Untangling the Multi-model Spread in 21st Century AMOC Projections

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1. Motivation

The Atlantic Meridional Overturning Circulation (AMOC) is an important component of of the climate system, transporting heat northward in the Atlantic Ocean.[1] The AMOC is projected to weaken over the 21st century.[2] However, there is a large uncertainty in the magnitude of this weakening across the Coupled Model Intercomparison Project (CMIP) models which is currently poorly understood, and has implications to the predictability of Europe's climate over the 21st century.[3] This poster shows a preliminary investigation into the model spread of AMOC weakening for future scenarios and comparing the difference in AMOC weakening between scenarios and models.

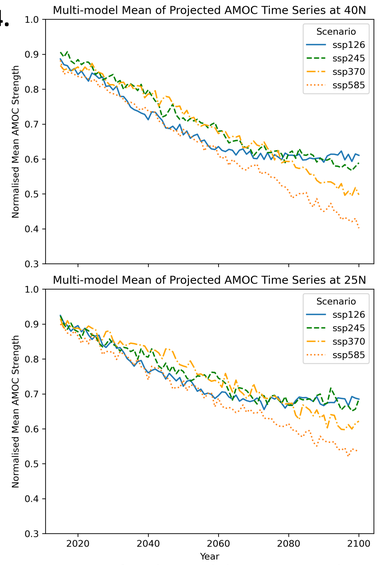
2. Data

This study makes use of 23 CMIP6 models, each using a single ensemble member. Experiments from the "shared socioeconomic pathway (ssp) scenarios", ScenarioMIP, are investigated[4]. In order of increasing effective radiative forcing, ssp126, ssp245, ssp370 and ssp585 are analysed where experiments available (see figure F2 for list of models) and compared to historical simulations.

3. Computation

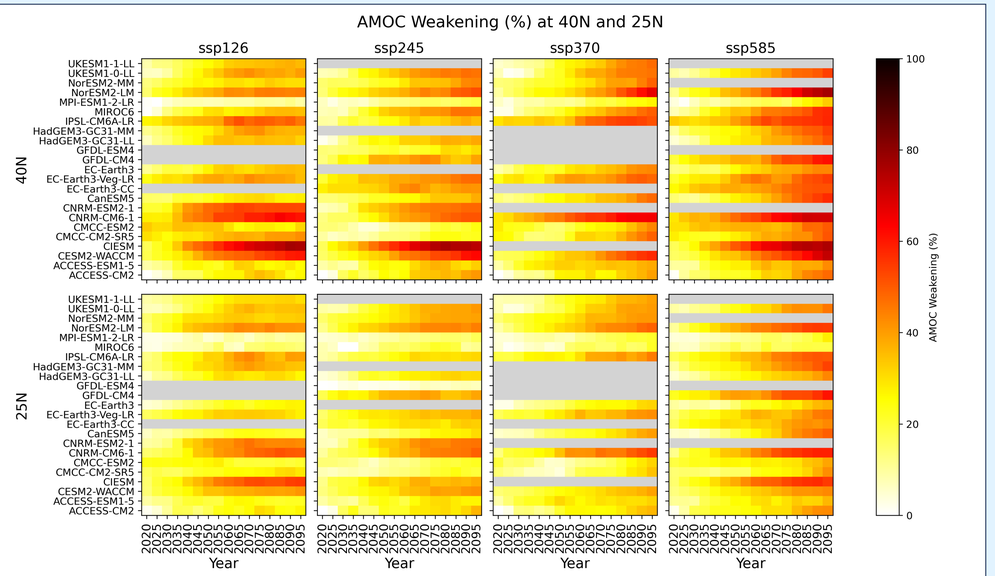
AMOC strength is defined as the maximum of the AMOC streamfunction across depths at each of the specified latitudes, with the streamfunction computed on depth levels. For each model, AMOC weakening is defined as the difference in AMOC strength between the future projection and the reference period 1995-2014 from the historical simulation, divided by the AMOC strength from the historical reference period. Depth maximums of the streamfunction are taken, then the annual or decadal mean is computed. Weakening is shown as a percentage decrease for ease of comparison.

4.



