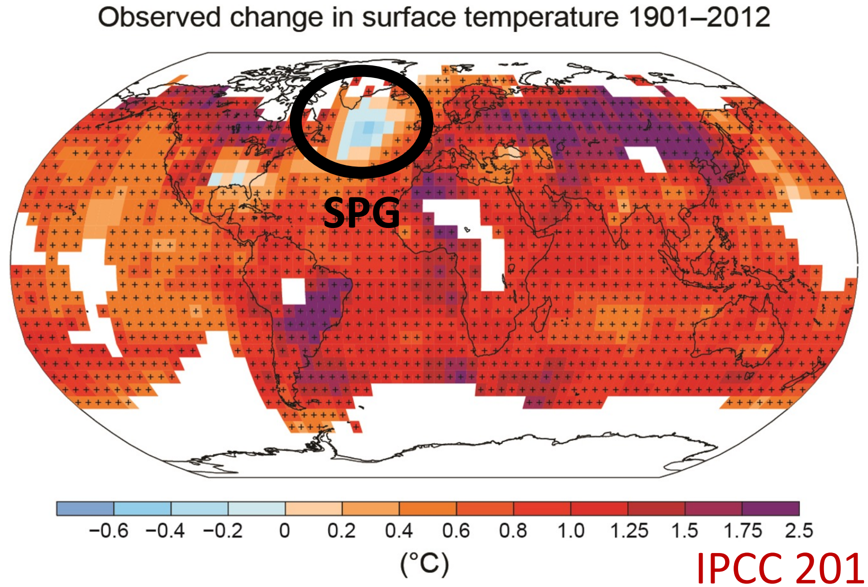
AMOC recent trends: A crucial role for the oceanic resolution and Greenland melting?

Didier Swingedouw

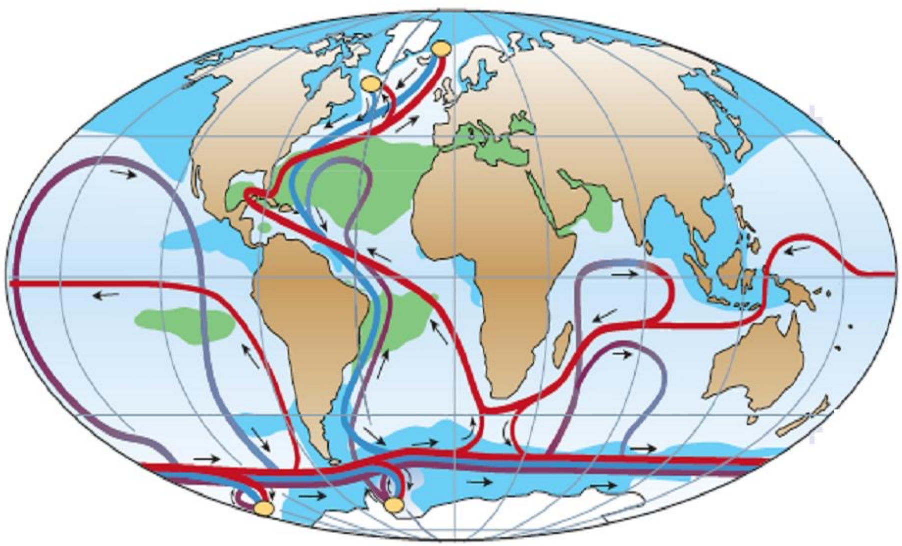
Marion Devilliers, Marie-Noelle Houssais, Christophe Herbaut, Anne-Cécile Blaizot, Juliette Mignot, Julie Deshayes, Gilles Garric, Mohamed Ayache

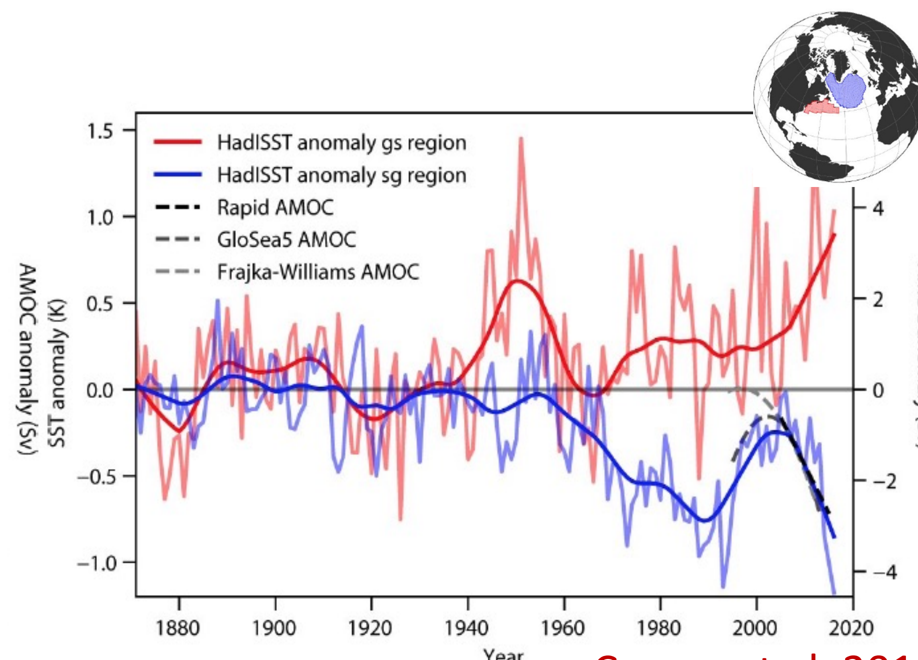
A change in the ocean circulation?

- There is an observed cooling and freshening of the subpolar gyre (SPG) over the last century (IPCC SROCC 2019)
- This could be a fingerprint of an on-going weakening of the Atlantic ocean circulation (by about 15% according to Caesar et al. 2018)



