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Monthly and seasonal variations in circulation and precipitation simulated by RegCM3 over India

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INDIA

Monthly and seasonal variations in circulation and precipitation simulated by RegCM3 over India

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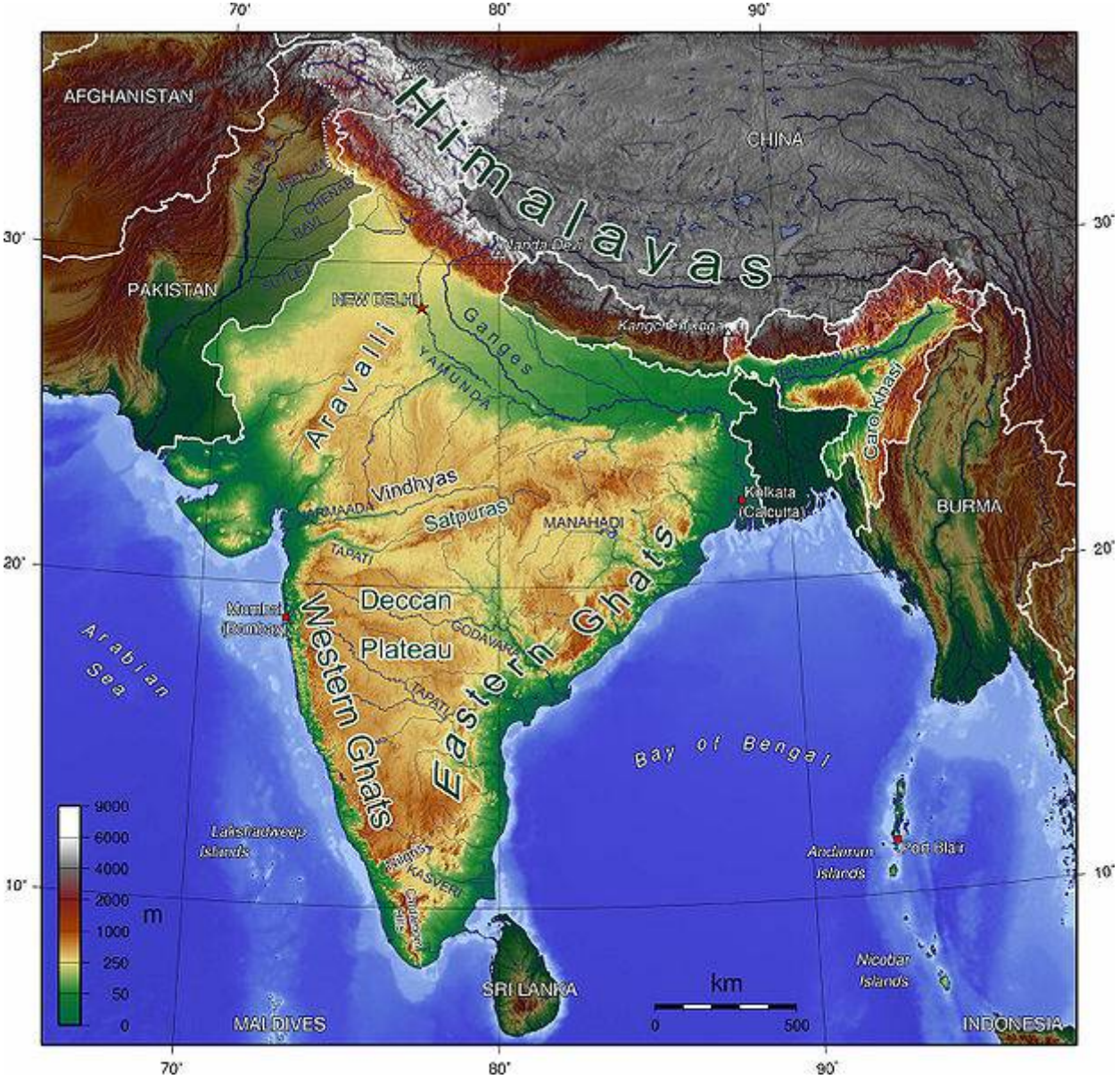
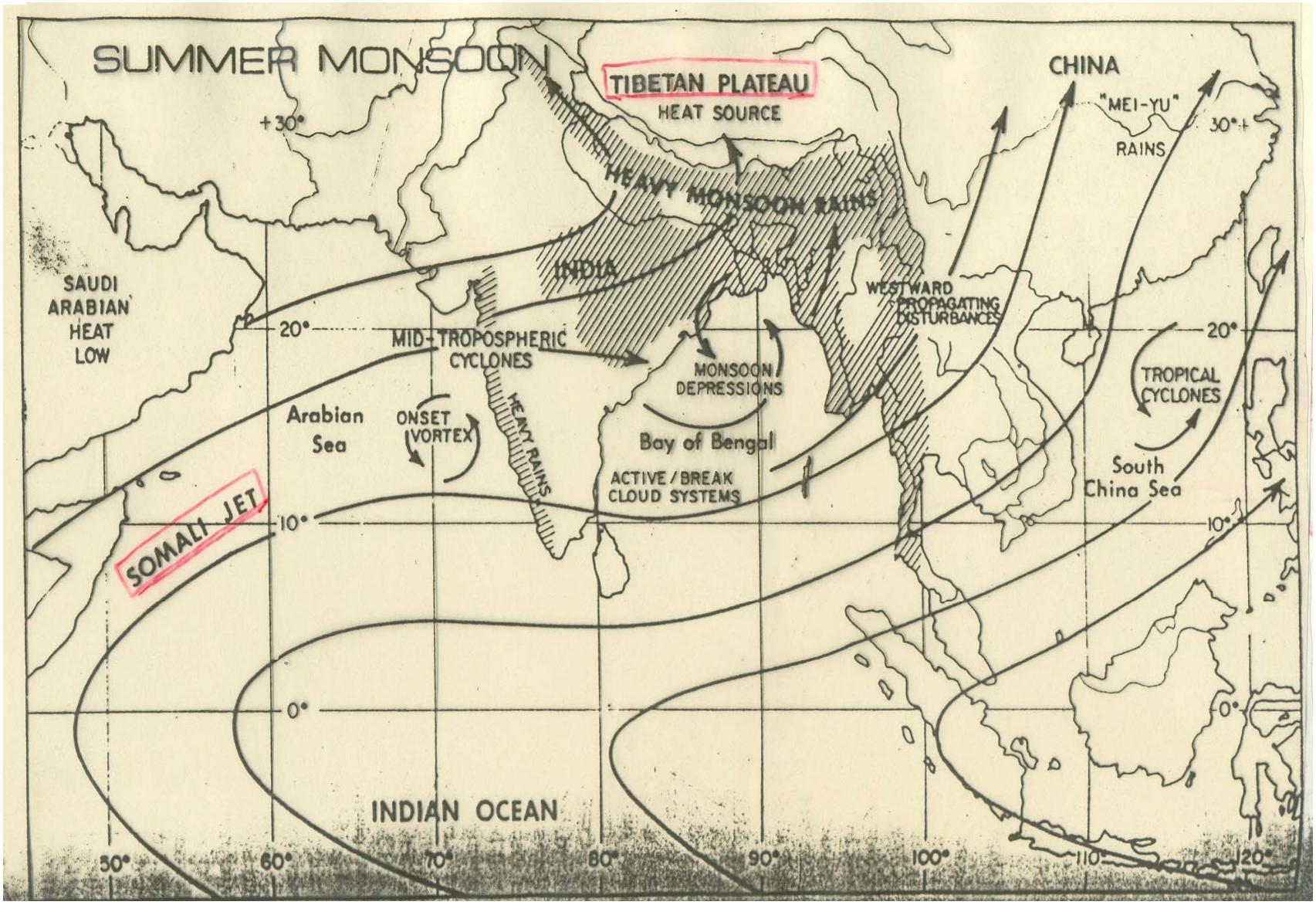
Indian Institute of Technology Delhi
New Delhi – 110 016

Scope of the talk

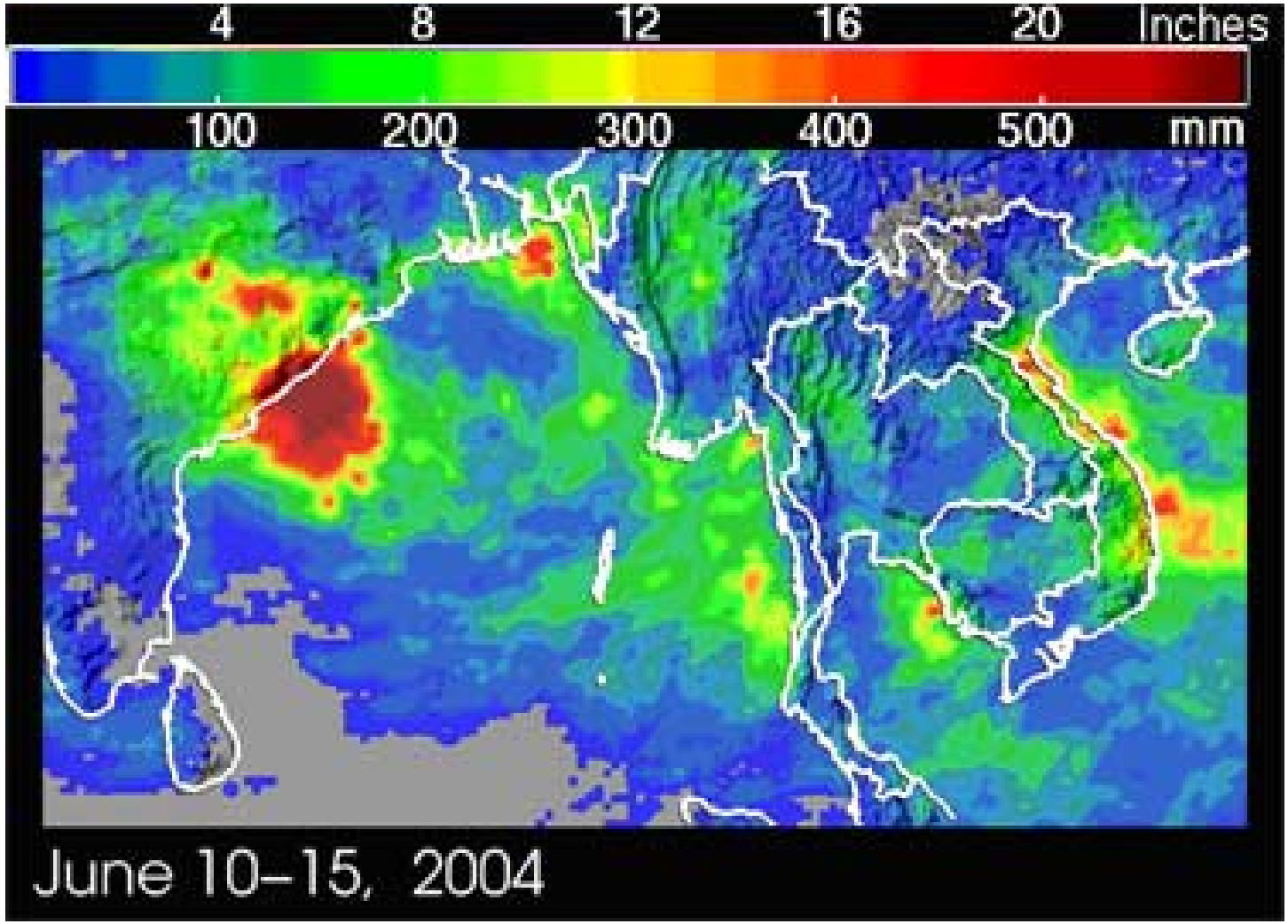
- Salient aspects of summer monsoon
- RegCM3 integrations at IITDelhi
- Monthly and seasonal results
- Biases in annual runs

Topographical map of India

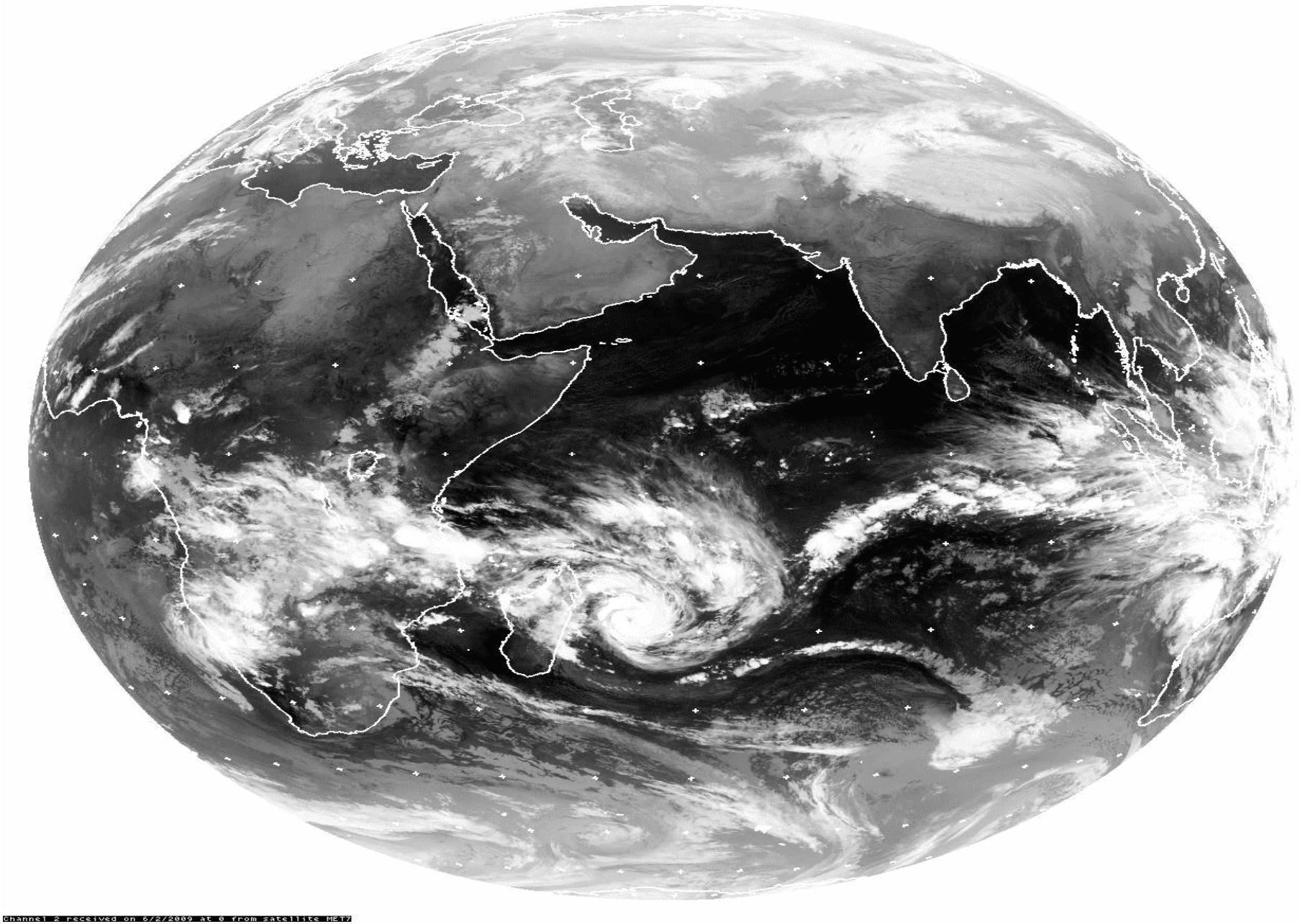



SUMMER MONSOON
TIBETAN PLATEAU
HEAT SOURCE
CHINA
"MEI-YU"
RAINS
30°+
+30°
HEAVY MONSOON RAINS
INDIA
SAUDI
ARABIAN
HEAT
LOW
20°
MID-TROPOSPHERIC
CYCLONES
WESTWARD
PROPAGATING
DISTURBANCES
MONSOON
DEPRESSIONS
TROPICAL
CYCLONES
Arabian
Sea
ONSET
VORTEX
HEAVY RAINS
Bay of Bengal
ACTIVE / BREAK
CLOUD SYSTEMS
South
China Sea
SOMALI JET
10°
0°
INDIAN OCEAN
50°
60°
70°
80°
90°
100°
110°
120°

Monsoon Depression & Rainfall



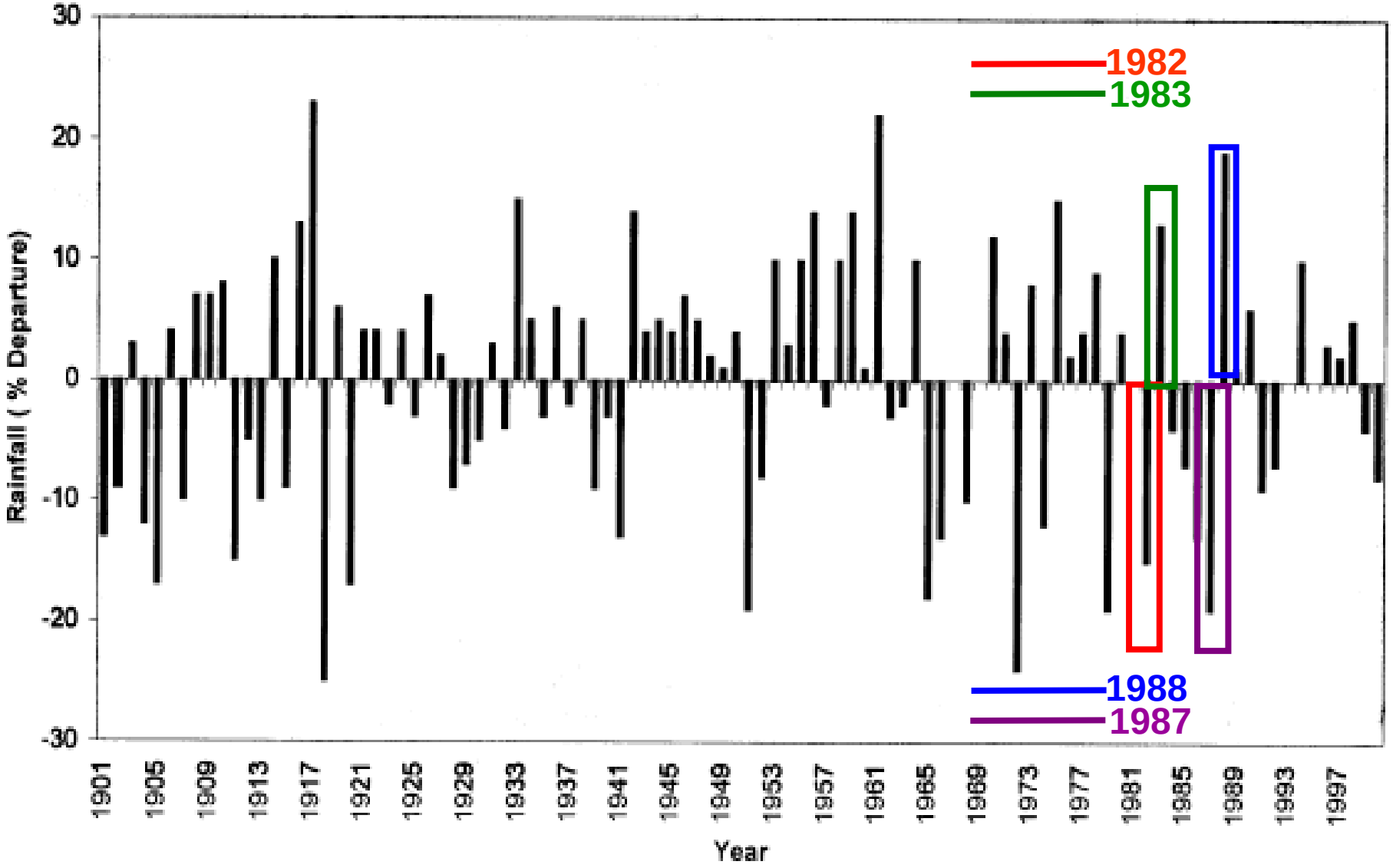
Western Disturbances



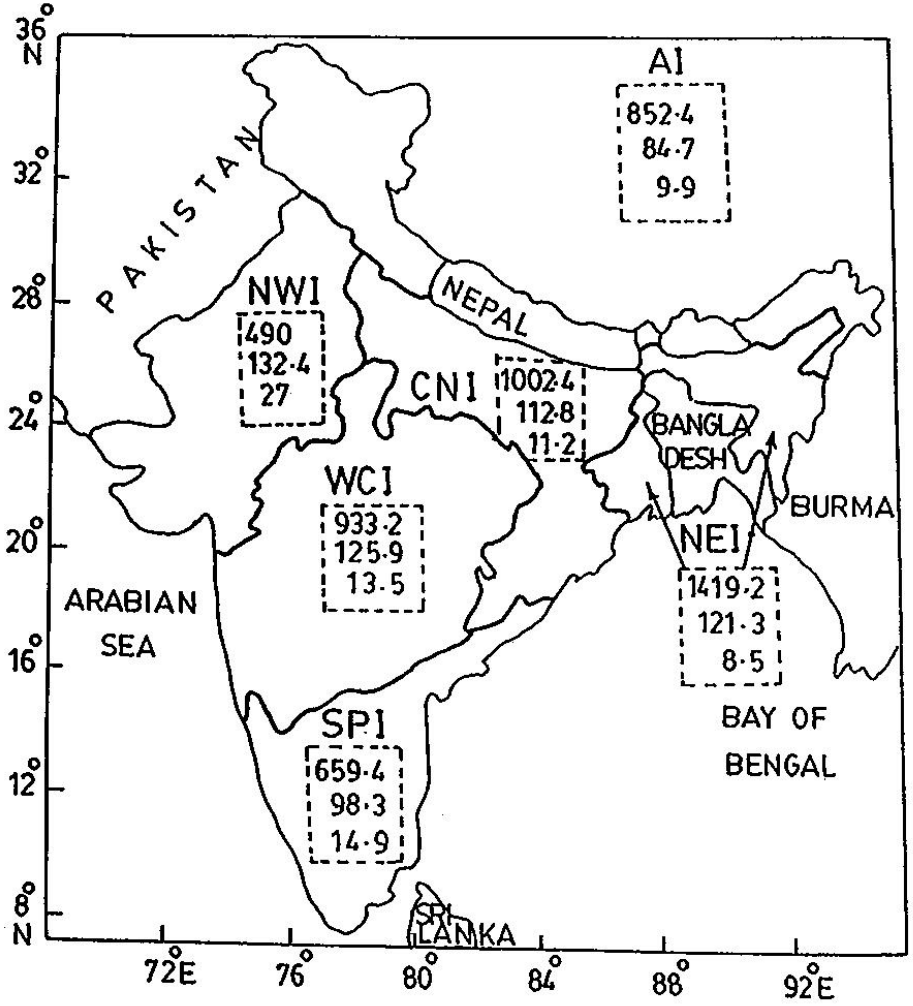
Major issues on Indian summer monsoon rainfall

- JJAS contribute more than 75% of annual rain {water, agriculture & power}
- Seasonal mean rain 86cm {+1 or -1 SD crucial for the economy: Hence policy}
- Major failure of rain in any monsoon month (mostly July) can disturb the whole situation
- Long breaks and active phases can change the sign of SD

Inter-annual variation of JJAS rainfall



Source: Rajeevan, Current Science, Vol. 81, No. 11, 10 December 2001



Five homogeneous zones of India. The numbers inside the zones indicate mean monsoon rainfall (mm), standard deviation (mm) and coefficient of variation (%) from top to bottom respectively

Dash et al., 2002, Mausam, 53(2), 133-144

Time scales of useful monsoon forecasts

- Seasonal for whole country: financial budget
- Seasonal for at least 5 homogeneous regions: agriculture, power, insurance
- Monthly regional: agriculture and power
- Medium range local (10days): agriculture
- Short range local: flood management, general public

Note: No dynamical model gives reasonably good monthly and seasonal forecasts and hence the use of statistical models by IMD.

