# Ocean Circulation Links to Global Sea Surface Temperature Biases in Climate Models

What are the biases and uncertainties of IPCC-AR5 climate models and what cause them?






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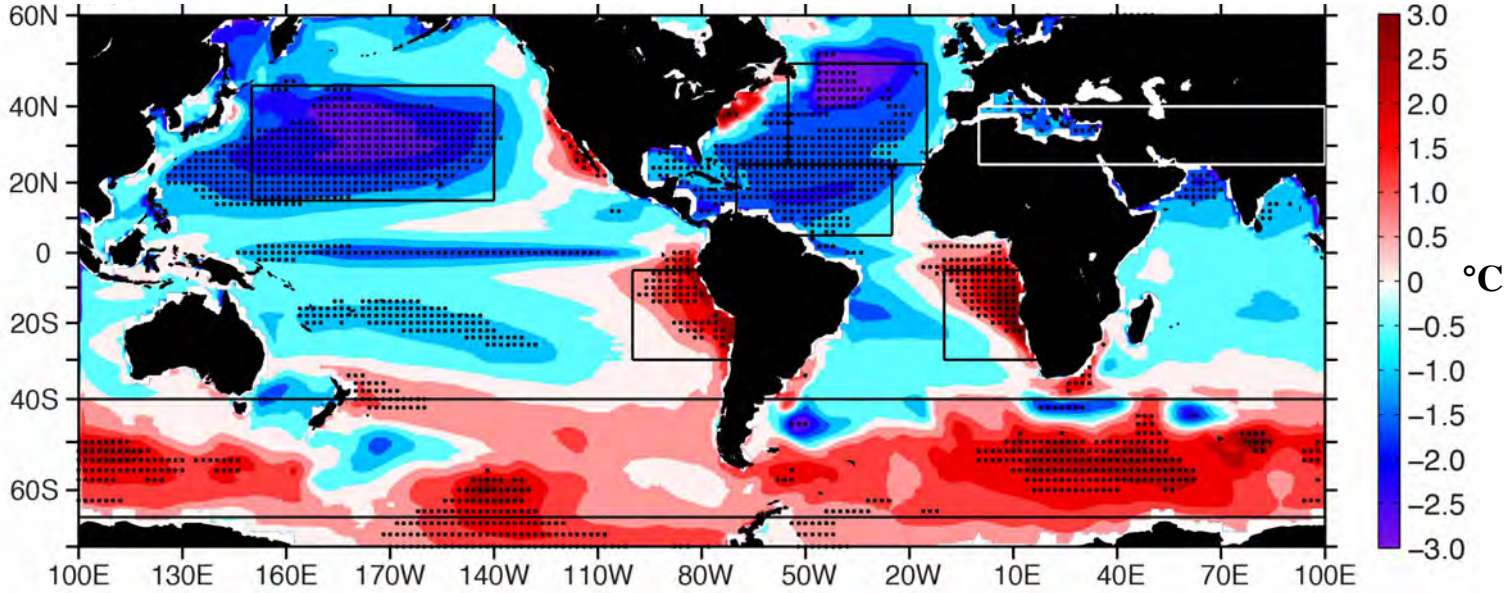
# Common patterns of global SST biases (or errors) are found in IPCC-AR5 climate models

Global SST biases averaged in 22 IPCC-AR5 models

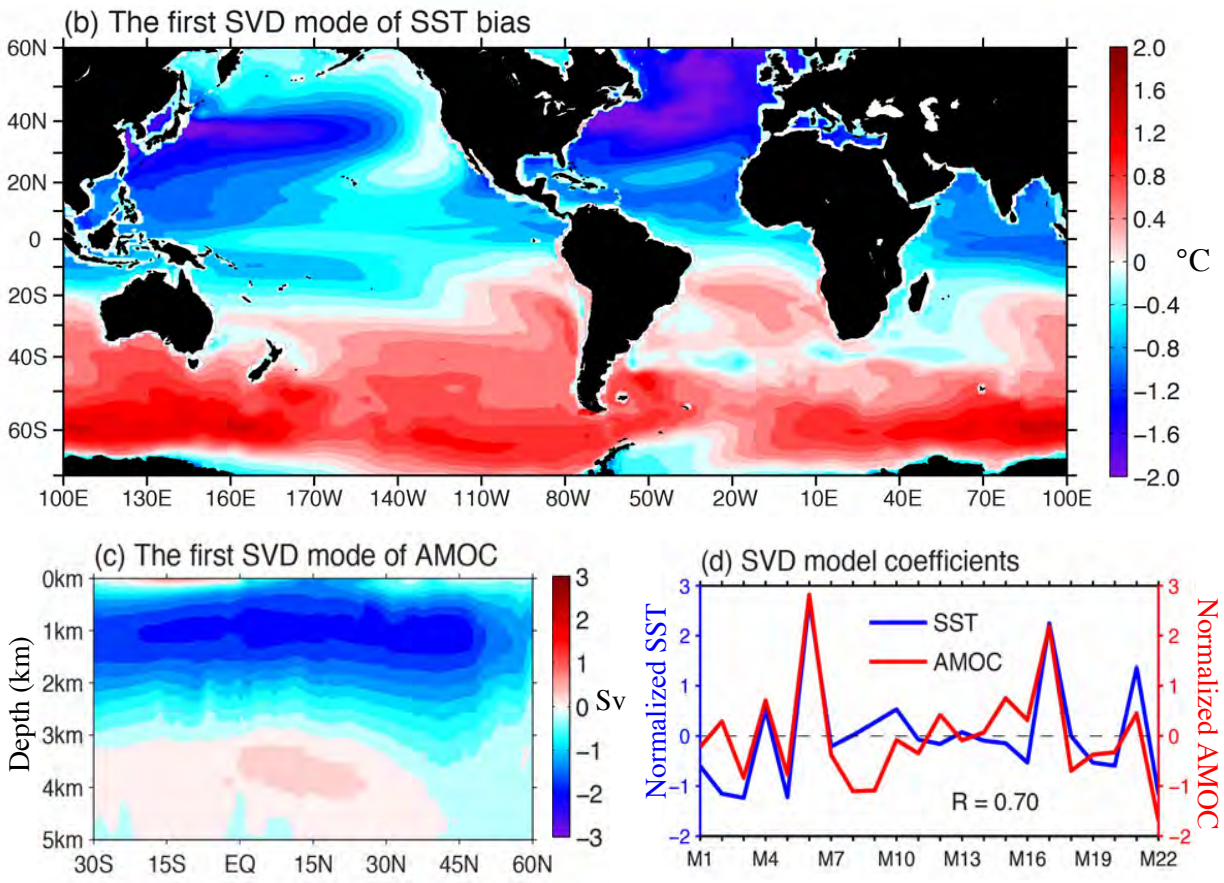



**Objectives**:

- Assess common SST biases and deficiencies in IPCC models.
- Examine link/cause of global model SST biases.
- Focus on remote links between regional SST biases.

