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Why is ENSO influencing northwest India winter precipitation in recent decades?

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Introduction

- Northwestern parts of India has mainly two rainy seasons, summer and winter

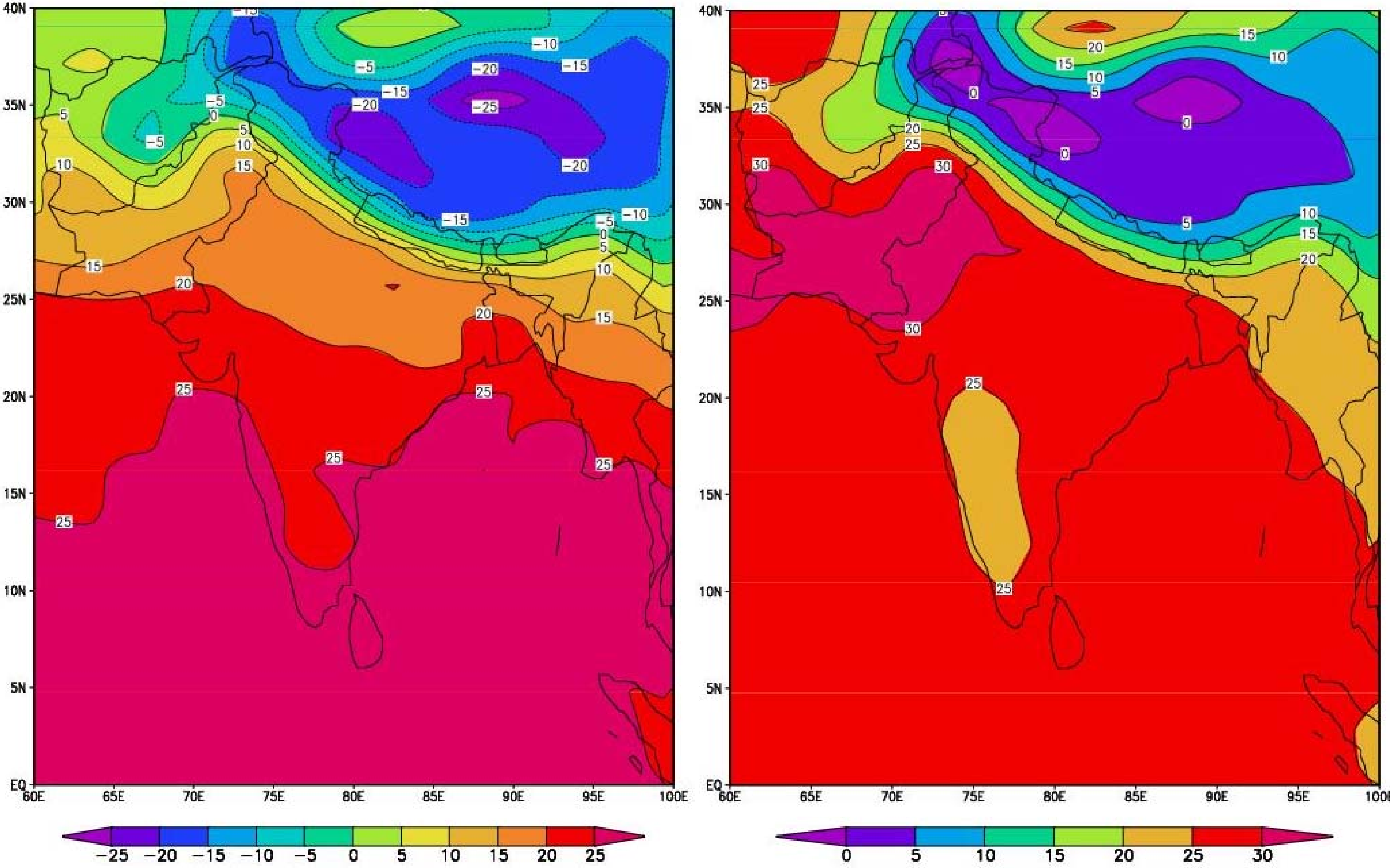
- The winter season consist months of December to March

- The precipitation during the season is mainly associated with the sequence of migratory mid-latitude synoptic systems known as '*western disturbances*'.

- The precipitation is very important for Rabi crops, particularly for wheat, as it supplements the irrigation/moisture and maintains low temperature for the crops.

- The precipitation in the form of snow over the hilly regions of north west India helps in maintaining the Glaciers extend which serves as the vast store-house of the water in different seasons for the great rivers which take their birth there.

