How does Anthropogenic Aerosol drive an increase in AMOC in CMIP6 historical simulations?

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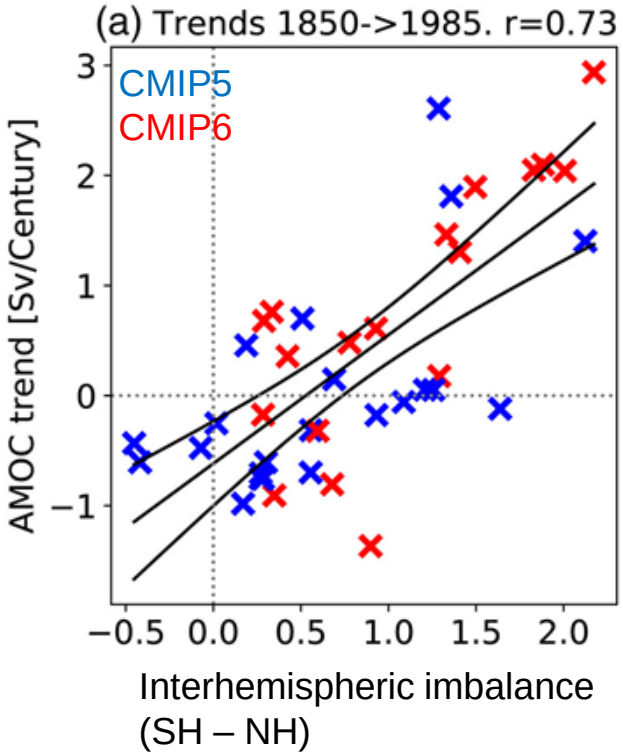
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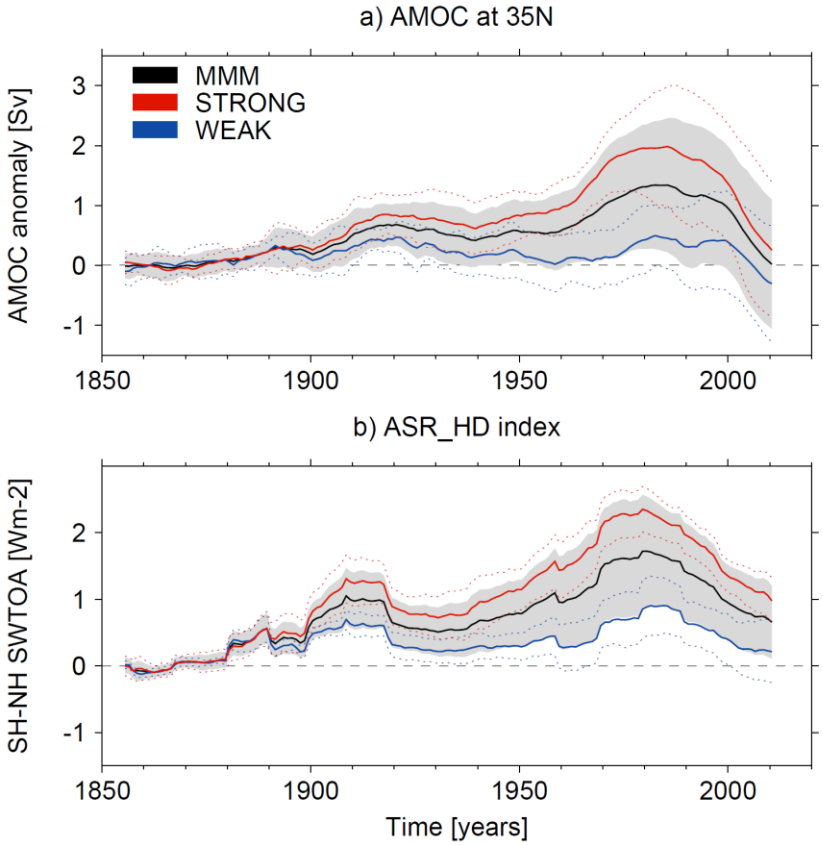
Motivation



