Exploring New Sources of Predictability for the South Asian Summer Monsoon

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TTA Workshop on "***Challenge in Monsoon Prediction***"

June 23 - July 4, 2014, Trieste, Italy

Acknowledgements

The work presented here is done largely by Dr. Rajib Chattopadhyay in collaboration with Dr. A. Suryachandra Rao and me.

INDIAN INSTITUTE OF TROPICAL METEOROLOGY PUNE

Background & Outline

- ❖Potential Predictability: ENSO primary source of Indian Summer monsoon (ISM) predictability
  - ❖However, only about 40% of ISM variability is related to ENSO. Another about 20% ISM variability may come from as yet unidentified predictable sources! What are these?
- ❖SST pattern during 2013: Indication of Extra-tropical SST influence on ISM!
- ❖Identification of canonical patterns of extra-tropical SST that influence ISM on seasonal time scale.
- ❖Origin of these patterns : Association with strong phase of extra-tropical decadal mode and weak tropical interannual mode.
- ❖Mechanism of teleconnection and test of hypothesis using AGCM experiments

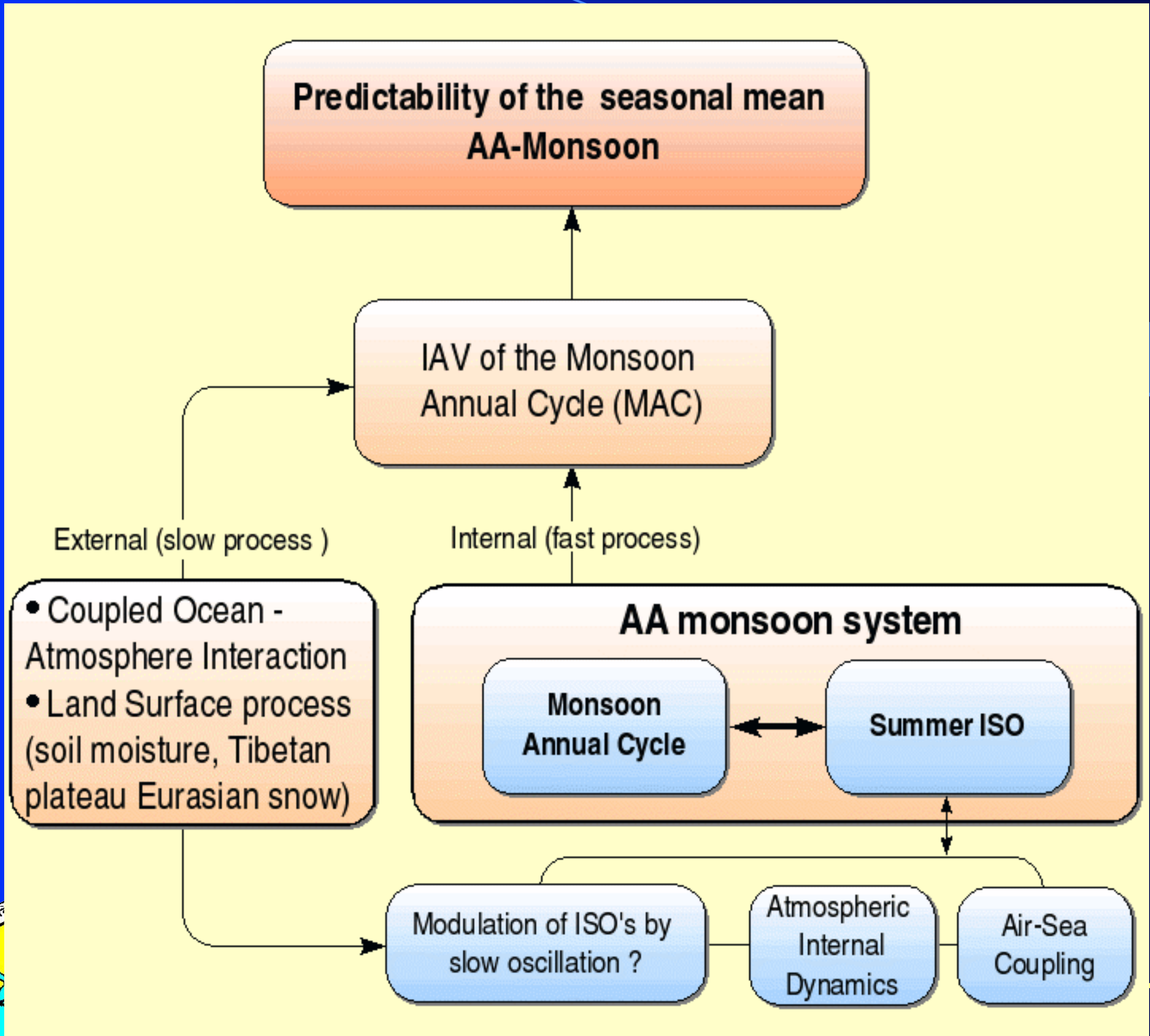
(Charney and Shukla, 1981; Shukla, 1981, 1988).

tropical climate is more predictable

than extra-tropics

Lau, 1985 , Sperber and Palmer 1996, Sugi et.al.1997, Brankovic and Palmer 1997, Brankovic and Palmer 2000, Sperber et. al. 2001, Kang et. al. 2002

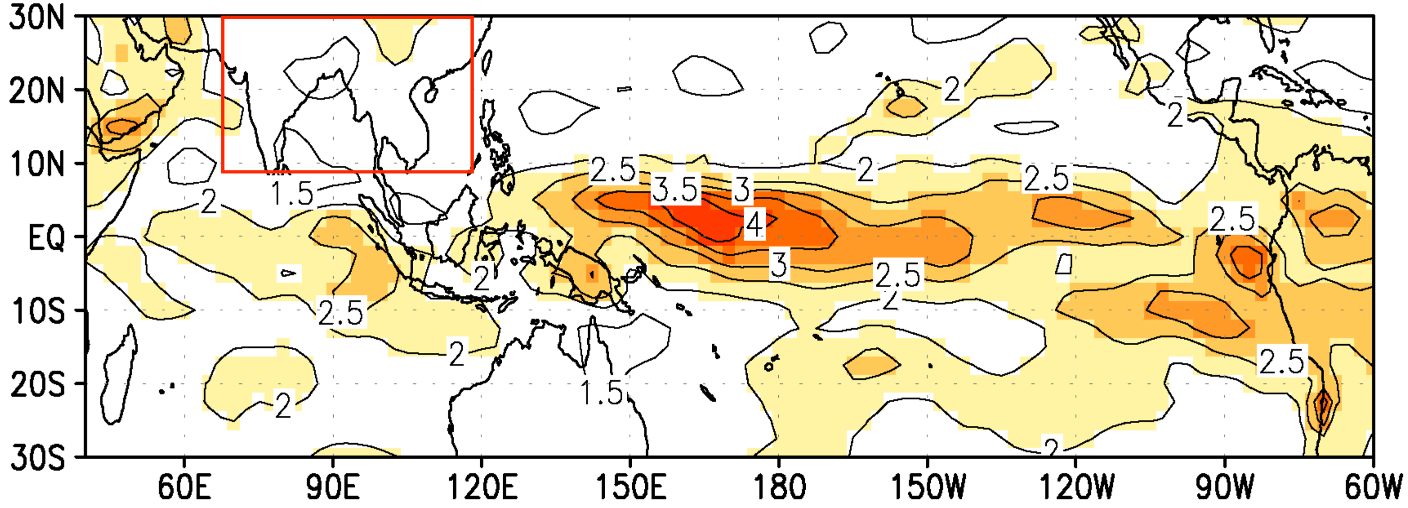
Limit on Potential Predictability of Monsoon



Goswami, Wu and Yasunari, 2006, J. Climate

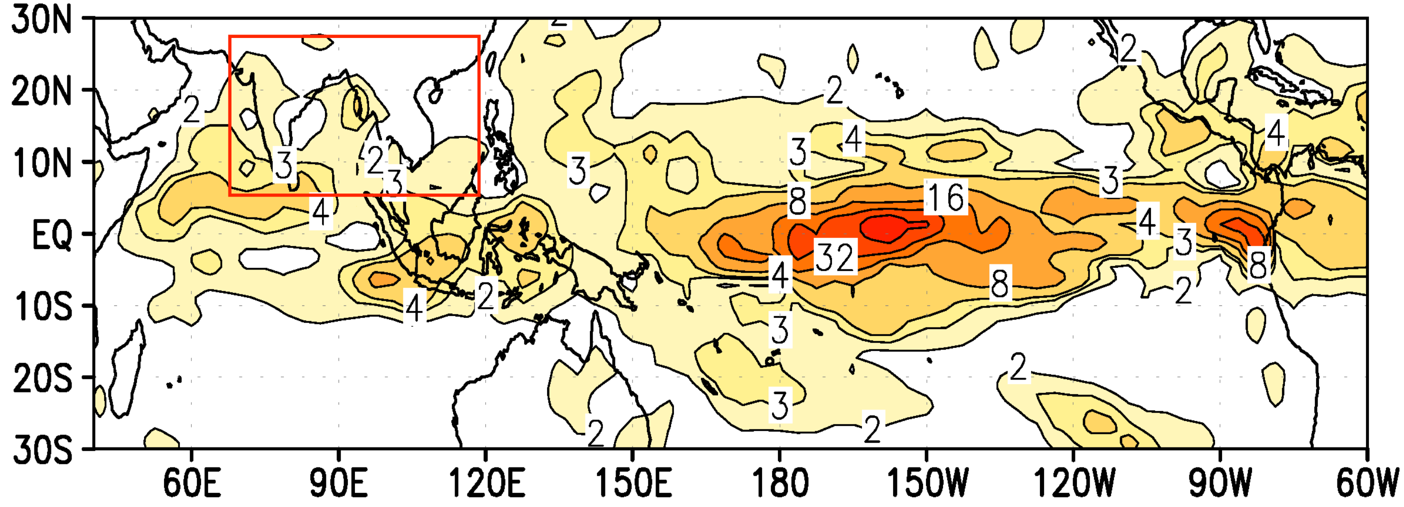
Estimates of potential predictability

F = 'total' /' internal' interannual variance



JJAS zonal winds at 850 hPa from NCEP reanalysis (Observation)

Goswami and Ajayamohan,2001



JJAS Precipitation from 5 ensemble simulations of 20 years by LMD model (another AGCM)

Goswami and Xavier, 2005

F ~ 2 ⇒ 50% or more of IAV is governed by Climate Noise!

