Impacts of the observed melting of Greenland ice sheet and Arctic land ice over the North Atlantic in a climate model

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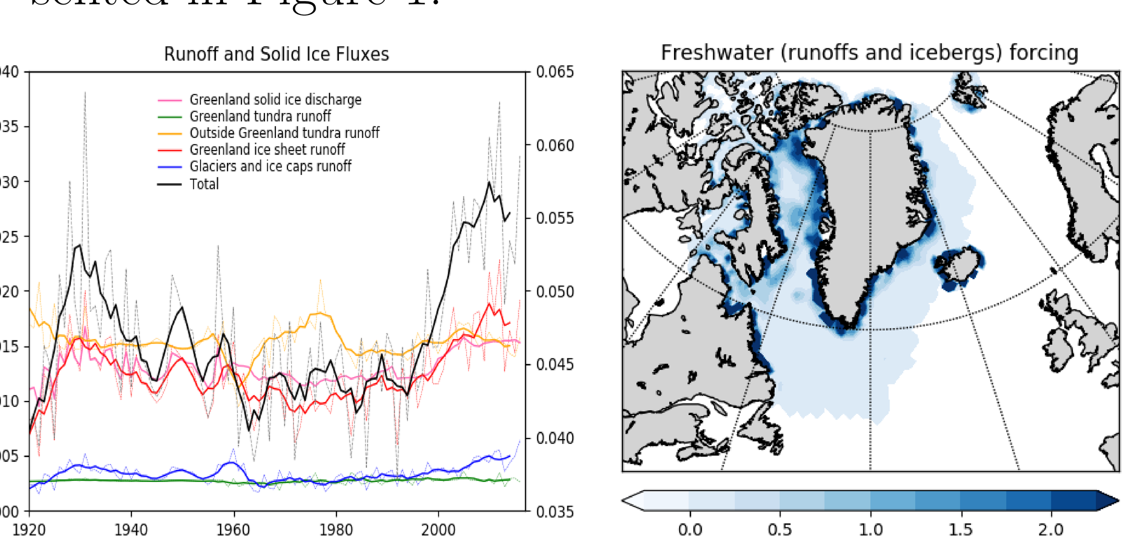
Introduction

Recent increase of surface melt and outlet glacier discharge from Greenland and surrounding glaciers and ice caps is changing the freshwater budget of the Arctic and sub-polar North Atlantic Oceans. Impact on the convection, with potential feedback on the strength of the Atlantic meridional overturning circulation (AMOC), which is showing signs of weakening ([1], [2]) is addressed. We compare two sets of five-member ensembles of historical runs from 1920 to 2014 with the coupled climate model IPSL-CM6-LR. One of the ensembles is forced with a realistic set of observational melting trends in order to account for its increase in the 1920s and the 1990s.

Methods

The freshwater release we use is based on a recent estimate from [3]. It is a combination of satellite observations and regional climate modelling. The tundra & ice runoff and solid ice component (icebergs included as liquid flux) are interpolated on the ORCA1 grid of the oceanic model (NEMO). The ALTIBERG project [4] spatial distribution of the North Atlantic icebergs is then applied to the solid ice component. Finally, the fluxes were extrapolated back in the past using a Greenland ice sheet mass budget closure over the 1840-2010 period [5]. Time series and spatial distribution of the fluxes are presented in Figure 1.



(a) Extended annual fluxes (b) Spatial distrib. (ORCA1)