2-meter surface temperature

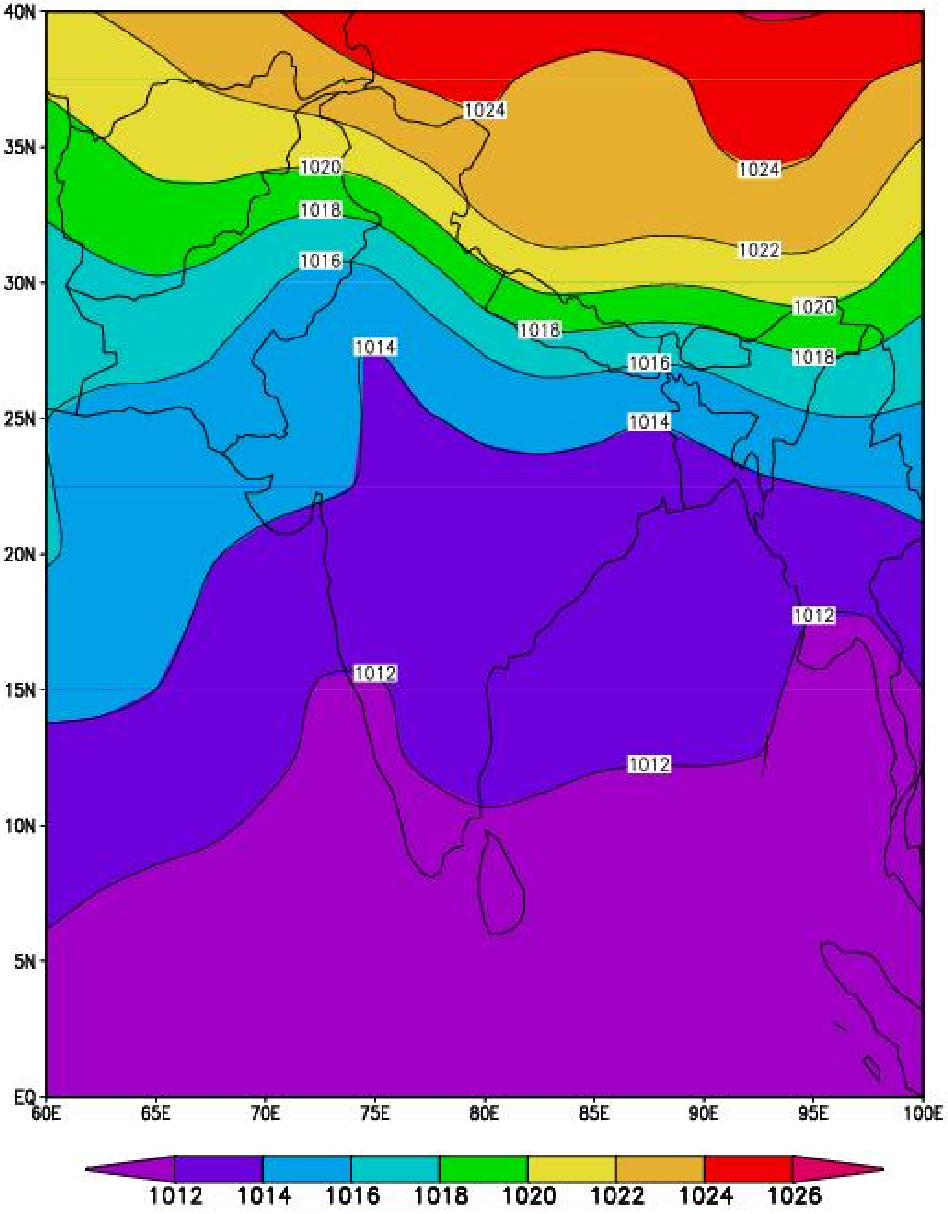


Winter

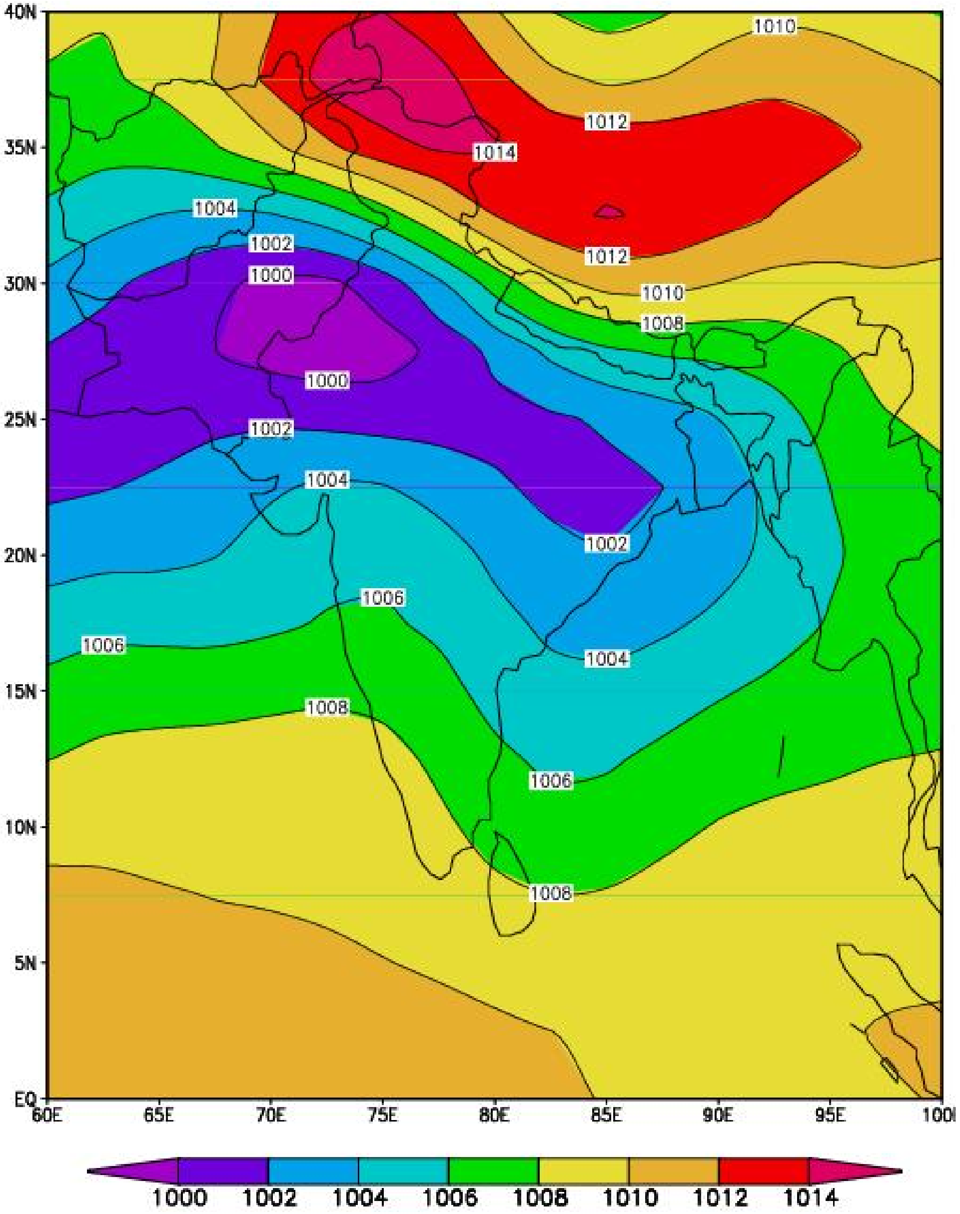
Summer

MSLP

Winter

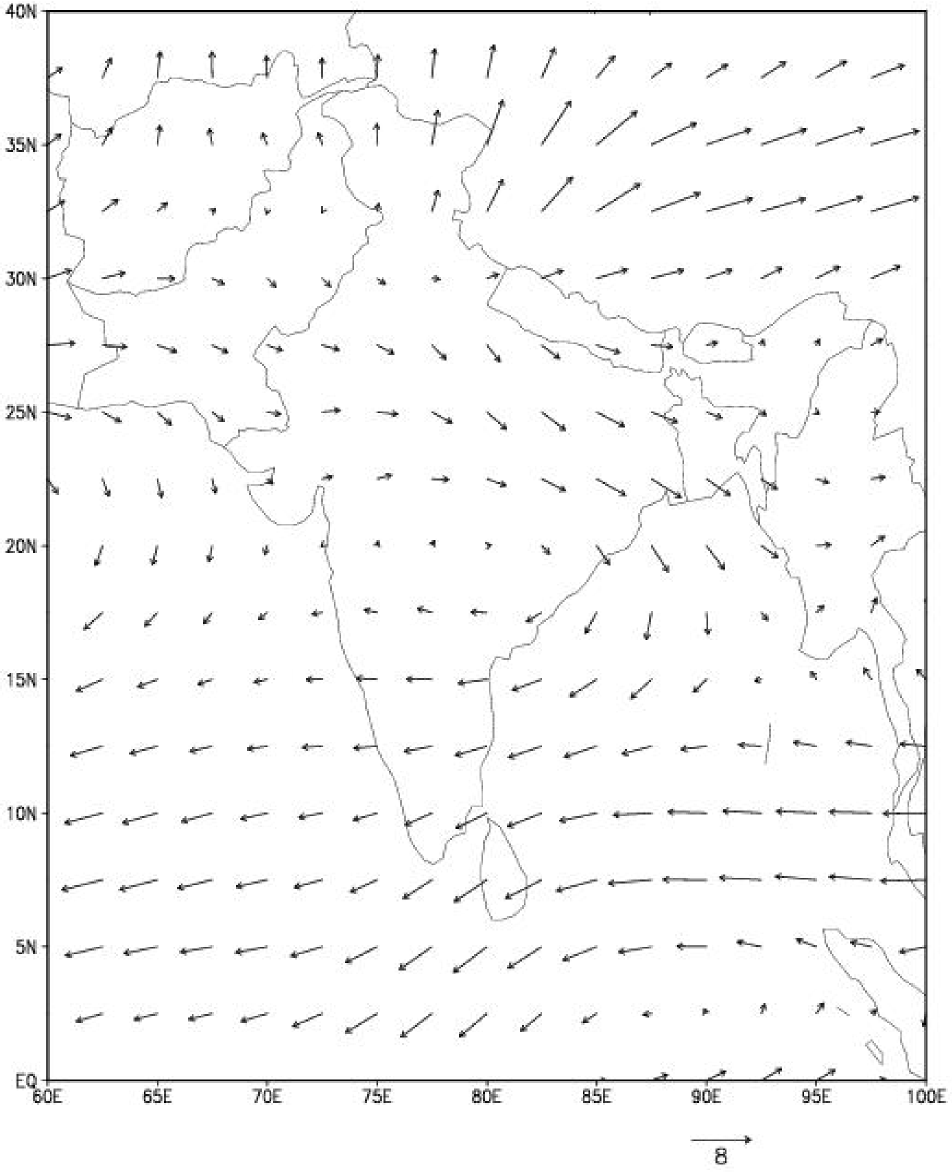


Summer

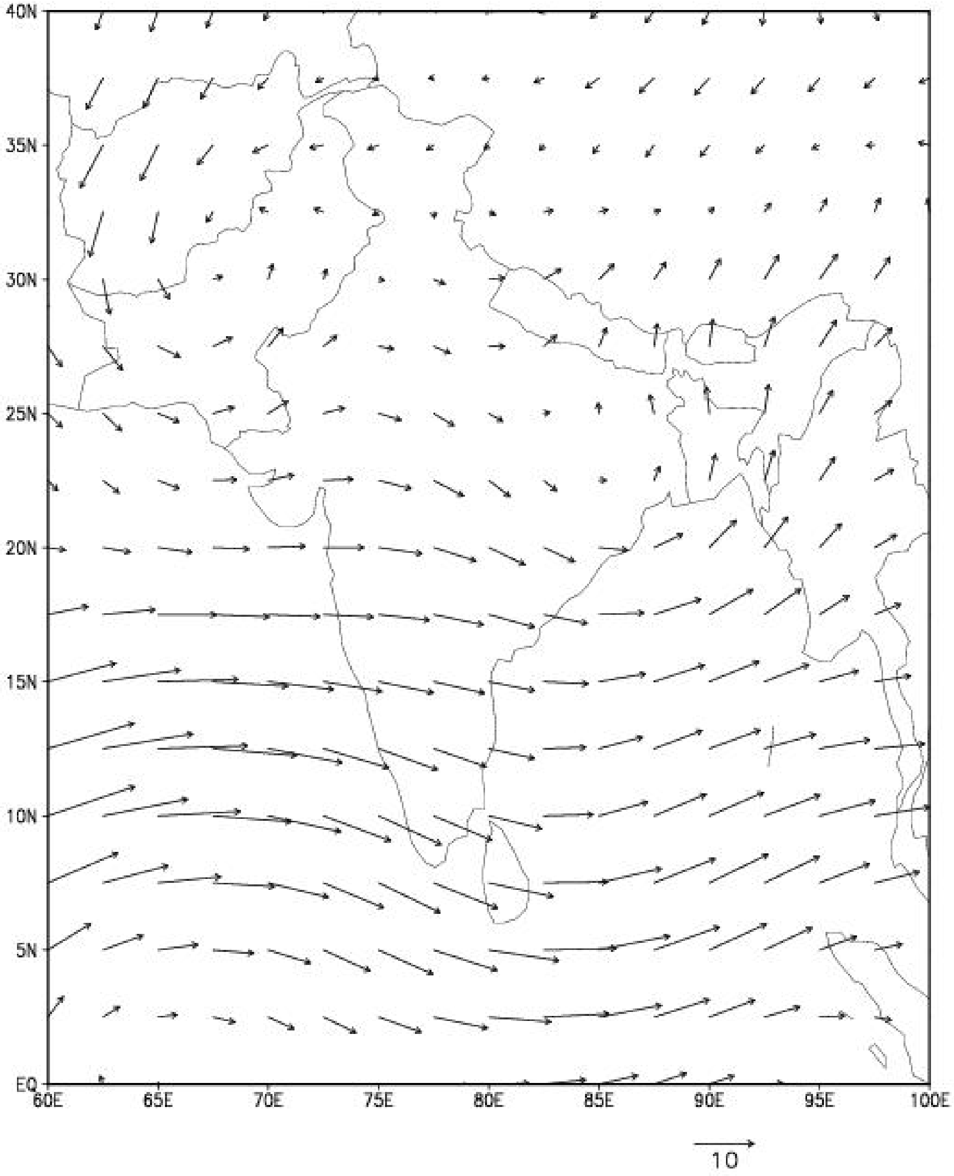


850 hPa wind patterns

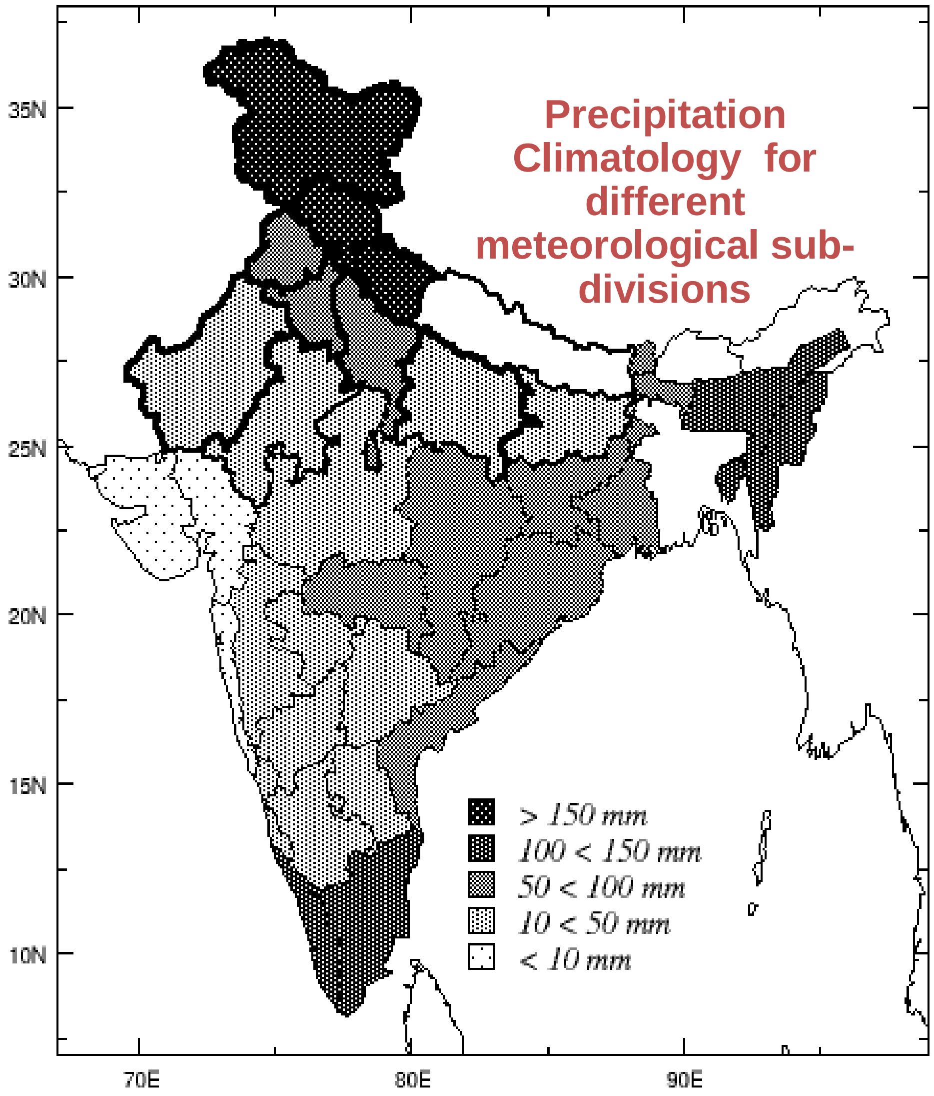
Winter



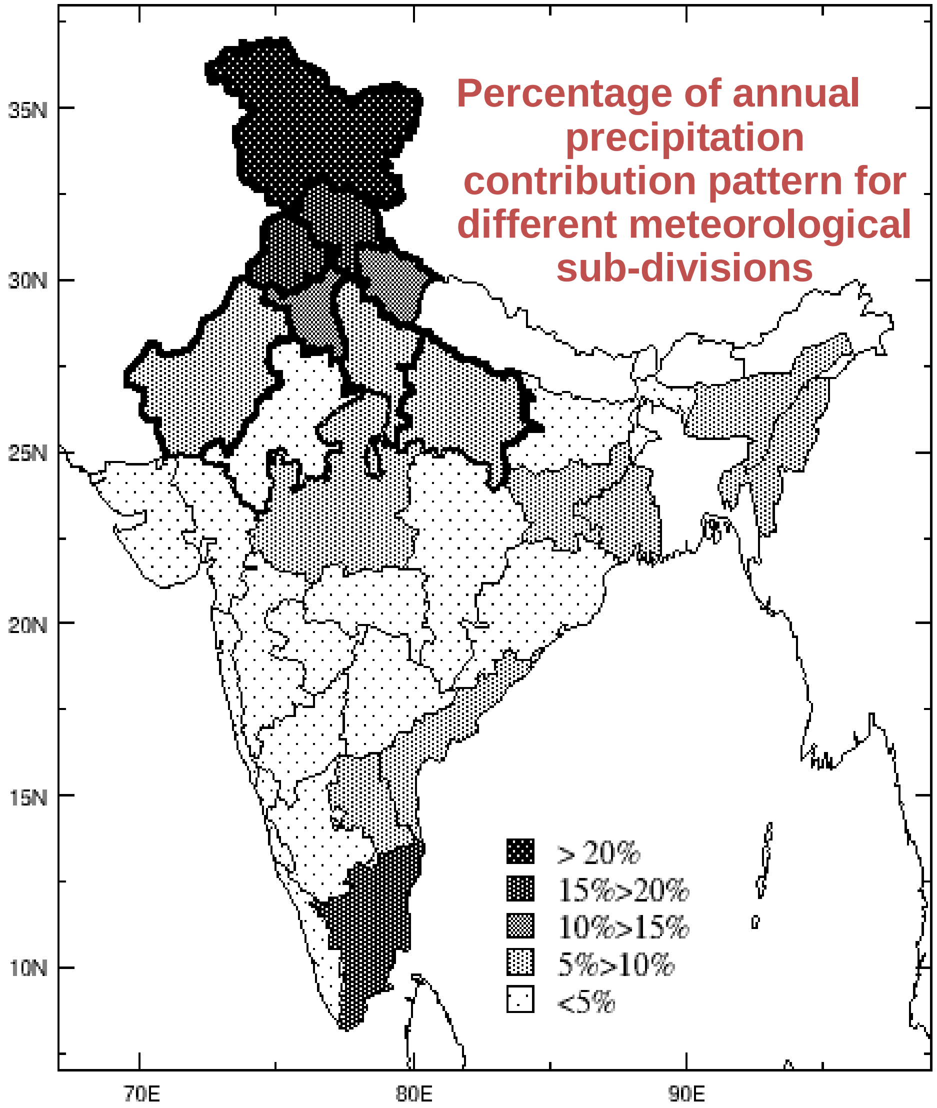
Summer



Precipitation Climatology (1902-2004) for the season DJFM



Precipitation Climatology for different meteorological sub-divisions

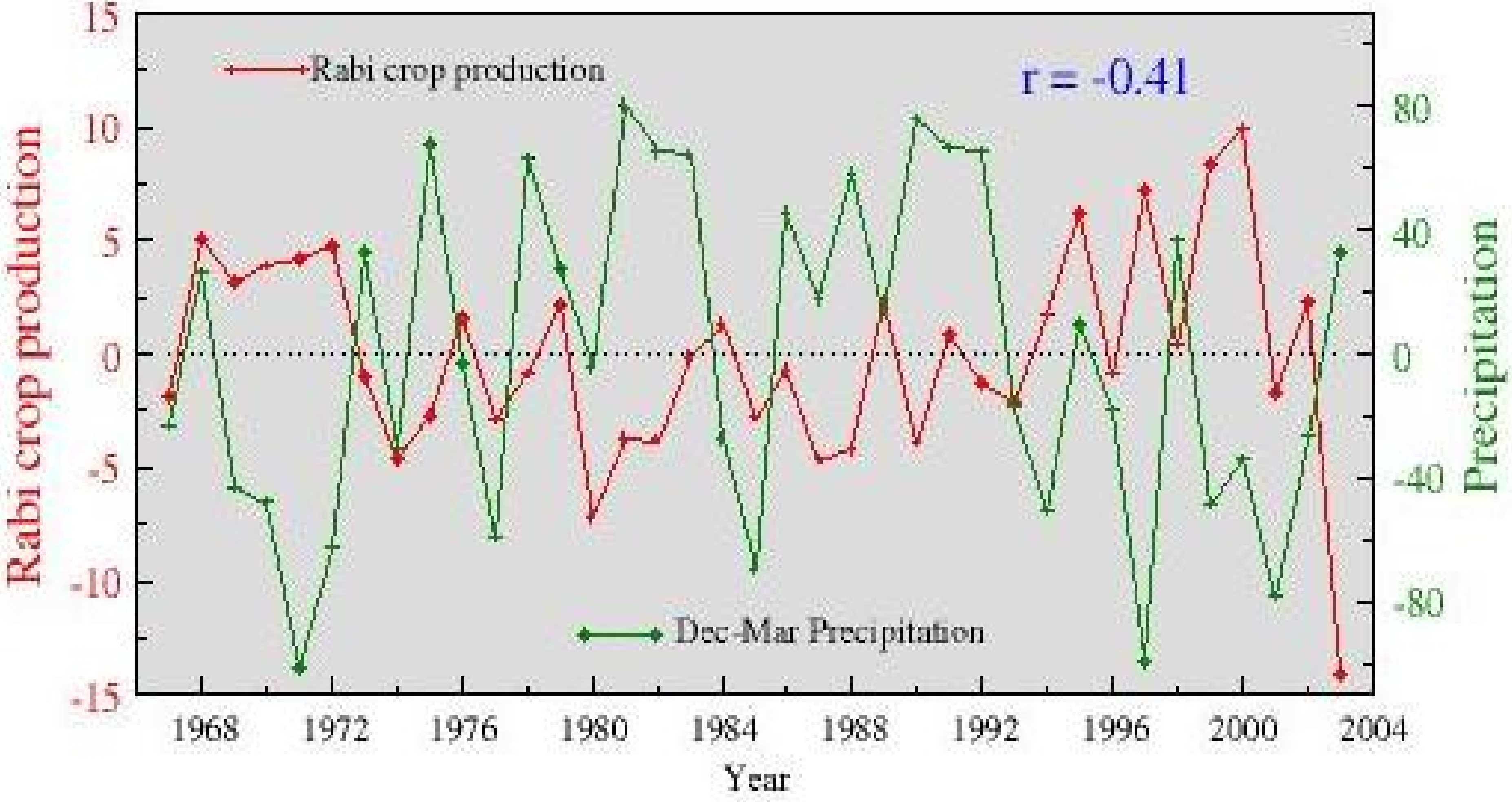


Percentage of annual precipitation contribution pattern for different meteorological sub-divisions

Seasonal Mean, percentage contribution, Standard Deviation and Coefficient of Variations of precipitation (mm) of different subdivisions of NW India (1902-2004) and their area in square Kilometers

Sub-division	*Mean (mm)*	*%*	*S.D..*	*C.V.*	*Area*
East Uttar Pradesh	**46.8**	**4.2**	**26**	**55.6**	**146509**
West Uttar Pradesh	**59.4**	**5.3**	**31**	**52.1**	**96782**
Uttaranchal	**184.9**	**16.6**	**78**	**42.1**	**51122**
Haryana	**57.9**	**5.2**	**33**	**56.7**	**45821**
Punjab	**93.7**	**8.4**	**44**	**46.6**	**50362**
Himachal Pradesh	**278.6**	**25.0**	**119**	**42.7**	**55673**
Jammu & Kashmir	**356.9**	**32.0**	**137**	**38.4**	**222236**
West Rajasthan	**15.5**	**1.4**	**12**	**79.6**	**195086**
East Rajasthan	**22.5**	**2.0**	**17**	**74.8**	**147063**

