Ocean response to a realistic Greenland Ice Sheet Melting in a climate model

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Photo: Steffen Olsen

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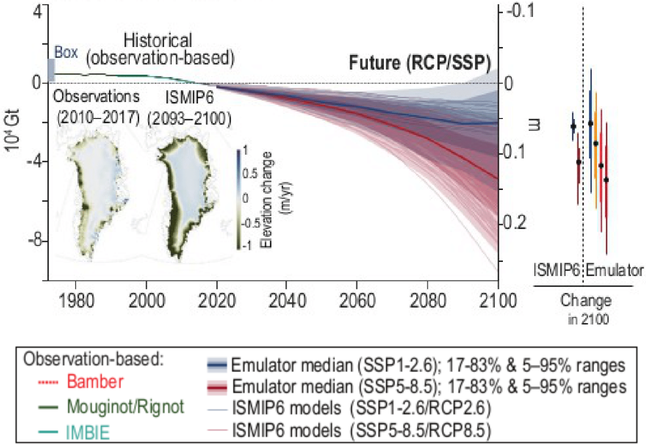
Context of the study

Recent and future change in Greenland ice sheet:



source: IPCC WGI 6th Assessment Report

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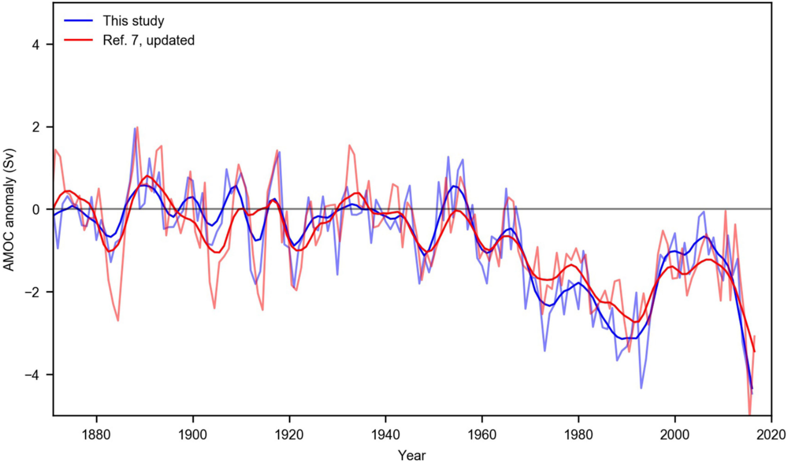
Context of the study

A possible slowing of the AMOC?



source: Caesar *et al.*, 2018

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The freshwater forcing experiment

Climate models can not afford an interactive ice sheet module
$\rightarrow$ we force the model externally

Méthodology:

- Disable the icebergs module in the climate model around Greenland
- Replace the runoff variable value with **a combination of reconstructed runoffs and iceberg** melting around Greenland
- Run a 10 member ensemble from 1920 to 2014 (*'Melting'* ensemble)
- Comparison with the control (*'Historical'*) 10 member ensemble

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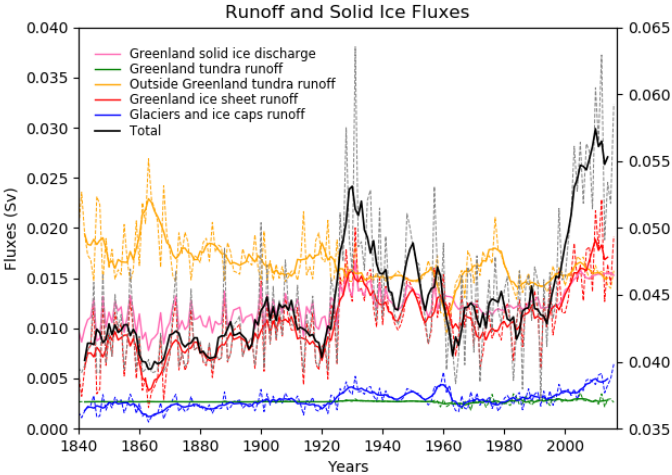
The freshwater fluxes dataset



Box and Colgan (2013): ice runoff from 1840 to 2012, annual values
Bamber *et. al*, 2018: all fluxes from 1958 to 2016, monthly values
→ **linear regression** to extend the fluxes in the past

