E3SM v2 biases in Atlantic climate mean state, variability, and change

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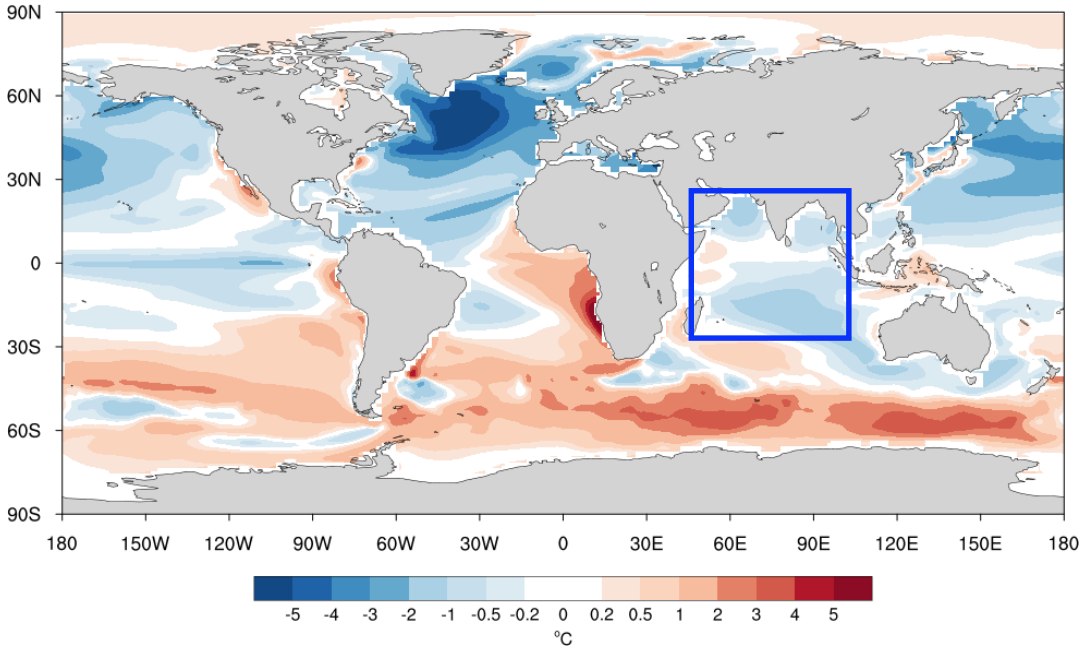
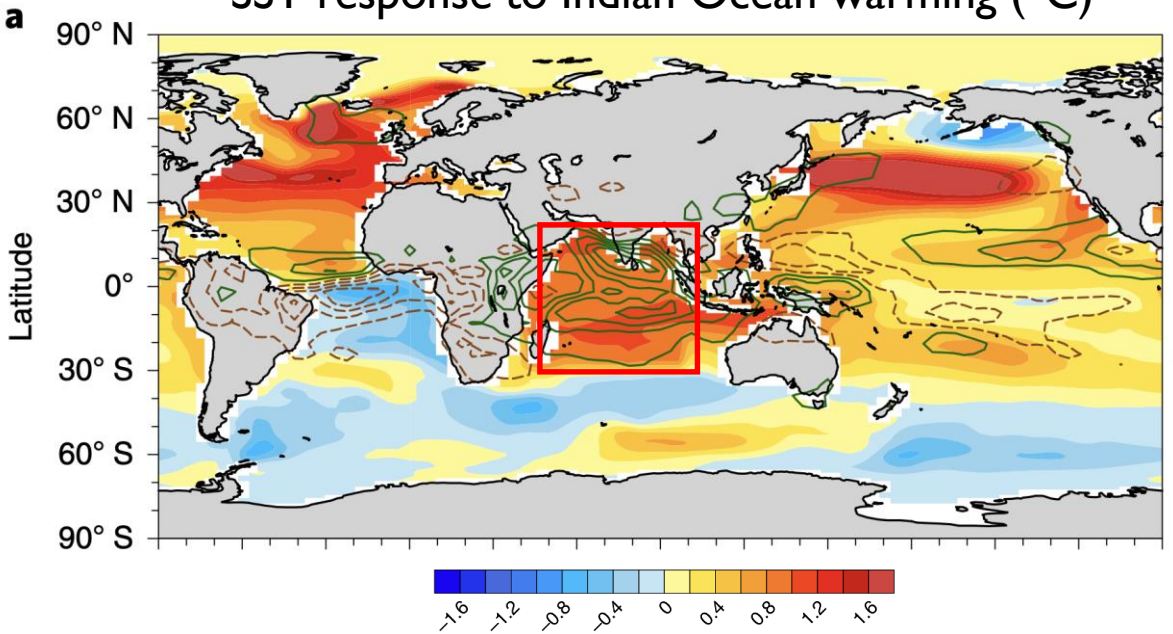
E3SMv2 biases in SST (°C)



SST response to Indian Ocean warming (°C)



RGMA project: The Effects of the Tropical Indian Ocean on the Atlantic Climate Mean State, Variability and Change in E3SM and Other Earth System Models

