Examining Global Precipitation Change and Variability during 1901-2010 using Observations and CMIP5 Outputs

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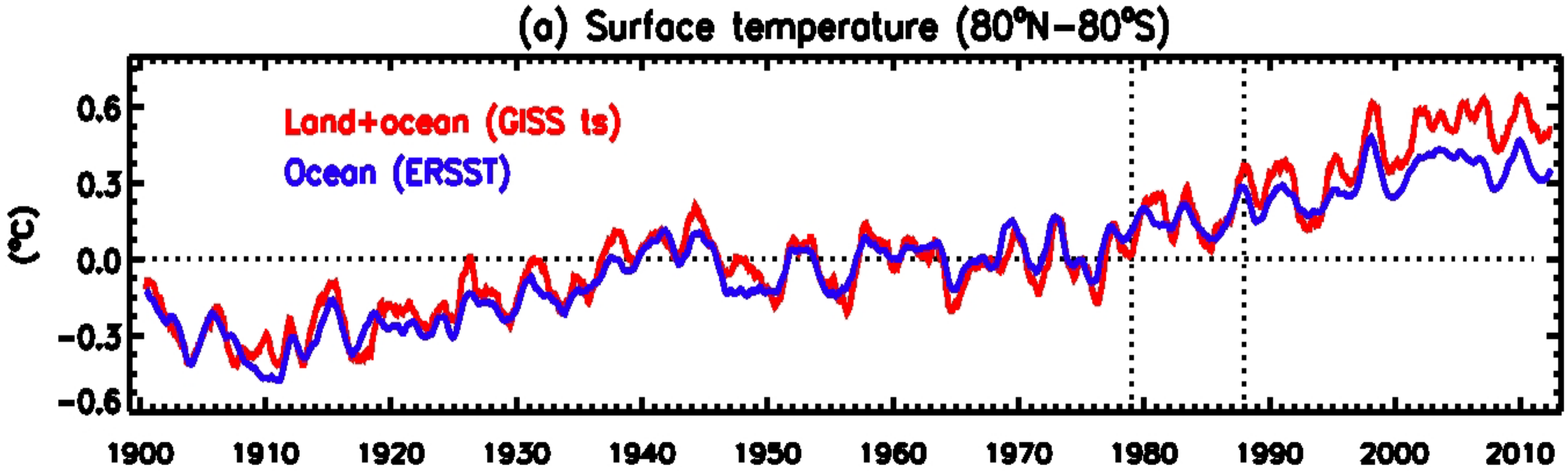
Time series of global mean surface temperature



- Global surface temperature has been increasing during the past over 100 years, but interrupted by evident interannual-to-interdecadal time scale variations;

- ***How may the global hydrological cycle specifically precipitation have varied/changed during the time period?***

Objectives:

1) Explore long-term (centennial-time scale) precipitation changes/trends including spatial patterns during the past over one hundred years; *(*Whether are these changes/trends dominated by the effects of anthropogenic greenhouse gases (GHG)?)*

2) Examine the effects of ocean-based (internal) interannual-decadal/interdecadal oscillations/modes on precipitation, such as Pacific Decadal Oscillation (PDO) and Atlantic Multidecadal Oscillation (AMO).

Data sets:

Precipitation:

1) GPCC full data reanalysis version 6 of monthly land precipitation *[1901-2010; on global grid with resolutions of 0.5°, 1.0°, and 2.5° (Schneider et al. 2013; Becker et al. 2013)]*
2) NOAA/CICS-Smith reconstructed (RECONS) monthly land+ocean precipitation primarily used over global ocean *[1900-2008; on global grid with resolution of 5°; reconstructed from modes derived from historical SST and sea level pressure data, constrained by rain-gauges over land, and further trained by the satellite-based global precipitation product (GPCP) for the post-1979 period (Smith et al. 2009, 2012)]*

Surface temperature:

1) NASA/GISS-surface temperature anomaly analysis (1880-present)
2) NOAA/NCEP extended reconstructed sea surface temperature (ERSST) v3b (1854-present)

CMIP5 simulations (*temperature and precipitation*):

1) Coupled historical experiments from multiple CMIP5 models (1880-2005), forced by (i) historical (total) natural and external radiative forcings (Hist), (ii) anthropogenic greenhouse-gas (GHG) forcing only (HistGHG), and (iii) historical natural radiative forcing only (HistNat); [------- multi-model ensemble means limit internal variations]
2) Atmosphere-only (AMIP) experiments from NASA/GISS Model E (1880-2010), forced by surface (observed SST & sea ice extent) and historical radiative forcings. [-------- include both (natural and anthropogenic) radiative forcings and oceanic-based variations]

Outline:

Part I. Long-term (centennial-time scale) precipitation changes/trends

Part II. Precipitation changes/variations associated with various decadal/interdecadal-scale factors/mechanisms in global SST

Part I. Long-term (centennial-time scale) precipitation changes/trends

- Observed and simulated (CMIP and AMIP) spatial patterns of global precipitation trends;
- Estimating/discriminating contributions from various physical mechanisms: natural, anthropogenic GHG and aerosols?
- Likely components of precipitation change/trend patterns related to anthropogenic GHG forcing

