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

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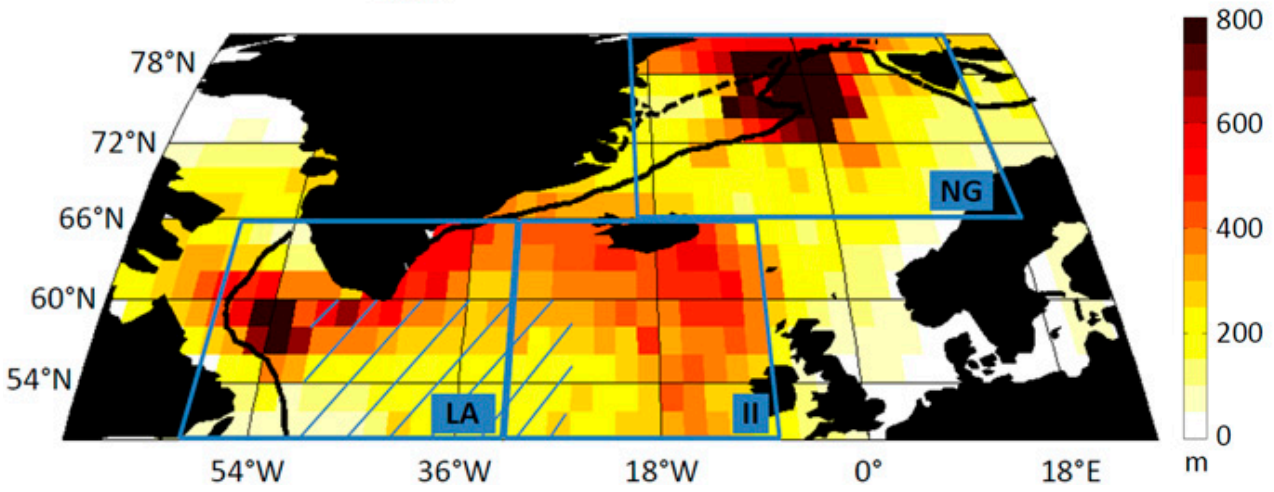
Rationale: MLD in the North Atlantic



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

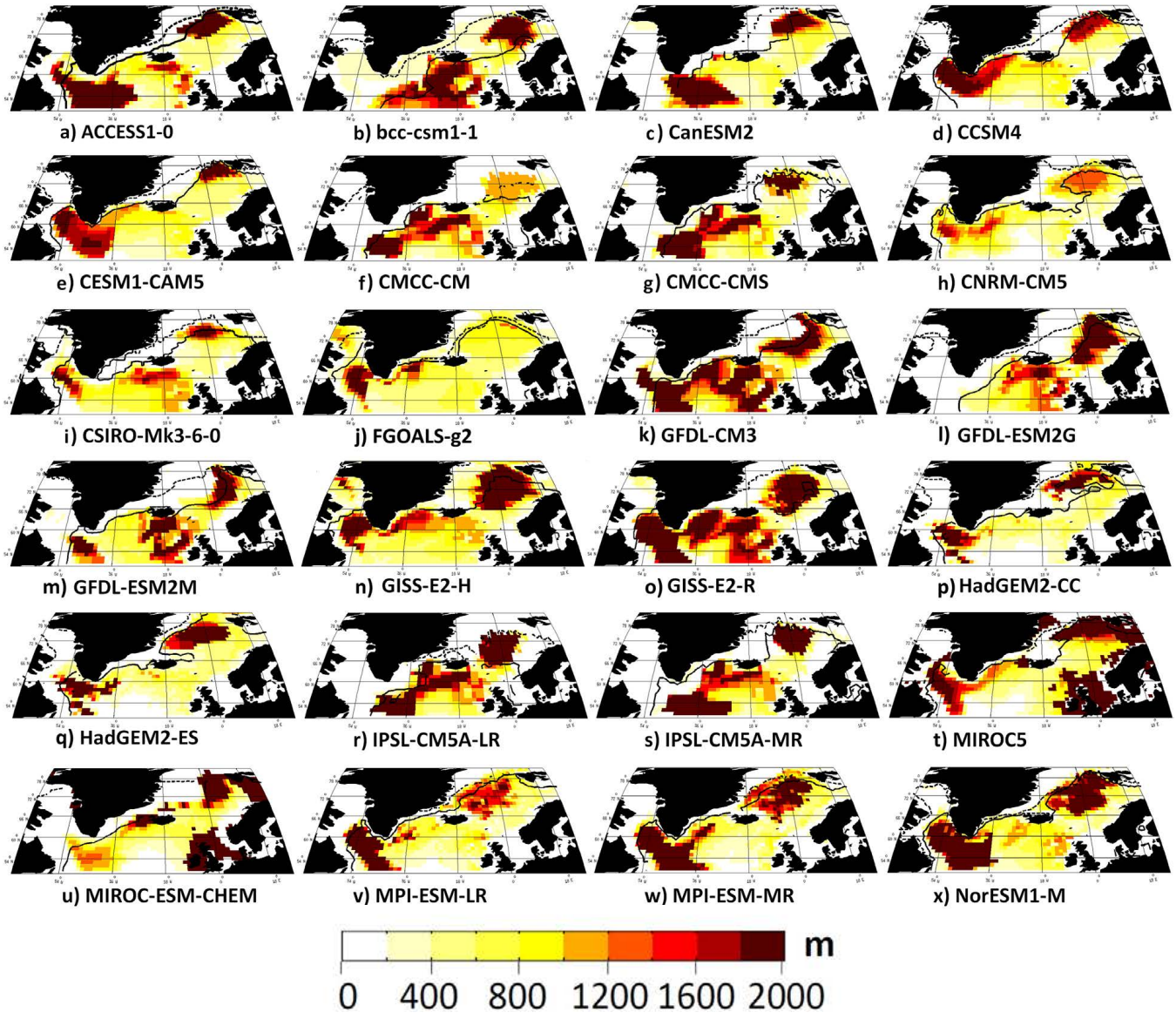
-> are on average tight to the sea ice edge, where we find huge T/S gradient and atmospheric flux

-> are symptomatic of dense water formation

Heuzé et al. 2015

Rationale: MLD in a warming climate ?

