Changes in the El Nino's spatial structure under global warming

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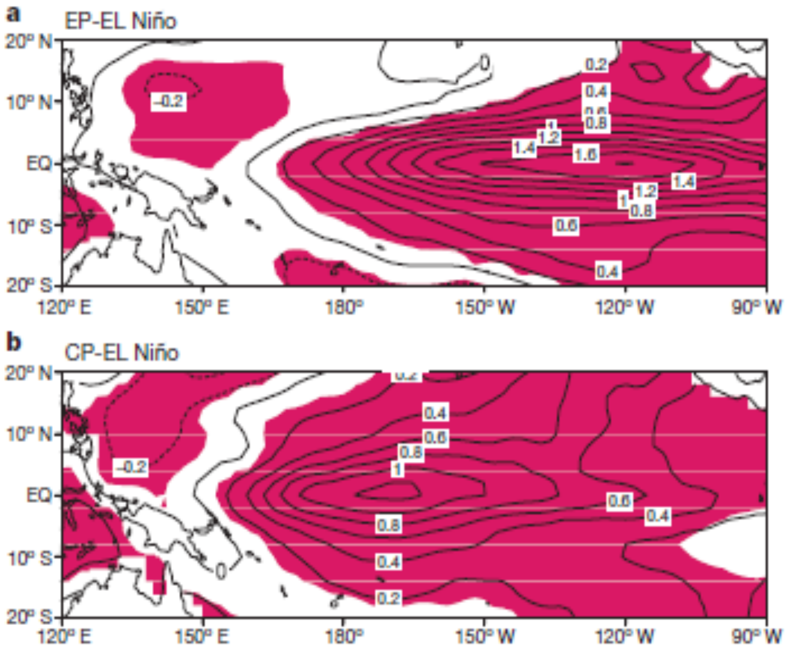
• Changes in El Nino spatial structure



Yeh et al. (2009)

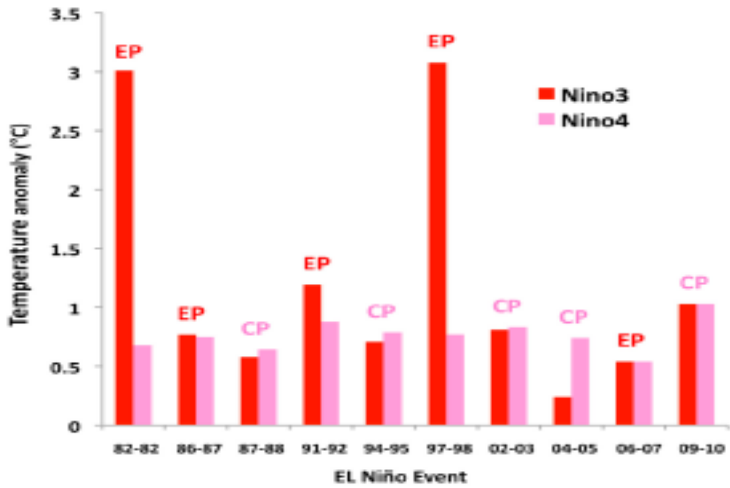


Figure 1. Nino3 (red) and Nino4 (pink) SST anomalies for El Niños between 1980 and 2010. Values are for the peak December to January season. Eastern Pacific (EP) and central Pacific (CP) events are labeled according to various indices described in the text.

McPhaden et al. (2009)

• Why the spatial structure of El Nino matters?

• Impact and teleconnections

- Central Pacific El Nino and decadal climate change in the North Pacific Ocean (Di Lorenzo et al. 2010, Nature Geoscience)♪
- Influence of El Nino Modoki on spring rainfall over South China (Feng et al. 2011, JGR)
- Effects of El Nino Modoki on winter precipitation in Korea (Kim et al. 2012, Climate. Dyn.)
- Teleconnections associated with the intensification of the Australia monsoon during the El Nino Modoki events (Taschetto et al. 2010)
- Central Pacific El Nino, the "Subtropical Bridge" and Eurasian Climate (2012, GRL)
- On the impact of central Pacific warming events on Atlantic tropical storm activity (Lee et al., 2010, GRL)
- Different El Nino Types and Tropical cyclone landfall in East Asia (Wang et al. 2013, J. Climate)

• Fundamental question

Which mechanisms are responsible for the changes in the spatial structure of El Nino (in climate models) ?

- Air-sea coupling strengths in the eastern Pacific

- Bjerknes feedback in the tropical Pacific

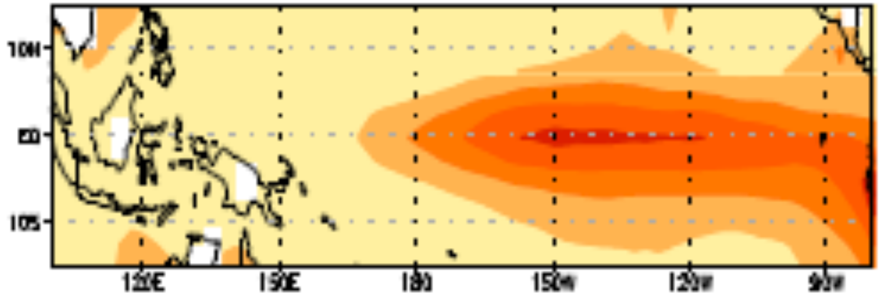
- Tropical Pacific mean state

• Air-sea coupling strengths in the eastern Pacific 1

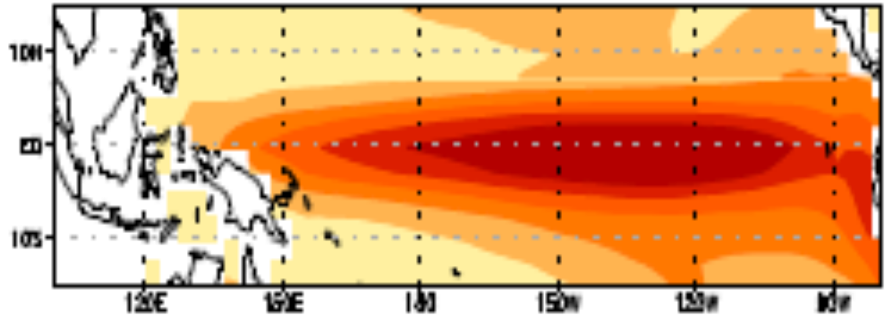
Table 1. Model Descriptions used in this study.

