Simulated Atlantic Multidecadal Variability (AMV) during the 20th Century in CESM Large Ensemble and Forced Ocean Simulations

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Motivations

Some recent studies have claimed that the AMV during the 20th century (20C) could have been forced by combined influence of greenhouse-induced warming and aerosol-induced cooling[1], in contrast to many previous studies stressing the role of internal variability. This externally forced AMV also appears in historical CESM Large Ensemble simulations (CESM-LE)[2], a large ensemble size (30) of which allows for quantifying a robust response to external forcing.

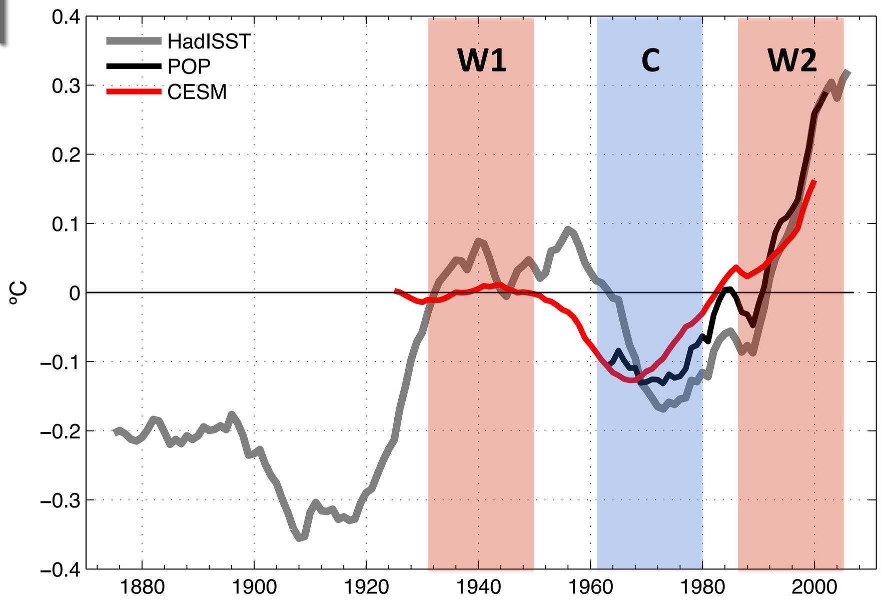
On the other hand, a recent study suggested that the AMV could be driven by wind forcing alone through modulations of gyre strength, which in turn result in a convergence or divergence of heat in the upper ocean[3].

These disparities suggest that, given its substantial influence on climate, we need to better understand the mechanism of the AMV. In this study, we explore and compare the mechanism of simulated AMV in CESM-LE and in its ocean component forced with a best available atmospheric dataset.

Key Questions and Answers

- ✓ ***Was the 20C AMV driven by external radiation forcing, as suggested in ref. 1?***
  No. While the AMV in CESM-LE appears to be related to external radiation forcing, as in ref. 1, a forced ocean simulation with climatological radiation almost entirely reproduces the AMV in the control simulation, which is in excellent agreement with the observed AMV. This result suggests the **external radiation forcing has a negligible role in driving the AMV**, at least, during the second half of the 20C.
- ✓ ***Was the 20C AMV driven mechanically by wind forcing, as suggested in ref. 3?***
  No. A forced ocean simulation only with interannually varying momentum fluxes shows that **wind forcing cannot produce the AMV alone.**
- ✓ **A suite of flux perturbation experiments using an ocean model suggests that changes in ocean circulations associated with turbulent heat fluxes are *ultimate mechanism* of the AMV**

