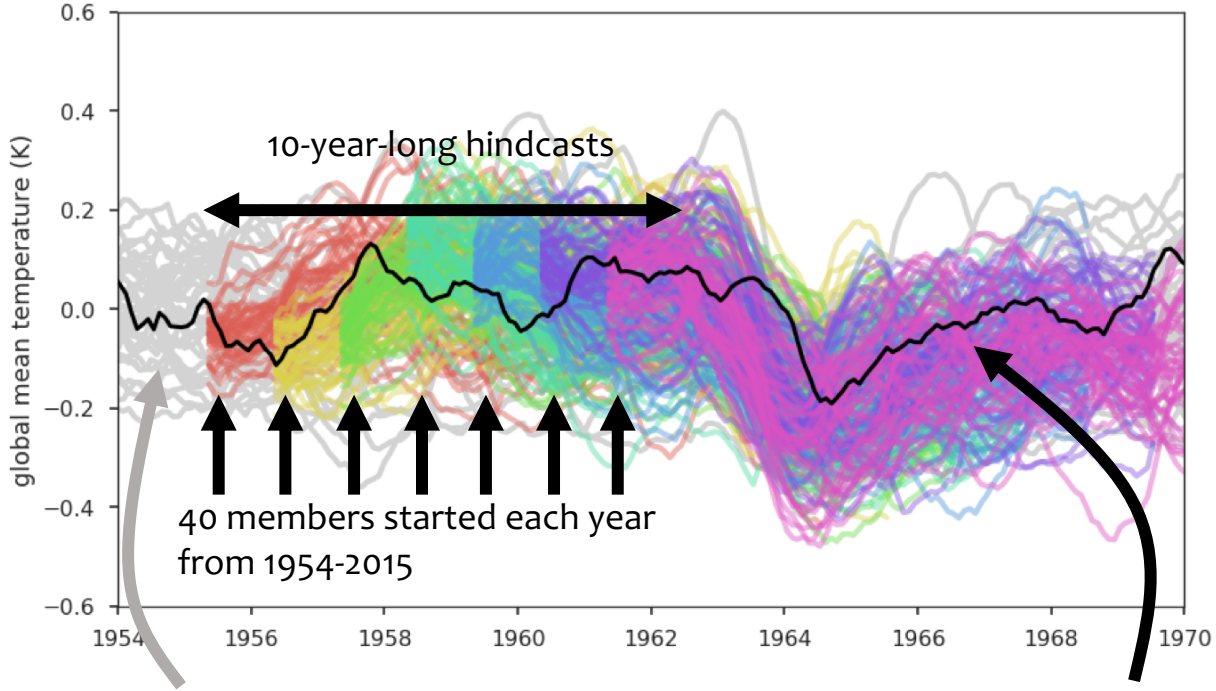
Sources of skill in Sahel precipitation hindcasts in the CESM Decadal Prediction Large Ensemble

Elizabeth Maroon (CIRES – CU Boulder), Steve Yeager (NCAR), Gokhan Danabasoglu (NCAR)

NASA

Community Earth System Model (CESM) Decadal Prediction Large Ensemble (DPLE)

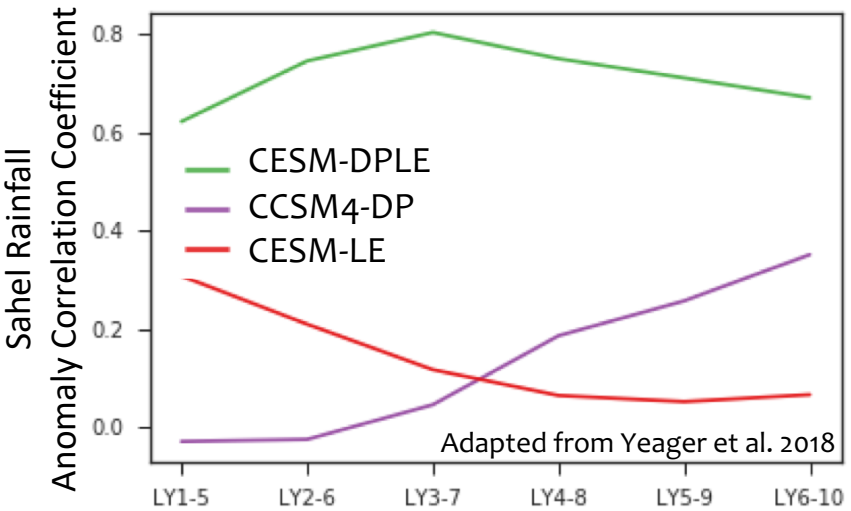


Same model configuration and forcing as the CESM Large Ensemble (LE) – Kay et al. (2015)

Ocean and sea ice full fields initialized from an adjusted CORE forced ocean-sea ice hindcast

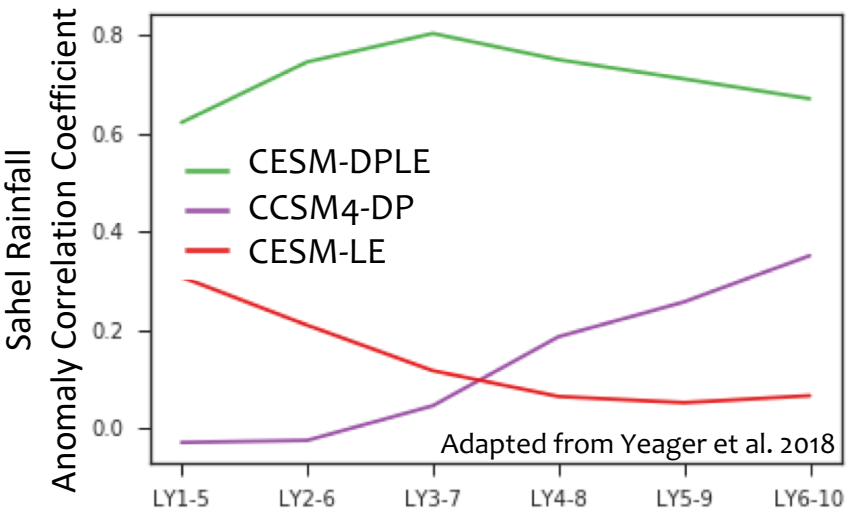
See Yeager et al. 2018 for more details

Improved skill in Sahel precipitation in the CESM DPLE from previous CCSM4 hindcasts. Why?



verified against CRU-TS4.0 precipitation (Harris et al. 2014)

Improved skill in Sahel precipitation in the CESM DPLE from previous CCSM4 hindcasts. Why?