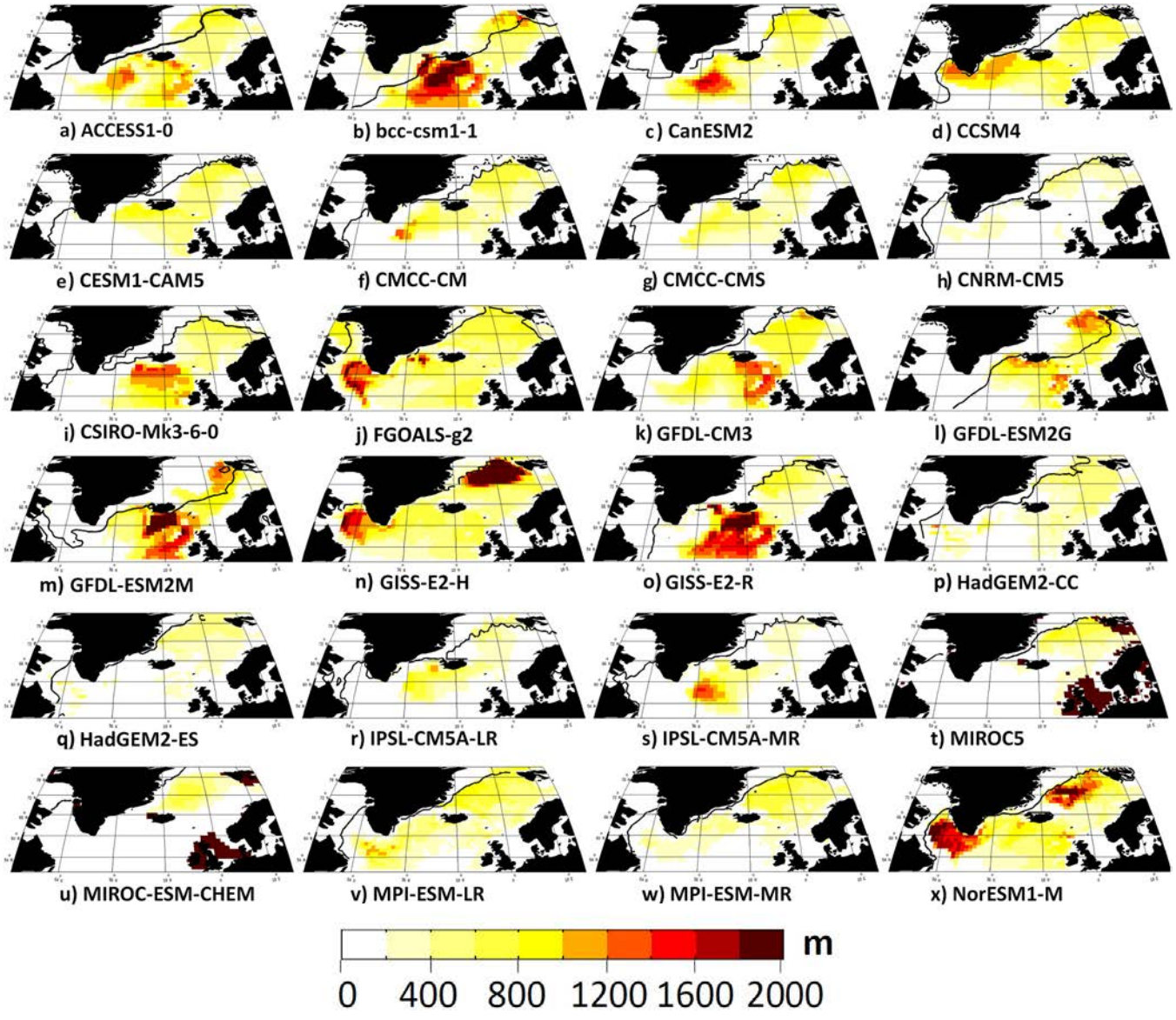
CMIP5 models – Max MLD over 1986-2005



Heuzé et al. 2015

Rationale: MLD in a warming climate ?

