ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE
MIAMI

Recent Atlantic multidecadal variability and other climate modes are dominated by external forcings

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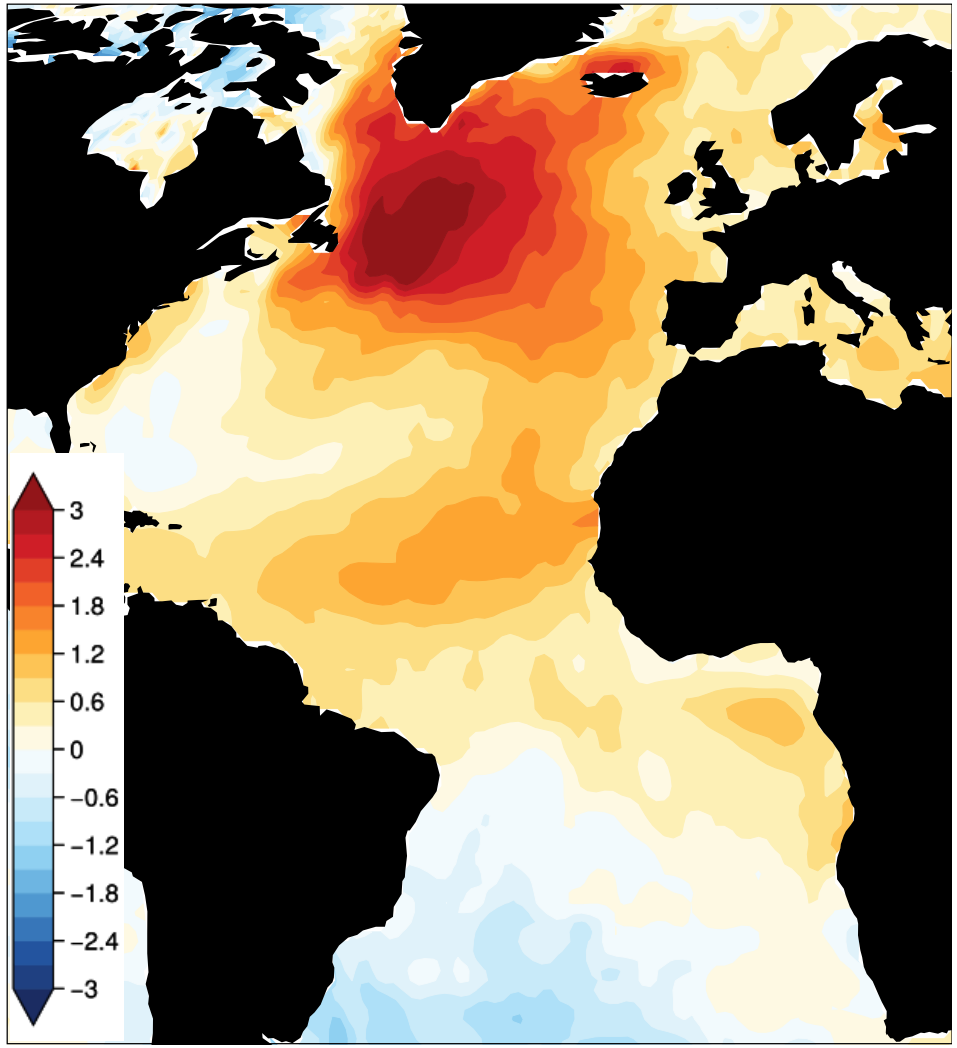
He, C., Clement, A. C., Kramer, S. M., Cane, M. A., Klavans, J. M., Fenske, T. M., &Murphy, L. N. (2023), Tropical Atlantic multidecadal variability is dominated by external forcing, *Nature*, **7983**, 521-527.
Clement, A. C., Cane, M. A., Klavans, J. M., He, C. &Murphy, L. N. (2025), A Signal-to-Noise Problem in Decadal Climate Modes, In Prep.

Cause of the AMCV is controversial



- AMV has widespread tropical impacts, such as hurricane and Sahel rainfall
  → AMCV

- Cause:
  Internal variability (AMOC, NAO; Zhang et al. 2019; Clement et al. 2015…)
  External variability (aerosols; Booth et al. 2012…)

- Question:
  What is the cause of the AMCV?

Motivation and Method

What is the cause of the recent AMCV that includes hurricanes, Sahel rainfall and AMV?

What about other major climate modes like NAO and PDO?

Previous studies usually investigate the AMCV for the whole past century, but anthropogenic emissions soured after WW II.

