LAMONT-DOHERTY
EARTH OBSERVATORY
THE EARTH INSTITUTE AT COLUMBIA UNIVERSITY

Decadal Variability of the East African Long Rains in Observations and Models

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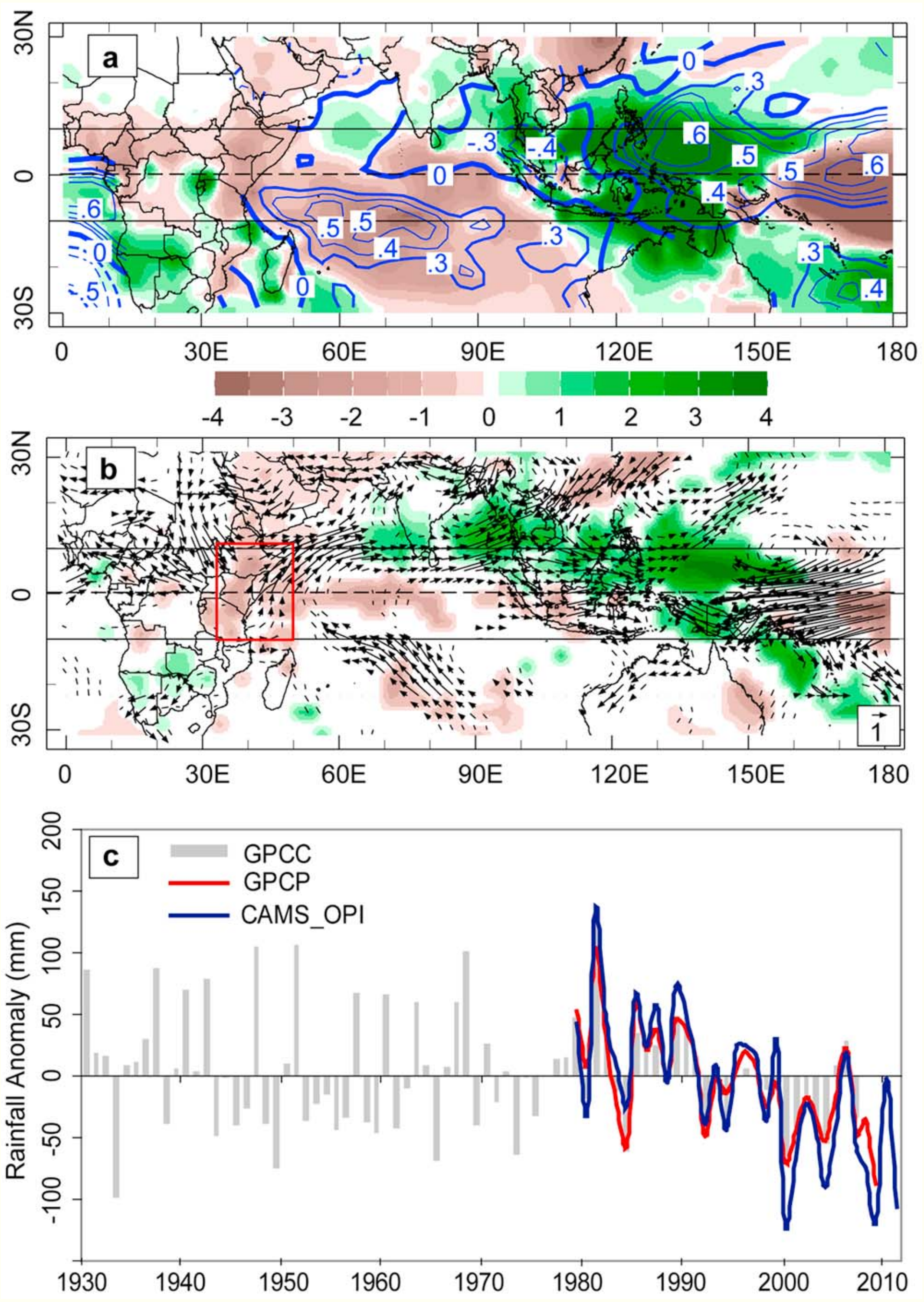
Lamont GloDecH Meeting on Wednesday June 12th

Outline

- Motivations
- Observational Data, Model Simulations and Methods
- Observed Results
- Model Results
- Conclusions

Motivations: I

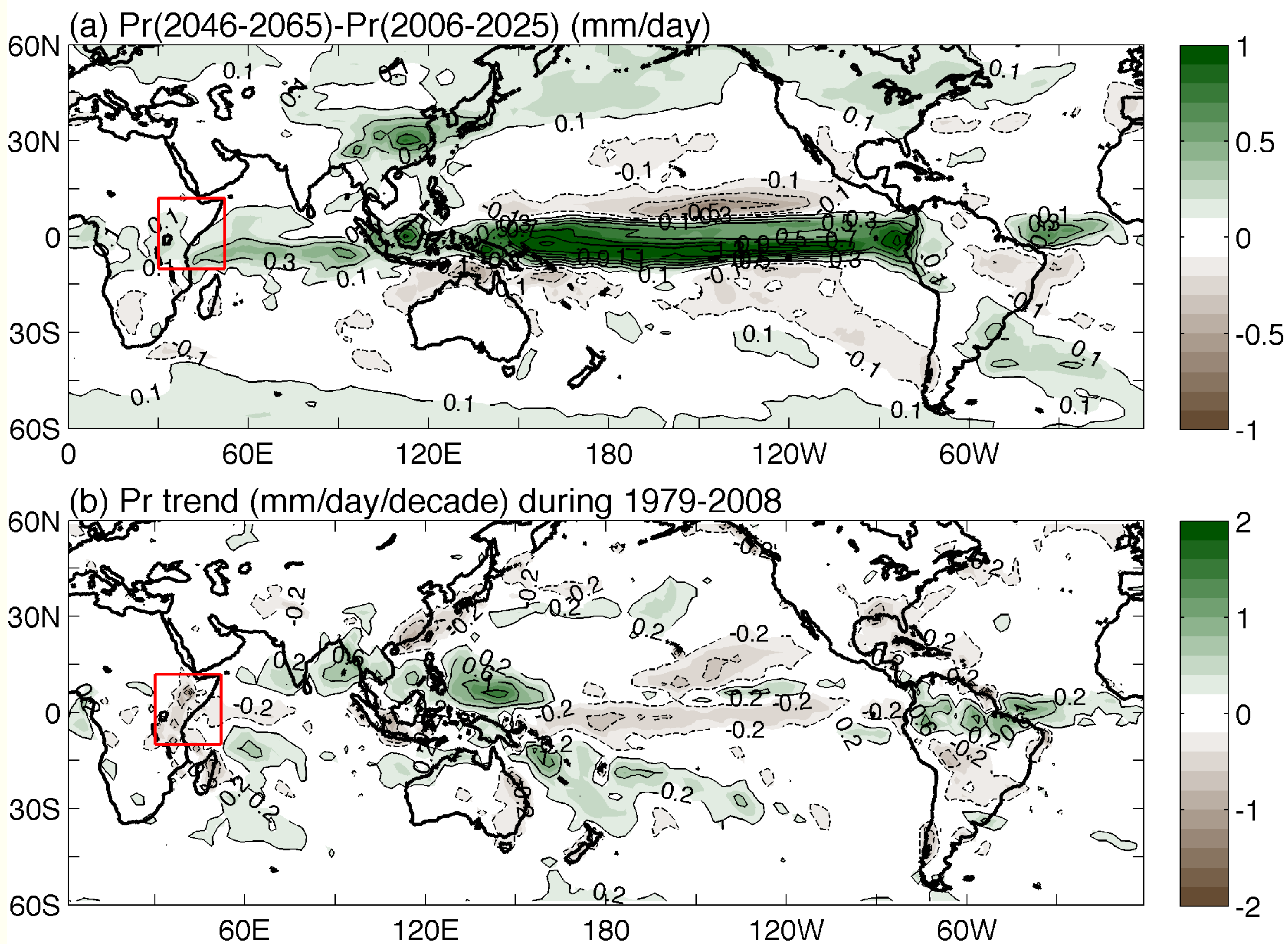
- The 2010-2011 East African drought
  - The 2010 below-normal short rains (OND rains): expected in a La Nina year
  - The 2011below-normal long rains (MAM rains): no clear forcings
- Might be associated with drying trend in recent decades (Williams et al. 2011, Lyon et al. 2012)
- What is the characteristic of the East African long rains in longer time scale, i.e. decadal variability?



(Lyon et al. 2012)

Motivations: II

- A contrast between CMIP5 model projections and the long rains trends in recent decades
  - CMIP5 model projections: wetting
  - Trends over the last three decades: drying
- Can we trust the model projections?



Key Questions

- What is the characteristic of the decadal variability of the East African long rains in the observations?
- What is the relationship with the observational SSTs?
- Are the simulations from the SST-forced models and the fully coupled models able to capture the these features?
- What does that imply for the model projections of the East African long rains in the near future?

Data and Models

- Precipitation: GPCC, GPCP, CMAP
- SST: ERSST
- IRI forecast models (SST-forced): ECHAM4.5, ECHAM5, CCM3.6
- CMIP5 AMIP experiment (SST-forced)
- CMIP5 historical experiment (fully coupled)

CMIP5 Models

12 CMIP5 AMIP experiment models

Table 1. Models of the CMIP5 AMIP experiment used in our analysis.

Model	Time Span	Ensemble #
CanAM4	1950-2009	4
CNRM-CM5	1979-2008	1
CSIRO-Mk3-6-0	1979-2009	10
GFDL-HIRAM-C180	1979-2008	3
GFDL-HIRAM-C360	1979-2008	2
GISS-E2-R	1880-2010	1
HadGEM2-A	1979-2008	1
inmcm4	1979-2008	1
IPSL-CM5A-LR	1979-2009	5
MPI-ESM-LR	1979-2008	3
MRI-AGCM3-2H	1979-2008	1
NorESM1-M	1979-2008	3

43 CMIP5 historical experiment models

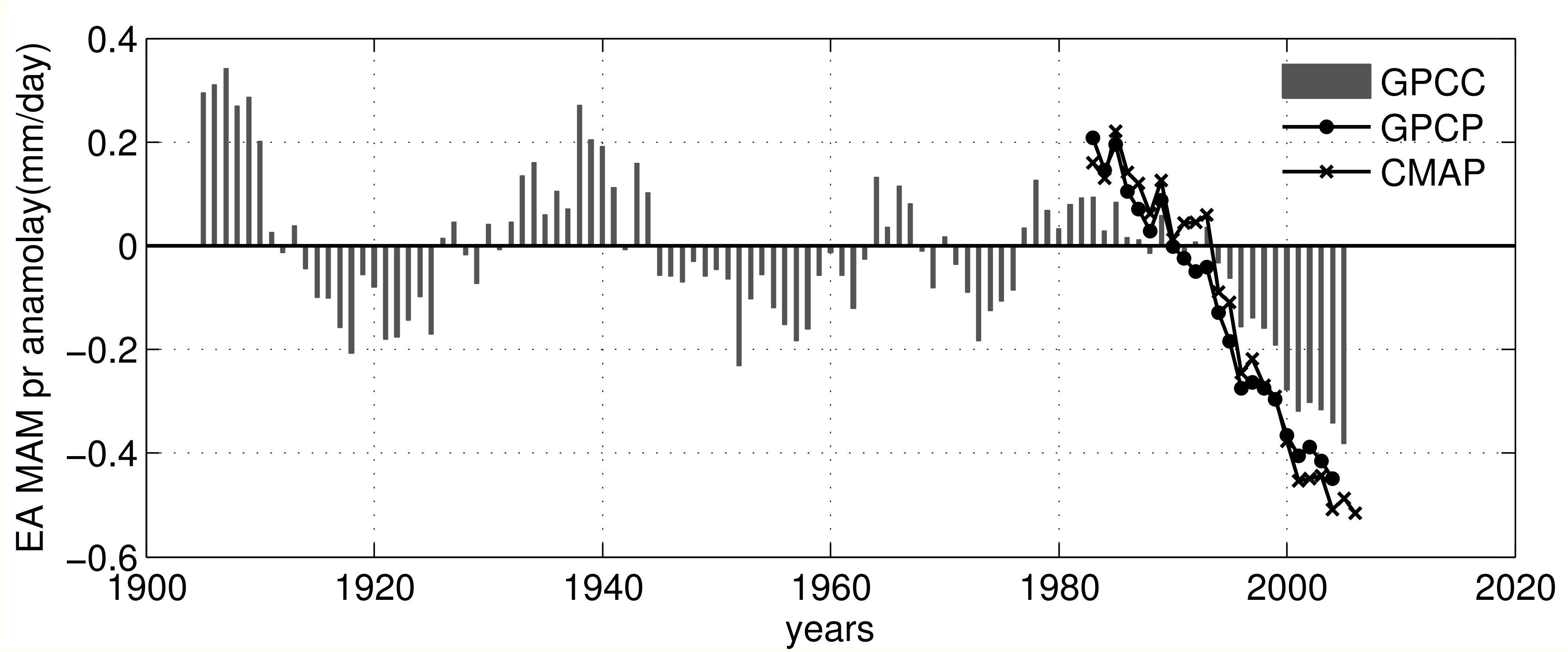
Table 2. Models of the CMIP5 historical experiment used in our analysis.

