Indian Summer Monsoon Simulations using RegCM in the context of CORDEX

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Scope of the presentation

- *Verification of RegCM3 in simulating the Indian summer monsoon circulation and rainfall*
- *Configuration of RegCM4 for summer monsoon precipitation*
- *CORDEX experiment status*

Simulation of Monsoons 1982-2009
(ICTP RegCM3)

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Initial Conditions: 25th April to 3rd May up to 30th September, 9-member
Horizontal grid distance: 55 Km
Domain chosen: 51^{O}E to 109^{O}E and 3^{O}S to 43^{O}N

Data used:

USGS Global 30 Arc-Sec. elevation datasets at 30' resolution to create terrain

USGS Global GLCC dataset at 30' resolution to create vegetation or landuse file

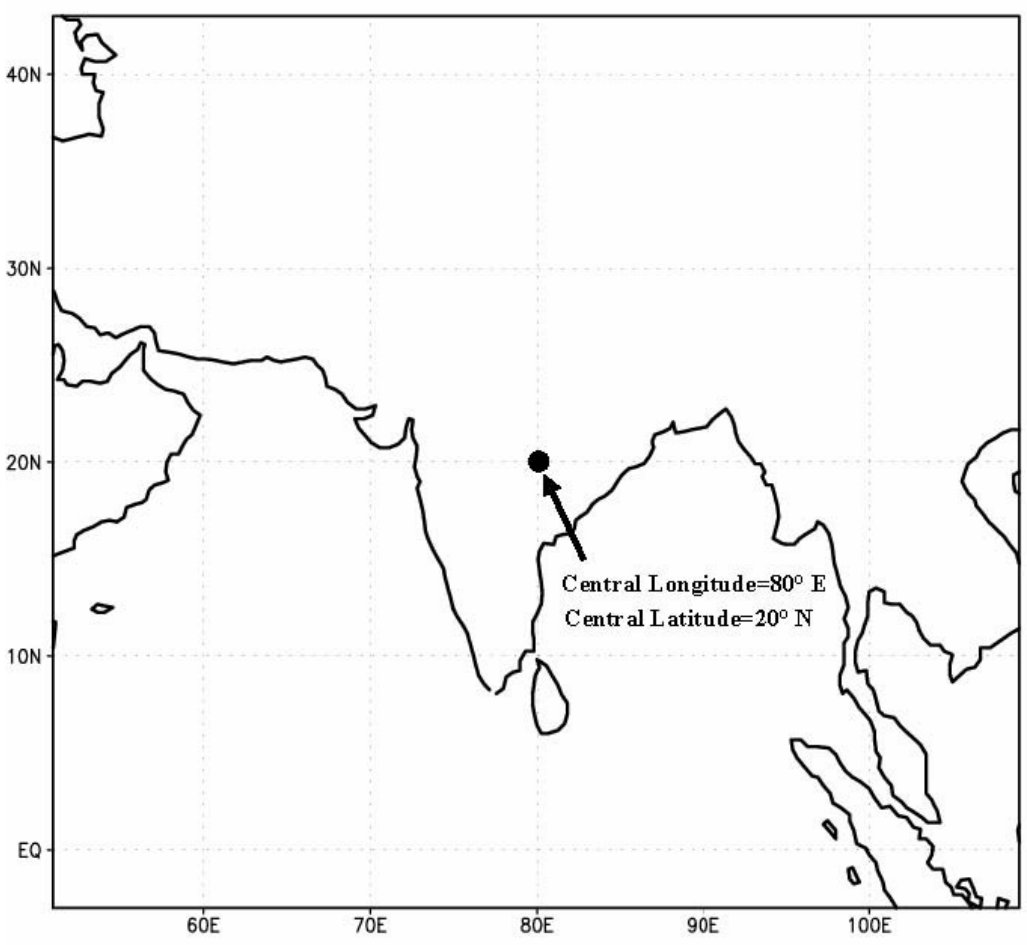
Weekly analysis OISST available from NOAA for integration

NCEP Reanalysis (NNRP1) are used for setting the initial and boundary conditions

Salient features of RegCM3

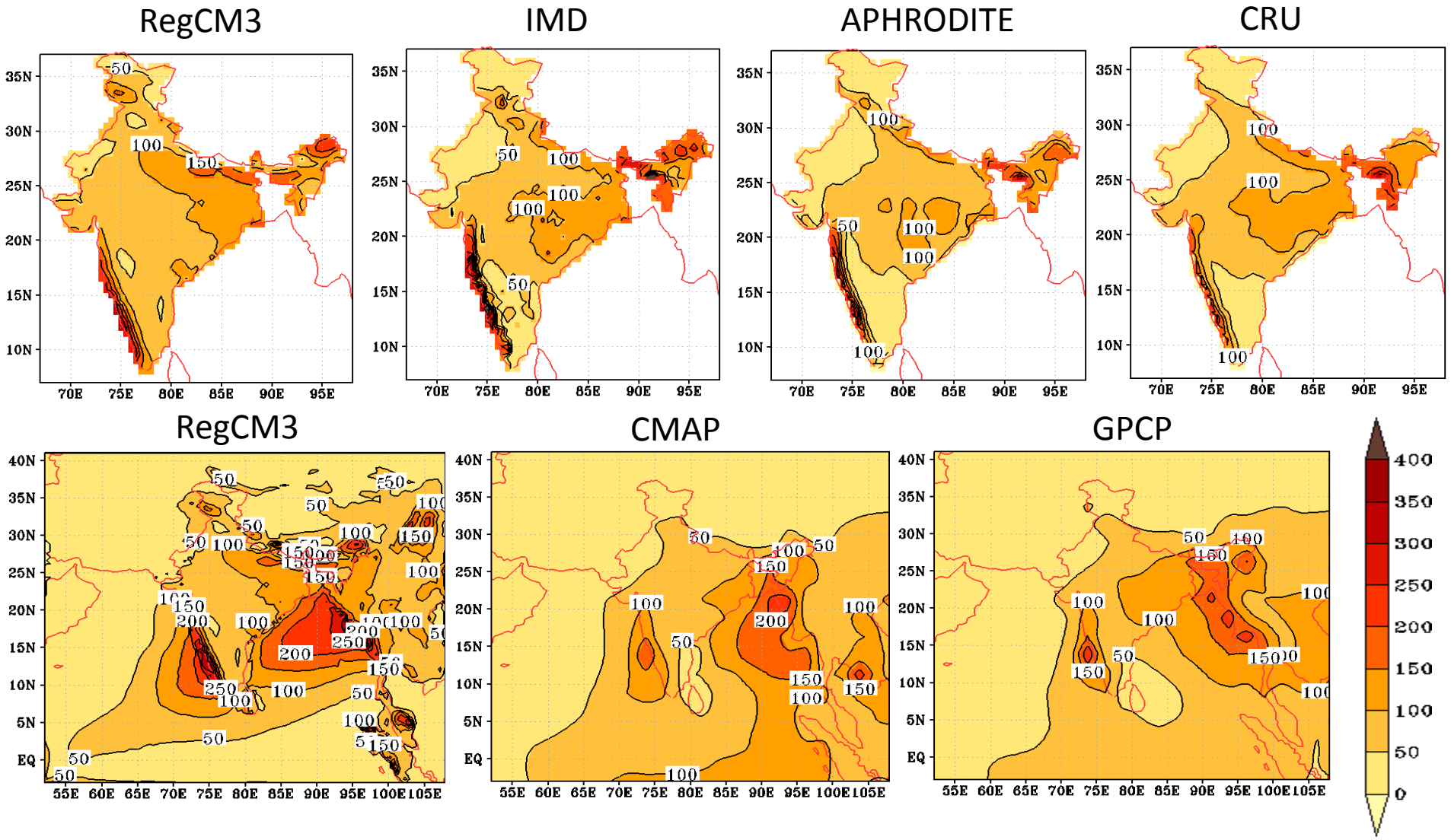
Prognostic Variables	u, v, ω, T, RH and ht
Horizontal Resolution	(118x99), 0.5 equivalent grids (55 Km)
Vertical Resolution	18 σ levels
Time step	150 seconds
Radiation Scheme	NCAR CCM3
Land Surface Physics	Biosphere-Atmosphere Transfer Scheme (BATS)
Planetary Boundary Layer Parameterization	Holtslag Scheme
Convective precipitation scheme	Fritsch-Chappell as the closure scheme in the Grell scheme
Large-Scale Precipitation Scheme	Subgrid Explicit Moisture Scheme (SUBEX)
Ocean flux Parameterization	Zeng Scheme
Lateral Boundary Treatment	Exponential Relaxation

Model domain used in RegCM3 simulations



- **Central Lat and Lon is 20°N, 80°E**
- **99 x 118 points along x-y direction**
- **Domain covers 51° E to 109° E and 3°S to 43°N with 55 km grid distance**

Climate of JJAS precipitation (cm) in RegCM3 and observation



Percentage difference in JJAS precipitation in RegCM3 and Observations

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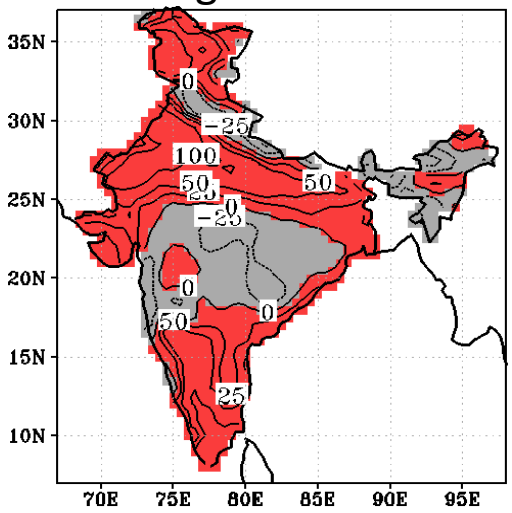
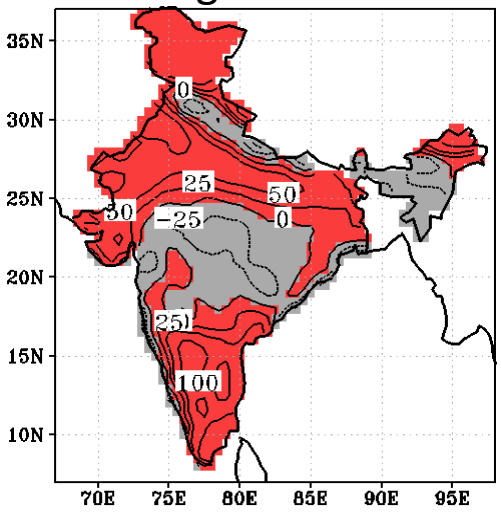
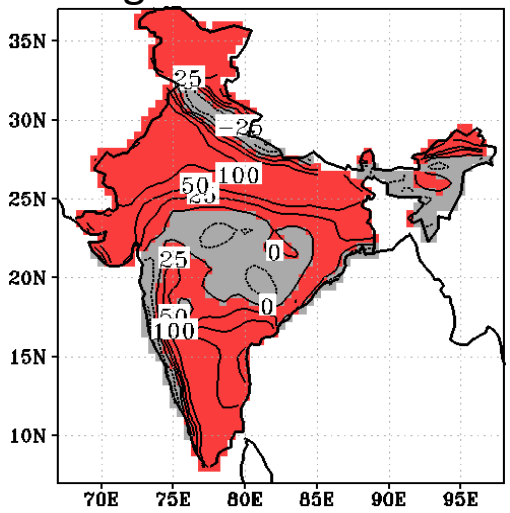
RegCM3-IMD



