How does anthropogenic aerosol forcing drive a strengthening of the AMOC in CMIP6 historical simulations?

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1. Background

- CMIP6 historical simulations show an increase in AMOC from 1850-1985 which wasn't present in CMIP5 due to stronger Anthropogenic Aerosol (AA) forcing (Menary et al, 2020, GRL).
- However, it is still not clear how AA forcing drives the AMOC, with both salinity and heat flux driven mechanisms discussed previously.

2. AMOC in CMIP6 historical runs, and stratifying into strong and weak Aerosol forcing

Use changes in interhemispheric imbalances in absorbed solar radiation (ASR_HD) to stratify models between **strong** and **weak** Anthropogenic Aerosol (AA) forcing.

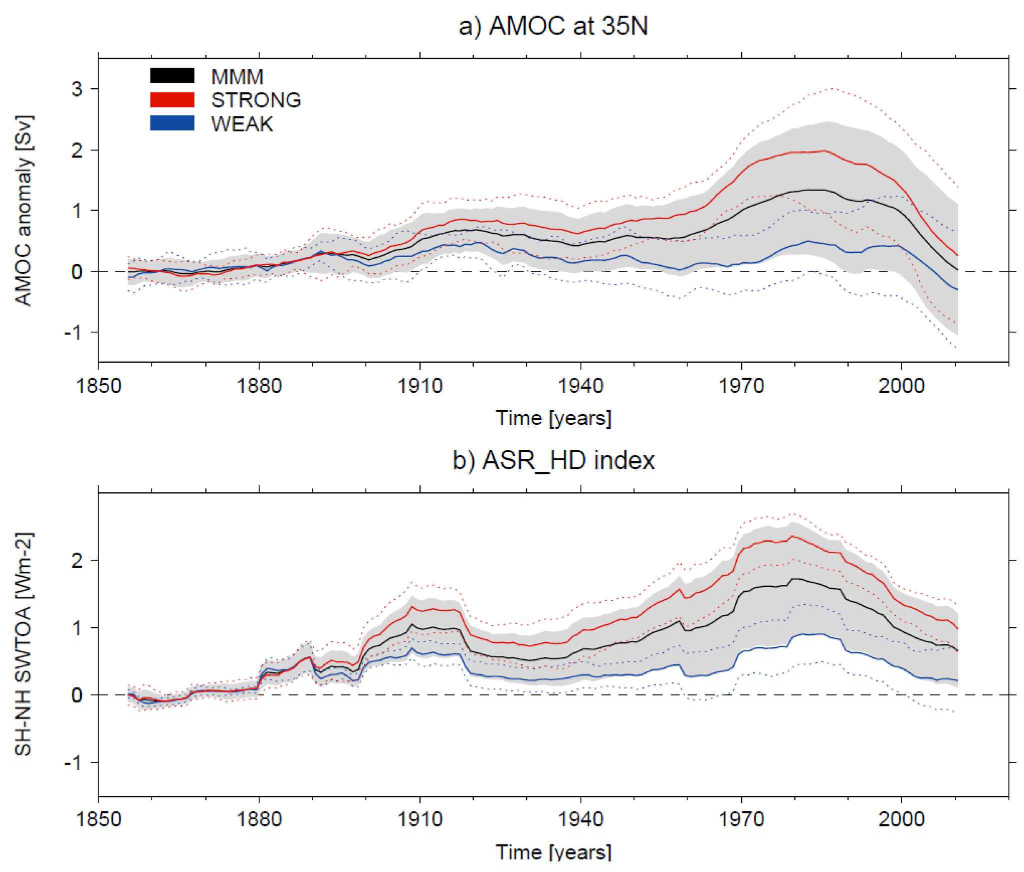


***Figure 1:** shows a) AMOC anomalies and b) ASR_HD anomalies for the multi-model mean (MMM), and strong and weak sub- ensembles. Anomalies are relative to 1850-1879) and grey shading and thin lines show the 1σ spread*

3. Surface forcing of AMOC

- Surface heat fluxes over the subpolar North Atlantic (fig 2) dominate surface density flux and also explain the spread in AMOC response.