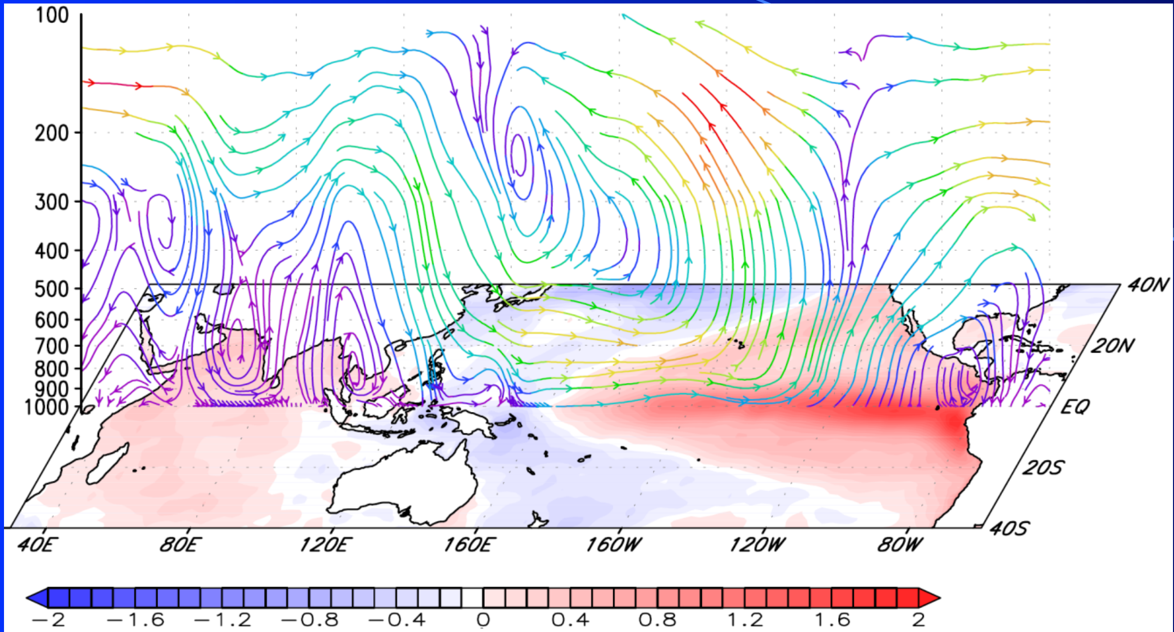
MONSOON

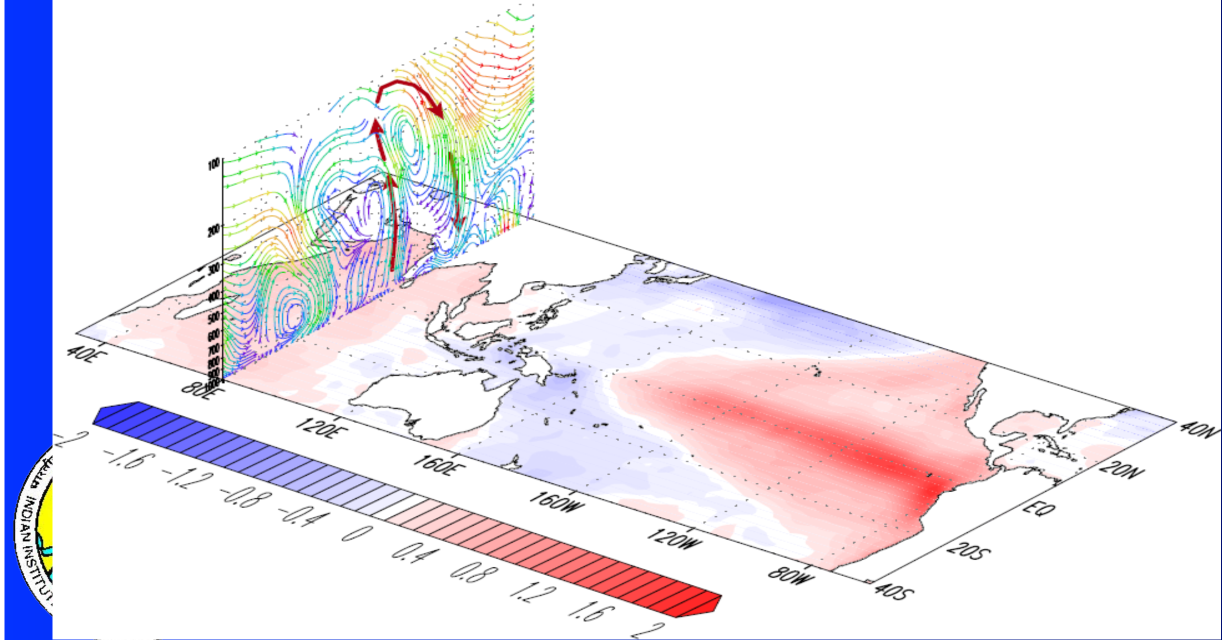
'External' Forcing

'Internal' Dynamics

(Goswami 1998; Ajaymohan and Goswami, 2003)

ENSO is considered primary source of monsoon predictability



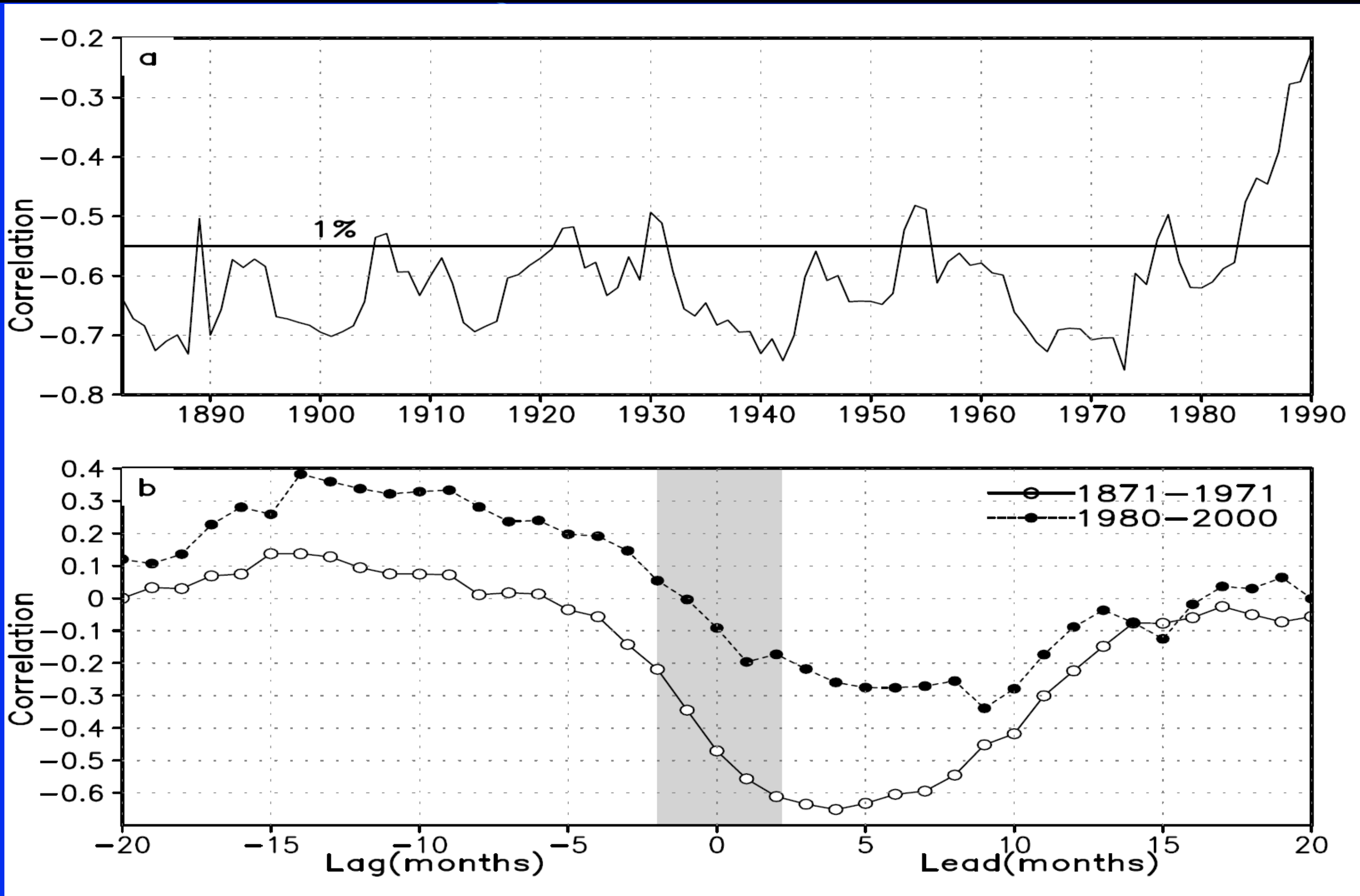


JJAS Composite of Walker circulation {(U,-ω) averaged <5S-5N>} based on 11 El Ninos between 1950 and 2002

(composite of El Nino SST (JJAS) is shown in the horizontal plane (shaded))

JJAS Composite of monsoon Hadley (MH) circulation {(V,-ω) averaged <70E-100E>} based on 11 El Ninos between 1950 and 2002

However, ENSO-Monsoon Relationship may be changing!



(a) 21-year sliding window correlation between AIR and Nino3 SST. (b) lead-lag correlation between AIR and Nino3 SST during the period 1871- 1971 and 1980-2000.

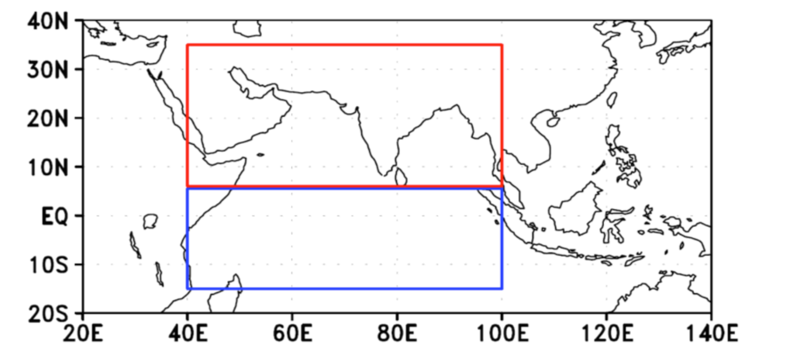
Goswami and Xavier, 2007, QJRMS

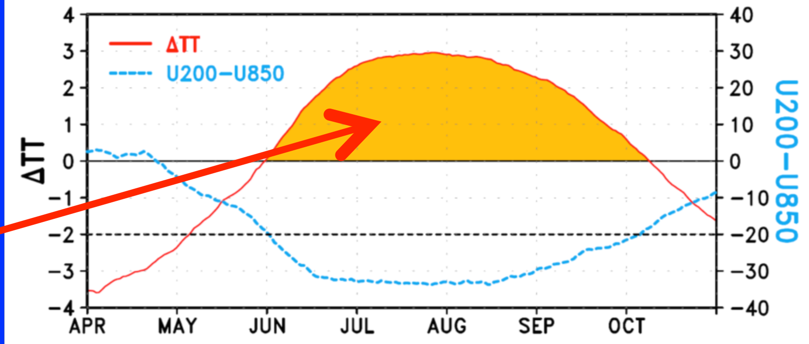
Counter-view

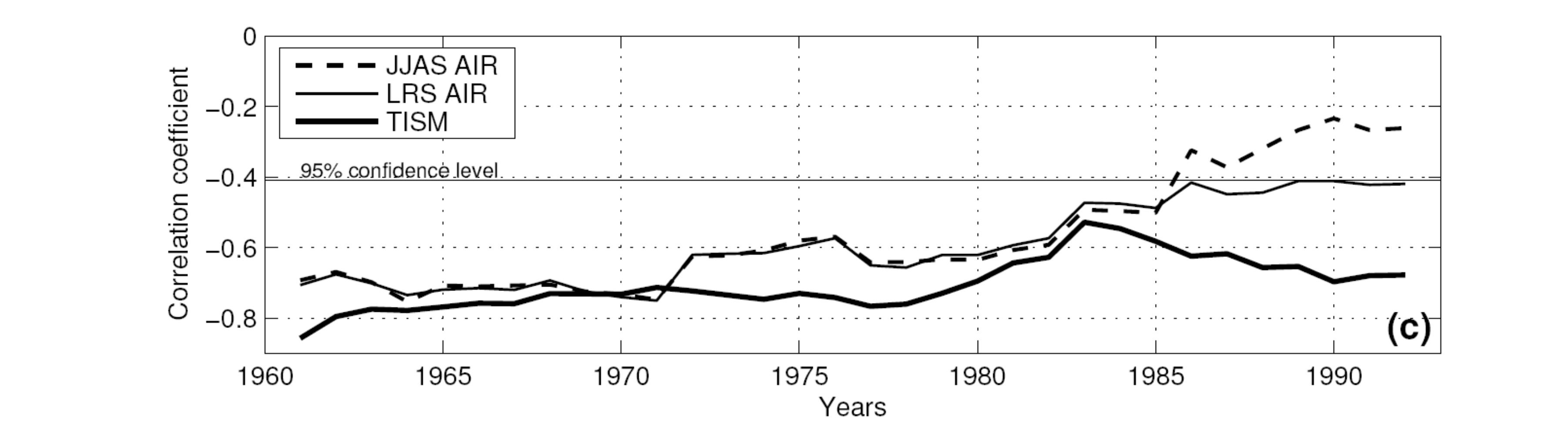
ENSO-Monsoon relation has not changed (e.g.TISM-LRS AIR)!