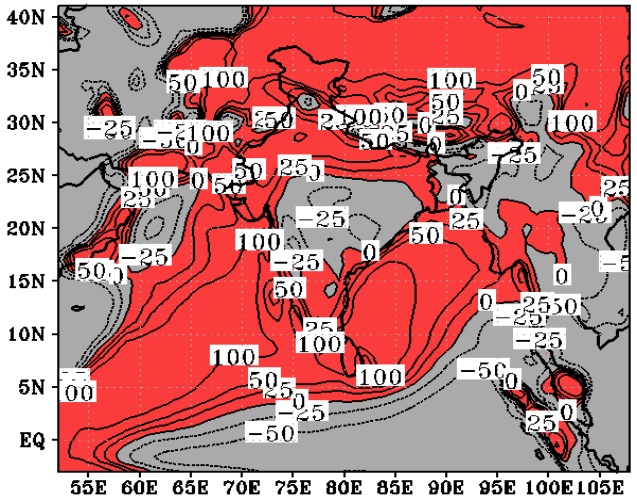
RegCM3-CRU



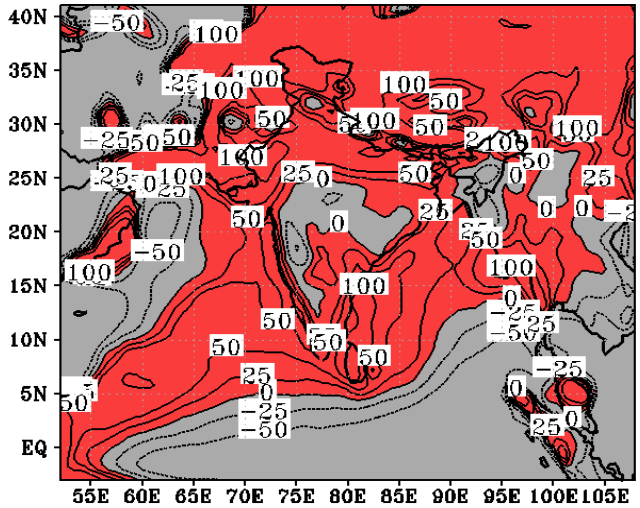
RegCM3-APHRODITE

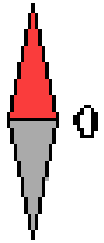


RegCM3-GPCP

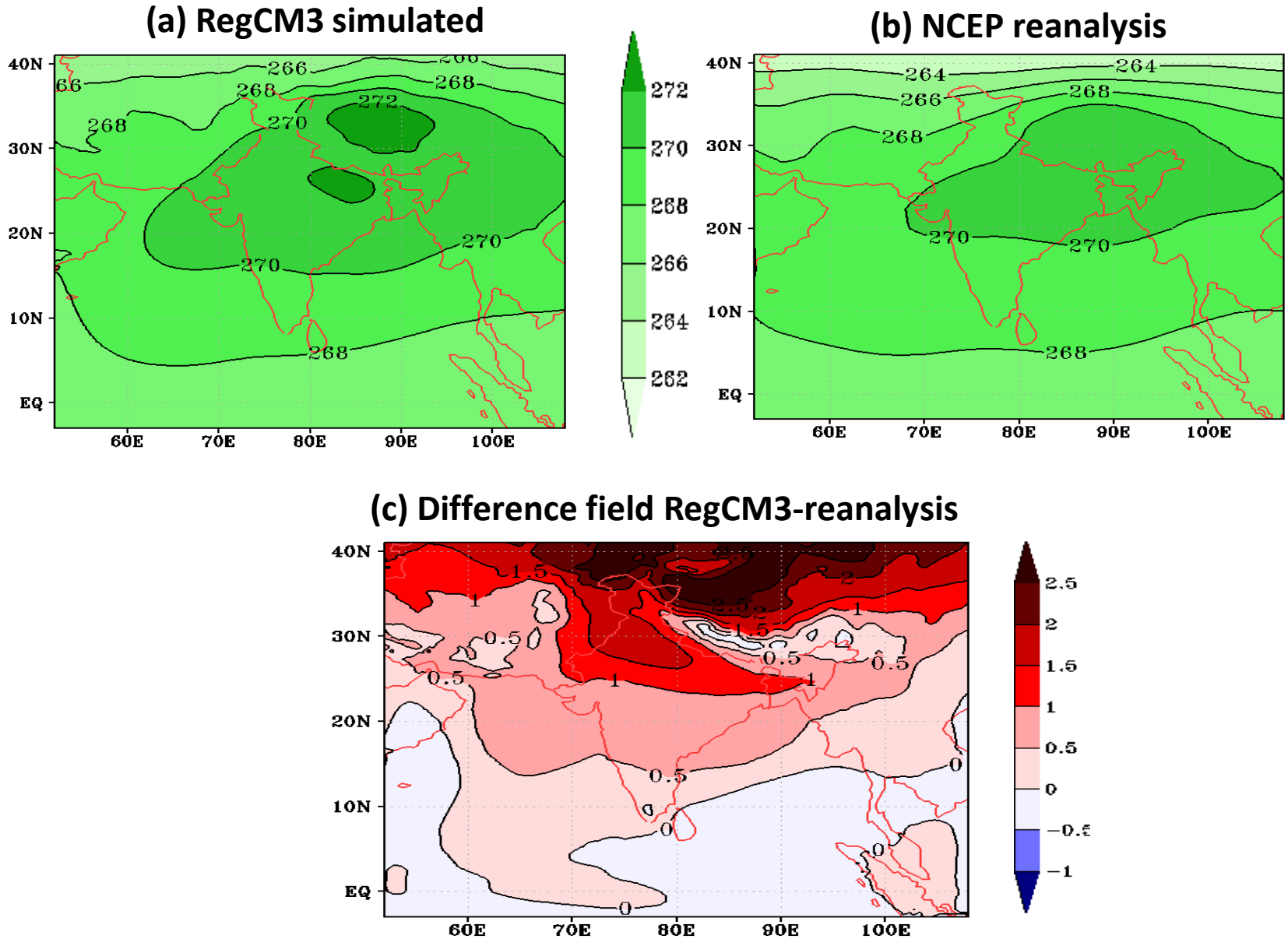


RegCM3-CMAP





JJAS 500 hPa temperature (K) for the period 1982-2009



JJAS Surface Temperature (°C) for the period 1982-2009

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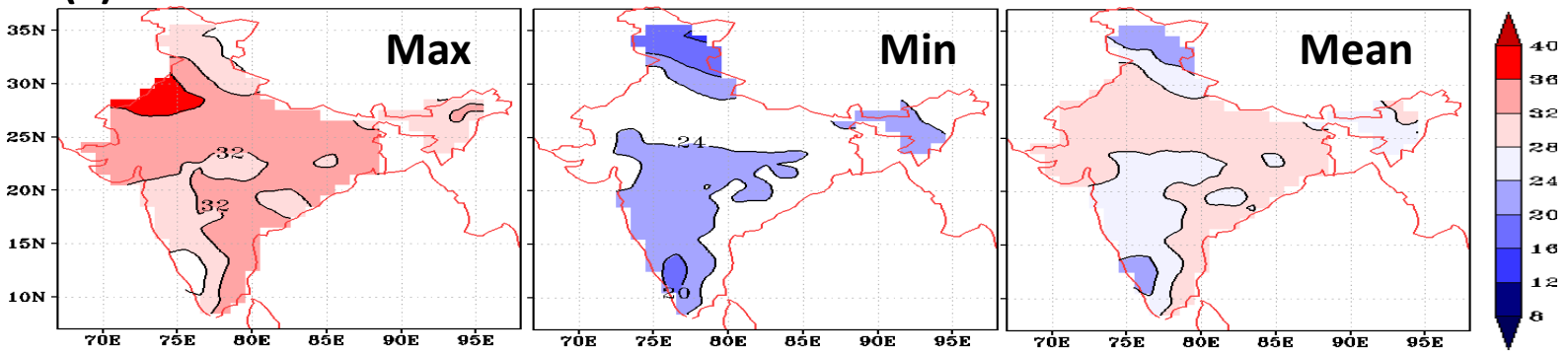
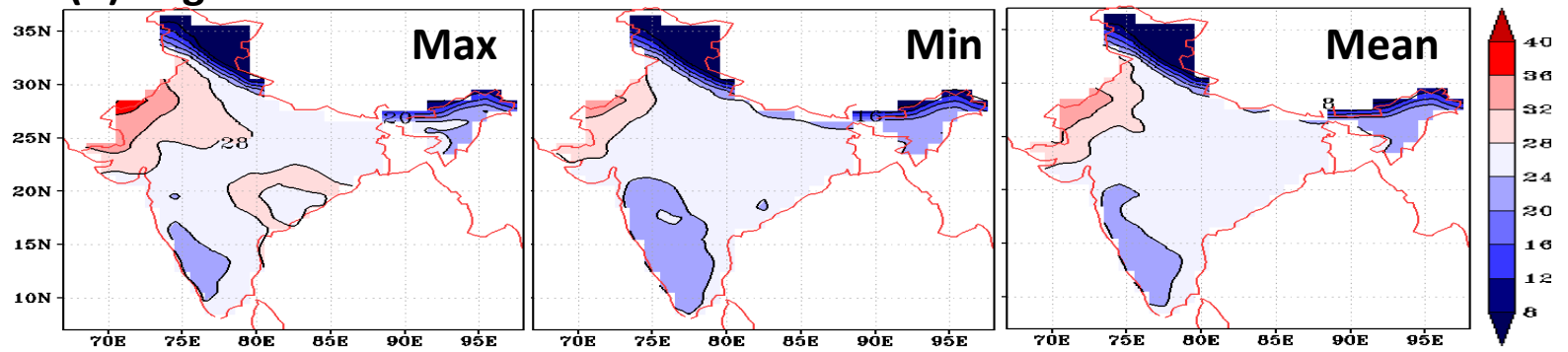
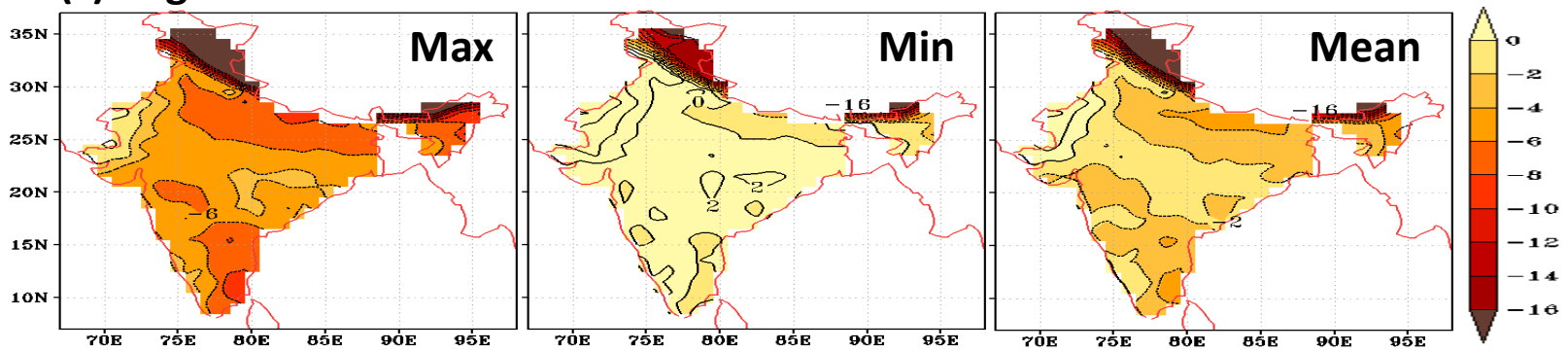
(a) IMD



(b) RegCM3

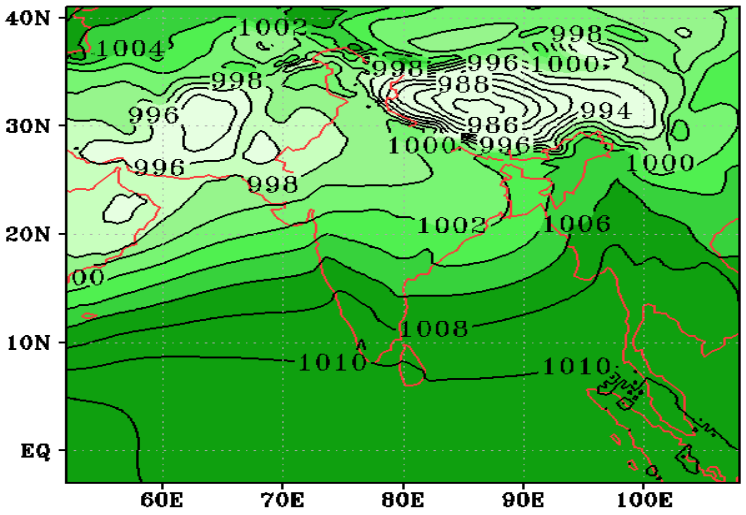


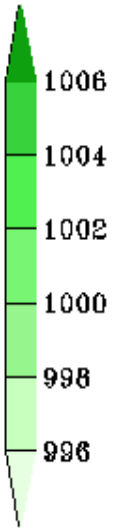
(c) RegCM3-IMD



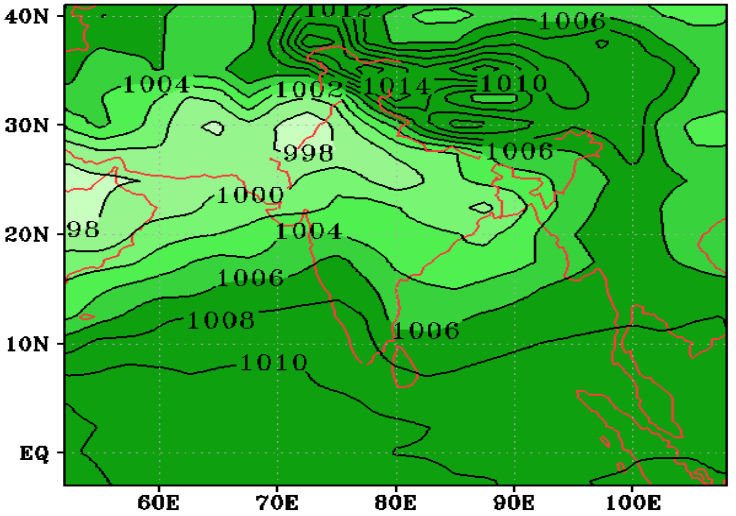
Mean Sea Level Pressure in July for the period 1982-2009

(b) RegCM3 simulated

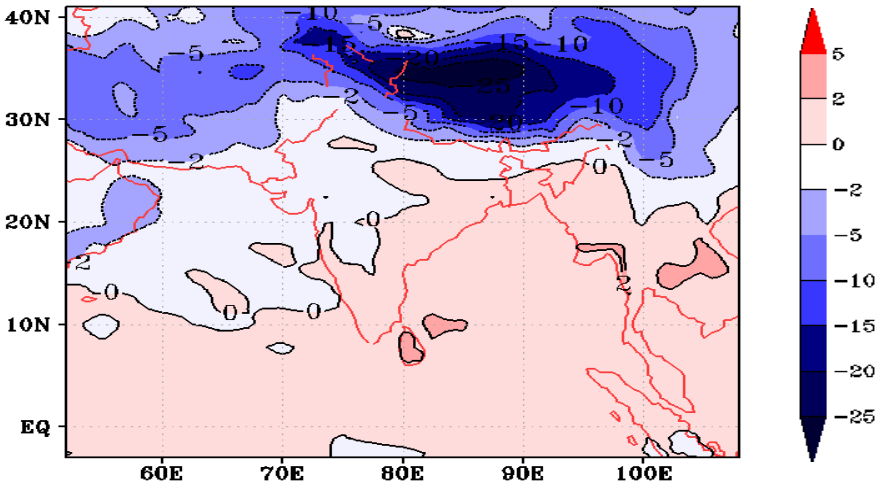




(a) NCEP Reanalysis



(c) Difference field RegCM3-reanalysis



JJAS 850hPa wind (m/s) for the period 1982-2009

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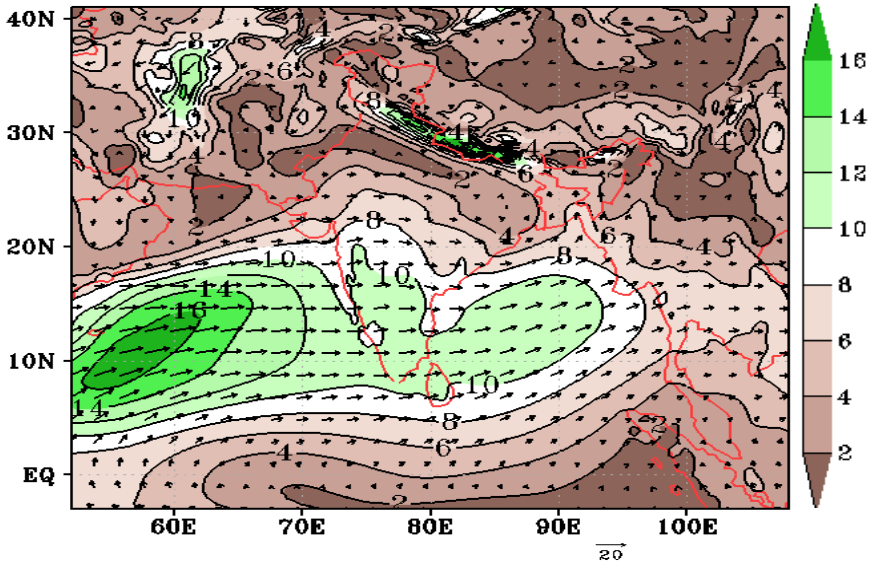
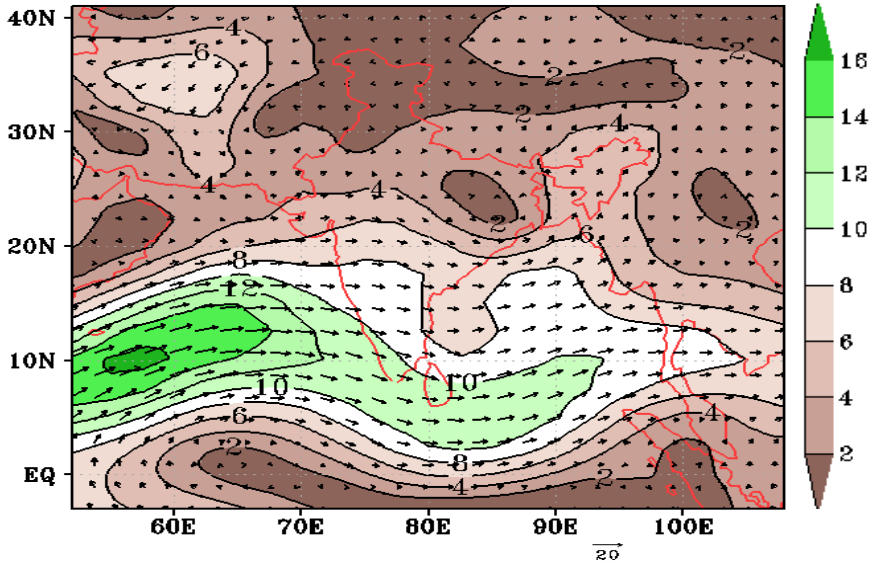
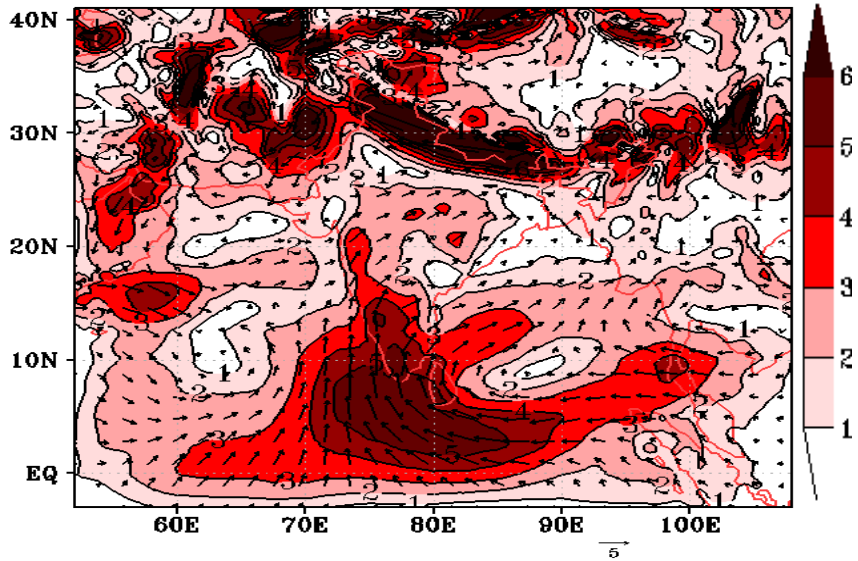
(a) RegCM3 simulated



(b) NCEP reanalysis



(c) Difference field RegCM3-reanalysis



JJAS 200 hPa wind (m/s) for the period 1982-2009

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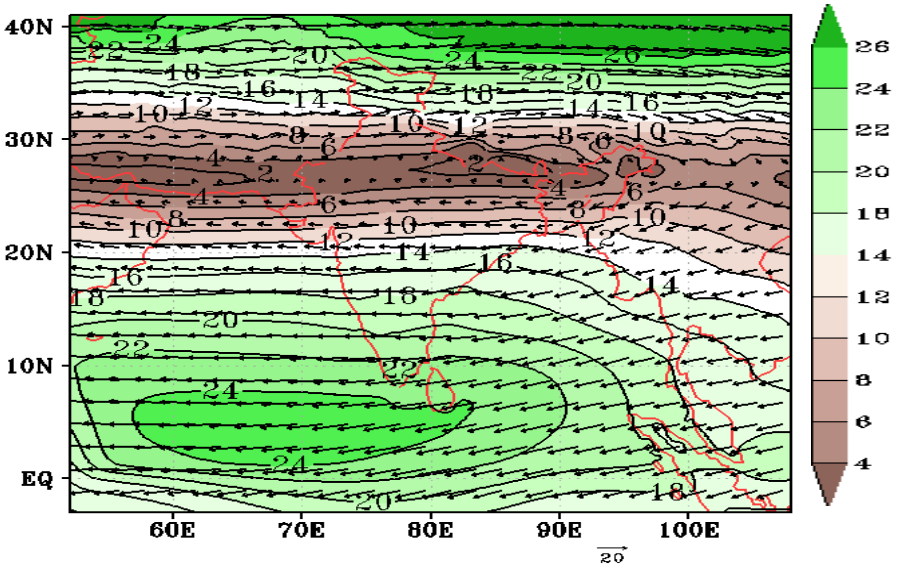
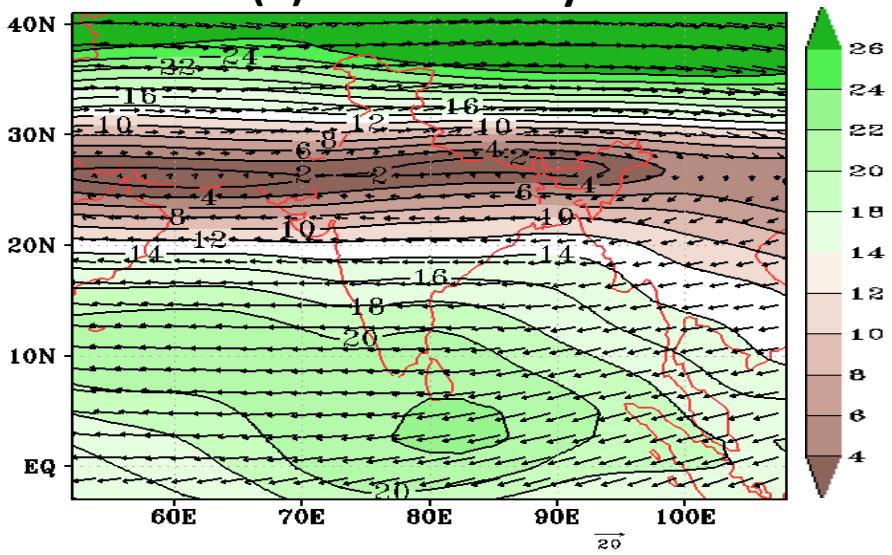
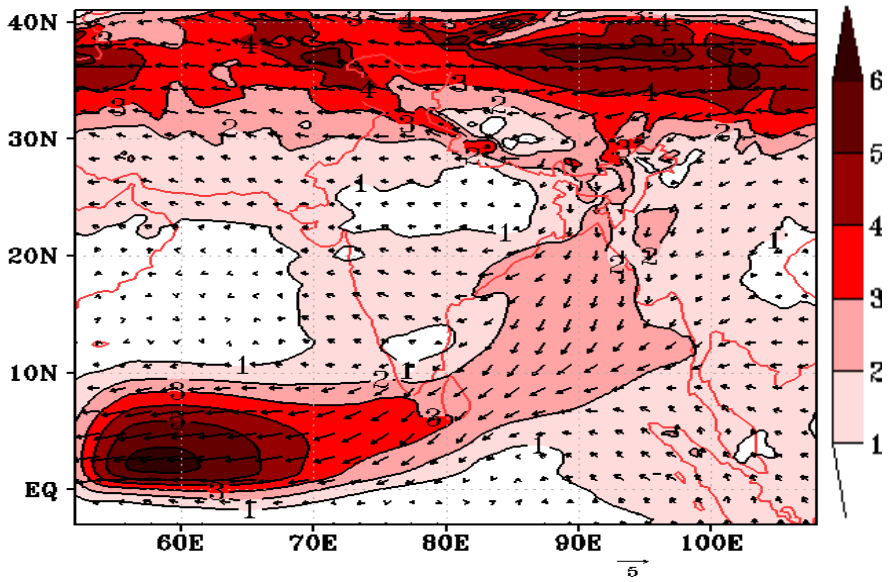
(a) RegCM3 simulated

