

CMIP5 Projections of two types of El Niño and their related tropical precipitation in the 21st century

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(CMIP5 Projections of Two Types of El Niño and Their Related Tropical Precipitation in the 21st Century, by X. Kang et al., 2016: Journal of Climate. DOI: 10.1175/JCLI-D-16-0413.1)



香港中文大學

The Chinese University of Hong Kong

地球系統科學課程

EARTH SYSTEM SCIENCE PROGRAMME

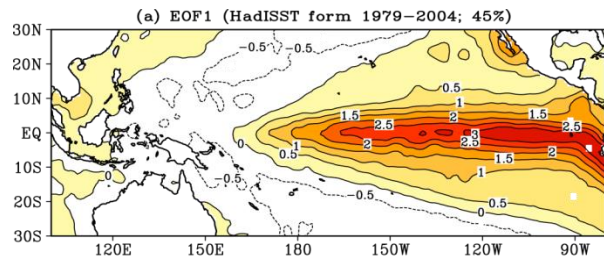
APCC, Busna

December 28, 2016

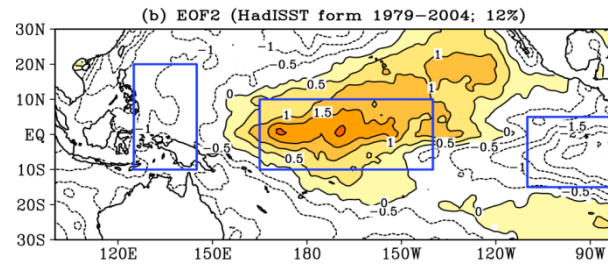
Background

Oceanic and Atmospheric components of El Niño

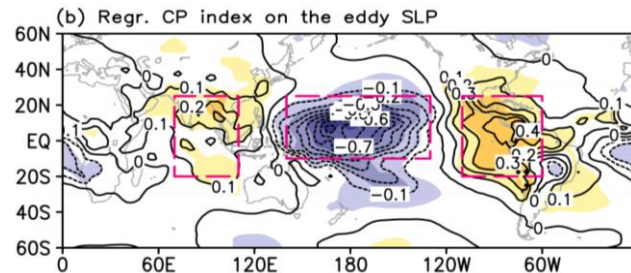
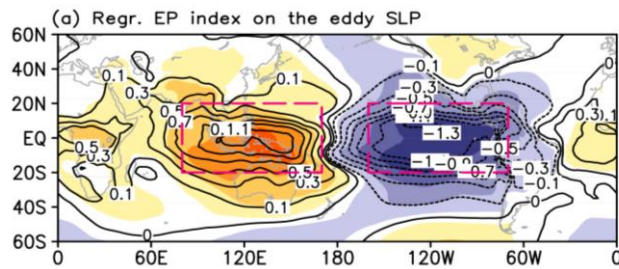
Eastern-Pacific (EP) El Niño



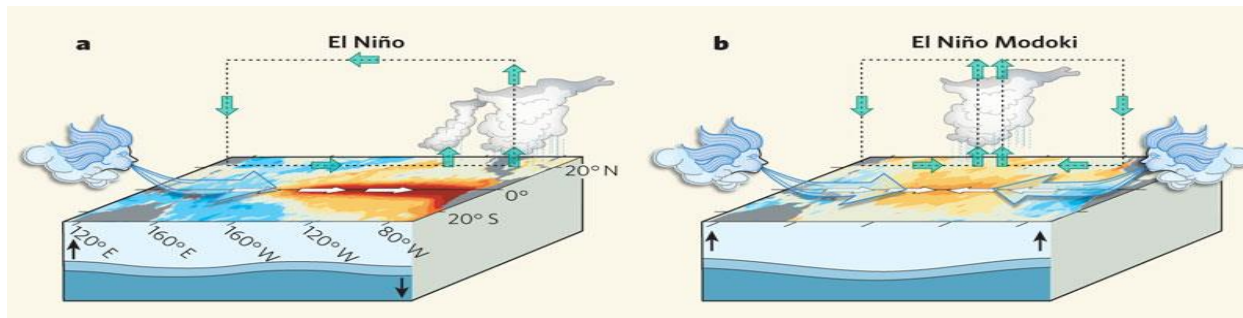
Central-Pacific (CP) El Niño



Ashok et al., 2007, JGR



Xu et al., 2013, Adv. Atmos. Sci.

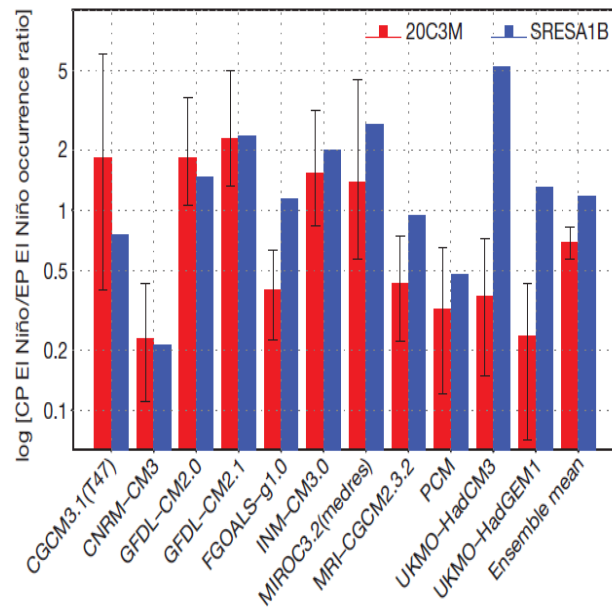


Ashok and Yamagata, 2009, Nature

LETTERS

El Niño in a changing climate

Sang-Wook Yeh¹, Jong-Seong Kug¹, Boris Dewitte², Min-Ho Kwon³, Ben P. Kirtman⁴ & Fei-Fei Jin³



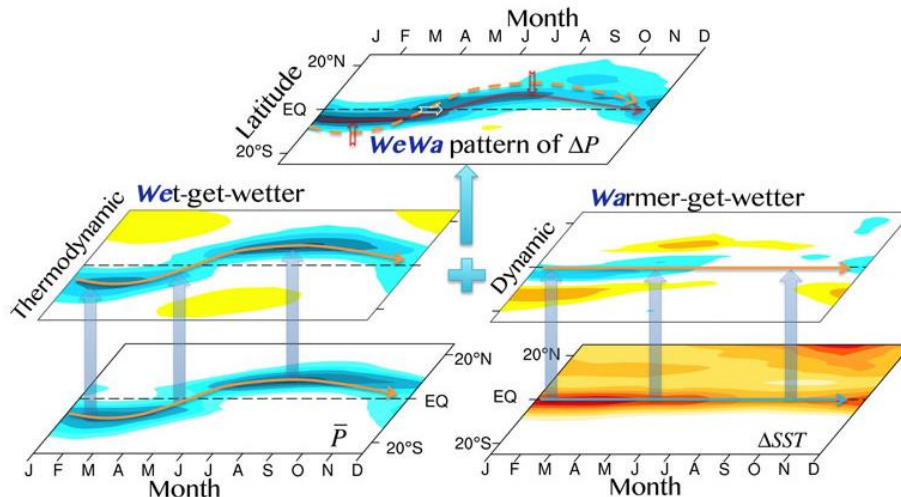
Yeh et al. (2009) used 11 models in total, and considered only one scenario of future climate change (SRES scenario A1B).

However, there is still no consensus about future changes of CP to EP El Niño ratio among all models (Power et al., 2013).

Background

Two effects on tropical rainfall change

- **“wet-get-wetter/dry-get-drier”**: increased rainfall in presently rainy regions (Held and Soden, 2006)
- **“warmer-get-wetter”**: increased rainfall where the rise in local SST exceeds the mean surface warming in the tropics (Xie et al., 2010)



Huang et al., 2013, Nature Geoscience

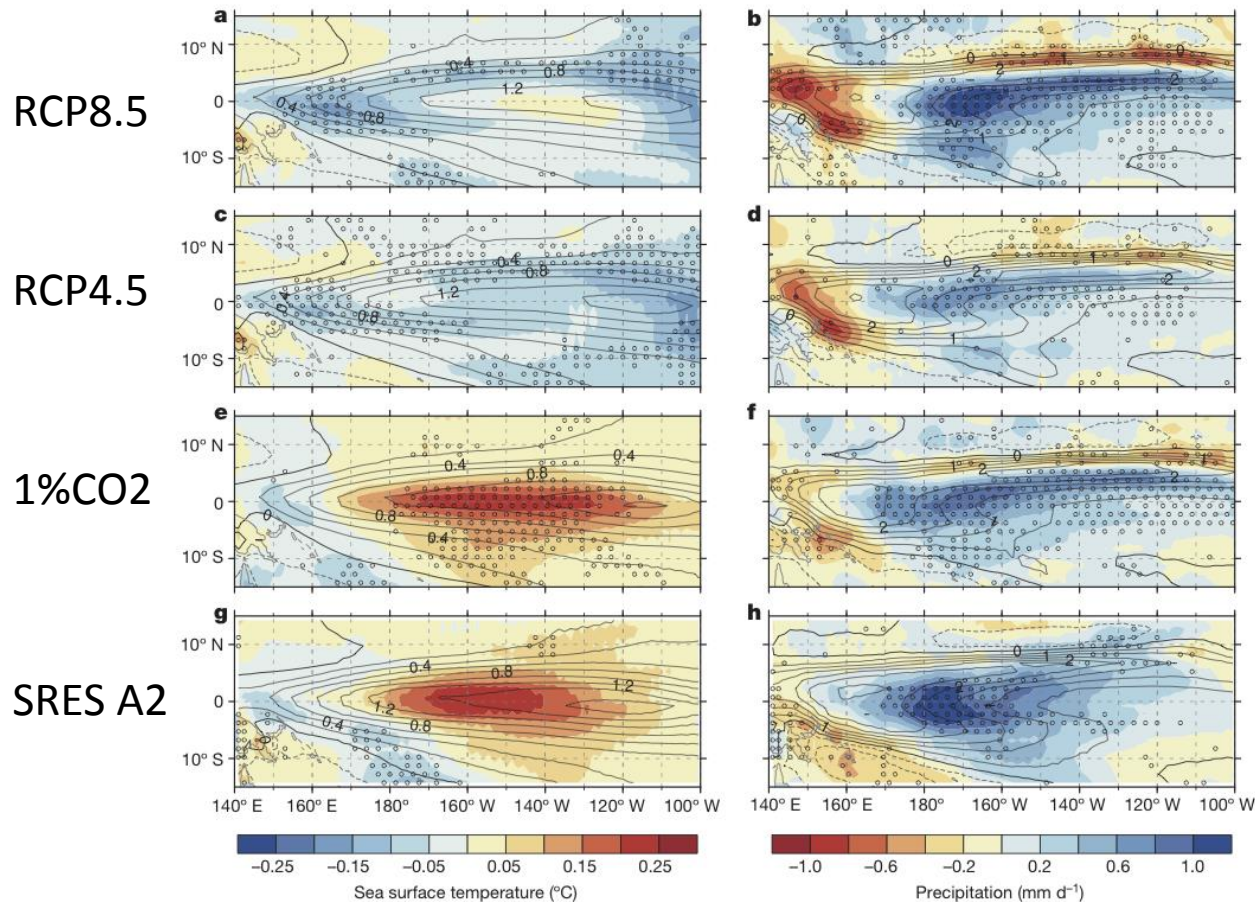
The seasonal mean rainfall, which is the sum of the annual mean and seasonal variations, combines the wet-get-wetter and warmer-get-wetter effects.