Poor correlation between Nino3-AIR is due to enhanced internal variability of AIR

TISM → integral of +ve ΔTT

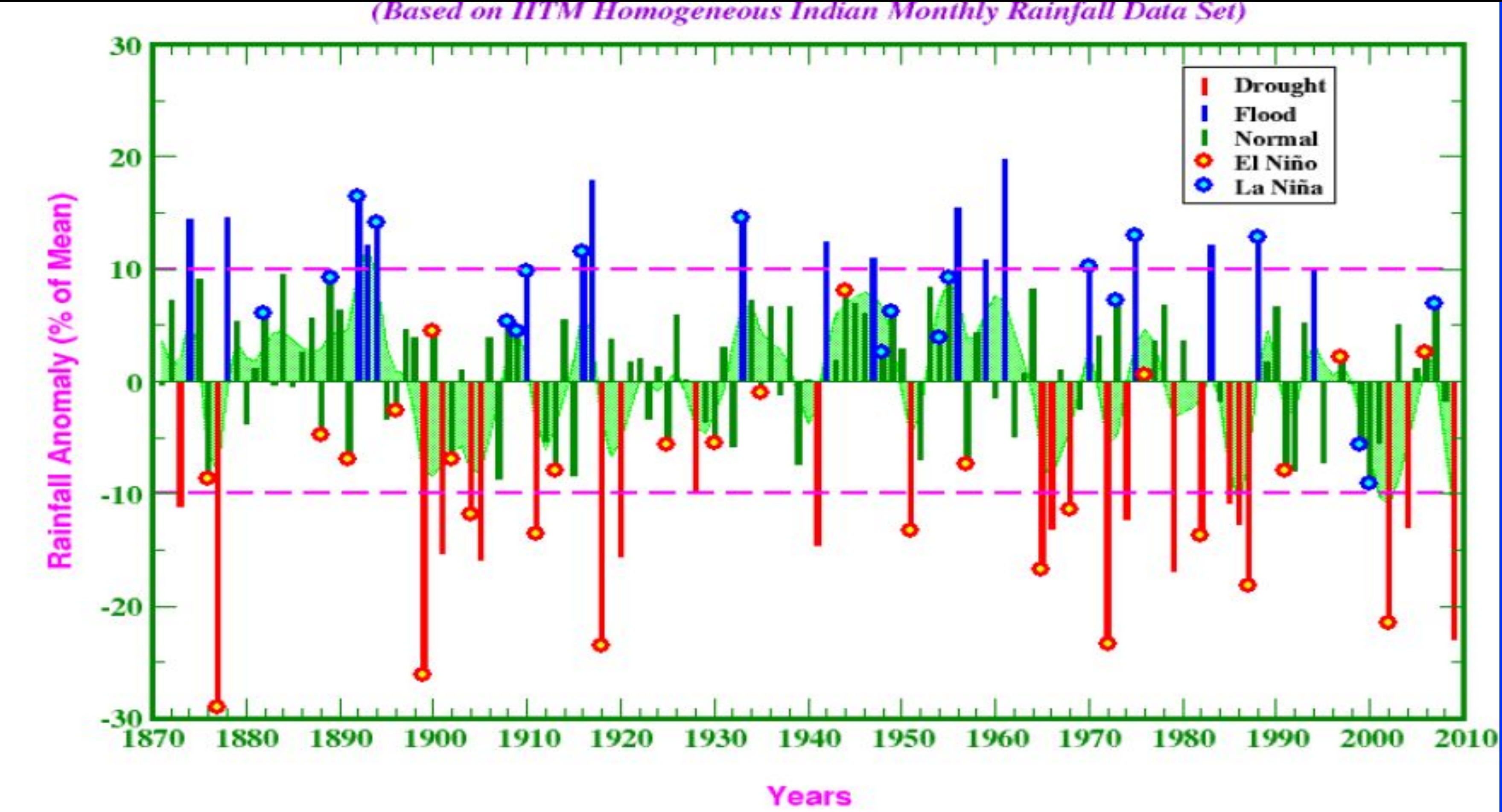






21-year running correlations between TISM and AIR for JJAS and rainfall during LRS

Monsoon Predictability Beyond ENSO?

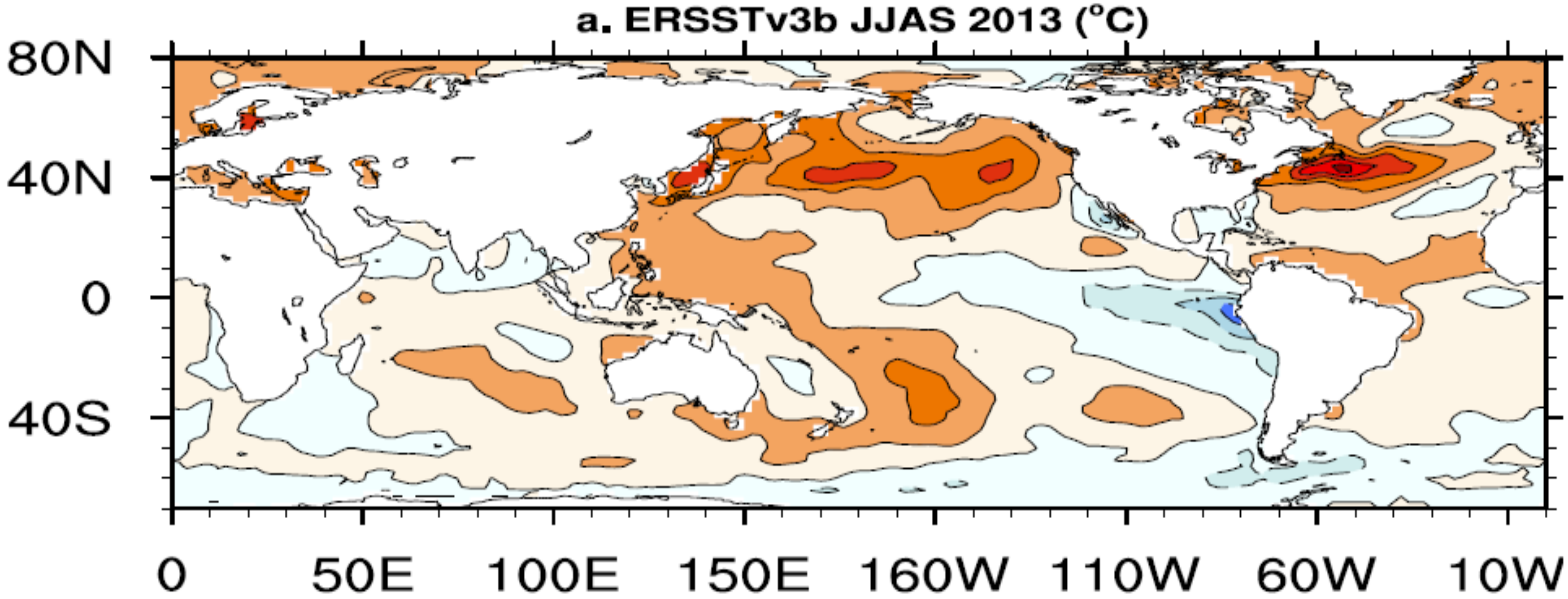


Many Floods unrelated to La Nina,

Many droughts unrelated to El Nino,

Could they be related to some other slowly varying predictable forcing?

2013: JJAS SST anomaly



ISMR

106% of long term mean

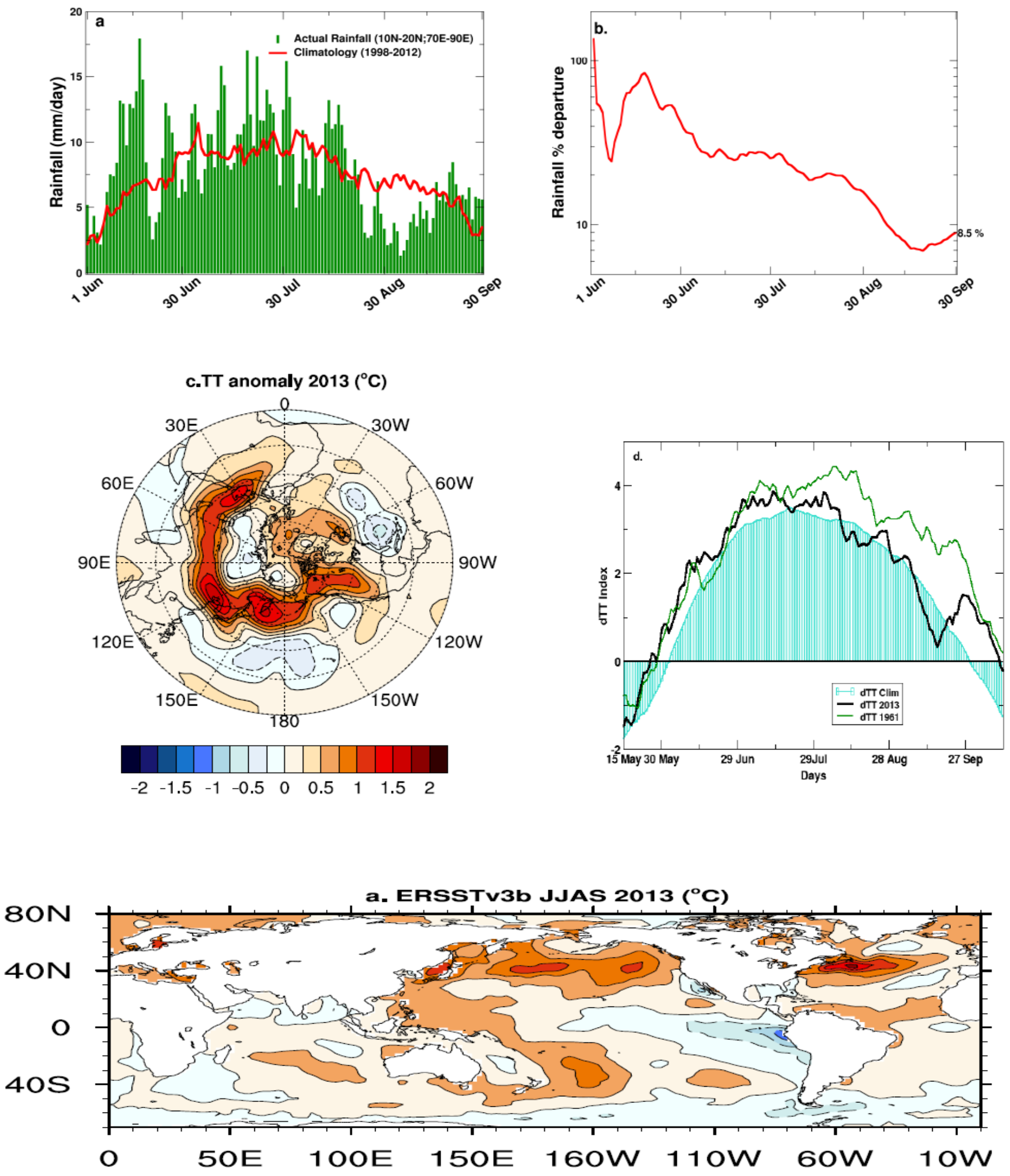


Figure 1: Some observed features of 2013 monsoon: (a) Daily evolution of All India rainfall, data from IMD. (b) Evolution of cumulative rainfall anomaly in ((d) Temporal evolution of dTT index for the year 2013 (black curve). Also shown here is the climatological evolution of dTT index as well as the evolution of dTT index for 1961.(e) Observed JJAS SST anomaly from ERSSTv3b

2013

(a)Daily rain over India

(b)Cumulative rain

(c)JJAS TT

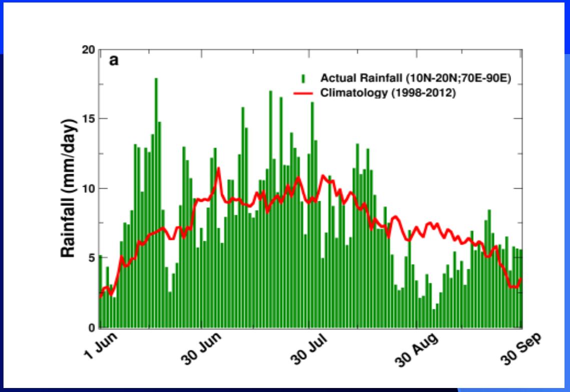
(d)Evolution of daily ΔTT

(e)JJAS SST anomaly

Hypothesis

Above normal ISM that are associated with weak La Nina, are driven by extra-tropical JJAS SST pattern similar to that during 2013!

1) Above normal ISM years defined by the daily rainfall being above climatology more than 60% of the days,
2) JJAS Nino3 index > -0.5 SD



Rank the years between 1960-2012 with the above two conditions and the top ranked years are 1961, 1967, 1990 and 1994 (beside 2013)

