ICTP-IITM-COLA TTA 2016, Trieste 13-17 June:
Workshop on “Grand challenges in monsoon modeling: Representation of processes in climate models” and TTA: “Towards Improved Monsoon Simulations”

Manish Joshi (IITM) and Fred Kucharski (ICTP/ESP)

‘Impact of systematic errors on the teleconnection of Interdecadal Pacific Oscillation to the Indian summer monsoon in CMIP5 models’

The ENSO-monsoon relationship on interannual and decadal time scales is a long-standing problem and extensively analysed.

Indian Monsoon–ENSO Relationship on Interdecadal Timescale

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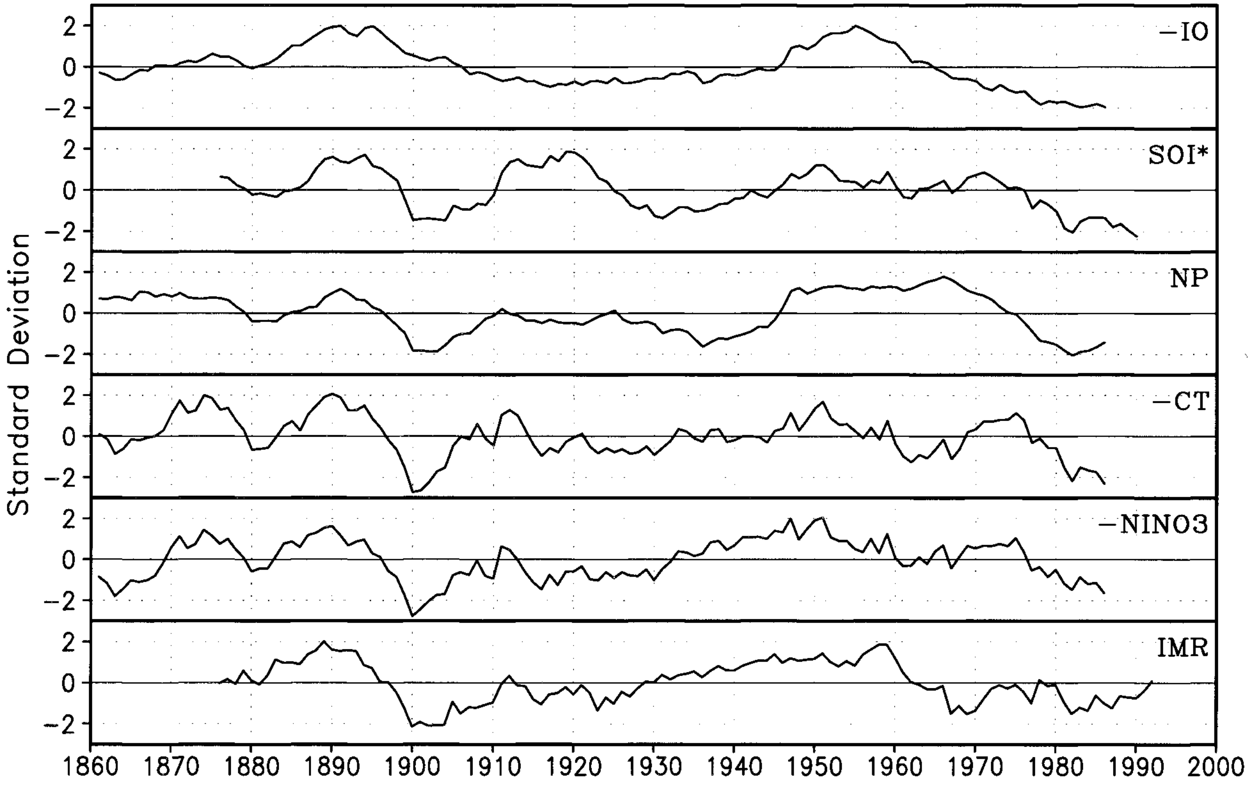
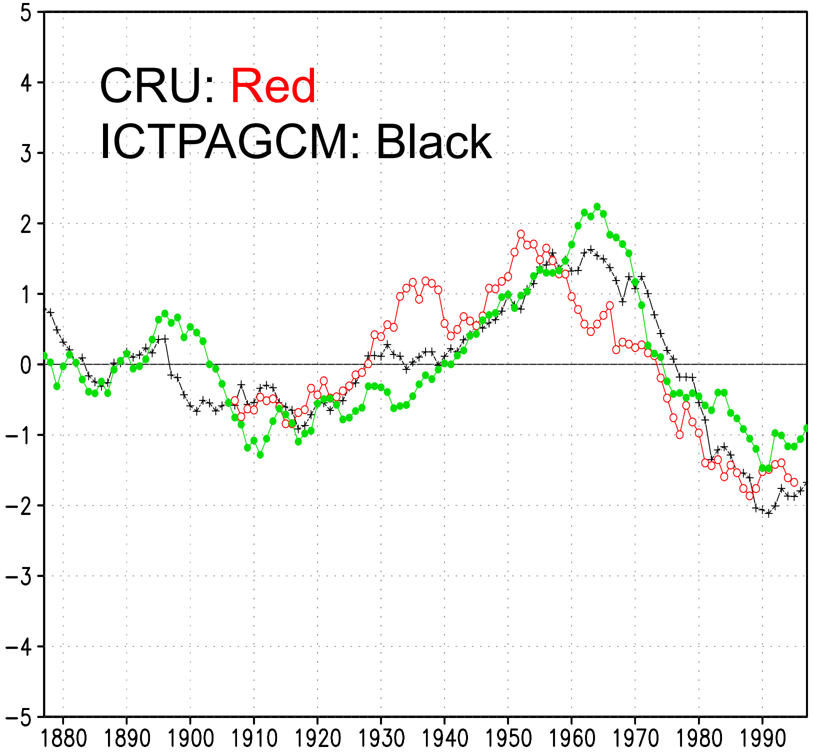
(Manuscript received 2 November 1998, in final form 8 April 1999)

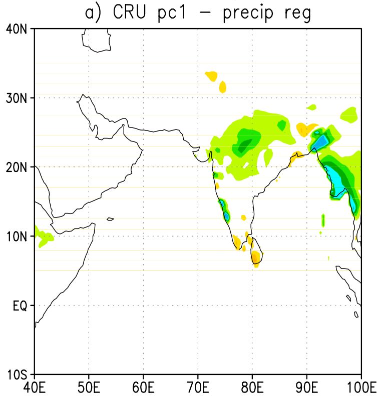


GEOPHYSICAL RESEARCH LETTERS, VOL. 33, L03709, doi:10.1029/2005GL025371, 2006

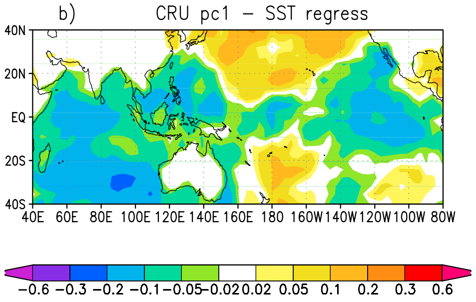
SST forcing of decadal Indian Monsoon rainfall variability

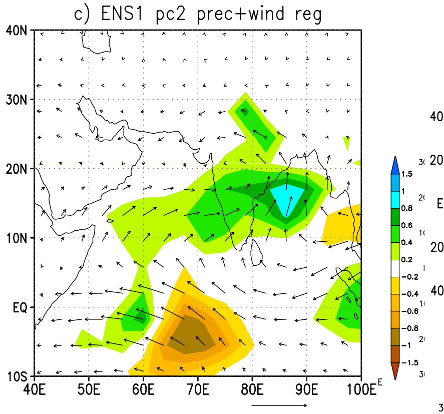
F. Kucharski, F. Molteni, and J. H. Yoo
Earth System Physics Section, Abdus Salam International Centre for Theoretical Physics, Trieste, Italy



