20th Century Sahel Rainfall Variability in IPCC Model Simulations and Future Projection

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With

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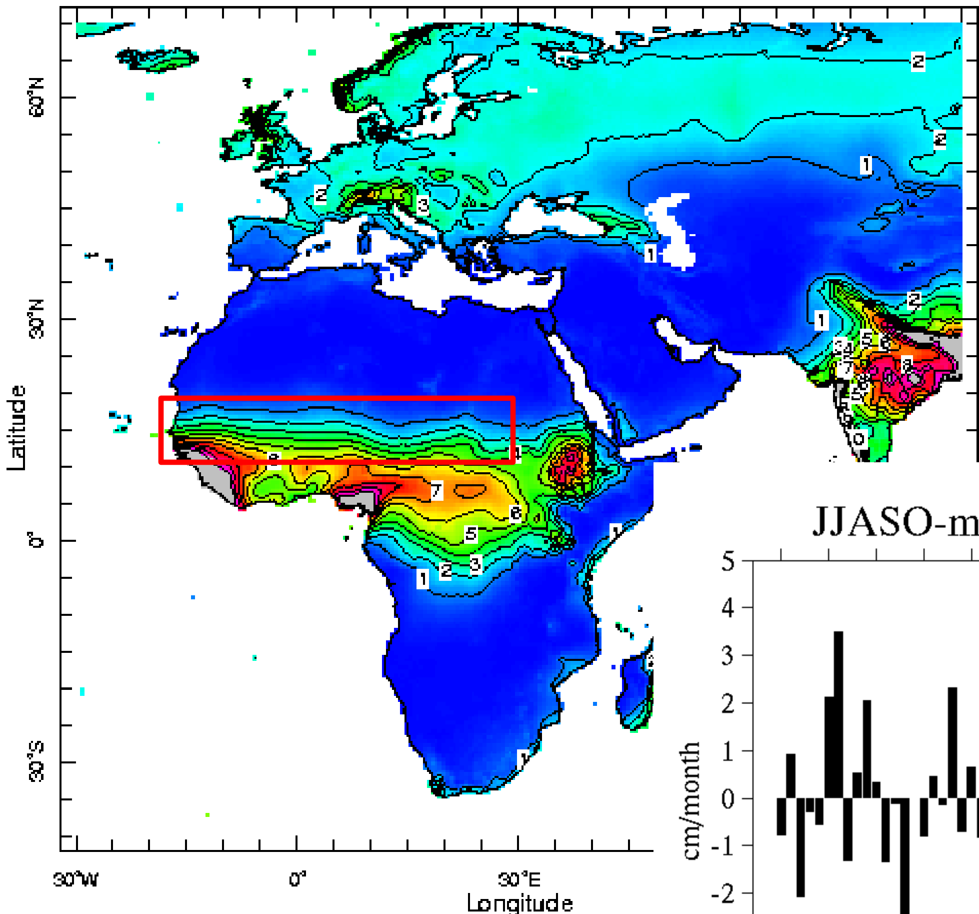
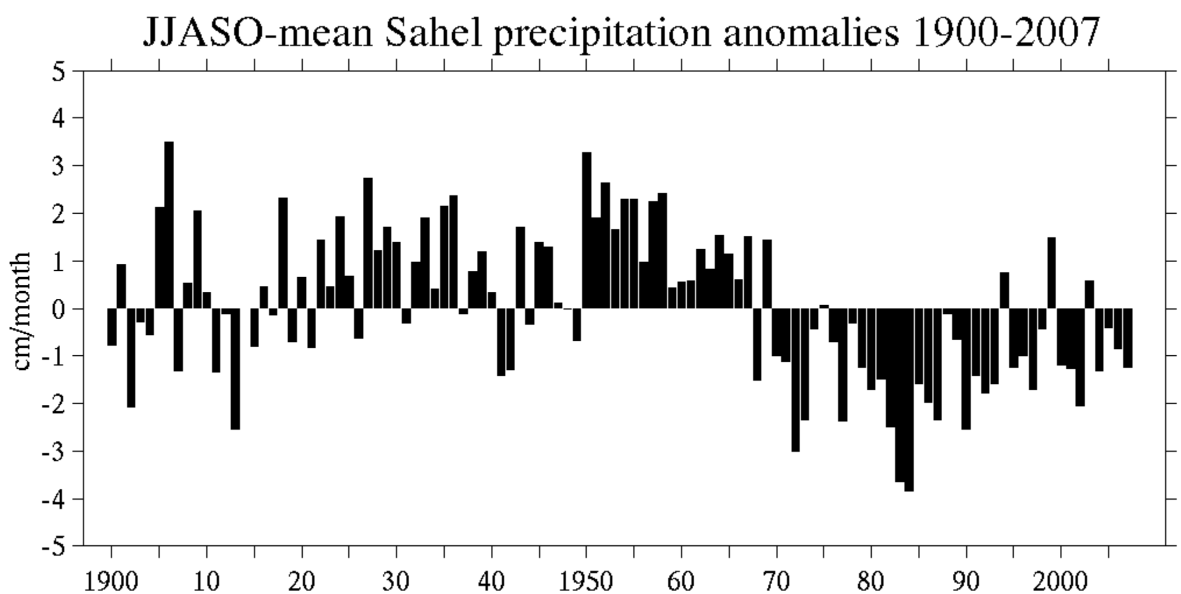
JJAS Rainfall Climatology (mm/day) from 1961-1990, CRU Data



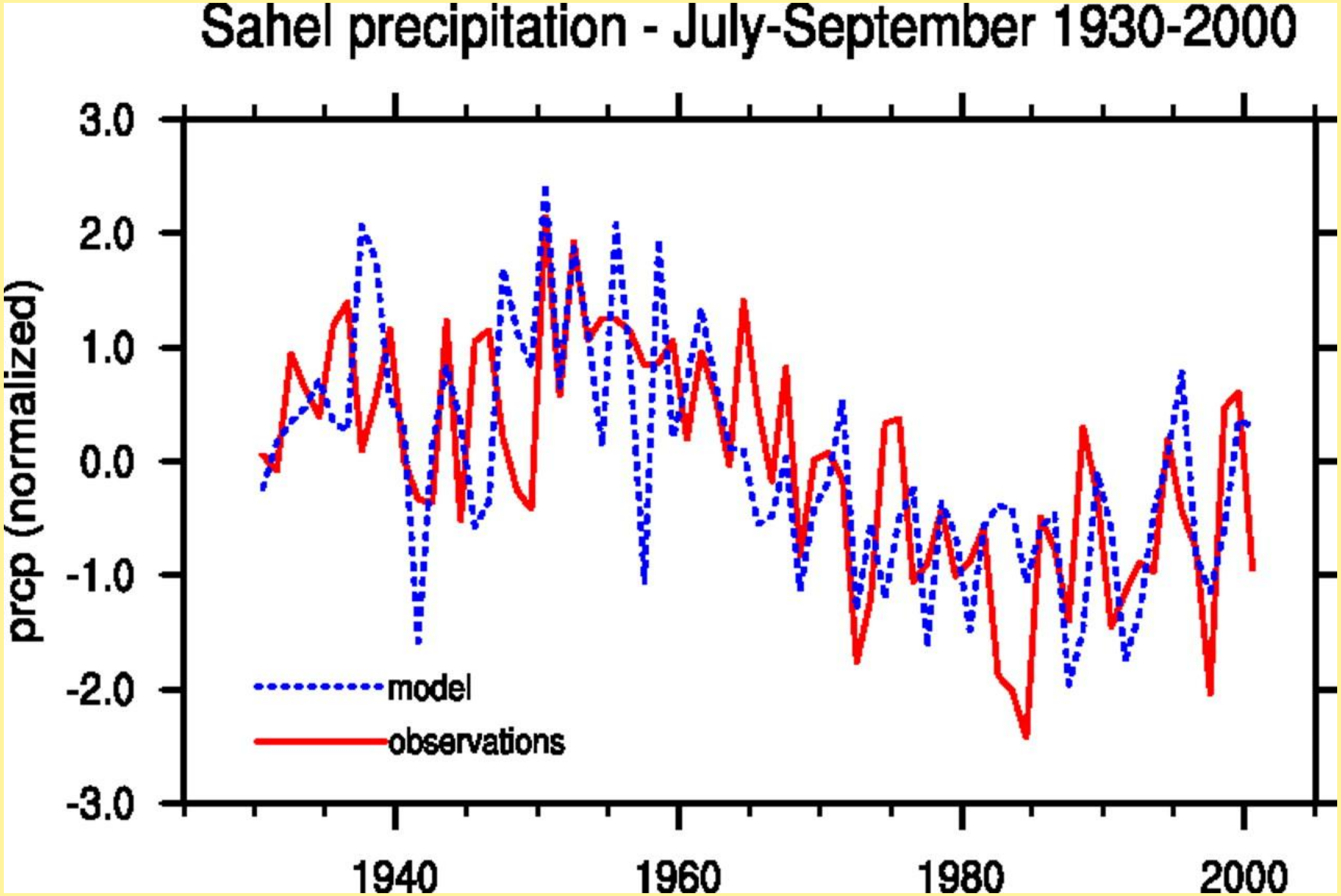


20-10N, 20W-10E; 1900-2007 climatology
NOAA Global Historical Climatology Network data

