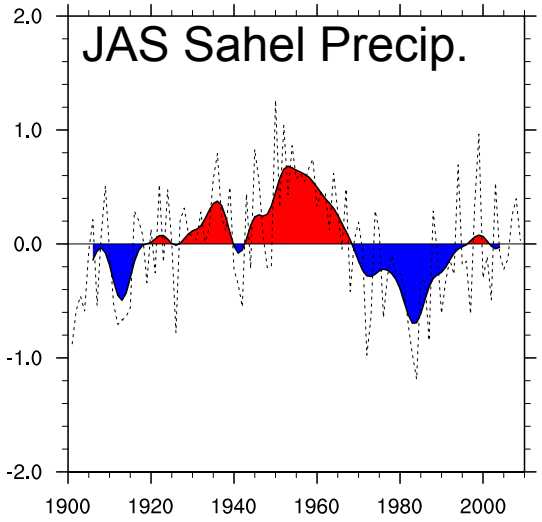
MULTI-DECADAL VARIABILITY OF WEST AFRICAN RAINFALL IN OBSERVATIONS AND CMIP5 SIMULATIONS

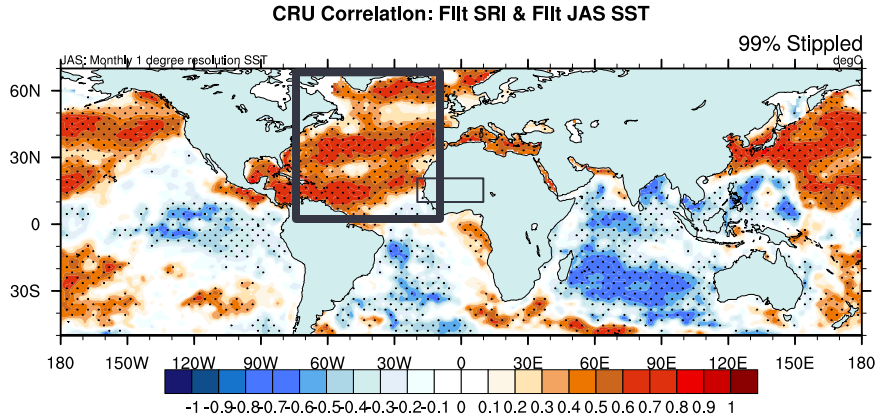
Elinor R. Martin and Chris Thorncroft

Department of Atmospheric and Environmental Sciences
SUNY Albany
emartin4@albany.edu

Multi-Decadal Variability of Sahel Rainfall

- Sahel rainfall large decadal variability
- Role of SST
- *Atlantic*:
  - AMO
  - Warm Atlantic -> wet Sahel
  - Warm Mediterranean -> stronger heat low and wet Sahel
- Indian:
  - Less well understood
  - Warm Indian -> dry Sahel
  - Changes in troposphere stability and E-W circulation





Do CMIP5 simulations capture the multi-decadal Atlantic SST – Sahel rainfall teleconnection?

Yes and no

What can we learn from the successful and unsuccessful simulations?

Datasets

- Precipitation: CRU (1901-2009): land only
- SST: HadISST (1901-2009)
- NCEP/NCAR Reanalysis (1948-2009): SLP, winds
- IPCC CMIP5 *historical and control coupled* simulations
  - Currently 21 models from 15 modeling centers
  - Each model 1 – 10 ensembles
  - 72 total runs (historical)
  - 19 total runs (control)
- Monthly resolution
- Filtering: low passed with 10 year cut off

Model Selection Criteria

1) AMO index decadal variance fraction

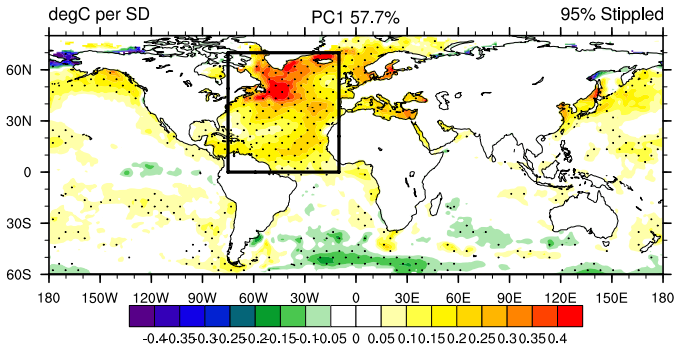
2) Sahel rainfall decadal variance fraction

3) Correlation between filtered Sahel rain and N. Atlantic SSTs (AMO)