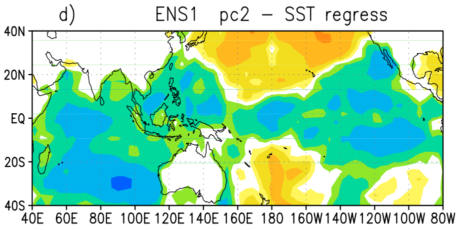


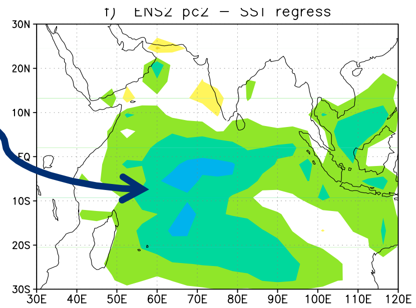
Obs





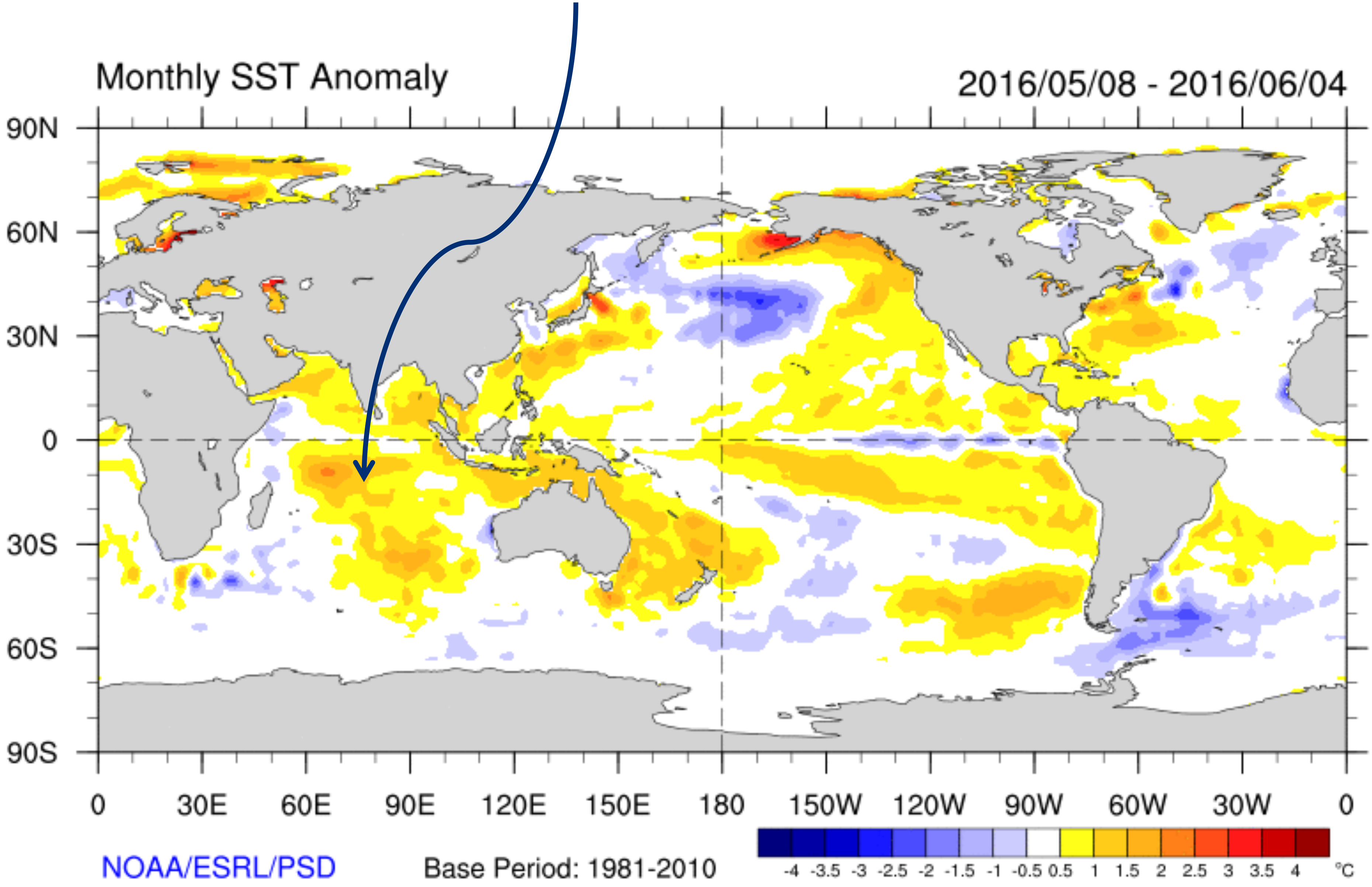
Model





In the same paper we show that South Eq. IO SST anomalies also play a crucial role in the ISMR decadal variabolity; later confirmed by Roxy Mathew Koll, Nat. Comm. 2015; It could be that this pattern actually help AGCMs to perfrom better in the decadal ENSO teleconnection that in the interannual

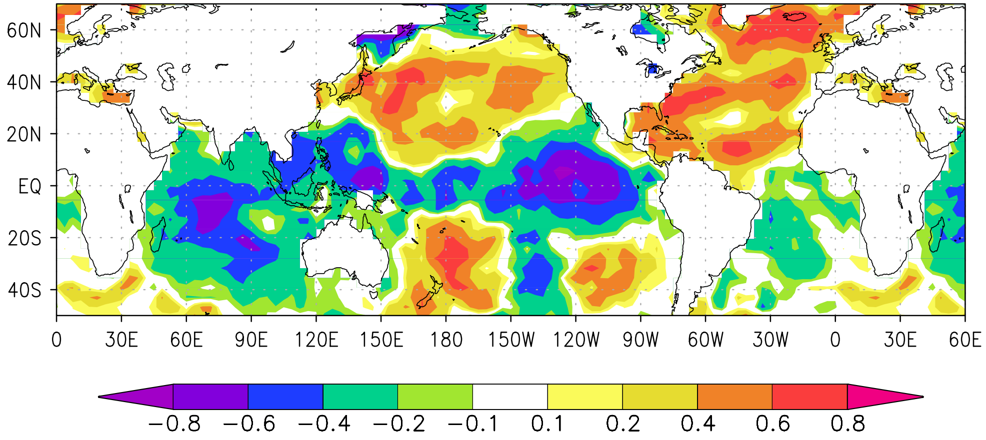
Also current monthly mean SST anomaly shows a similar pattern



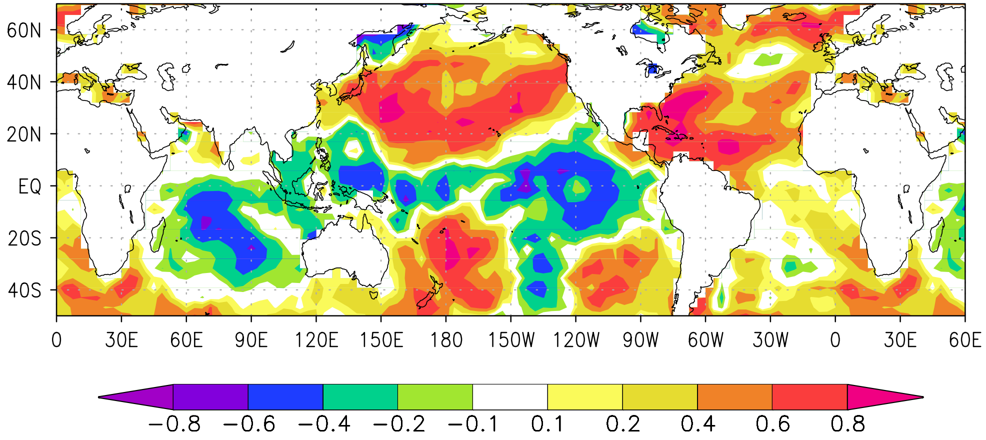
Results could be confirmed by C20C Project AGCMs: Correlation of an IMR index with SSTs

CRU Obs

(a) Corr Decadal IMR CRU−SST 07/94



(b) Corr Decadal IMR ENSL−SST 07/94



Multimodel ensemble mean

Kucharski et al, 2009, C20C multimodel paper, Climate Dynamics

Interdecadal Pacific Oscillation (IPO; Parker et al., 2007, Folland et al. 1999) is the name now given to the decadal Pacific ENSO-like variability

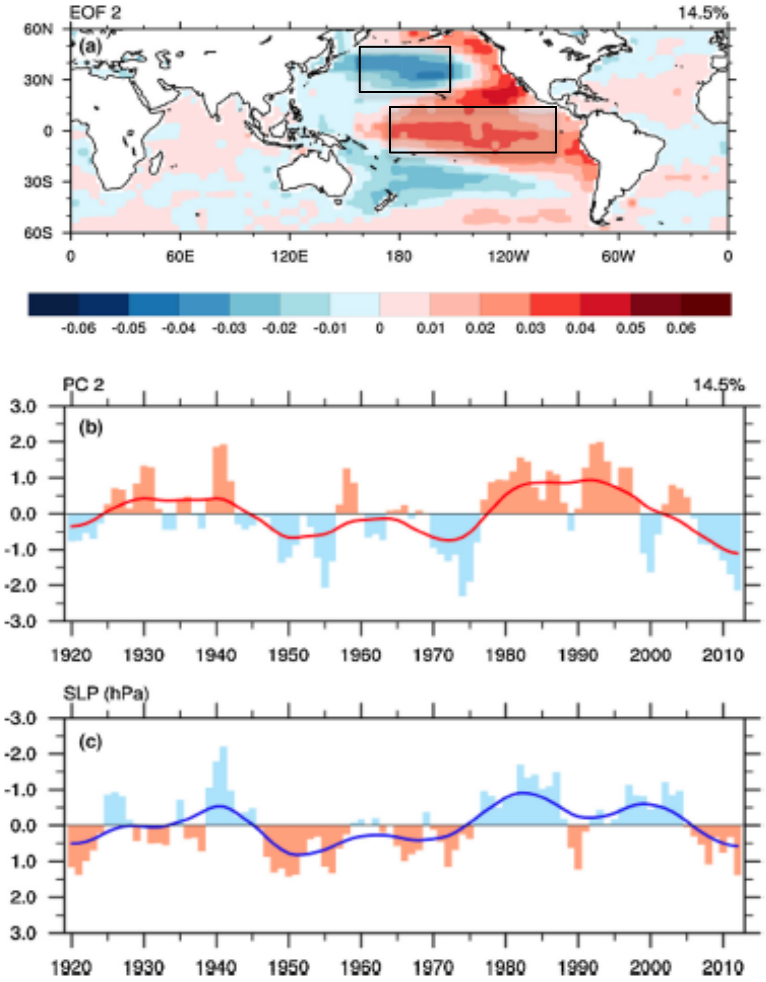


Fig. 1 **a** The second leading EOF of the 3-year moving averaged sea surface temperature from HadISST for 1920–2012 and 60°S–60°N, and **b** the time series of the associated principle component (PC, *bars* for annual data, the *red curve* is a smoothed time series obtained by applying a 9-year moving average twice to the annual *bars*). **c** Time series of 3-year moving averaged winter (November–March) sea level pressure (hPa, *bars* for yearly values) represented by the first leading EOF for the North Pacific (27.5°–72.5°N and 147.5°E–122.5°W). The *blue curve* is a smoothed time series obtained by applying a 9-year moving average twice to the *bars*

From Dong and Dai (2015)

Several IPO definitions:

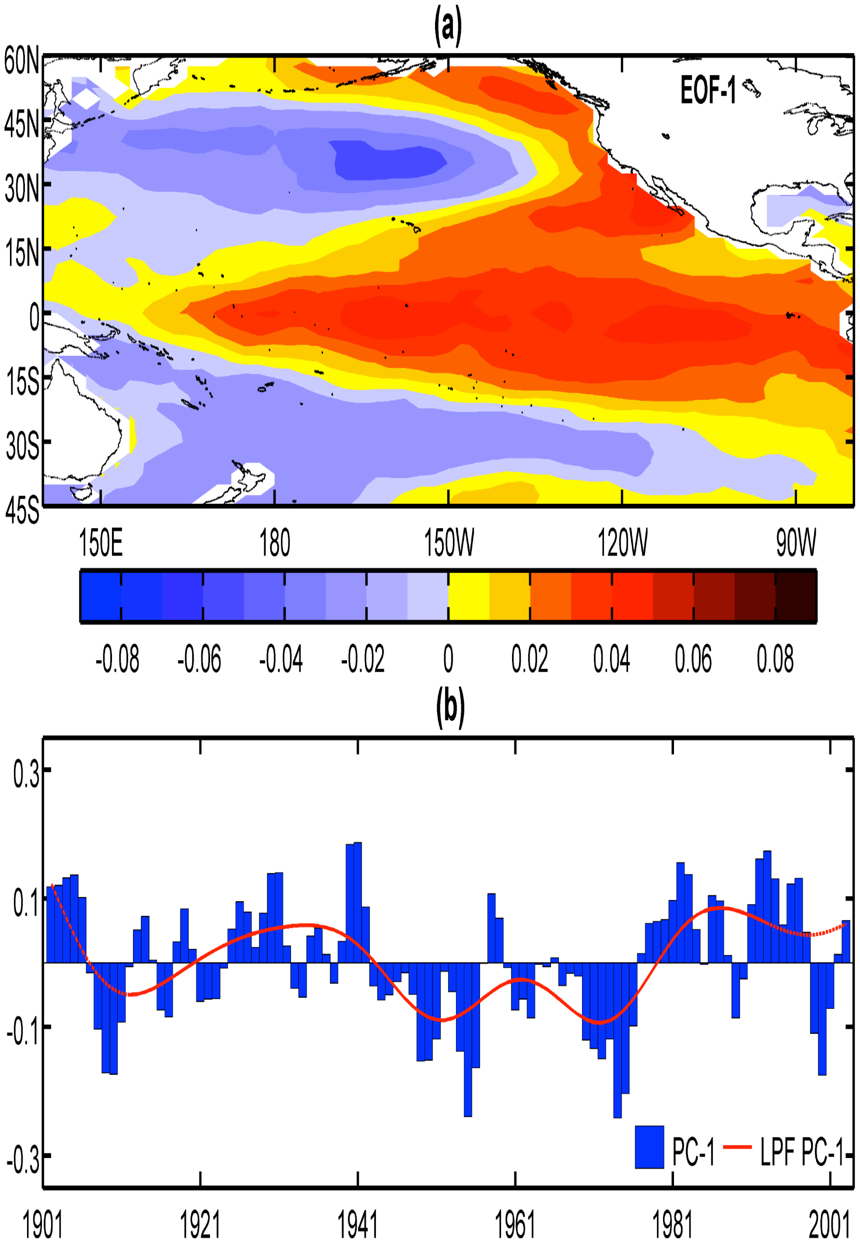
a) Second EOF of Global low-pass filetered SSTs

b) First EOF of Global **detrended** SSTs

c) Box definitions using area averages in a tropical and extratropical boxes

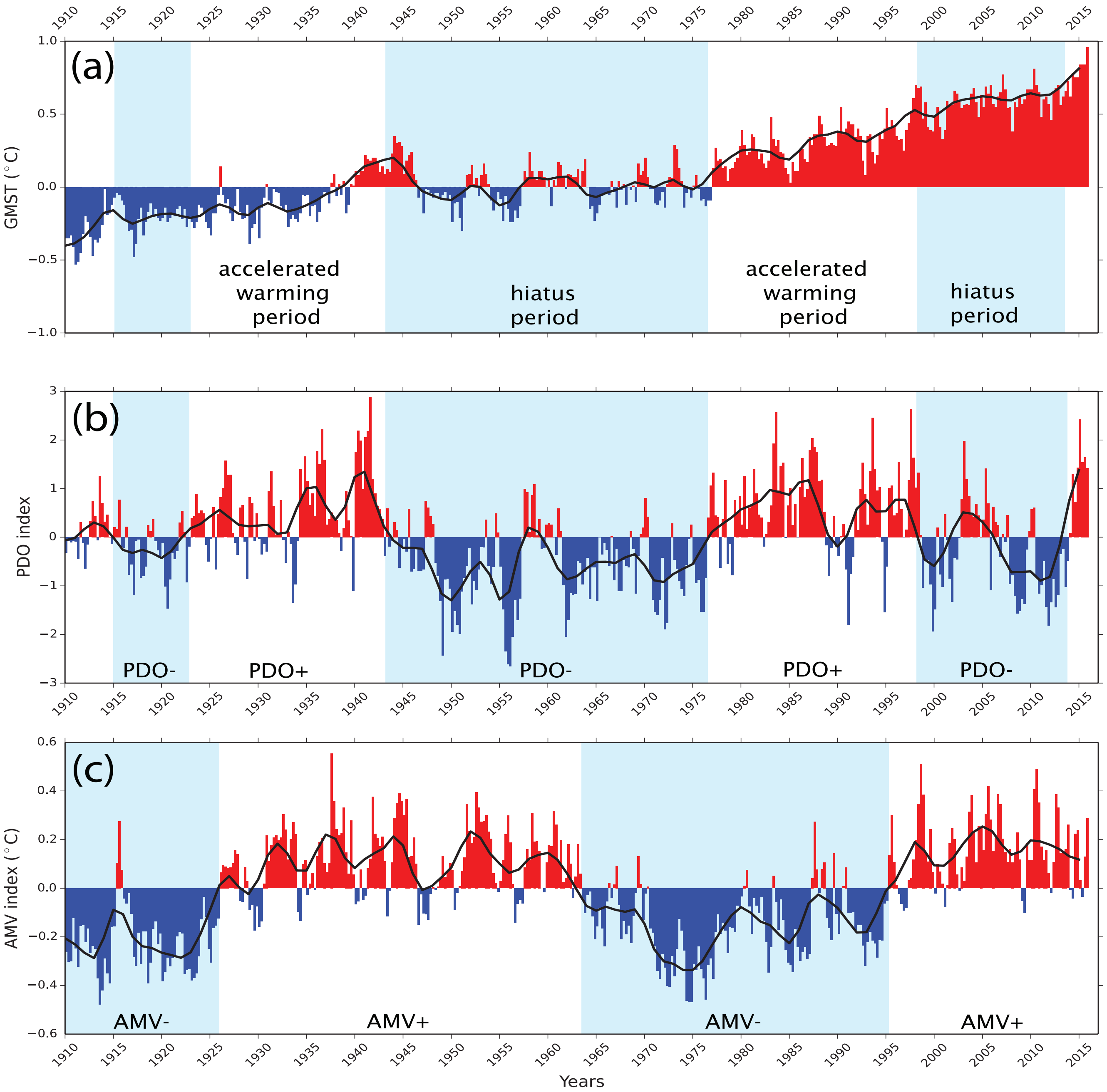
Also note that IPO is similar to PDO, which is defined as EOF in the North Pacific (or again as are average SST).

Interdecadal Pacific Oscillation (IPO) as used in our study



The first EOF (EOF-1) of the detrended smoothed (3-year moving average) annual mean SSTAs computed over the Pacific basin (45°S to 60°N, 140°E to 80°W) and **b** the time series of the associated first principle component [PC-1; blue bars for annual data and the red curve is a smoothed time series obtained by applying Butterworth low-pass filter (order 4, cut-off frequency 21-year) to the annual bars]

A lot of fuzz about IPO/PDO because of apparent relation to global warming



From Farneti, 2016

Mechanisms for IPO/PDO variability (many theories, a few are):

a) ENSO forcing with reddening of spectrum in the North Pacific due to Ocean mixed-layer interactions (Newman et al., 2003, Schneider and Cornuelle, 2005)

b) Oceanic bridge to extratropics including subtropical Cell Variability (Kleeman et al. 1999; McPhaden and Zhang 2002; Klinger et al. 2002; Nonaka et al. 2002; McCreary and Lu 1994)

c) Both atmospheric and Ocean bridge work constructively together (Farneti et al., 2013)

Pacific interdecadal variability driven by tropical–extratropical interactions

Riccardo Farneti · Franco Molteni ·
Fred Kucharski

Clim Dyn
DOI 10.1007/s00382-013-1906-6

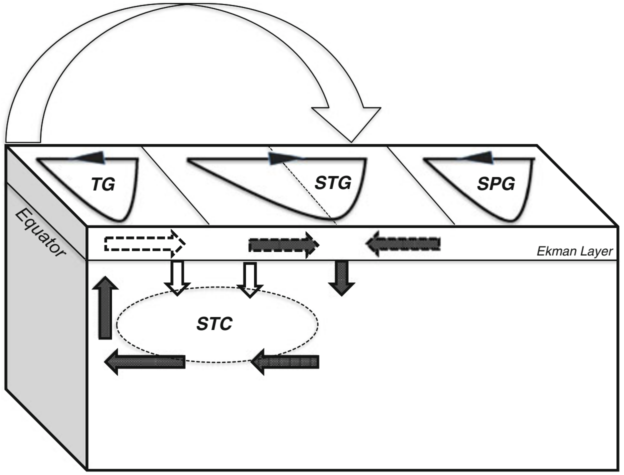
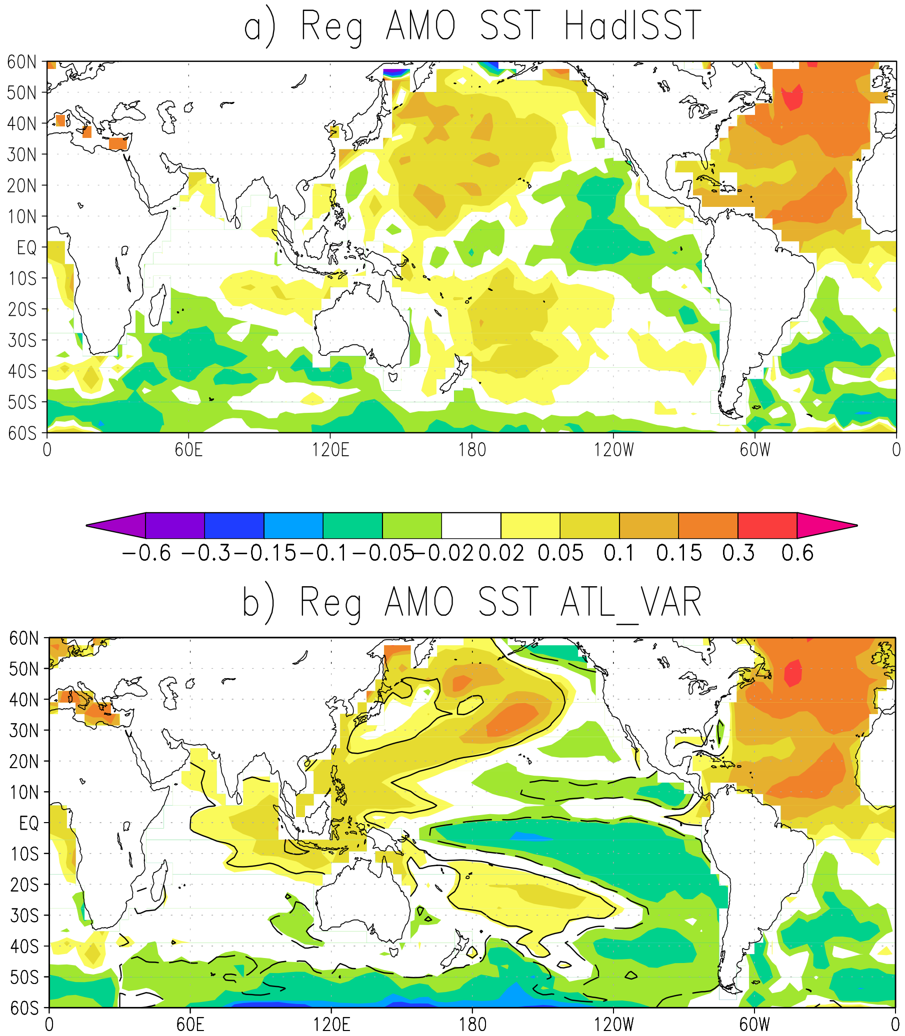