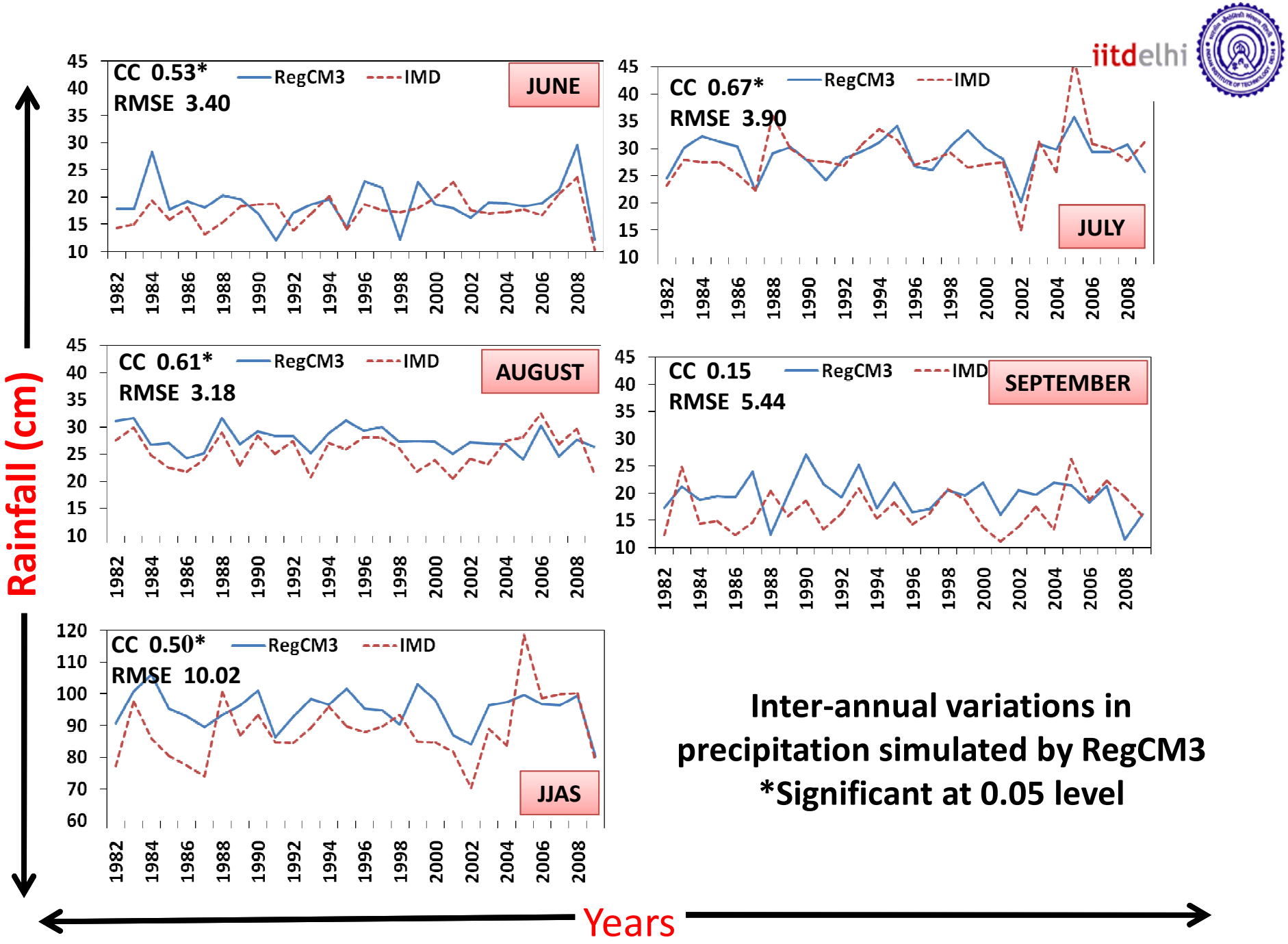


(b) NCEP reanalysis

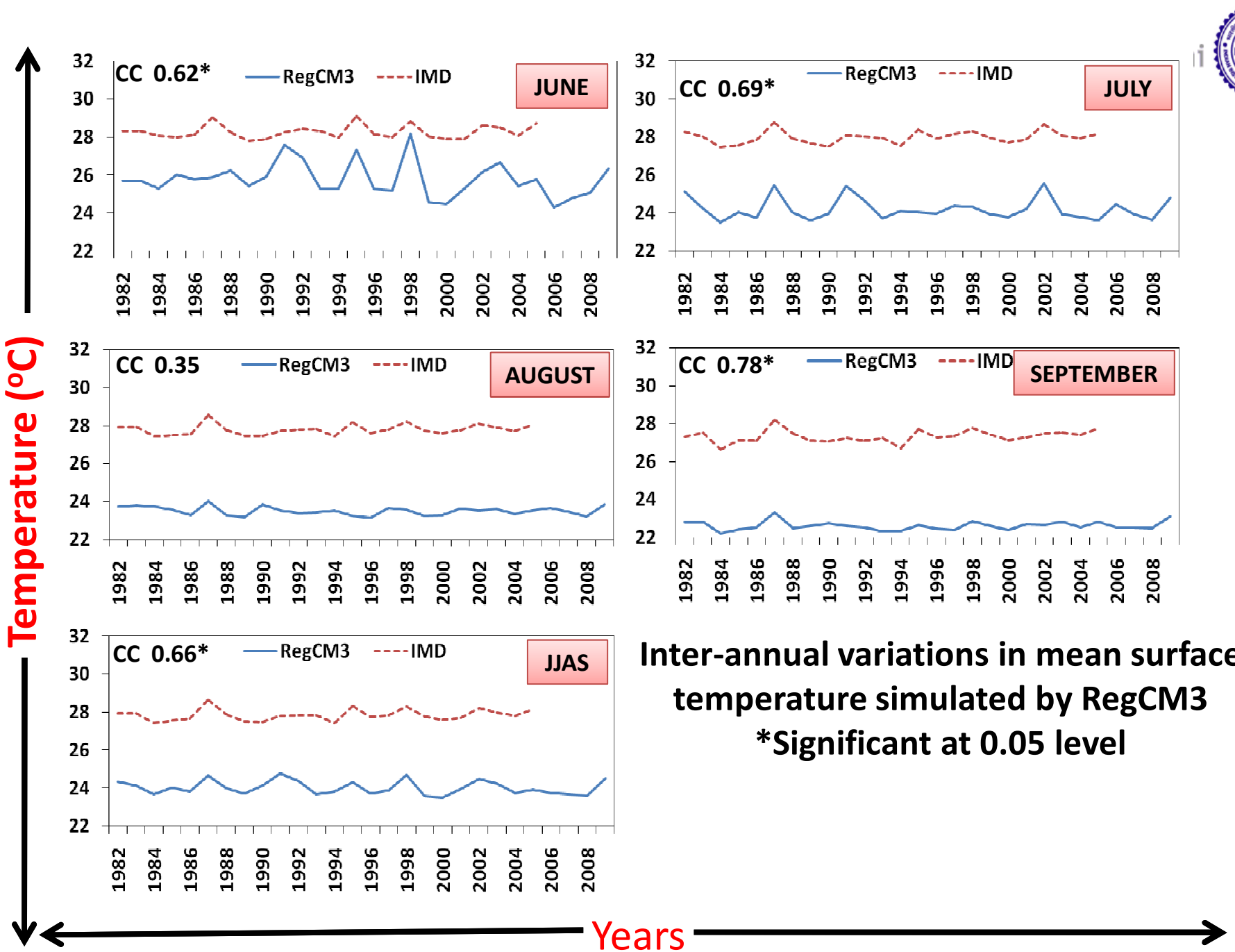


(c) Difference field RegCM3-reanalysis



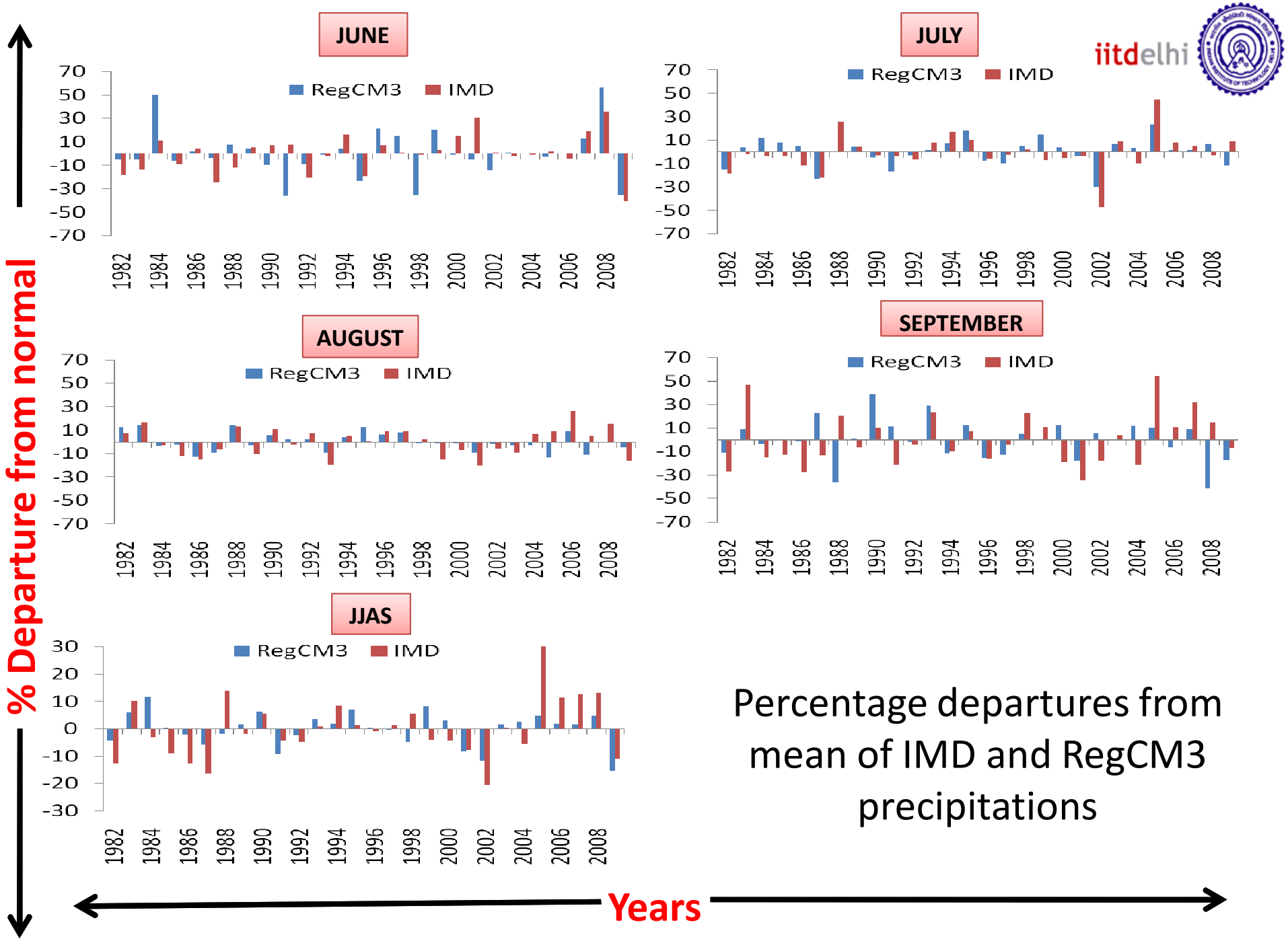


Inter-annual variations in precipitation simulated by RegCM3
***Significant at 0.05 level**



Inter-annual variations in mean surface temperature simulated by RegCM3

***Significant at 0.05 level**


JUNE
JULY
AUGUST
SEPTEMBER
JJAS
RegCM3
IMD
% Departure from normal
Years
Percentage departures from mean of IMD and RegCM3 precipitations
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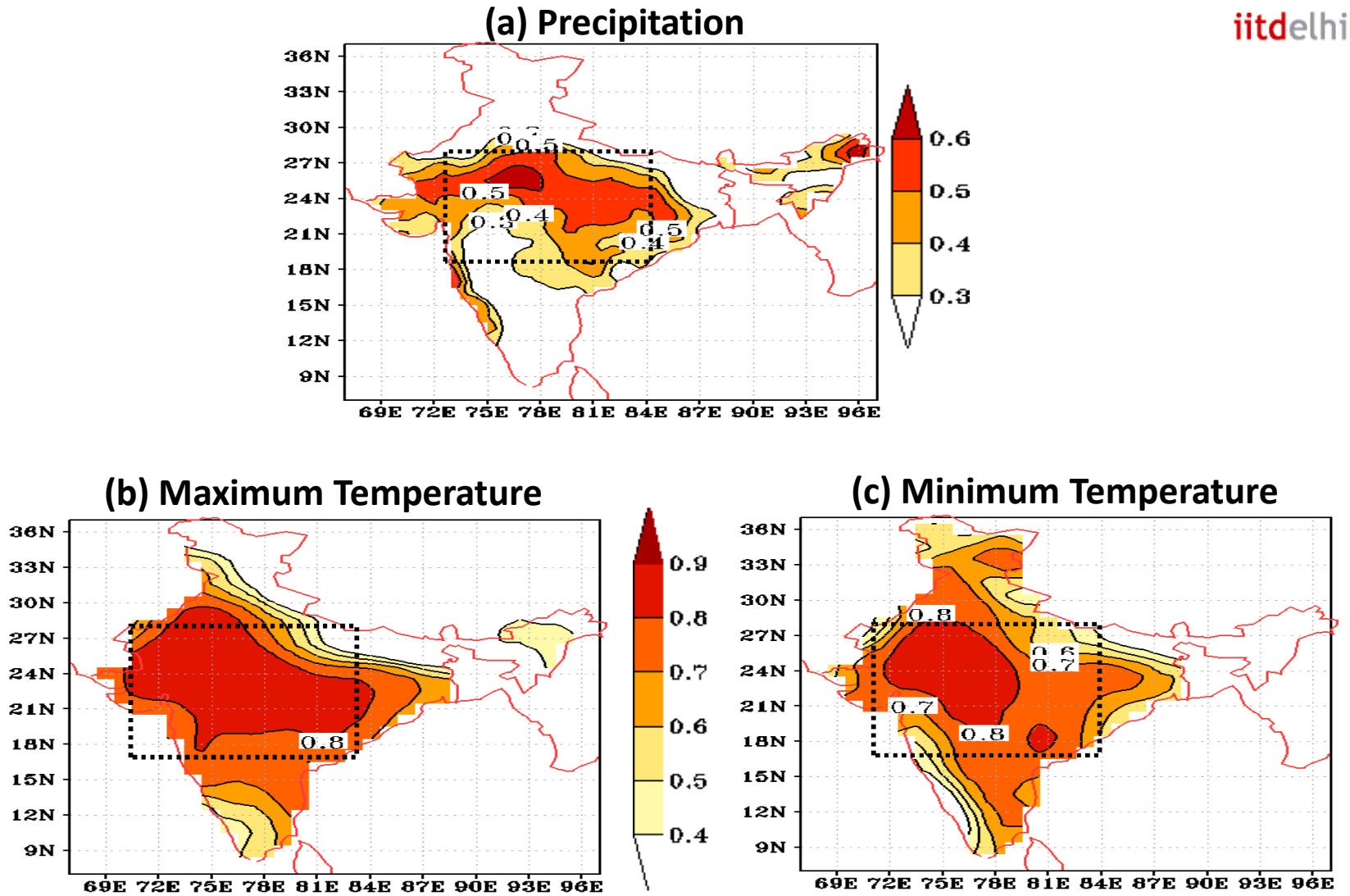
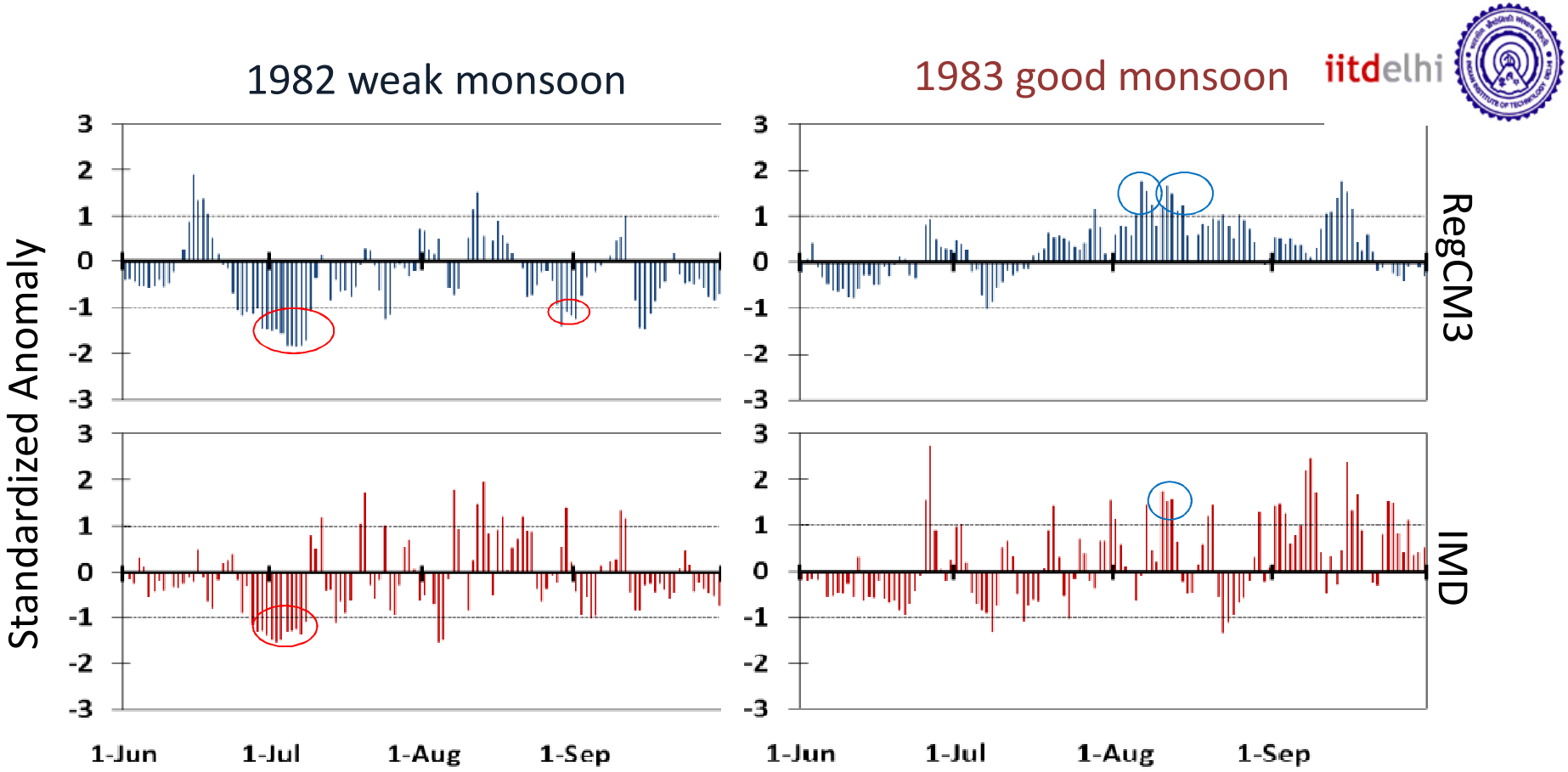