RegCM3 integrations at IITD

From April to end of September:

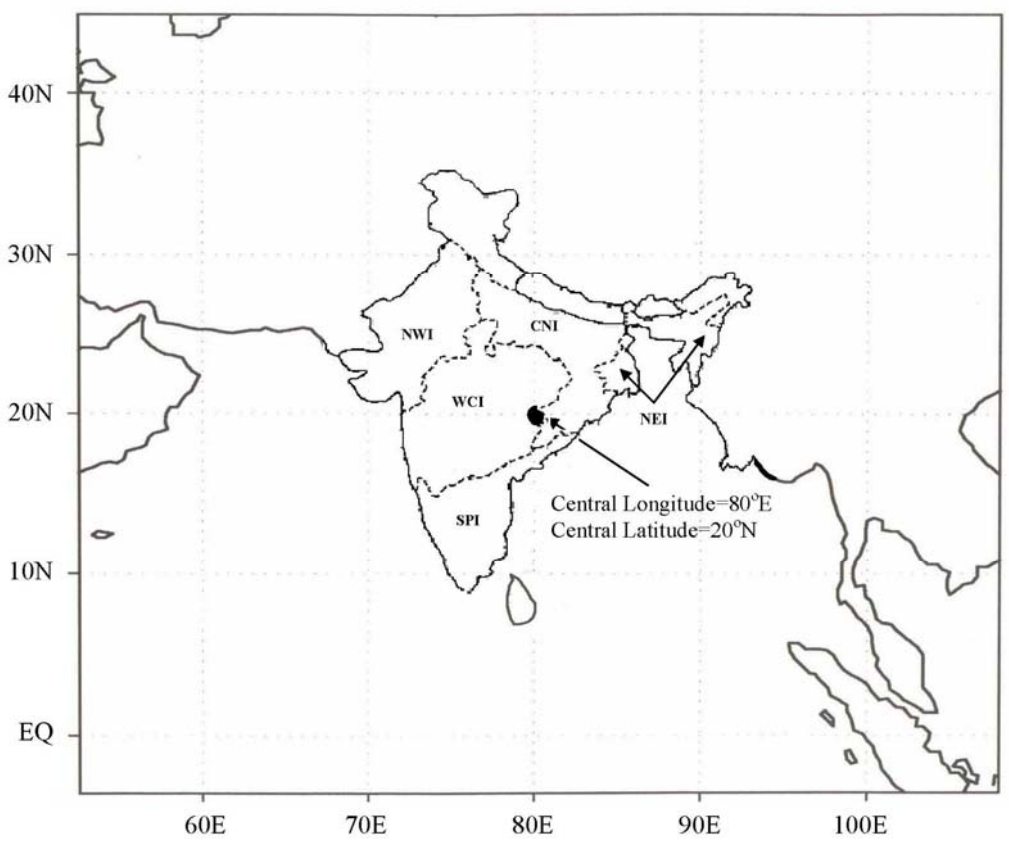
- Four monsoon seasons (1993-1996)
- Contrasting monsoons (1982-1983)
- 27 monsoon seasons (1982-2008)

From 1 Jan to 31 Dec:

- Annual runs for 21yrs (1980-2000)

Continuously:

- CORDEX experiments (in progress)



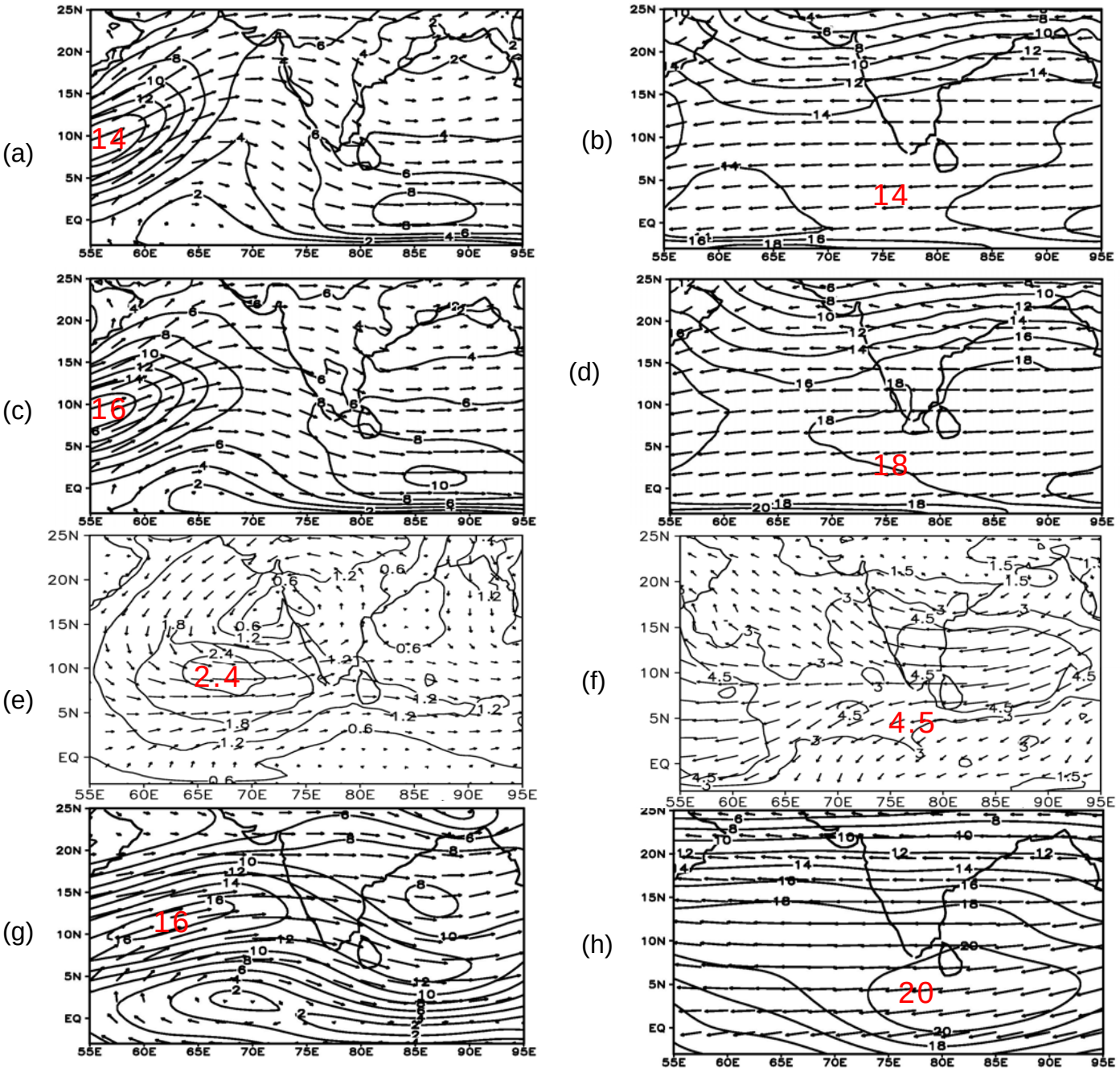
Model domain used in RegCM3 and the five homogeneous zones of India such as North West India (NWI), West Central India (WCI), Central Northeast India (CNI), North East India (NEI) and South Peninsular India (SPI) (Parthasarathy et al., 1995)

Central Lat and Lon-20°N,80°E

101 X 115 Points along XY

Domain covers 55°E to 105°E and 5°S to 45°N with 55km resolution

Dash et al., 2006, *Theor. Appl. Climatol*, special issue, 1-12.

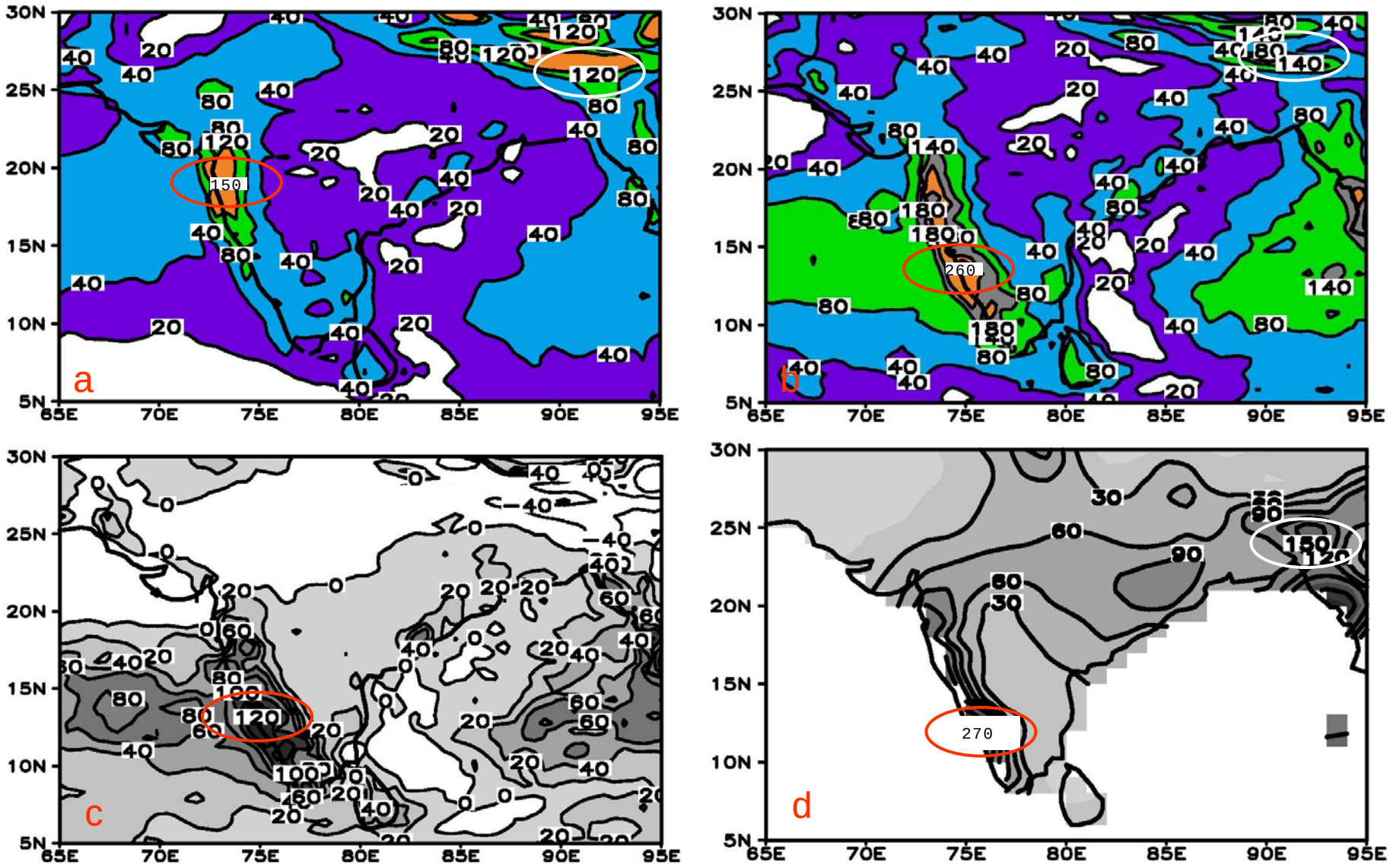


JJAS average wind (m/s). The left and right panels refer to levels 850hPa and 200hPa respectively. (a) and (b) are winds with Kuo scheme whereas (c) and (d) are those with Grell scheme. (e) and (f) are wind differences (Grell-Kuo) and (g) and (h) are NCEP/ NCAR reanalyzed winds

The characteristics of the lower and upper level monsoon winds simulated with the Kuo scheme are weaker than the Grell scheme.

The values of wind at 850hPa and 200hPa with Grell scheme are close to that of NCEP/NCAR Reanalysis.

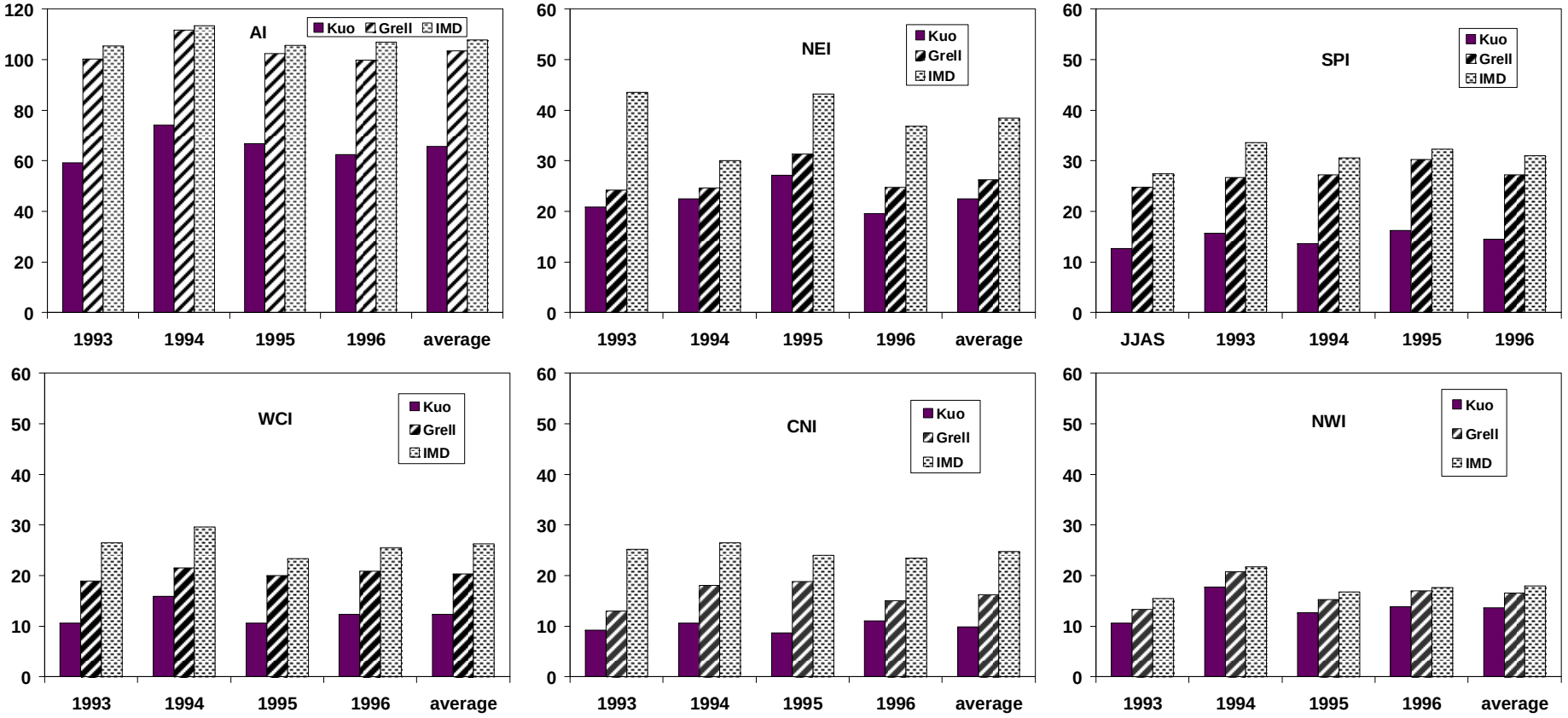
Dash et al., 2006, *Theor. Appl. Climatol*, special issue, 1-12.



JJAS average accumulated rainfall (cm) for (a) Kuo, (b) Grell, (c) Grell – Kuo and (d) GPCC rainfall

Dash et al., 2006, *Theor. Appl. Climatol*, special issue, 1-12.

Comparison of JJAS mean rainfall (cm) over All-India and its five homogeneous zones simulated by RegCM3 in Kuo and Grell convection schemes with IMD observed rainfall



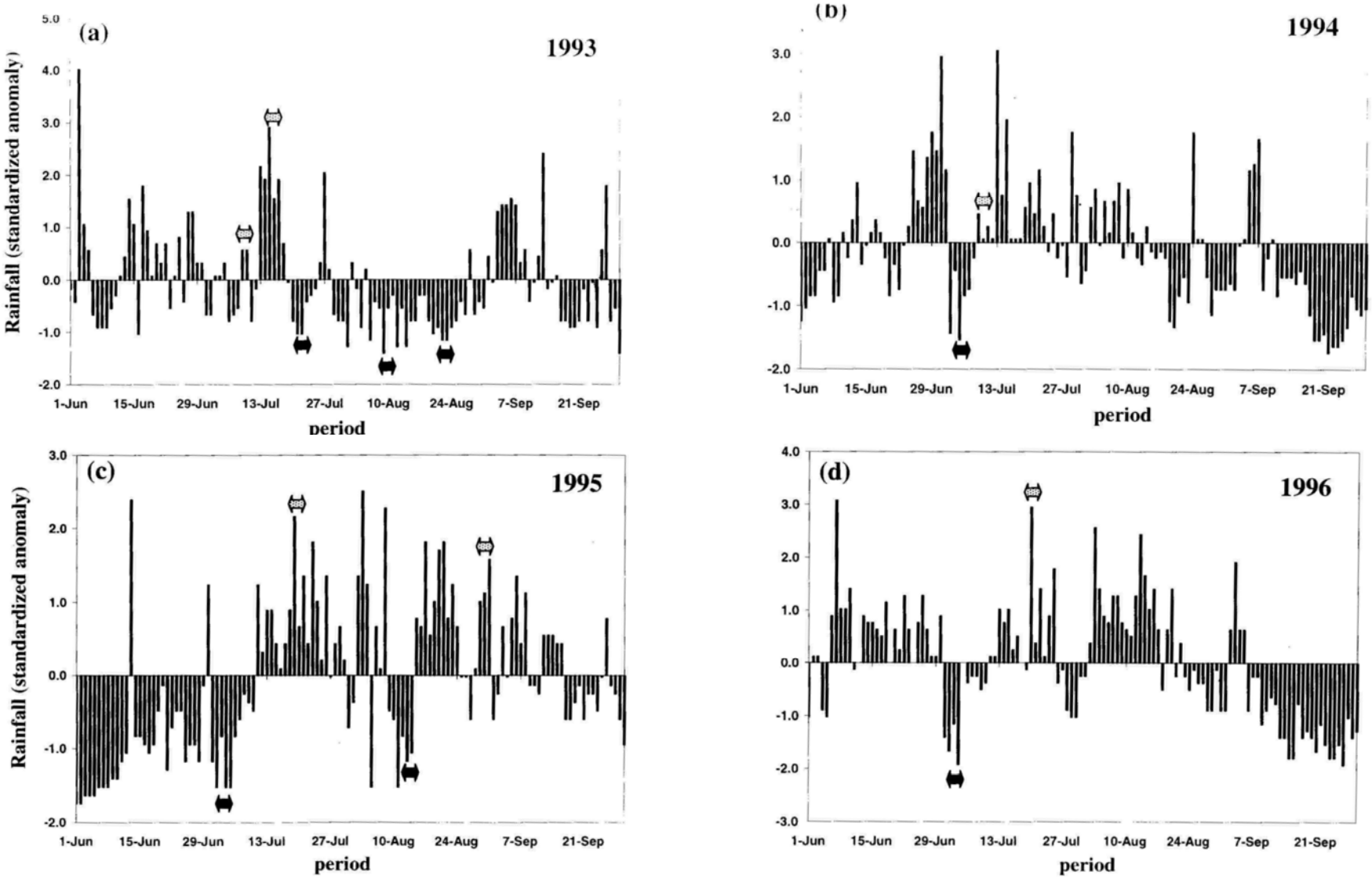
Good agreement between RegCM3 and IMD rainfall for AI, NWI, WCI and SPI in all four years.

Precipitation is underestimated over CNI and NEI.

Grell scheme simulates more rainfall than Kuo scheme for all four years for AI and its five homogeneous zones.

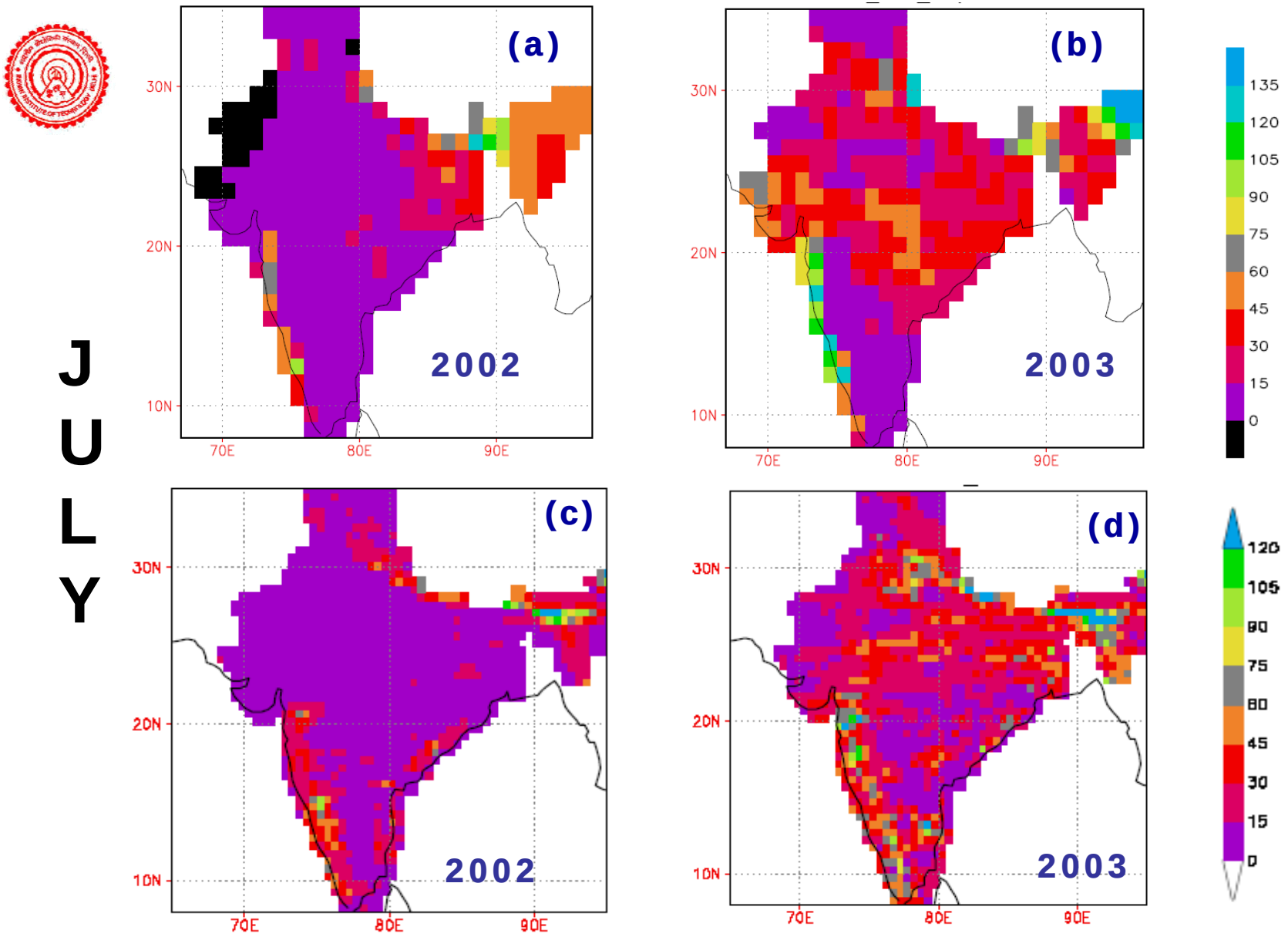
Precipitation with Grell scheme is more realistic than Kuo scheme.

Dash et al., 2006, *Theor. Appl. Climatol*, special issue, 1-12.