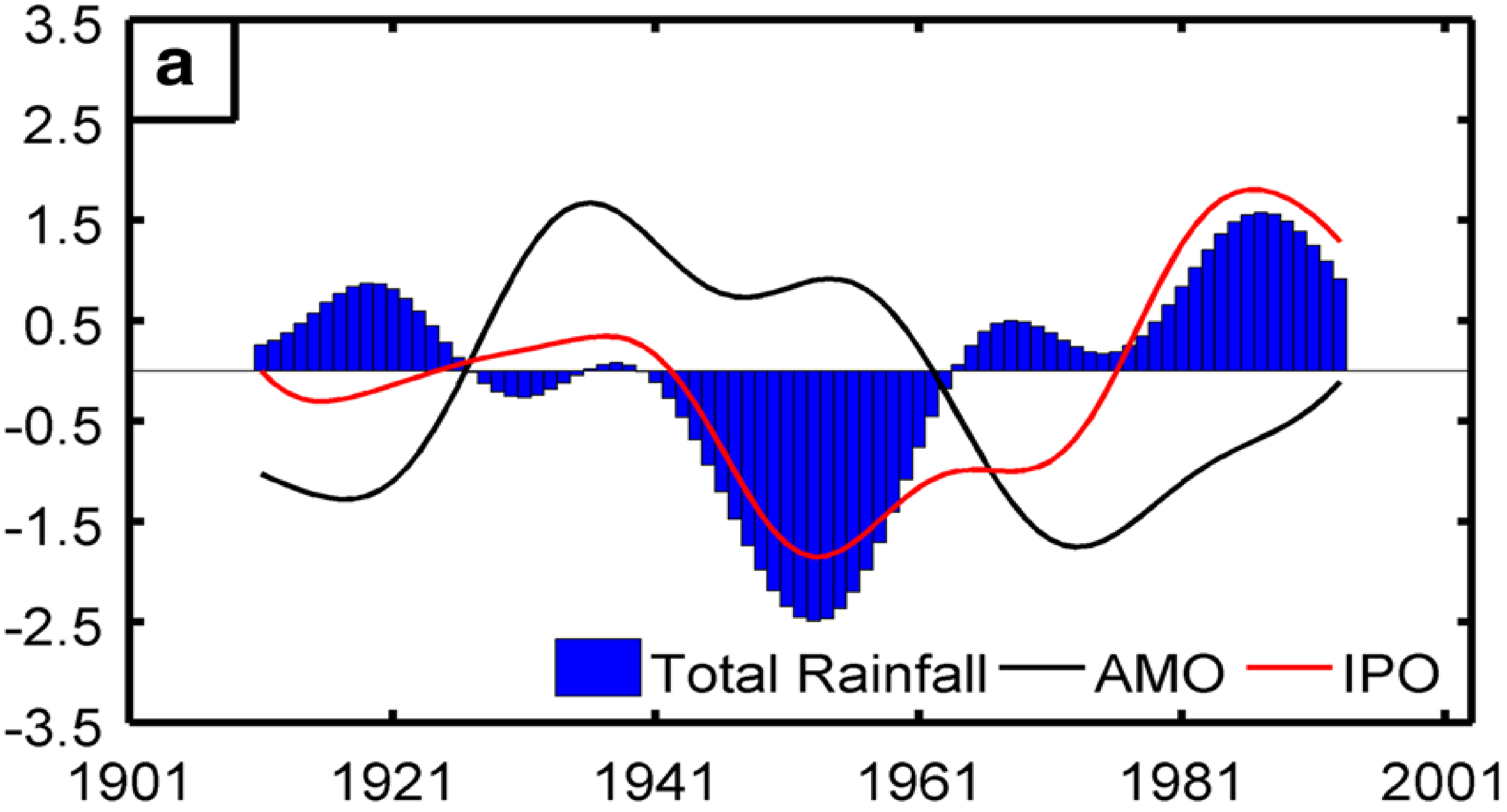
Fig. 16 Schematic of the putative tropical-subtropical Pacific interactions at decadal time scales. Shown are the horizontal gyres (*TG*: tropical gyre, *STG*: subtropical gyre, *SPG*: subpolar gyre) and subtropical vertical cell (*STC*: subtropical cell). See text for details. Adapted from Klinger and Haine (2013)

There could be even a forcing of part of IPO-like variability from the Atlantic Multidecadal Oscillation as shown in Kucharski et al., Atmosphere, 2016 and Kucharski et al., Climate Dynamics, 2016



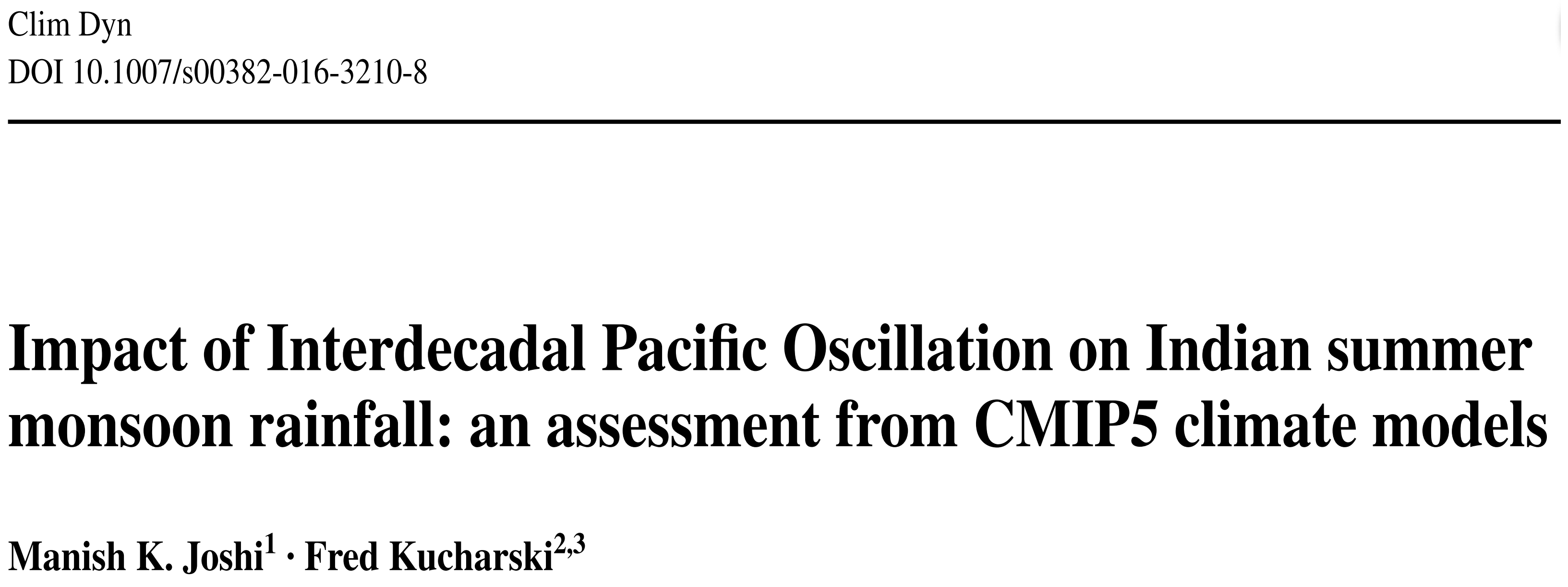
From: Kucharski et al., 2016

Coming back to IPO and Indian monsoon raifall



From: Joshi & Rai, Climate Dynamics, 2015

In the following I'll present results from the following paper fresh out of the press



Clim Dyn
DOI 10.1007/s00382-016-3210-8

Impact of Interdecadal Pacific Oscillation on Indian summer monsoon rainfall: an assessment from CMIP5 climate models

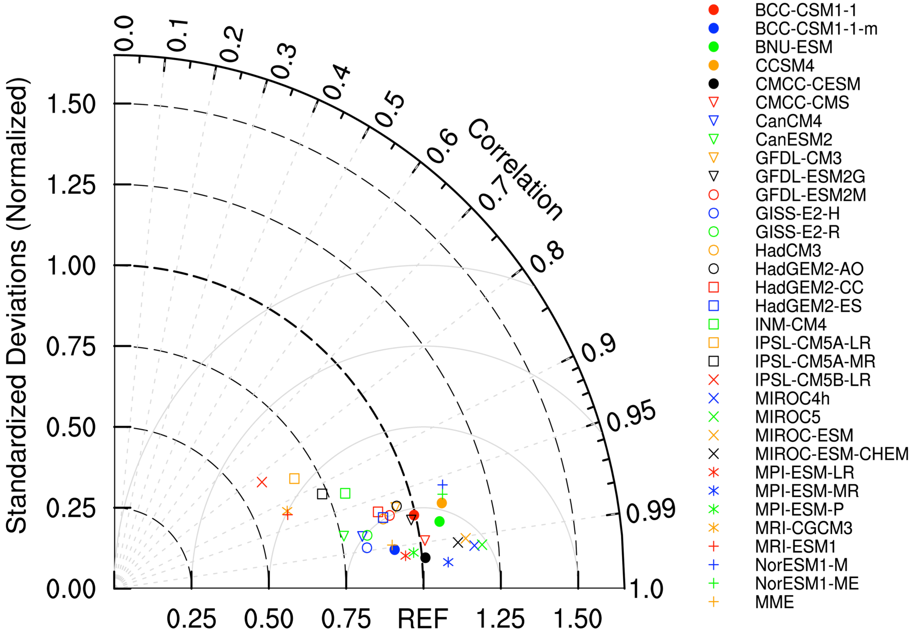
Manish K. Joshi[1] · Fred Kucharski[2,3]