Model	Time Span	Ensemble #
ACCESS1-0	1850-2005	1
ACCESS1-3	1850-2005	1
bcc-csm1-1	1850-2012	3
bcc-csm1-1-m	1850-2012	3
BNU-ESM	1850-2005	1
CanCM4	1961-2005	10
CanESM2	1850-2005	5
CCSM4	1850-2005	6
CESM1-BGC	1850-2005	1
CESM1-CAM5	1850-2005	3
CESM1-CAM5-1-FV2	1850-2005	4
CESM1-FASTCHEM	1850-2005	3
CESM1-WACCM	1955-2005	4
CMCC-CESM	1850-2005	1
CMCC-CM	1850-2005	1
CMCC-CMS	1850-2005	1
CNRM-CM5	1850-2005	10
CSIRO-Mk3-6-0	1850-2005	10
FGOALS-g2	1900-2005	5
FGOALS-s2	1850-2005	3
FIO-ESM	1850-2005	3
GFDL-CM3	1860-2005	5
GFDL-ESM2G	1861-2005	3
GFDL-ESM2M	1861-2005	1
GISS-E2-H	1850-2005	5
GISS-E2-R	1850-2005	6
HadCM3	1860-2005	10
HadGEM2-CC	1960-2004	3
HadGEM2-ES	1860-2004	4
inmcm4	1850-2005	1
IPSL-CM5A-LR	1850-2005	5
IPSL-CM5A-MR	1850-2005	1
IPSL-CM5B-LR	1850-2005	1
MIROC-ESM	1850-2005	3
MIROC-ESM-CHEM	1850-2005	1
MIROC4h	1950-2005	3
MIROC5	1850-2005	4
MPI-ESM-LR	1850-2005	3
MPI-ESM-MR	1850-2005	3
MPI-ESM-P	1850-2005	2
MRI-CGCM3	1850-2005	3
NorESM1-M	1850-2005	3
NorESM1-ME	1850-2005	1

Methods

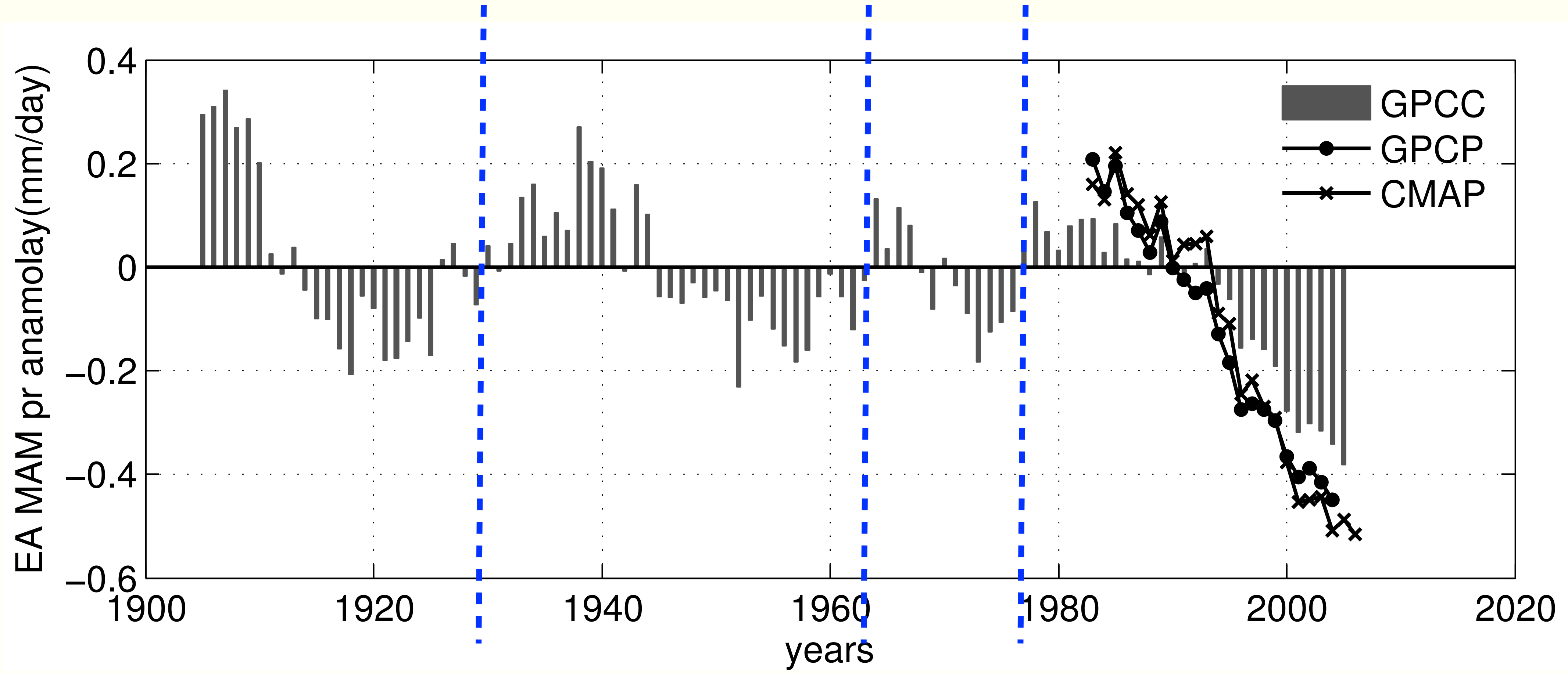
- A nine-year running average is applied to all the data to focus on the decadal time scale
- To reveal the SST-Precipitation relationship, we use:
  - Regression of SST on the East African long rains
  - Composite of SST anomalies over dry East African long rains seasons
- SST data has had global average removed
- EOF analysis is utilized to identify the SST modes associated with the long rains

Observed Results: Long Rains History



- Linear trends after 1983 (mm/day/decade): 0.21 (GPCC), 0.33 (GPCP), 0.35 (CMAP)
- Recent drying trend is most likely part of the natural decadal variability

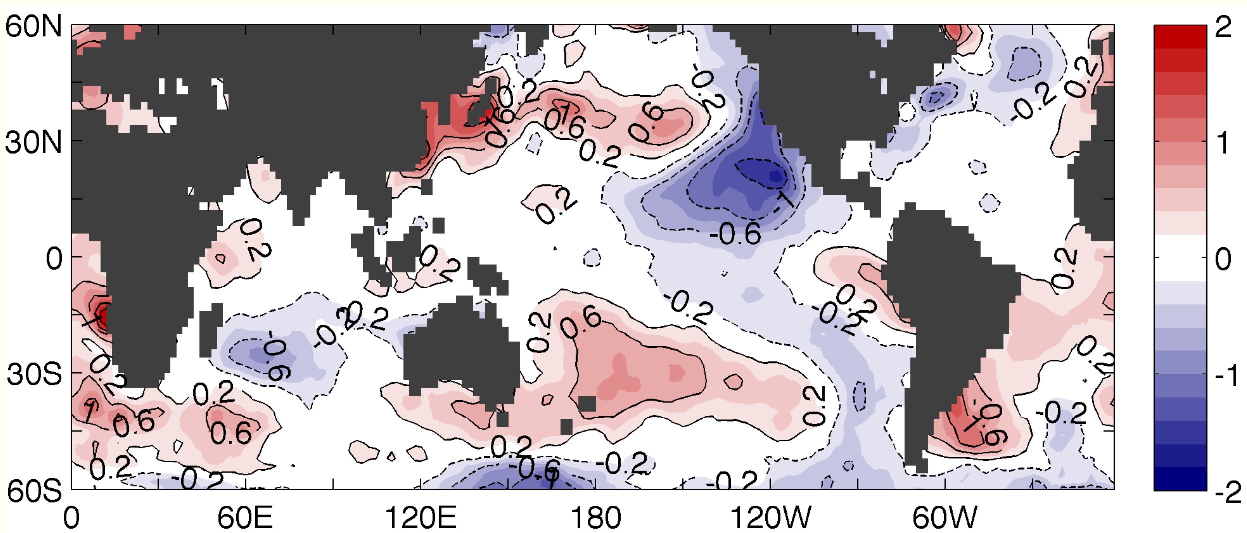
Observed Results: Long Rains History



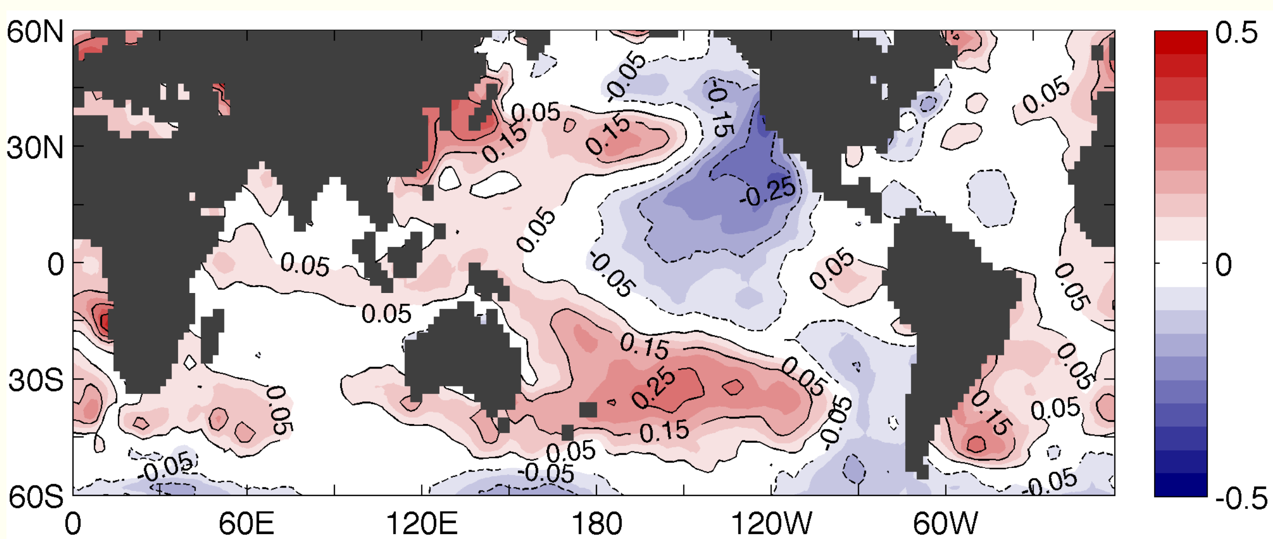
- Linear trends after 1983 (mm/day/decade): 0.21 (GPCC), 0.33 (GPCP), 0.35 (CMAP)
- Recent drying trend is most likely part of the natural decadal variability
- Approximate four cycles in GPCC

Observed Results: SST-Pr Relationship

Regression of SST on the negative of long rains (K/mm/day)



Composite of SST over dry long rains seasons (K)



Observed Results: SST-Pr Relationship

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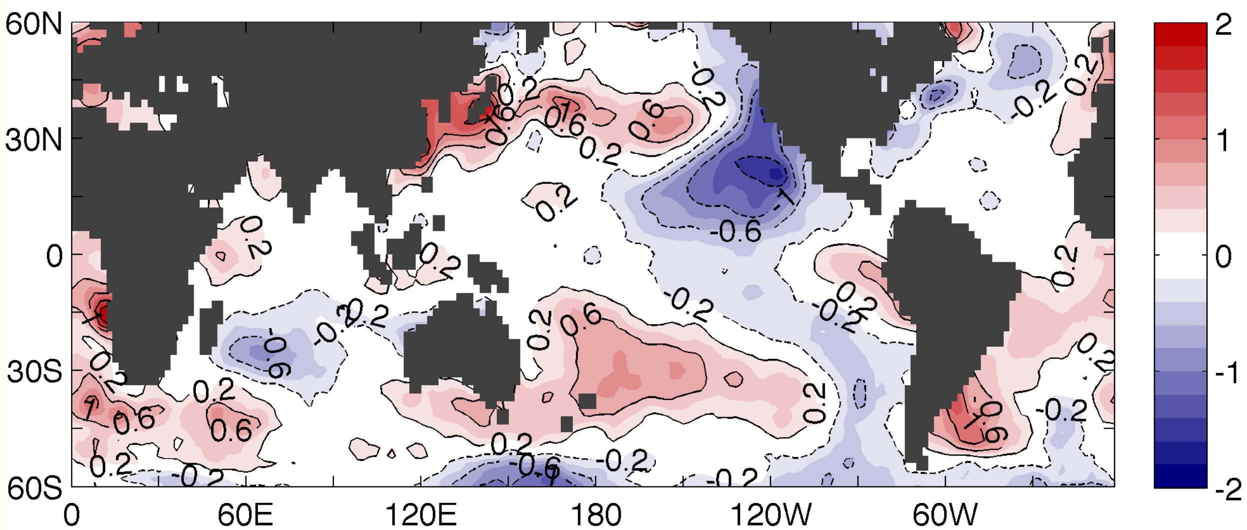
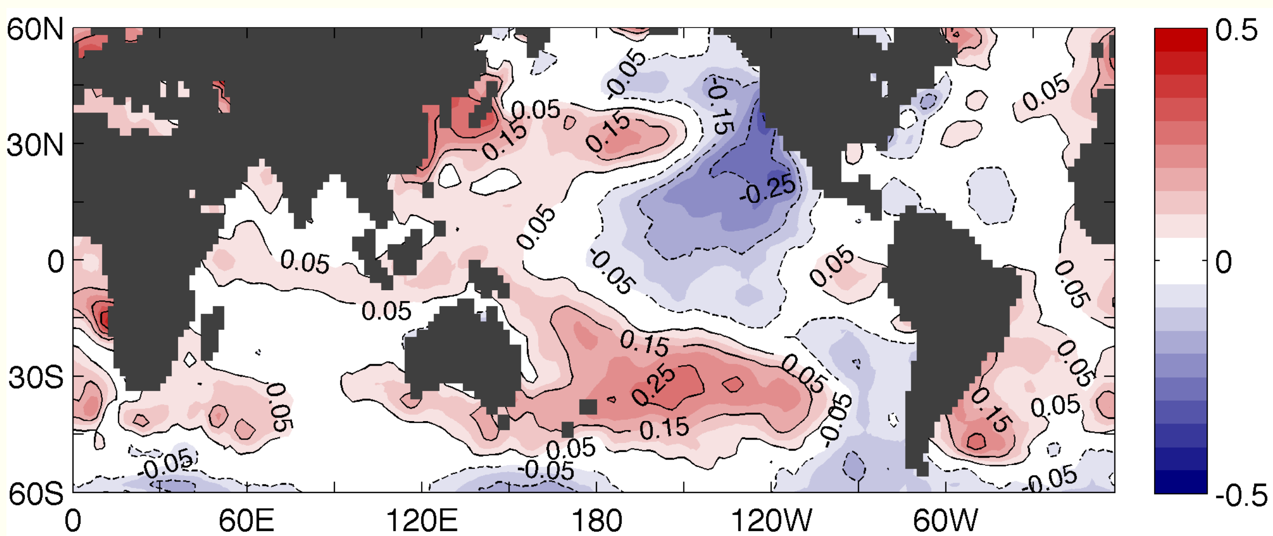


Composite of SST over dry long rains seasons (K)