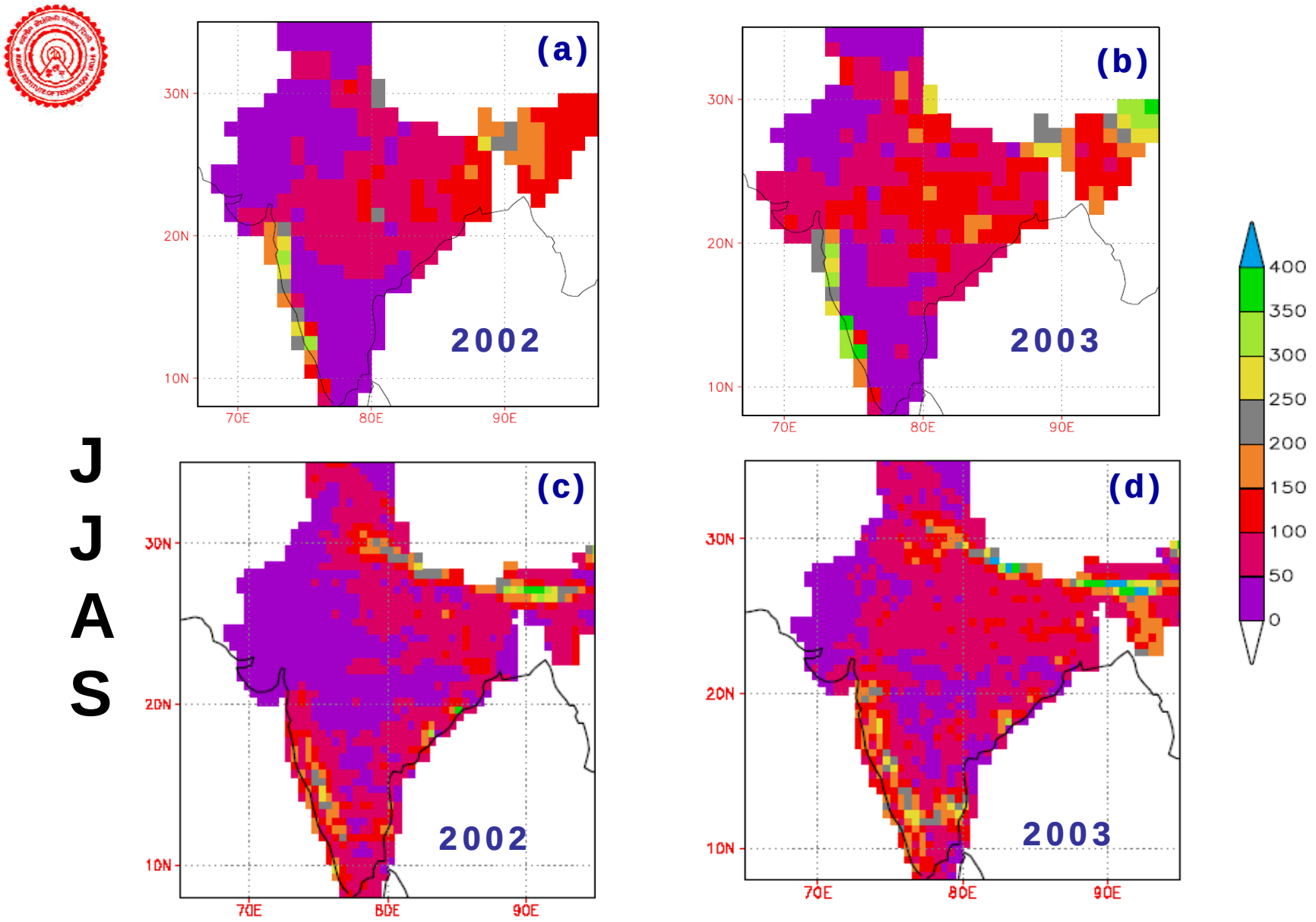


Standardized anomaly of daily rainfall over India in JJAS as simulated by RegCM3 for the years 1993-1996. The solid and shaded arrows below and above the vertical bars represent the days of break and active monsoon phases respectively as defined by IMD.

Dash et al., 2006, *Theor. Appl. Climatol*, special issue, 1-12.



Gridded Rainfall (cm) in the month of July observed by IMD in (a) 2002 and (b) 2003; simulated by RegCM3 in (c) 2002 and (d) 2003



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Gridded Rainfall (cm) for JJAS observed by IMD in (a) 2002 and (b) 2003; simulated by RegCM3 in (c) 2002 and (d) 2003.

Comparison of rainfall simulated by IITD Spectral GCM, RegCM3 and measured by IMD in 2002 and 2003

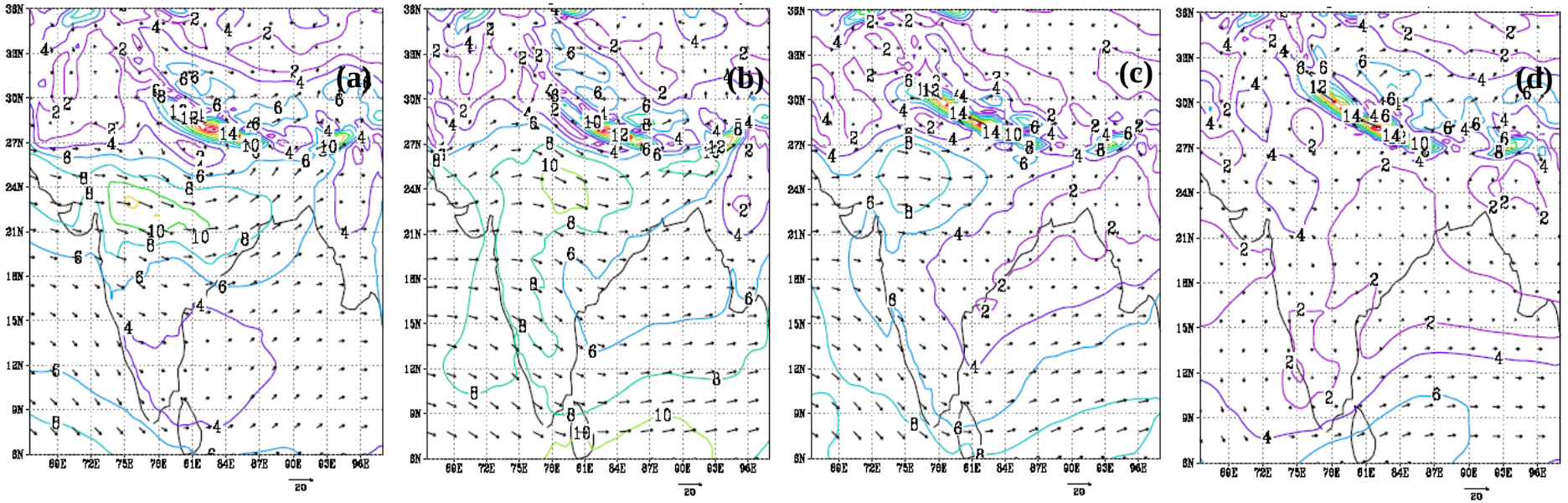
Years	2002				2003			
Source	*IMD*		*RegCM*	*T80*	*IMD*		*RegCM*	*T80*
Months	***% of normal***	***Gridded (cm)***	***Gridded (cm)***	***Gridded (cm)***	***% of normal***	***Gridded (cm)***	***Gridded (cm)***	***Gridded (cm)***
June	104	16.2	15.9	16.8	109	16.9	19.1	15.9
July	46.5	14.2	13.9	15.4	107	31.4	30.2	*39.0*
August	96	24.8	23.1	25.0	95	24.6	23.0	23.0
September	90	15.4	16.1	16.8	96	16.5	16.1	12.5
JJAS	81	70.6	69.0	74.0	102	89.4	88.4	90.4

Comparison of RegCM3 (30km) simulated rainfall with observed rainfall of IMD for year 2002

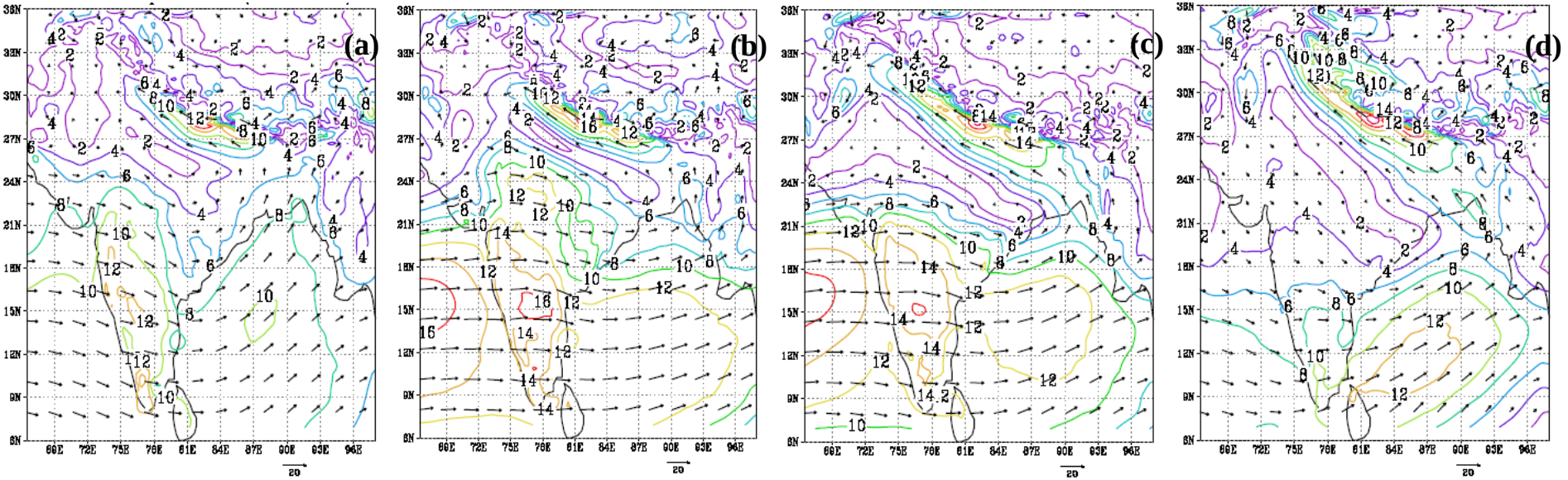
Member	June	July	August	September	JJAS
Member-1	17.00	14.83	24.32	15.84	70.99
Member-2	15.52	14.80	24.37	15.86	70.55
Member-3	15.46	14.80	24.13	15.70	70.09
AVERAGE	**15.99**	**14.81**	**24.28**	**15.80**	**70.88**
IMD	**16.2**	**14.2**	**24.8**	**15.4**	**70.6**

Comparison of RegCM3 (30km) simulated rainfall with observed rainfall of IMD for year 2003

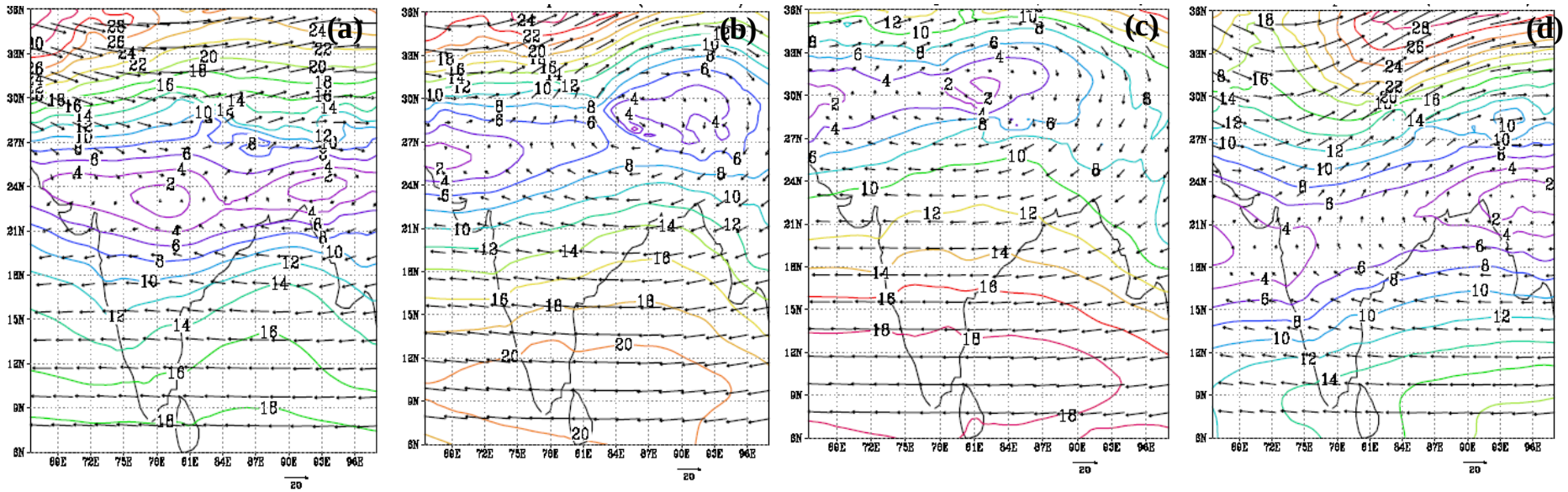
Member	June	July	August	September	JJAS
Member-1	19.00	30.94	24.52	16.98	91.44
Member-2	18.91	30.97	24.71	16.90	91.49
Member-3	18.74	30.89	24.44	16.71	90.78
AVERAGE	**18.89**	**30.93**	**24.56**	**16.87**	**91.25**
IMD	**16.9**	**31.4**	**24.6**	**16.5**	**89.4**



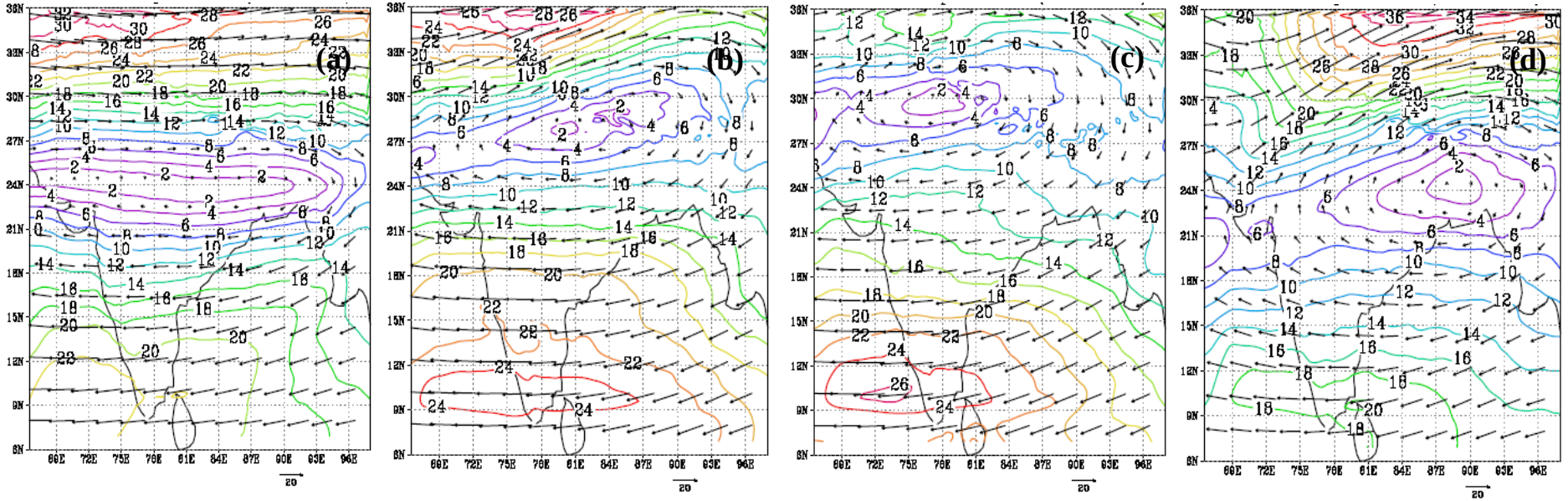
Monthly mean winds of RegCM3 (55Km) for 2002 at 850hPa June, July, Aug & Sep



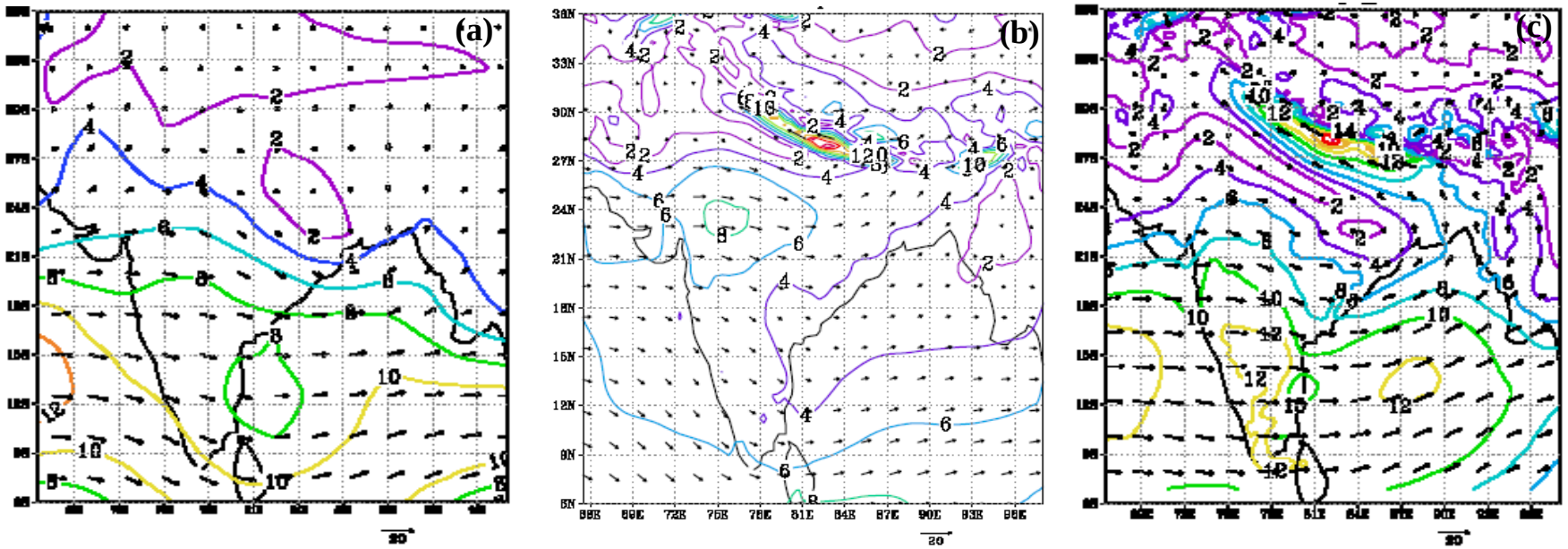
Monthly mean winds of RegCM3 (30Km) for 2002 at 850hPa June, July, Aug & Sep



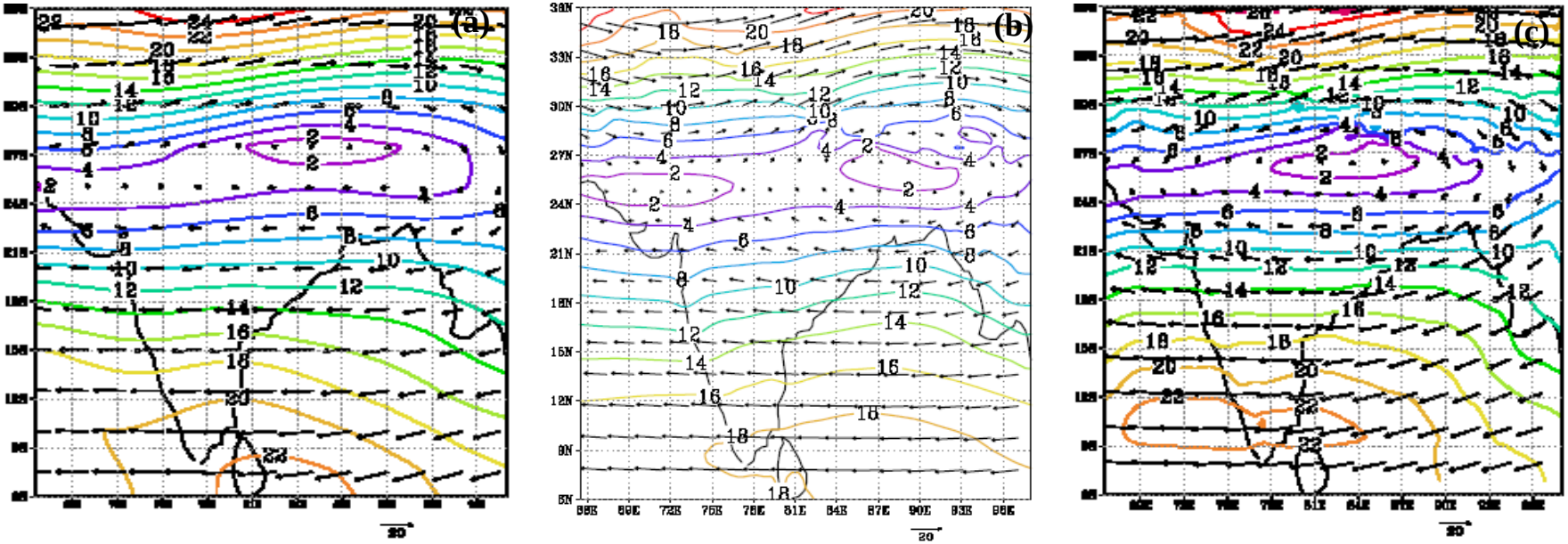
Monthly mean winds of RegCM3 (55Km) for 2002 at 200hPa June , July, August & September



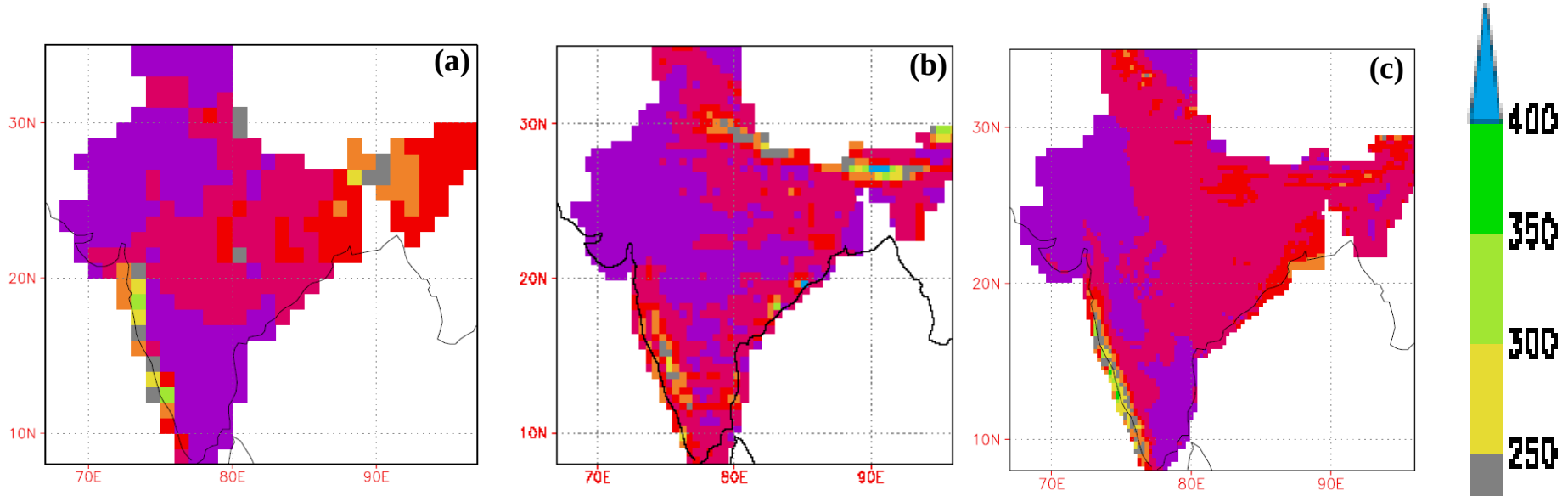
Monthly mean winds of RegCM3 (30Km) for 2002 at 200hPa June , July, August & September