Modeling Center	Model Number	CMIP3 Model Name	CMIP5 Model Name
CCCma	1	CCCMA-CGCM3.1 (t63)	CanESM2
NCAR	2	CCSM3	CCSM4
CNRM-CERFACS	3	CNRM-CM3	CNRM-CM5
CSIRO-QCCCE	4	CSIRO-MK3.5	CSIRO-Mk3-6-0
LASG/IAP;LASG-CESS	5	FGOALS-g1.0	FGOALS-g2
NOAA GFDL	6	GFDL-CM2.1	GFDL-ESM2G
MOHC	7	UKMO-HadCM3	HadGEM2-CC
MOHC	8	UKMO-HadGEM1	HadGEM2-ES
INM	9	INMCM3-0	INM-CM4
IPSL	10	IPSL-CM4	IPSL-CM5A-LR
MIROC	11	MIROC3.2(hires)	MIROC-ESM
MRI	12	MRI-CGCM2-3-2a	MRI-CGCM3

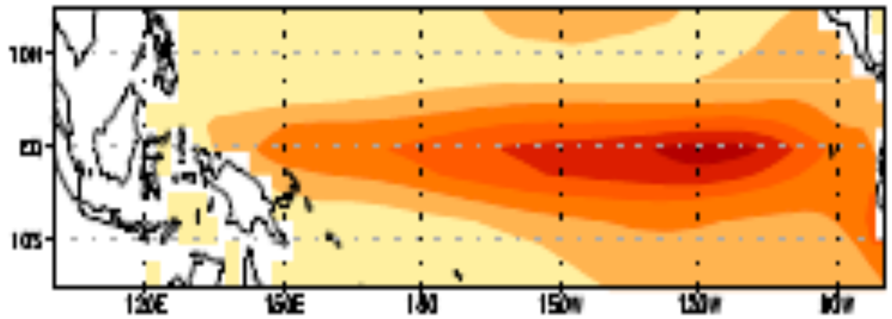
(a) OBS ERSST (1950-2000)♪



(b) MME CMIP3 Historical run (1950-2000)♪



(b) MME CMIP5 Historical run (1950-2000)♪



• Air-sea coupling strengths in the eastern Pacific 2

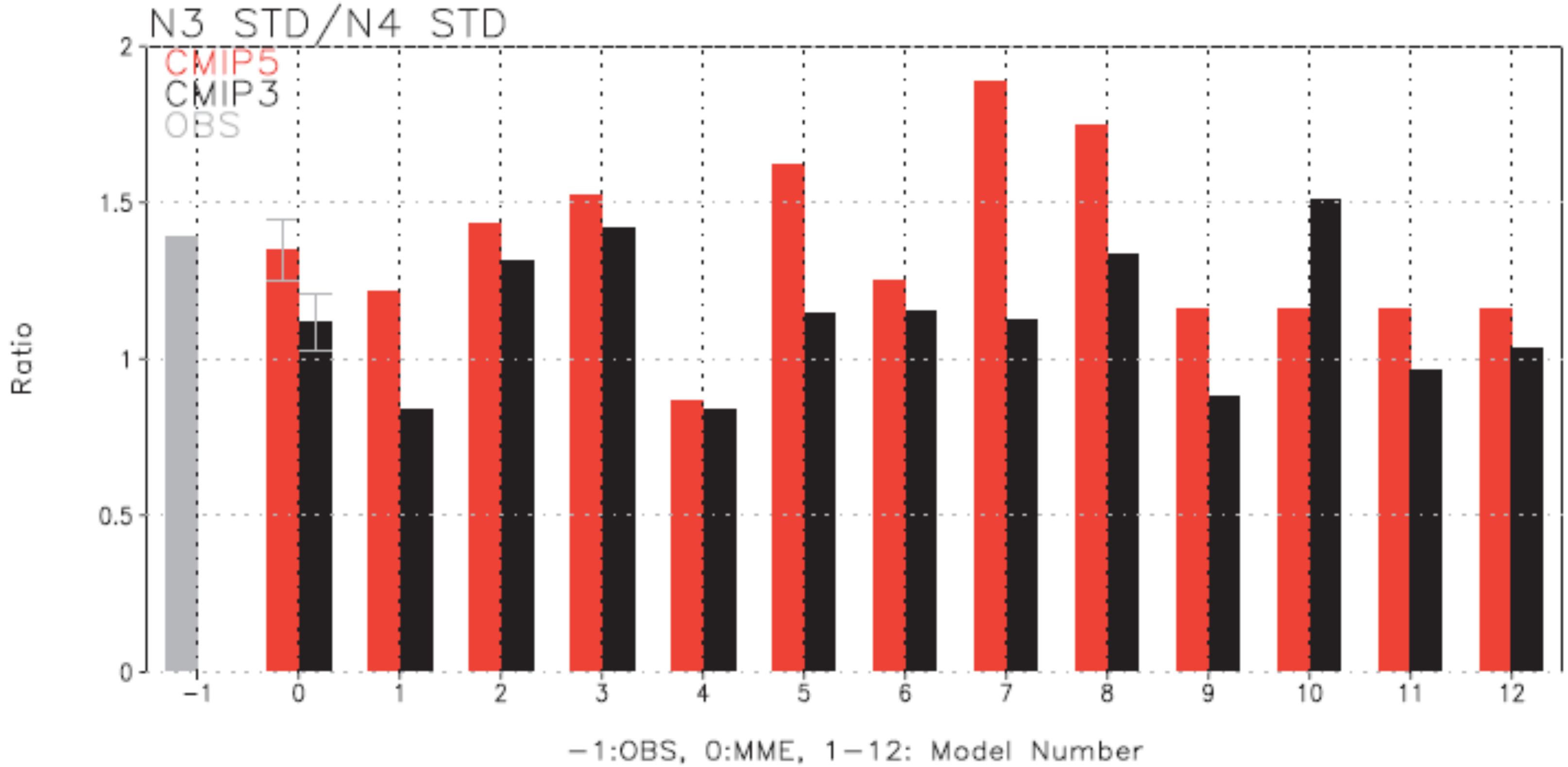


FIG. 3. As in Fig. 2, but for the ratio of the STD of the Niño-3 index to that of the Niño-4 index from CMIP5 (red bars) and CMIP3 (black bars) models during 1950–2000.

