Multi-model analysis of the effect of future reductions in Short-Lived Climate Forcers on the North Atlantic Circulation

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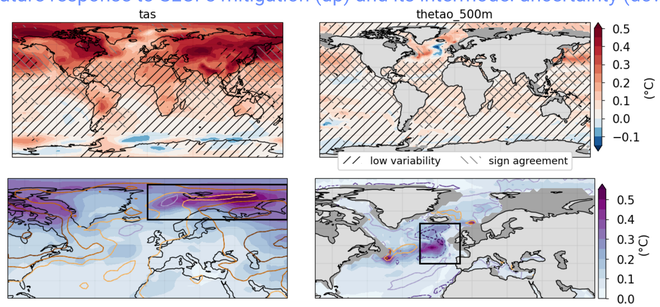
RESEARCH QUESTION

Short-Lived Climate Forcers (SLCFs) are chemically and physically reactive compounds with atmospheric lifetimes shorter than a decade. These species have been previously related with **thermodynamic changes in the North Atlantic** ocean (NA). Particularly, in areas of deep water formation that contribute to the Atlantic Meridional Overturning Circulation (AMOC) (e.g. Hassan et al., 2022; Liu et al., 2024).

However, due to the limited observational records the reconstruction and **modelling of NA ocean dynamics is still uncertain**.

Temperature response to SLCFs mitigation (up) and its intermodel uncertainty (down)



METHODOLOGY

We isolate the climate response to SLCFs mitigation in the **period 2025-2054** through a **multi-model analysis** of simulations from the AerChemMIP-CMIP6 initiative (Collins et al., 2017).

We compare different scenarios of SLCF emission (**aerosols, tropospheric ozone and precursors**):

response = ssp370 − ssp370-lowNTCF

Experiment	Description
ssp370	SSP3-7.0 reference
ssp370-lowNTCF	low SLCF emissions (SSP1)

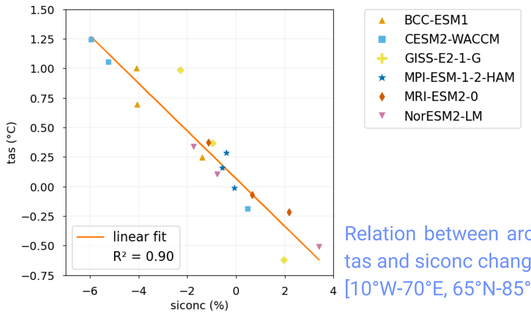
We use a **7 model ensemble**. All of which have interactive chemistry and aerosols, contributed with **3 members** and had AMOC variables available.

Models
BCC-ESM1
GISS-E2-1-G
MRI-ESM2-0
NorESM2-LM
CESM2-WACCM
MPI-ESM-1-2-HAM
EC-Earth3-AerChem

RESULTS

We focus on **two uncertainty signals**: Arctic surface air temperature (tas) and mean ocean temperature in the 1st 500m (thetao) in the Eastern North Atlantic (ENA).

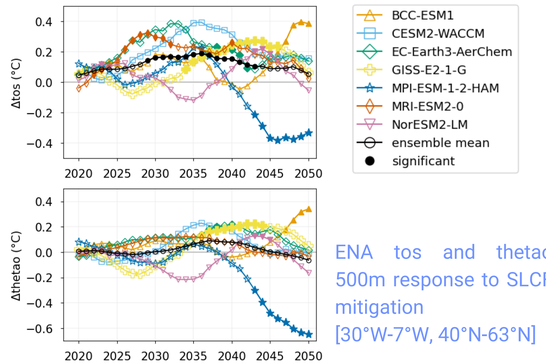
The **Arctic tas** response to SLCFs mitigation is greatly **related to regional sea ice concentration** (siconc). Therefore the model spread in sea ice representation explains the uncertainty in the temperature response.



Relation between arctic tas and siconc changes [10°W-70°E, 65°N-85°N]

The ocean temperature response in the **ENA region** suggests a **model dependency** in the dominating mechanisms.

The **low signal-to-noise ratio** suggests 3 members are not enough to filter model internal variability as suggested by Griffiths et al. (2025).

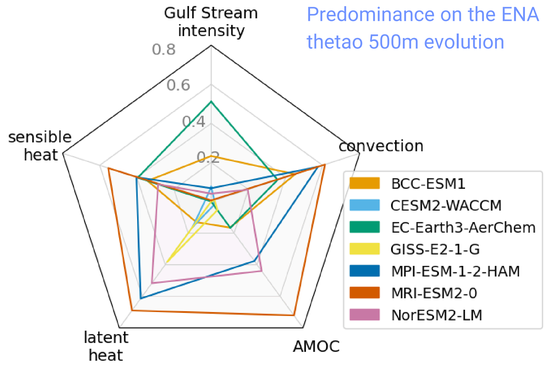


ENA tos and thetao 500m response to SLCF mitigation [30°W-7°W, 40°N-63°N]

We regress the thetao values with indexes of **potential mechanisms driving temperature.**

Local surface heat fluxes and convection appear as dominant factors however larger circulation such as AMOC and Gulf Stream strenngth are determinant in some models

Predominance on the ENA thetao 500m evolution



TAKE AWAYS

- Stronger **SLCFs mitigation leads to** stronger climate warming in the Northern Hemisphere.
- **High intermodel variability in the North Atlantic** response to SLCFs mitigation.
- Potential driving factors of the NA temperature responses are sea ice concentration, surface heat fluxes, AMOC strength and regional convection.
- **Ensemble size and forcing strength** are main limiting factors of the study.

FUTURE WORK

- To further characterise NA circulation responses and its uncertainty, we will evaluate **other regions** such as the **Subpolar North Atlantic Gyre** and the **Gulf Stream** area.
- As anthropogenic SLCFs mitigation efforts progress, investigating the **role of natural emissions in the future** and their interaction with climate becomes crucial.

Note to the modelling community:

The differing responses between models underscores the need for broad model participation in AerChemMIP2.

Expanding the diversity of contributing models, the ensemble sizes and the range of emission configurations would help capture real uncertainty and enable more robust assessments of the ocean circulation under different air quality policies.

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References

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