Global Precipitation Change and Long-Term Climate Variability during the 1901-2010 Period

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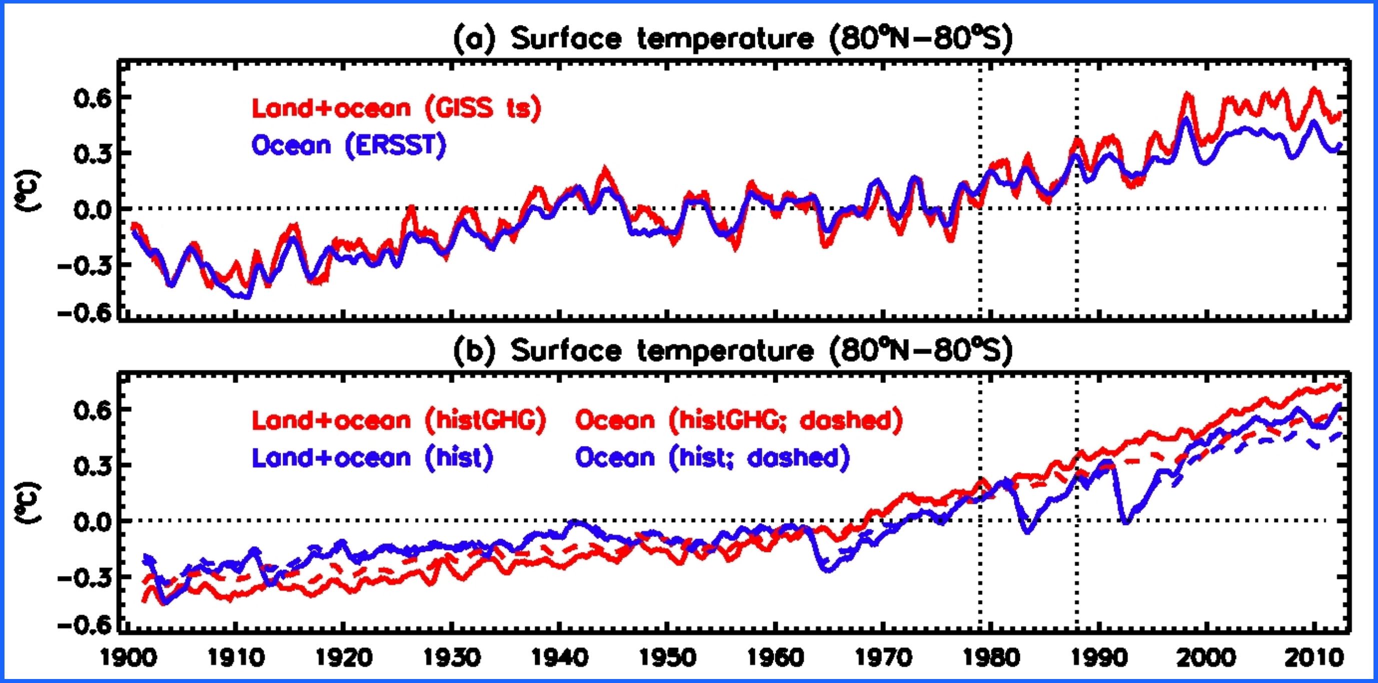
Time series of global surface temperature

Obs

CMIP5



- Global surface temperature has been increasing during the past over 100 years, but with evident interannual-to-decadal-scale oscillation;

- ***How may the global hydrological cycle have responded to temperature changes?***

Objectives:

1) Improve our understanding of long-term precipitation changes/trends during the (current) GPCC period (1901-2010) specifically by focusing on spatial distributions;

2) Examine the effects of both global warming and (internal) decadal/multi-decadal oscillations on the global hydrological cycle;

3) Assess the capabilities of GCM simulations (CMIP5) (and reanalysis products) in reproducing observed precipitation variations/changes

Data sets:

Observations:

1) **Monthly land precipitation from the GPCC Full Data Reanalysis Version 6**
   - 1901-2010, on global grid with resolutions of 0.5°, 1.0°, and 2.5°

2) NASA/GISS-surface temperature anomaly analysis & Sea surface temperature (SST) from NOAA/NCEP ERSST v3b

NOAA/CICS reconstructed monthly precipitation:

- 1900-2008, on global grid with resolution of 5°

CMIP5 simulations (NASA/GISS-Model E):

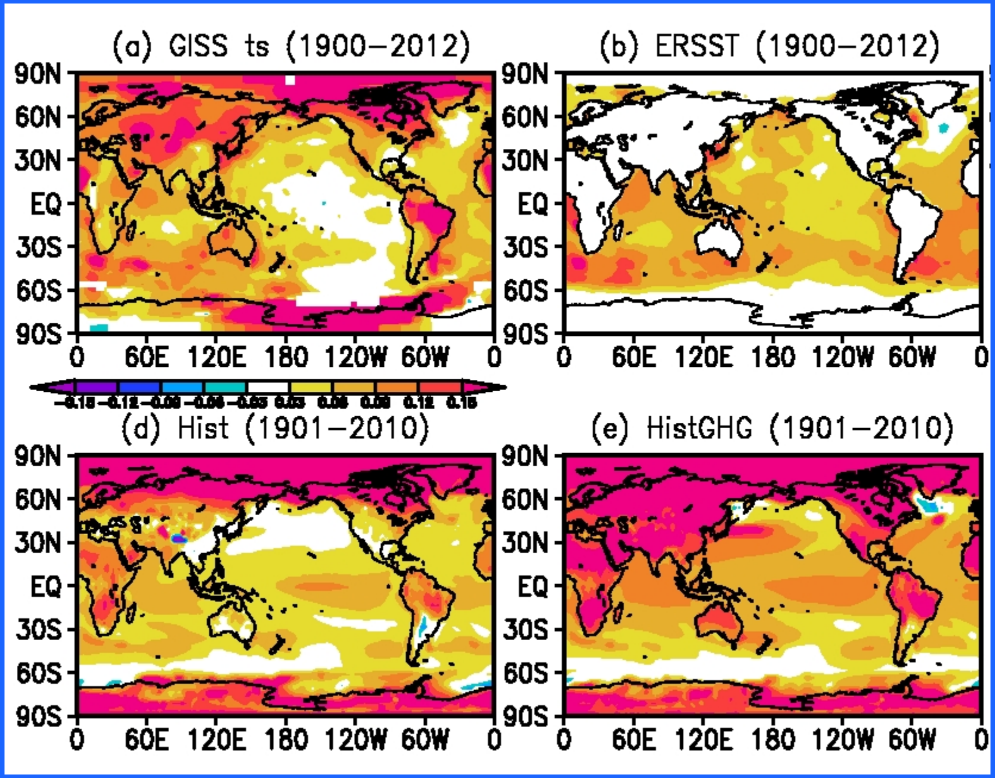
1) AMIP (driven by observed SST & sea ice), *including both forced responses (to various radiative forcings) and internal oscillations*;
2) Historical runs [coupled simulations forced by (i) both natural and external radiative forcings (Hist) and (ii) green-house-gas forcing only (HistGHG)].