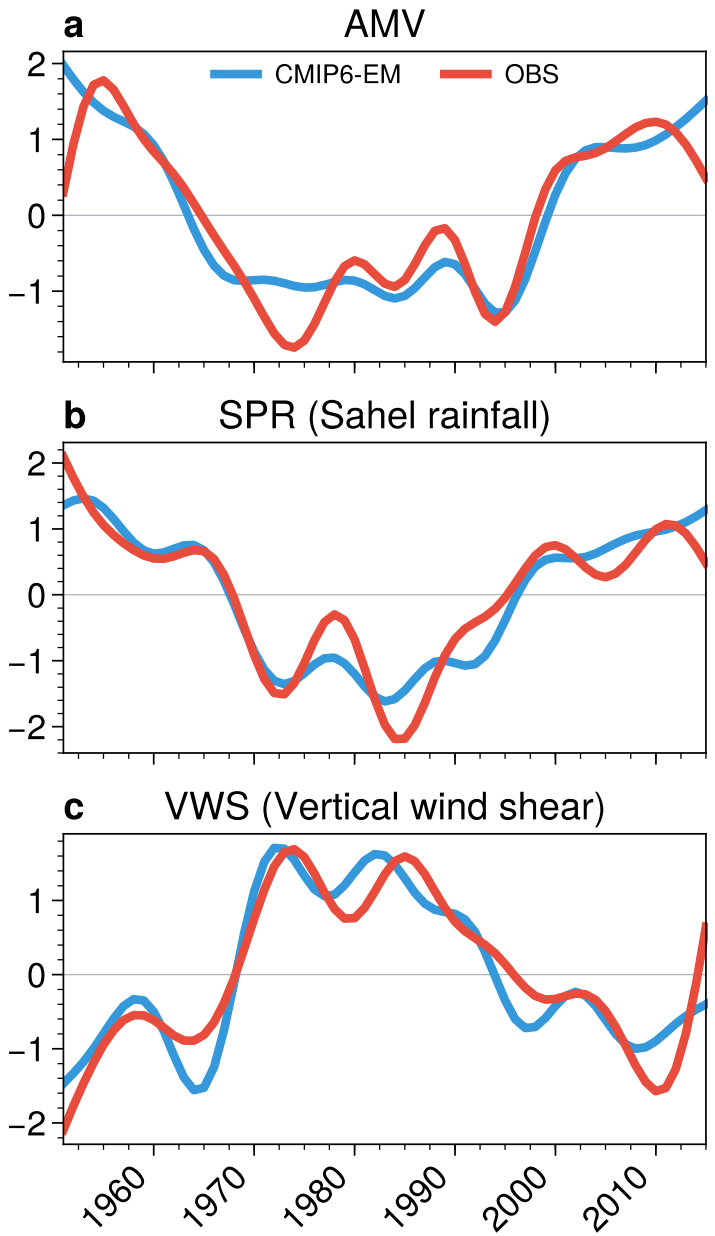
Time period

- 1950-2014, when reliable OBS are available for Hurricanes and Sahel Rainfall

CMIP6

- Historical simulation: 46 models (in total 402 ensemble members)
- DAMIP, each single-forcing run has 70~100 members to quantify externally forced response

More than r^2=80% variance in real-world AMCV is forced.



- Detrended* and normalized
- Simulation is highly correlated with OBS, r>0.9

Forced variability

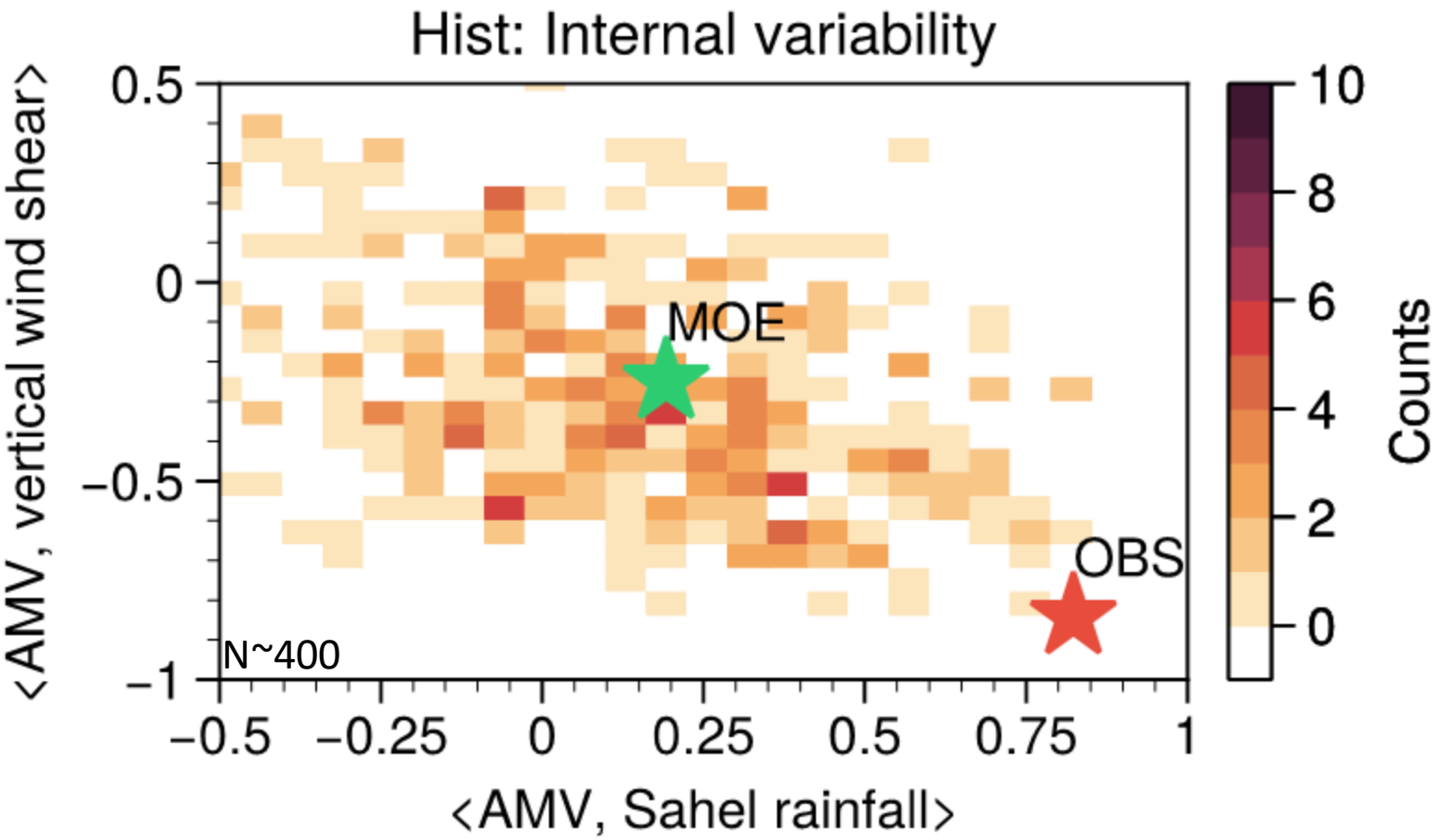
- $Obs = \alpha EM + \epsilon$

Internal variability

- More than r^2=80% variance is forced

*: all time series are detrended in the model and obs. Model has a spurious trend in tropical Atlantic climate.

