



The Abdus Salam  
**International Centre  
for Theoretical Physics**



**2356-26**

**Targeted Training Activity: ENSO-Monsoon in the Current and Future Climate**

*30 July - 10 August, 2012*

**Trends and Decadal Variability in Monsoon**

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# Trends and Decadal Variability in Monsoon

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Targeted Training Activity  
El Niño-Southern Oscillation and Monsoon in the Current and Future Climate  
The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy  
30 July-10 August 2012

# Outline

**Trend in precipitation over India**

**Decadal modes in monsoon**

**Space-time structure of decadal oscillations**  
**Relation with SST decadal variability**

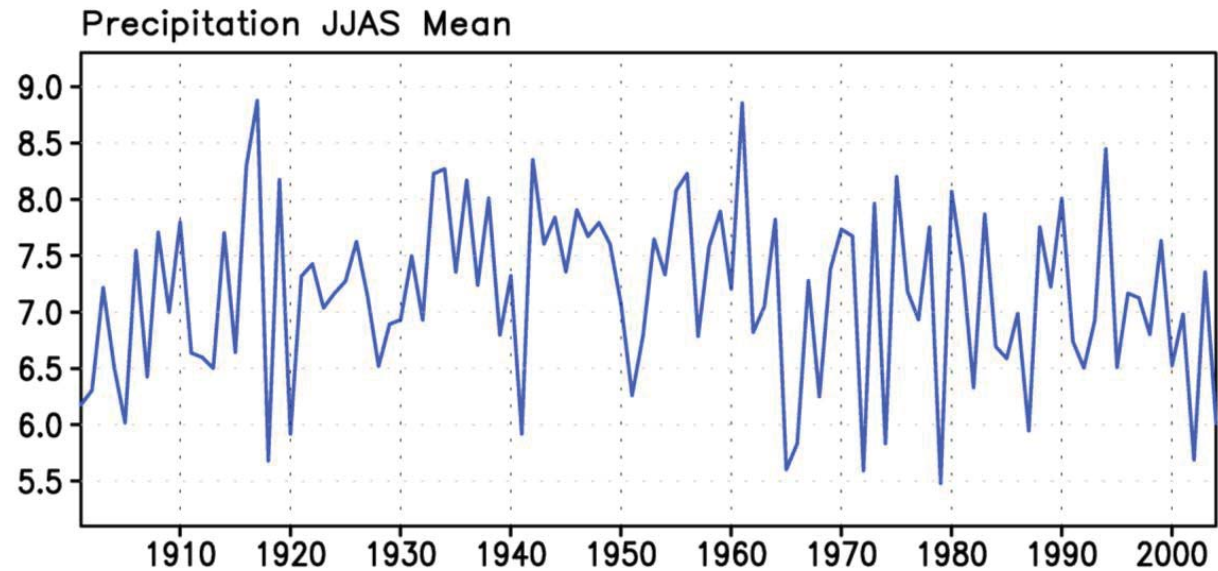
**Decadal Variability: Lakshmi Krishnamurthy, GMU, Ph.D. Thesis**