The 5-ensemble means of model outputs are used here to limit internal oscillations

- **Spatial distributions of linear trends during 1901-2010**
  (presumably dominated by global warming)

- **Decadal/multidecadal-scale variations/changes**

Linear changes/trends of global surface temperature



Obs

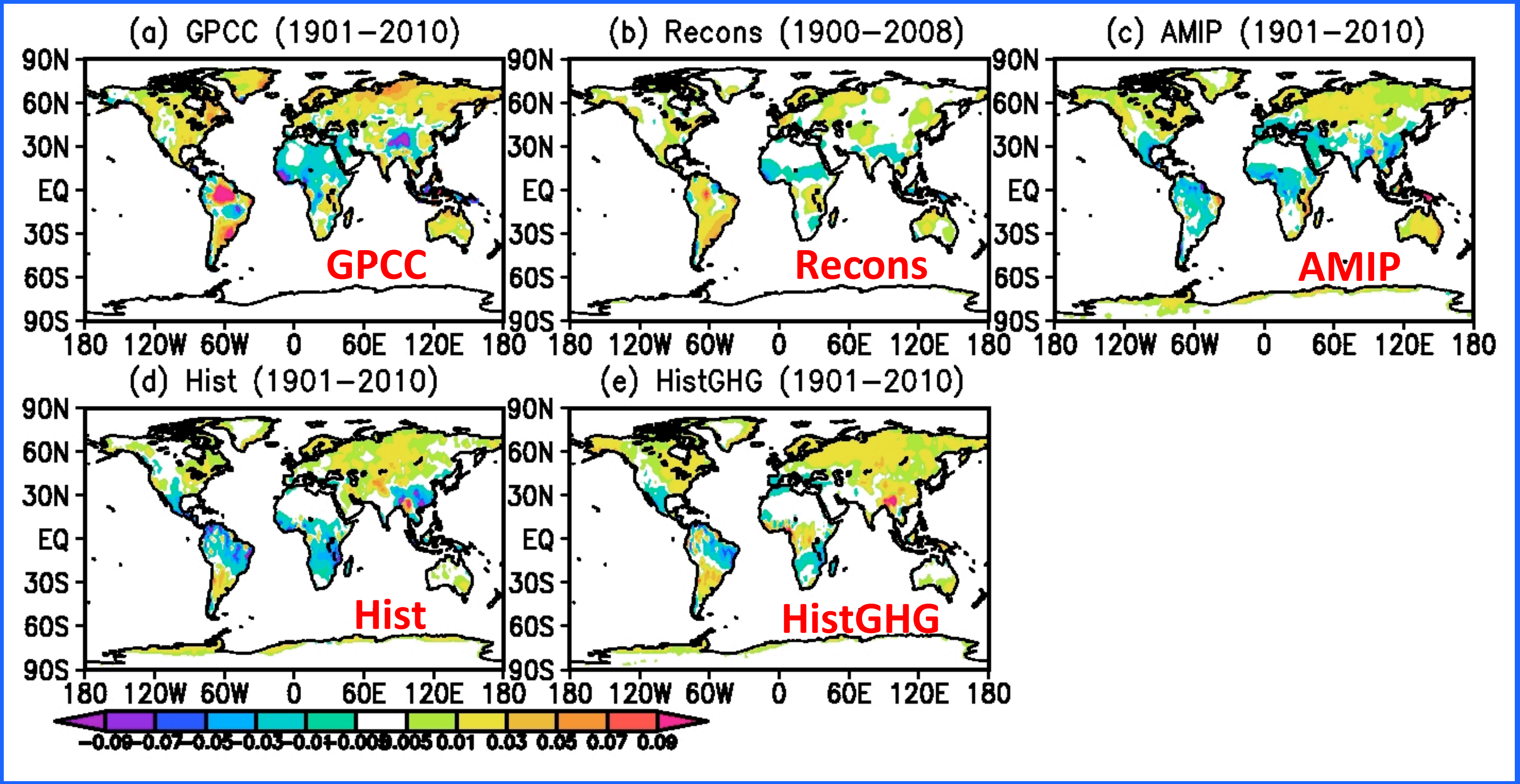
Obs

Hist

HistGHG

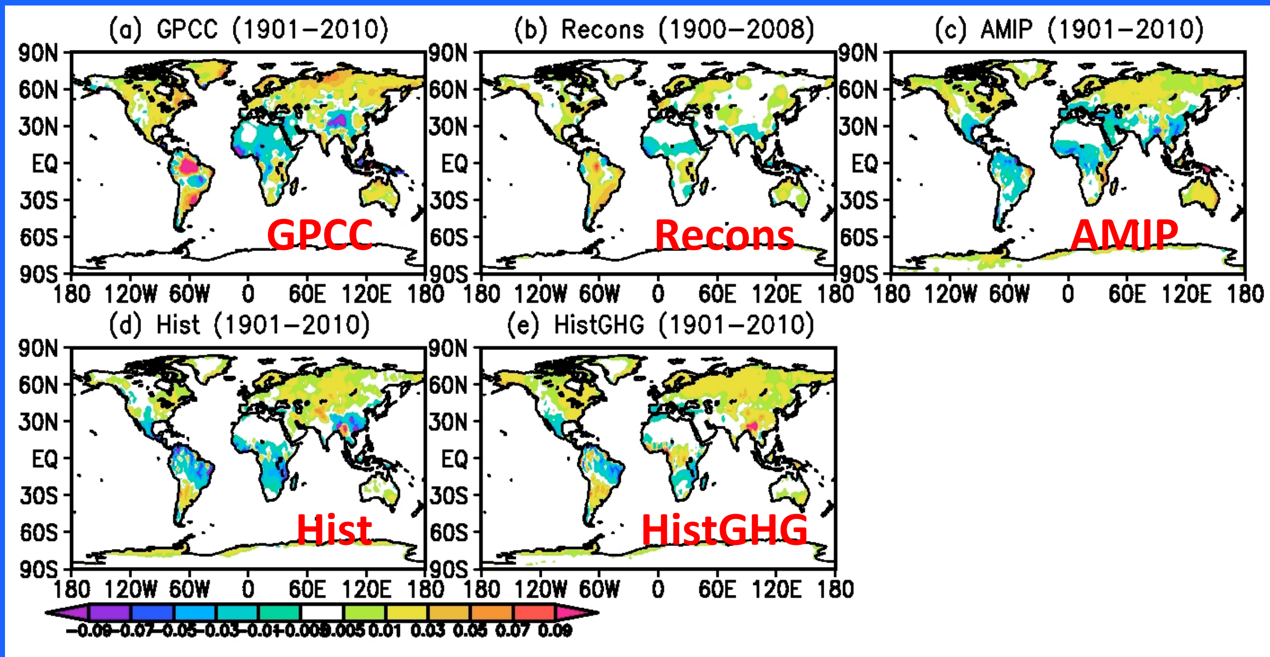
- Surface temperature keeps increasing during the past century especially over land and in the NH mid-high latitudes;
- CMIP5 runs catch general spatial features of temperature changes, but with much more intense temperature increase over lands, especially in the NH mid-higher latitudes;
- ***Two observations have some inconsistencies specifically in the Pacific basin. Model simulations also show a warming peak in the tropical Pacific.***