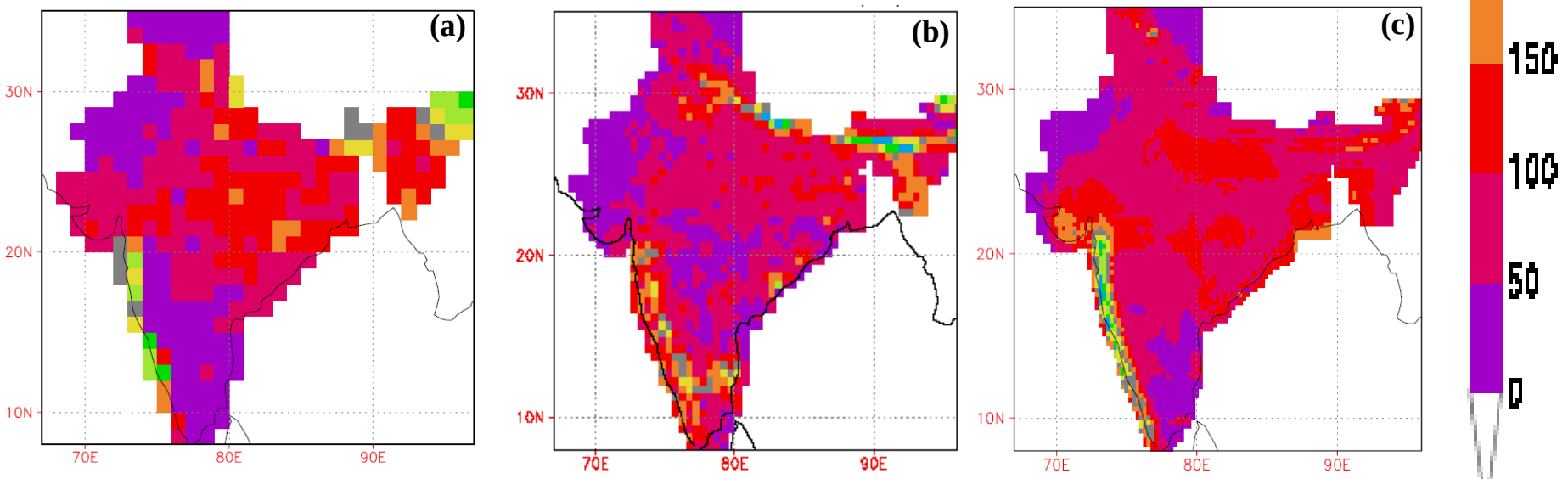
JJAS winds for **2002 at 850hPa** (a) NCEP/NCAR (b) RegCM3 (55Km) (c) RegCM3 (30Km)



JJAS winds for **2002 at 200hPa** (a) NCEP/NCAR (b) RegCM3 (55Km) (c) RegCM3 (30Km)



JJAS rainfall for 2002 (a) IMD (110Km) (b) RegCM3 (55Km) (c) RegCM3 (30Km)



JJAS rainfall for 2003 (a) IMD (110Km) (b) RegCM3 (55Km) (c) RegCM3 (30Km)

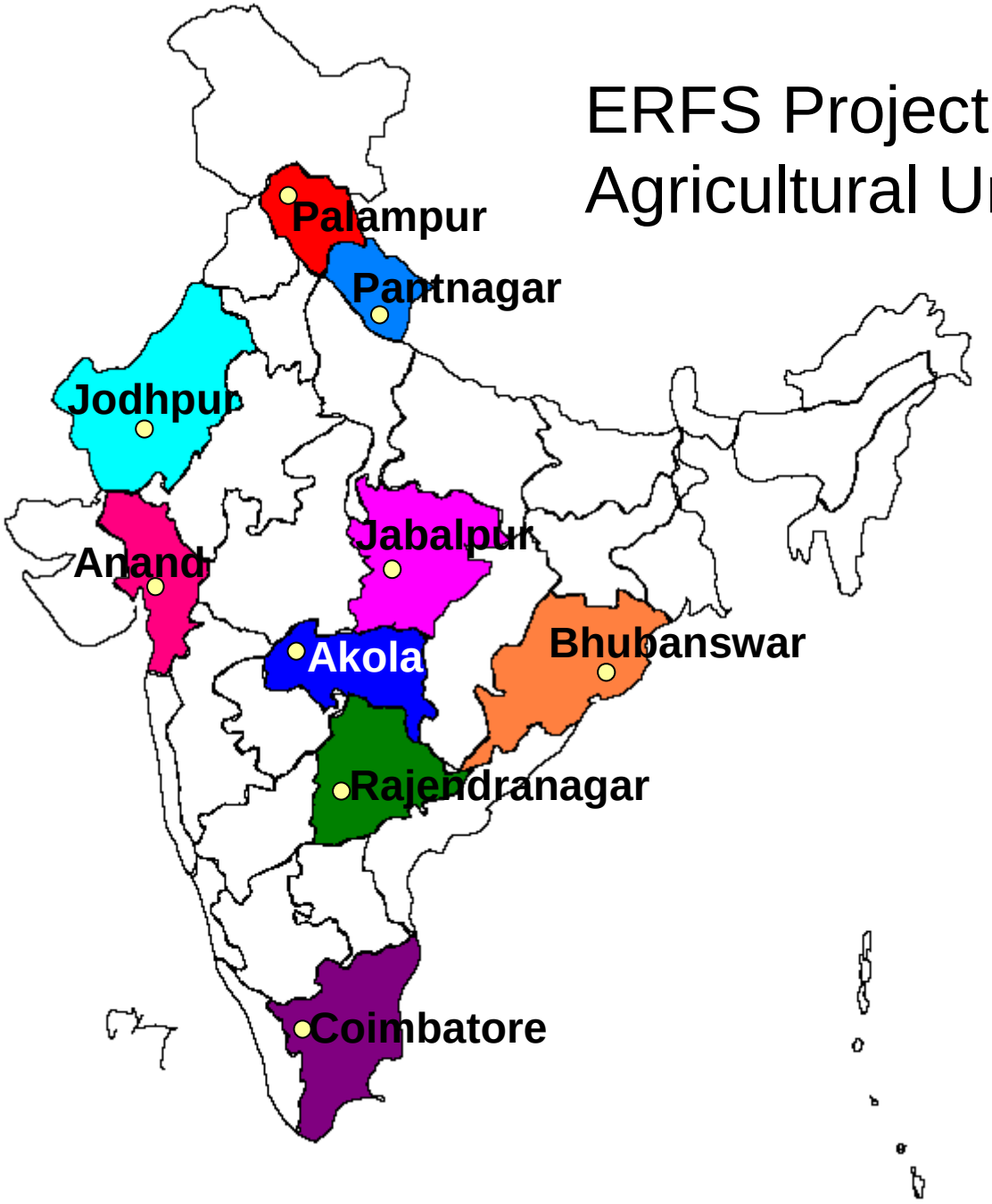
Summary of results at 55 & 30km

RegCM3 at 55km resolution simulates well the Indian summer monsoon circulation and rainfall over landmass

Wind and temperature simulated at 30km resolution of RegCM3 are closer to the NCEP reanalysed fields than those simulated at 55km

Further downscaling by dynamical and statistical methods are being done for application in agriculture

ERFS Project
Agricultural Universities



Objectives of 21 annual runs

To examine variations in precipitation and circulation simulated by RegCM3 over India in the time scales of:

- **Inter-annual**
- **Inter-seasonal**
- **Intra-seasonal**

Experimental Design & Data Used

- **Period of integration: 1-1-1980 to 31-12-2000**
- **Initial Conditions: ERA40**
  (6hrly, 2.5^0x2.5^0,23plevels)
- **Boundary Conditions: GISST**
  (Global SST weekly, 1^0x1^0)
- **Vegetation/Landuse: GLCC BATS, 10min**
- **Elevation: GTOPO BATS, 10min**

Physics Combination

- **Radiation : NCAR CCM3**
- **PBL : Holtslag's scheme**
- **Convective : Grell with Fritsch and Chappel Closure**
- **Large scale precipitation : Subgrid Explicit Moisture Scheme (SUBEX)**
- **Ocean flux parameterization : Zeng's ocean flux**

Years	RegCM3	With Regression	IMD0.5
1980	105.51	87.84	92.81
1983	107.07	88.30	96.72
1985	66.24	76.34	80.19
1988	110.8	89.39	100.31
1991	108.69	88.78	83.93
1992	106.39	88.10	83.86
1993	120.13	92.13	88.95
1994	131.51	95.46	95.32
1995	105.3	87.78	89.77
1996	116.54	91.08	87.41
1997	103.96	87.39	89.26
1998	105.85	87.94	92.93
1999	113.51	90.19	84.43
2000	110.6	89.34	84.08

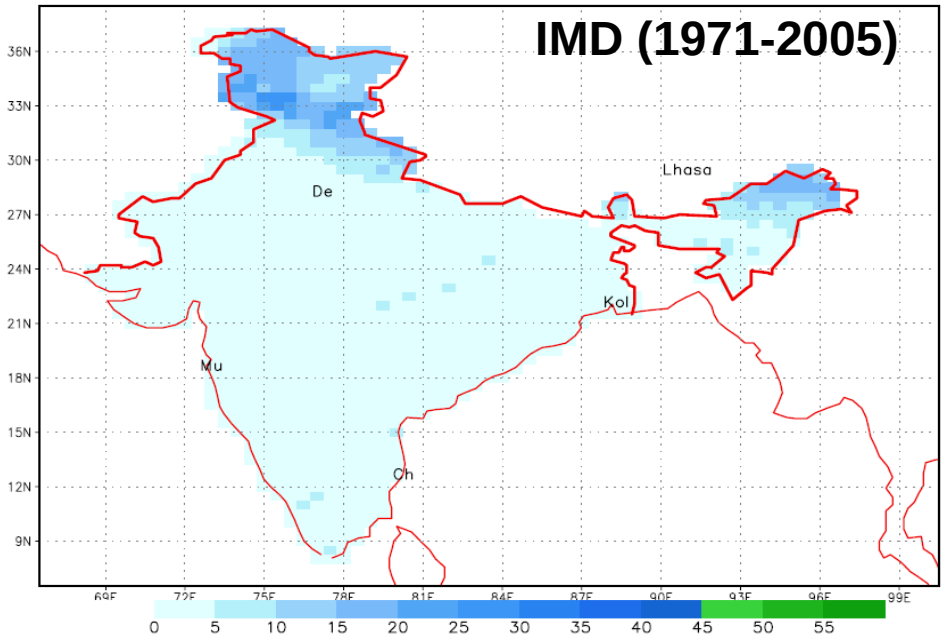
Comparison of Convective schemes in 1994 simulation

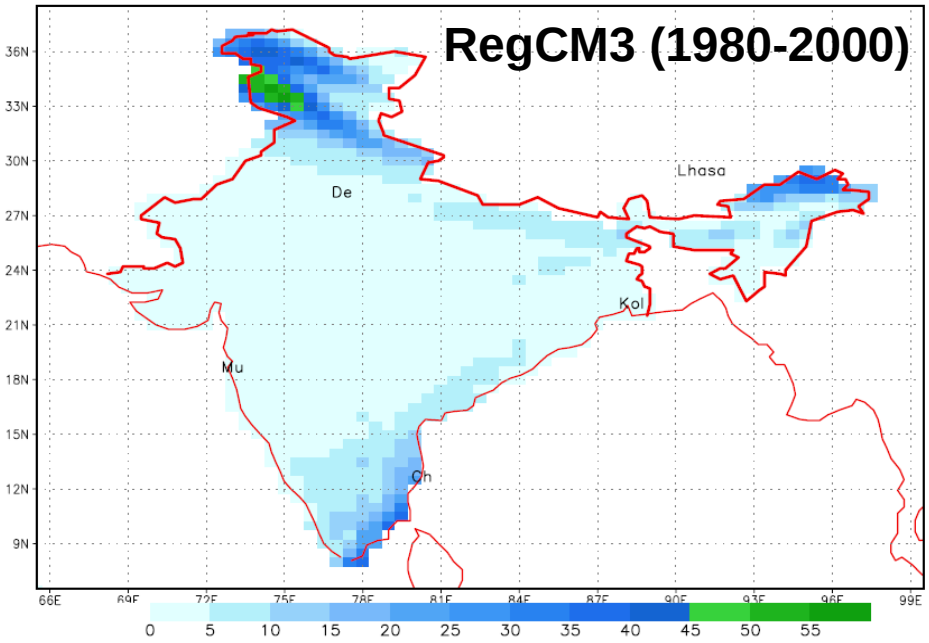
Type of scheme	Grell Arakawa	Grell Fritsch	Anthes	Emanuel	IMD
JJAS Rainfall (cm)	75	111.3	56	72.9	95.32

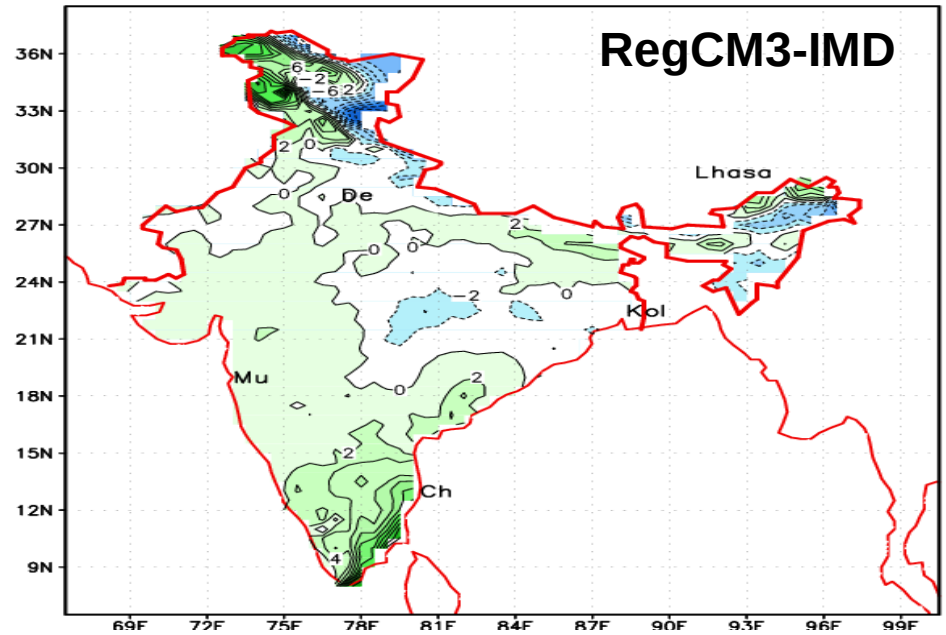
Indian seasons and months

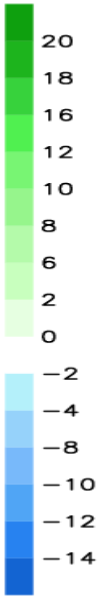
Season	Months
Pre-Monsoon	*March-April-May (MAM)*
Monsoon	*June-July-August-September (JJAS)*
Post-Monsoon	*October-November-December (OND)*
Winter	*January-February (JF)*

Winter Rainfall (cm) Climatology



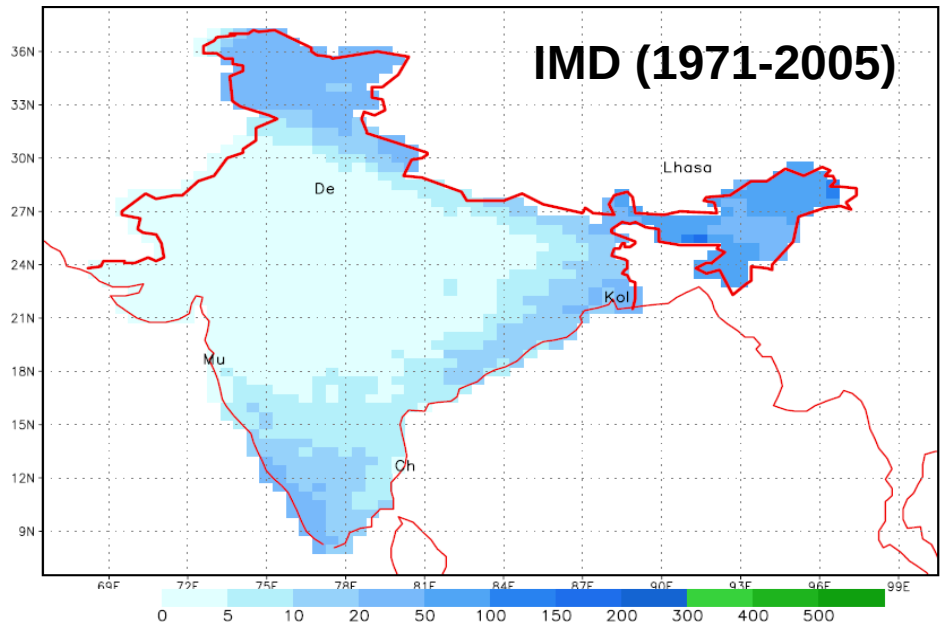


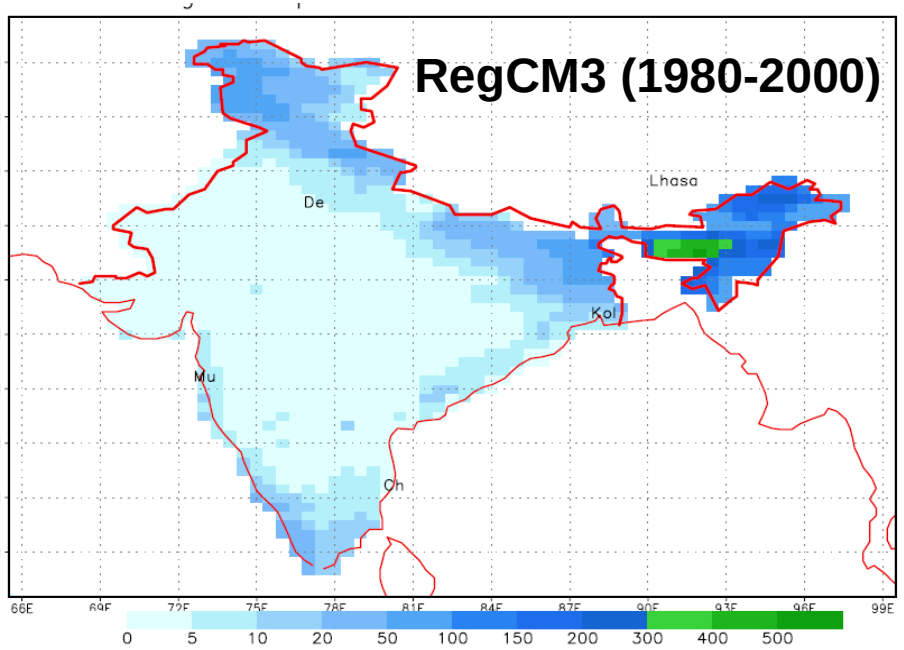


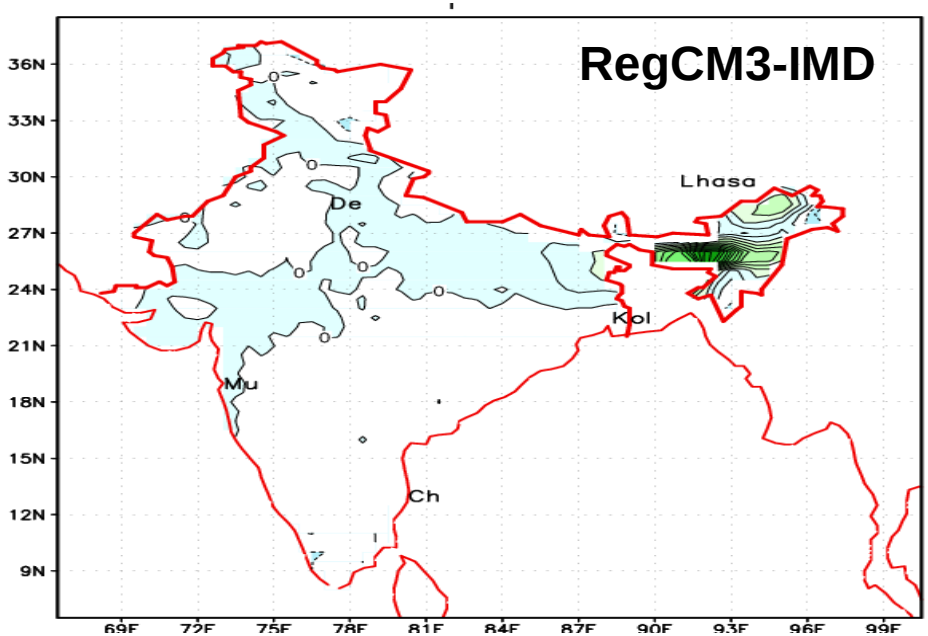


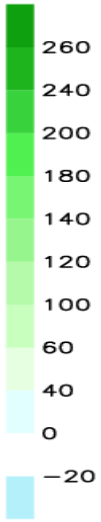
Winter rainfall mostly in J&K and NE due to western disturbances. Simulated rain in the south incorrect.

Pre-Monsoon Rainfall (cm) Climatology



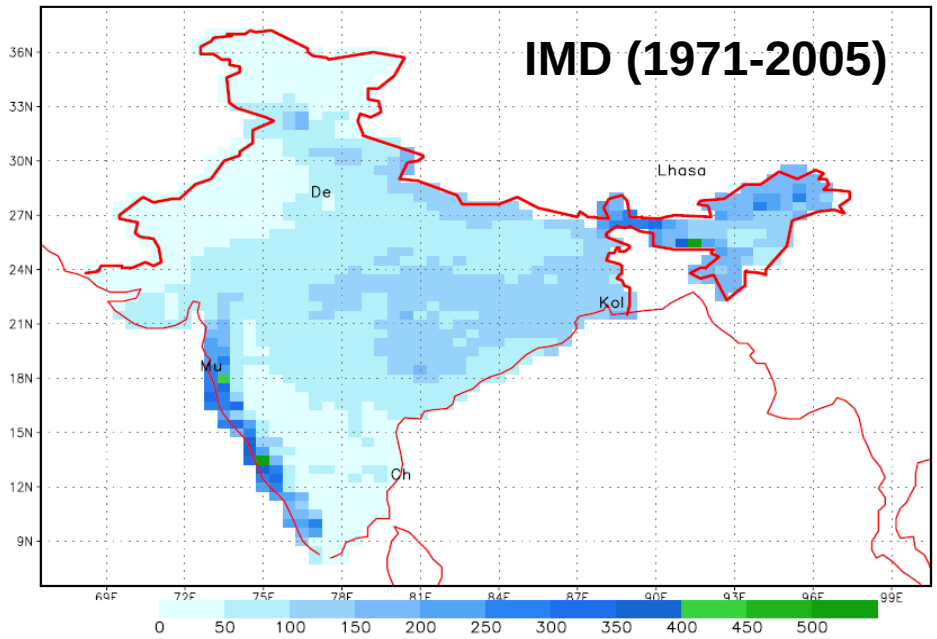


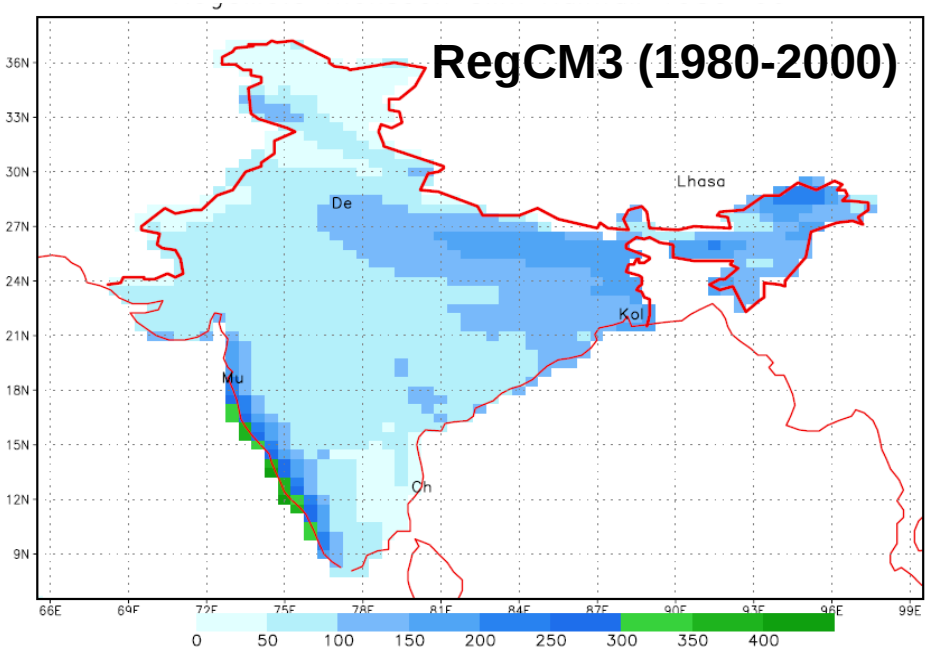


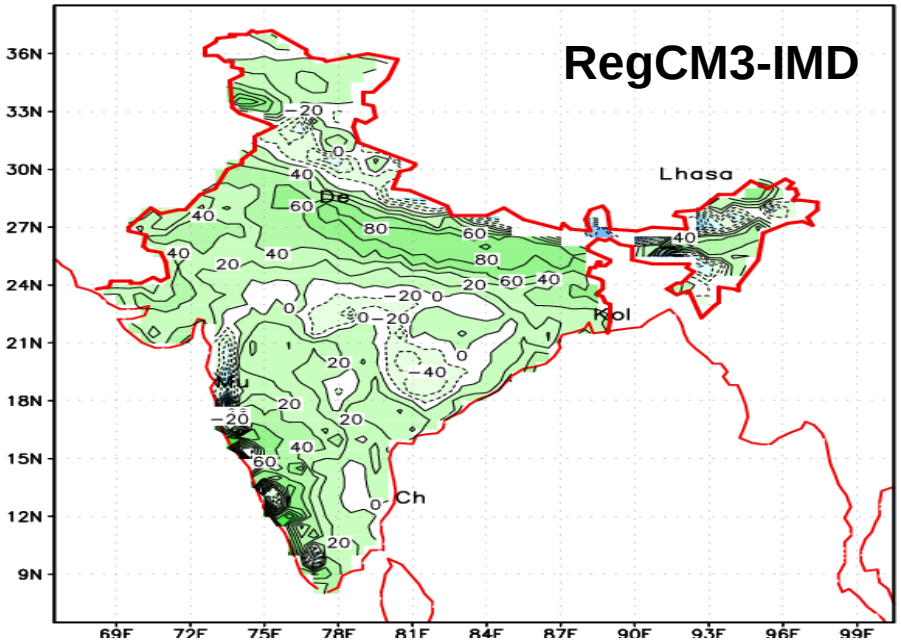


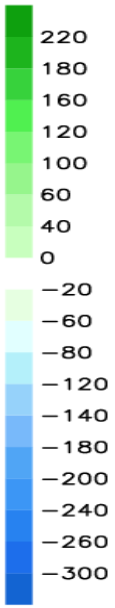
Pre-monsoon Simulated rainfall compares well with IMD observations except for small part of North-East India.