August 8, 2024 @ EESM PI Meeting

U.S. DEPARTMENT OF ENERGY
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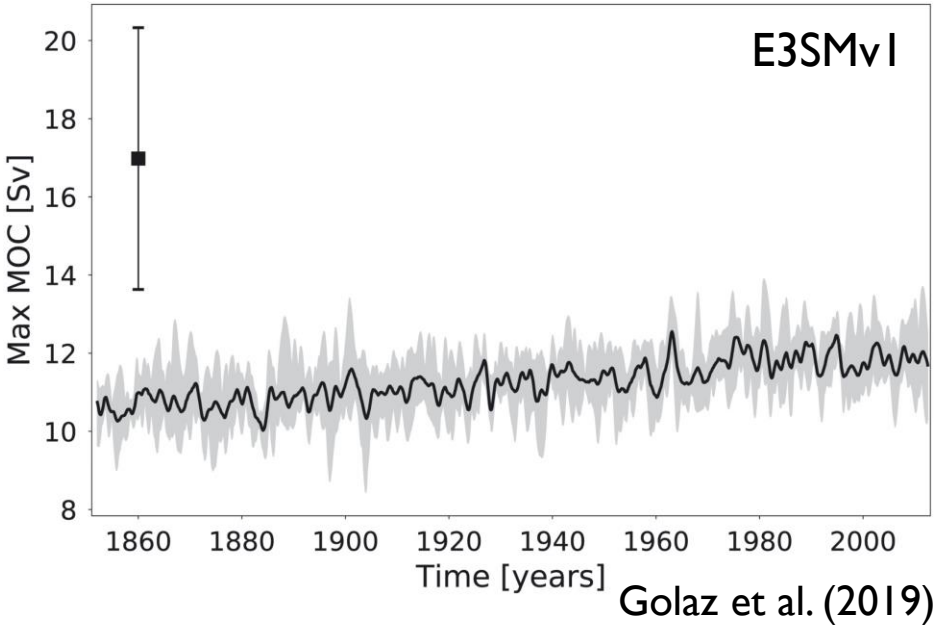
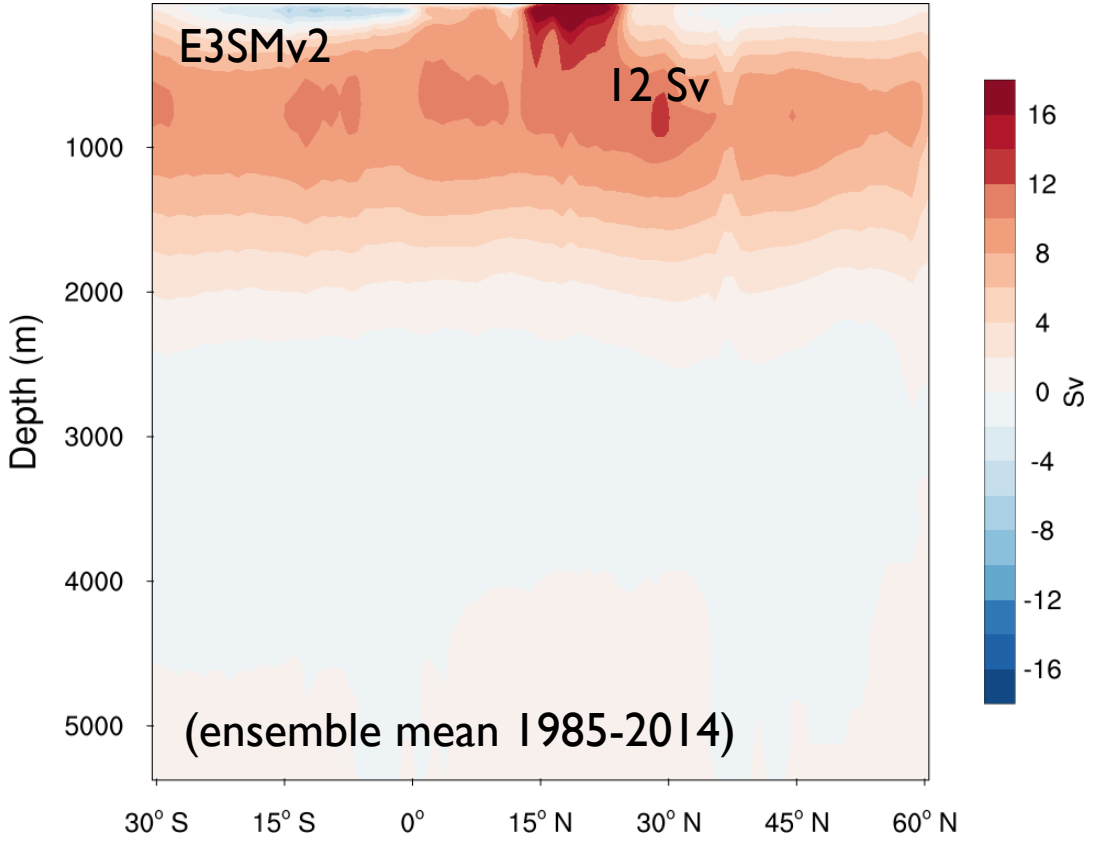
E3SMv2 bias in the Atlantic meridional overturning circulation (AMOC)



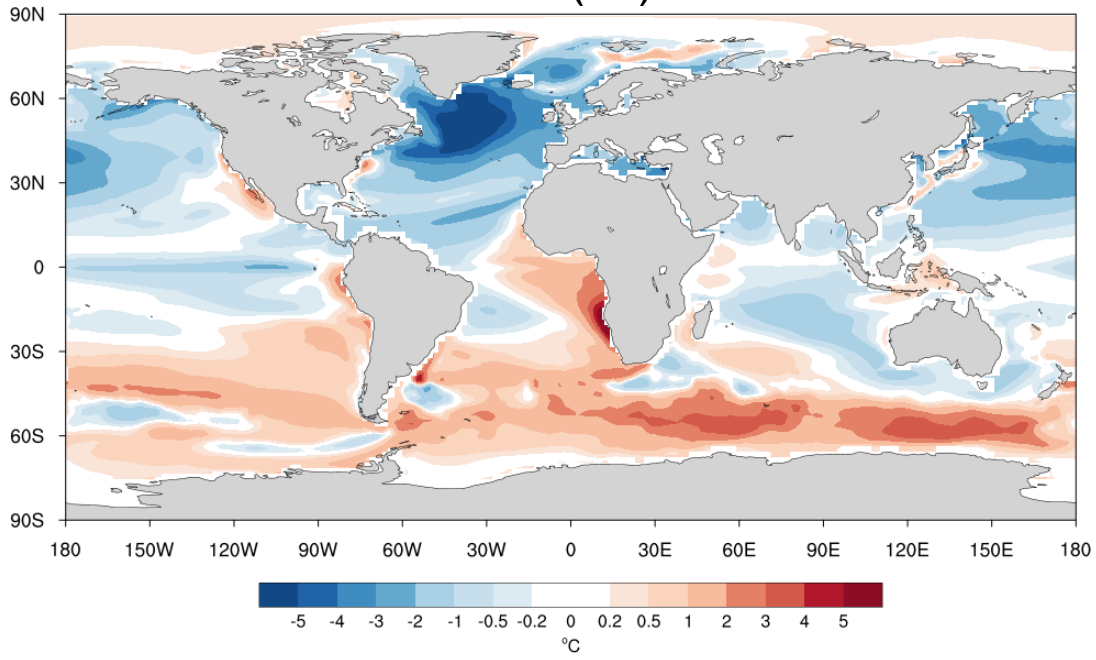
Golaz et al. (2019)