The collaborators: UCLA and Ocean University of China.

# Global SST biases and the Atlantic Meridional Overturning Circulation (AMOC)




Key findings:

- Spatial patterns of the first SVD mode of SST biases resemble the mean model SST biases (top panel).
- The corresponding AMOC mode is weakened (low left panel).
- Time series of SST biases and AMOC are highly correlated (low right panel).

Conclusion:

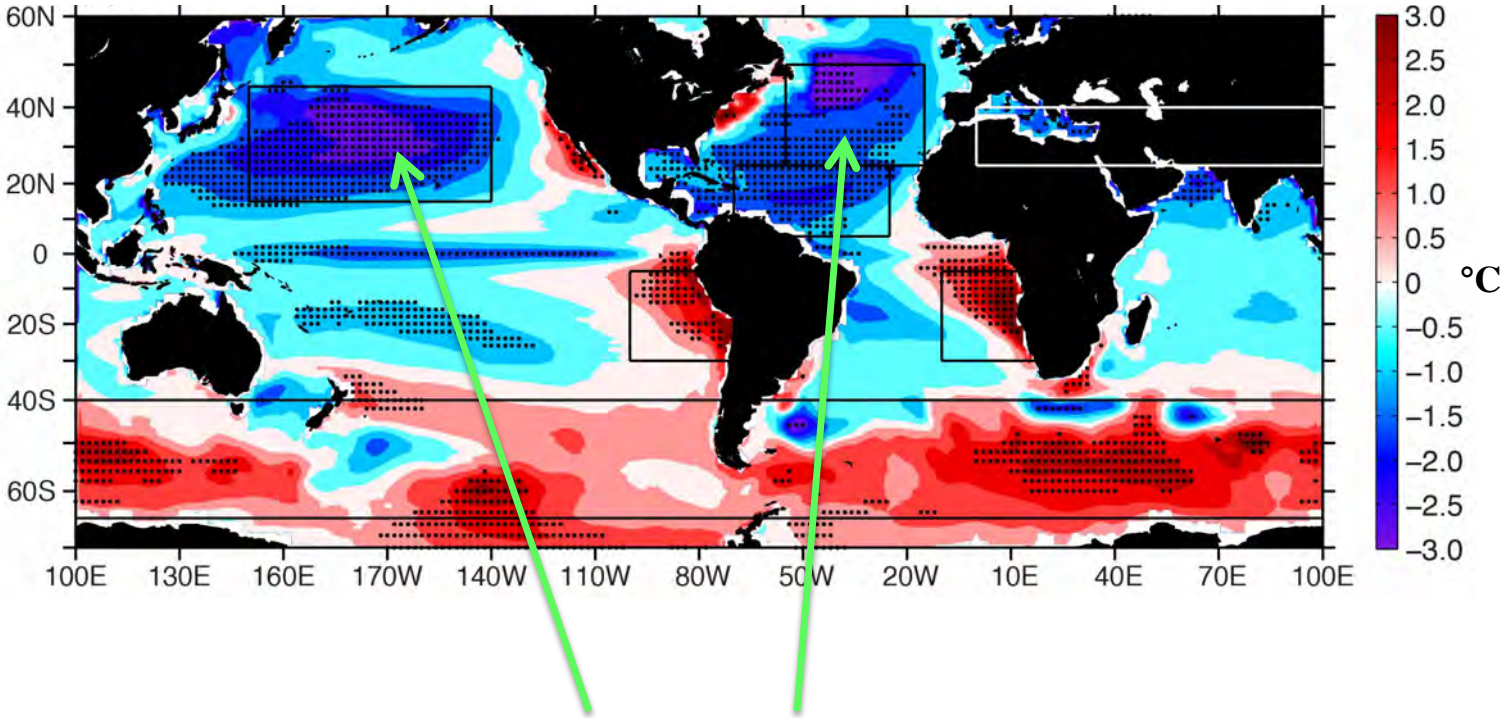
- Global SST biases increase as the AMOC circulation weakens.



Wang et al. (2014, *Nature CC*)