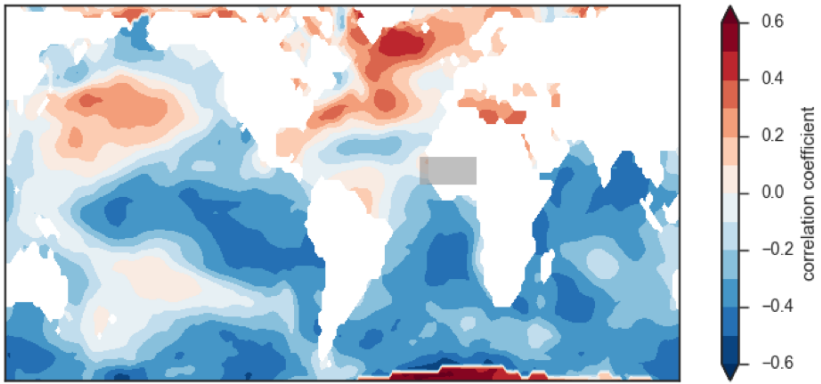


CESM and CCSM4 decadal prediction hindcasts differ:

- CAM5 (CESM) versus CAM4 (CCSM4) atmosphere
- Ocean Biogeochemistry in CESM
- Number of ensemble members (40 in CESM vs 10 in CCSM4)
- Initialization start date (Nov 1 in CESM versus Jan 1 in CCSM4)
- Hindcast simulations used for full field ocean initial conditions

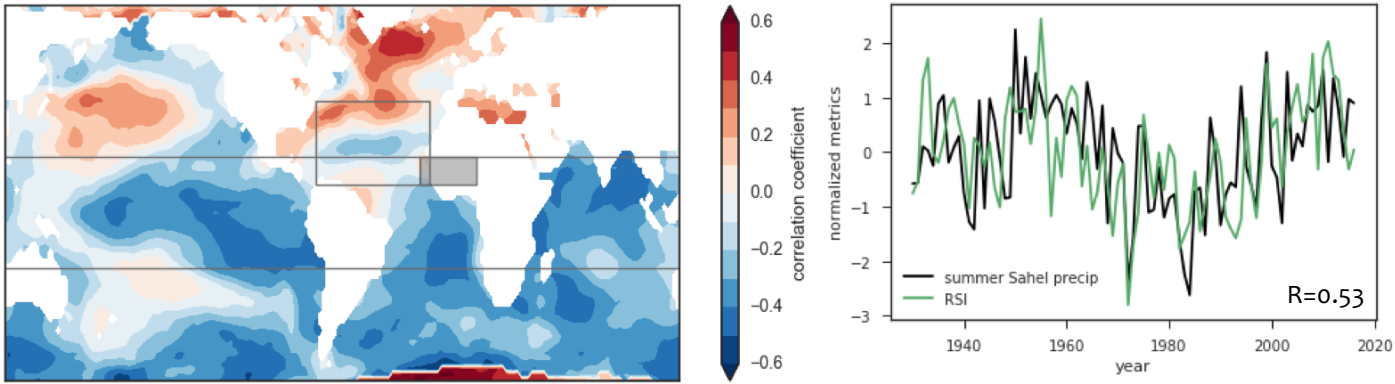
verified against CRU-TS4.0 precipitation (Harris et al. 2014)

Correlation of summer Sahel precipitation with SST



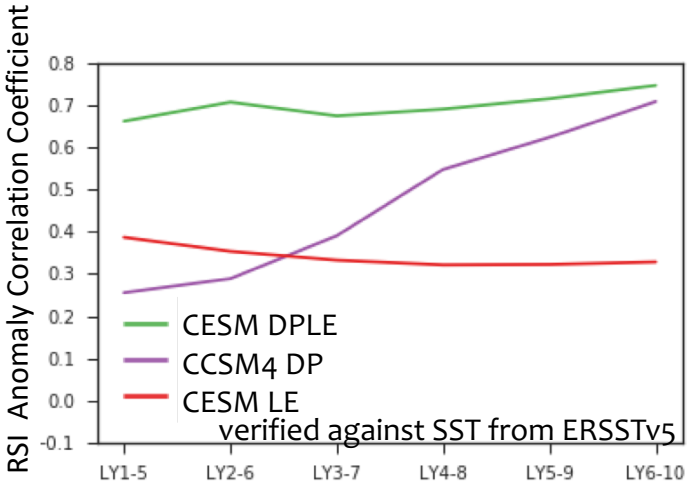
ERSSTv5 SST
CRU-TS4.0 precipitation (Harris et al., 2014)

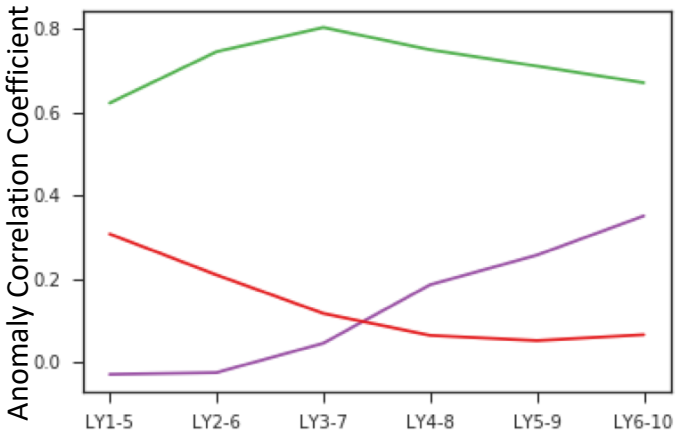
Relative SST Index (*RSI – Martin and Thorncroft 2014*) captures both North Atlantic and tropical SST variability



ERSSTv5 SST
CRU-TS4.0 precipitation (Harris et al., 2014)

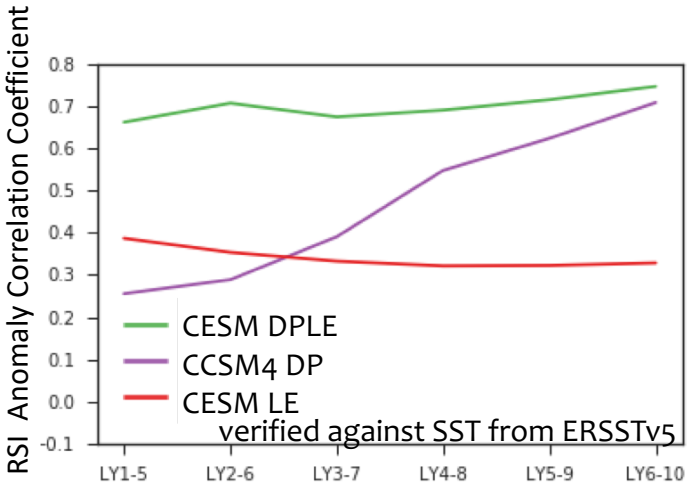
Skillful hindcasts of RSI in CESM-DPLE and later forecast years of CCSM4-DP.