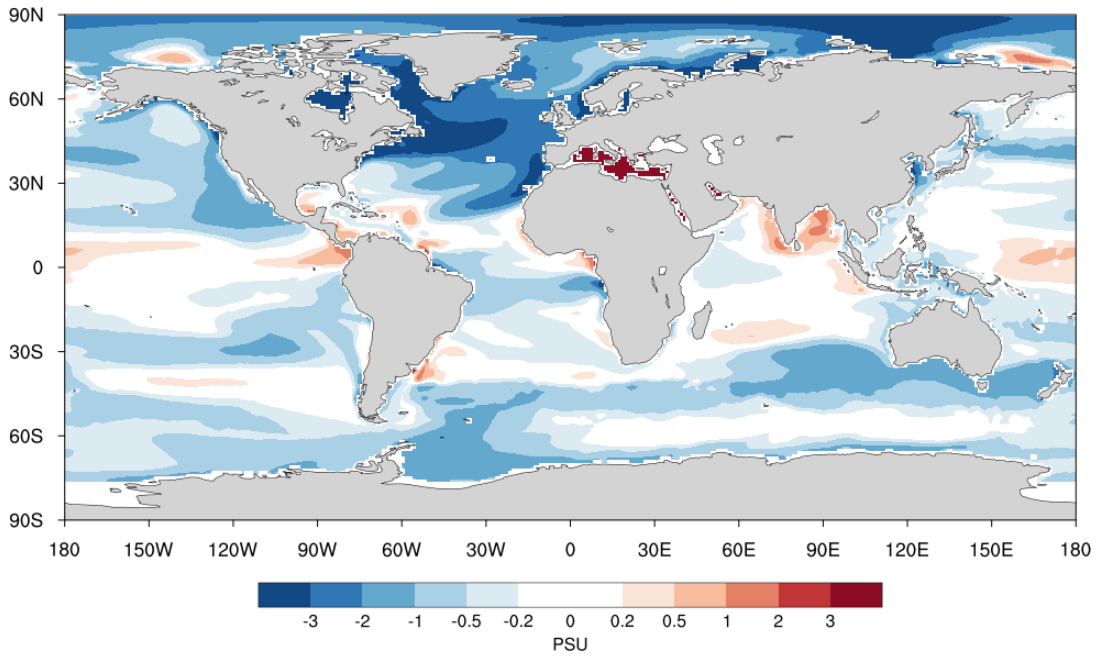
- Too weak AMOC (by ~5 Sv): a persistent bias since E3SMv1

E3SMv2 biases in sea surface temperature (SST) and salinity (SSS)

SST (°C)



SSS (PSU)

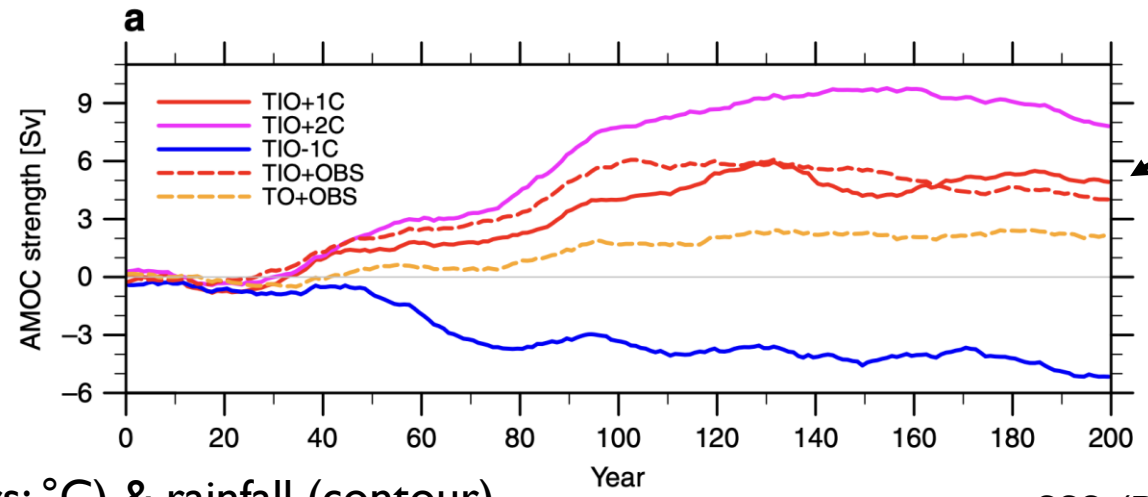


- SST biases
  - Too cold North Atlantic
  - Too warm South Atlantic
  - Too cold North Pacific
  - Too warm Southern Ocean
  - Too cold Indian Ocean

- SSS biases
  - Too fresh North Atlantic
  - Too fresh S.E. subtropical Atlantic
  - Too salty Indian Ocean