LETTER

doi:10.1038/nature12580

Robust twenty-first-century projections of El Niño and related precipitation variability

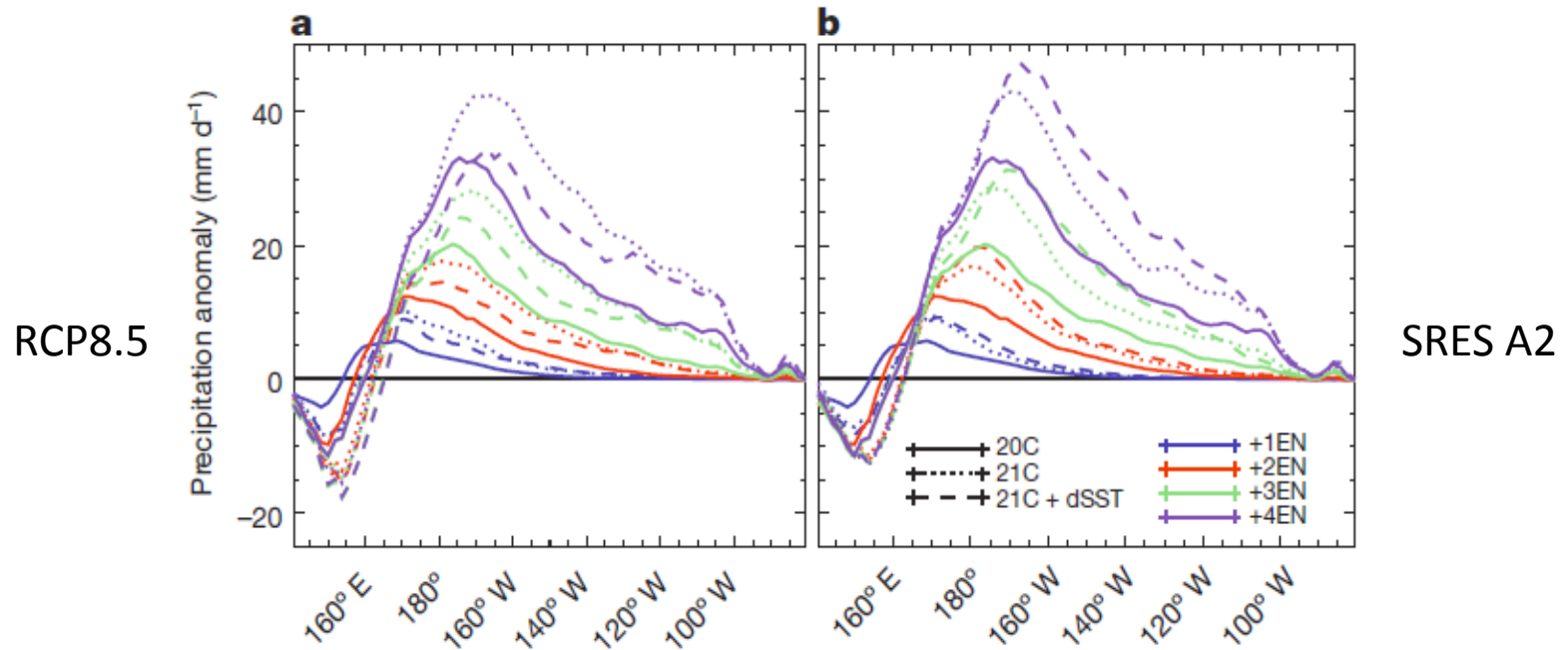
Scott Power¹, François Delage¹, Christine Chung¹, Greg Kociuba¹ & Kevin Keay¹



MME of 21 minus 20-century filtered SST (left) and precipitation (right) anomalies in El Niño years.

Background

Tropical precipitation associated future El Niño



The projected changes in El Niño precipitation anomalies will tend to intensify and expand the El Niño-driven drying in the west Pacific, and **reinforce El Niño-driven precipitation increases east of the dateline**, which are primarily determined by a **nonlinear response to the background-state SST** under the global warming (Power et al. 2013).

Scientific questions

- **How well do CMIP5 climate models simulate two types of El Niño?**
- **How would the changes (frequency and amplitude) of two types of El Niño under global warming?**
- **How would two types of El Niño affect the projected tropical precipitation changes under global warming?**

Outline

1. Introduction
2. Data and methodology
3. Model evaluation on two types of El Niño
4. Projected changes of EP- and CP-ENSO
(Frequency and Amplitude)
5. Robust changes of the tropical precipitation associated with ENSO
6. Summary and discussion

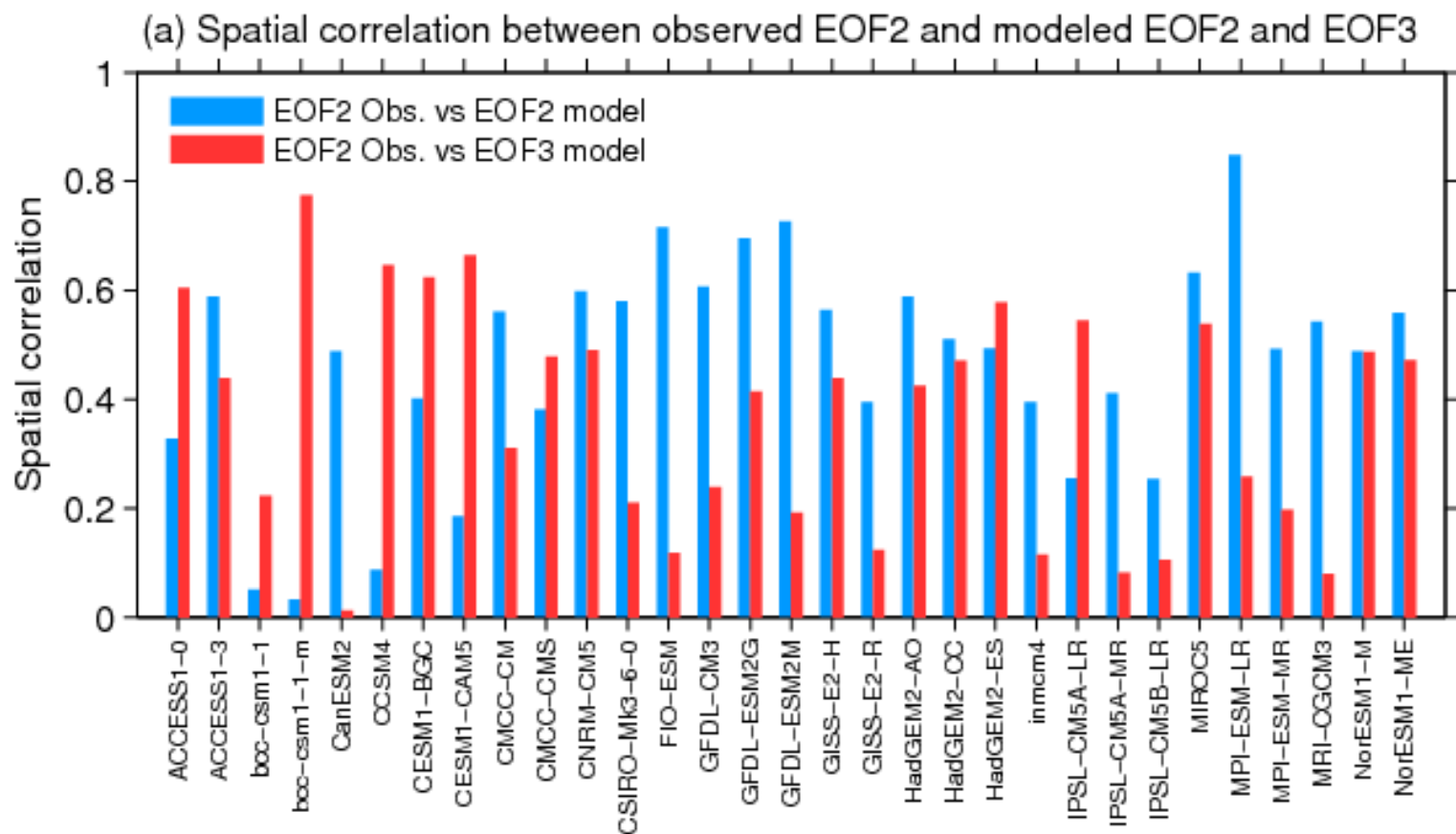
Data and Method

- ❑ **Observation:** HadISST (1950-1999)
- ❑ **Model data (31 CMIP5 coupled global climate models):**
 - Historical anthropogenic and natural forcings (historical, 1950-1999)
 - Future greenhouse gas under the Representative Concentration Pathway 8.5 emission scenarios (RCP8.5, 2050-2099)
- **Monthly mean data are smoothed with a 3-month running average to suppress subseasonal variability**
- **Remove the linear trend and decade signals (> 9 years)**
- **Empirical Orthogonal Function (EOF) analysis of the monthly observed and modeled SST anomalies**