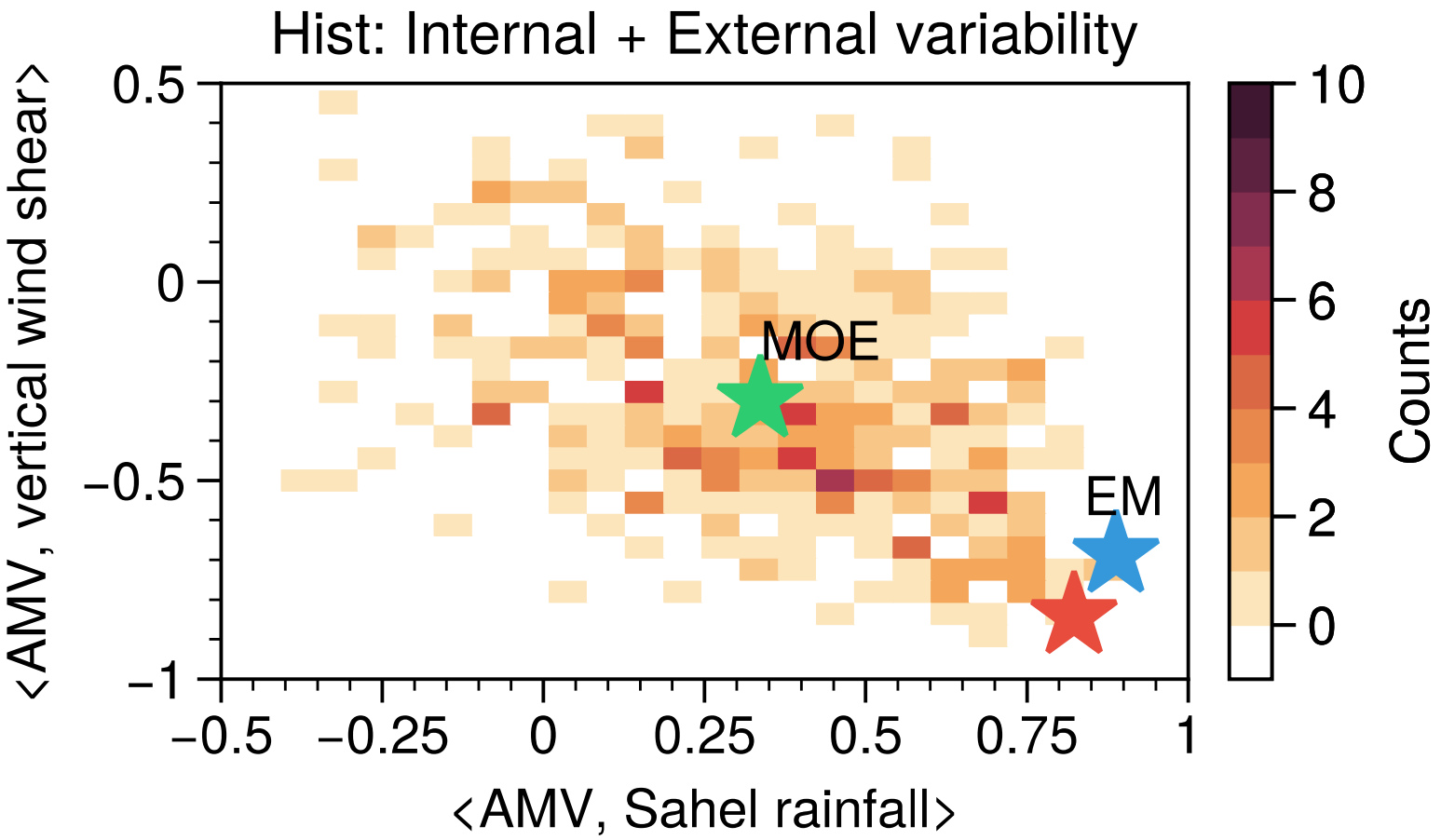
Internal Variability alone cannot produce the real-world AMCV



- If real world is a twin of internal variability, they shall share the same DNA
- DNA: covariability in AMCV
- Likelihood: 0 out of 400

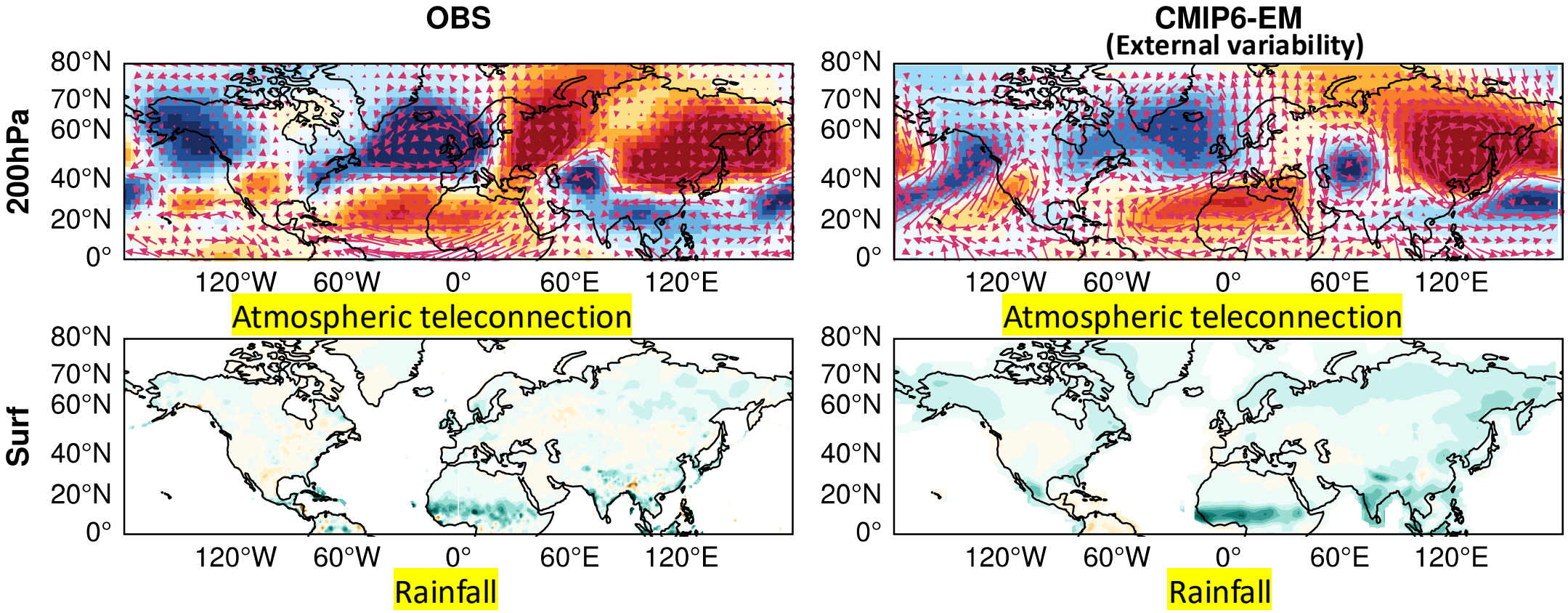
Genetic test 1: DNA shows internal variability is very unlikely to explain real world

The post-1950 real-world AMCV only emerges in forced response



Genetic test 2: DNA shows observed AMCV can only be explained by external forcing