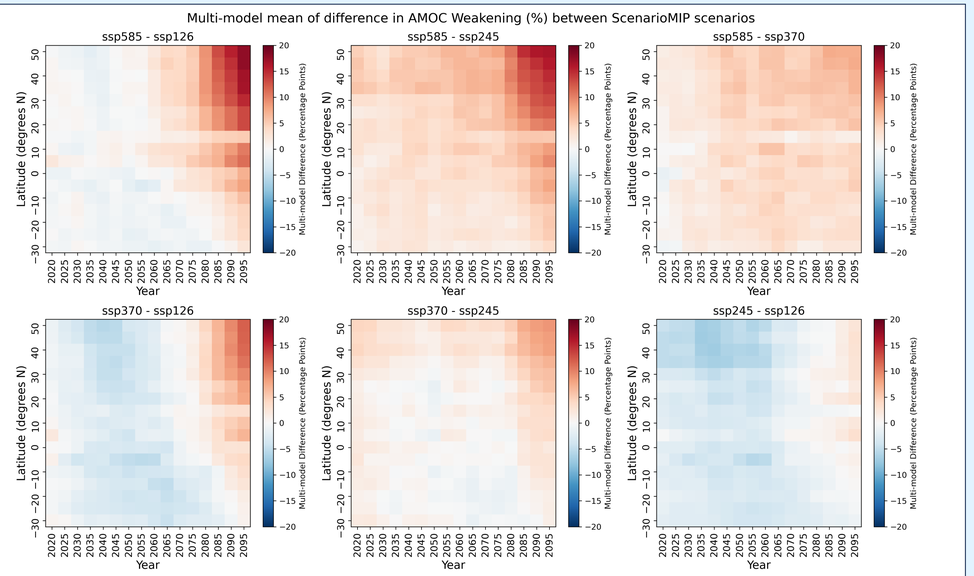
F1: Timeseries of multi-model mean annual mean AMOC strength, normalised to the historical reference period for the four future scenarios at 40˚N (top) and 25˚N (bottom). Note that the models used in the multi-model mean are different for each scenario, dependent on data availability.

5.



F2: Percentage weakening of the AMOC for model for each scenario at 40˚N (top row) and 25˚N (bottom row). The years on the x-axis represent the centre of a decadal mean. This figure clearly shows the multi-model spread of weakening by 2100. It also highlights differences in model behaviour between experiments, such as CMCC-CM2-SR5 showing a slight strengthening in ssp370, and hints of latitude dependency on the magnitude of weakening, such as MIROC6 in all scenarios. A grey line represents no available data for that experiment.

6.



F3: The difference in the multi-model mean percentage AMOC weakening between scenarios at latitudes ranging from 30˚S to 55˚N. A positive (red) difference means the "more severe" scenario has greater weakening, and vice versa for blue. Note that ssp126 is weaker than both ssp245 and ssp370 before 2070. This is likely related to increased aerosol emissions in the latter scenarios, known to strengthen the AMOC.[5] Additionally, divergence between experiments, particularly evident in the ssp585 – ssp126 figure, appears to originate in the high latitudes and travel south with time.

7. Summary

- At 25˚N, the ranges of AMOC weakening by 2090-2099 are: ssp126: 10%-55%; ssp245: 7%-49%; ssp370: 21%-55%; ssp585: 19%-61%.
- Differences between scenarios are greatest in the northern Atlantic, and are less pronounced in the southern Atlantic
- Before 2070, scenarios ssp245 and ssp370 have less AMOC weakening across the whole basin relative to the ssp126 scenario.
- The AMOC response in ssp370 and ssp585 appears offset but comparable throughout the basin and across the 21st century.

8. Future Plans

Exploring physical properties for each model and experiment to try to isolate model-dependent behaviour which influences the AMOC strength. The initial plan is to look at meridional and zonal density gradients across the Atlantic basin, variations in sea ice extent, and how this relates to temperature and salinity biases.

9. References

1. Towards two decades of Atlantic Ocean mass and heat transports at 26.5° N (Johns et al., 2021); 2. IPCC Chapter 9, (Fox-Kemper et al., 2021); 3. Future climate change shaped by inter-model differences in Atlantic meridional overturning circulation response (Bellomo et al., 2021); 4. The Scenario Model Intercomparison Project (ScenarioMIP) for CMIP6 (O'Neill et al., 2016); 5. Aerosol-Forced AMOC Changes in CMIP6 Historical Simulations (Menary et al., 2020)

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