• Air-sea coupling strengths in the eastern Pacific 3

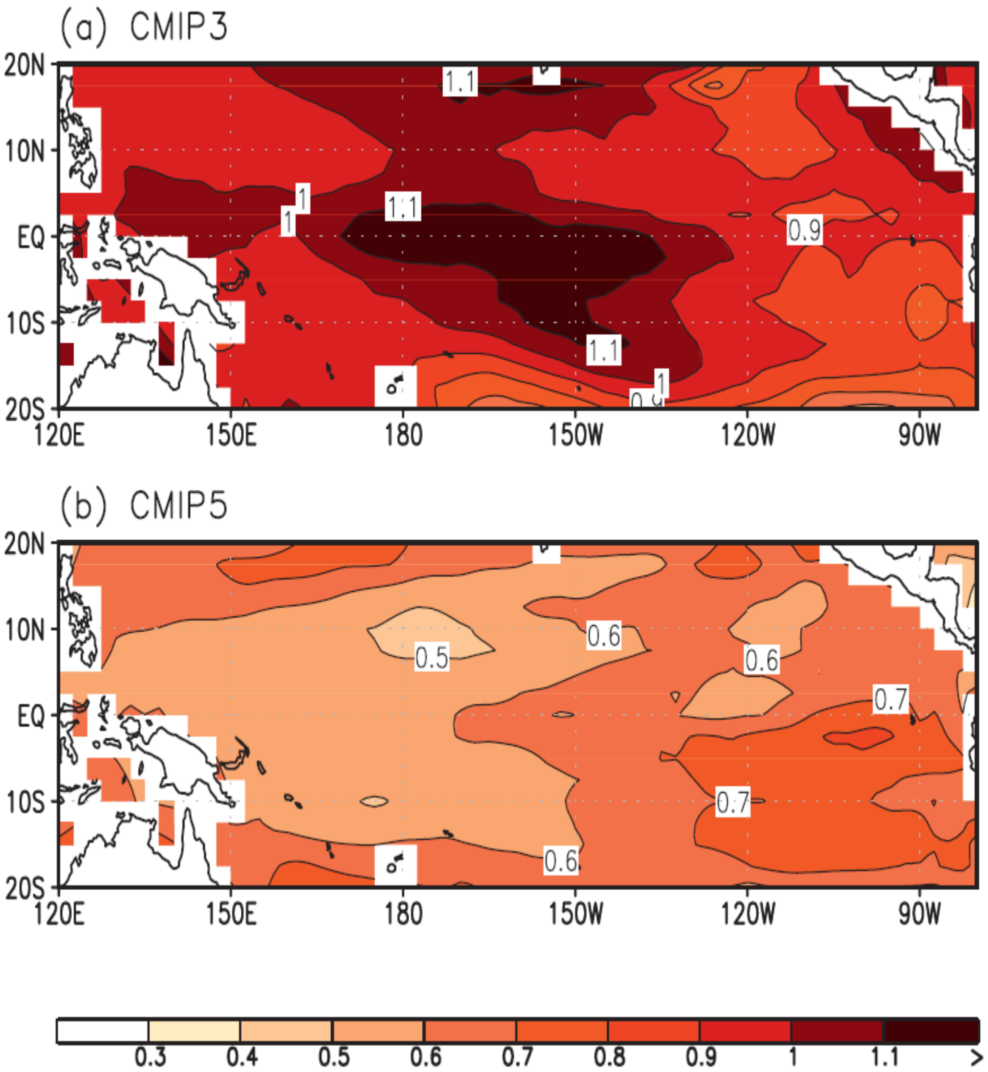


FIG. 1. The linear trends of SSTA [°C (100 yr)$^{-1}$] from 1950 to 2000 in (a) the CMIP3 MME and (b) the CMIP5 MME.

Linear trends of SST in the CMIP 3 MME♪

Linear trends of SST in the CMIP 5 MME♪

• Air-sea coupling strengths in the eastern Pacific 4

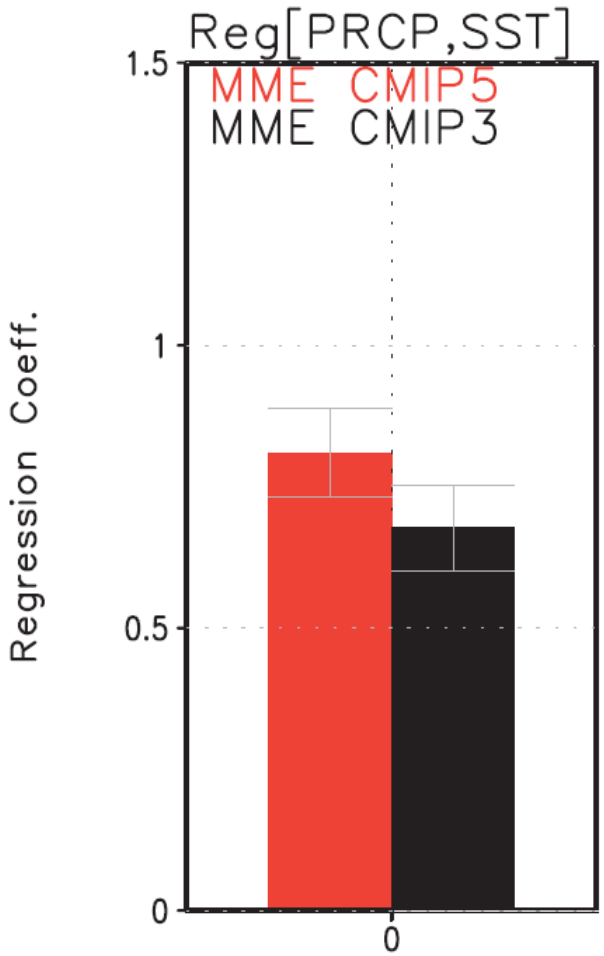


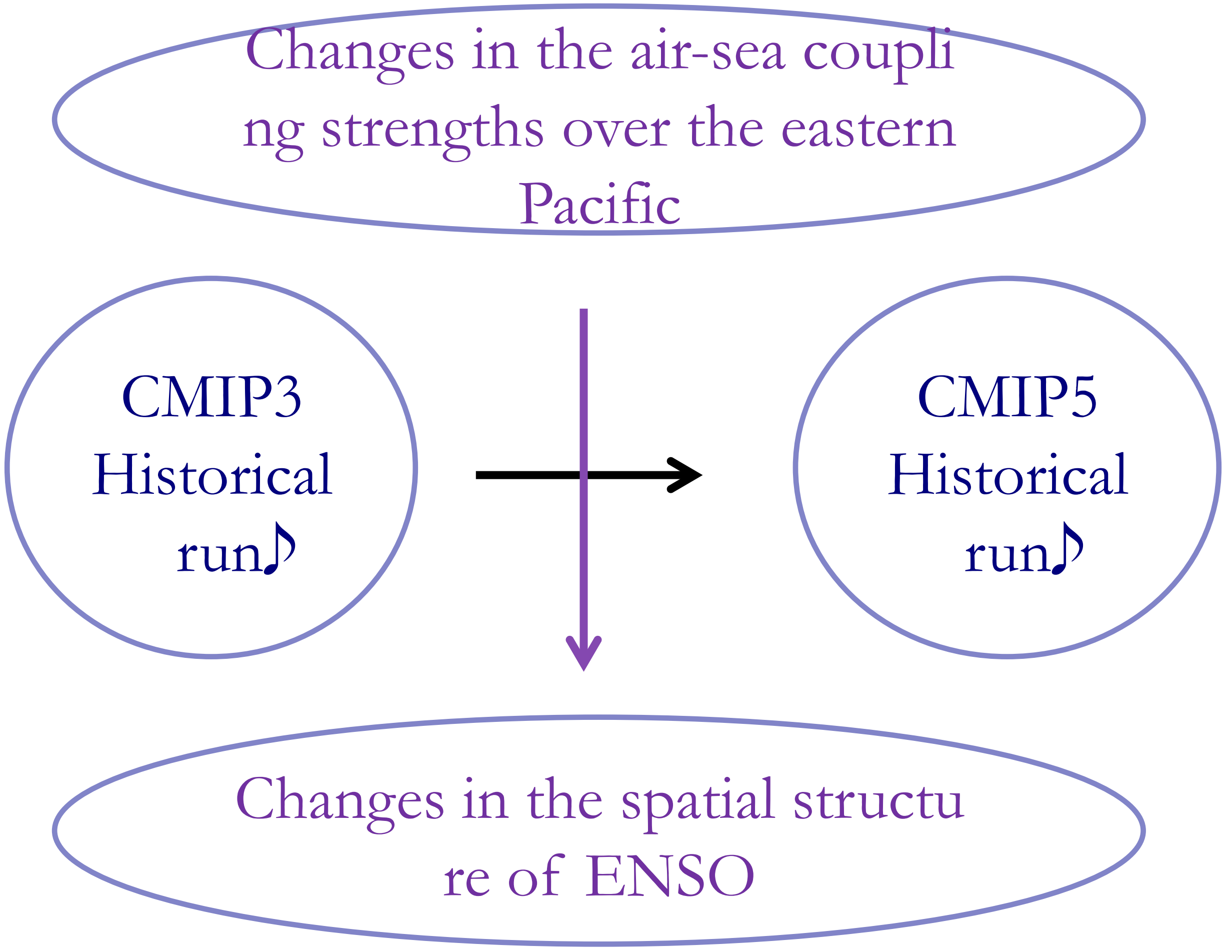
FIG. 4. The MME of precipitation regression coefficients over the Niño-3 region with respect to the Niño-3 SSTA (mm day^{-1} $°C^{-1}$) during 1950–2000 using CMIP3 (black bar) and CMIP5 (red bar) CGCMs. The gray error bars denote 90% confidence level using the STD of ratio values among CMIP models.