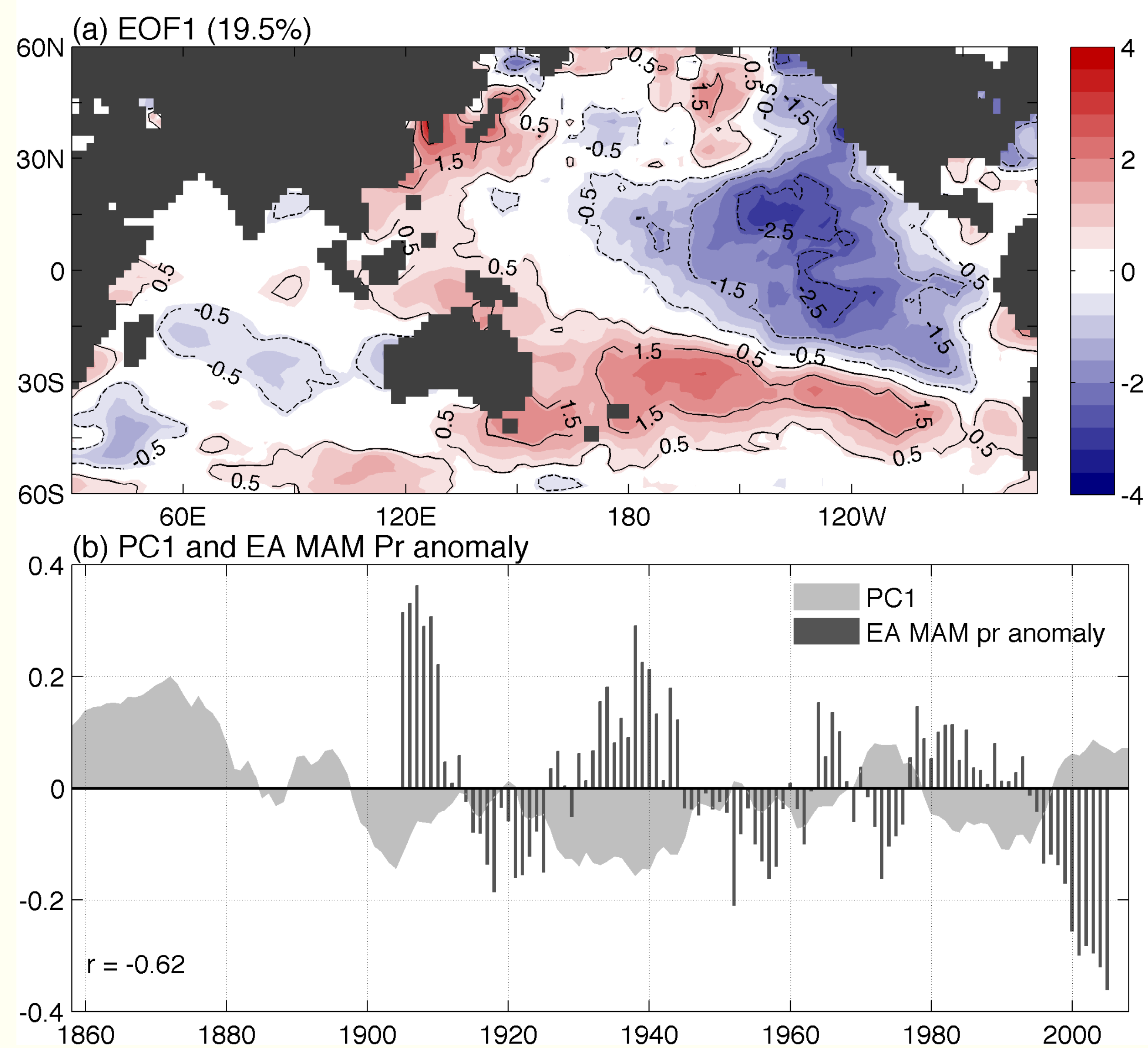
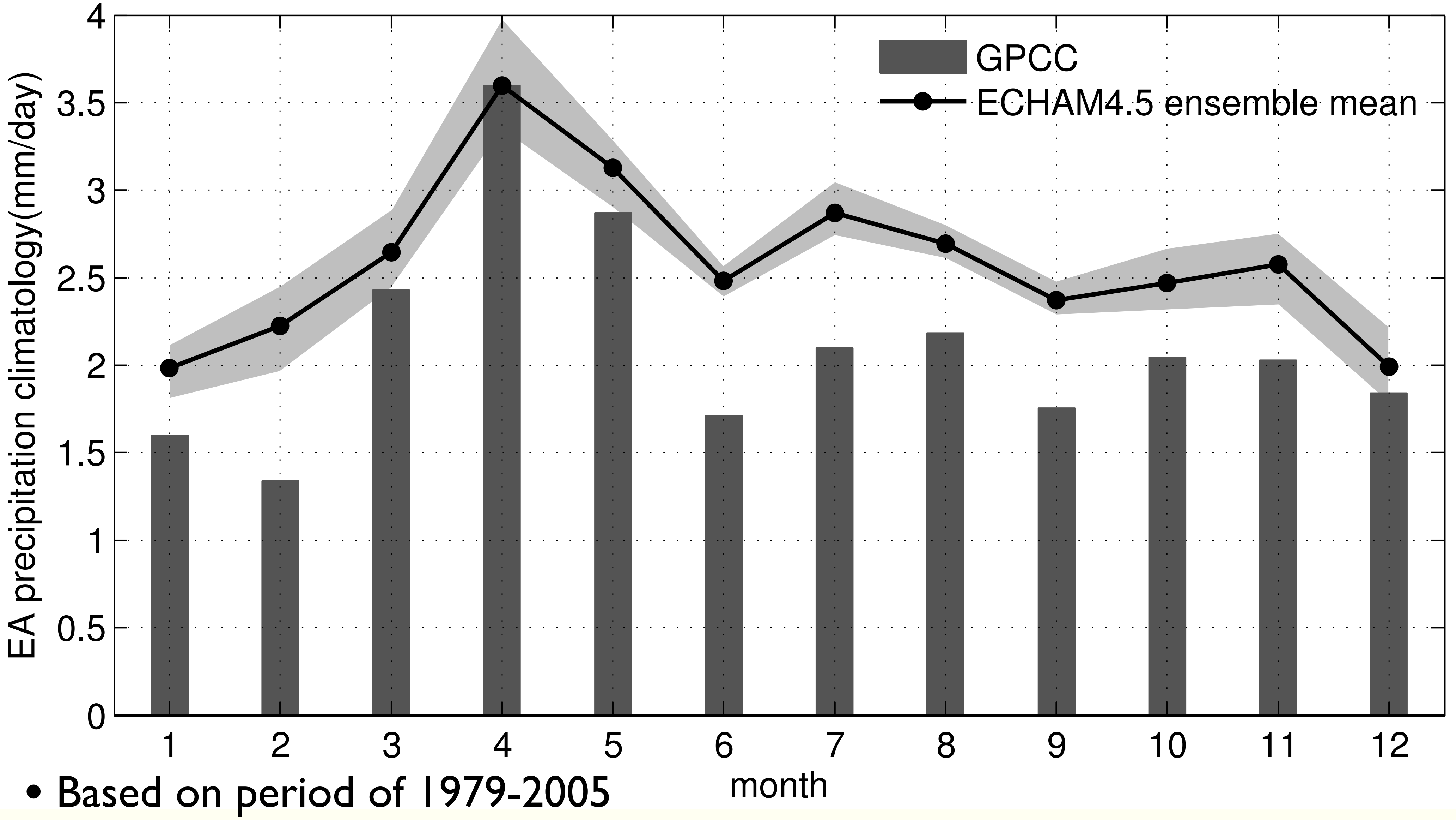


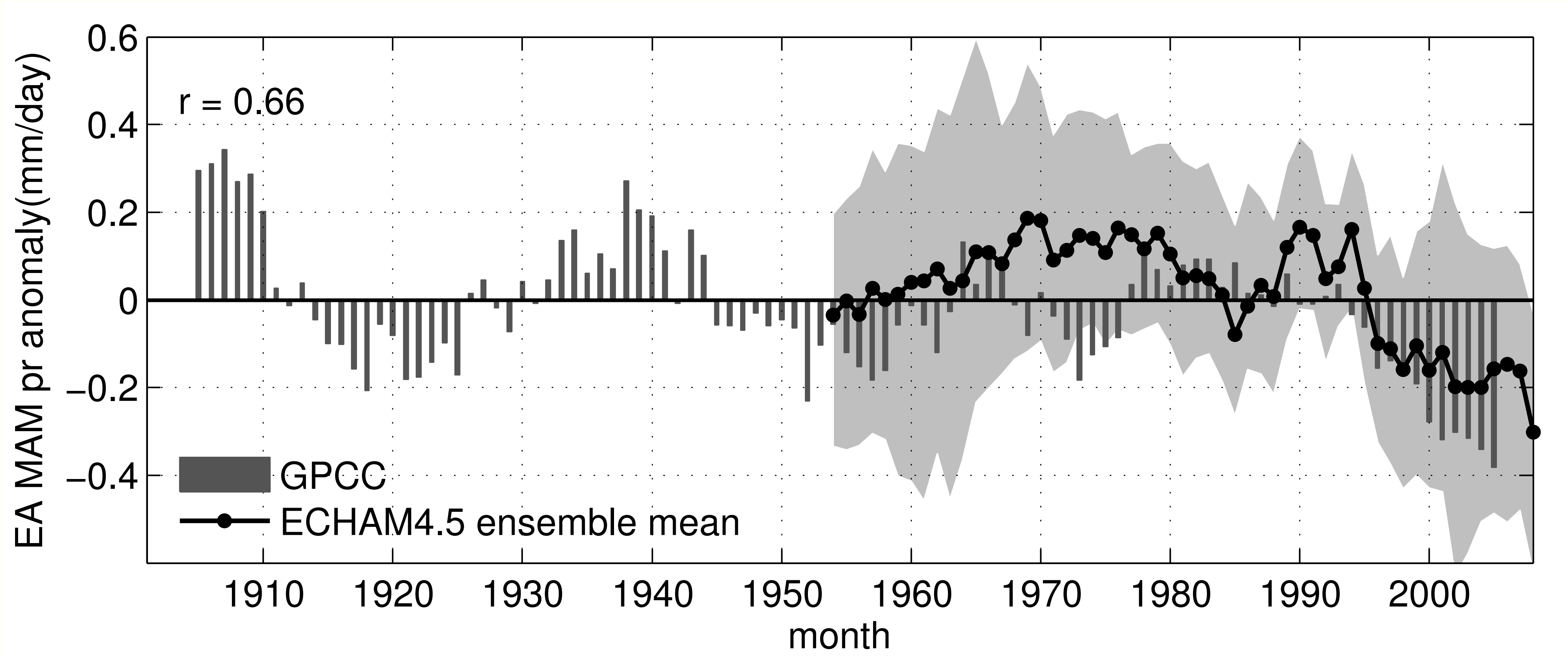
Fig. 3. The first EOF of the ERSST in MAM after removing the global-averaged SST and performing a 9-year running average. (a) The first EOF spatial pattern. (b) The first principle component (time series from the EOF analysis, lighter gray area plot, unit K) and East Africa MAM precipitationanomaly (gray bars, unit mm/day).

ECHAM4.5: Climatology



- Based on period of 1979-2005
- Captures the long rains nicely
- Overestimates in other seasons

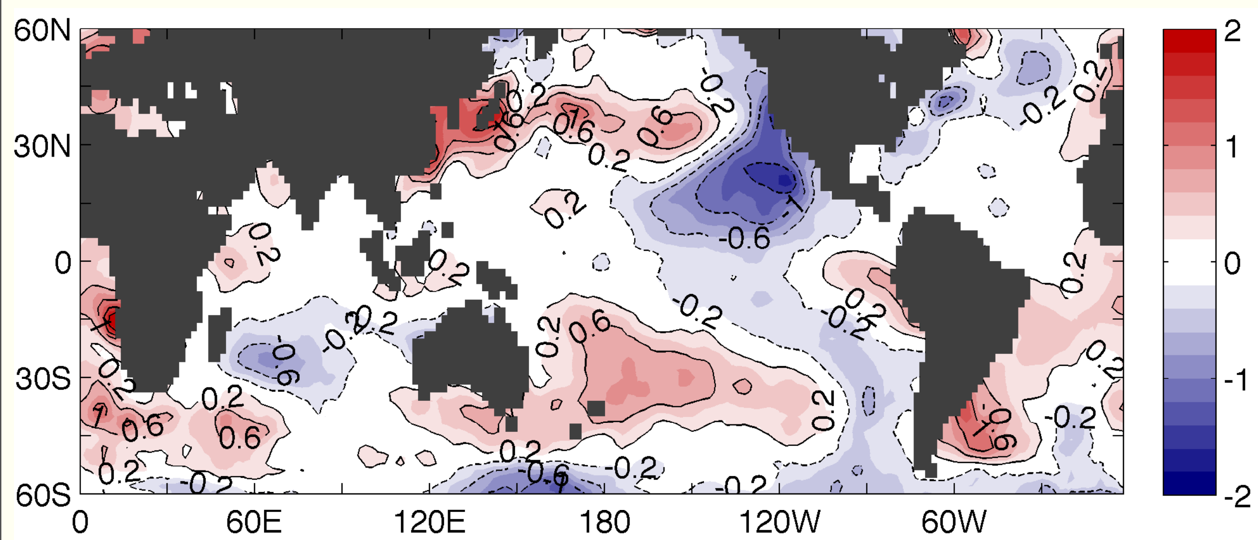
ECHAM4.5: Time Series



- Captured:
  - drying trend in recent decades
  - wetting trend from the middle 1950s to the late 1960s
- Not captured:
  - wetting trend in the 1970s
- Broad spread across ensemble members, indicating intense internal variability