**EMD: Zhaohua Wu, FSU**

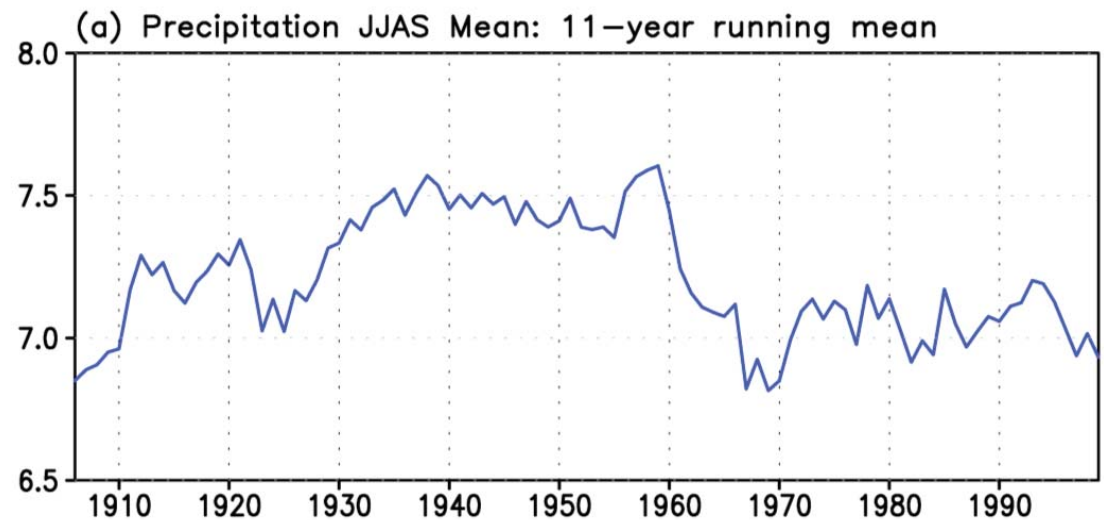
## Seasonal mean rainfall

Central India average  
of rainfall

JJAS seasonal mean



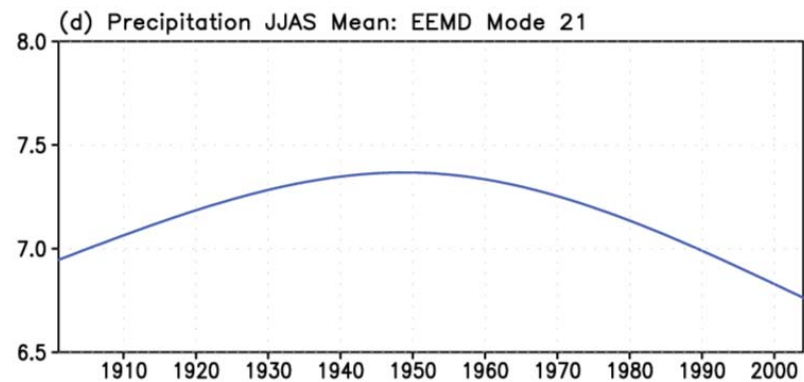
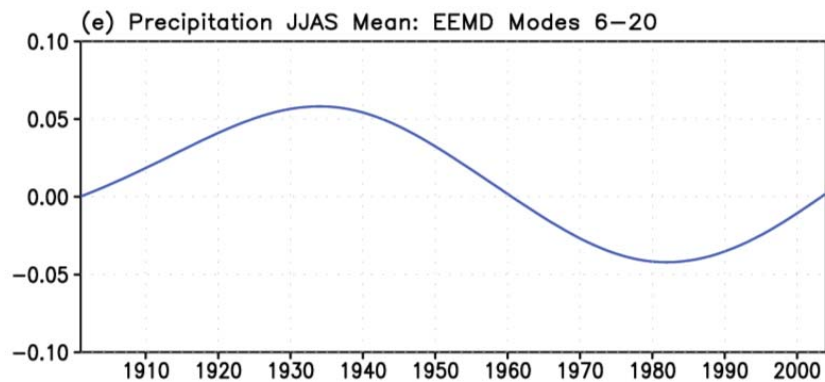
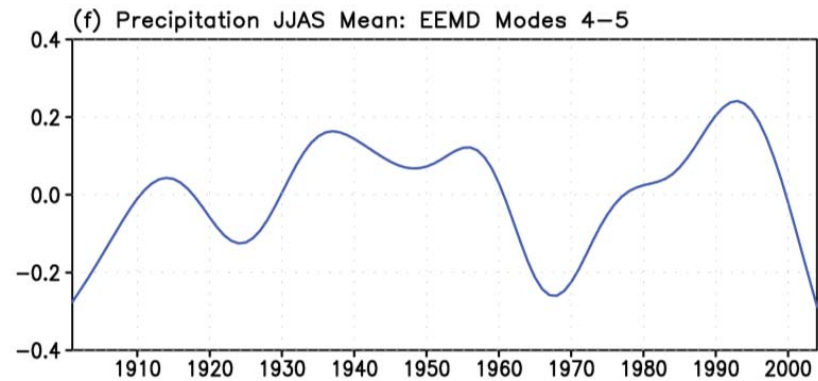
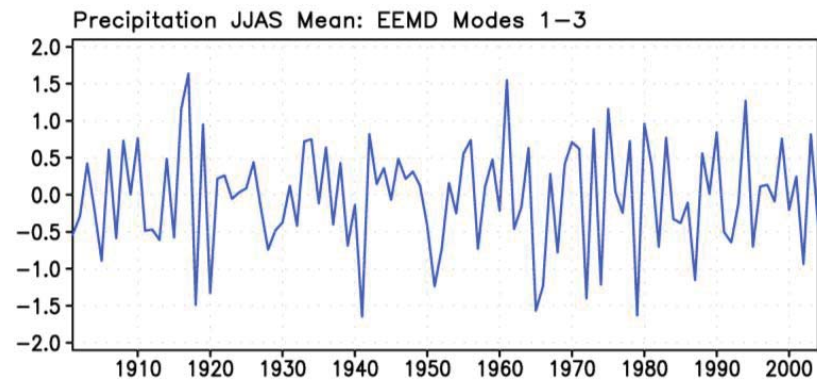
11-year running mean of  
JJAS seasonal mean