Linear changes/trends of global precipitation

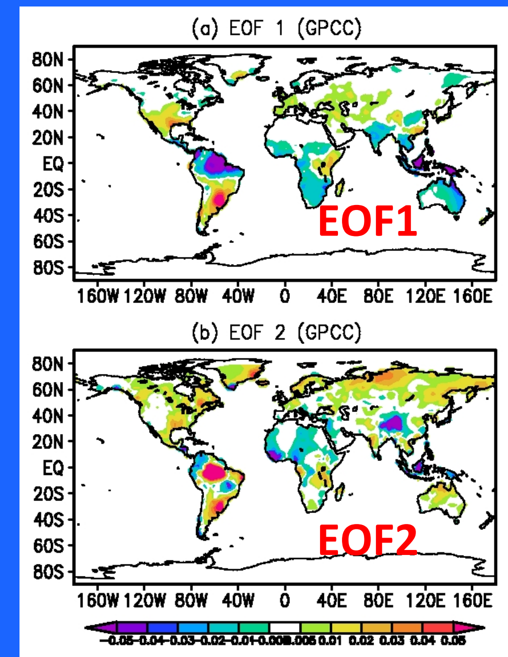


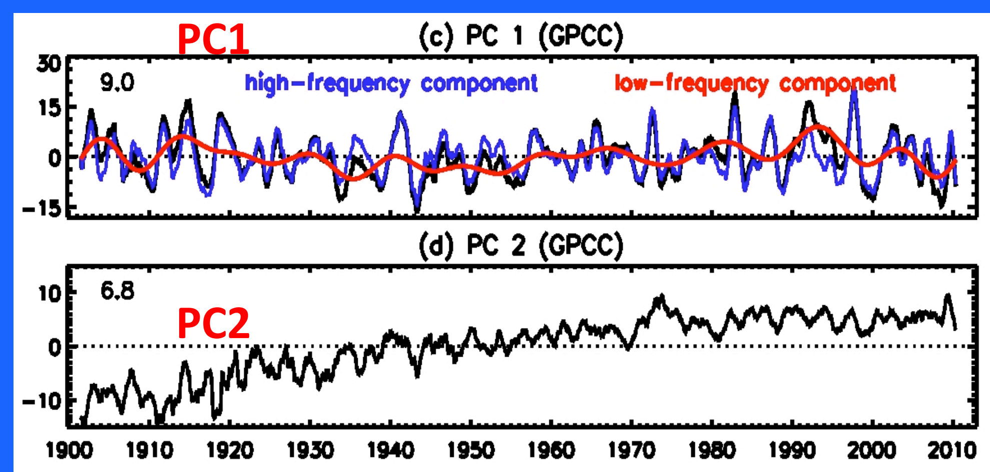
- Precipitation increase in mid-higher latitudes;
- Decrease in tropical/subtropical regions;
- Consistencies in spatial features from observation, reconstruction, and model simulations: *NH mid-high latitudes, West Africa, Australia, etc., **suggesting the dominance of global warming effect***

Linear trends of global precipitation



EOFs of GPCC precipitation



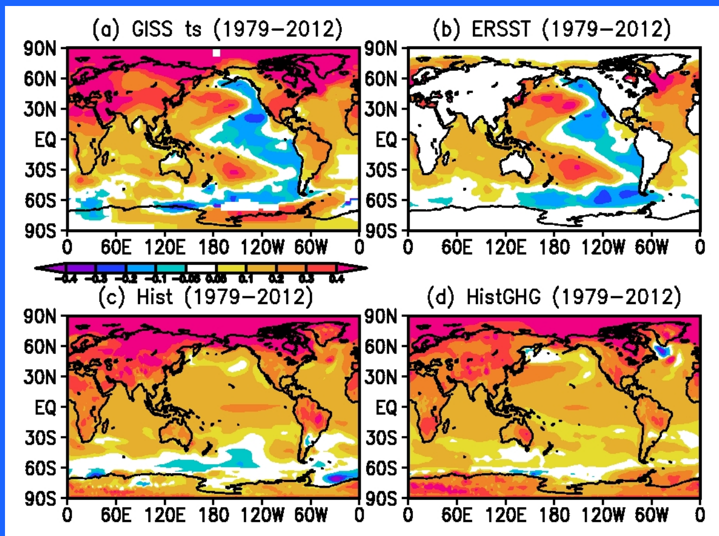


- EOF1/PC1: ENSO & decadal-scale signals
- **EOF2/PC2: long-term changes/ trends**

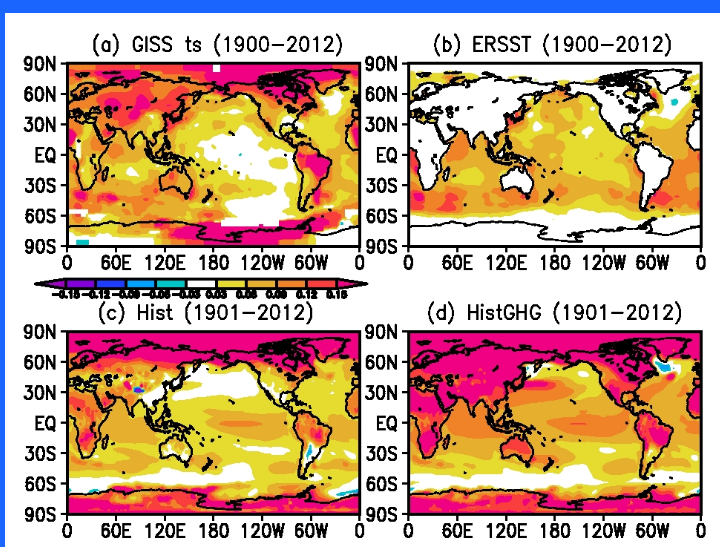
Existence of the Effects of decadal/multi-decadal variability