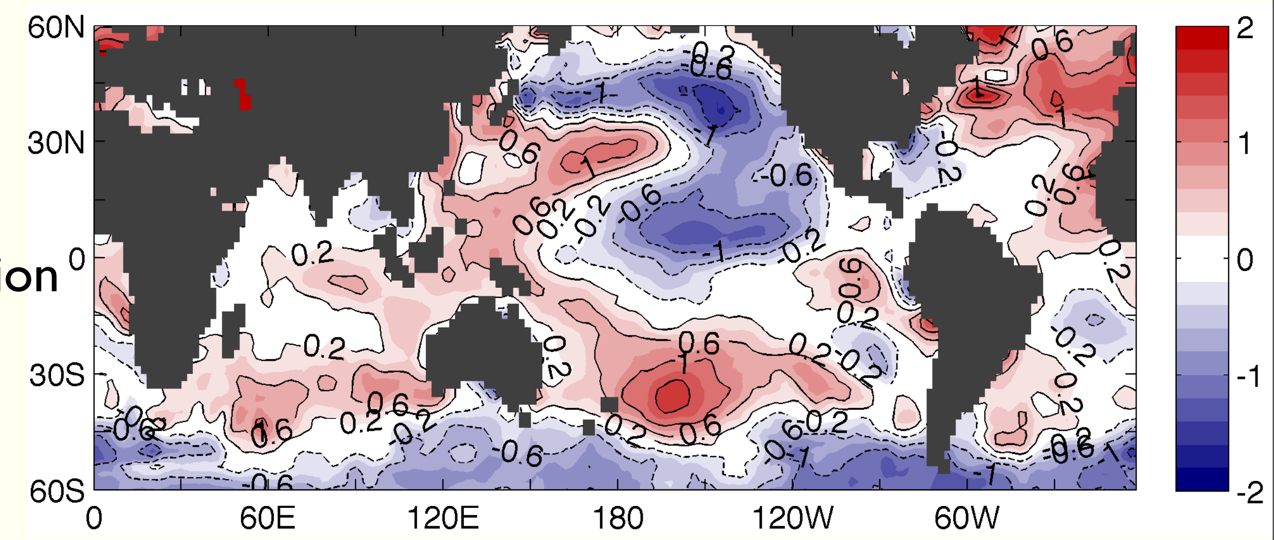
ECHAM4.5: SST-Pr Relationship

GPCC



Regression

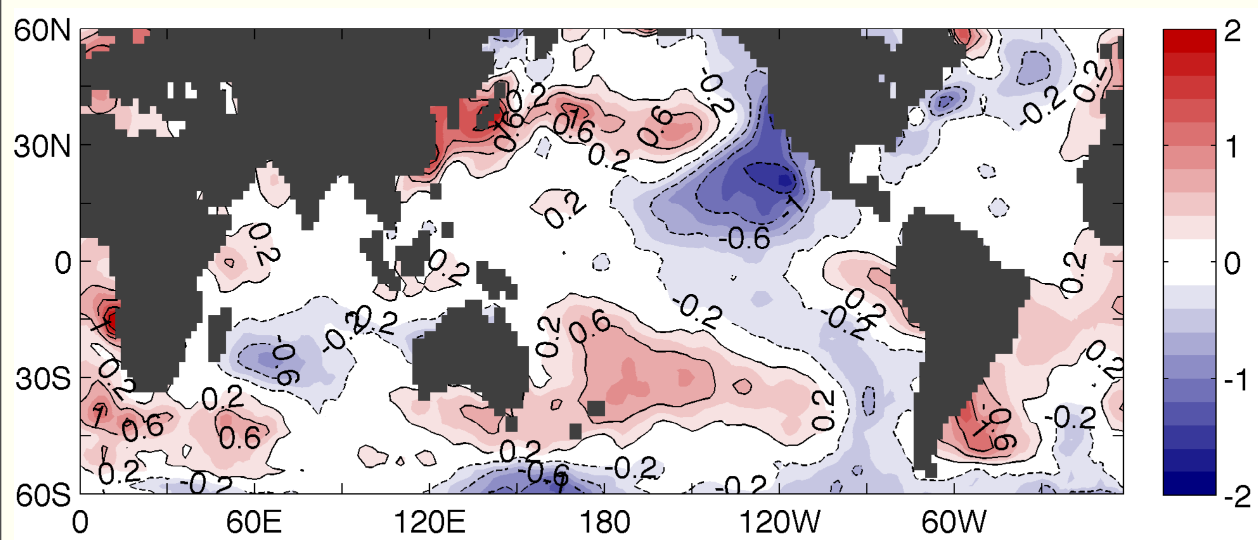
ECHAM4.5



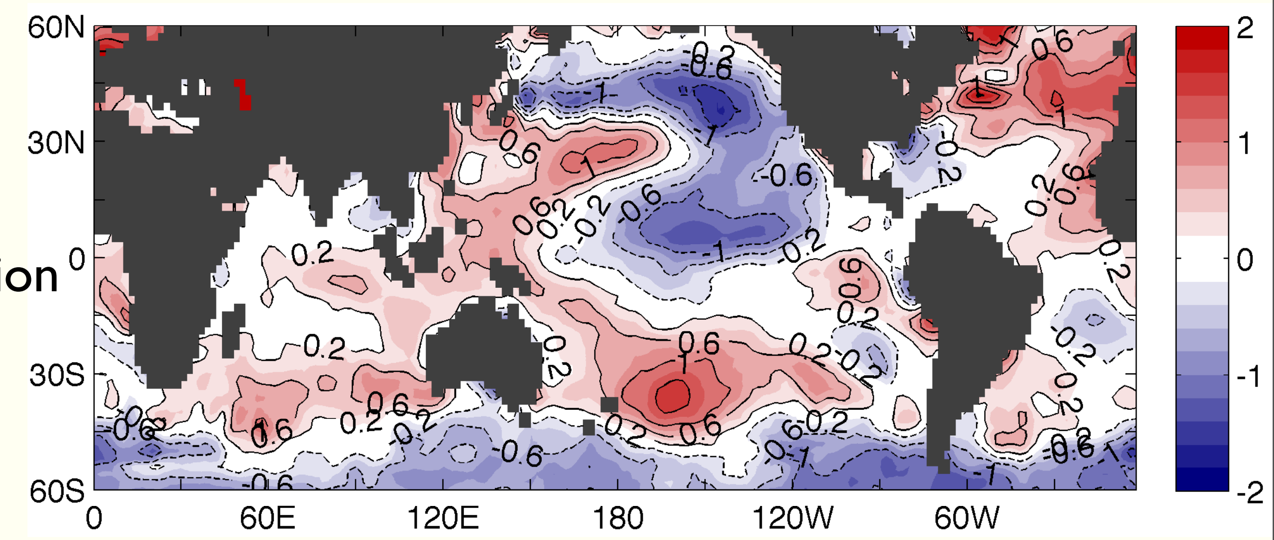
ECHAM4.5: SST-Pr Relationship

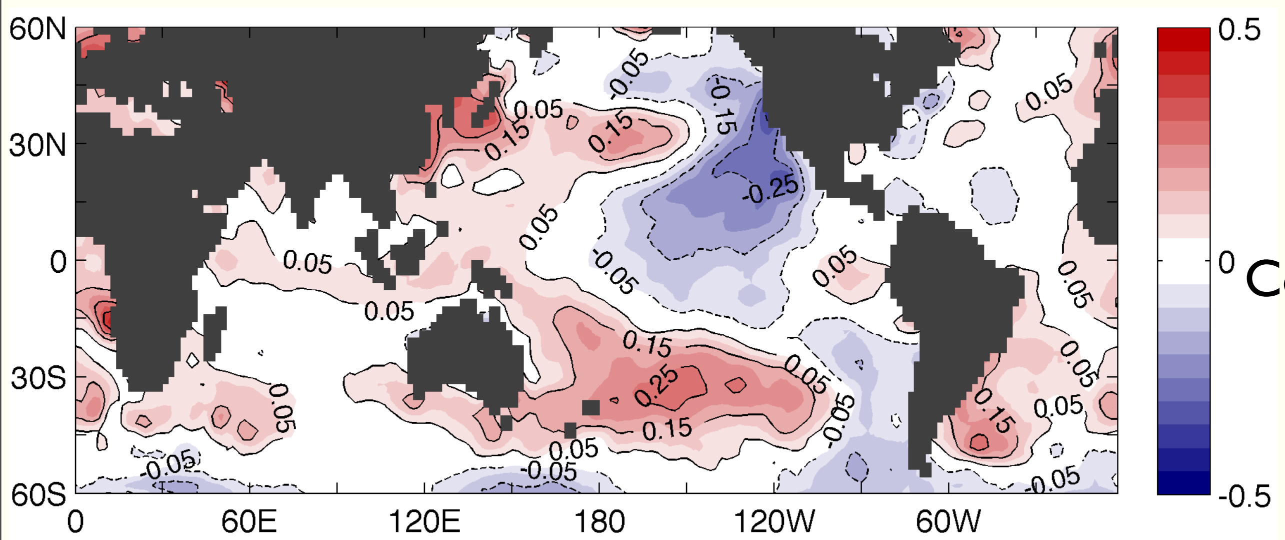
GPCC

ECHAM4.5

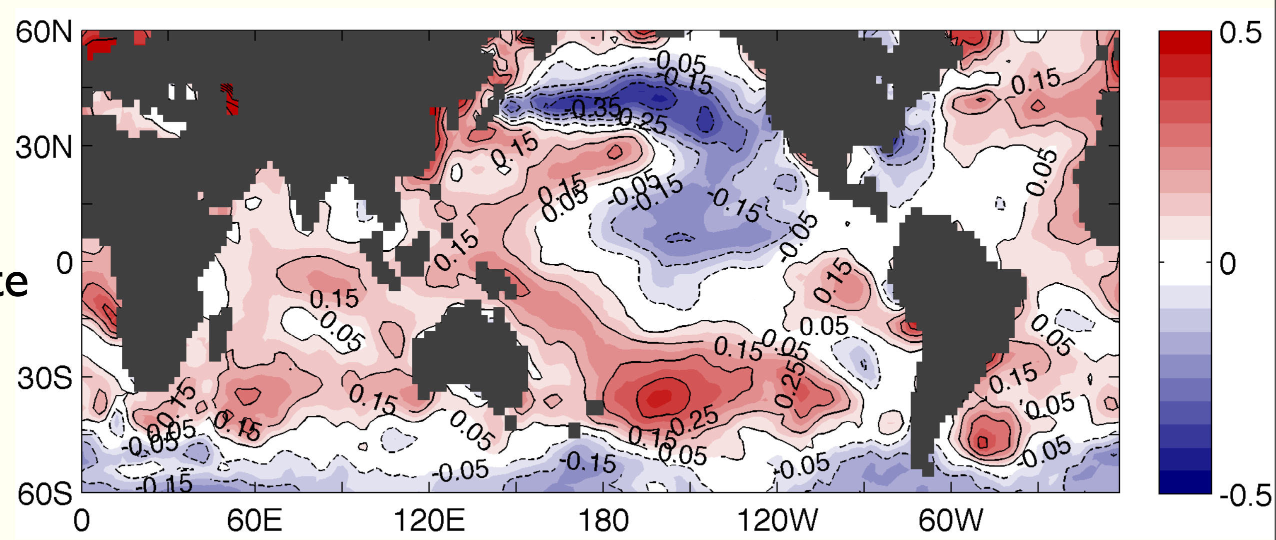


Regression



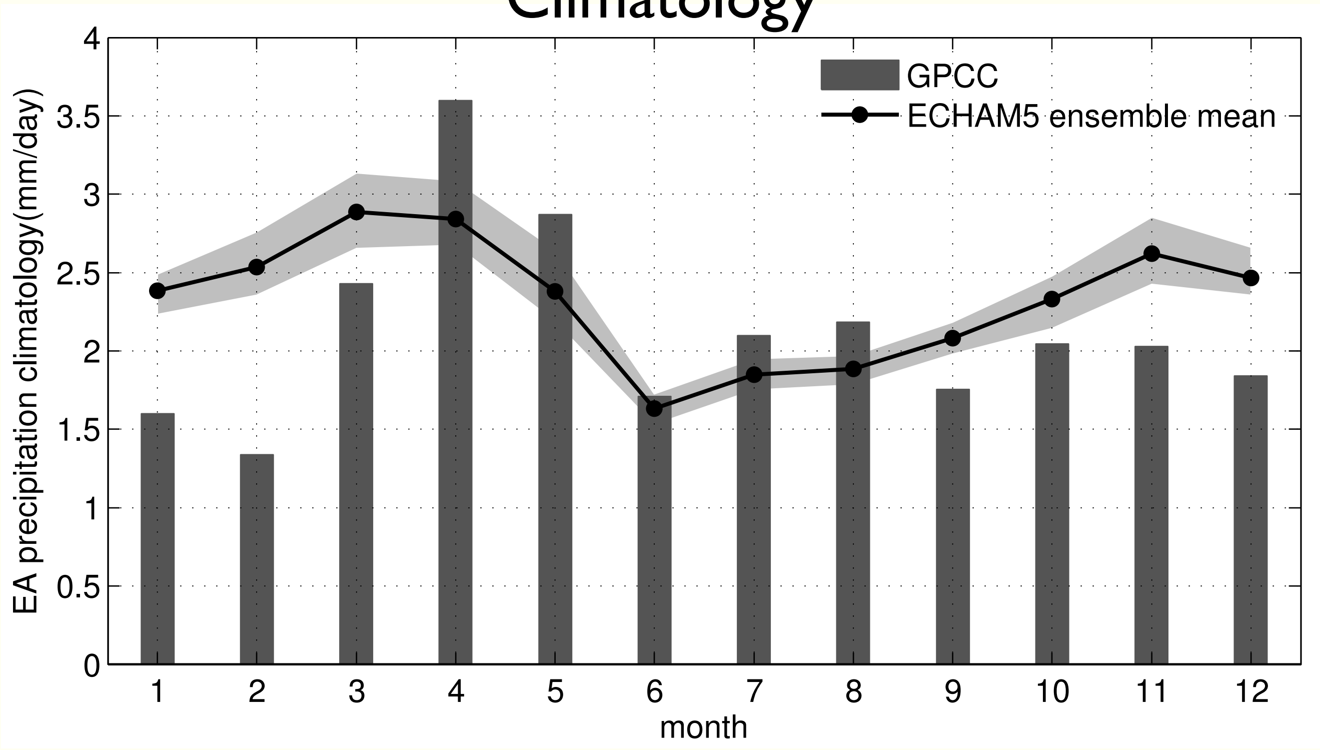


Composite

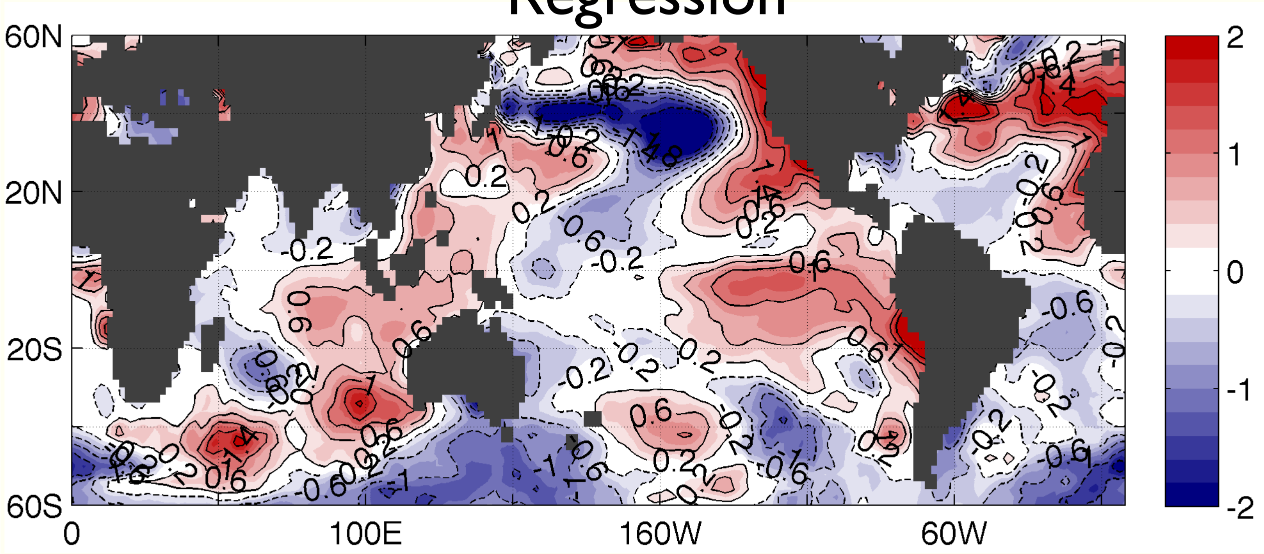