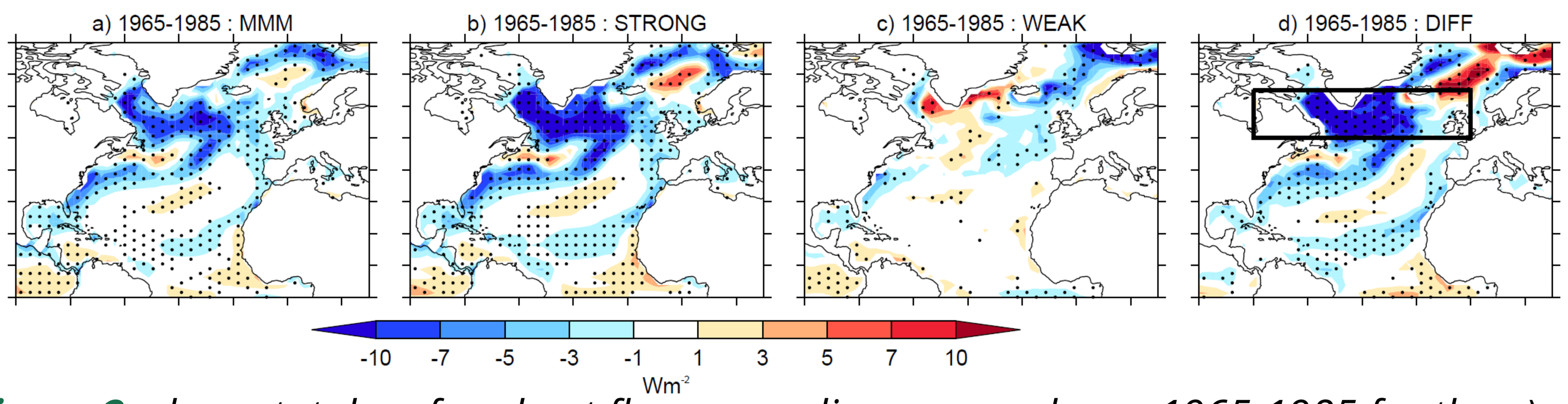


***Figure 2:** shows total surface heat flux anomalies averaged over 1965-1985 for the a) **MMM**, b) **strong** and c) **weak** ensembles. D) shows b-c. Anomalies are relative to 1850-1879. Stippling shows significance.*

- Spread in heat fluxes is dominated by turbulent heat fluxes and not solar (fig 3). AA forcing drives AMOC indirectly.
- Although there is an atmospheric circulation response to AA – turbulent heat fluxes appear to be primarily dominated by changes in surface temperatures and humidity (fig4).

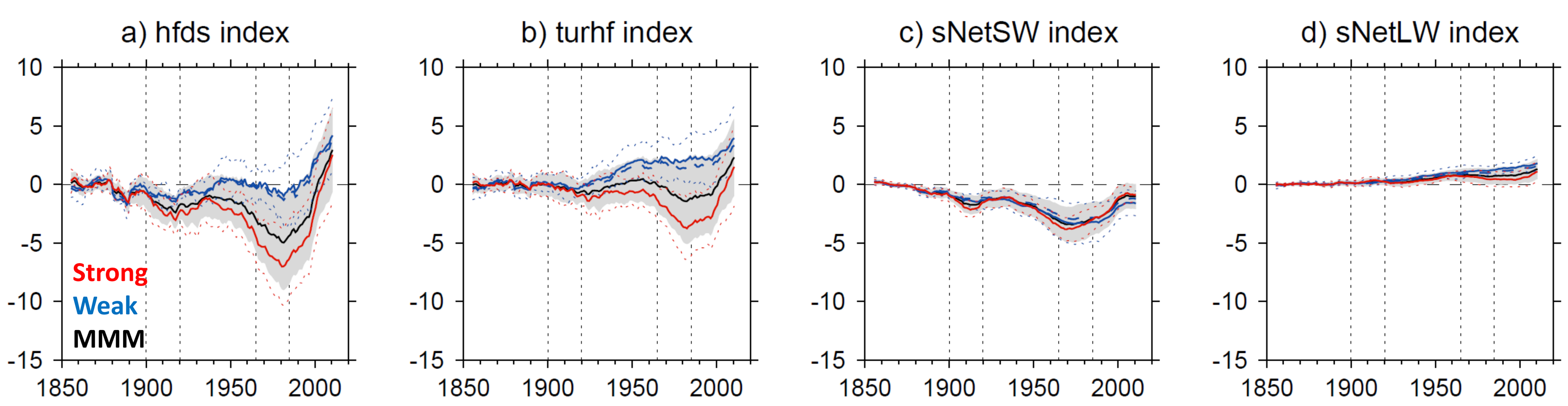
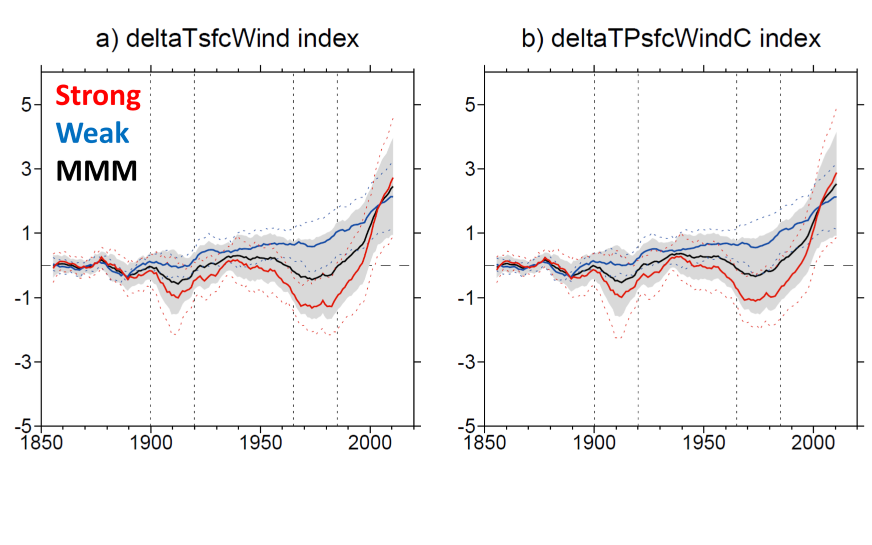