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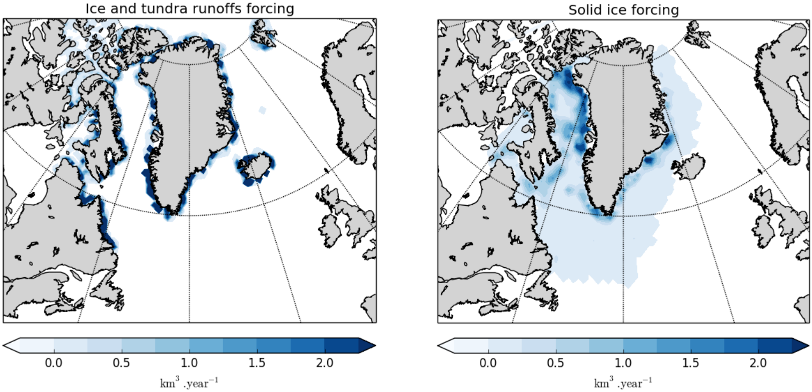
Freshwater fluxes spatial distribution



Spatial distribution of the freshwater fluxes forced around Greenland into the ocean (1920-2014 average). Satellite-based location of the icebergs from the Altiberg project and Mercator.

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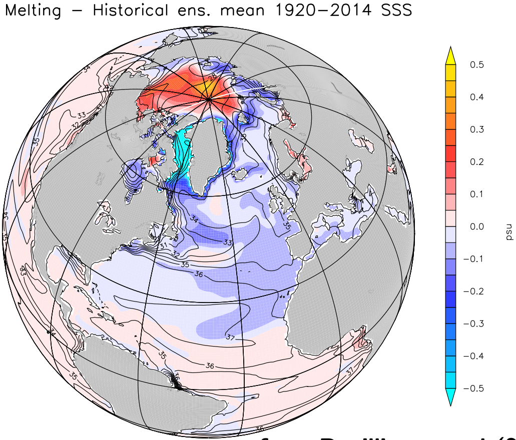
Modification of the sea surface salinity



from Devilliers et. al (2021)

- Higher salinity in the Artic may come from enhanced northward subsurface Atlantic waters (*Swingedouw et. al, 2015*)
- Wide freshening over the North Atlantic
  → increased sea ice cover

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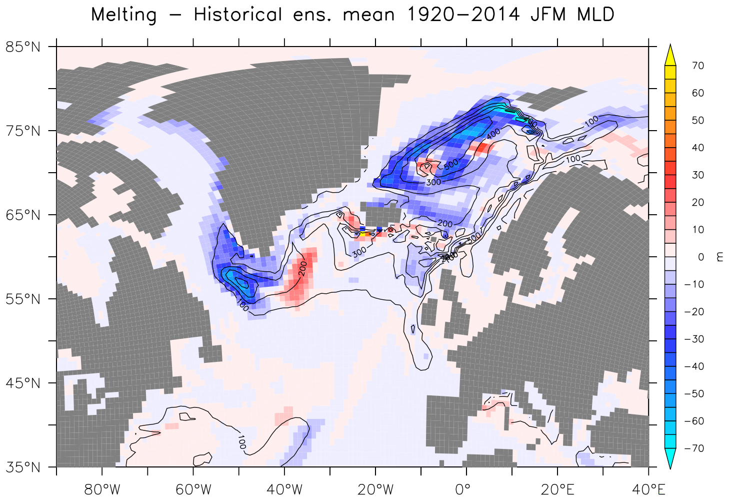
Changes in convection sites



Irminger Sea convection site is more active in the Melting ensemble.
Reduction of convective activity in the Labrador
and Nordic Seas.