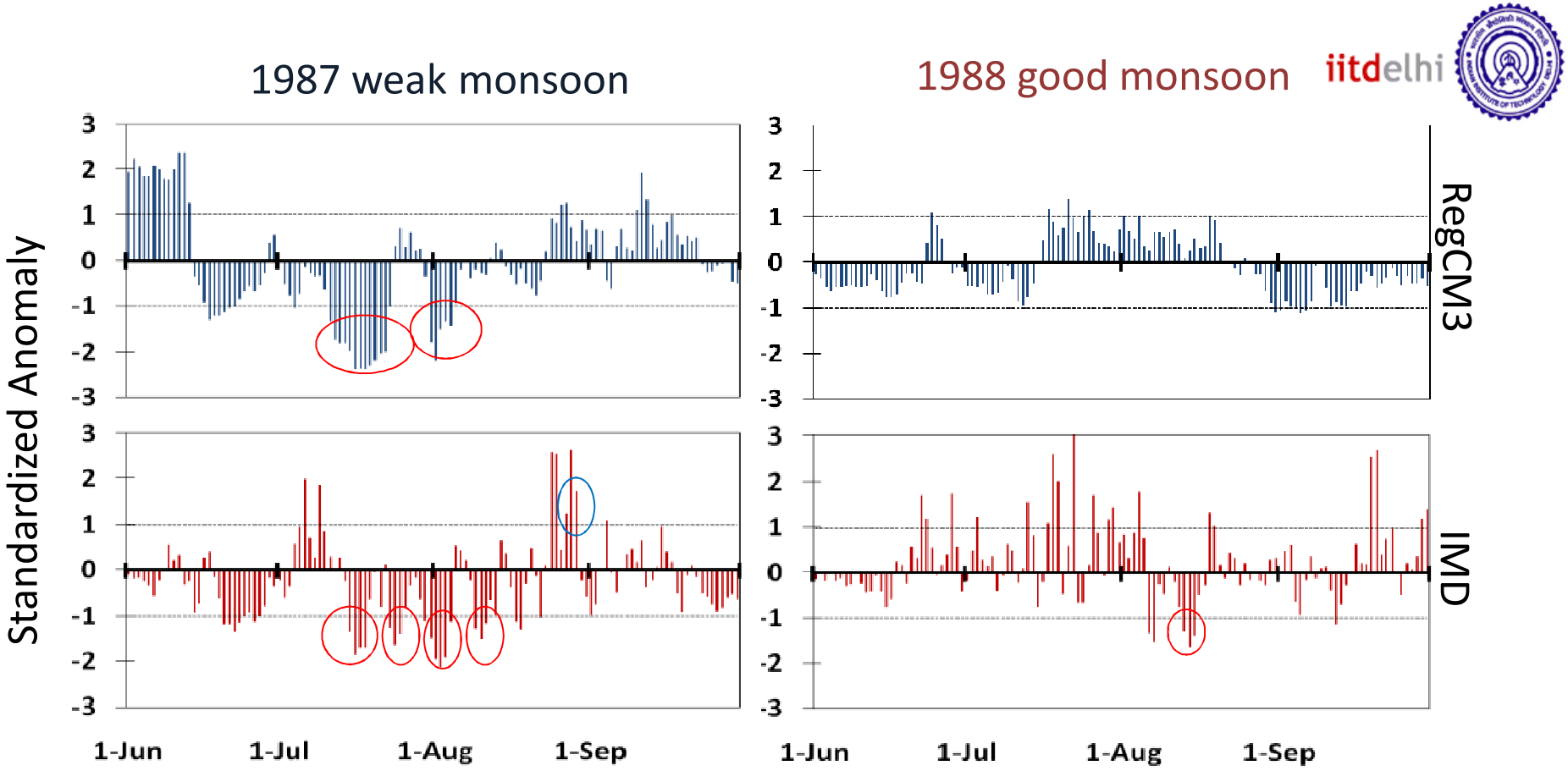
Temporal correlation coefficients (CCs) between IMD observed and RegCM3 simulated JJAS (a) precipitation, (b) maximum surface temperature and (c) minimum surface temperature. The contours are obtained by applying 9-point smoothing to the gridded values. CCs are significant at 5% level

For the evaluation of intra-seasonal oscillation, four pairs of contrasting monsoon years have been chosen:

1982-83, 1987-88, 1992-93, 2002-03



Monsoon active spells (blue circle) and break spells (red circles) in the contrasting monsoon years are shown over central India (15-25°N, 75-85°E), the monsoon core zone.



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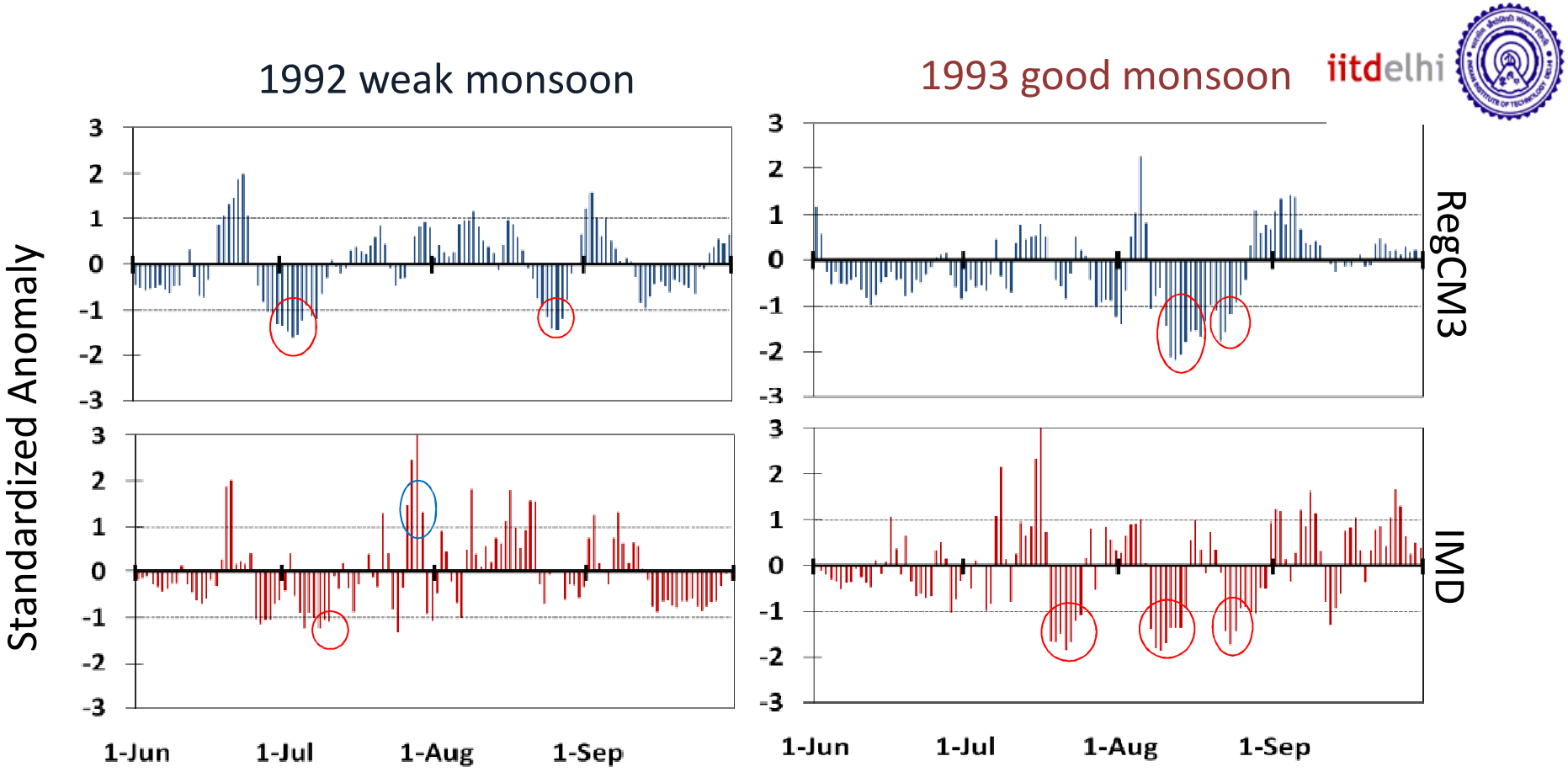

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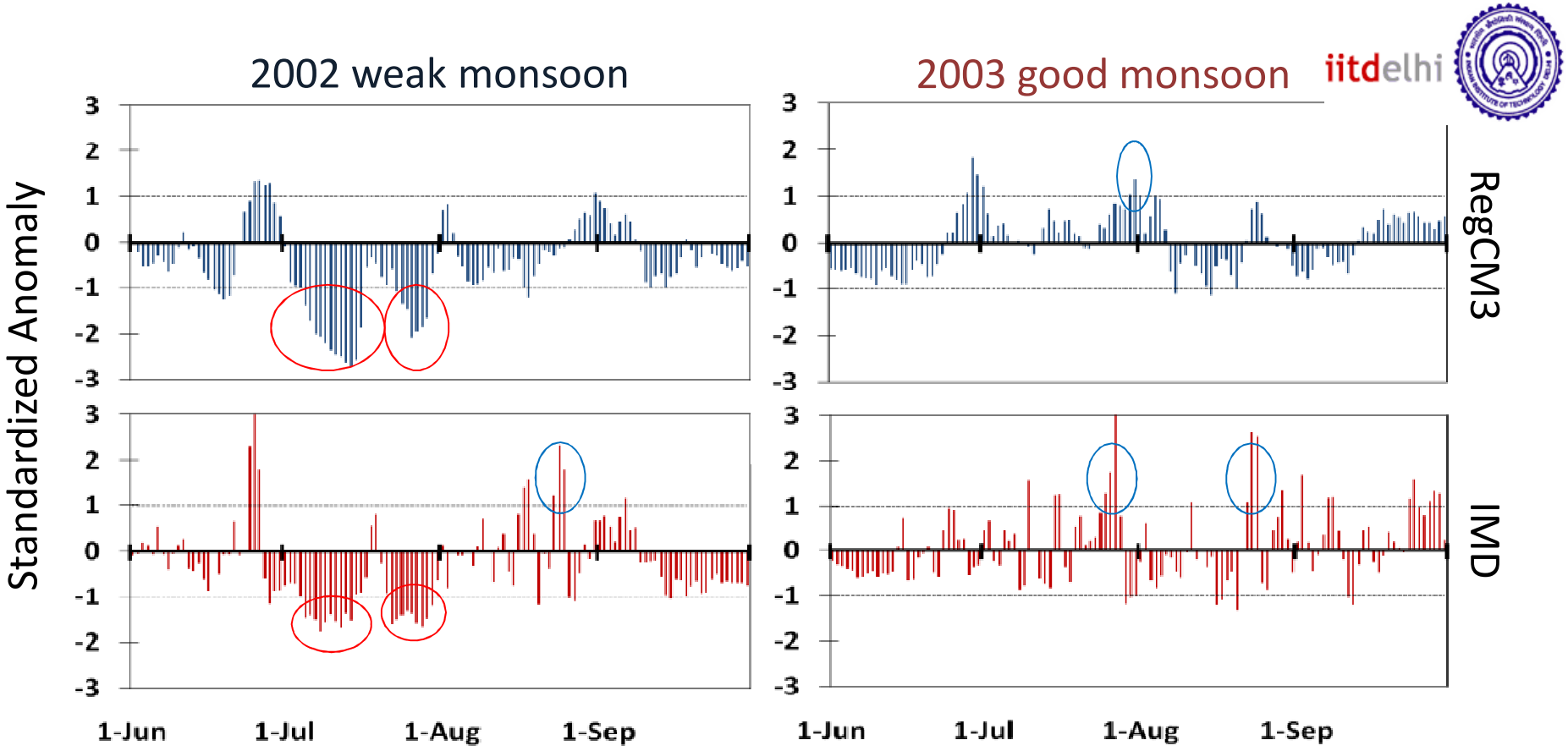

Monsoon active spells (blue circle) and break spells (red circles) in the contrasting monsoon years are shown over central India (15-25°N, 75-85°E), the monsoon core zone.

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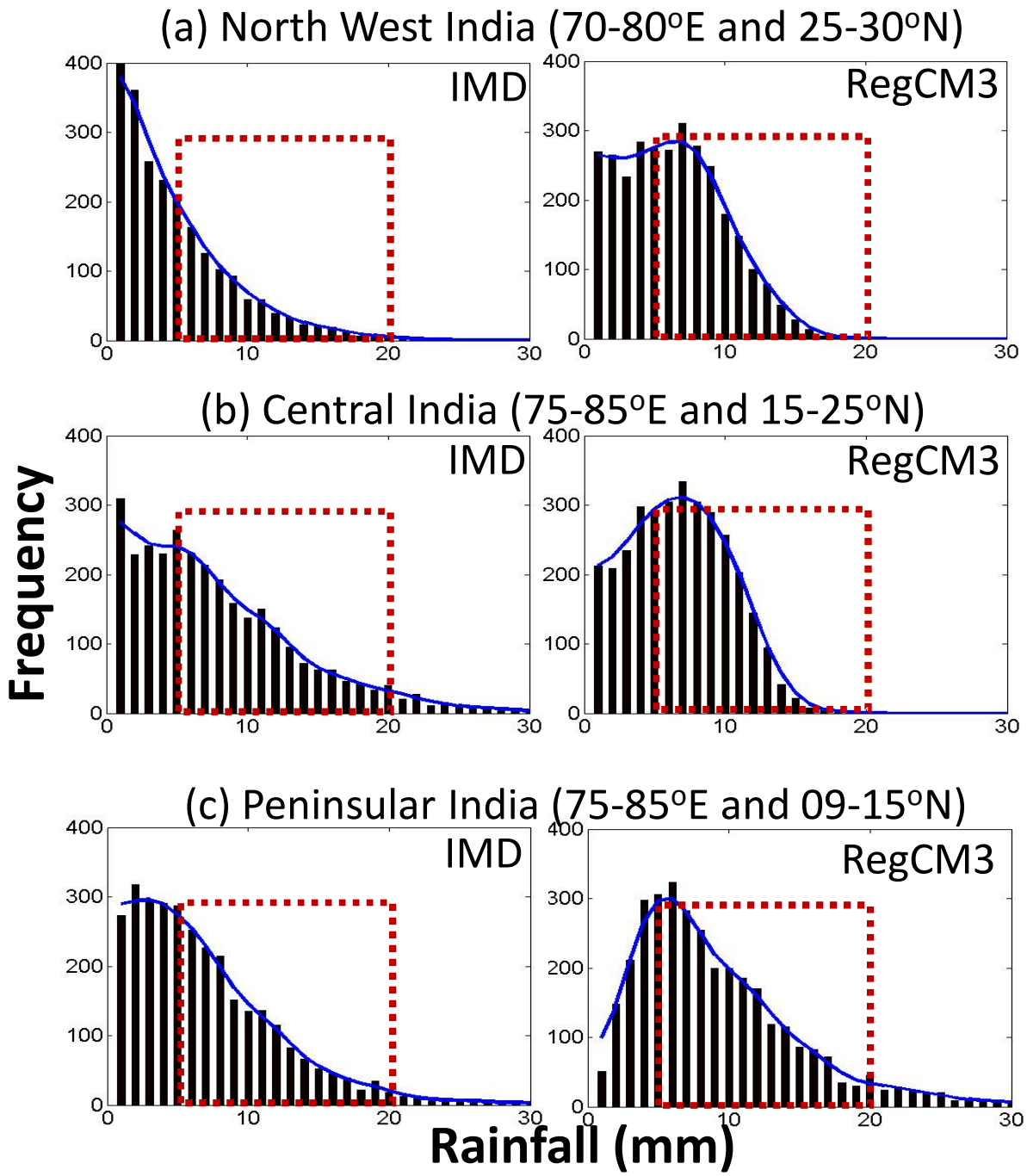
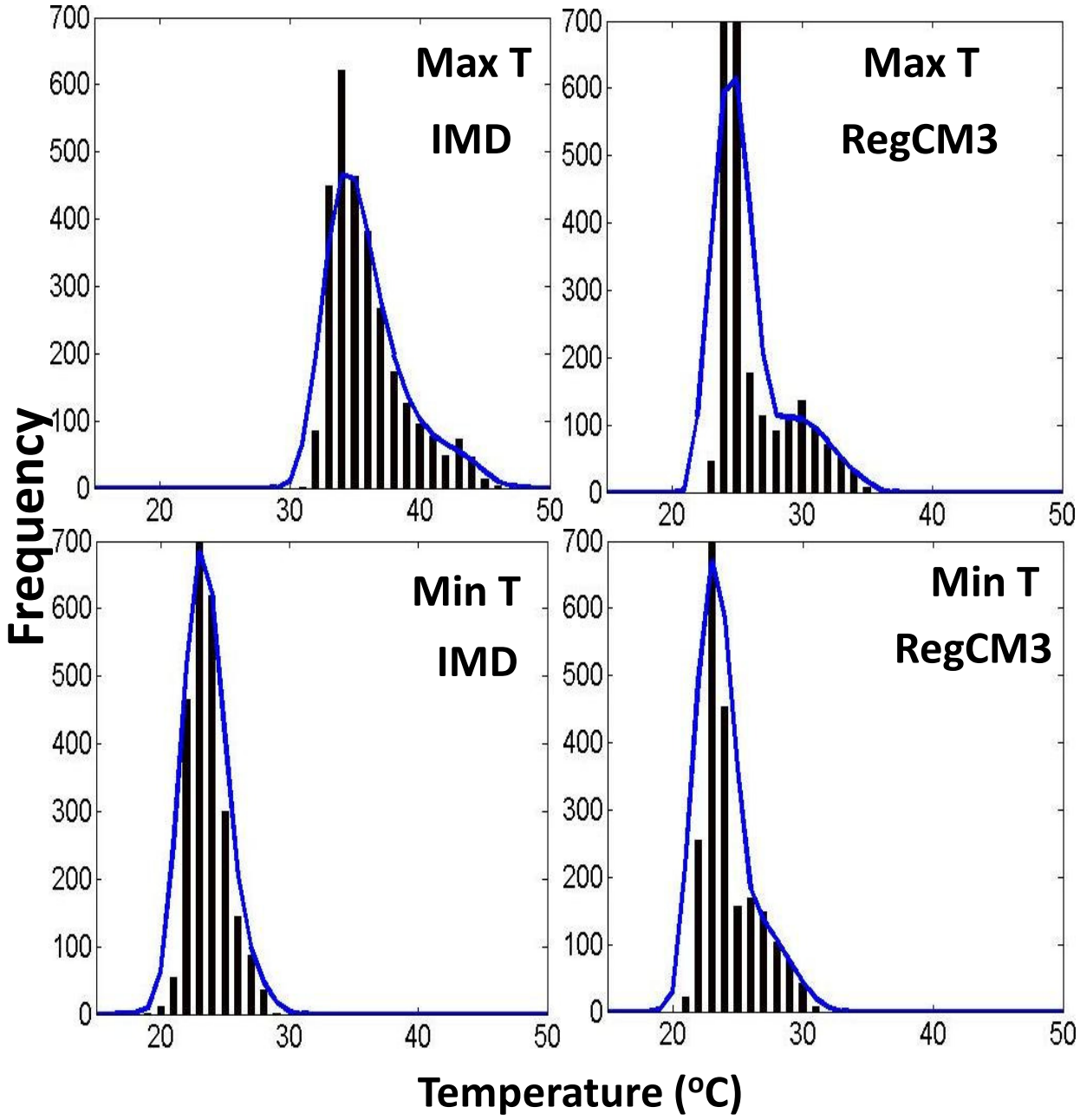
Total active and break events in contrasting years