ECHAM5

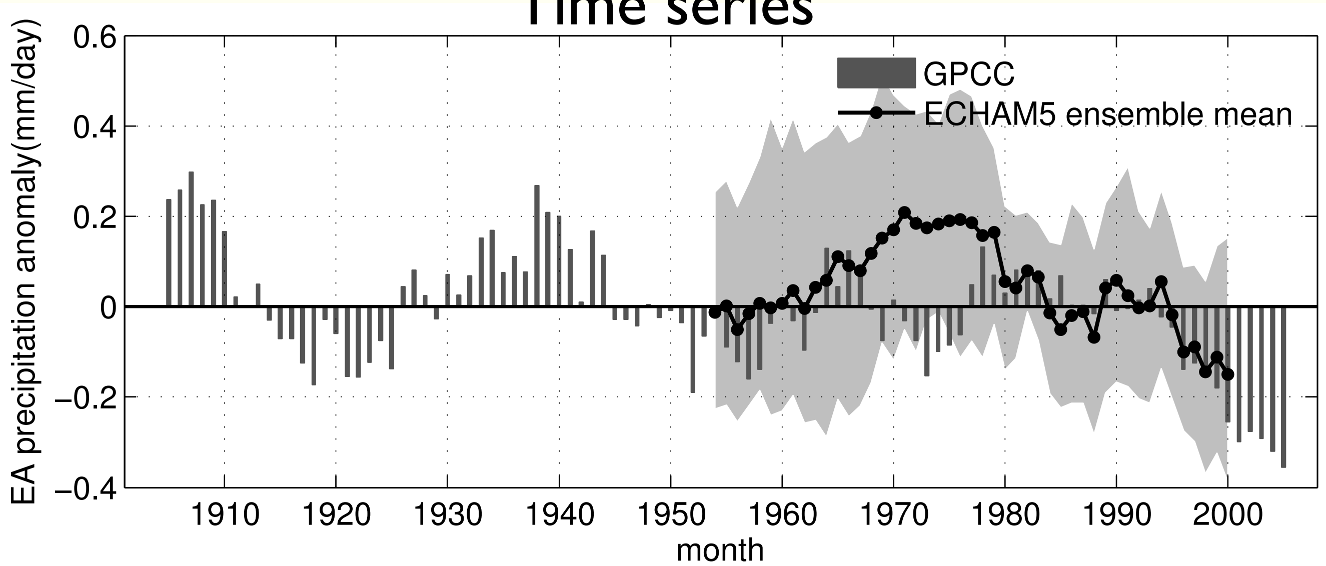
Climatology



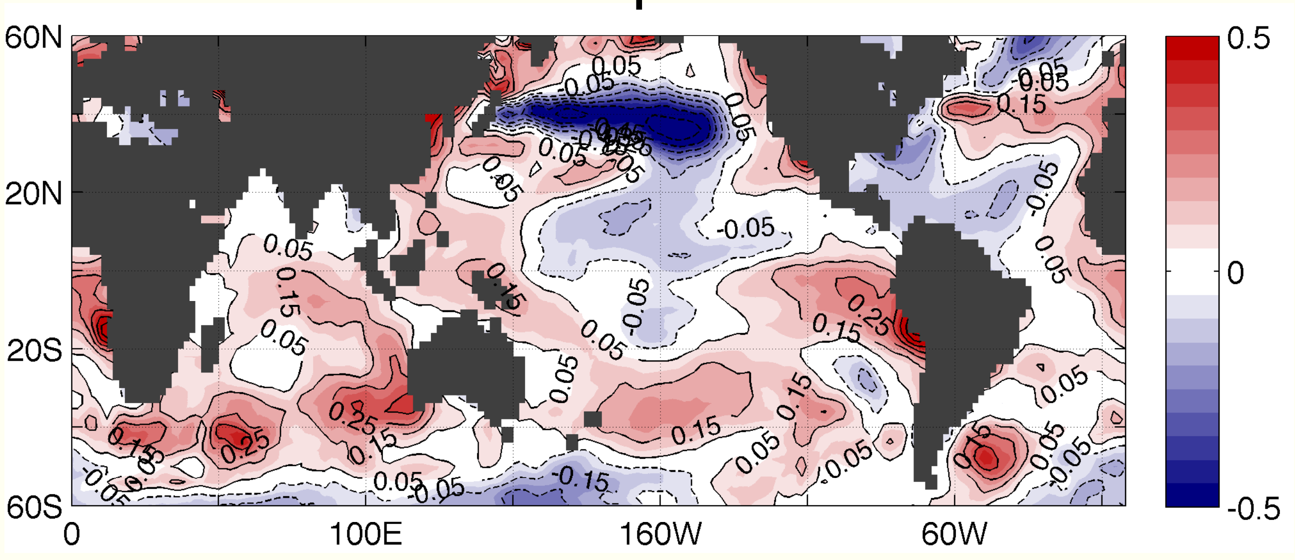
Regression



Time series

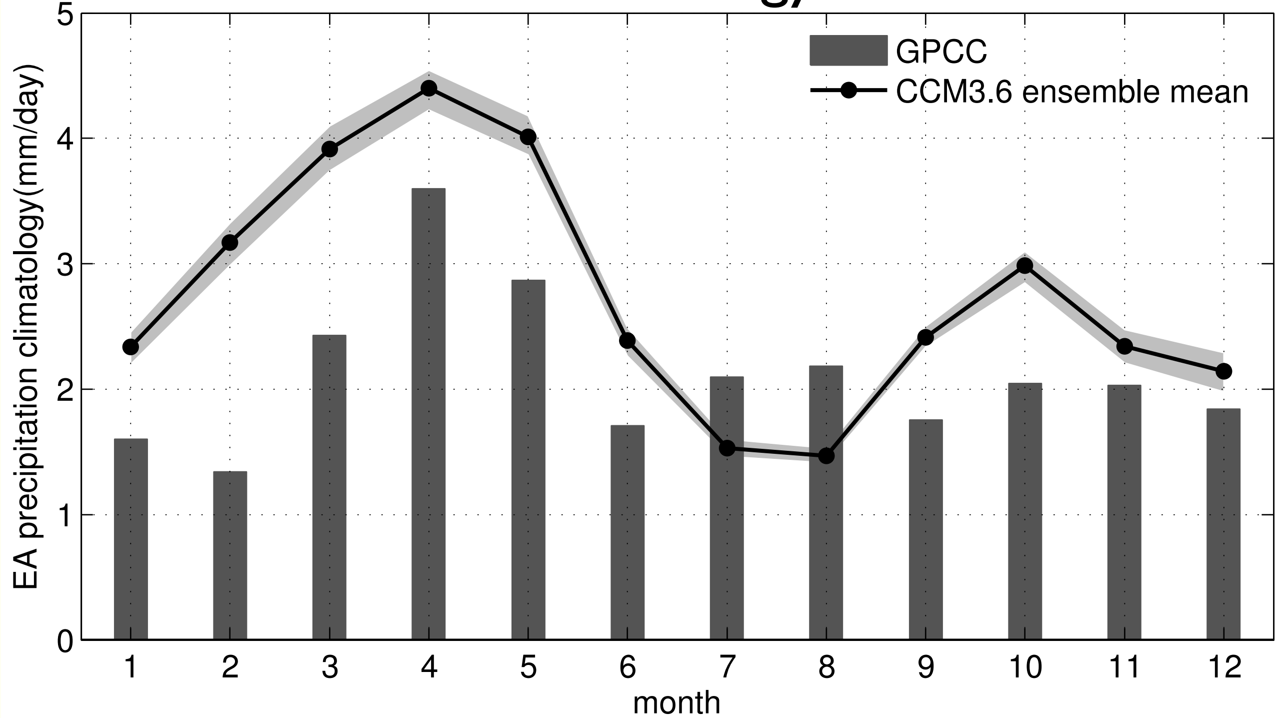


Composite

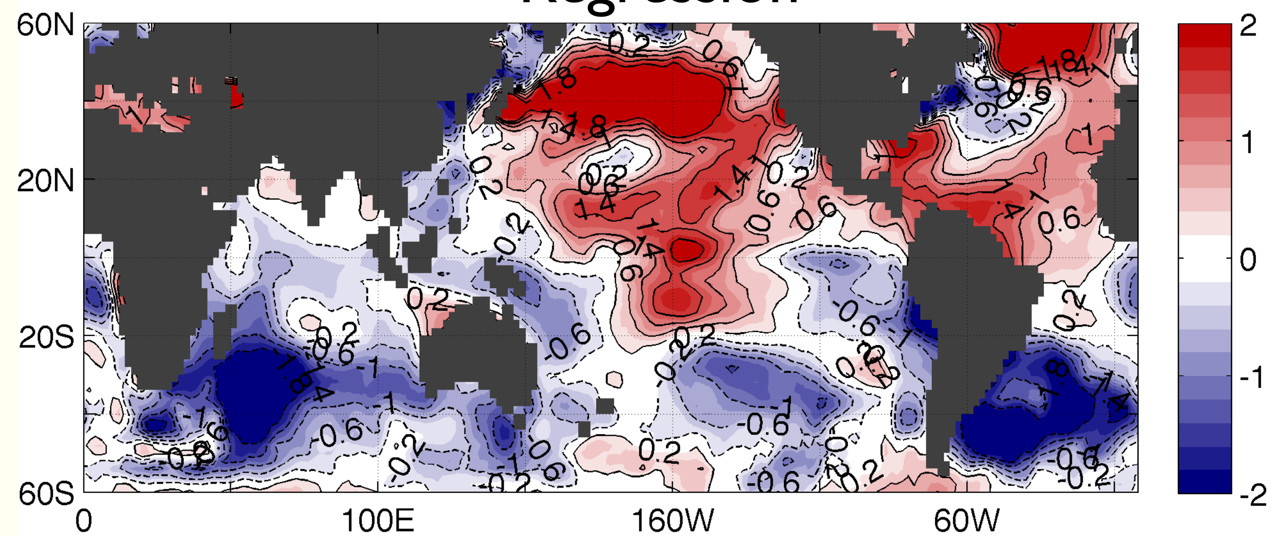


CCM3.6

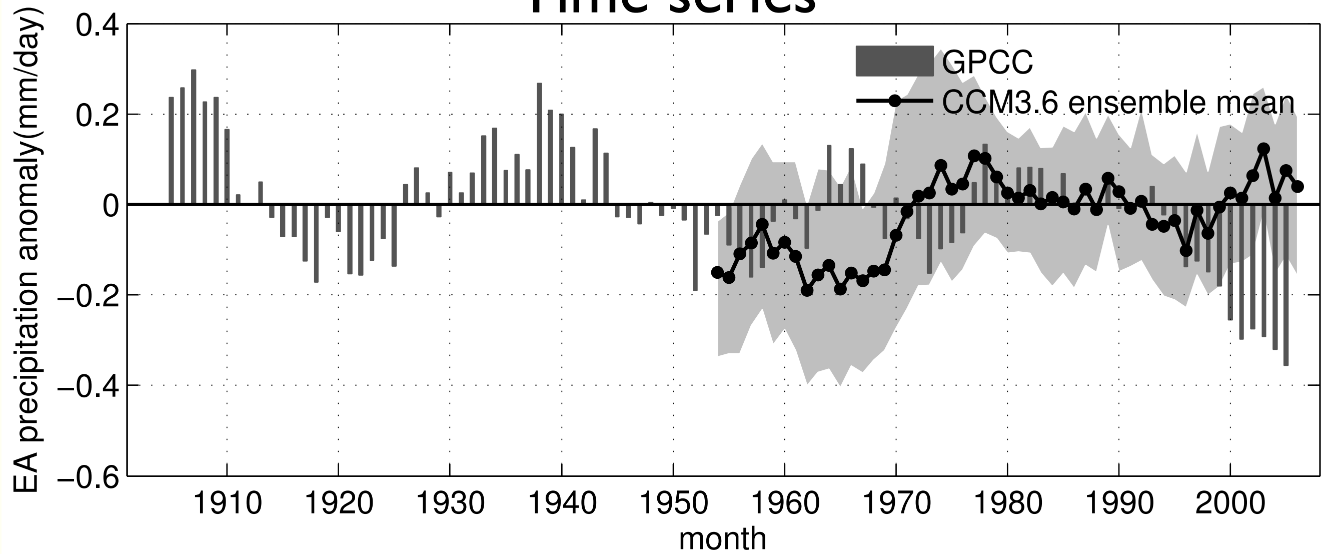
Climatology



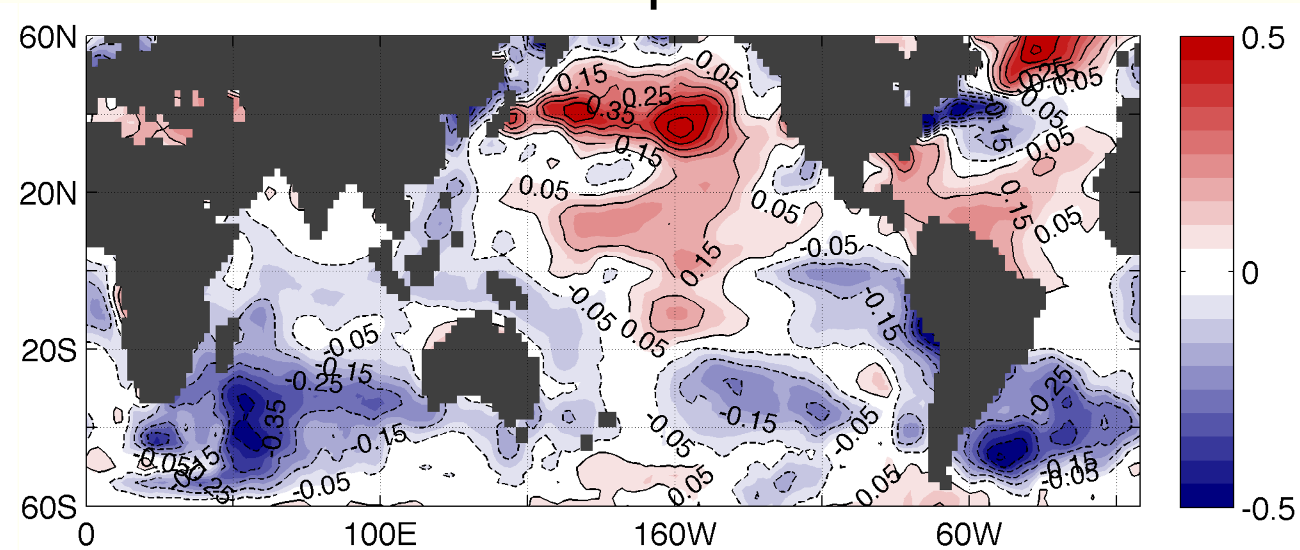
Regression



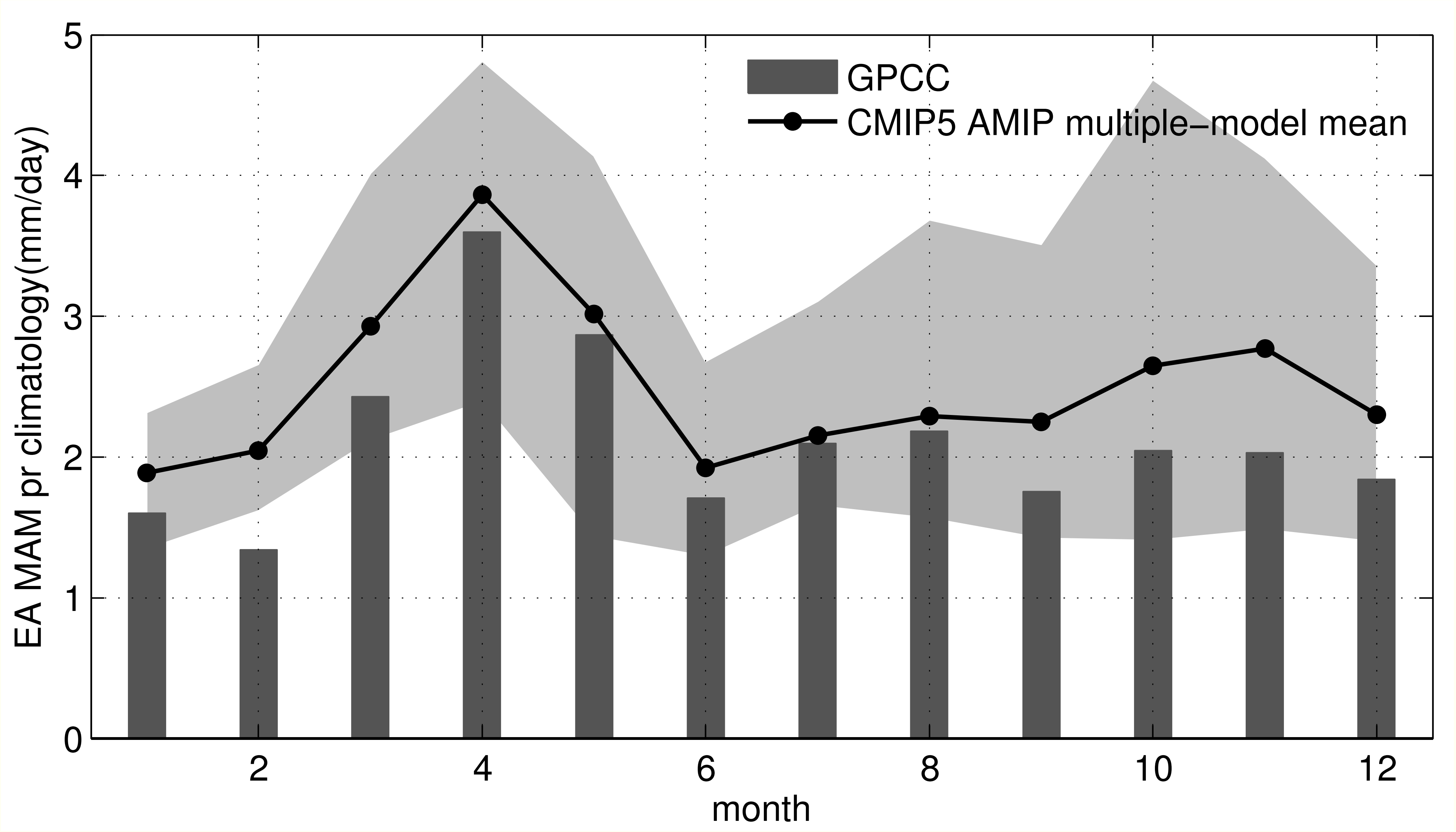