Proposed Mechanisms:

- Land-atmosphere feedbacks through natural and human-induced vegetation and land cover change
- Response of the African summer monsoon to global sea surface temperature forcing
  - warmer-than-average low-latitude waters around Africa, which, by favoring the establishment of deep convection over the ocean, weaken the continental convergence associated with the monsoon
- Aerosol forcing
  - causes North Atlantic cooling relative to the South Atlantic, which shifts the ITCZ southward

Fig. 1. Indices of Sahel rainfall variability



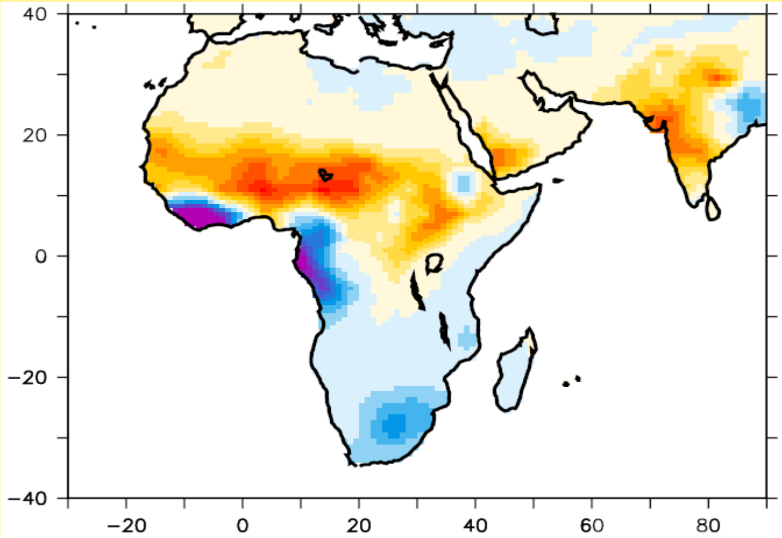
A. Giannini et al., Science 302, 1027 -1030 (2003)

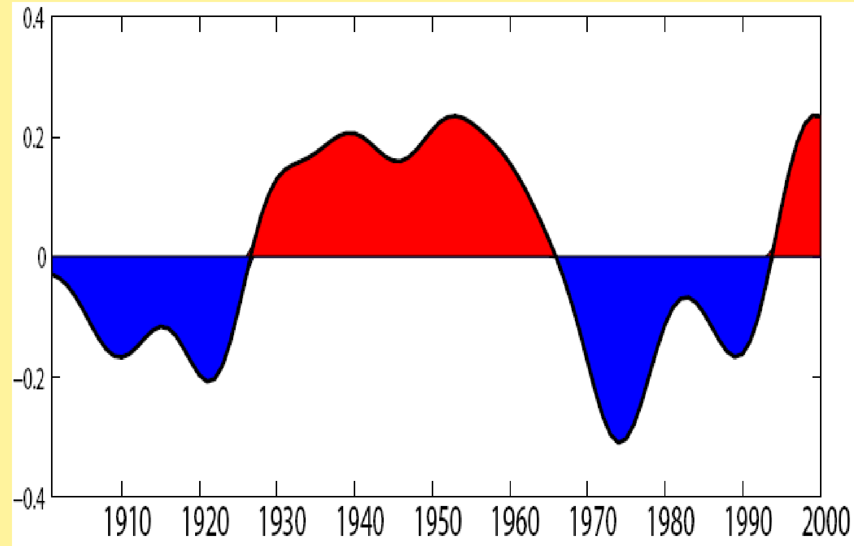
Published by AAAS

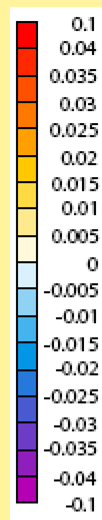
Regression of modeled LF JJAS Rainfall Anomaly on modeled AMO Index

(Delworth et al.)

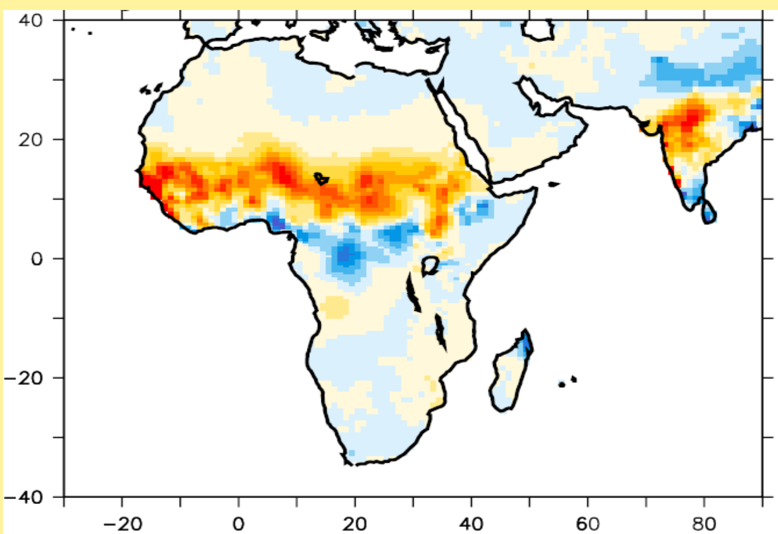
Modeled AMO Index



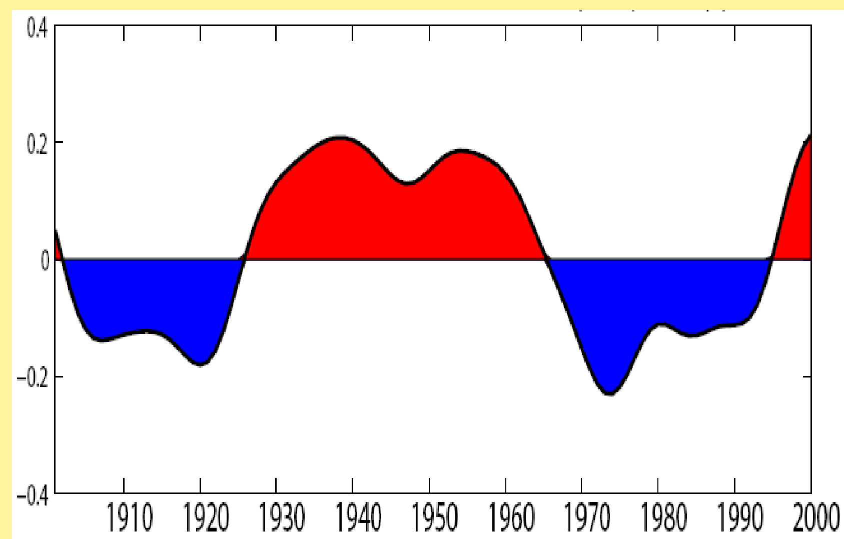




Regression of observed LF JJAS Rainfall Anomaly (CRU data) on observed AMO Index



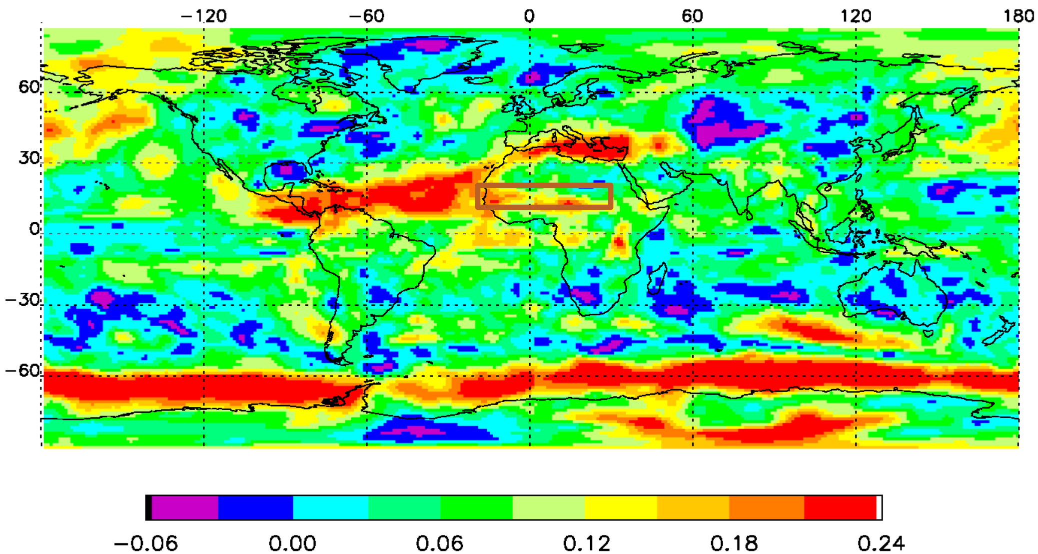
Observed AMO Index



- Central Questions:
- How much of the Sahel rainfall trend is due to anthropogenic forcing and how much due to internal variability on multi-decadal time scales (AMO)?
- What is the future Sahel rainfall trend (projection)?