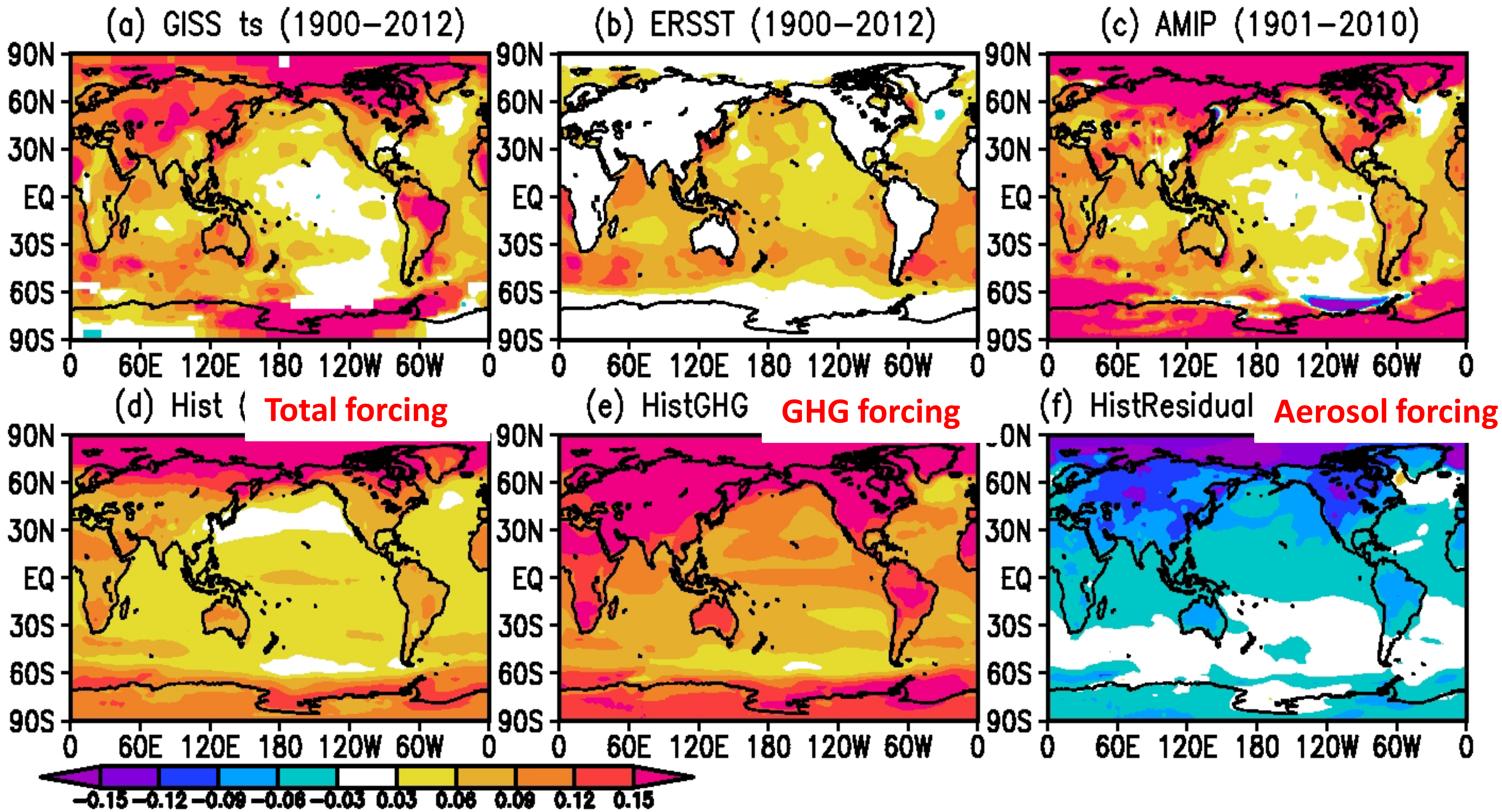
Precipitation products:

- Over land: GPCC (& RECONS), NASA GISS/AMIP, CMIP5 (Hist, HistGHG, HistNat)
- Over ocean: RECONS, NASA GISS/AMIP, CMIP5 (Hist, HistGHG, HistNat)

Estimating anthropogenic aerosol effect in temperature and precipitation using (multi-model) CMIP5 historical simulations:

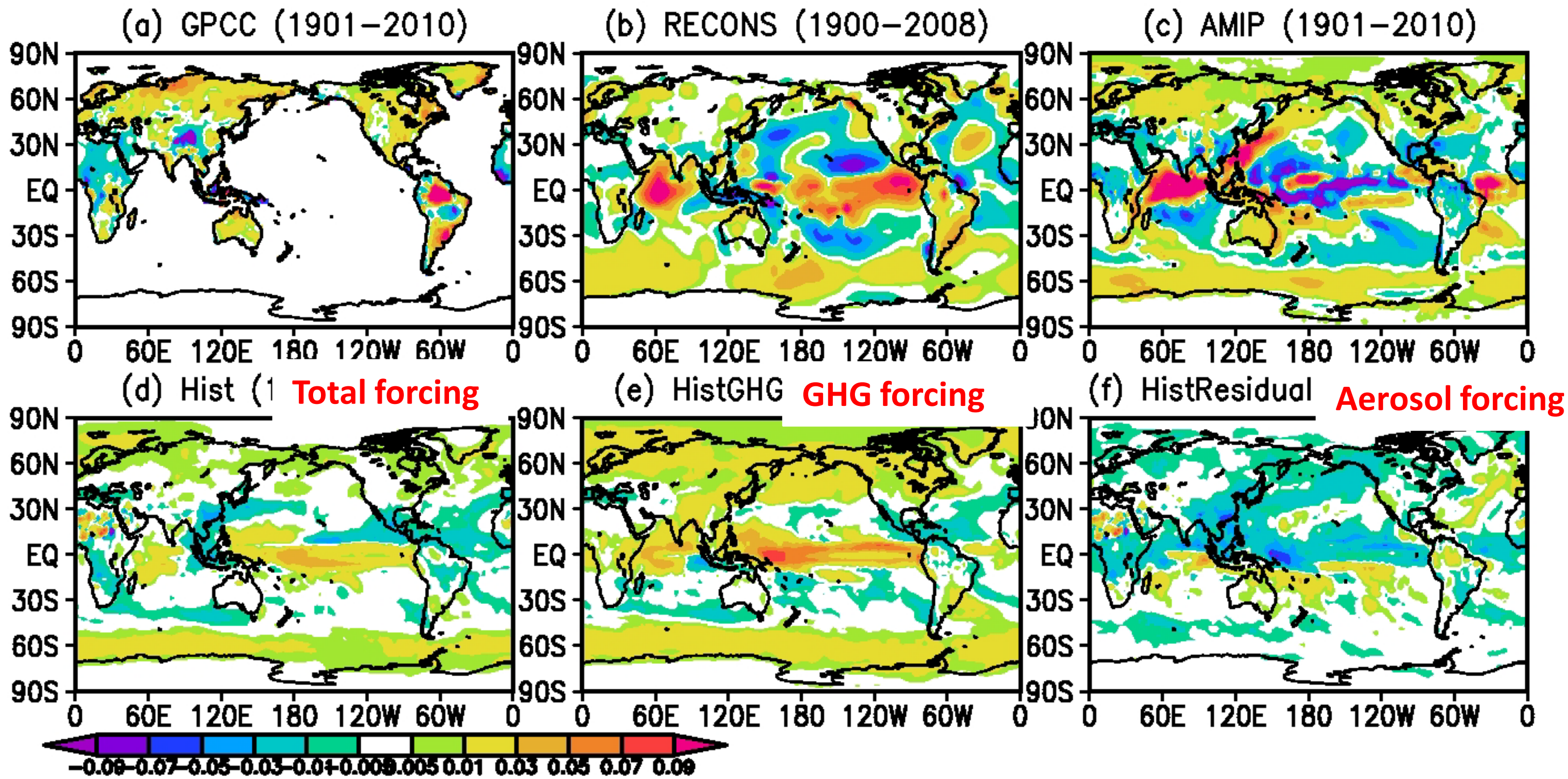
HistResidual = Hist (total) **– HistGHG -HistNat**

Long-term changes/trends in surface temperature



- Surface temperature keeps increasing during the past century especially over land and in the NH mid-high latitudes;
- CMIP5 historical (Hist) runs can catch general spatial features of temperature changes, but with differences in detail over several regions in the NH mid-higher latitudes; Also, HistGHG shows much intense warming globally compared to observations and Hist, because of the opposite (cooling) effect from aerosols (HistResidual);
- Aerosol effect is primarily in NH, forming an interhemispheric surface temperature gradient.

Long-term changes/trends in precipitation



Over land:

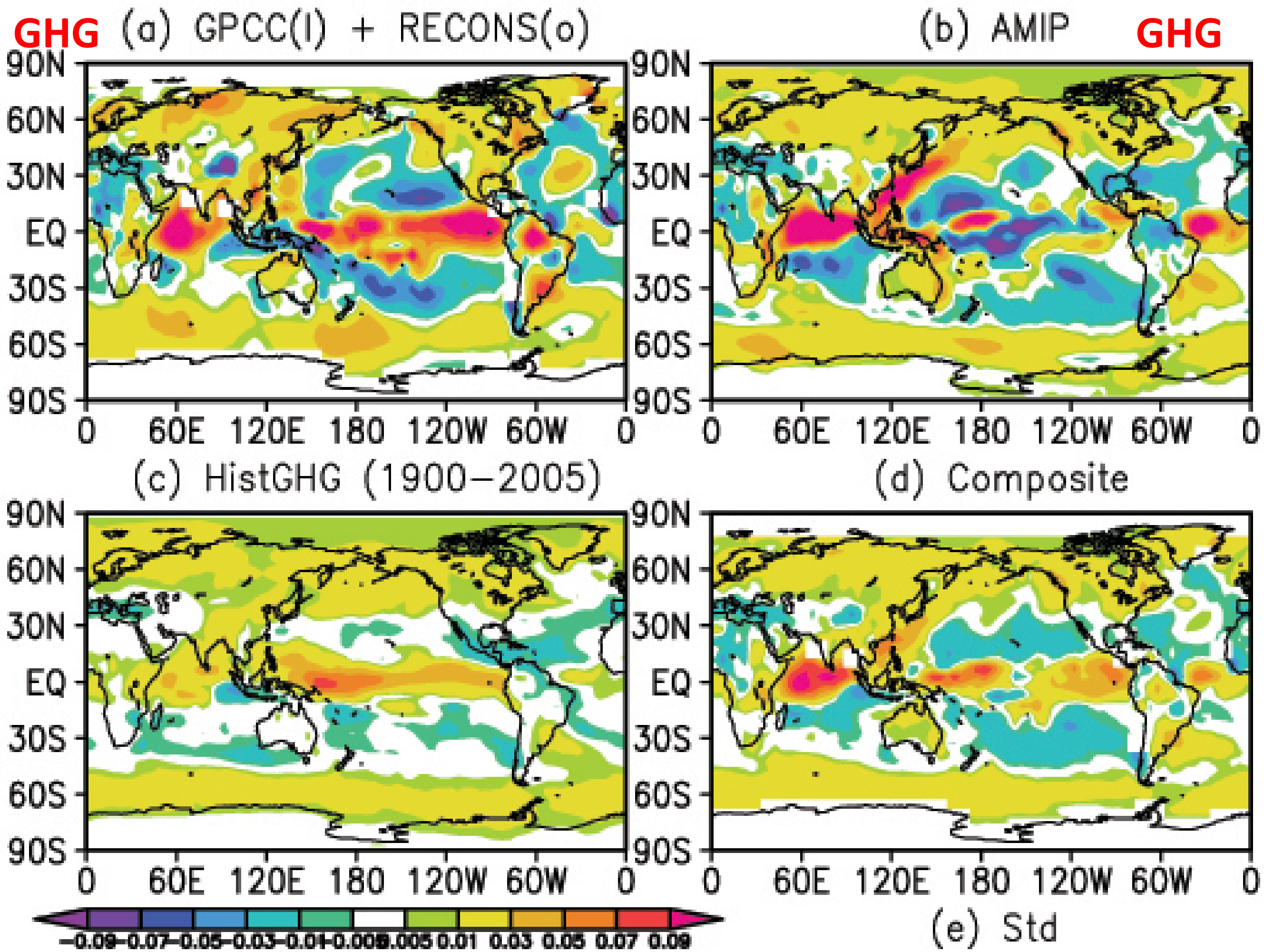
- ➢ Precipitation increase in mid-higher latitudes; decrease in tropical/subtropical regions;
- ➢ Consistencies in spatial features in GPCC, RECONS, AMIP, and Hist: for instance, *NH mid-high latitudes, part of West Africa, Australia, etc.*