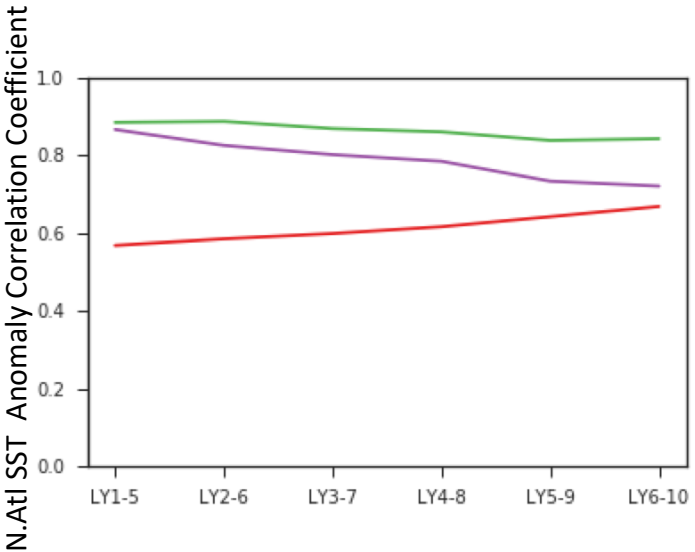




Adapted from Yeager et al. 2018

CESM-DPLE and CCSM4-DP both have predictive skill for North Atlantic SST variability: Need to look at tropics





Adapted from Yeager et al. 2018

Two possibilities for improved Sahel prediction in CESM:

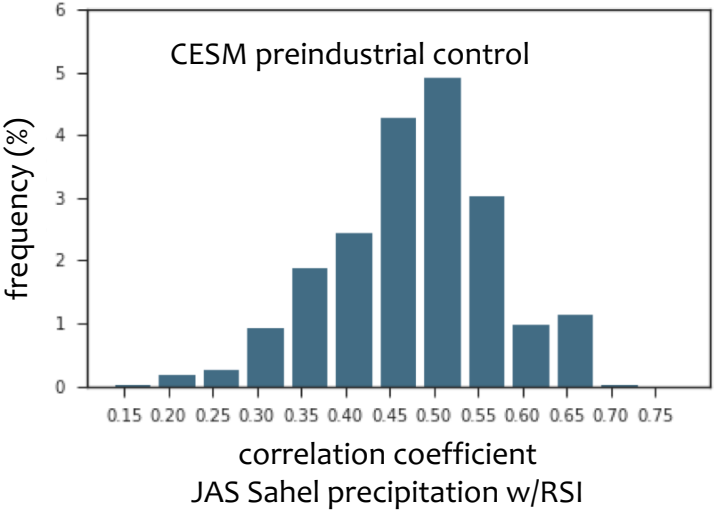
1. Improved model

   More realistic SST relationship with Sahel precipitation in CESM than in CCSM4

2. Improved initialization

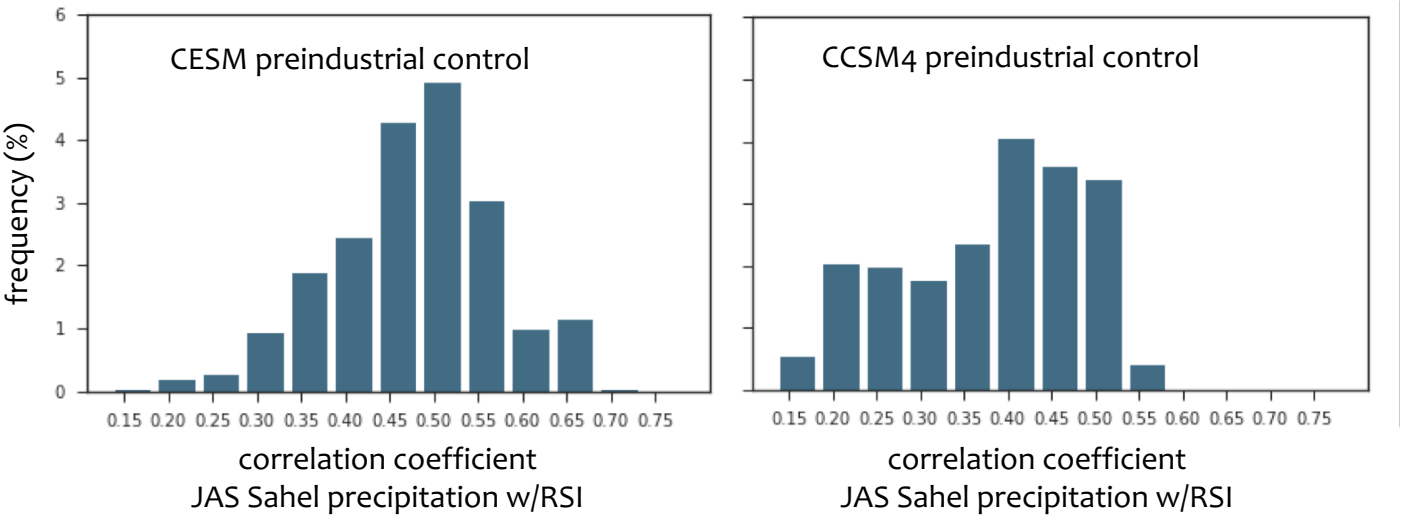
   Less initialization shock in CESM-DPLE than in CCSM4-DP