Atlantic climate response to ~1 °C Indian Ocean warming in a coupled GCM

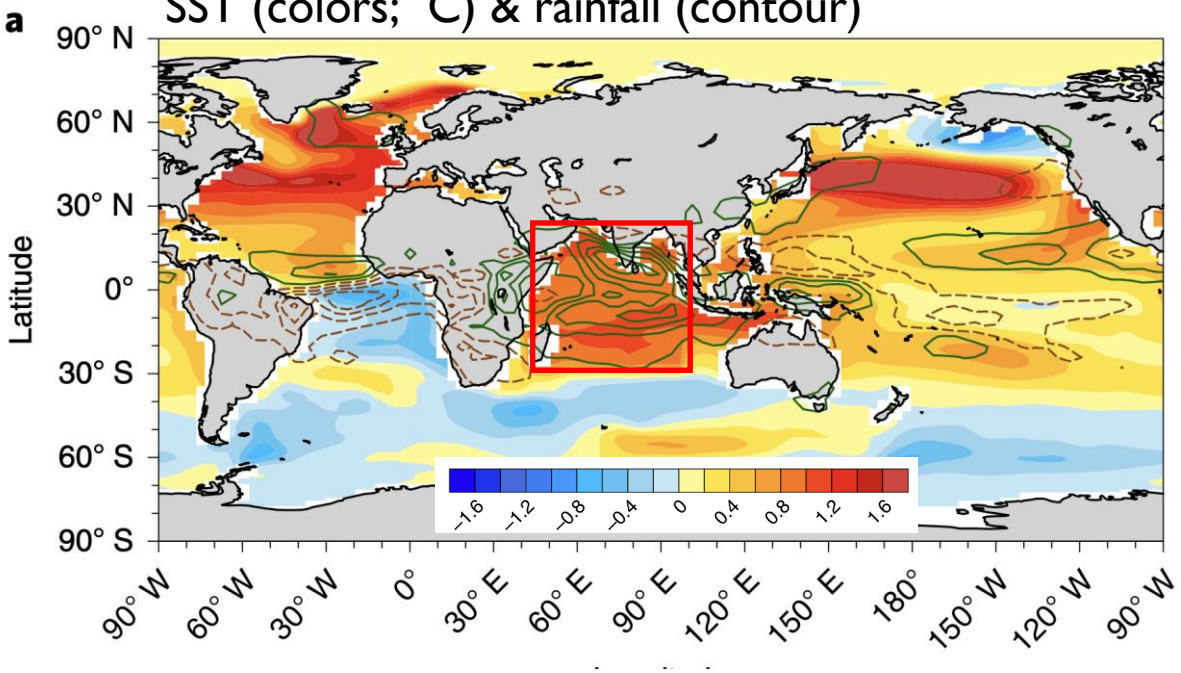
Modeling results based on CESM1



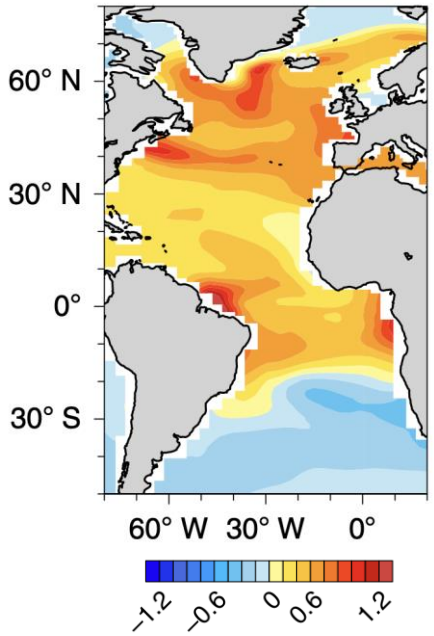
AMOC response to ~1 °C Indian Ocean warming (red solid)

Hu and Fedorov (2019, 2020)

SST (colors; °C) & rainfall (contour)



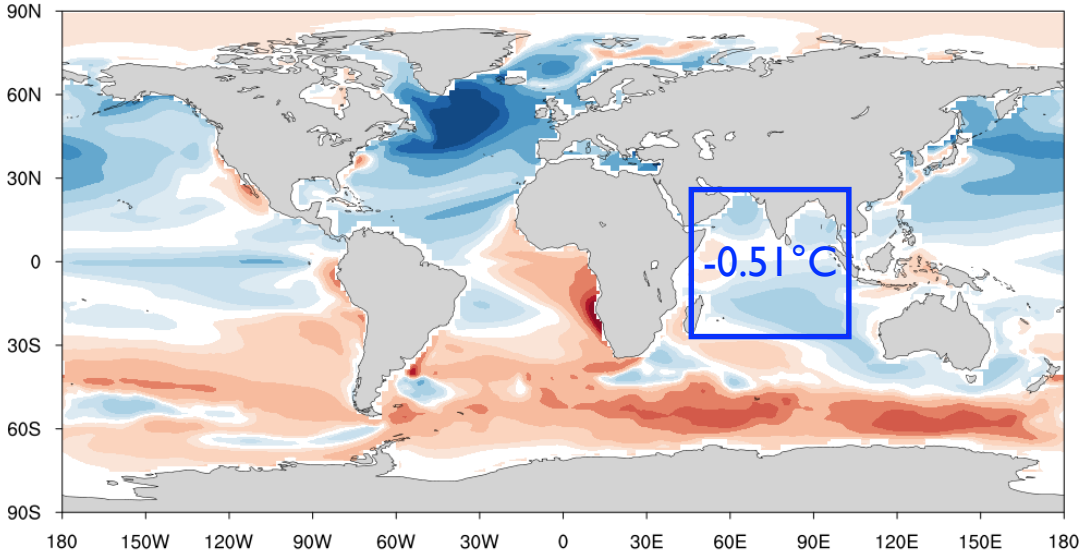
SSS (PSU)



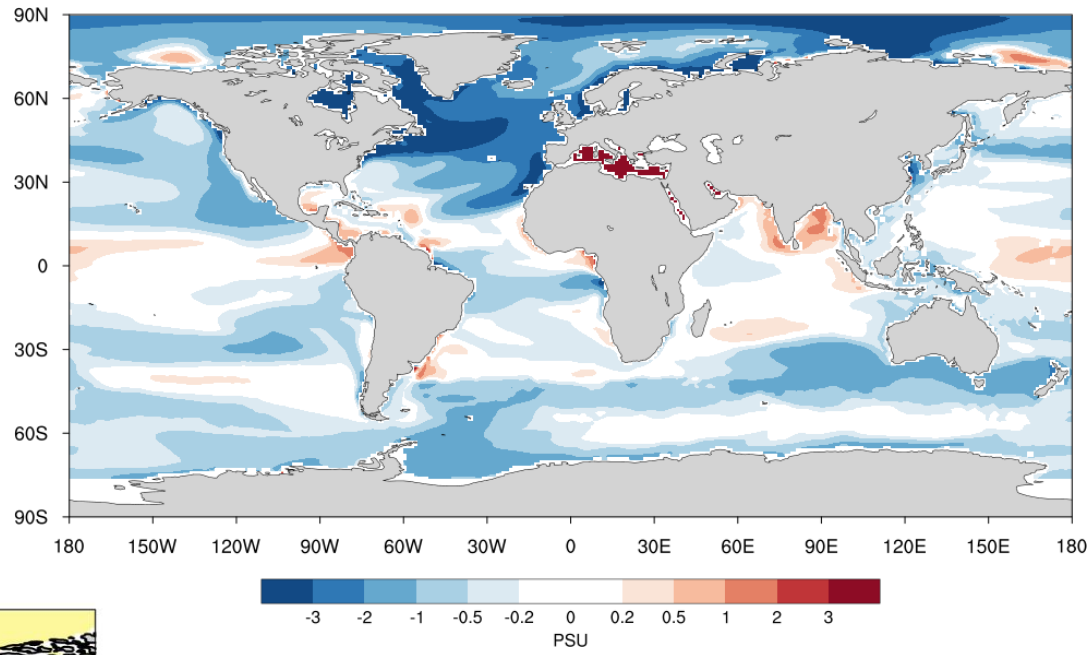
- Warmer Indian Ocean → rainfall reduction over tropical Atlantic → Saltier Atlantic → AMOC strengthening