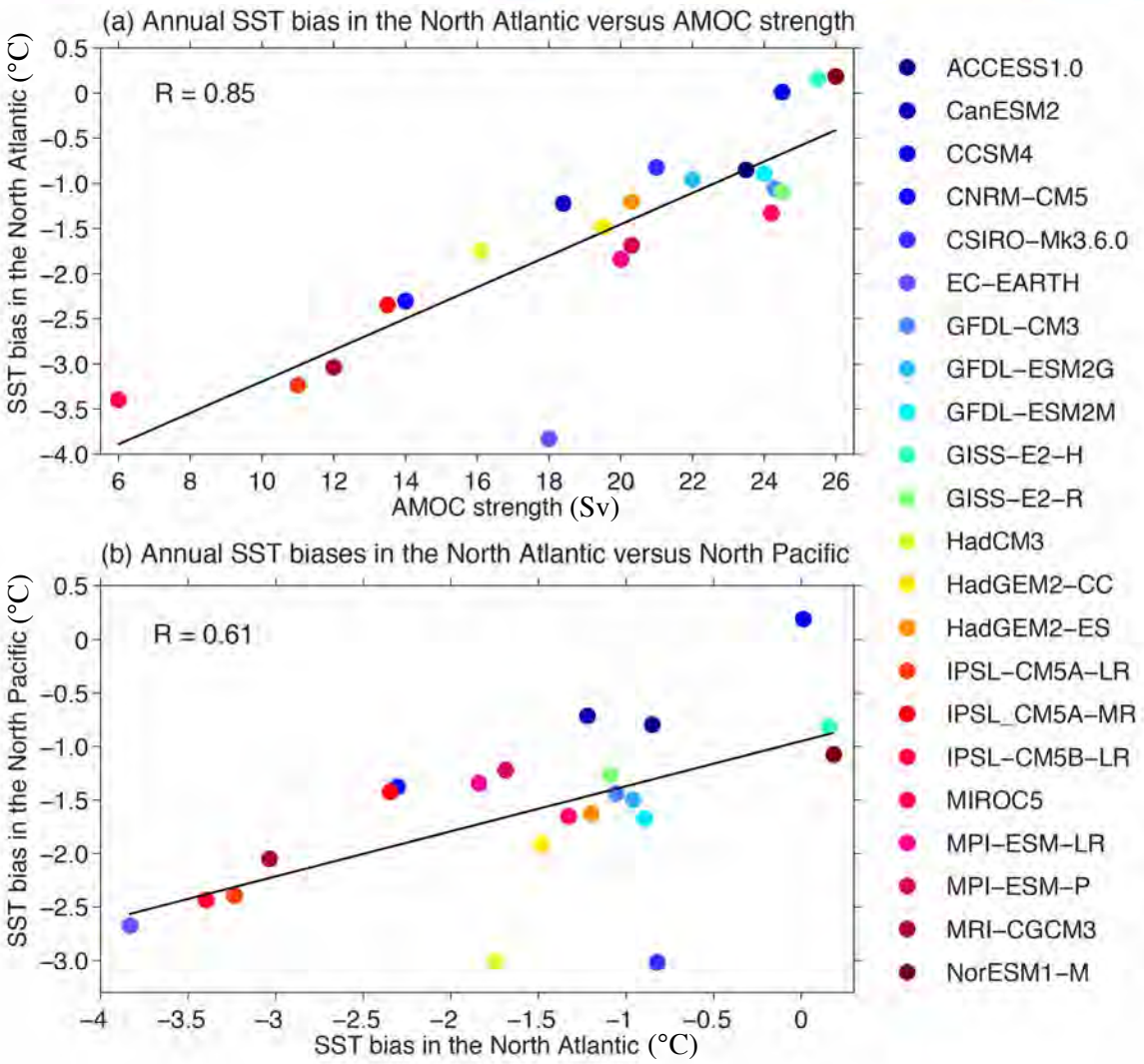
# Regional view: The SST biases in the North Atlantic and North Pacific

Global SST biases averaged in 22 IPCC-AR5 models




Why do both the North Pacific and Atlantic have the cold SST biases?

# Relationships of SST bias in the North Atlantic with the AMOC and SST bias in the North Pacific




Key findings:

- Cold SST bias in the North Atlantic is stronger when the AMOC is weaker, and *vice versa* (top panel).

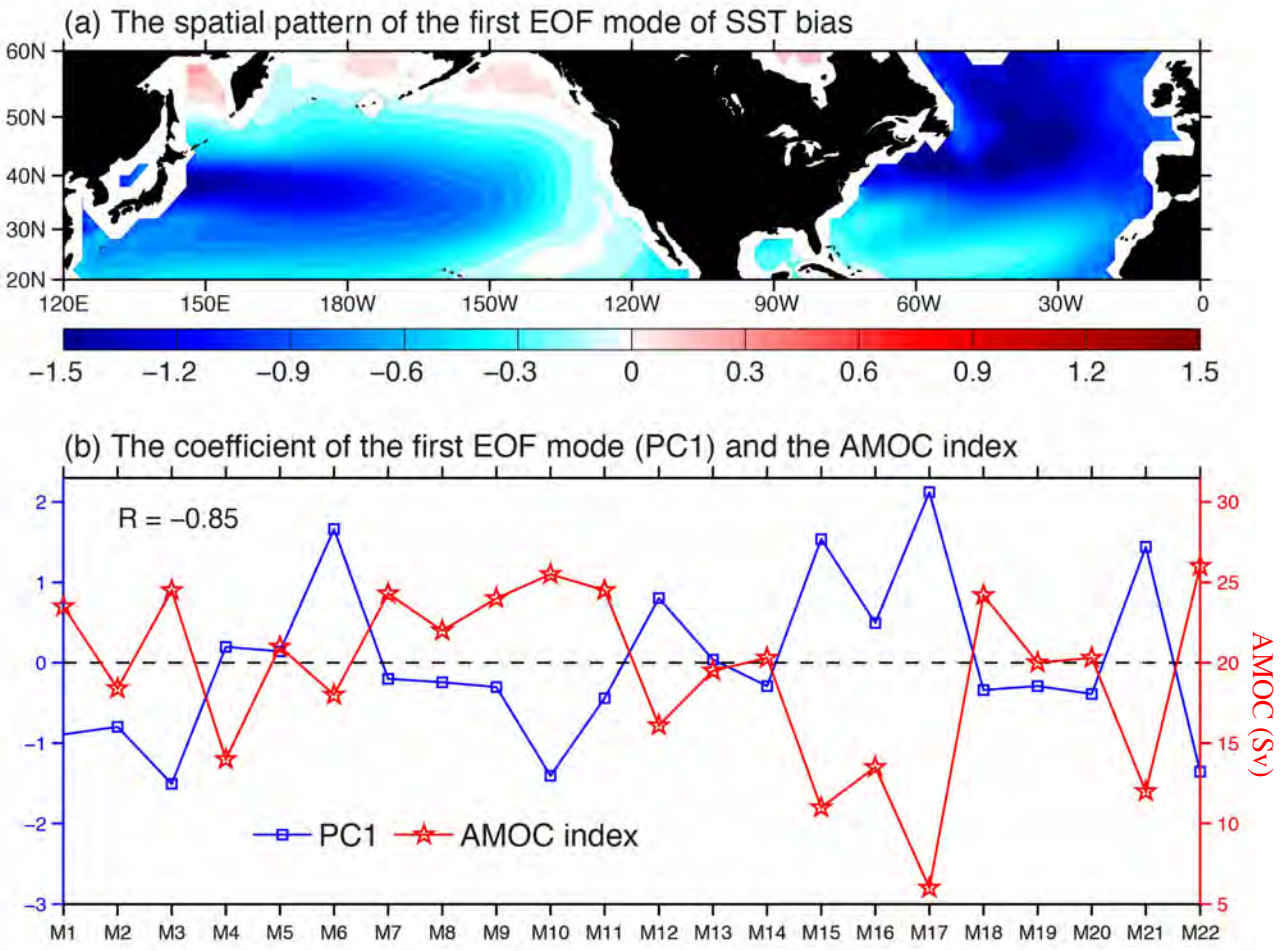
- SST bias in the North Pacific is linked to that in the North Atlantic (low panel).