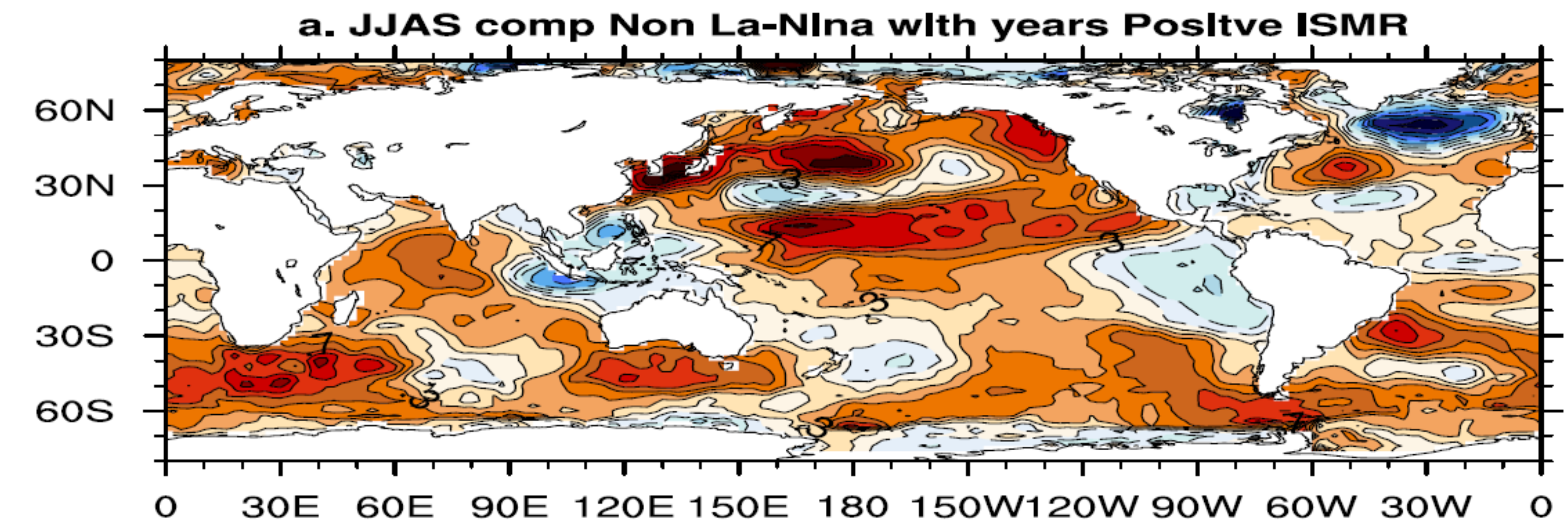
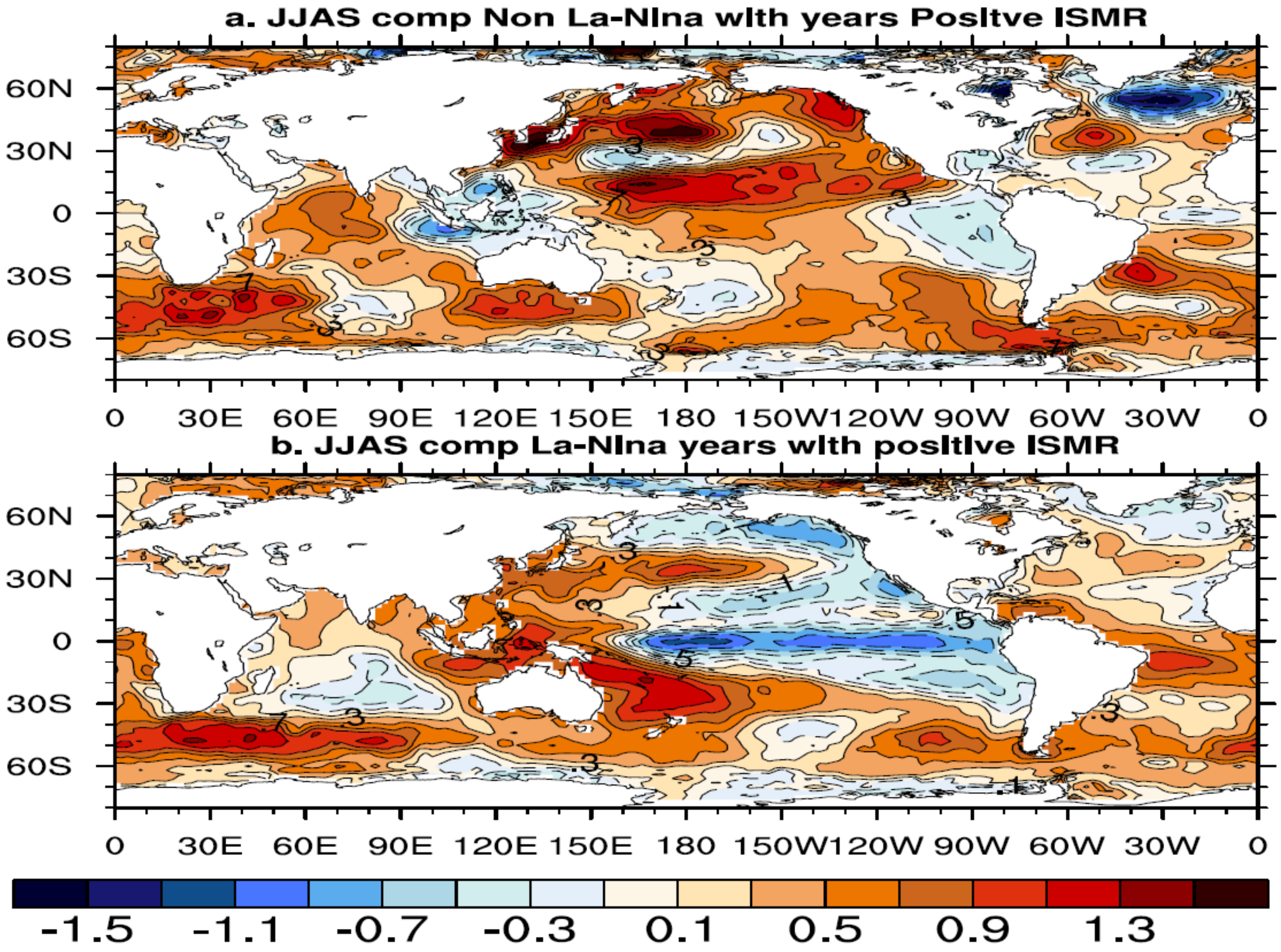


Figure 2: The JJAS composite of SST (standardized anomalies) (a)for the years when rainfall anomaly is above climatology for most of the days during common top years as defined in Table-1.(b) for the canonical La Nina years excluding the years in Table-1.



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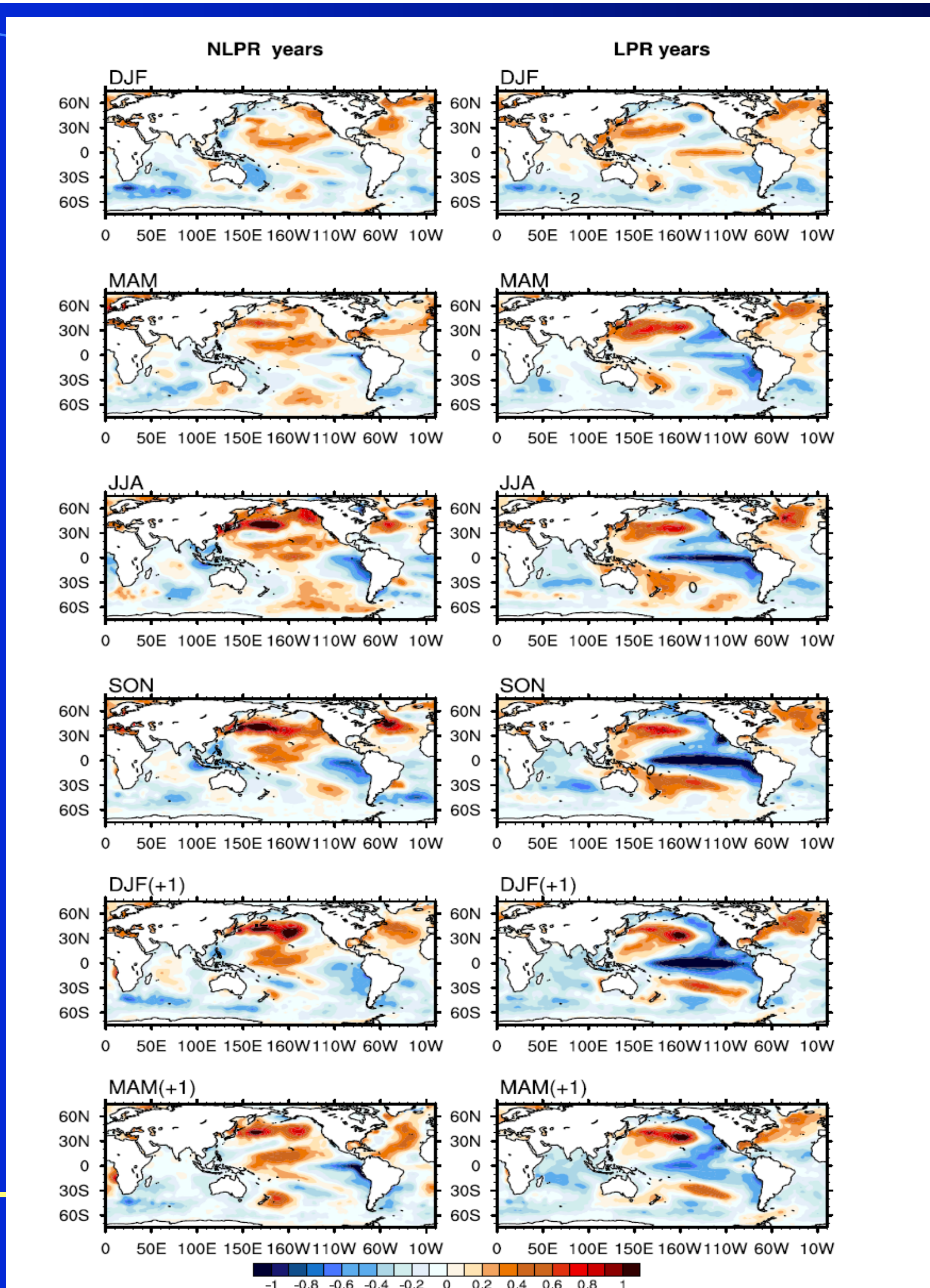
Seasonal evolution of NLPR years



Seasonal evolution of LPR years

What is the origin of the Extra-tropical SST anomaly pattern?

Hypothesis

It is associated with the strong phase of the extra-tropical multi-decadal mode when the tropical inter-annual mode is going through a transition.

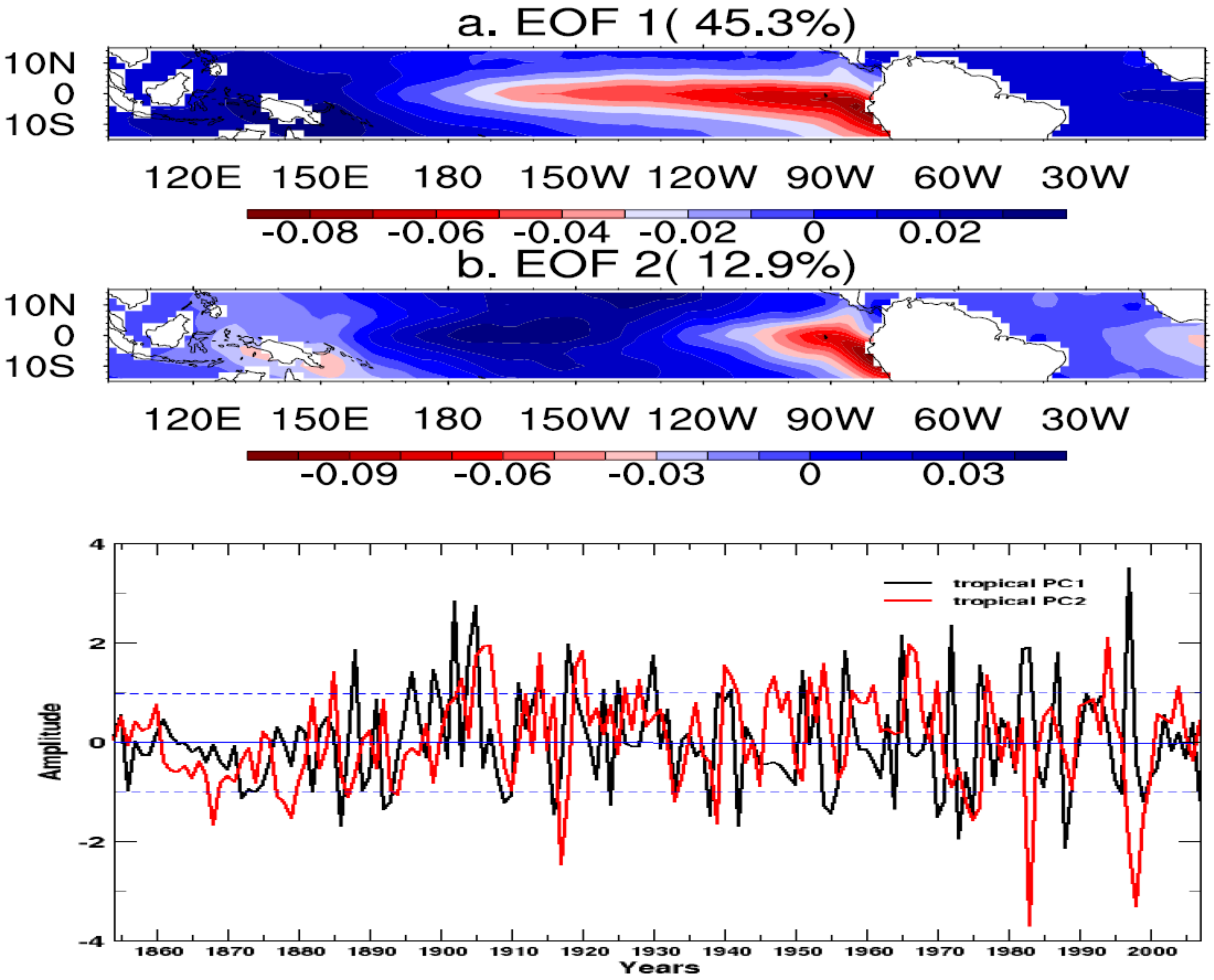


Figure 4: EOFs of tropical SST (ERSSTv3b)during JJAS (1854-2012) for the Pacific-Atlantic region (15°S-15°N,100°E-2°W).