AMCV-induced atmospheric bridge is also driven by external variability

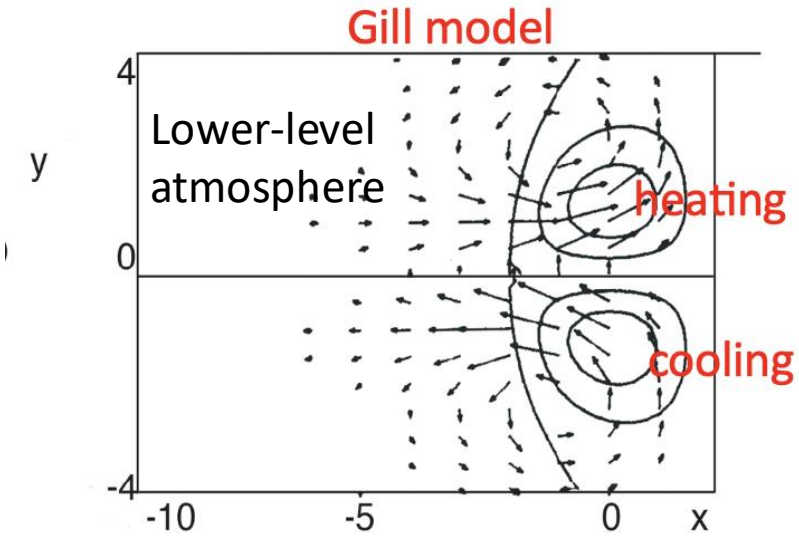


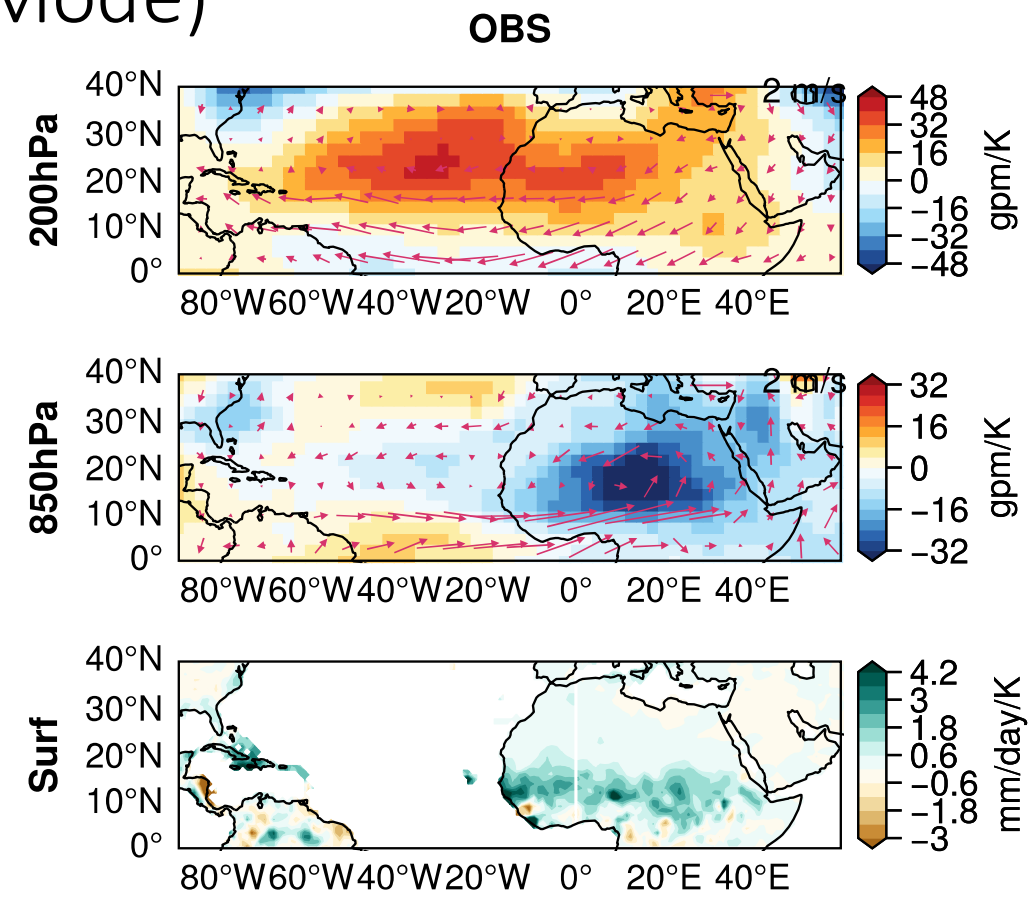
Regressing circulation and rainfall on AMV

Genetic test 3: AMCV-induced teleconnection is forced

Si et al. 2022; Ting et al. 2014; He et al. 2023

Sahel rainfall and NA hurricanes driven by tropical Atlantic meridional SST contrast (AMM, Atlantic Meridional Mode)