Year-to-year Variation of detrended Rabi crop production and NWIWP

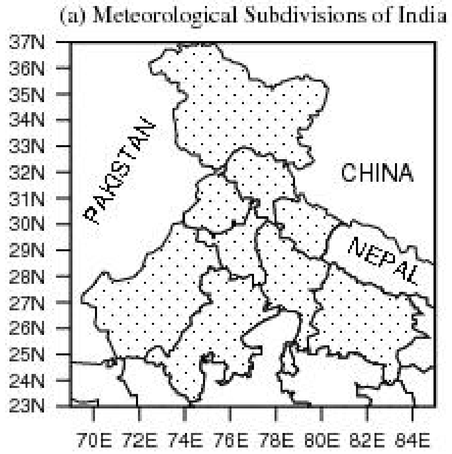


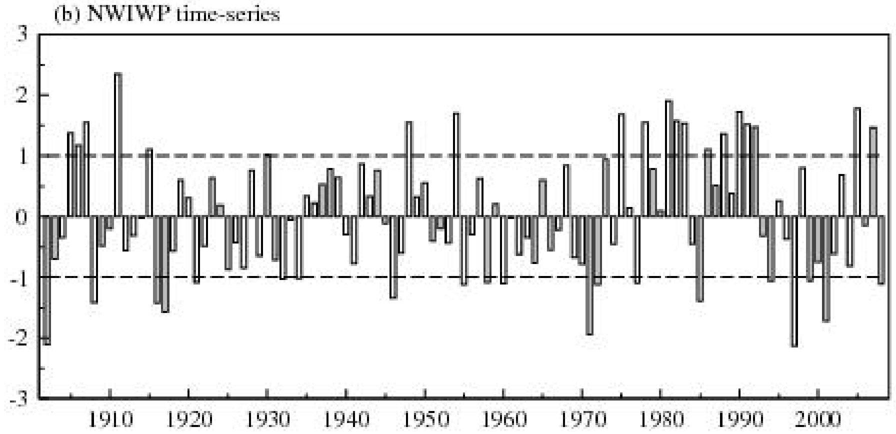
Statistical Properties of NWIWP (1902-2004)

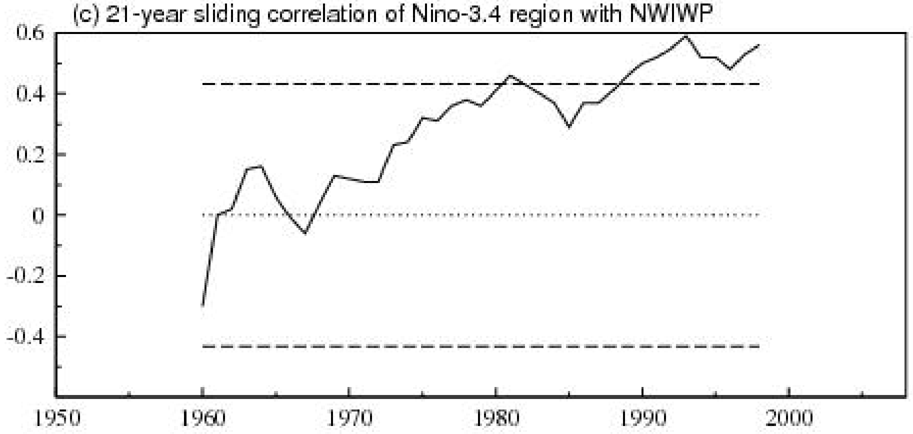
Variable	*Value*
Mean	129.2 mm
Percentage of annual rainfall	15.2%
Standard Deviation	45.7 mm
Coefficient of variation	35.3%
Median	120.7 mm
Range	207.2 mm
Lowest rainfall	31.6 mm in 1997
Highest rainfall	238.8 mm in 1911
Auto-correlation coefficient	0.114

Why is ENSO influencing northwest India winter precipitation in recent decades?

This study examines decadal changes of the ENSO influence on the IAV of NWIWP. The analysis is based on correlations and regressions performed using IMD records based on station data and re-analysis fields from 1950 to 2008. We find that the IAV of NWIWP is influenced by the ENSO phenomenon in the recent decades. This conclusion is supported by a consistency across the different observational datasets employed in this study and confirmed by numerical modeling. A physical mechanism for such an influence is proposed, by which western disturbances (WDs) are intensified over north-west India because of a baroclinic response due to Sverdrup balance related to large-scale sinking motion over the western Pacific during the warm phase of ENSO. This response causes an upper level cyclonic circulation anomaly north of India and a low-level anticyclonic anomaly over southern and central India. The cyclonic circulation anomaly intensifies the WDs passing over NW India.







(a) Geographical location of NW India

(b) The time series of NWIWP for the period 1902-2008

(c) 21-year sliding correlation between Nino-3.4 region SST and NWIWP index

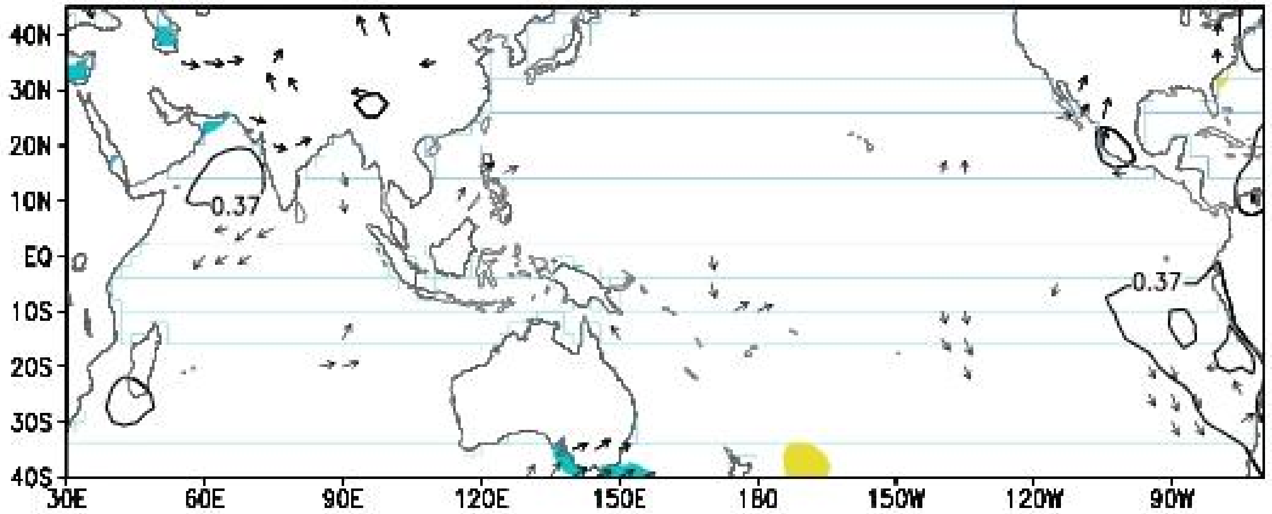
The CC of the Niño-3.4 and NWIWP is 0.46 for the period 1968-2008 (41 years), which is statistically significant at the 99% level.

In 107-years period (1902-2008), there are

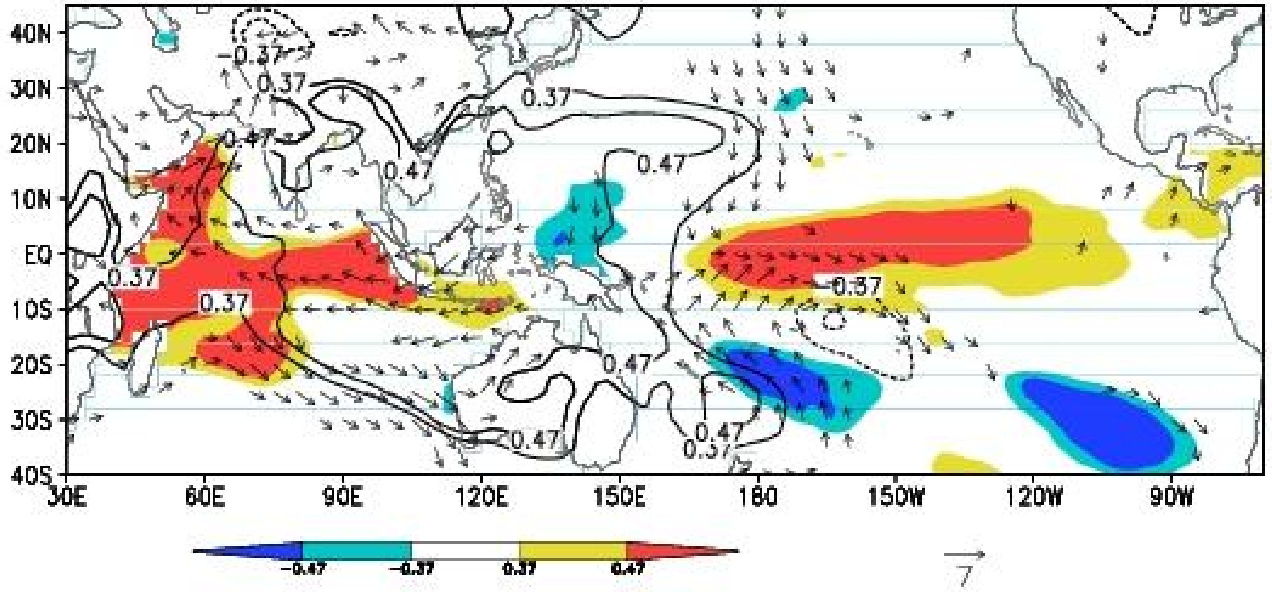
20 excess years
20 deficient years
Mean = 130.1 mm
Standard Deviation (SD) = 46.2 mm
Coefficient of Variation (CV) = 35.5%

To examine the differences in circulation features associated with the secular variations of ENSO, we have constructed concurrent correlations and regressions for the equal data length time slices 1950-1978 and 1980-2008, for which the reanalysis data are available

(a) period 1 (1950–1978)

