The Abdus Salam
International Centre
for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

2356-5

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

30 July - 10 August, 2012

ENSO-South Asian Monsoon

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ENSO-South Asian 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

Some basic relations between monsoon and ENSO

Seasonally persistent modes of monsoon – ENSO and IOD

Relative roles of ENSO and IOD modes

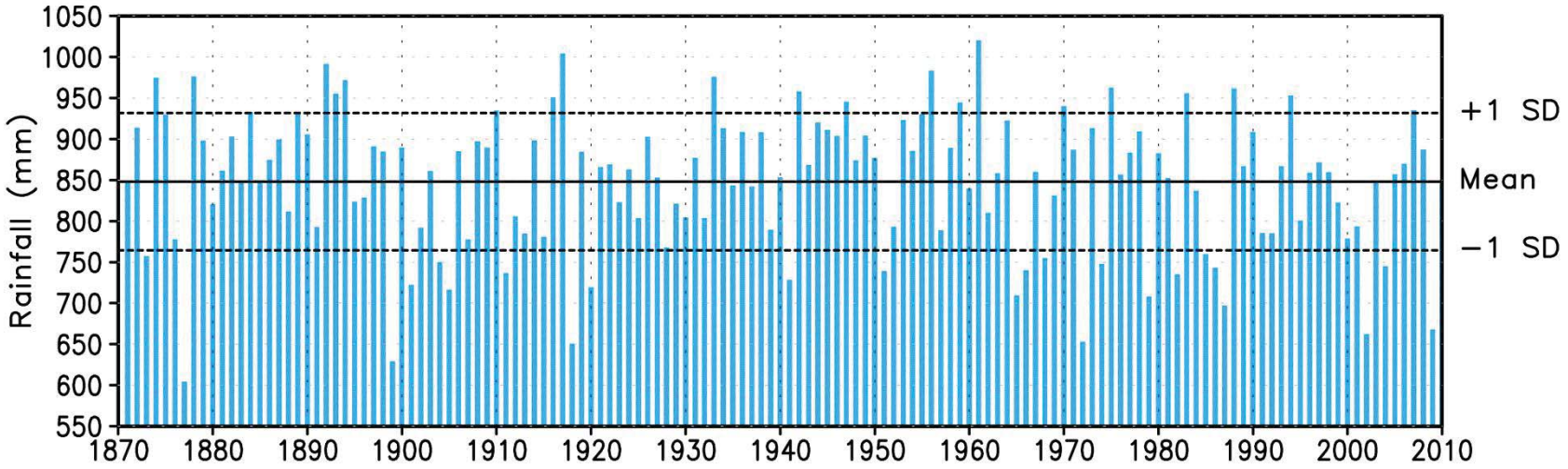
Relation between persistent monsoon modes and SST

Interannual Variability of Indian Monsoon Rainfall

The long-term mean of JJAS seasonal IMR index (rainfall area averaged over India) is 852 mm (about 7 mm/day).
The standard deviation is 83 mm (about 0.7 mm/day), about 10% of the long-term mean.

The JJAS seasonal mean of rainfall exhibits a pronounced interannual variability.
There are several flood (above-normal rainfall) years and several drought (below-normal rainfall) years, crossing 1 standard deviation.
There were 18 flood years and 23 drought years during 1871-2010.

JJAS Seasonal IMR index



Monsoon and ENSO

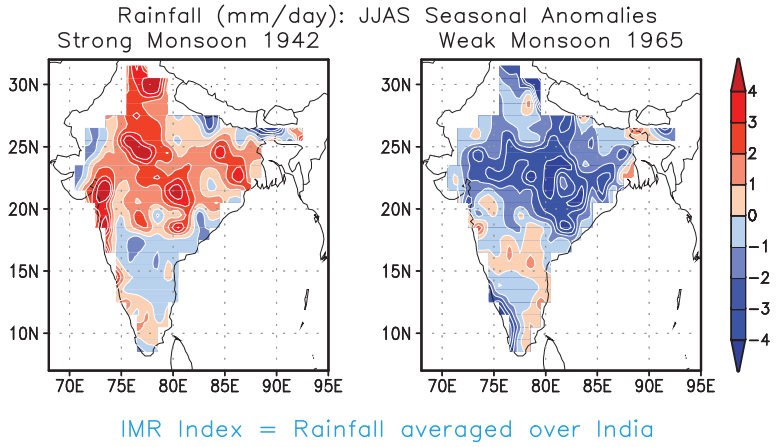
There are many years when strong (weak) monsoon season is followed by La Niña (El Niño) condition over the Pacific Ocean.

1942

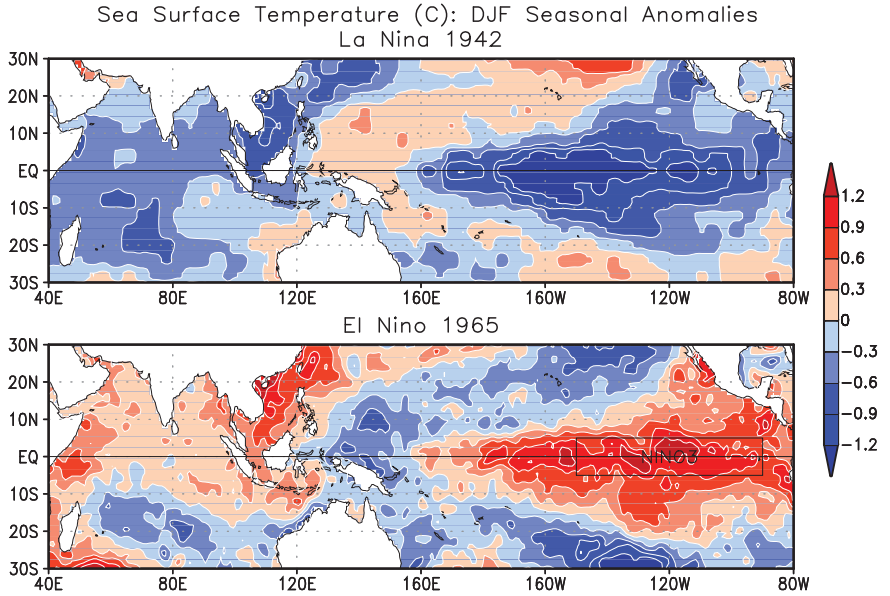
Strong or flood monsoon season
La Niña in the Pacific Ocean

1965

Weak or drought monsoon season
El Niño in the Pacific Ocean



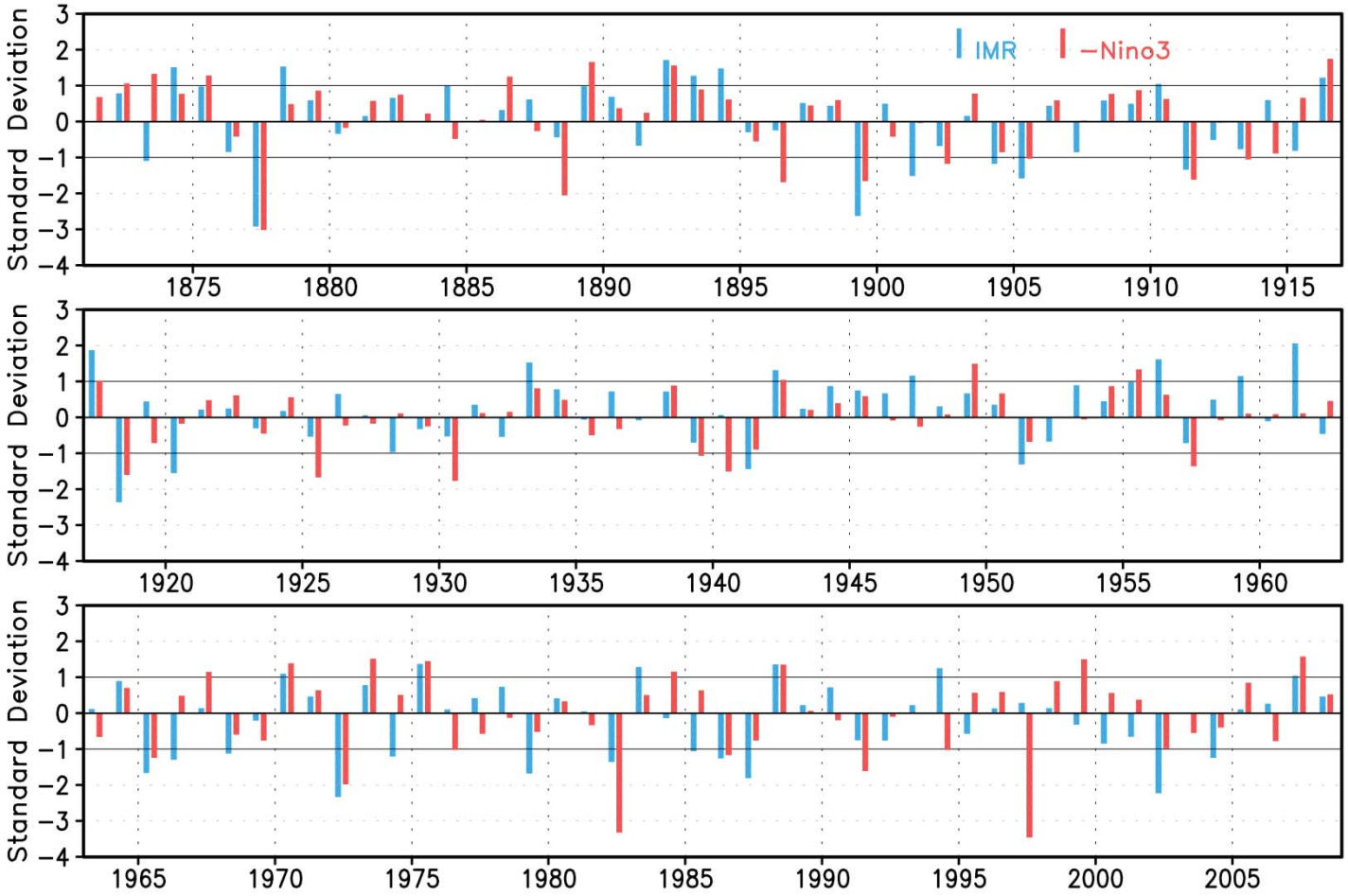
IMR Index = Rainfall averaged over India