Correlation of CESM Relative SST Index and summer Sahel precipitation



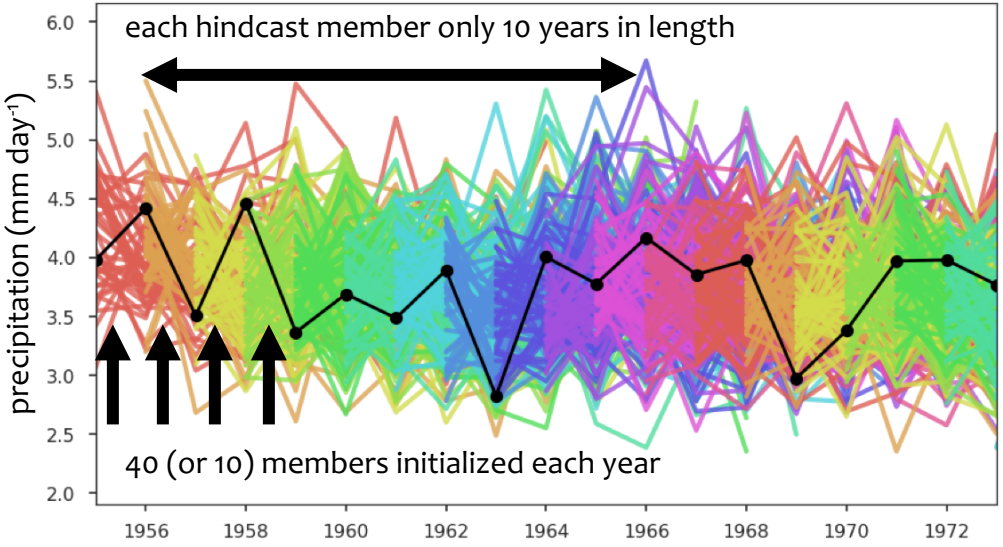
Bootstrapped distribution:
1000 randomly drawn 62-year time series of RSI and associated summer Sahel precipitation from a long CESM preindustrial control simulation

Summer Sahel precipitation is better correlated with Relative SST Index in CESM than CCSM4



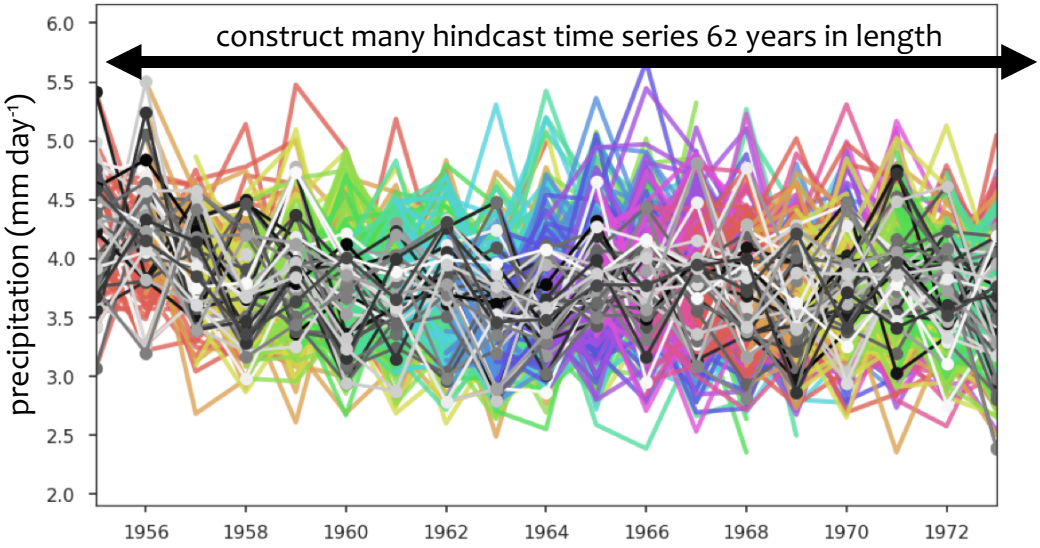
Martin and Thorncroft: more skillful decadal predictions in models with higher RSI/Sahel correlation

Generating bootstrapped hindcasts from the CESM-DPLE and CCSM4-DP



Construct a 62-year long time series of "year N" hindcasts by randomly selecting one of the 40 members for each start time

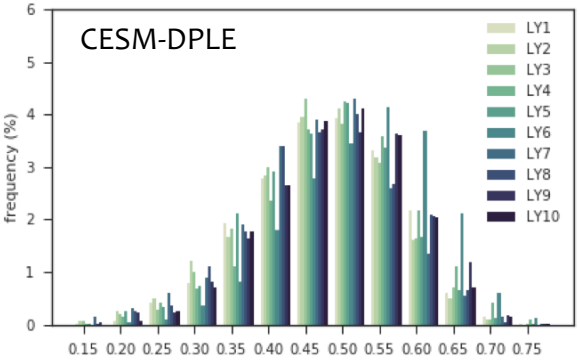
Generating bootstrapped hindcasts from the CESM-DPLE and CCSM4-DP



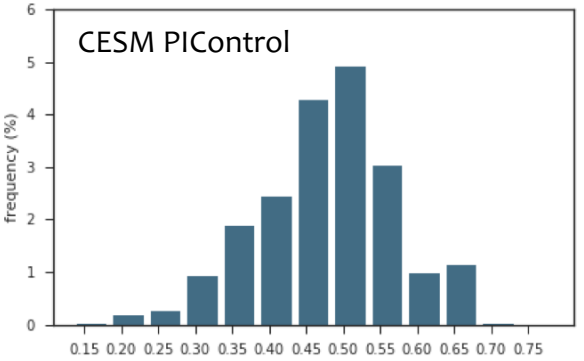
Construct a 62-year long time series of "year N" hindcasts by randomly selecting one of the 40 members for each start time