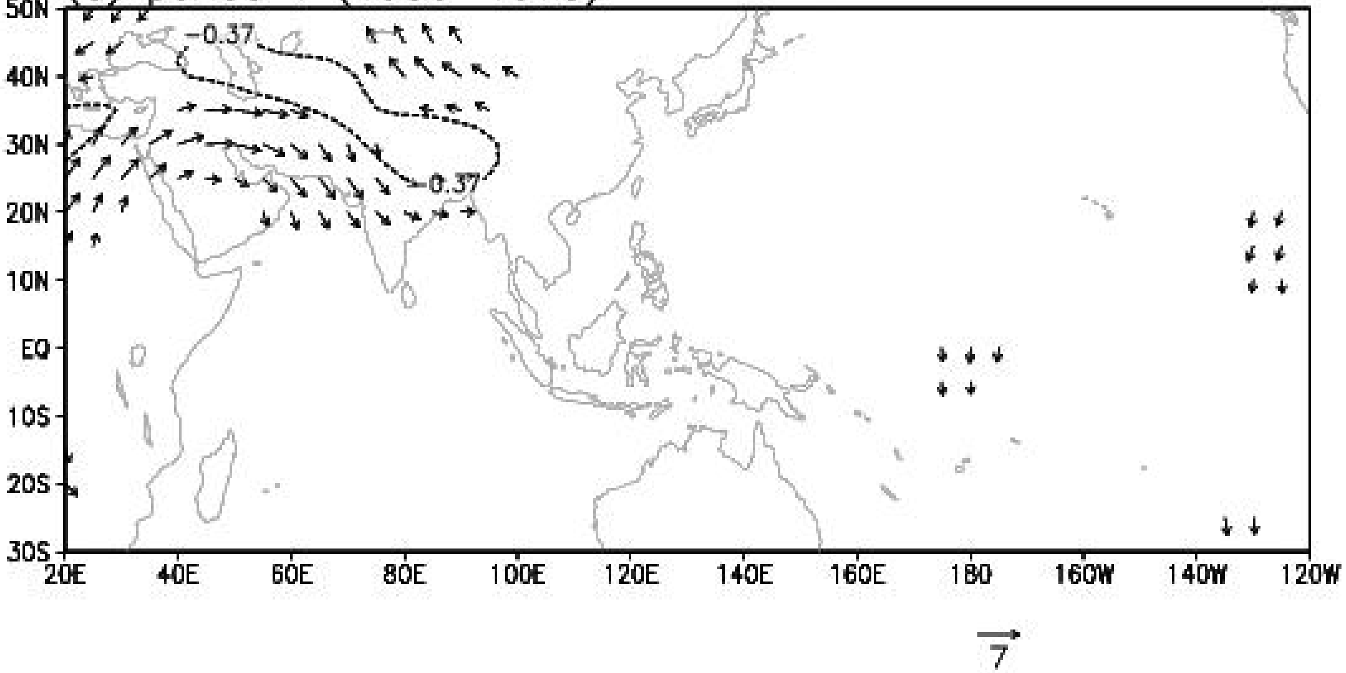


(b) period 2 (1980–2008)

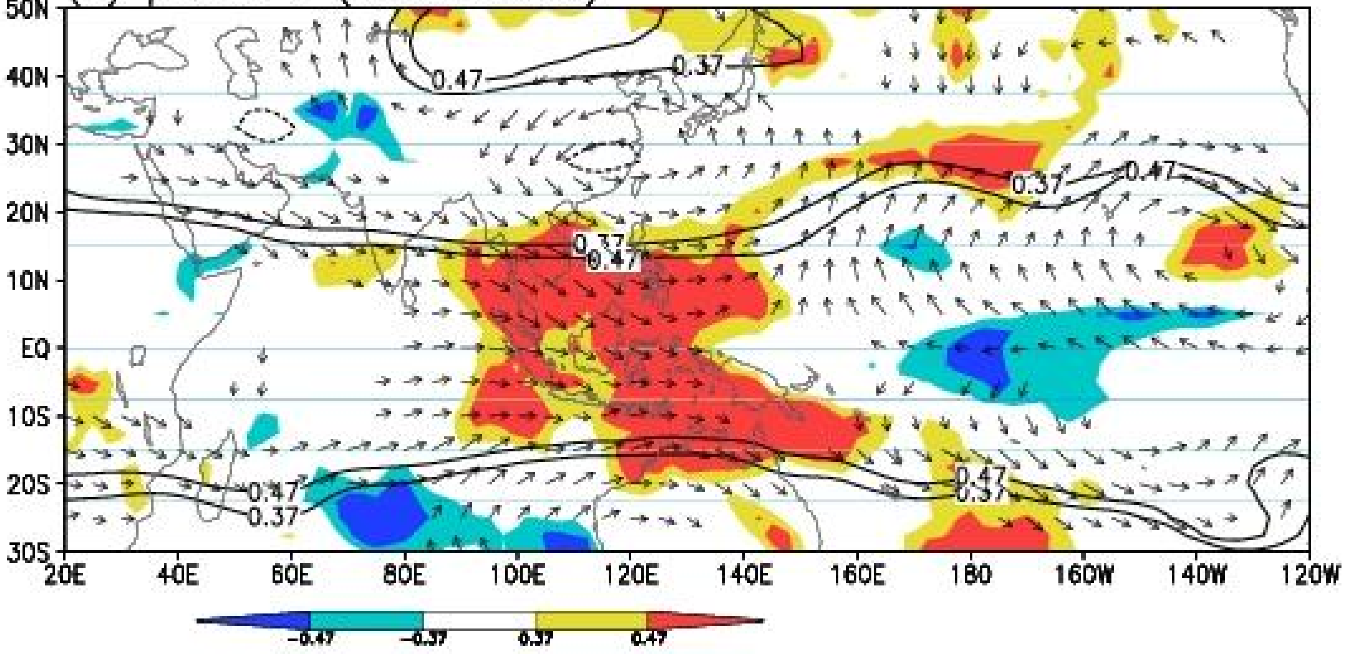


correlation of SST and MSLP and regression of 850-hPa winds with NWIWP during (a) period 1 (1950-1978) and (b) period 2 (1980-2008).

(a) period 1 (1950–1978)

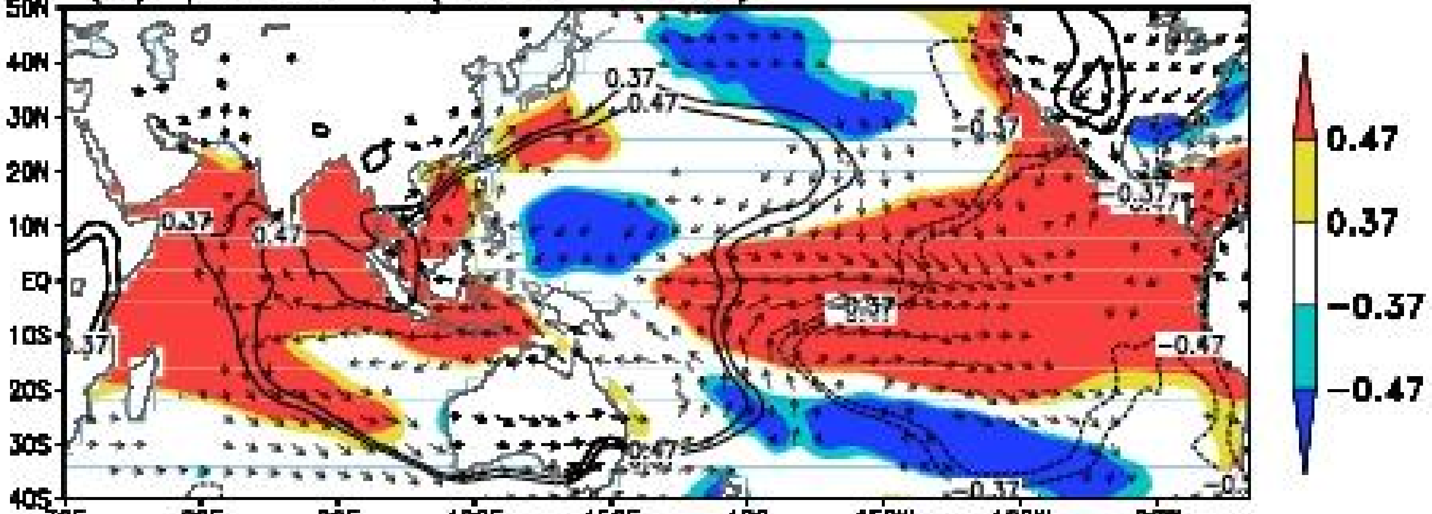


(b) period 2 (1980–2008)

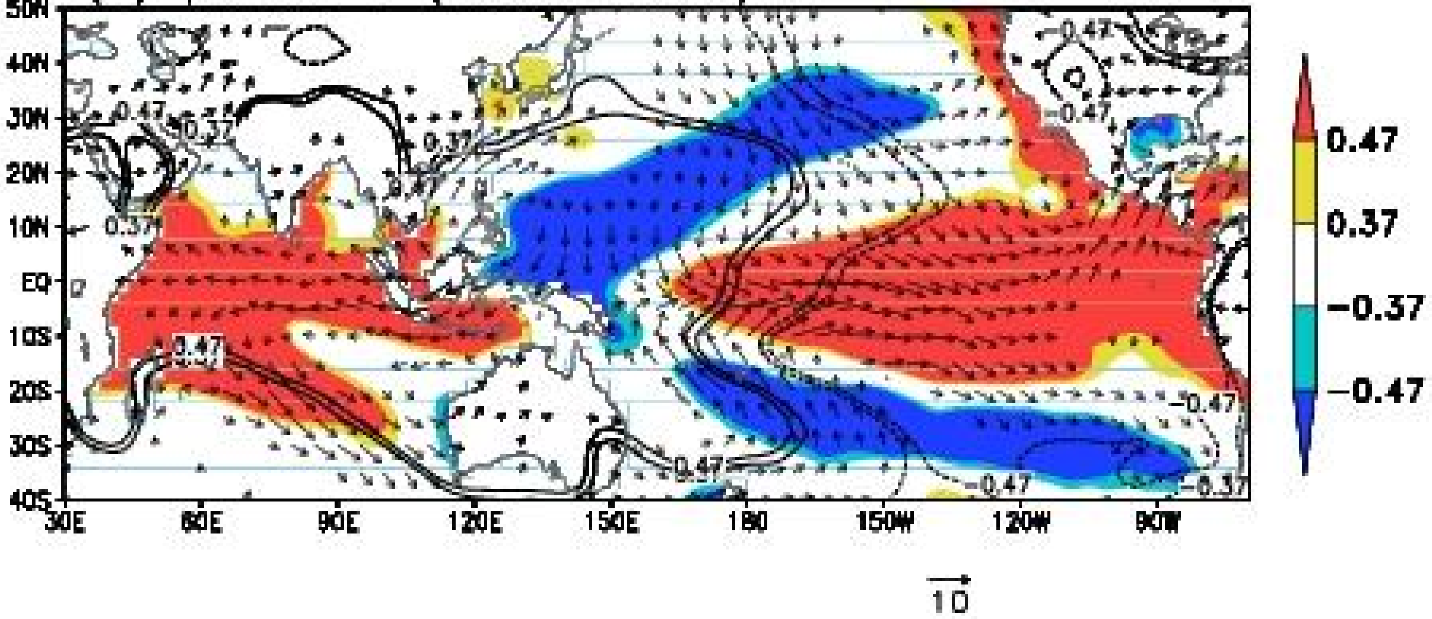


correlation of 200-hPa geopotential and regression of 200-hPa winds with NWIWP during (a) period 1 and additional correlation of OLR during (b) period 2.