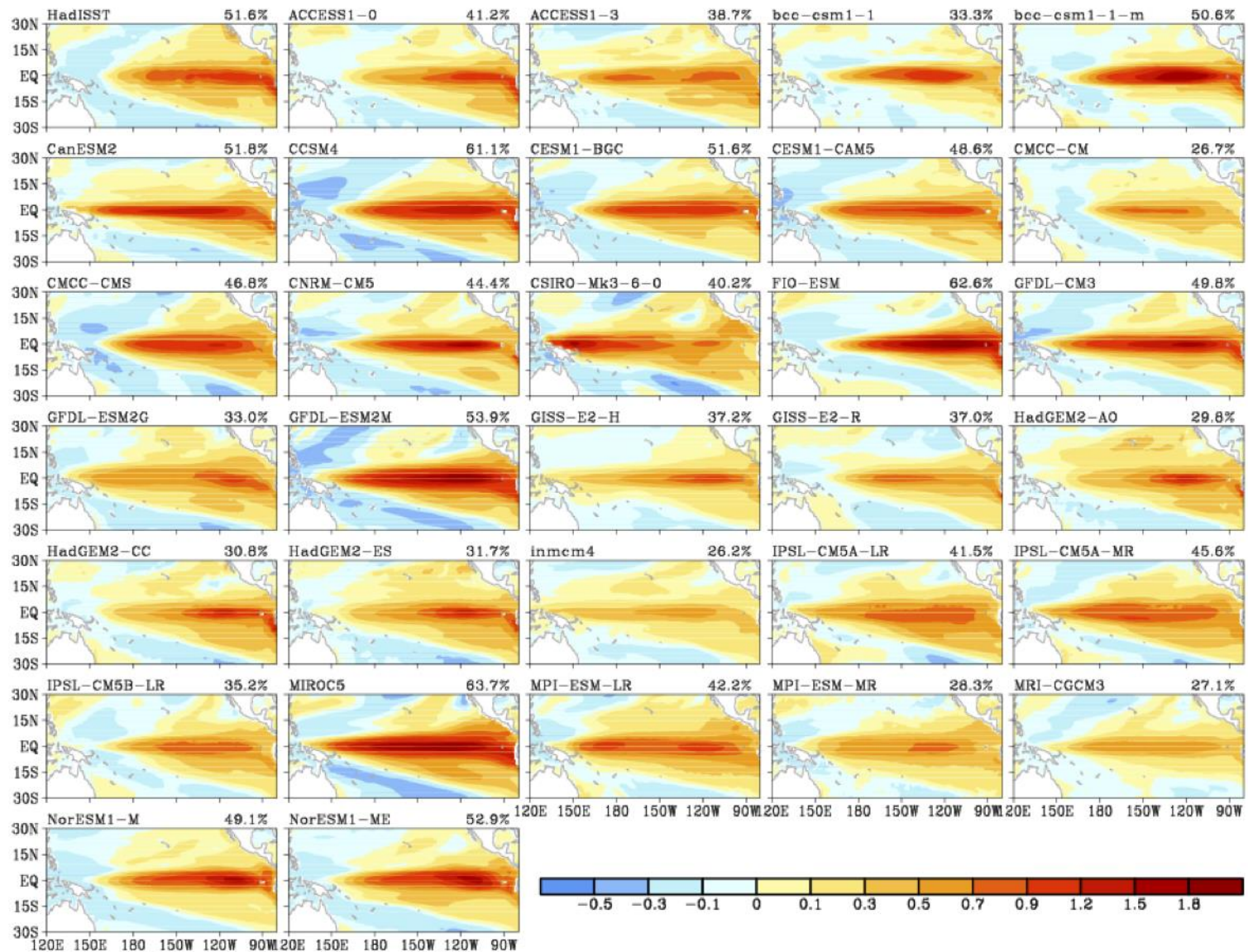
CMIP5 models used in the study

No.	Model	No.	Model	No.	Model
1	ACCESS1-0	12	CSIRO-Mk3-6-0	23	IPSL-CM5A-LR
2	ACCESS1-3	13	FIO-ESM	24	IPSL-CM5A-MR
3	bcc-csm1-1	14	GFDL-CM3	25	IPSL-CM5B-LR
4	bcc-csm1-1-m	15	GFDL-ESM2G	26	MIROC5
5	CanESM2	16	GFDL-ESM2M	27	MPI-ESM-LR
6	CCSM4	17	GISS-E2-H	28	MPI-ESM-MR
7	CESM1-BGC	18	GISS-E2-R	29	MRI-CGCM3
8	CESM1-CAM5	19	HadGEM2-AO	30	NorESM1-M
9	CMCC-CM	20	HadGEM2-CC	31	NorESM1-ME
10	CMCC-CMS	21	HadGEM2-ES		
11	CNRM-CM5	22	inmcm4		

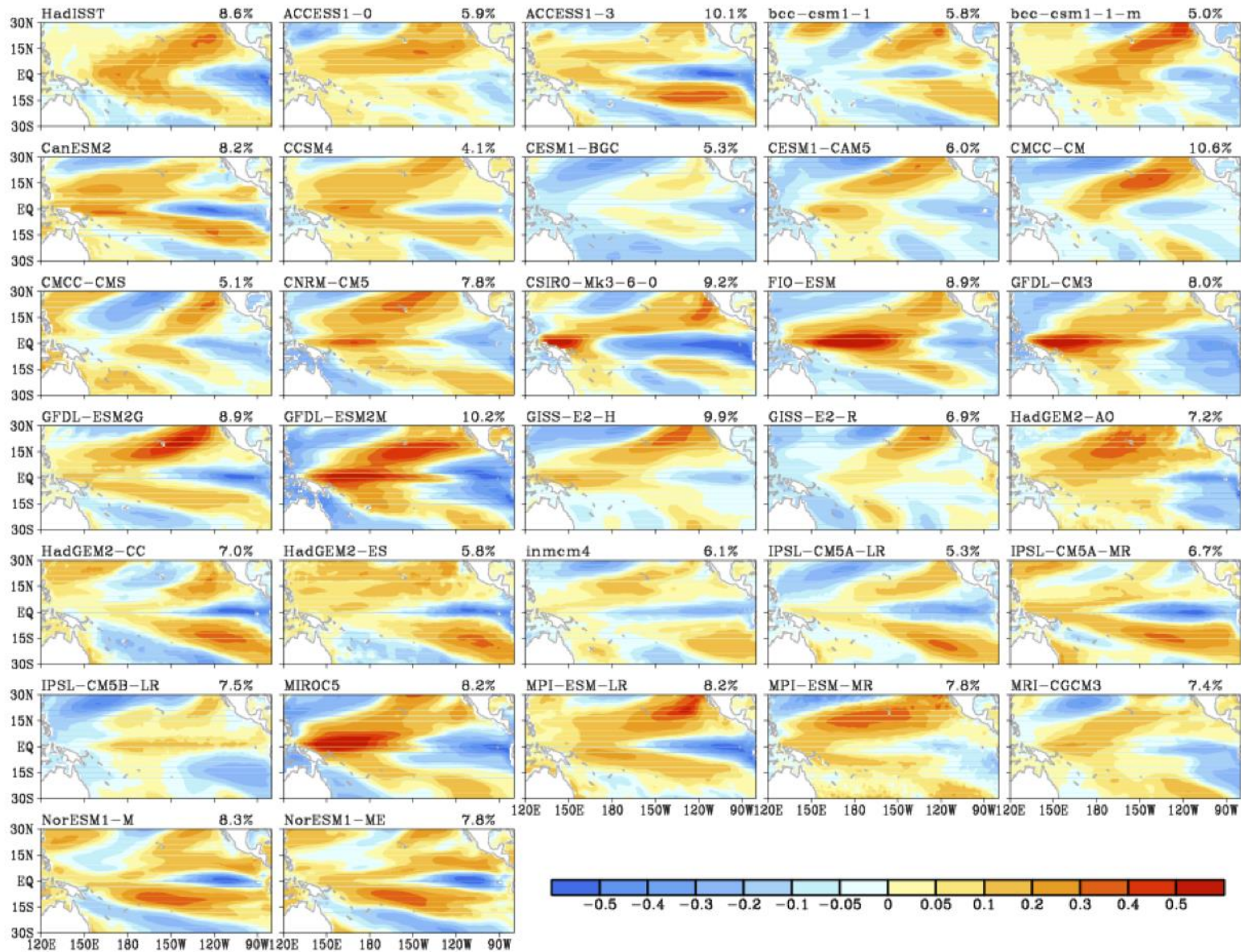
Spatial correlation coefficient between observed EOF2 and both EOF2 and EOF3 in each model



EOF patterns of SST anomalies for the **EP-El Niño** in the historical simulation