*What is the mechanism for linking the SST biases in the North Atlantic and Pacific?*



Wang et al. (2014, *Nature CC*)

# Inter-model Empirical Orthogonal Function (EOF) analysis of SST biases in the North Atlantic and North Pacific




Key findings:

- A cold North Atlantic Ocean corresponds to a cold North Pacific Ocean (top panel).
- Principal component (PC1) is strongly and negatively correlated with the AMOC index (low panel).

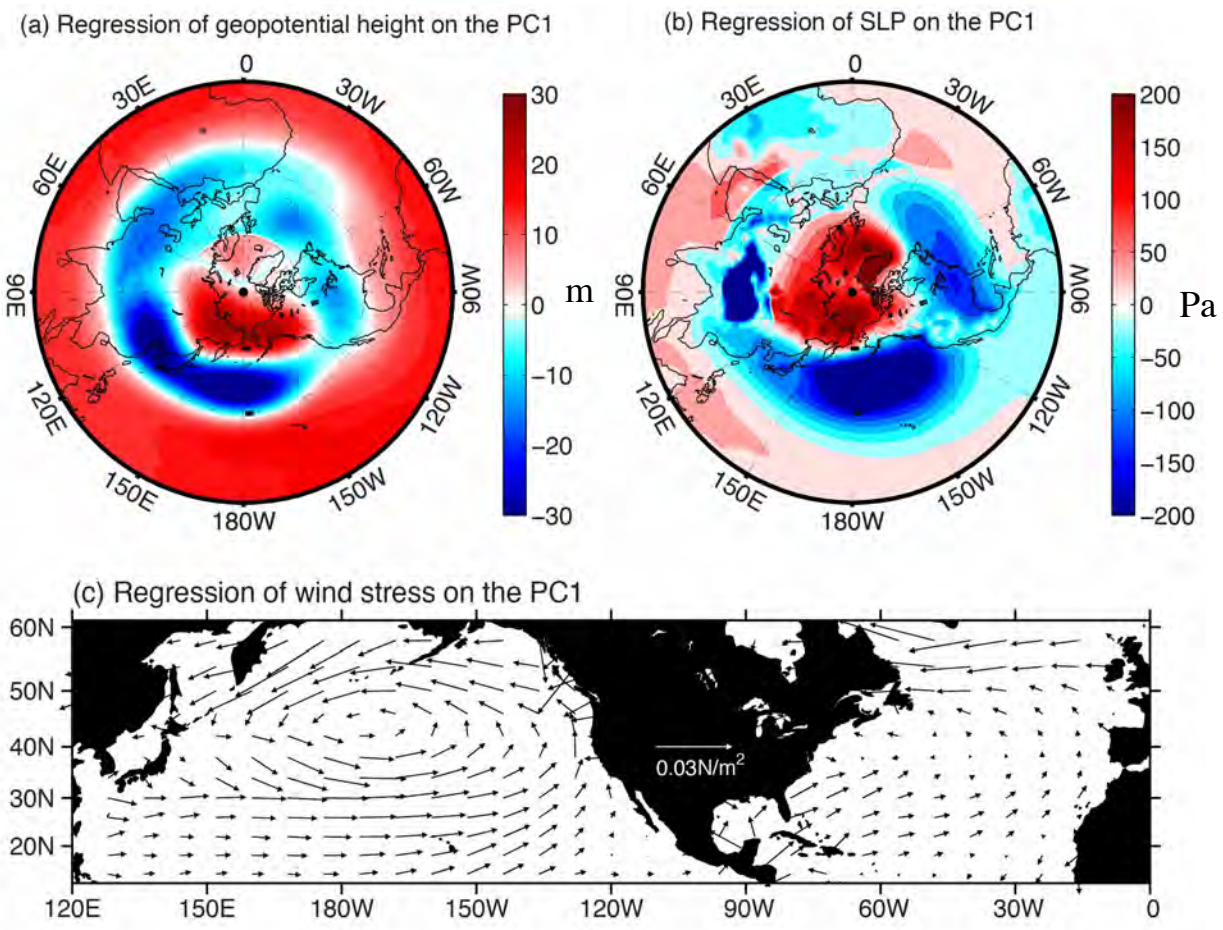
Conclusion:

- A weak AMOC causes cold SST bias in the North Atlantic which is associated with cold bias in the North Pacific.