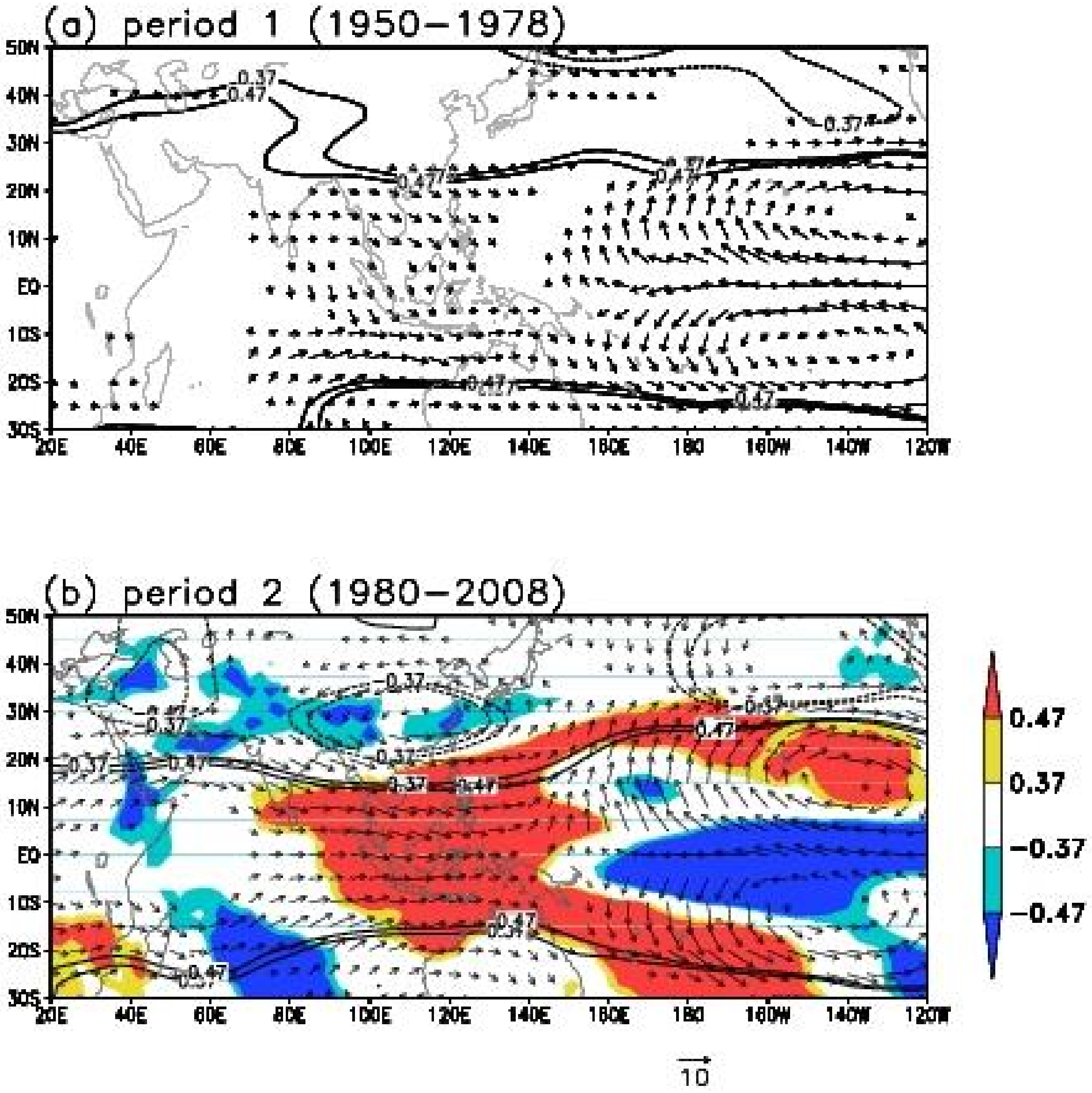
(a) period 1 (1950−1978)



(b) period 2 (1980−2008)



Same for Nino-3.4 indices (SST, MSLP and 850-hPa wind)



Same for Nino-3.4 indices (200-hPa height and wind, and OLR)

Nino-3.4 SST index

	Period 1 (1950-1978)	Period 2 (1980-2008)
MEAN	26.64°C	26.81°C
S.D.	0.80°C	0.99°C

To support the results from the observational data, we use ensembles of Atmospheric General Circulation Model (AGCM) simulations performed for the CLIVAR International “Climate of the 20th Century” (C20C) Project. These integrations cover the period from 1950-2002.

Two sets ensembles are used. The first ensemble (25 members, CNTRL) is forced globally with observed SSTs from the HadISST dataset , in the second ensemble (10 members, EXP1), SST anomalies are prescribed only in the tropical Pacific region (130°E to coast of south and central America, 20°S to 20°N), climatological monthly varying SSTs are used elsewhere. The purpose of EXP1 is to isolate the effects of tropical Pacific SSTs in ENSO events on the large-scale circulation in the Indian Ocean region.

Regression analysis

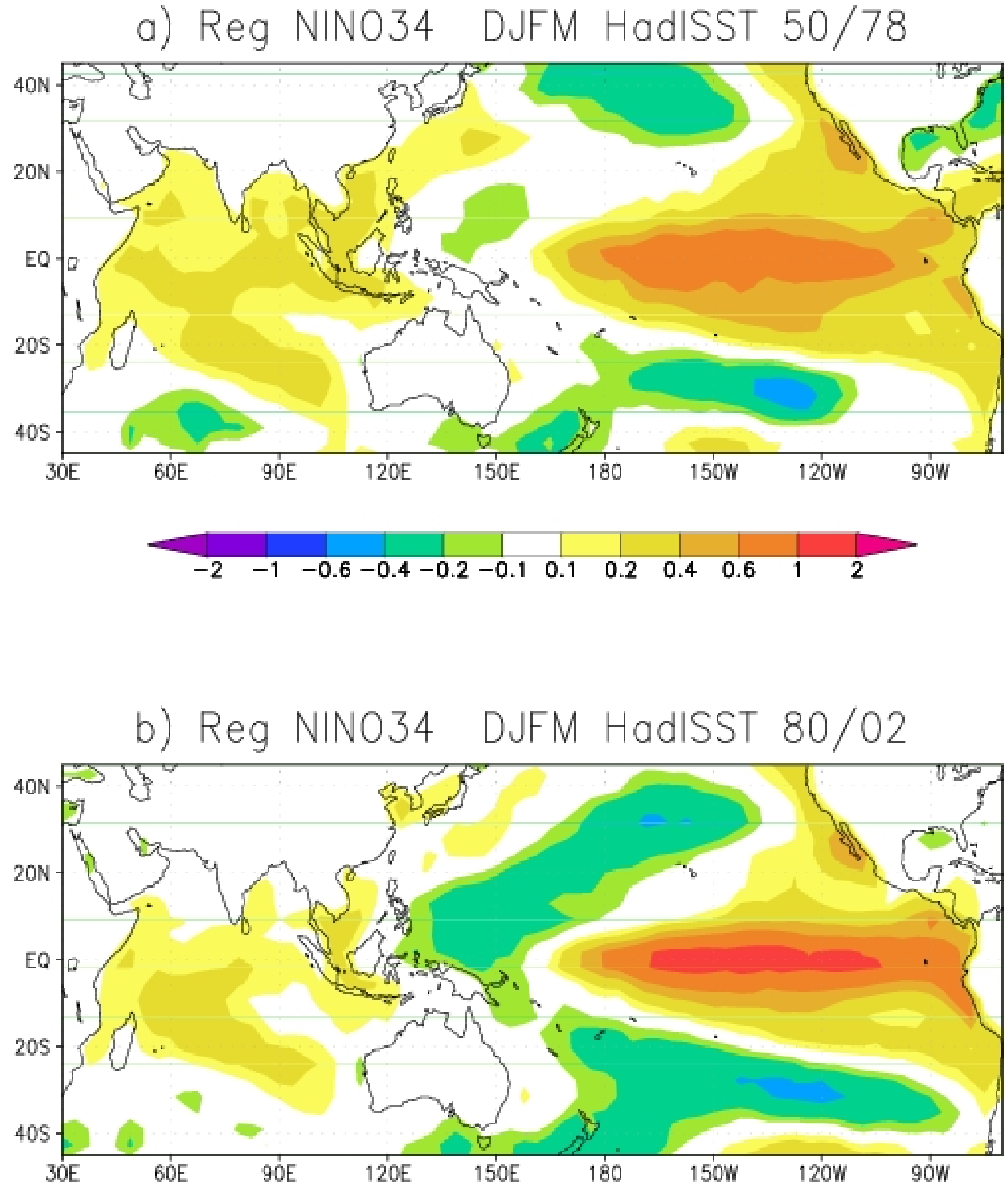
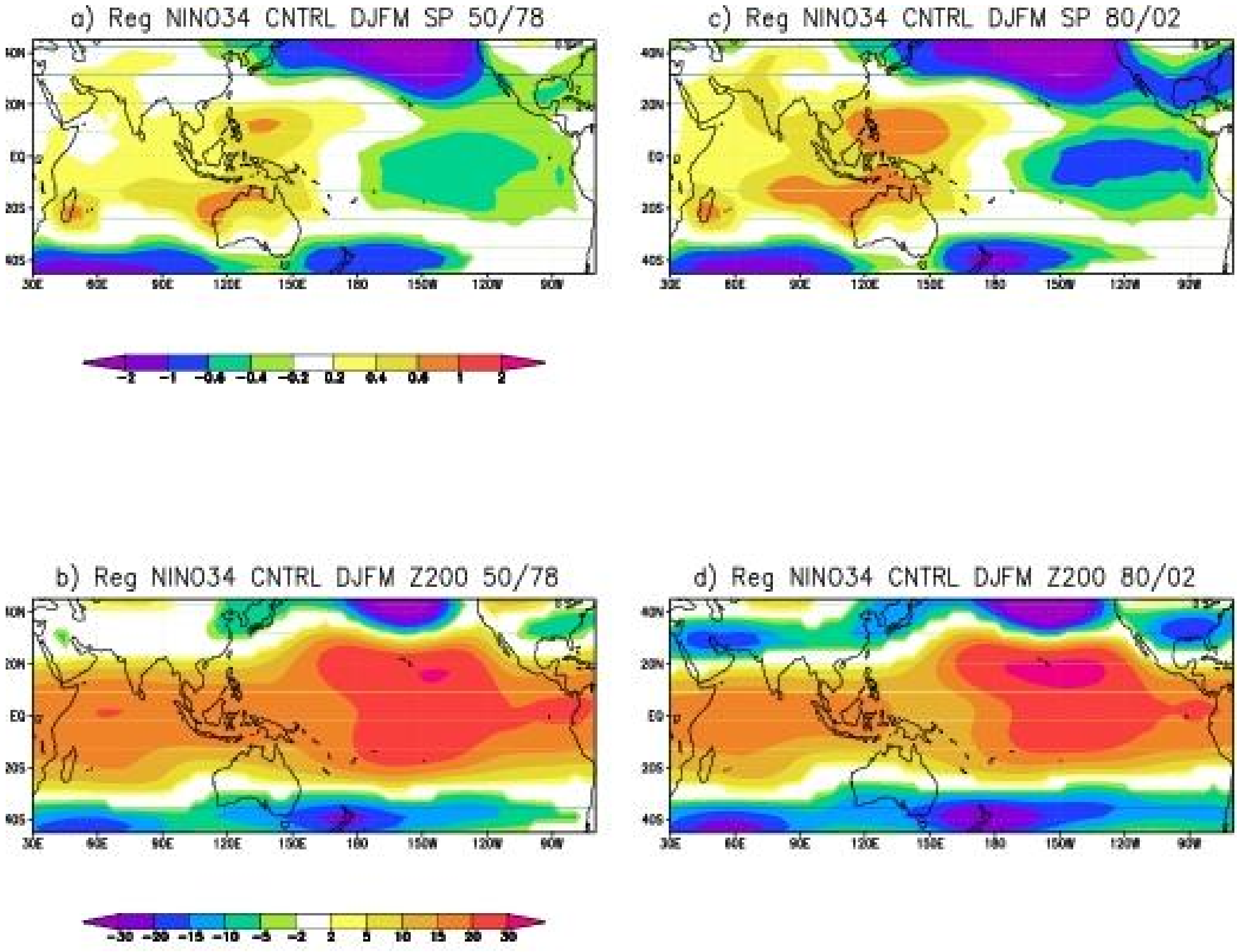