Repeat the random selection many, many times

Same Sahel-SST relationship in CESM across hindcast lead times

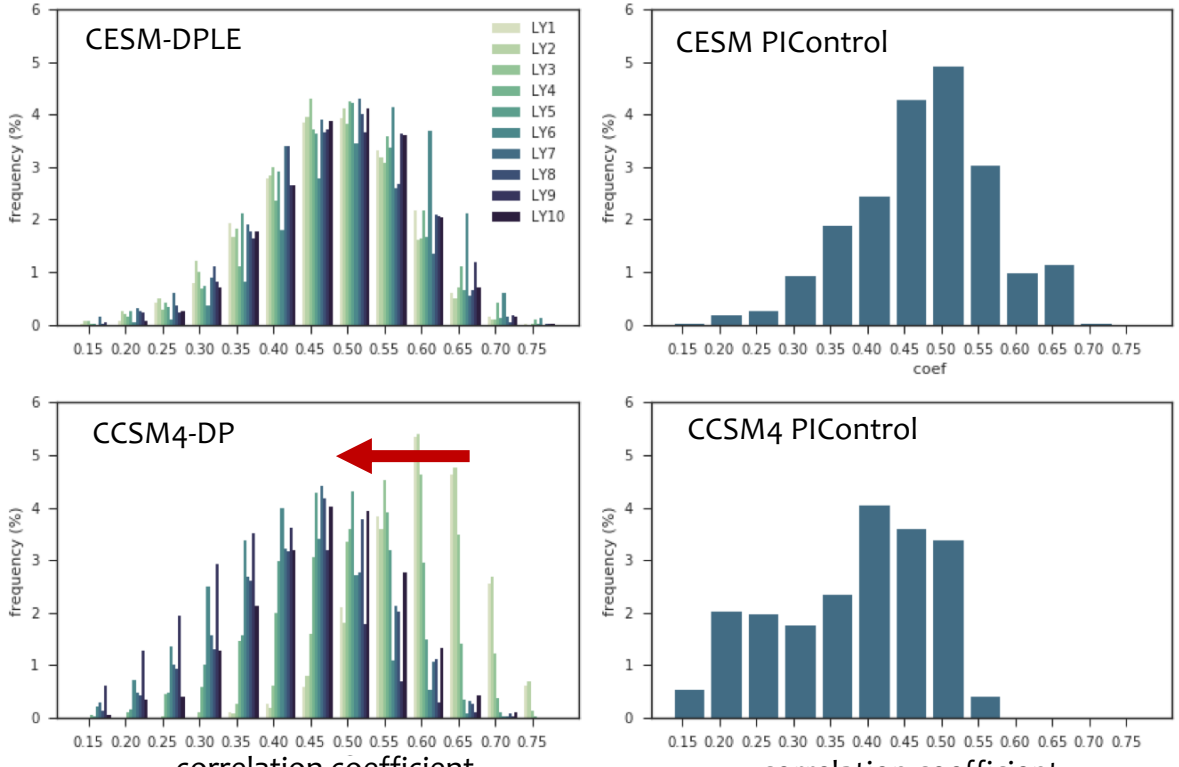


correlation coefficient
JAS Sahel precipitation w/RSI



correlation coefficient
JAS Sahel precipitation w/RSI

Sahel-SST relationship in CCSM4-DP weakens with hindcast lead time



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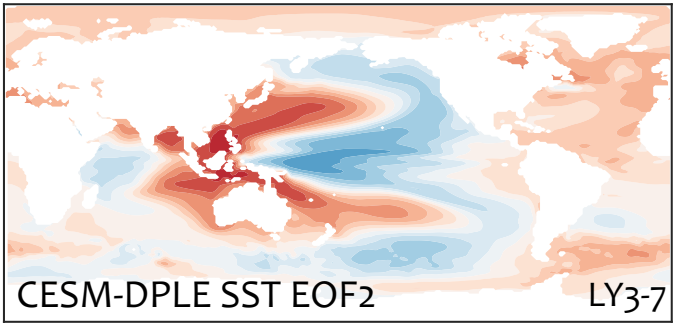
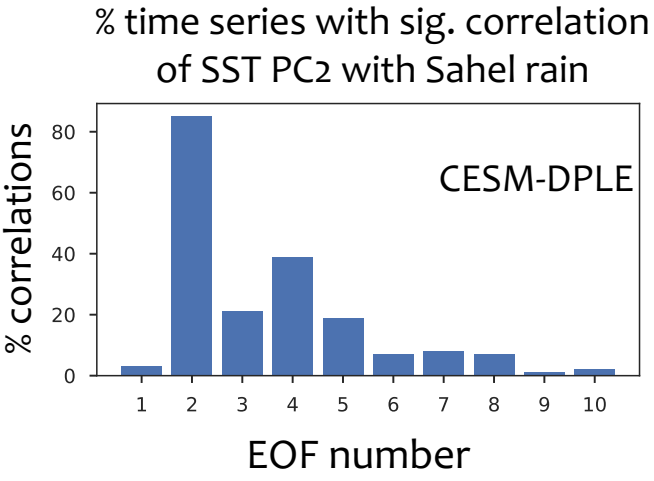
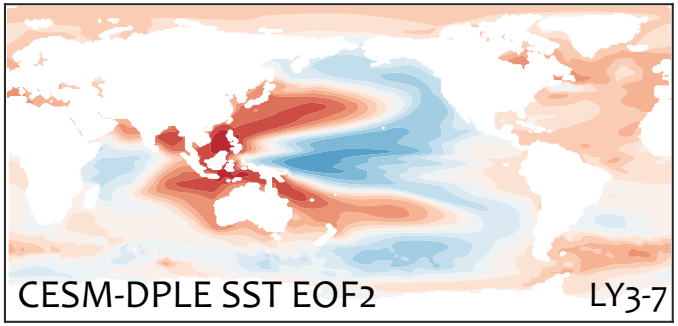
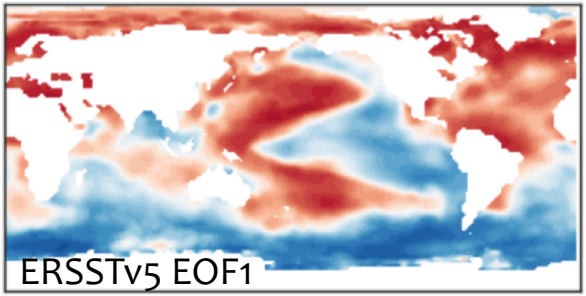
CESM-DPLE: Sahel rain related to DPLE SST EOF2

