# Potential for deep convection in the Arctic Basin under a warming climate and contribution to the AMOC

**Camille Lique**

Laboratoire d'Océanographie Physique et Spatiale, France

Matthew Thomas

Yale University, USA

Helen Johnson, Yves Plancherel

*University of Oxford, UK*

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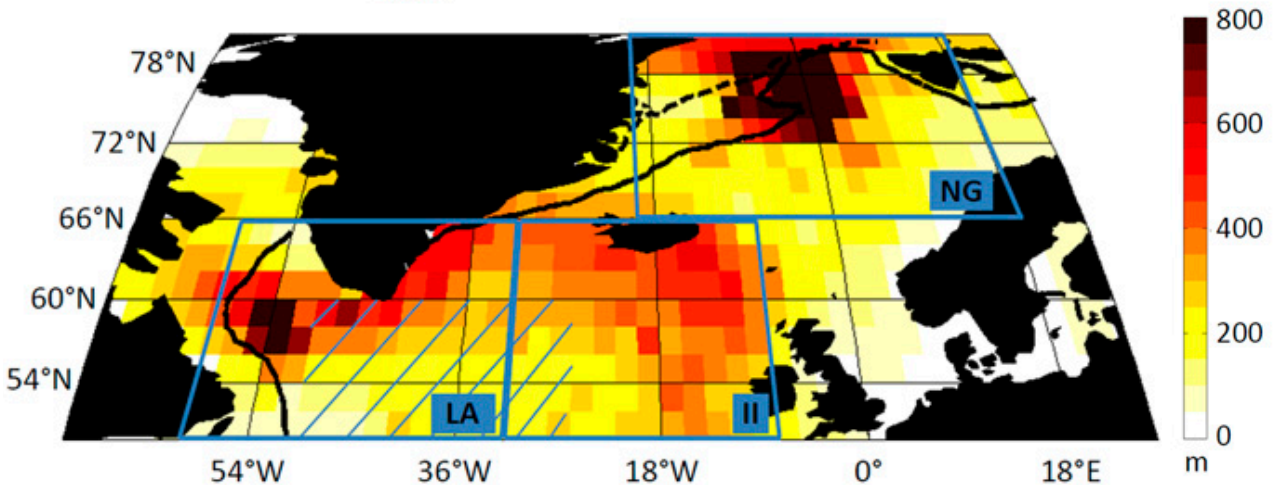
# Rationale: MLD in the North Atlantic




***Mean March MLD***
*(climatology from de Boyer Montégut et al. 2004)*
***and sea ice edge position.***

Today, in the North Atlantic, deep Mixed Layer Depths (MLDs):

> are found only in a few sites

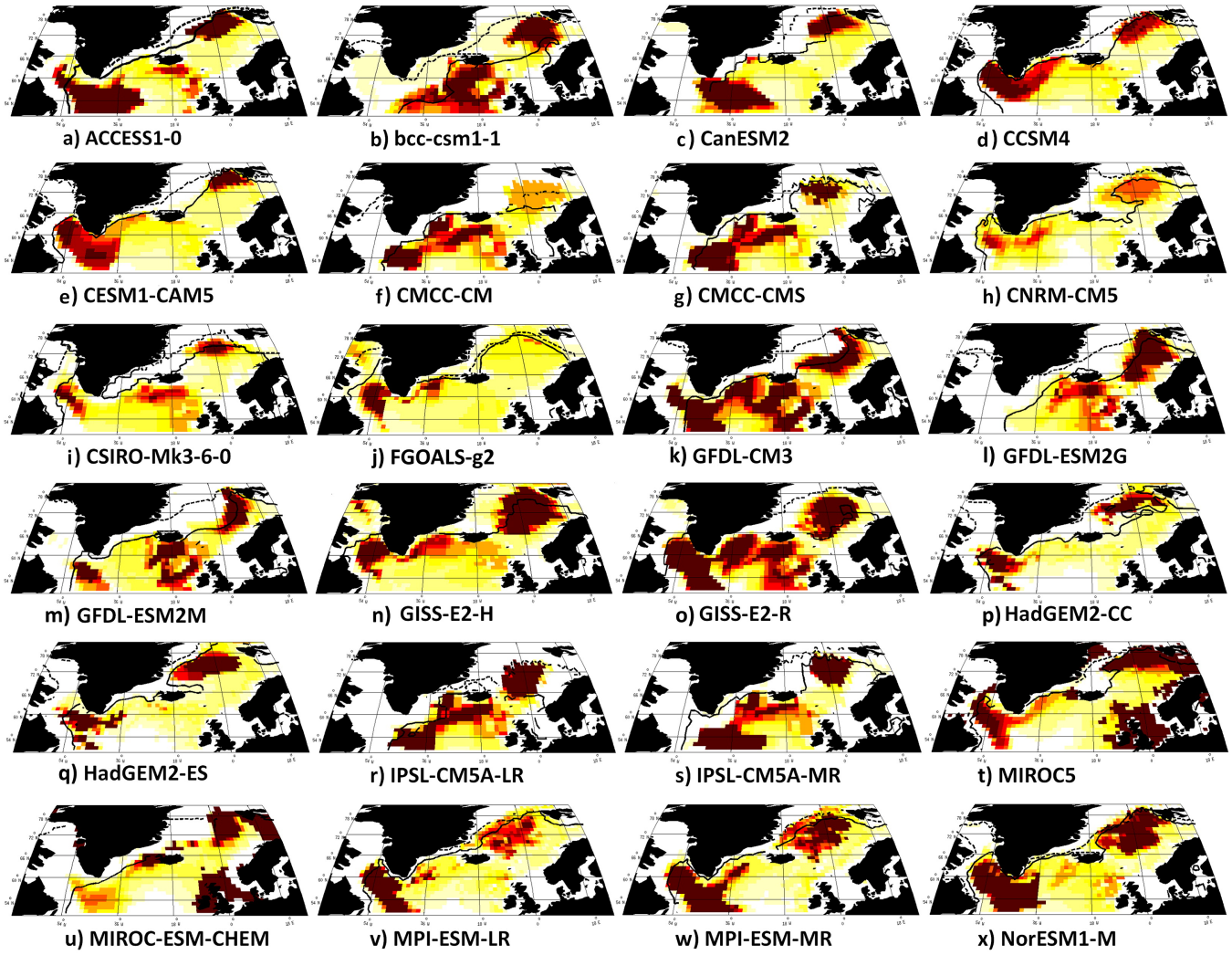
> are on average tight to the sea ice edge, where we find huge T/S gradients and atmospheric flux