Figure 1: Final freshwater fluxes dataset

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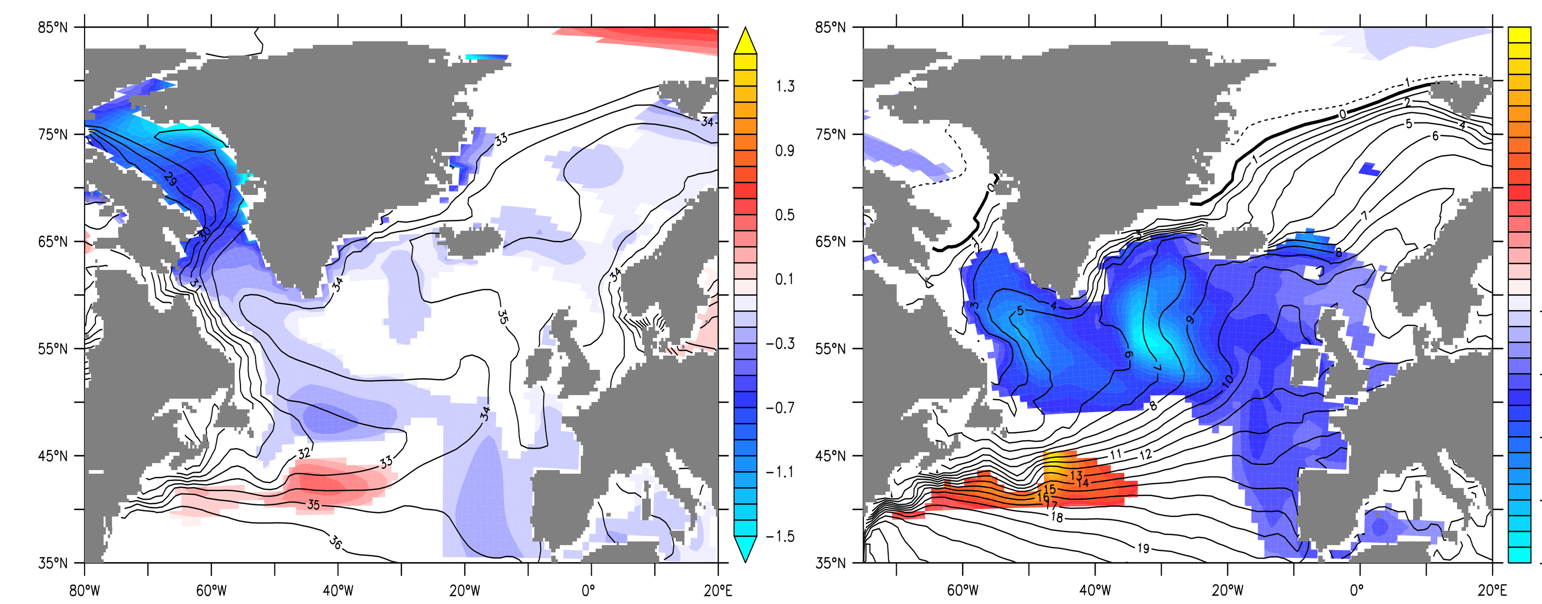
Freshwater fingerprint

Historical ensemble: 5 members run of the IPSL-CM6-LR model for the period 1920-2014 with transient forcing.
"Melting" ensemble: 5 members run for the same period, with icebergs and runoffs fluxes being overwritten over the area in Figure 1b.
Total forced fluxes are $\simeq$ 10 mSv higher annually in the Melting ensemble in the 1920s and 2000s.



(a) SSS difference (b) SST difference

Figure 3: Melting - Historical ens. mean difference (95 % signif.), averaged over 1984-2014. Contour lines are the Historical ens. mean levels.

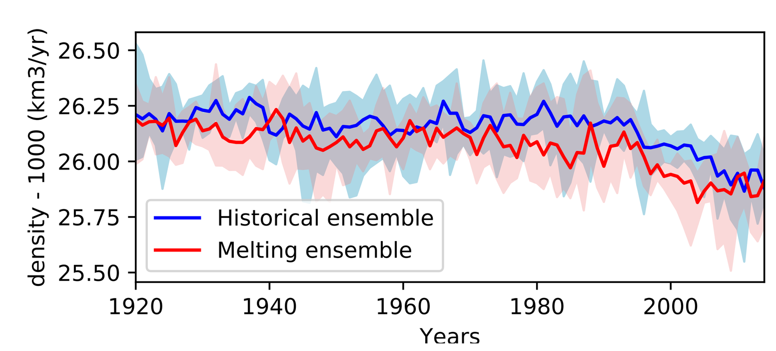


Figure 2: Surface density (45-80°N, 70°W-10°E) time series for the 2 ens. means.