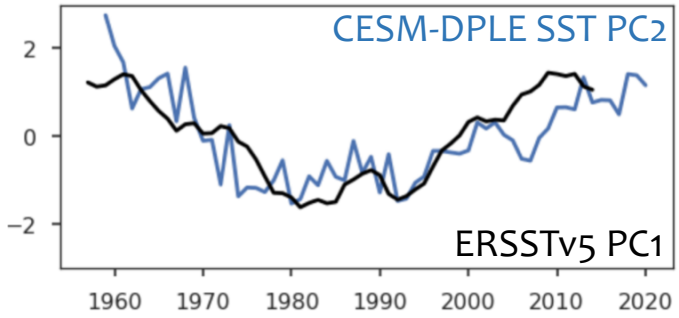




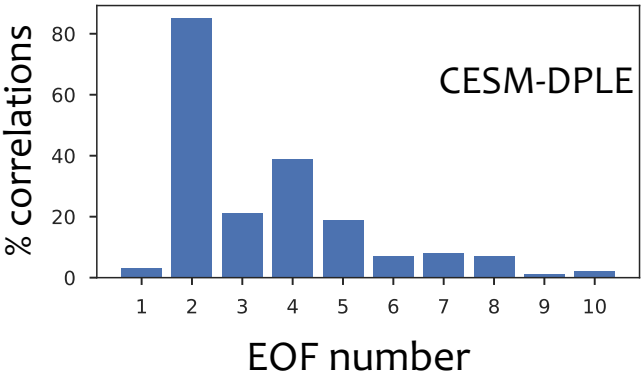
CESM-DPLE: Sahel rain related to DPLE SST EOF2



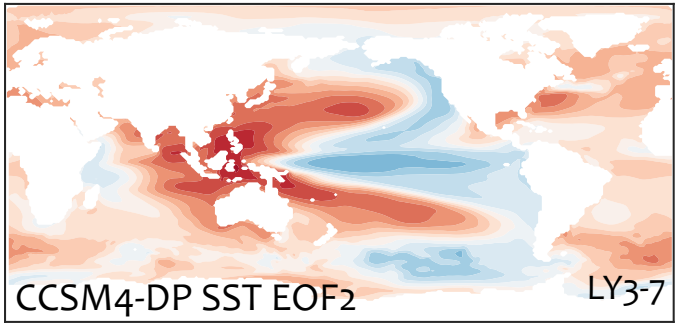


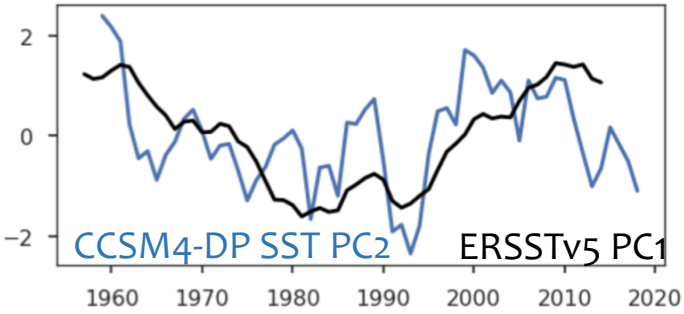


% time series with sig. correlation of SST PC2 with Sahel rain

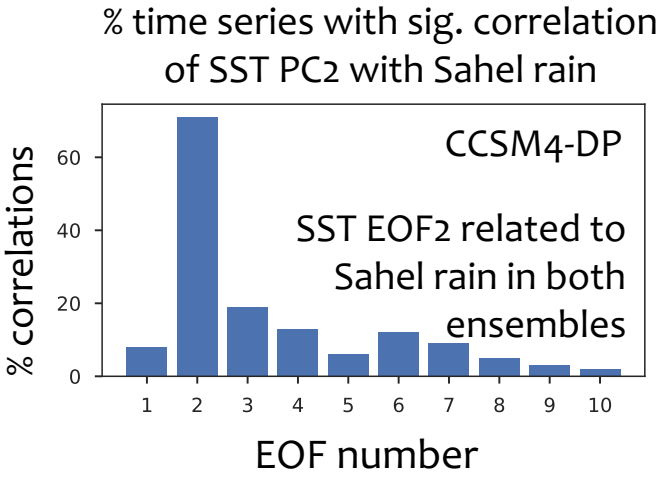


CCSM4-DP: Evolution of ensemble mean SST is wrong



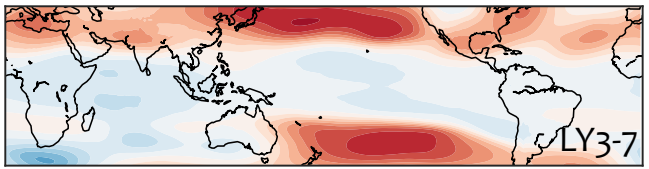


Initialization shock in tropical Pacific: see Yeager et al. (2018), Teng et al. (2016)