The SSTA variability in the eastern tropical Pacific can be largely ch anged by air–sea coupled processes (Ch oi et al. 2009).♪

A greater amount of warming in the easter n tropical Pacific relative to the western tro pical Pacific in CMIP5 can amplify the SST A variability in the eastern tropical Pacific t hrough enhanced air-sea coupled processes …♪

• Changes in El Nino spatial structure

…. An enhancement of air-sea coupling strengths over the eastern P acific may contribute to increase the SSTA variability in the eastern P acific♪



• Bjerknes feedback in the tropical Pacific 1

There exist physical feedback processes that lead to changes in ENS O amplitude. These processes are associated with the changes in ther mocline feedback and surface zonal advective feedback, which are als o associated with a Bjerknes feedback♪

$$\tau_x' = \alpha \, SST_{E-W} \quad (1)$$

τ_x' : Anomalous zonal wind stress over the central Pacific♪

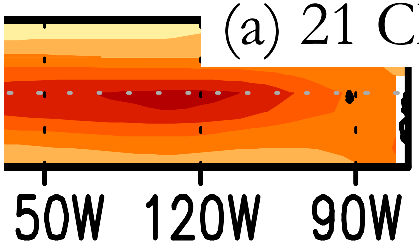
SST_{E-W} : the east minus west anomalous SST difference.♪

• Bjerknes feedback in the tropical Pacific 2

Archive	Modeling Group	CMIP ID	Integration period
21 CMIP5 Historical run	CSIRO-BOM	**ACCESS1-0**	156 year
	BCCR	**BCC-CSM1.1**	156 year
	CCCMA	**CanESM2**	156 year
	NCAR	**CCSM4**	156 year
	Météo-France	**CNRM-CM5**	156 year
	CSIRO-QCCCE	**CSIRO-Mk3-6-0**	156 year
	LASG	**FGOALS-g2**	110 year
	NOAA / GFDL	**GFDL-CM3**	145 year
	NOAA / GFDL	**GFDL-ESM2G**	145 year
	NOAA / GFDL	**GFDL-ESM2M**	145 year
	NASA / GISS	**GISS-E2-R**	156 year
	Hadley Centre / Met Office	**HadGEM2-CC**	145 year
	Hadley Centre / Met Office	**HadGEM2-ES**	145 year
	INM	**INM-CM4**	156 year
	IPSL	**IPSL-CM5A-LR**	156 year
	IPSL	**IPSL-CM5A-MR**	156 year
	CCSR, JAMSTEC	**MIROC5**	156 year
	CCSR, JAMSTEC	**MIROC-ESM**	156 year
	MPI-M	**MPI-ESM-LR**	156 year
	MRI	**MRI-CGCM3**	156 year
	NCC	**NorESM1-M**	156 year
21 CMIP3 Historial run	BCCR	**BCCR-BCM2.0**	150 year
	CCCMA	**CCCMA_CGCM_3.1**	151 year
	CCCMA	**CCCMA_CGCM_3.1_t63**	140 year
	Météo-France	**CNRM-CM3**	140 year
	CSIRO-QCCCE	**CSIRO-Mk3.0**	130 year
	CSIRO-QCCCE	**CSIRO-Mk3.5**	130 year
	NOAA / GFDL	**GFDL-CM2.0**	140 year
	NOAA / GFDL	**GFDL-CM2.1**	140 year
	LASG	**IAP_FGOALS-g1.0**	150 year
	INGV	**INGV_ECHAM4**	100 year
	INM	**INM-CM3.0**	131 year
	IPSL	**IPSL-CM4**	141 year
	CCSR, JAMSTEC	**MIROC3.2_HIRES**	101 year
	CCSR, JAMSTEC	**MIROC3.2_MEDRES**	141 year
	University of Bonn, KMA	**MIUB_ECHO-G**	150 year
	MRI	**MRI-CGCM2.3.2a**	150 year
	Hadley Centre / Met Office	**UKMO-HadCM3**	140 year
	Hadley Centre / Met Office	**UKMO-HadGEM1**	140 year
	MPI	**MPI_ECHAM5**	140 year
	NCAR	**NCAR-CCSM3.0**	140 year
	NCAR	**NCAR_PCM1**	110 year

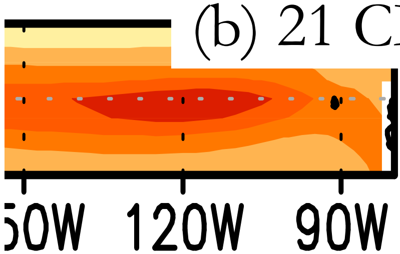
• Bjerknes feedback in the tropical Pacific 3