Linear trend of surface temperature

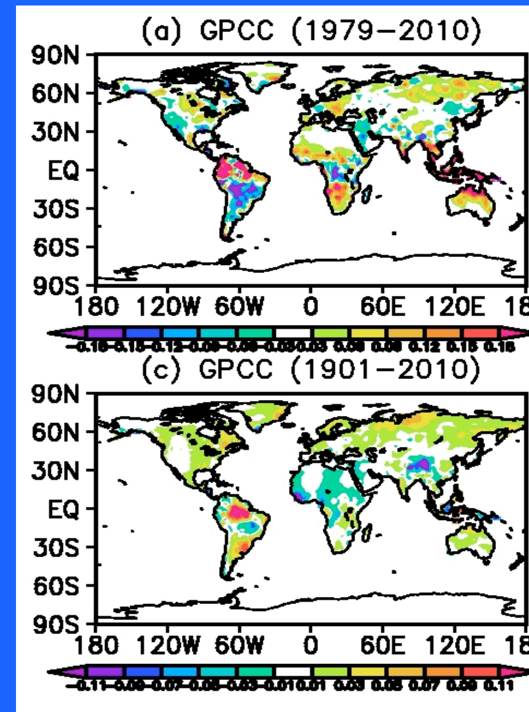
1979-2012



1900-2012



Linear trend of precipitation



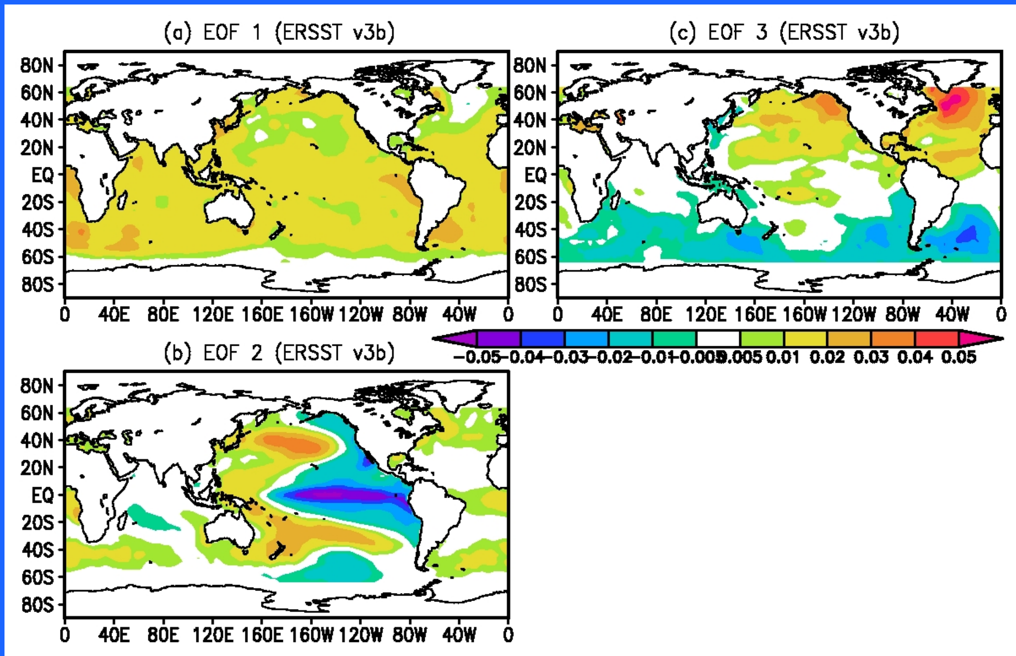
1979-2010

1901-2010

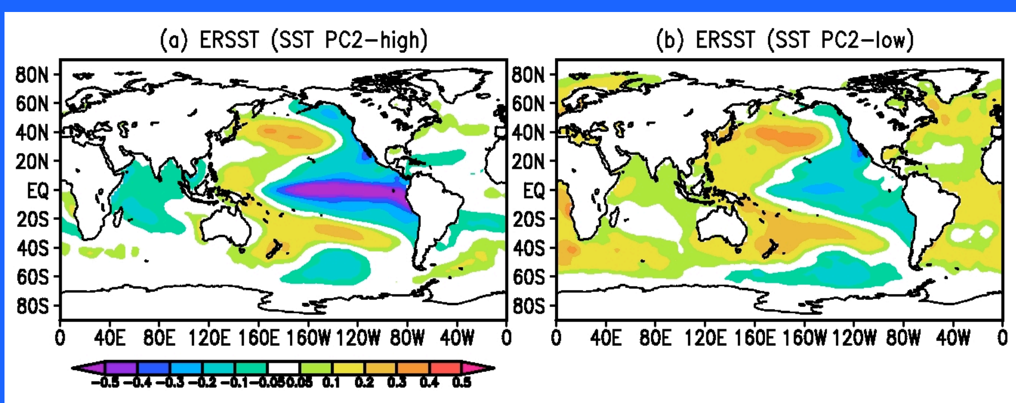
Comparisons of spatial structures during the two time periods indicate *the impact of decadal-scale oscillations in* both temperature and precipitation, ***confounding estimating long-term changes/trends for relatively short-data record.*** For instance, precipitation trends in the past three decades

EOF analysis of SST anomalies between 65ºN-65ºS (1900-2012)