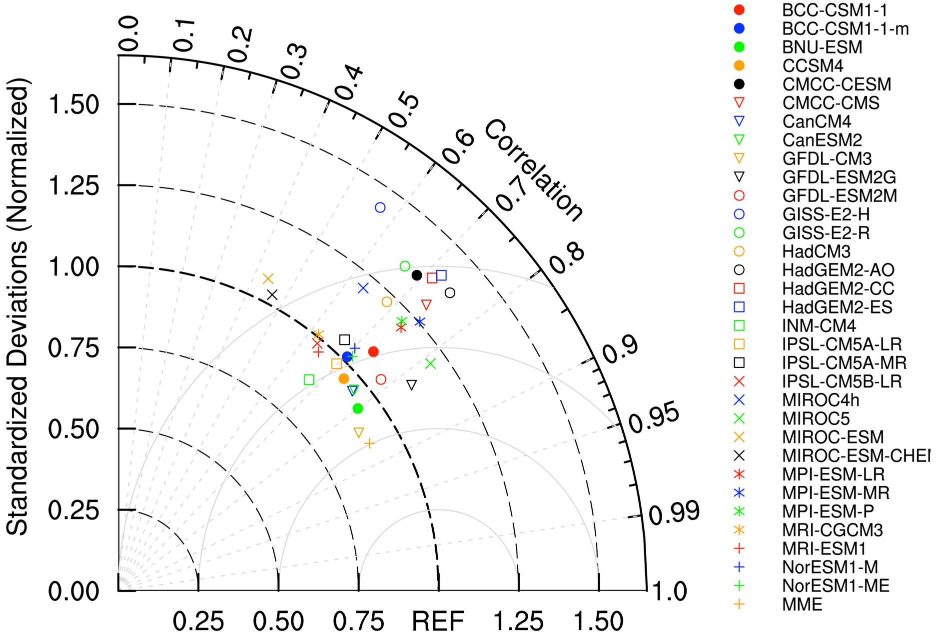
The beauty contest!

List of CMIP5 models (32)

Model	**Institution**	**Resolution (Latitude x Longitude)**
BCC-CSM1-1	Beijing Climate Center, China Meteorological Administration, China	64 x 128
BCC-CSM1-1-m	Beijing Climate Center, China Meteorological Administration, China	160 x 320
BNU-ESM	College of Global Change and Earth System Science, Beijing Normal University, China	64 x 128
CCSM4	National Center for Atmospheric Research, USA	192 x 288
CMCC-CESM	Centro Euro-Mediterraneo per I Cambiamenti Climatici, Italy	48 x 96
CMCC-CMS	Centro Euro-Mediterraneo per I Cambiamenti Climatici, Italy	96 x 192
CanCM4	Canadian Centre for Climate Modelling and Analysis, Canada	64 x 128
CanESM2	Canadian Centre for Climate Modelling and Analysis, Canada	64 x 128
GFDL-CM3	Geophysical Fluid Dynamics Laboratory, USA	90 x 144
GFDL-ESM2G	Geophysical Fluid Dynamics Laboratory, USA	90 x 144
GFDL-ESM2M	Geophysical Fluid Dynamics Laboratory, USA	90 x 144
GISS-E2-H	NASA Goddard Institute for Space Studies, NY	90 x 144
GISS-E2-R	NASA Goddard Institute for Space Studies, NY	90 x 144
HadCM3	Met Office Hadley Centre, UK	73 x 96
HadGEM2-AO	National Institute of Meteorological Research/Korea Meteorological Administration, South Korea	145 x 192
HadGEM2-CC	Met Office Hadley Centre, UK	145 x 192
HadGEM2-ES	Met Office Hadley Centre, UK	145 x 192
INM-CM4	Institute for Numerical Mathematics, Russia	120 x 180
IPSL-CM5A-LR	Institut Pierre-Simon Laplace, France	96 x 96
IPSL-CM5A-MR	Institut Pierre-Simon Laplace, France	143 x 144
IPSL-CM5B-LR	Institut Pierre-Simon Laplace, France	96 x 96
MIROC4h	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology, Japan	320 x 640
MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology, Japan	128 x 256
MIROC-ESM	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies, Japan	64 x 128
MIROC-ESM-CHEM	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies, Japan	64 x 128
MPI-ESM-LR	Max Planck Institute for Meteorology (MPI-M), Germany	96 x 192
MPI-ESM-MR	Max Planck Institute for Meteorology (MPI-M), Germany	96 x 192
MPI-ESM-P	Max Planck Institute for Meteorology (MPI-M), Germany	96 x 192
MRI-CGCM3	Meteorological Research Institute, Japan	160 x 320
MRI-ESM1	Meteorological Research Institute, Japan	160 x 320
NorESM1-M	Norwegian Climate Centre, Norway	96 x 144
NorESM1-ME	Norwegian Climate Centre, Norway	96 x 144

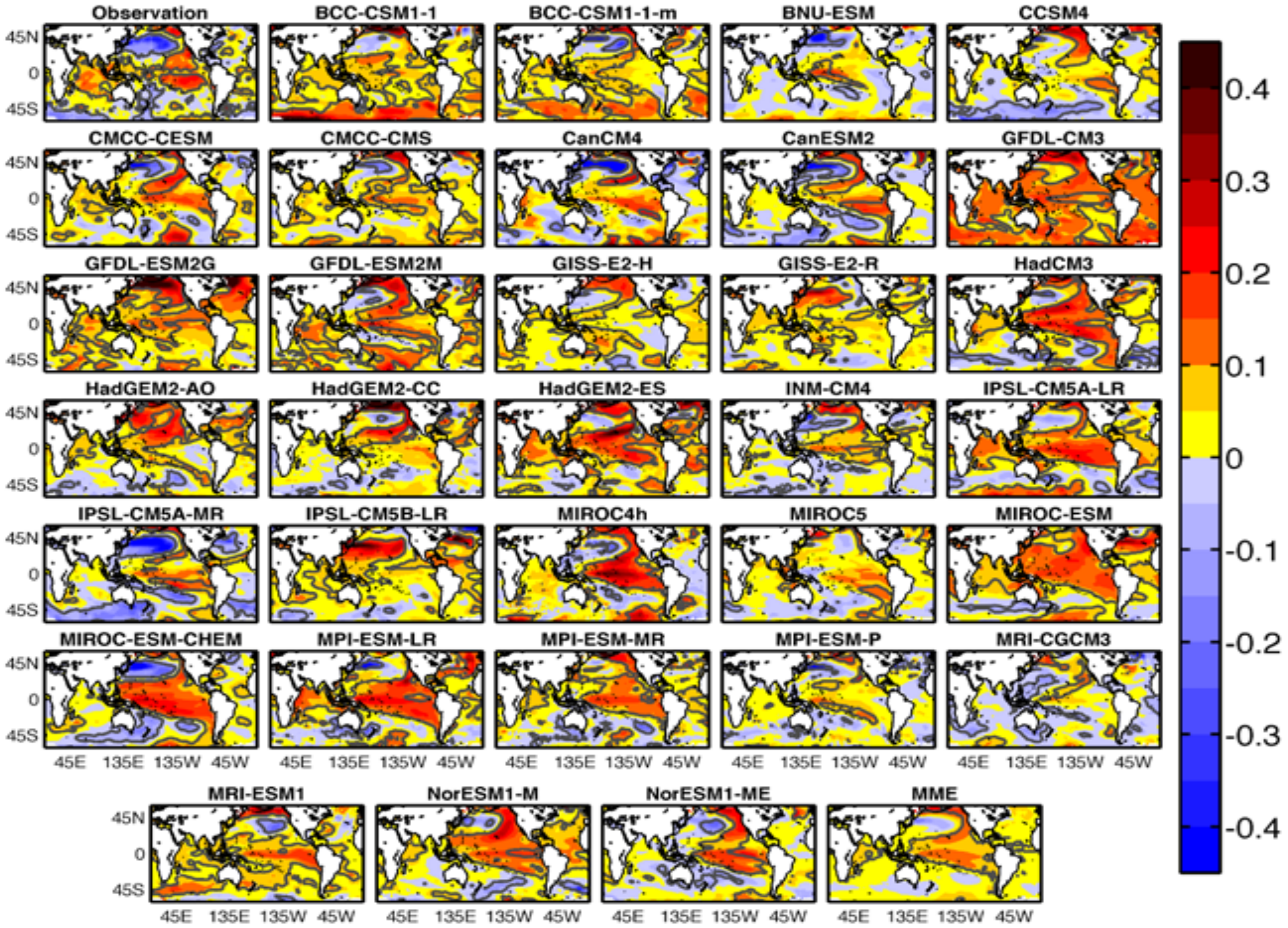
Basic validation of Monsoon representation: Taylor diagrams