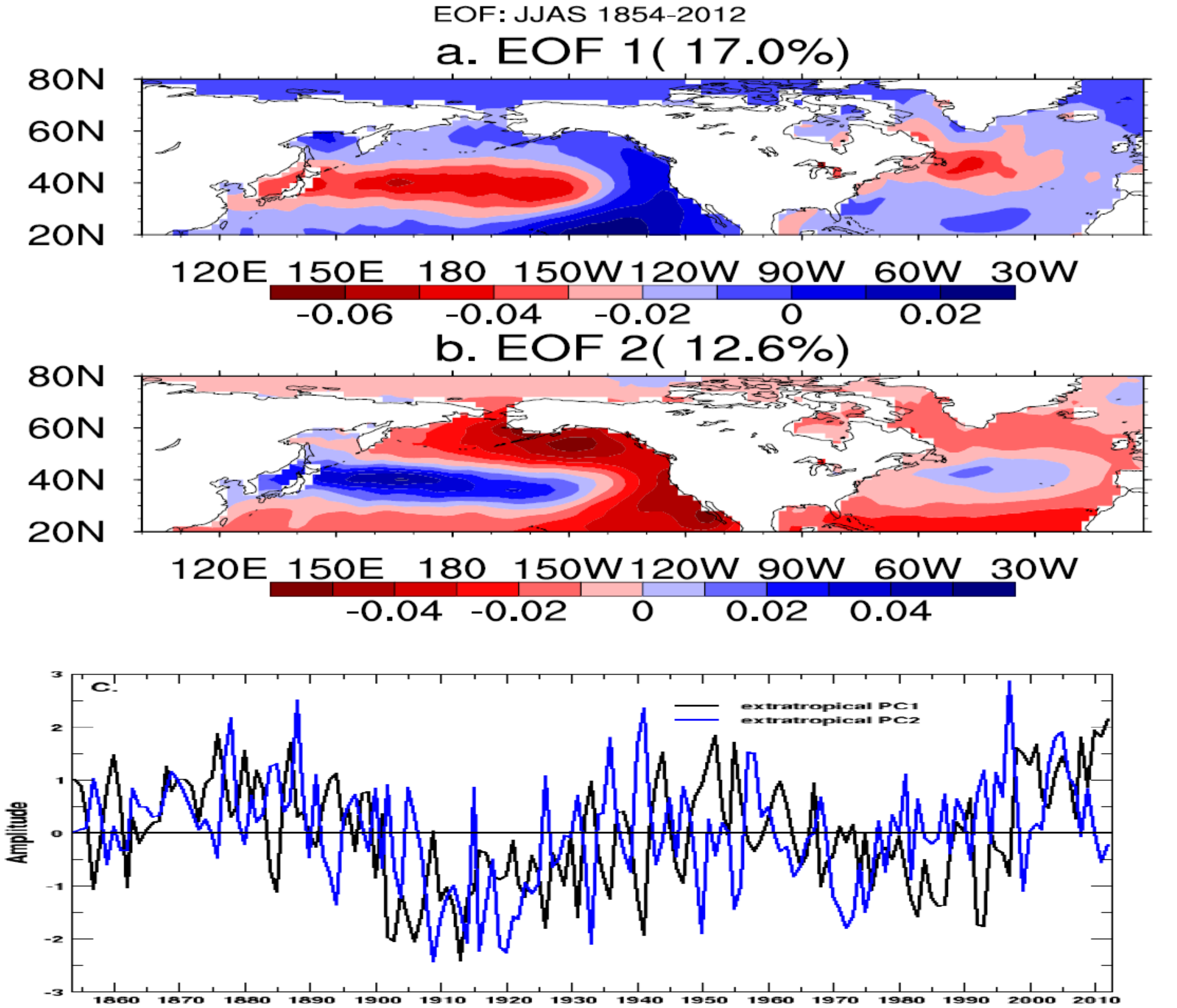
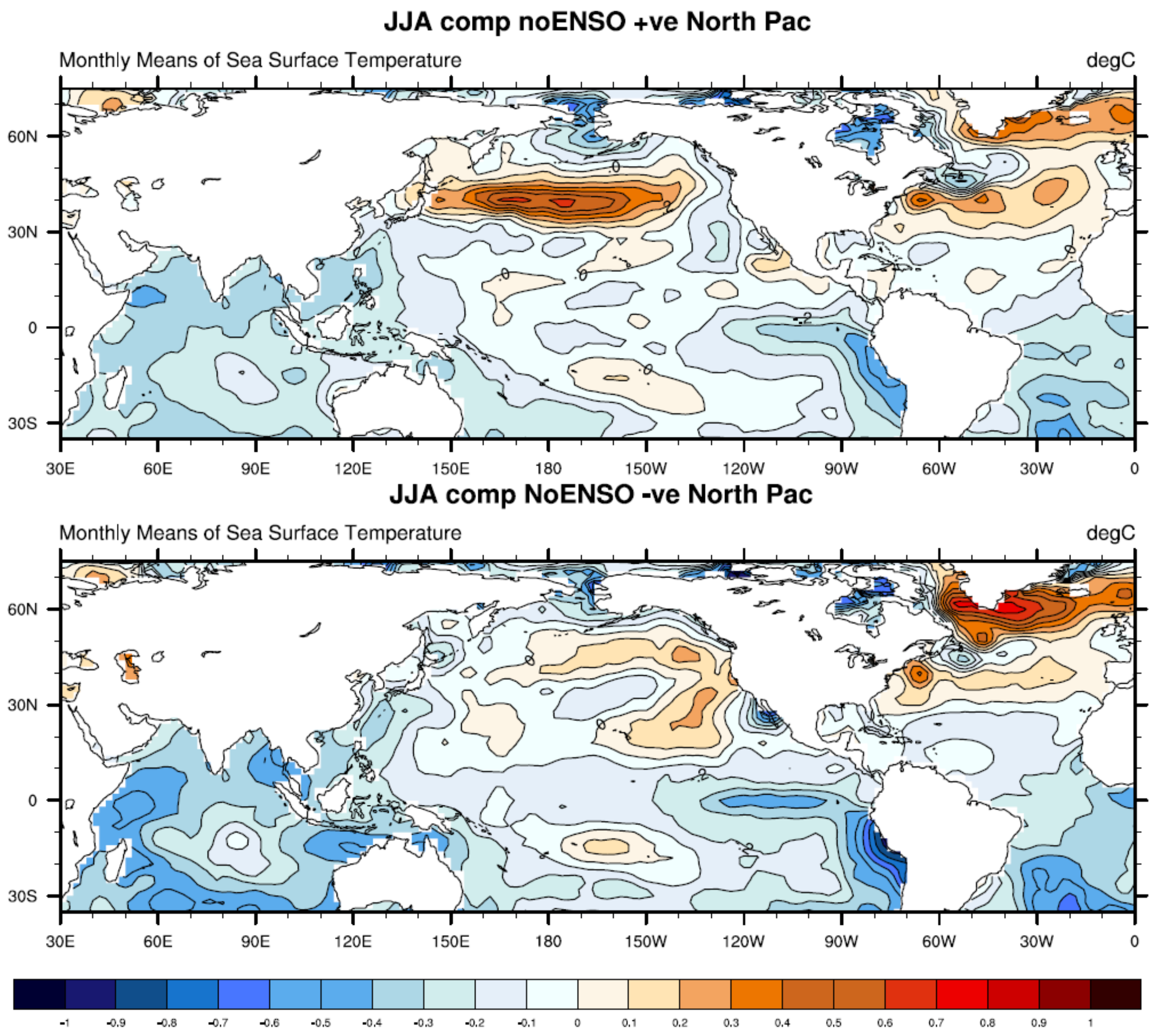
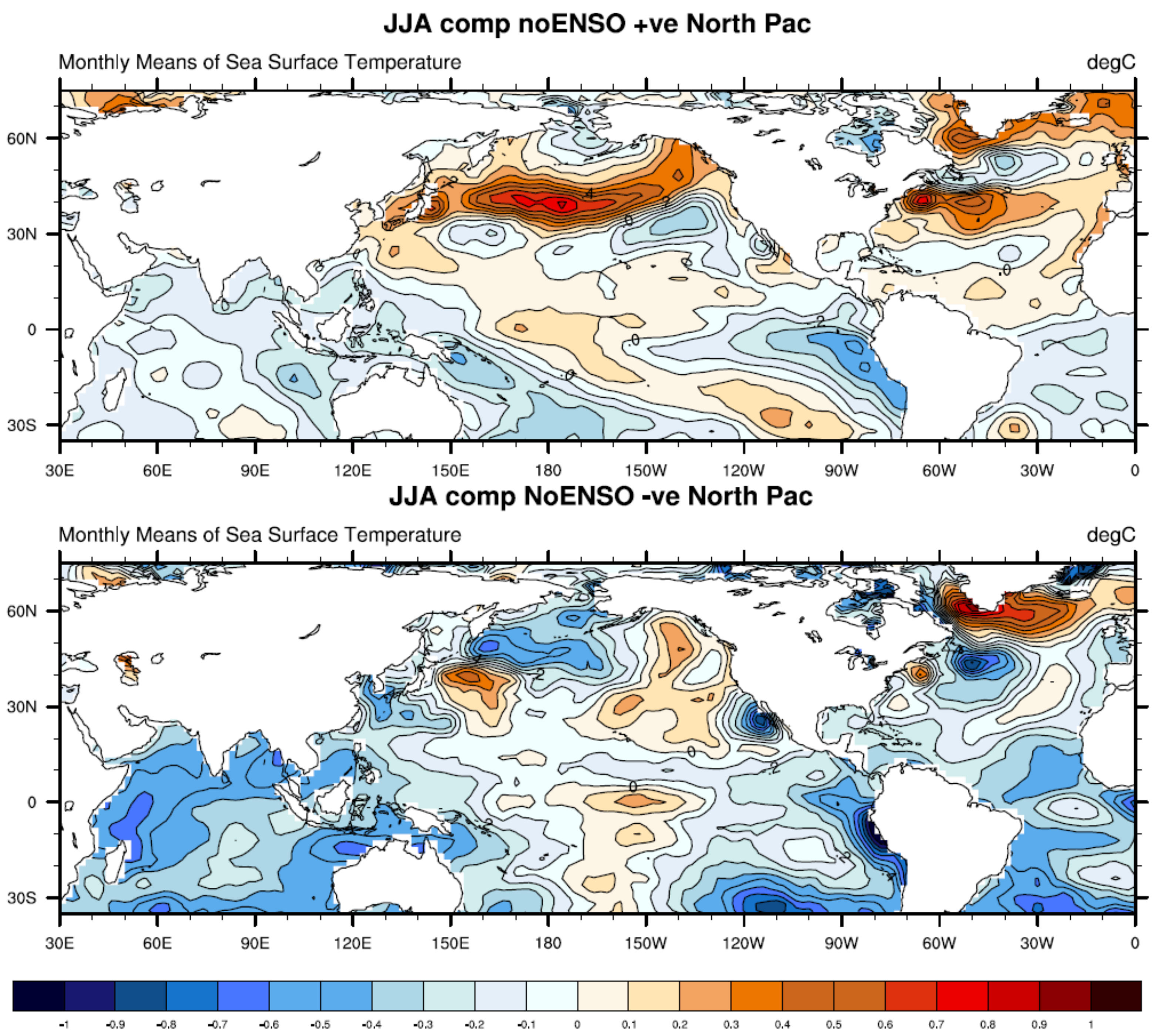


Figure 5: EOFs of northern hemispheric SST (ERSSTv3b) during JJAS (1854-2012) for the region (20°N-80°N,100°E-2°W).



Composite JJA SST for years with extra-tropical PC 1 > +1SD

Composite JJA SST for years with extra-tropical PC 1 < -1SD



Composite JJA SST for years with extra-tropical PC 1 > +1SD and ISM > + 0.5 SD

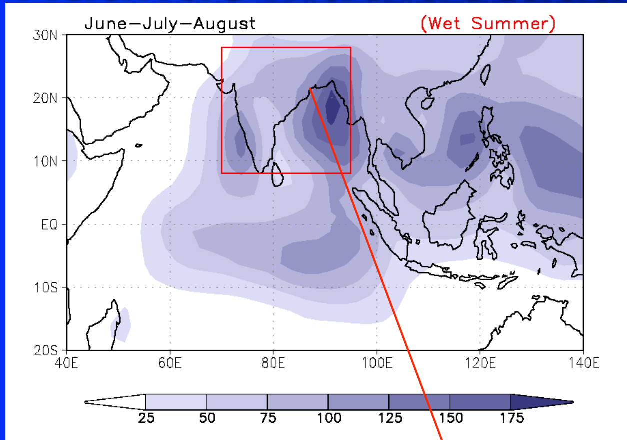
Pattern→A

Composite JJA SST for years with extra-tropical PC 1 > +1SD and ISM < - 0.5 SD

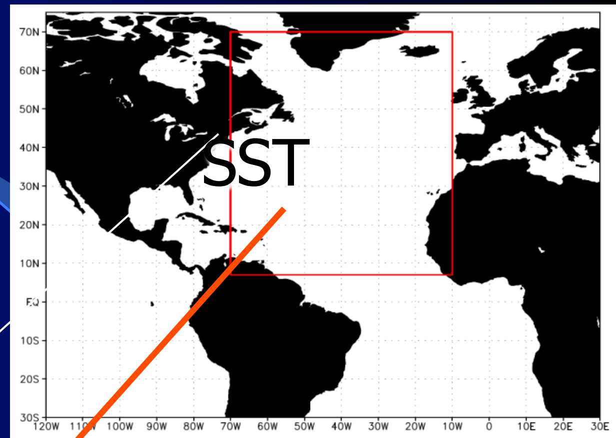
Pattern →B

What is the mechanism through which the north-Pacific and north-Atlantic SST influence the ISM rainfall?