> are symptomatic of dense water formation

***Heuzé et al. 2015***

# Rationale: MLD in a warming climate ?

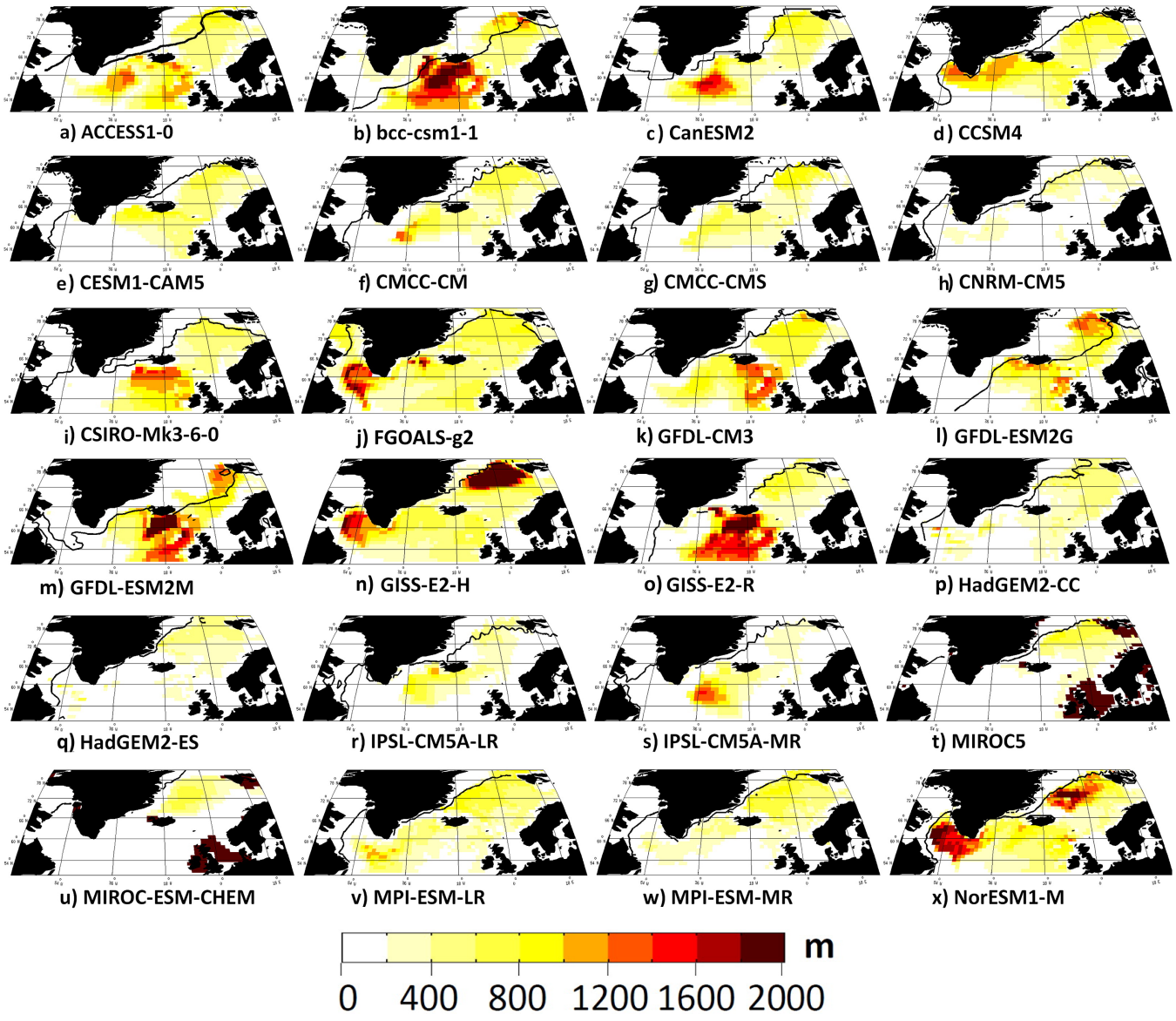
## *CMIP5 models – Max MLD over 1986-2005*