Figure 6: Regression of observed SSTs onto the Nino3.4 index. a) 1950–1978, b) 1980–2002. Units are K.

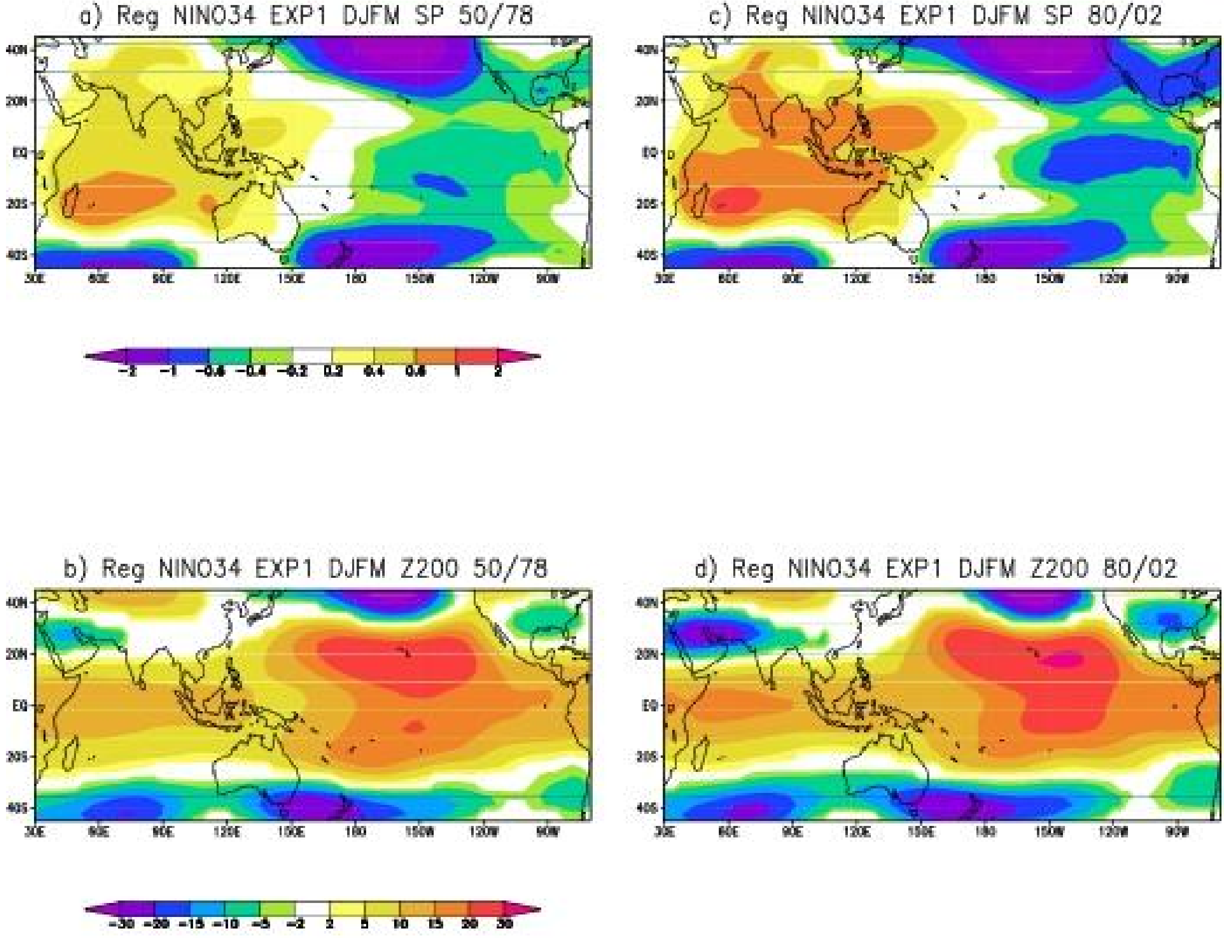
Regression of observed SSTs onto the Nino3.4 index.

a) 1950-1978,

b) 1980-2002.



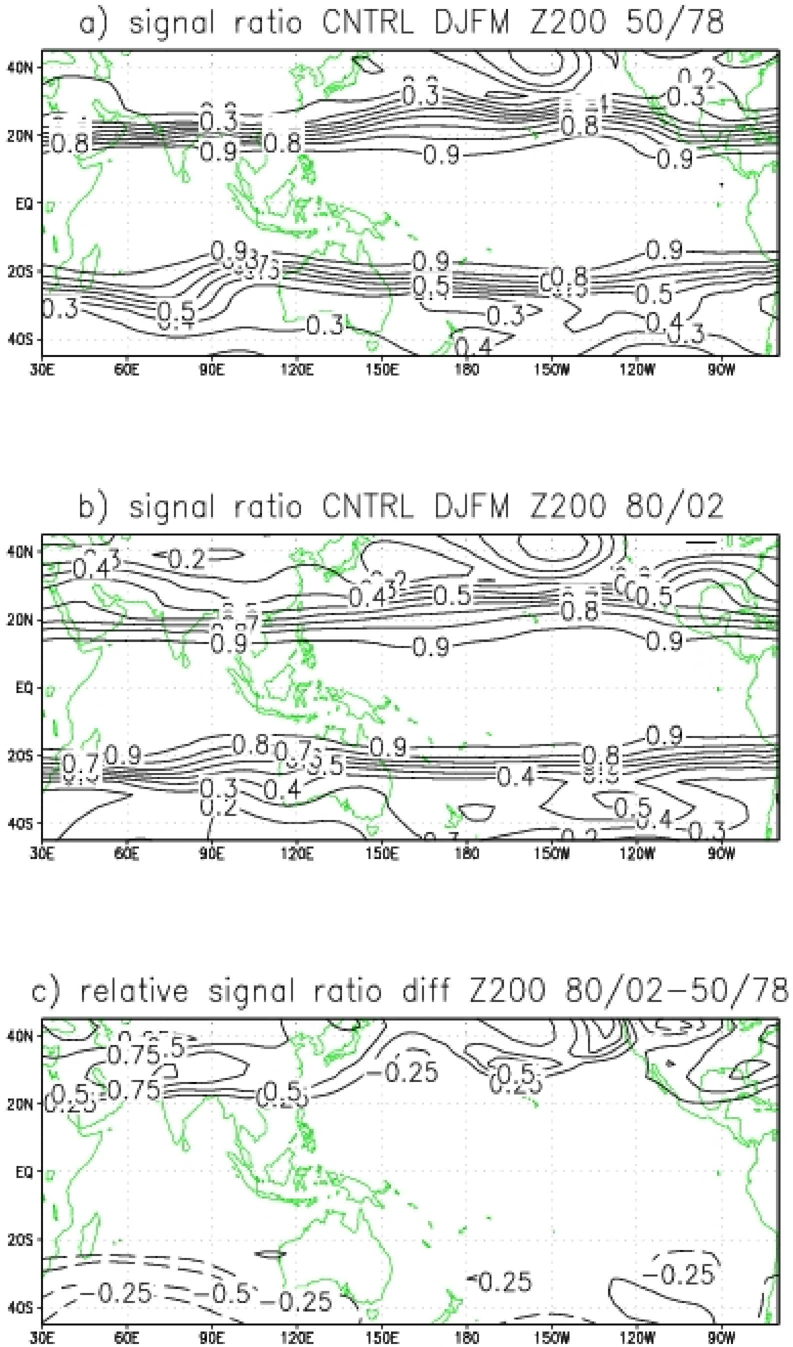
Regression onto the Nino3.4 index of modeled (CNTRL) a) surface pressure 1950-1978, b) 200-hPa geopotential height 1950-1978, c) surface pressure 1980-2002, d) 200-hPa height 1980-2002.



Regression onto the Nino3.4 index of modeled (EXP1) a) surface pressure 1950-1978, b) 200-hPa geopotential height 1950-1978, c) surface pressure 1980-2002, d) 200-hPa height 1980-2002.