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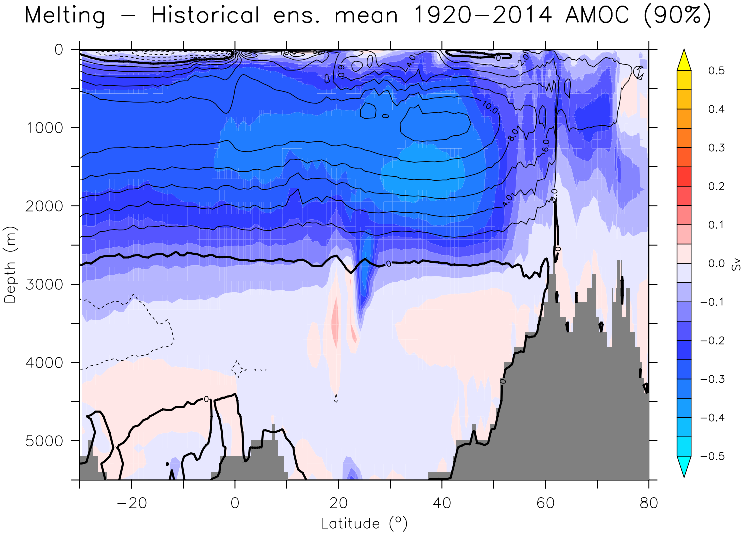
A slowing of the AMOC



Decrease up to 0.4 Sv the AMOC
over the period 1920-2014

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Similar experiment at a $1/24^\circ$ resolution

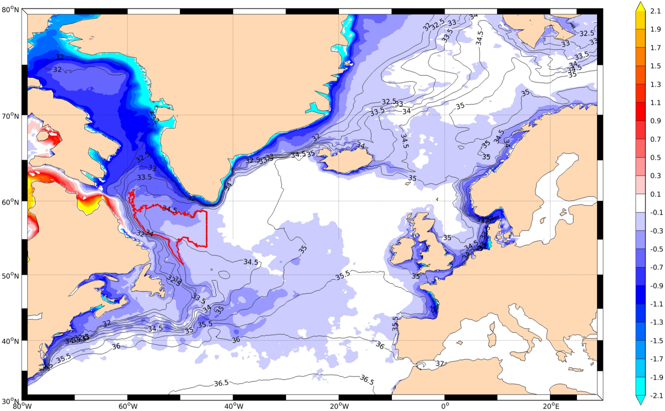
The same dataset is used with an ocean-only simulation at $1/24^\circ$ resolution in the Arctic-North Atlantic Ocean performed over the period 2004–2016 with the NEMO 3.6 model.

Article recently published in Frontiers, april 2022:
"AMOC Recent and Future Trends: A Crucial Role for Oceanic Resolution and Greenland Melting?"
doi:10.3389/fclim.2022.838310

On-line seminar upcoming soon:
https://blue-action.eu/training/climate-coffees
19 May 2022, 11:00-11:40 AM

Enhanced spread of freshwater towards the Labrador Sea

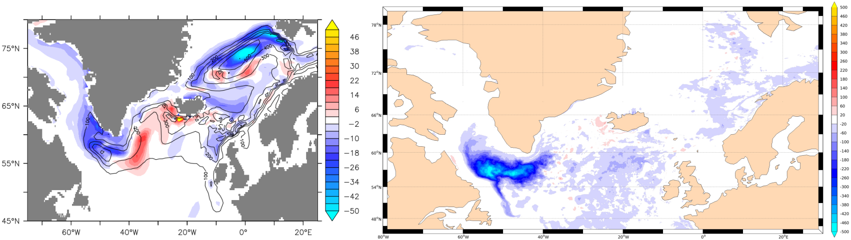
Melting - Historical SSS (psu) over 2004–2016



A more realistic transport of the freshwater released around the shelves provides, through eddies, a stronger lateral exchanges between the fine-scale boundary current and the convective basin in the Labrador Sea.

Convection reduced in the HR simulation

Melting - Historical JFM MLD in the two experiments



In the HR version, the MLD anomalies over the whole period exceed 300 m, which is about half of the mean state value.

AMOC (45°N) weakens by about **2 Sv** after only 13 years, far more strongly than what is found in the LR (CMIP6) model.