Monsoon Rainfall (cm) Climatology



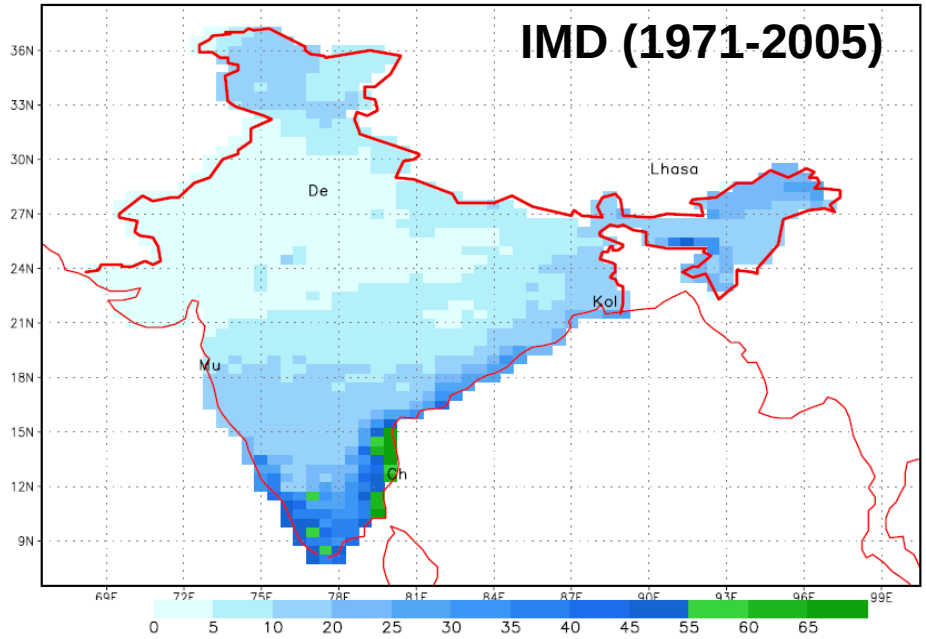


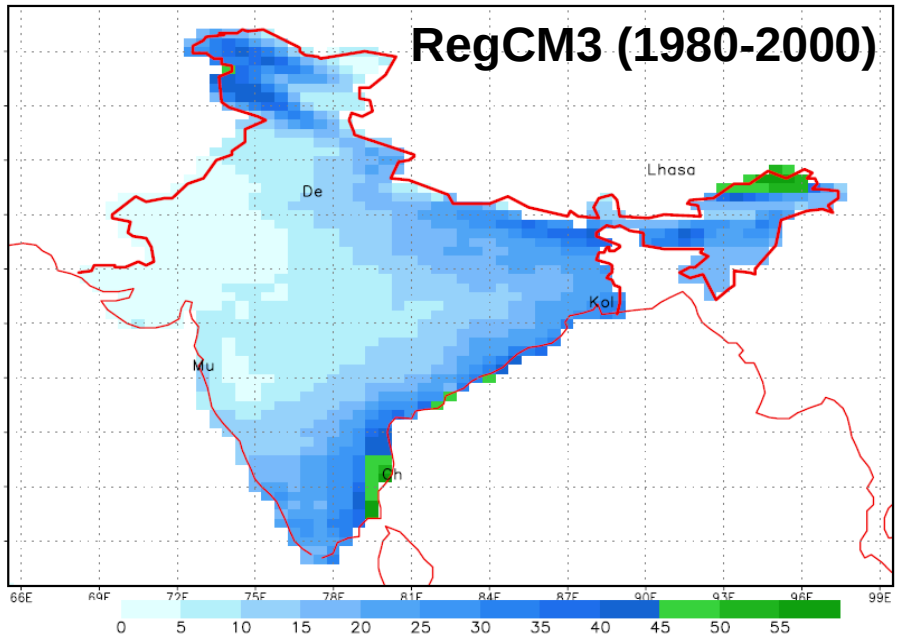


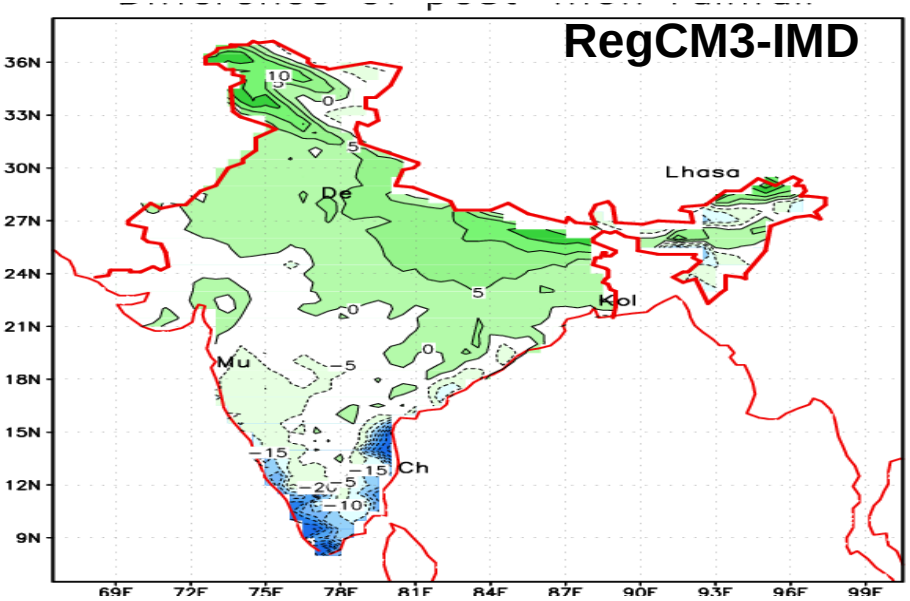


Monsoon rain over estimated by RegCM3 basically over Western Ghats and Monsoon Trough regions; the two major rain belts

Post-monsoon Rainfall (cm) Climatology



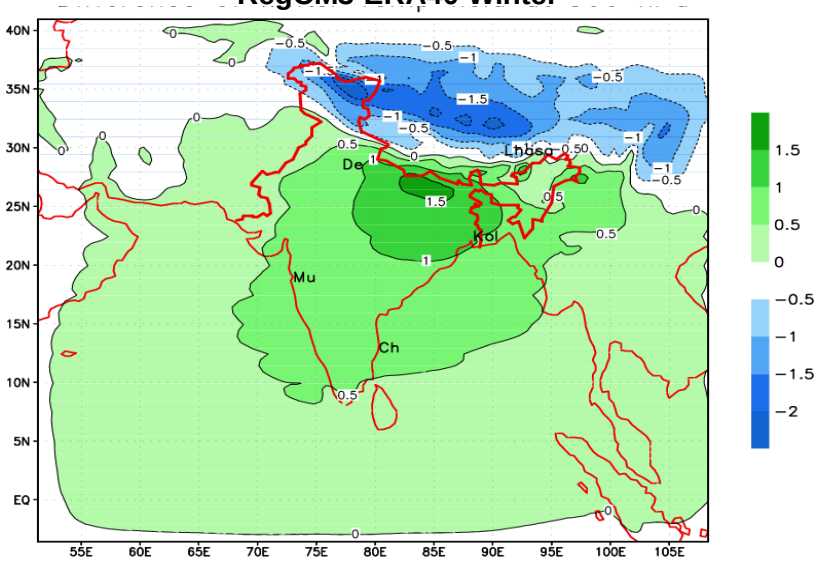




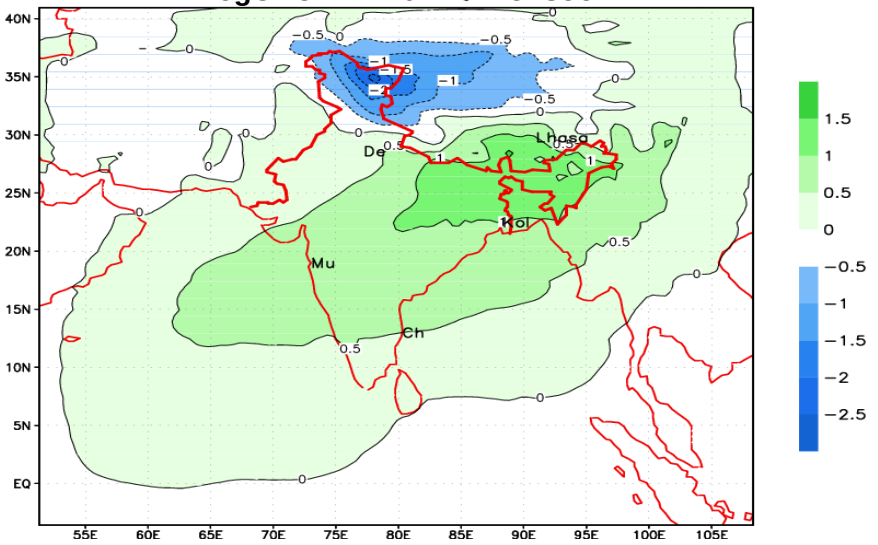
Post-Monsoon rain differences are less; maximum up to 20cm in North India. Negative anomalies in the south India indicate less NE monsoon rain by model.