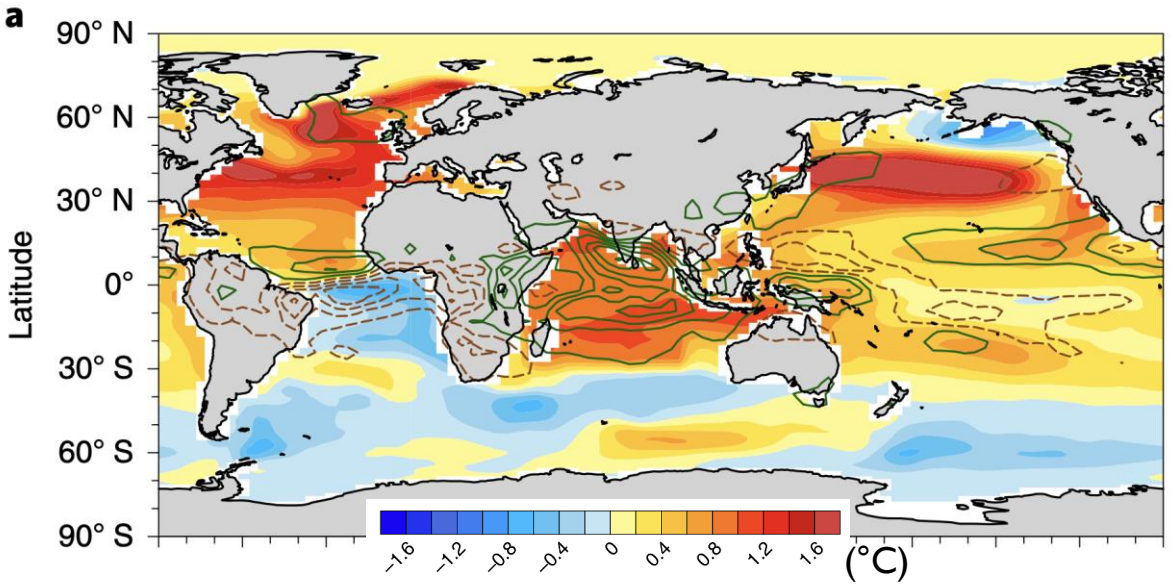
A tropical origin of E3SMv2 biases in AMOC and Atlantic mean state?

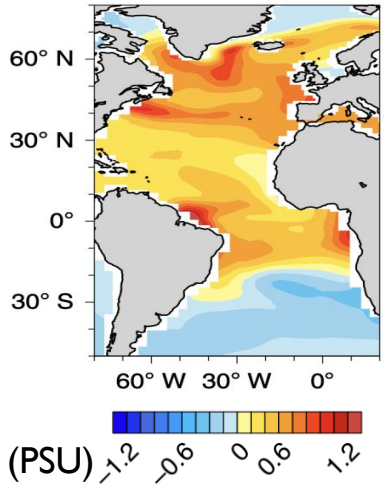
E3SMv2 biases in SST (°C)



E3SMv2 biases in SSS (PSU)





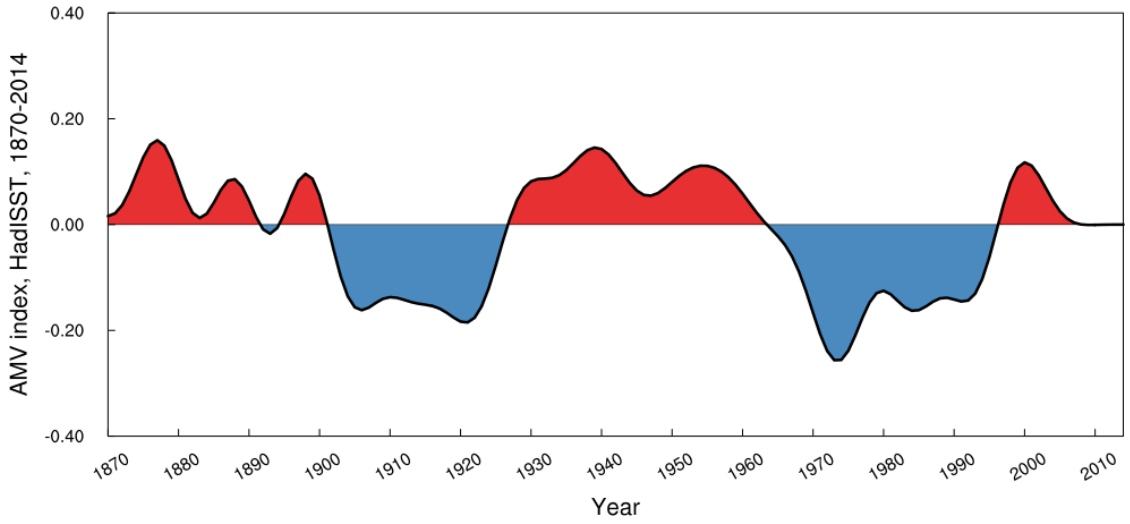


Modeling results based on CESM1

Hu and Fedorov (2019, 2020)

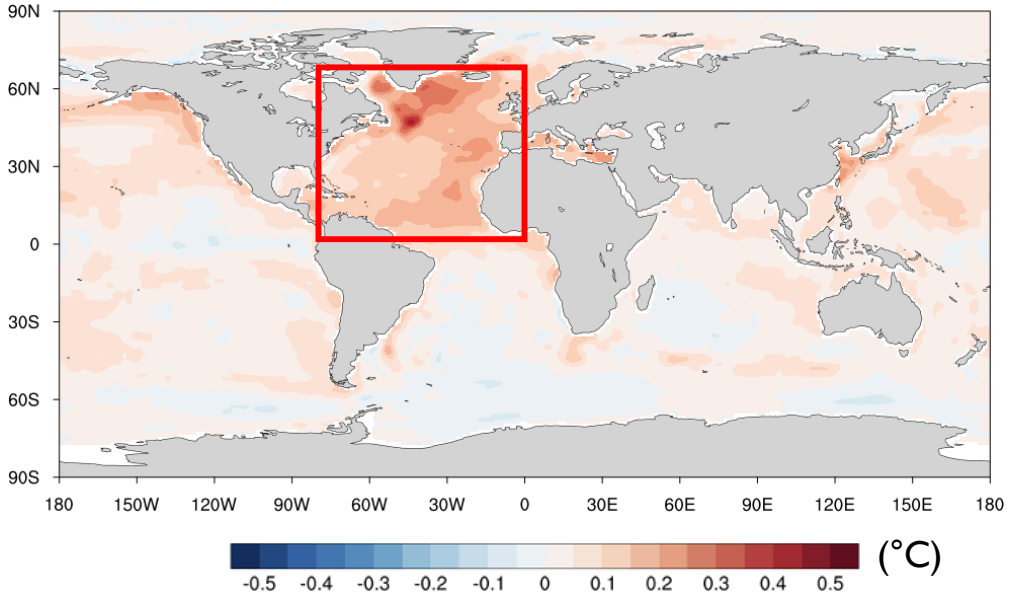
Atlantic multidecadal variability (AMV)