- Historically forced AMOC trends in CMIP6 and CMIP5 are *largely* proportional to forced change in interhemispheric energy imbalance (Menary et al, 2020)
- Uncertainty over 1850-1985 is largely due to Anthropogenic Aerosol forcing
- But how is the AMOC affected by the forcing?
- Menary et al, 2013 suggest that evaporation controlled salinity anomalies dominate
- Hassan et al, 2021, argue changes in downwelling shortwave and wind-forced turbulent heat fluxes dominate…

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Split CMIP ensemble into sub-ensembles

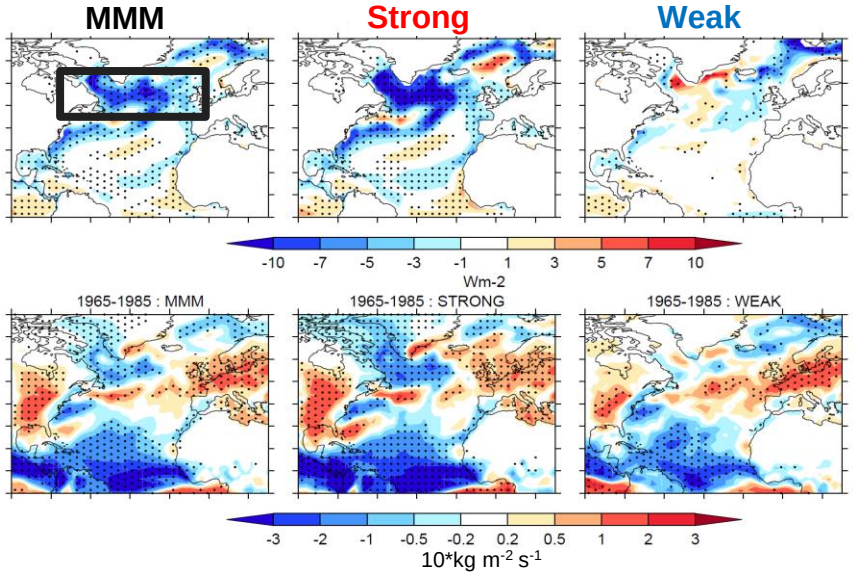


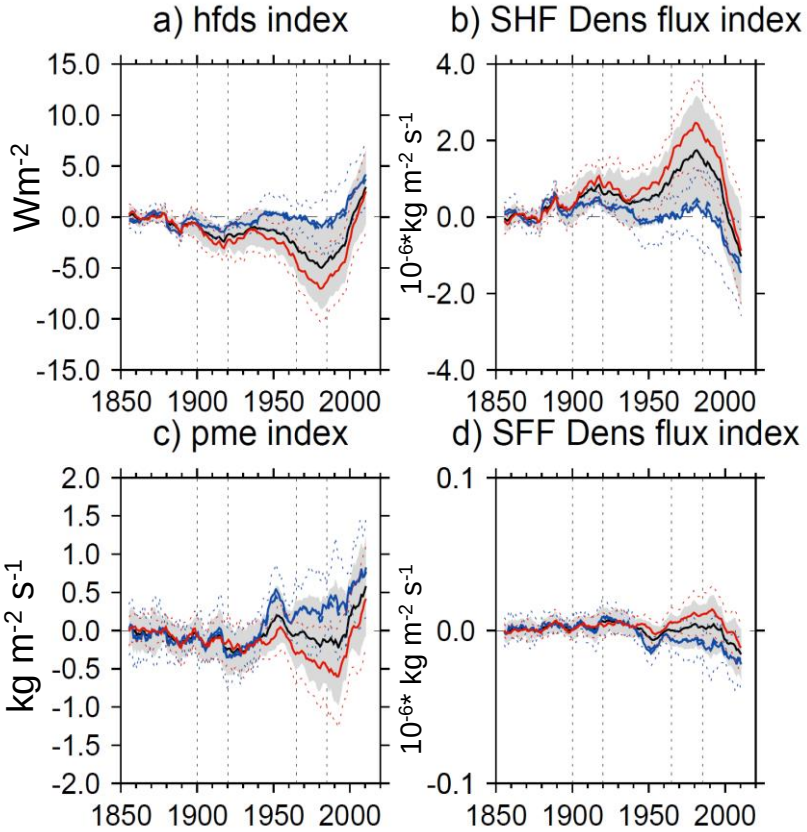
- Split CMIP6 ensemble based on ASR_HD index (10 'strong' vs 8 'weak')
- Increase in AMOC to 1985 is only seen in the strong models, which have a substantially larger increase in ASR_HD
- weak models have little change in AMOC, and a much smaller change in ASR_HD