*Heuzé et al. 2015*

# Rationale: MLD in a warming climate ?

## *CMIP5 models – Max MLD over 2081-2100 (RCP8.5)*



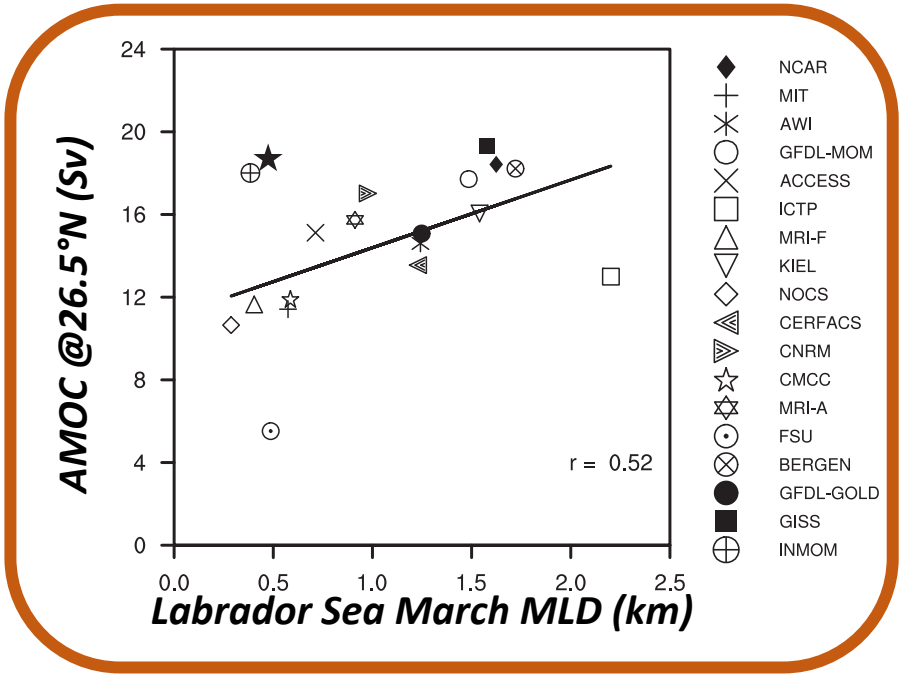

*Large spread between models*

*…. But a consistent tendancy for MLDs to become shallower where MLD are deep in present day conditions*

***Heuzé et al. 2015***

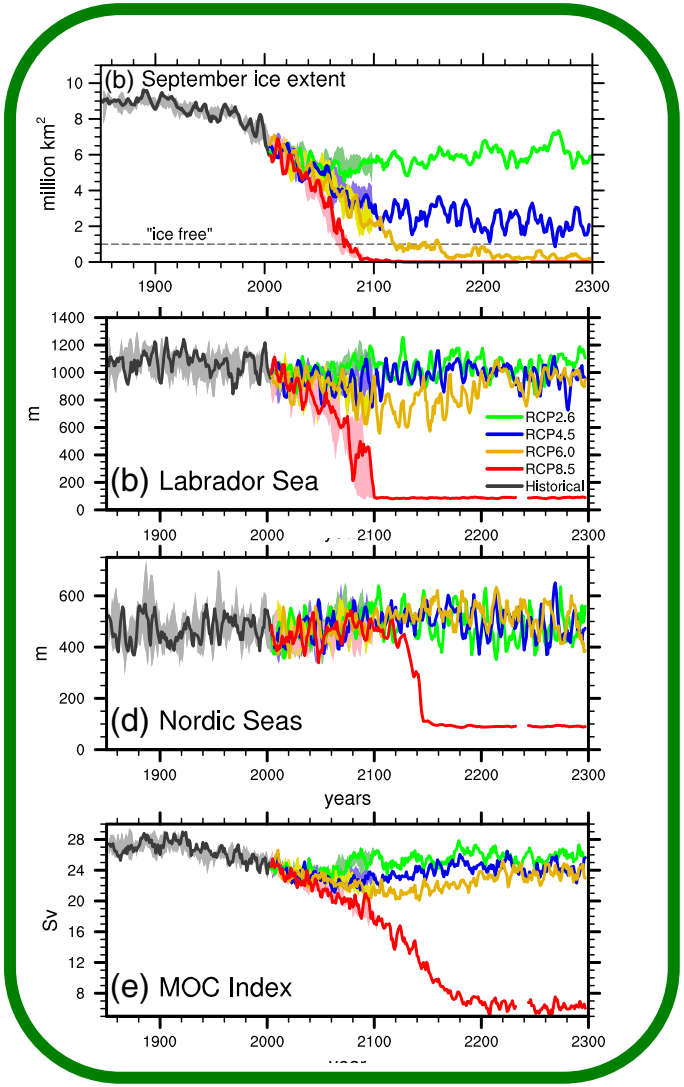
# Rationale: MLD & AMOC

Model results suggest a link between MLD and AMOC intensity (although the processes at play are not fully understood)




*Across models (here COREII exercise)*

*Over time in one coupled model (here CCSM4-CMIP5)*




*Danabasoglu et al. 2013; Jahn & Holland 2013*

# Objectives & Methods

## QUESTIONS

*Under a warming climate:*

- Is there a potential for deep convection in the Arctic Basin, as the sea ice edge retreats northward ?
- Could it impact the AMOC ?

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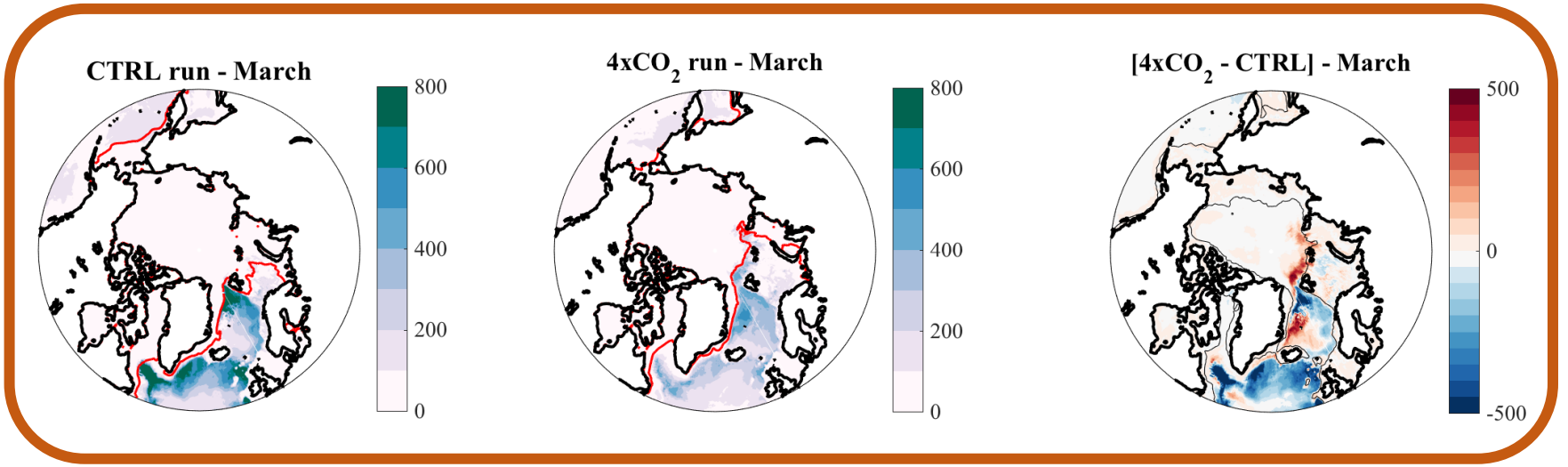
## TOOLS