Over ocean:

- ➢ Large discrepancy in the tropical Pacific and Atlantic, in particular for AMIP.

✓ HistGHG shows more intense precipitation increase globally than Hist, while aerosols (HistResidual) tend to shift precipitation southward.

Long-term precipitation changes/trends related to anthropogenic GHG



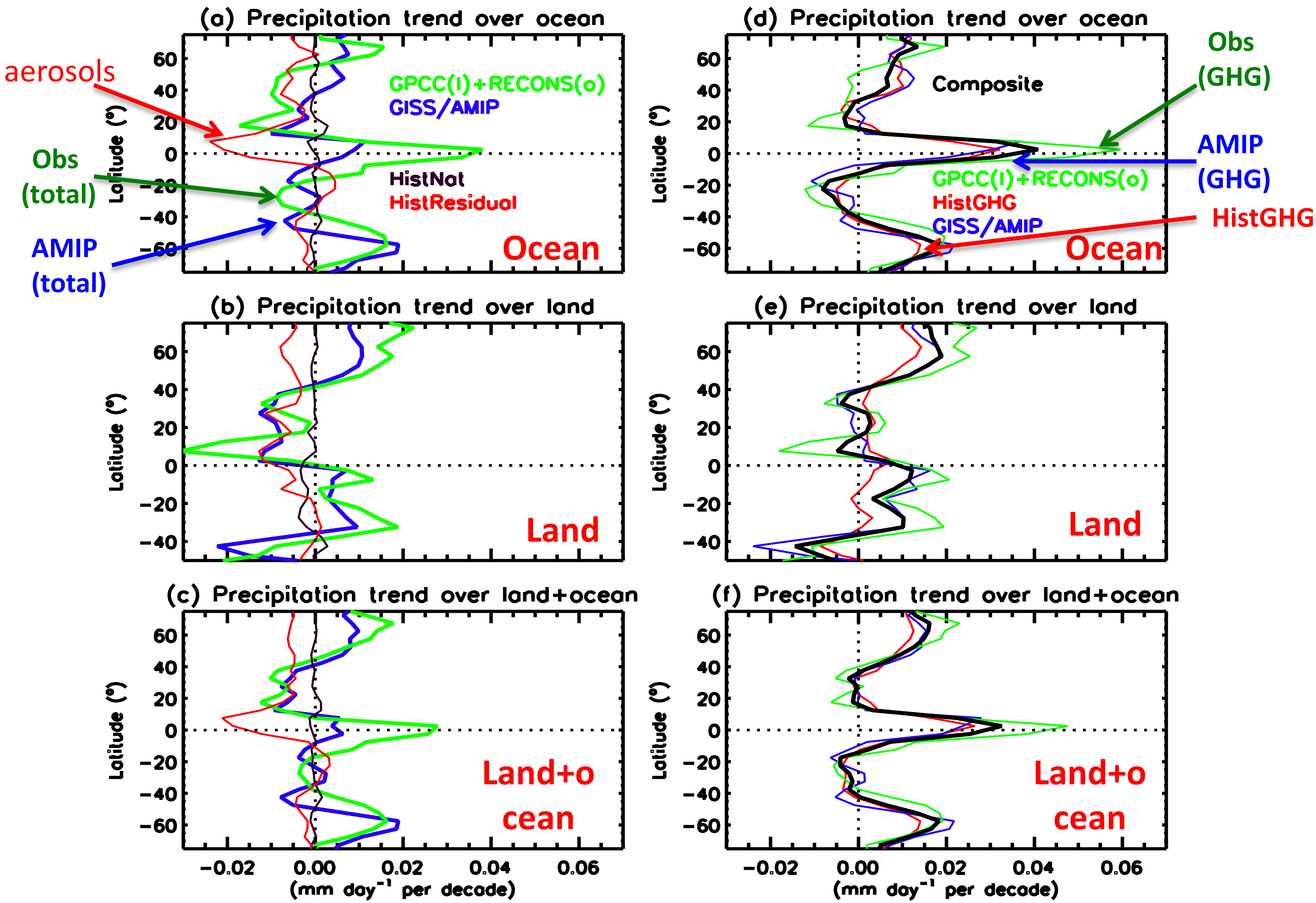
Estimate GHG-related changes in (a) observations and (b) AMIP:

(a) [GPCC (over land)+RECONS (over ocean)] – *[HistResidual (aerosols)+HistNAT]*;
(b) AMIP (5-member-mean) - *[HistResidual (aerosols)+HistNAT]*

Long-term precipitation changes/trends related to anthropogenic GHG

Observed (total) changes/trends & estimated HistNat and HistResidual

GHG-related changes/trends in observations & HistGHG



Summary I:

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

- Further comparisons between GPCC, the reconstruction and CMIP5 simulations suggest that these observed long-term changes/trends specifically spatial structures could be related to the effects of both anthropogenic GHG and aerosols.

