Frequency of extreme El Niño and La Niña events under global warming

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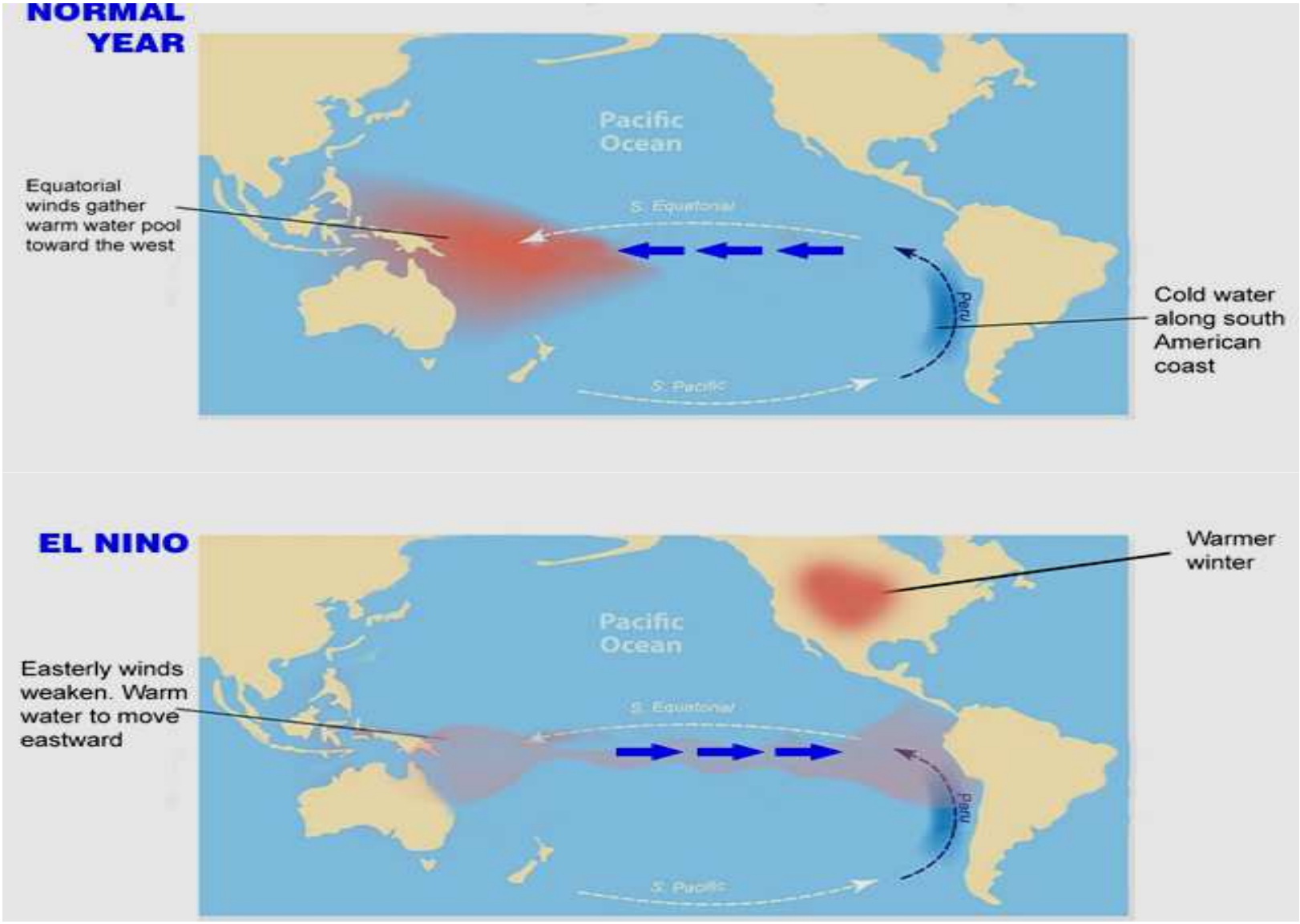
Introduction