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Surface density flux

Total surface heat flux (hfds, top) and precip minus evaporation (pme, bottom) anomaly (1965-1985 minus 1850-1879)

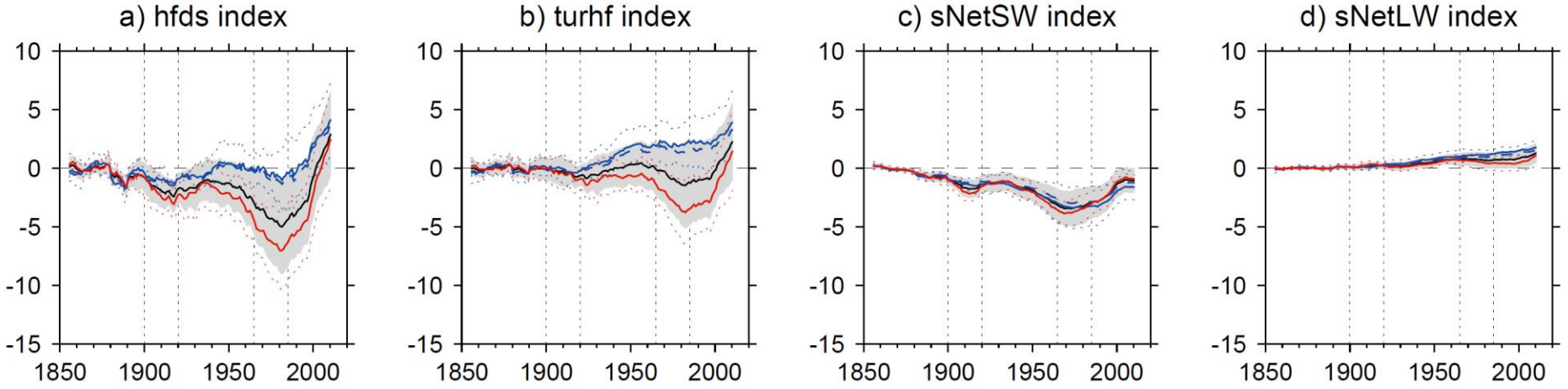




- Heat flux dominates both the total density flux and difference between strong and weak models (*note different y-axis*)
- AMOC changes is a result of SPNA heat loss!
- **What dominates heat fluxes changes?**

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Subpolar surface heat budget