Seasonal Temperature Anomalies at 500hPa

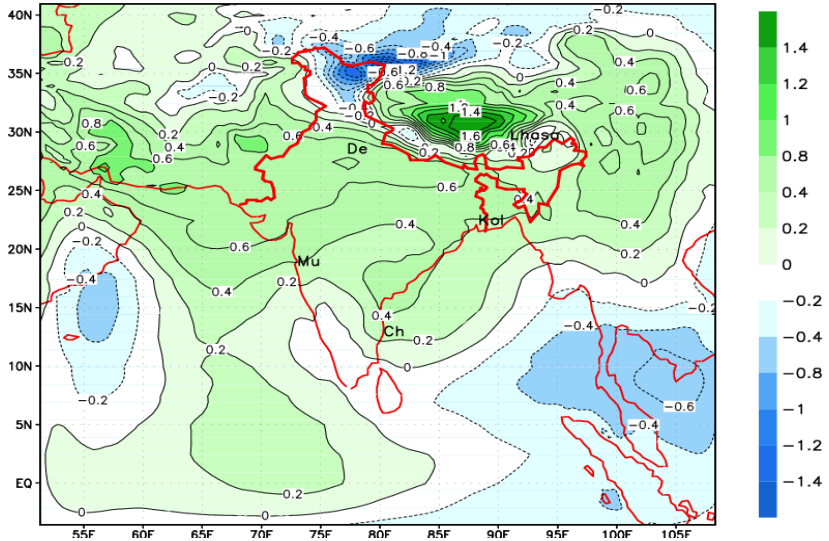
RegCM3-ERA40 Winter



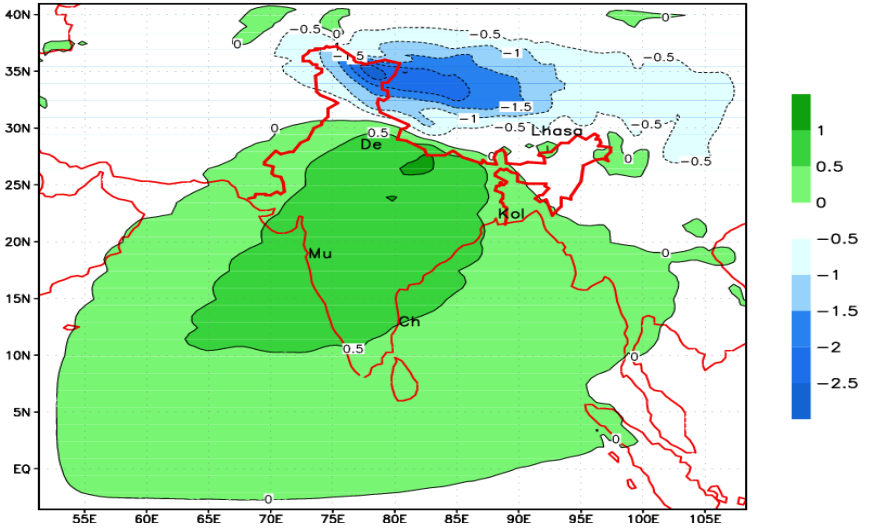
RegCM3-ERA40 Pre-Monsoon



RegCM3-ERA40 Monsoon

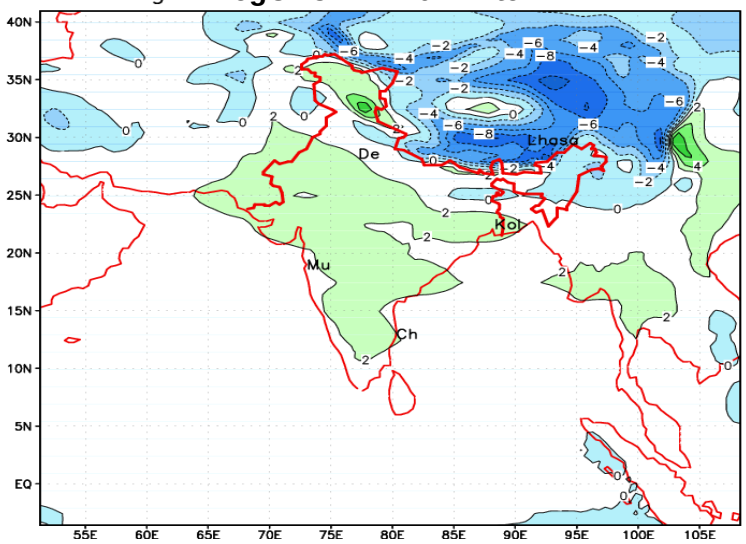


RegCM3-ERA40 Post-Monsoon

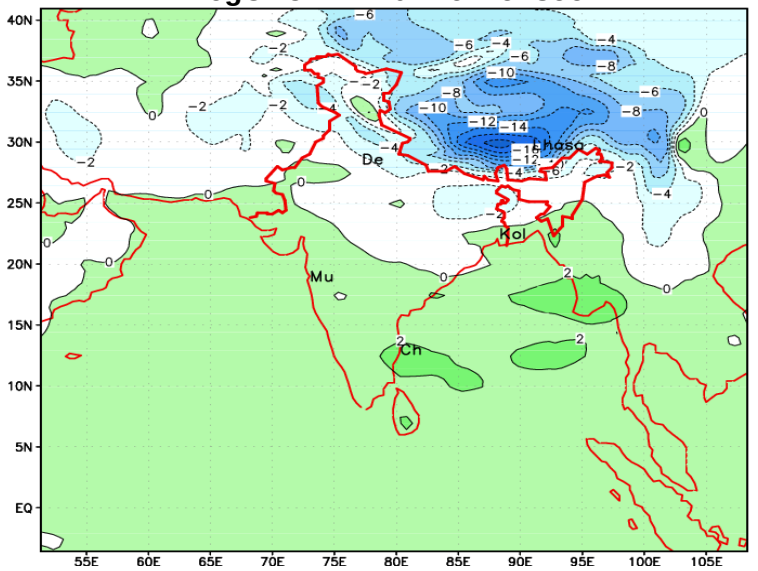


Seasonal SLP Anomalies

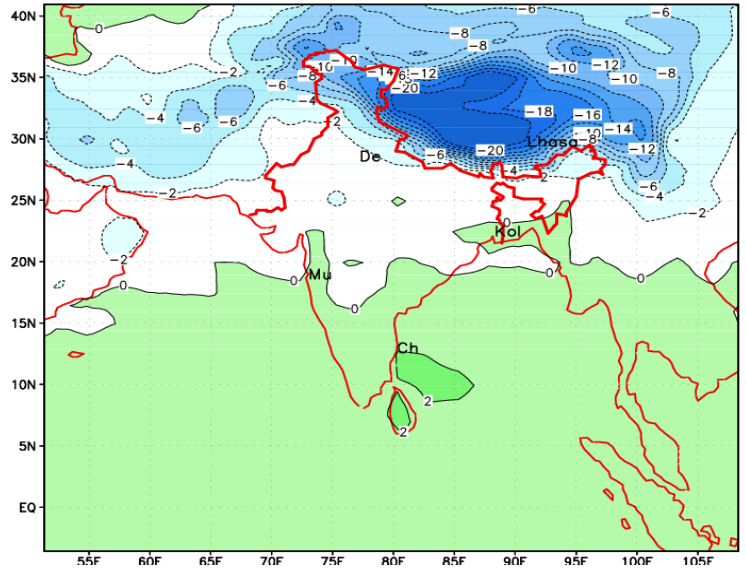
RegCM3-ERA40 Winter



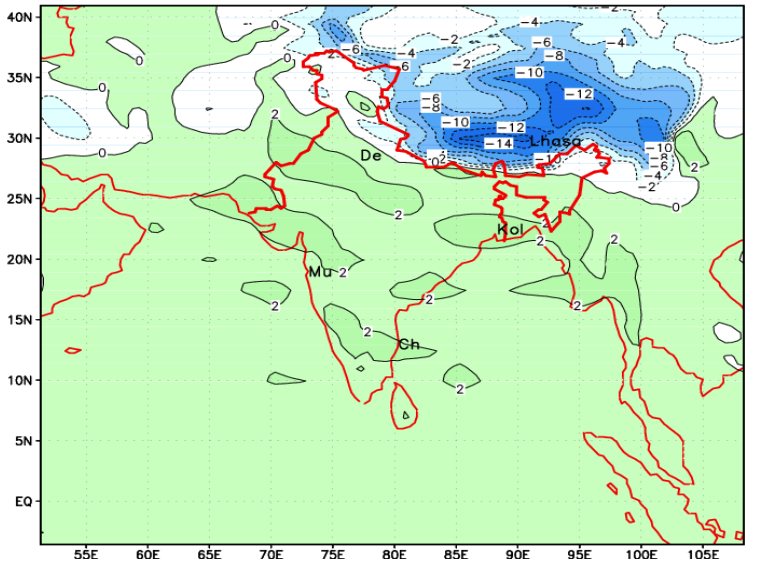
RegCM3-ERA40 Pre-Monsoon



RegCM3-ERA40 Monsoon

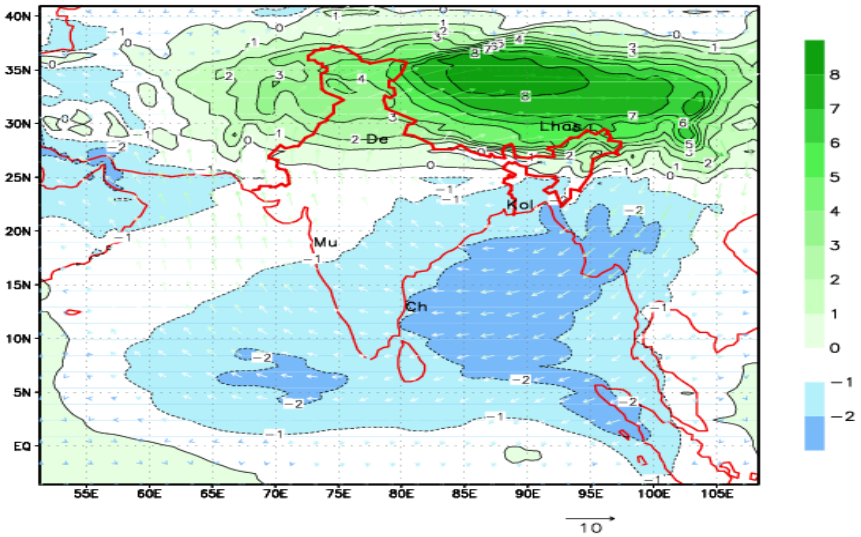


RegCM3-ERA40 Post-Monsoon

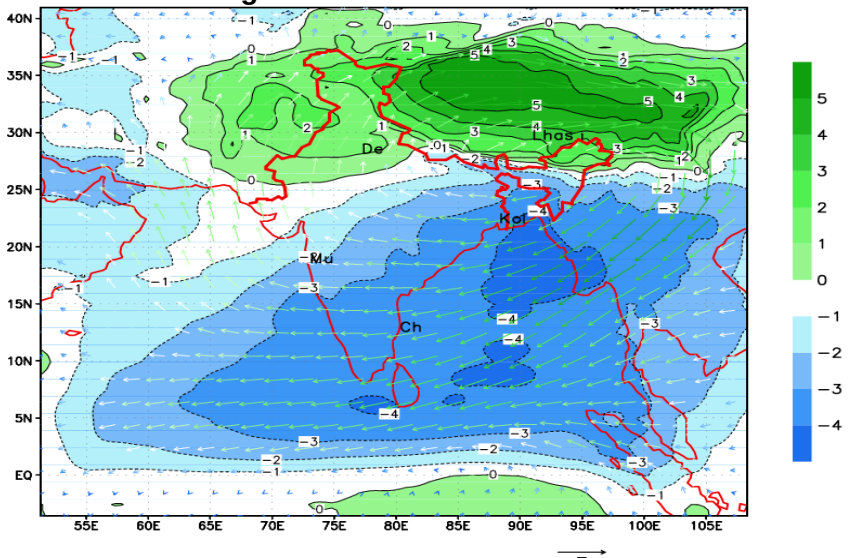


Seasonal Wind Anomalies at 200hPa

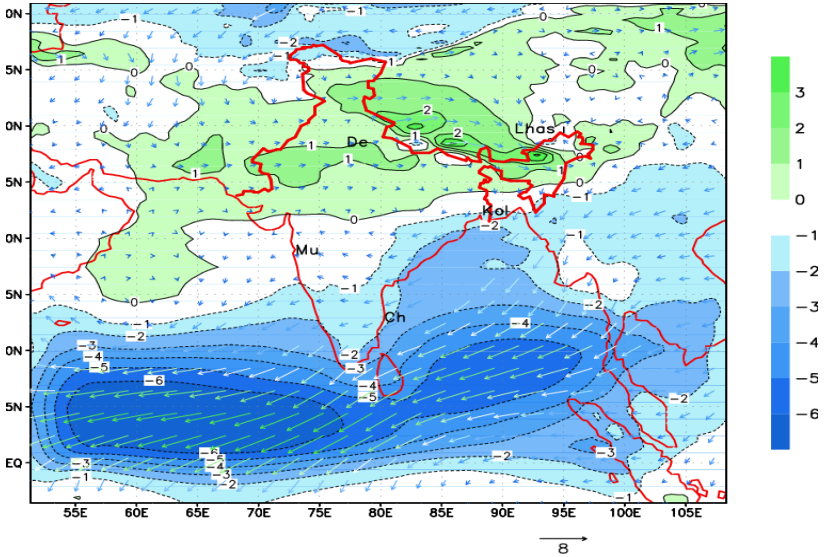
RegCM3-ERA40 Winter



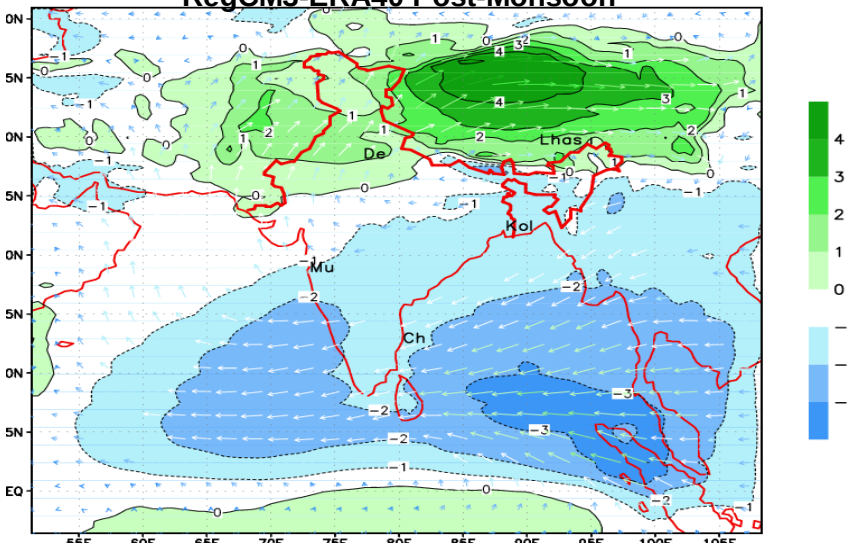
RegCM3-ERA40 Pre-Monsoon



RegCM3-ERA40 Monsoon

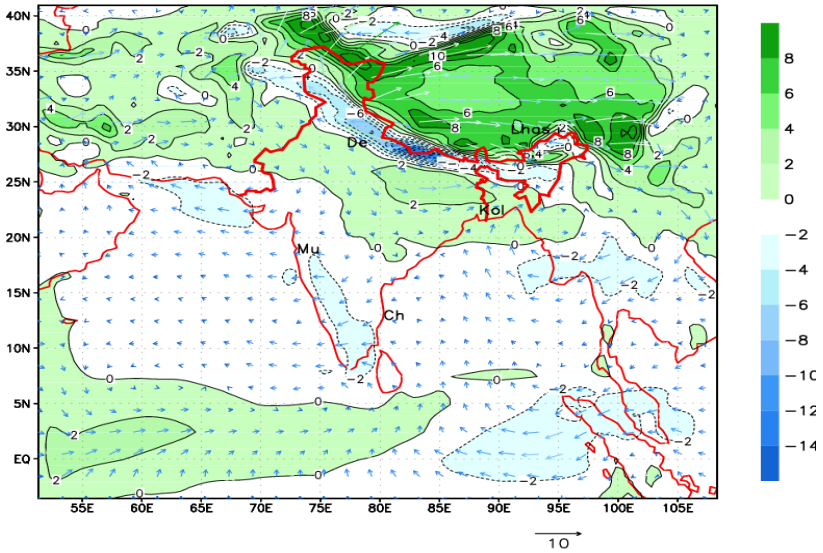


RegCM3-ERA40 Post-Monsoon

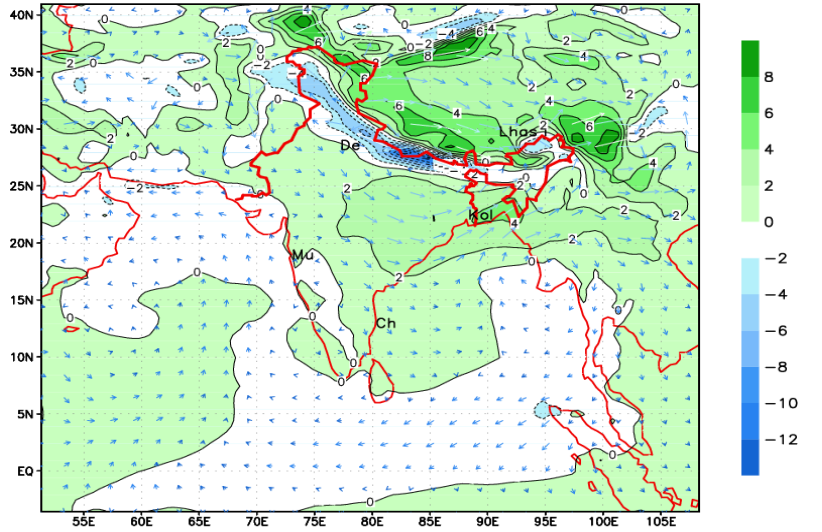


Seasonal Wind Anomalies at 850hPa

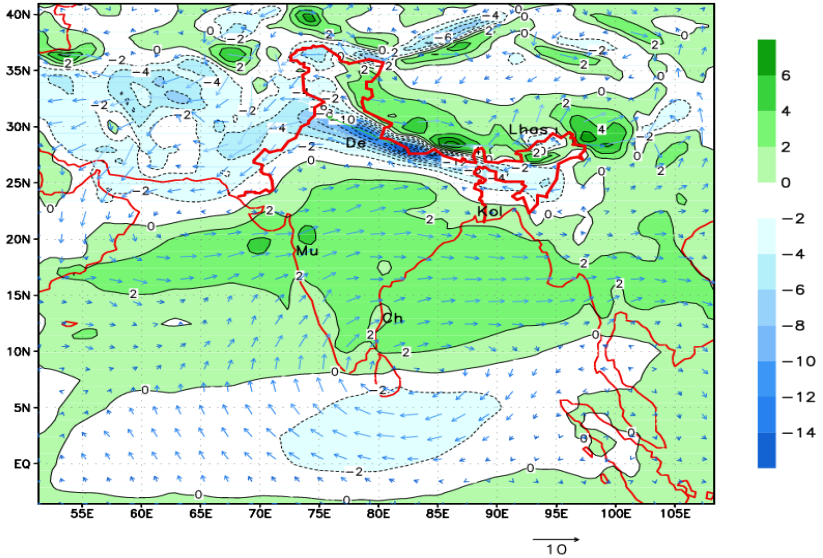
RegCM3-ERA40 Winter



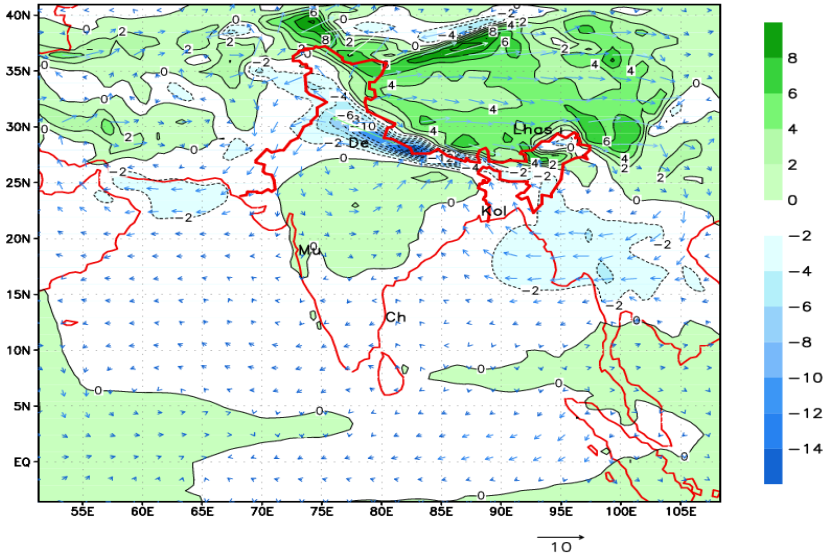
RegCM3-ERA40 Pre-Monsoon



RegCM3-ERA40 Monsoon

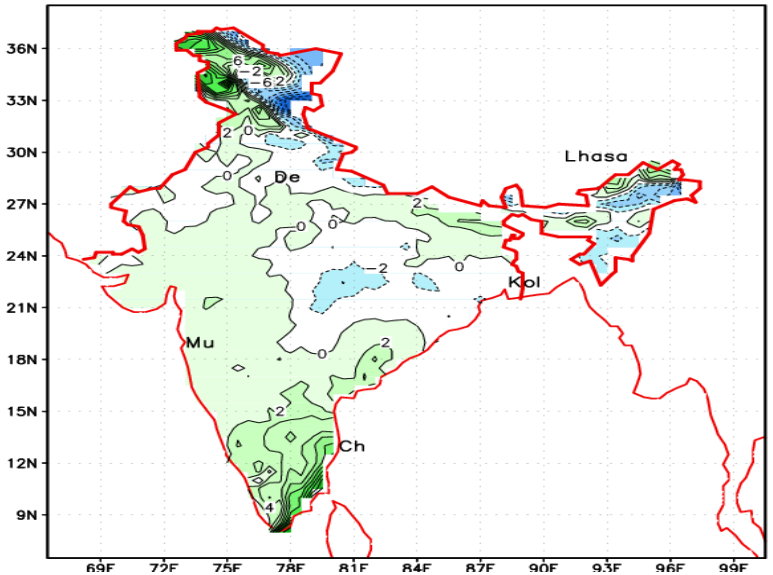


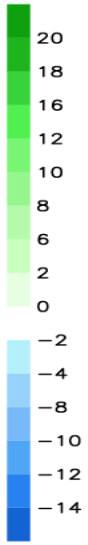
RegCM3-ERA40 Post-Monsoon



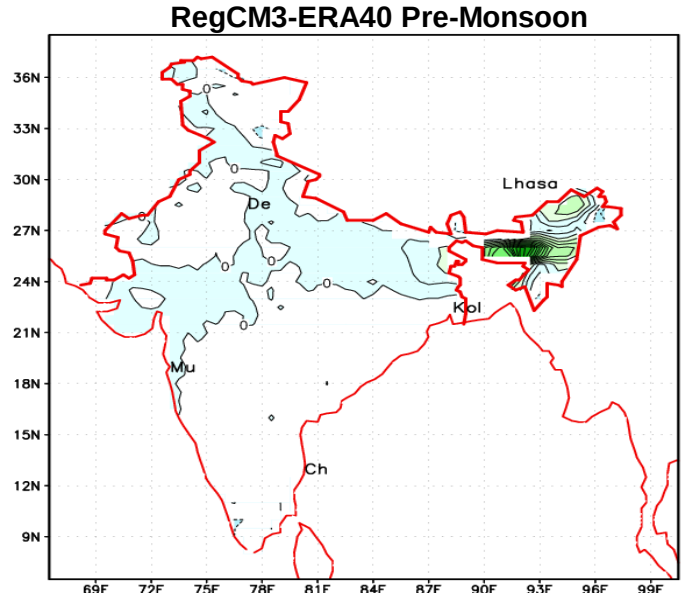
Seasonal Rainfall Anomalies

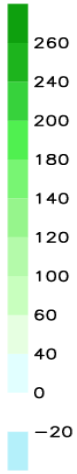
RegCM3-ERA40 Winter



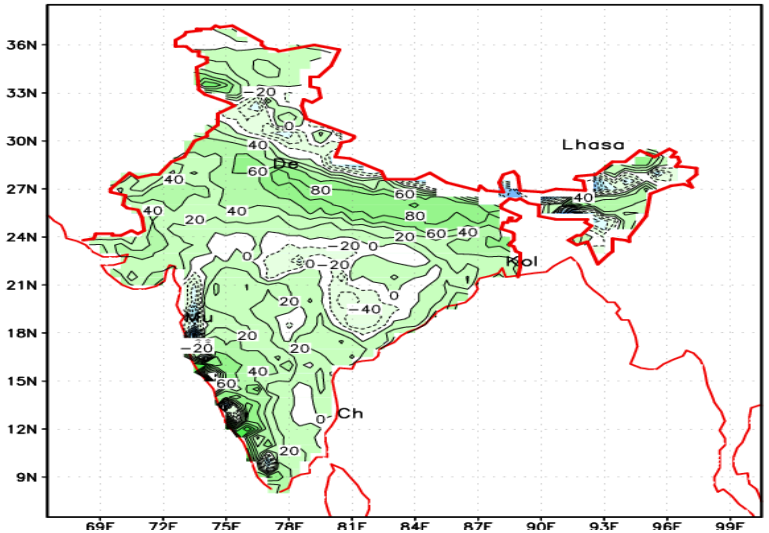


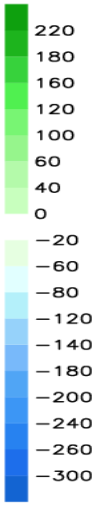
RegCM3-ERA40 Pre-Monsoon



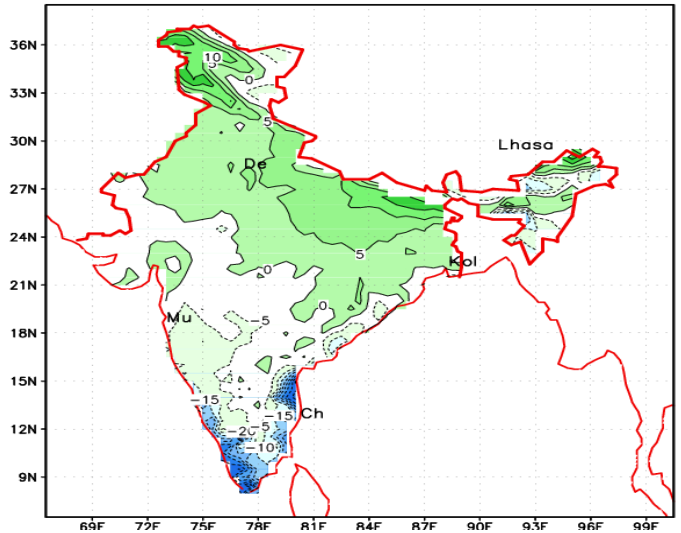


RegCM3-ERA40 Monsoon

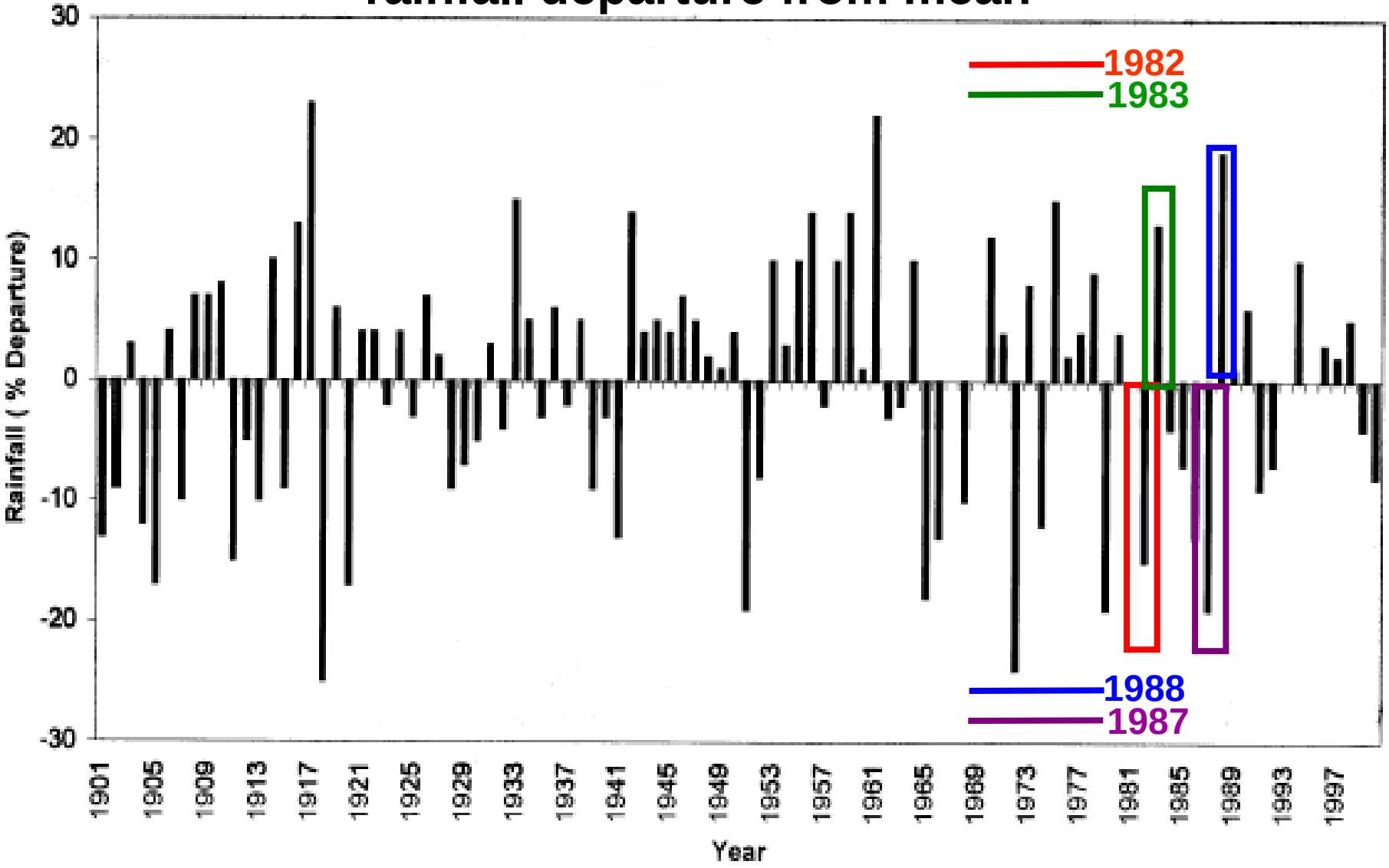




RegCM3-ERA40 Post-Monsoon



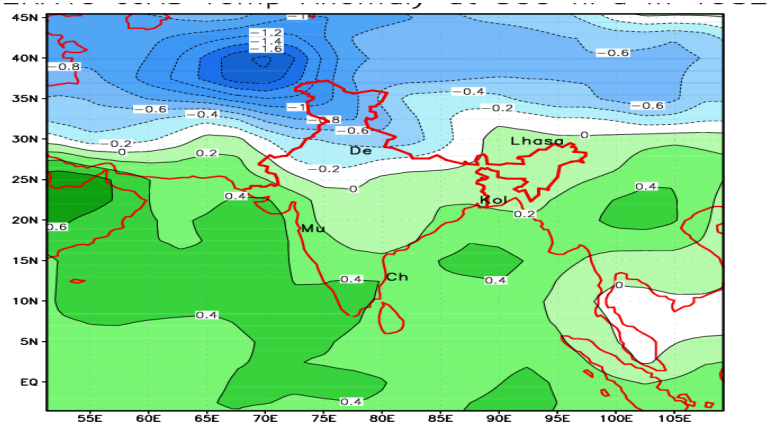
Selections of Extreme Years based on IMD rainfall departure from mean



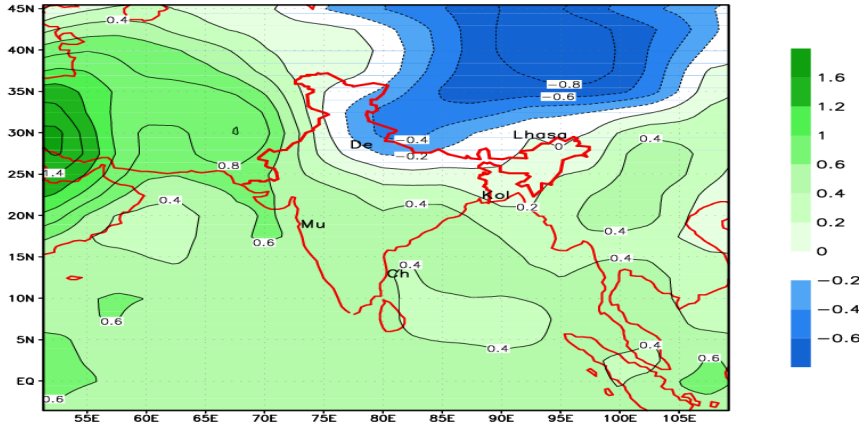
Source: Rajeevan, Current Science, Vol. 81, No. 11, 10 December 2001

JJAS Temperature Anomaly (°C) at 500hPa 1982-1983

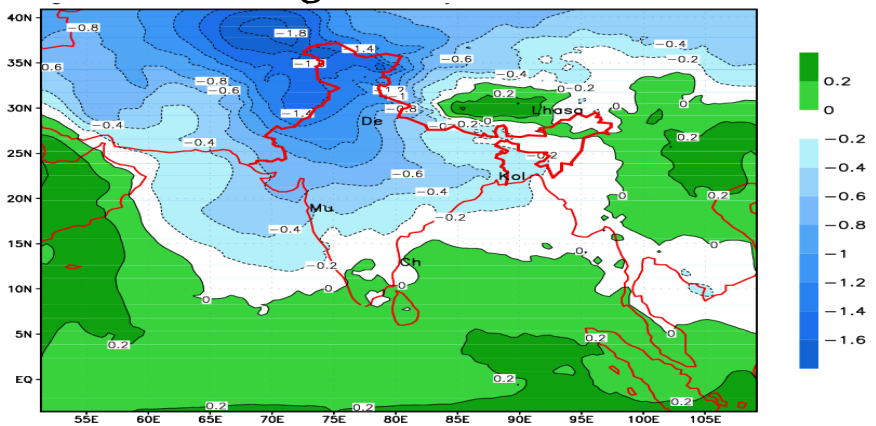
ERA40 1982



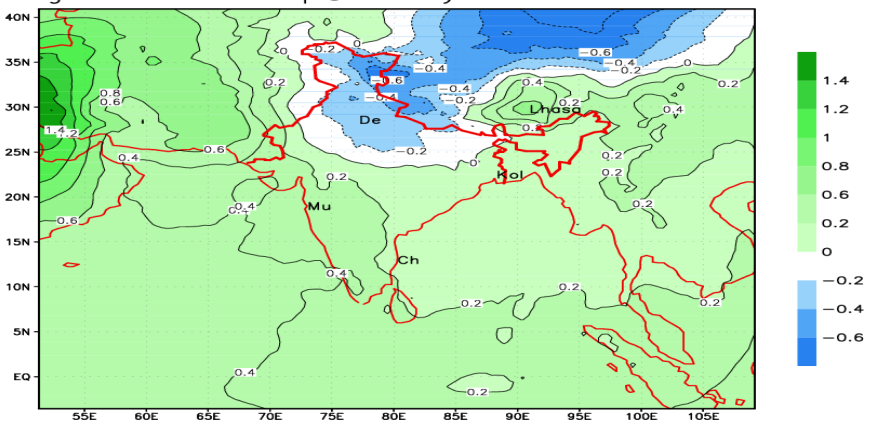
ERA40 1983



RegCM3 1982



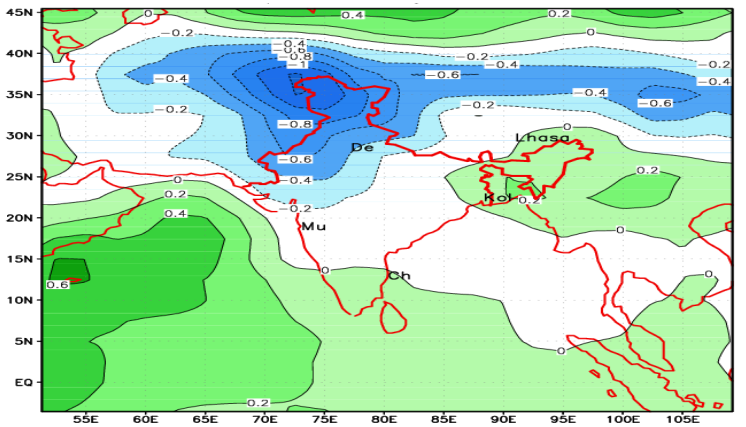
RegCM3 1983



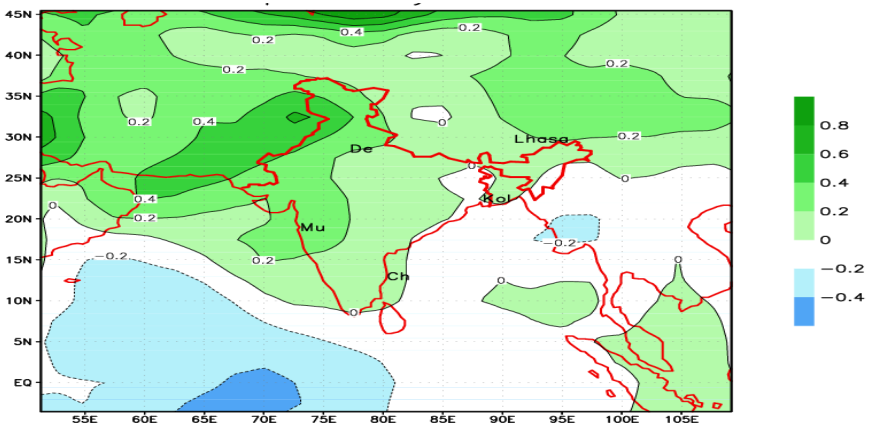
Temperature anomalies in the contrasting years agree qualitatively. Deficient year results closer than excess year.