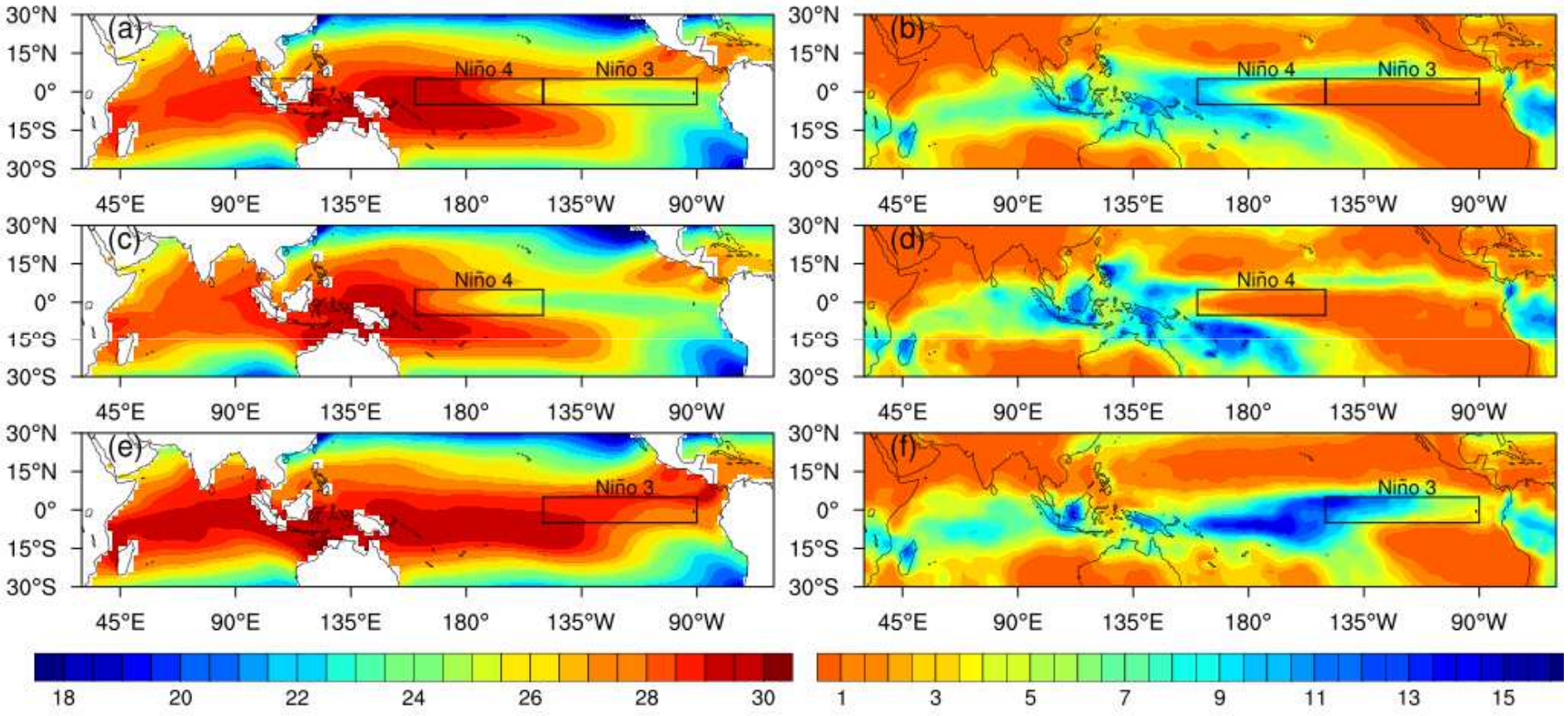


ENSO is a quasi-periodical natural phenomenon occurring in the tropical Pacific

Introduction

SST (ºC)
Extended Reconstructed SST version 5 (ERSSTv5)

Rainfall (mm day^{-1})
Global Precipitation Climatology Project (GPCP)