	Observations	CMIP5 Historical Mean
AMO decadal variance	66 %	45 %
Sahel rainfall decadal variance	43 %	15 %
Correlation Sahel rain and N. Atl SST	0.56	0.31

Models: SST Patterns

OBS



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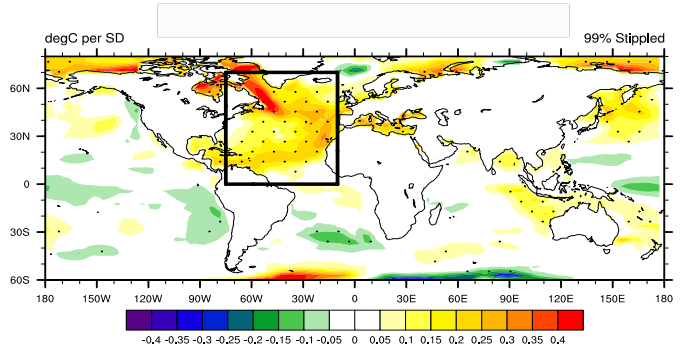

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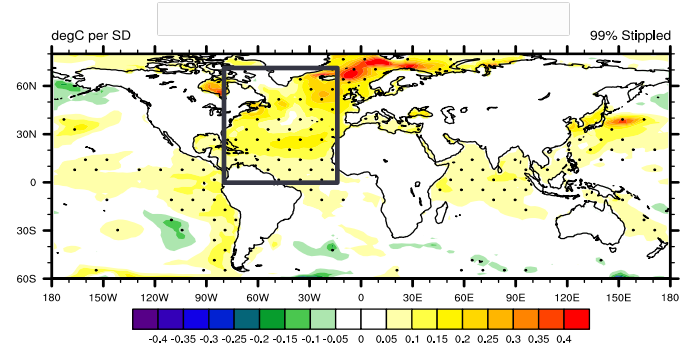
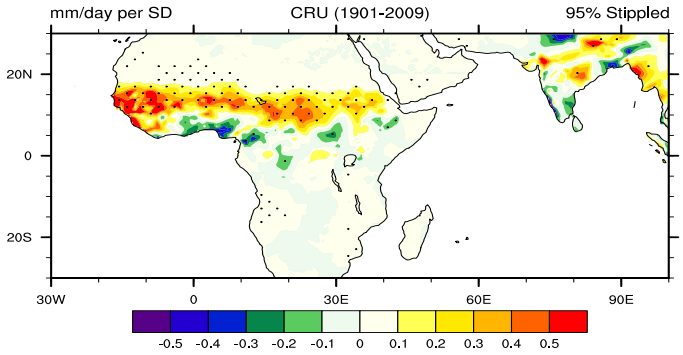


- Leading EOF of JAS SST (detrended and filtered) in N. Atlantic ~AMO
- Regression onto principal component
- Positive signal across N. Atlantic with three maxima:
  - Subpolar region
  - Tropics
  - Mediterranean
- "Good" models successful in simulating leading SST pattern across entire N. Atlantic
- "Poor" models have weaker signal and less signal in tropics

Models: PR Patterns

OBS



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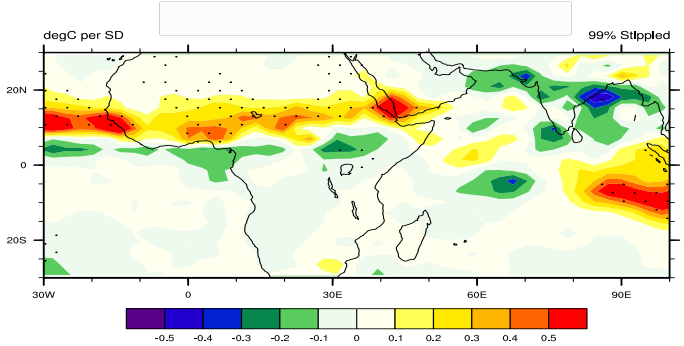