NINO3 Index = SSTA ave(150W−90W, 5S−5N)

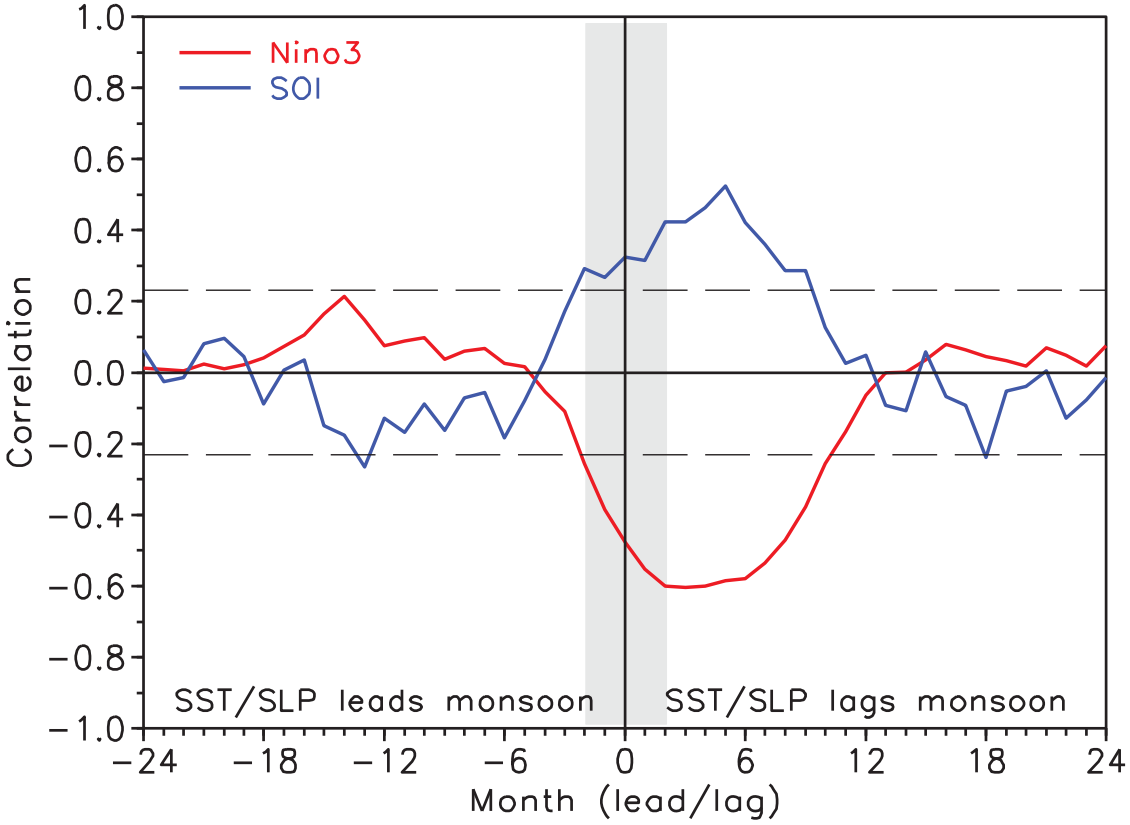
Monsoon rainfall and ENSO SST

JJAS Indian rainfall (IMR index) and DJF ENSO SST (NINO3 index)
A number of La Niña (El Niño) years are associated with strong (weak) monsoon years.
There are also exceptions such as 1997. Correlation = −0.6



Lagged relation between monsoon and ENSO

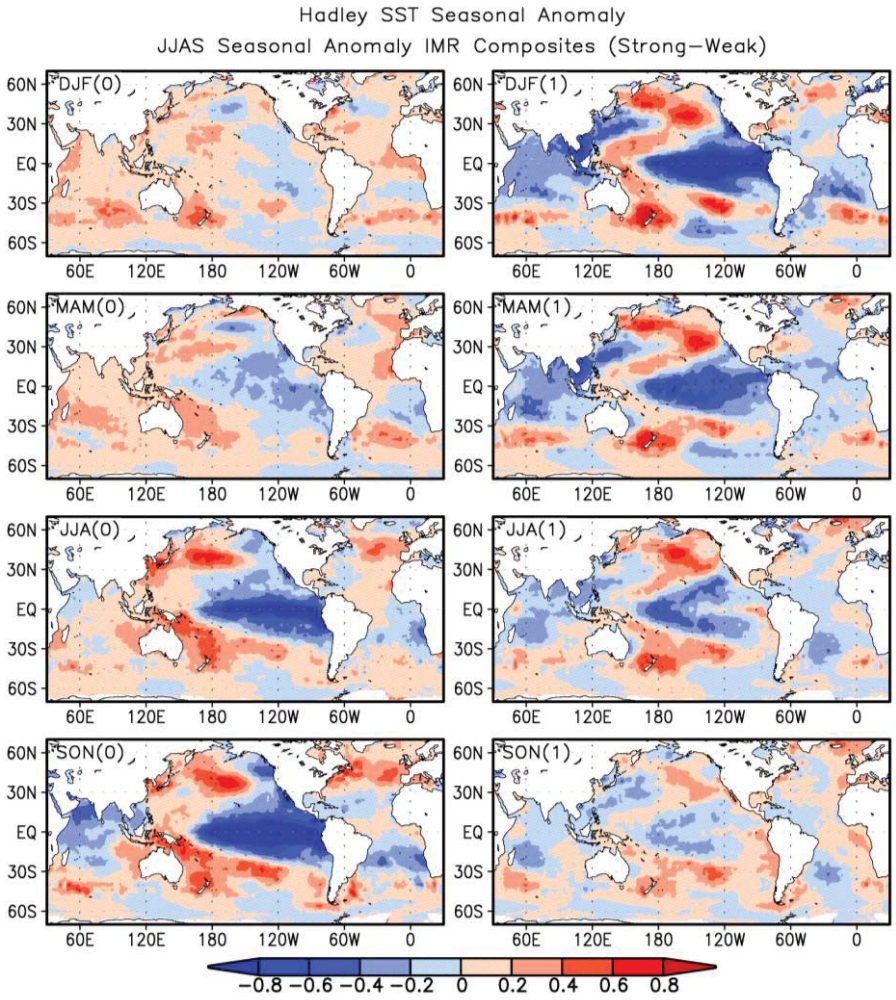
Lag correlation of monthly ENSO indices (NINO3 and SOI) with JJAS seasonal Indian monsoon rainfall index.
Strongest correlation occurs during October-January following the monsoon season.



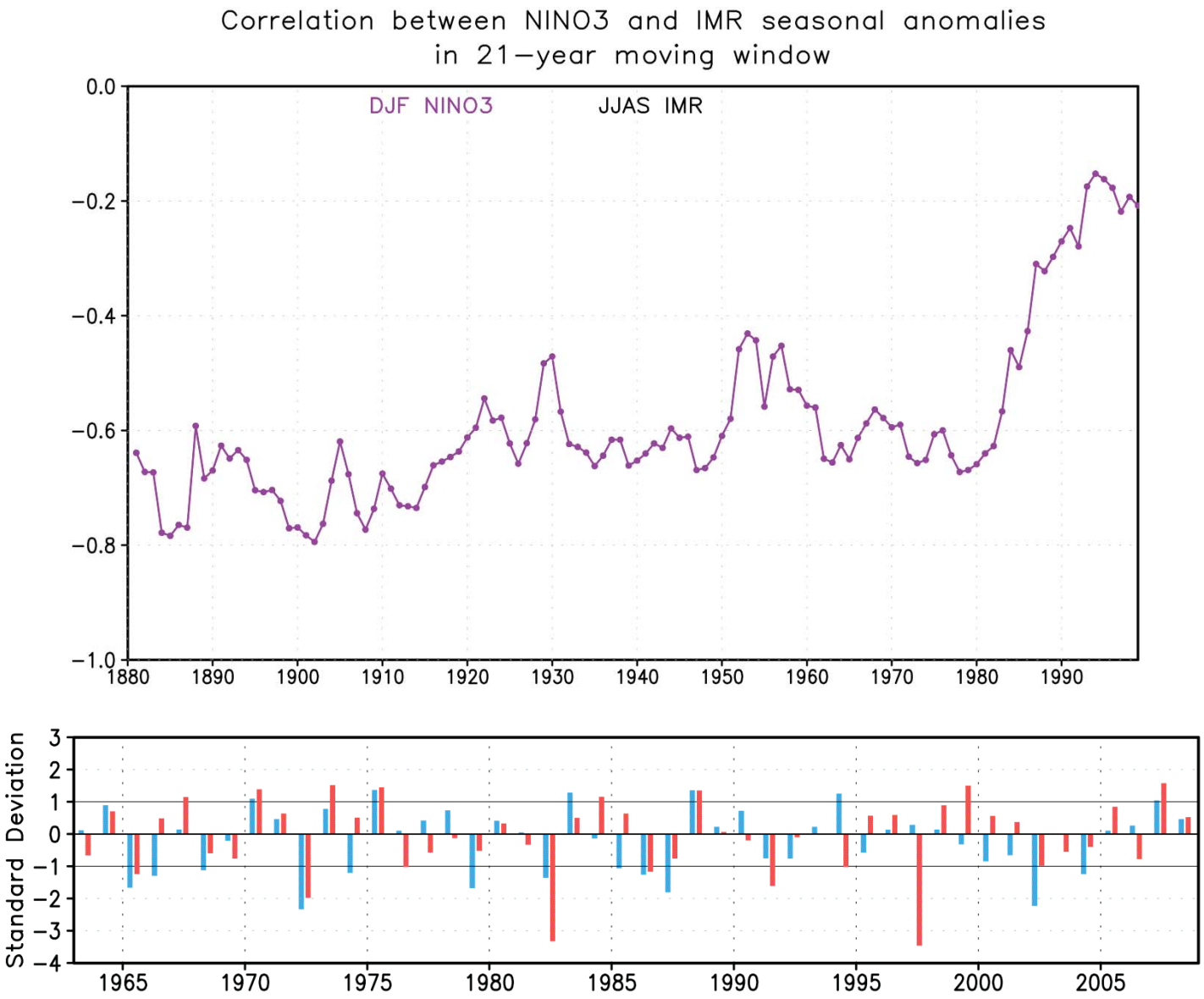
Lagged relation between monsoon rainfall and SST