Atlantic mutlidecadal variability (AMO) and Indian monsoon



Goswami et al. 2006, GRL, vol.33, L02706



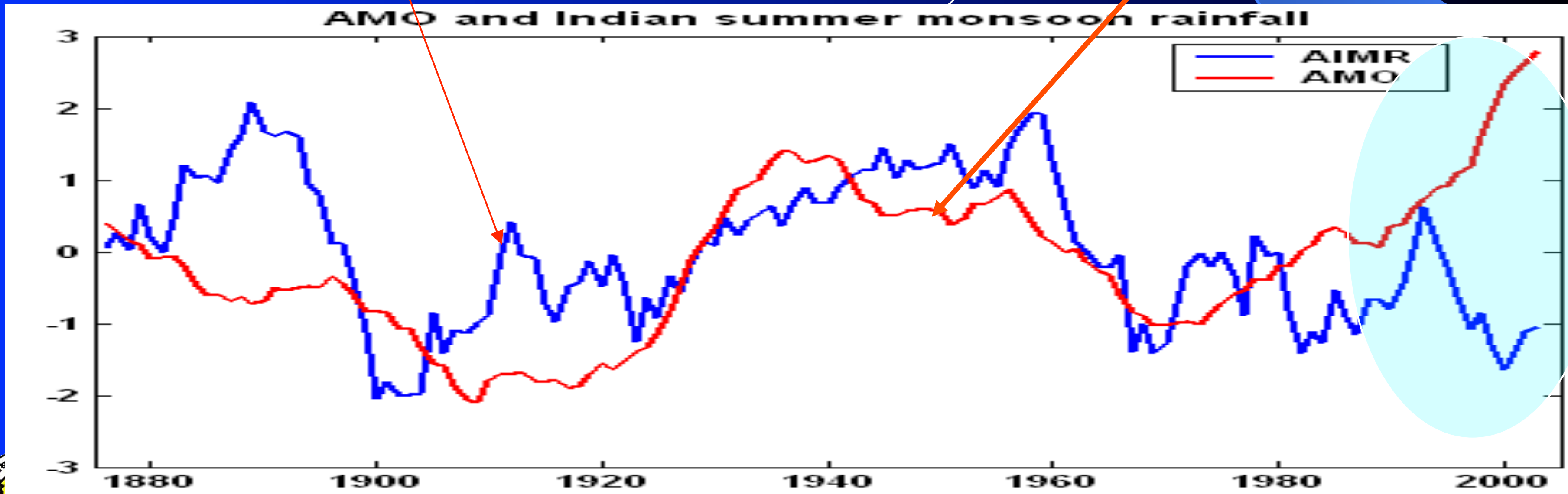
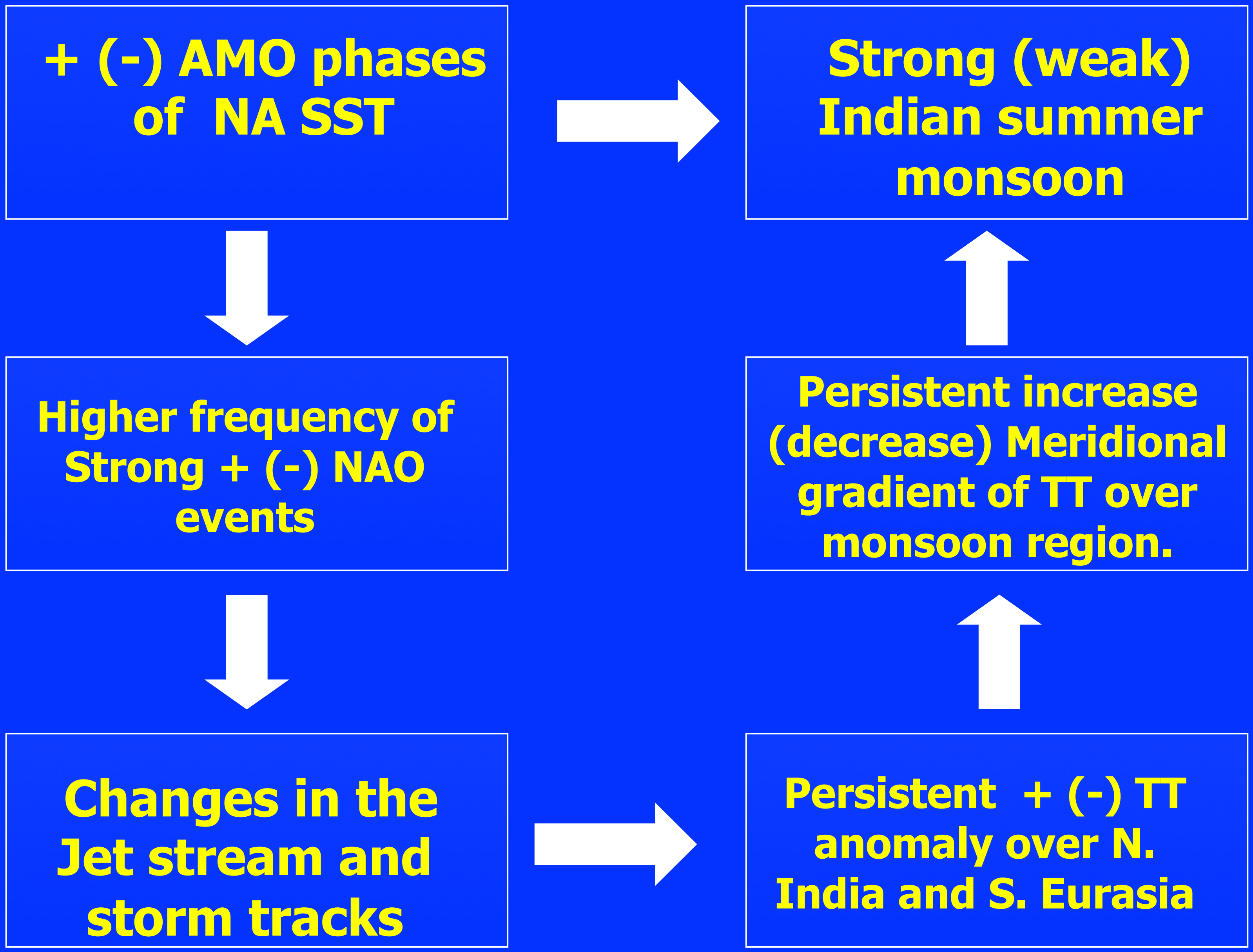
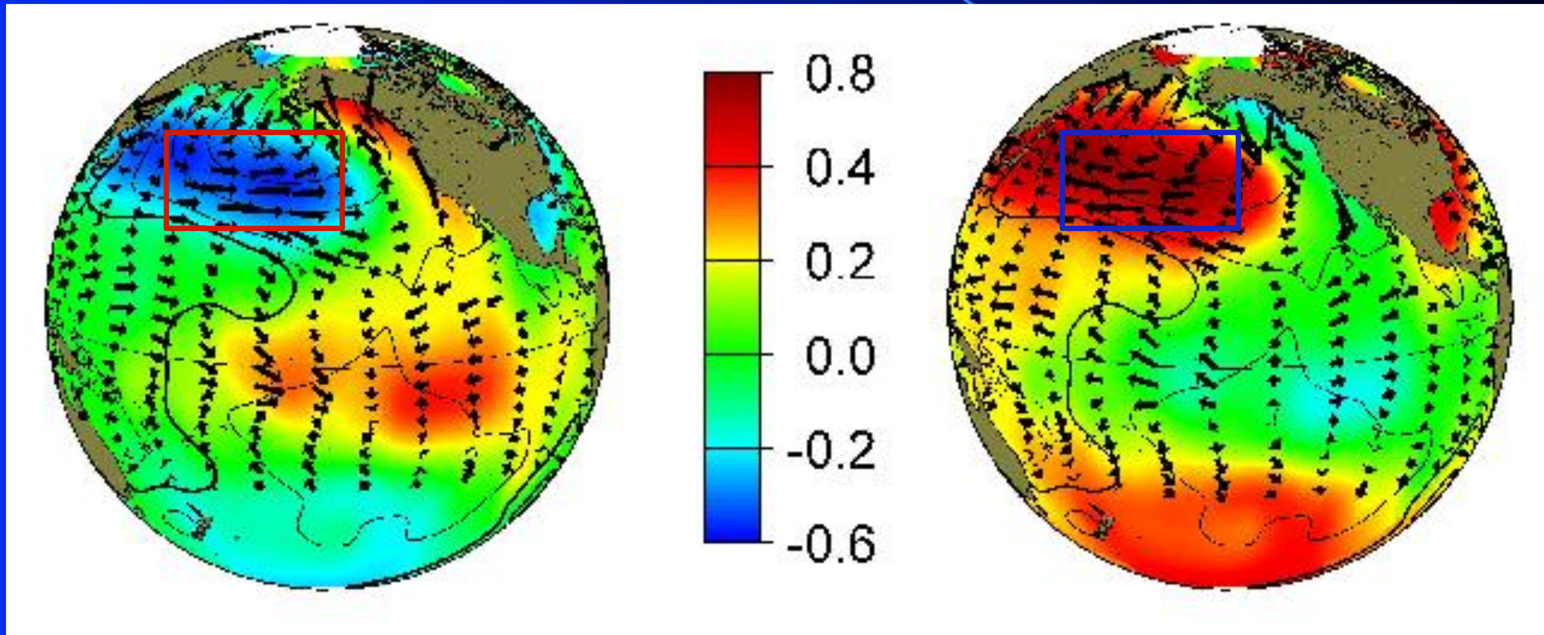


Figure 7: Multidecadal oscillation of AIR (red line, obtained from 11-yr running mean of JJAS mean all India rainfall) and Atlantic multidecadal oscillation (AMO, black line). AMO is based on 60-month running mean of monthly anomalies averaged over Atlantic north of Equator.



Goswami et. Al, 2006, Li et al. 2008, Lu et al. 2006, Liu et al. 2009

Pacific Decadal Oscillation (PDO)



SST (shaded), Sea Level Pressure (contours) and surface windstress (arrows) anomaly patterns during warm and cool phases of PDO