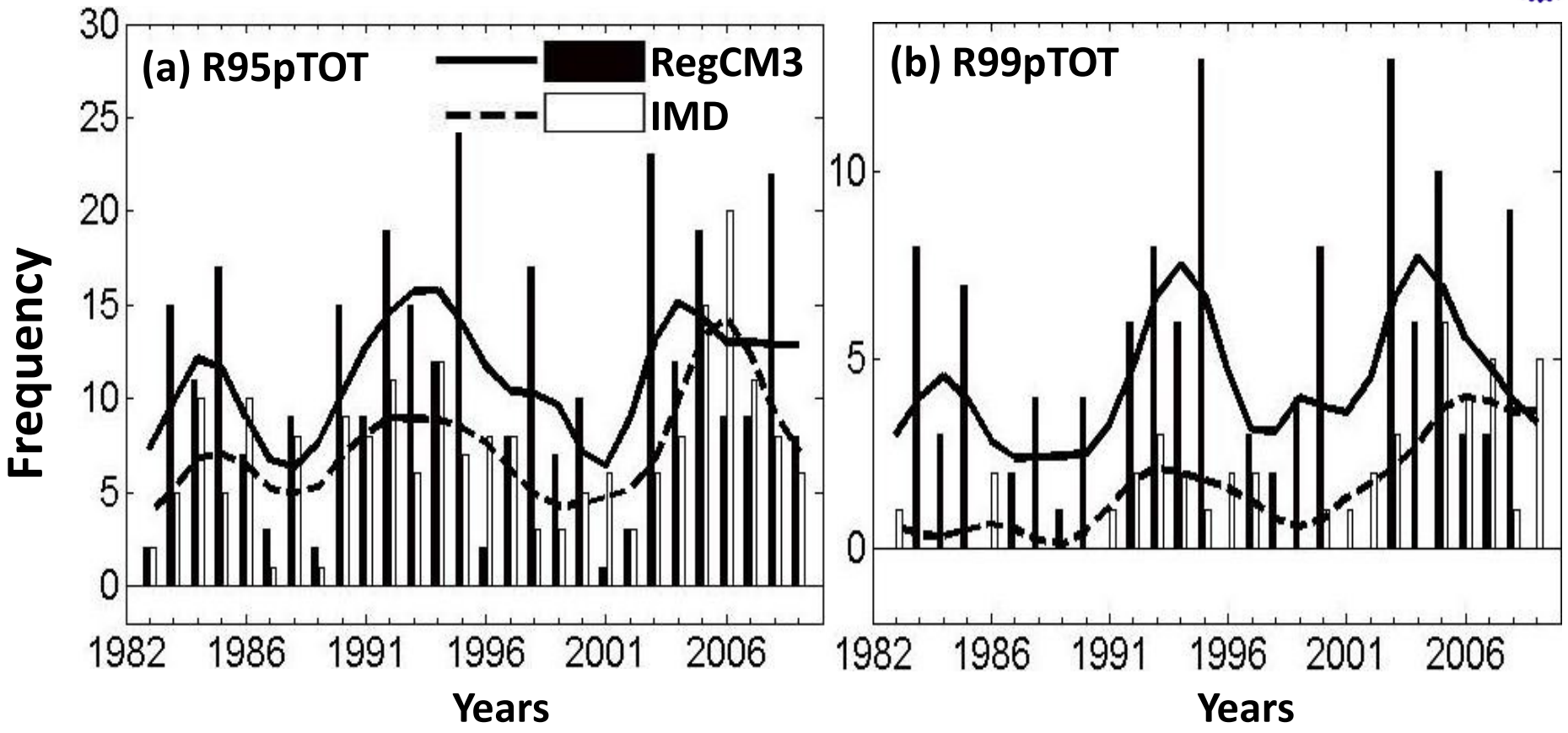
	RegCM3	IMD
Break spells	10	13
Active spells	3	7
Break days	71	72
Active days	12	22



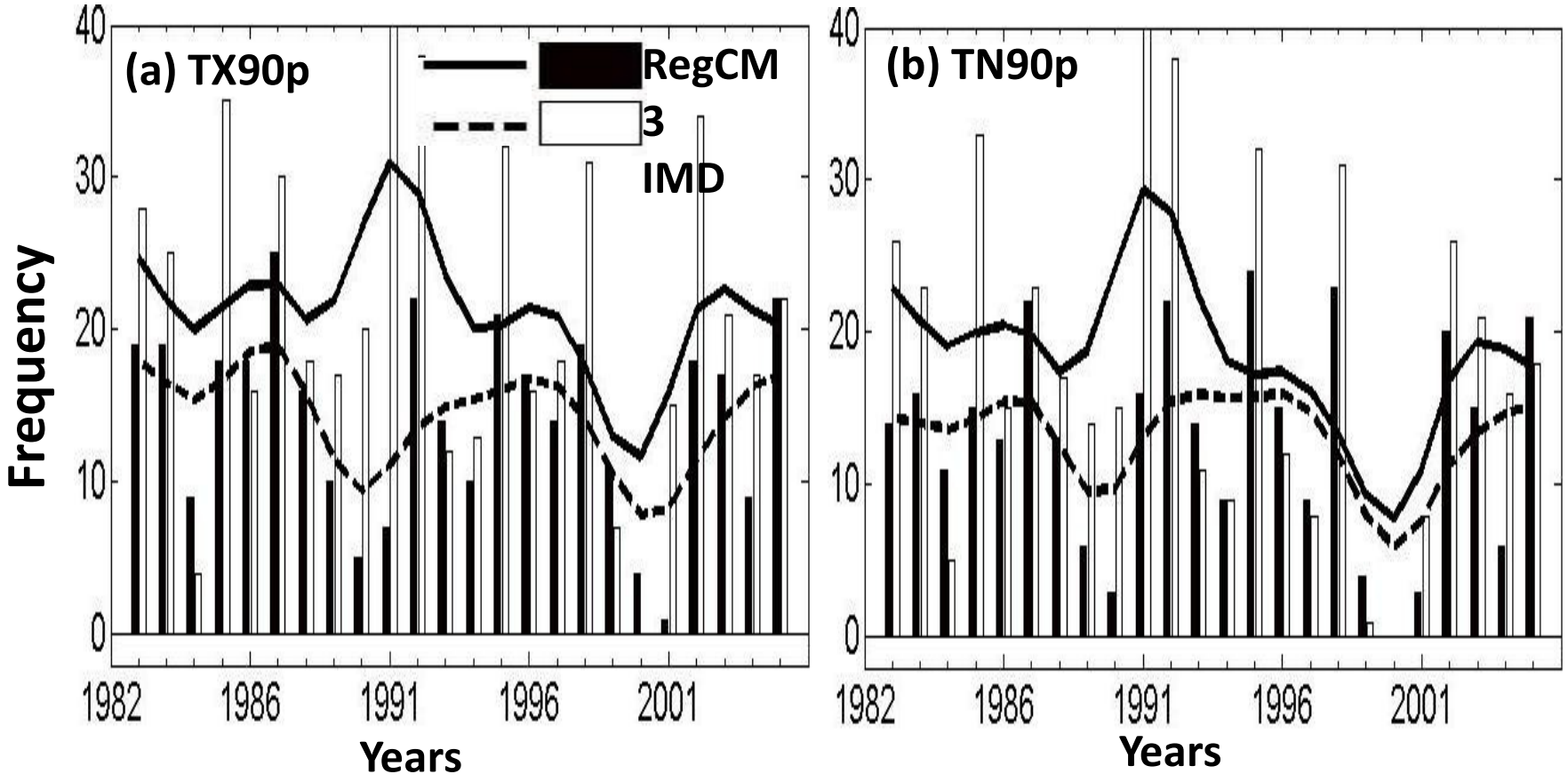
Frequency distribution of area weighted average daily rainfall from June to September. The smooth curves are obtained using 5-point binomial filter.



Frequency distribution of RegCM3 simulated and IMD observed area weighted daily maximum and minimum temperatures from June to September The smooth curves are obtained using 5-point binomial filter.



Frequency of yearly occurrence of (a) very wet days and (b) extremely wet days in JJAS in the period 1982-2009 over the Central India domain (70-86°E and 19-25°N) are shown in bars. The smooth curves are obtained using 5-point binomial filter



Frequency of yearly occurrence of (a) warm days and (b) warm nights in JJAS in the period 1982-2005 over the Central India domain (70-83°E and 17-28°N) are shown in bars. The smooth curves are obtained using 5-point binomial filter

Results from RegCM3 simulations

- **Best simulation of rainfall and temperature by RegCM3 is over the Central India.**
- **Dry bias is observed over Central India and wet over Northwest and Peninsular India.**
- **In the model simulations, shift in MSLP is observed over the foothills of Himalayas and Tibet.**
- **Monsoon breaks in the model are of longer life span that those actually observed.**
- **The model simulates less number of active spells in central India than those observed.**
- **The inter-annual characteristics of both the rainfall and temperature extremes simulated by RegCM3 are well in phase with those observed**

RegCM4.1.1

- It is fourth generation of RegCM
- It was released in June 2011

New features of RegCM4.1.1

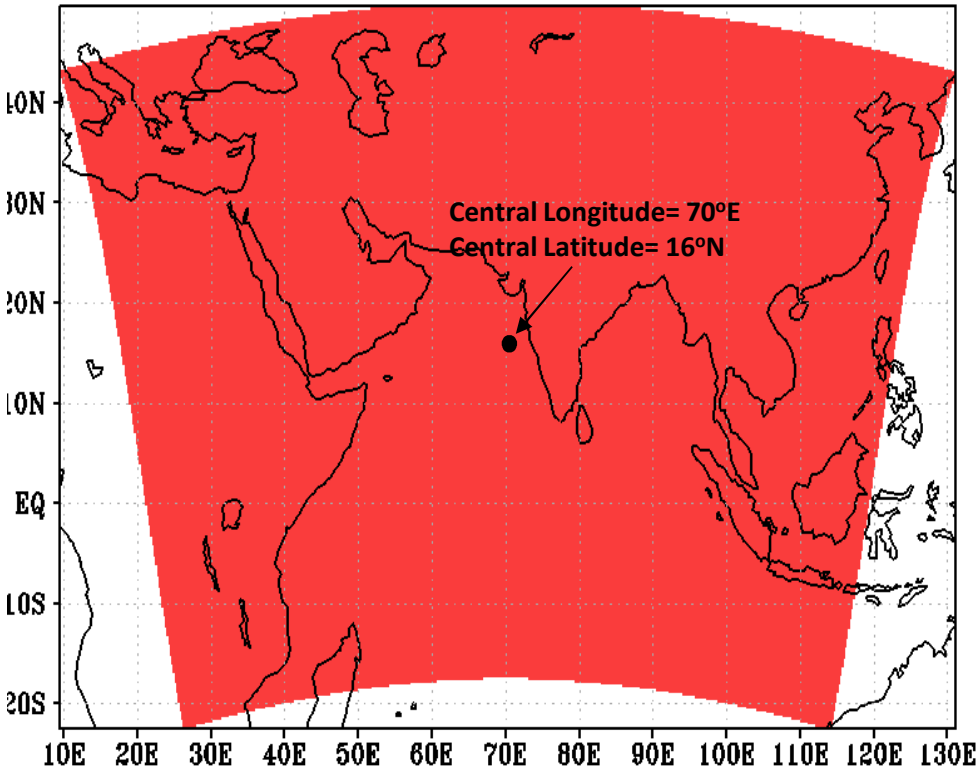
- Includes new land surface, planetary boundary layer and air-sea flux schemes
- A mixed convection and tropical band configuration
- Modifications to the radiative transfer and boundary layer schemes
- Full upgrade of the model code towards improved flexibility, portability and user friendliness

Salient features of RegCM4.1.1

Horizontal Resolution	(160x224), 0.5 equivalent grids (50 Km)
Vertical Resolution	18 σ levels
Time Step	90 seconds
Domain Projection	Rotated Mercator
Radiation Scheme	NCAR CCM3
Land Surface Physics	Biosphere-Atmosphere Transfer Scheme (BATS)
Planetary Boundary Layer Parameterization	Holtslag's Scheme
Convective Precipitation Scheme	Over both land and ocean Grell scheme with Fritsch-Chappell as the closure scheme
Large-Scale Precipitation Scheme	Subgrid Explicit Moisture Scheme (SUBEX)
Ocean flux Parameterization	Zeng's Scheme
Lateral Boundary Treatment	Exponential Relaxation (20 grid points width are selected for lateral buffer zone)

Domain details

South Asia CORDEX Domain



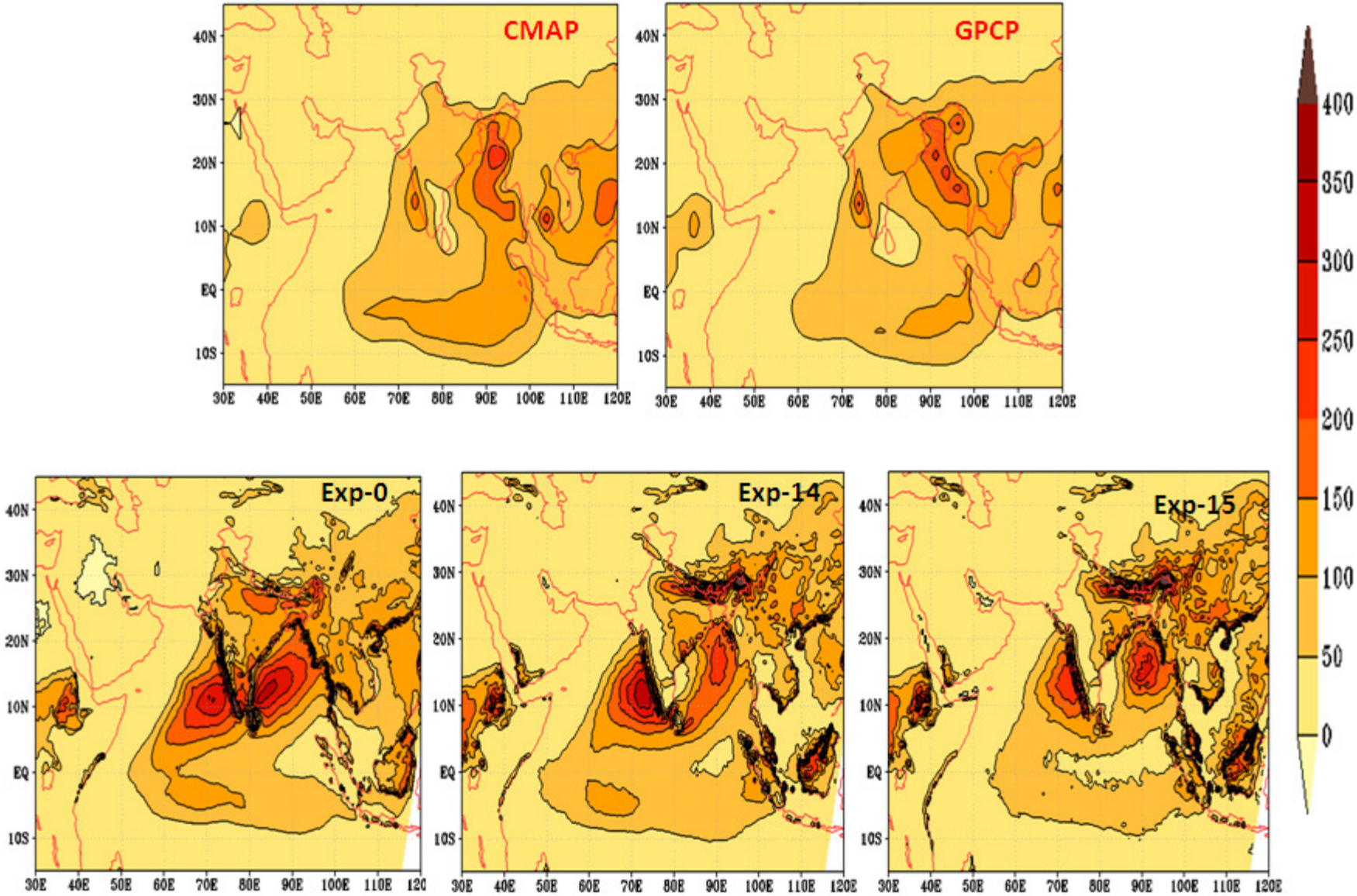
Model: RegCM4.1.1
Grid points: Y direction-160
Grid Points: X direction-224
Horizontal Resolution: 50Km
Simulation Period: 6 Years
01 Jan 1998 to 31 Dec 2003