Lead-lag composites of SST anomalies based on (strong-weak) IMR

Strong SST anomalies in the Pacific start during the monsoon season and peak during the following DJF.



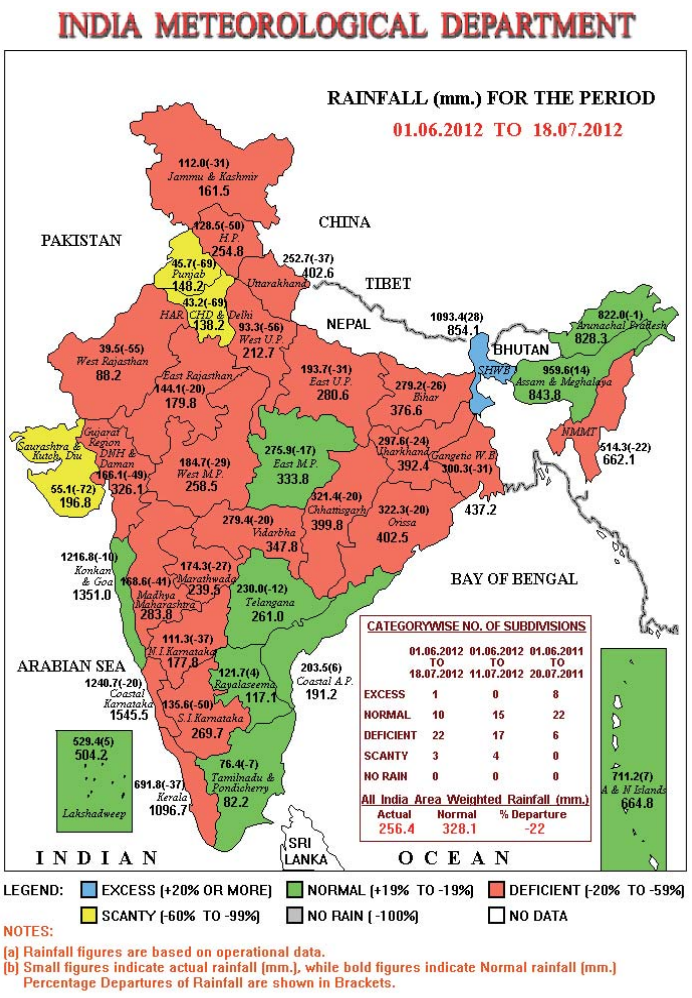
Decadal-scale variation in monsoon-ENSO relation