Observed AMV index (HadISST)



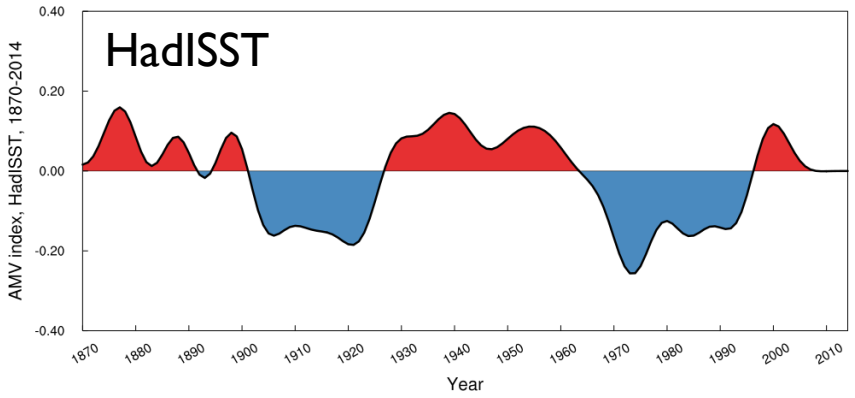
AMV index: linear detrended, 10-year low-pass filtered, SST anomaly averaged in the North Atlantic (0°-65°N, 80°W-0°)

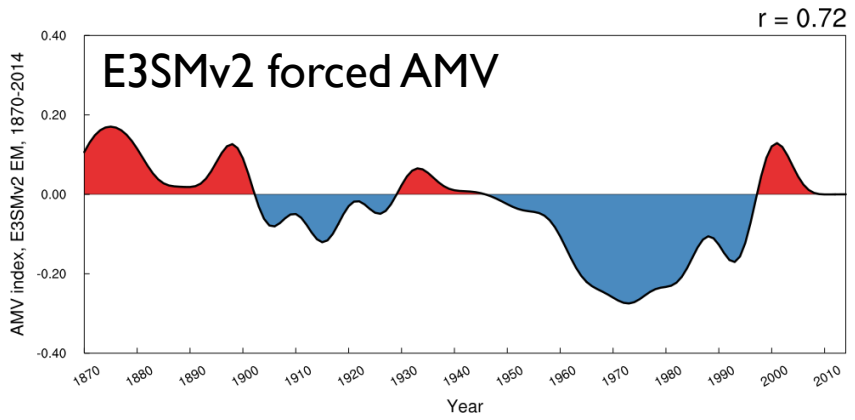
Observed AMV pattern (HadISST)



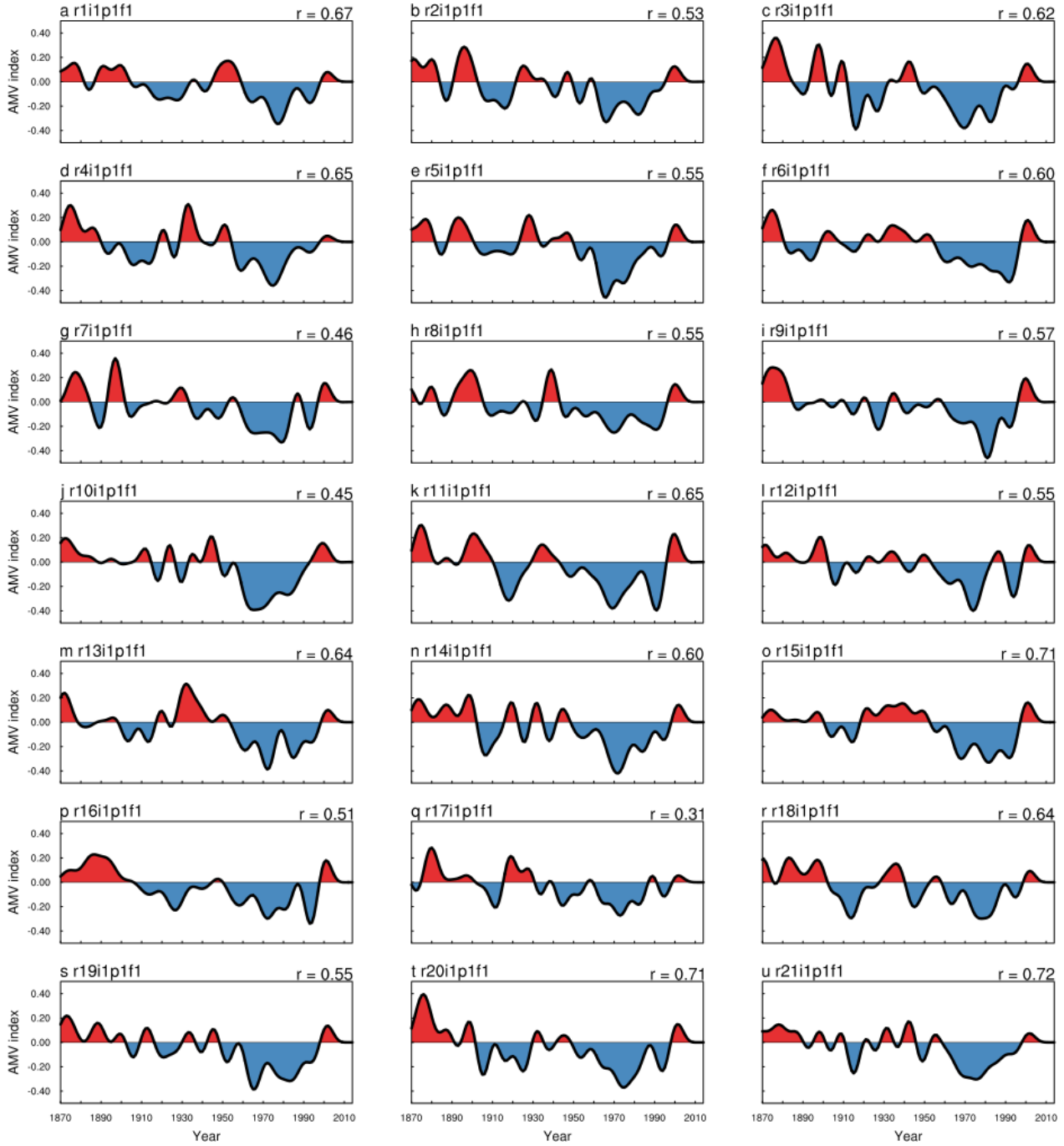
AMV pattern: linear detrended, 10-year low-pass filtered SST anomaly regressed on the normalized AMV index