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



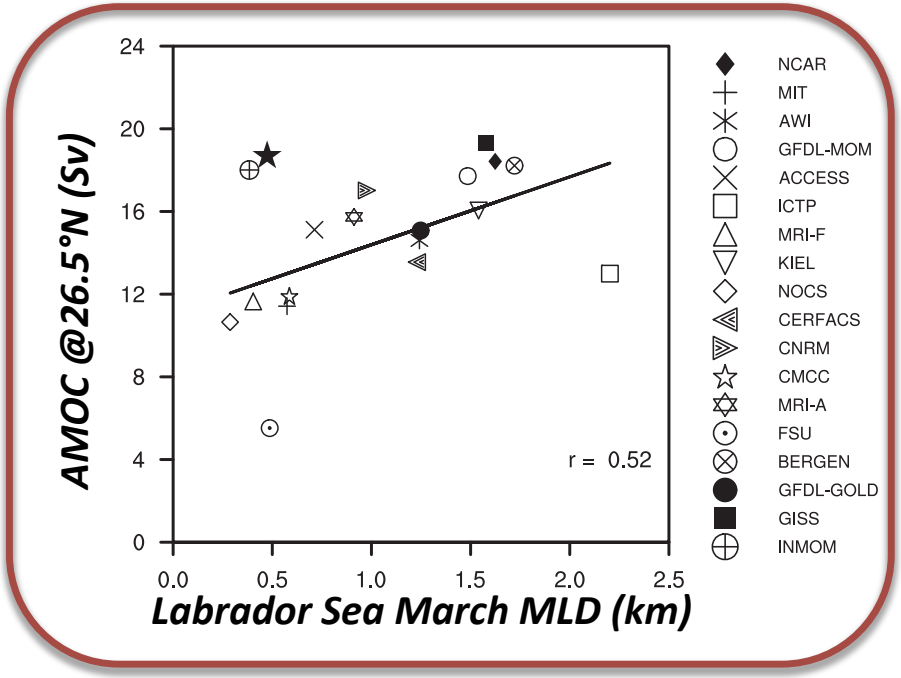
Large spread between models

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

Heuzé et al. 2015

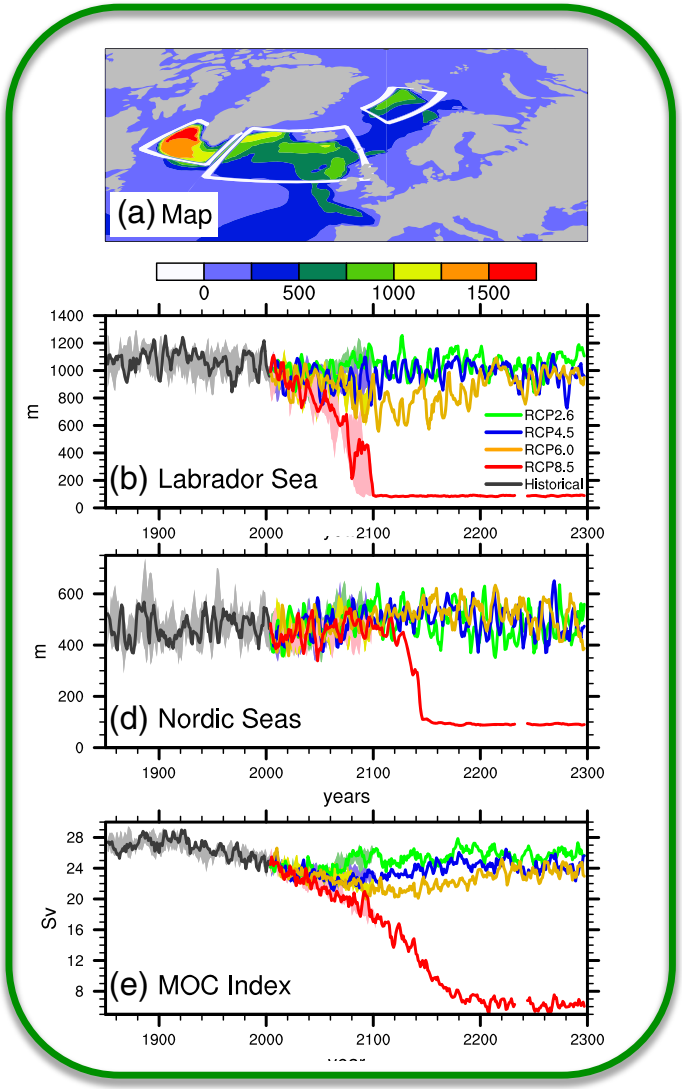
Rationale: MLD & AMOC

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

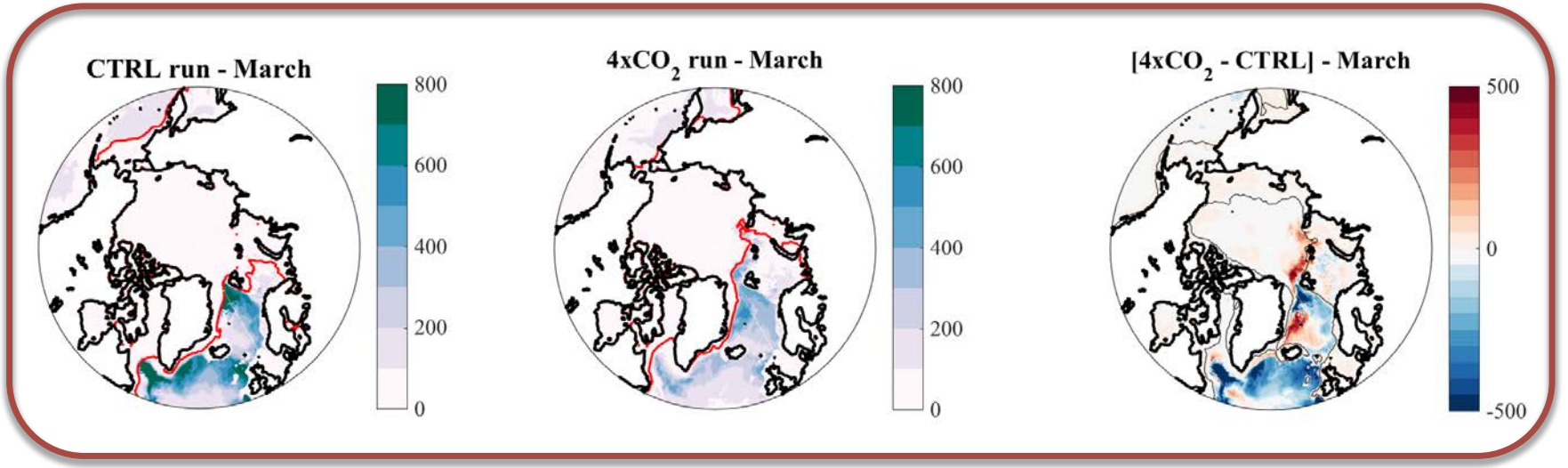
Under a warming climate:

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

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* (average of the last 10 years)