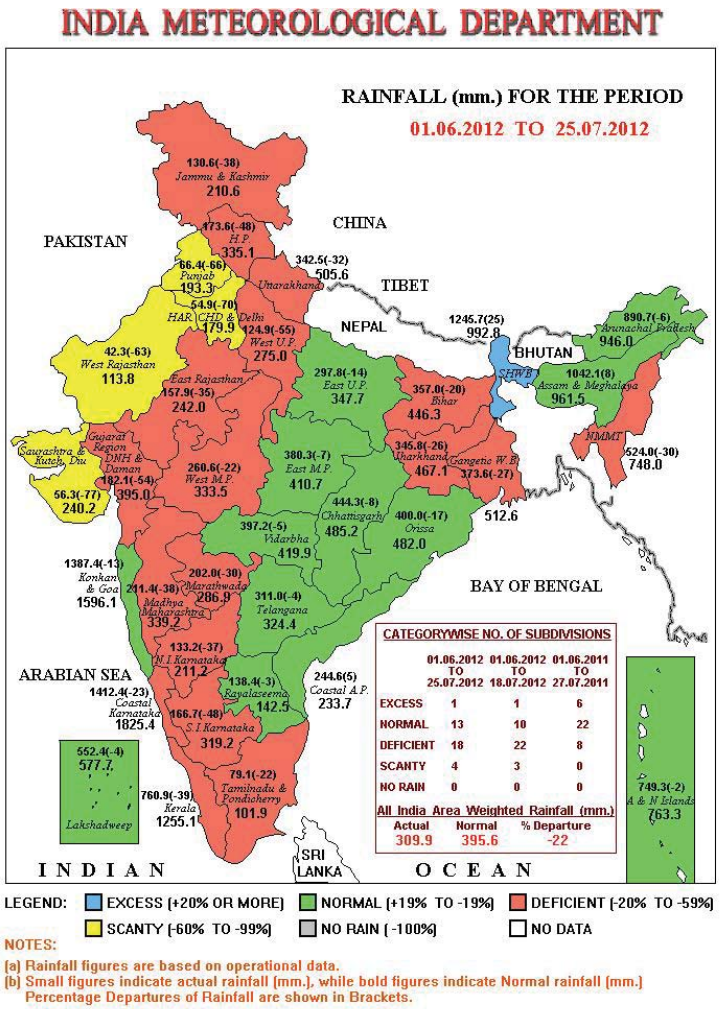
2012 Monsoon

Deficient rainfall over most of India

1 June-18 July 2012



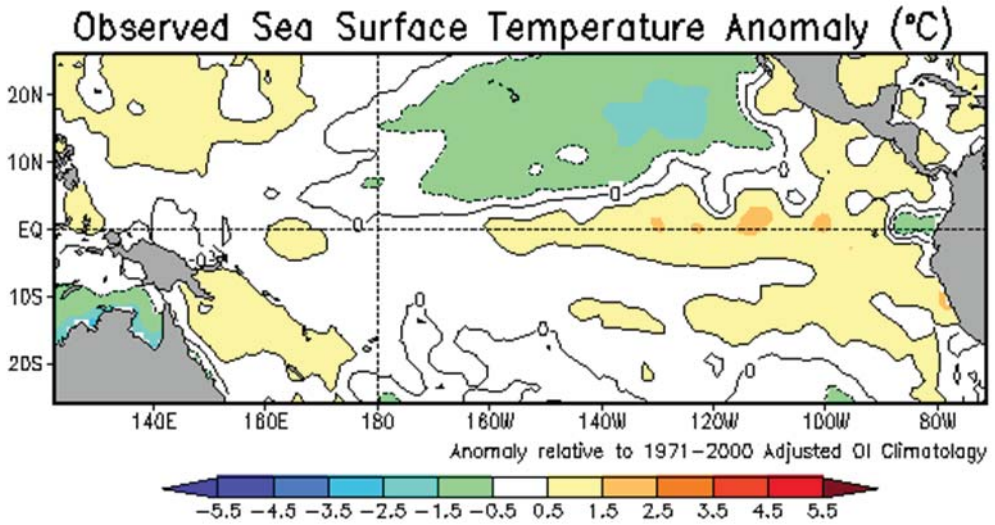
1 June-25 July 2012



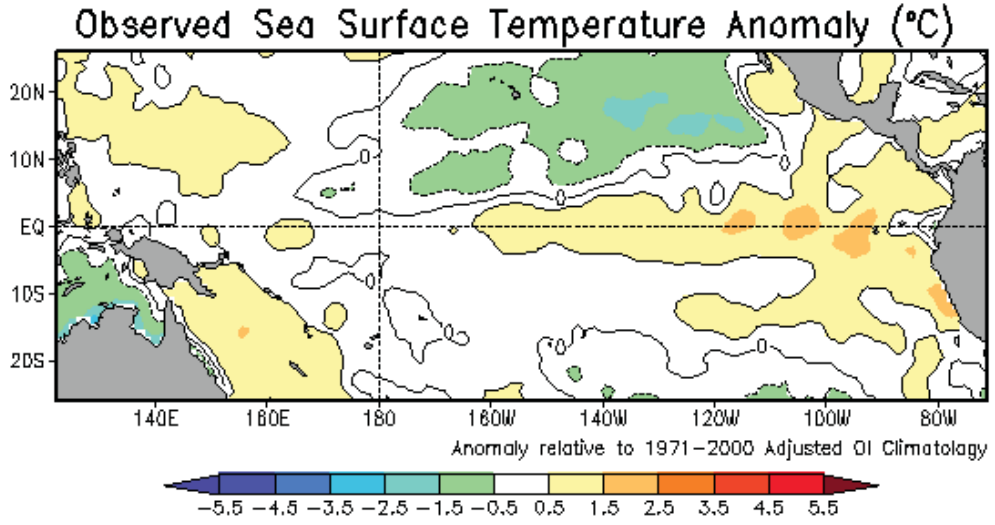
2012 ENSO

Developing El Niño

7-day average centered on
11 July 2012



7-day average centered on
18 July 2012

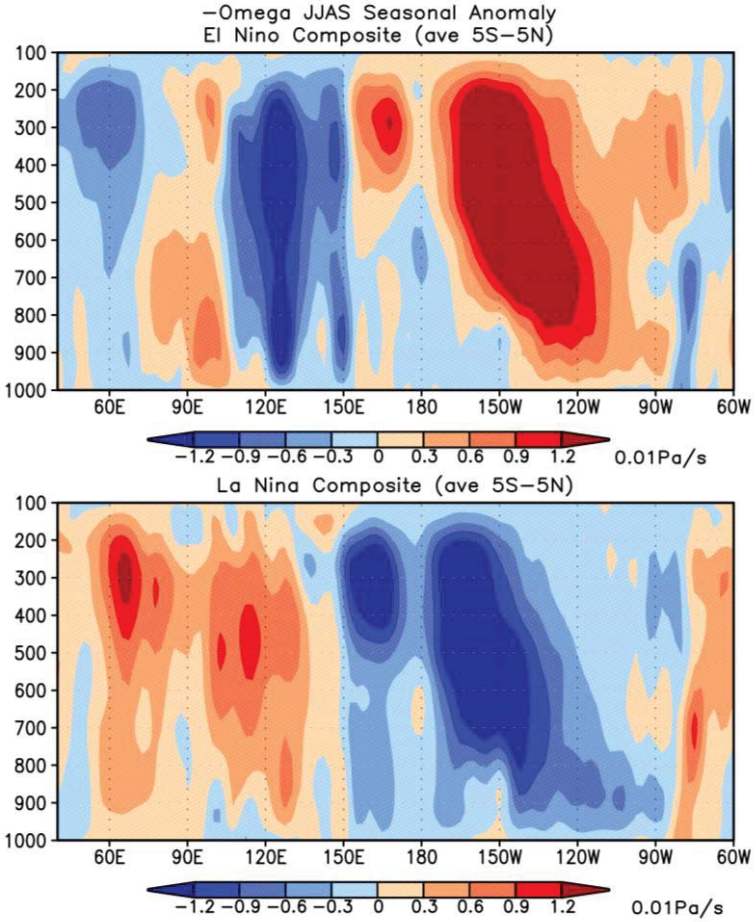


NCEP/EMC
Global Climate & Weather
Modeling Branch

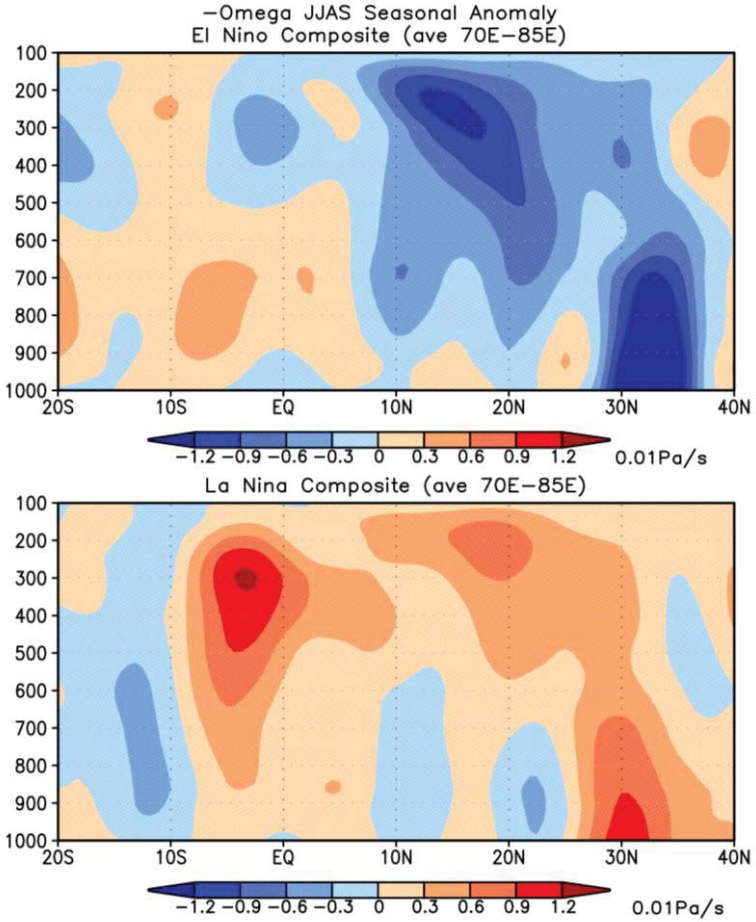
Monsoon-ENSO Teleconnection

ENSO-monsoon connection is described through Walker and Hadley circulations.

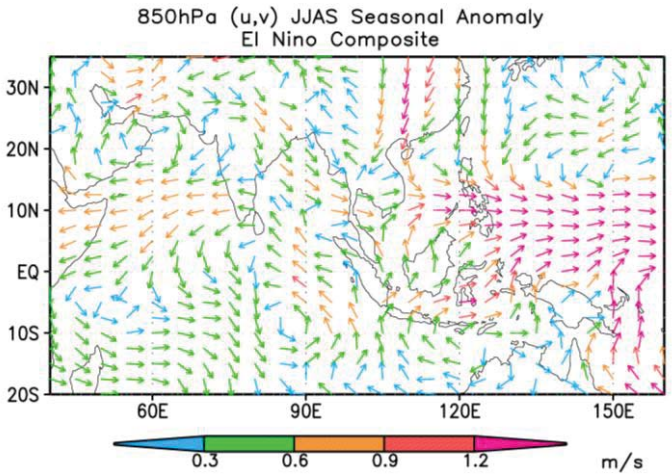
Walker Circulation

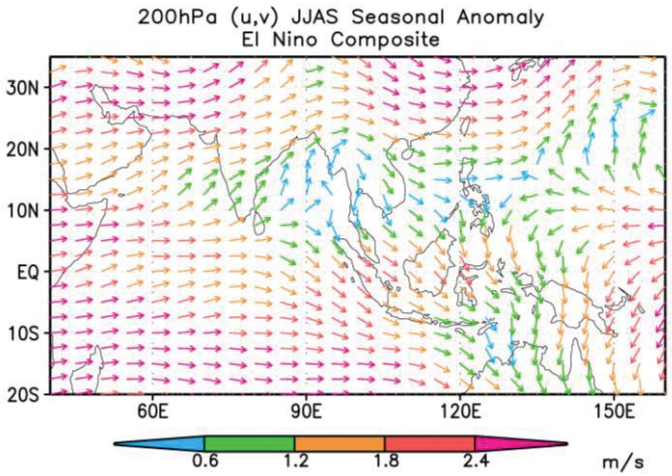


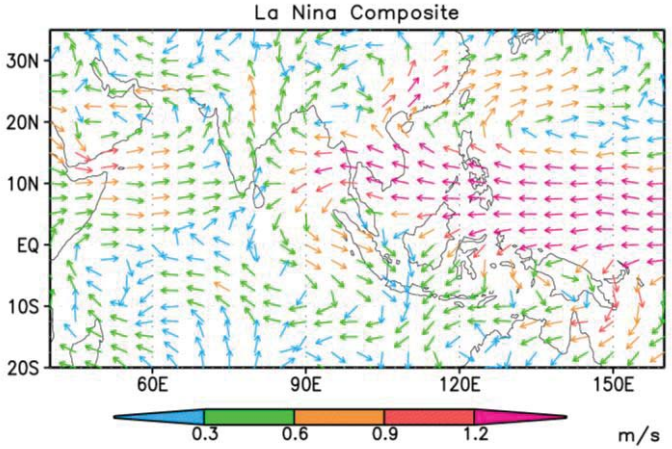
Hadley circulation

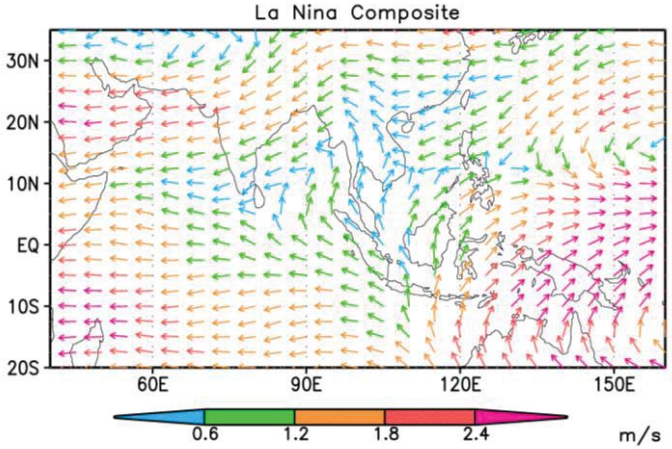


Monsoon-ENSO Teleconnection









Predictability of Seasonal Monsoon

Optimism for long-range prediction of monsoon

Charney-Shukla hypothesis (1981)

"… a large part of the low-latitude variability is due to boundary anomalies in such quantities as sea surface temperature, albedo and soil moisture, which having long time constants, are more predictable than the flow instabilities."