EOF patterns of SST anomalies for the CP-El Niño in the historical simulation

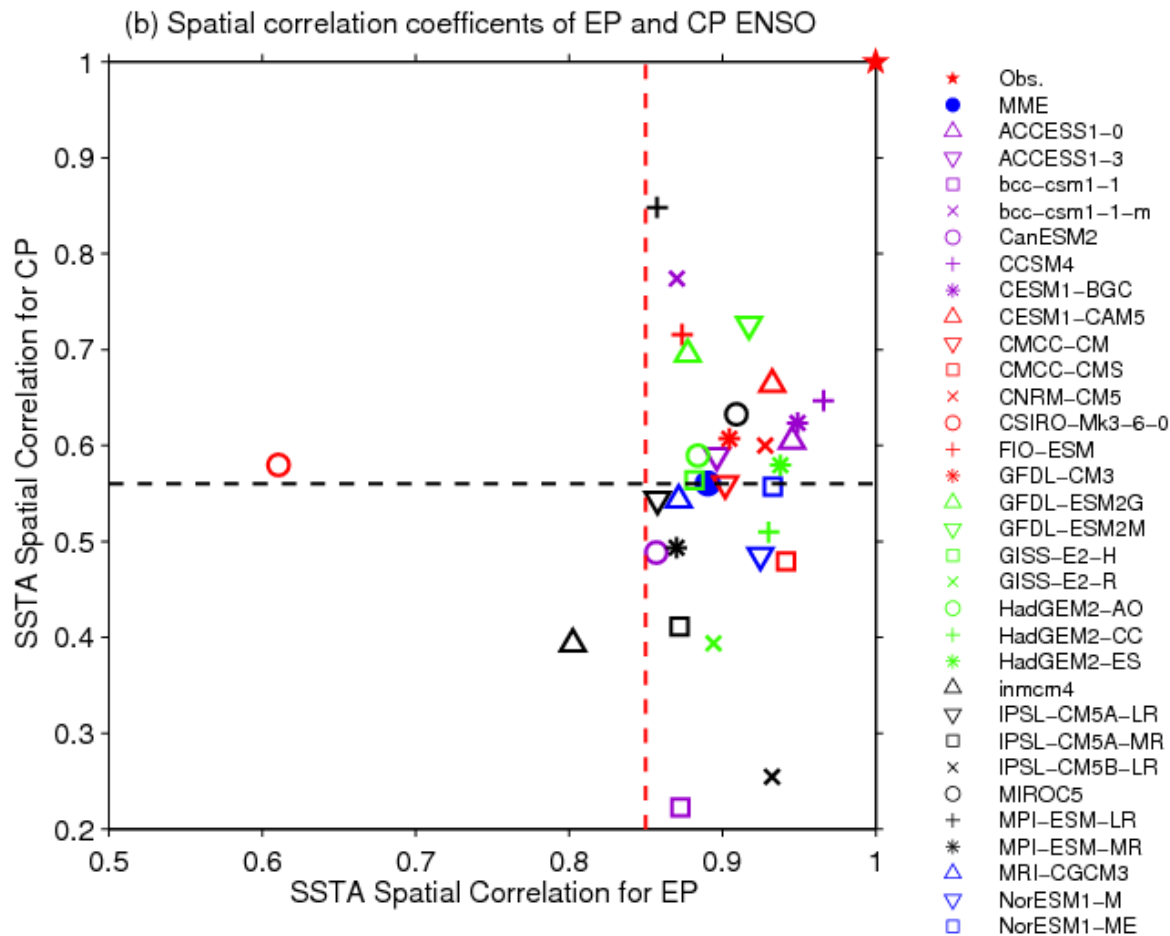


Selection criteria of CP-El Niño mode

- we chose the CP-El Niño modes that the observed and modeled EOFs are most closely resembled “Modoki” defined by Ashok et al (2007):

Types	EOF modes	Models
EP El Niño	EOF1	All models
CP El Niño	EOF2	Rest of models
	EOF3	ACCESS1-0, bcc-csm1-1, bcc-csm1-1-m, CCSM4, CESM1-BGC, CESM1-CAM5, CMCC-CMS, HadGEM2-ES, IPSL-CM5A-LR

Scatterplots of pattern correlations between the observed and model SST anomaly patterns for EP El Niño and CP El Niño



MMM of ACCs:

EP type: 0.89 ± 0.06

CP type: 0.56 ± 0.13

The CMIP5 models are found more capable of simulating the observed EP El Niño but less capable of the observed CP El Niño mode.

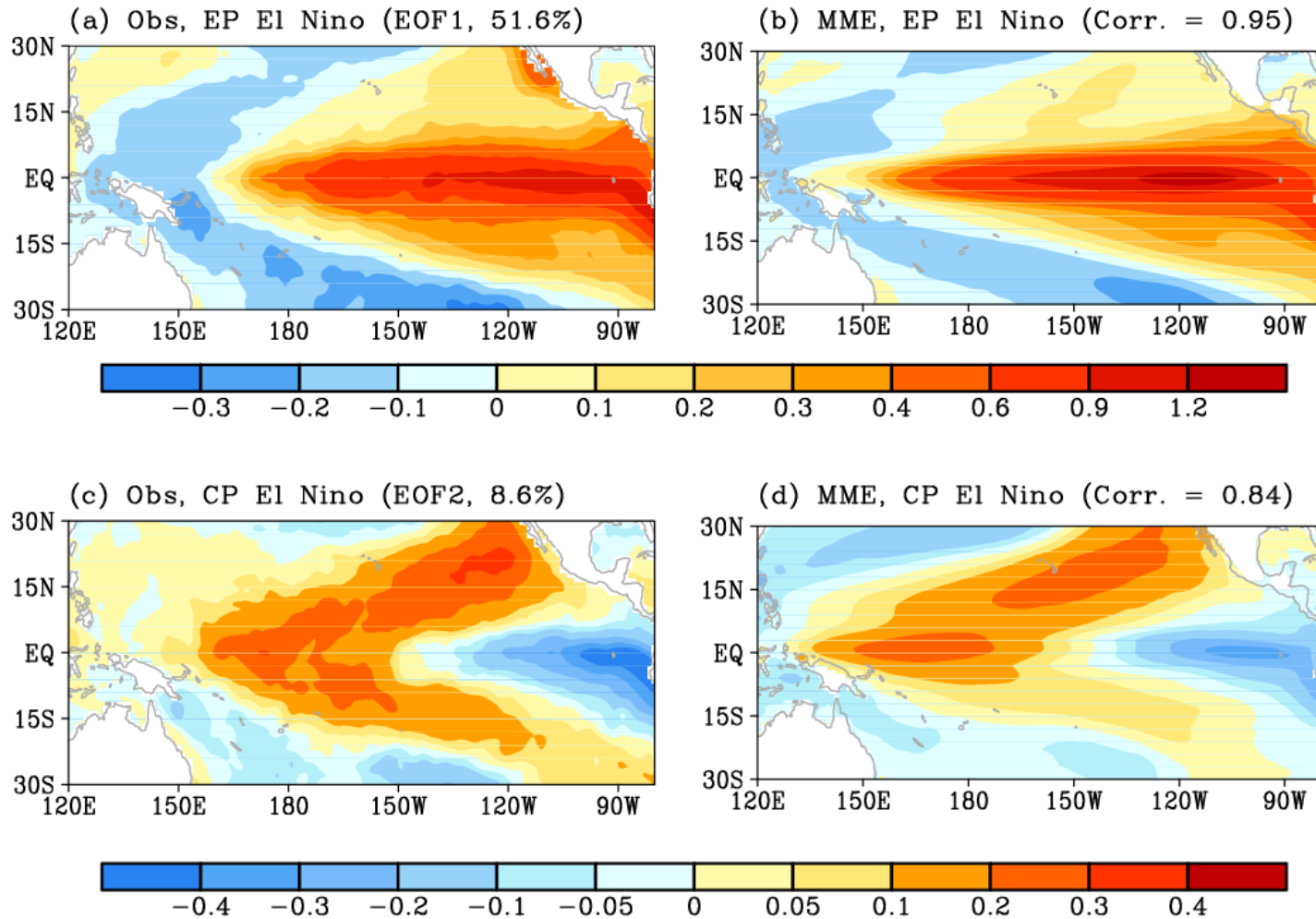
Selecting CMIP5 Models which can simulate both the observed EP- and CP-El Niño well

Criteria:

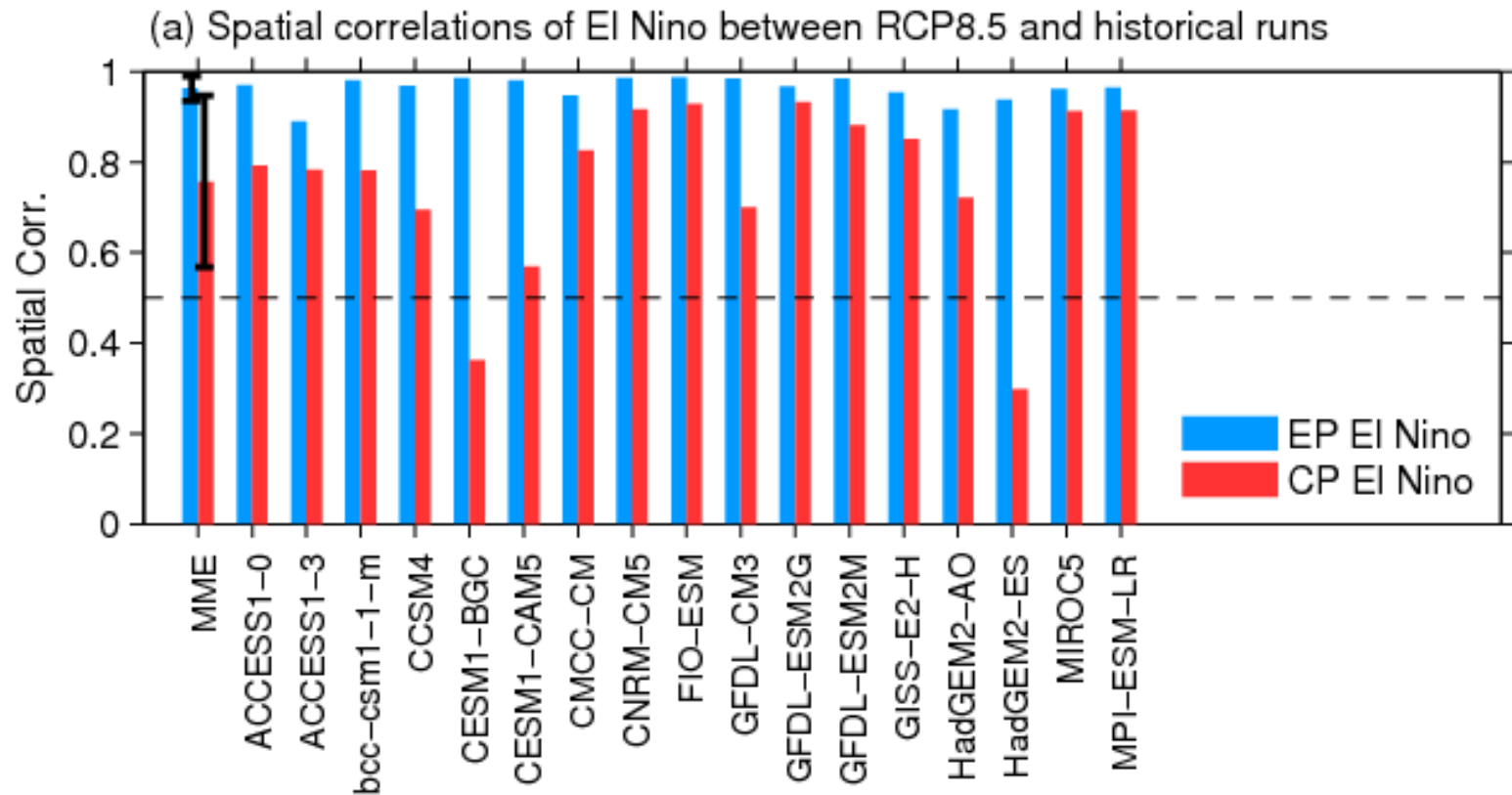
Pattern Correlation coefficients are larger than 0.56
(The value is the multi-model mean for the CP El Niño).

No.	Model	No.	Model	No.	Model
1	ACCESS1-0	7	CMCC-CM	13	GISS-E2-H
2	ACCESS1-3	8	CNRM-CM5	14	HadGEM2-AO
3	bcc-csm1-1-m	9	FIO-ESM	15	HadGEM2-ES
4	CCSM4	10	GFDL-CM3	16	MIROC5
5	CESM1-BGC	11	GFDL-ESM2G	17	MPI-ESM-LR
6	CESM1-CAM5	12	GFDL-ESM2M		

Observed and model simulated EP and CP El Niño in 1950-1999



Spatial correlation of EP and CP El Niño between historical and RCP8.5 simulations



Criteria of EP and CP El Niño events

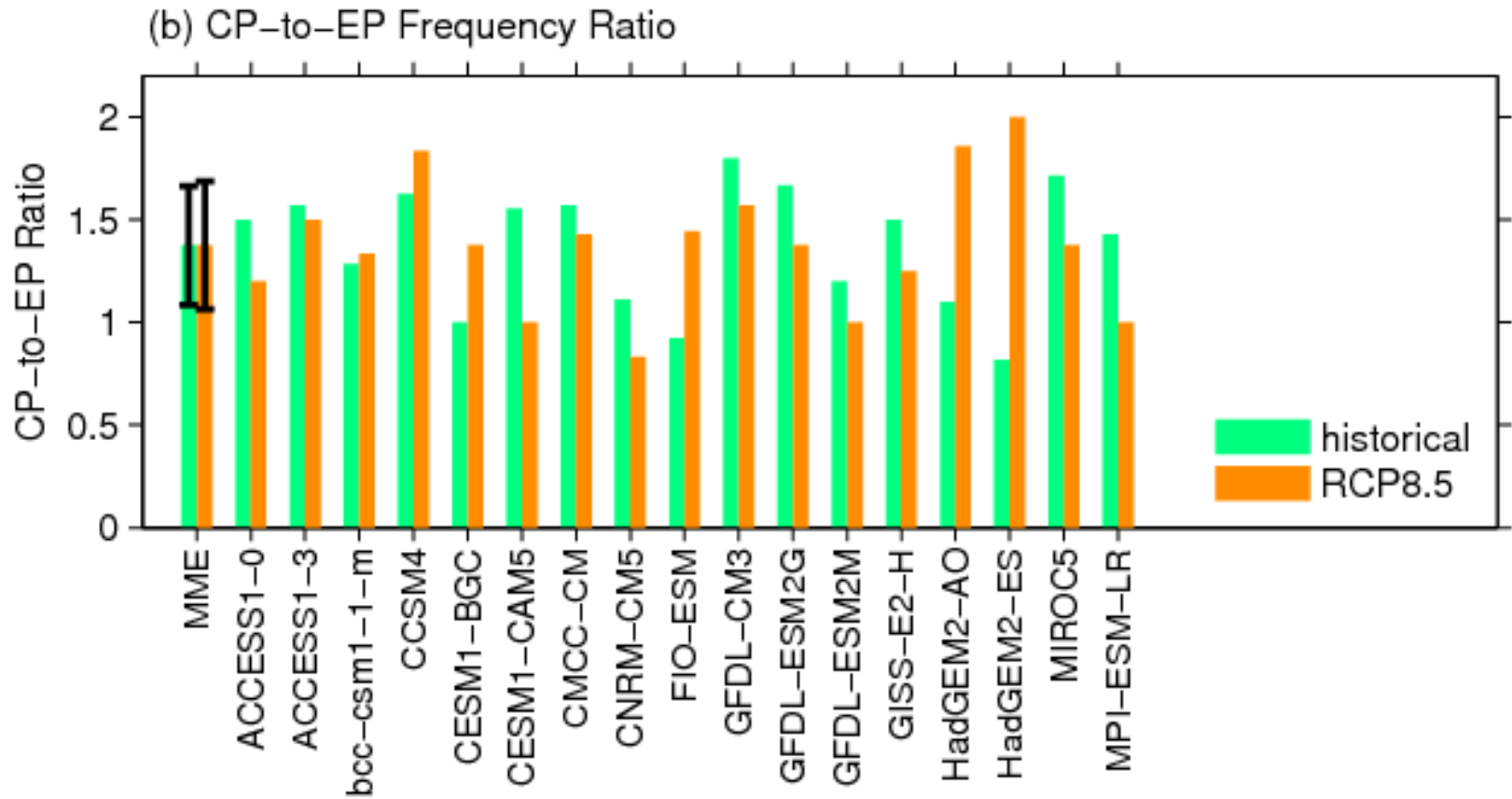
- **The EP El Niño events:**

The winter mean (November to March, NDJFM) PC1 value is greater than one standard deviation.

- **The CP El Niño events:**

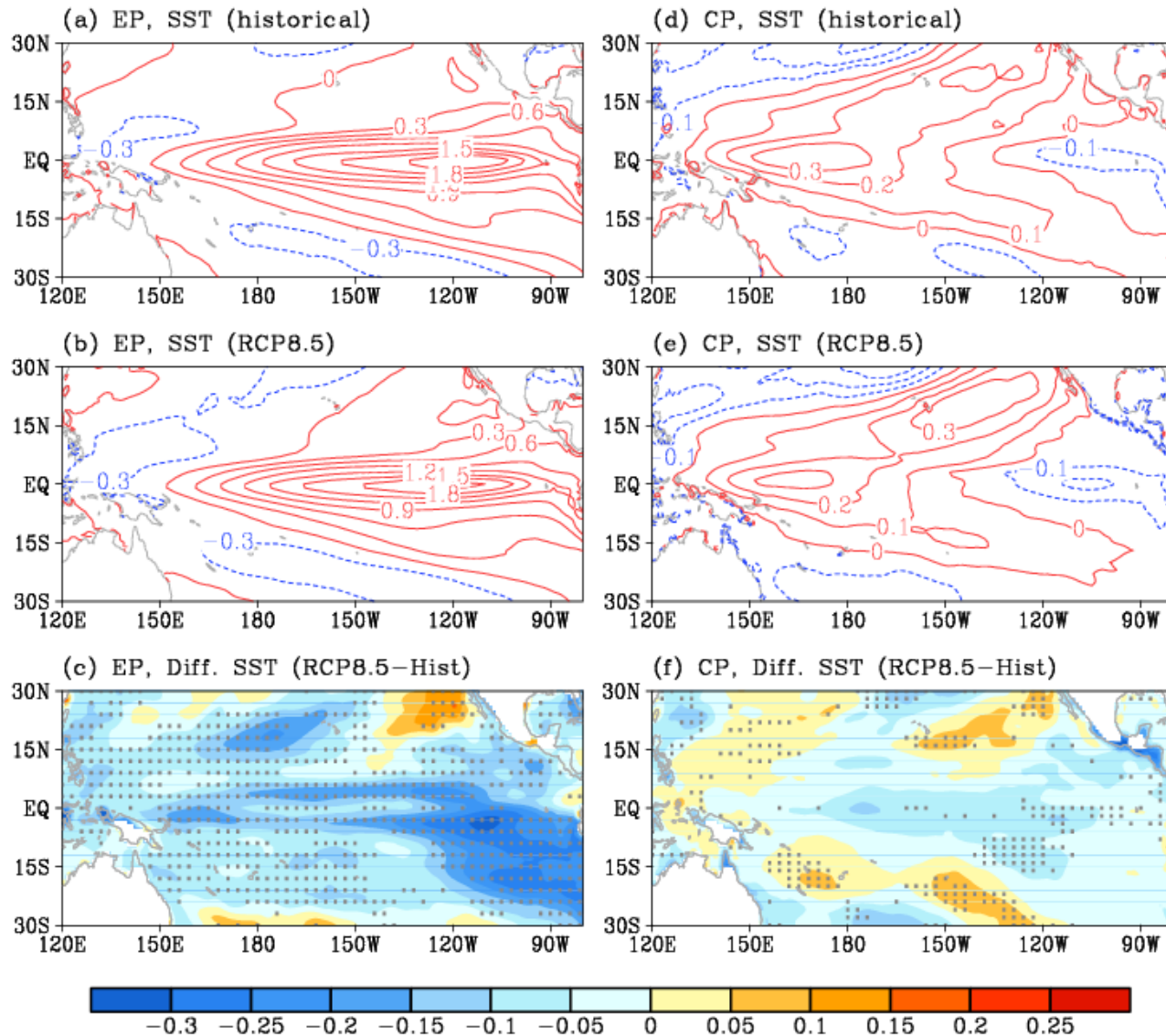
The winter mean (November to March, NDJFM) PC2 value is greater than 0.8 standard deviation.