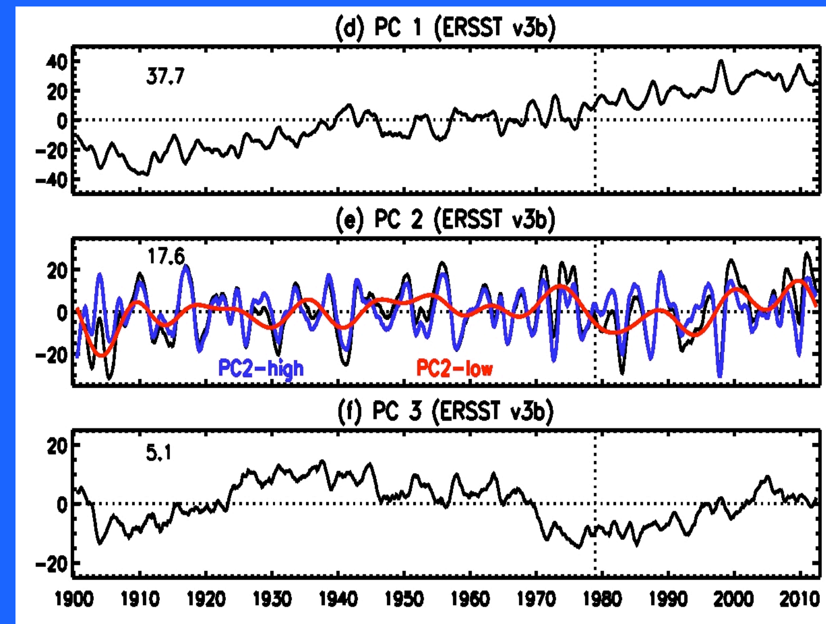
Three leading EOFs



Further decomposition of EOF 2



Three leading PCs



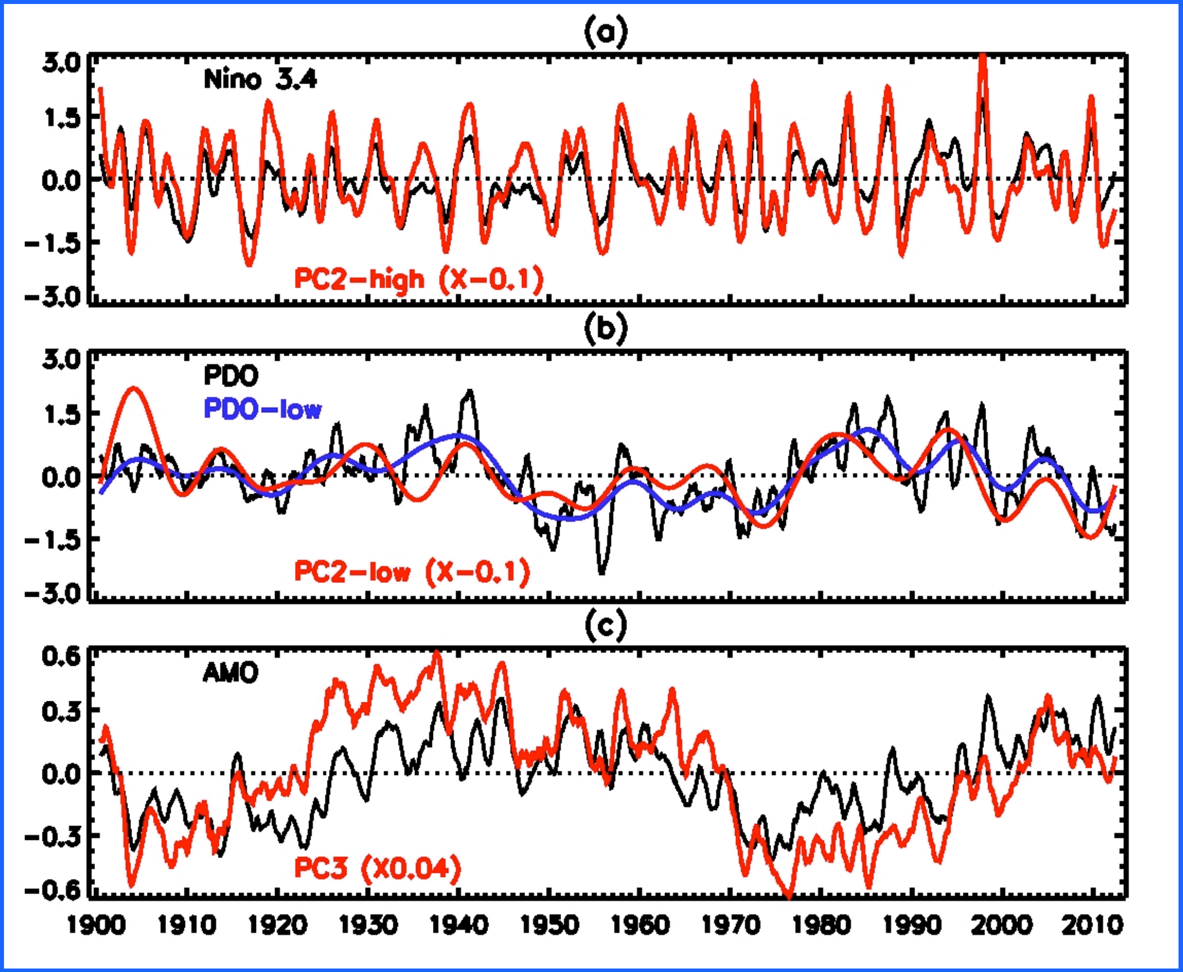
PC1: long-term change/trend;

PC2: ENSO & PDV;

PC2-high: ENSO;

PC2-low: PDV;

PC3: AMO



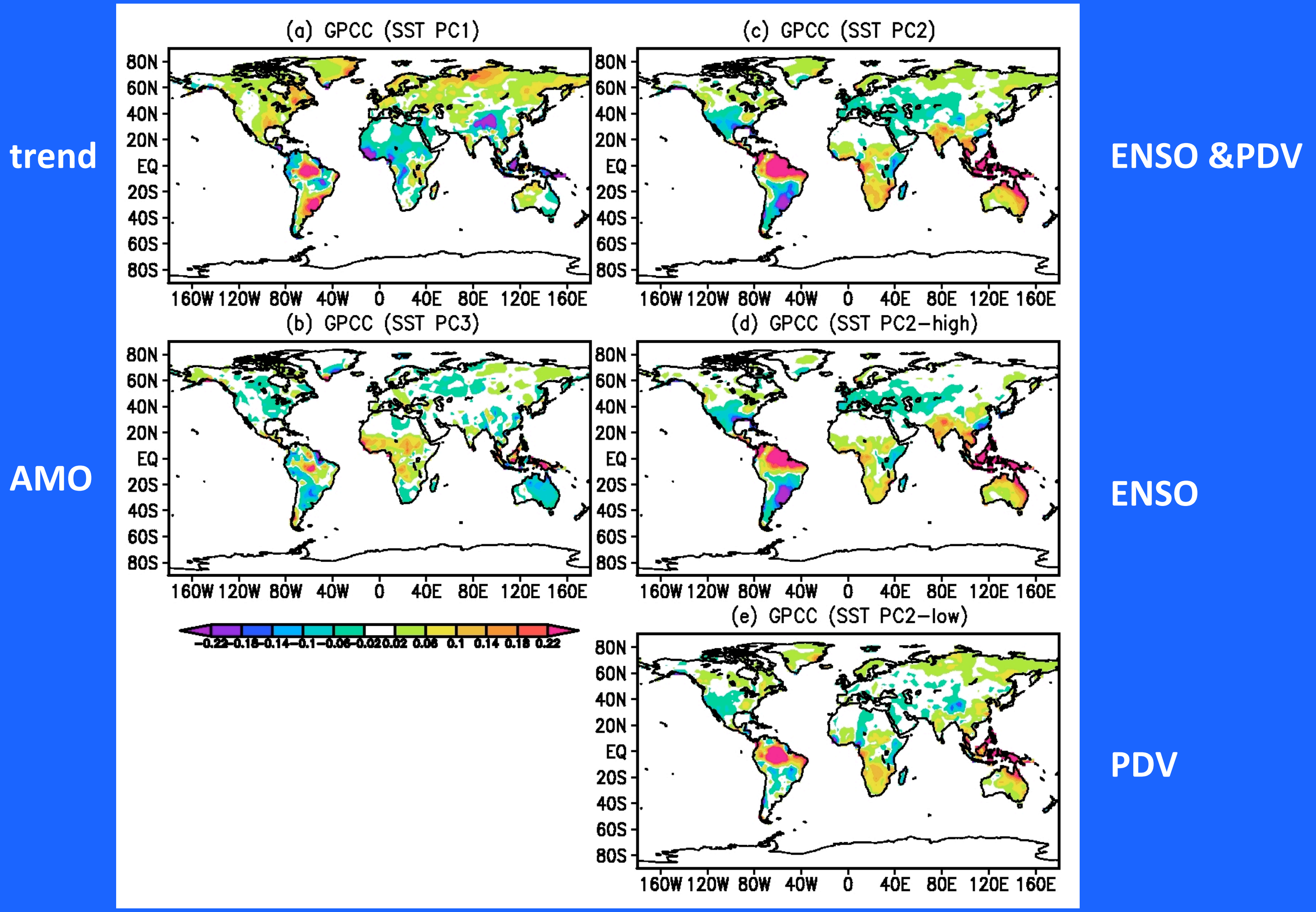
PC2-high & Nino 3.4

PC2-low & PDO index
(ϒ=0.49)