Conceptual model based on Charney-Shukla hypothesis

The seasonal mean monsoon rainfall consists of an externally forced large-scale persistent (nearly the entire season) component and an intraseasonal component that is independent of external forcing. (Krishnamurthy and Shukla 2000)

Modify the conceptual model to consider monsoon as a coupled phenomenon

Multichannel Singular Spectrum Analysis (MSSA)

Data $X_l(t)$, at $l=1, \ldots, L$ grid points (channels)
and $t=1, \ldots, N$ equally spaced in time

Make M lagged copies of the data and construct
$M \times N'$ Lagged data matrix $\boldsymbol{Y}$, $N' = N - M + 1$

Compute the grand lag-covariance matrix
$\boldsymbol{C} = (1/N')\, \boldsymbol{Y}^T\boldsymbol{Y}$, $LM \times LM$ matrix

Diagonalize $\boldsymbol{C}$ and obtain

Eigenvectors $\boldsymbol{E}_k = \{E_k l(j)\}$, $k=1, \ldots, LM;$ $j=1, \ldots, M$

PCs $A_k(t) = \sum_j \sum_l X_l(t+j-1)\, E_{kl}(t)$, $t=1, \ldots, N'$

RCs (Reconstructed Components) $R_{kl}(t) = (1/M) \sum_j A_k(t-j+1)\ E_{kl}(j)$

RCs have the same spatial extent and time length as the original data.
The sum of all the RCs is equal to the original data.
The MSSA modes are thus obtained in a data-adaptive manner.

MSSA of OLR and rainfall over the monsoon region

MSSA of daily data was performed over the monsoon MJO region.

Oscillatory and persisting (or trend) components in the form of RCs were obtained from the EOFs and PCs

Observed data:

Daily OLR anomalies over 40°E-160°E, 35°S-35°N for 1975-2002
Daily Rainfall anomalies over India for 1901-1970
JJAS season
Lag window: 60 days at one day interval

Dominant modes obtained from MSSA:

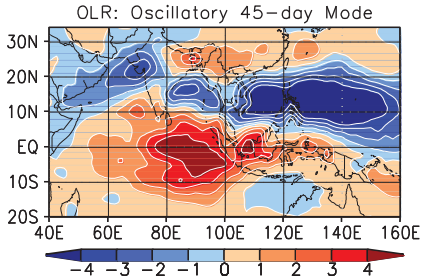
45-day oscillatory mode (pair)

Two Seasonally persistent modes

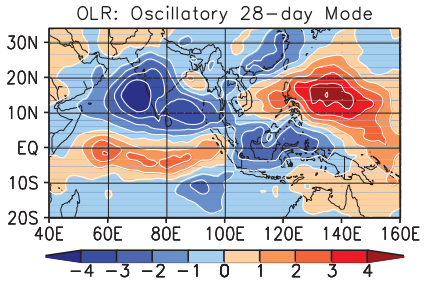
28-day oscillatory mode (pair)

Indian monsoon modes

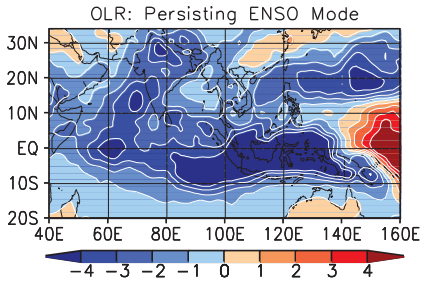
Oscillatory mode with a broad-band spectrum centered at 45-day period. This mode propagates northeastward and describes active/break cycle.



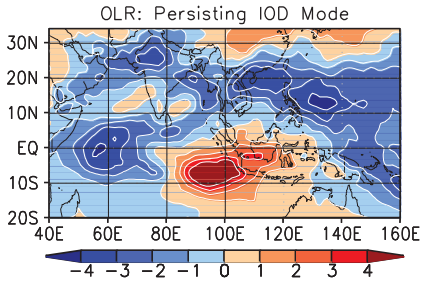
Oscillatory mode with a broad-band spectrum centered at 28-day period. This mode propagates northwestward and also describes active/break cycle.



Seasonally-persistent mode related to ENSO.
The same pattern persists throughout the season but changes from year to year.



Seasonally-persistent mode related to Indian Ocean dipole (IOD).
The same pattern persists throughout the season but changes from year to year



Seasonal mean rainfall over India

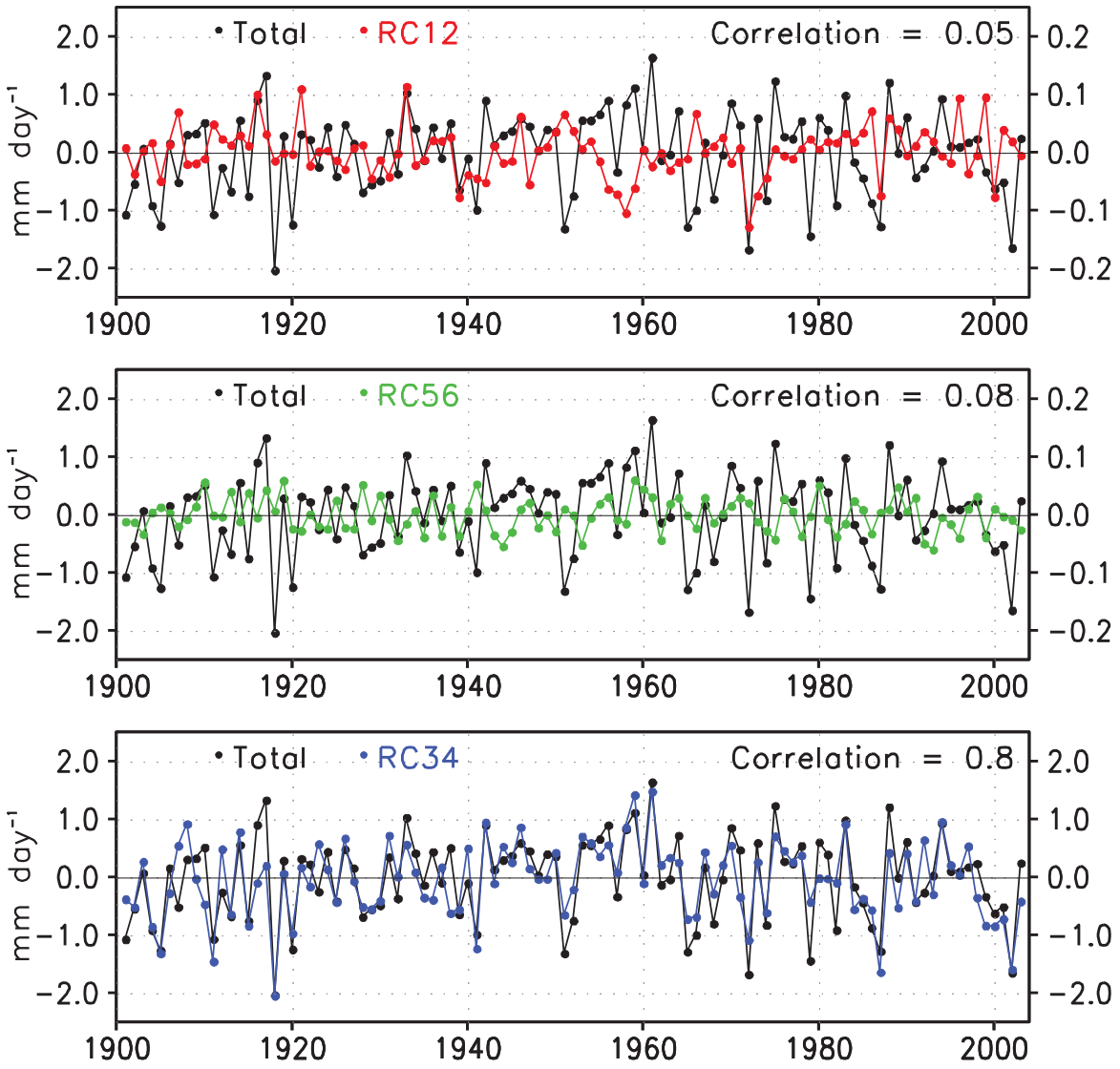
MSSA of rainfall over India 1901-2004

45-day mode

28-day mode

ENSO + Dipole modes (most contribution to the seasonal mean and best correlation)