(a) 21 CMIP3 MME Historical run♪



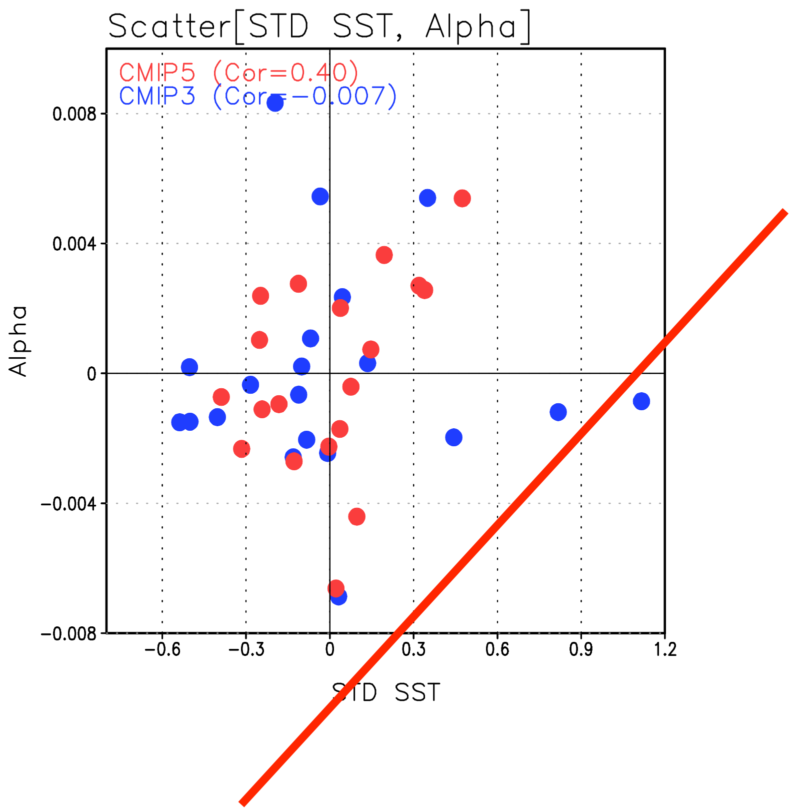
CGCM3.1 (e) CCCMA-CGCM3.1_t63

(b) 21 CMIP5 MME Historical run♪



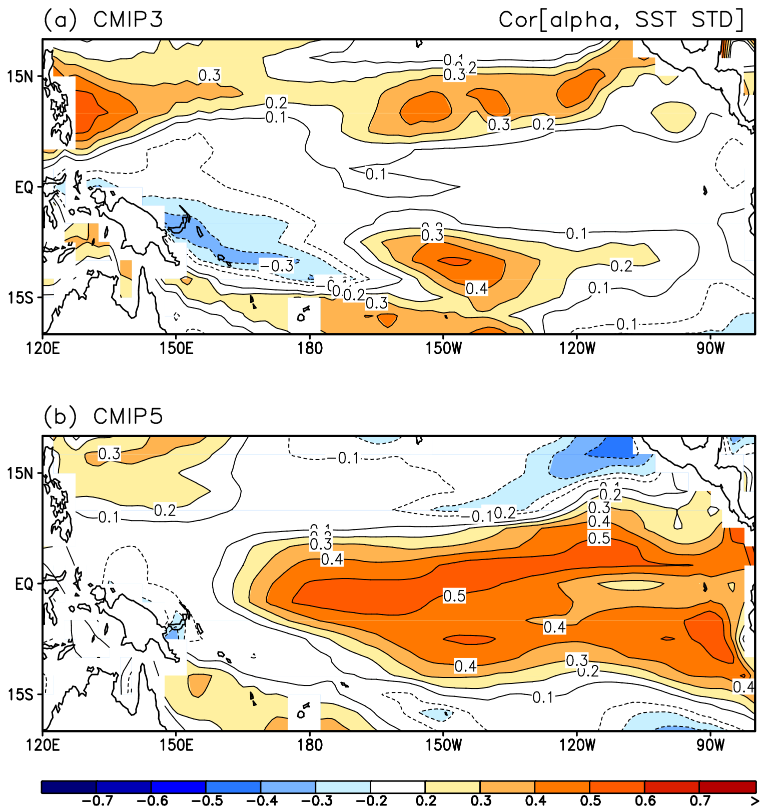
(e) CanESM2

• Changes in the Bjerknes feedback in the tropical Pacific 4



Scatter plots between SSTA S.D. in the eastern Pacific and Alpha in the 21 CMIP3 and CMIP5 models, respectively.