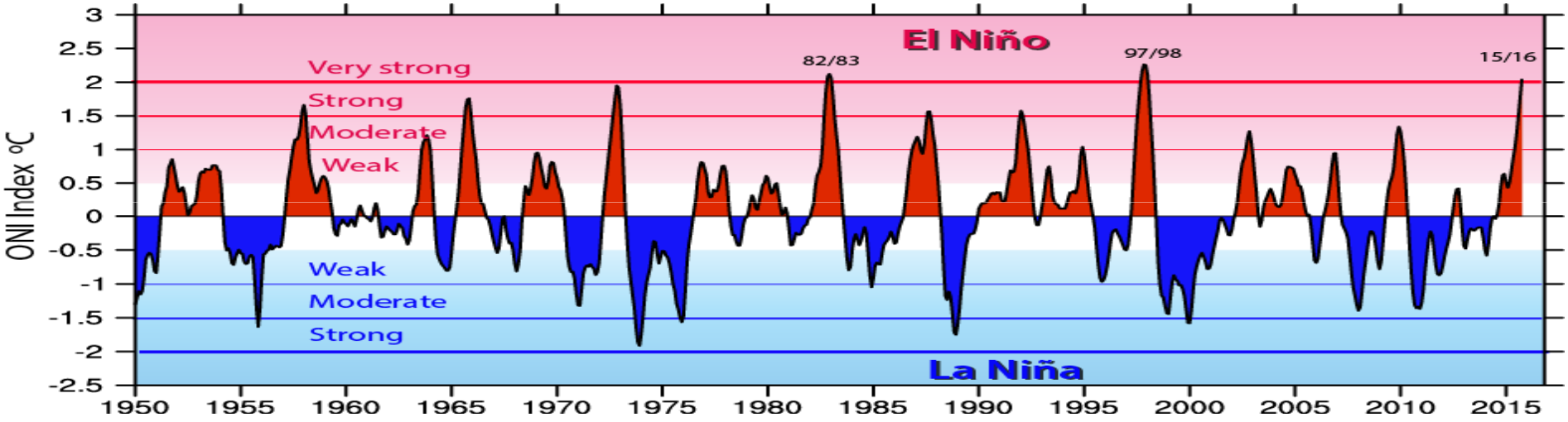


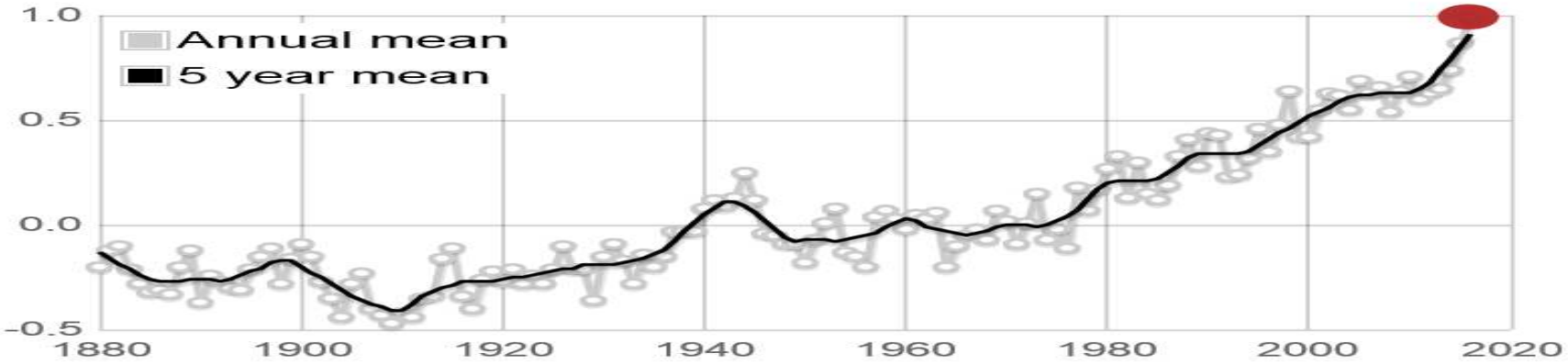
Boreal winter SST and rainfall for (a, b) 12 neutral phases, (c, d) two very strong La Niña in 1988-89 and 1998-99 and (e, f) three very strong El Niño in 1982-83, 1997-98 and 2015-16.

Motivation

Does global warming affect characteristics of ENSO?

- Most very strong El Niño events occurred during the past half century, in 1982-83, 1997-98 and 2015-16
- Most strong La Niña events also occurred in recent decades, in 1988-89, 1998-99, 1999-2000, 2007-08 and 2010-11





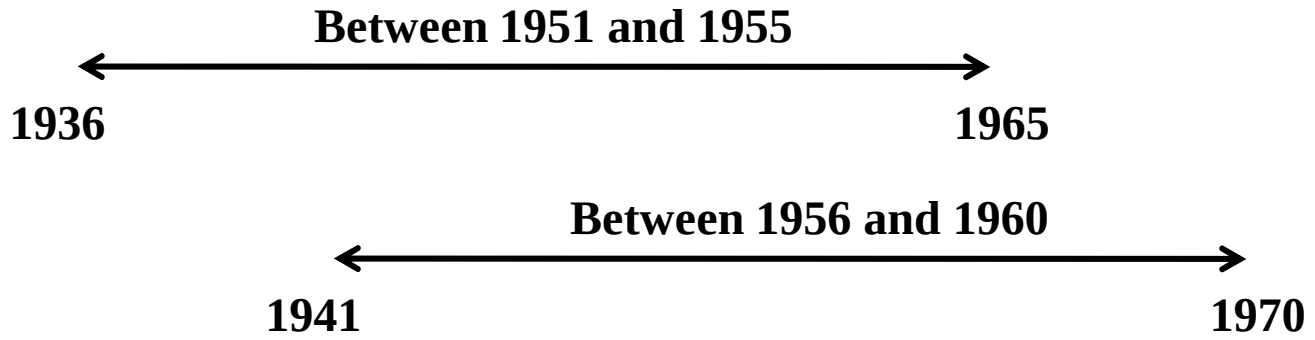
Methodology

The number of very strong ENSO events in the future period (**2050-2099**) under the **RCP4.5** and **RCP8.5** scenarios relative to that in the historical period (**1950-1999**) is analyzed using outputs of **14 GCMs** participating in **CMIP5**

