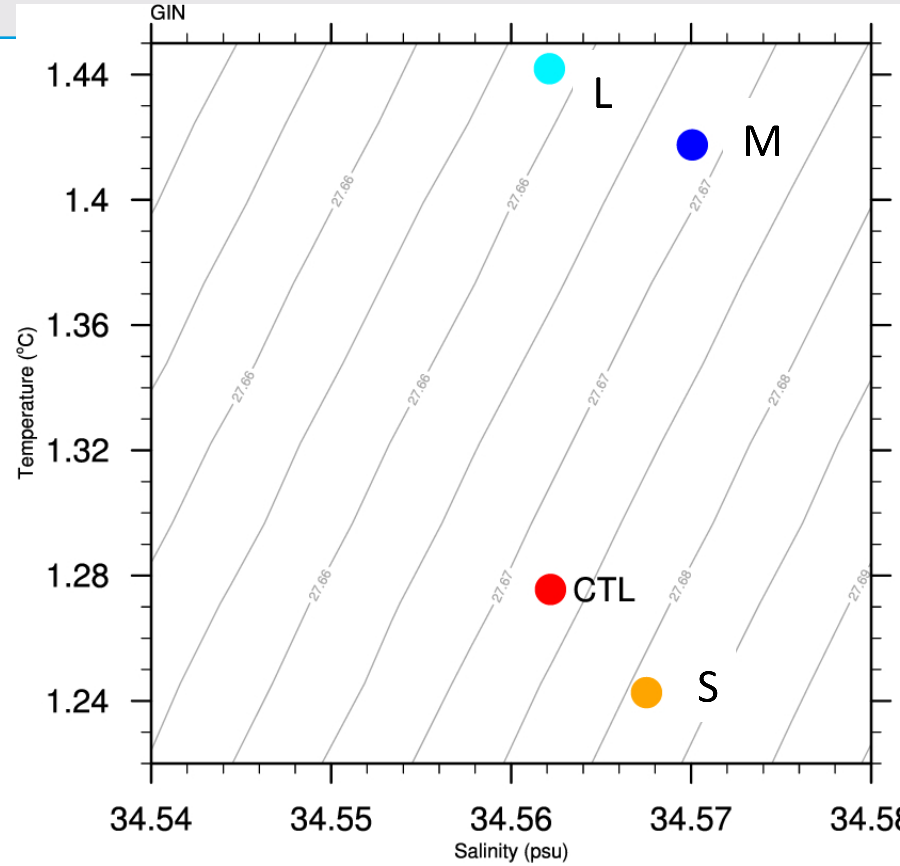






Zoom North Atlantic: T/S diagrams GIN and LABRADOR





T and S integrated over the first 700 m