- **CORDEX domain experiments have been conducted using ARGO, HPC cluster of ICTP for Indian summer monsoon configuration**
- **One year climate run on 32 processors on ICTP cluster takes about 7 hrs CPU time**

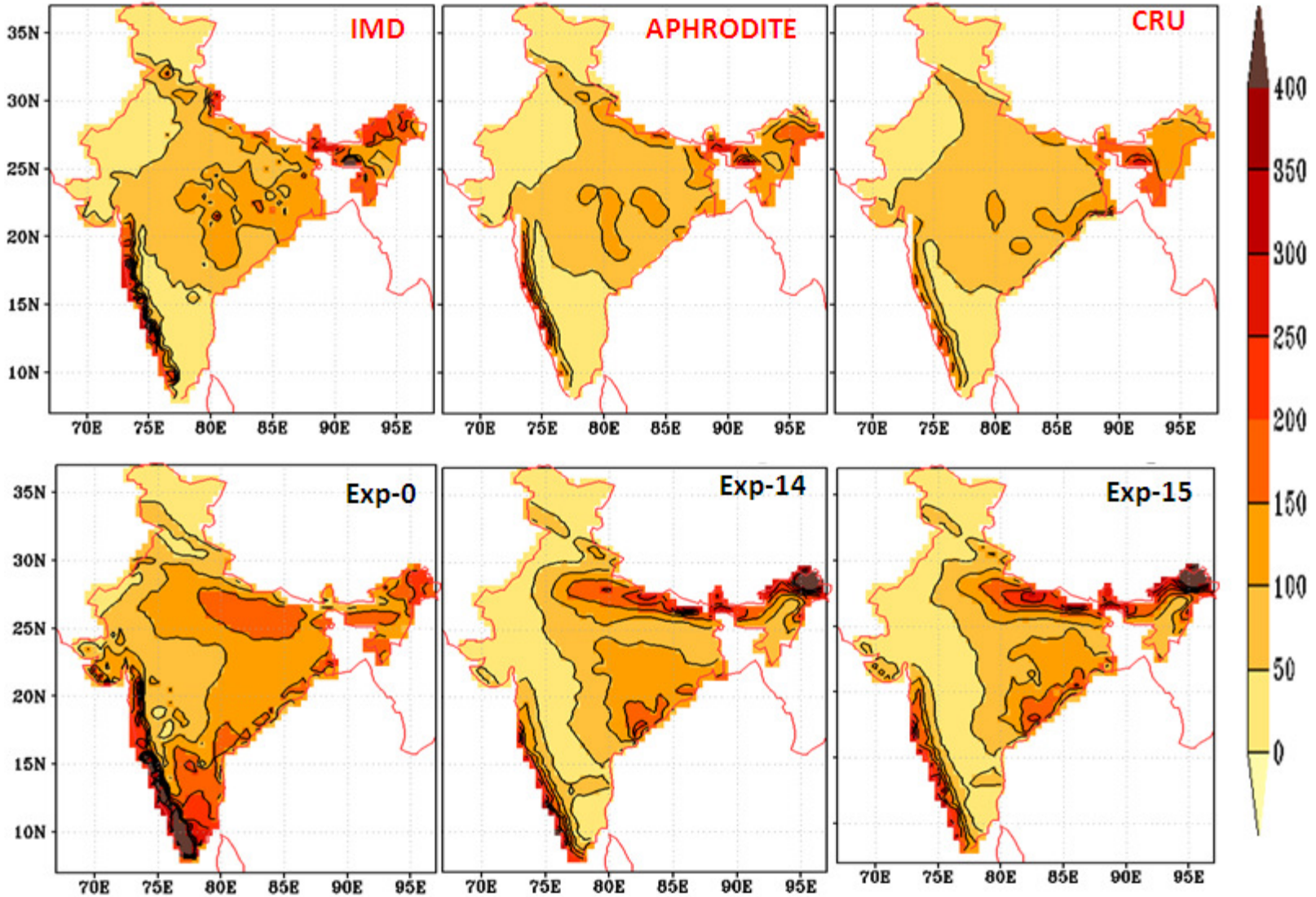
Experiments conducted

Exp-0 default settings (Table 1) + with irrigated crop	**Exp-1** modified Grell over land and ocean + with irrigated crop	**Exp-2** modified Grell over land and ocean + removed irrigated crop
Exp-3 modified Grell over land and ocean + removed irrigated crop + dtauc15	**Exp-4** modified Grell over land and ocean + removed Irrigated crop + dtauc25	**Exp-5** modified Grell over land and ocean + removed irrigated crop + rsmincrop
Exp-6 modified Grell over land and ocean + removed irrigated crop + rsminforest_fcmax	**Exp-7** modified Grell over land and **2nd time over ocean** + removed irrigated crop	**Exp-8** modified Grell **2nd time over ocean** + removed irrigated crop
Exp-9 modified Grell over land and ocean + Emanuel over land + removed irrigated crop	**Exp-10** modified Grell **2nd time over ocean** + Emanuel over land + removed irrigated crop	**Exp-11** modified Grell over ocean + Emanuel over land + with irrigated crop
Exp-12 modified Grell over ocean + Emanuel over land + with irrigated crop + modified Zeng	**Exp-13** modified Grell **2nd time over ocean** + Emanuel over land + removed irrigated crop + modified Zeng	**Exp-14** modified Grell **2nd time over ocean** + Emanuel over land + removed irrigated crop + modified Zeng + rsmincrop
Exp-15 modified Grell over ocean + Emanuel over land + removed irrigated crop + modified Zeng + rsmincrop		

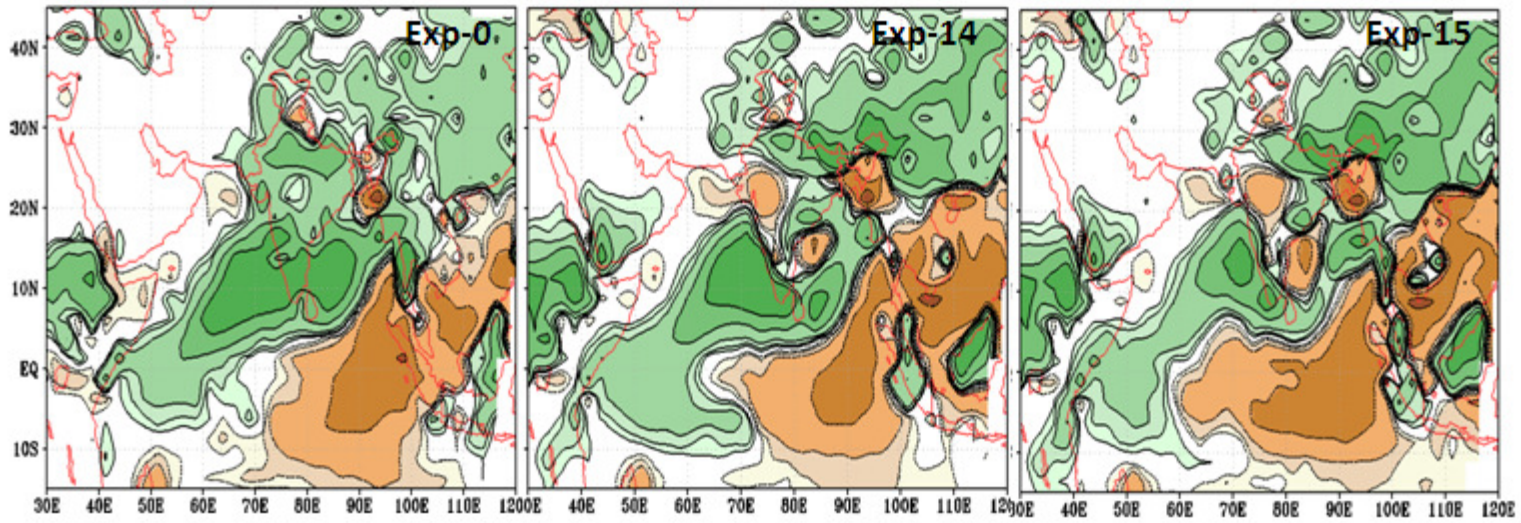
1998-2003 JJAS accumulated rainfall (cm)



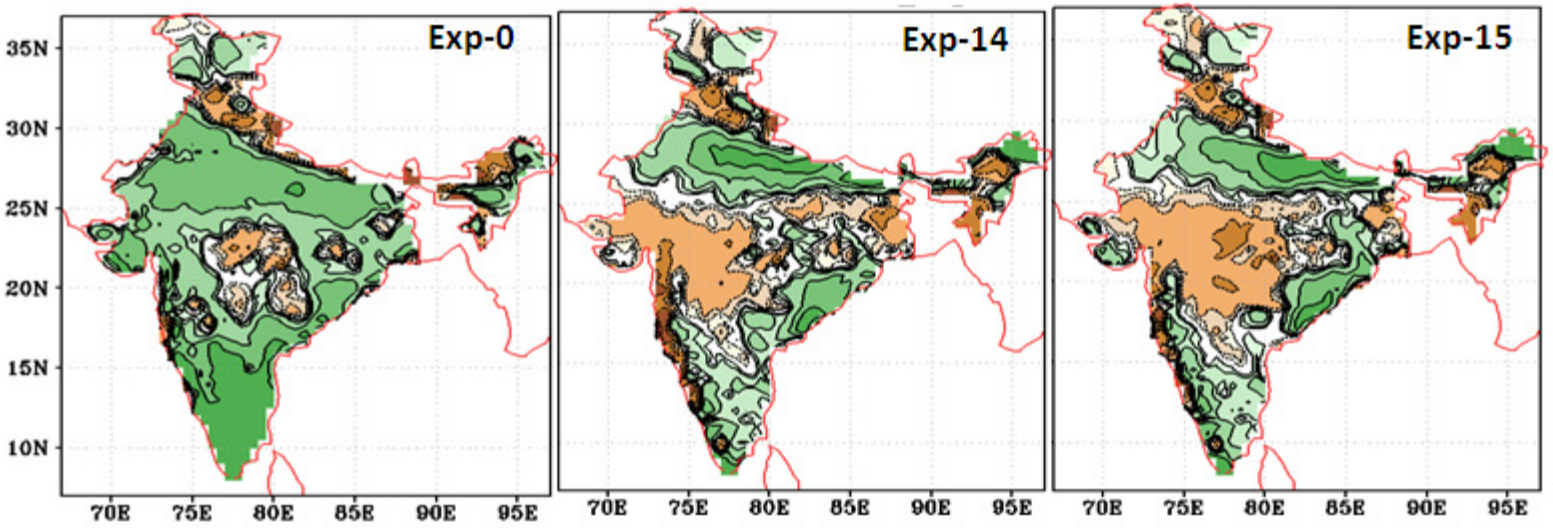
1998-2003 JJAS accumulated rainfall (cm) over Indian land

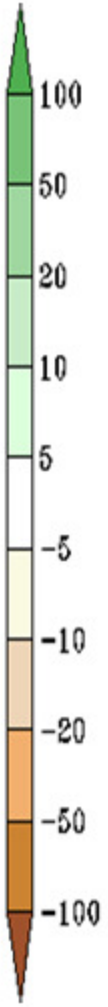


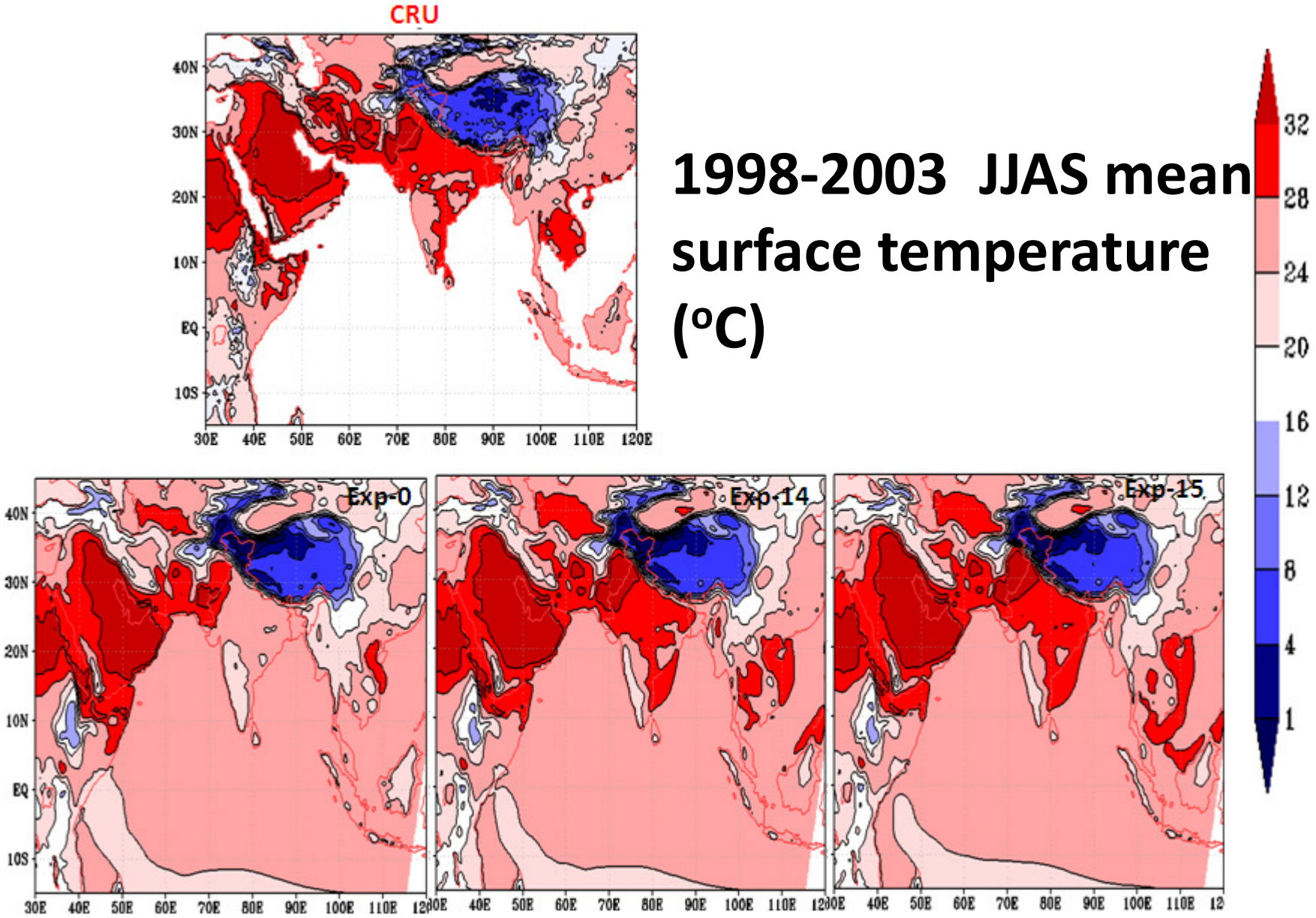
Bias between RegCM4.1.1 and CMAP observed JJAS accumulated rainfall (cm) climatology



Bias between RegCM4.1.1 and IMD observed JJAS accumulated rainfall (cm) climatology