- Composite patterns (*best estimate?*) of GHG-related precipitation changes/trends could not only improve our understanding of the past climate change, but also provide certain guidance for climate projections in the coming decades.

Part II. Precipitation changes/variations associated with various decadal/interdecadl-scale factors/mechanisms in global SST

- Identify long-term change signal and interannual-interdecadal/multidecadal oscillations in global SST through an EOF analysis of SST anomalies between 65°N-65°S;
- Compare regressed precipitation anomalies to identified SST indices in both observations and NASA GISS/AMIP

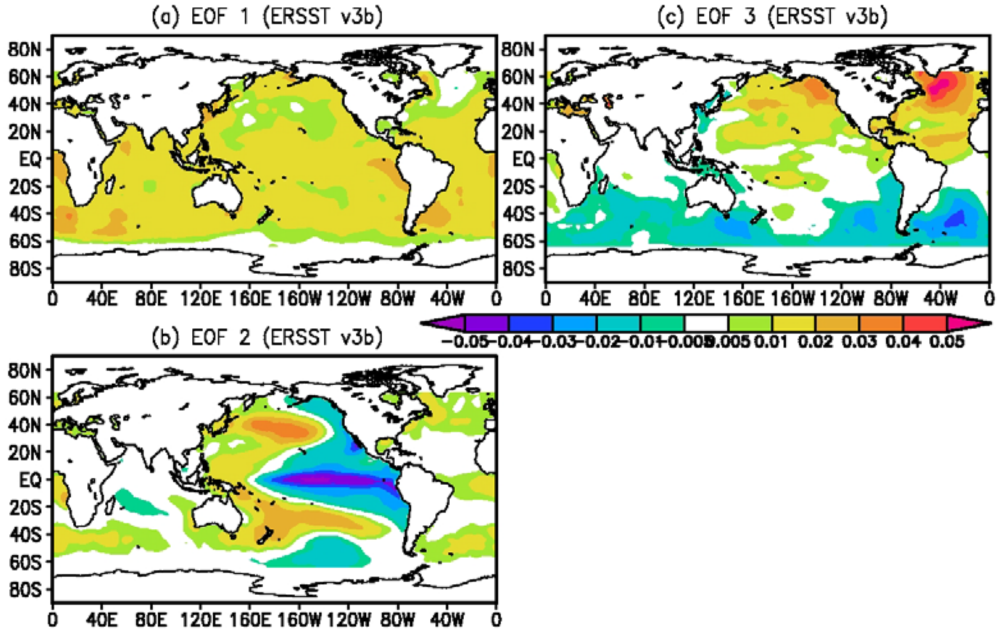
Precipitation products:

- Over land: GPCC (& RECONS), NASA GISS/AMIP
- Over Ocean: RECONS, NASA GISS/AMIP

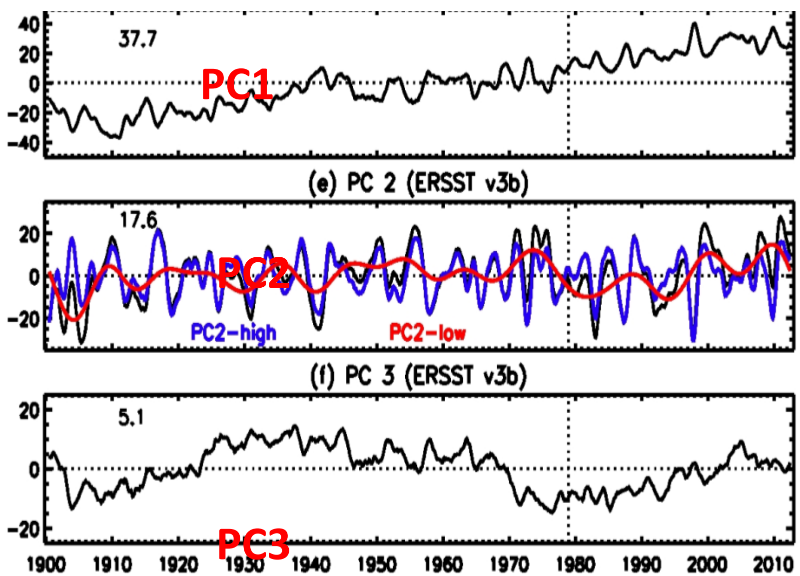
SST-based physical modes/mechanisms:

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

Three leading SST EOFs



Leading SST PCs



Further decomposition of EOF2/PC2

PC2-high

PC2-low

<u>**SST indices**</u>**:**

PC1: long-term change/trend;

PC2: ENSO & PDV;