# Seasonal Mean Rainfall

Empirical Mode Decomposition (EMD)  
JJAS seasonal mean rainfall over India

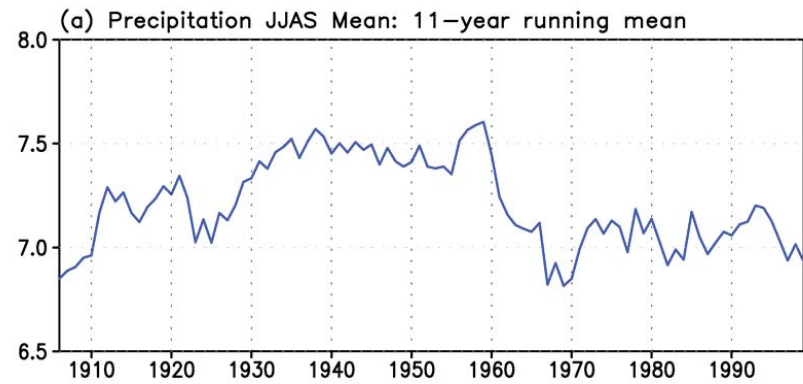
Central India averages of EMD modes



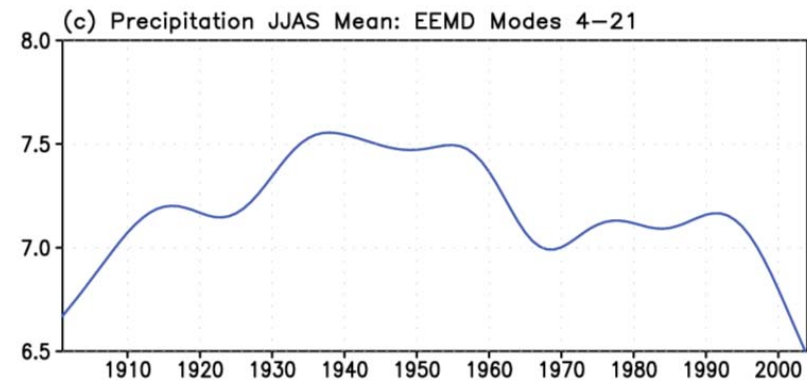
# Seasonal Mean Rainfall

JJAS seasonal mean  
Central India average

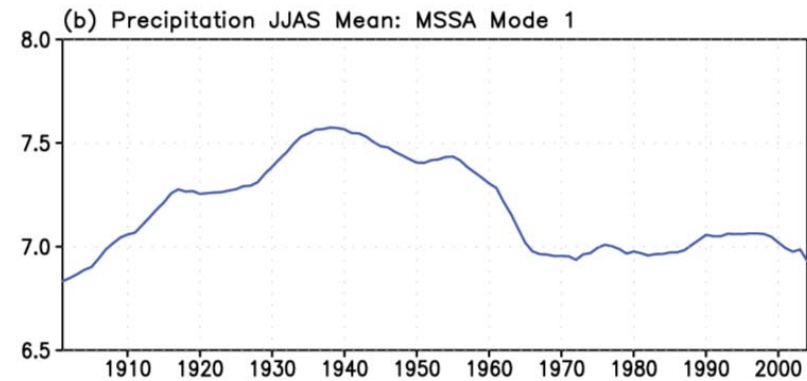
11-year running mean



EMD modes 4-21  
(Decadal + trend)

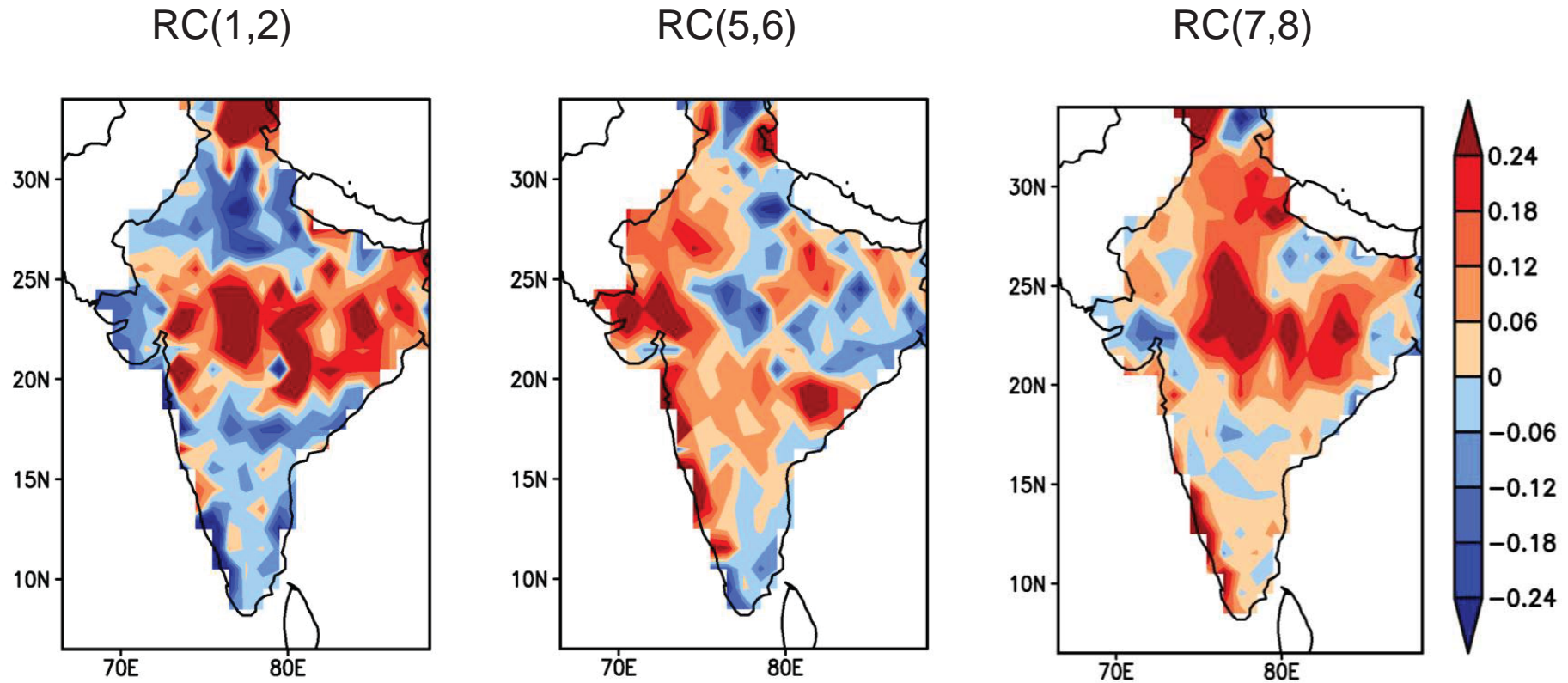


MSSA of seasonal mean (RC1)



## Decadal Variability of monsoon rainfall in observations

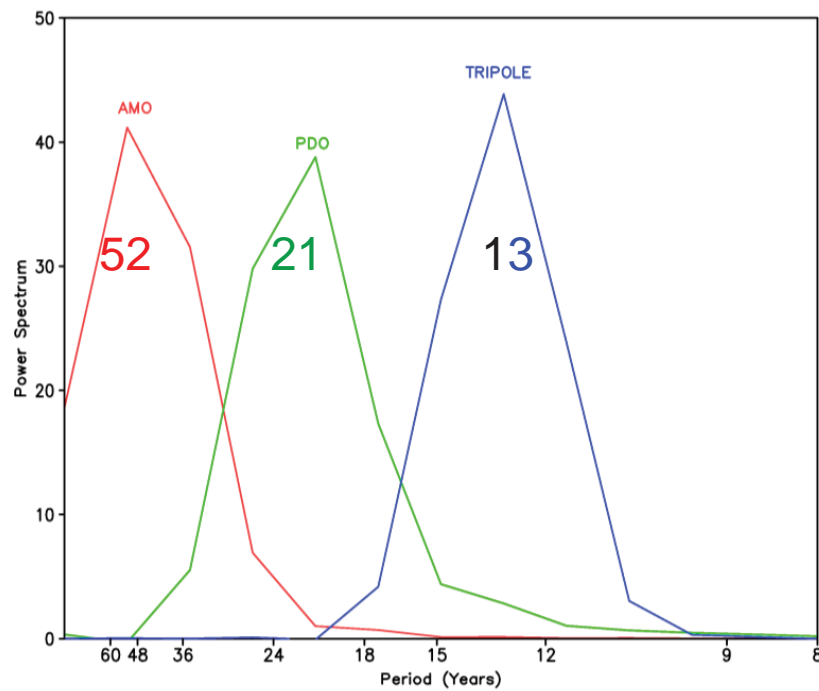
MSSA modes of rainfall over India  
JJAS seasonal mean rainfall 1901-2004  
Three decadal-scale oscillations