JJAS Temperature Anomaly (°C) at 500hPa 1987-1988

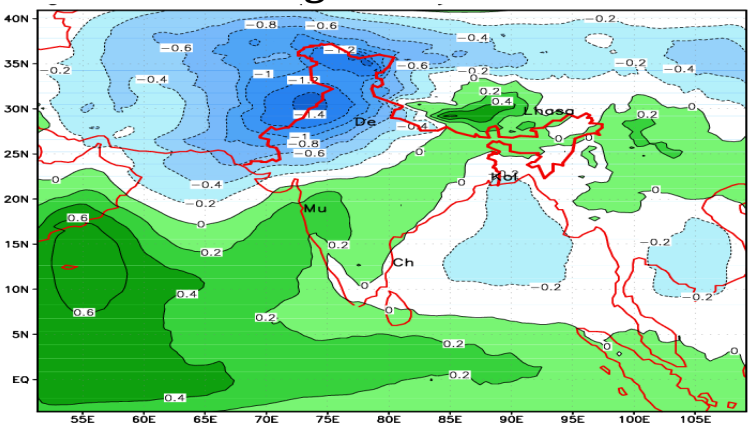
ERA40 1987



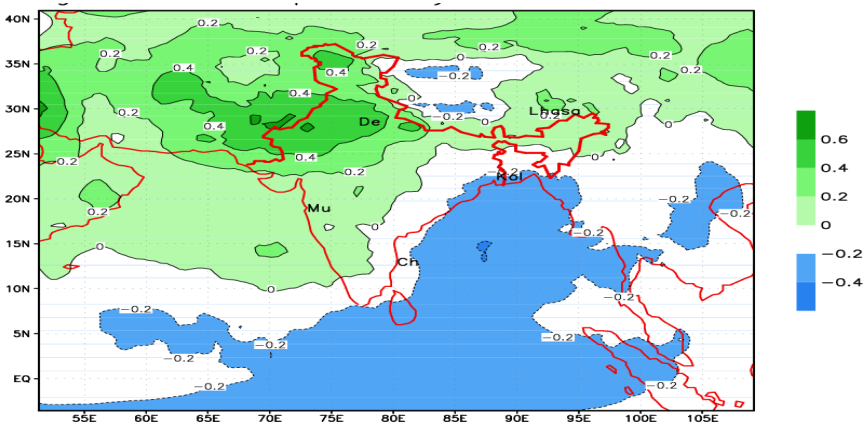
ERA40 1988



RegCM3 1987



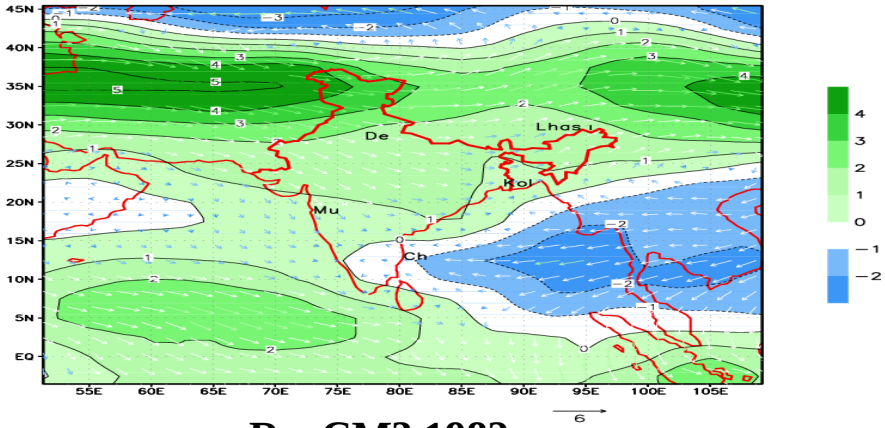
RegCM3 1988



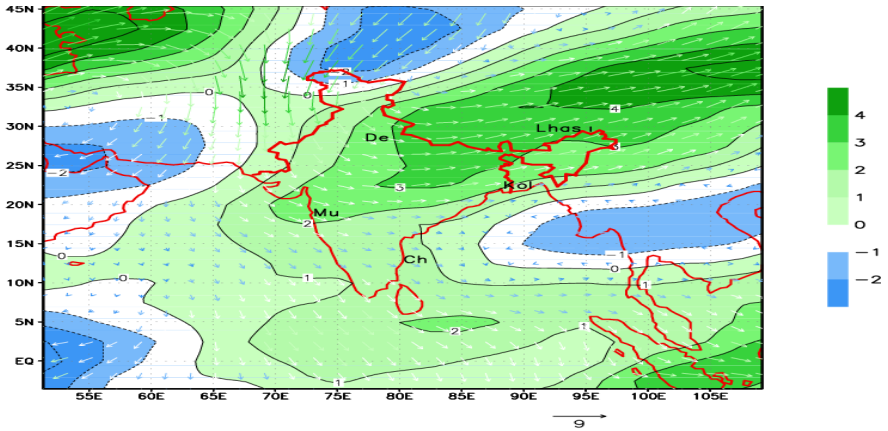
As in 1982-1983, the deficient year 1987 agrees better than excess year 1988.

JJAS Wind Anomalies at 200hPa 1982-1983

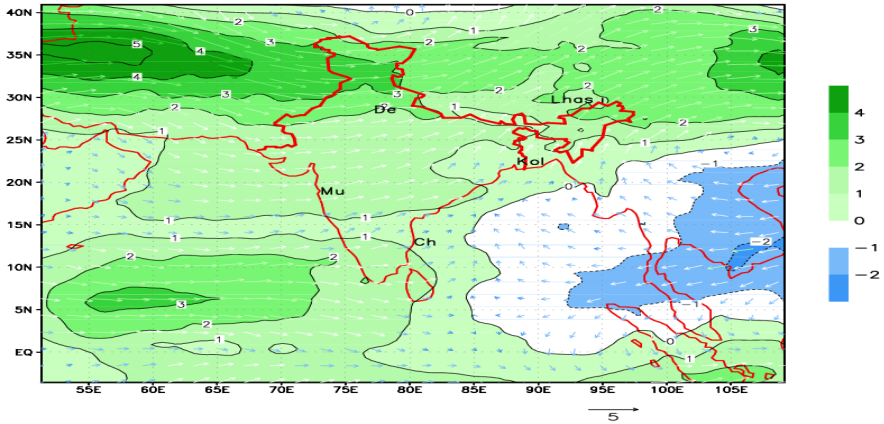
ERA40 1982



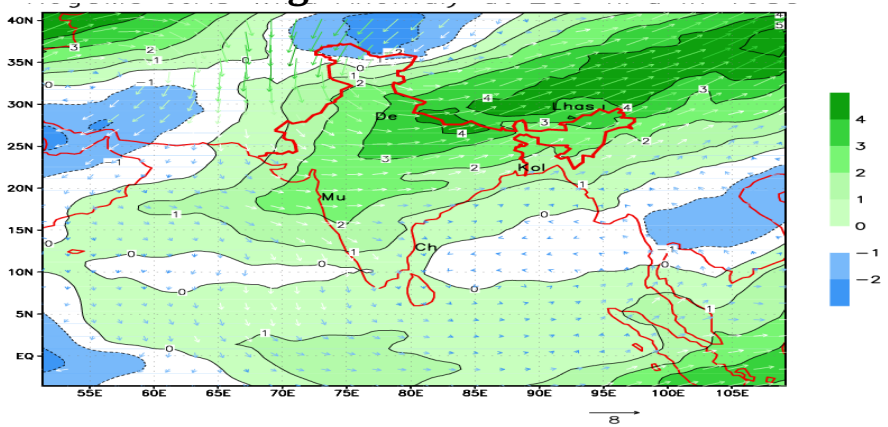
ERA40 1983



RegCM3 1982



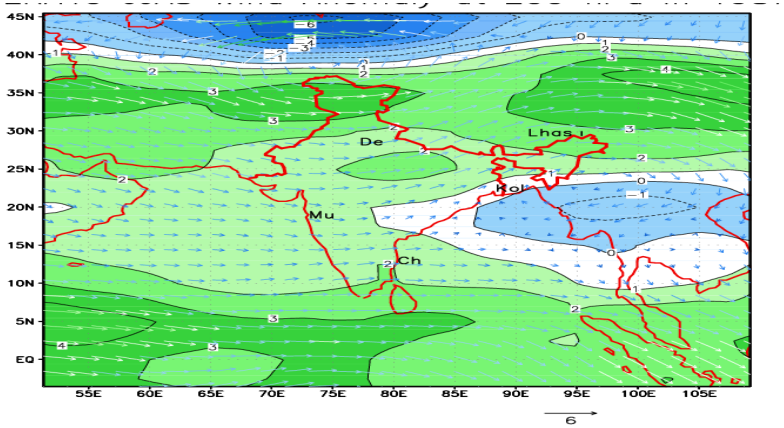
RegCM3 1983



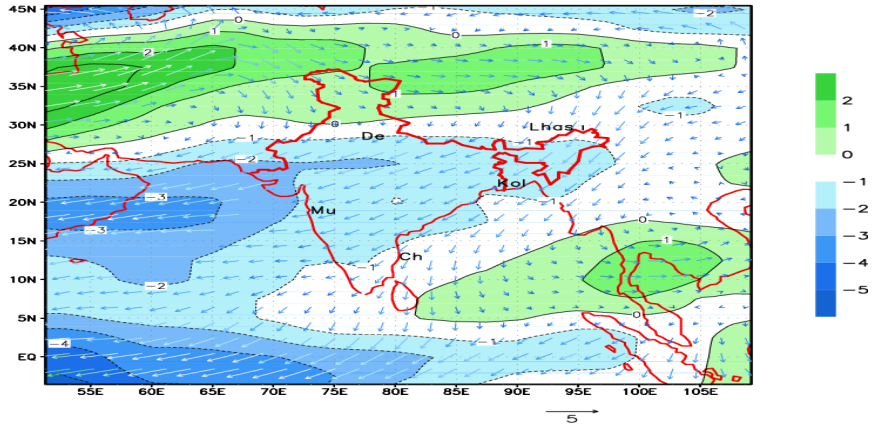
In 1982 and 1983 observed and model simulated anomalies are similar

JJAS Wind Anomalies at 200hPa 1987-1988

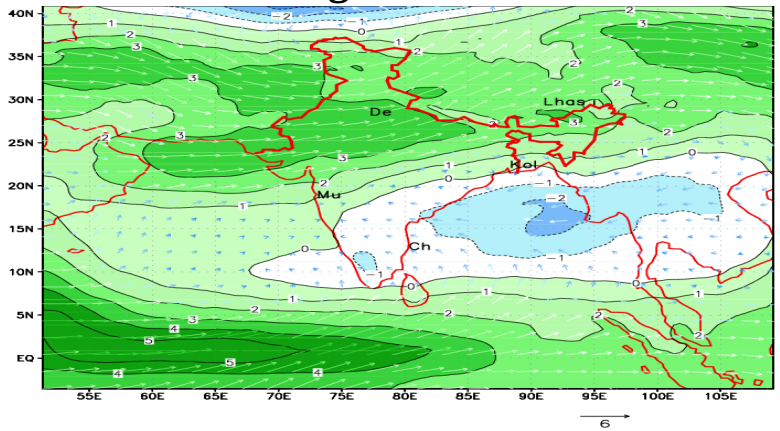
ERA40 1987



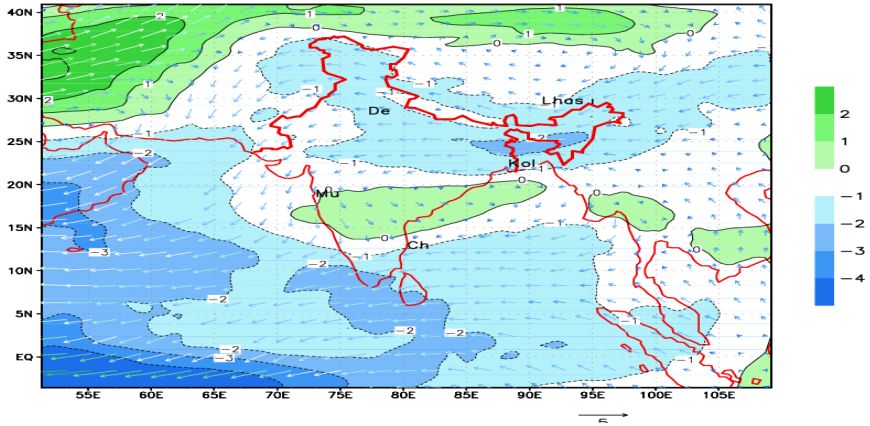
ERA40 1988



RegCM3 1987



RegCM3 1988



Weak and strong anticyclonic circulation patterns simulated by the model for 1987 and 1988 respectively.

Linear Regression Method

General form of linear regression is:

$$\mathbf{Y_j = b_0 + b_1 X_j + e_j \quad for\ j = 1,2,.....N}$$

where,

Y_j is the corrected value

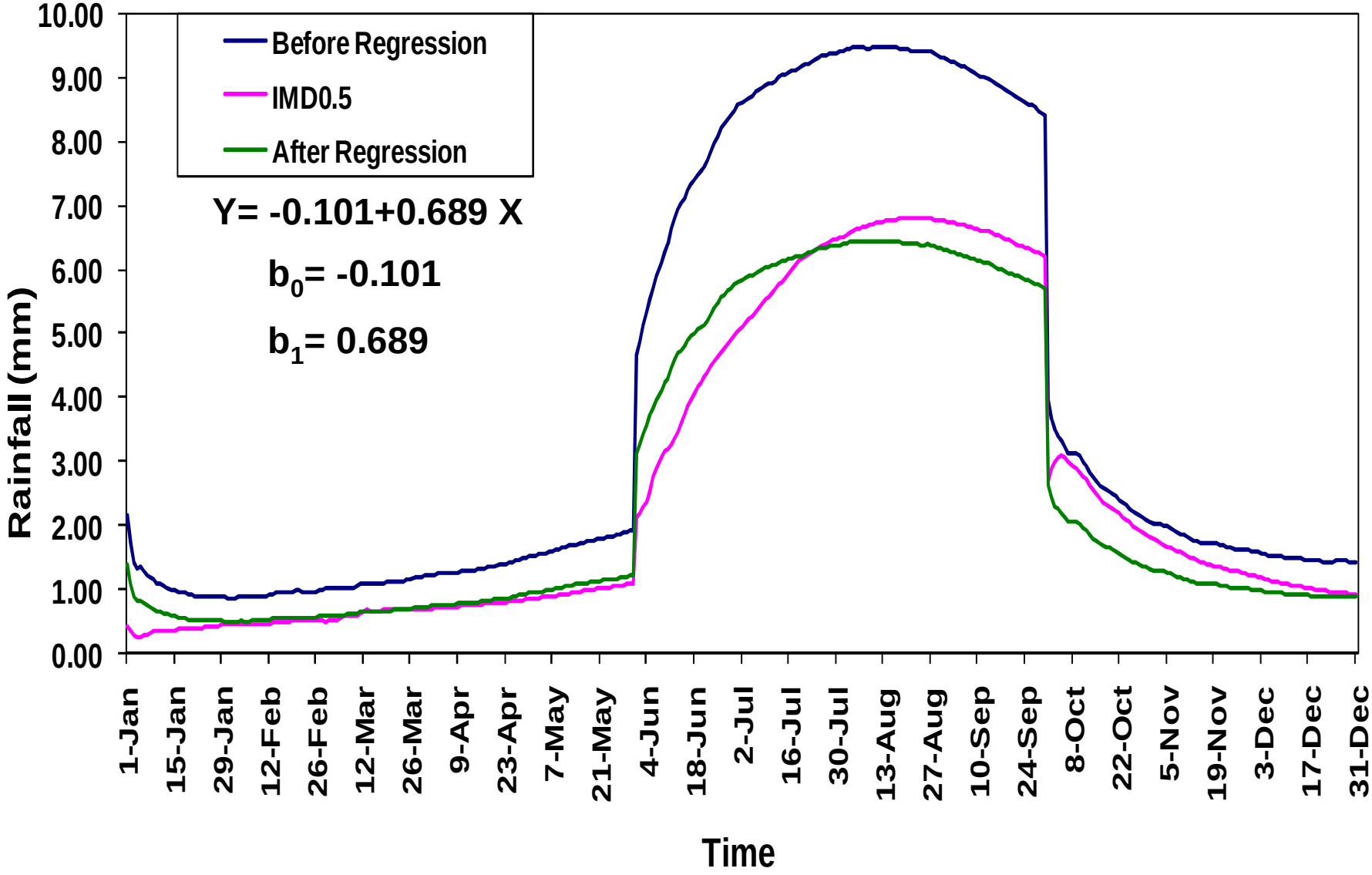
X_j is the model simulated value

b_0 , b_1 are regression parameters (unknown)

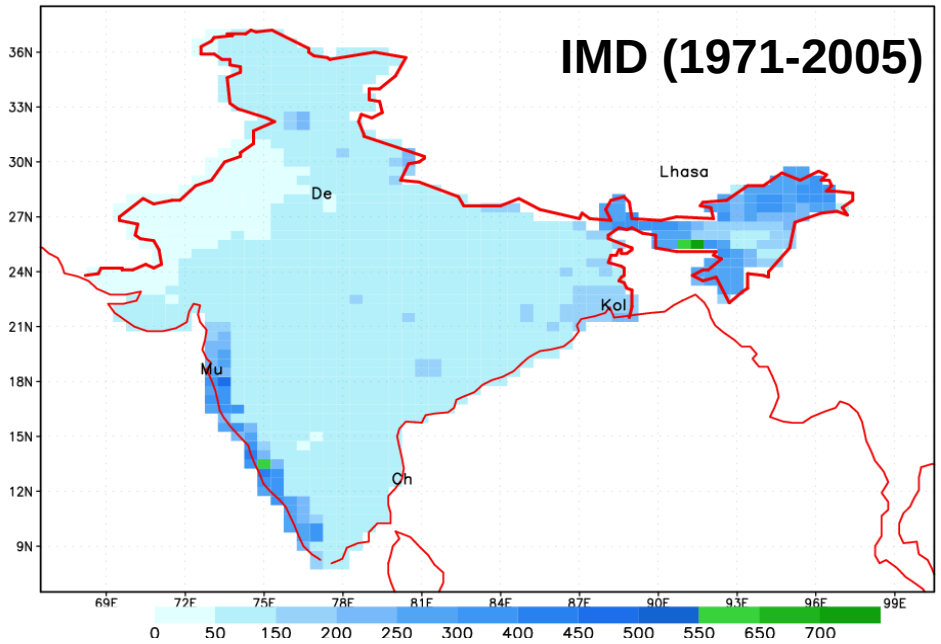
e_i is an estimated error term for j^{th} observation and assumed to be sampled independently from a normal distribution $N(0, \sigma_e.)$

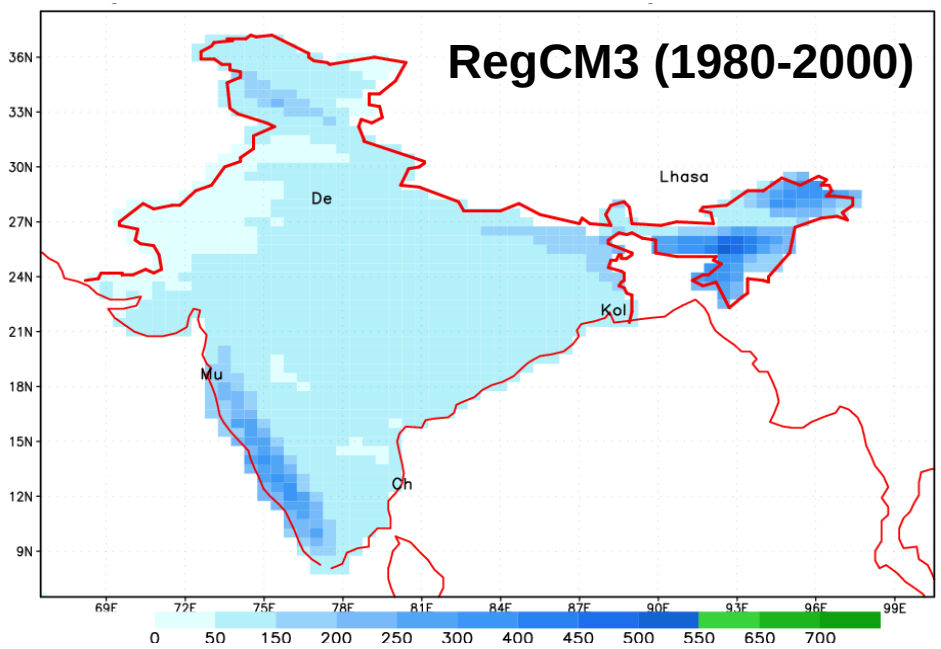
The task of linear regression is to find unknown parameters b_0 , b_1 which can be obtained efficiently using least square method.