All-India average of total rainfall anomaly and RCs



Seasonal Mean ENSO and IOD modes

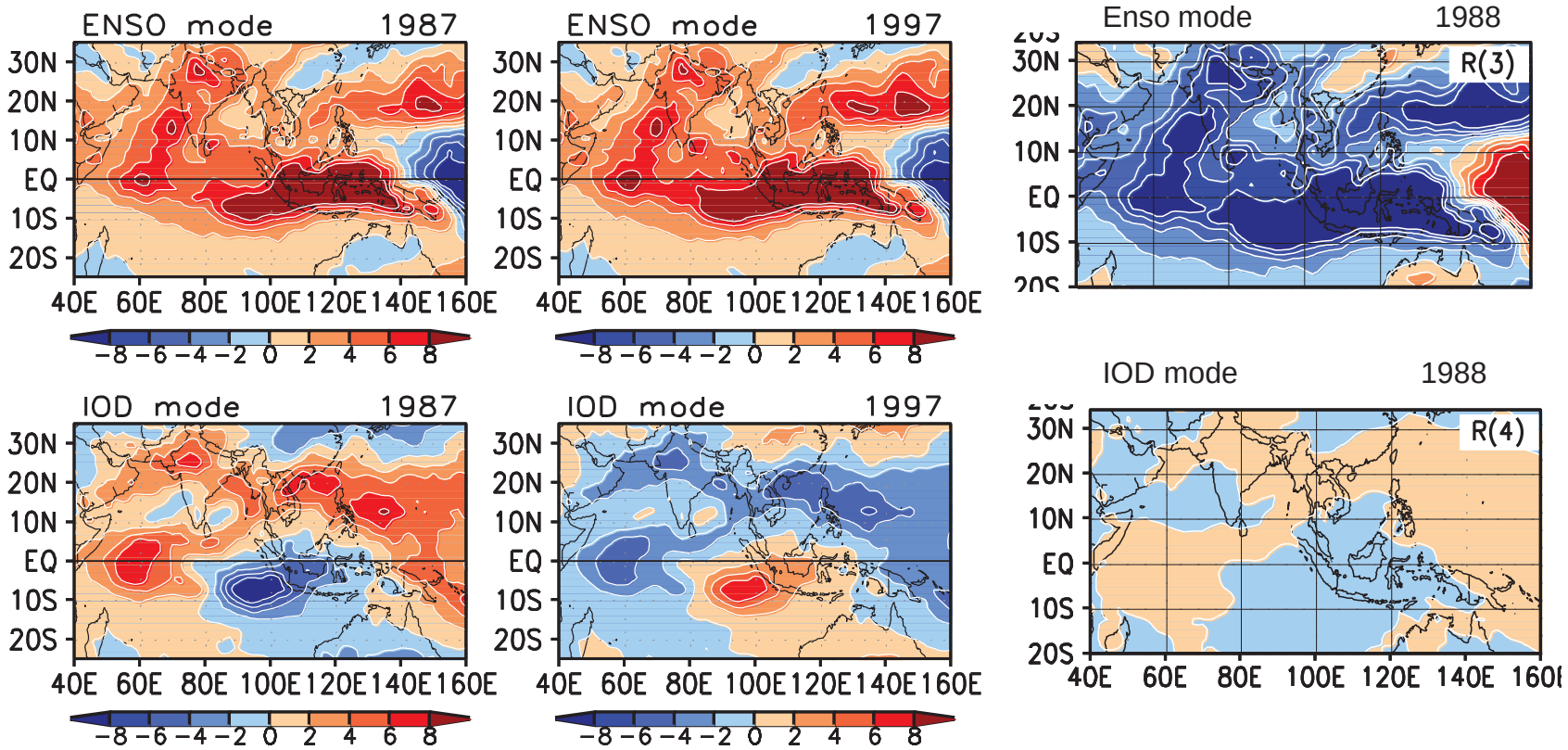
JJAS Seasonal Mean

The seasonal mean depends on the relative values of the ENSO and IOD modes

1987 ENSO and IOD add up over India (Constructive interference)

1997 ENSO and IOD oppose over India (Destructive interference)

1988 ENSO is strong but IOD is negligible

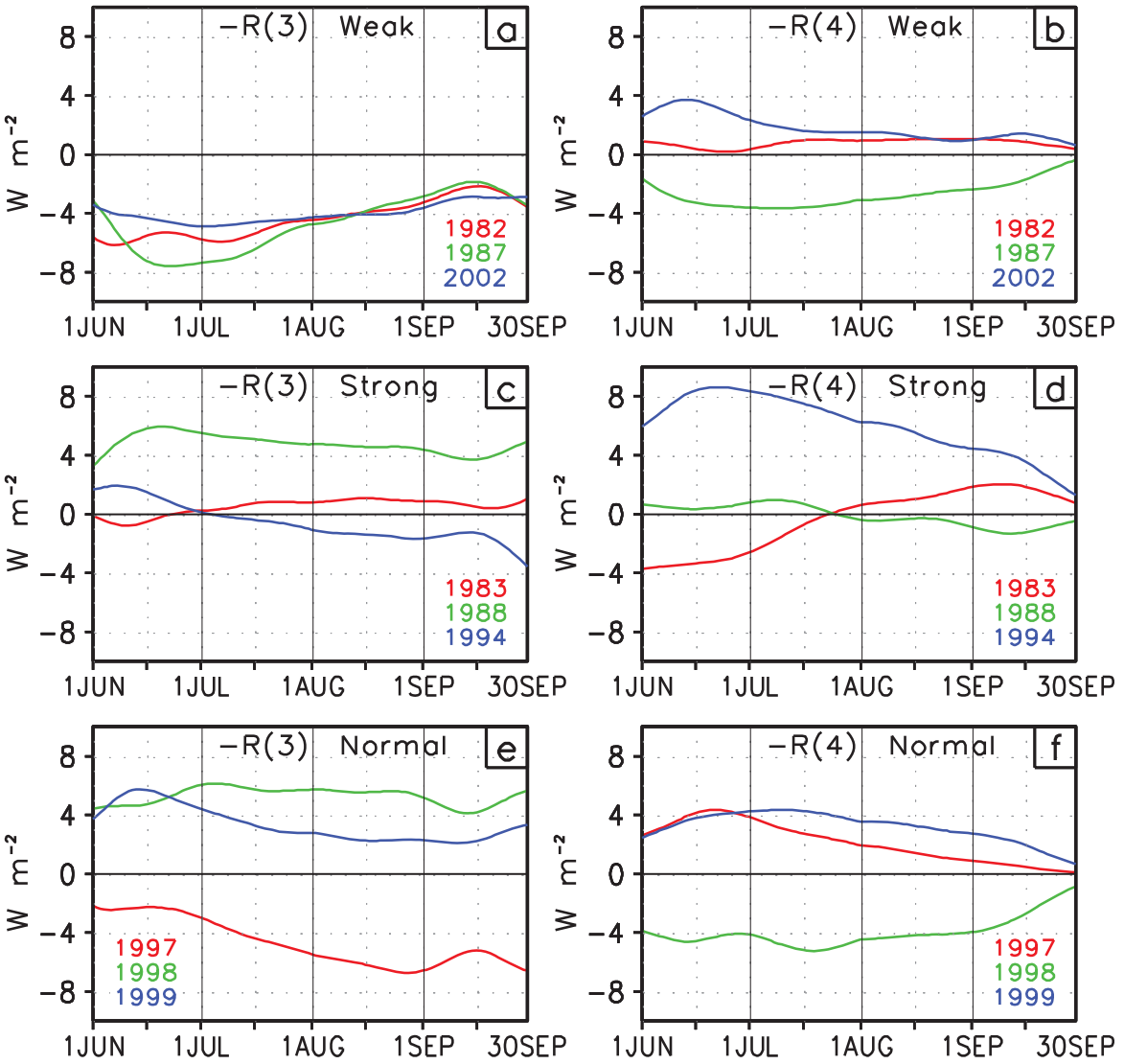


Relative roles of persistent modes

Which modes decide whether it is strong, weak or normal monsoon?

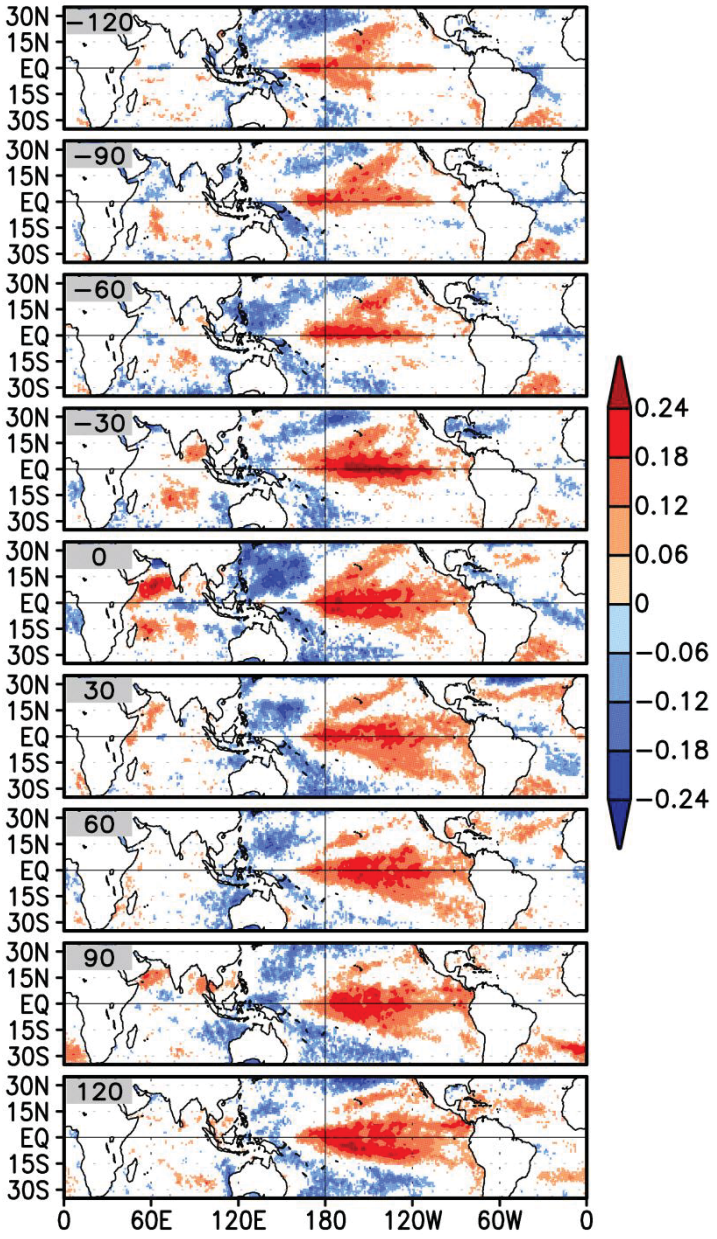
Constructive and destructive interference between ENSO and IOD

Daily ENSO (RC3) and IOD (RC4) OLR modes, area averaged over India, for weak, strong and normal monsoon years