- Outputs from two coupled climate models
  > *Met-Office HiGEM (high res: 1/3° for the ocean)* Shaffrey et al. 2009
  > *CNRM climate model (ORCA1 for the ocean)* Voldoire et al. 2013
- Comparison of two runs: *CTRL and 4 x $CO_2$ (roughly comparable with RCP8.5)*
- ARIANE Lagrangian model (Blanke & Raynaud 1997) applied offline to the CNRM model, following the method of Thomas et al. 2015

# MLD change in *HiGEM*

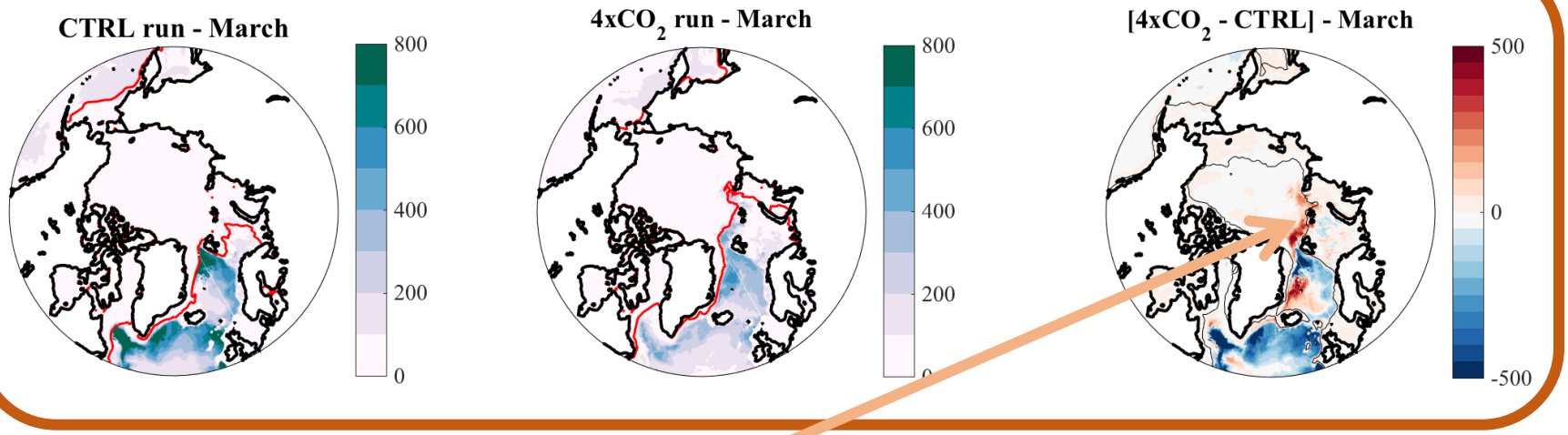



***MLD (in meters, computed with a criteria in density) and position of the sea ice edge :***

> *shallower MLD in the North Atlantic*

> *deeper MLD in the Nordic sea and the Eurasian Basin of the Arctic Ocean, close to the new sea ice edge*