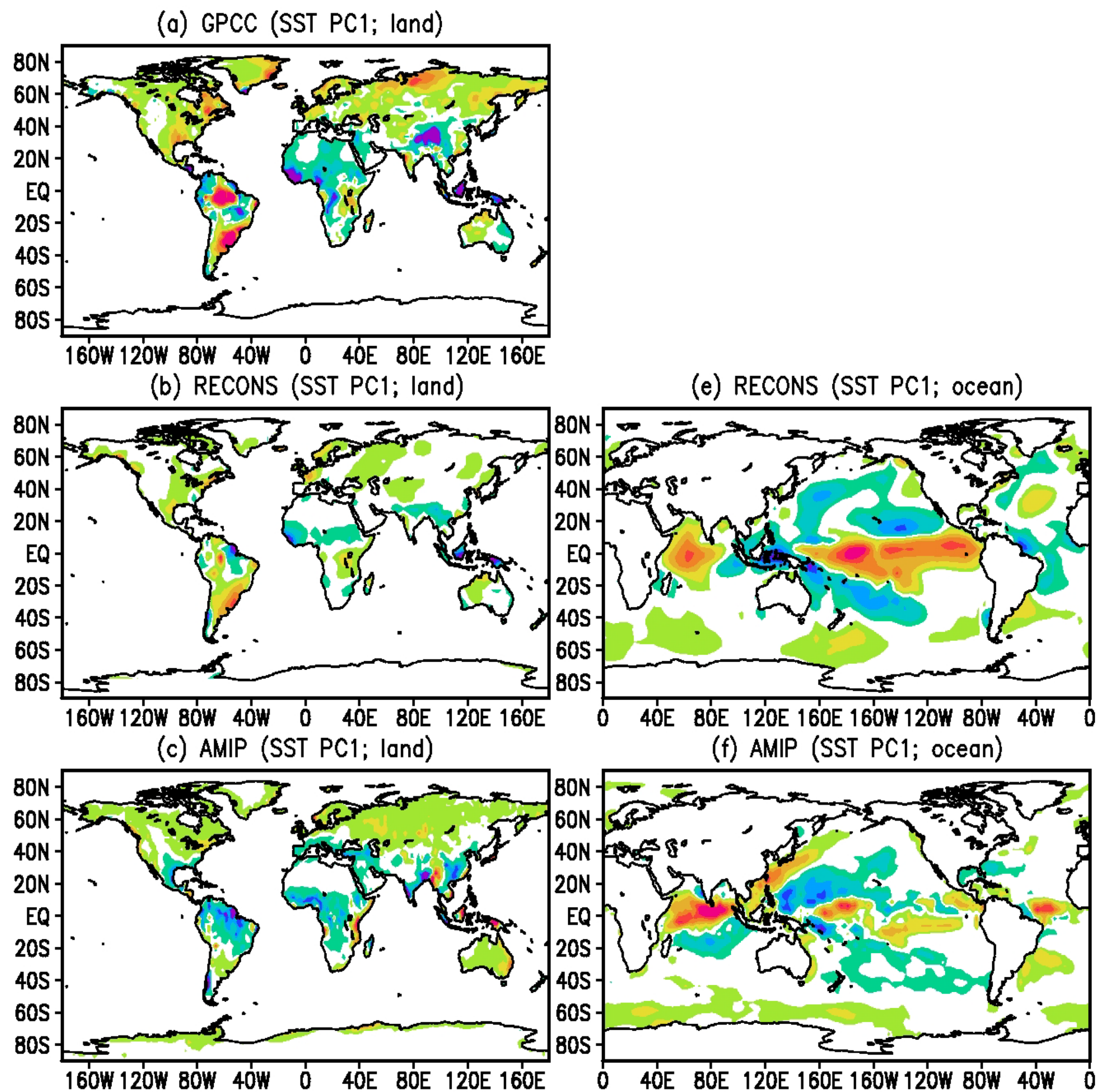
PC2-high: ENSO;

PC2-low: PDV;