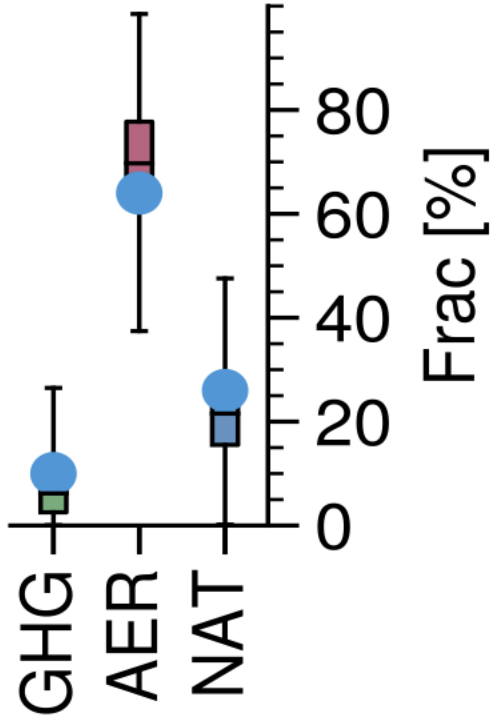




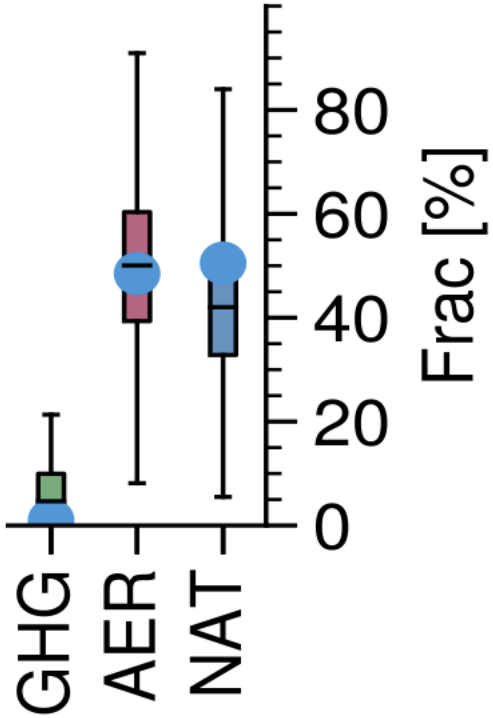
- Asymmetric heating across the equator
- Sahel rainfall and vertical wind shear are mostly driven by AMM.

Tropical AMCV mostly driven by anthropogenic and volcanic aerosols, but AMV is additionally impacted by GHG.