Models	Institute	Atmospheric grid (°)		Oceanic grid (°)	
		Latitude	Longitude	Latitude	Longitude
bcc-csm1-1	Beijing Climate Center, China Meteorological Administration	2.7906	2.8125	0.33331, 1	1.0
bcc-csm1-1-m	Beijing Climate Center, China Meteorological Administration	2.7906	2.8125	0.33331, 1	1.0
CanESM2	Canadian Centre for Climate Modelling and Analysis	2.7906	2.8125	0.9303, 1.1407	1.40625
CESM1-BGC	National Science Foundation, Department of Energy, National Center for Atmospheric Research	0.9424	1.25	lat (i, j)	lon (i, j)
CESM1-CAM5	National Science Foundation, Department of Energy, National Center for Atmospheric Research	0.9424	1.25	lat (i, j)	lon (i, j)
GFDL-CM3	Geophysical Fluid Dynamics Laboratory	2.0	2.5	0.33441, 1	1.0
GFDL-ESM2M	Geophysical Fluid Dynamics Laboratory	2.0	2.5	0.33441, 1	1.0
GISS-E2-H	NASA Goddard Institute for Space Studies	2.0	2.5	2.0	2.5
HadGEM2-CC	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)	1.25	1.875	0.33961, 1	1.0
IPSL-CM5B-LR	Institut Pierre-Simon Laplace	1.8947	3.75	lat (i, j)	lon (i, j)
MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	1.4008	1.40625	0.5, 0.5	1.40625
MPI-ESM-MR	Max Planck Institute for Meteorology (MPI-M)	1.8653	1.875	lat (i, j)	lon (i, j)
MRI-CGCM3	Meteorological Research Institute	1.12148	1.125	0.5, 0.5	1.0
NorESM1-M	Norwegian Climate Centre	1.8947	2.5	lat (i, j)	lon (i, j)

Methodology

The Oceanic Niño Index (**ONI**) is used to identify ENSO events, a three-month central running means of SST anomalies in the Niño 3.4 region (5ºS-5ºN, 170º-120ºW) relative to a centered 30-year climatology



If the ONI for at least 5 consecutive months become equal or greater (smaller) than 0.5 (-0.5), an El Niño (a La Niña) is diagnosed