***Figure 3:** shows total surface heat flux anomalies averaged over the subpolar North Atlantic (45-65N) for the a) total heat flux, b) turbulent heat fluxes, c) net solar, and d) net longwave. Anomalies are relative to 1850-1879.*

***Figure 4:** shows a) anomalies of air-sea temperature contrast (deltaT) * surface wind speed. b) shows the same but now with anomalous deltaT and climatological wind speed*



Summary

- AMOC in CMIP6 historical simulations increases over 1850-1985 due to Anthropogenic Aerosol forcing – but there is a large diversity of responses (0 – 3 Sv).
- Increased turbulent heat flux cooling, not solar, dominates surface forcing of AMOC.
- Turbulent heat fluxes are largely due to a cooler and dryer atmosphere – and appear consistent with cold air advection from continental regions.
- Models with strong changes in AMOC have too large a cooling over many regions over the Northern Hemisphere. Suggests AMOC response is to large?

4. Continental Origins of AMOC signal?

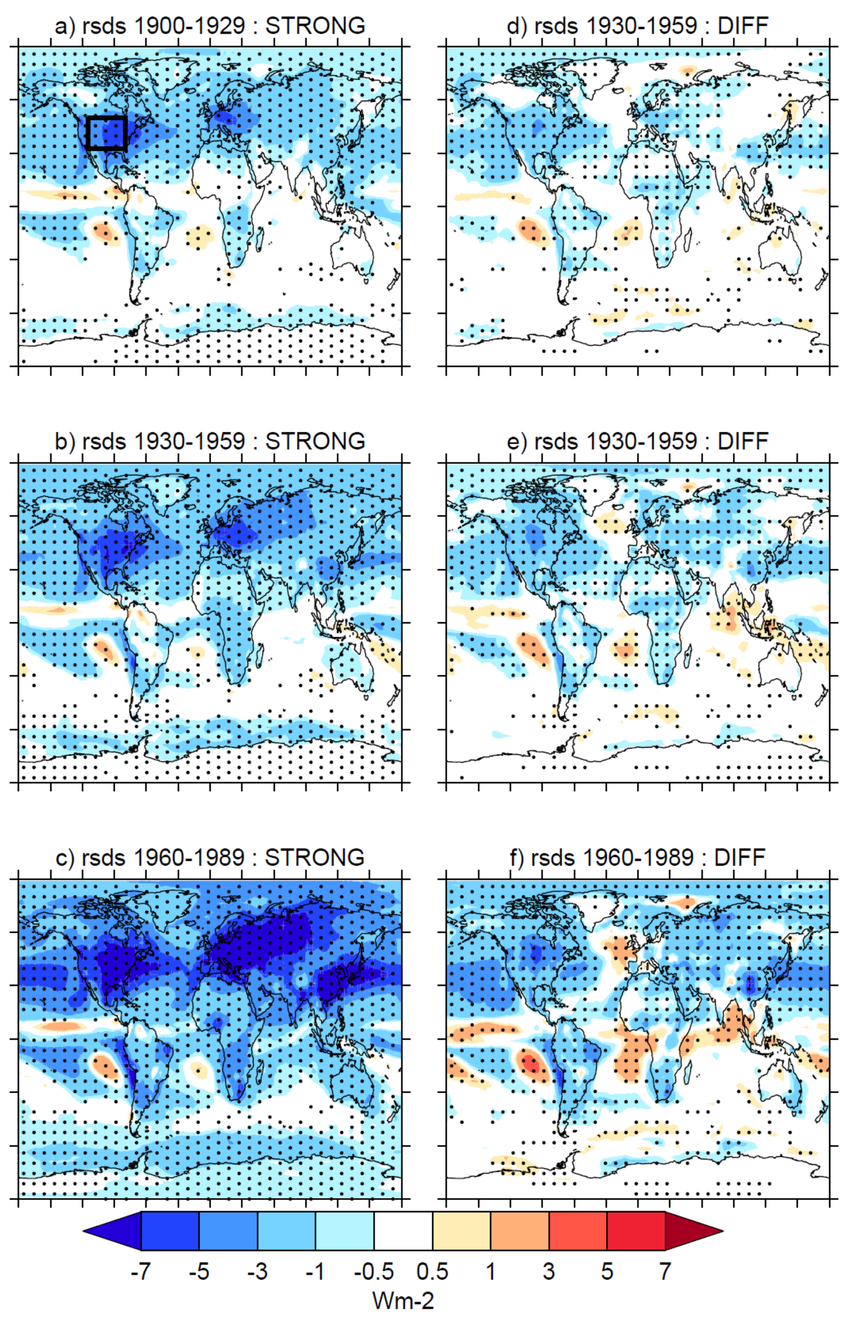


***Figure 5:** shows anomalies in downwelling surface shortwave (rsds) in **strong** models (left) and the **strong – weak** (right). All anomalies relative to 1850-1879 and stippling shows where anomalies are significant.*

- Main difference in downwelling shortwave (rsds) is over continents (fig 5), especially North America.
- Subpolar cooling consistent with cold dry air being advected from the continents?
- Cooling over North America too large in strong models (fig 6) – AMOC response too strong?

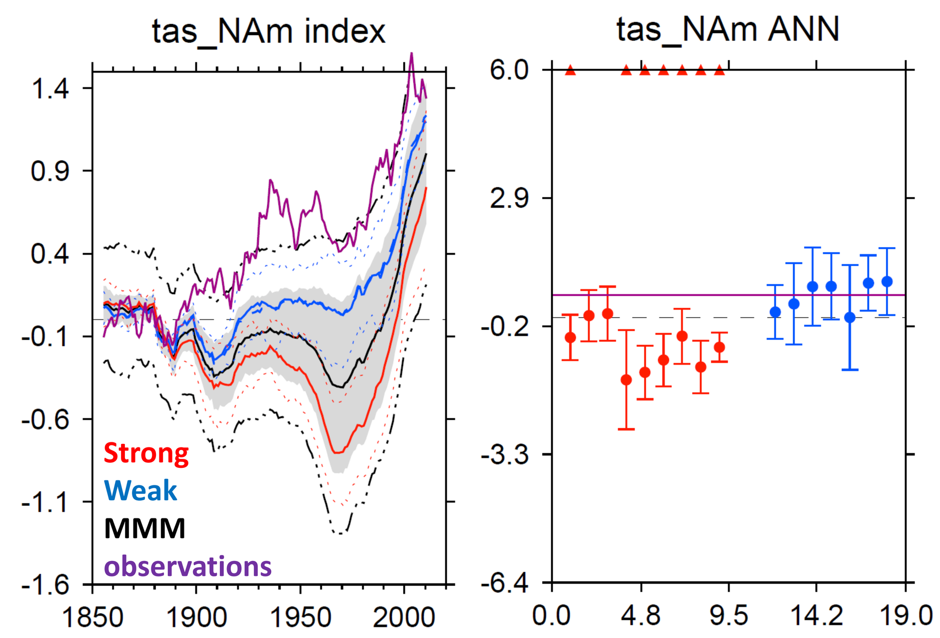


***Figure 6:** left shows anomalies of North American Surface temperature in the **MMM**, **strong** and **weak** ensembles as well as **observations** (BEST). Right shows spread of linear trends computed over 1900-1980 in individual members of each model compared to observations. Triangles indicate where observations lie outside 90% confidence interval based on individual members*