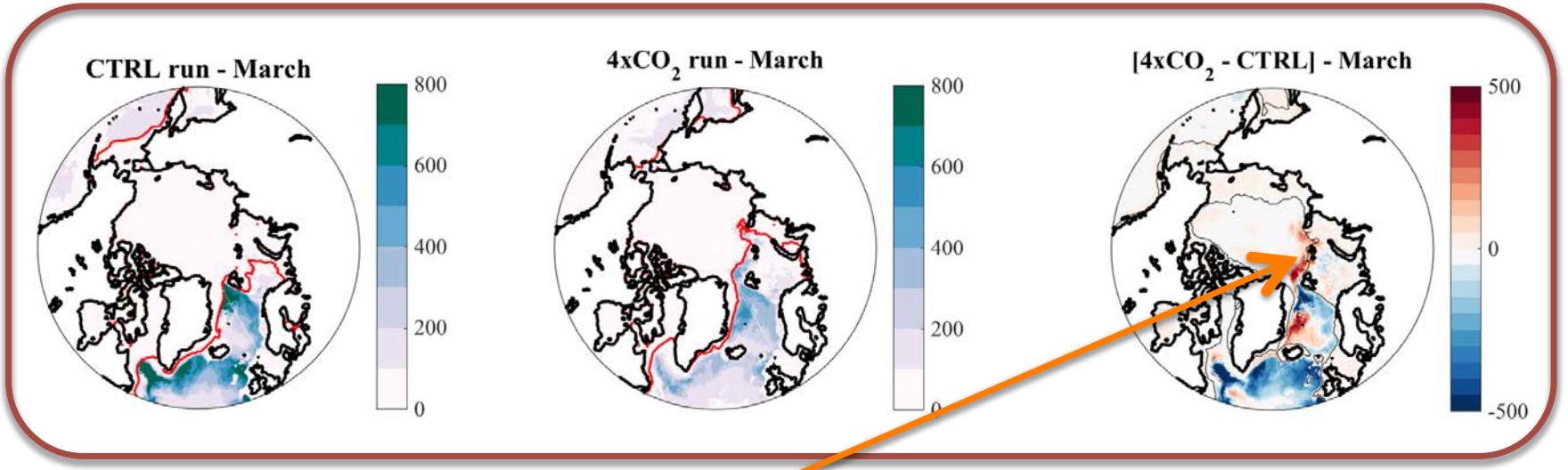


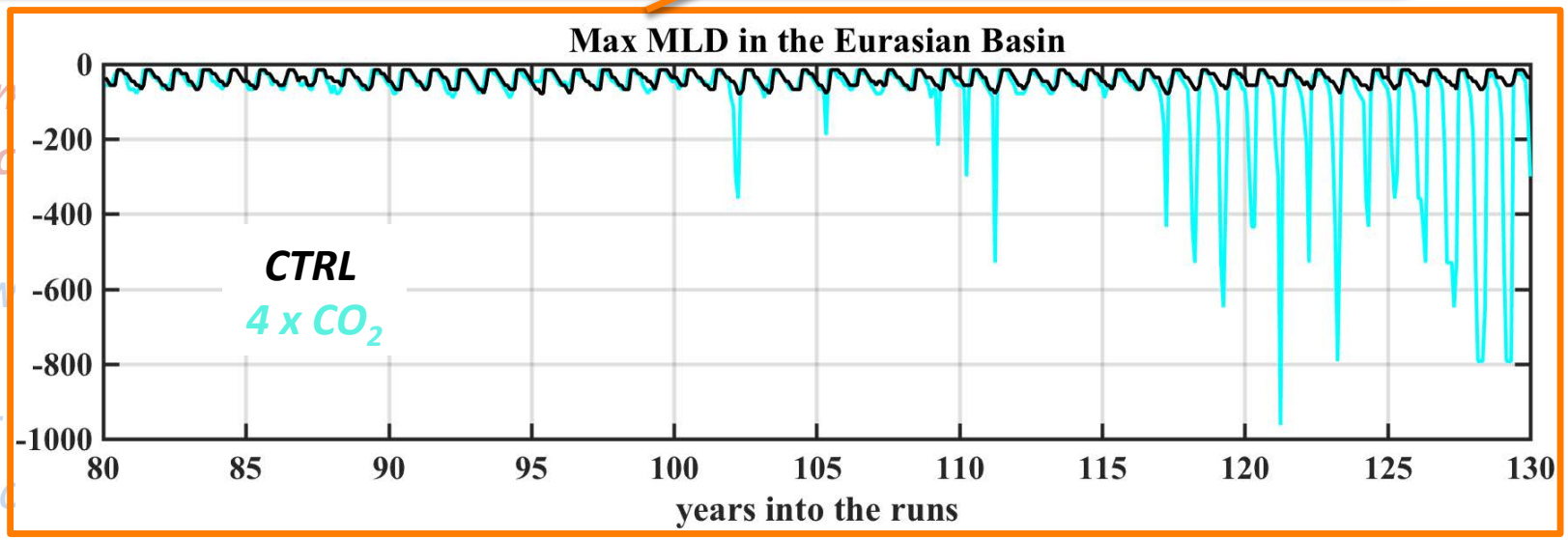
MLD (in meters, computed with a criteria in density) and position of the sea ice edge :

-> 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* (average of the last 10 years)