Great uncertainty in CP-to-EP ratio in the future

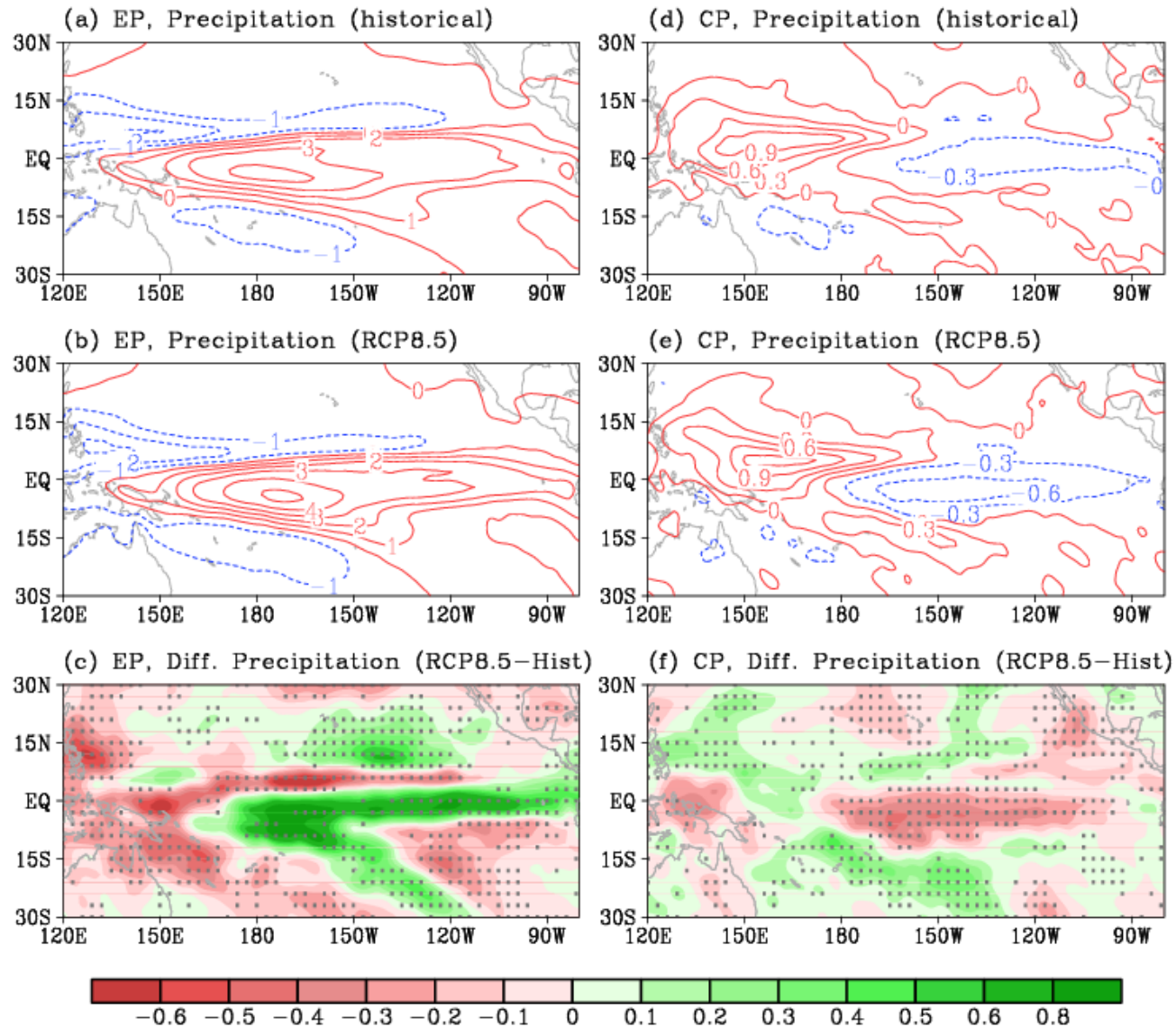


MME of differences between 21C (RCP8.5) and 20C (Historical)

SST anomalies

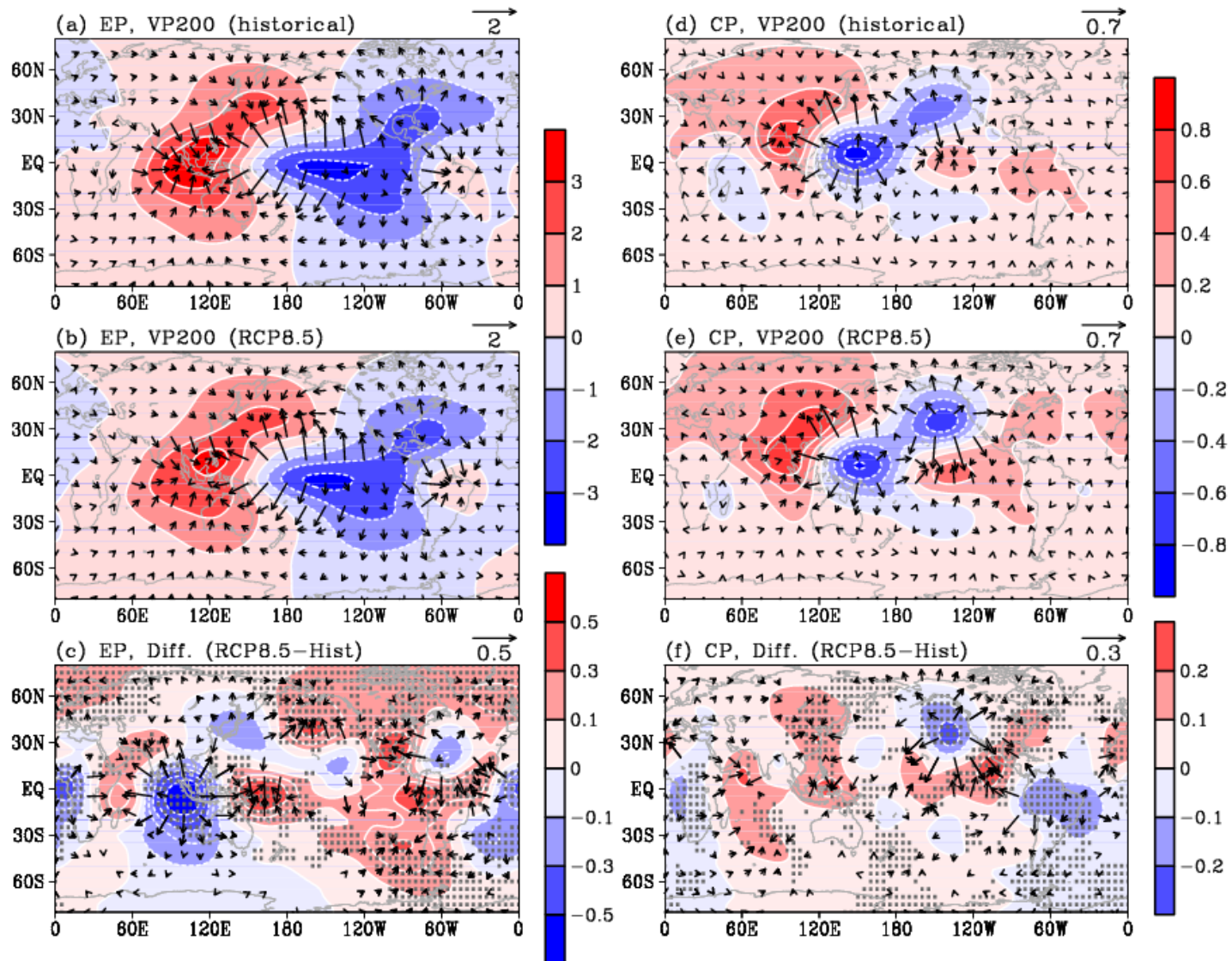


MME of differences between 21C (RCP8.5) and 20C (Historical) precipitation anomalies



MME of differences between 21C (RCP8.5) and 20C (Historical)