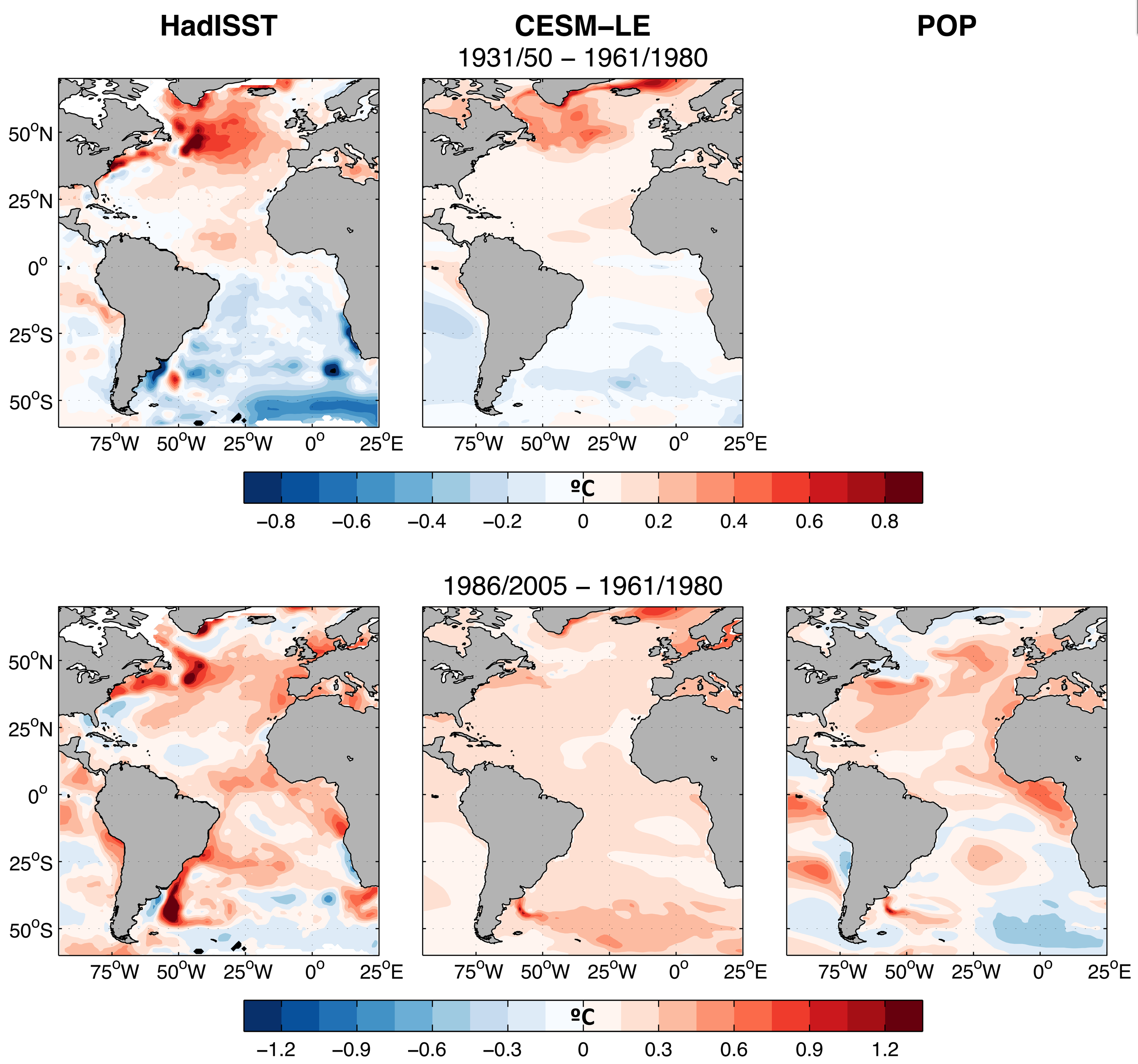
Fig.1 NA SST anomalies (AMV index)



averaged over the North Atlantic (0 – 60ºN). All anomalies are relative to the respective 1958-2005 mean (~ 18ºC in HadISST and ~ 21ºC in both CESM-LE and POP). All time series are smoothed using a 11-yr running mean.

- CESM-LE reasonably reproduces the observed AMV, similar to ref. 1
- The AMV in POP shows an excellent agreement, better than CESM-LE, with the observations for the available time span.

