EGU22-7698
https://doi.org/10.5194/egusphere-egu22-7698
EGU General Assembly 2022

The challenge of reconciling in-situ observations, instrumental and paleo reconstructions, and climate model simulations of the AMOC in the 20th century

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The recent IPCC AR6 report highlighted that, in contrast to ocean variables such as sea level and ocean heat content, where predicted and simulated rises due to anthropogenic climate change are being borne out by observations, the Atlantic Meridional Overturning Circulation (AMOC) has not conclusively shown a predicted decline and that, in fact, contradictions remain between observations and simulations through the 20th century.

The AMOC is at its weakest in 1000 years based on a compilation of paleo and instrumental proxies (Caesar et al. 2021). However, a reconstruction based on in-situ hydrographic profiles and informed by AMOC variability derived from the RAPID array shows no decline in the past 30 years (Worthington et al. 2021). Here, we show that there is no contradiction between these two results: when taken with the appropriate lag, the in-situ reconstruction matches with sea surface temperature (SST) reconstructions and the pattern of paleo proxies.

Convergence is evident in observations and reconstructions of the AMOC since the 1990s but what of prior to this? Instrumental reconstructions based on SSTs show a decline in the AMOC in the mid-20th century. The impact of the AMOC on SSTs is significant, especially on long timescales, but is not the only factor impacting SSTs. Alternative explanations for the mid 20th century cooling of Atlantic SSTs are that the cooling is linked with sulphate aerosol emission (Menary et al. 2020). This surface cooling may have led to a strengthening AMOC—the converse relationship to SST-based AMOC proxies.

We conclude by considering the challenges of instrumental-based reconstructions of the AMOC and potential avenues for reconciliation of outstanding contradictions to settle a baseline from which to observe the future AMOC slowdown that is near-universally predicted by climate models.

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