AMV index in E3SMv2



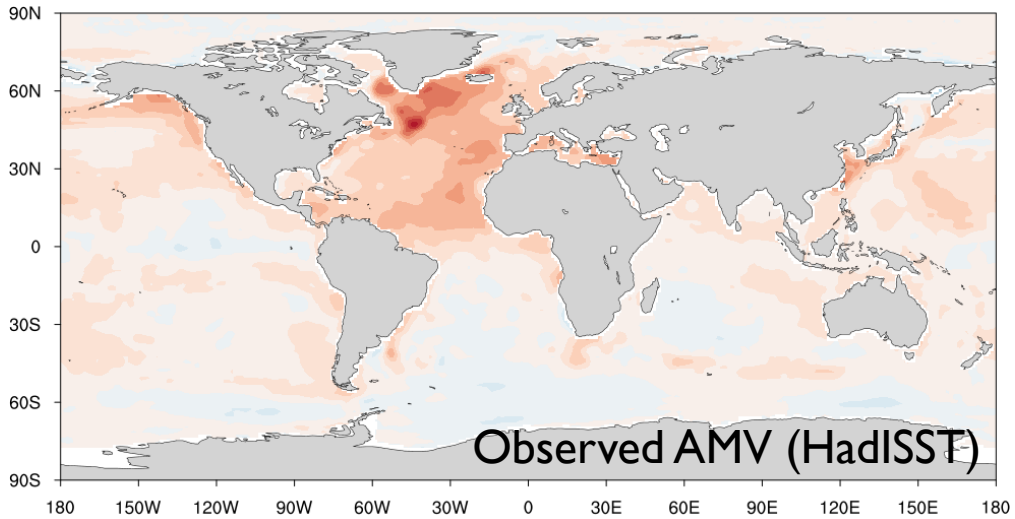


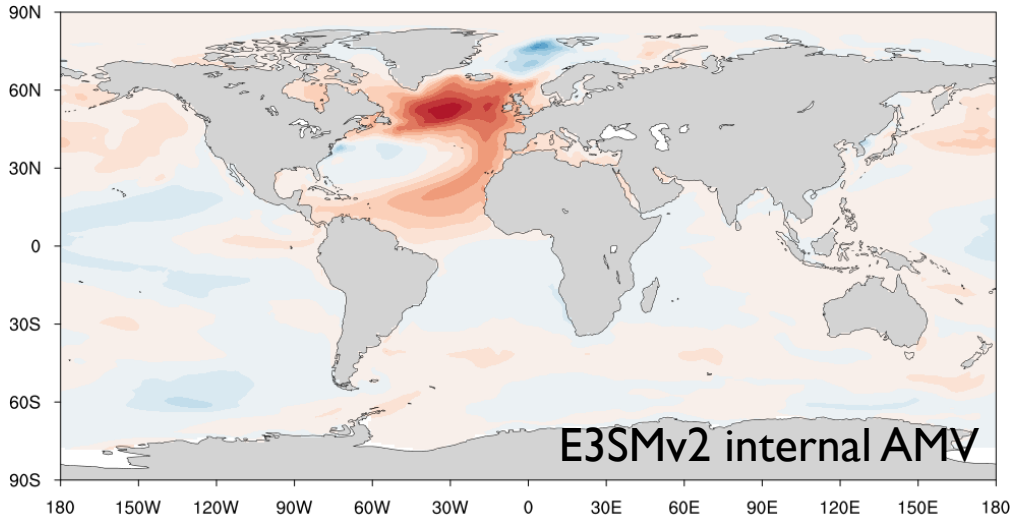
- Forced AMV can explain 52% of the observed AMV variations.