5. Feedbacks that amplify AMOC response

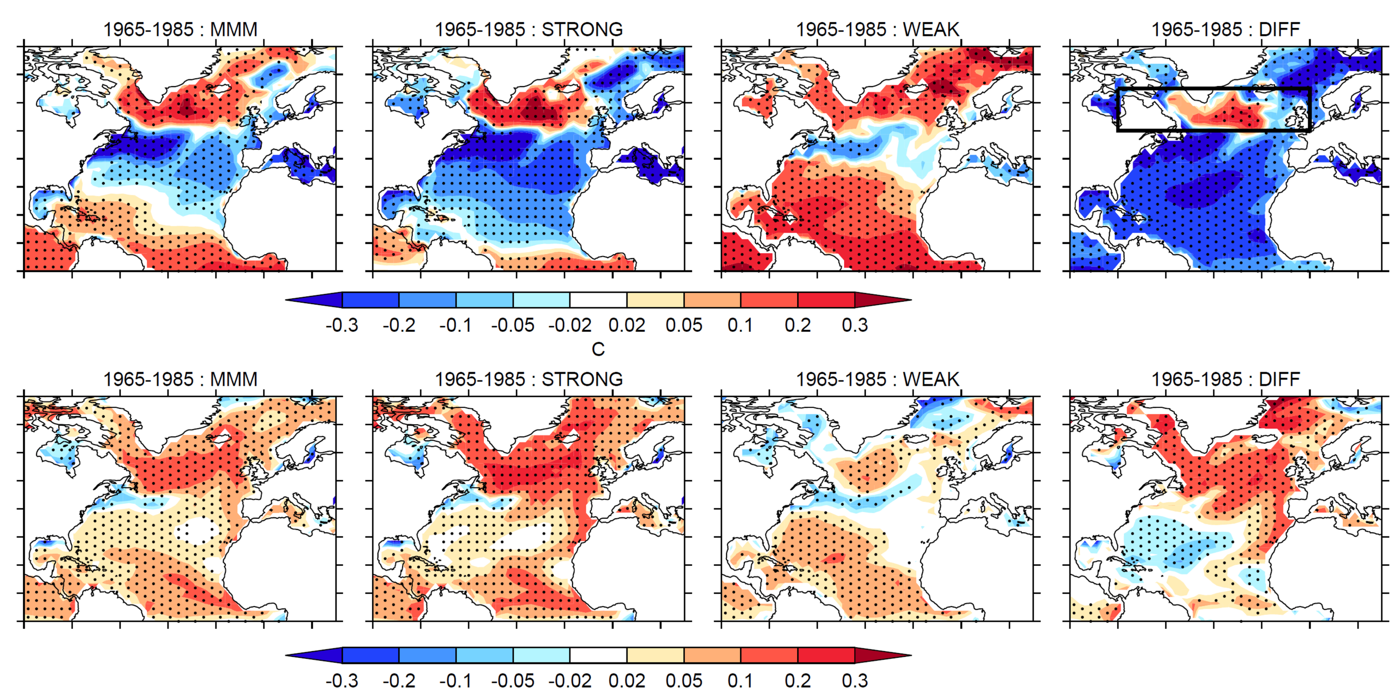


***Figure 7:** anomalies in surface temperature (tos) and surface salinity (sos) for the **MMM**, **strong**, and **weak** models, and the difference (**strong – weak**). All anomalies relative to 1850-1879 and stippling shows where anomalies are significant.*

- Both surface temperature (tos) and surface salinity (sos) increase in strong models relative to weak and are consistent with the strengthened AMOC.
- They both act as positive feedbacks on AMOC via increased turbulent heat flux cooling (tos) and by increasing surface density (sos).

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