The additional freshwater leads to a decrease of salinity in Baffin bay (Fig. 3a). The anomaly spreads to the South-East as the freshwater leaks towards the subtropical gyre causing a cooling of the surface waters (Fig. 3b) and an increase of the sea ice cover (Fig. 4) up to the Barents sea.

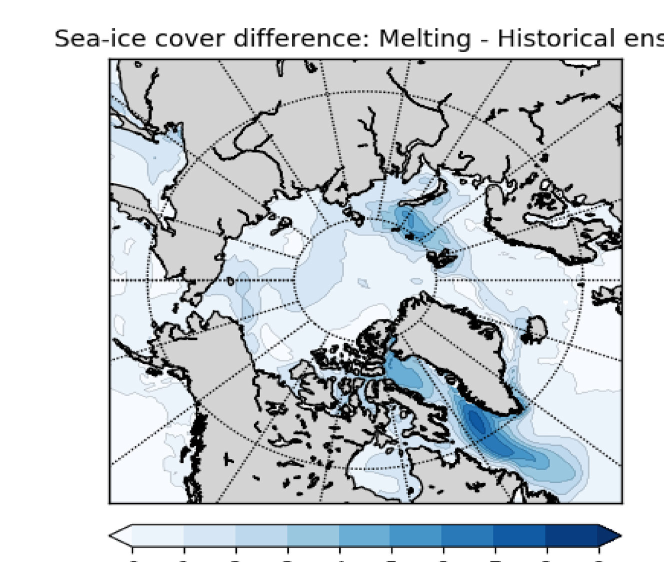


Figure 4: Sea Ice cover difference (1984-2014)

Convection and overturning circulation

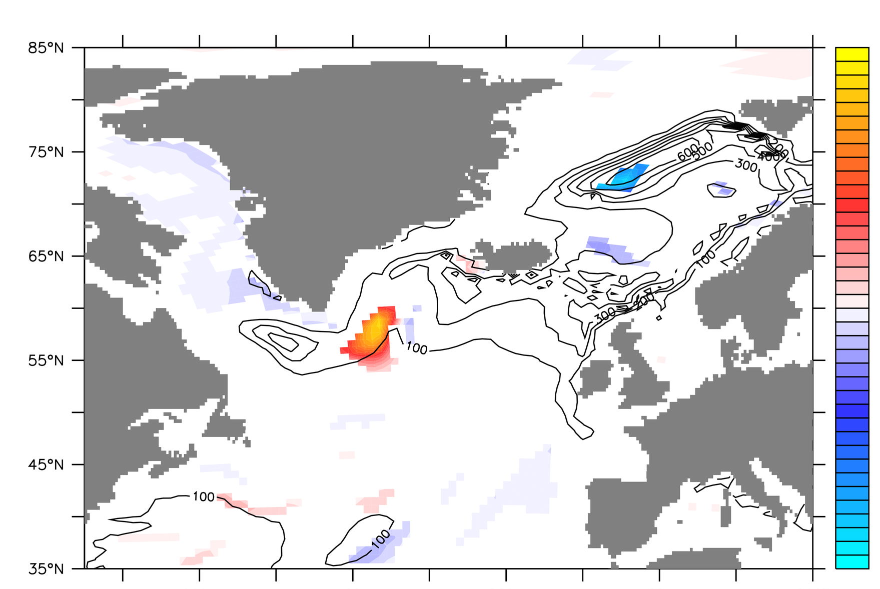


Figure 5: winter(FMA) MLD difference (95 % signif.) between the 2 ens. means, 1984-2014 averaged. Contour lines are the Historical ens. mean levels.