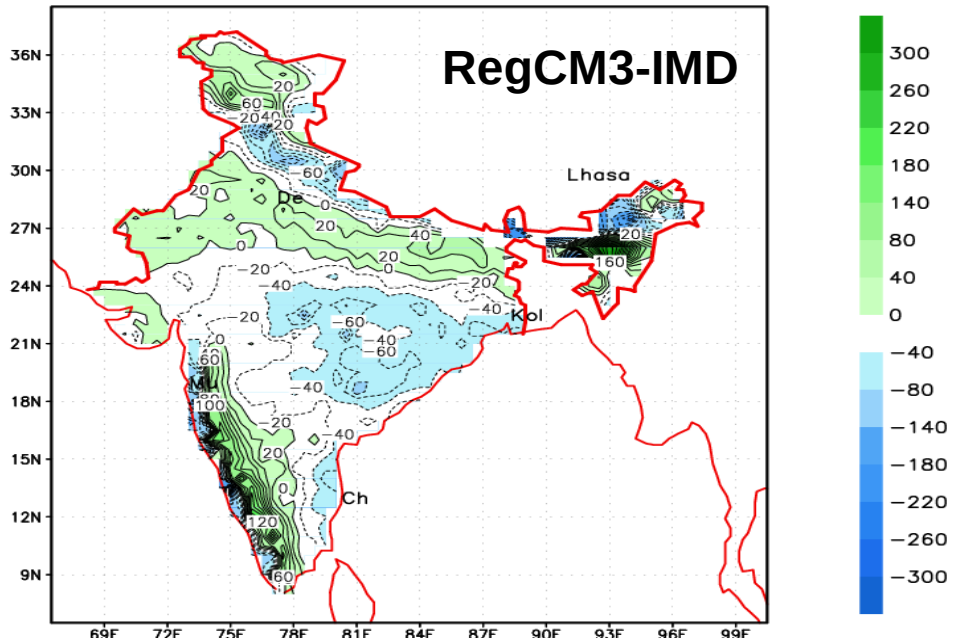
Daily Rainfall Climatology after Linear Regression



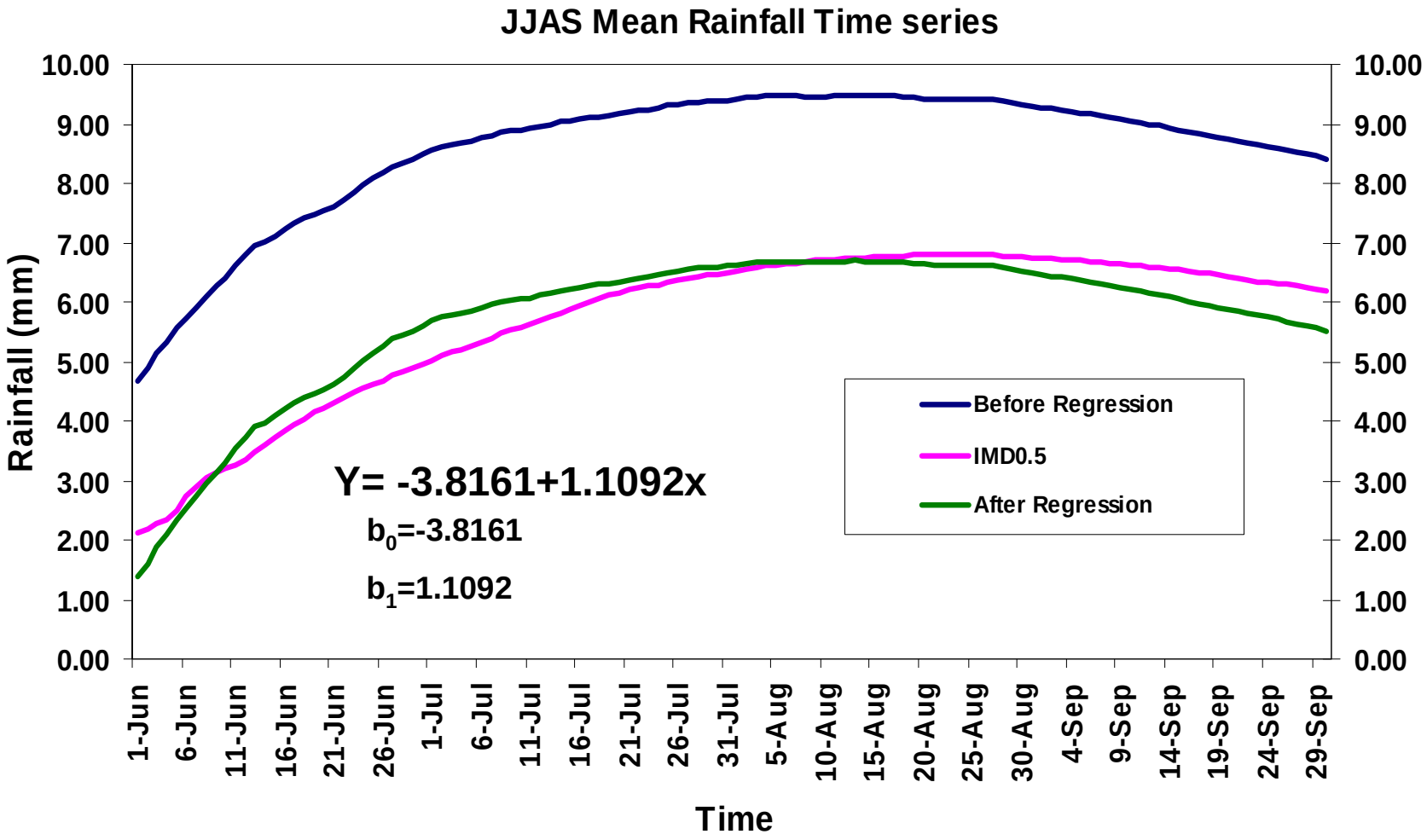
Annual Rainfall (cm) Climatology after Regression

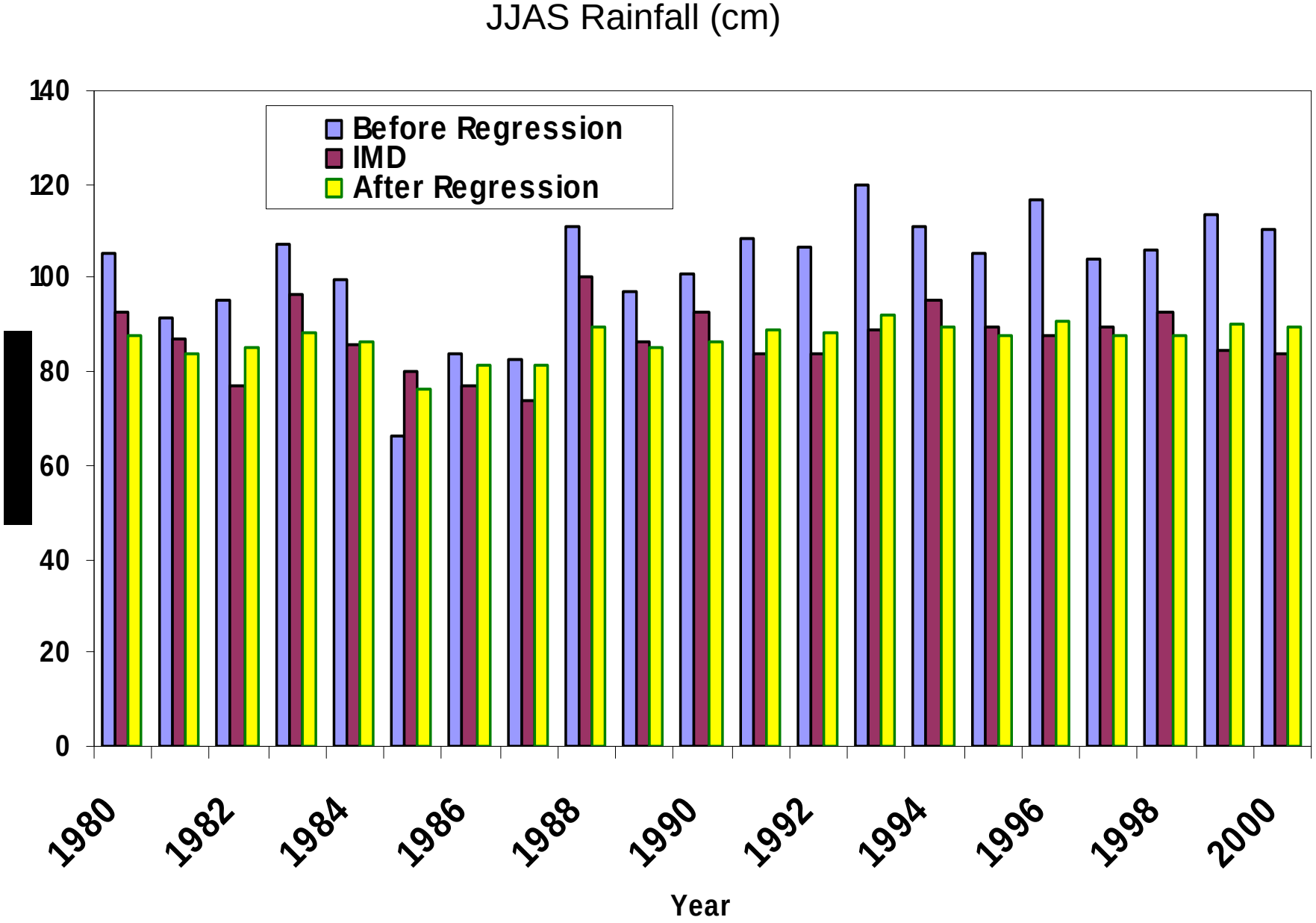




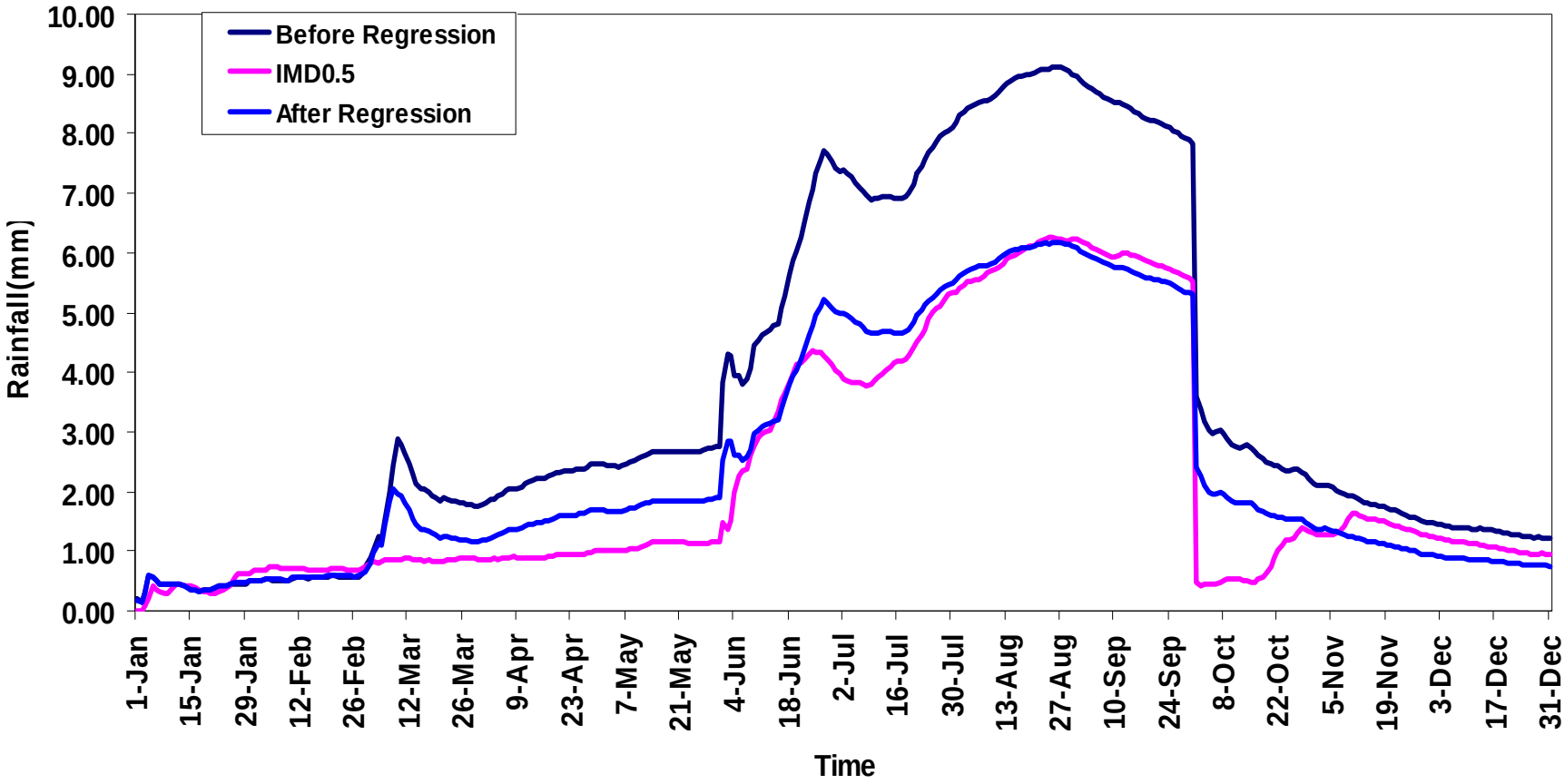


After regression correction differences reduce by about 50% in the two rain belts during summer monsoon

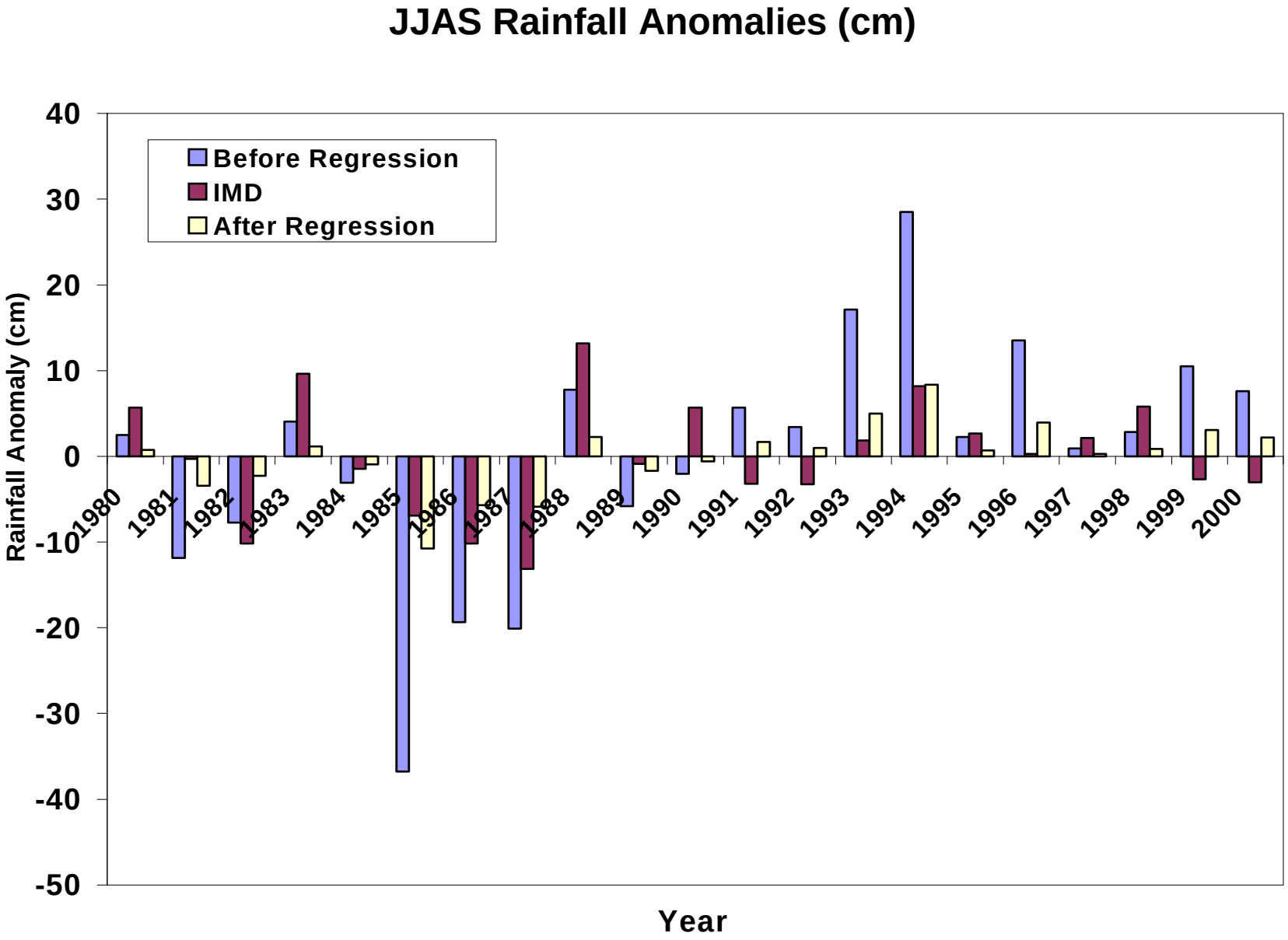

JJAS Mean Rainfall Time series
Rainfall (mm)
Time
Before Regression
IMD0.5
After Regression
Y= -3.8161+1.1092x
b0=-3.8161
b1=1.1092
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1-Jun
6-Jun
11-Jun
16-Jun
21-Jun
26-Jun
1-Jul
6-Jul
11-Jul
16-Jul
21-Jul
26-Jul
31-Jul
5-Aug
10-Aug
15-Aug
20-Aug
25-Aug
30-Aug
4-Sep
9-Sep
14-Sep
19-Sep
24-Sep
29-Sep


JJAS Rainfall (cm)
Before Regression
IMD
After Regression
140
120
100
80
60
40
20
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
Year

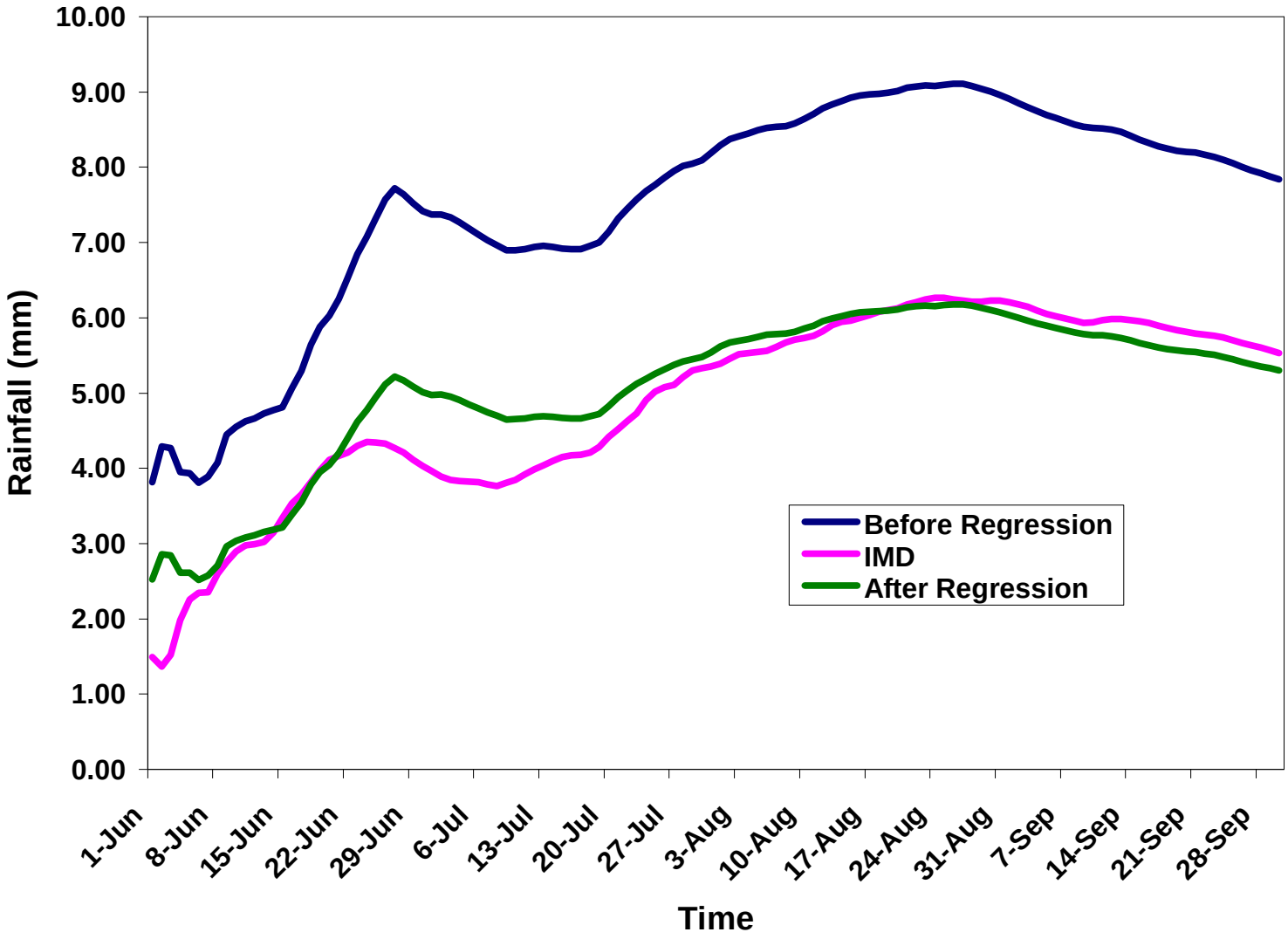
Daily Rainfall Time Series of 1982



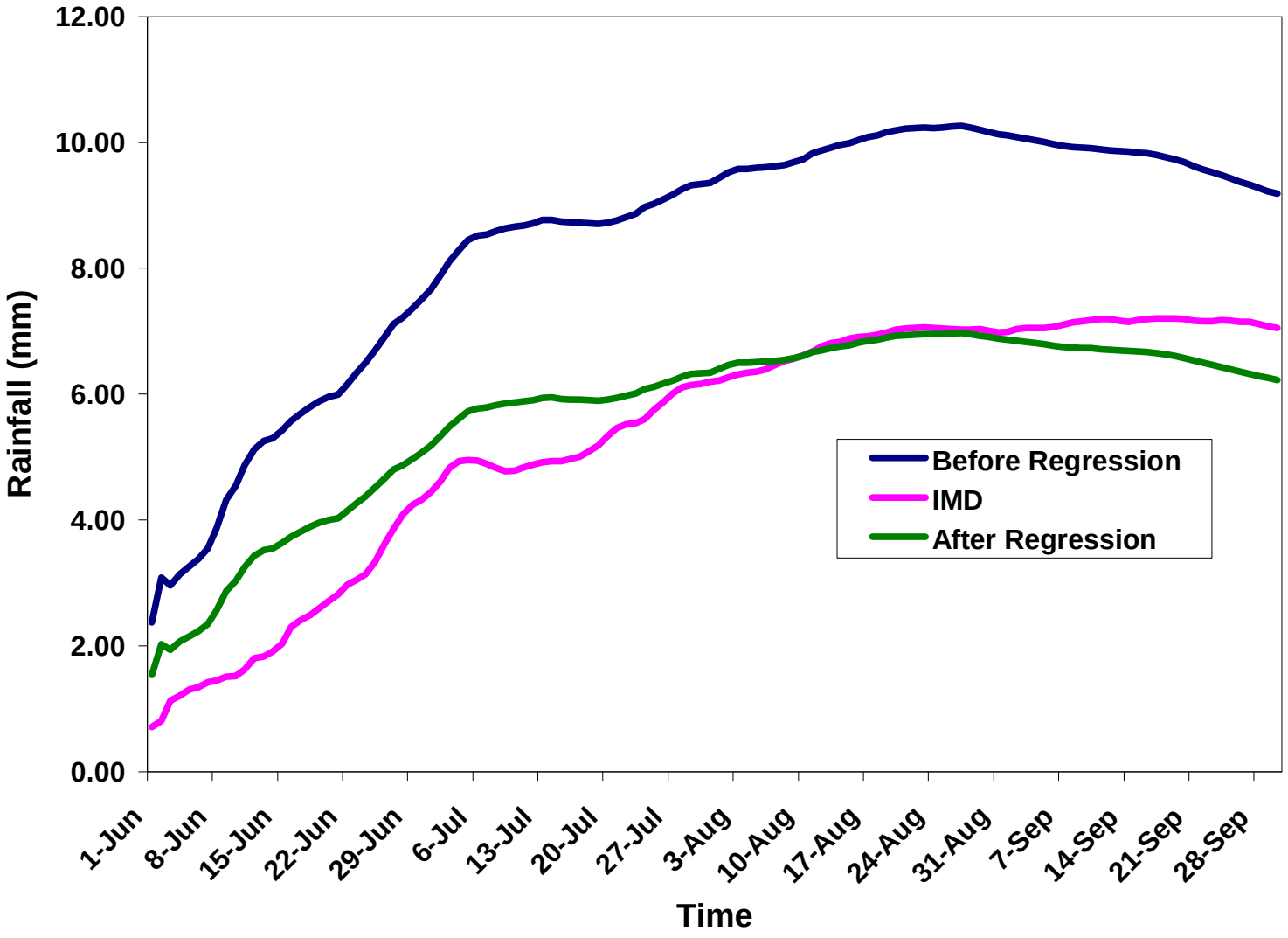
The daily rainfall simulated by the model follows IMD observed rainfall time series but intensities are more. Regression correction reduces errors to large extent.


JJAS Rainfall Anomalies (cm)
Before Regression
IMD
After Regression
Rainfall Anomaly (cm)
40
30
20
10
0
-10
-20
-30
-40
-50
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
Year

JJAS Rainfall (mm) 1982



JJAS Rainfall (mm) 1983



Summary

- **Seasonal runs with initial data of 25th April simulate summer monsoon circulation and rainfall well.**
- **Annual runs with initial data of 1st January simulate too much of summer monsoon rain over land areas.**
- **Analysis indicates warming by about 1.5C at 500hPa which decreases the surface pressure, sets the monsoon winds much early and hence makes the monsoon circulation and rainfall stronger.**
- **Bias correction by regression helps to some extent.**
- **The interplay between the Himalayas and the parameterisation schemes need to be re-examined, especially the PBL and land cover and use schemes.**

Thank You for your Attention