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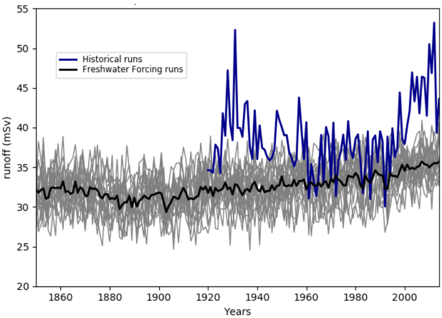
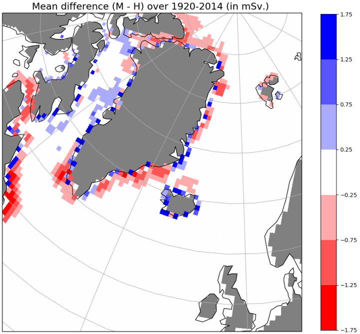
Amount of supplementary runoff fluxes

Comparison between freshwater forcing runs and historical runs





Max. diff. in runoff is: **17.7 mSv** and 5.5 mSv on average over 1920-2014 $\rightarrow$ we increase the runoff by about 16511 km^3 spread over the 95 years ($\simeq$ 5.5 mSv)

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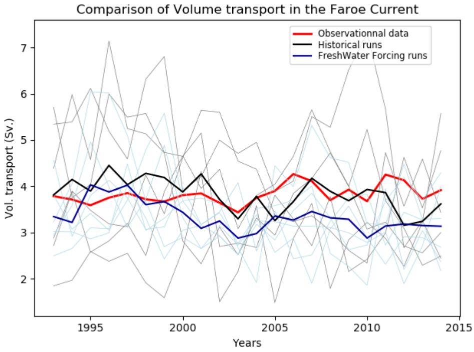
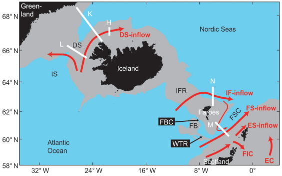
Zoom on the Faroe Current





Obs. data from Hansen, *et. al* (2015)

Can we improve the model trends in key section? Work in progress...

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Take home message

- Climate models usually do not include a realistic input of runoff and calving fluxes from Greenland and surrounding regions, so we force here the models externally.
- The supplementary freshwater introduced has a small but yet statistically significant impact on the convection sites of the North Atlantic and the Nordic seas.
- The low resolution seems to limit this impact due to unresolved key meso-scale processes $\longrightarrow$ new studies with HR models or Machine Learning solution are needed to assess properly the impact of the increasing meltwater fluxes.

Future work: EC-Earth3

- Develop the same set-up with EC-Earth3, focus on the salinity signal found in the Arctic with IPSL-CM6-LR
- Apply the freshwater forcing to EC-Earth3-HR (ORCA025) to investigate the impact of spatial resolution
- Use of Deep learning approaches to correct the freshwater fluxes trajectories

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Thank you for your attention!

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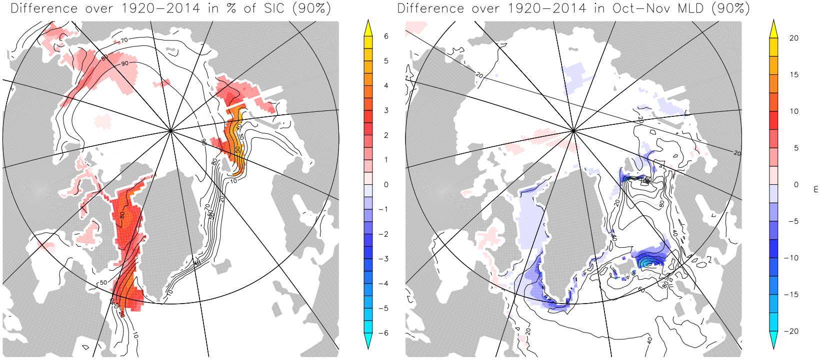
Impact on SIC and MLD with IPSL-CM6-LR



October-November MLD is lower in the Nordic and Labrador Seas which leads to an increase of SIC over the period 1920-2014 which goes up to the Barents sea

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Bibliographie

- **Bamber et al, 2018**: Land Ice Freshwater Budget of the Arctic and North Atlantic Oceans: 1. Data, Methods, and Results
- **Box and Colgan, 2013**: Greenland Ice Sheet Mass Balance Reconstruction. Part III: Marine Ice Loss and Total Mass Balance (1840–2010)
- **Caesar et al., 2018**: Observed fingerprint of a weakening Atlantic Ocean overturning circulation
- **Thornalley et al., 2018**: Anomalously weak Labrador Sea convection and Atlantic overturning during the past 150 years
- **Swingedouw et al., 2015**: Decadal fingerprints of freshwater discharge around Greenland in a multi-model ensemble

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