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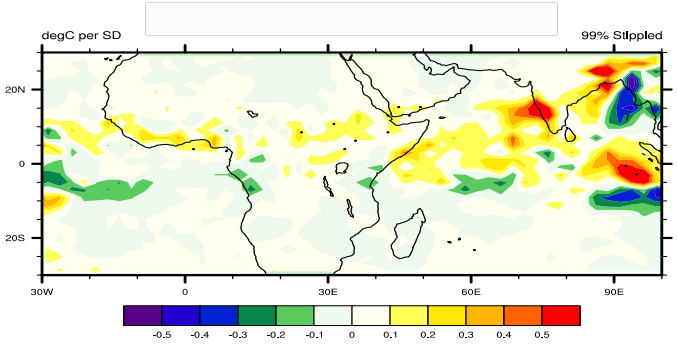
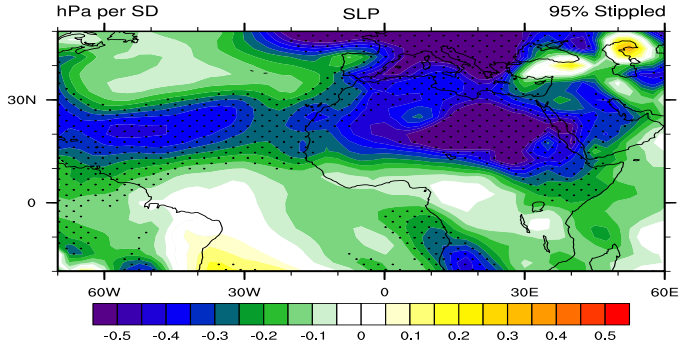


- Positive signal across Sahel and negative (drying) at coast
- "Good" models are successful in simulating +/- signal in West Africa
- "Poor" models have much weaker West African precipitation response to N Atlantic SSTs

Models: SLP Patterns

OBS



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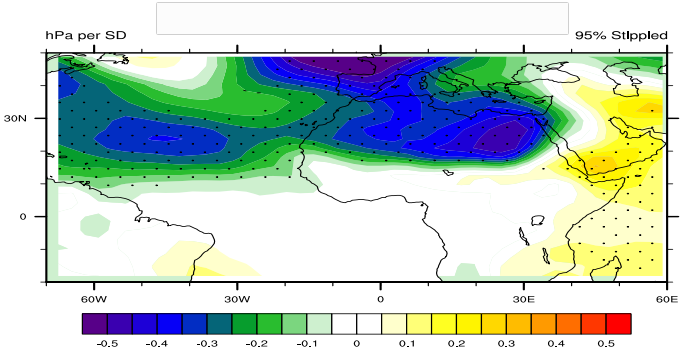

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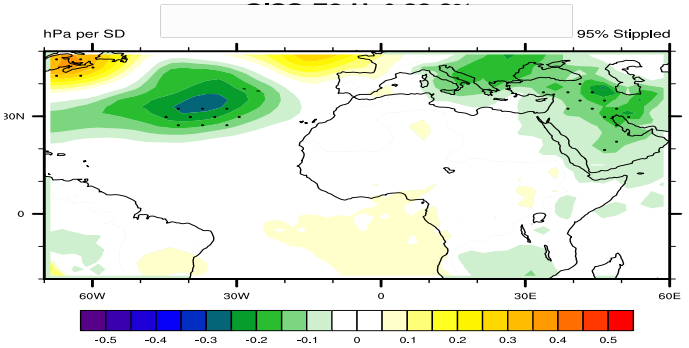
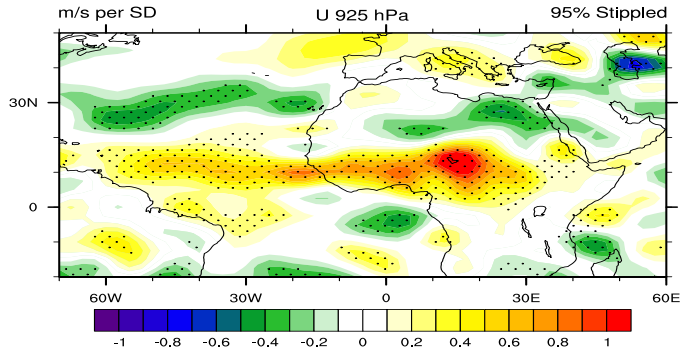


- Low SLP across Atlantic and Sahara associated with warm N. Atlantic (AMO)
- "Good" models successful in simulating response across N. Atlantic and Sahara
- "Poor" models have weaker response and less signal in the Sahara

Models: 925 hPa U Patterns

OBS



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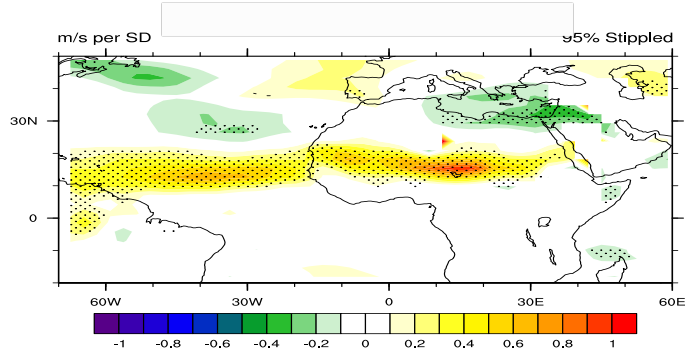