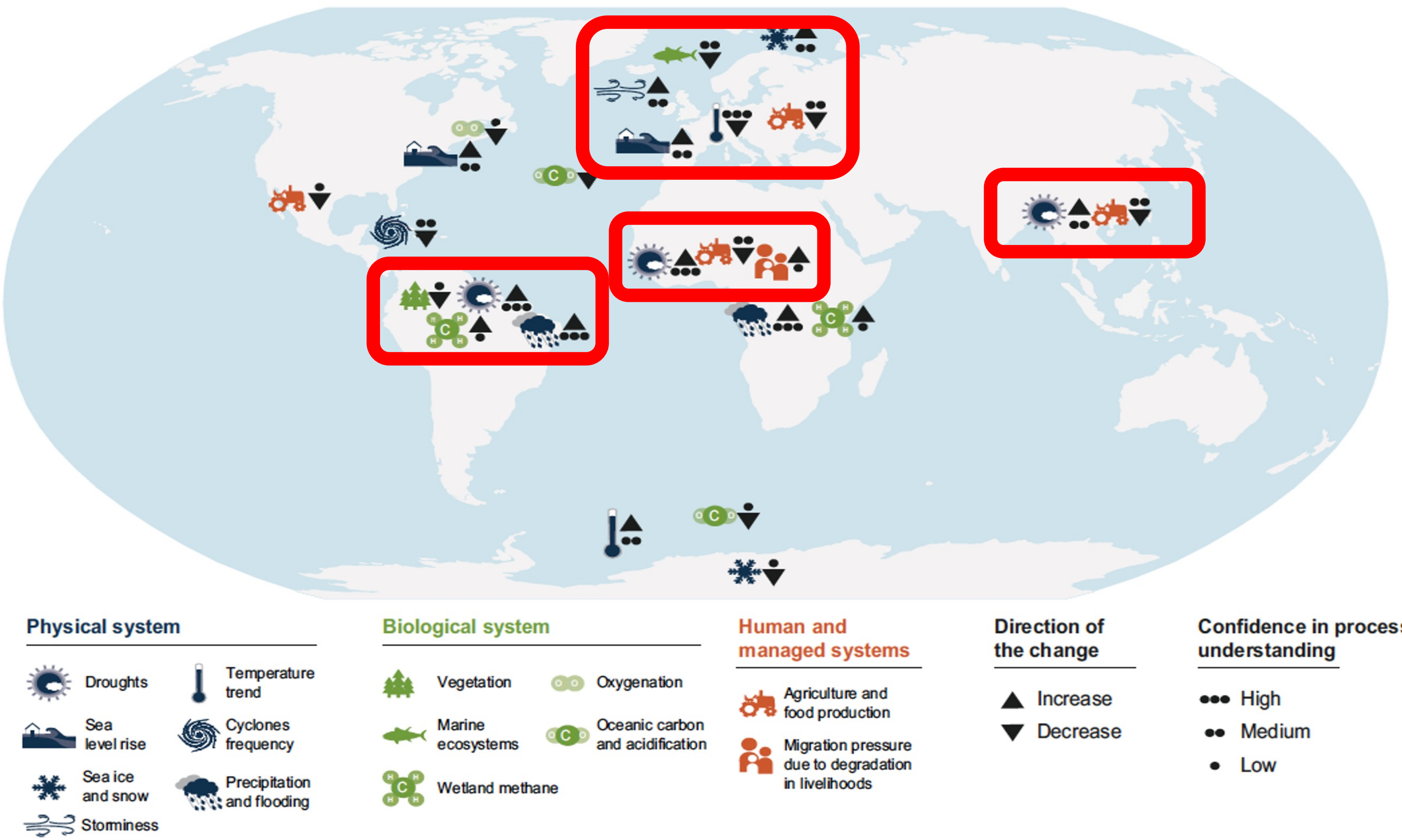
IPCC 2013





Caesar et al. 2018

Large-scale impact of a substantial weakening in the Atlantic circulation



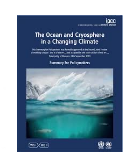
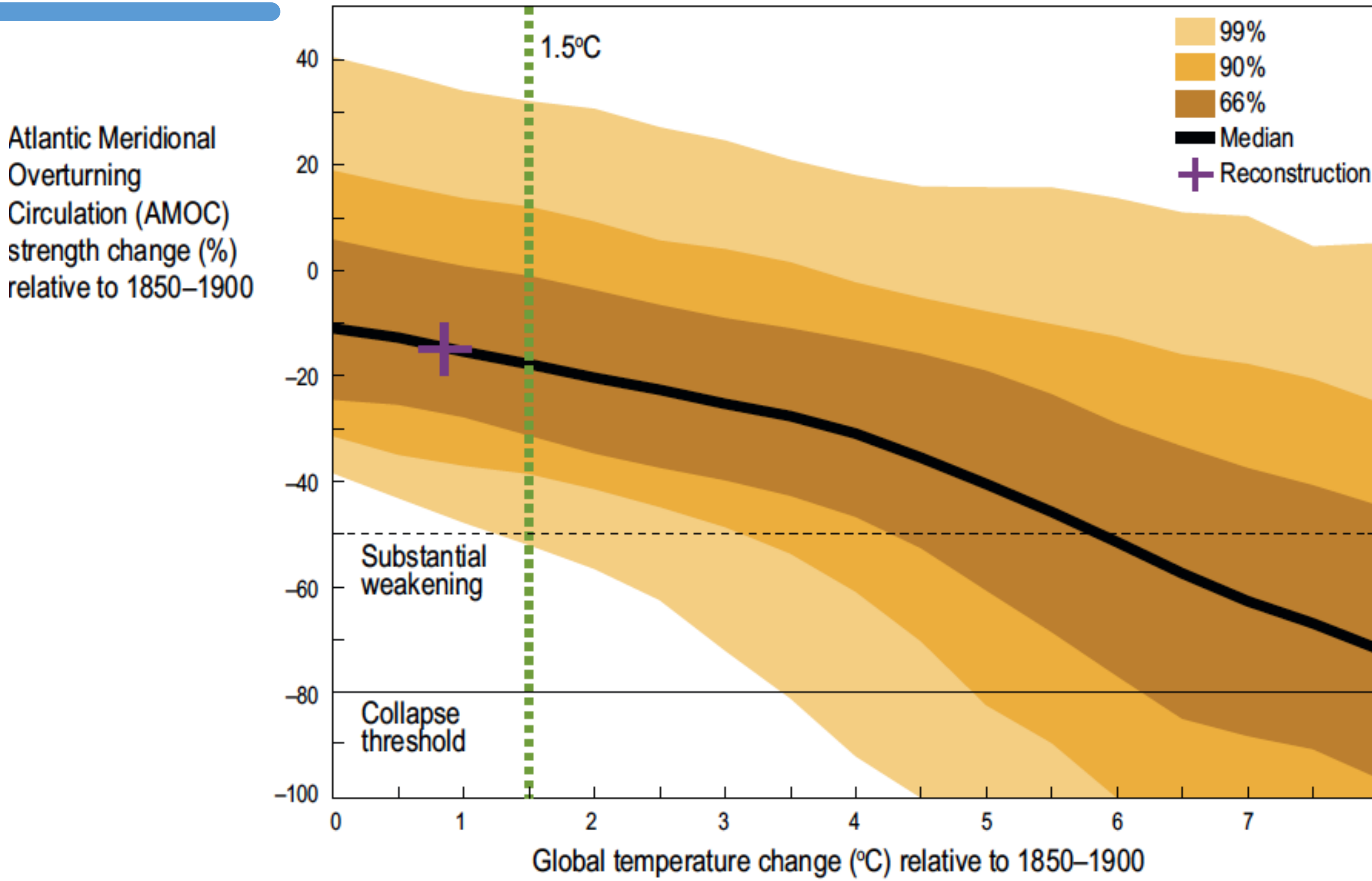


Fig. 6.10 from IPCC SROCC report, 2019

Risk of AMOC substantial weakening



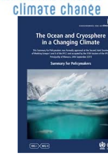
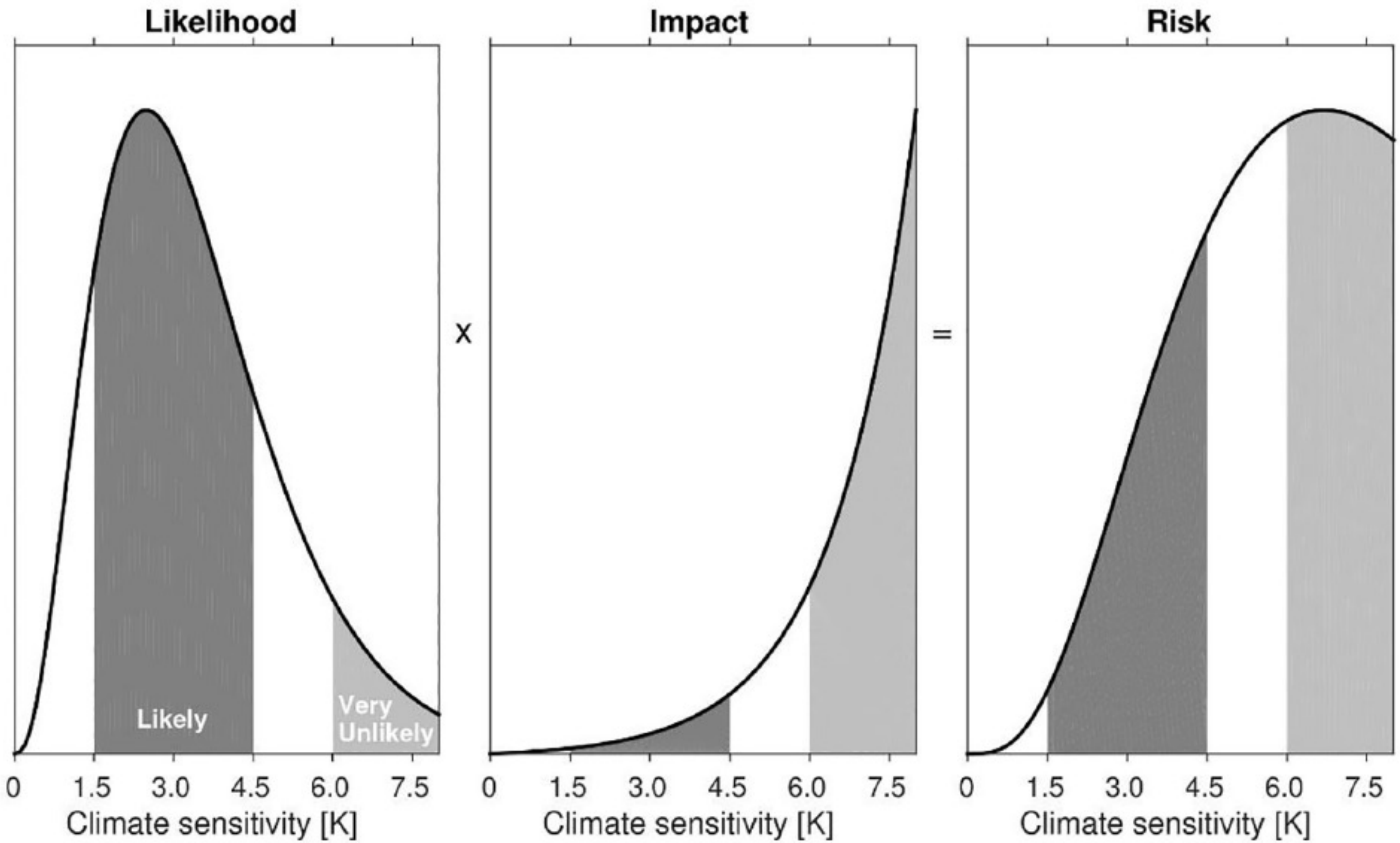