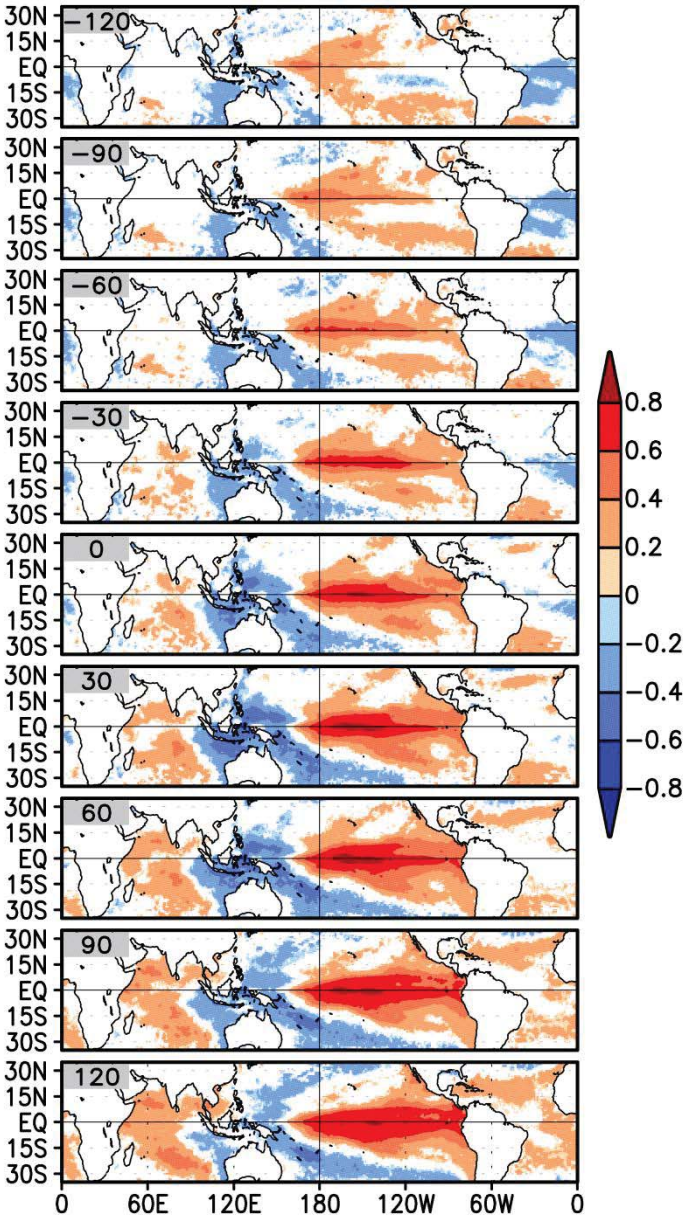
Seasonal monsoon rainfall and SST

Lagged daily correlation between the IMR index of total rainfall anomalies and SST



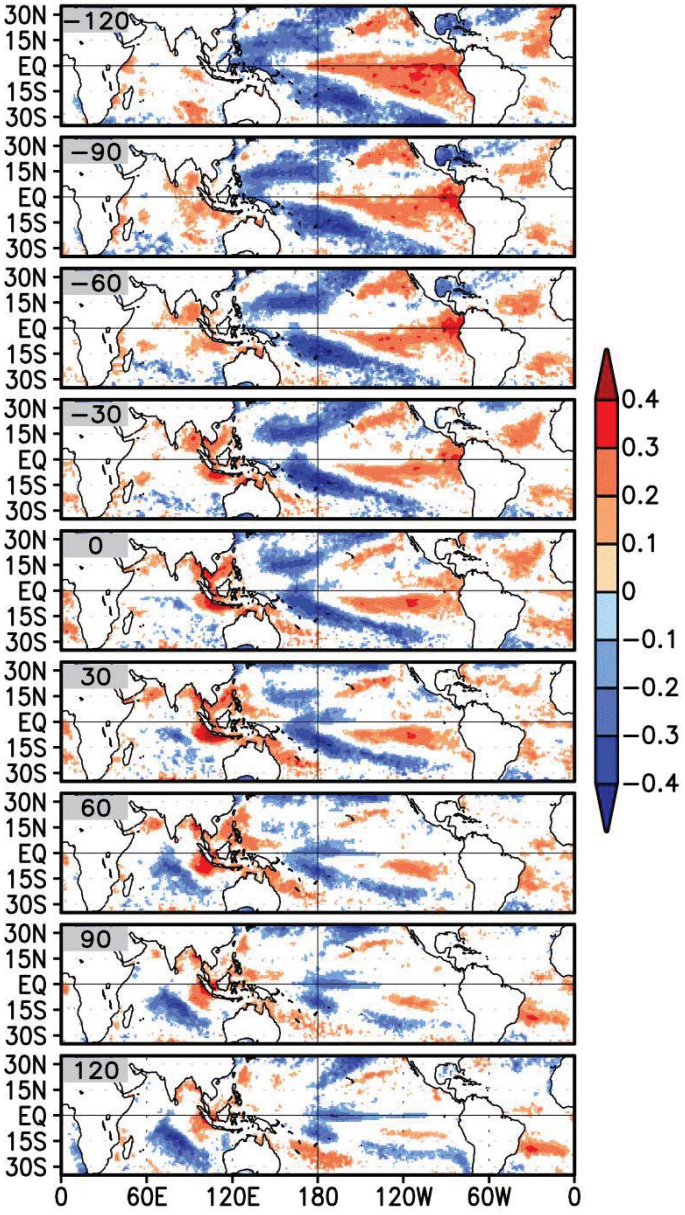
Persistent monsoon modes and SST

Lagged daily correlation between the IMR index of the ENSO monsoon mode and SST



Persistent monsoon modes and SST

Lagged daily correlation between the IMR index of the IOD monsoon mode and SST



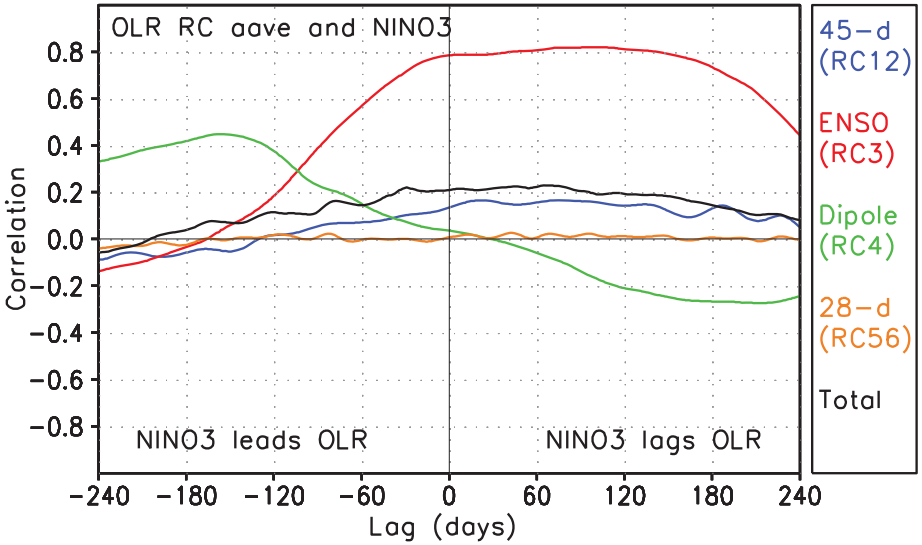
Lagged Relation with SST

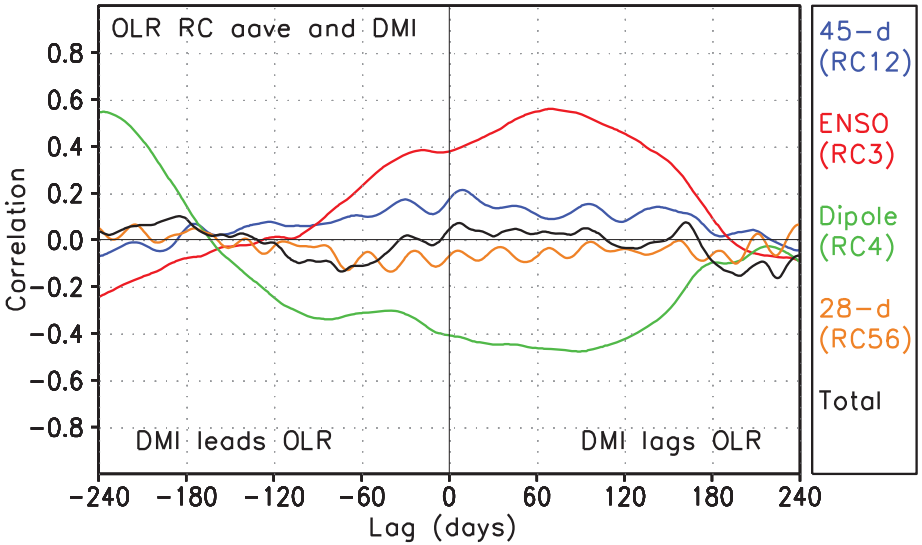
Lagged correlation between daily OLR RC indices and daily SST indices

OLR RC indices are area averaged over India (land)

NINO3 index:
SSTA (150°W-90°W,5°S-5°N)