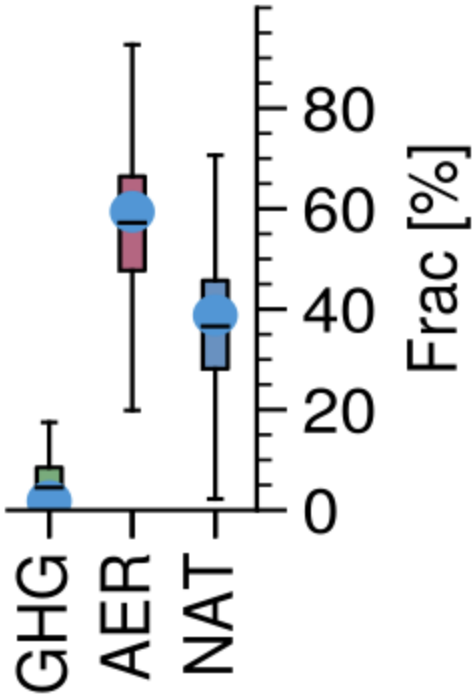
(SPR) Sahel Rainfall



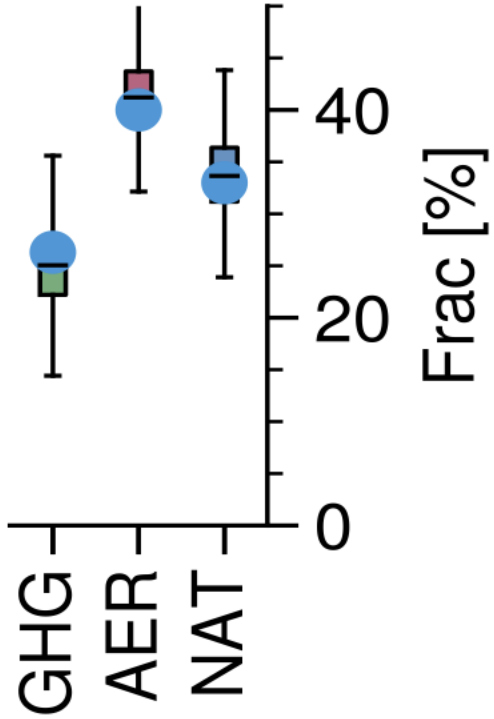
(VWS) Hurricane



AMM

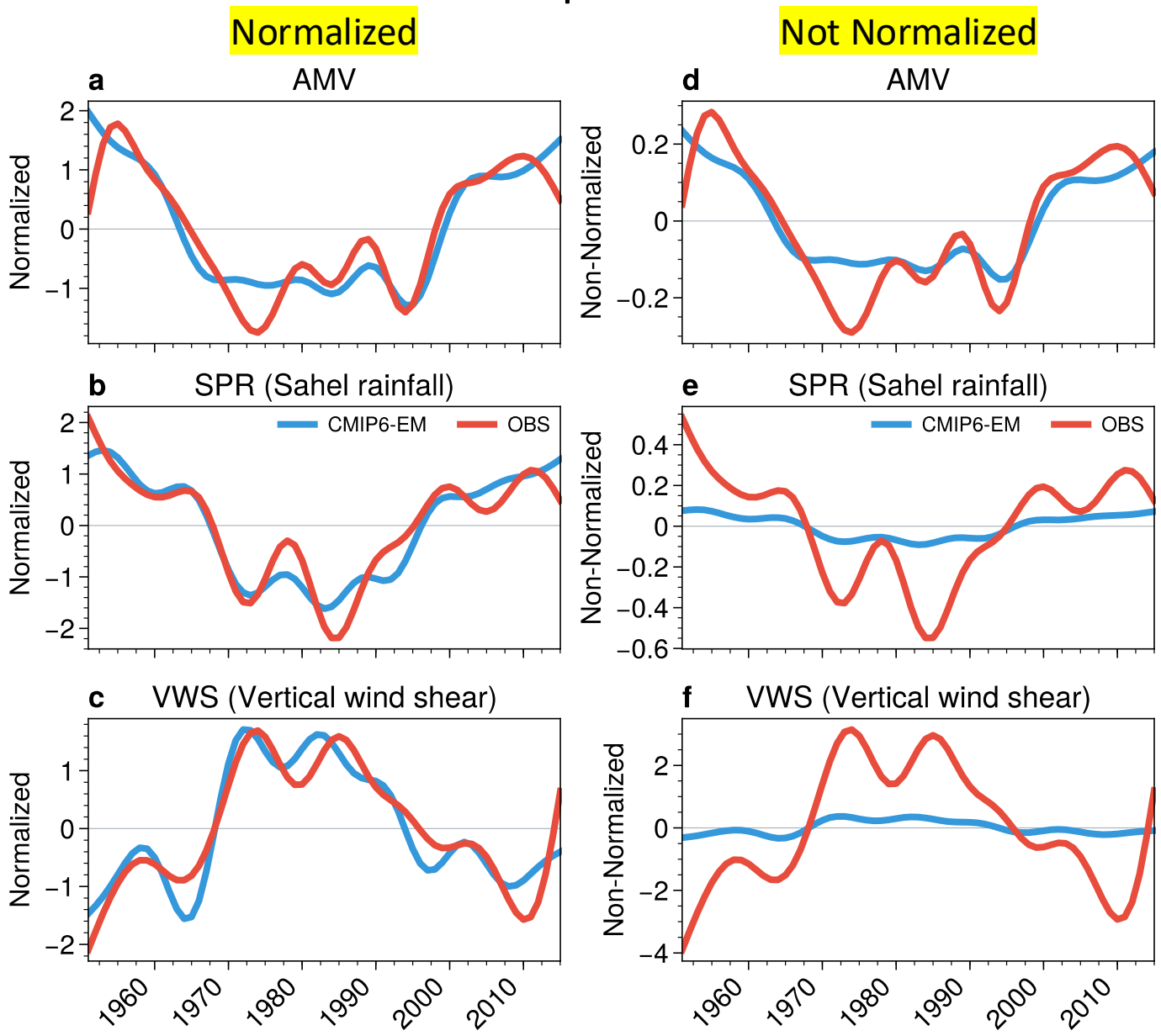


AMV



GHG: greenhouse gases
AER: anthropogenic aerosols
NAT: natural forcing

Modeled forced responses are muted.

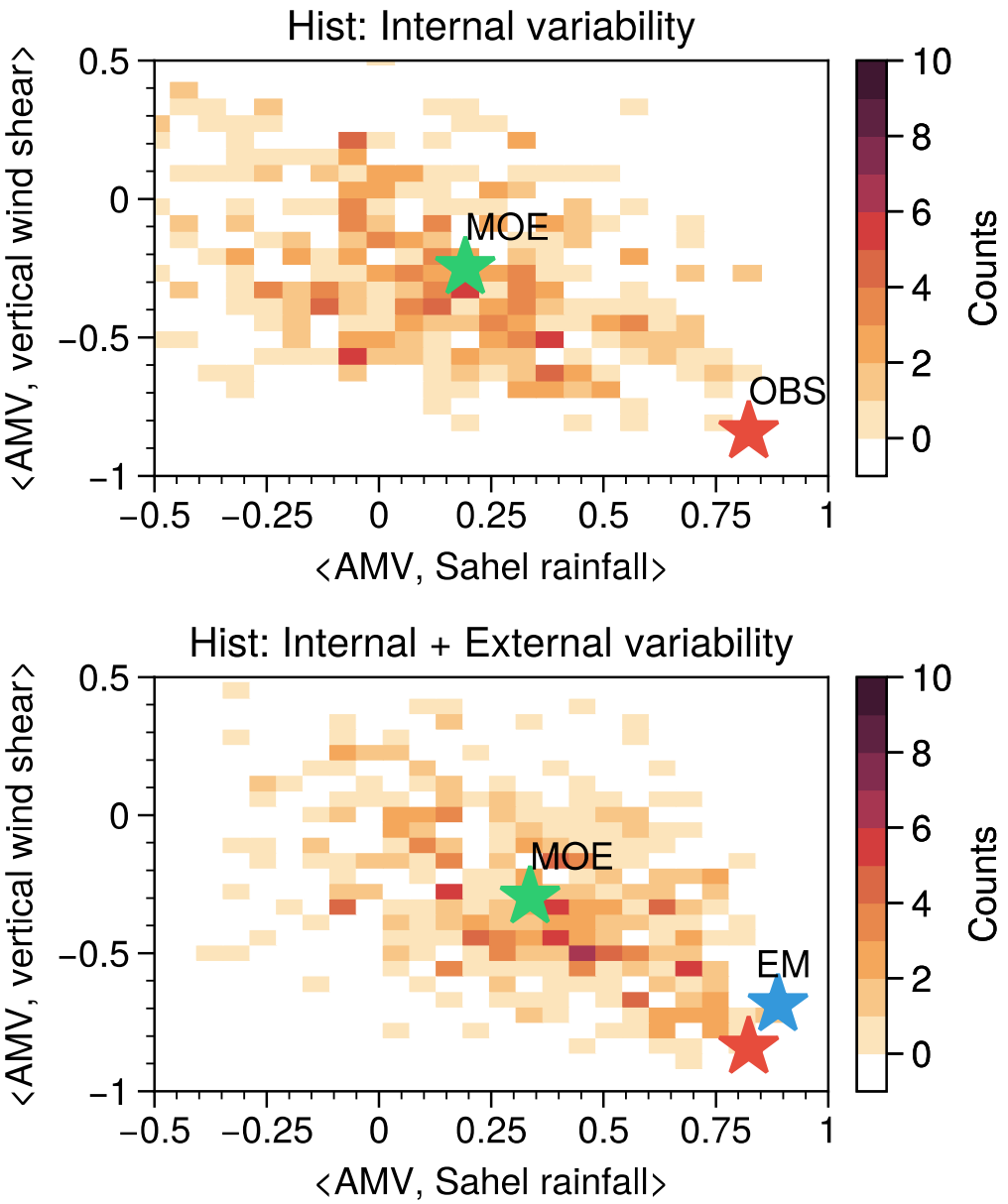