0.5≤ ONI <0.9: weak El Niño

1.0≤ ONI <1.4: moderate El Niño

1.5≤ ONI <1.9: strong El Niño

2.0≤ ONI: very strong El Niño

-0.9≤ ONI <-0.5: weak La Niña

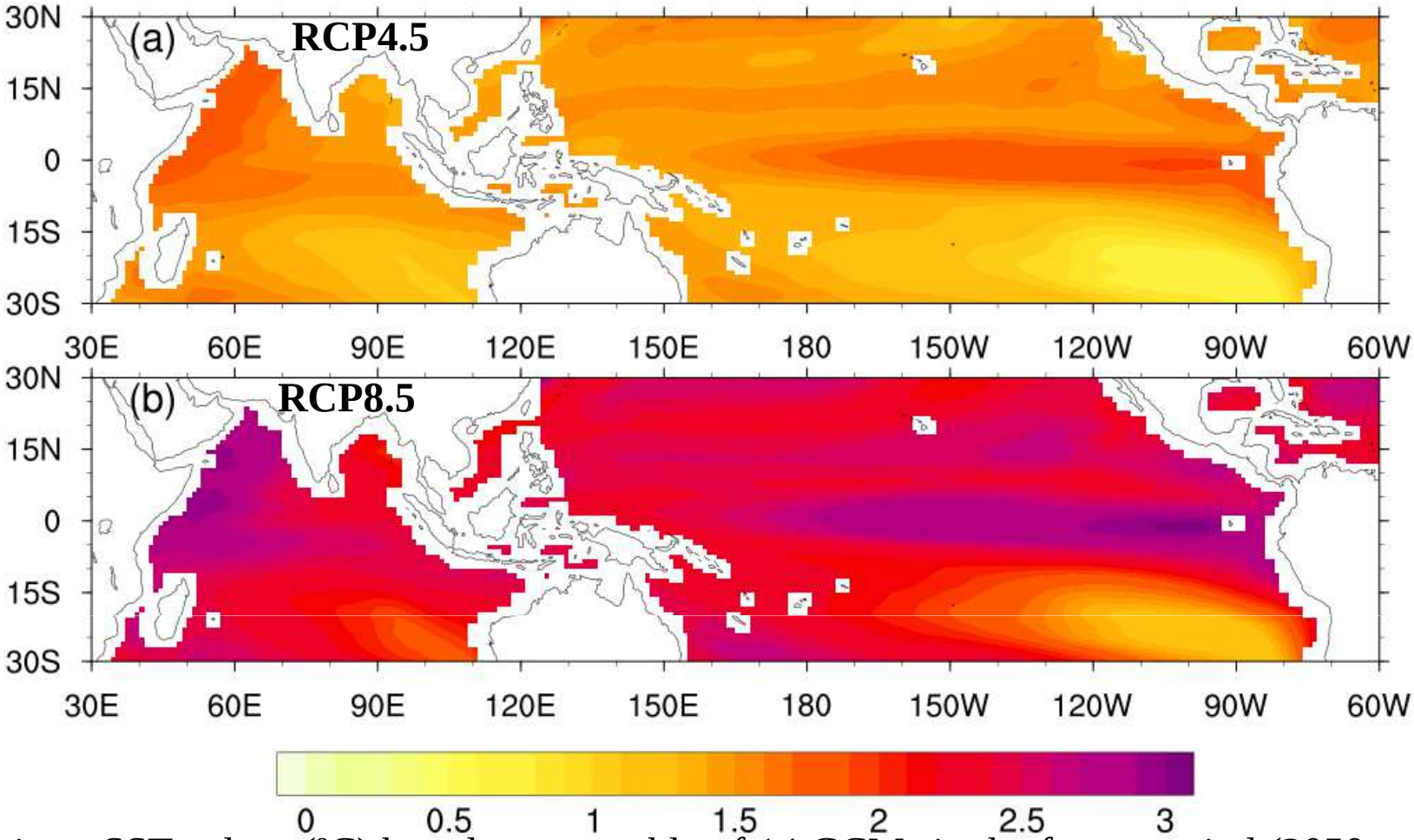
-1.4≤ ONI <-1.0: moderate La Niña

-1.5≤ ONI <-1.9: strong La Niña

ONI ≤-2.0: very strong La Niña

(should be valid for at least three consecutive months)