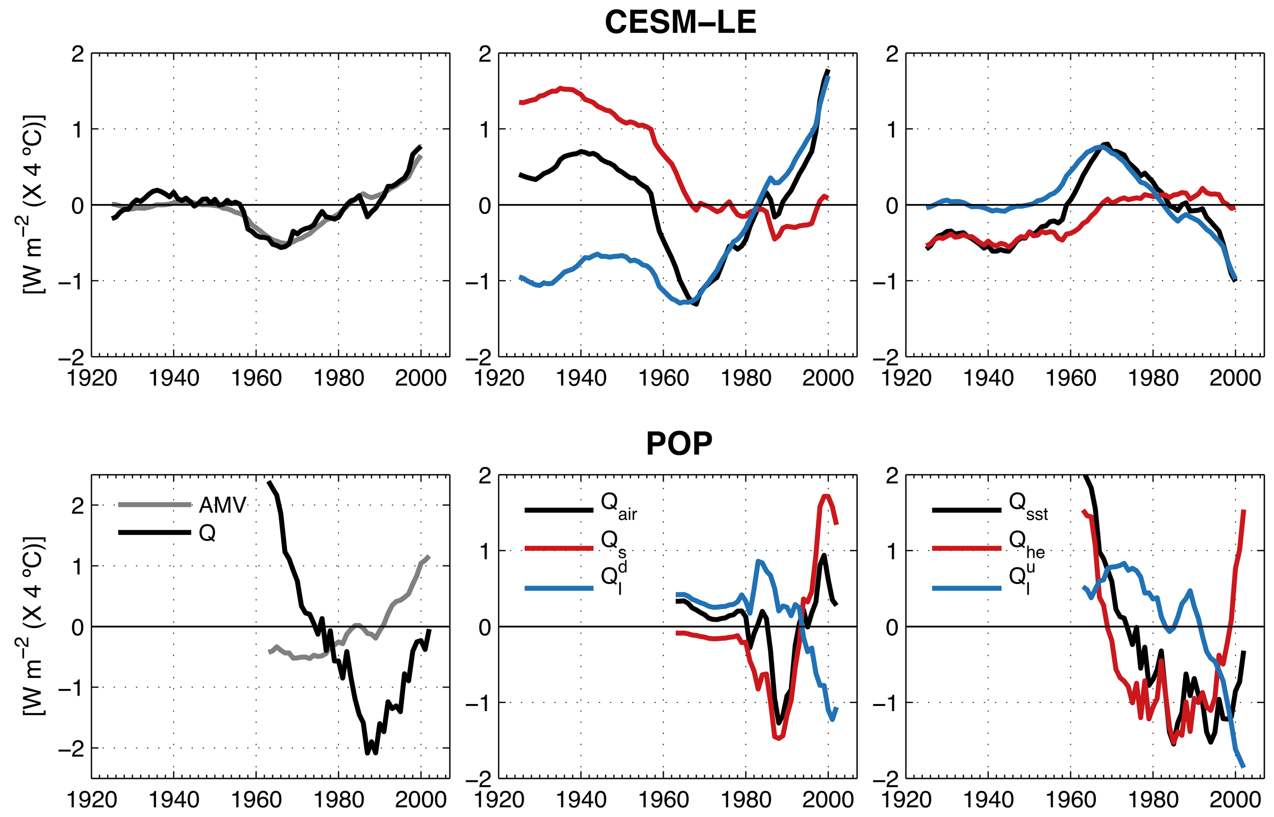
Fig.2 SST difference, W1 – C (top) and W2 – C (bottom)



- CESM-LE reasonably reproduces the observed AMV pattern in W1 – C, but not in W2 – C
- In both differences, CESM-LE does not pick up the observed intense warming along GS/NAC
- POP reasonably reproduces the observed spatial difference in W2 – C including the intense GS/NAC warming