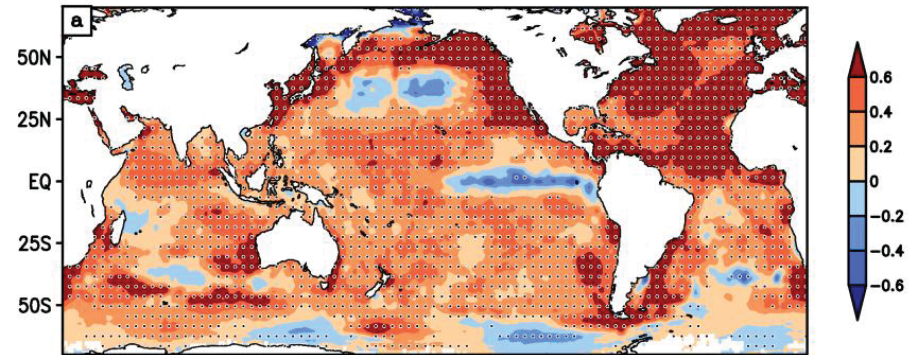
# Decadal Variability of monsoon rainfall in observations

Power spectra of the monsoon decadal modes.

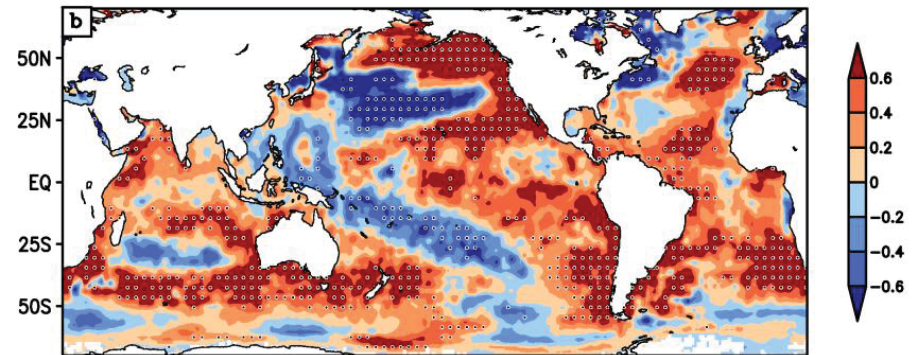
Regressions on SST



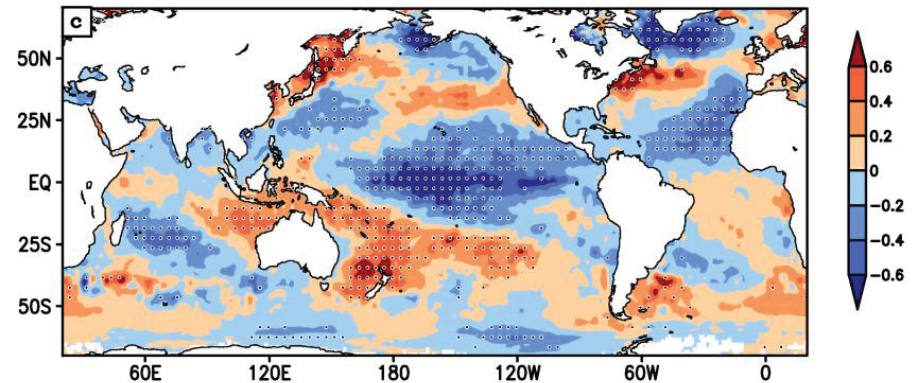
RC(1,2)



RC(5,6)



RC(7,8)