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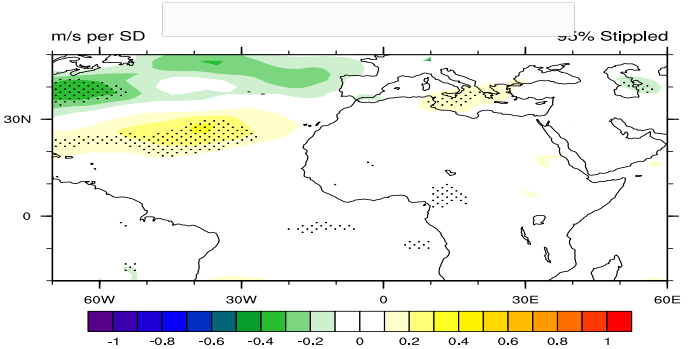
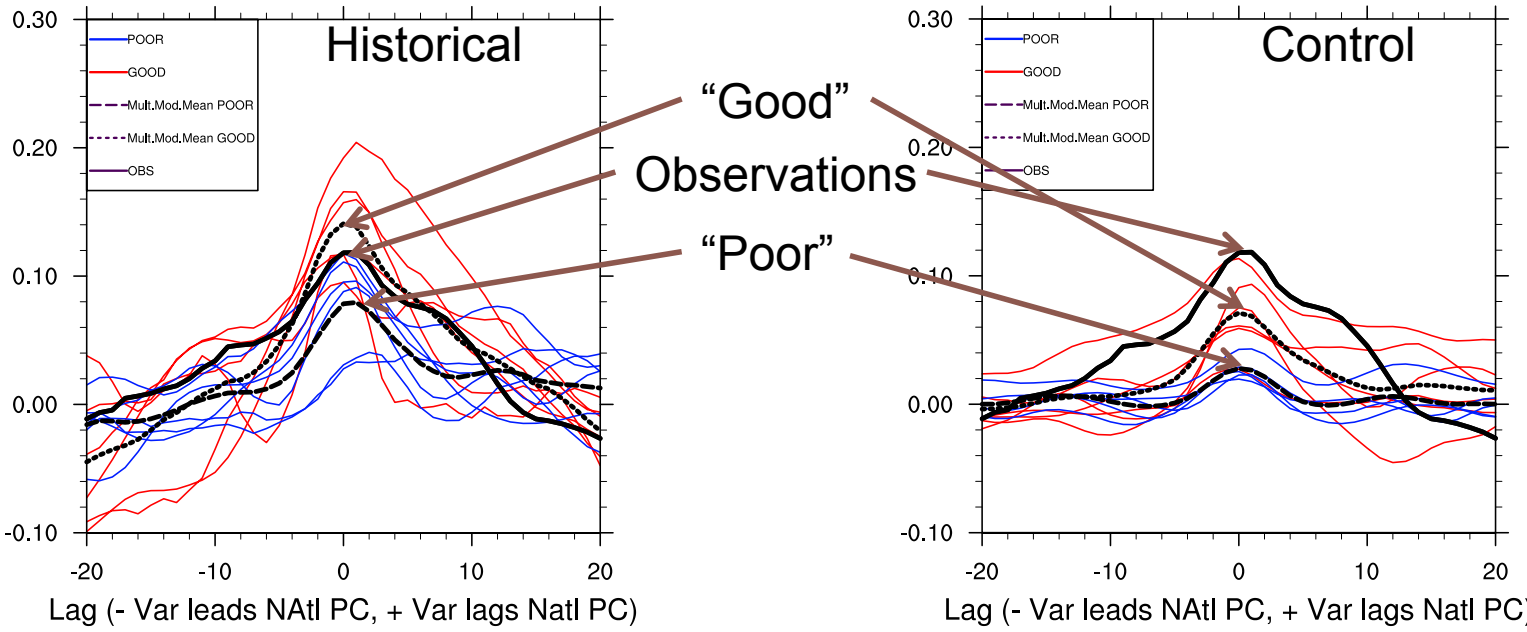


- As expected, westerly (onshore) winds increase as N. Atlantic warms
- "Good" models successful in simulating westerly wind response, especially over ocean (land signal weaker)
- "Poor" models have some westerly signal over the ocean but very weak

SST Evolution

Lag regression of tropical SSTs onto N. Atlantic SST (multi-decadal) principal component



- As seen in SST regression plots, *poor model group has weaker tropical SST* signal through evolution