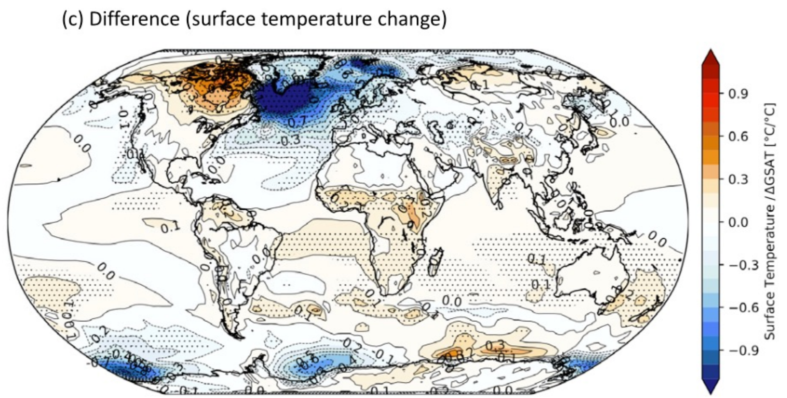
Fig. 6.9 from IPCC SROCC report, 2019

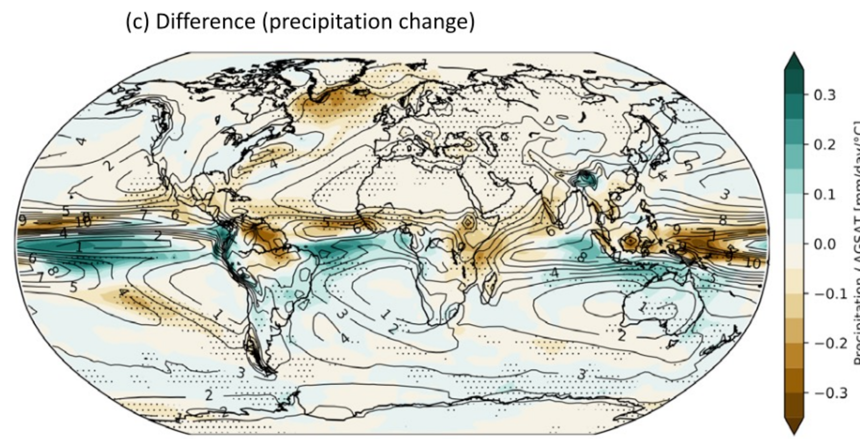
Low probability-high impact event

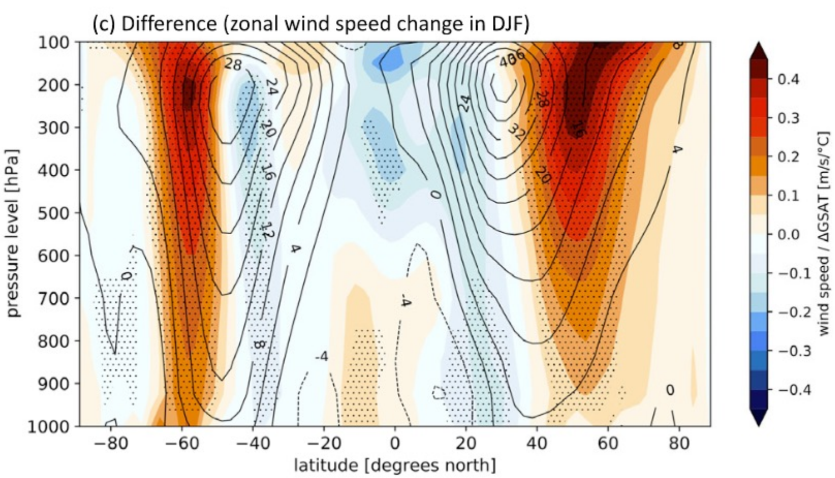


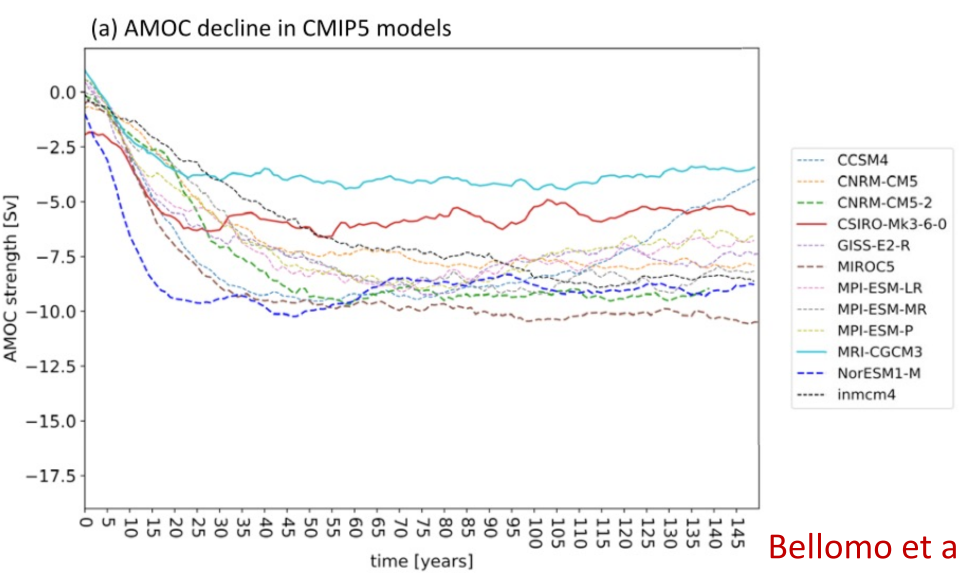
Sutton 2018

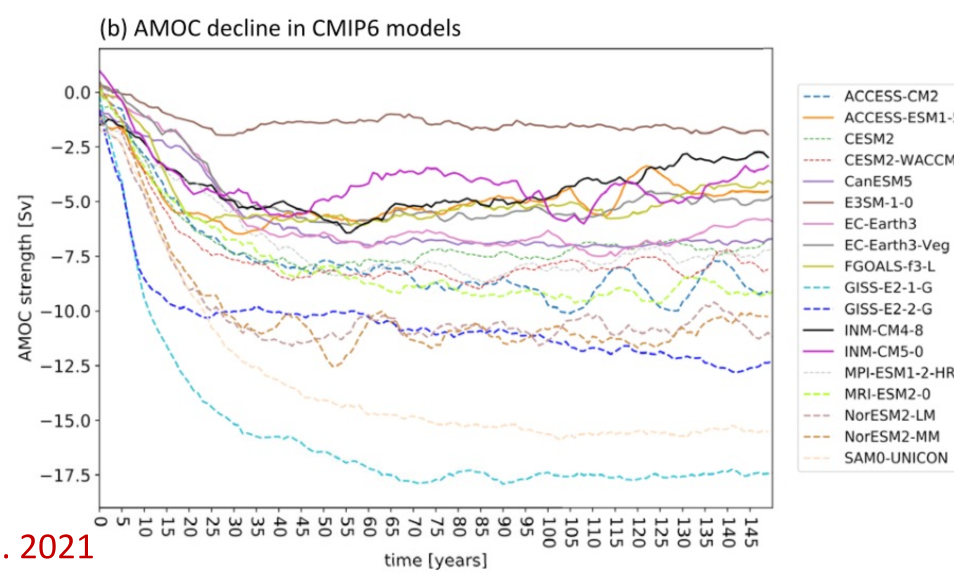
Still so much AMOC uncertainty in CMIP6







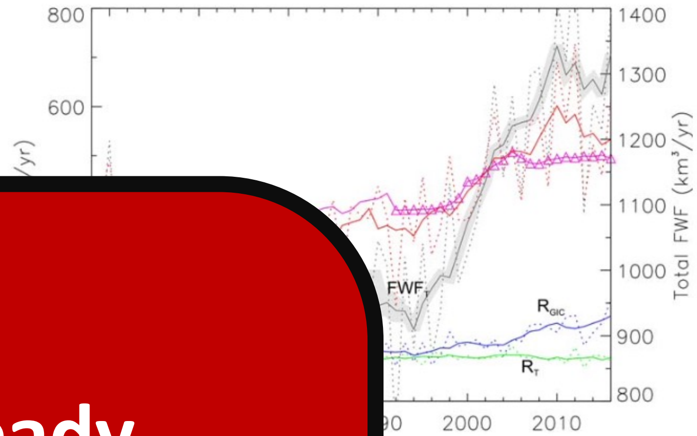




Bellomo et al. 2021

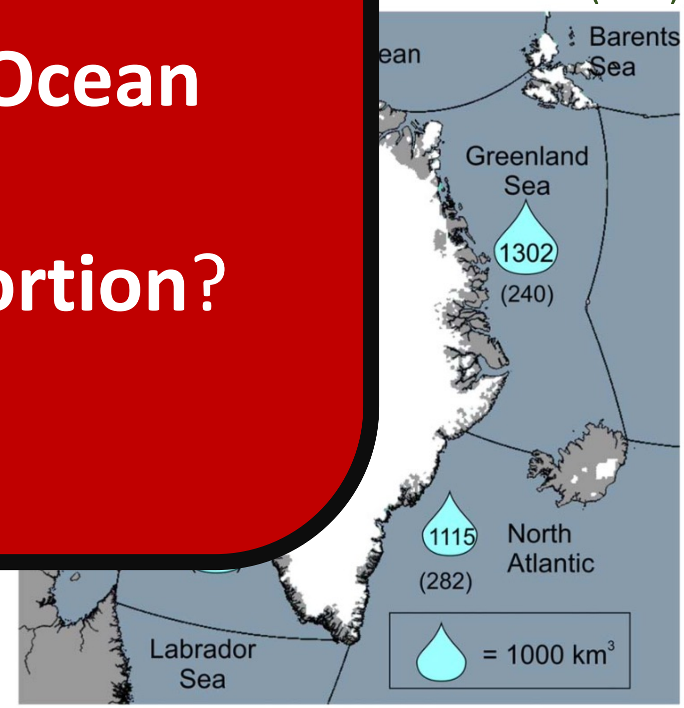
What about GrIS melting?