Forced signal

we calculated from the 25-member CNTRL ensemble the ratio of the forced variance of the 200-hPa height field to the total variance in the two periods 1950-1978 and 1980-2002.The forced variance is derived from the ensemble mean in which the noise component is filtered out, whereas the total variance is derived from the mean variance of individual ensemble members. In order for a signal to be detectable (and relevant) the ratio-of-variance should be larger than 0.2



a) signal ratio CNTRL DJFM Z200 50/78

b) signal ratio CNTRL DJFM Z200 80/02

c) relative signal ratio diff Z200 80/02–50/78

Figure 9: Ratio of forced variance (derived from the ensemble mean of CNTRL) to total variance a) 1950–1978, b) 1980–2002, c) difference of b) and a) divided by the mean of a) and b).

Ratio of forced variance (derived from the ensemble mean of CNTRL) to total variance a) 1950-1978, b) 1980-2002, c) difference of b) and a) divided by the mean of a) and b).

Sensitivity experiment

To confirm that the mean ENSO SST regression differences in period 1 and period 2 play a role, we performed 3 additional idealized AGCM experiments, each being integrated for 50 years, and the results are analyzed in the DJFM season: A simulation with monthly varying climatological SSTs (CLIM), one with the constant SST anomaly added to the monthly varying climatology (ANOM1), and one with the constant SST anomaly added (ANOM2).

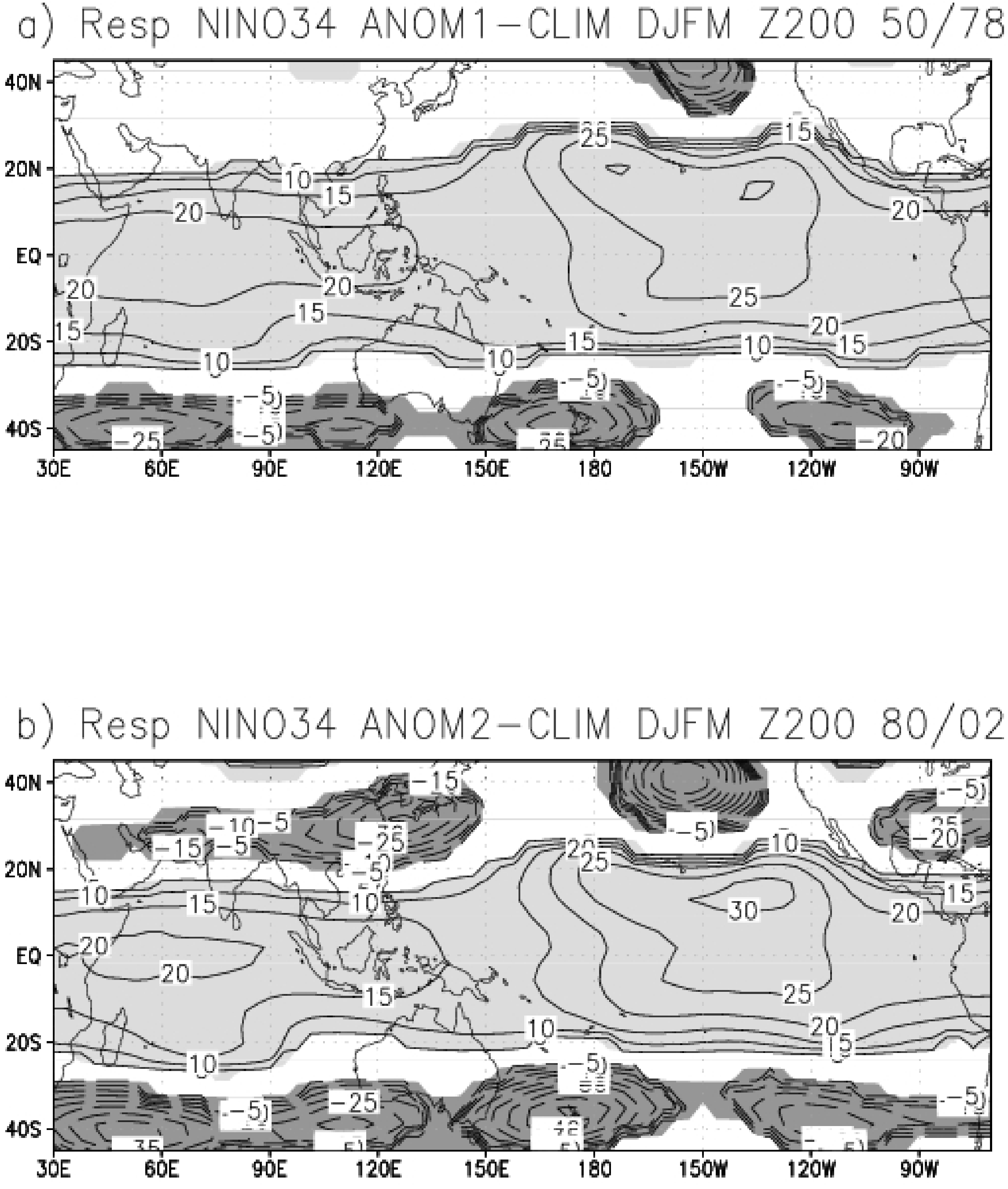
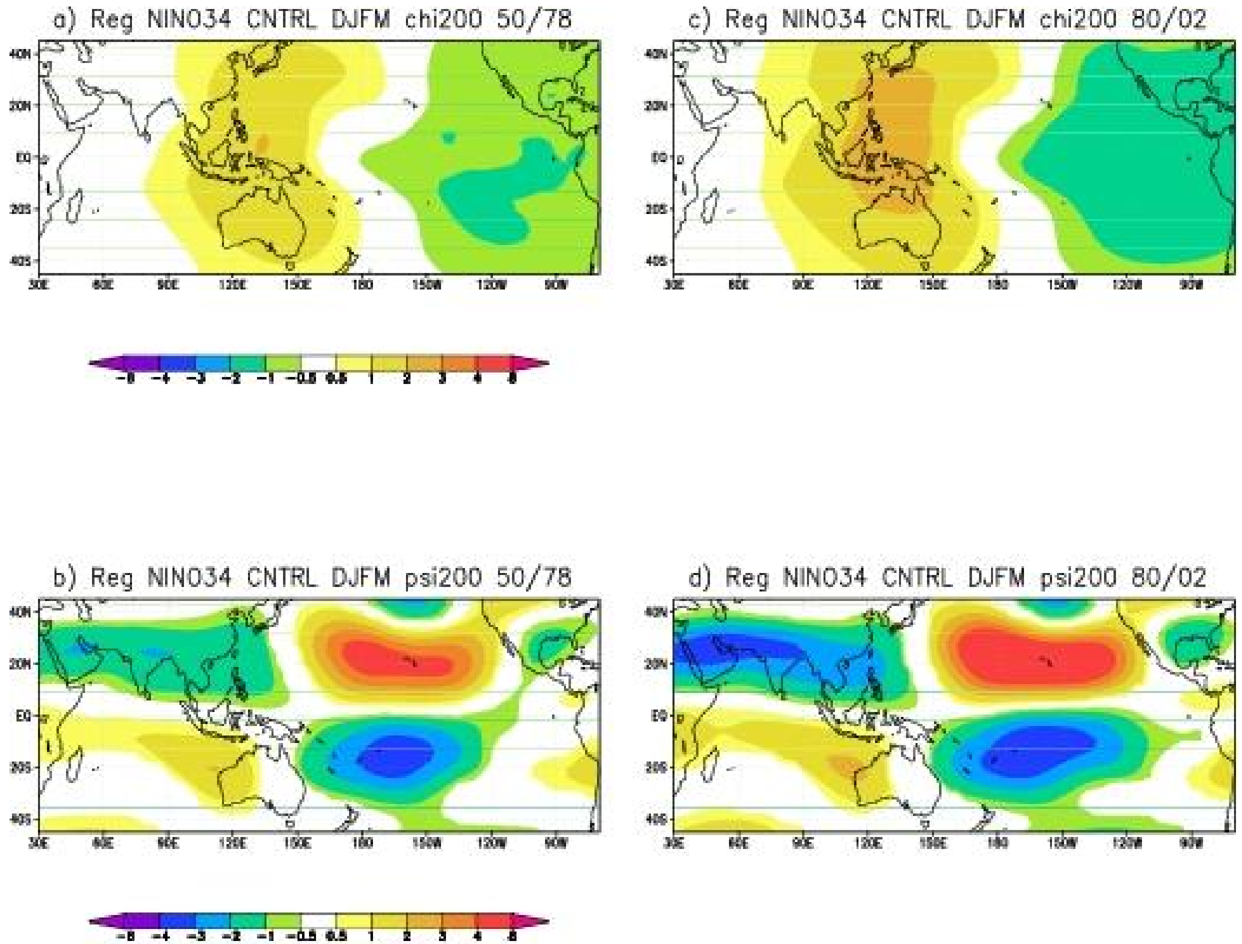


Figure 10: Responses of 200 hPa height to idealized SST forcing of Fig. 6, a) ANOM1–CLIM (period 1), b) ANOM2–CLIM (period 2). Units: m

Response of 200 hPa height (m) to idealized SST forcing of Fig. 6, a) ANOM1-CLIM (period 1), b) ANOM2-CLIM (period 2).

Physical mechanism



Regression onto the Nino3.4 index of modeled (CNTRL) a) 200-hPa velocity potential 1950-1978, b) 200-hPa eddy streamfunction 1950-1978, c) 200 hPa velocity potential 1980-2002, d) 200-hPa streamfunction 1980-2002.

Conclusions

Conclusions

- In the recent decades the ENSO relationship with NWIWP has increased.
- The change of this relationship is likely due to the change in strength of the tropical atmospheric response to ENSO.
- The Walker circulation response has strengthened and has also increased the compensating upper-level convergence and subsidence in the large surrounding regions of the cool SST anomaly in the warm-pool region.

Continue …

- This is generating an increased rotational flow response at about 25°N over East and South Asia via Sverdrup balance. The upper-level cyclonic circulation anomaly near the Caspian Sea intensifies the WDs passing through it and hence the NWIWP.
- The modeling results confirm the findings from the observational analysis. Furthermore, they show that the (ENSO) forced signal over the northwest Indian region has strongly increased in recent decades. Therefore, the ENSO influence may be more detectable in the post-1979 period.

Continue …

- A further sensitivity experiment confirmed that the change of ENSO strength and the corresponding response in the Western Pacific force a substantial part of the changes in the ENSO responses between period 2 and period 1.

Future Scope

- However, a more detailed analysis of the influence of individual ENSO events on the Indian region in the winter season is desirable and will be performed in a future paper. This could be of particular interest also in relation to Climate Change. For example, as a recent paper by Yeh et al. (2009) shows that the ratio of Central Pacific to Eastern Pacific ENSO events may increase in future climate scenarios.

Thank you