Wang et al. (2014, *Nature CC*)

# Mechanism for linking the SST biases in the North Atlantic and North Pacific




Key findings:

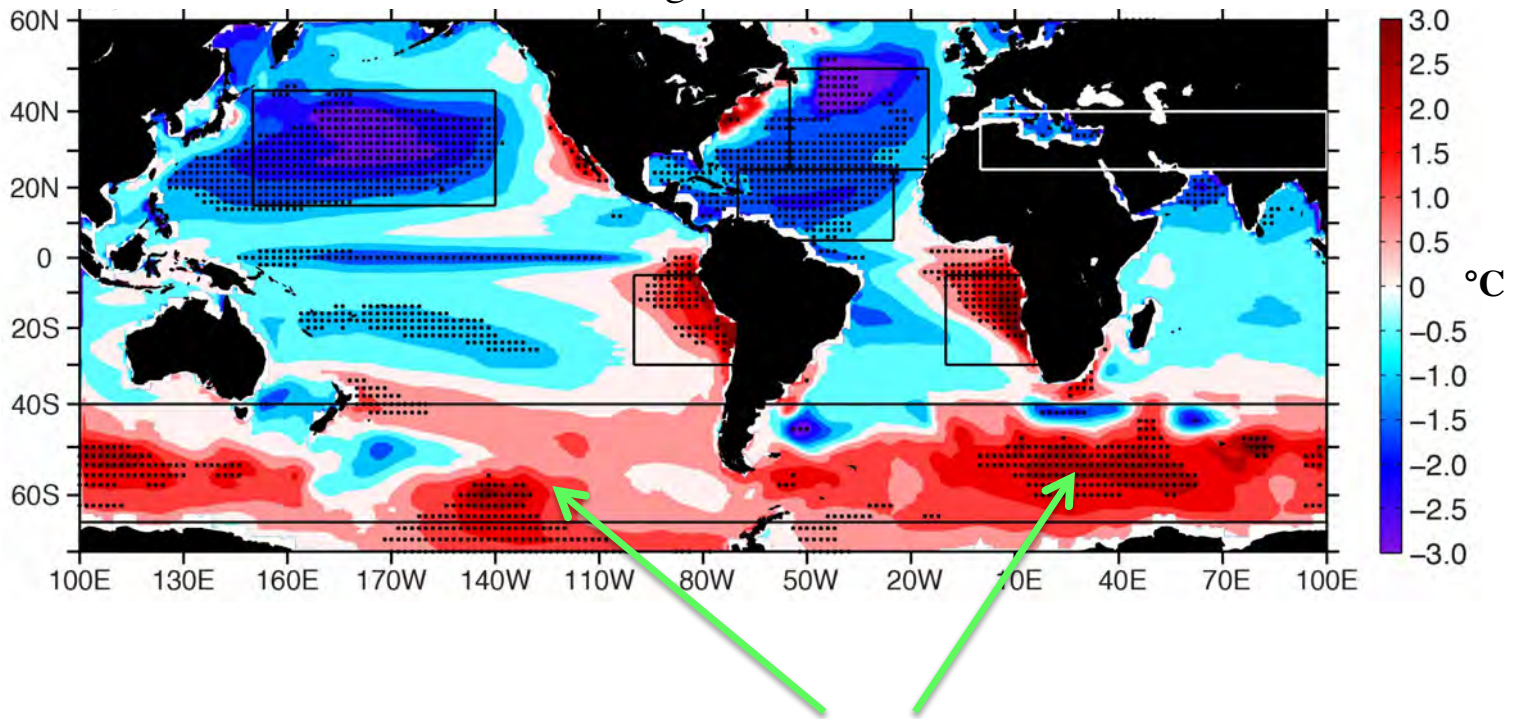
- Pattern resembles the N.H. annular mode (top panels).
- Negative SLP anomalies in North Atlantic correspond to a deepening of the Aleutian low (top right panel) and an intensification of westerly winds in North Pacific (low panel).

Conclusion:

- Intensified westerly winds cool the North Pacific Ocean through enhanced latent heat flux and southward ocean advection associated with Ekman transport.

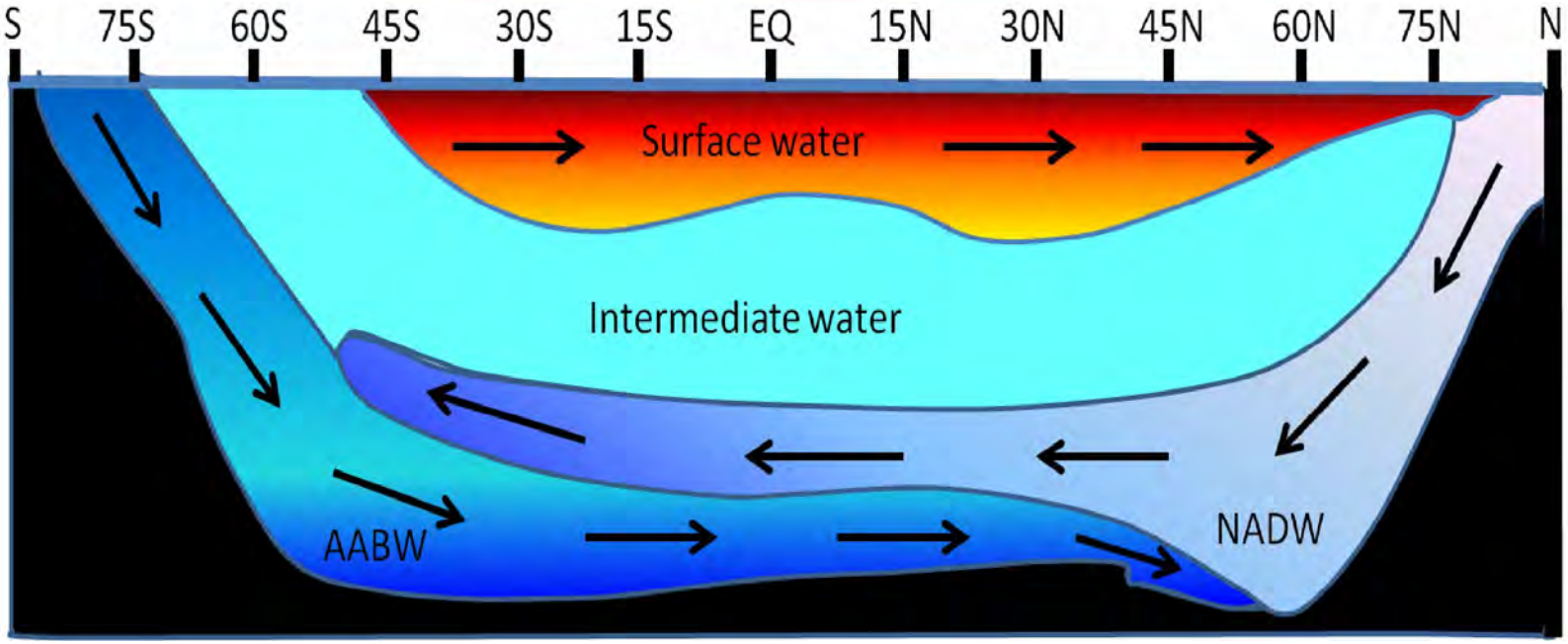
# Regional view: The warm SST biases in the Southern Ocean and ocean circulation

Global SST biases averaged in 22 IPCC-AR5 models




What cause the warm SST biases in the Southern Ocean?