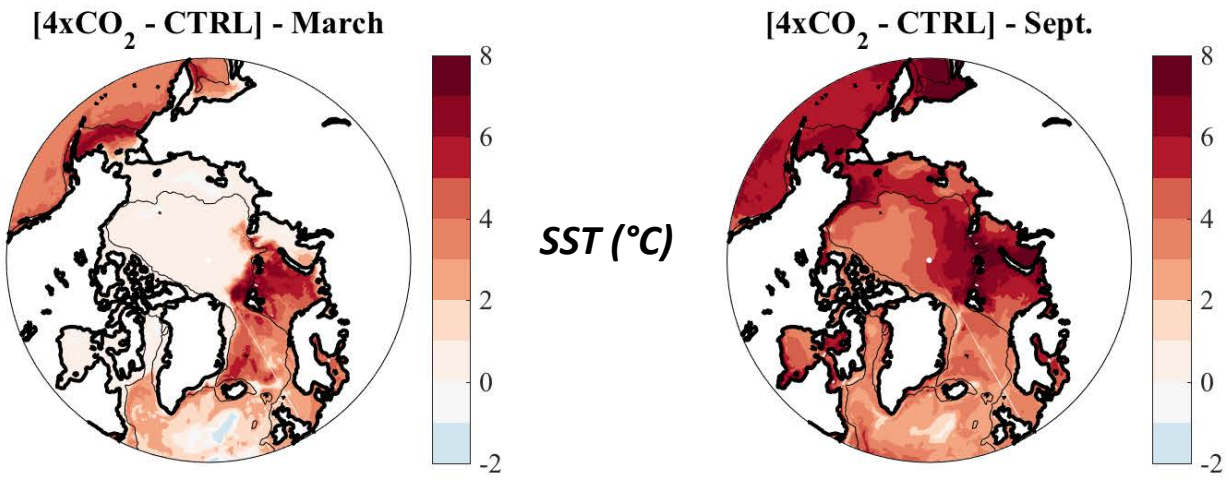
MLD (in r
the sea ic

-> shallow

-> deeper
Ocean, cl

-> 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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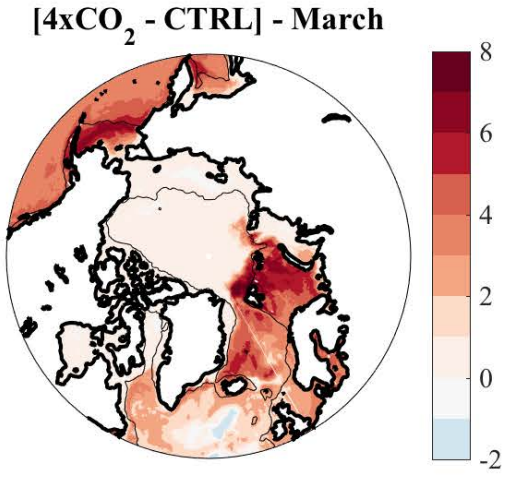
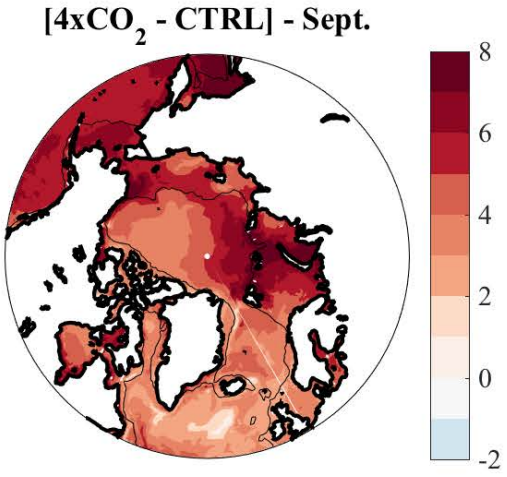


SST (°C)



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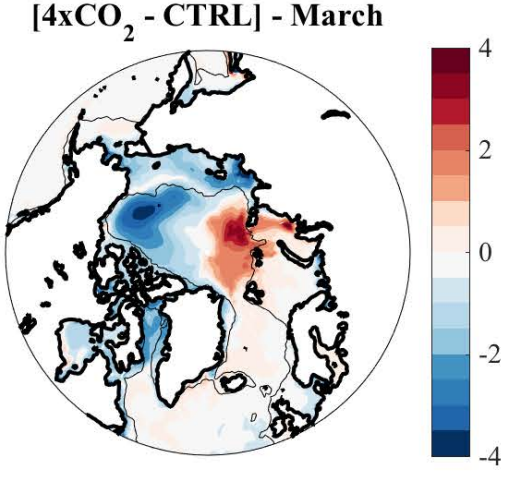
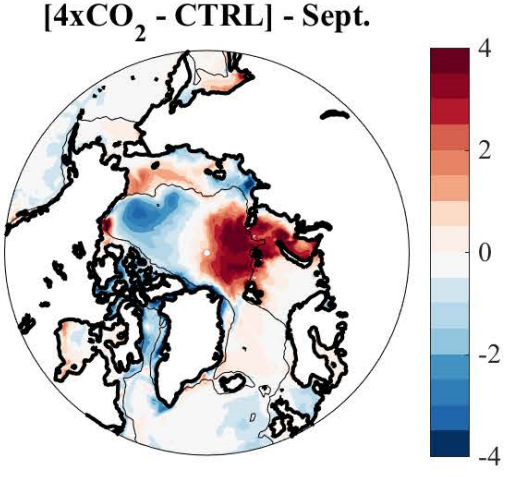


SSS (psu)

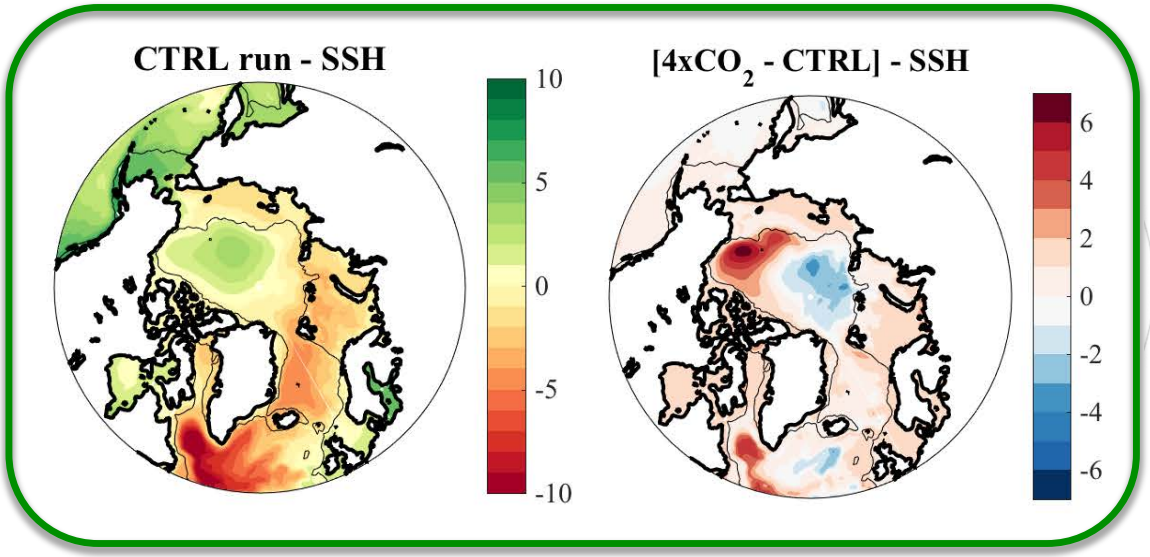


Change in SSS:

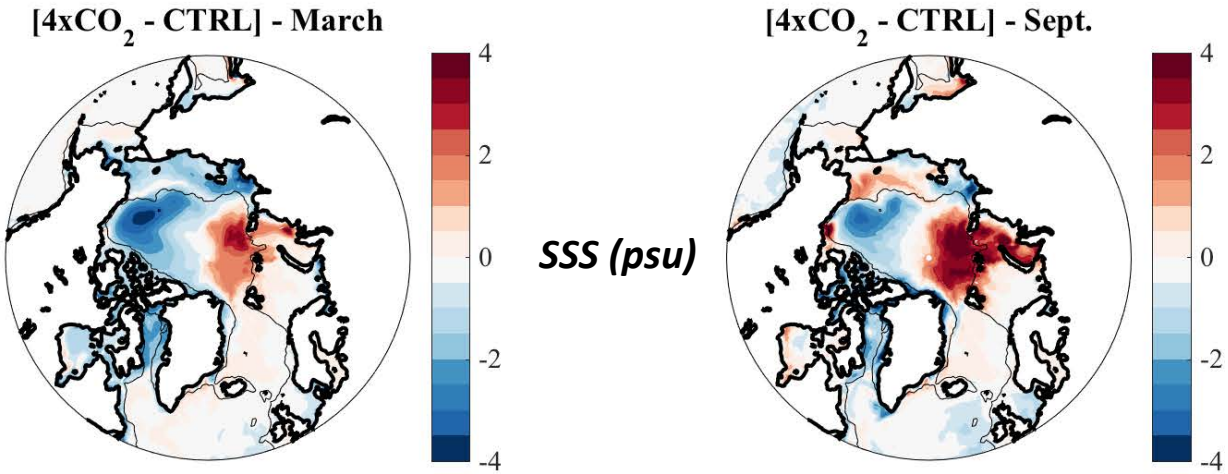
-> strong freshening in the Canadian Basin (spin up of the Beaufort Gyre)

-> 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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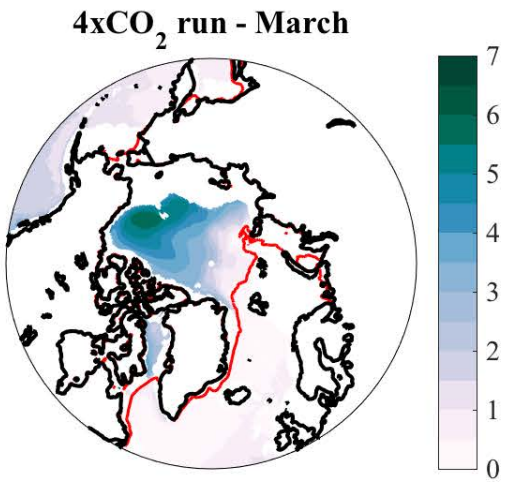
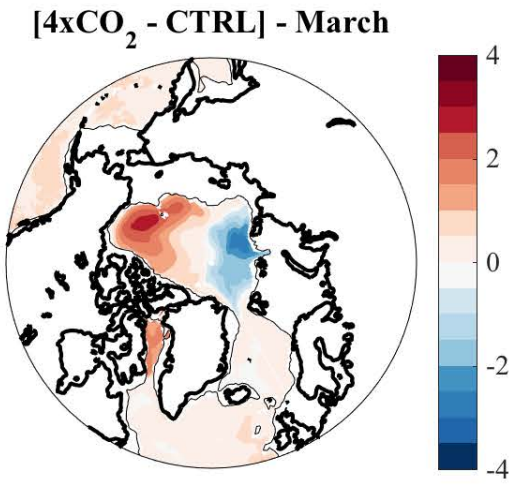


Stratification
(defined as the density difference between 500m and the surface, in kg/m³)



-> Change in SSS imprint on surface density

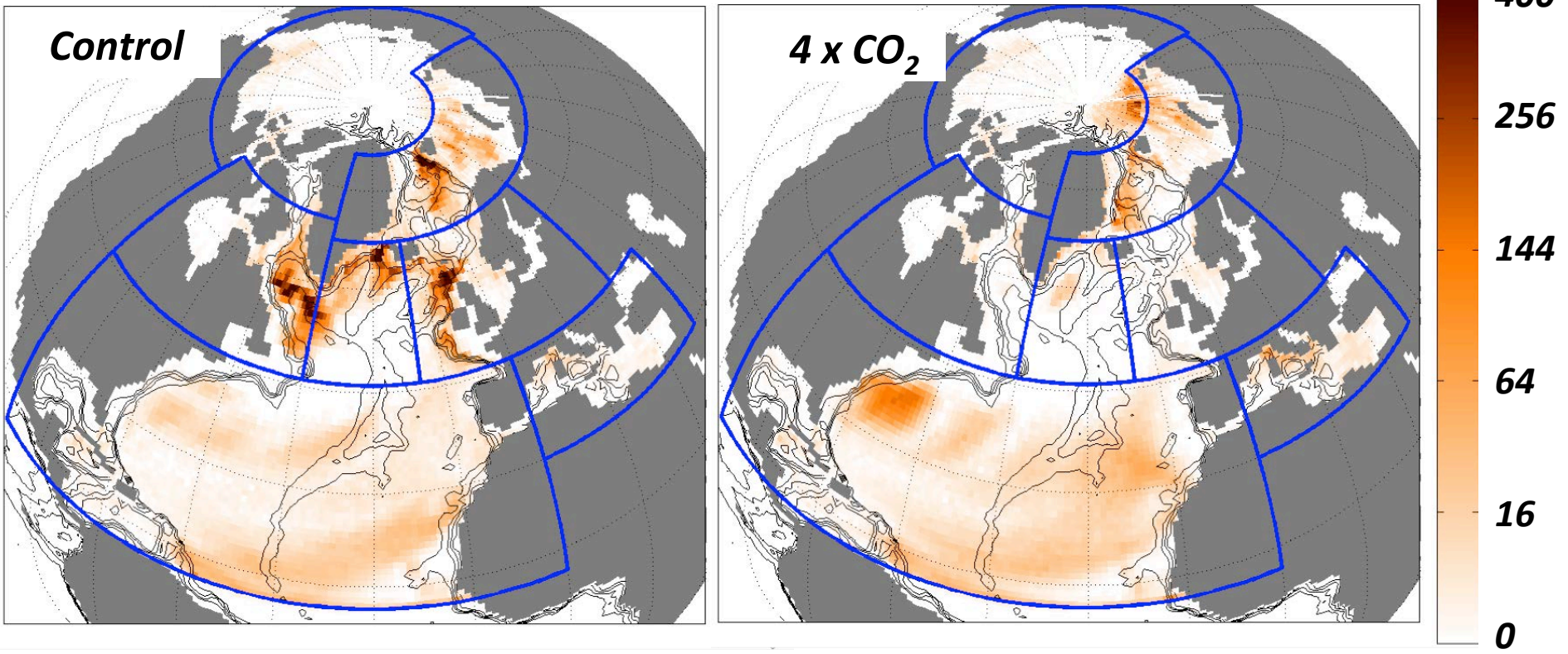
-> Results in large changes of stratification

- ✧ *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 ?