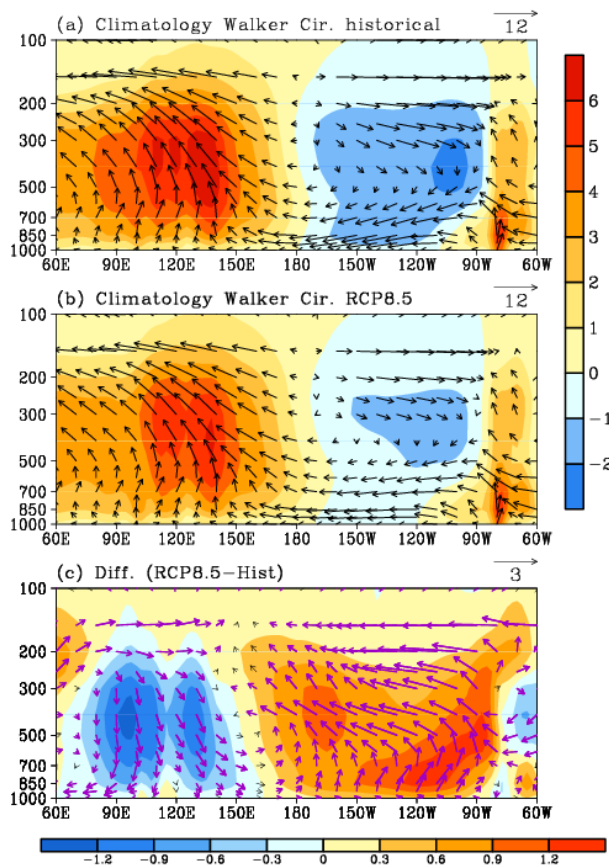
Velocity Potential anomalies at 200 hPa



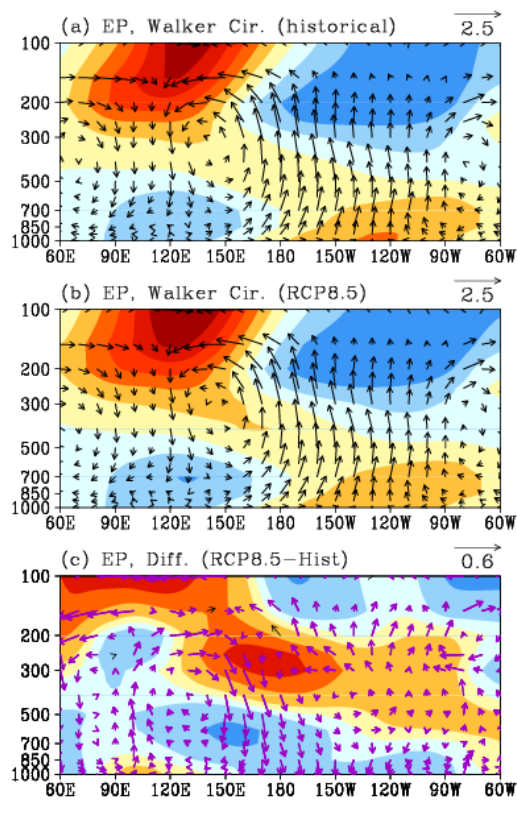
MME of differences between 21C (RCP8.5) and 20C (Historical)

Walker circulation Averaged from 5S to 5N (vector) and vertical velocity (shaded)

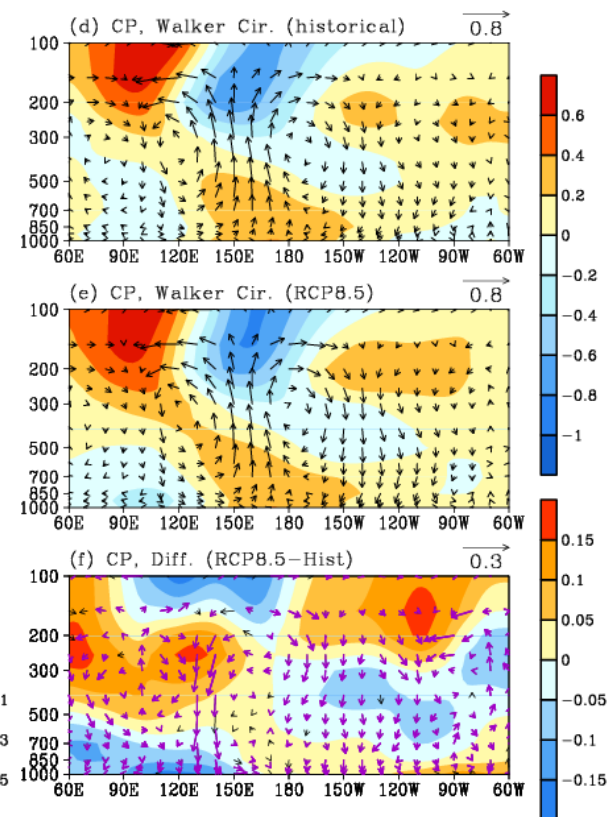
Mean state



EP El Niño



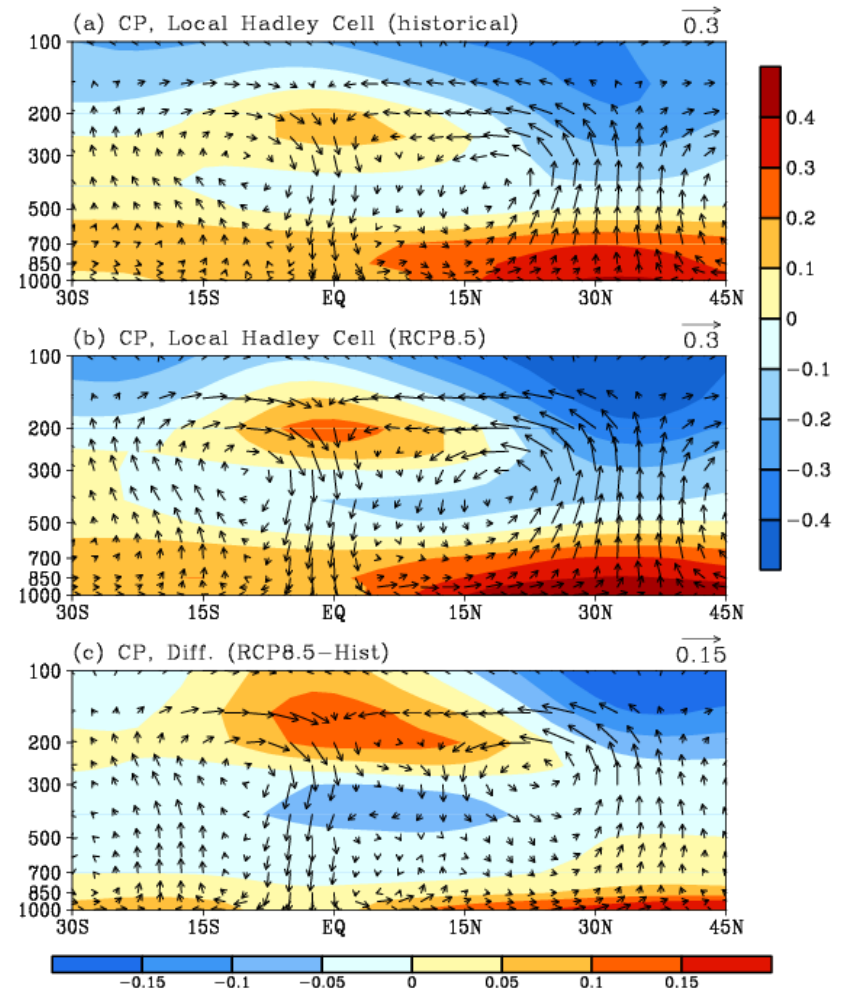
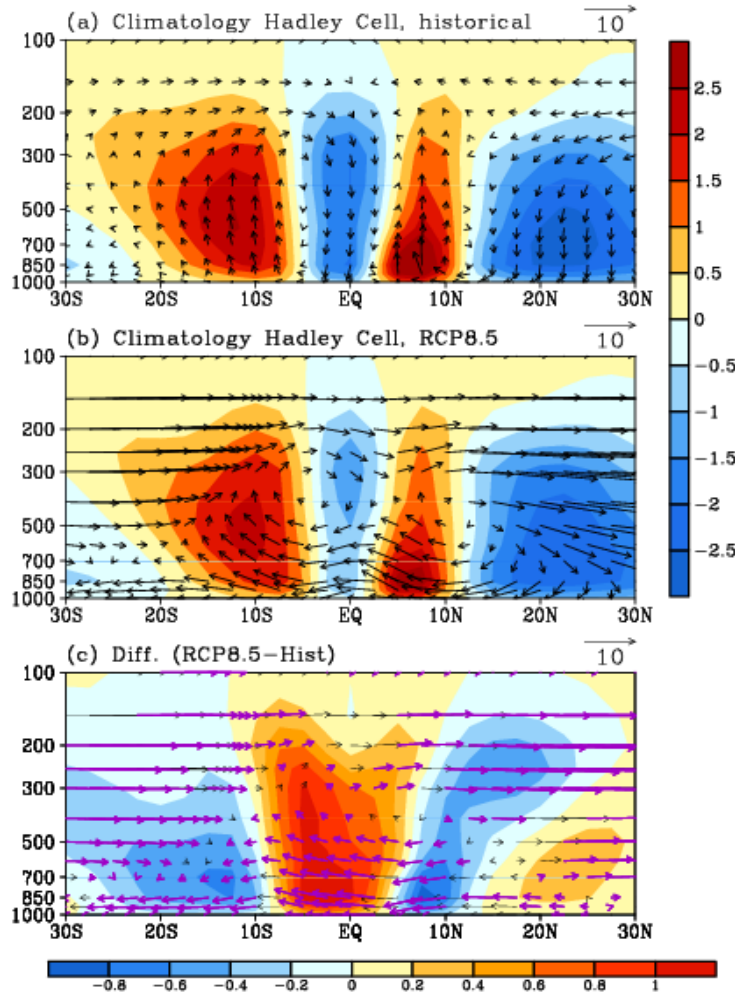
CP El Niño