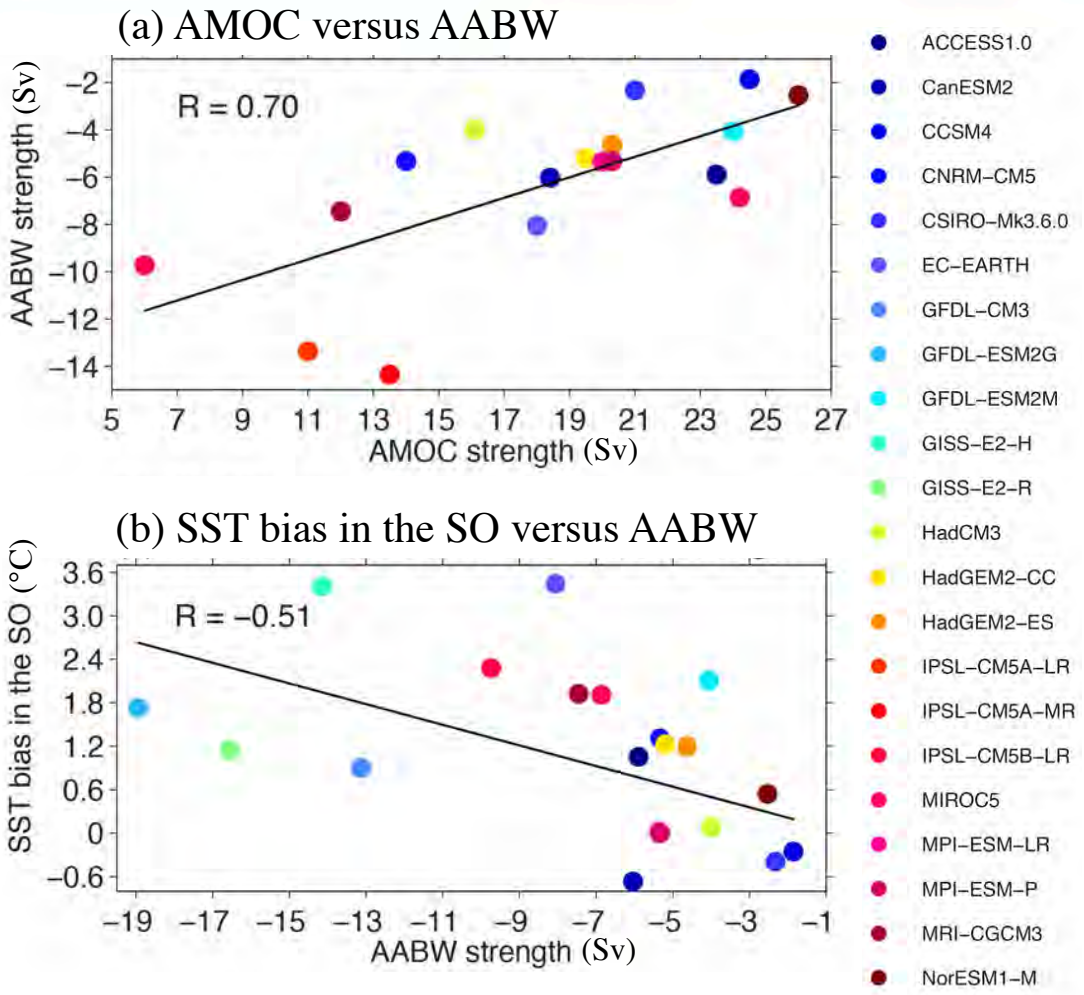
# The AMOC and Antarctic Bottom Water (AABW)




- Associated with the AMOC, two principal water masses circulate in the deep ocean: North Atlantic Deep Water (NADW) and Antarctic Bottom Water (AABW).

- The AABW index is defined by the minimum of the Global Meridional Overturning Circulation (GMOC) streamfunction between 60°S-80°S.

# The warm SST biases in the Southern Ocean and ocean circulation




Key findings:

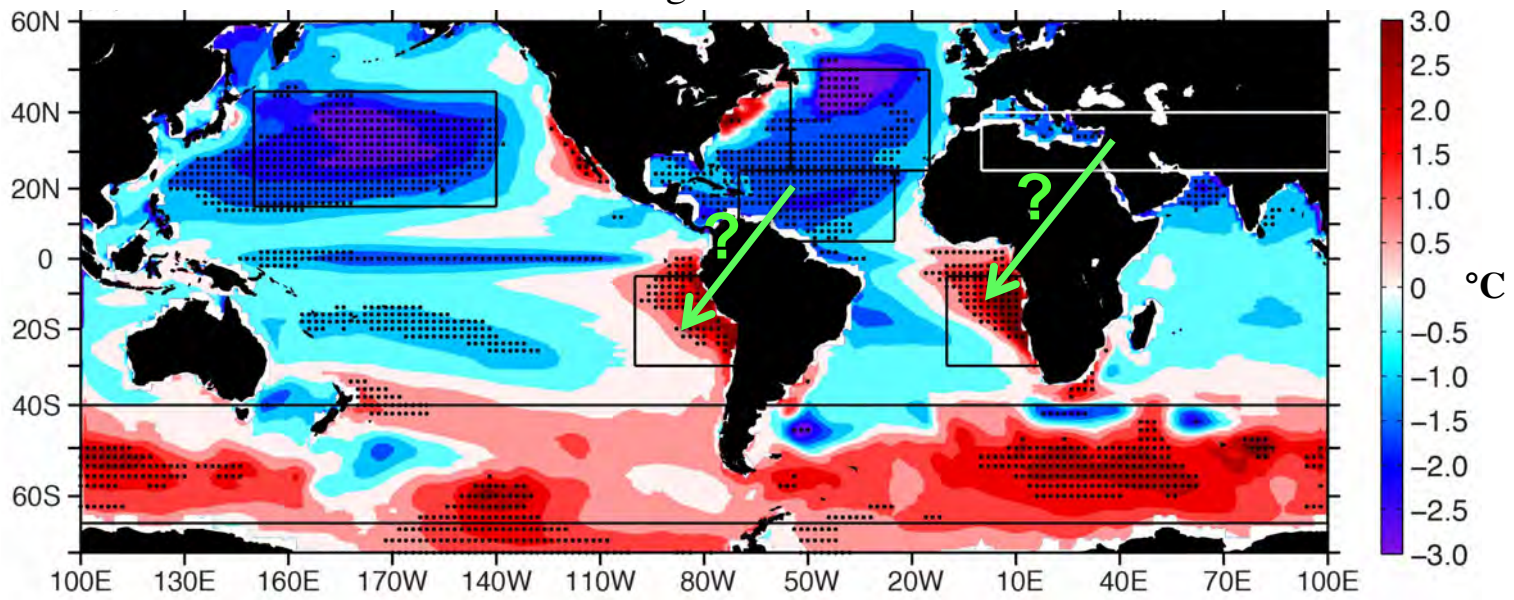
- An inverse relationship between the AMOC and AABW (top panel). This is consistent with that a reduction in the density of NADW associated with a weakened AMOC allows dense surface water in the Southern Ocean (SO) to penetrate into the deep sea (i.e., an enhanced convection).

- This enhanced convection is associated with increased convective mixing in the SO, which favors surface warming in the SO (low panel).


Wang et al. (2014, *Nature CC*)

# Regional view: Interhemispheric link between SST biases in the tropical North Atlantic and southeastern Pacific

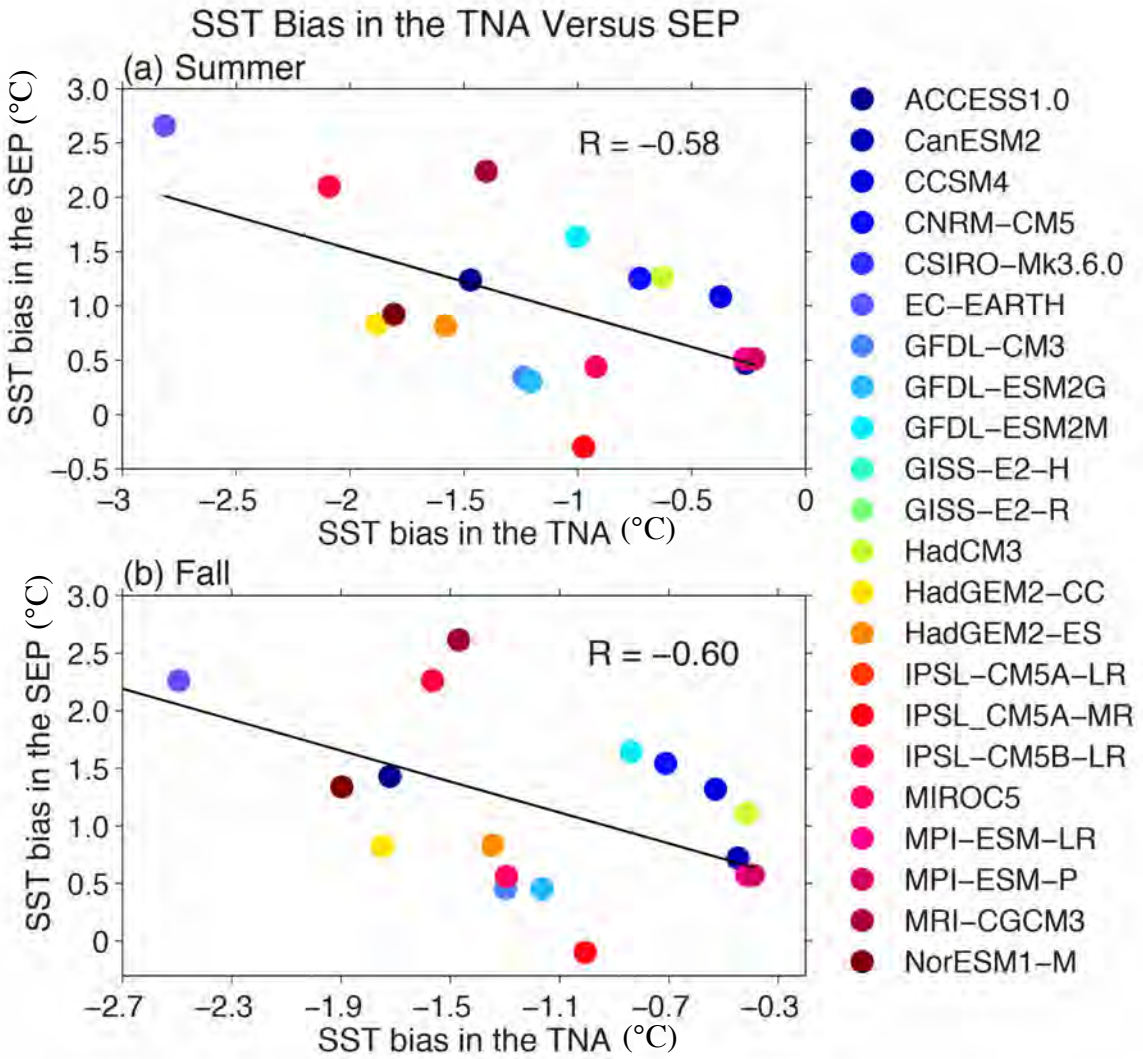
Global SST biases averaged in 22 IPCC-AR5 models




- Warm SST bias in the tropical southeastern Pacific (SEP) can be influenced by cold bias in the tropical North Atlantic (TNA).