• Changes in the Bjerknes feedback in the tropical Pacific 5

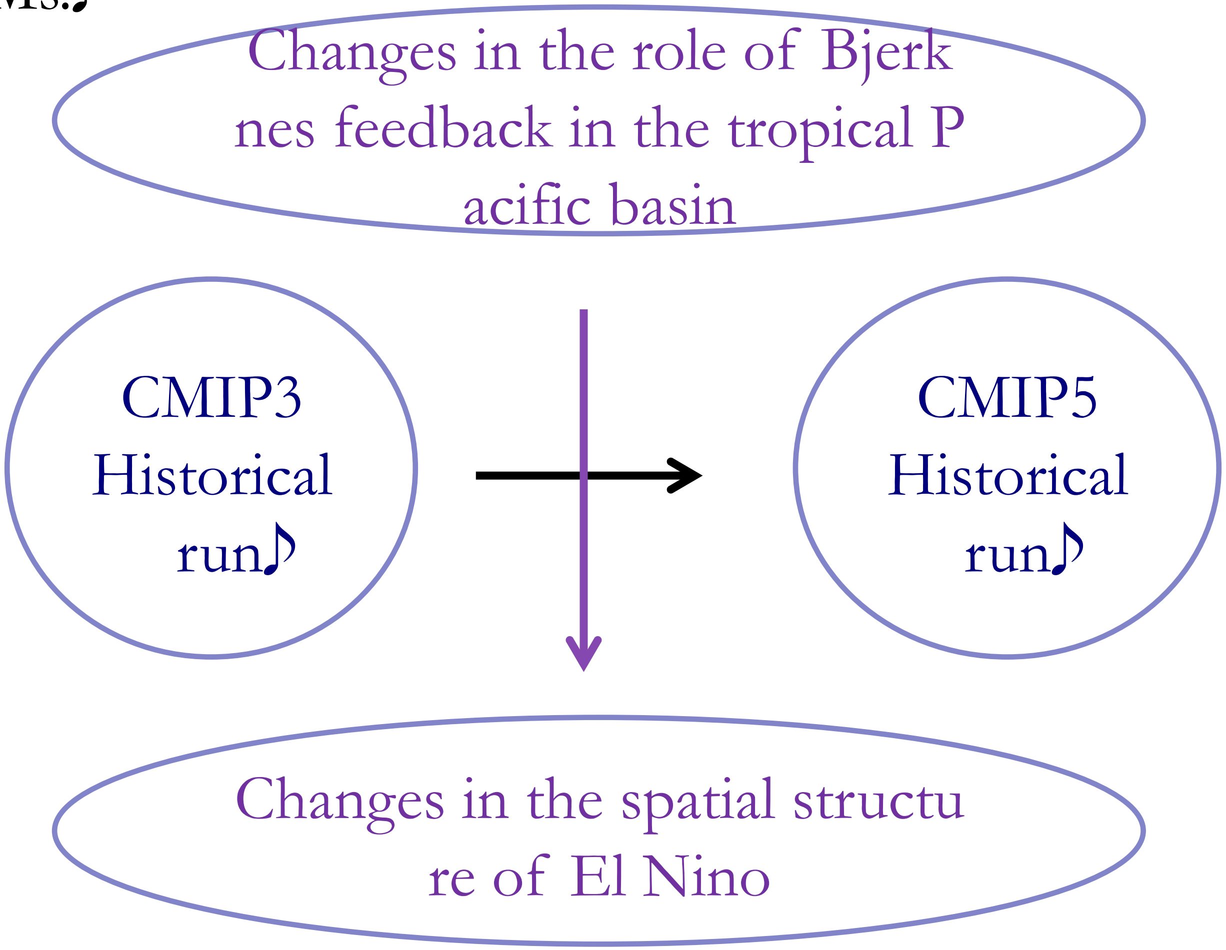


21 CMIP3 MME♪

21 CMIP5 MME♪

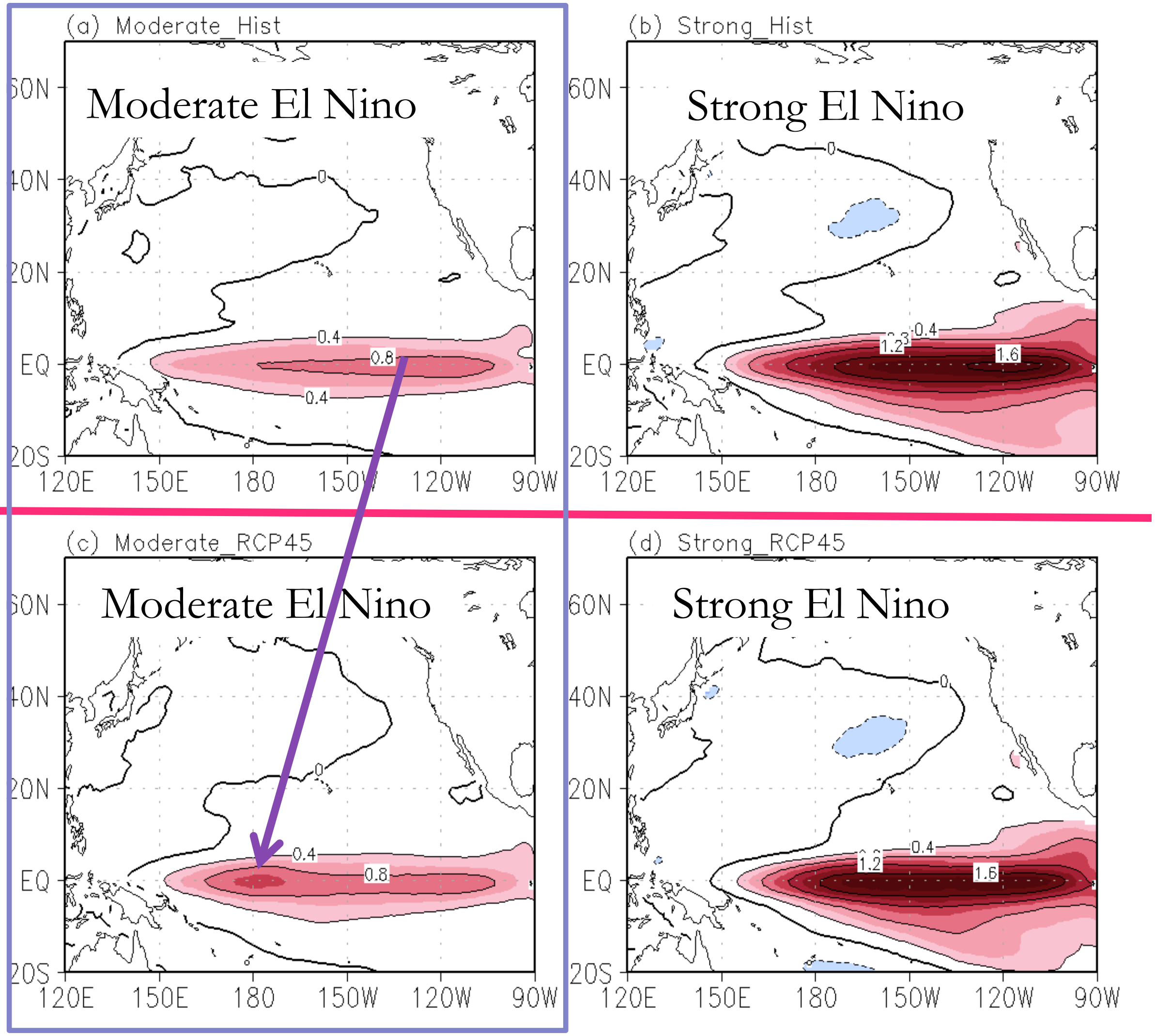
• Changes in El Nino spatial structure

The Bjerknes feedback plays a role to influence the variability of SST A in the eastern Pacific among CMIP5 CGCMs, but not among CMIP3 CGCMs.♪



• Tropical Pacific mean state 1

CMIP5 Historical run: 1905-2005



CMIP5 RCP 4.5 run: 2100-2200

Model #	Model
1	CanESM2
2	CCSM4
3	CESM1-CAM5
4	CNRM-CM5
5	CSIRO-Mk3-6-0
6	GISS-E2-R
7	HadGEM2-ES
8	IPSL-CM5A-LR
9	MPI-ESM-LR
10	NorESM1-M