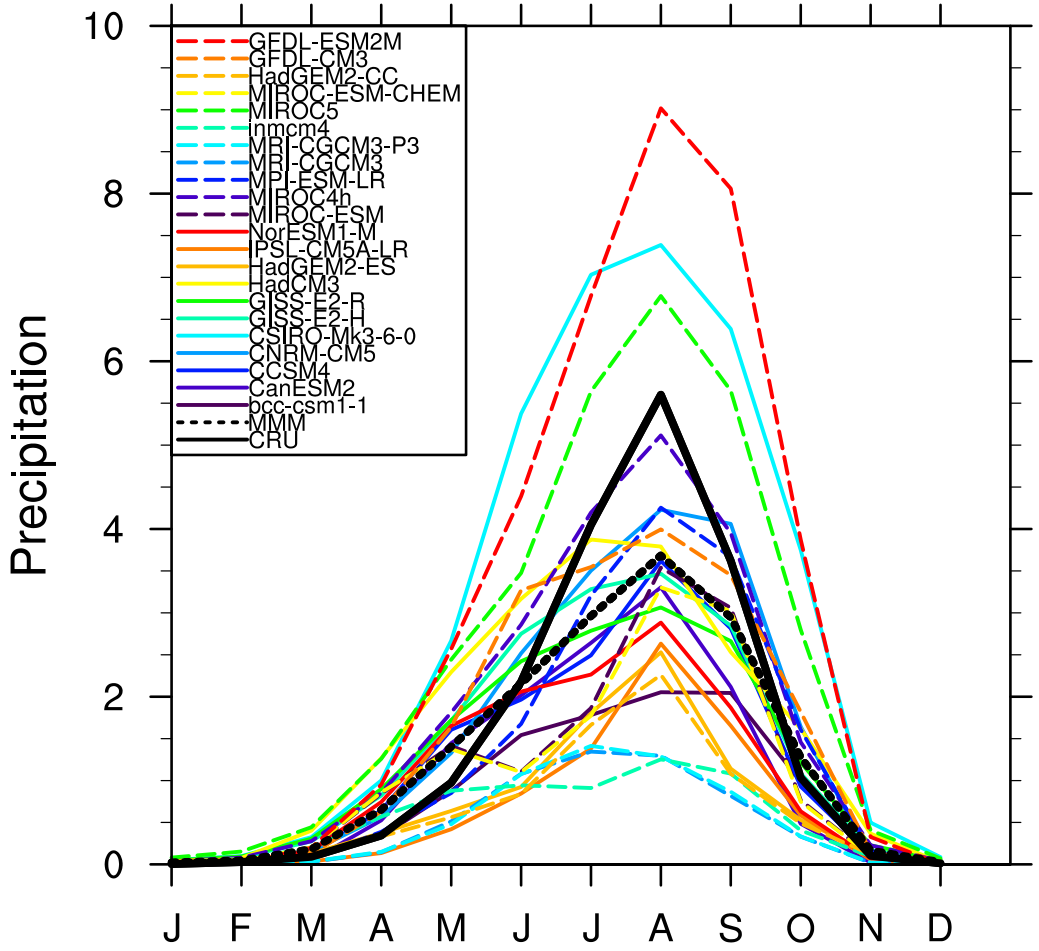
- Weaker tropical SST signal also seen in control simulations (same 12 models), suggesting simulation internal variability partially responsible?

Summary

- Selected two groups of models to investigate the multi-decadal connection between Atlantic SST and Sahel rainfall
- “Good” group:
  - Successful representation of SST pattern and mechanisms connected to rainfall response
- “Poor” group:
  - AMO-like pattern of SSTs in subpolar region but tropical signal weak, so atmospheric response unlike observations
- Results consistent with Sutton and Hodson (2007) modeling study: Tropical part of AMO SST forces the tropical (West African) response
- Similar results are also seen in the control experiments, suggesting that poor simulation of internal variability patterns or ocean dynamics may be causing the incorrect SST patterns. What about the role of sulphate aerosols?