Time series



Composite

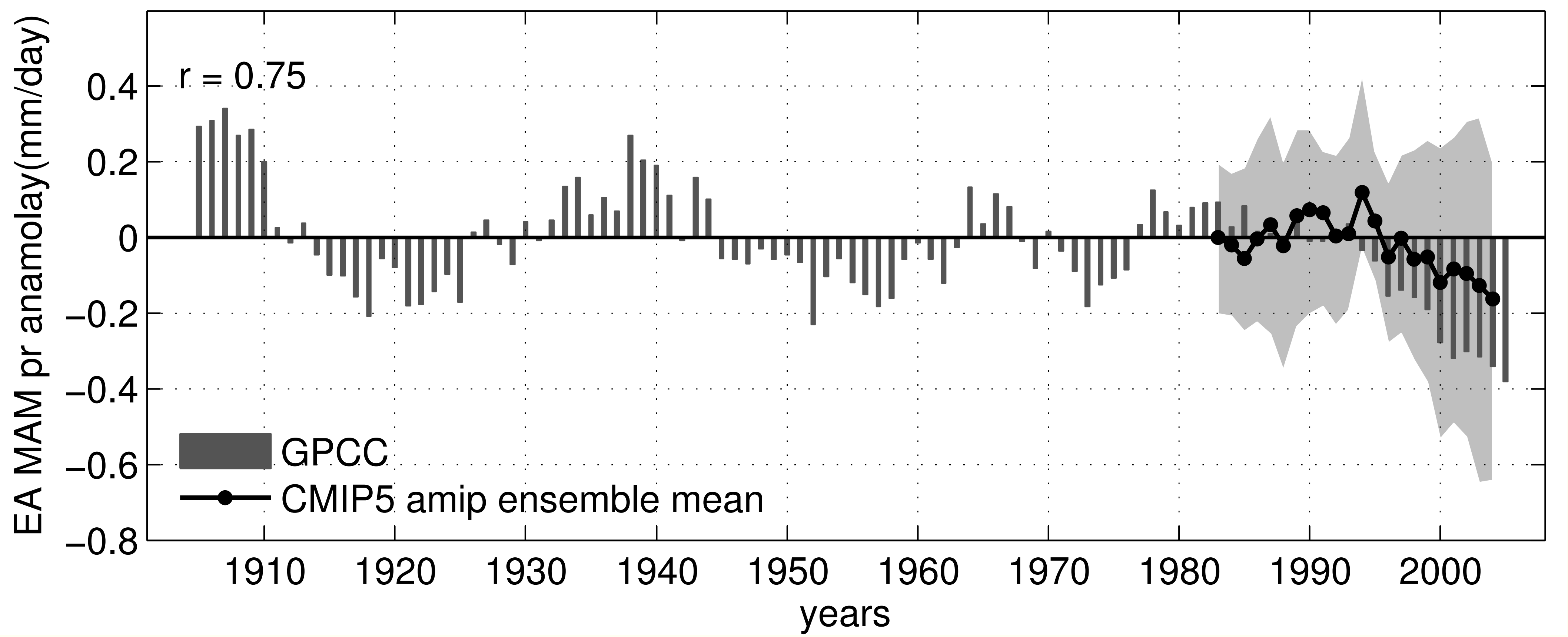


CMIP5 AMIP: Climatology



- Multimodel mean captures the climatology
- Broad spread across individual models

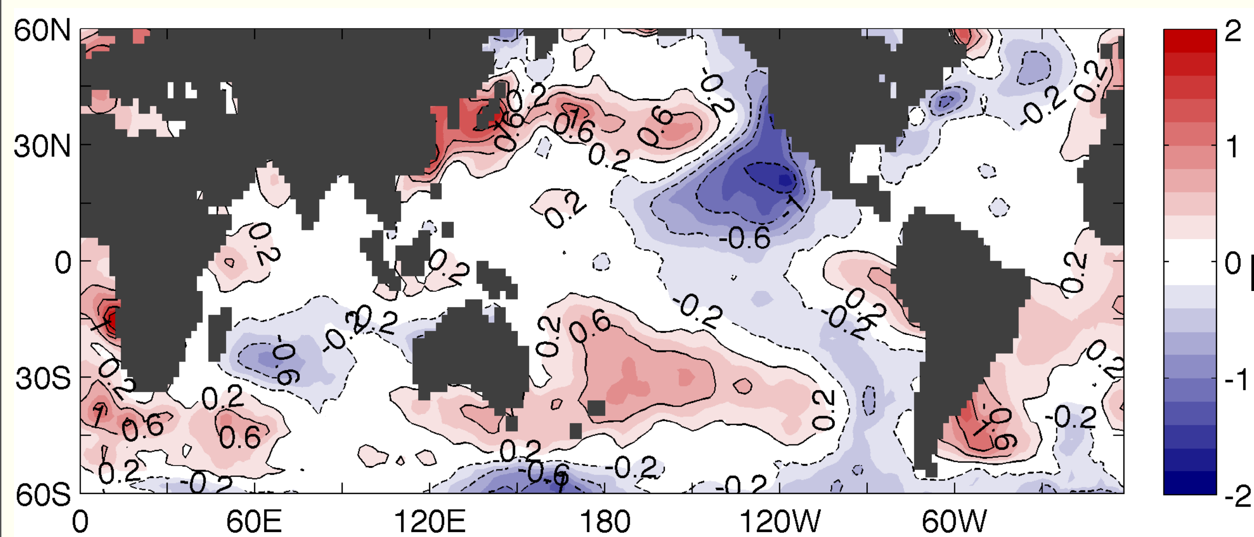
CMIP5 AMIP: Time Series



- Multimodel mean captures the recent drying trend, although the trend is not as strong as the observed
- Intense internal variability among individual models