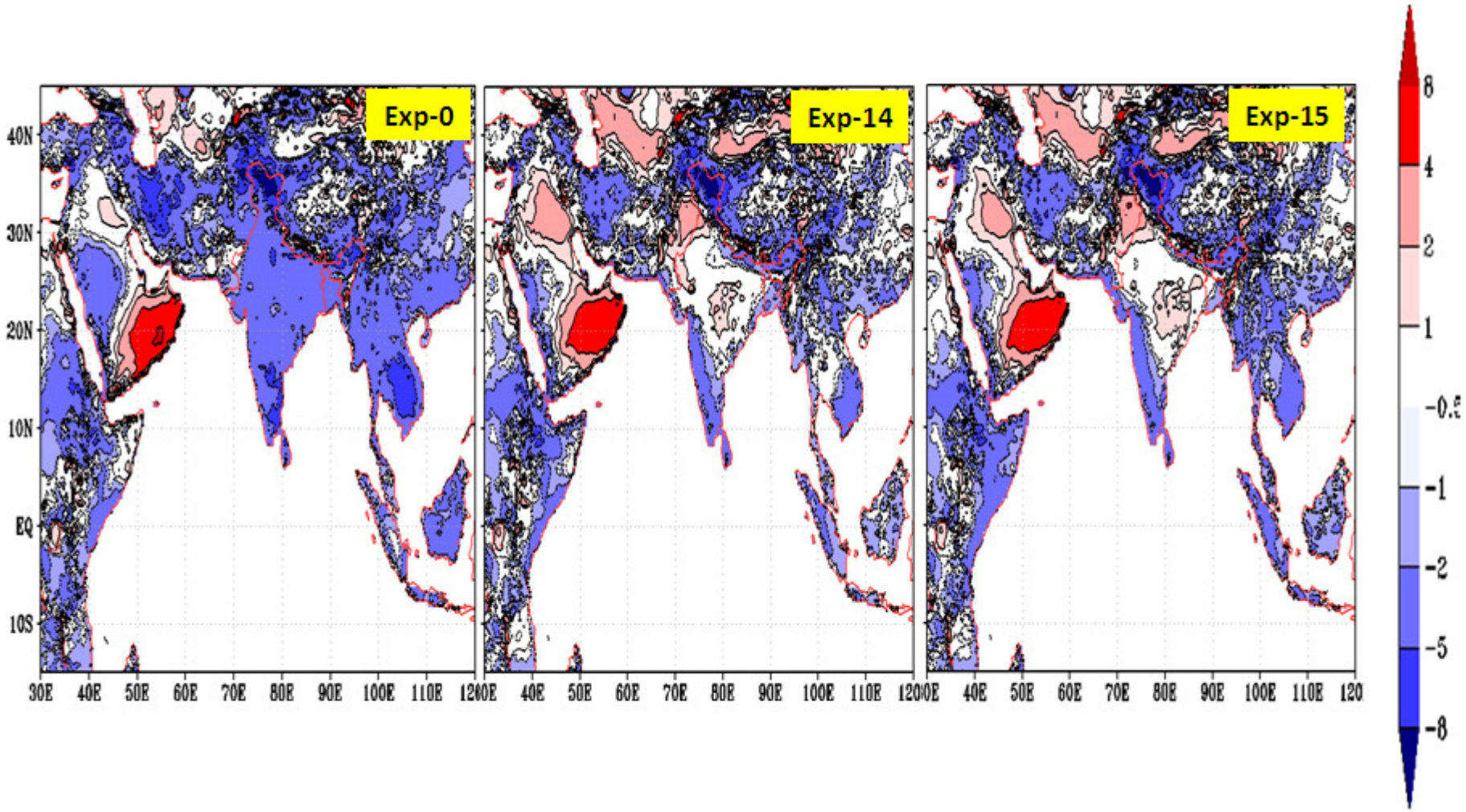


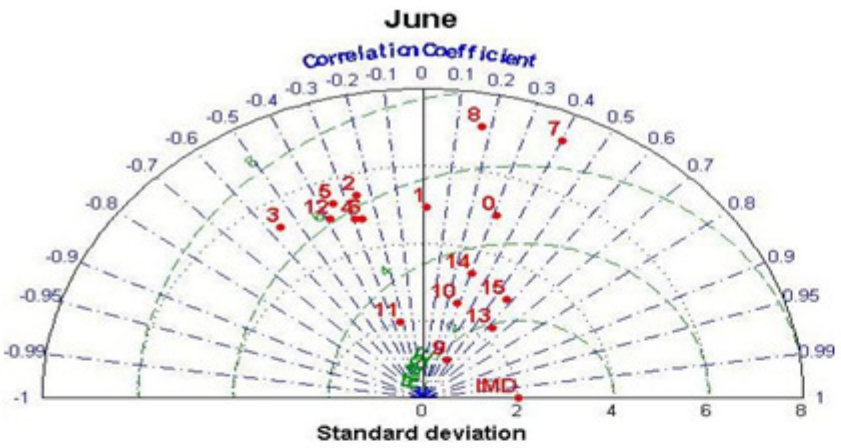


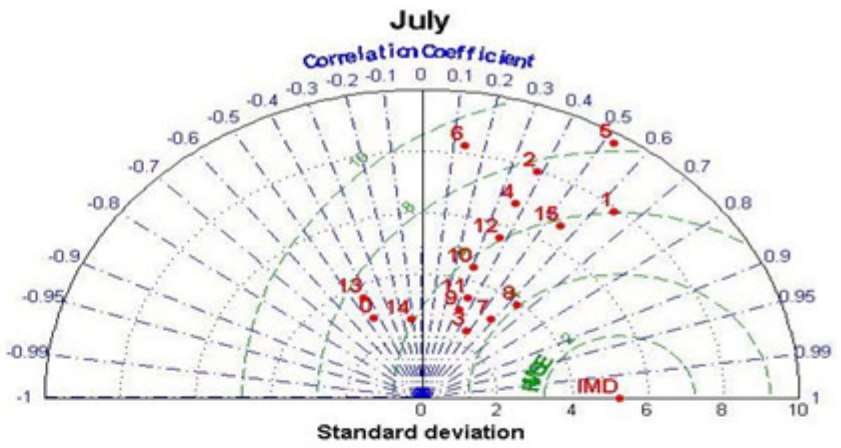


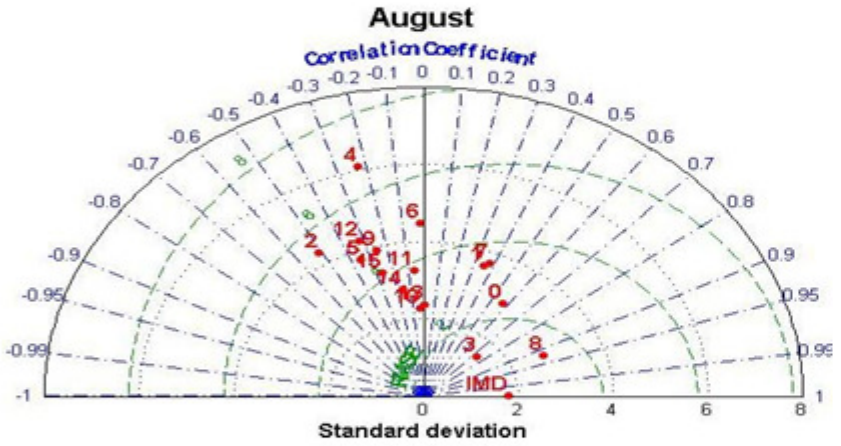
1998-2003 JJAS mean surface temperature (°C)

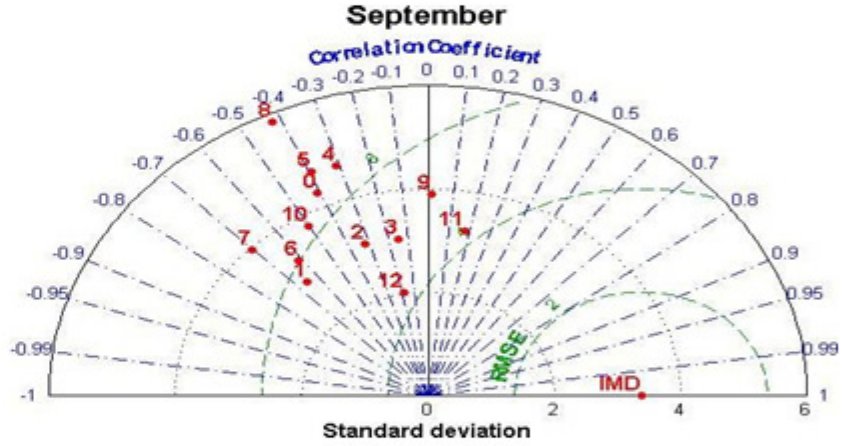
Bias between RegCM4.1.1 simulated and CRU observed climatology of JJAS mean surface temperature (°C) from 1998-2003

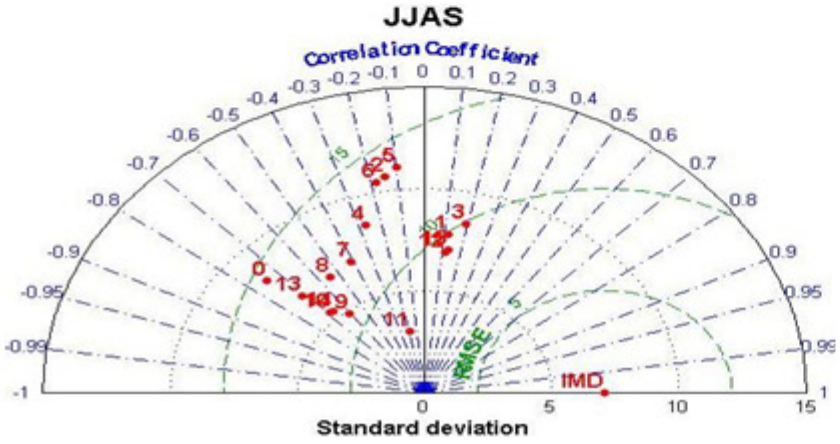












Taylor diagram of correlation coefficient, root-mean-square difference, and standard deviation of RegCM4.1.1 simulated precipitation (cm) in different experiments (0-15) are shown with respect to IMD observation as reference. Area weighted average of accumulated precipitation during each month from June to September as well as season as a whole is considered over Indian land points for six years from 1998-2003.

Results of default setting experiment:

- High overestimation of rainfall almost over entire India except in some parts of central India
- The spatial distribution of precipitation is also not well simulated by the model when it is compared to IMD gridded rainfall
- Over the Bay of Bengal and Arabian Sea the rainfall is highly overestimated
- Mean surface temperatures indicate cold bias all over the country by around 2 to 5 ^{o}C

Results of experiment-14 and 15:

- Exps-14 and 15 show satisfactory results in terms of rainfall and temperature bias and inter-annual variation compared to the earlier experiments.

- Exp-14 indicates better bias pattern than Exp-15 while Exp-15 shows better inter-annual variability in the seasonal rainfall

Conclusions based on the results of experiments:

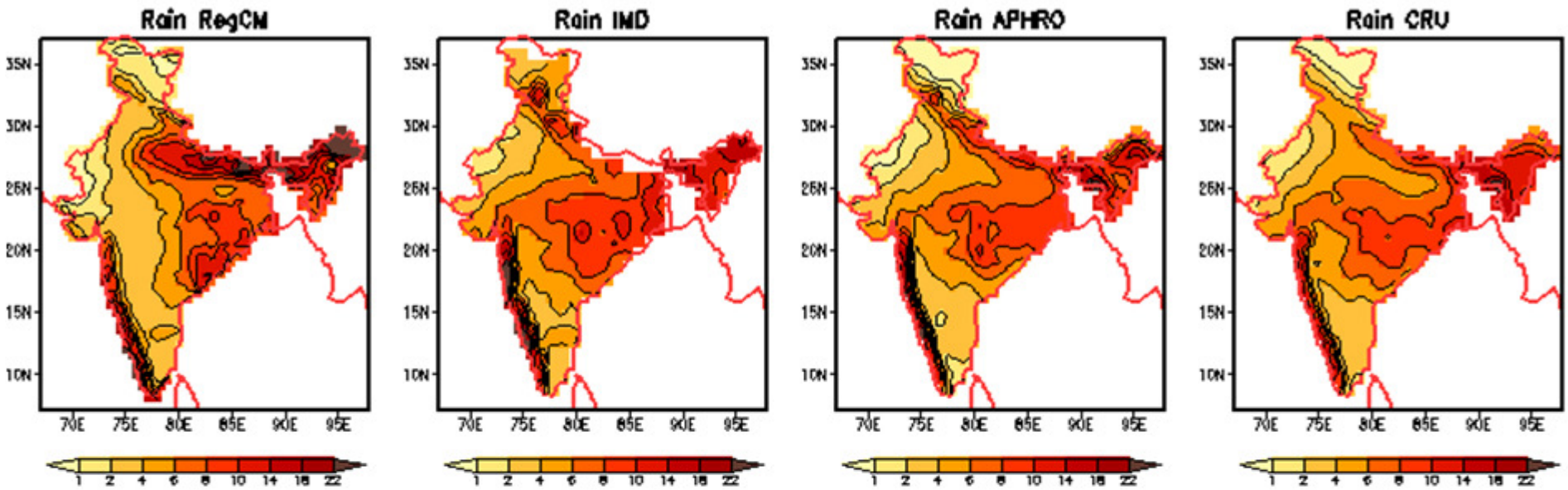
- Both temperature and rainfall biases are considerably reduced when Emanuel convection parametrization is introduced over land and Grell over ocean.

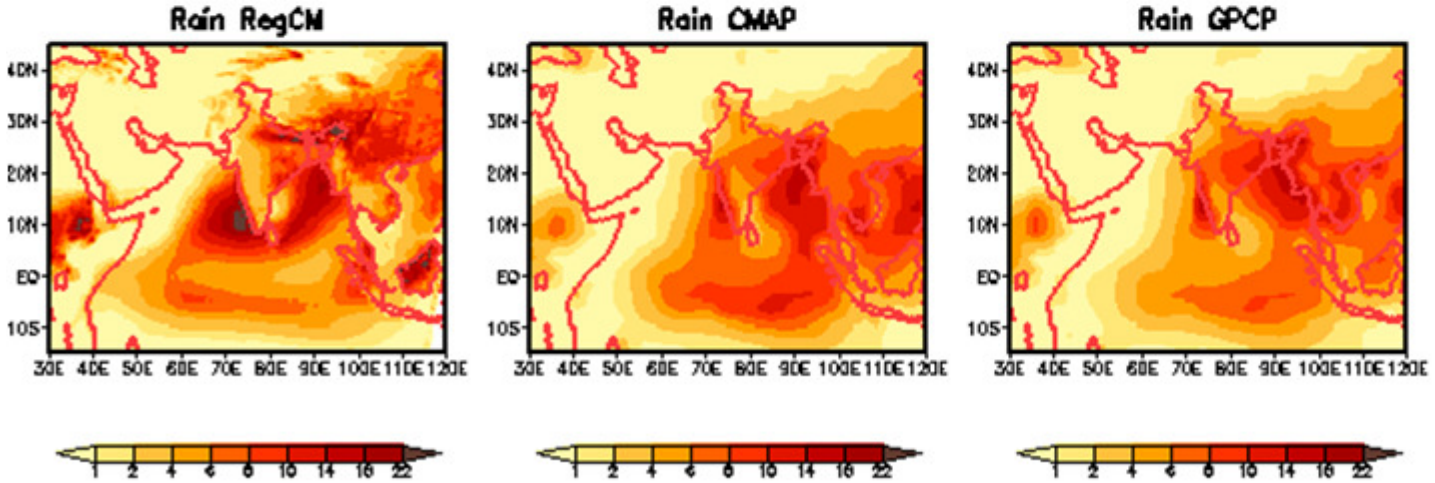
- Precipitation over central India increased to some extent by reducing the minimum stomatal resistance there for the dominant landuse type in India that is crop.

- It is also observed that the dry bias over ocean is improved due to the use of Zeng's ocean model roughness formula.

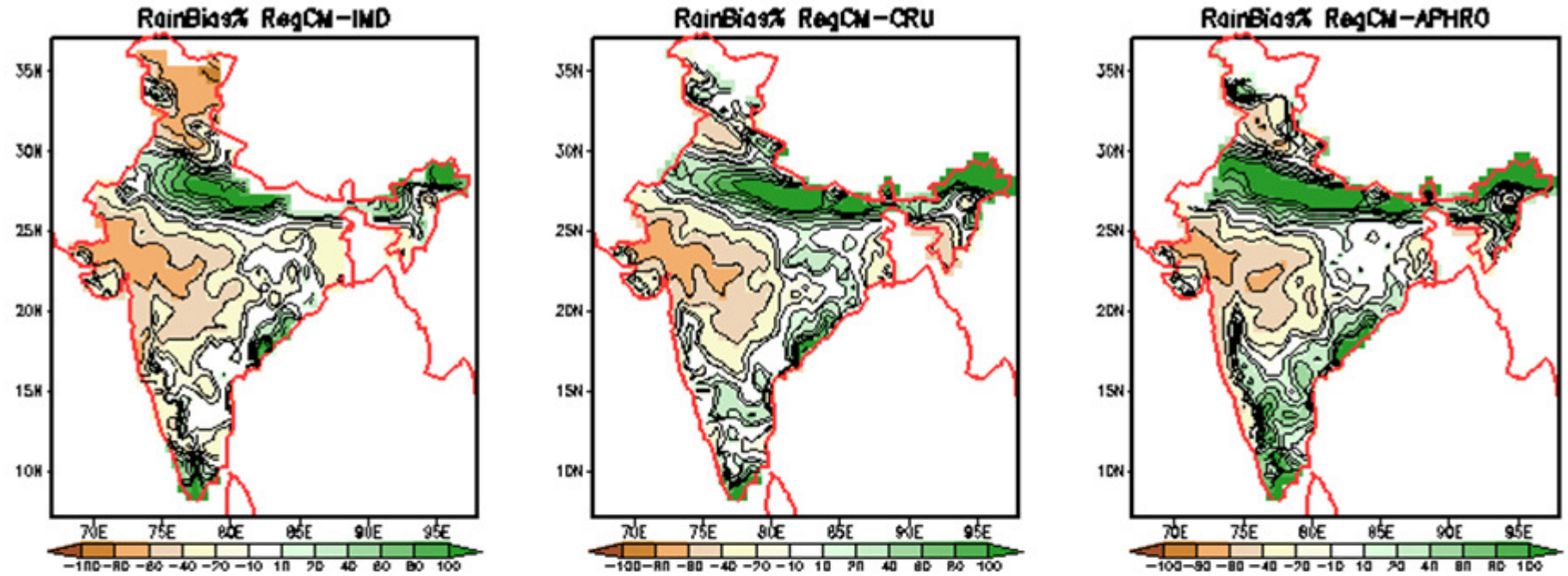
- Rainfall bias has further been reduced over the ocean by modifying the Grell ocean parameters such as Precipitation Efficiency and shear effect on Precipitation Efficiency.

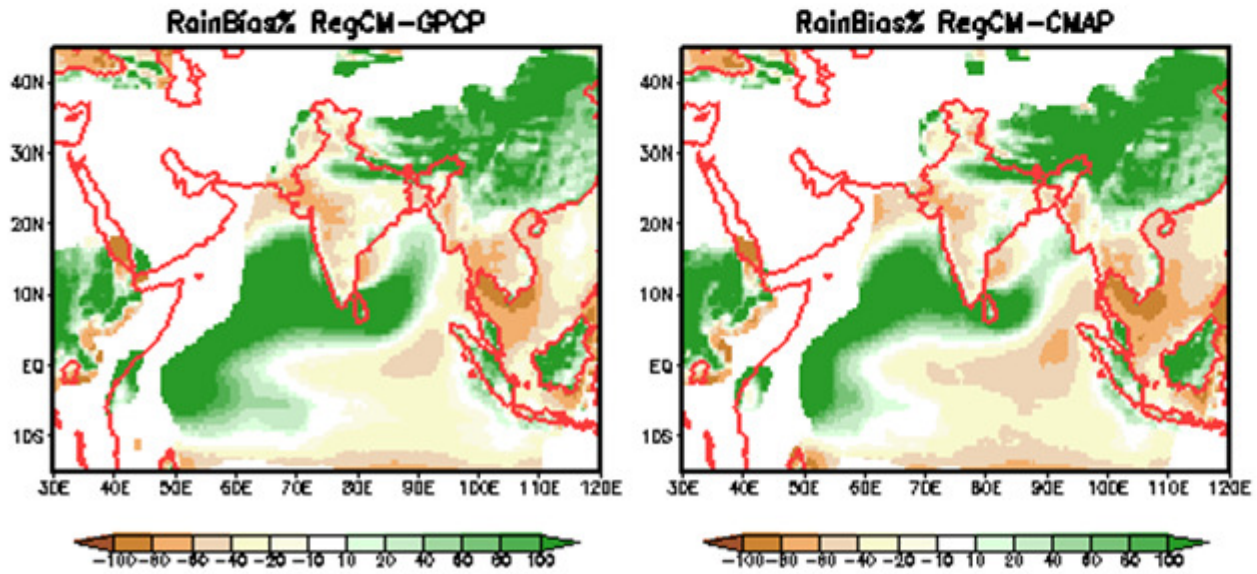
Exp-14 configuration is used to integrate the model with ERA-Interim boundary conditions for the longer period 1989-2008 spanning 20 years