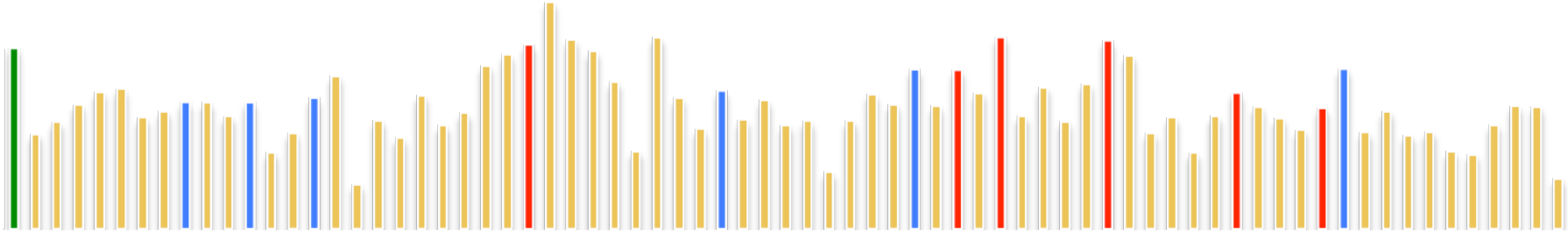
Sahel Precipitation Annual Cycle

- 10°N – 20°N, 20°W – 10°E
- Ensemble mean annual cycle
- Summer peak is simulated
- Most models underestimate summer peak and overestimate spring

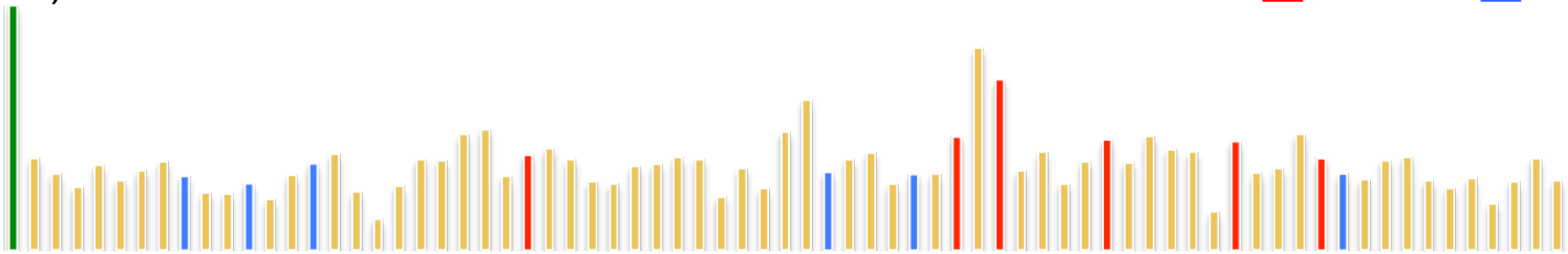


Model Selection Criteria

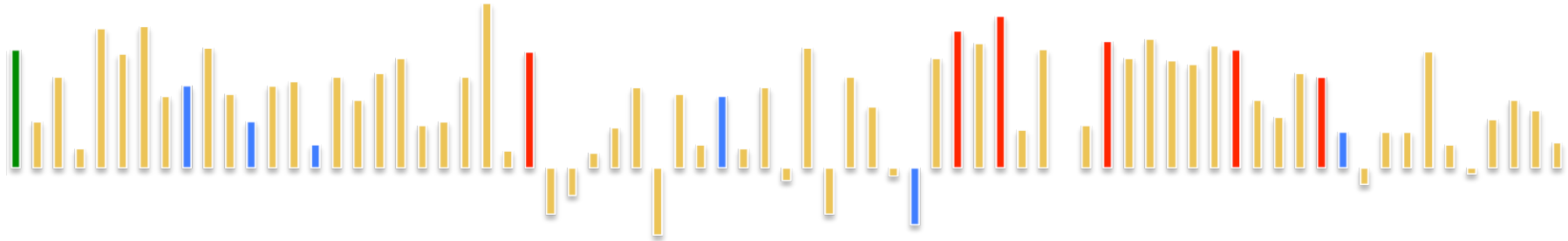
1) AMO index decadal variance fraction ☑ ☑