Ratio of Forced and Total Variance for Multi-decadal Precipitation Variability in IPCC Models

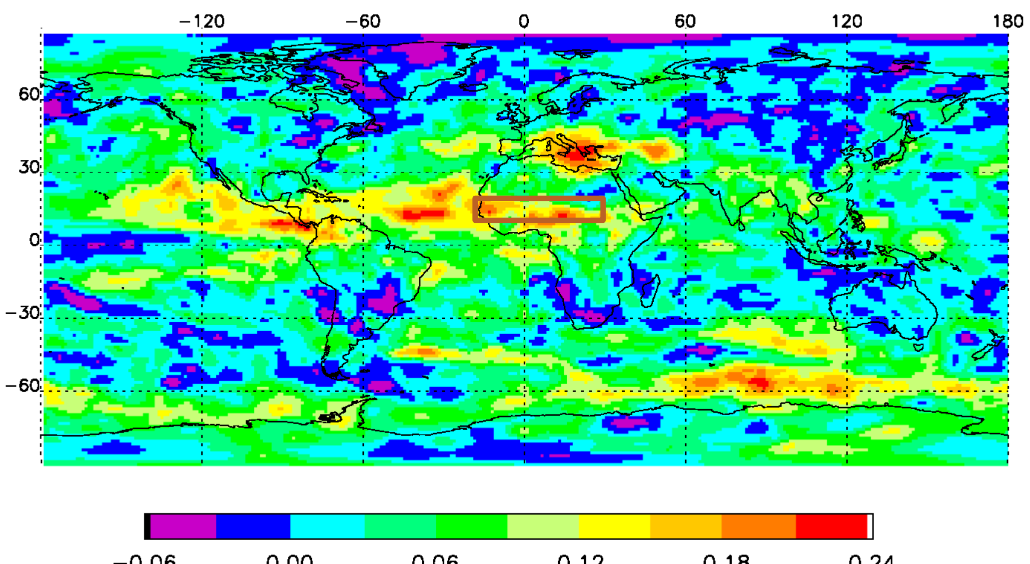
Annual



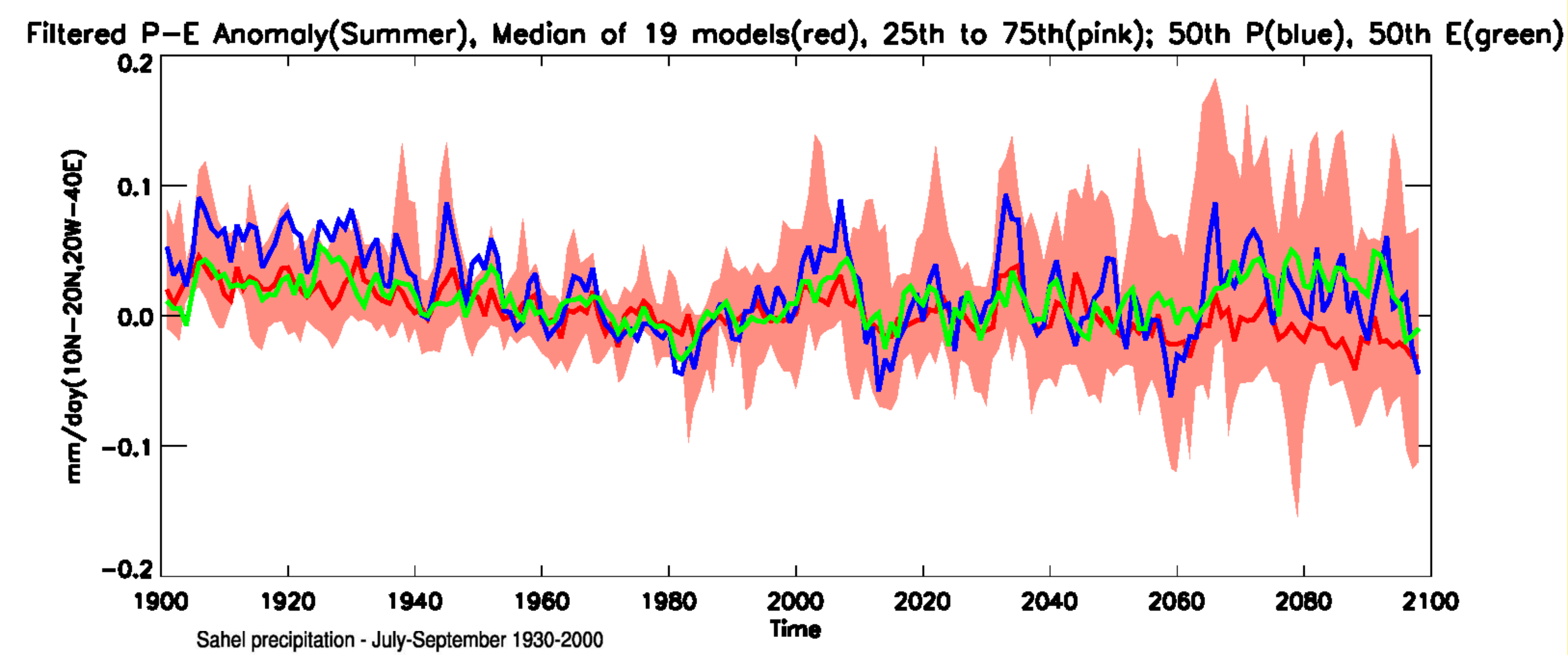
R = Forced Variance/Total Variance

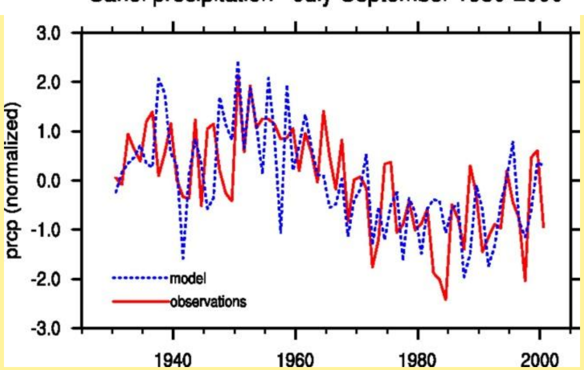
$$r = \frac{\sigma_F^{\ 2}}{\sigma_T^{\ 2}} = \frac{\sigma_a^{\ 2} - \frac{1}{(N-1)}\sigma_I^{\ 2}}{\sigma_T^{\ 2}}$$

JJAS



Modeled changes in summer mean precipitation minus evaporation over the Sahel region averaged over ensemble members for each of the 19 models





Modeled changes in annual mean precipitation minus evaporation over the Mediterranean region averaged over ensemble members for each of the 19 models