PC3: AMO

(1) Long-term precipitation change/trend: SST PC1

GPCC

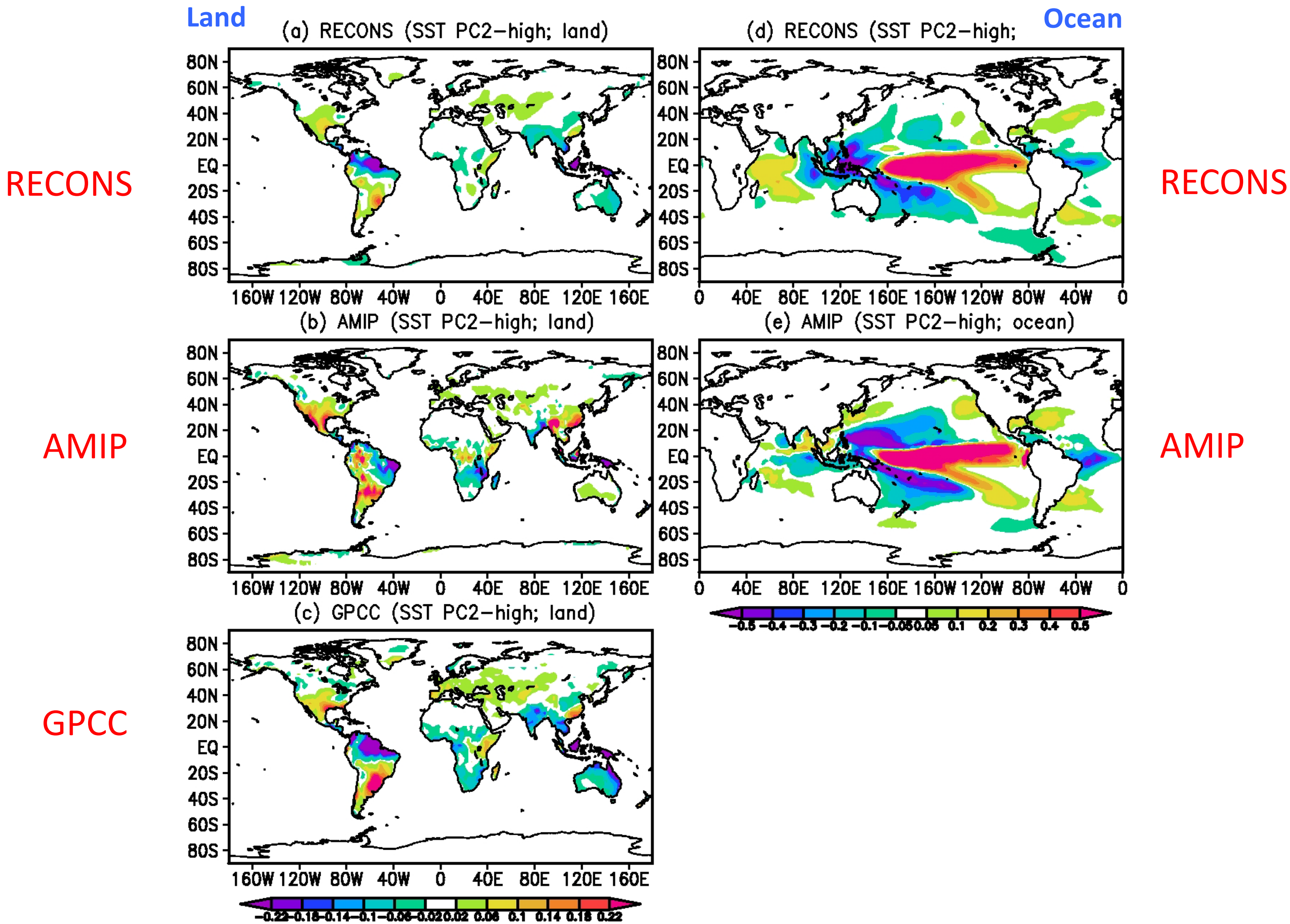


RECONS

AMIP

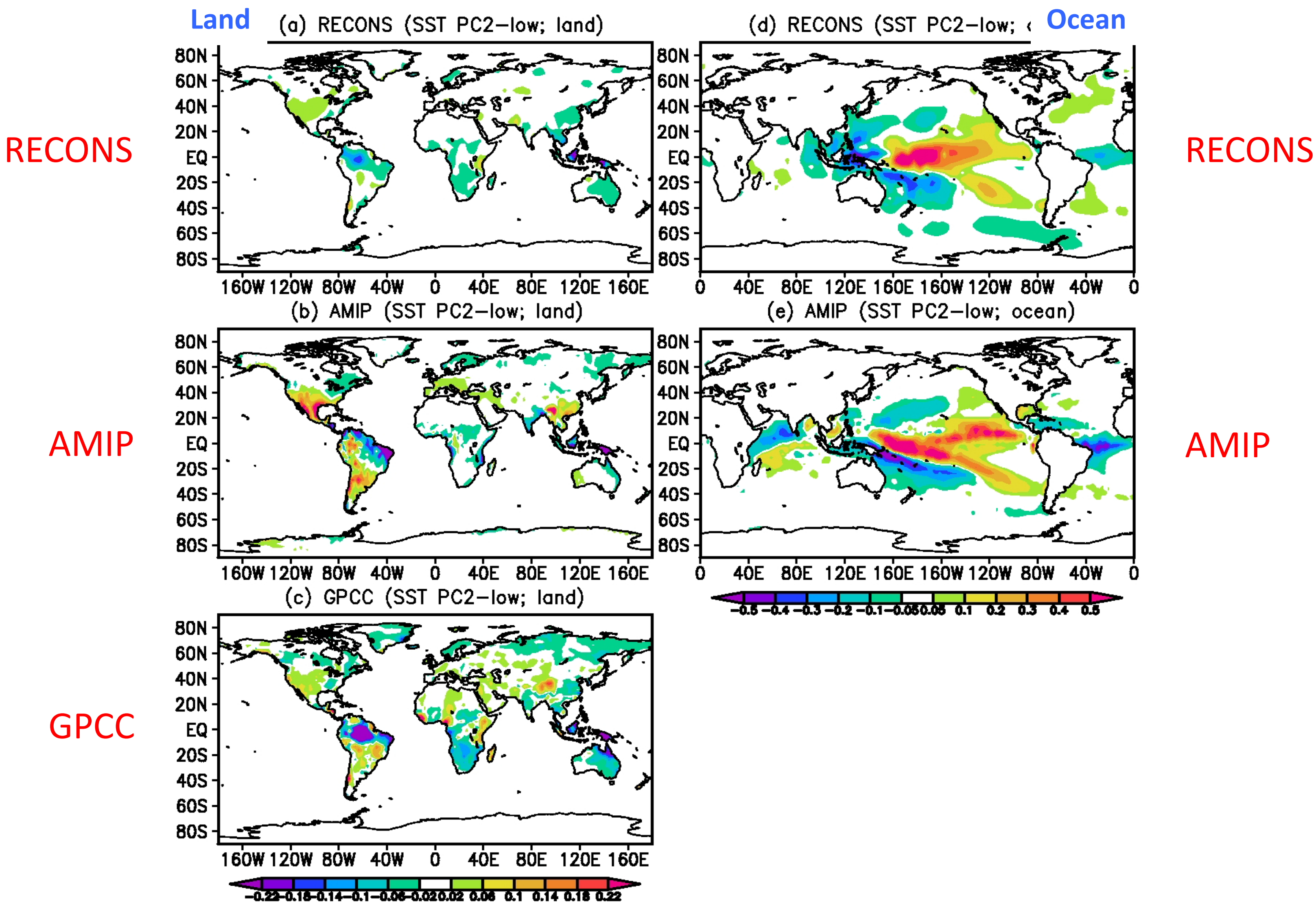
- Spatial structures of regressed precipitation anomalies are generally in agreement with those for respective linear trends;
- AMIP precipitation anomalies in tropical Pacific tend to be more similar to RECONS than AMIP precipitation trends.