Annual cycle of ISMR

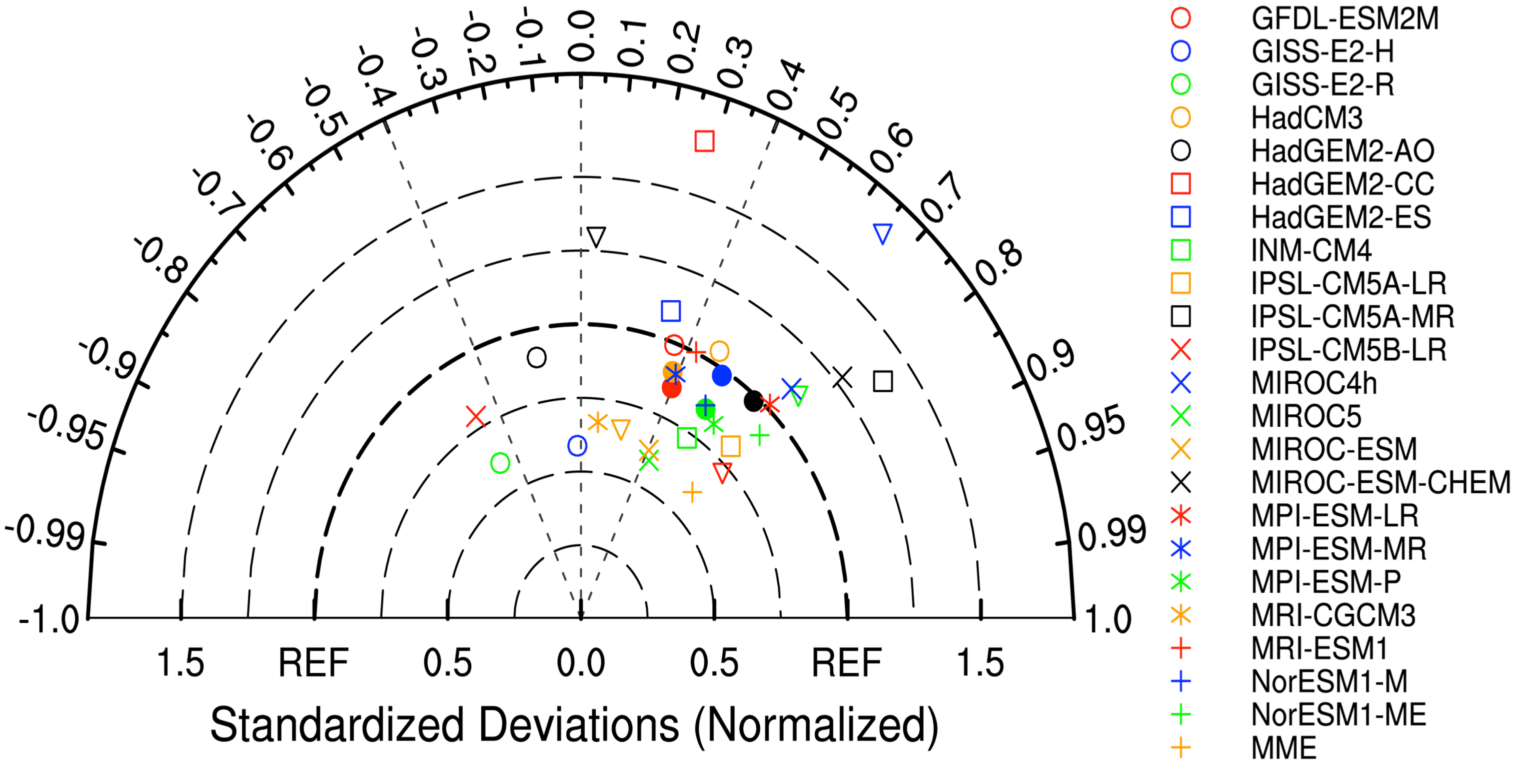

Spatial pattern of JJAS ISMR

Note that none of these metrics is used to exclude models from the analysis

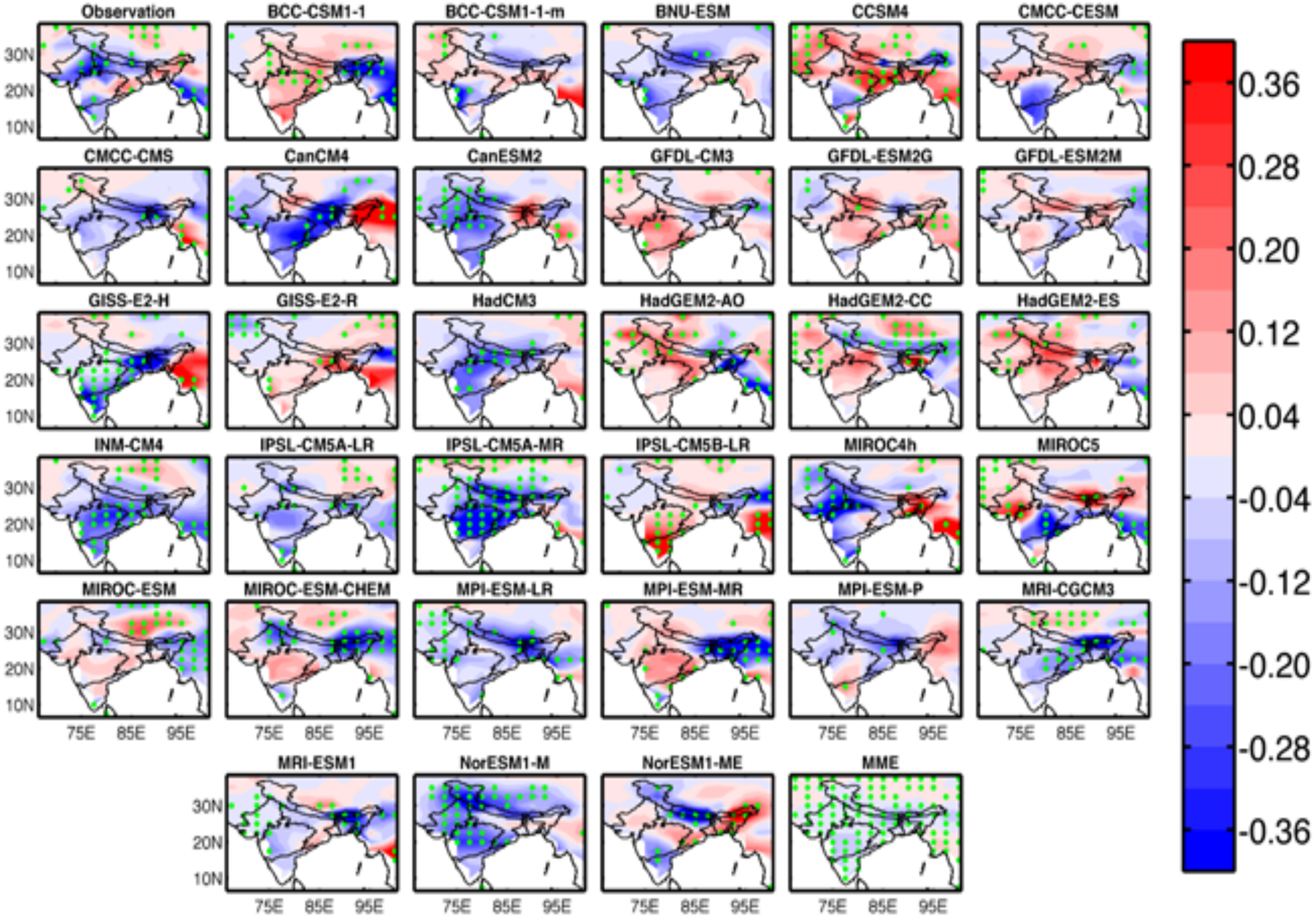
Basic validation of IPO pattern; definition such that eastern Equatorial SST anomalies are positive (some uncetrtainty due to this criterion); pattern not always well reproduced



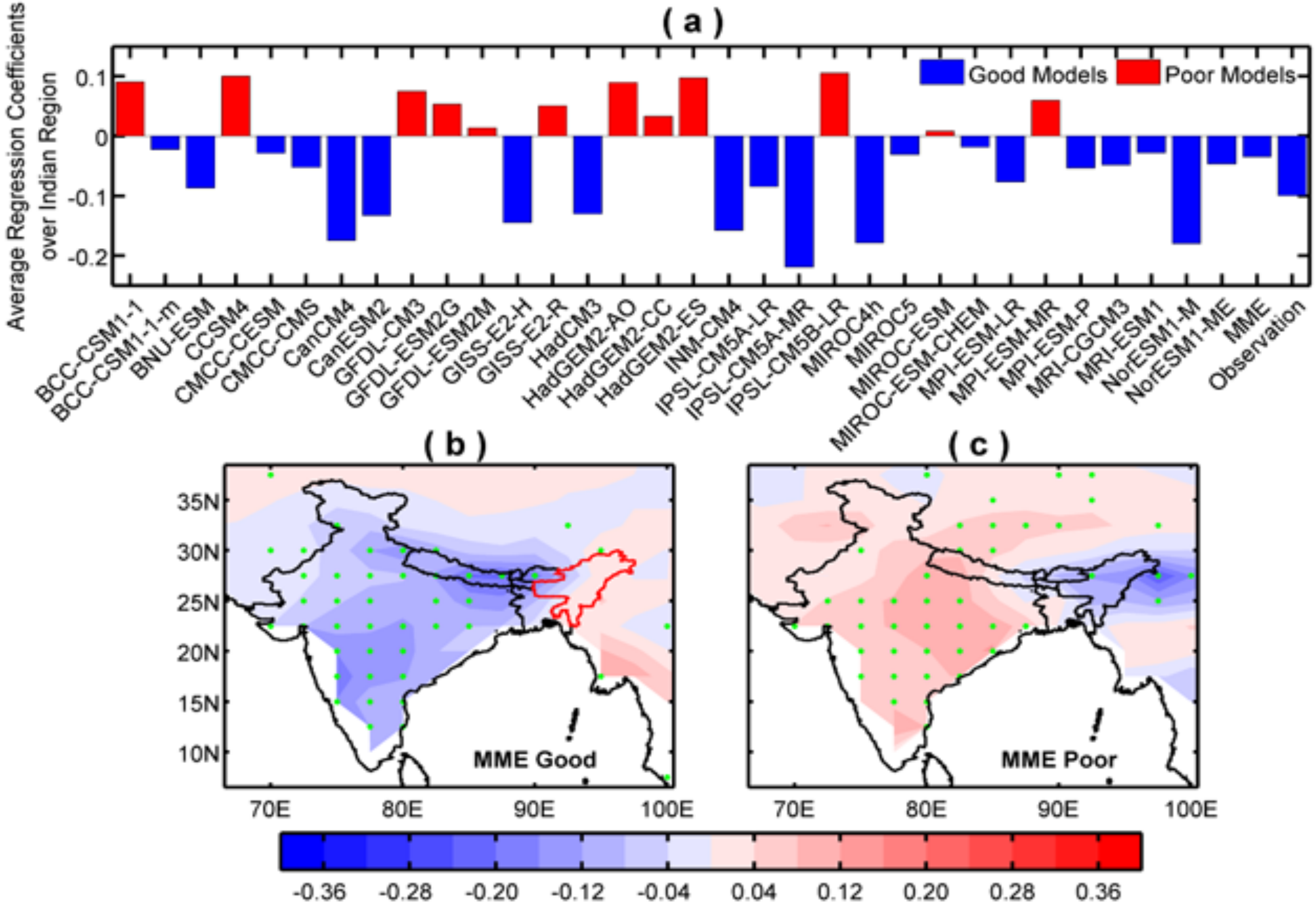
Basic validation of IPO pattern; Taylor diagrams of spatial patterns correlation