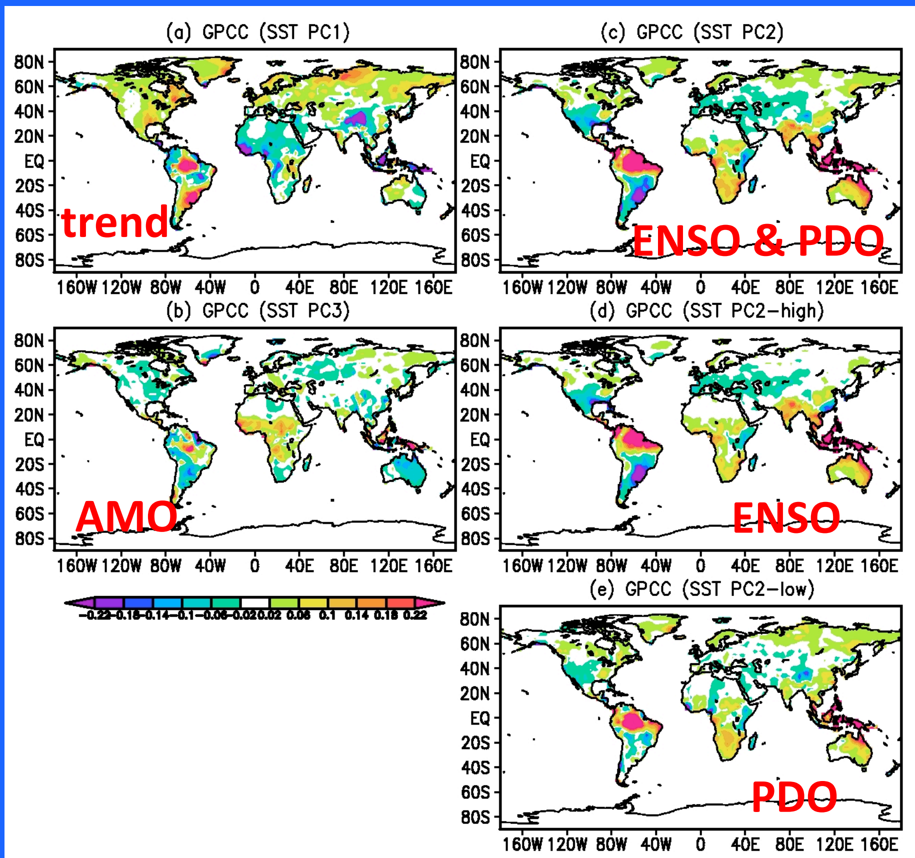
PC3 & AMO index
(ϒ=0.72)

PC1: long-term change/trend;
PC2: ENSO & PDV;
PC2-high: ENSO;
PC2-low: PDV;
PC3: AMO