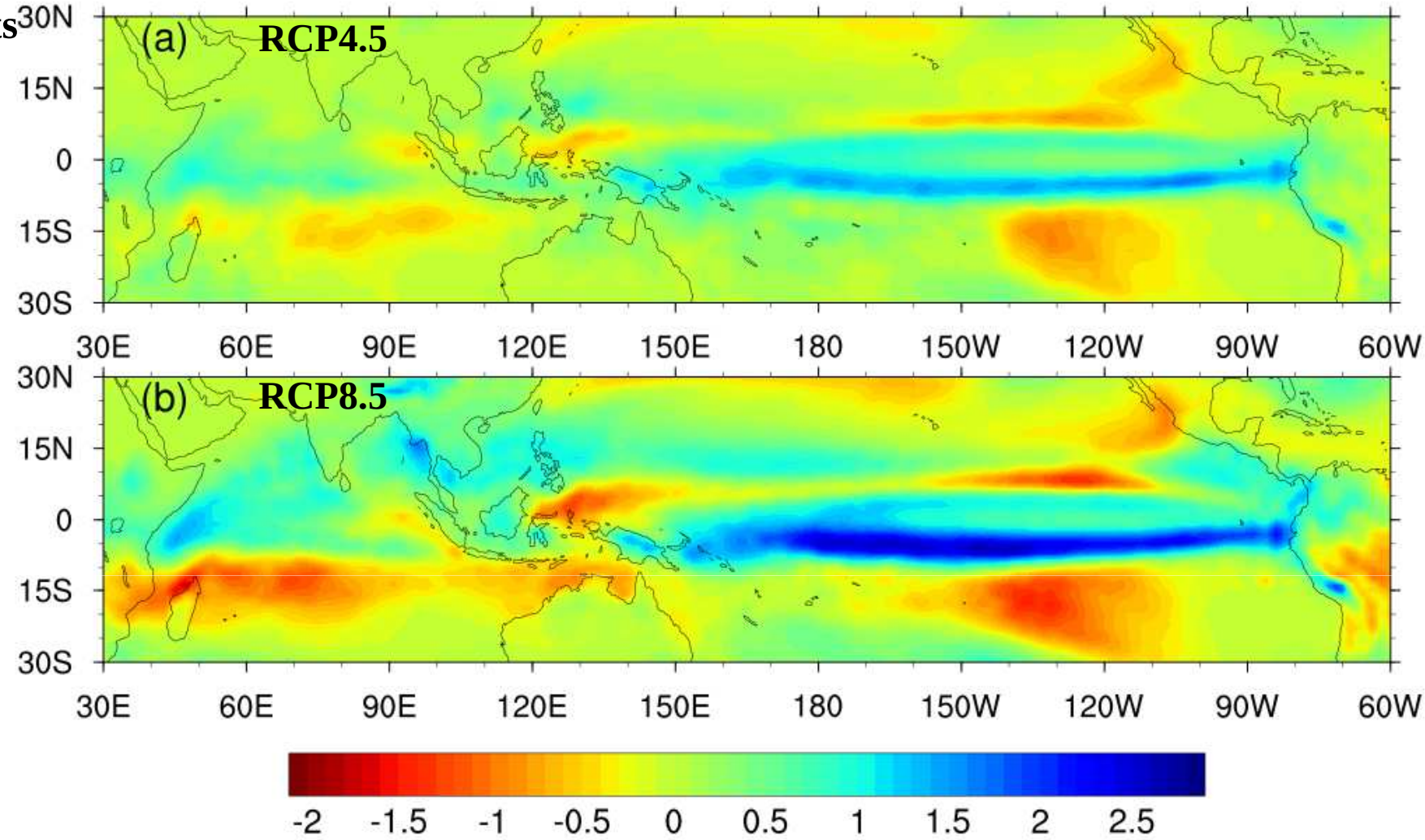
Results



Boreal winter SST values (ºC) based on ensemble of 14 GCMs in the future period (2050-2099) minus those in the historical period (1950-1999)

- **Eastern equatorial Pacific warms at a faster rate than western equatorial Pacific (an El Niño-like pattern)**
- **Zonal SST gradient across the equatorial Pacific is weakened; thus easterly trade winds will be weakened**

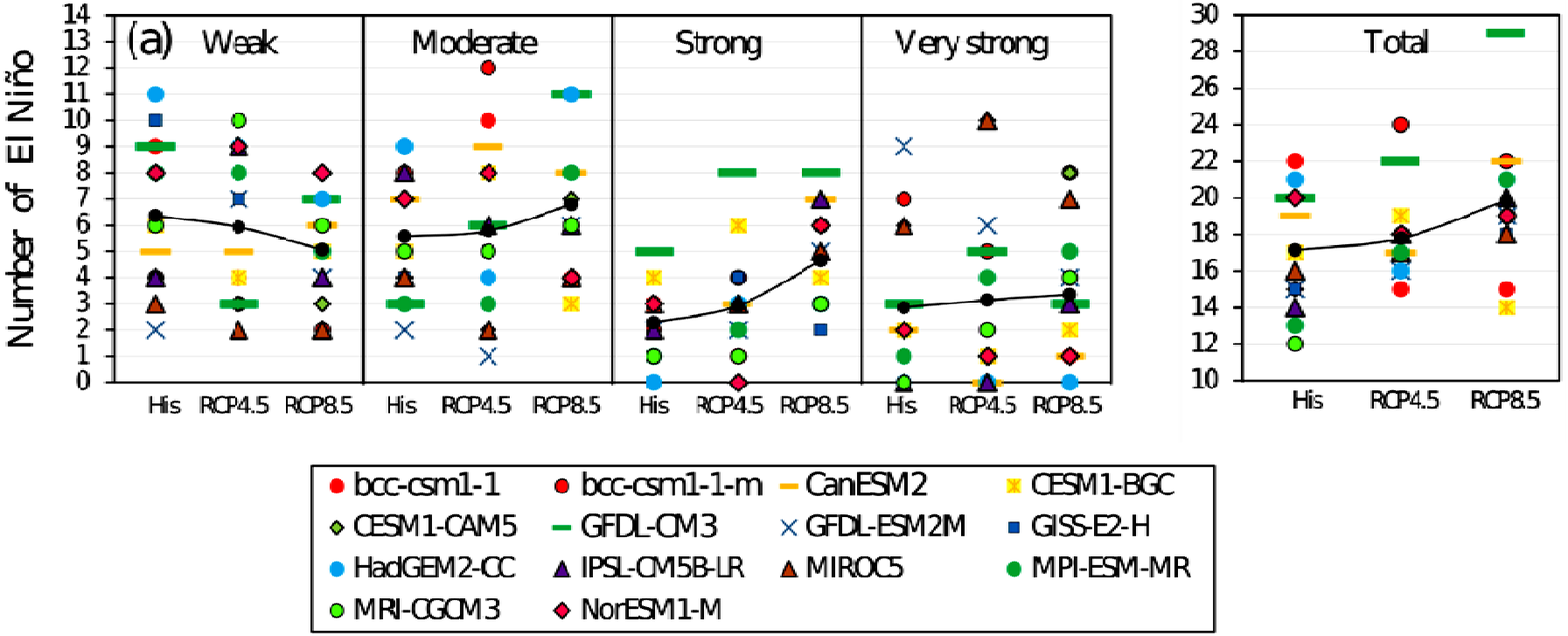
Results



Boreal winter mean rainfall values (mm day^{-1}) based on ensemble of 14 GCMs in the future period (2050-2099) minus those in the historical period (1950-1999)