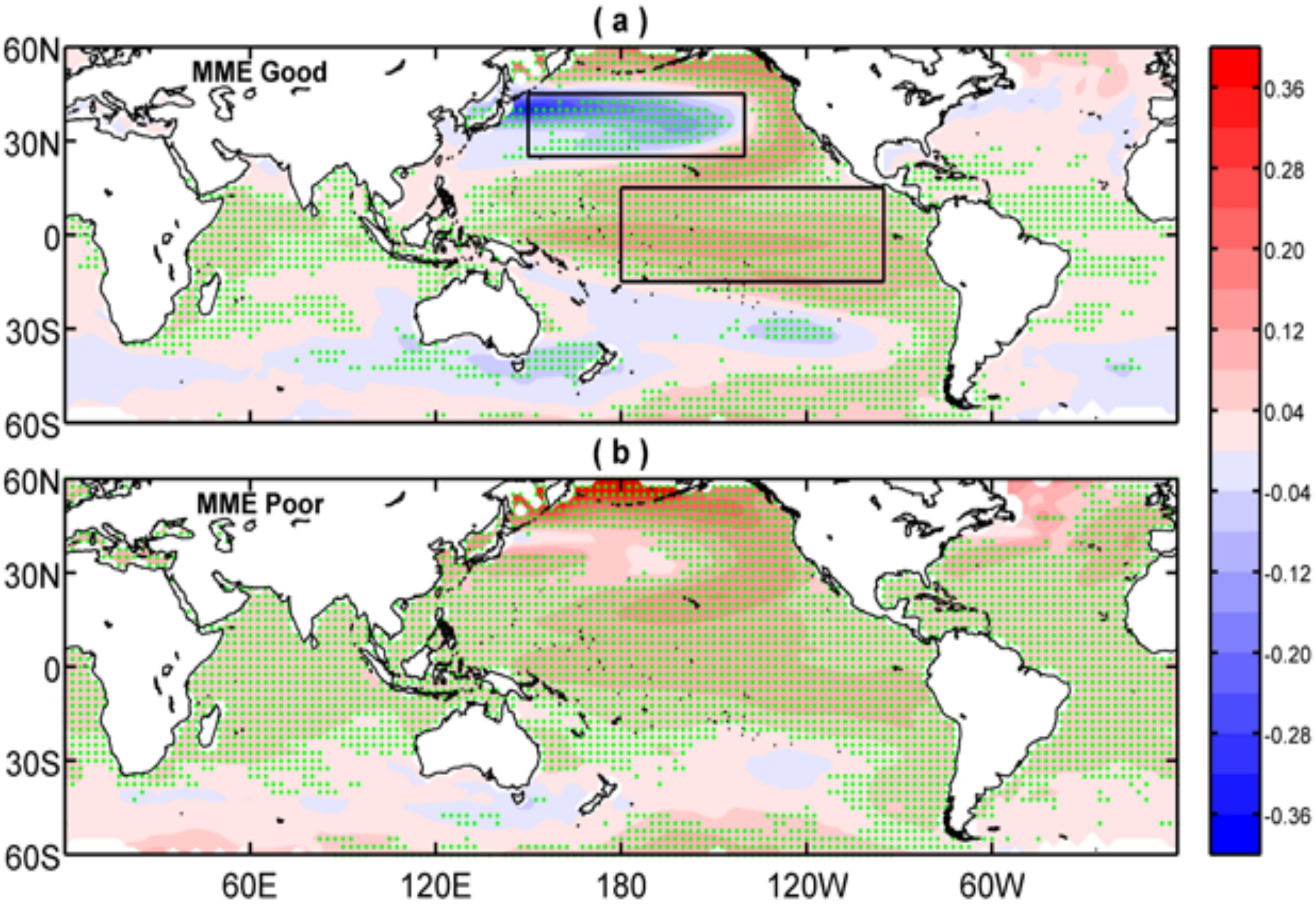
Teleconnection of IPO with Indian monsoon based on linear regression of the normalized IPO index with rainfall in the Indian region



Consider area average rainfall IPO regression over Indian land mass to distinguish 'good' from 'poor' models



Lets look at the mean IPO SST regressions of 'good' and poor' models

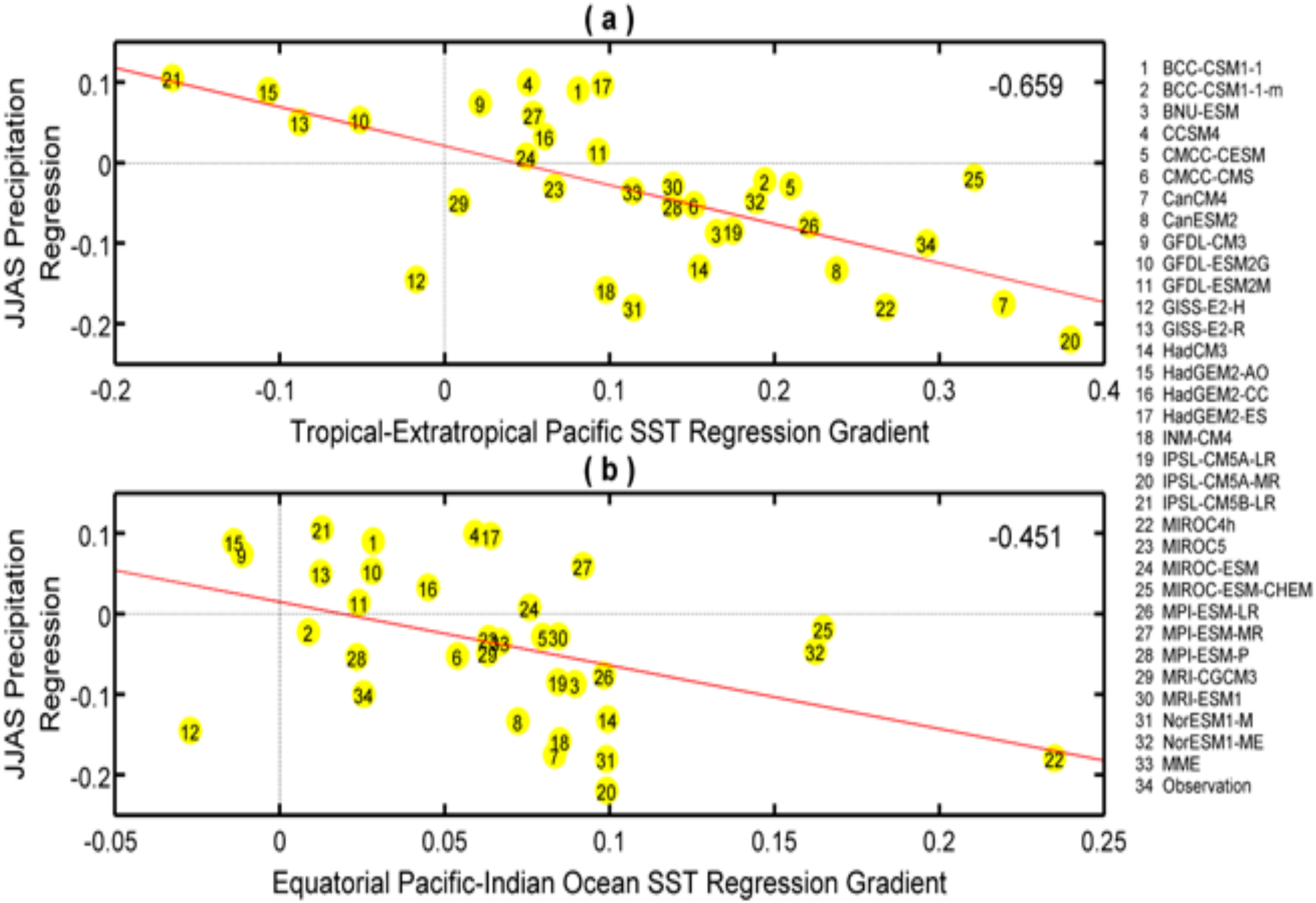


Good

Poor

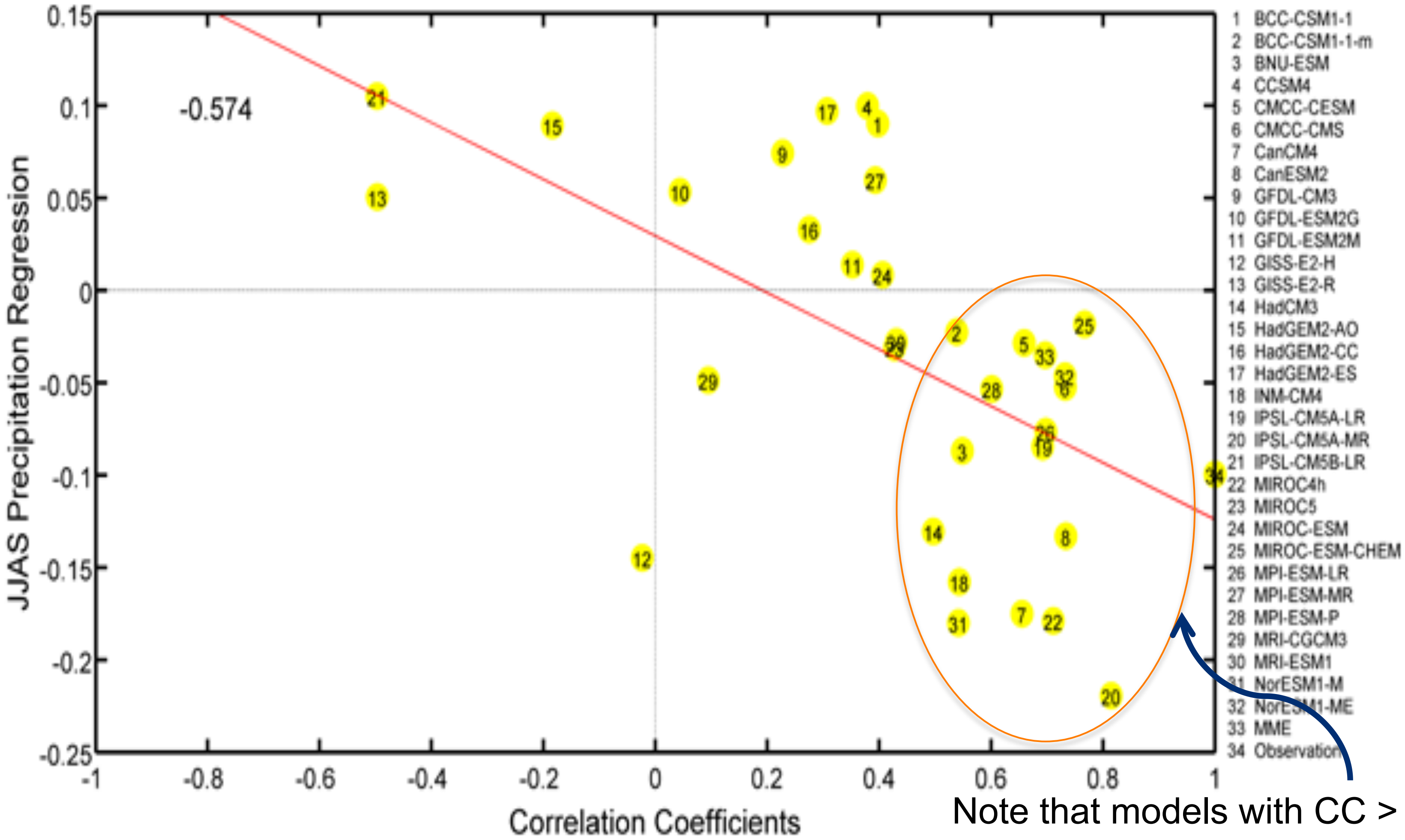
There are some striking featues characterizing good and poor models, particularly tropical-extratropical SST anomaly gradient

Motivates to have a look at some scatter plots



Tropical-extratropical SST anomaly gradient provides strong relationship, but why?