# MLD change in *HiGEM*




***MLD (in n***

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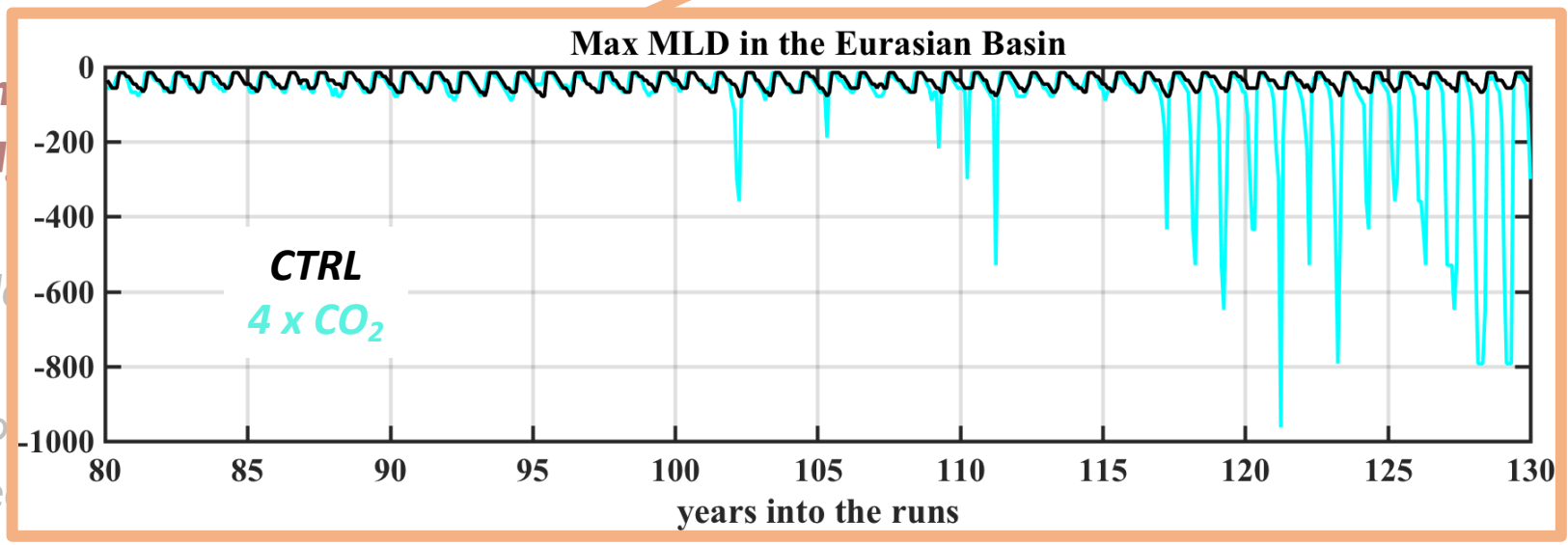
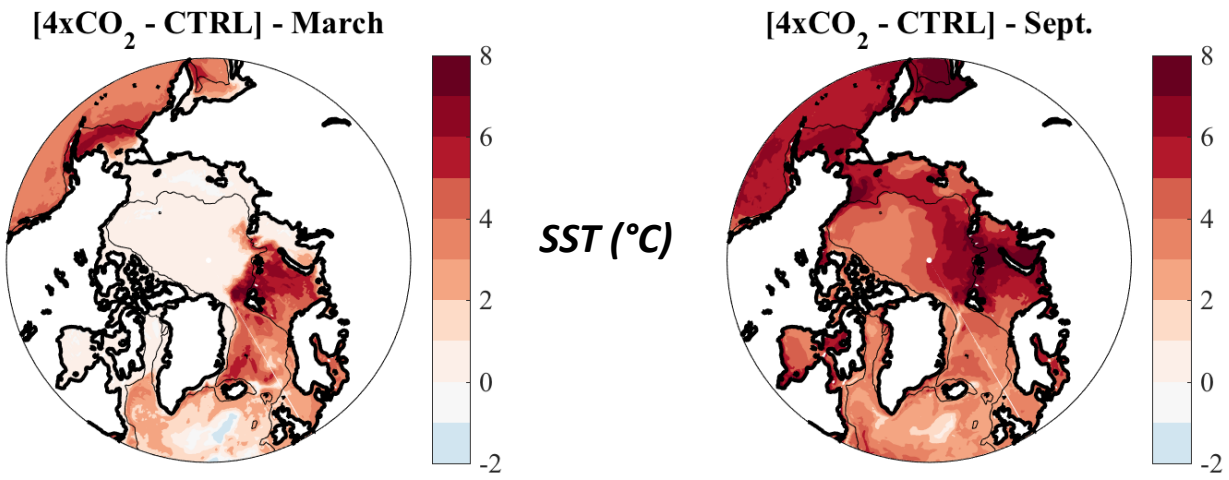



> *MLD can reach up to 1000 m in the Eurasian Basin*

# Favorable conditions for deep convection in the Arctic




***Change in SST:***

*> response to the atmosphere, modulated by the presence of sea ice*

*> large increase of the seasonal cycle*

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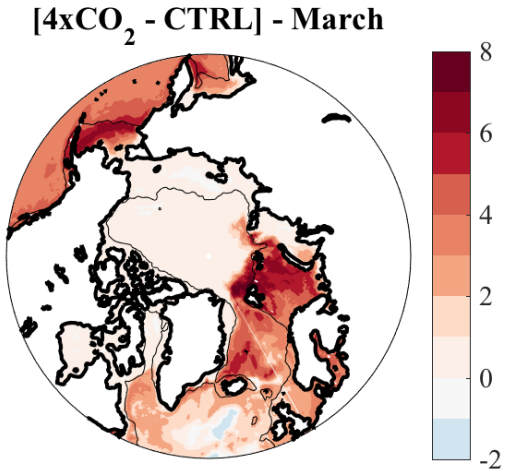
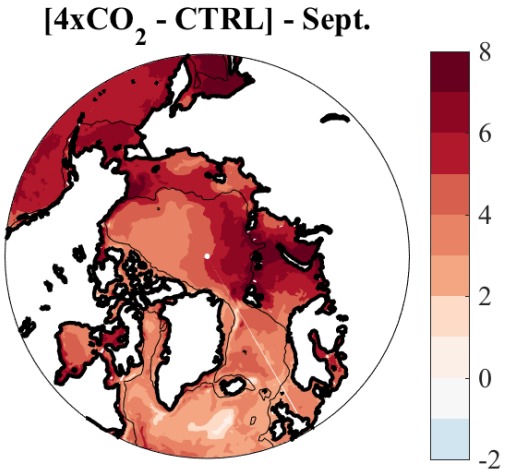



SST (°C)