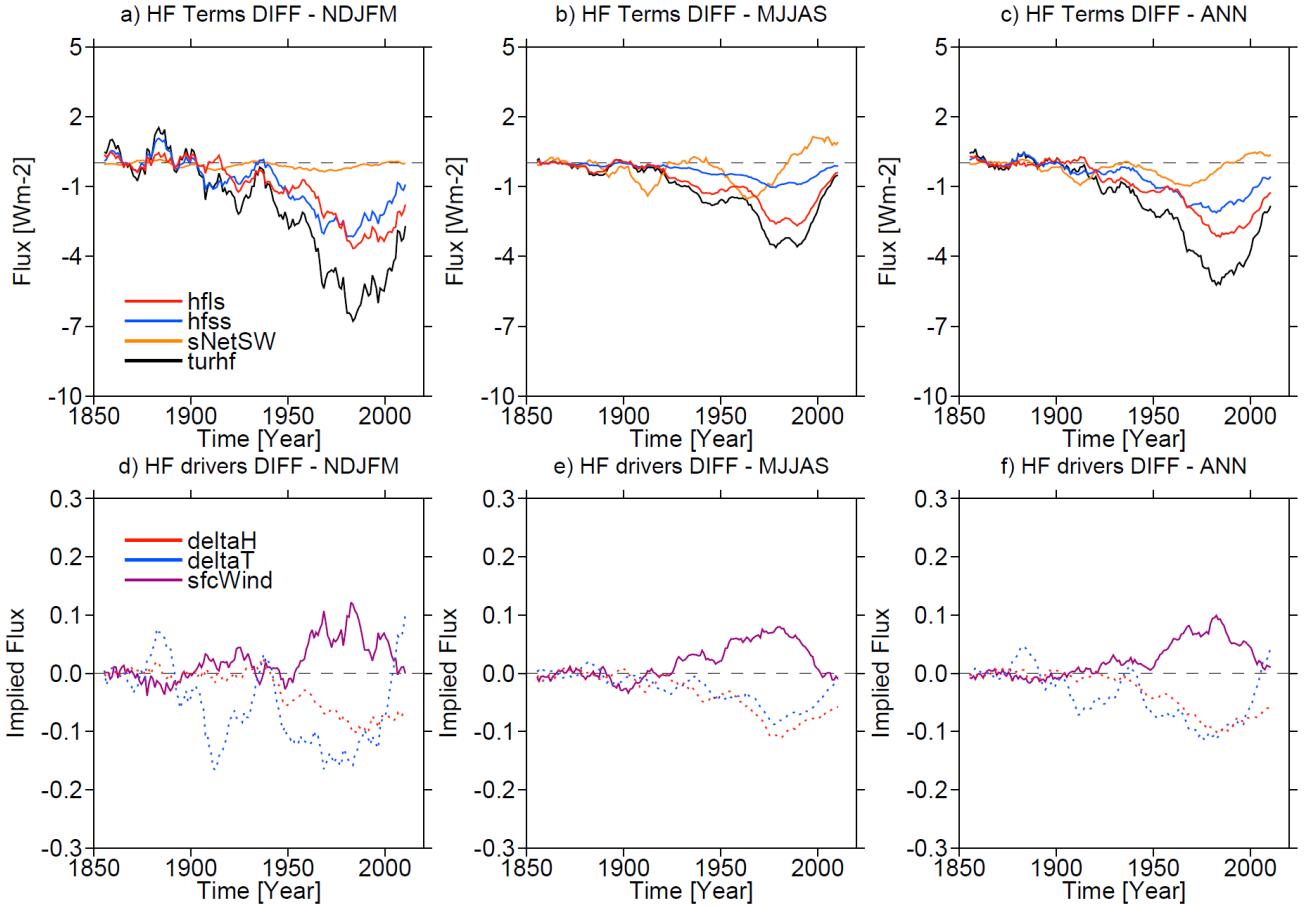
- Net shortwave contributes significantly to the total heat loss (hfds) but the changes are very similar between **strong** and **weak** models
- Net shortwave **cannot** explain difference in AMOC between models – although still likely contributes to delaying AMOC weakening in **weak**.
- *Turbulent heat fluxes explain the spread in the models AMOC*