2) Sahel rainfall decadal variance fraction ☑ ☒

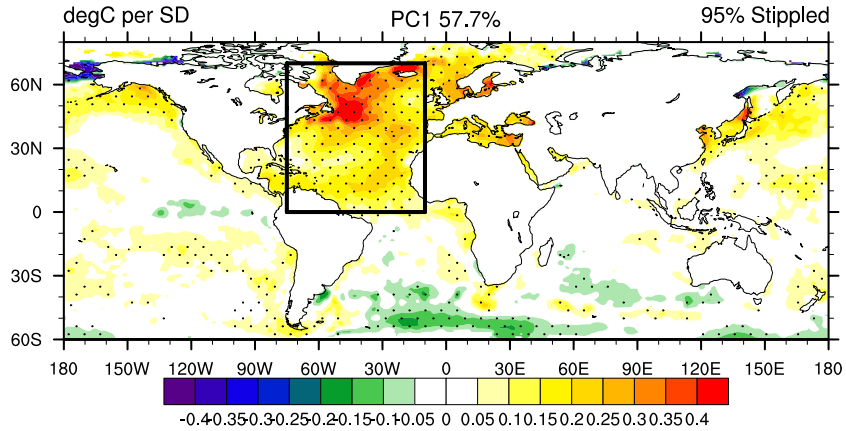


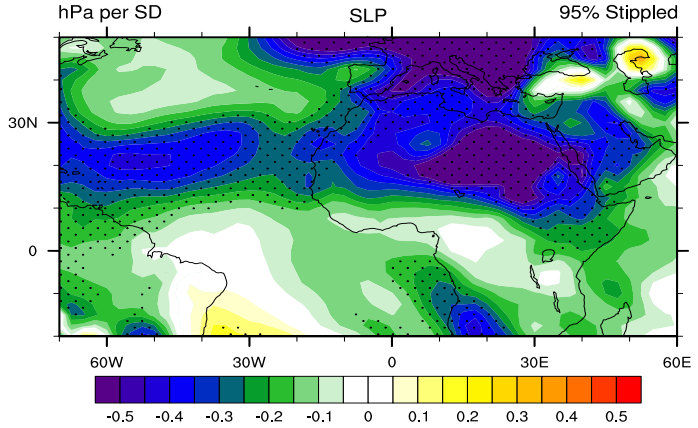
3) Correlation btw filtered Sahel rain and N. Atlantic SSTs (AMO) ☑ ☒

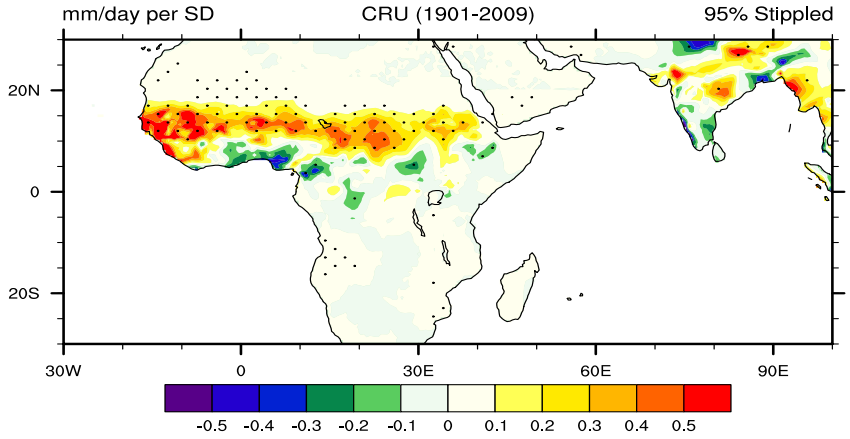


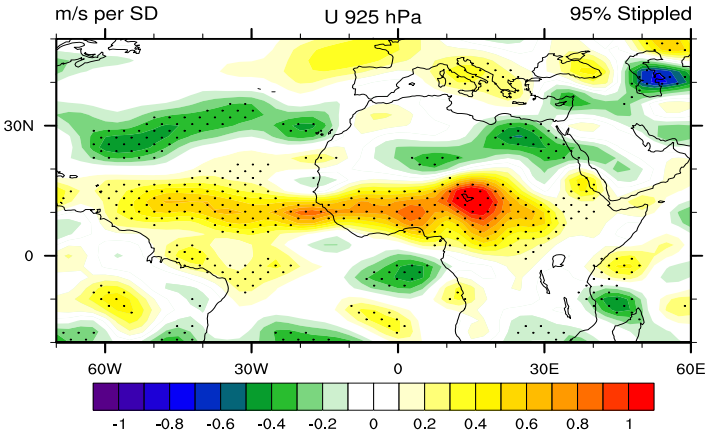
Observed Patterns of Variability

- Leading EOF of JAS SST (detrended and filtered) in N. Atlantic ~AMO
- Regression onto principal component