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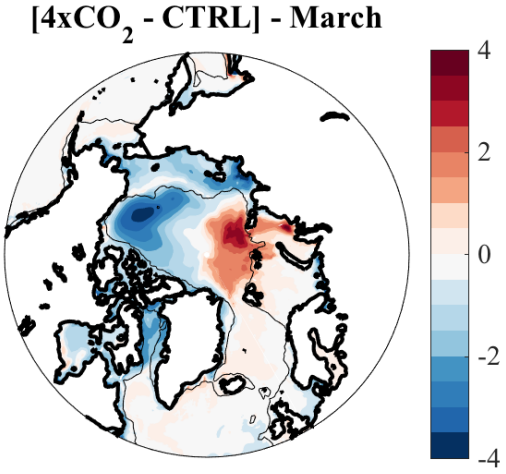
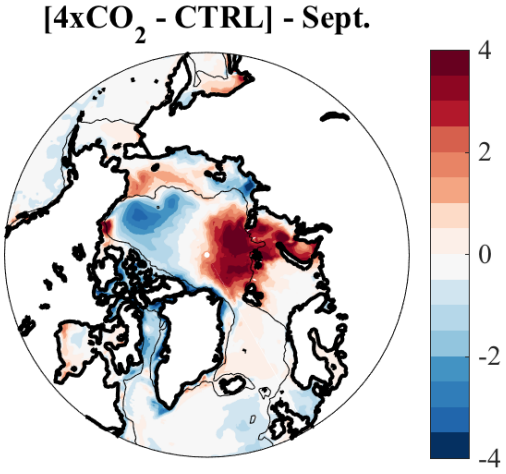



SSS (psu)

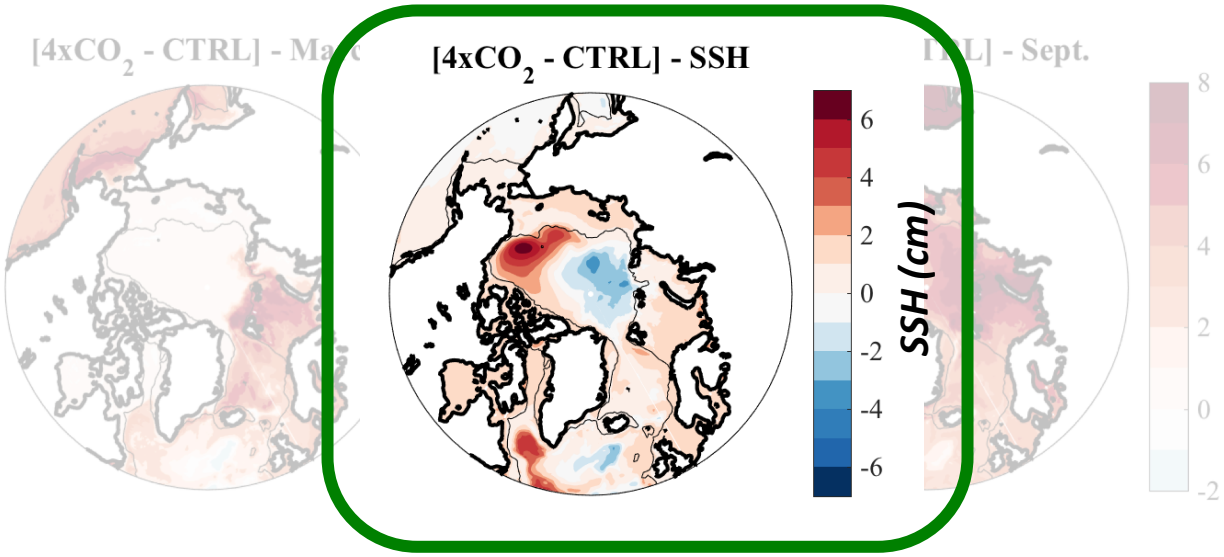



## Change in SSS:

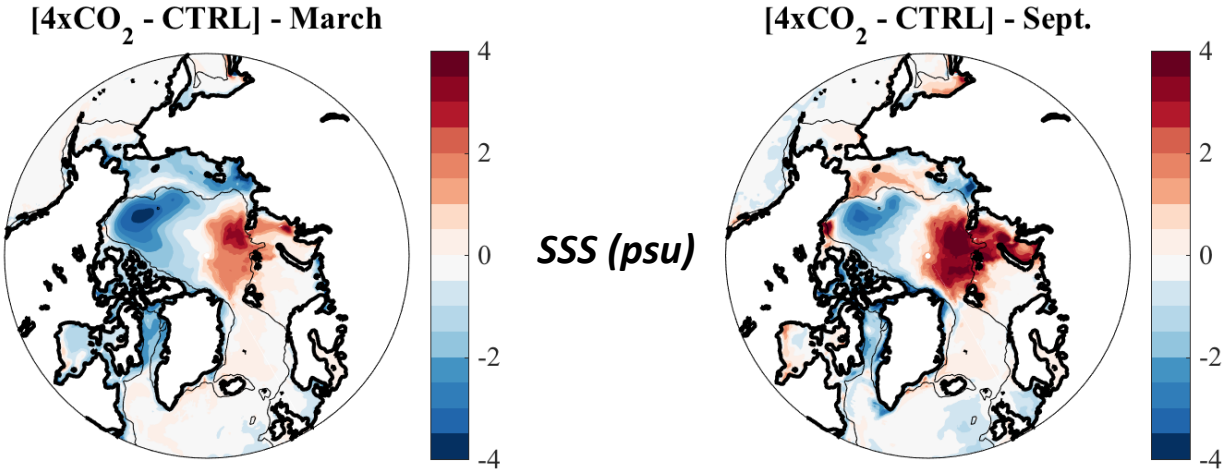
> *strong freshening in the Canadian Basin (spin up of the Beaufort Gyre)*

> *SSS increases in the Eurasian Basin (AW inflow influence)*

# Favorable conditions for deep convection in the Arctic




Intensification of the gyres, resulting from the increasing transfer of momentum to the ocean as sea ice cover is reduced