Land-ice freshwater components from Greenland region (km^3/yr).



Has Greenland melting already impacted the North Atlantic Ocean circulation and in which proportion?

…ter from land-ice … 1960-1990 (km^3).

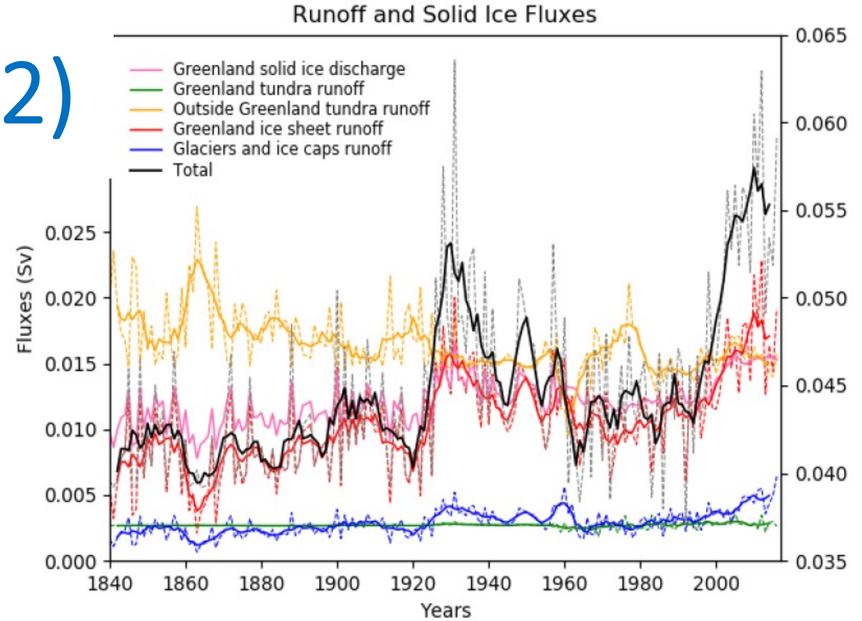


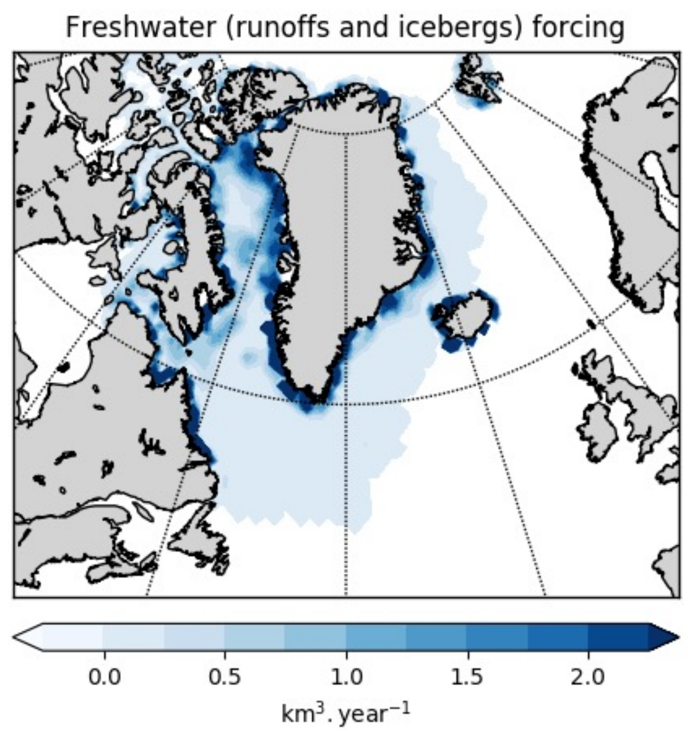
- Model resolution can play a crucial on the way GrIS melting is spread in the North Atlantic

Bamber et al. 2018

Materials and methods (1/2)

- Use of Bamber et al. (2018) recent reconstruction
- Extension back to 1840 following Box and Colgan (2013)
- Overwrite runoff and calving in the the Greenland region by those observation-based fluxes
- Use of 20 members of IPSL-CM6A-LR historical simulations (low resultion, LR) including this melting since 1920 (**Melting ensemble**)
- Comparison with historical simulations from IPSL-CM6A-LR starting from same initial conditions (historical **Control ensemble**)



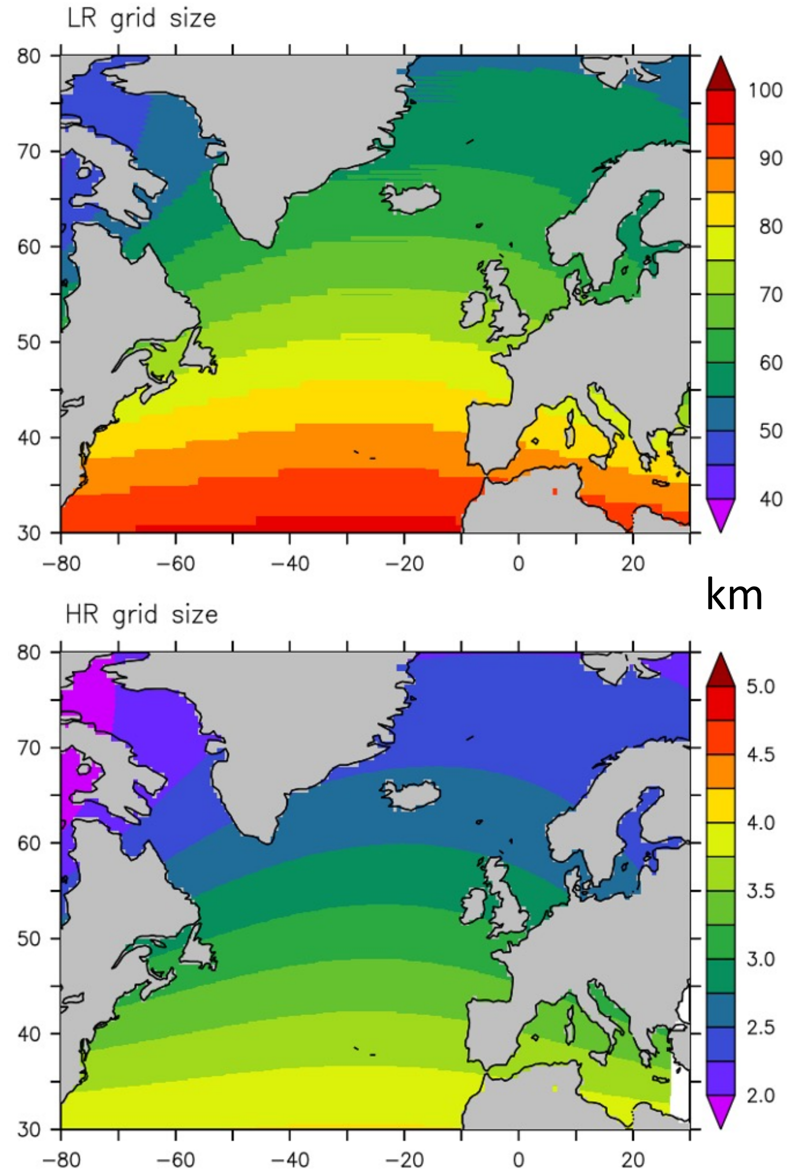


Devilliers et al. 2021

BLUE ACTION

Materials and methods (2/2)