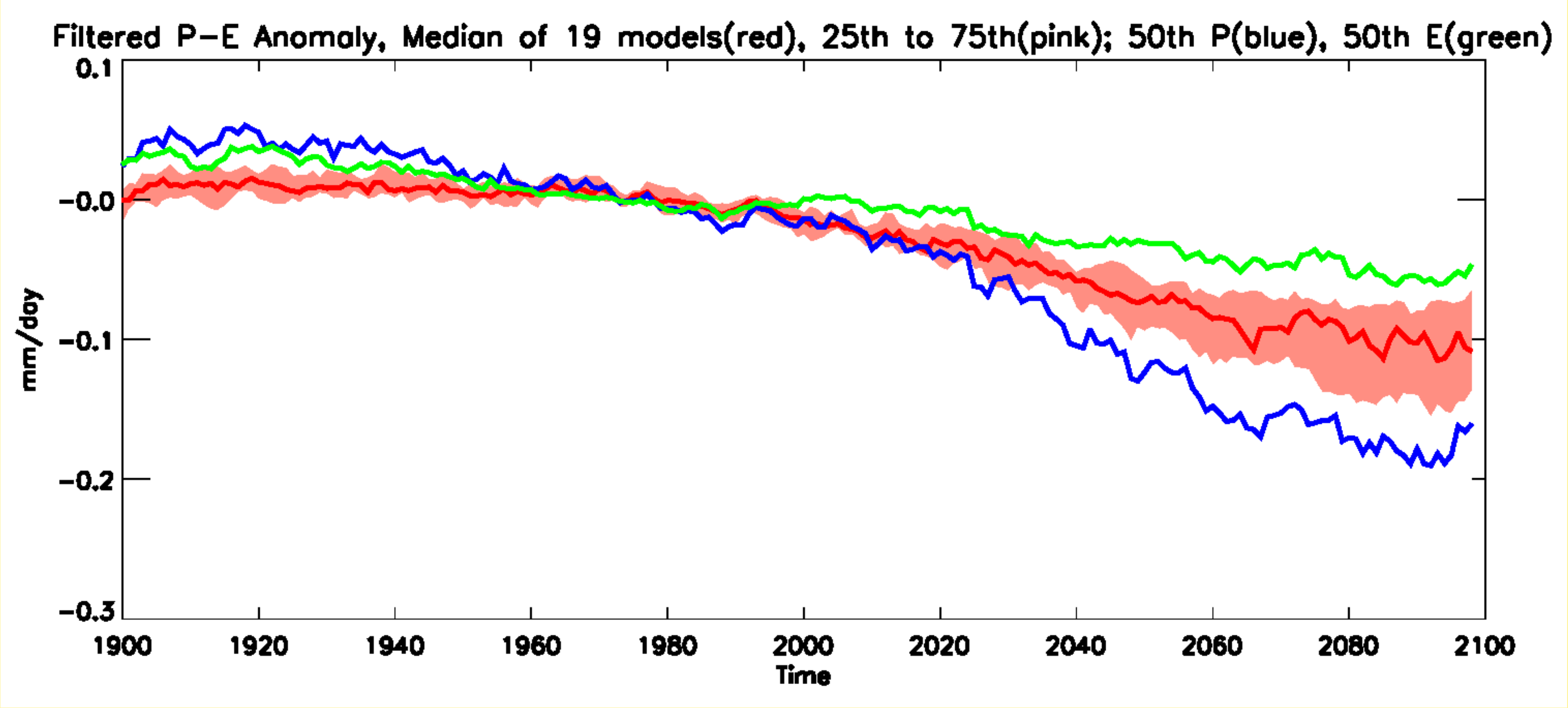
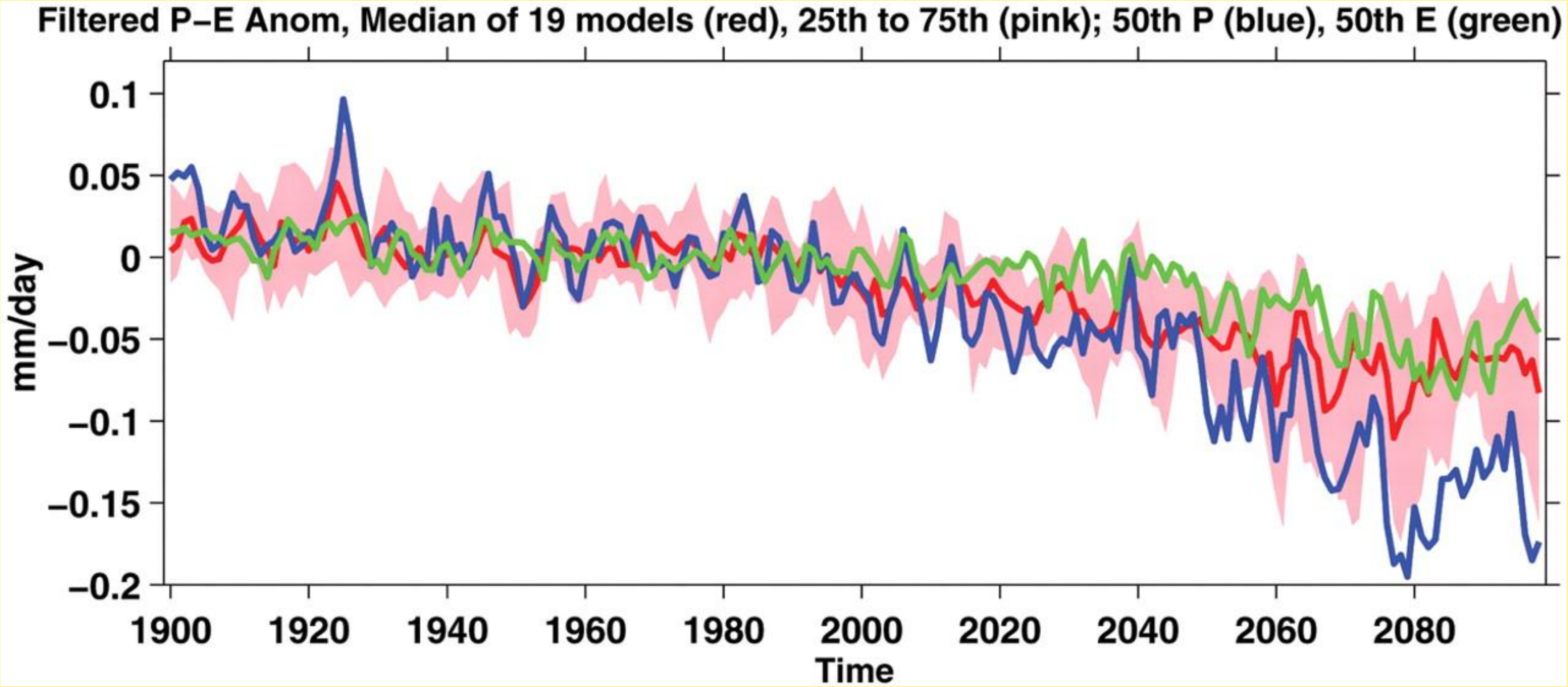


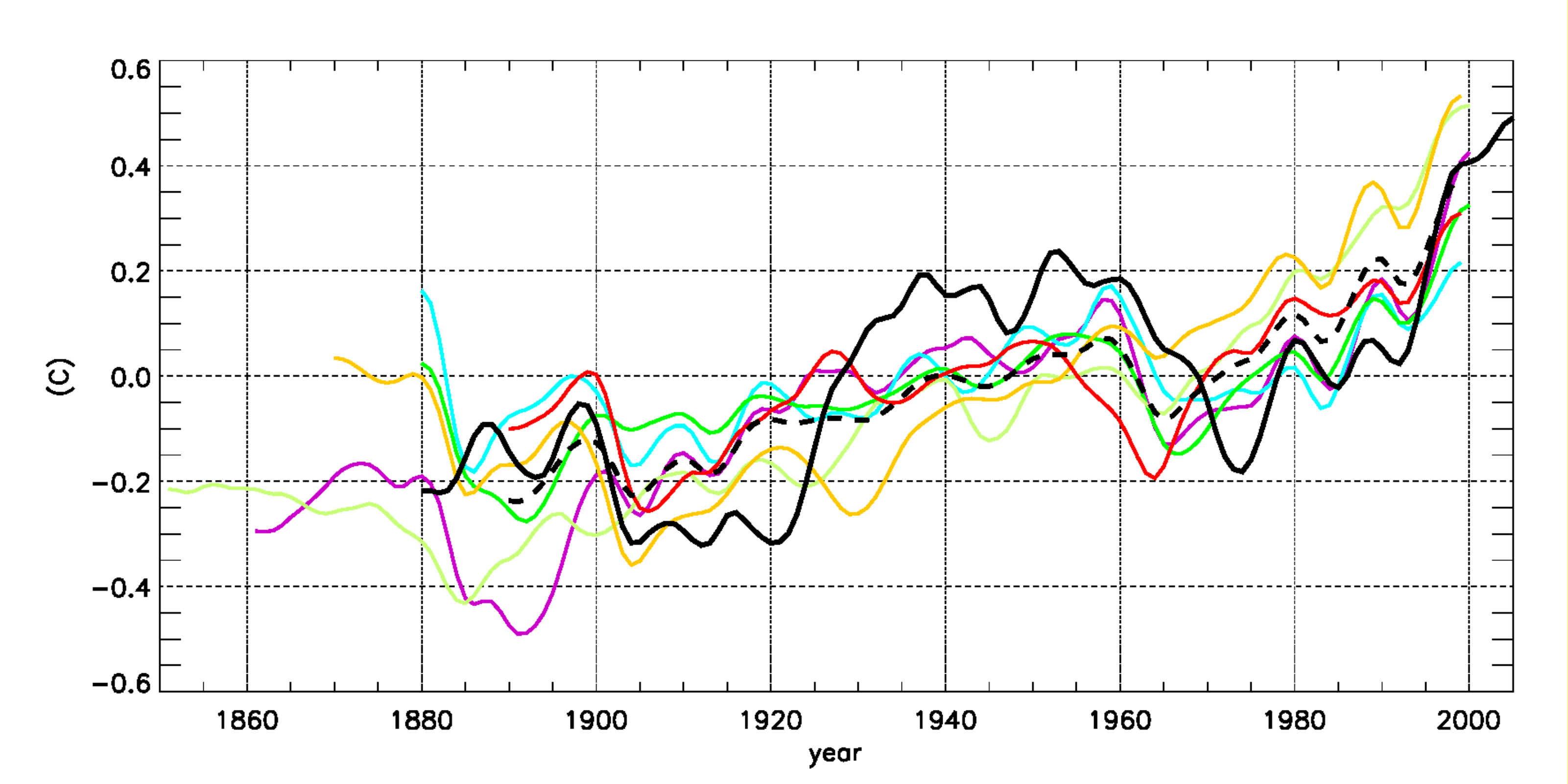
Fig. 1. Modeled changes in annual mean precipitation minus evaporation over the American Southwest (125{degrees}W to 95{degrees}W and 25{degrees}N to 40{degrees}N, land areas only), averaged over ensemble members for each of the 19 models