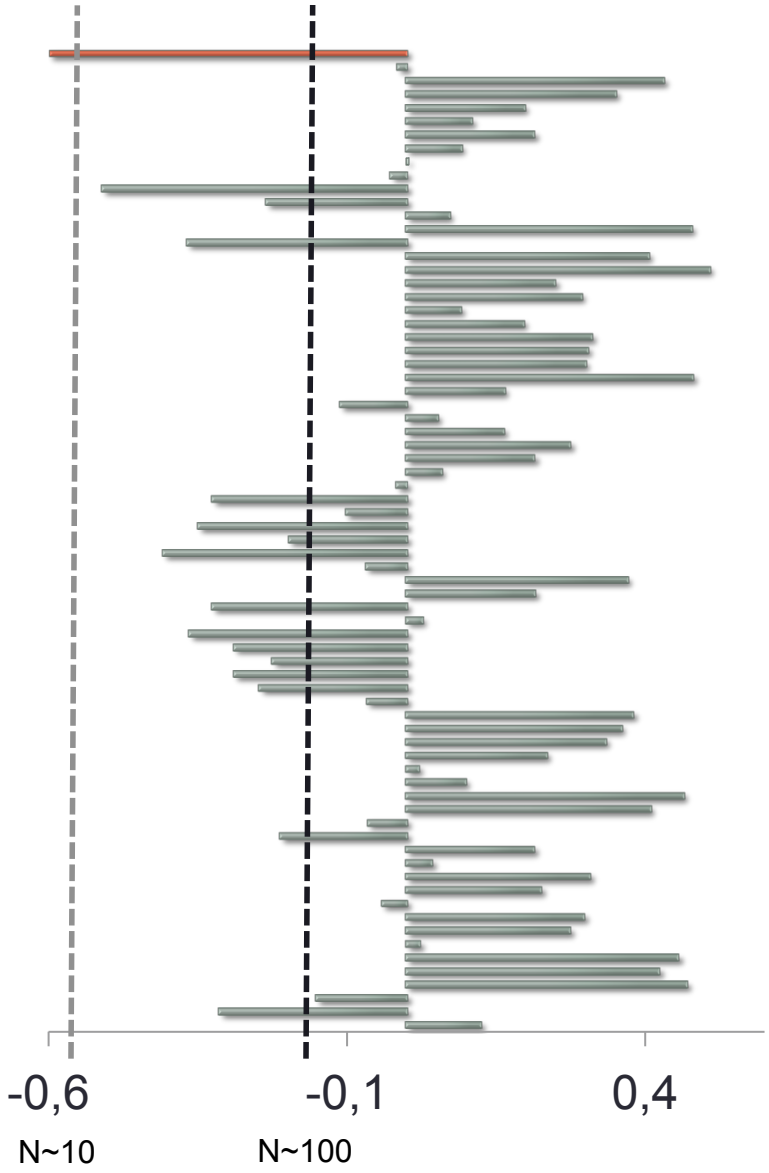








Filtered SRI vs Indian SST

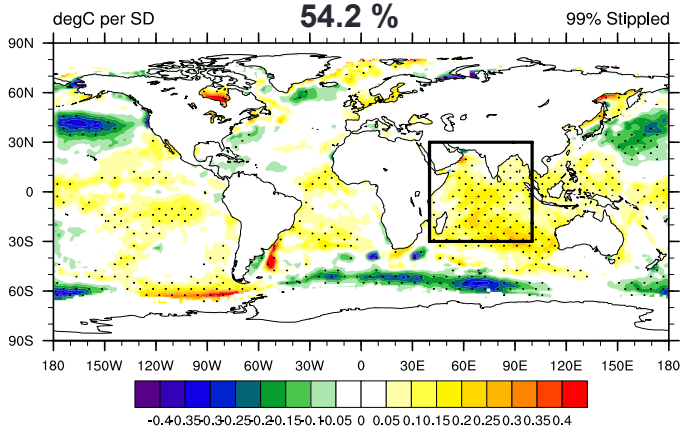


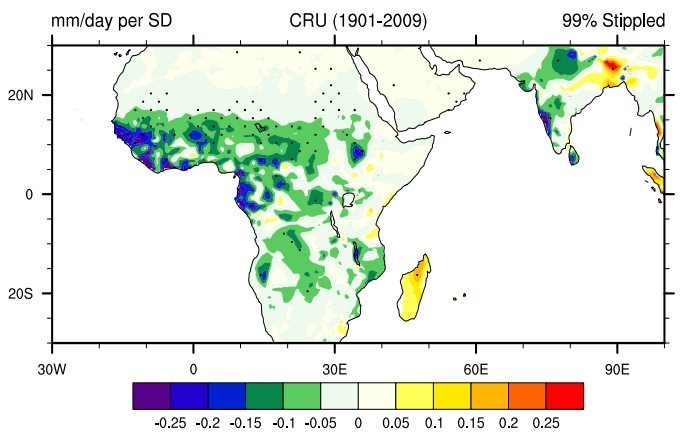
- Correlations between filtered SRI and Indian SST
- Observed value is large and negative (-0.60)
- Model output mixed between positive and negative
- Over 50 % of ensembles are positive!
- Important note: In observations Atl. and Ind. not correlated, but in model output they are often highly correlated

Patterns of Variability: Indian

- Leading EOF of JAS SST (detrended and filtered) Indian Ocean
- Regression of SST and rainfall onto principal component
- Models struggle to get any signal over West Africa

OBS.





ONE MODEL