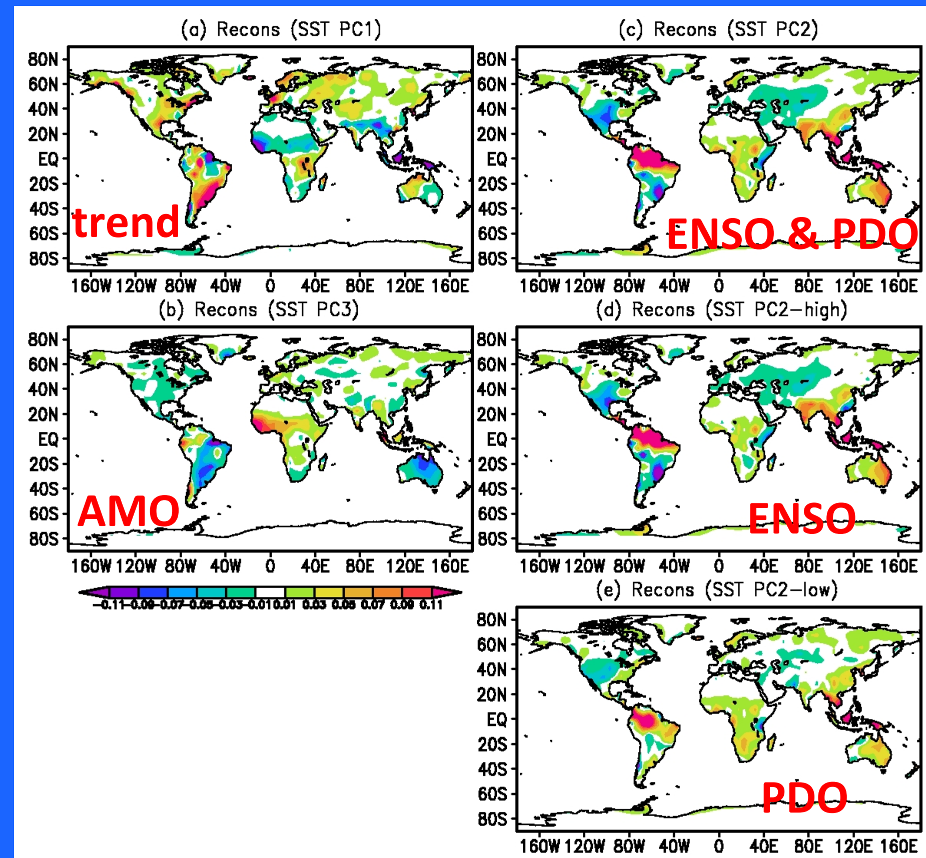
Regression maps of GPCC precipitation



Regression maps of GPCC precipitation

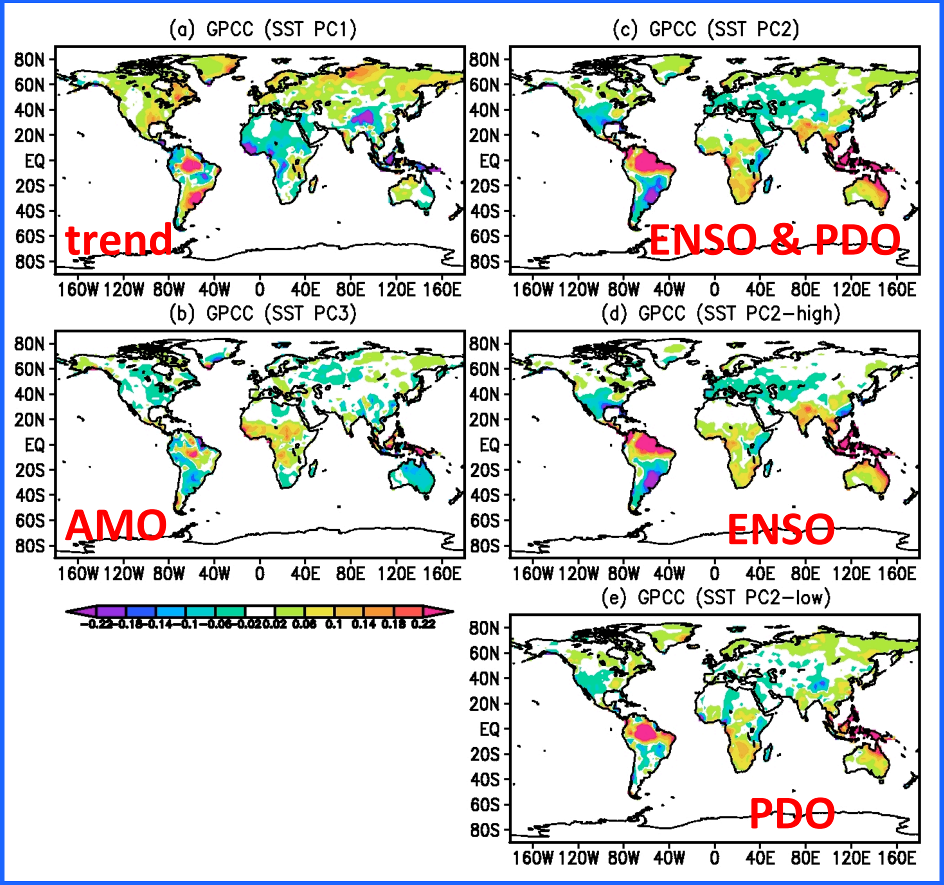


Regression maps of reconstructed precipitation

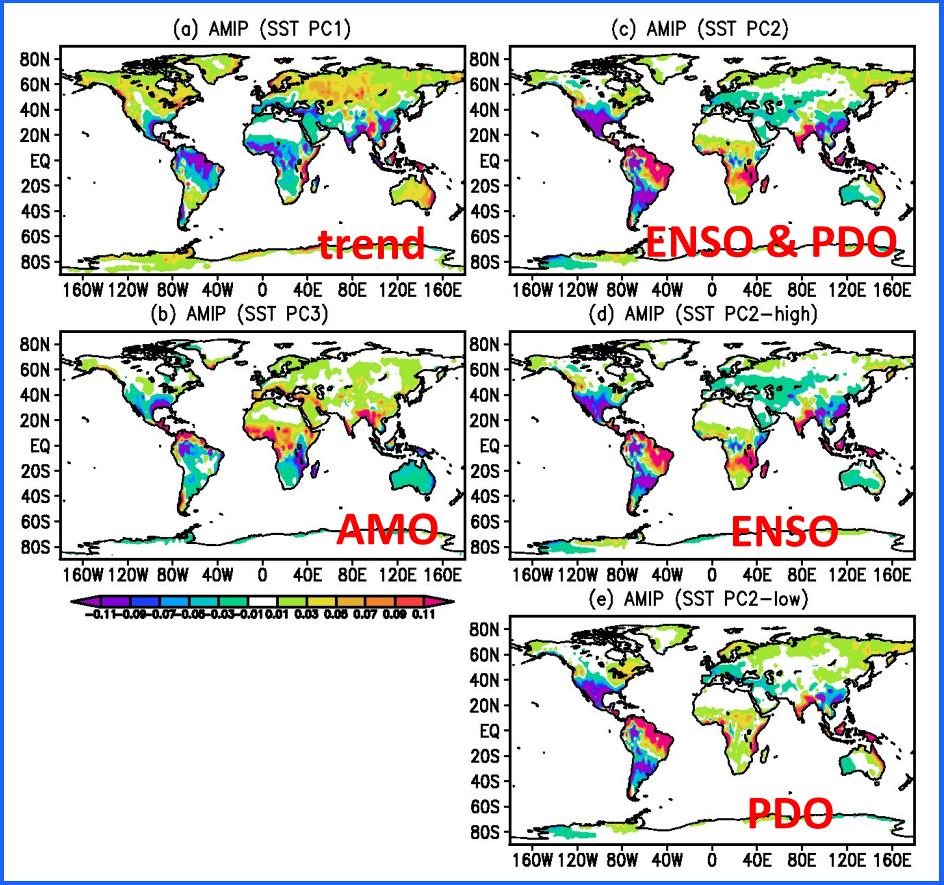


Consistency between GPCC and reconstructed precipitation

Regression maps of GPCC precipitation



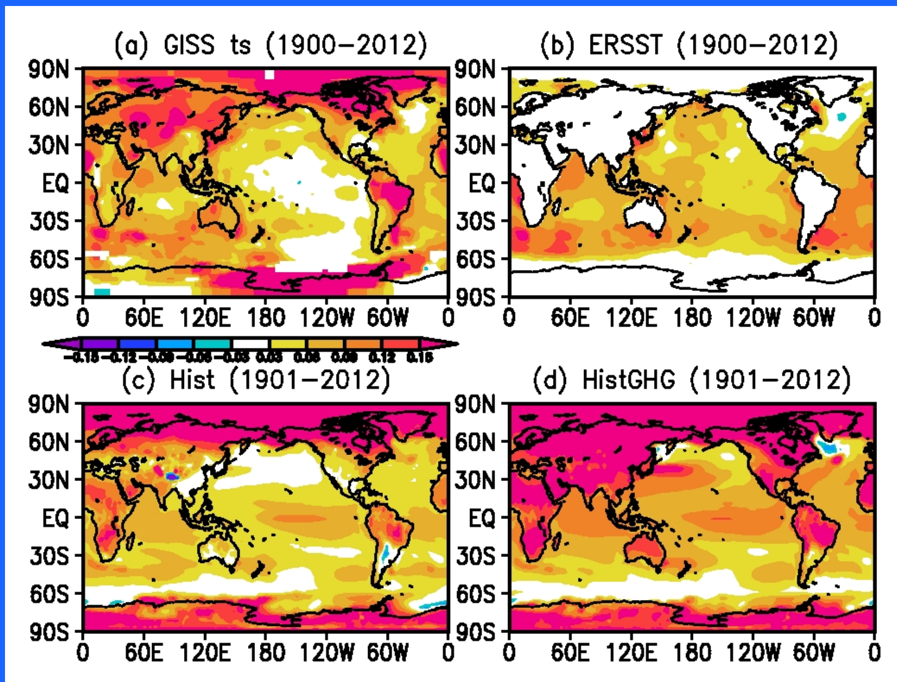
Regression maps of AMIP precipitation



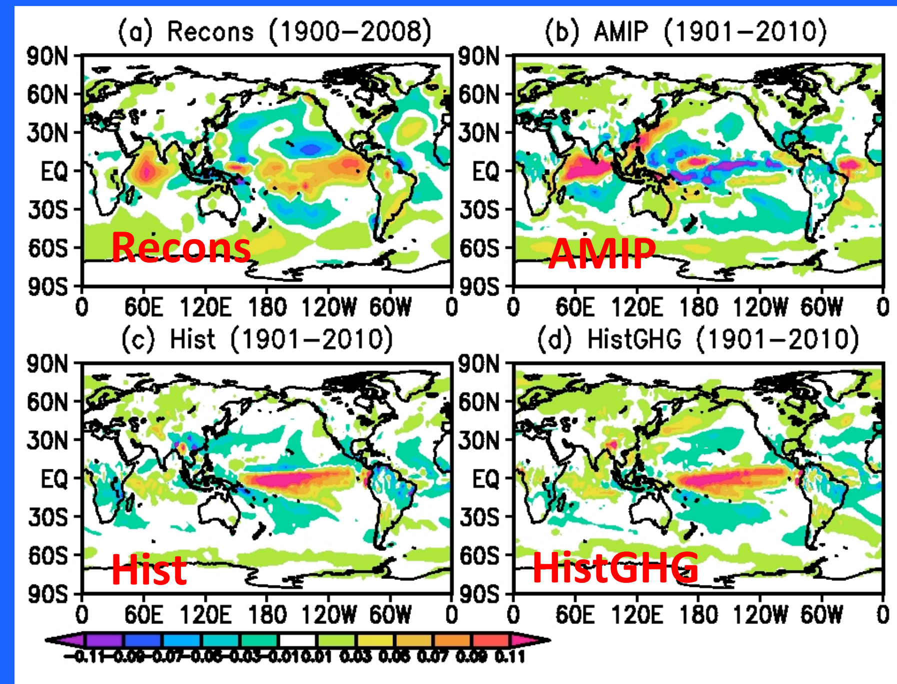
Consistency between GPCC and AMIP;
Discrepancy in several regions; and AMIP precipitation anomalies tend to be weaker

Global Oceans

Linear trend of surface temperature



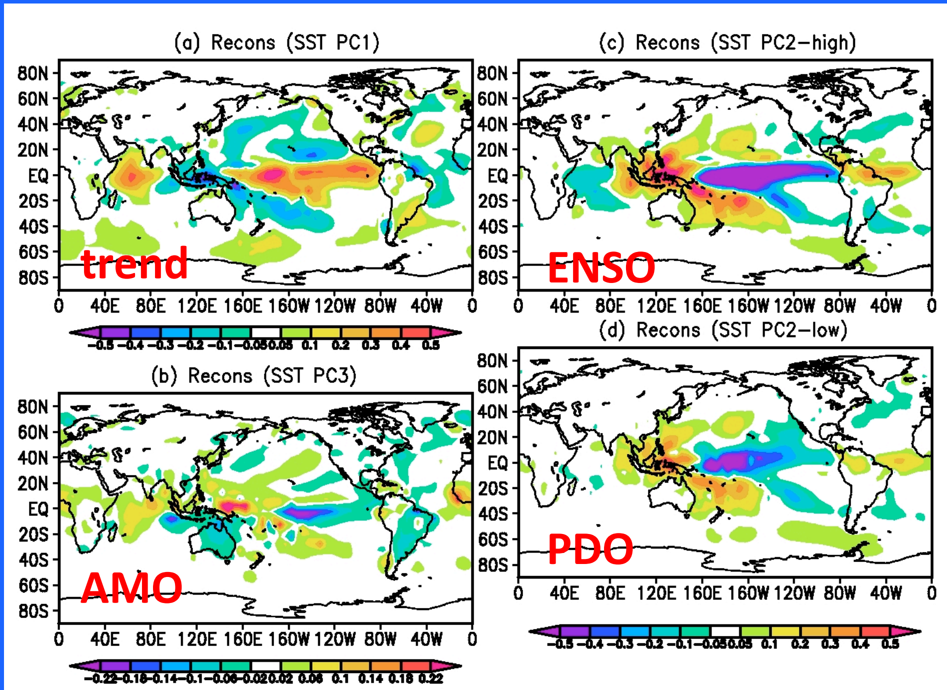
Linear trend of precipitation



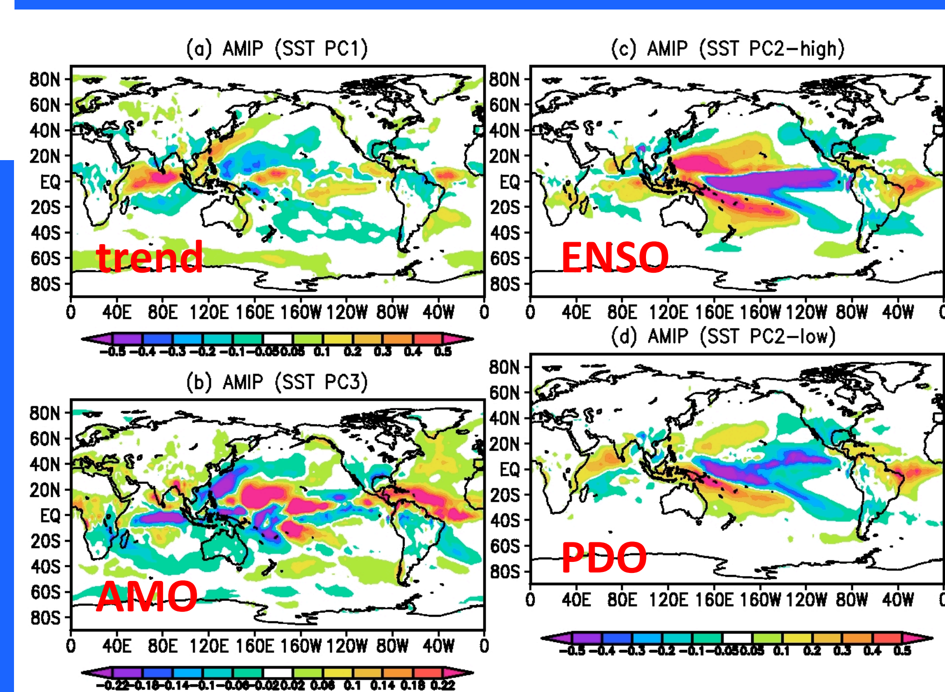
Large discrepancy in precipitation trends in the tropical Pacific and Atlantic, possibly because of no observational constrains over oceans before 1979 (?)

Regression maps of precipitation

Reconstruction



AMIP



Consistency for ENSO & PDV,
but not for AMO

Summary:

- Precipitation increases are observed in the northern hemisphere (NH) mid-higher latitudes during 1901-2010, with reductions primarily appearing in the tropical/subtropical lands including tropical Africa, part of South America, and the northern India-Tibetan region. These features are in general confirmed by the NOAA/CICS reconstruction and the NASA-GISS/CMIP5 simulations.

- Further comparisons between GPCC, the reconstruction and CMIP5 simulations suggest that these observed long-term changes/trends could mostly be related to various radiative forcings in particular the GHG effect.

- Decadal/multi-decadal oscillations including PDV and AMO, in addition to interannual variability (ENSO), can effectively influence/modulate global precipitation changes/variations as well, specifically their spatial patterns.

- Thus, a combined impact from both global warming (GW) and decadal/multi-decadal oscillations (PDV and AMO), in addition to ENSO, makes the estimation of regional (and even global mean) precipitation change extremely difficult when the length of time period considered is relatively short. *(For instance, the recent debate on the precipitation trend during the satellite period.)*