- Similarly, warm SST bias in the tropical southeastern Atlantic can be influenced by cold bias in the region of the West African and Indian monsoons.

# Interhemispheric link between SST biases in the tropical North Atlantic and southeastern Pacific




Key finding:

- The cold SST bias in tropical North Atlantic (TNA) is associated with the warm SST bias in the tropical southeastern Pacific (SEP).

Mechanism:

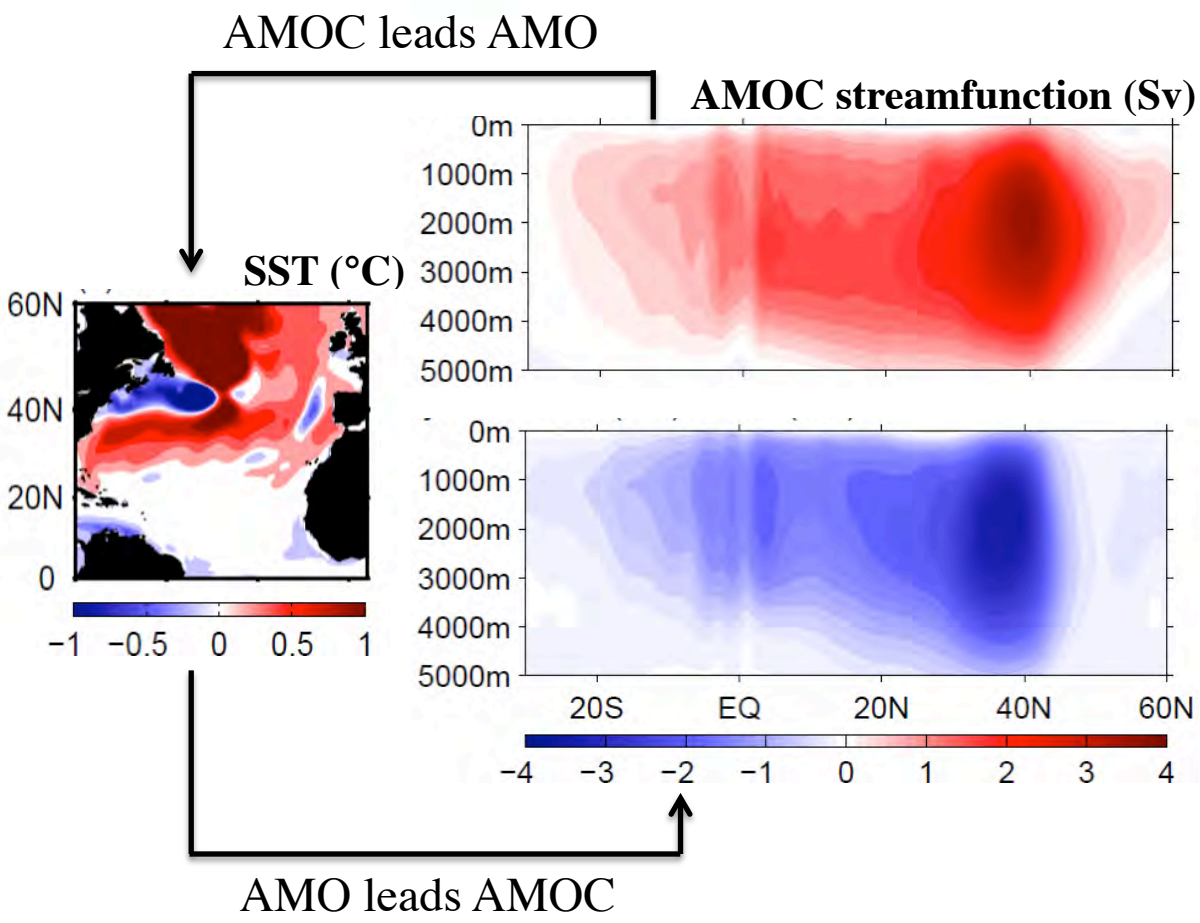
- The cold bias in TNA weakens the regional Hadley circulation which reduces the surface southeasterly wind in the SEP and thus warms the SEP SST.


Wang et al. (2014, *Nature CC*)

- The AMOC simulations in climate models are very important for the global SST biases.

- What are mechanisms for the AMOC and why do climate models show an oscillation of the AMOC?

# Interaction between the AMOC and AMO, and AMOC's oscillation on multidecadal timescale




Key findings:

- The AMOC leads: Strong AMOC is associated with warm phase of the AMO.
- The AMO leads: Warm phase of the AMO corresponds to weak AMOC.
- This indicates that the AMOC and AMO interact with each other.
- This is consistent with the theoretical work of the delayed advective oscillation for the AMOC by Lee and Wang (2010, *JC*)

# Summary and Future Work

- The AMOC and AMO interact with each other, supporting an oscillation of the AMOC on multidecadal timescale.
- Common patterns of global SST biases in IPCC-AR5 climate models are found to link with AMOC simulations.
- Our results indicate that improving the simulation of regional processes may not be enough for overall better model performance, as the effects of remote biases may override them.
- It is critical to NOAA's goals to improve our understanding of climate and ocean circulation and help reduce climate model biases and uncertainties.

# Thank you very much

# Questions?

# References


Lee, S.-K., and C. Wang, 2010: Delayed advective oscillation of the Atlantic thermohaline circulation. *J. Climate*, **23**, 1254-1261.

Wang, C., L. Zhang, S.-K. Lee., L. Wu, and C. R. Mechoso, 2014: A global perspective on CMIP5 climate model biases. *Nature Climate Change*, in press.

Zhang, L., and C. Wang, 2013: Multidecadal North Atlantic sea surface temperature and Atlantic meridional overturning circulation variability in CMIP5 historical simulations. *J. Geophys. Res.*, **118**, 5772–5791, doi:10.1002/jgrc.20390.

Interhemispheric link between SST biases in tropical southeastern Atlantic (SEA) and SAT (Surface Air Temperature) biases in the region of the West African and Indian monsoons (WAIM).