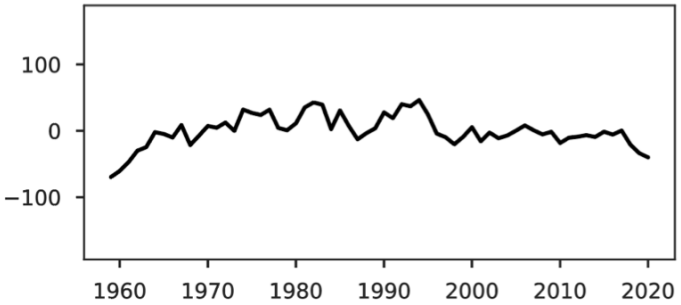


500 hPa evolution matches SST evolution

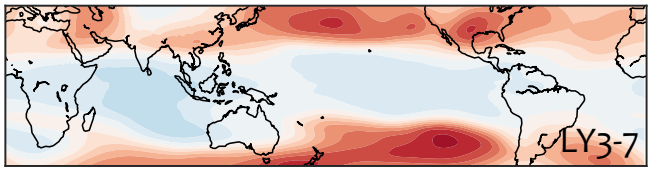
CESM-DPLE 500 hPa EOF2



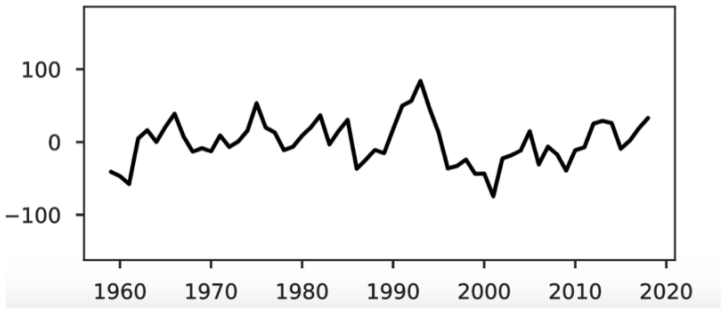
CESM-DPLE 500 hPa PC2



CCSM4-DP 500 hPa EOF2



CCSM4-DP 500 hPa PC2



Conclusions

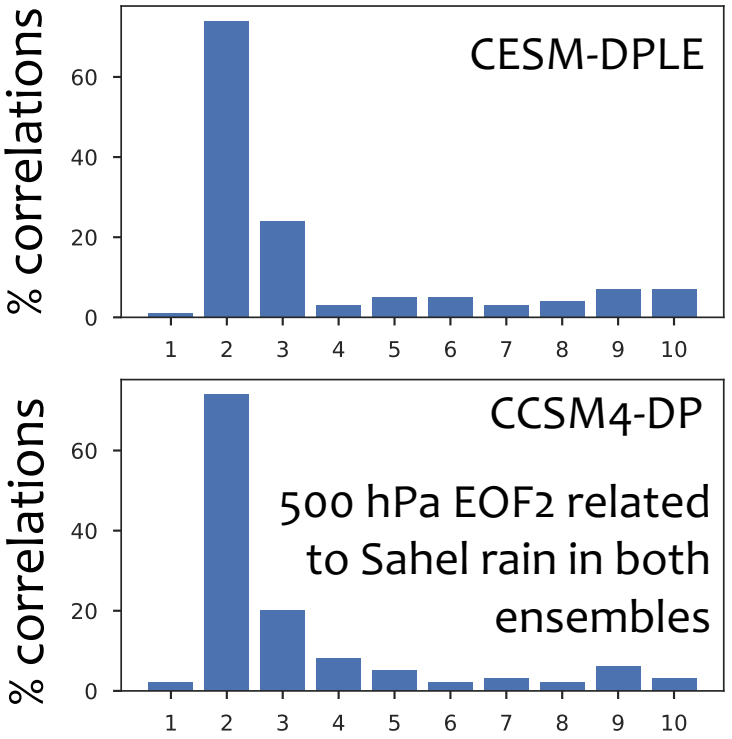
- Improved skill in CESM-DPLE Sahel precipitation hindcasts is due to:

  (1) improved model representation of Sahel-SST connections in CESM from CCSM4 and,

  (2) improved Pacific initialization in the CESM-DPLE from the CCSM4-DP

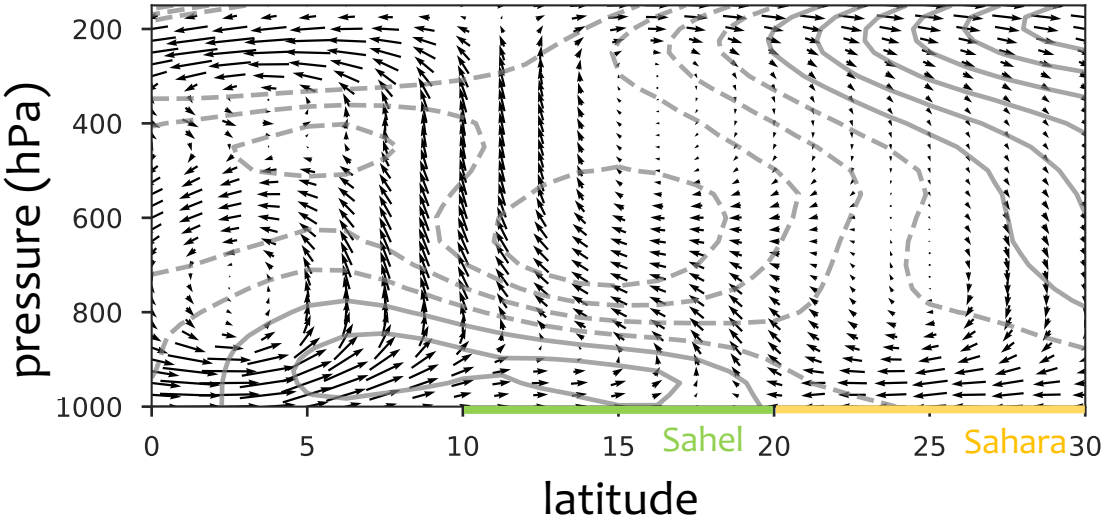
- Both CESM-DPLE and CCSM4-DP are capturing the global patterns of variability that are correlated with Sahel precipitation, but in CCSM4-DP, the evolution is mistimed because of initialization shock

Extra slides


% correlations
CESM-DPLE
60
40
20
0
1
2
3
4
5
6
7
8
9
10
% correlations
CCSM4-DP
500 hPa EOF2 related to Sahel rain in both ensembles
60
40
20
0
1
2
3
4
5
6
7
8
9
10

West African (20°W-10°E) climatological summer

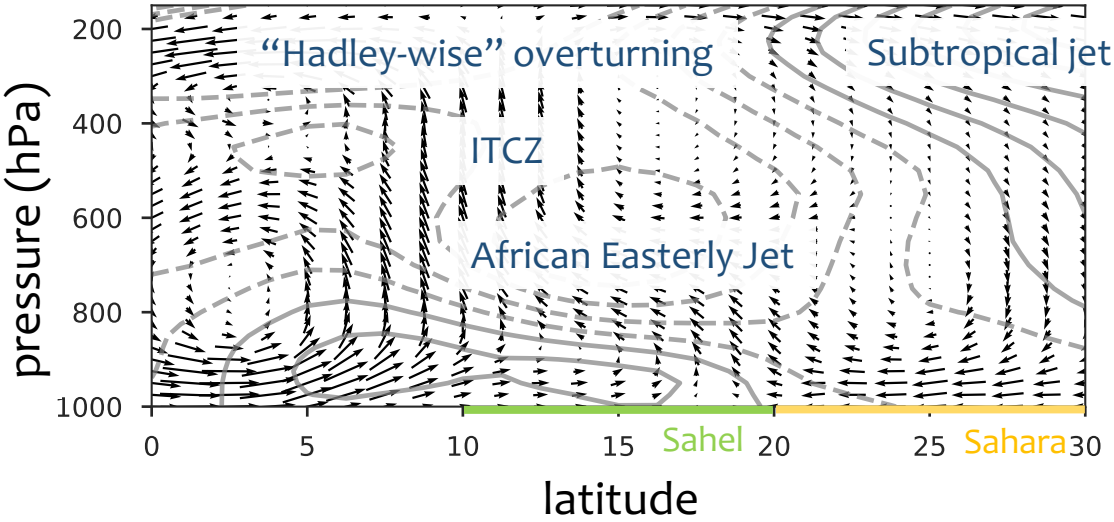
u (contours), *v*, *w* (arrows)