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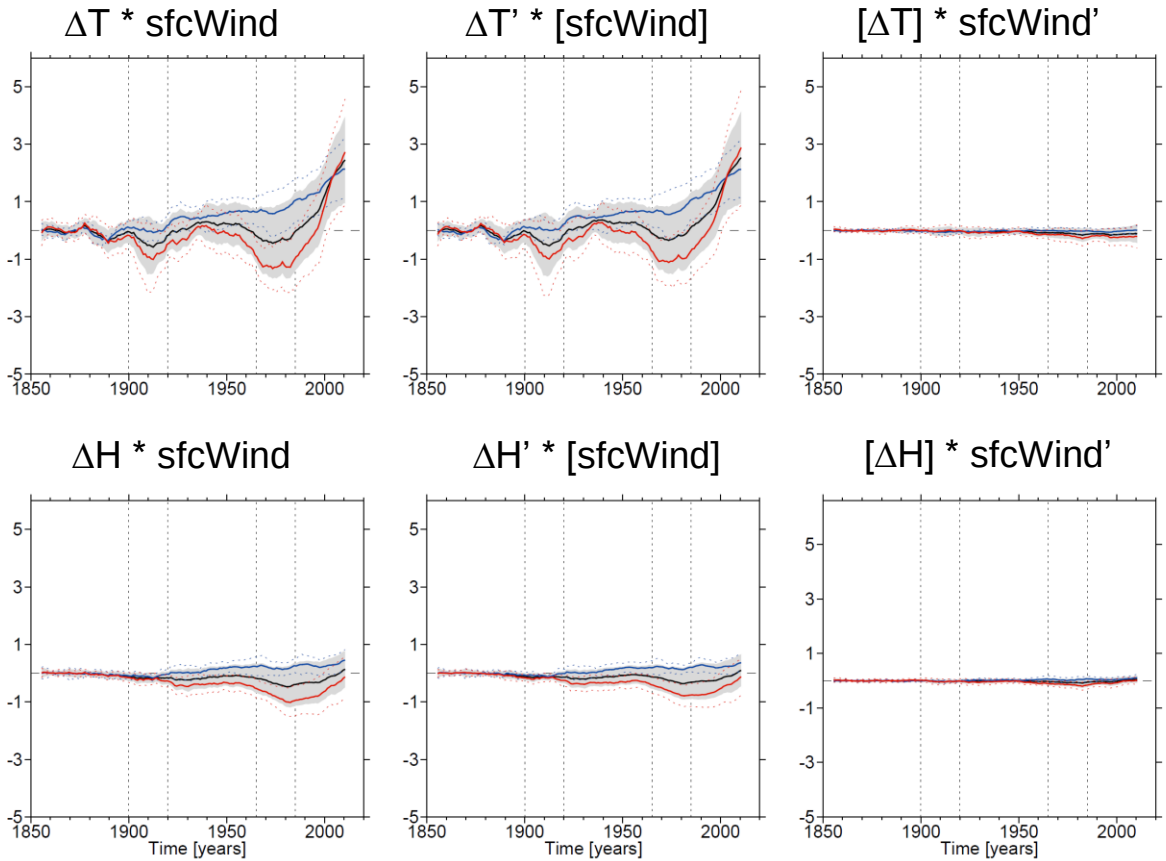
Surface heat flux *differences* (strong – weak)

- Heat loss seasonally dependent
- Heat loss largest in winter due to sensible (hfss) and latent (hfls) heat fluxes
- Turbulent HF ∝ air-sea contrasts in temperature (ΔT) and humidity (ΔH), and wind (sfcWind).