R. Seager et al., Science 316, 1181 -1184 (2007)

Published by AAAS

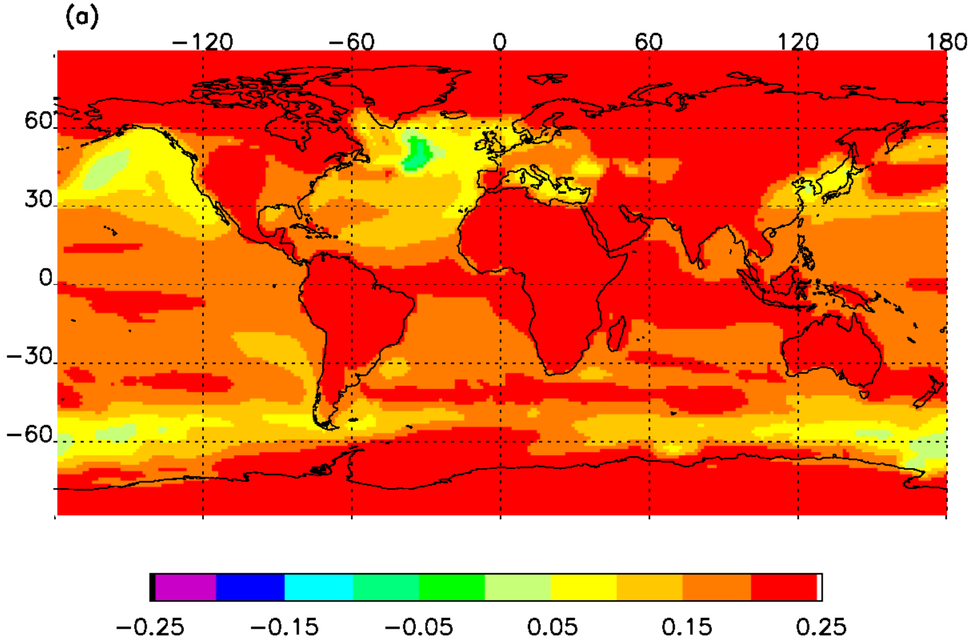
North Atlantic SST index (NASSTI) averaged over the ocean grids from equator to 60°N, and 7.5°W to 75°W.

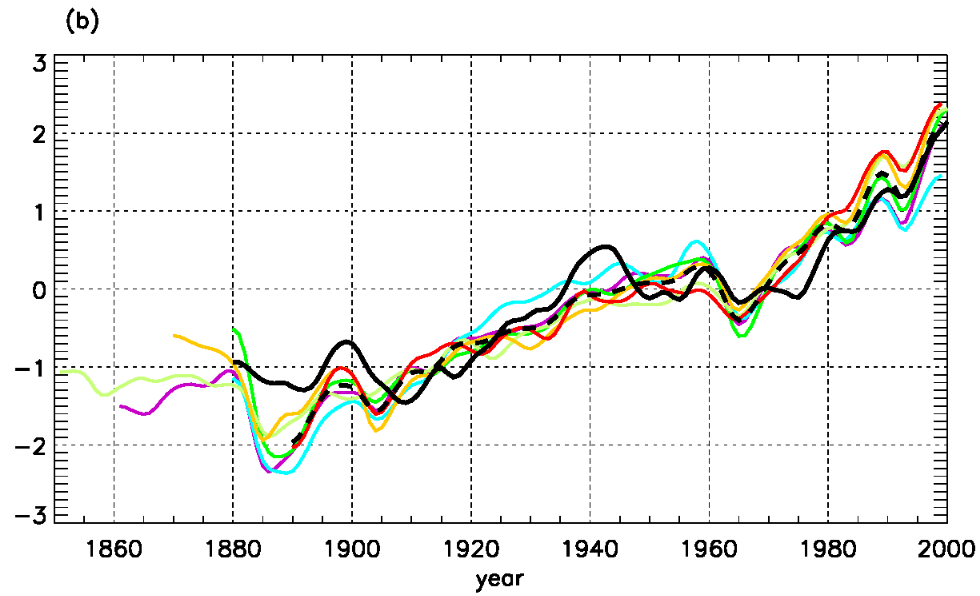


Black solid line: observations

Color lines: coupled ocean-atmosphere models of the IPCC 20th century simulations averaged over multiple realizations starting from different initial conditions

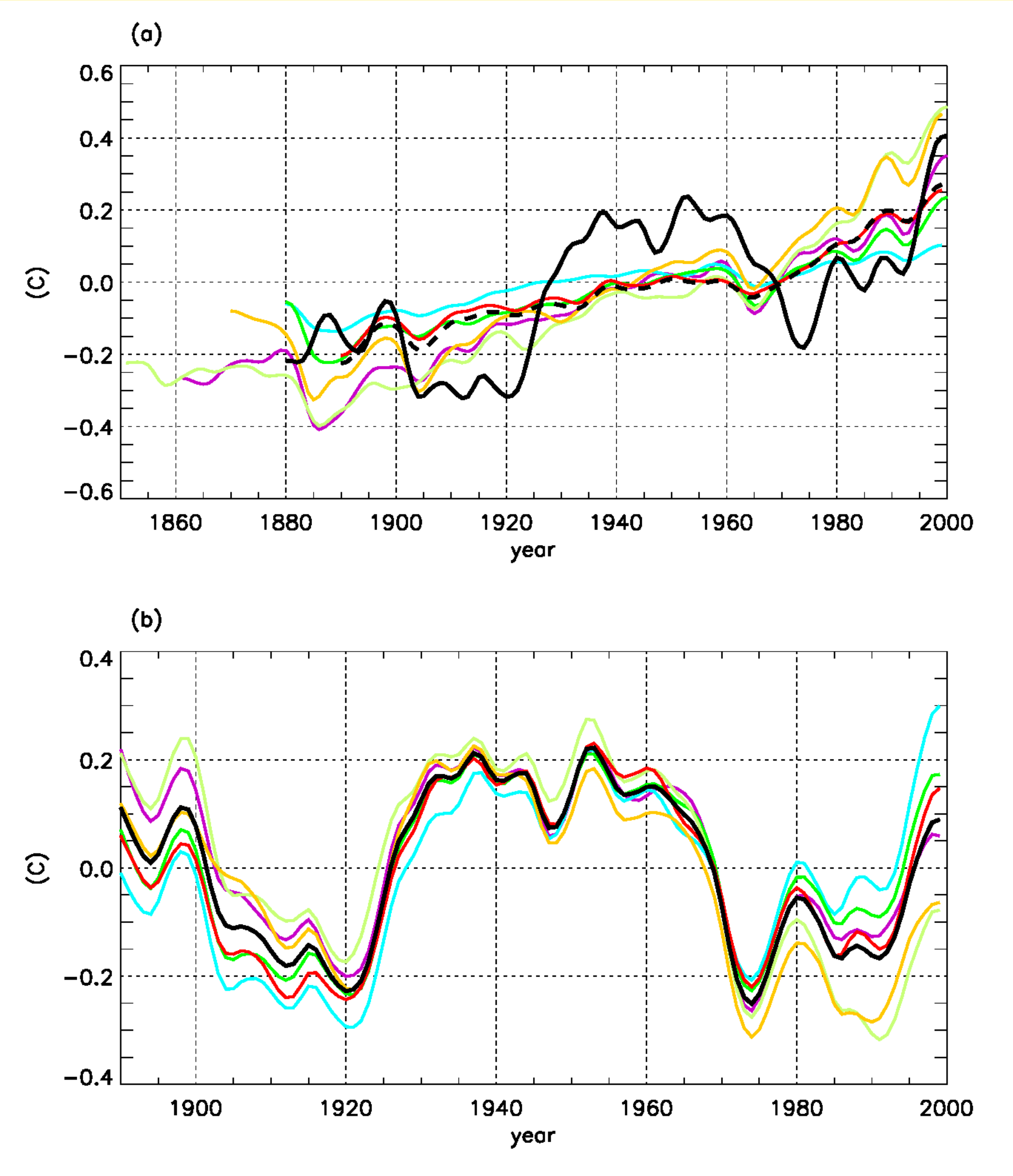
Dashed black line: average of all models.