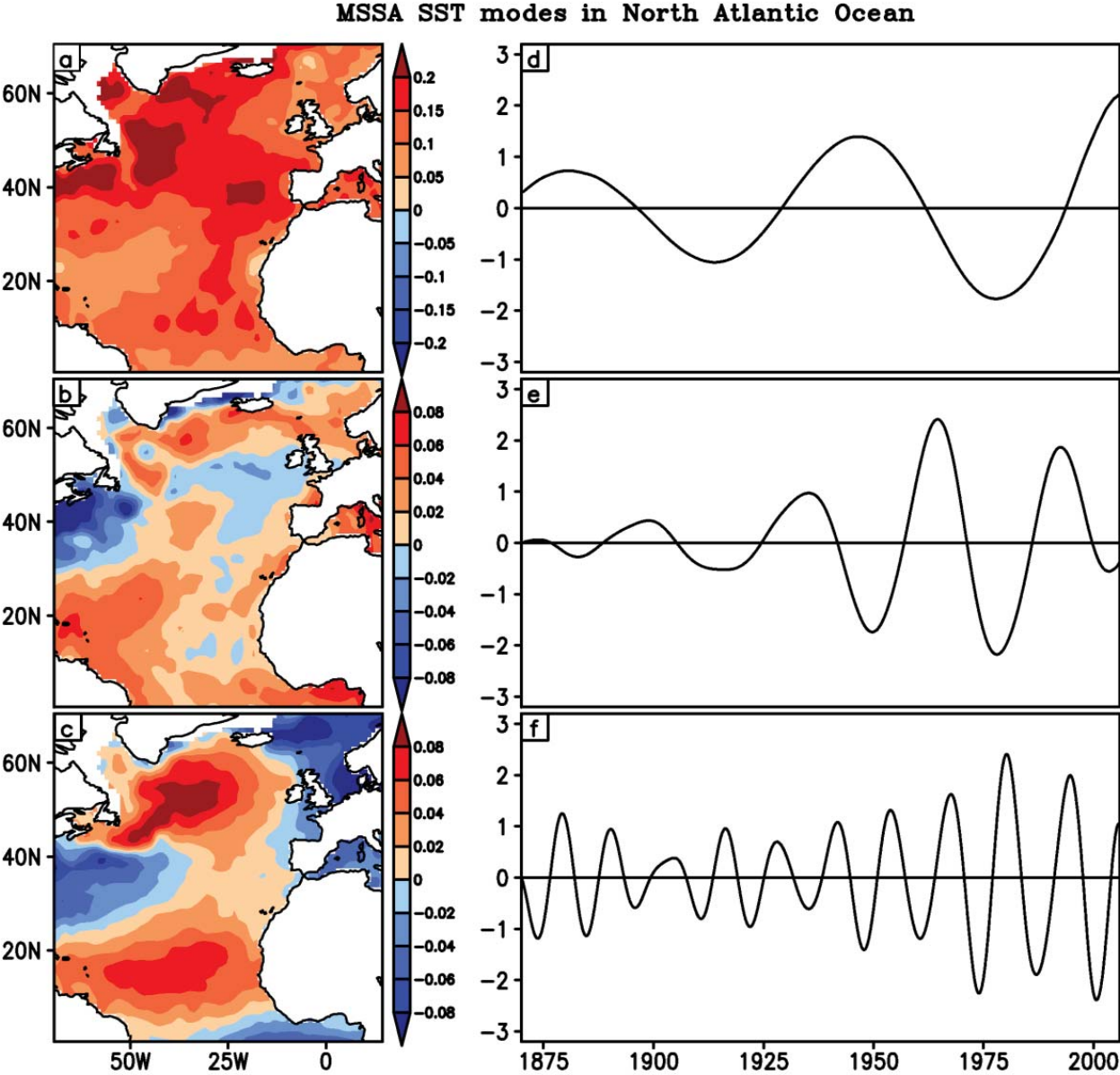
## Decadal Variability of monsoon rainfall in observations

<b>Mode</b>	<b>Var in RM5</b>	<b>Var in total</b>	<b>Relation</b>
<b>RC (1,2)</b>	<b>37%</b>	<b>8.9%</b>	<b>AMO</b>
<b>RC (5,6)</b>	<b>15%</b>	<b>3.6%</b>	<b>PDO</b>
<b>RC (7,8)</b>	<b>9%</b>	<b>2%</b>	<b>Tripole</b>

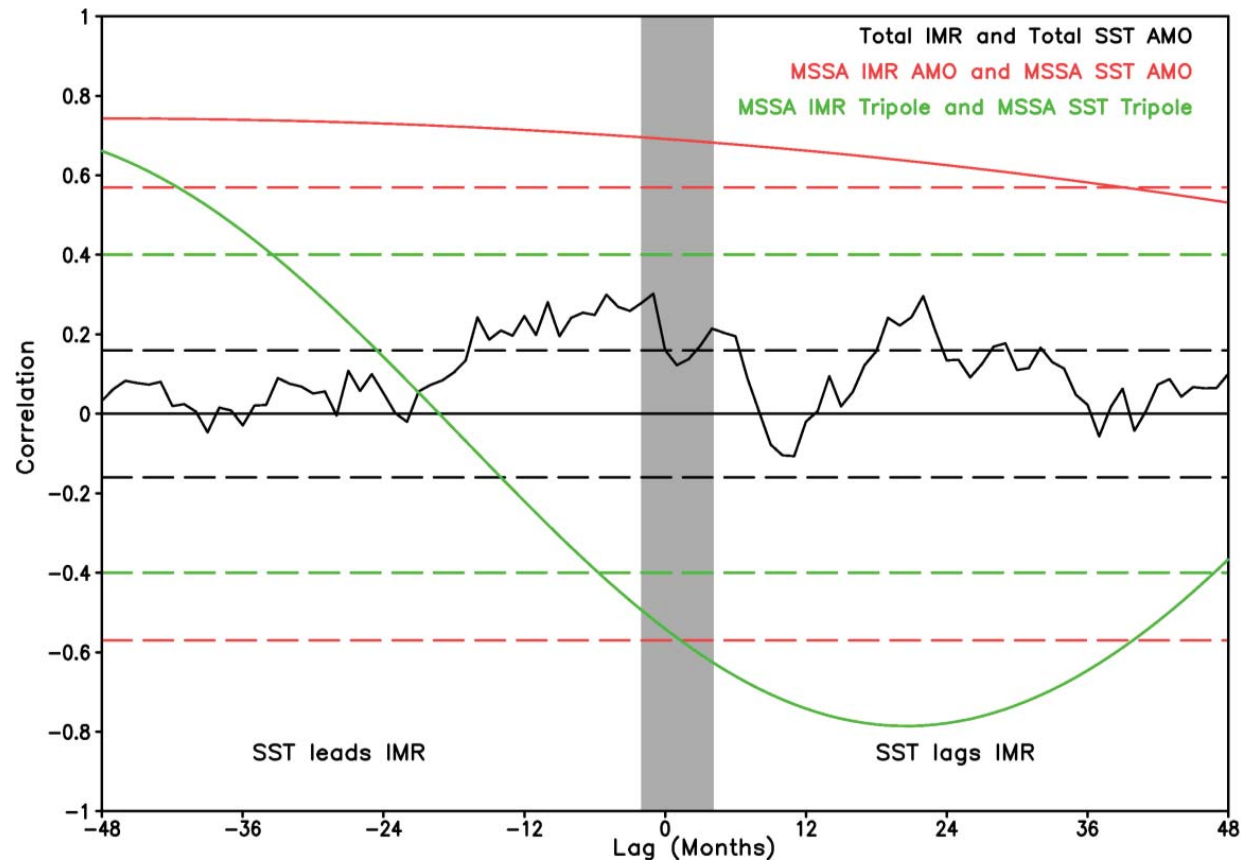
# Decadal Modes in SST over North Atlantic in Observations