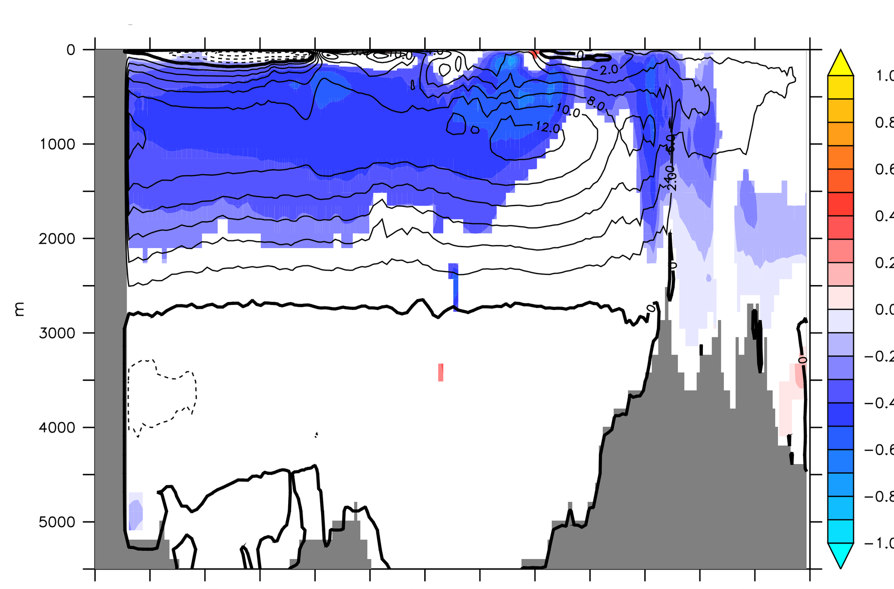


Figure 6: Atlantic Meridional Streamfuntion difference (95 % signif.) between the 2 ens. means, 1984-2014 averaged. Contour lines are the Historical ens. mean levels.

In 4 members out of 5 the convection in enhanced in the Irminger sea and reduced in the Norwegian sea.
The Atlantic meridional overturning circulation is slowing by a maximum of 0.5 Sv.

[1] L. Caesar et al., *Nature*, 556:191–196, 2018.
[2] David J. R. Thornalley et al., *Nature*, 556:227–230, 2018.
[3] J. L. Bamber et al., *Journal of Geophysical Research: Oceans*, 123(3):1827–1837, 2018.
[4] J. Tournadre et al., *Journal of Geophysical Research: Oceans*, 121(1):327–349, 2015.
[5] J. E. Box and W. Colgan, *Journal of Climate*, 26(18):6990–7002, 2013.
[6] A. R. Friedman et al., *Geophysical Research Letters*, 44(4):1866–1876, 2017.