Top: Spatial structure of the first mode of the signal-to-noise maximizing EOF analysis averaged over the six IPCC AR4 models. Shown are regressions of annual-mean, low-pass filtered surface temperature on the S/N maximizing PC1.

Bottom: signal-to-noise maximizing PC1 for each of the six models. The dashed black line shows the six model average PC1 and the solid black line is the standardized global mean surface temperature from the GISS surface temperature dataset



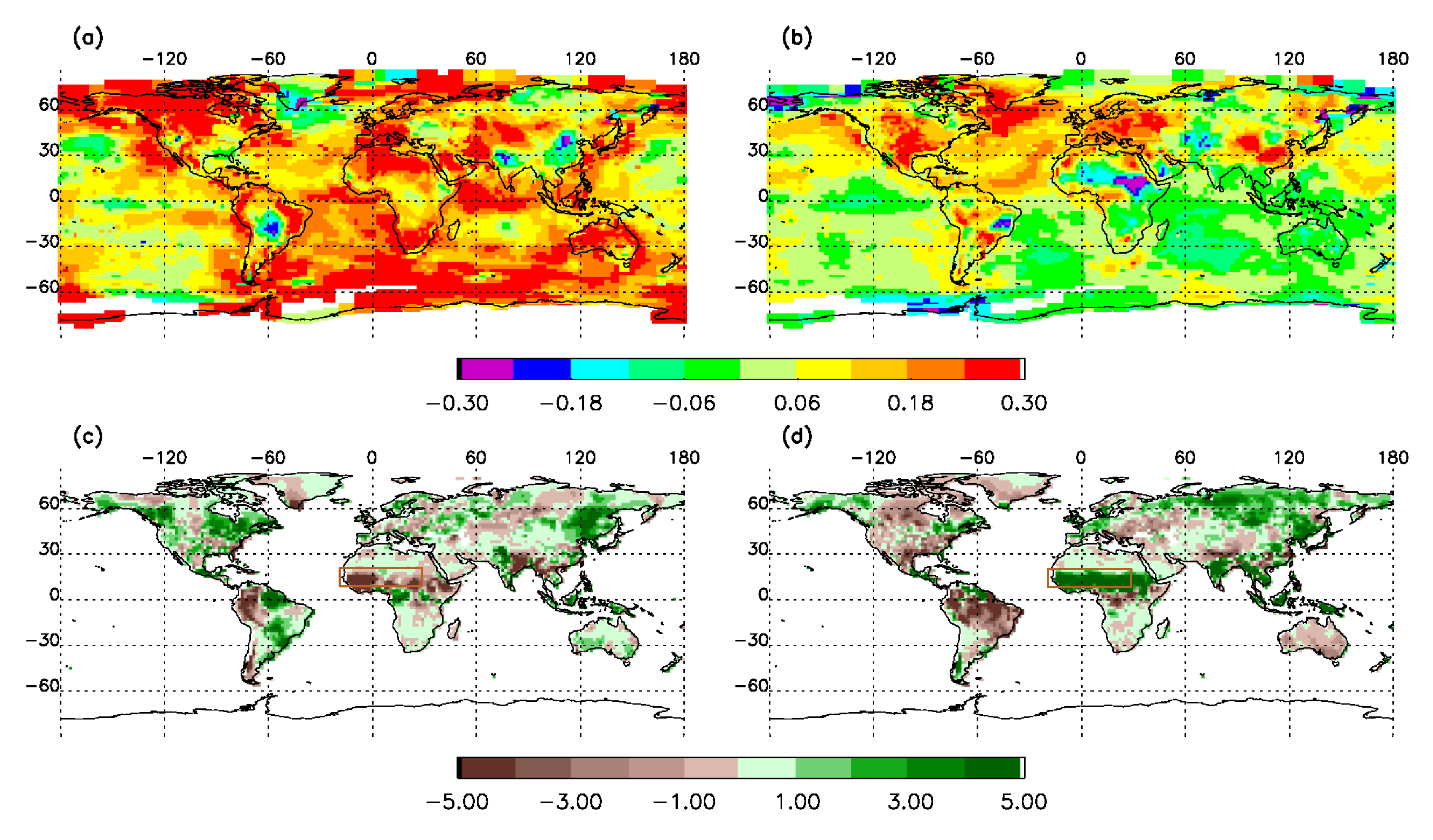
Top: Projection of North Atlantic SST index onto the S/N maximizing PC1 in each of the participating models (ensemble averaged, color lines) and the observed North Atlantic SST index (black line).

Bottom: Observed internally generated AMO index constructed by subtracting from the observed index the model estimates of the forced North Atlantic SST (dashed line in top panel). The black line of the bottom plot is the average across all six models.

JJAS Observations (CRU Data)