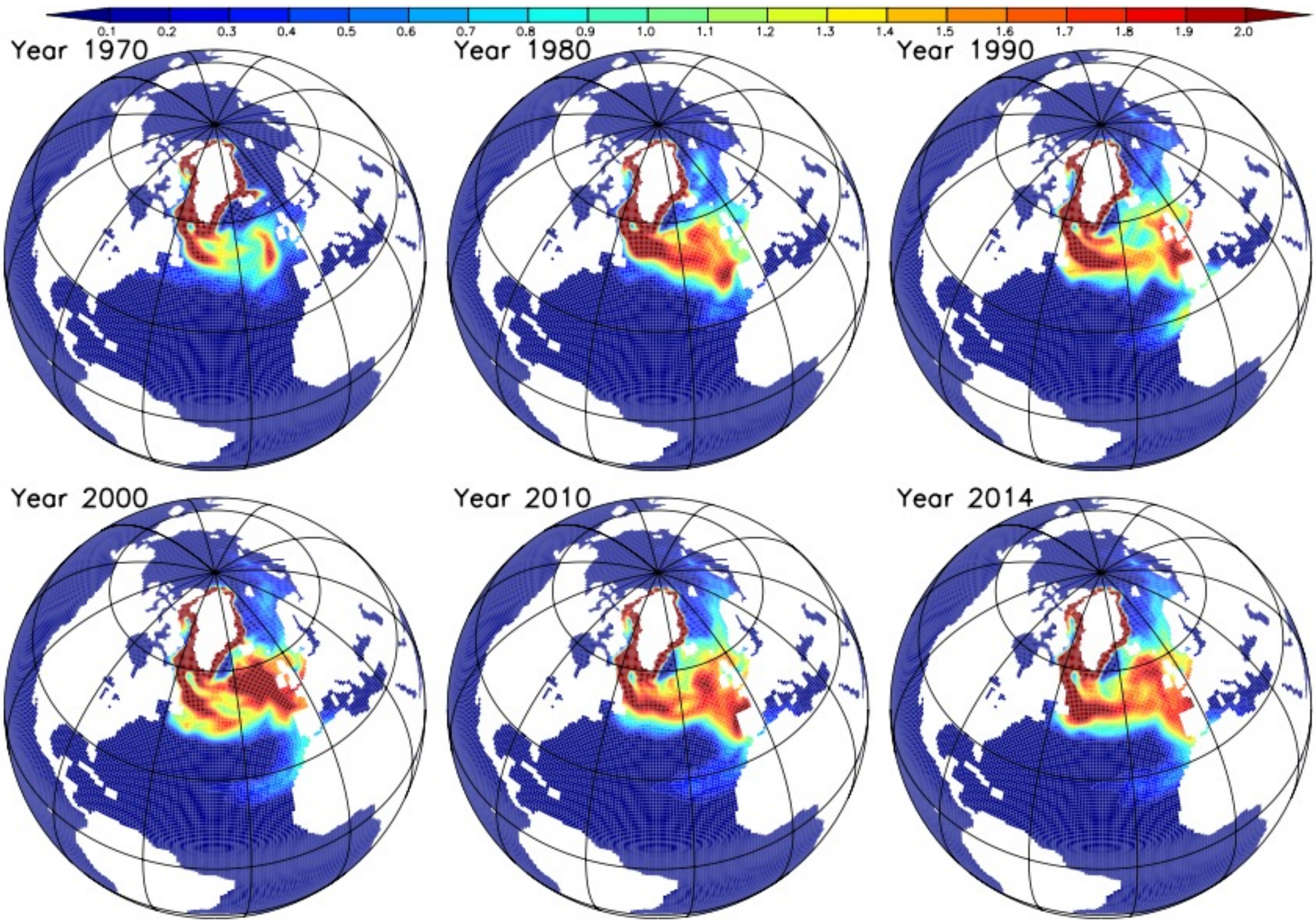
- High resolution (HR) model (2-3 km in the North Atlantic) ocean-only model is also integrated from 2004
- There is no salinity restoring at all in this model (to avoid removing the freshwater perturbation signal)
- Twin simulations, one (named **Melting**) with observed GrIS melting and the other (named **Control**) without (plus a few additionnal freshwater sources from the Arctic. Effect under evaluation, but weak apparently)
- Only 13 years of simulation due to high CPU cost (but planning to continue them)