- Hundreds of ensemble members to isolate the forced responses.
- Forced responses are muted.
  -> Model is dominated by internal variability

  -> Low signal2noise ratio in models

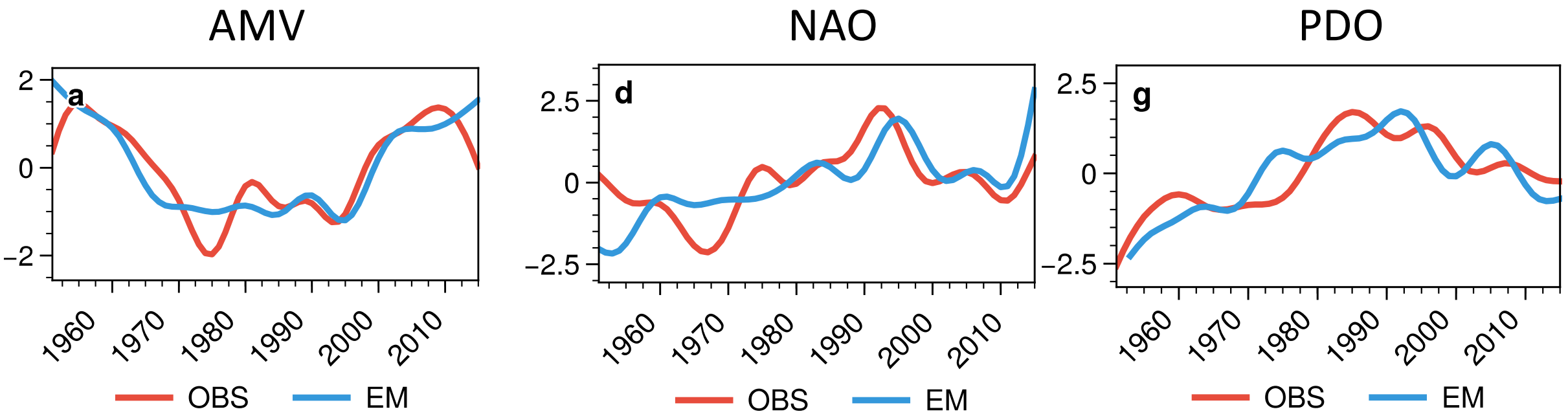
*: all time series are detrended in the model and obs. Model has a spurious trend in tropical Atlantic climate.