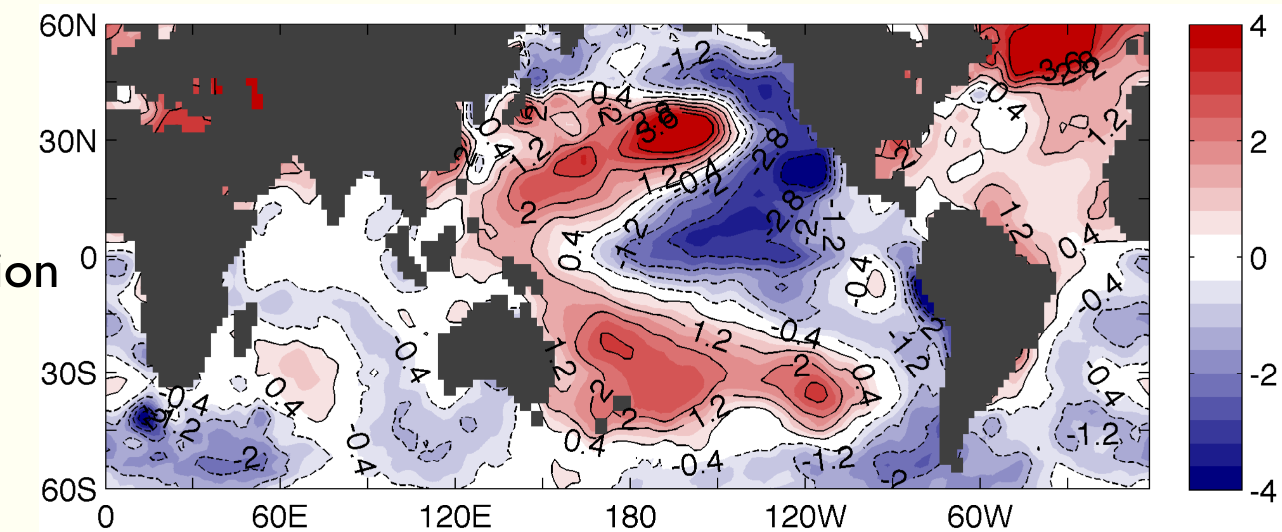
CMIP5 AMIP: SST-Pr Relationship

GPCC

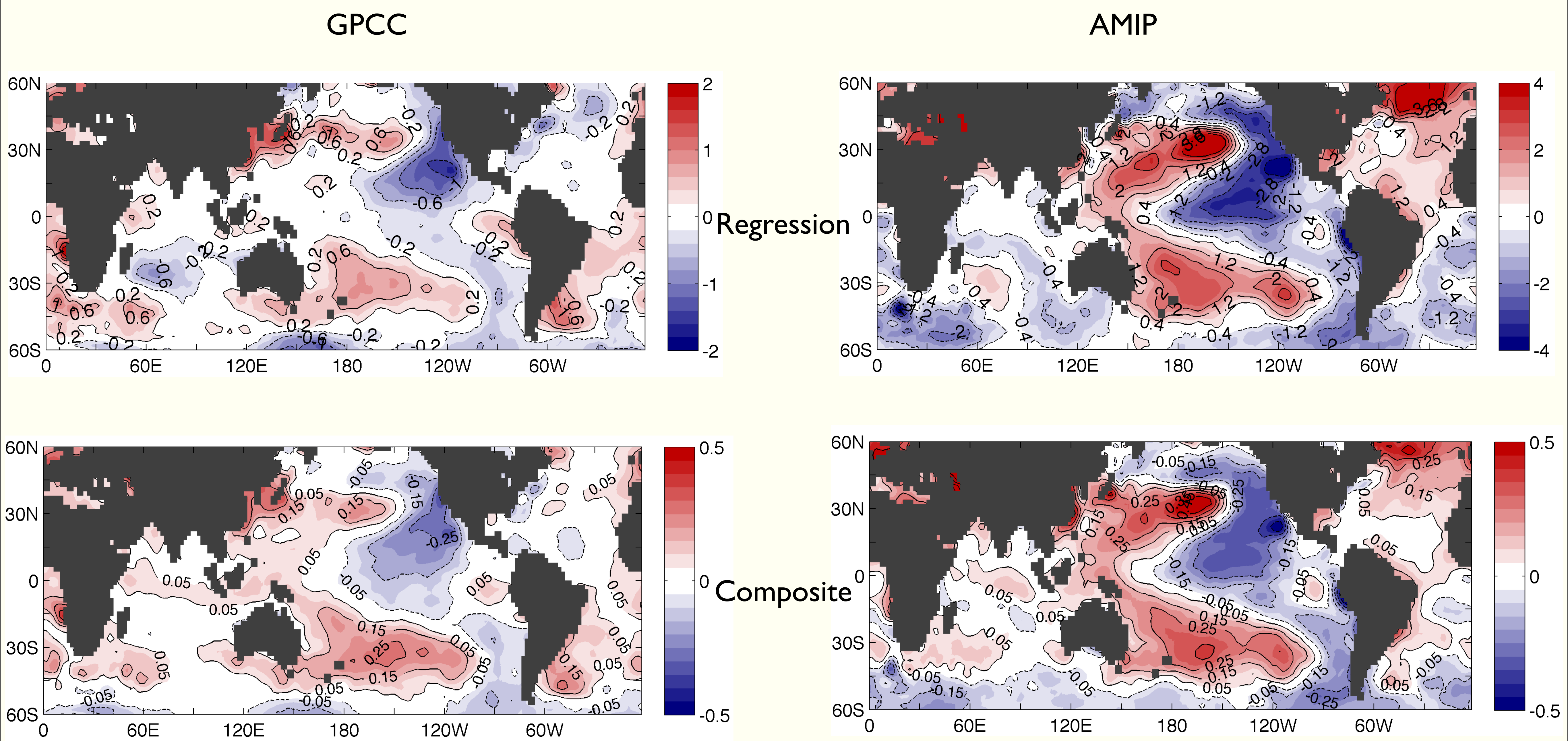


Regression

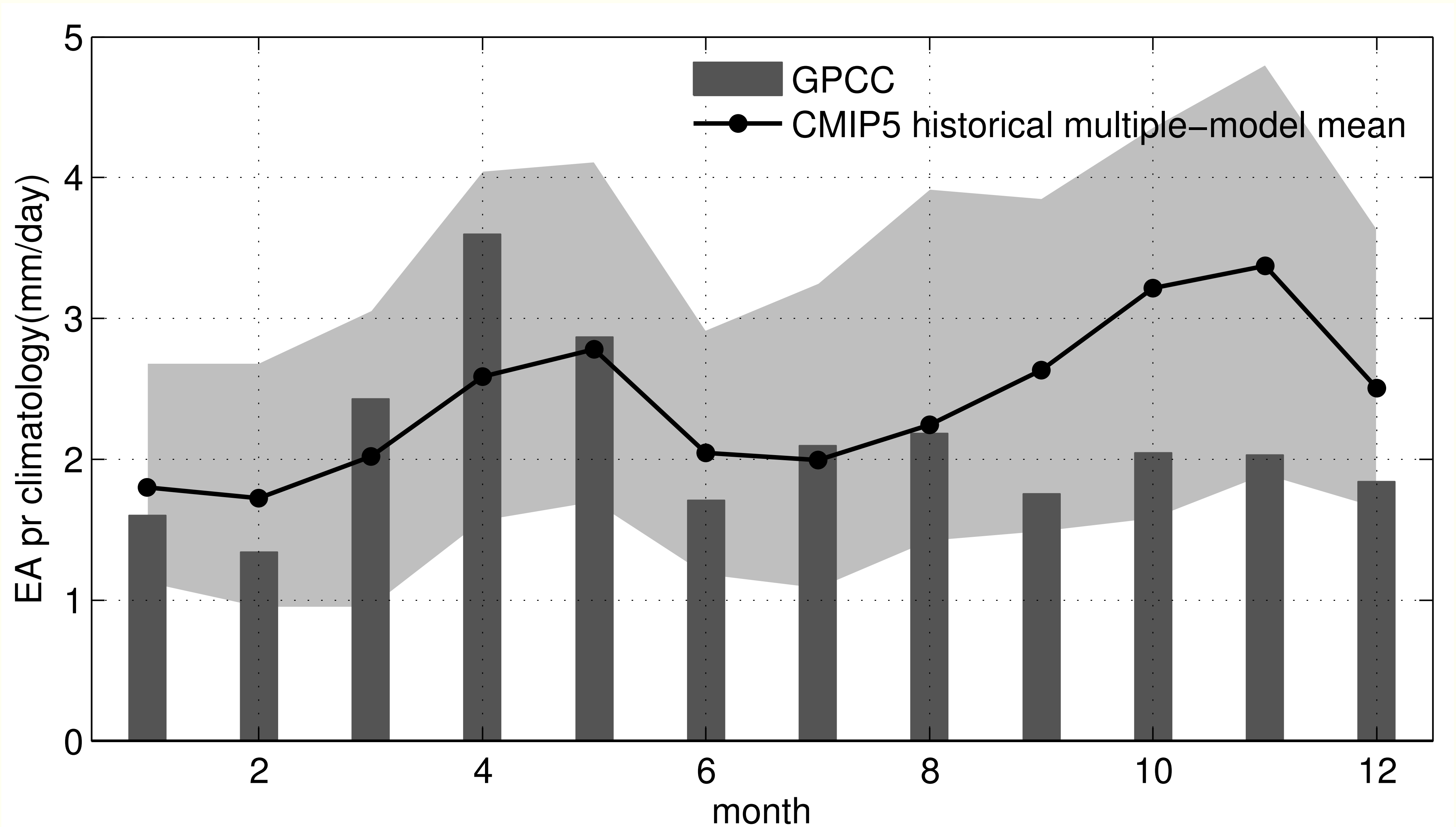
AMIP



CMIP5 AMIP: SST-Pr Relationship

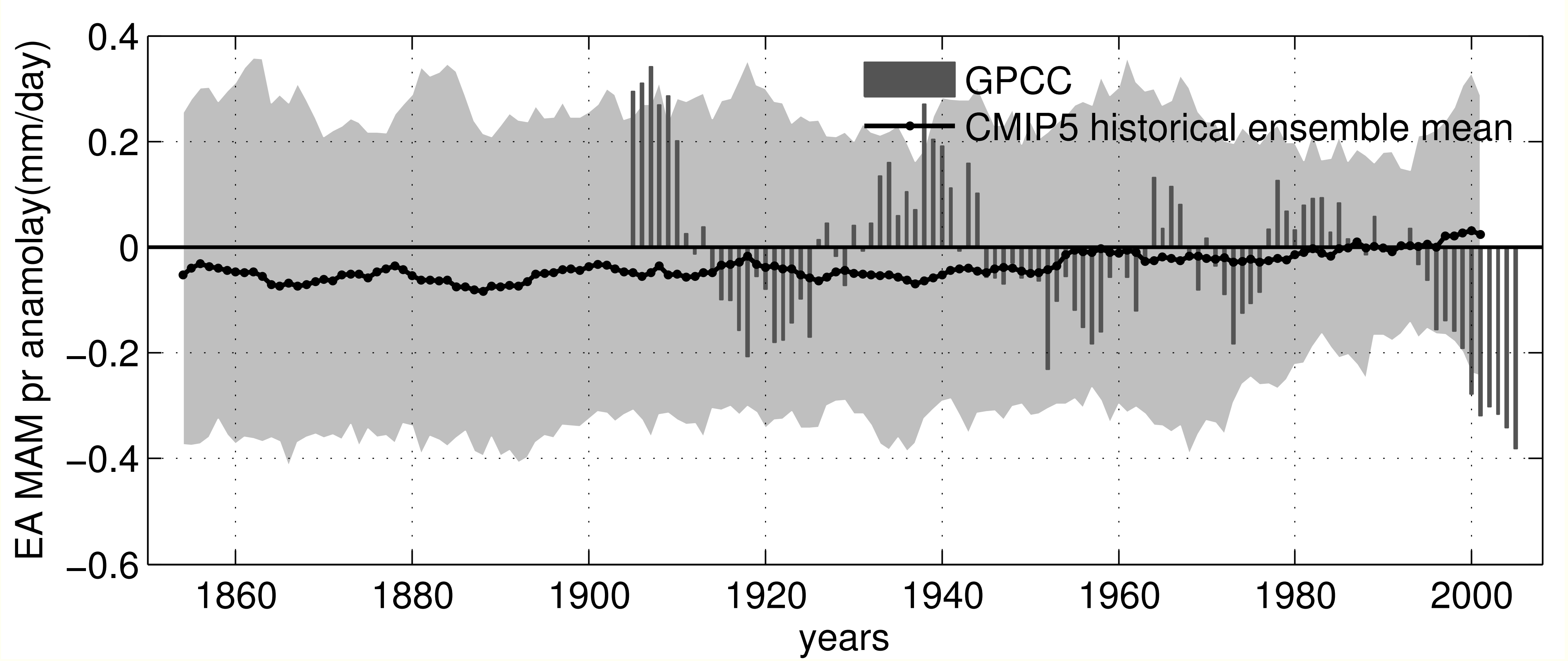


CMIP5 Historical: Climatology



- Multimodel mean underestimates the long rains and overestimates the short ranis
- Broad spread across individual models

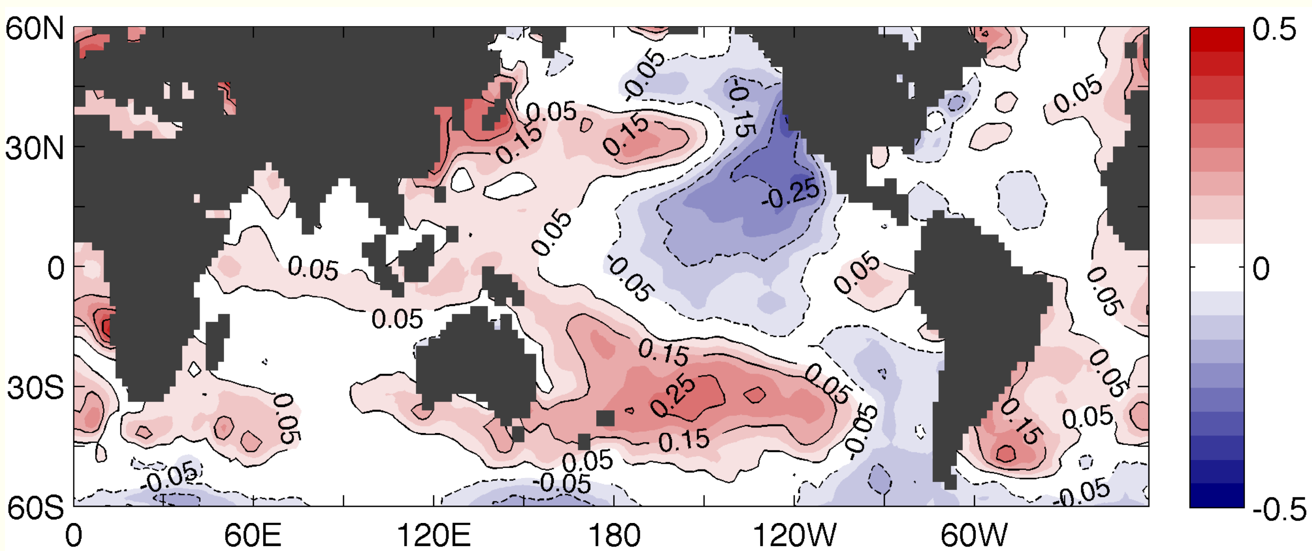
CMIP5 Historical: Time Series



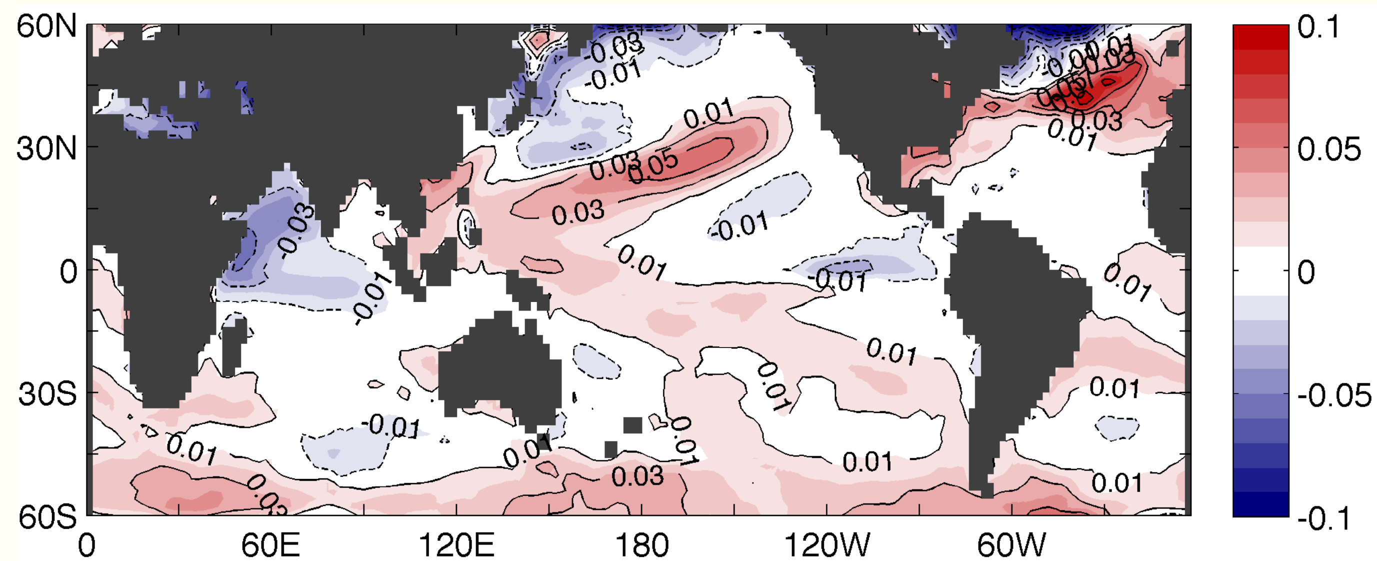
- Multimodel mean only shows weak wetting trend after the 1950s
- Internal variations among individual models dominate the multimodel mean