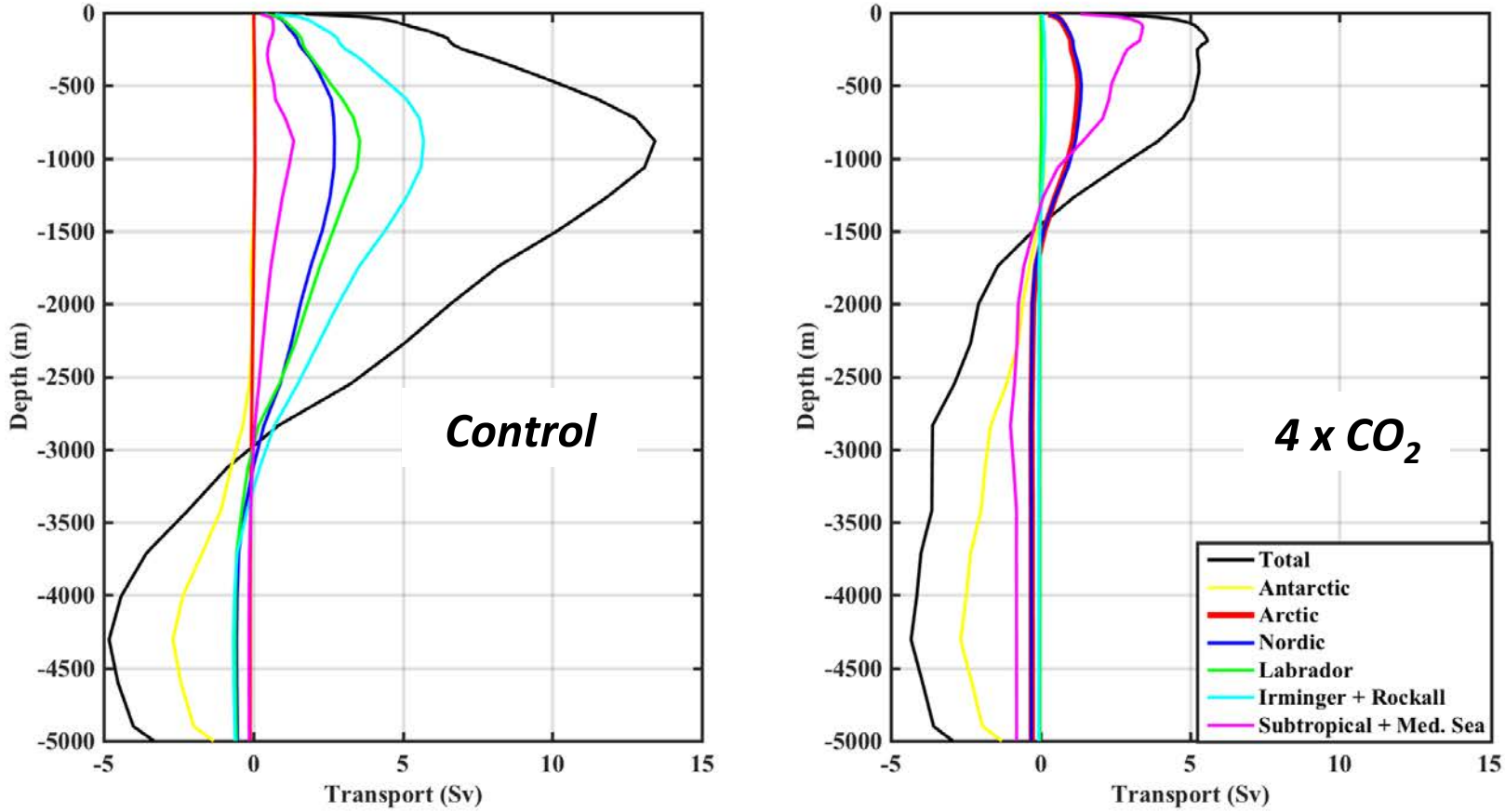
Subduction rate (m/yr) of water that ends at 10°N computed with ARIANE applied to CNRM - ORCA1



-> <u>backward computation</u>: Millions of particles are seeded in the southward flow at 10°N and run backward in time until they subduct (i.e when they intercept the base of the time-varying mixed layer)

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**

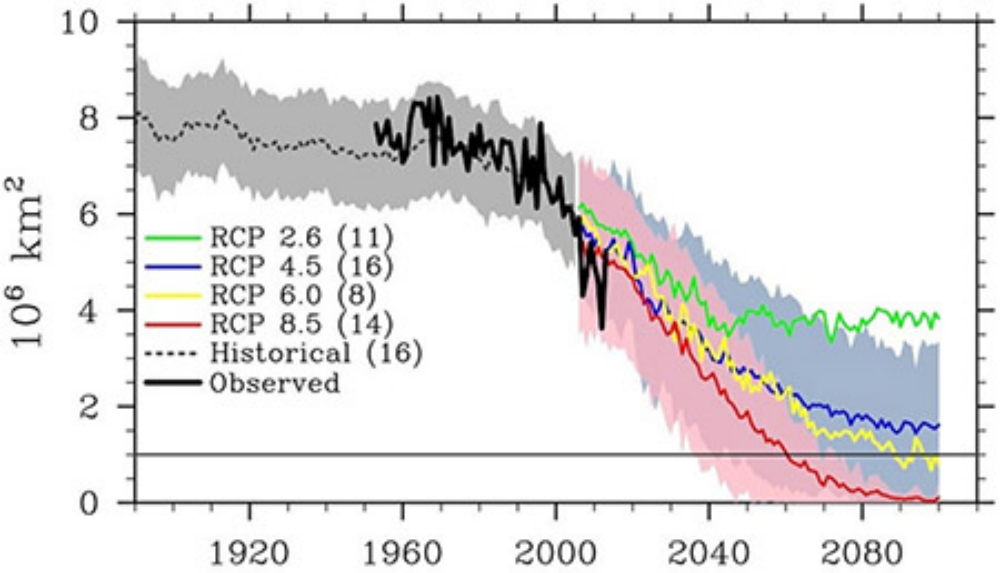
  Lagrangian analysis of the CNRM model suggests that emerging subduction in the the Arctic Ocean and the subtropical gyre could contribute significantly to the AMOC…