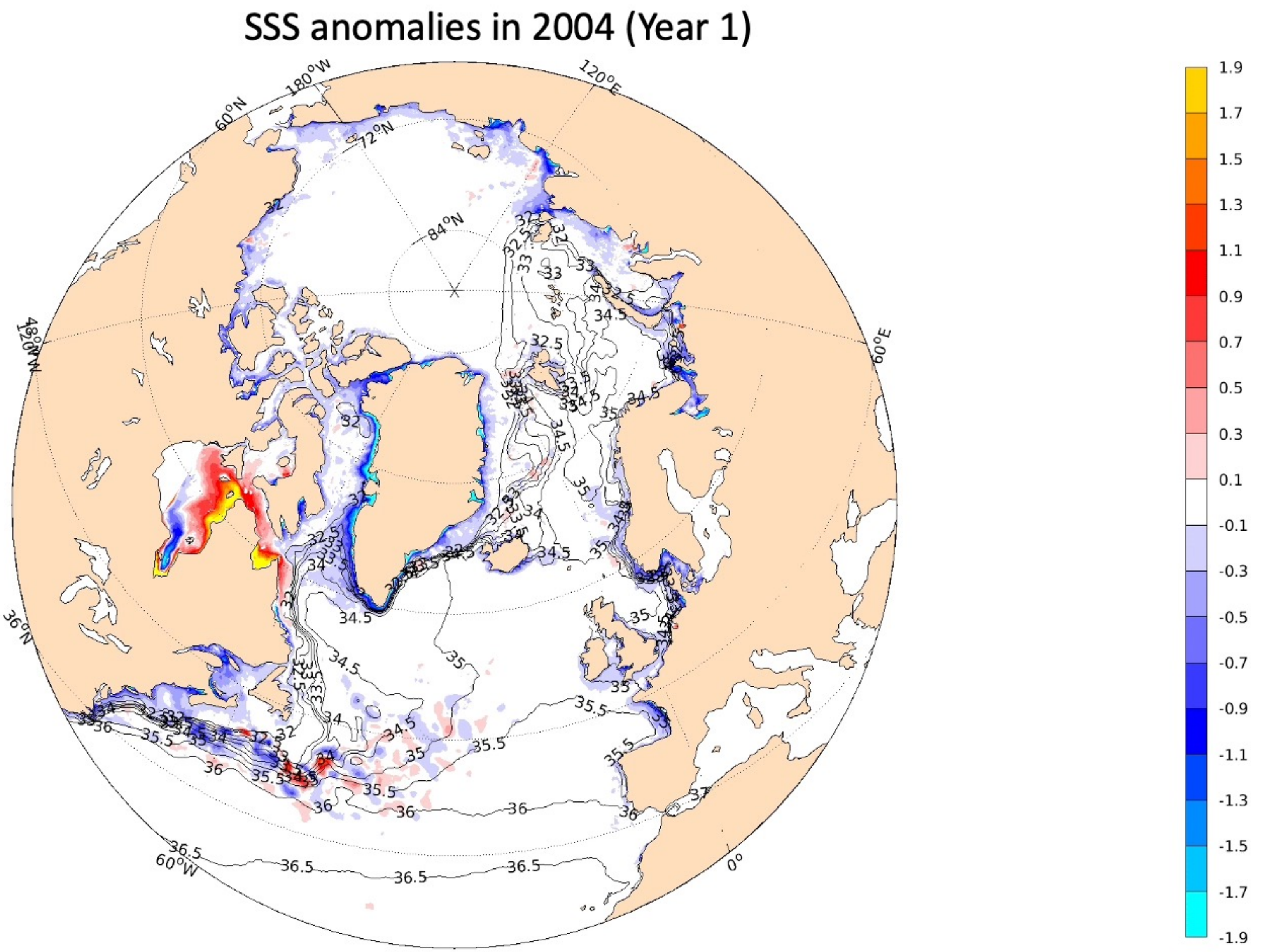
Swingedouw et al. 2022

Propagation of the perturbation in LR simulations

Passive tracer spread in IPSL-CM6A-LR

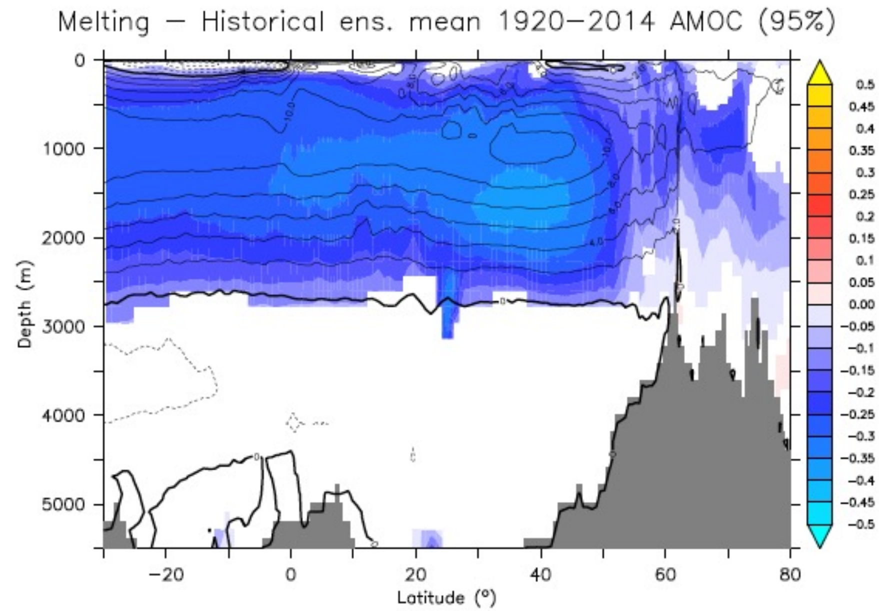


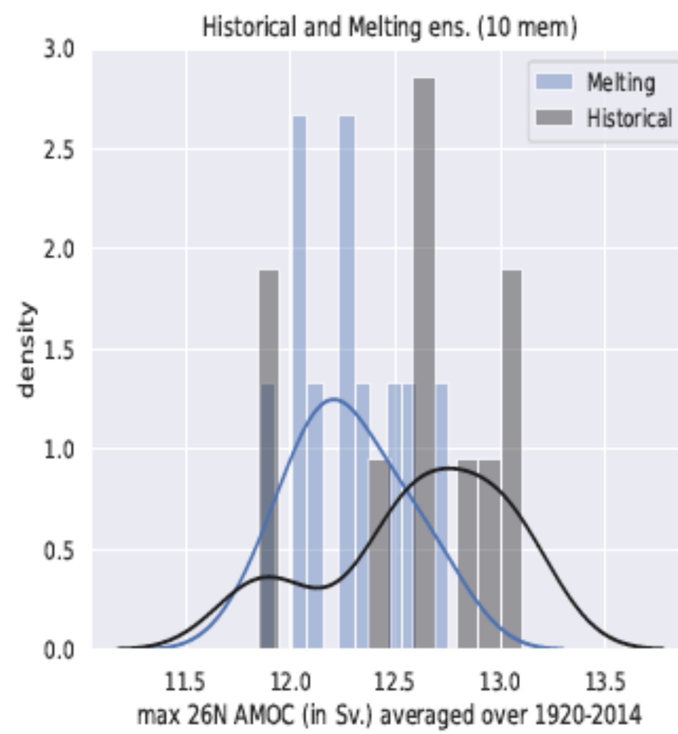
Propagation of the perturbation in HR simulations



Impacts on the AMOC in IPSL-CM6A-LR model

- The AMOC is slightly affected by the additional freshwater input (need for a large ensemble to go beyond internal variability…)
- It weakens by **0.20 ± 0.39 Sv** at 45°N
- Far less than the 3 ± 1 Sv estimated by Caesar et al. (2018)





Devilliers et al. 2021

BLUE ACTION

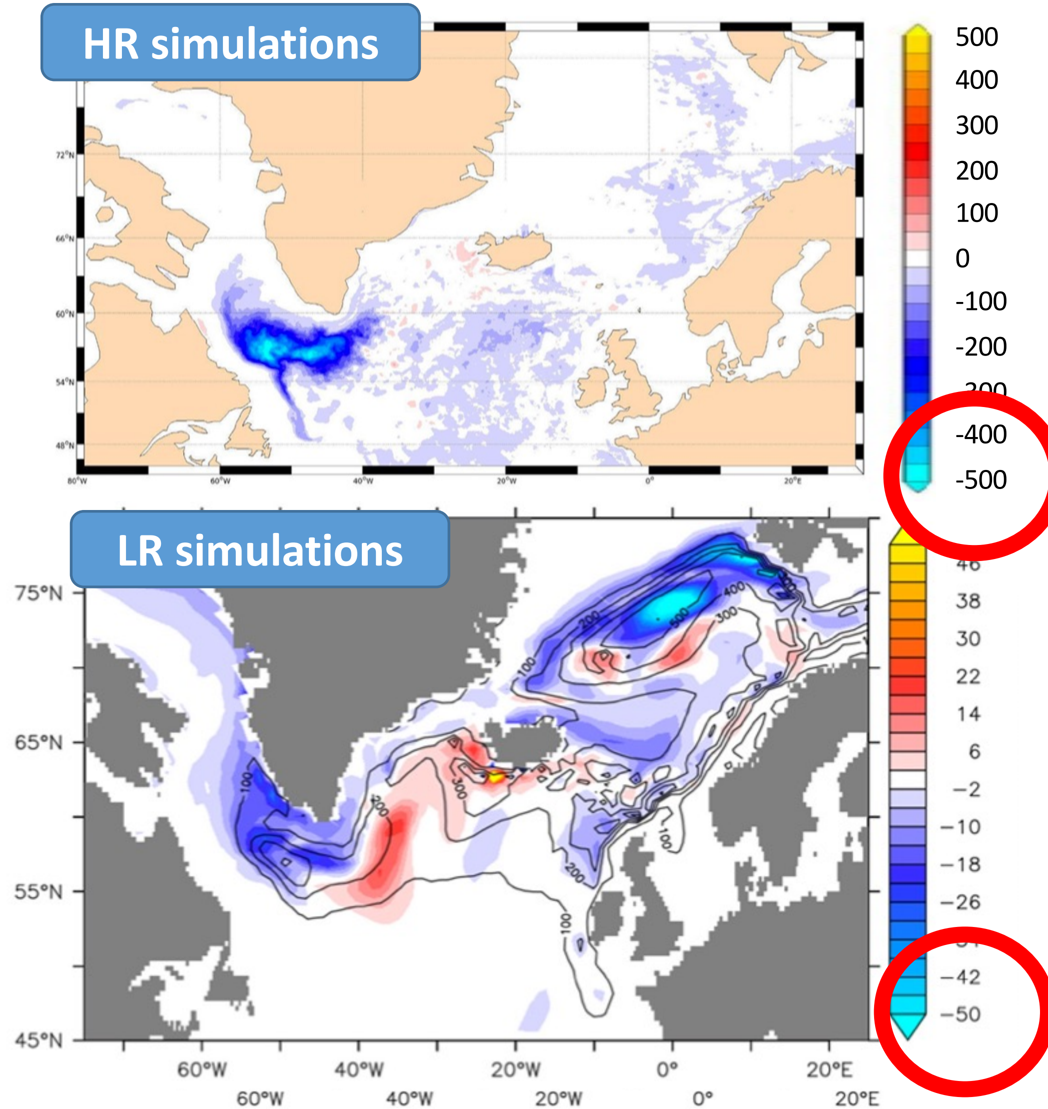
Impacts of oceanic resolution on GrIS impact

- We compare IPSL-CM6A Low Resolution (**LR, 50-60 km**) run with very High Resolution (**HR, 2-3 km**) simulations from an ocean-only model

- Similar impact on salinity, but one of order of magnitude larger (while shorter simulation, and only slightly larger perturbation)

- The same is true for mixed layer depth: one order of magnitude stronger weakening of Labrador Sea convective activity in HR simulations