Fig.3 Surface heat flux anomalies

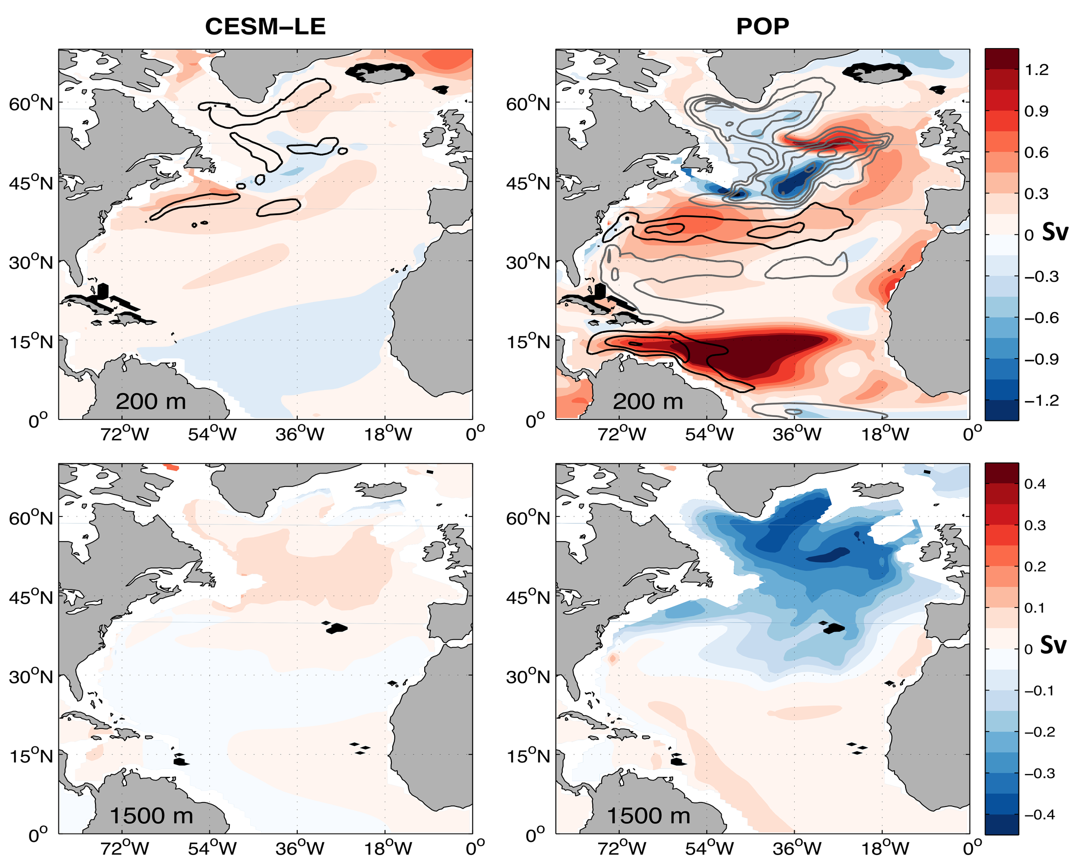
averaged over the AMV region and relative to the respective 1958-2005 mean. All time series are smoothed using a 11-yr running mean. Note that shortwave and downwelling long wave radiation in POP are from satellite-based data (ISCCP-FD) since 1984



- The AMV in CESM-LE appears to be driven by combined effects of shortwave and downwelling longwave radiation
- However, their changes during the late 20C is not consistent with observations (POP)
- In addition, the AMV in POP does not appear to be driven by either radiation or total net surface heat flux

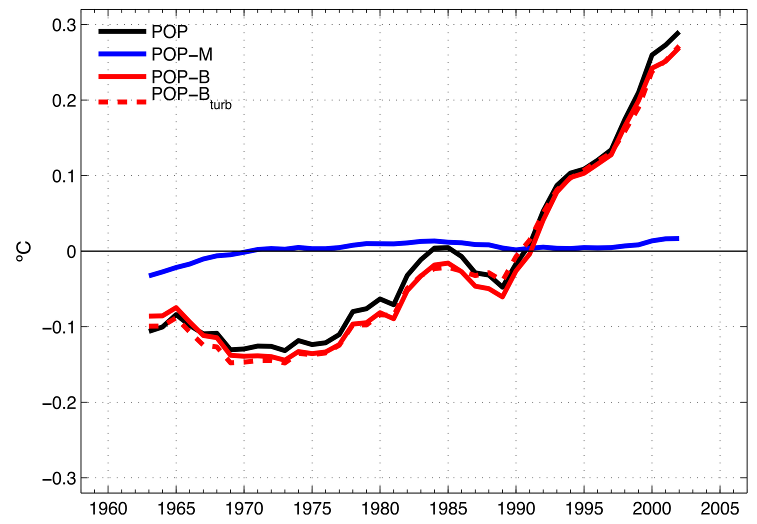
Fig.4 Barotropic streamfunction (BSF) and T_{sub} differences (W2 – C)

BSF difference in contours (interval: 1 Sv) and T_{sub} difference in color



- While the AMV in CESM-LE is not linked to changes in ocean circulations
- The AMV in POP appears to be associated with changes in ocean circulations, including the AMOC