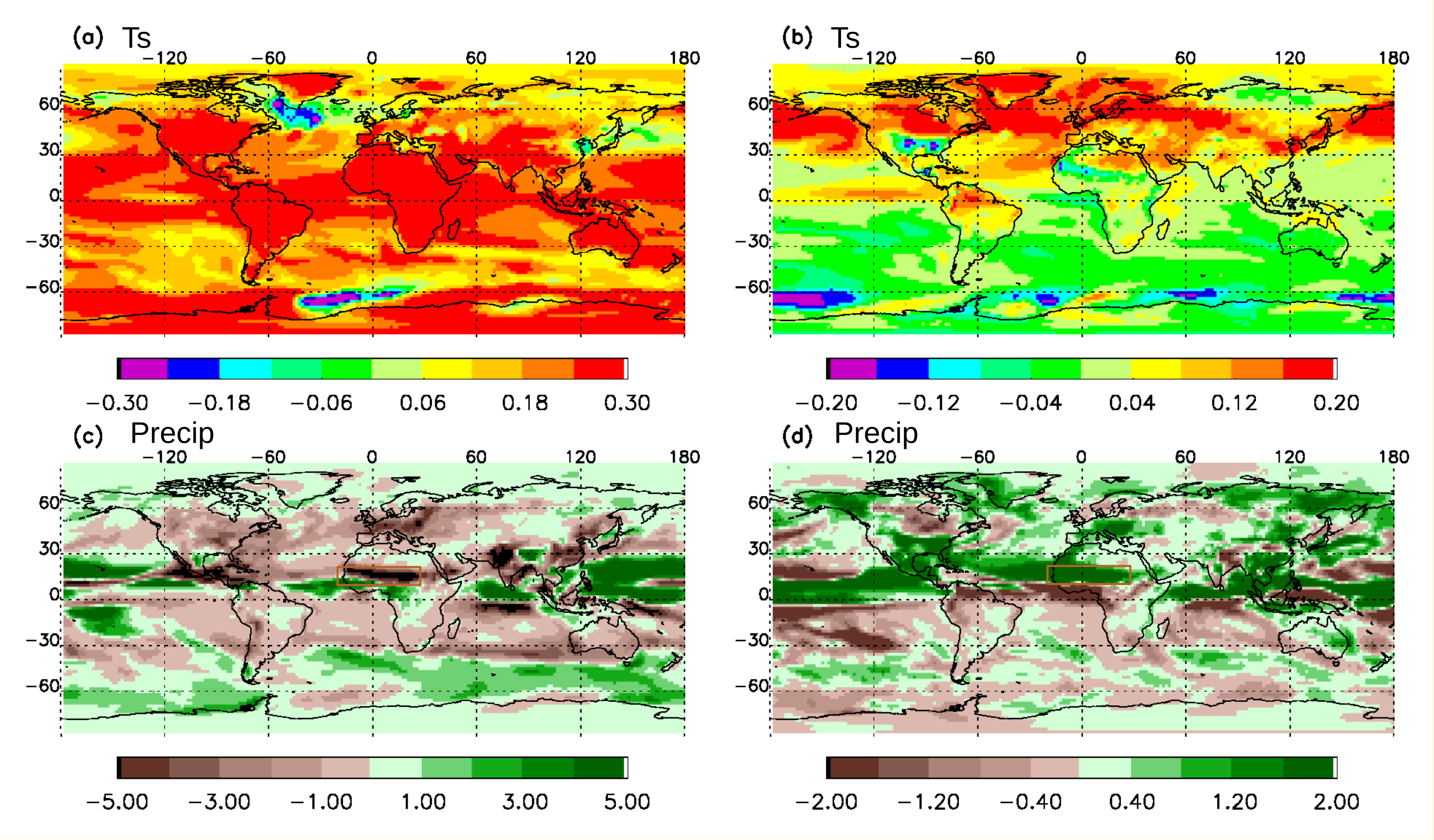
Regression to Forced NASSTI

Regression to AMO



JJAS GFDL CM2.1

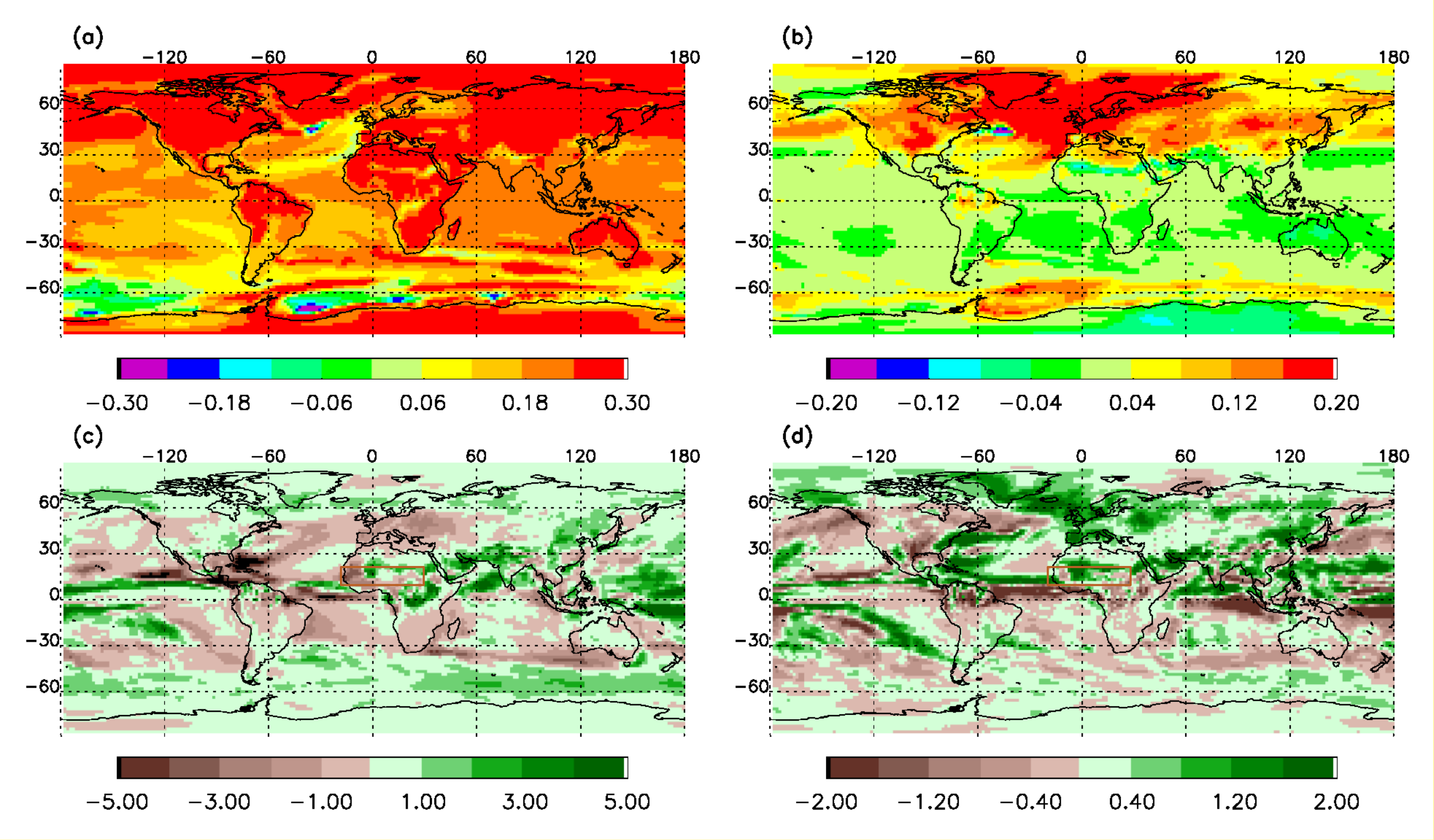
Regression to Forced NASSTI   Regression to AMO