AMO

Tripole



# Relation between monsoon and SST decadal modes in observations

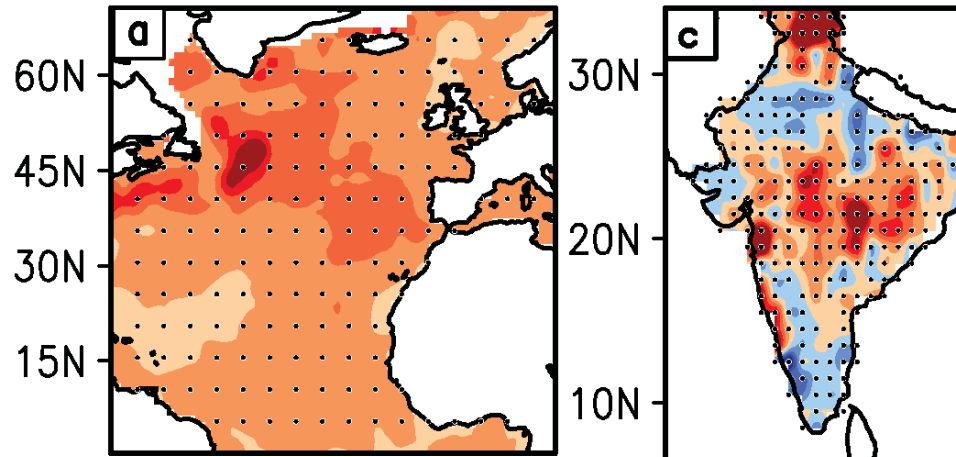


AMO: Positive correlation between monsoon and SST

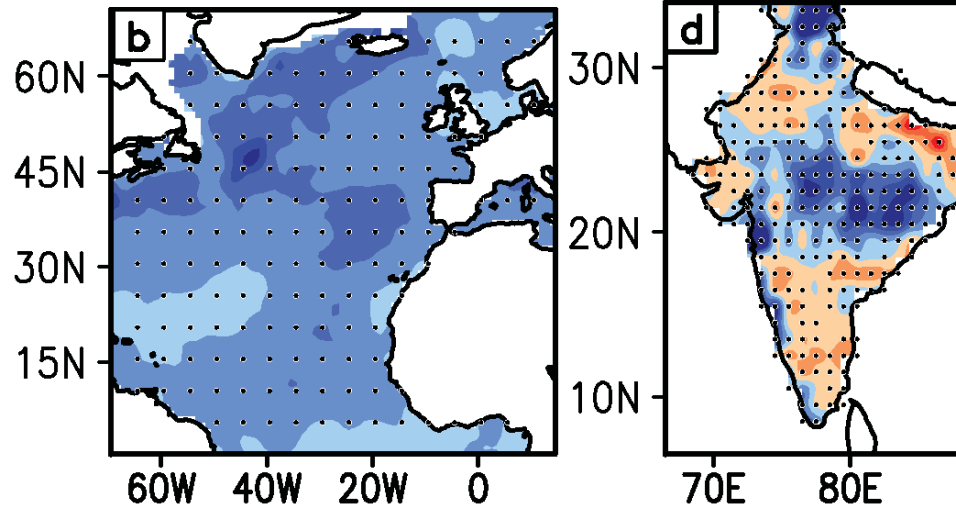
Tripole: Negative correlation between monsoon and SST during and after monsoon season