- Historical run: 190
5-2005

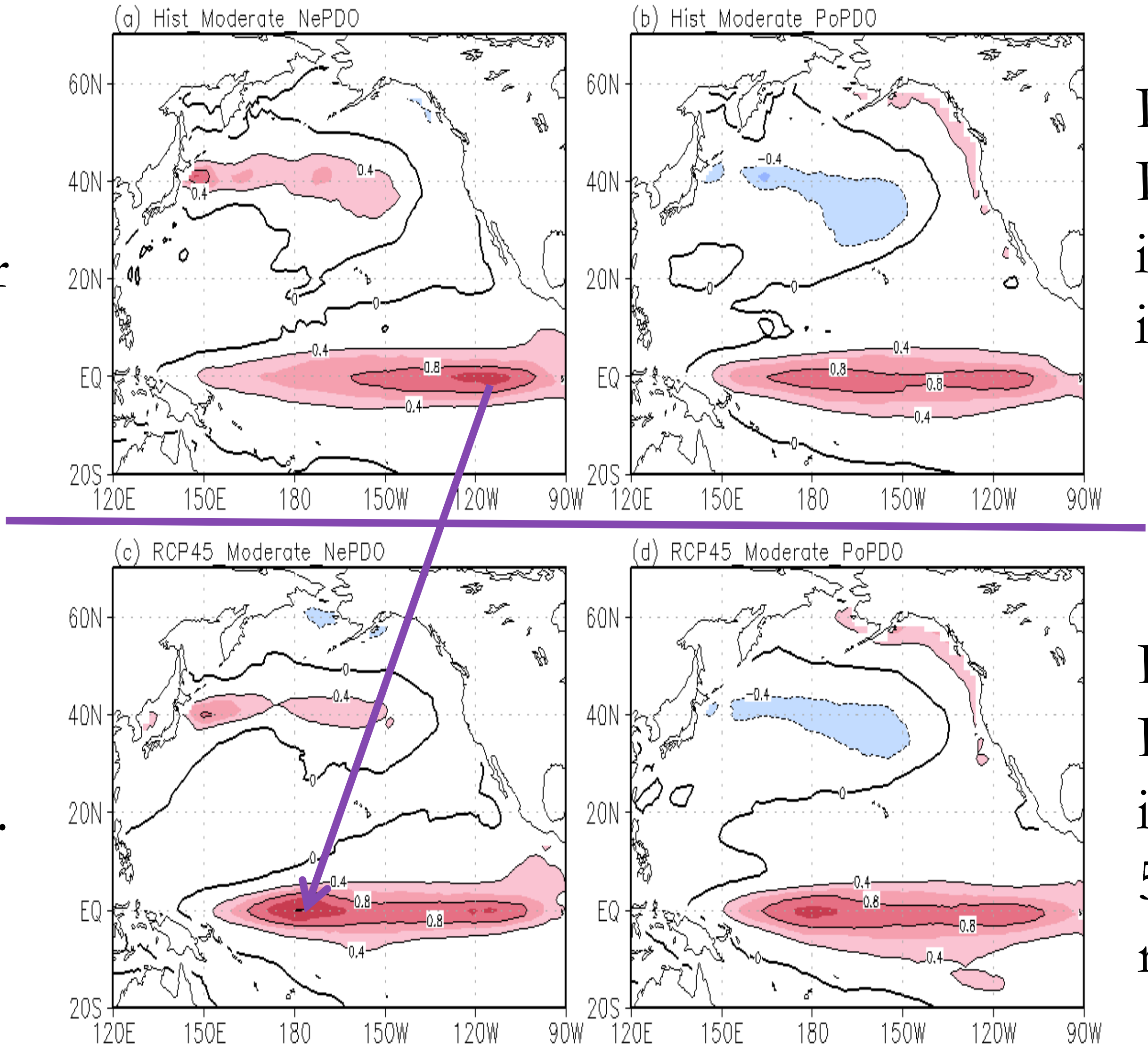
- RCP 4.5 run:
2100-2200

• Tropical Pacific mean state 2

Changes in the moderate El Nino along with a positive and negative PDO♪

Negative PDO phase in the Histor ical run♪

Positive PDO phase in the Histor ical run♪

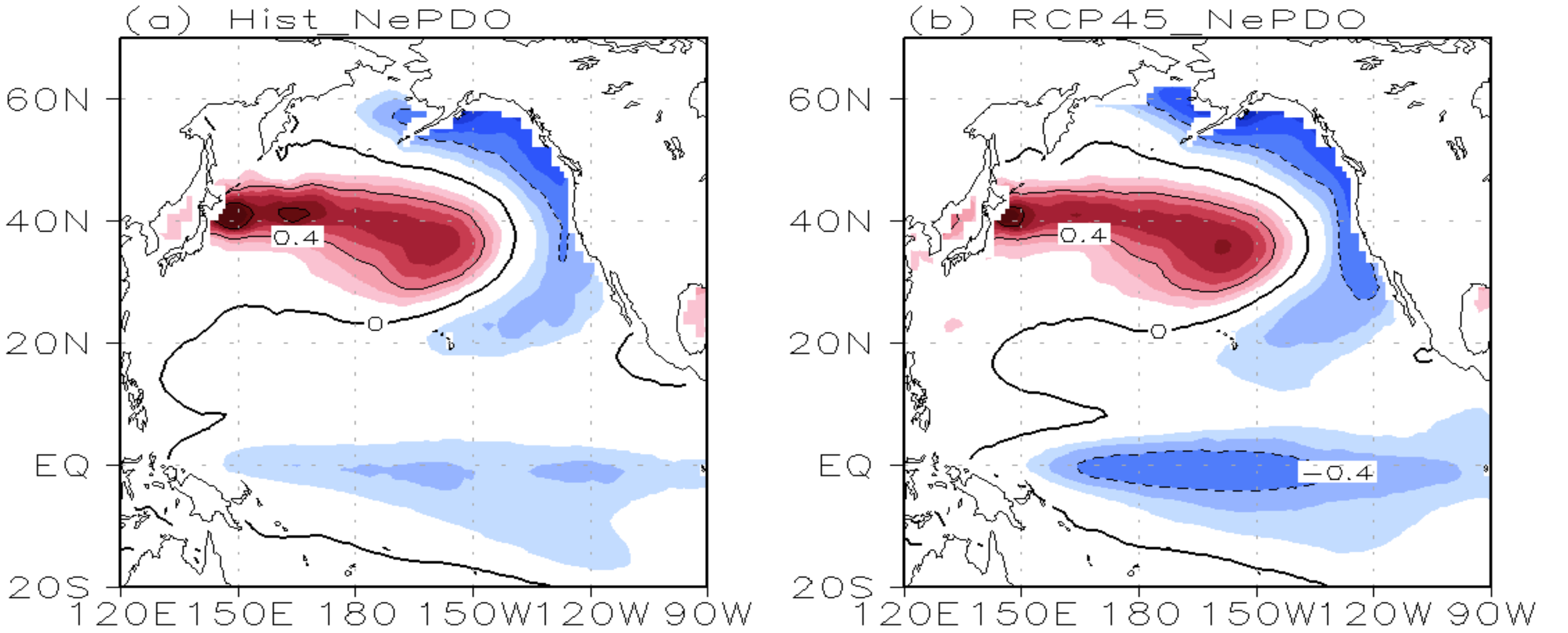


Negative PDO phase in the RCP4. 5 run♪

Positive PDO phase in the RCP4. 5 run♪

• Tropical Pacific mean state 3

Tropical Pacific mean state under a negative phase of PDO♪



- An enhancement of zonal advective feedback processes

• Changes in El Nino spatial structure

…. It is found that there exist the changes in spatial structure of El Nino under a negative phase of PDO (mostly due to moderate El Nino) from the Historical run to the RCP 4.5 run…