Signal to noise (forced to internal) problem in the post-1950 AMCV



- Single model member is dominated by internal variability (signal2noise is low)
- Single real-world realization (OBS) is dominated by external forcing (signal2noise is high)
- This signal to noise paradox is similar to that in the predictability community.

NAO and PDO are also influenced by external forcings



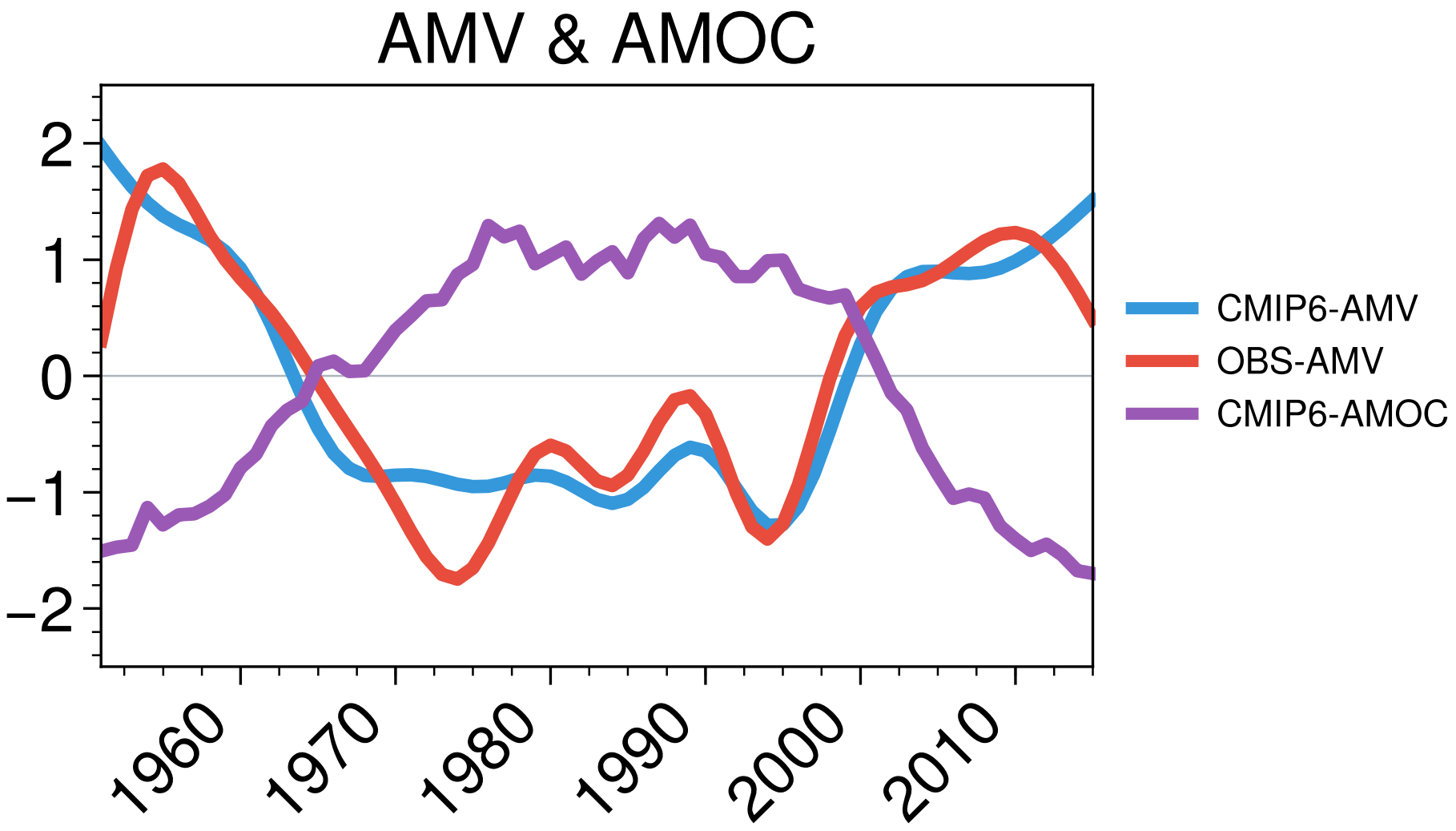
Klavans et al. 2021; 2025

Take home message

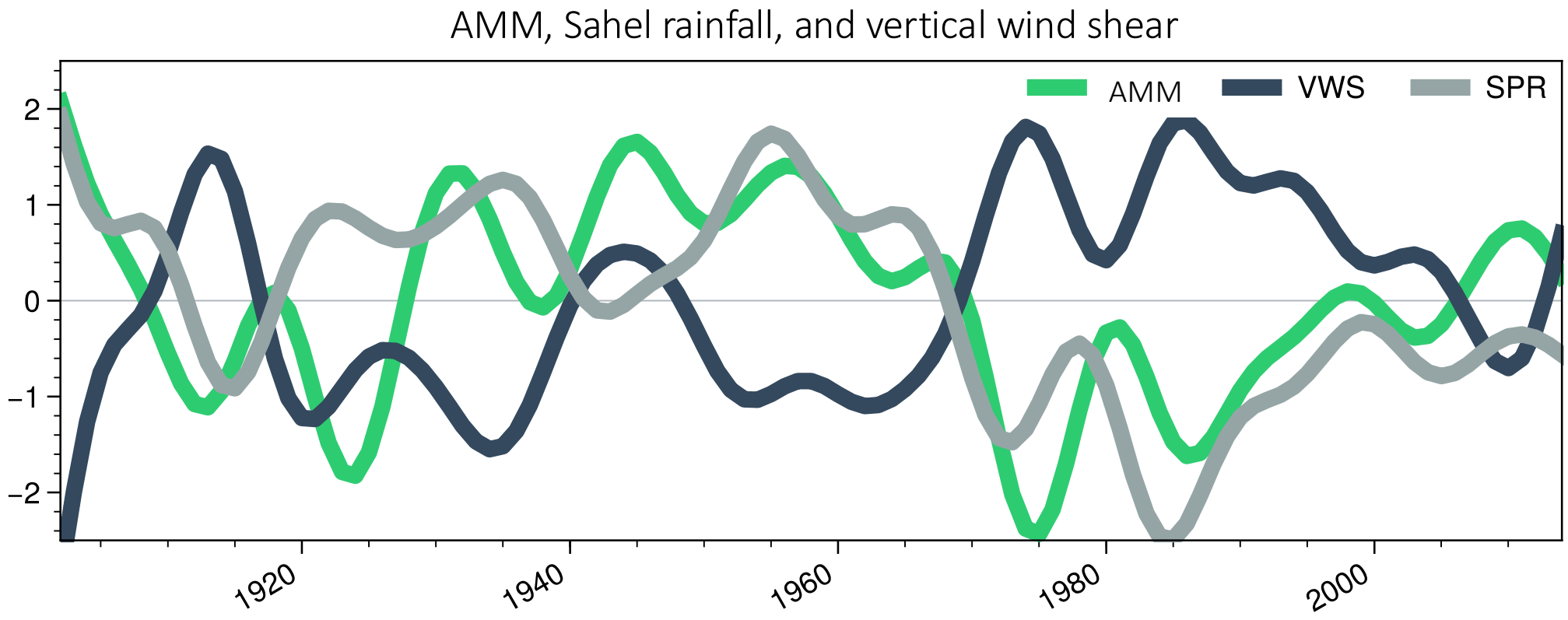
- Recent tropical AMCV is driven to anthropogenic and volcanic aerosols
- AMM better interprets tropical impacts than AMV
- NAO and PDO are also influenced by external forcings
- Signal to noise problem in climate models (open question)
- **What about pre-1950 period? What about the AMOC? Check our paper!**

backup

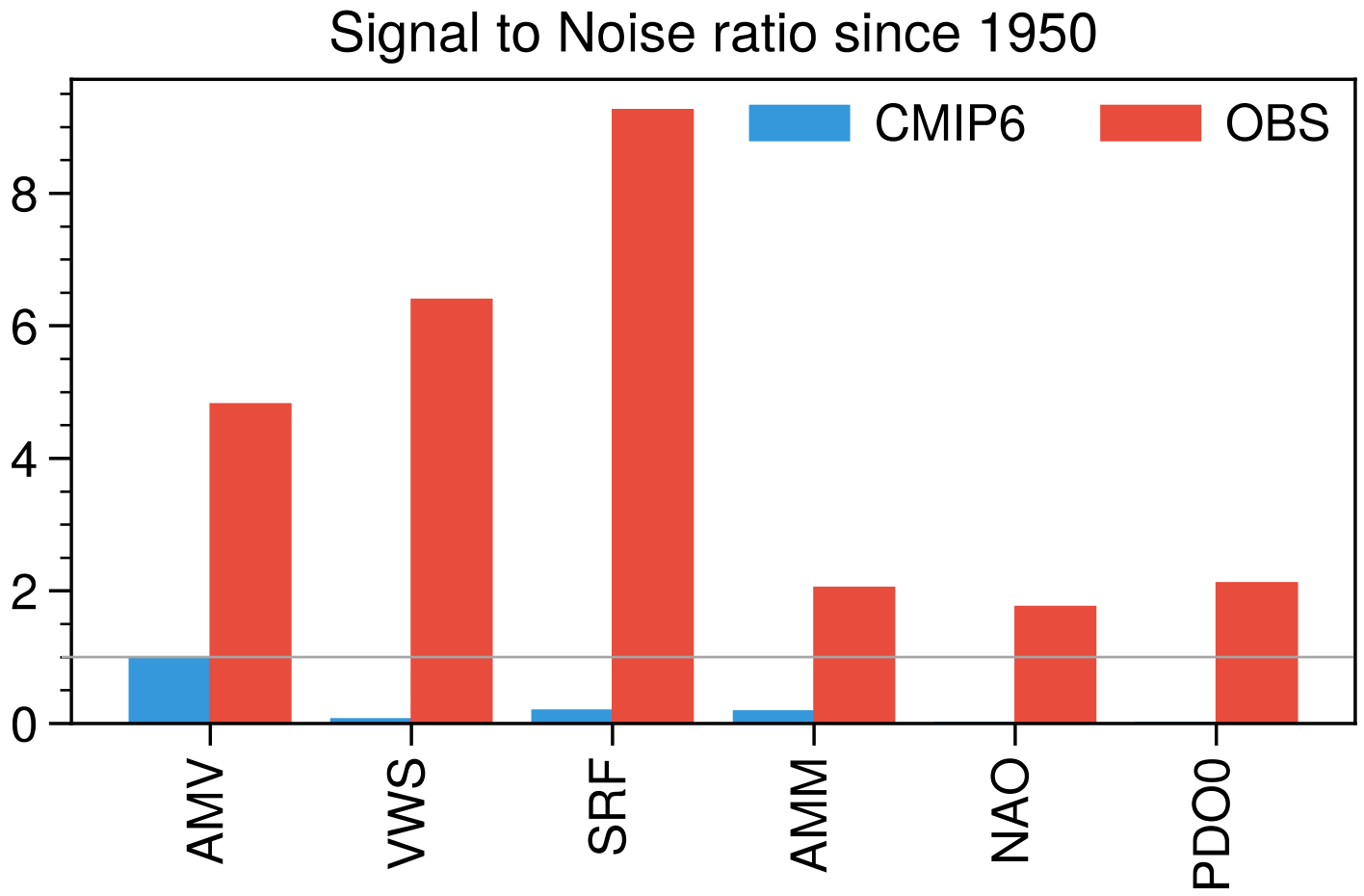
AMOC is the extramarital affair of AMV, attempting to disrupt the marriage between AMV and external forcing.



AMM naturally removes global warming



Signal to noise problem in NH climate modes



Real-world climate modes are mostly driven by external forcing.

Model's climate modes are dominated by internal variability.