- **The convective zone may shift to central and eastern equatorial Pacific in boreal winter under global warming**

Results

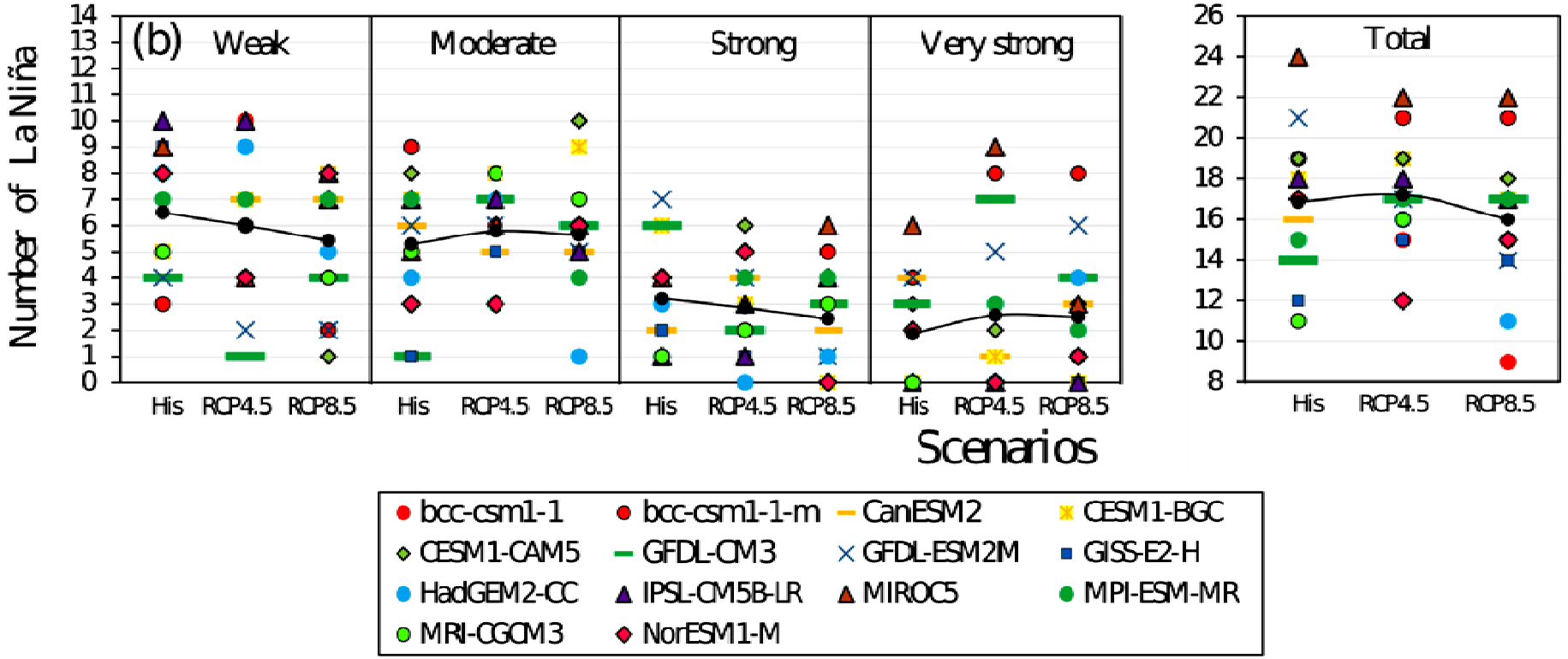


The number of El Niño events based on ensemble of 14 GCMs in the historical (1950-1999) and future (2050-2099) periods

Total El Niño events: RCP4.5: +2% RCP8.5: +16%

A slight increase in the number of very strong El Niño (10 & 18 % for RCP4.5 & RCP8.5, respectively)

Results



The number of La Niña events based on ensemble of 14 GCMs in the historical (1950-1999) and future (2050-2099) periods

Total La Niña events: RCP4.5: +2% RCP8.5: -5%

A greater increase in the number of very strong La Niña (38 & 35 % for RCP4.5 & RCP8.5, respectively)

Conclusions

- **Eastern equatorial Pacific warms at a faster rate than western equatorial Pacific under global warming**

- **Zonal SST gradient and thus easterly trade winds weaken across the equatorial Pacific under global warming**