using JRA-55, CITATION

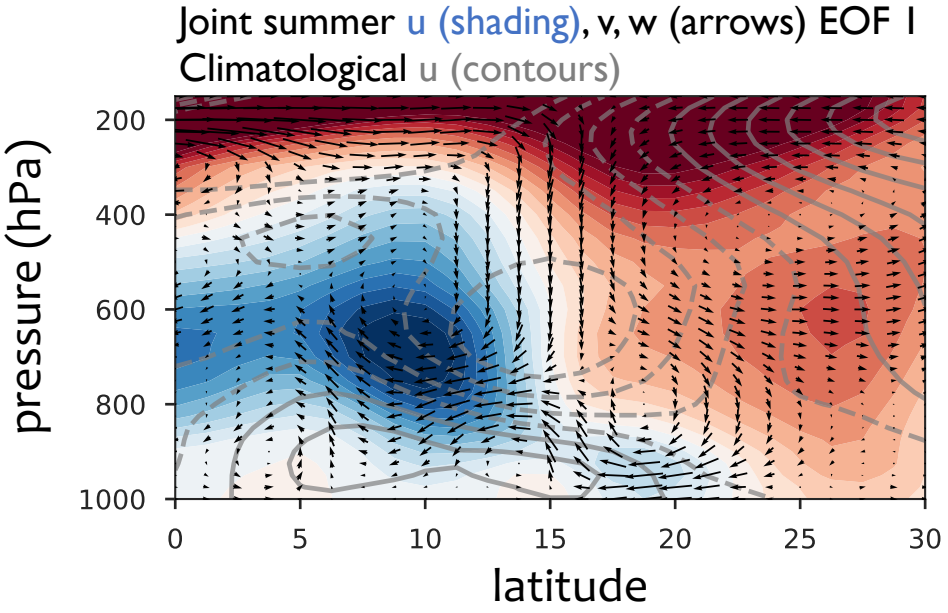
West African (20°W-10°E) climatological summer

u (contours, negative dashed), *v*, *w* (arrows)



using JRA-55, CITATION

ITCZ subsidence, advection from Sahara, and southward shifted jets associated with low Sahel rain

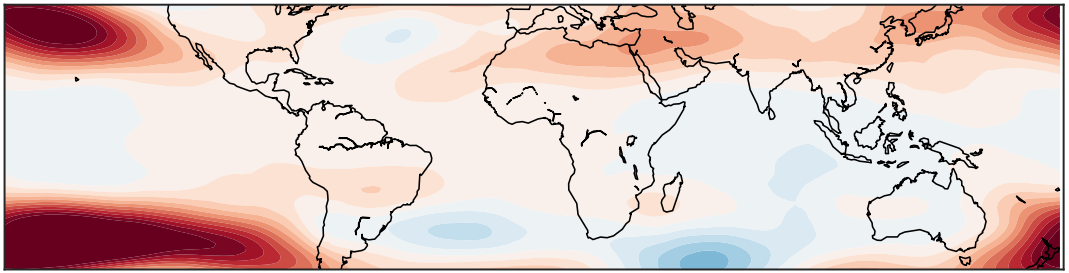


$R_{u,v,w\ JPC1,Sahel}$=-0.75

using JRA-55, CITATION

Low Sahel rainfall also associated with global contraction of tropics

500 hPa heights EOF2



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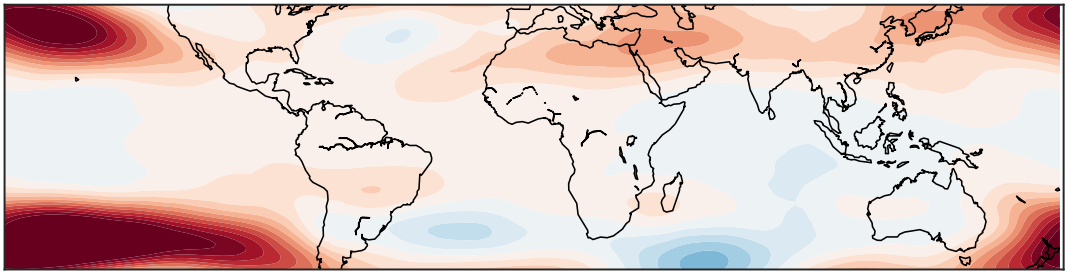
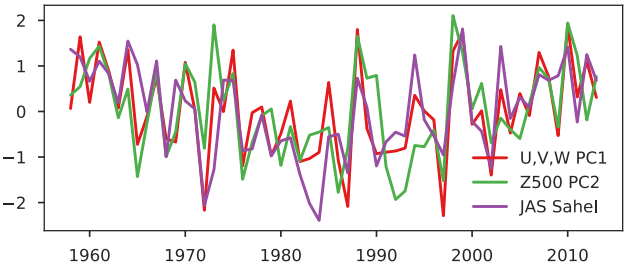




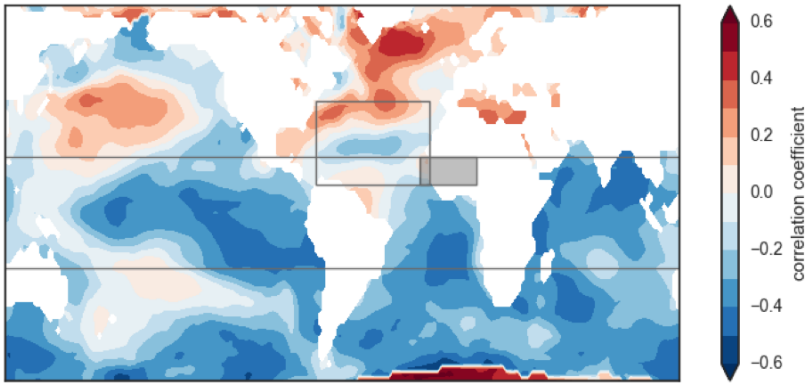
Observed Correlations

$R_{Z500\ PC2,Sahel}$=0.46

$R_{u,v,w\ JPC1,Sahel}$=-0.75

$R_{Z500\ PC2,uvw\ JPC1}$=-0.74

Relative SST Index (*RSI – Martin and Thorncroft 2014*) captures both North Atlantic and tropical SST variability



ERSSTv5 SST
CRU-TS4.0 precipitation (Harris et al., 2014)

EOF 2 of observed annual mean SST (ERSSTv5)