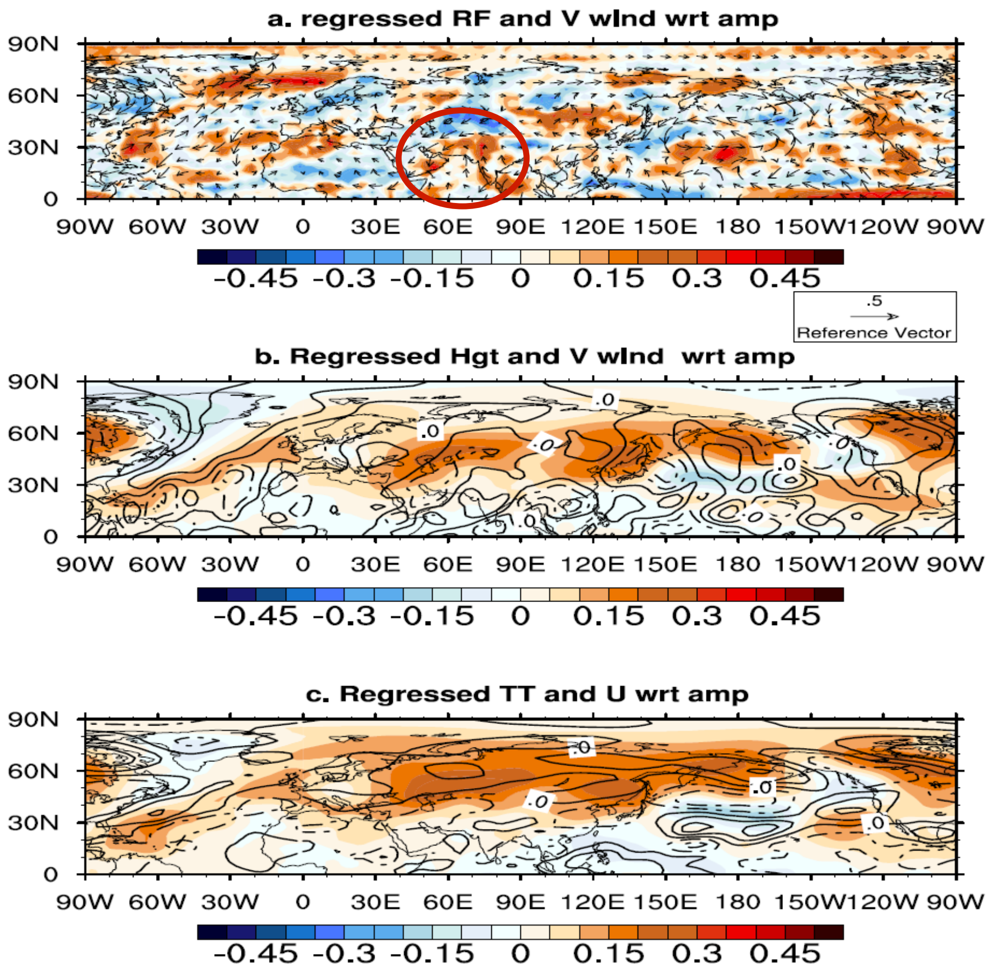
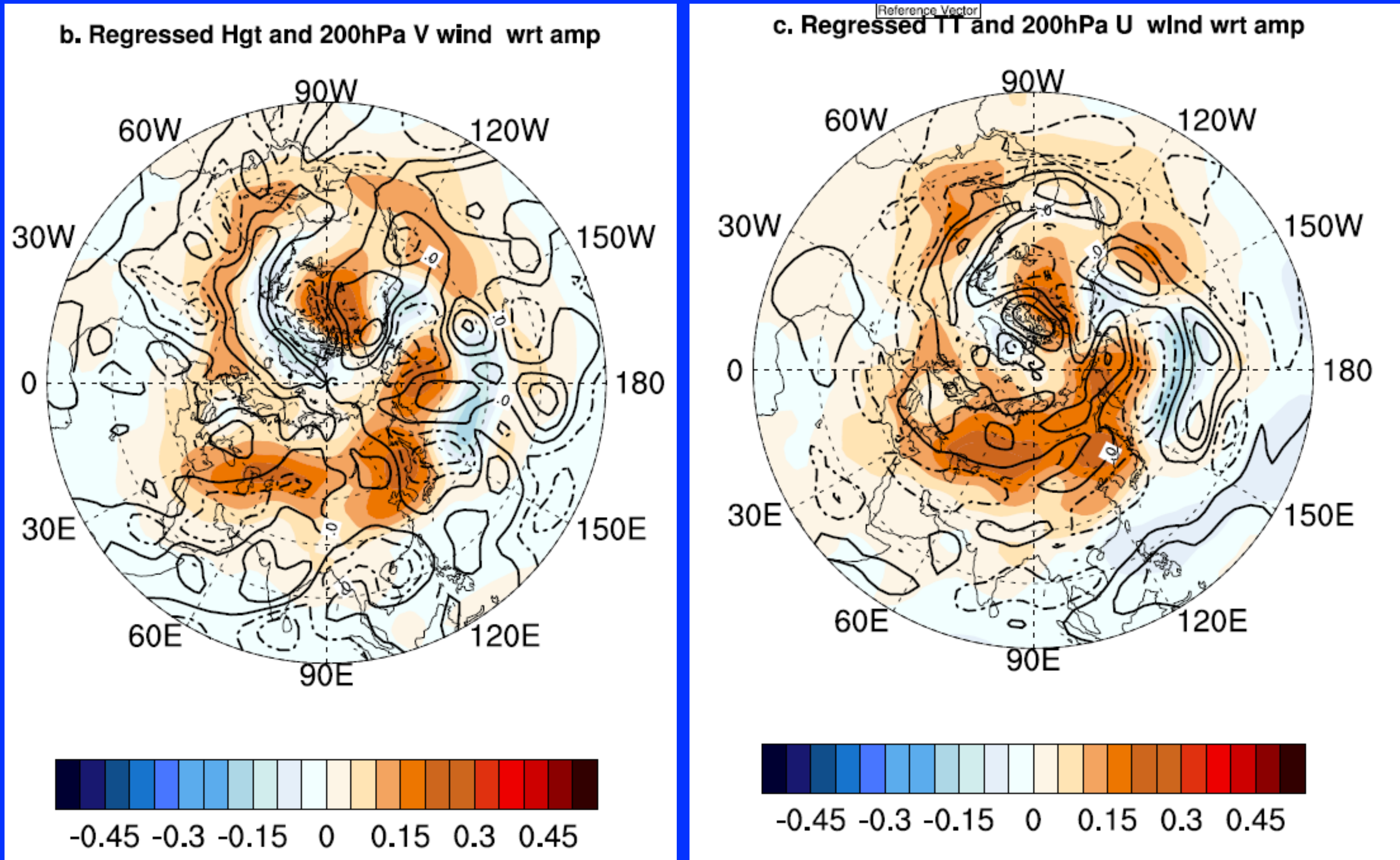


Figure 8: (a) Regressed rainfall (shaded) and vector wind at 200hPa with respect to the amp (=EPC1*EPC1+EPC2+EPC2) for the JJA season. (b) Same as (a) but showing regressed geopotential height at 200hPa (shaded) and meridional (V) wind as contours.(c) Same as (a) but showing regressed TT (shaded) and zonal (U) wind contours.Contours are of intervals of 0.1. Regression of Wind , Geopotential height and TT data are computed for the period 1955-2007 and the rainfall data is computed for the period 1979-2007. The regression is computed with respect to standardized anomaly of all the fields.

Support for the proposed mechanism from observations

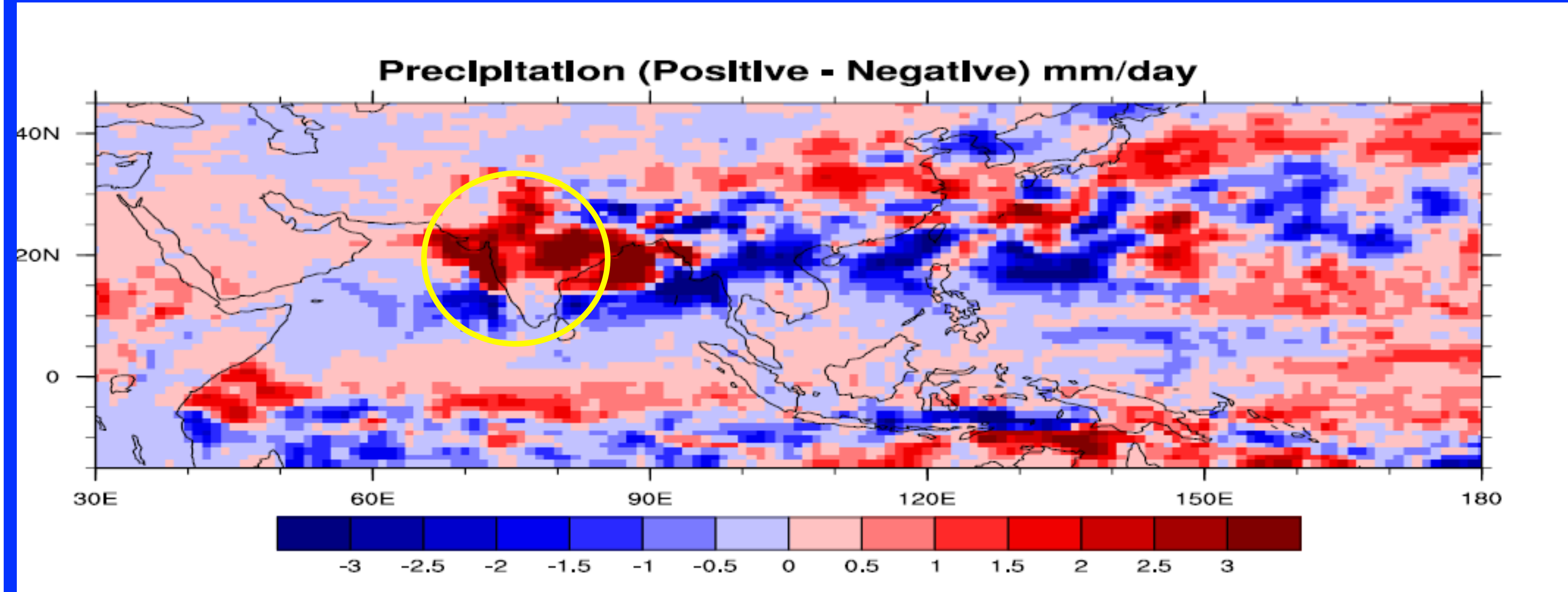
Support for the proposed mechanism from observations



Regressed with the ampl. of the extra-tropical inter-decadal mode (PC1**2 +PC2**2)

(b) 200 hPa Hgt and meridional wind (V), © 200 hPa zonal wind (U) and TT

Does the SST Pattern→A and Pattern→B over the extra-tropics force enhanced/decreased ISM rainfall?



Difference in JJAS precipitation simulated by GFS forced by climatological SST plus Pattern→A and Pattern→B north of 15N.

A 5-member ensemble simulations have been made for each case

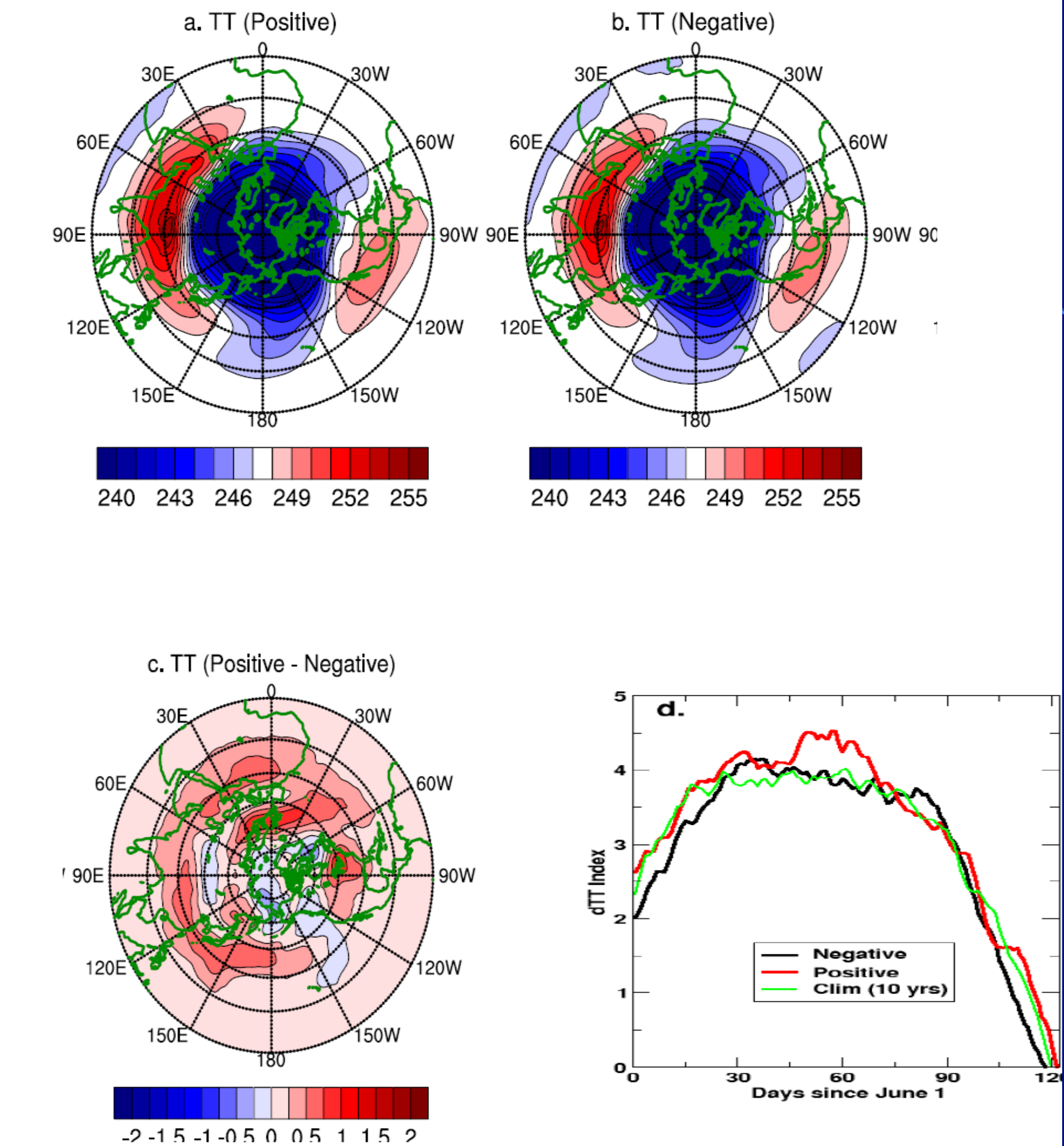
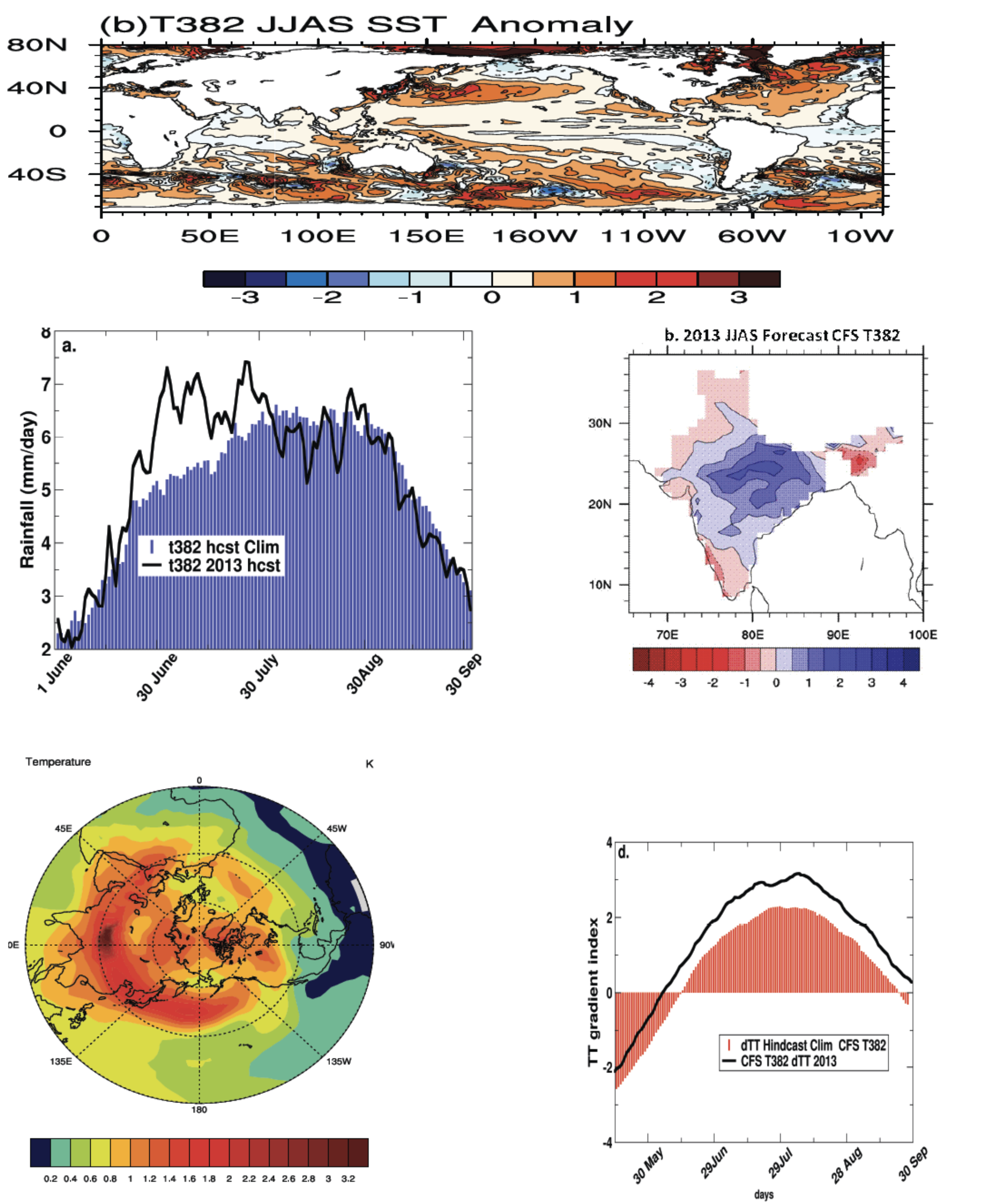