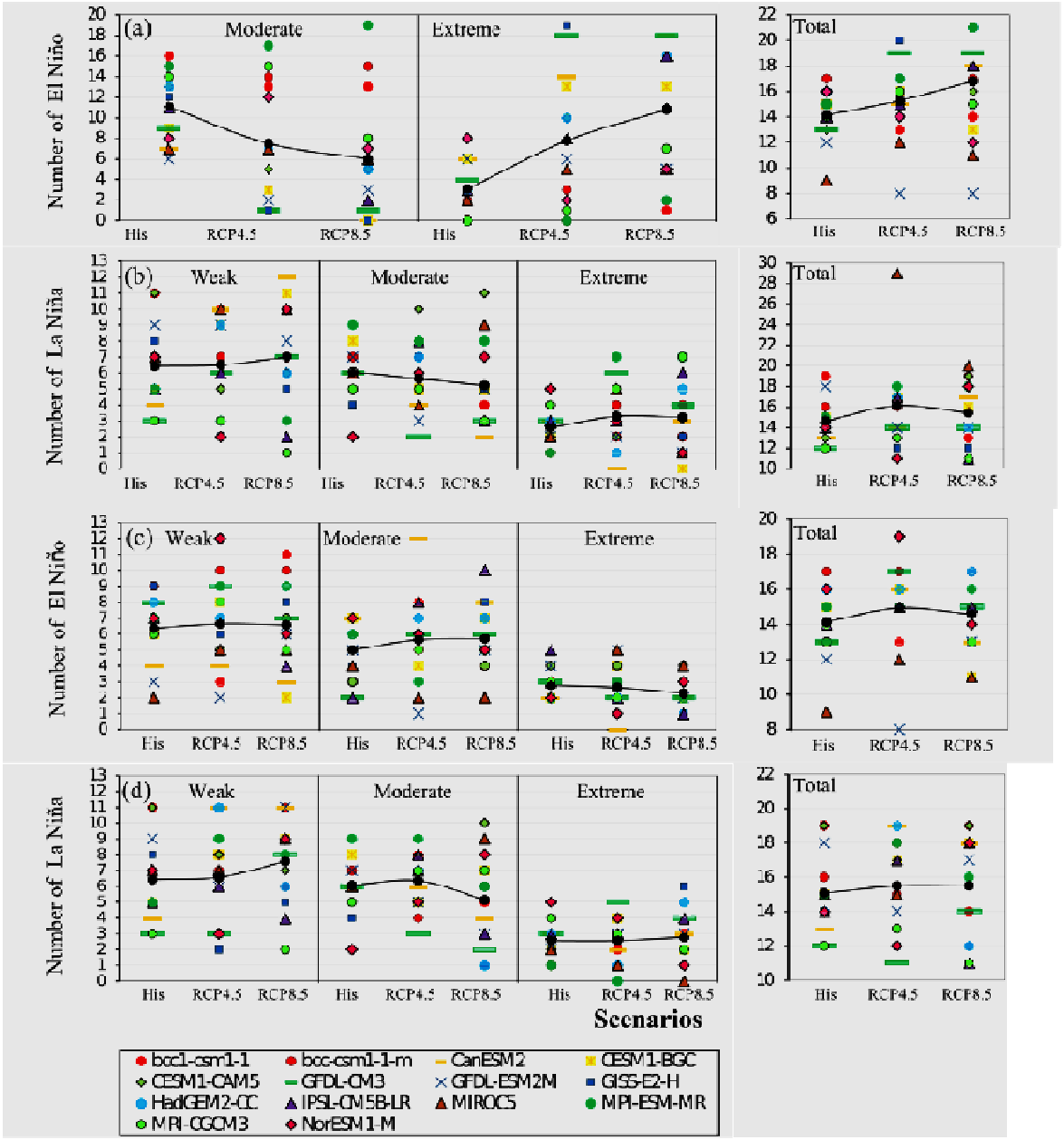
- **The convective zone may shift to central and eastern equatorial Pacific in boreal winter under global warming**

- **A slight increase in the number of very strong El Niño (10 & 18 % for RCP4.5 & RCP8.5) is predicted in the second half of the 21st century**

- **A greater increase in the number of very strong La Niña (38 & 35 % for RCP4.5 & RCP8.5) is predicted compared to the number of very strong El Niño**

Marjani S, **Alizadeh-Choobari O**, Irannejad P (2019) Frequency of extreme El Niño and La Niña events under global warming. *Climate Dynamics*, in press. http://dx.doi.org/10.1007/s00382-019-04902-1

Thanks for your attention



(a, b) Based on the Cai index, (c, d) based on the modified Cai index