Photography encouraged

Long-term trends improvement

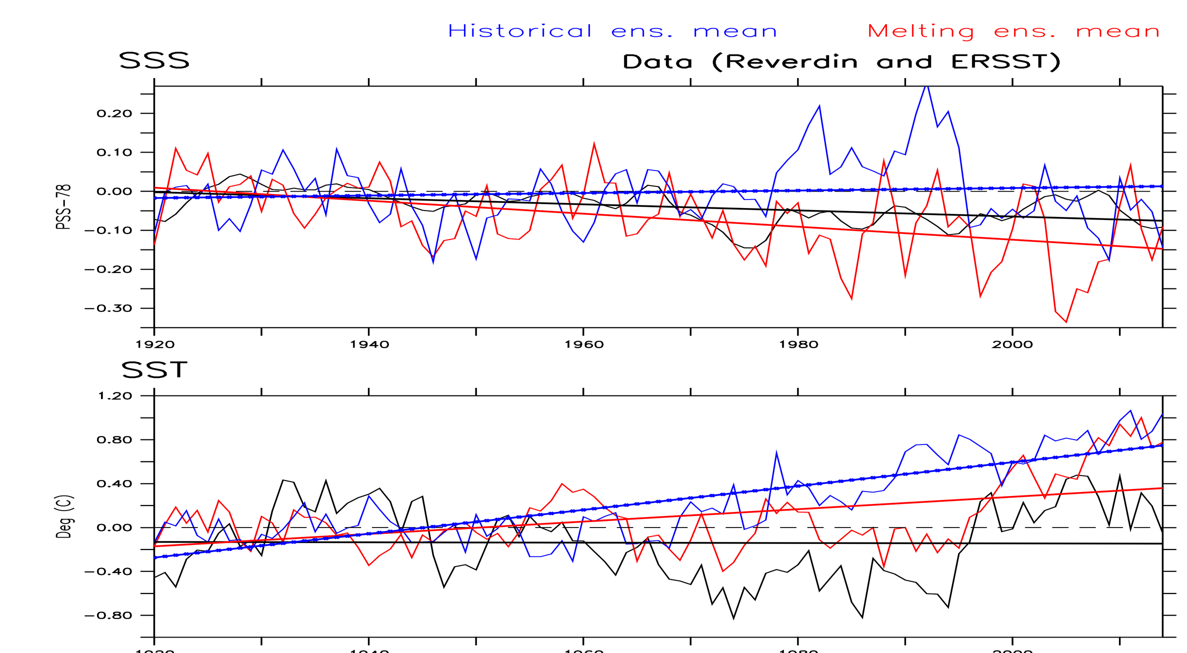
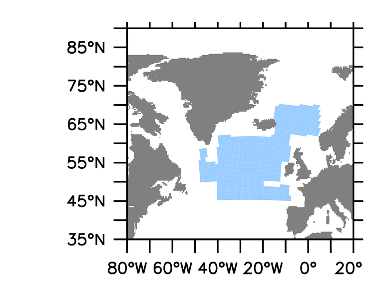


Figure 7: SSS and SST anomalies trends and time series

SSS and SST anomalies (ref: 1920-1940) are compared in the blue zone (side figure) for both ensemble means to observations (Fig. 7).



DATA: an in situ SSS data set from [6] (denoted "Reverdin") and ERSST.v4.

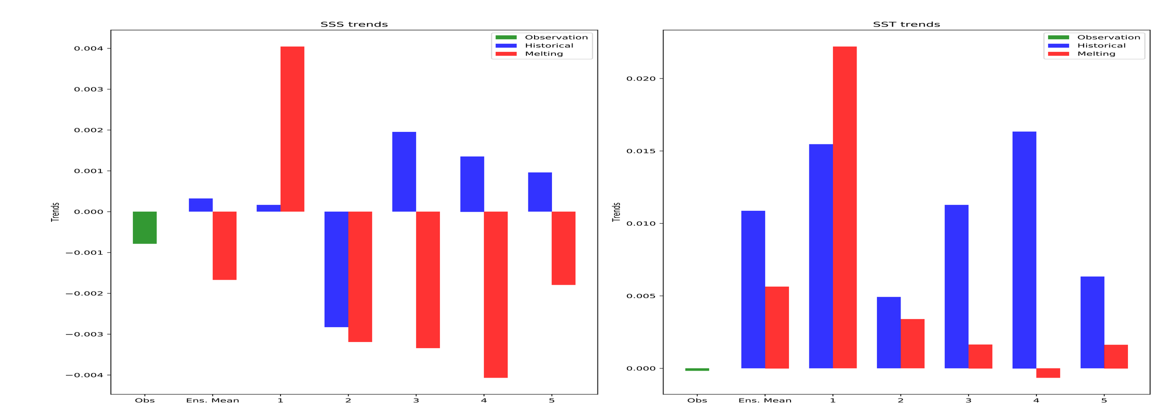


Figure 8: SSS and SST anomalies trends

Figure 8 shows that Melting ens. mean trends are closer to observations than Historical, in 3 out of 5 members for the SSS, 4 out of 5 for the SST.

Conclusion and future work

Including a realistic Greenland and surrounding land ice melting from the 1920s **improves the simulated salinity and temperature trends in the North Atlantic under historical conditions**. Impacts on oceanic convection and AMOC through density modification are observed in the Melting ensemble. Extrapolation of the future melting trend up to 2100 should bring relevant information on North Atlantic convection and potential additional slowdown of the AMOC by Greenland melting.

Acknowledgements

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