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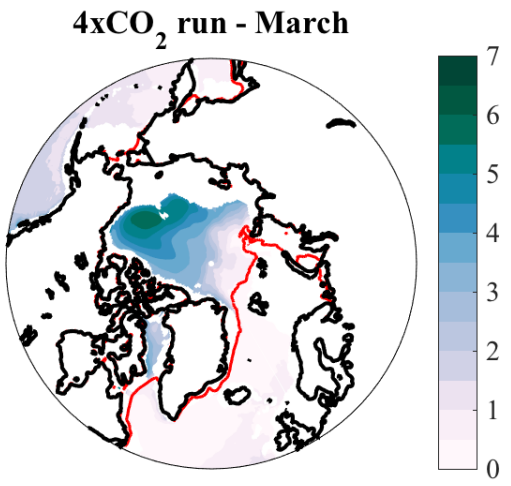
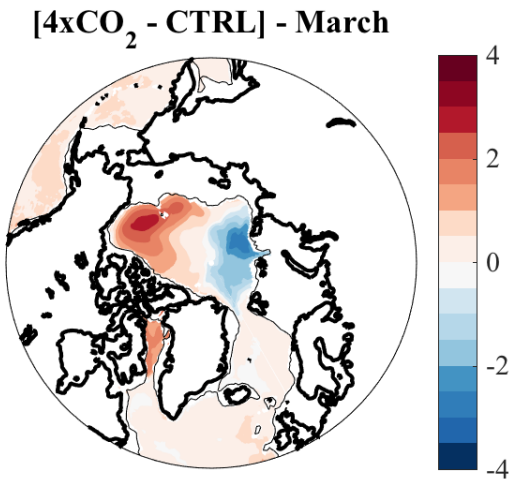
# Favorable conditions for deep convection in the Arctic




***Stratification***
*(defined as the density difference between 500m and the surface, in kg/m³)*




> Change in SSS imprint on surface density

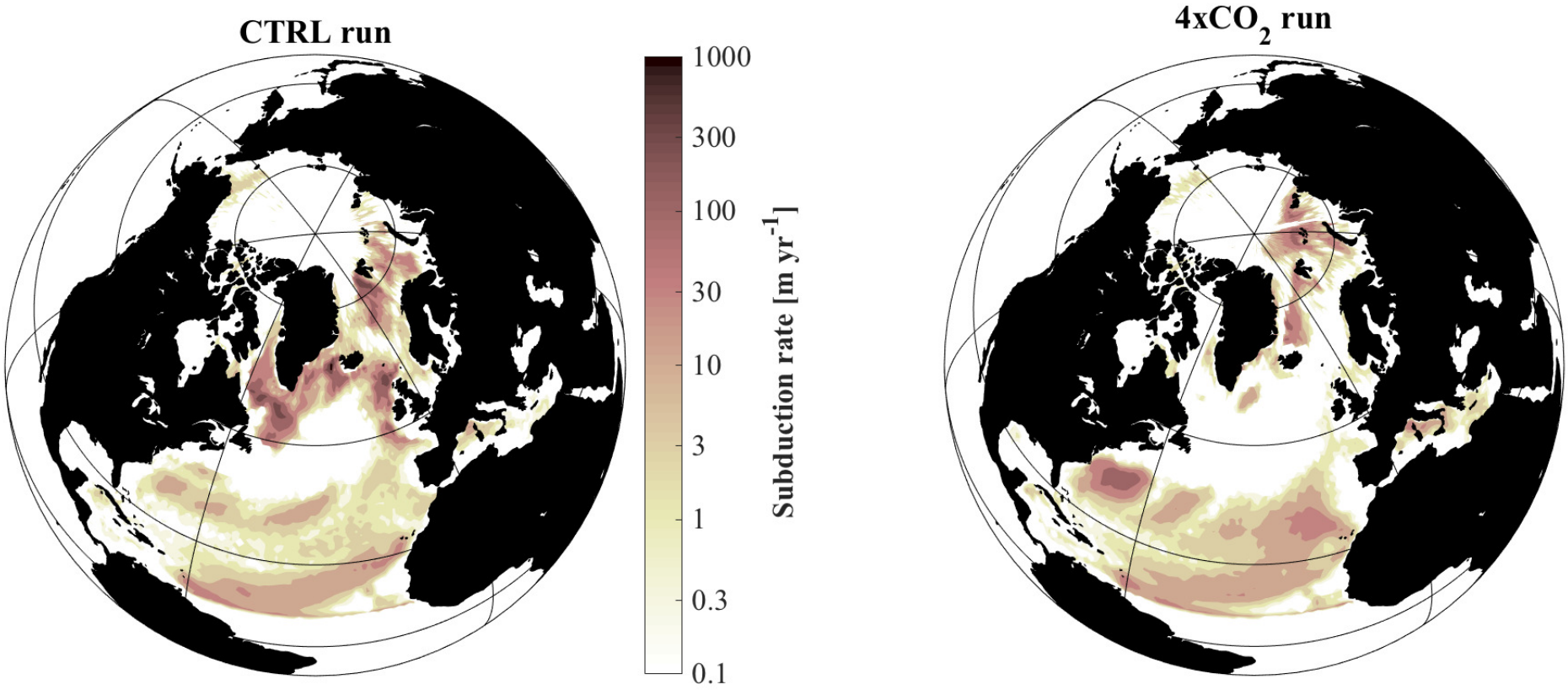
> Results in large changes of stratification

- ✧ Enhanced in the Canadian Basin
- ✧ Suppressed in the Eurasian Basin

> Lack of stratification in the Eurasian Basin allows for the emergence of deep convection in years when sea ice retreats the most.