# AMO composites in observations

Warm AMO

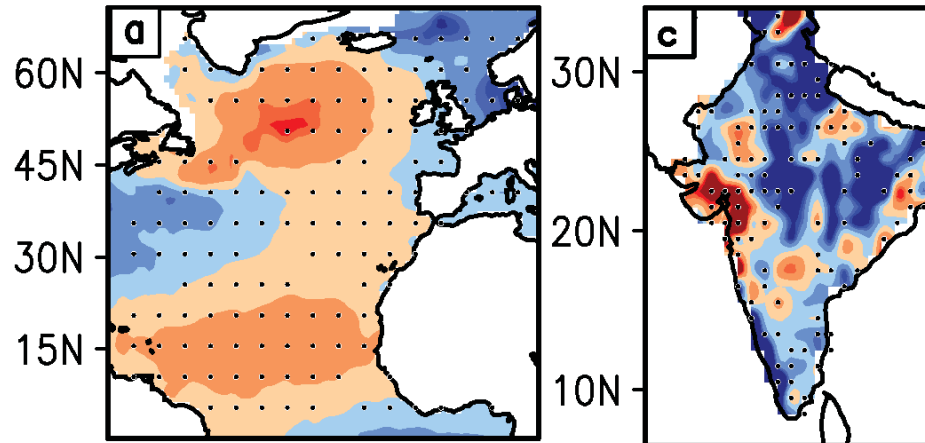


Cold AMO

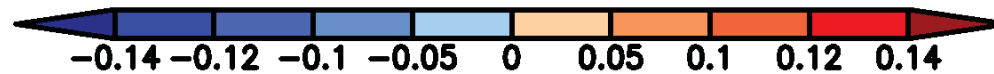
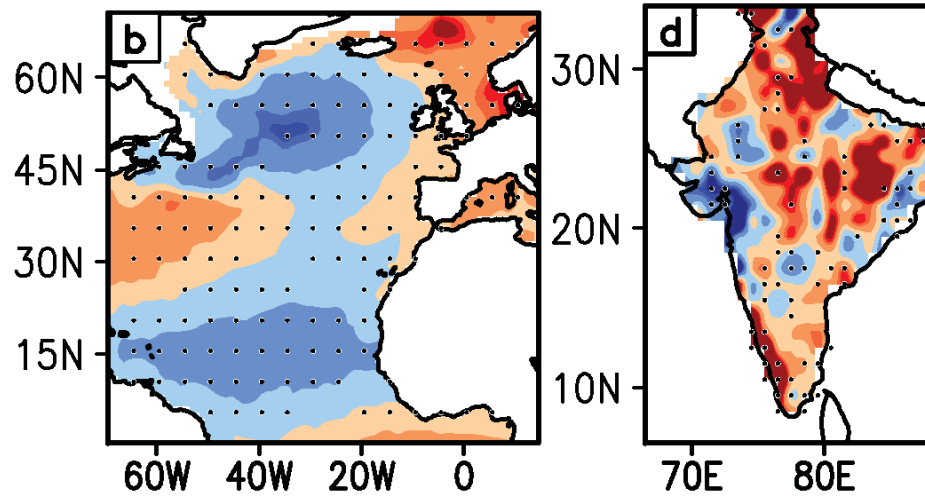


# Atlantic tripole composites in observations

Warm tripole



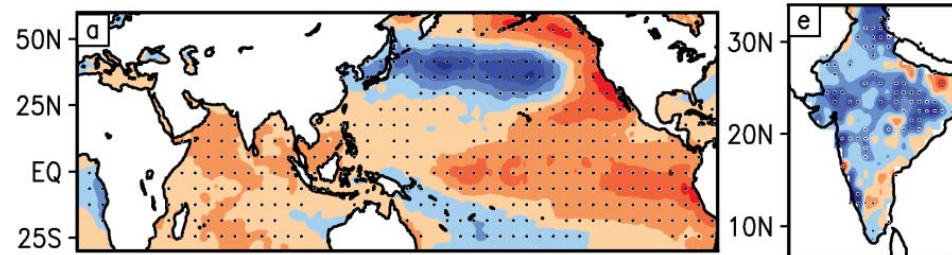
Cold tripole



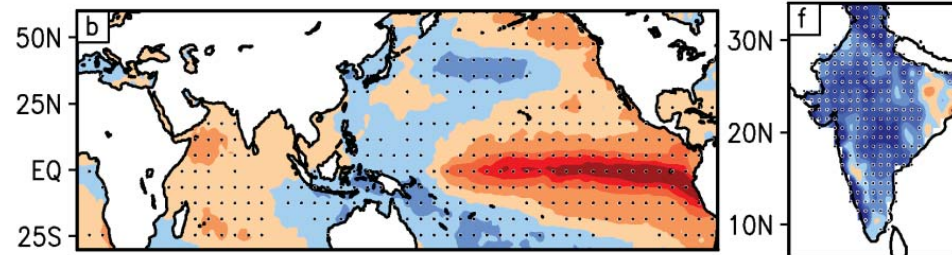
## PDO and ENSO composites

When PDO and ENSO are in (out of) Phase, the ENSO-monsoon relation Is enhanced (reduced).

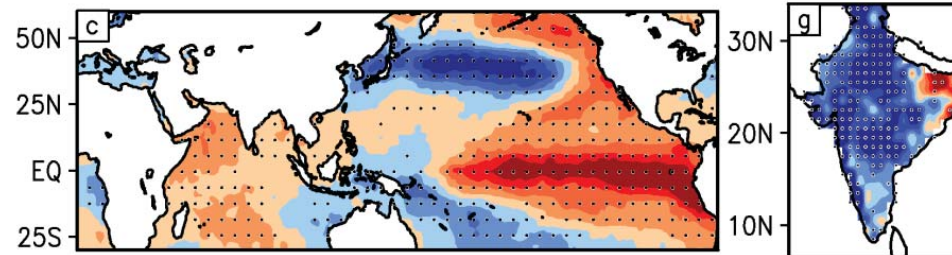
Warm PDO



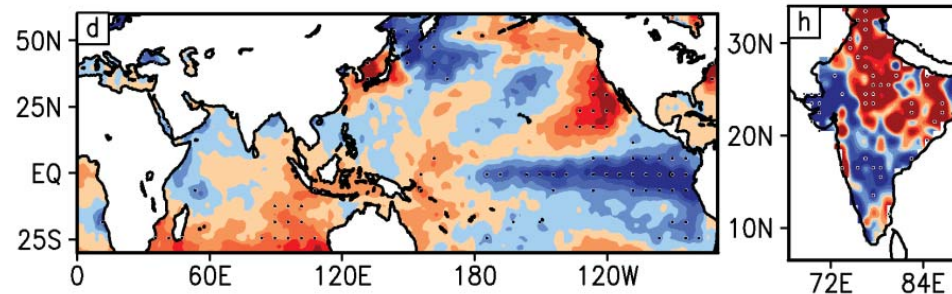
El Niño



Warm PDO and El Niño



Warm PDO and La Niña



## Decadal monsoon modes in coupled model

Model control: NCAR CCSM4 20C3M

Model experiments:

<b>Experiment</b>	<b>Description</b>	<b>Purpose</b>
<b>EXP-NP</b> 120°E-240°E; 20°N-60°N	Climatological SSTs prescribed in <b>North Pacific</b> domain and coupled elsewhere.	Isolate influence of decadal variability in North Pacific on monsoon.
<b>EXP-NA</b> 290°E-375°E; 0°N-70°N	Climatological SSTs prescribed in <b>North Atlantic</b> domain and coupled elsewhere.	Isolate influence of decadal variability in North Atlantic on monsoon.