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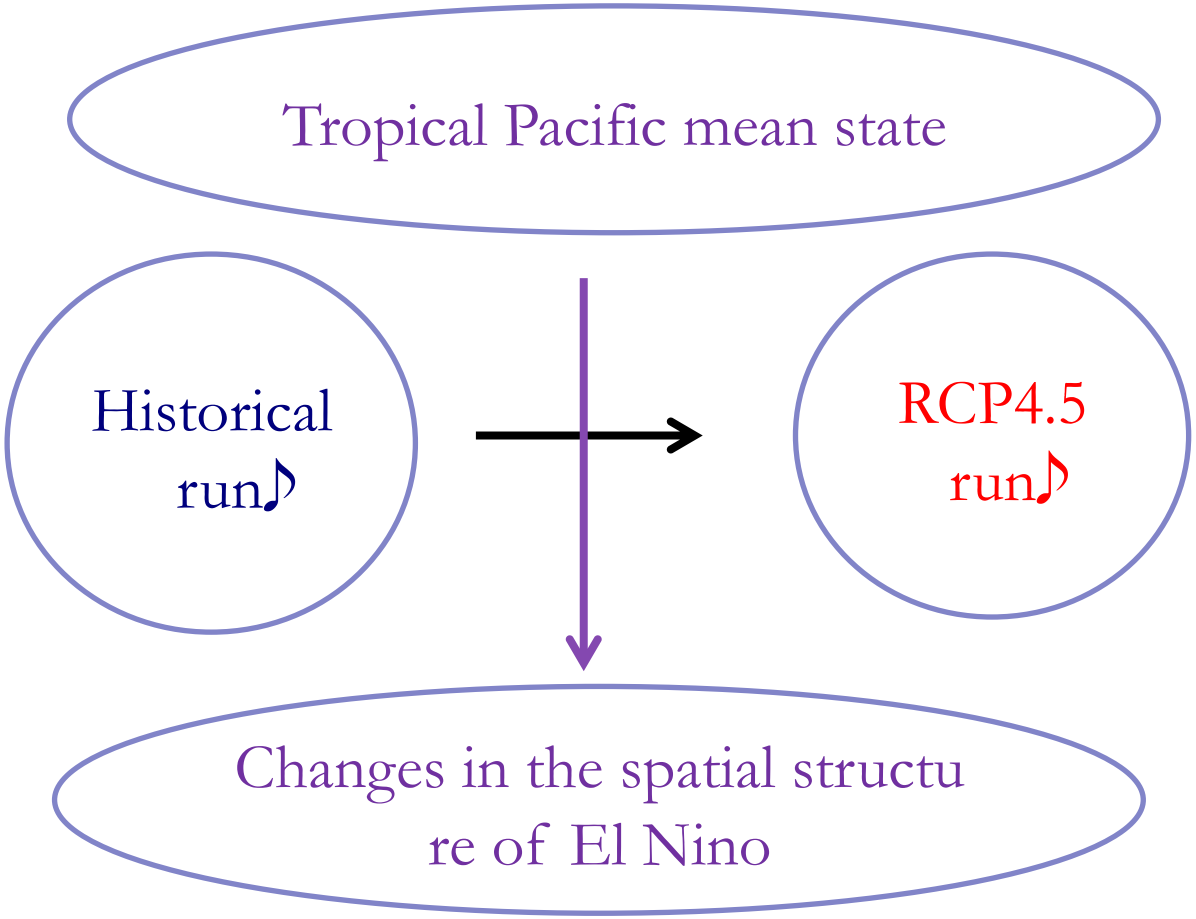


- Hypothesis

Global Warming♪

- Air-sea coupling strengths in the eastern Pacific
- Bjerknes feedback in the tropical Pacific
- Tropical Pacific mean state♪

Changes in El Nino spatial structure

Thank you♪

• Changes in the air-sea coupling strengths in the eastern Pacific 5

Before the late 1990 After the late 1990

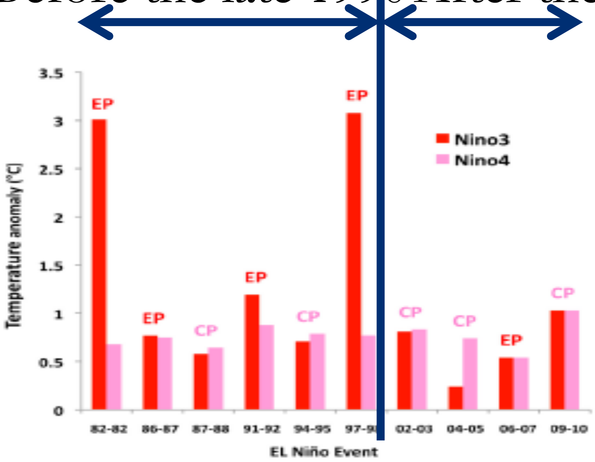
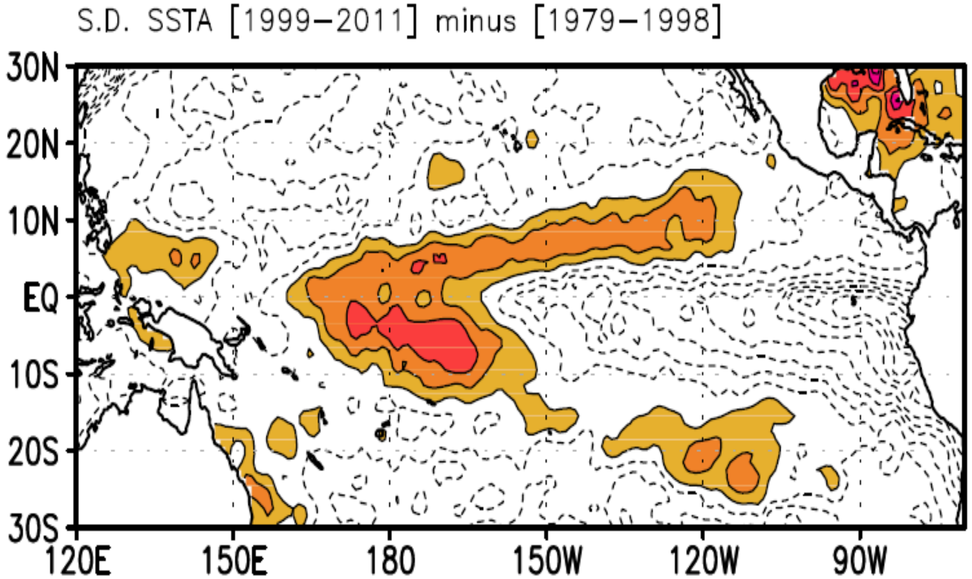


Figure 1. Nino3 (red) and Nino4 (pink) SST anomalies for El Niños between 1980 and 2010. Values are for the peak December to January season. Eastern Pacific (EP) and central Pacific (CP) events are labeled according to various indices described in the text.

	Precipitation Regression Coefficient over the NINO3 region wrt NINO3 SST index
Before the late 1990	1.38
After the late 1990	0.28



• Mechanism of frequent occurrence of CP El Nino

.. the recent predominance of standing CPW(Central Pacific Warmin g) arises from a dramatic decadal change characterized by a grand La Nina-like background pattern and strong divergence in the central Pa cific atmospheric boundary layer…(Xiang et al. 2012)

..Mean state change (i.e., a cooling (warming) over tropical eastern (w estern) Pacific) is associated with more frequent occurrence of CP El Nino during 1999-2010…A shift to the La Nina-like interdecadal me an state is responsible for more frequent occurrence of CP-type El N ino…(Chung and Li, 2013)

♪