- **What term dominates?**



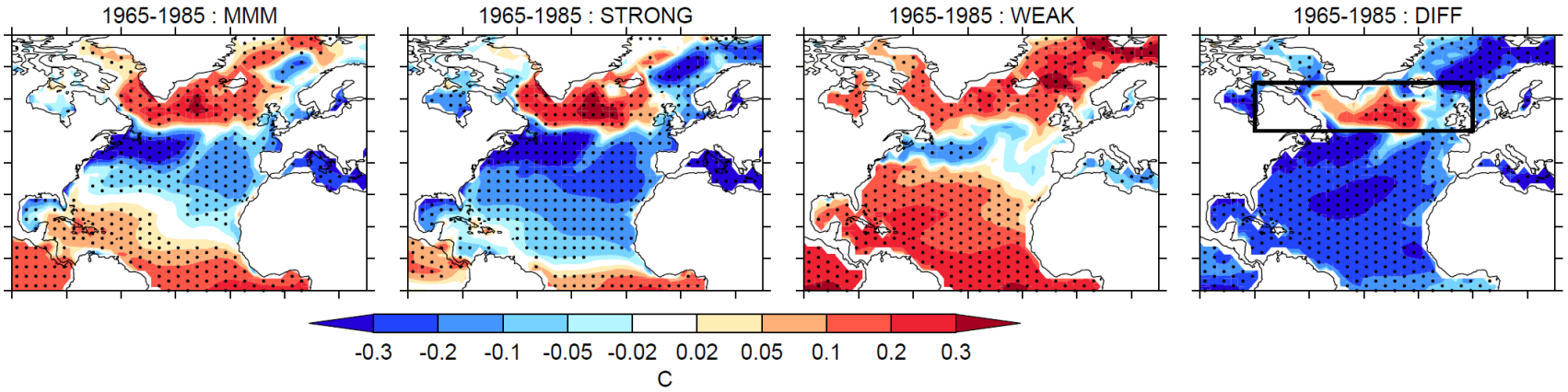
Drivers of turbulent heat flux



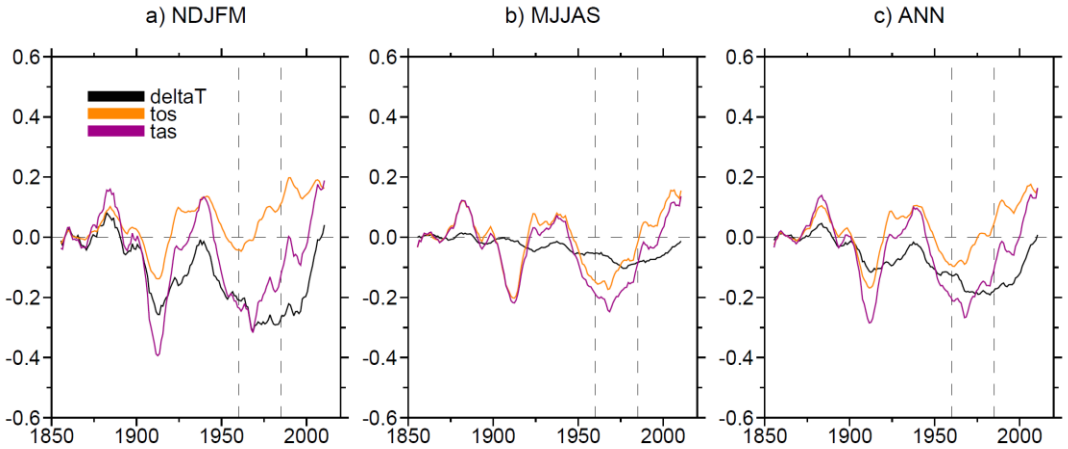
- Linearly decompose sensible and latent heat flux terms to explore role of anomalies (') and mean ([]) differences
- Turbulent HF driven by anomalous thermodynamic differences at air-sea interface
- Surface wind anomalies play a negligible role

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Feedback on DeltaT from AMOC spinup



- Subpolar North Atlantic warms in Strong models – consistent with AMOC increase
- Thus, subpolar warming increases ΔT → more cooling..
- Positive feedback on AMOC? (*makes causality challenging!*)



Summary and conclusions

The externally forced AMOC increase in CMIP6 from 1850-1985 is consistent with the external forcing of subpolar buoyancy fluxes.

- Downwelling shortwave plays little role in explaining the spread in forced AMOC changes, instead turbulent heat fluxes dominate the buoyancy forcing of the AMOC.
- Turbulent heat flux is driven by the thermodynamic differences at the air-sea interface (i.e. air temperature *minus* sea surface temperature)
- There is a significant atmospheric circulation response, but it is small and wind stress changes play little role in the forced SPNA turbulent heat flux and, hence, AMOC response.
- Spinup of the AMOC warms the subpolar North Atlantic and acts as a positive feedback on the heat-loss (and AMOC?).

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