JJAS NCAR CCSM3

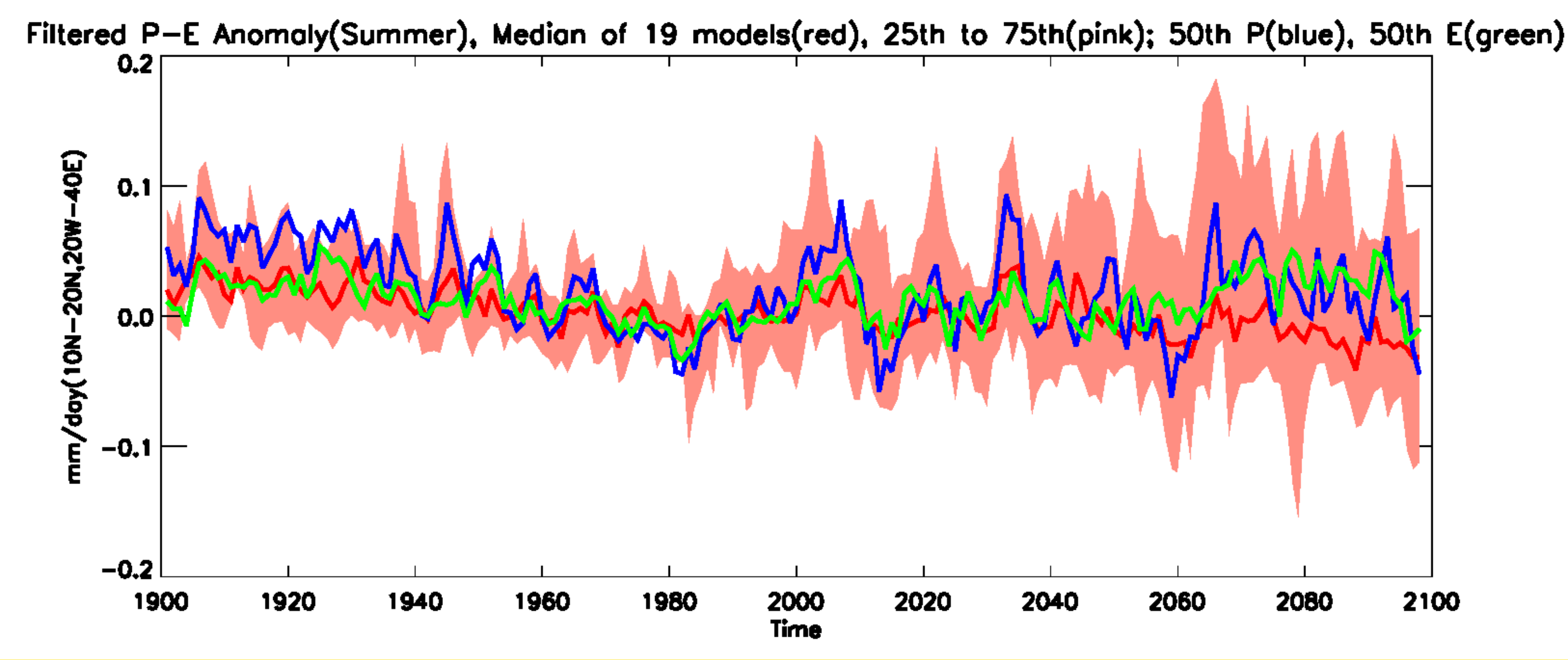
Regression to Forced NASSTI

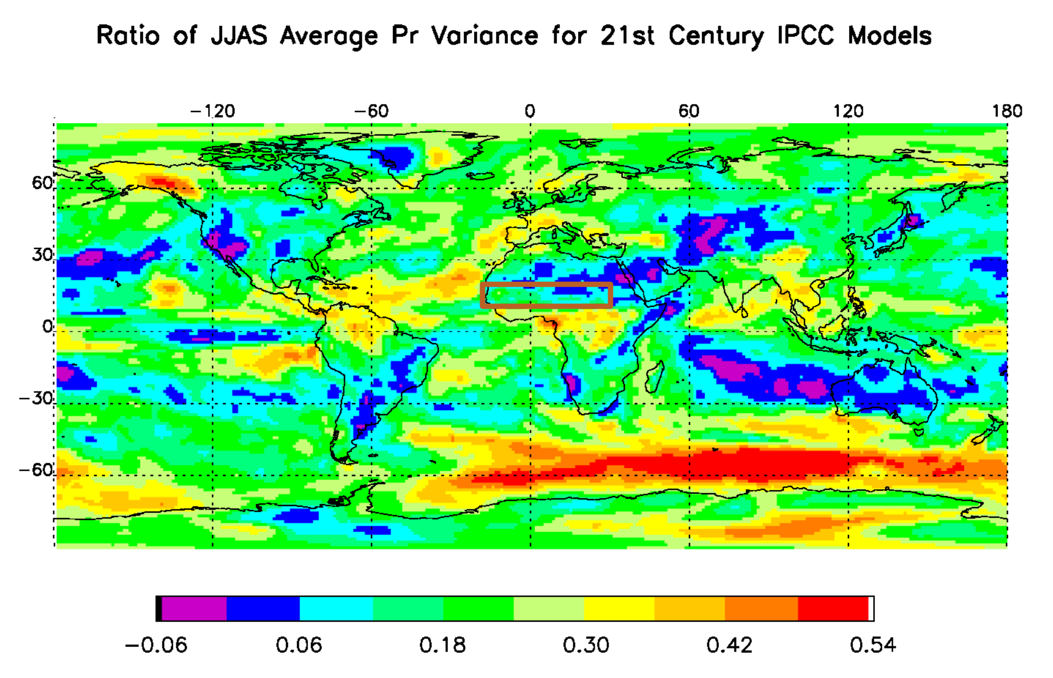
Regression to AMO

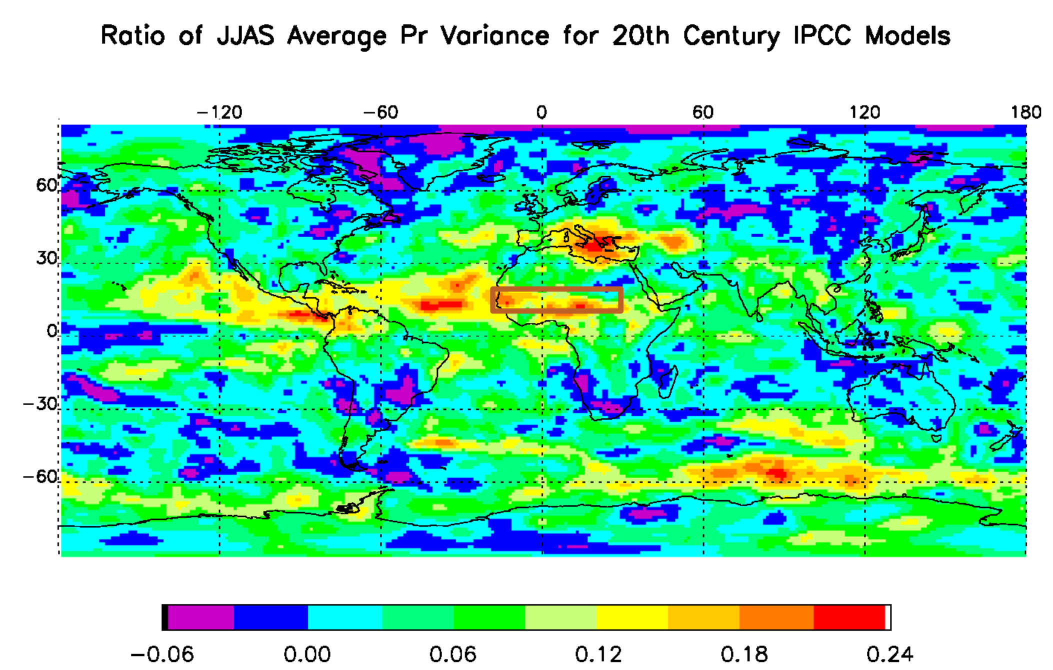


Future Trend in Sahel Rainfall?

- •Forced variability – suggests drying trend
- Natural variability – wet trend in positive phase
- Future? – Model uncertainty is large; indicates large influence of internal variability?



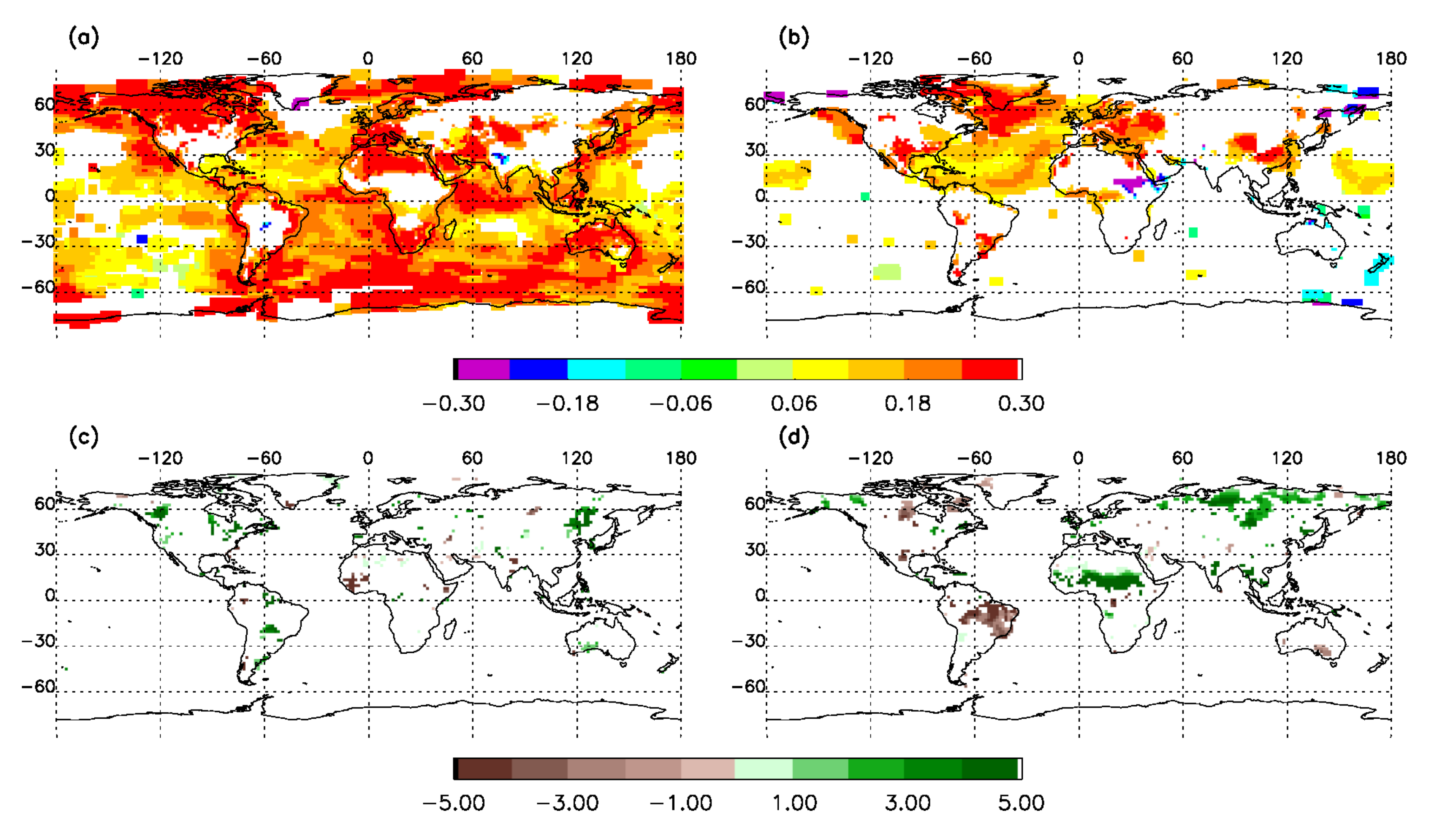

Ratio of JJAS Average Pr Variance for 21st Century IPCC Models
-120
-60
0
60
120
180
60
30
0
-30
-60
-0.06
0.06
0.18
0.30
0.42
0.54


Ratio of JJAS Average Pr Variance for 20th Century IPCC Models
-120
-60
0
60
120
180
60
30
0
-30
-60
-0.06
0.00
0.06
0.12
0.18
0.24

JJAS Observations (CRU Data)

Regression to Forced NASSTI (95%)

Regression to AMO (95%)



Forced Variance (Top) versus Total Variance (Bottom)