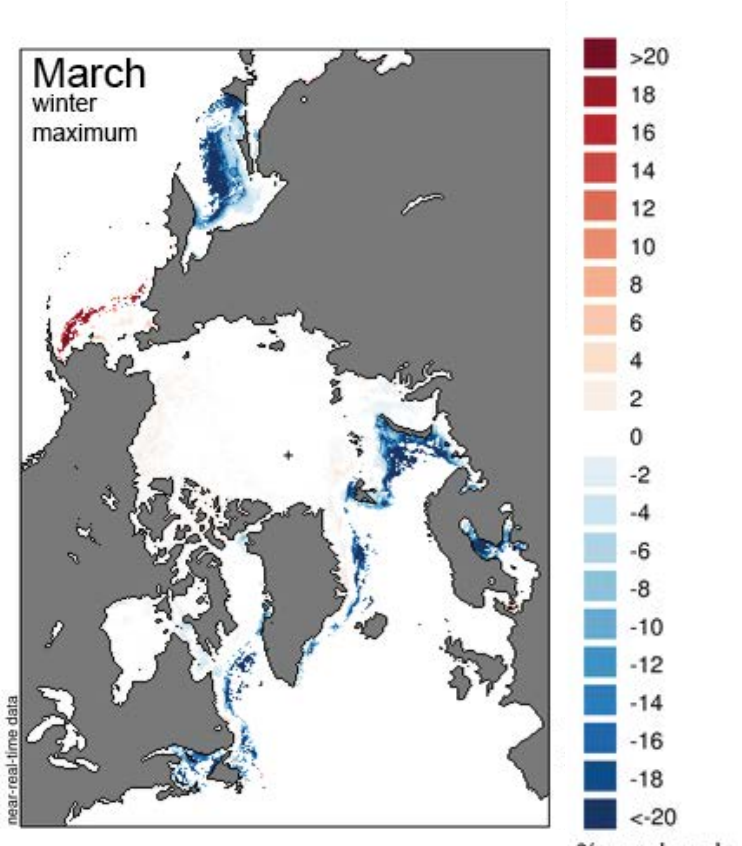
  - ➢ *A changing Arctic may not just be a threat for the AMOC*

When could we expect a convective Arctic ?

Observed and projected September sea ice extent :

-> Arctic sea ice is shrinking faster than predicted by CMIP5 models.





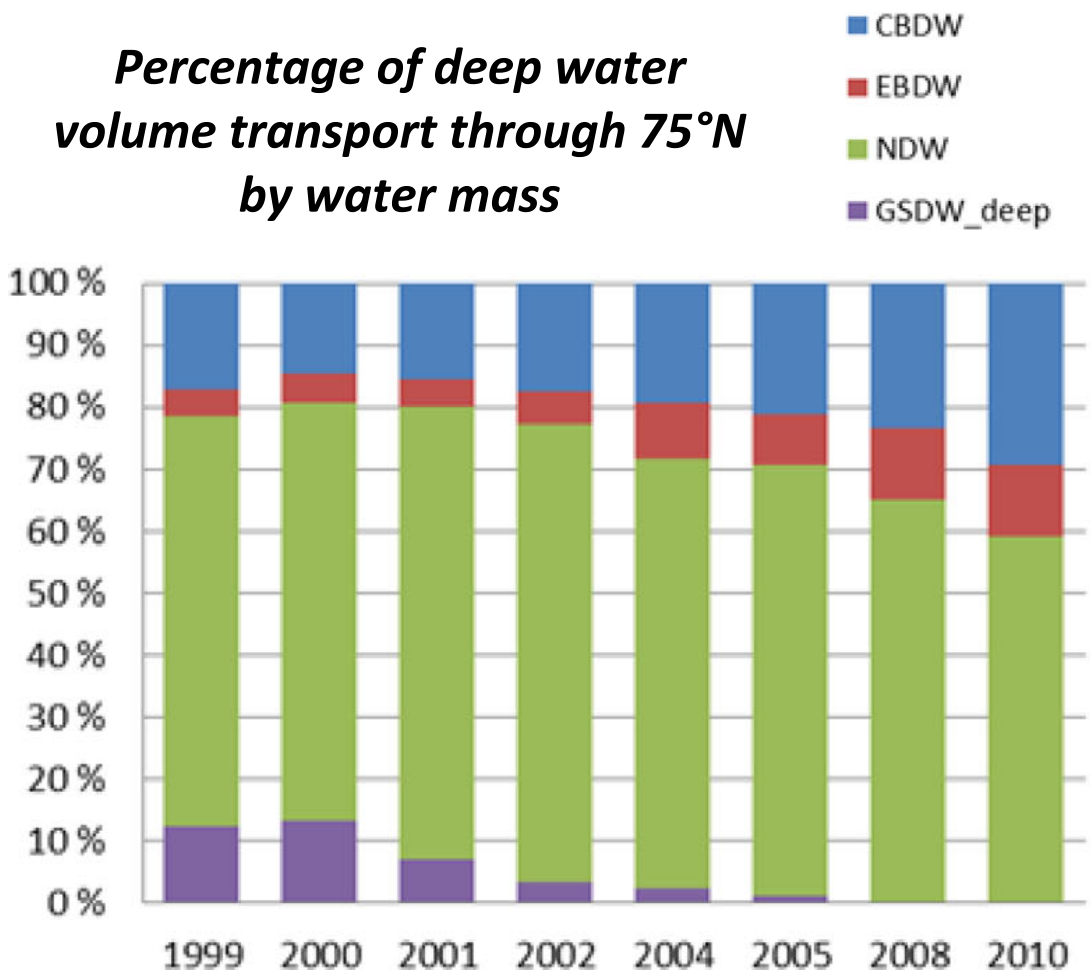
Trend of March sea ice concentration over 1979-2015 (in %/per decade):

-> Larger negative trends on the Atlantic side

IPCC 2013; NSIDC

Any evidence that things are already changing ?

Percentage of deep water volume transport through 75°N by water mass



-> contribution from dense water formed in (or passing by) the Arctic is increasing

-> export of Arctic-origin dense water has switched from being an intermittent feature to a permanent feature over the past decade.

Marnela et al. 2016; Langehaug & Falck 2012; Somavilla et al. 2013

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