(2) ENSO-related precipitation anomalies: SST PC2-high



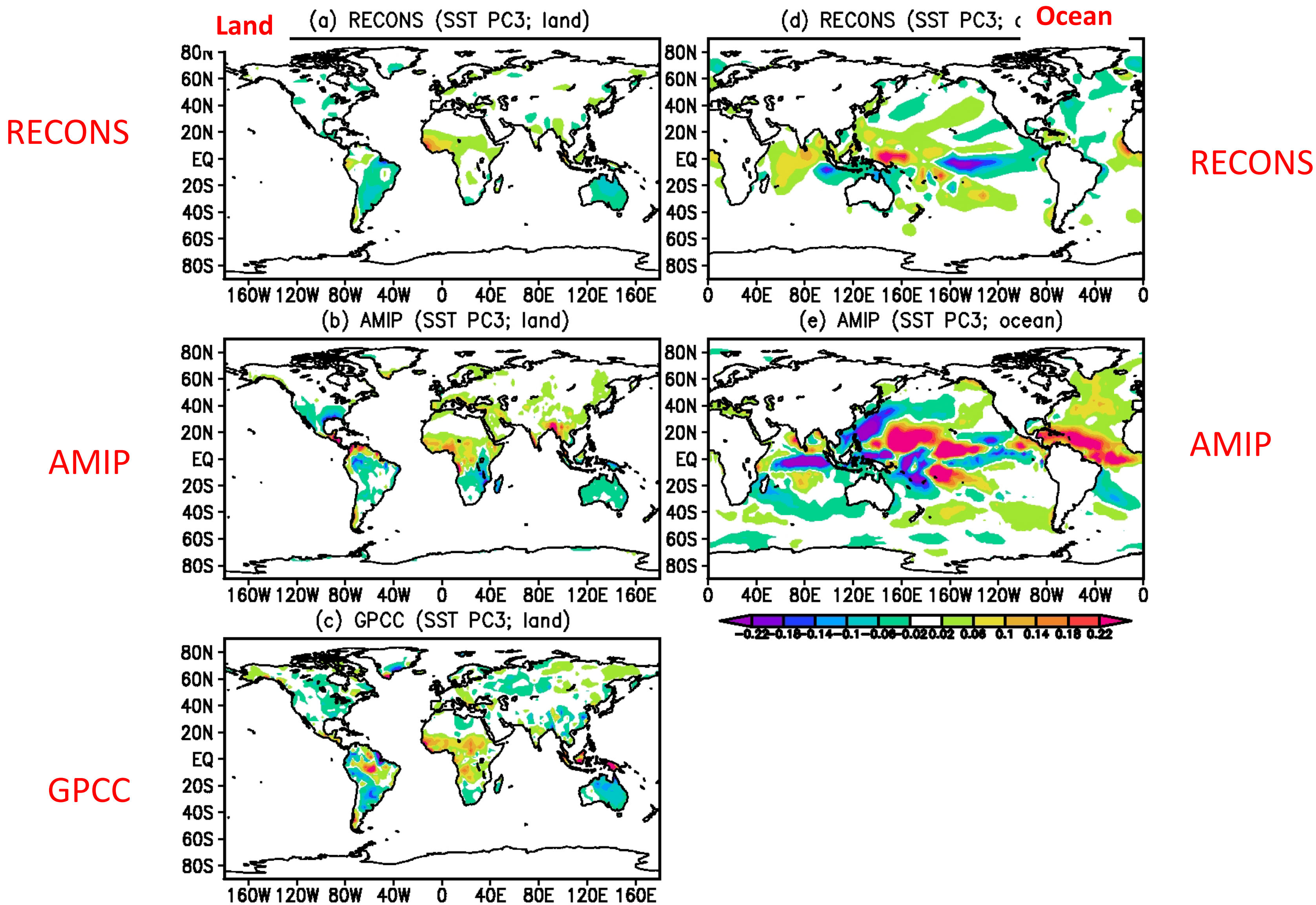
Consistency can be found over land, though with differences in intensity; Over ocean, differences in spatial structures of anomalies appear in the tropical oceans.

(3) PDV-related precipitation anomalies: SST PC2-low



- Over land, consistency is seen among GPCC, RECONS, and AMIP. RECONS and AMIP tend to be weaker especially in northern mid-high latitudes;
- Over ocean, similarities appear, though with detailed discrepancies.

(4) AMO-related precipitation anomalies: SST PC3



Consistency over land, including West Africa, North and part of South America, Australia, etc.; *large discrepancy over ocean, not only in the Indian Ocean and Pacific, but also in the Atlantic*

Summary II:

- Decadal/interdecadal (ocean-based) variations/modes, including PDV and AMO, in addition to interannual variability (ENSO), can effectively influence/modulate global precipitation changes/variations, in particular their spatial patterns;

- RECONS and AMIP can catch relatively well these variations over land. Over ocean, general consistency between RECONS and AMIP can be found for ENSO and PDV, but not for AMO;

- Thus, on the decadal/interdecadal time scales, precipitation variations specifically spatial features result from a combined impact from these (internal) mechanisms and anthropogenic effects including GHG-related global warming and aerosols-related (mostly in the NH) cooling;

- This indicates that accurately estimating regional (and even global mean) precipitation changes is difficult when the length of time period considered is relatively short.