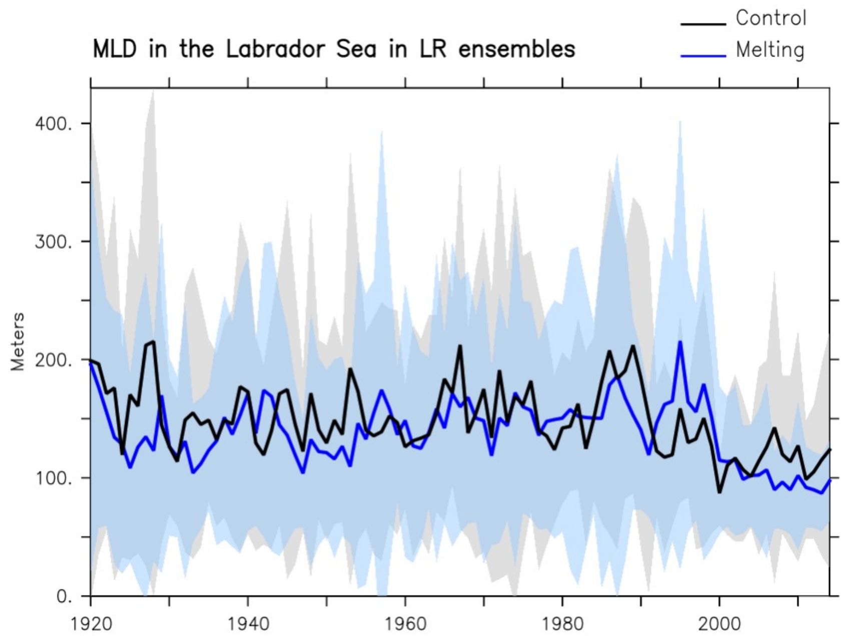
Mixed layer depth anomalies



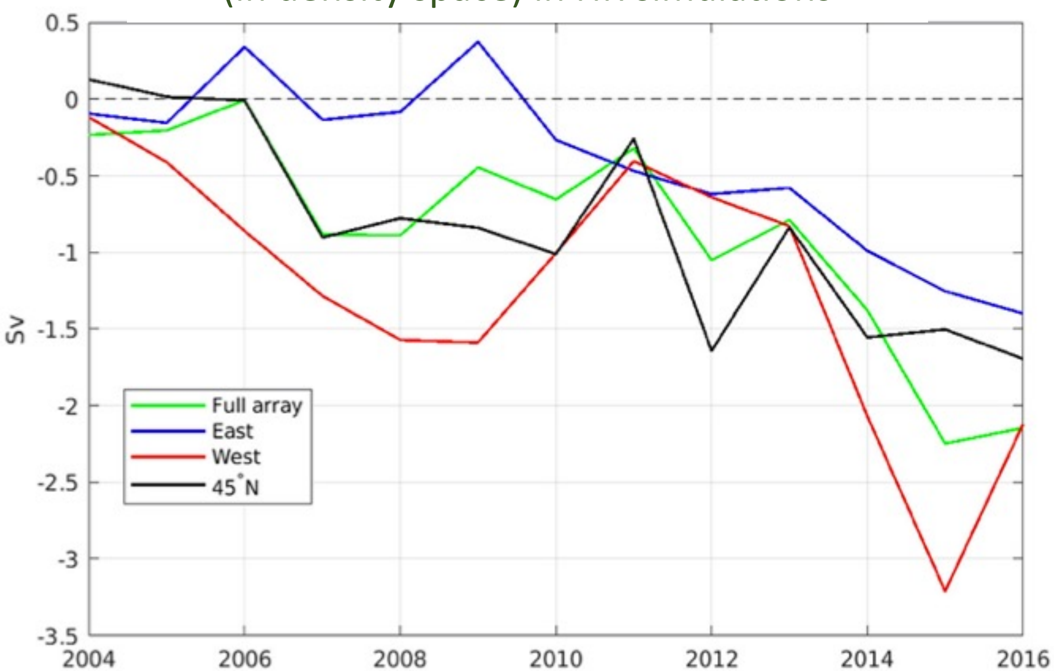
Swingedouw et al. (2022)

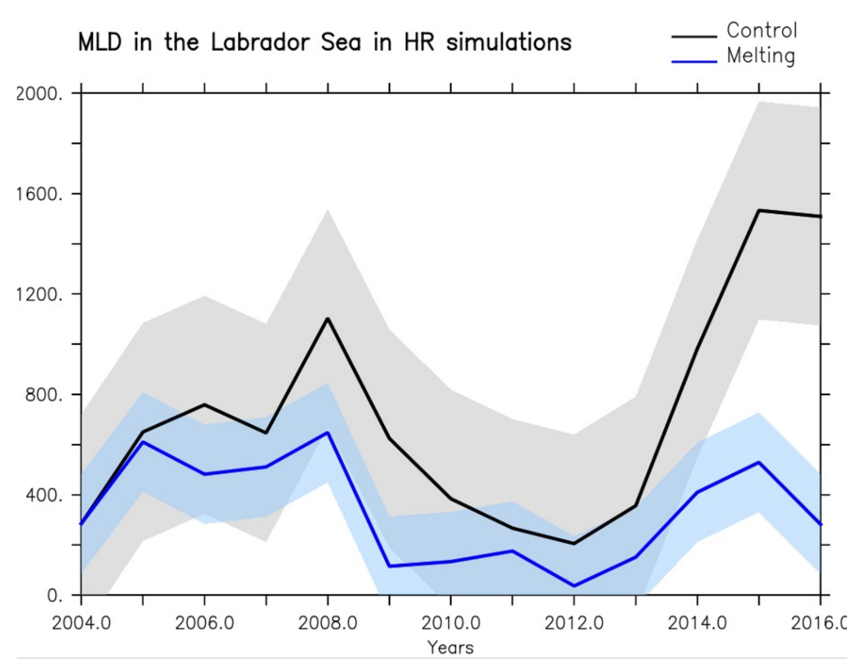
Impacts of oceanic resolution on GrIS impact

- Higher impact of Greenland melting on the Labrador Sea
- And on the AMOC



Anomalies of AMOC indices
(in density space) in HR simulations

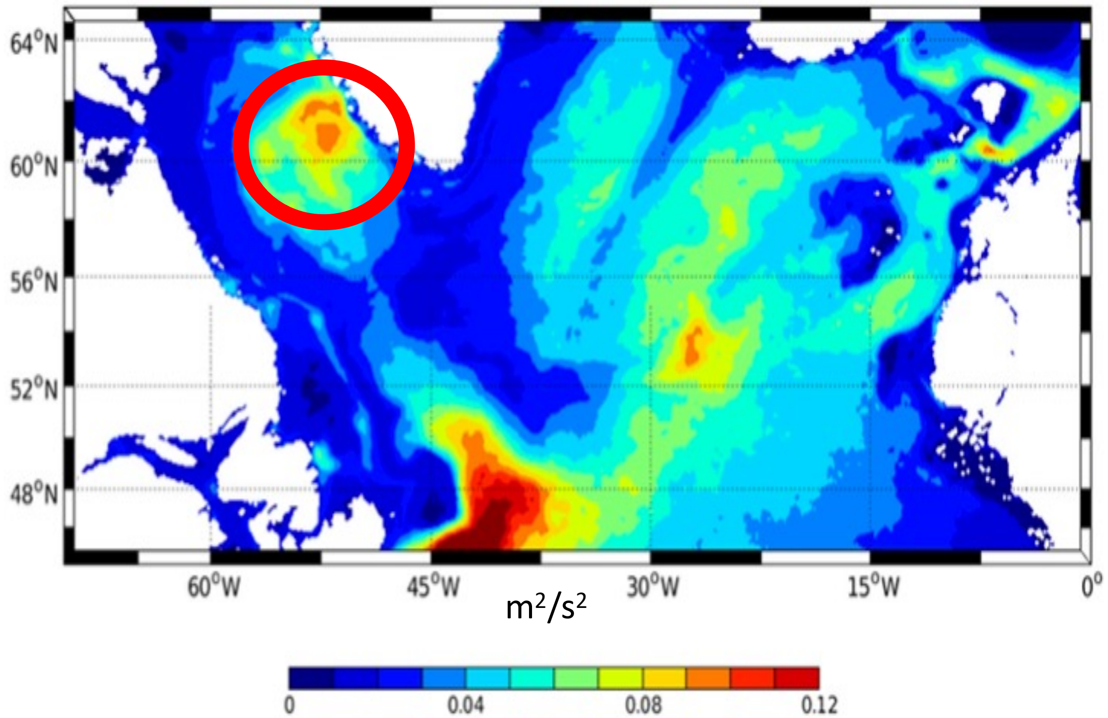




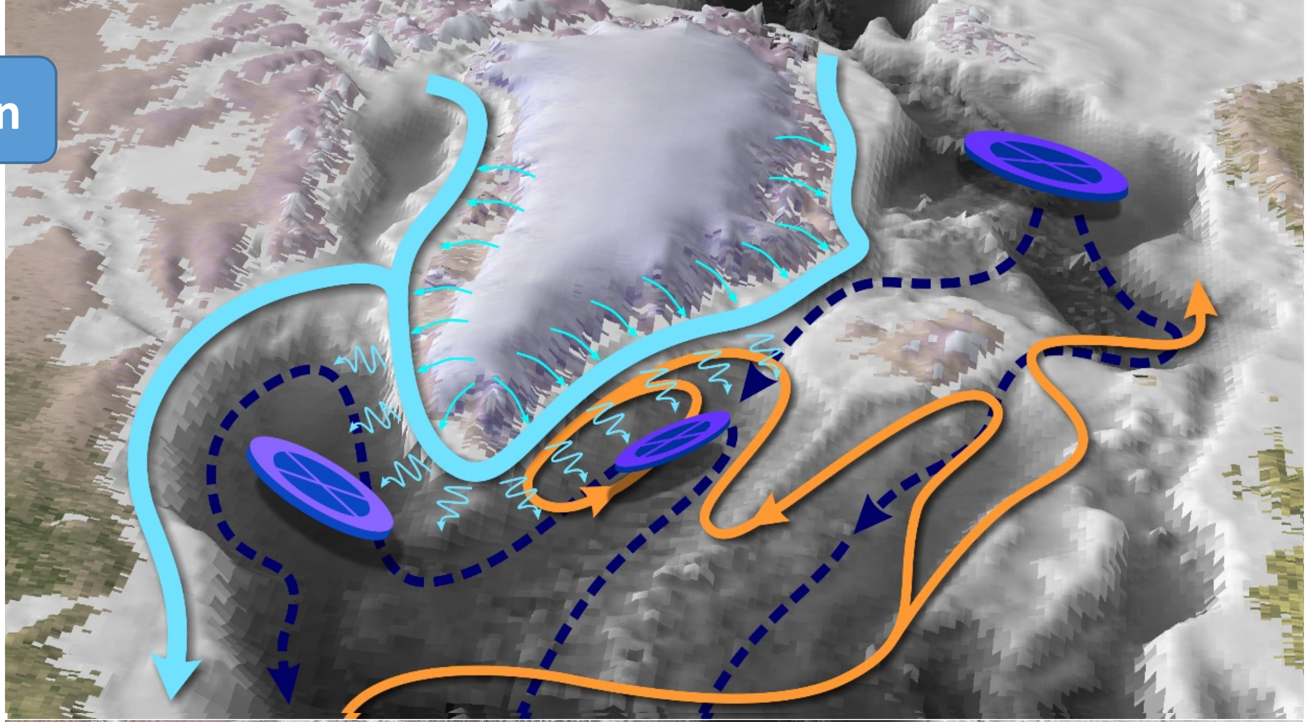
What can explain the differences ?