CMIP5 Historical: SST-Pr Relationship

GPCC



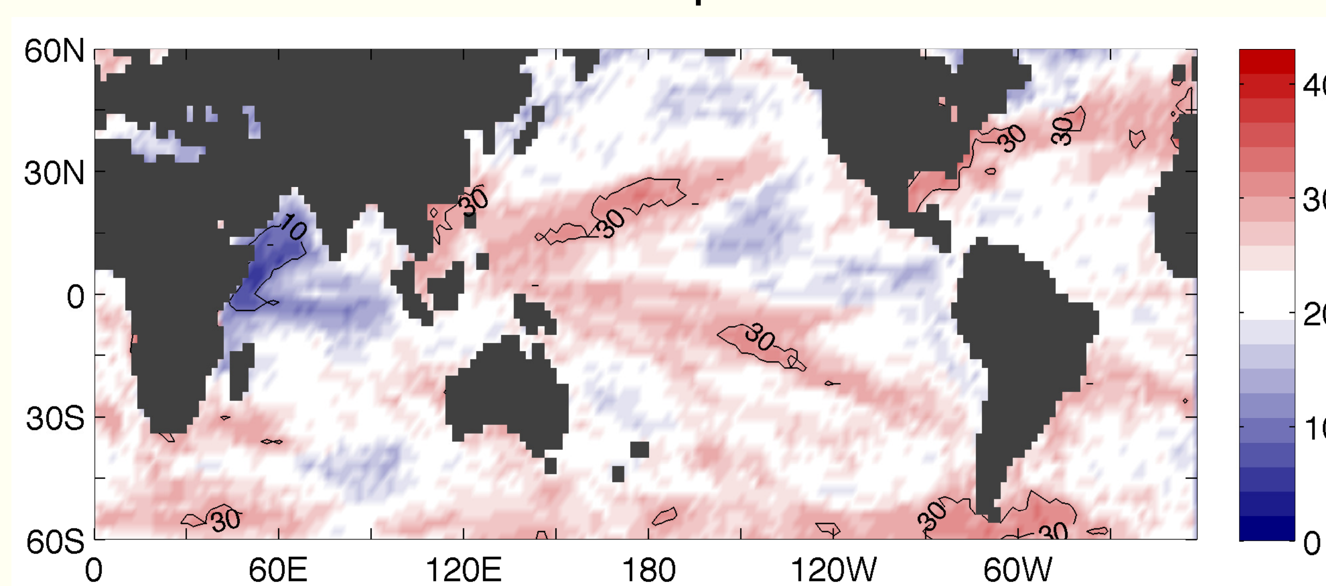
Composite of SST over dry long rains seasons (K)



- Weak SST anomalies in CMIP5 historical multimodel mean relative to that of GPCC

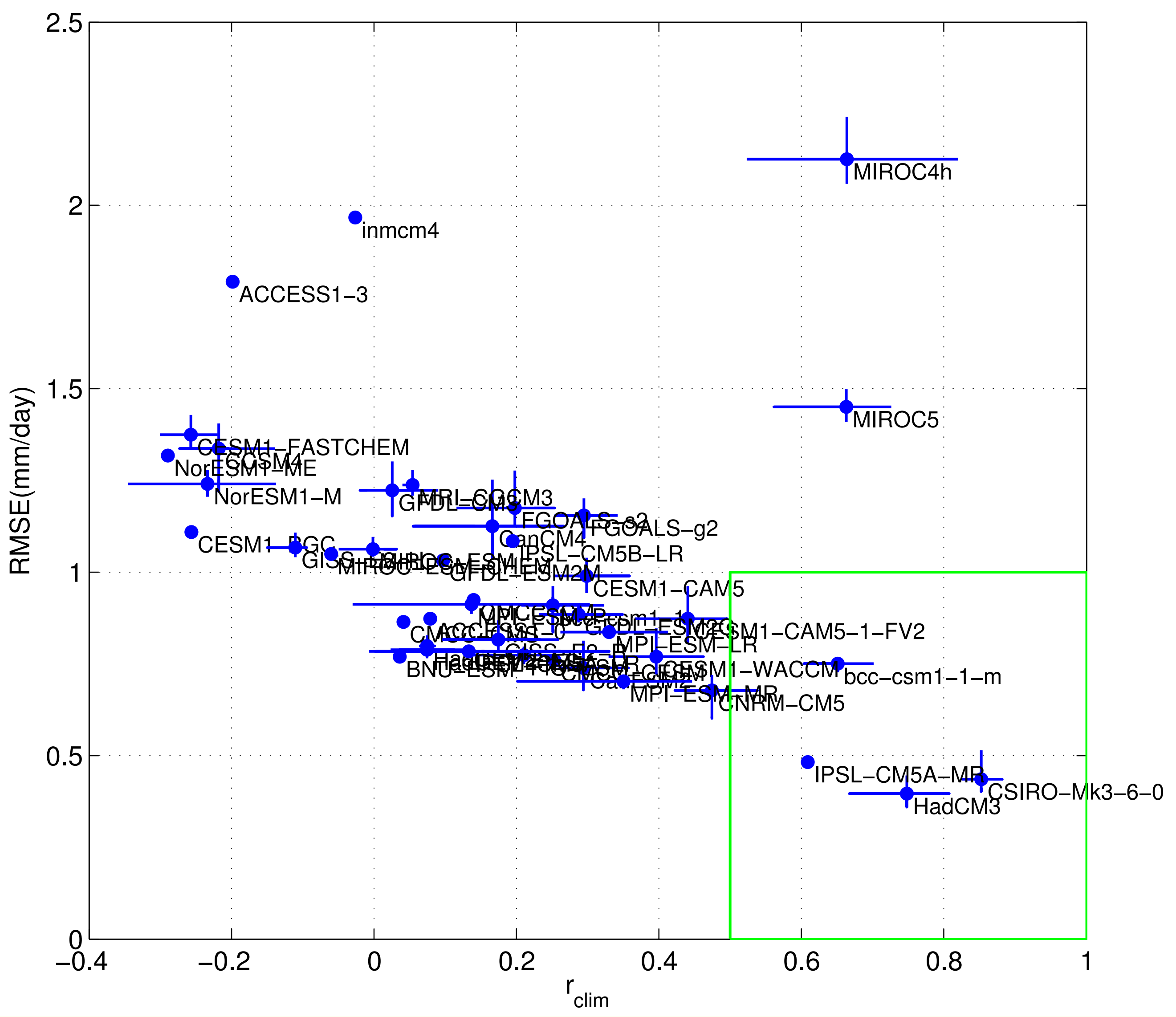
- Significant negative SSTs over the western tropical Indian ocean

Number of models with positive SST anomalies



CMIP5 Historical: Individual Models

Correlation and RMSE for climatology



CMIP5 Historical: Individual Models

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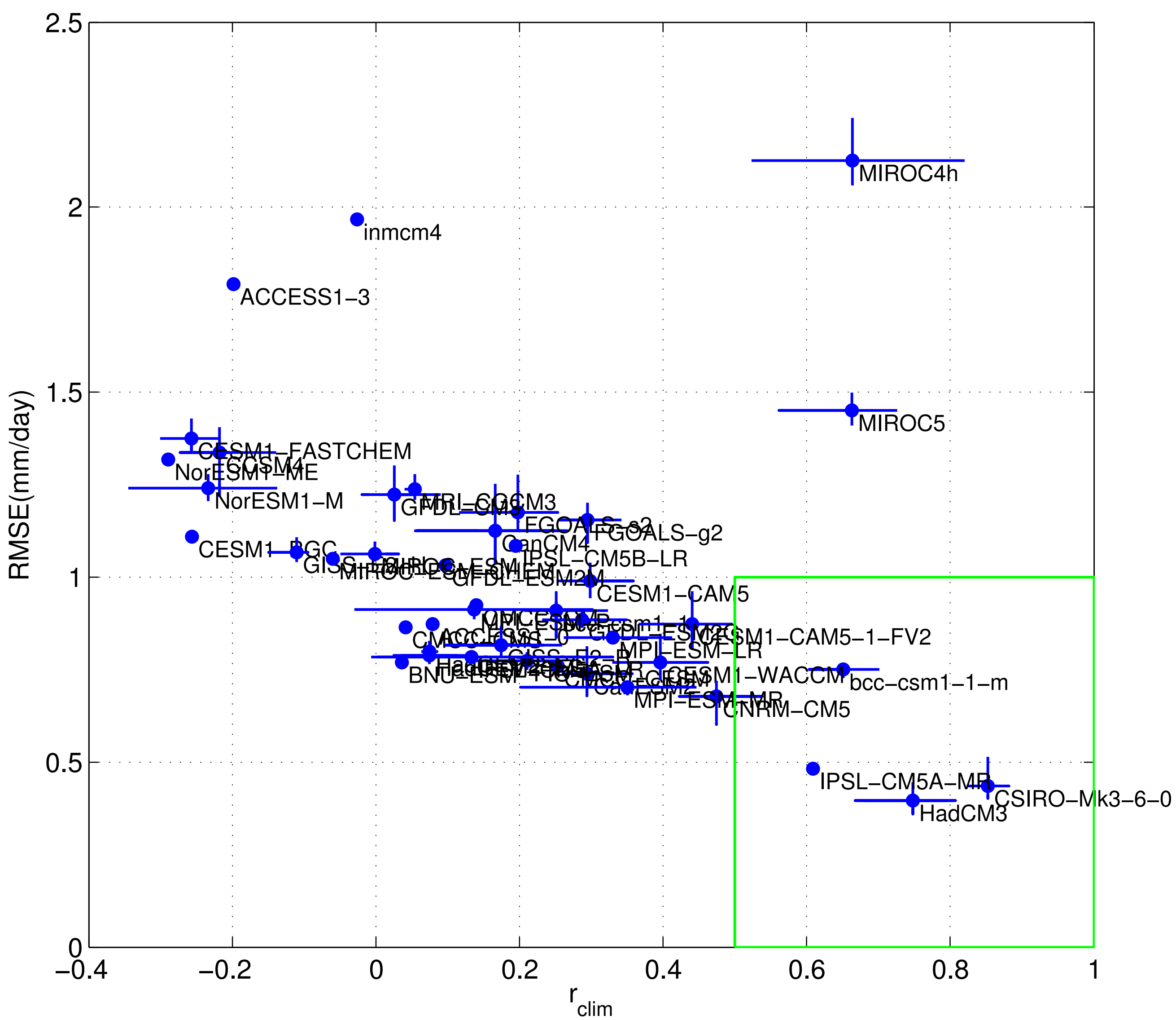

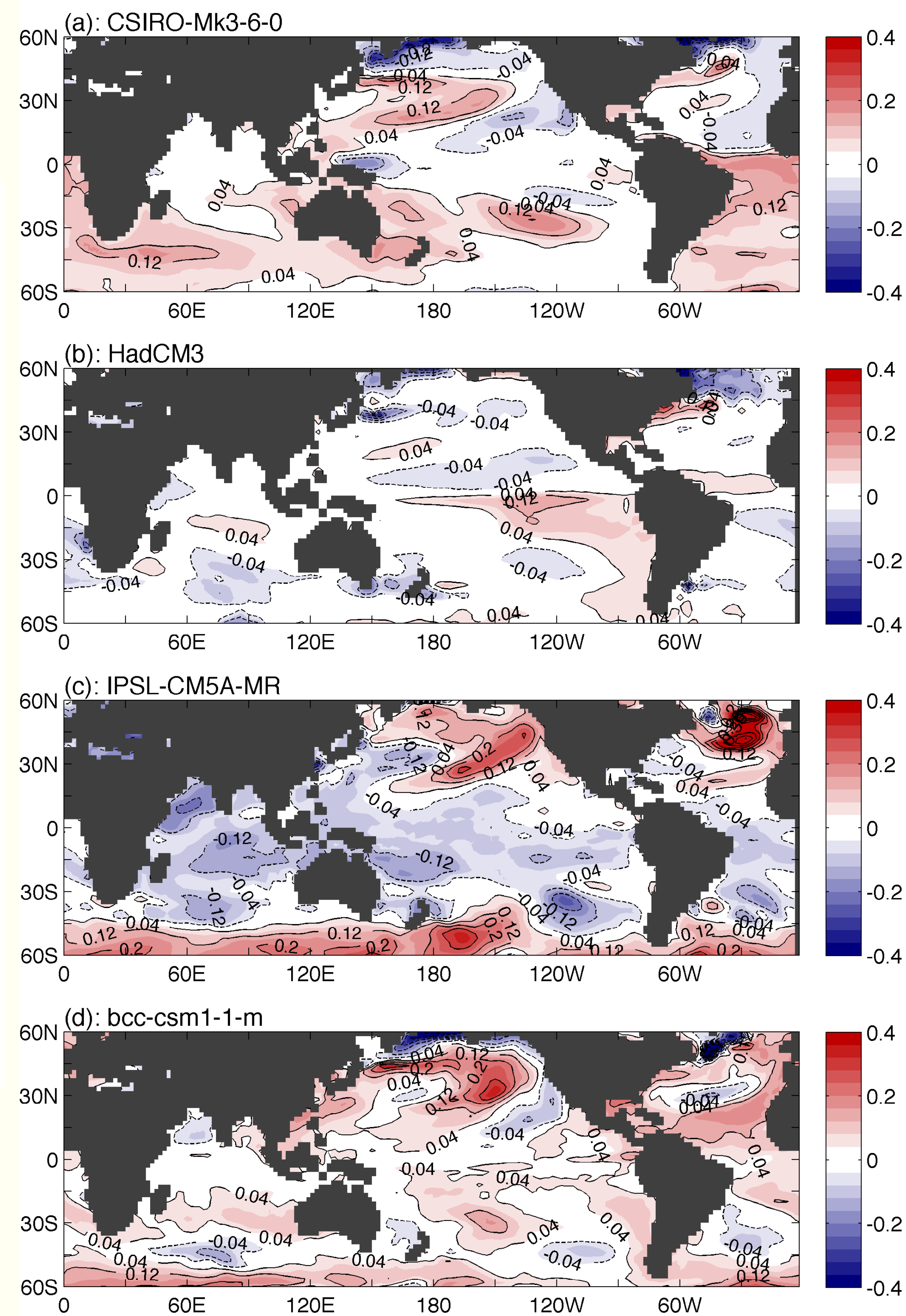

Conclusions

- The drying trend of the East African long rains in recent decades most likely arose from decadal variability of natural origin.
- The decadal variability of the East African long rains can be explained by the decadal variability of SST over the Pacific ocean. The dry phases are associated with positive SST anomalies over the western tropical Pacific and negative anomalies over the central tropical Pacific.
- The SST-forced IRI forecast models are able to capture the climatology and the SST anomaly pattern associated with decadal variability. However, not all the models perform well.
- The SST-forced models of the CMIP5 AMIP experiment are also able to capture the climatology of the East African precipitation although with ranging skills among individual models. The simulated East Africa long rains anomaly, while only available over a short period, does capture the recent observed drying trend in the multimode mean. The associated SST anomaly pattern is also consistent with that observed.
- The multimodel mean of the fully coupled models of the CMIP5 historical experiment underestimates the East Africa long rains and overestimates the short rain with considerable range of performance among the individual models. The multimodel mean of the precipitation anomalies shows only a weak wetting trend since 1950 that is much smaller than internal variability. The SST anomaly pattern associated with the dry phase of the East African long rains is associated with a SST gradient over the tropical Pacific, although the magnitude of this is weak compared to observations.

Thank you!