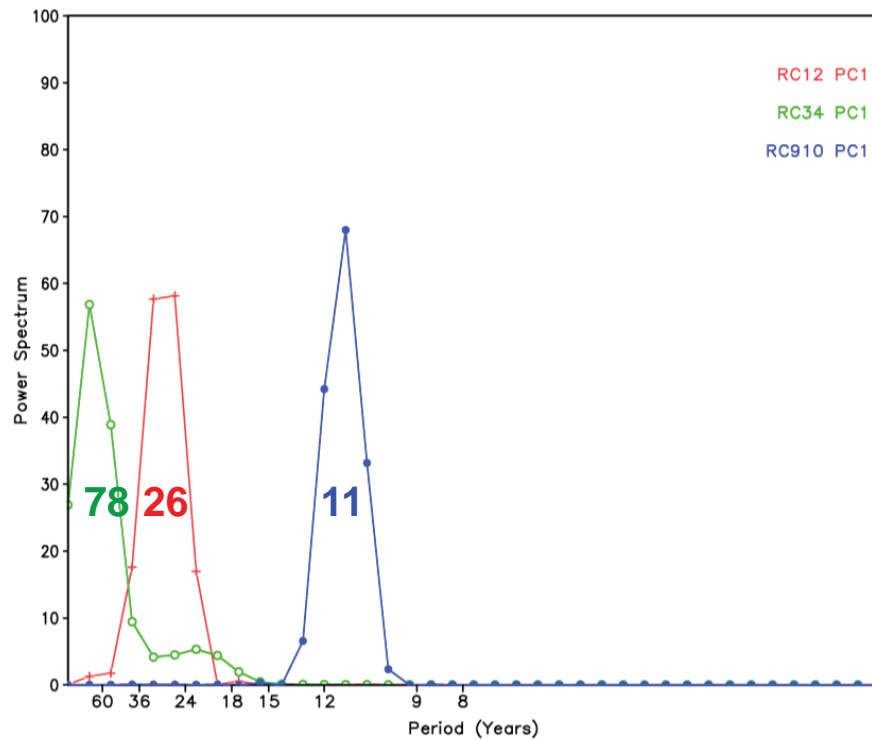
# Decadal Variability of monsoon rainfall in the model

## NCAR CCSM4 control run

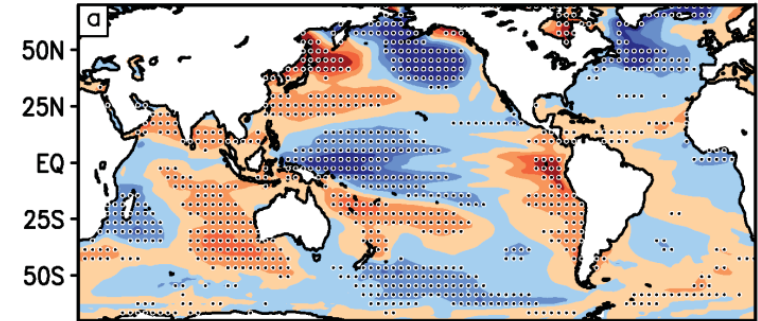
MSSA of monsoon rainfall

Power spectra of the monsoon decadal modes.

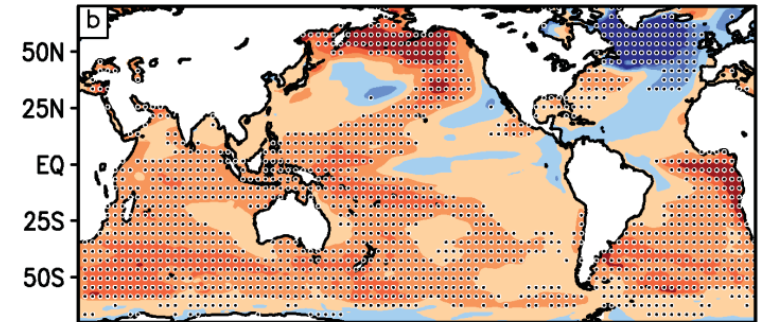
Regressions on SST



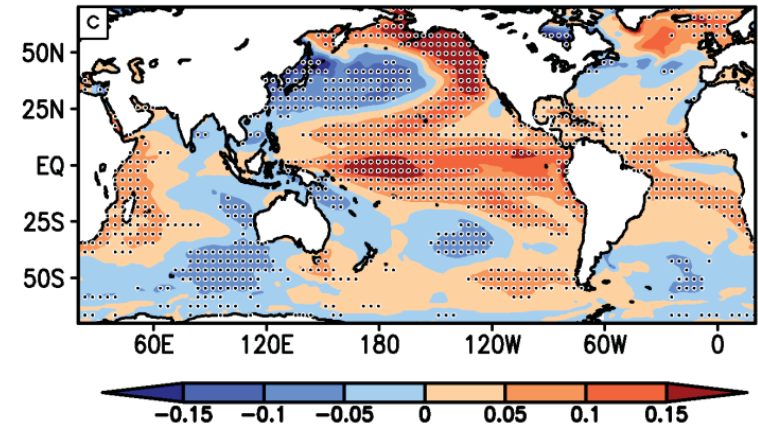
RC(1,2)



RC(3,4)



RC(9,10)





## Decadal Variability of monsoon in model experiments

### 1. EXP-NP (Climatological SST in North Pacific)

Absence of PDO related mode in monsoon rainfall

### 2. EXP-NA (Climatological SST in North Atlantic)

Absence of AMO and tripole related modes in monsoon rainfall

# Summary

**Seasonal mean rainfall over India has an increasing trend during 1901-1950 and decreasing trend during 1951-2004**

**Indian monsoon rainfall has three decadal modes on the timescales of AMO, Atlantic tripole and PDO**

**SST AMO and IMR – Positive correlation**

**SST Tripole and IMR – Negative correlation**

**SST PDO and IMR – Negative correlation**

**When PDO and ENSO are in (out of) phase, the ENSO-monsoon relation enhanced (reduced)**