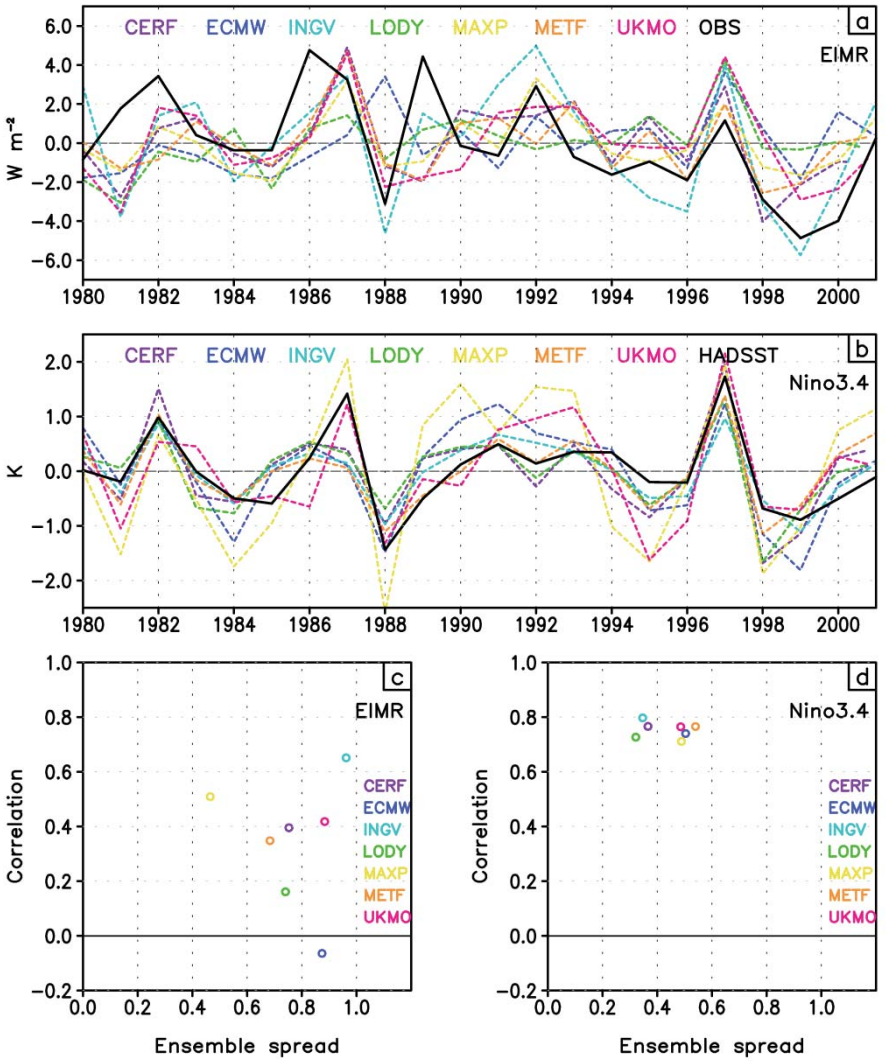
Dipole Mode Index (DMI):
SSTA (50°E-70°E,10°S-10°N)
− SSTA (90°E-110°E,10°S-0°)





Coupled model simulations

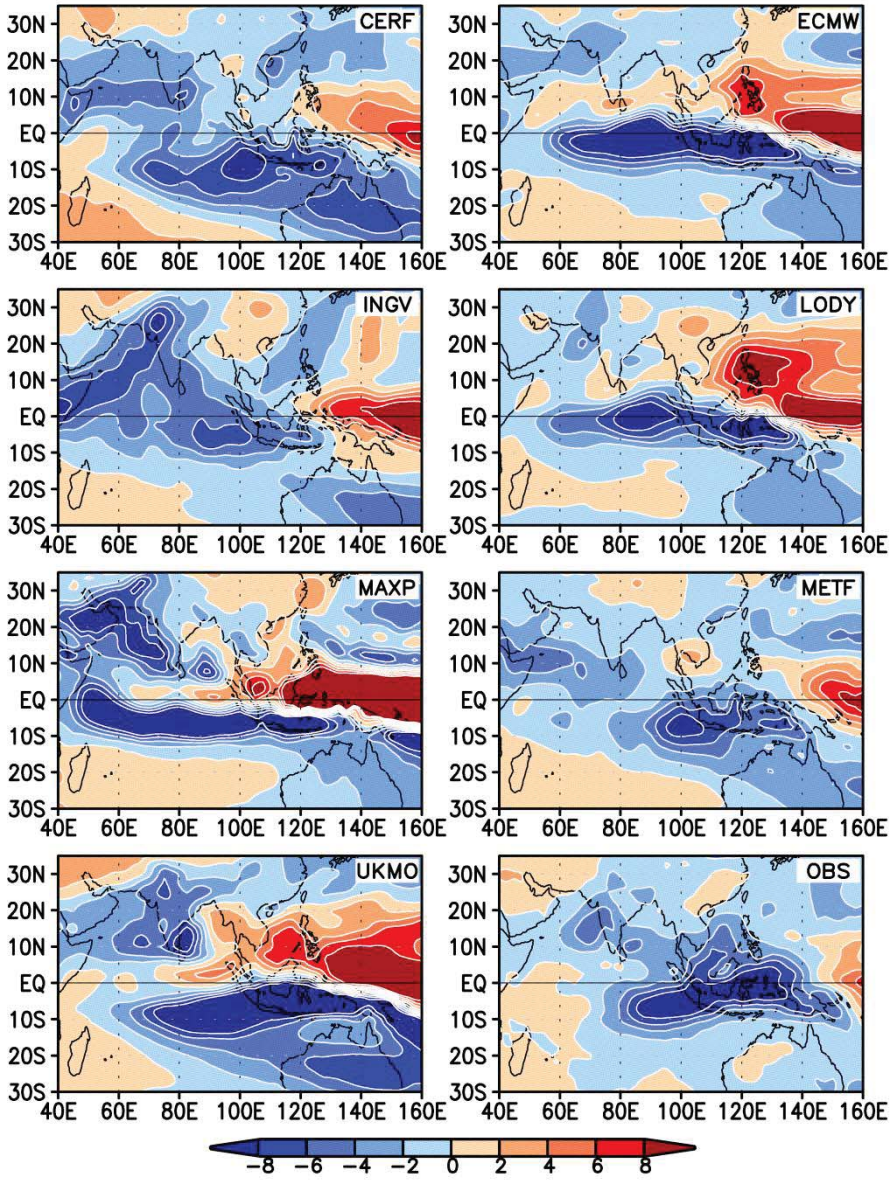
DEMETER simulations



Coupled model simulations

DEMTER simulations

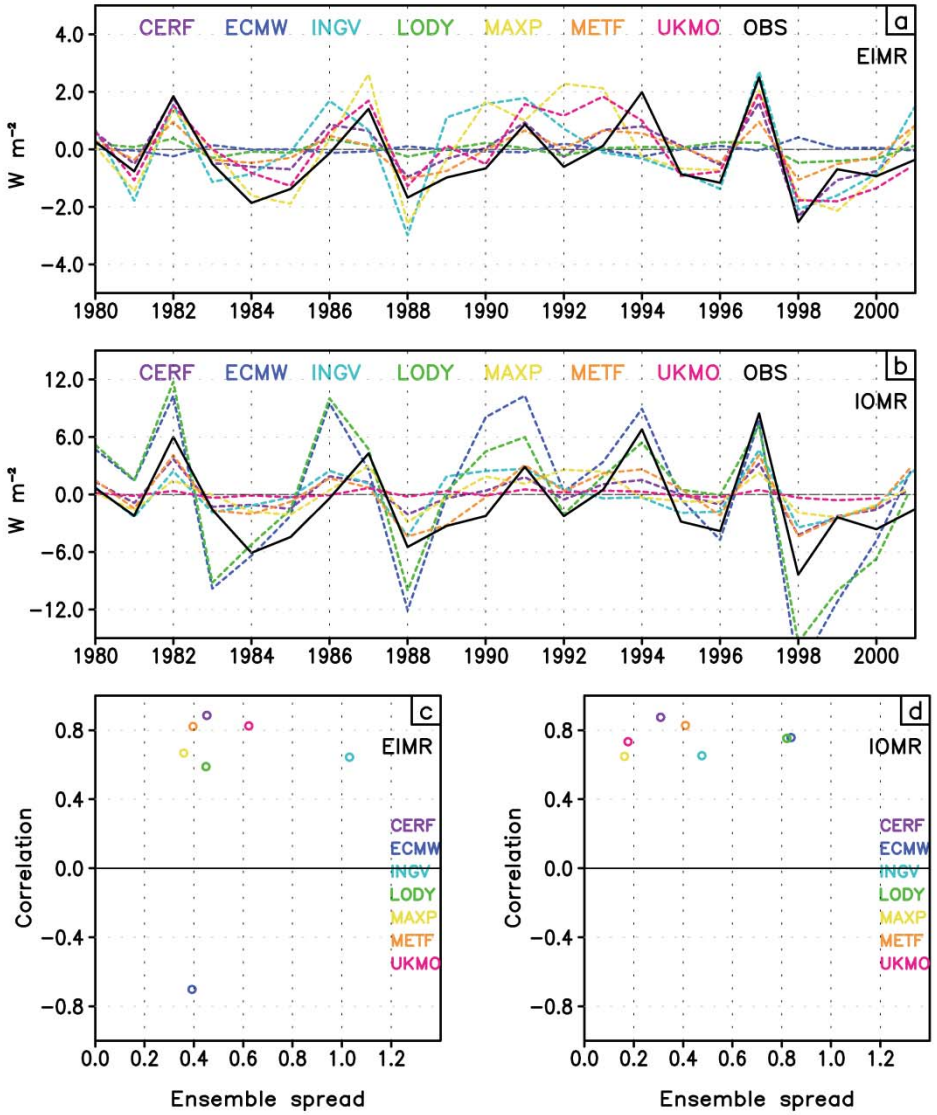
ENSO mode in rainfall



Coupled model simulations

DEMETER simulations

ENSO mode



Summary

Monsoon rainfall is deficient (excess) during many El Niño (La Niña) years

Total seasonal monsoon rainfall has moderate correlation with ENSO during the monsoon season.

Monsoon rainfall has two seasonally persistent modes – ENSO and IOD

The ENSO monsoon mode has strong lead/lag correlation with ENSO SST index

The relative strengths of ENSO and IOD modes determine the seasonal rainfall