- The currents around Greenland are fine-scale (a few thenth of kilometers) and are too wide in the LR simulations
- There is a hotspot of eddy formation just west of the Greenland tip, bringing directly the melt water collected around Greenland into the Labrador Sea center

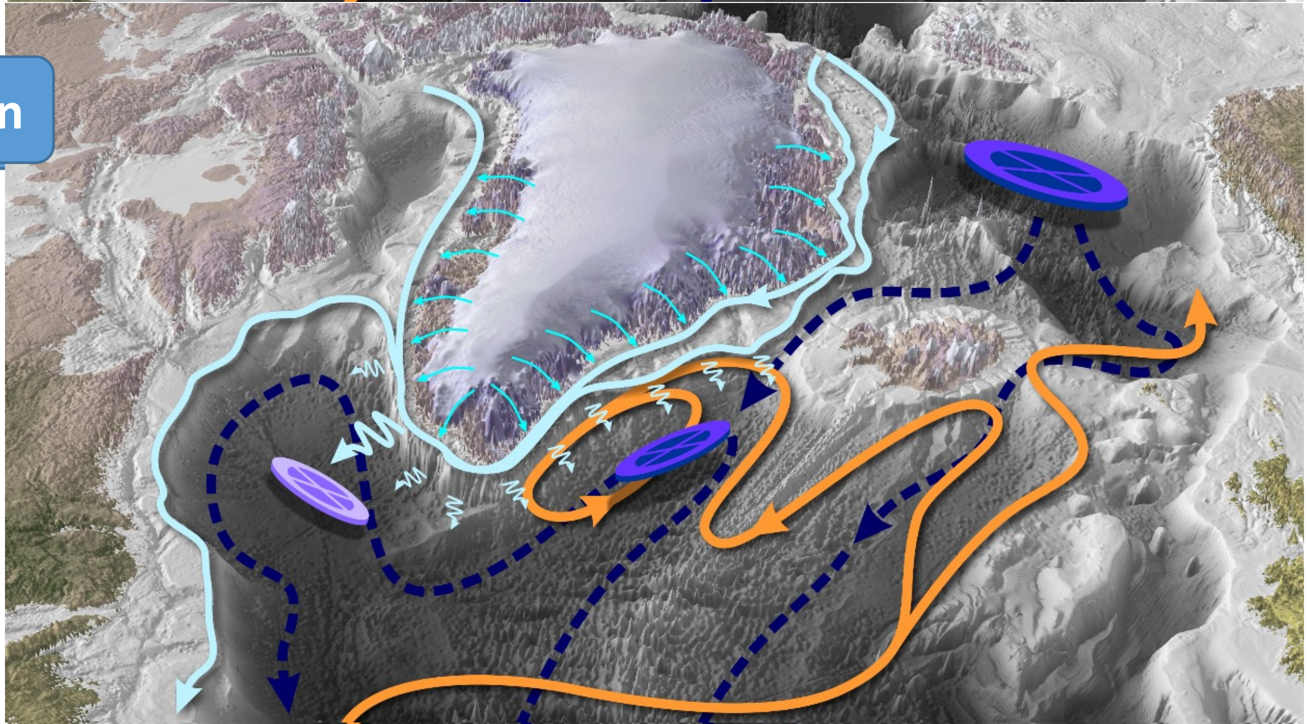
Eddy Kinetic energy in HR simulation



Low Resolution



High Resolution



Courtesy of
Vincent Hanquiez

Key take-home messages

- Large uncertainty in future AMOC fate, whose impacts might be worldwide
    - ➢ Adaptation plans should include such low probability – high impact scenarios
- Potential on-going changes in the AMOC and SPG have not been well attributed yet using CMIP6 models
- It seems that in the CMIP6-type models, on-going land-ice melting in the Greenland regions have a minor impact in terms of AMOC weakening
- This melting has a far stronger impacts in a high resolution (HR) model than in a CMIP6-type one (and could explain potential on-going AMOC weakening)
- This might be related with fine-scale processes that are not properly parametrized (e.g. eddy mixing, size of boundary currents)
- Given the computing cost of HR, there is a need to improve those parametrizations

didier.swingedouw@u-bordeaux.fr

@DidierSwing

Thank you!

BLUE ACTION

frontiers | Frontiers in Climate

ORIGINAL RESEARCH
published: 04 April 2022
doi: 10.3389/fclim.2022.838310

Check for updates

AMOC Recent and Future Trends: A Crucial Role for Oceanic Resolution and Greenland Melting?

Didier Swingedouw[1*], *Marie-Noëlle Houssais*[2], *Christophe Herbaut*[2], *Anne-Cecile Blaizot*[2], *Marion Devilliers*[3] and *Julie Deshayes*[2]

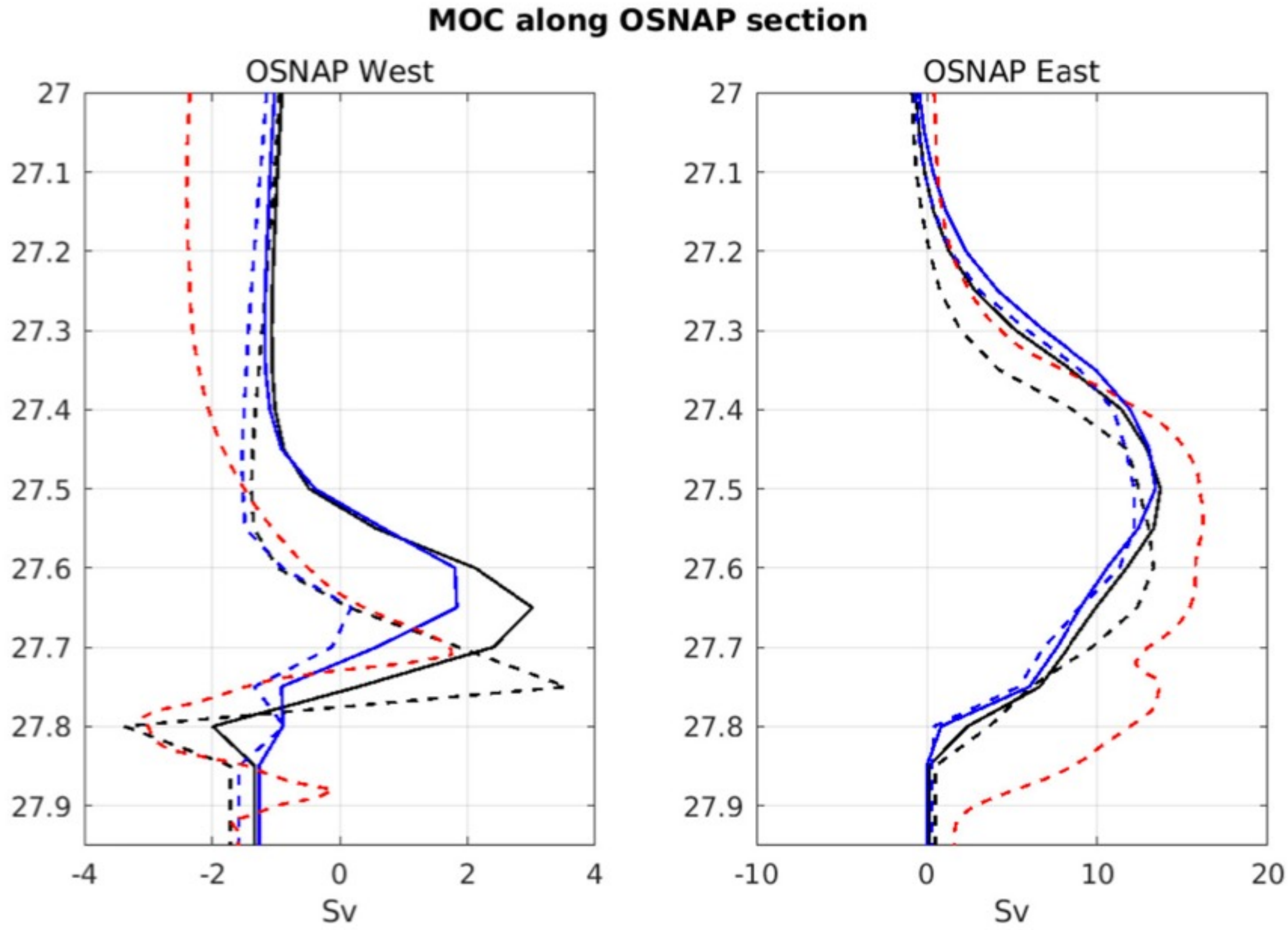


FIGURE 8 | MOC (in Sv) along the OSNAP array, west on the left and east on the right, computed in density (sigma 0, expressed in kg/m^3) space in the HR simulations. The thick black line stands for the average over the period 2004–2016 in control simulation, the thick blue line for the same average in the melting simulation. The dotted lines are showing the year 2015 in control (black), melting (blue), and observations (red) from Lozier et al. (2019).