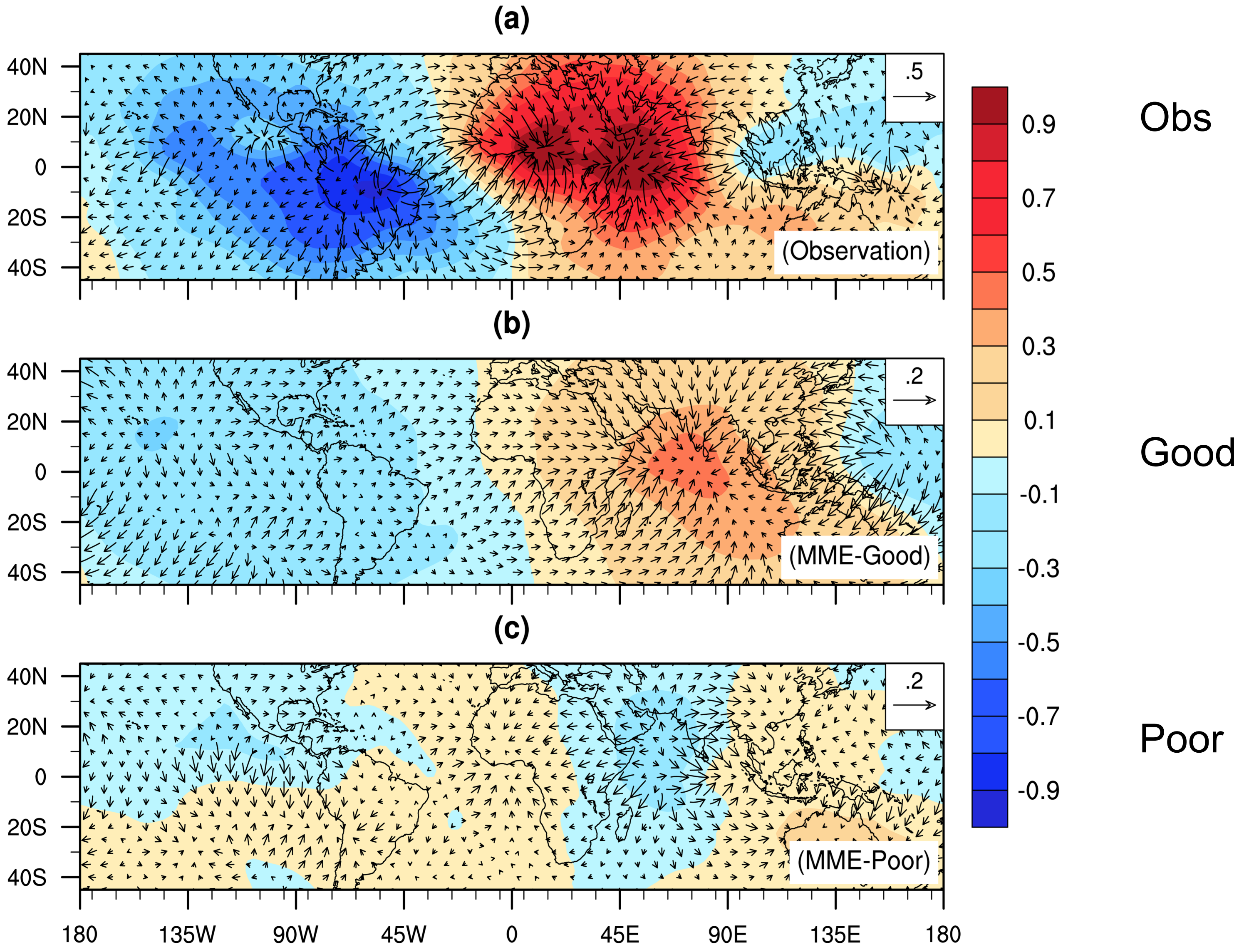
Motivates to have a look at some scatter plots: IOP SST anomaly pattern correlation with obs vs mean Indian rainfall regression



Note that models with CC > 0.5 all show ‘good’ rainfall regressions

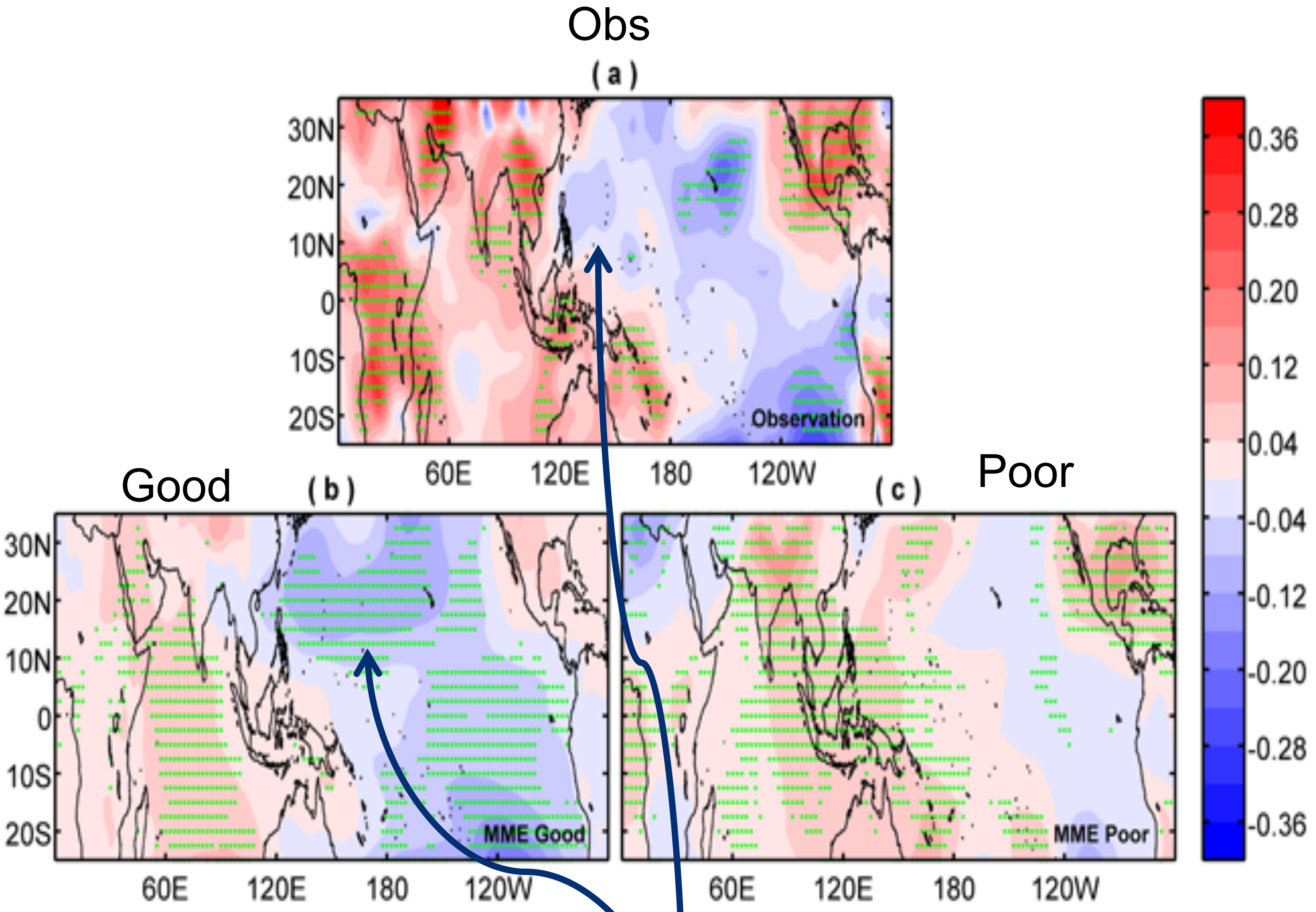
Overall, the IPO SST pattern matters! So, it is worth trying to understand why some models do not reproduce a correct IPO pattern; is it related to a lack of STC involvement in the IPO dynamics? This should be addressed indeed, we currently do with PhD student)

Lets have a look at some atmospheric features of the IPO-Indian Monsoon teleconnection: 150 hPa velocity potential



Adjustment of the Walker circulation is much clearer in the good models

Lets have a look at some atmospheric features of the IPO-Indian Monsoon teleconnection: Surface Pressure



One speculation why tropical-extratropical SST anomaly gradient is so important could be that by changing baroclinicity it modifies adjustment of the Walker circulation by inducing a low pressure in the northern subtropics or it could simply be a coincidence?; a hypothesis to be tested through idealised AGCM simulations.

Conclusions:

- There is a strong teleconnection from the Eastern Pacific to the Indian summer monsoon on interannual to (multi-) decadal timescales.
- The physical mechanism for this teleconnection is related to a modification of the Walker circulation.
- IPO (or PDO) are the (multi-) decadal counterparts of the interannual Pacific ENSO variability.
- CMIP5 models reproduce on average the Indian Monsoon Climatology and annual cycle reasonable well.
- CMIP5 models reproduce the observed IPO spatial pattern with varying success.
- Models with a better IPO pattern also reproduce the teleconnection with the Indian Monsoon better, irrespective of the models ability to reproduce the Indian Monsoon climatology. Of particular relevance are tropical-extratropical SST gradient and zonal SST gradient (e.g. eastern Pacific minus Indian Ocean).
- It needs to be further investigated why some models do not reproduce the IPO spatial pattern satisfactorily.