Figure 10: TT index plot for (a) positive phase, (b) negative phase, (c) Difference between positive and negative phases of the mode. (d) temporal evolution of dTT index.

The Pattern →A forces enhanced TT in northern India and southern Eurasia leading to a stronger monsoon

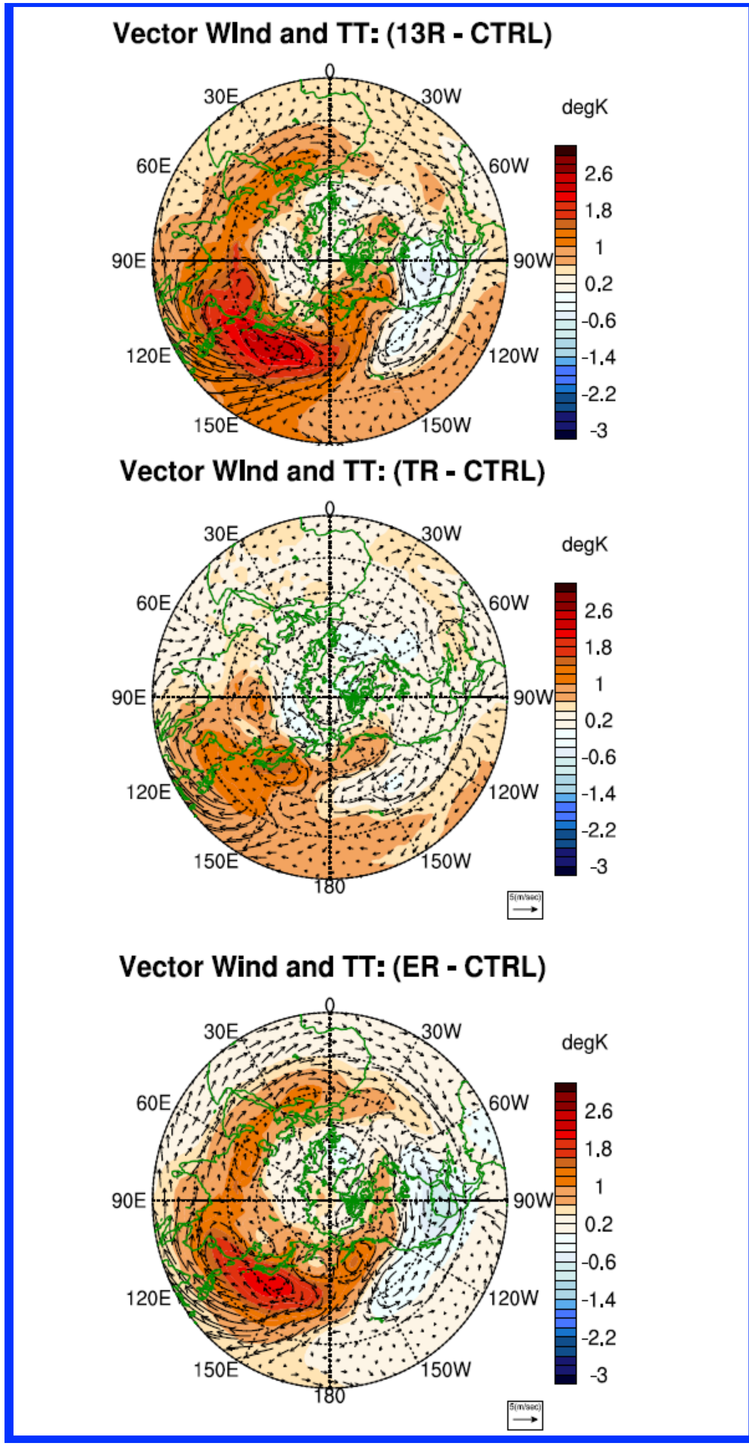


Successful forecast of 2013 ISM by CFSv.2 from Feb. 2013 initial conditions.

27-member ensemble predictions

→ Models are able to simulate such patters today!

Figure 11: The CFS T382 real time forecast for the year 2013 (a) SST anomaly (b) rainfall annual cycle(black) averaged over Indian land for the year 2013 compared to the evolution of model simulated climatological annual cycle (blue bars). (c) JJAS spatial average of rainfall anomaly. (d)TT index anomaly forecast using T382 for the year 2013, (e) evolution of dTT index during June to September (black) and its hindcast climatology (red bars). (rainfall units: mm/day; TT units: deg K; SST unit: deg K).



Can we say that the above normal rainfall over India during 2013 was forced by the extra-tropical SST anomalies?

GFS experiments, 5-member ensemble each

CTRL→ forced by climatological JJAS SST

13R→forced with observed JJAS SST anomalies , global

TR→ Observed SST anomalies only between 15S and 15N, climatology elsewhere

ER→ Climatological SST between 15N and 15S, observed elsewhere

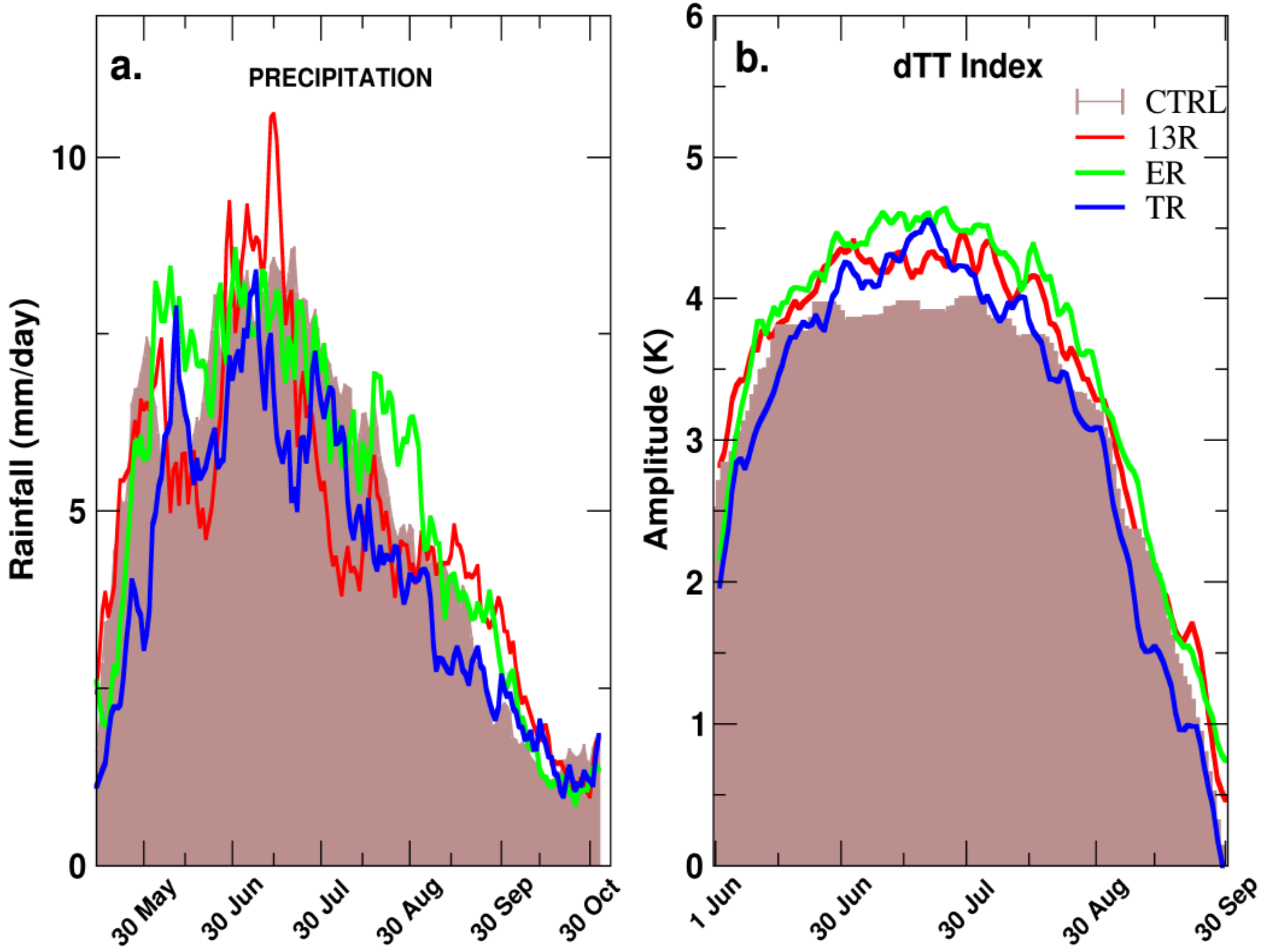


Figure 13: (a) Evolution of rainfall annual cycle for the 2013 SST forced run 13R, TR run, ER run and the CTRL run. (b) evolution of ensemble mean dTT the three runs and the CTRL run.

Conclusions

- Looking beyond the ENSO, we discover that there are certain extra-tropical SST patterns in the north Pacific and north Atlantic that can influence the south Asian monsoon rainfall,

- We show that these patterns are associated with strong phases of the multi-decadal variability when the tropical SST anomalies are weak (ENSO going through a transition).

- Persistent change in the position of the jet steam due to the north-south temperature gradients in the Pacific and Atlantic sectors → stationary waves → north-south TT gradient over south Asian monsoon region → monsoon rainfall

- With models able simulate and predict these SST patterns, prospects of south Asian monsoon prediction improves!

Thank You

For your attention