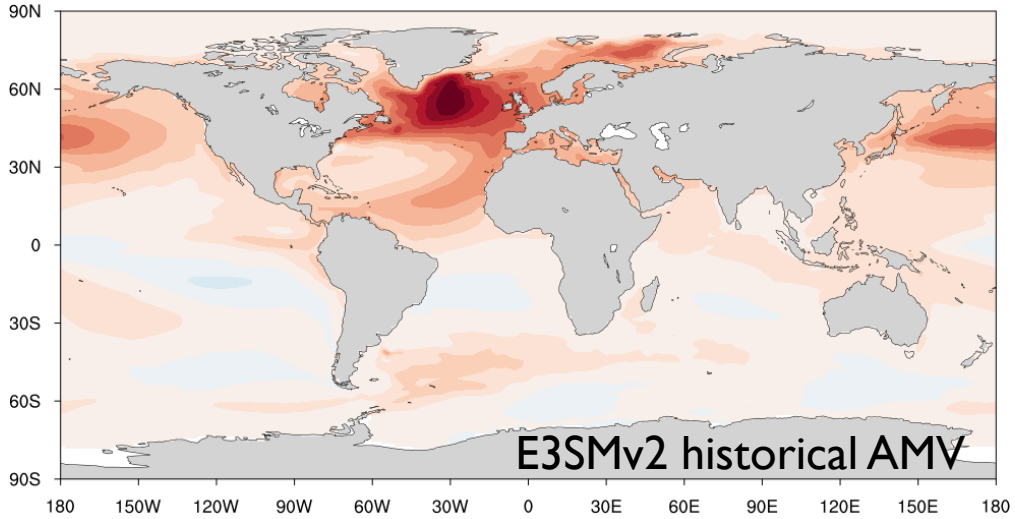


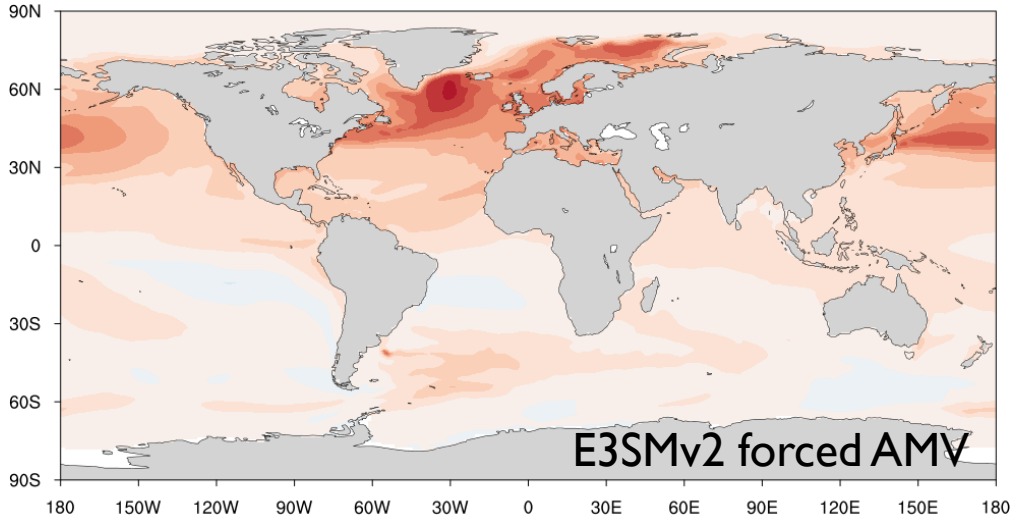
Li et al., *in prep.*

AMV pattern in E3SMv2





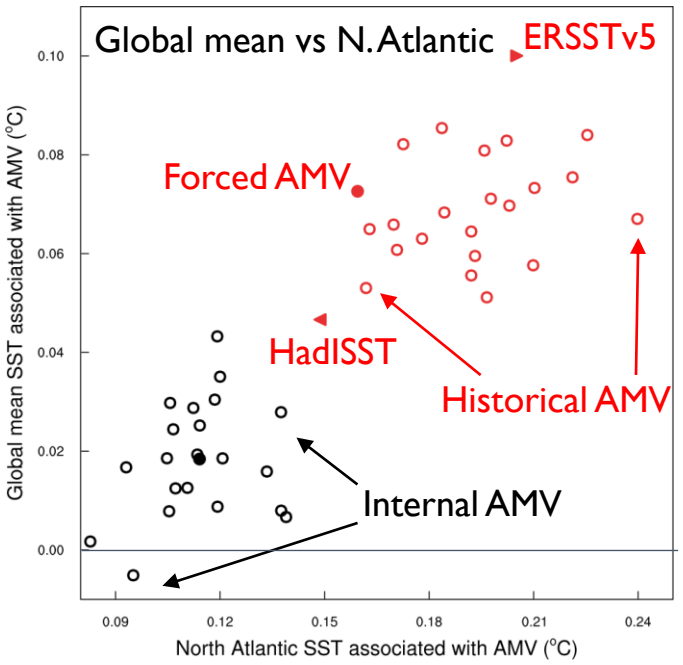


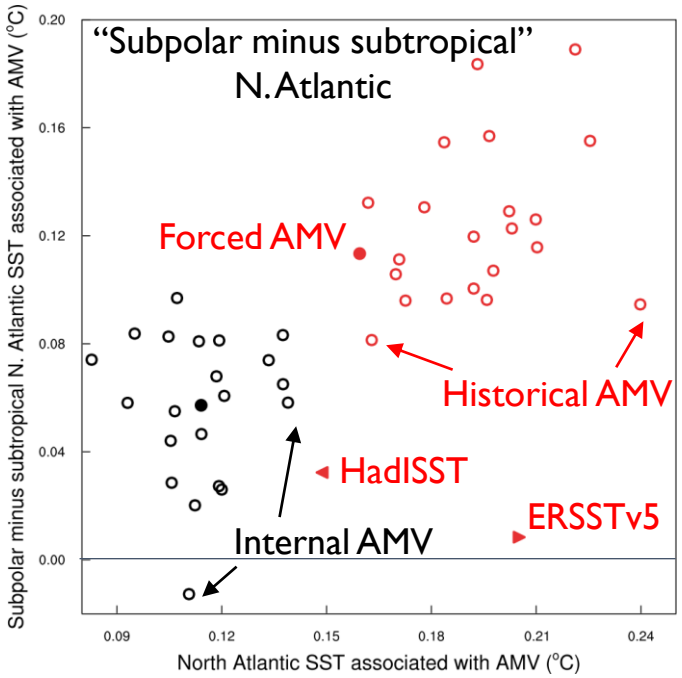


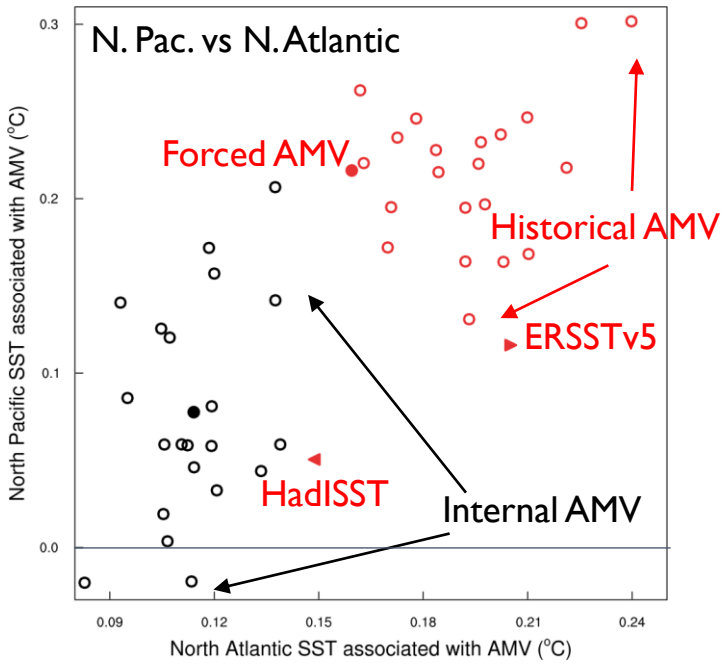
Li et al., *in prep.*

- Internal and forced AMVs both explain some features of the observed AMV pattern.
- E3SMv2 historical AMV is associated with too strong subpolar ocean warming in the NH.

AMV pattern in E3SMv2







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Li et al., *in prep.*

Summary and ~~conclusions~~ hypotheses

- A tropical origin of E3SMv2 mean state biases in the Atlantic
  - Correcting the Indian Ocean cold bias may strengthen the AMOC (by ~3 Sv, estimated) and lead to a warmer and saltier Atlantic, both contributing to the reduction of Atlantic mean state biases

- E3SMv2 performance in AMV
  - E3SMv2 reasonably captures the observed AMV variations (~52% explained by the forced AMV), but it produces too strong warming in the subpolar Northern Oceans.
  - Internal and forced AMVs, based on E3SMv2 large ensemble, are associated with distinctive global patterns, both accounting for some features of the observed AMV

- Are E3SMv2 biases in AMV pattern inherently connected to the Atlantic mean state biases?

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