MME of differences between 21C (RCP8.5) and 20C (Historical) Local Hadley Cell (vector) and vertical velocity (shaded)

Mean state

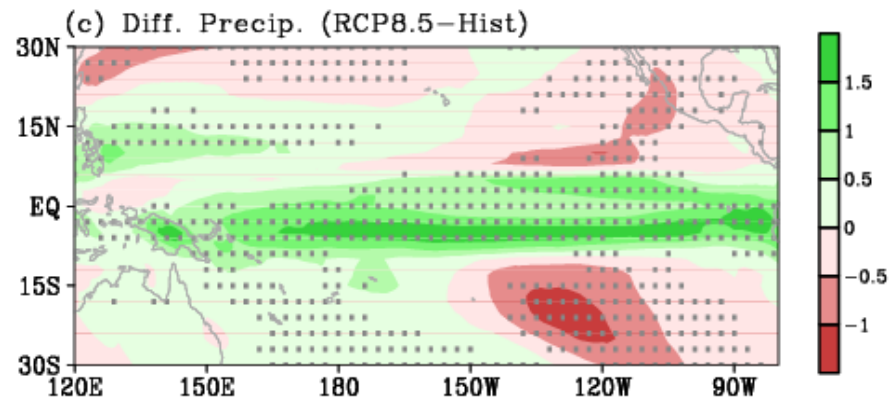
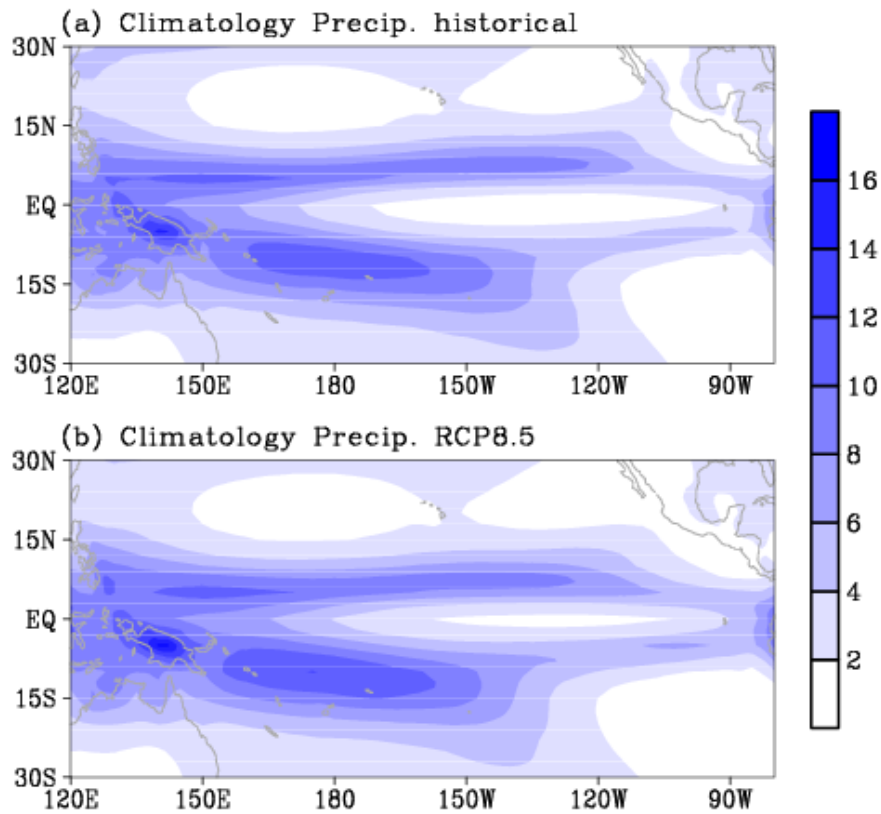
CP El Niño



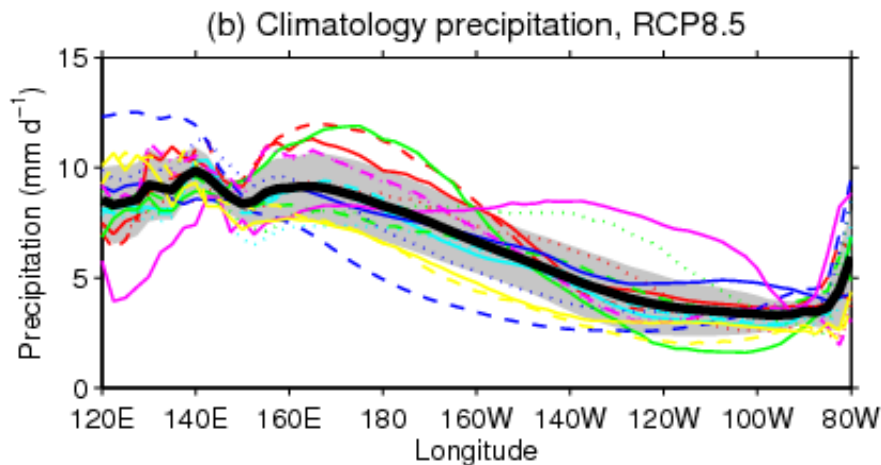
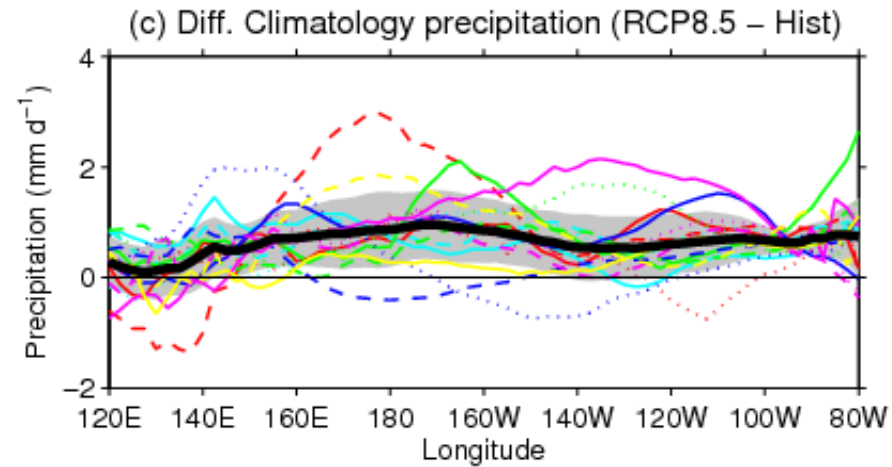
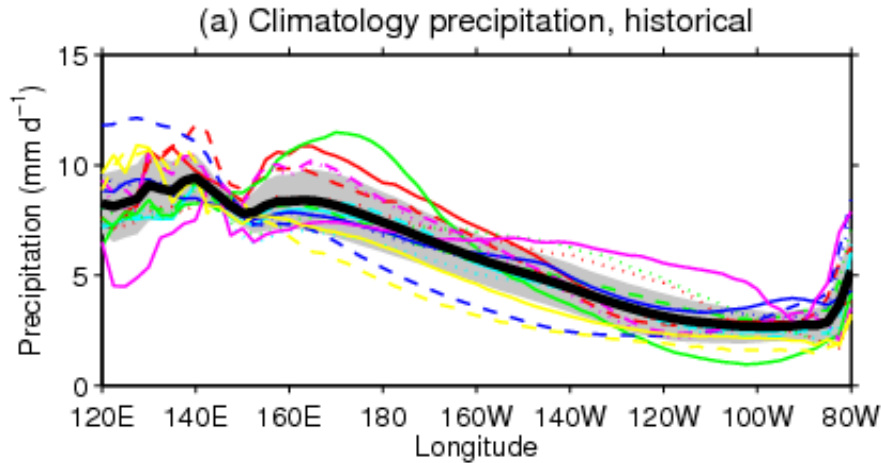
Averaged from 180 to 100W

Scaled by -50

MME climatology precipitation in the 21C (RCP8.5) and 20C (Historical) and their differences



Zonal structures of the winter climatology precipitation averaged between 10S to 5N in the 20C (Historical) and 21C (RCP8.5) and their differences



- Multi-Model Mean
- ACCESS1-0
- - ACCESS1-3
- ... bcc-csm1-1-m
- CCSM4
- - CESM1-BGC
- ... CESM1-CAM5
- CMCC-CM
- - CNRM-CM5
- ... FIO-ESM
- GFDL-CM3
- - GFDL-ESM2G
- ... GFDL-ESM2M
- GISS-E2-H
- - HadGEM2-AO
- ... HadGEM2-ES
- MIROC5
- - MPI-ESM-LR

Shaded regions represent the spread of the 17 CMIP5 models included in the ensemble mean.

Summary

- The CMIP5 models are found more capable of simulating the observed EP El Niño (100%) but less capable of the observed CP El Niño (17 out of 31).
- The EP El Niño intensity is found to decrease in the future, while the MME changes of CP El Niño SST intensity is not robust changes under global warming. There also exists no consensus on how the relative frequency of CP to EP El Niño may change in the future.
- Robust projected changes in the EP and CP El Niño-driven tropical precipitation variability are found in the tropical Pacific. Under a warmer background climate, stronger positive (negative) rainfall anomalies are found in the tropical eastern and central (central-to-western) Pacific during EP El Niño, whereas rainfall over the equatorial eastern Pacific seems to be even more suppressed when CP El Niño occurs.
- The patterns of the projected precipitation changes are primarily determined by the El Niño types, but robust projected changes in precipitation anomalies during El Niño years depend strongly on the background-state precipitation response to global warming.

Observed and model simulated EP and CP El Niño related precipitation anomalies