# Importance for the AMOC ?

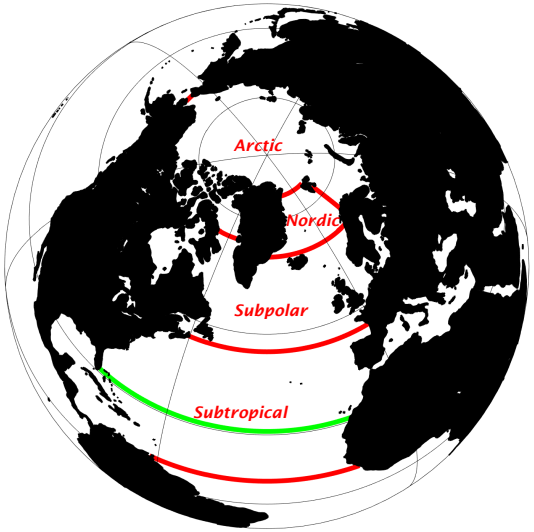
- We determine the origin of the water masses flowing southward at 10°N (i.e. where they have subducted at the base of the mixed layer), using the Lagrangian model ARIANE applied to CNRM-ORCA1

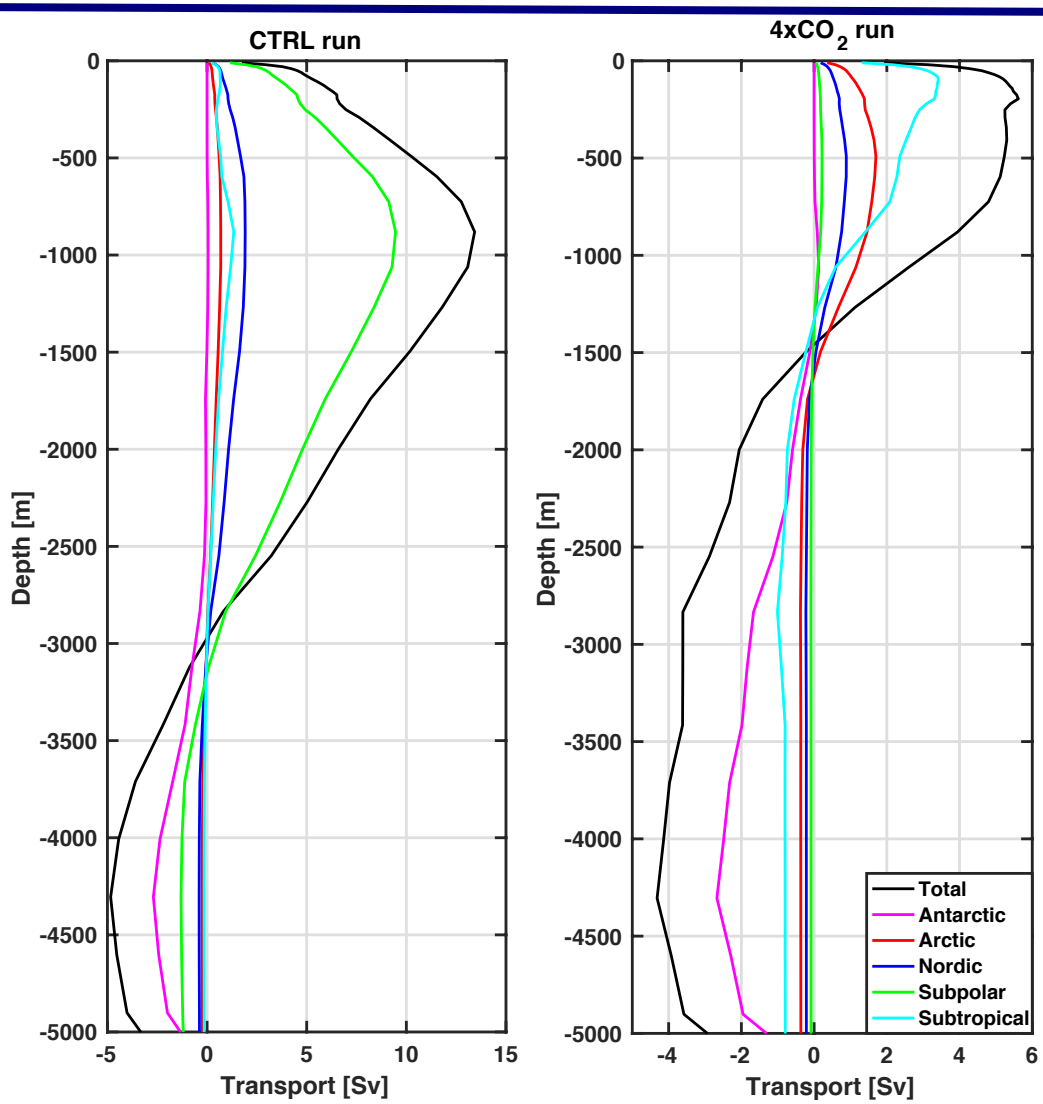



- Zonal shift :
  > the Arctic and the Subtropics become increasingly important
  > No more subduction in the subpolar gyre.

# Importance for the AMOC ?

***Contribution to the AMOC at 26°N computed with ARIANE applied to CNRM - ORCA1***




> *Zonal shift of the main contributions to the AMOC*

- *Arctic becomes increasingly important*
- *increase of the subtropical contribution (due to change in stratification)*

# Summary

*Under a warming climate:*

- Is there a potential for deep convection in the Arctic Basin, as the sea ice edge retreats northward ? **YES**

  *Results from the HiGEM model suggest that:*

  - ✧ *The Arctic Ocean surface will become warmer and saltier in the Eurasian Basin*
  - ✧ *… which results in the supression of startification and provides favorable conditons for deep convection*
  - ✧ *Deep MLD (down to 1000m) are found in the Eurasian, near the sea ice edge*

- Could it impact the AMOC ? **YES**

  *Lagrangian analysis of the CNRM model suggests that emerging subduction in the the Arctic Ocean (and the subtropical gyre) could contribute significantly to the AMOC…*

  *> A changing Arctic may not just be a threat for the AMOC*


Lique, Johnson & Plancherel (2018): Emergence of deep convection in the Arctic Ocean under a warming climate, *Climate Dynamics*

Lique & Thomas (2018): Latitudinal shift of the Atlantic Meridional Overturning Circulation source regions under a warming climate, *Nature Climate Change*