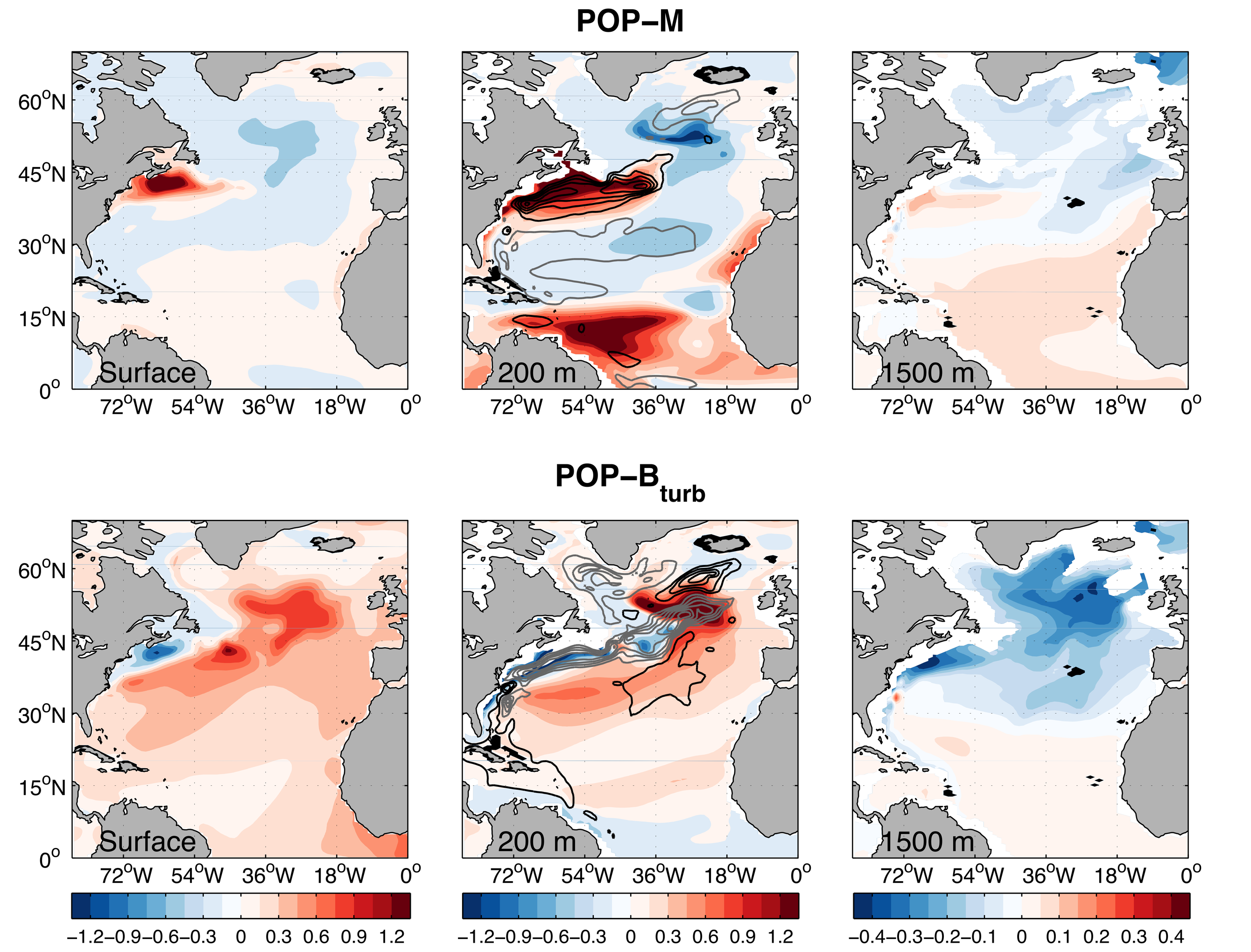
Fig.5 NA SST anomalies in flux perturbation experiments* using POP



***Flux perturbation experiments[4]**

POP-M	interannually varying momentum fluxes
POP-B	interannually varying buoyancy fluxes
POP-B$_{turb}$	interannully varying latent (and evaporation) and sensible heat fluxes

Fig.6 SST, T_{sub}, and BSF differences (W2 – C) in flux perturbation runs.



- A suite of experiments clearly demonstrates that the AMV, at least during the late 20C, is driven by AMOC changes associated with buoyancy forcing, particularly due to turbulent heat fluxes[4]
- And effects of both radiation and momentum forcing on the AMV are negligible

References

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