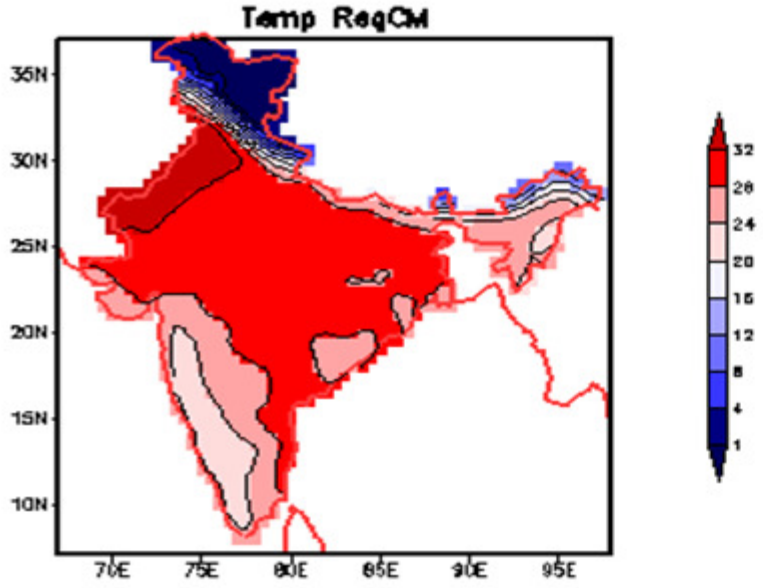
JJAS accumulated rainfall (mm/day) from 1990-2008

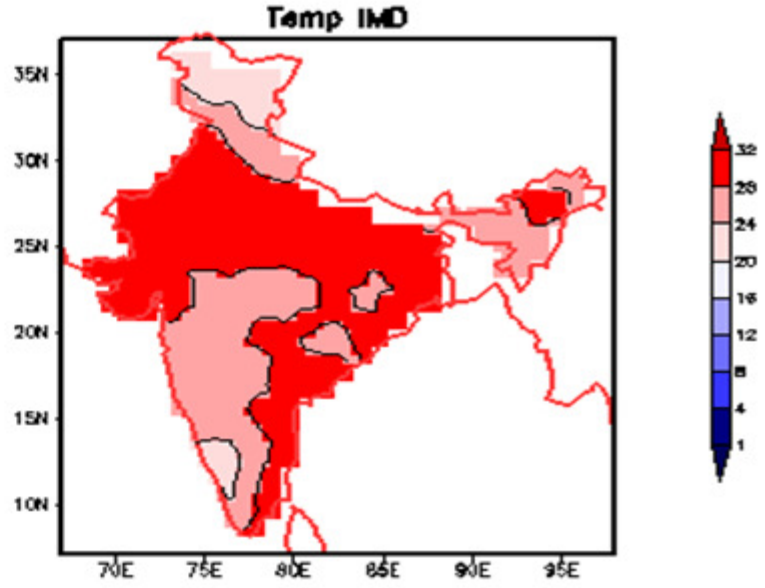


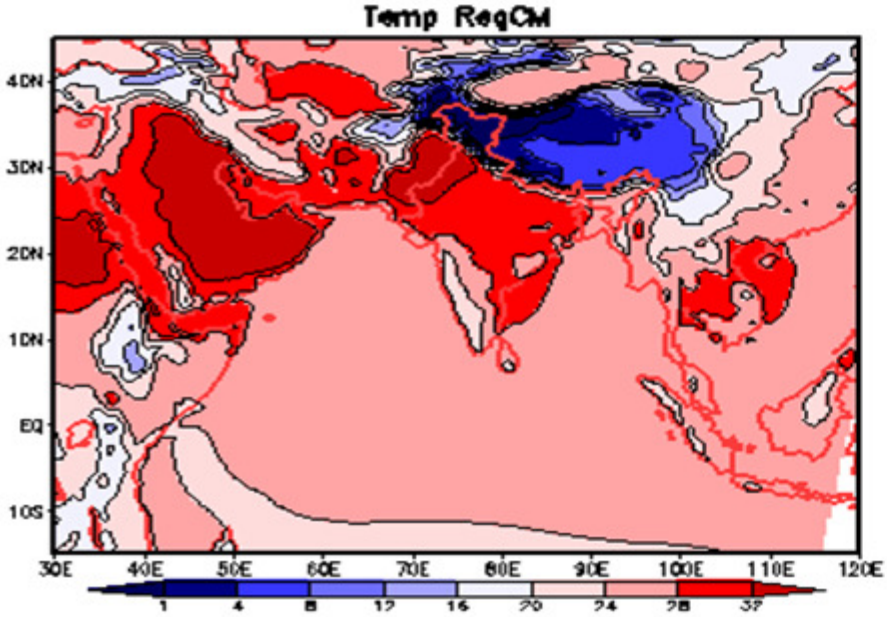


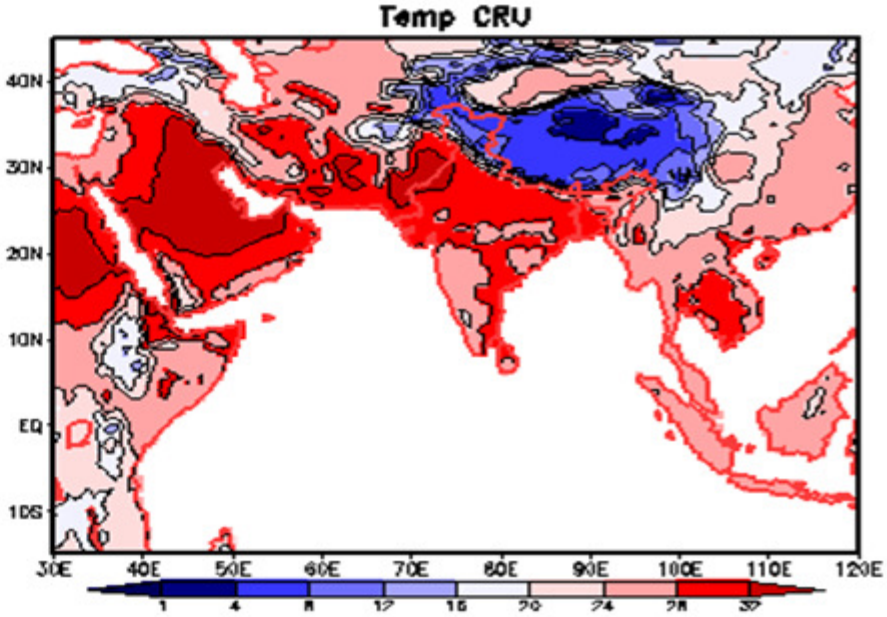
Percentage Bias between RegCM4.1.1 and IMD mean JJAS rainfall (mm/day) for 1990-2008

JJAS mean surface temperature (°C) from 1990-2008

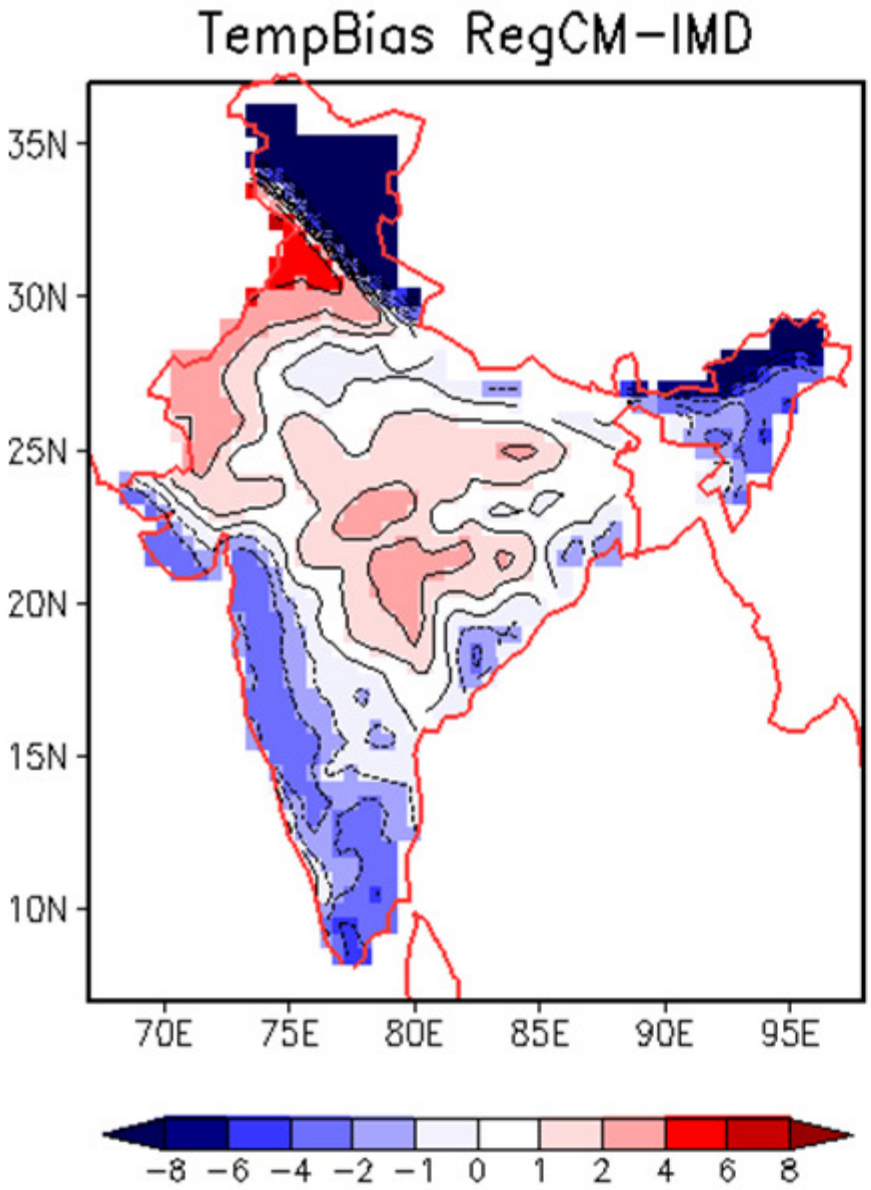


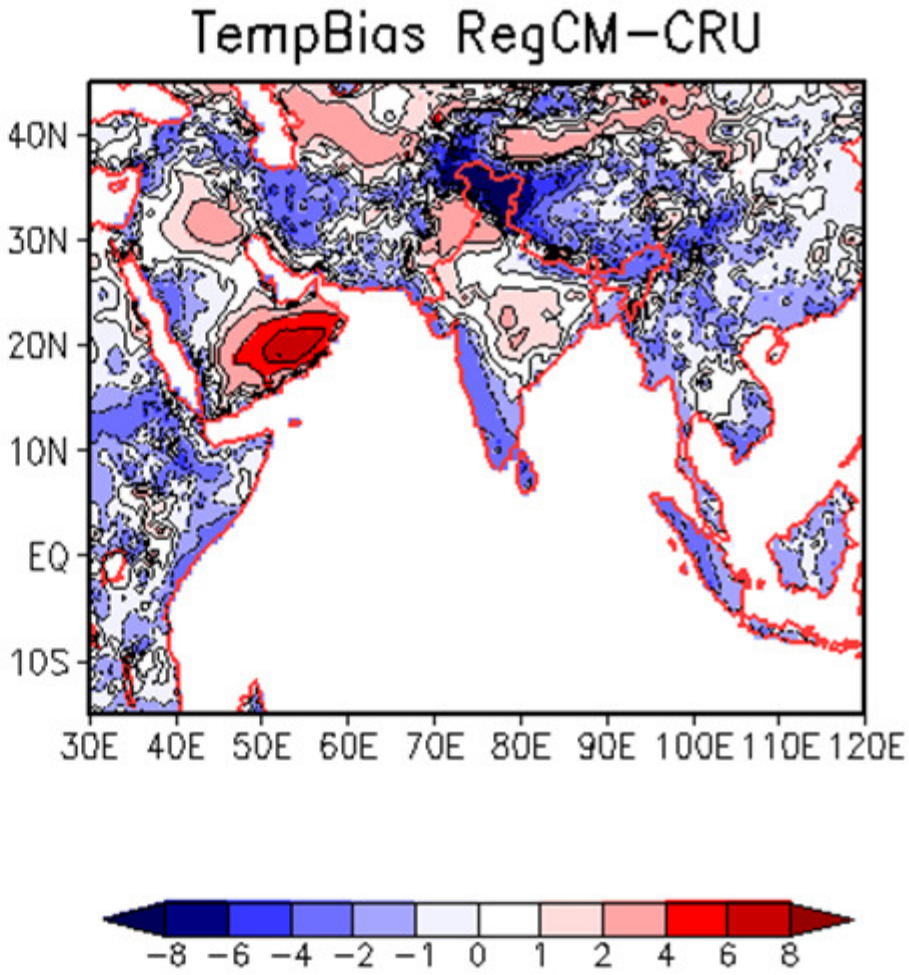


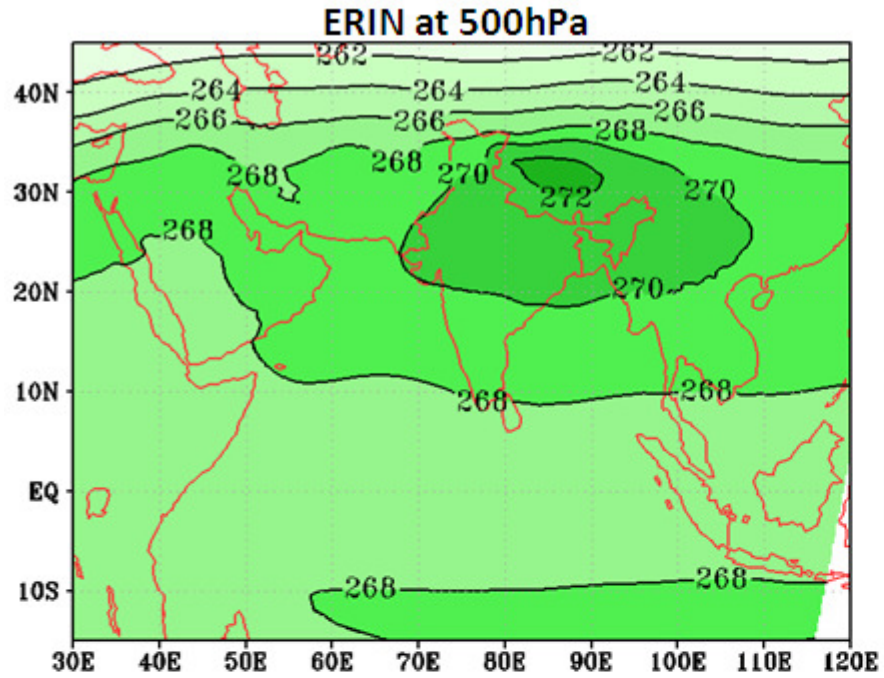




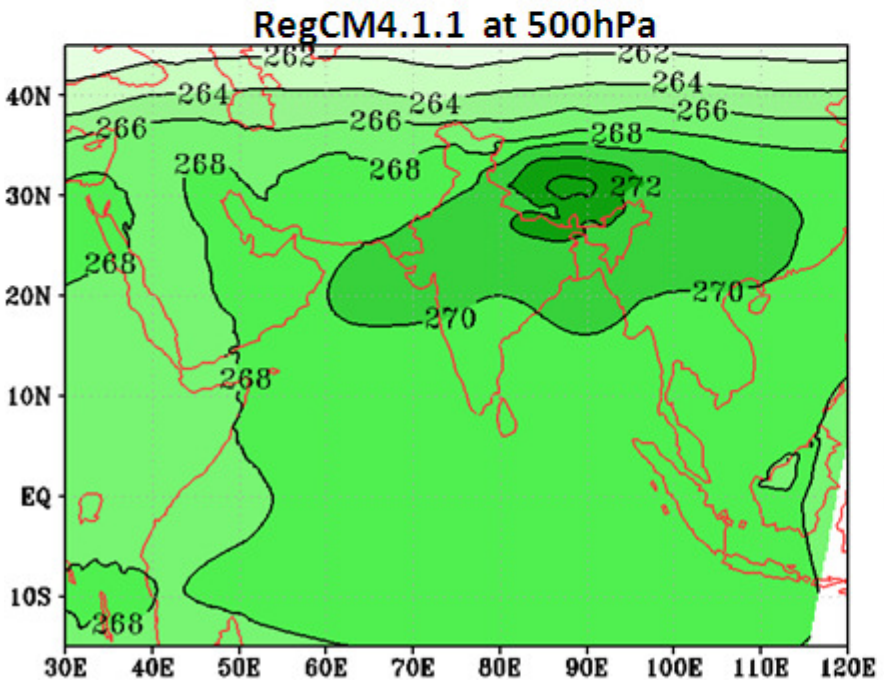
Bias between RegCM4.1.1 and CRU surface temperature (°C)

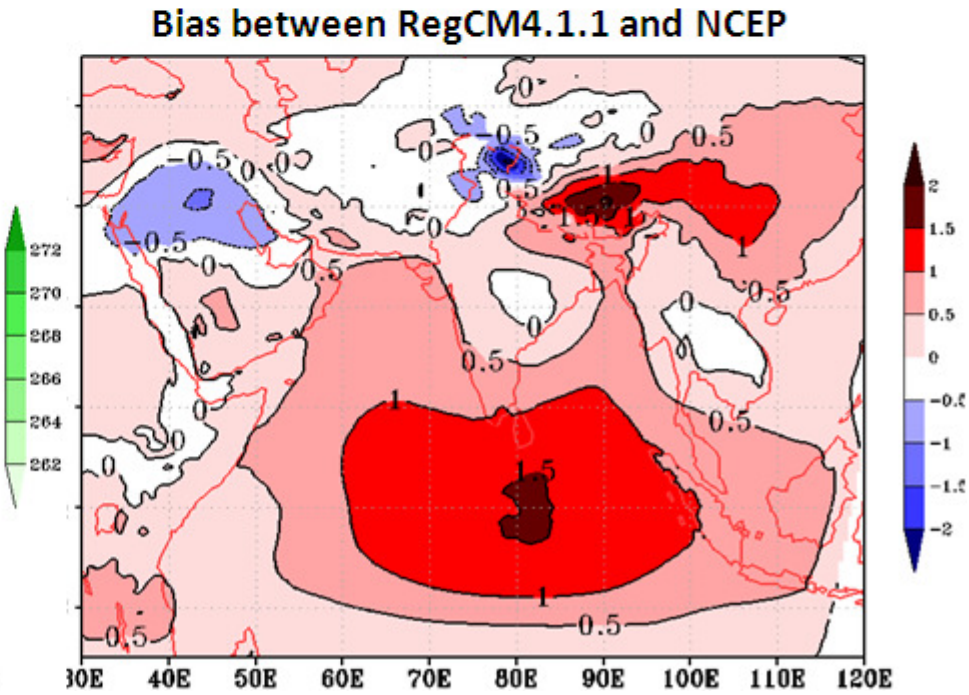




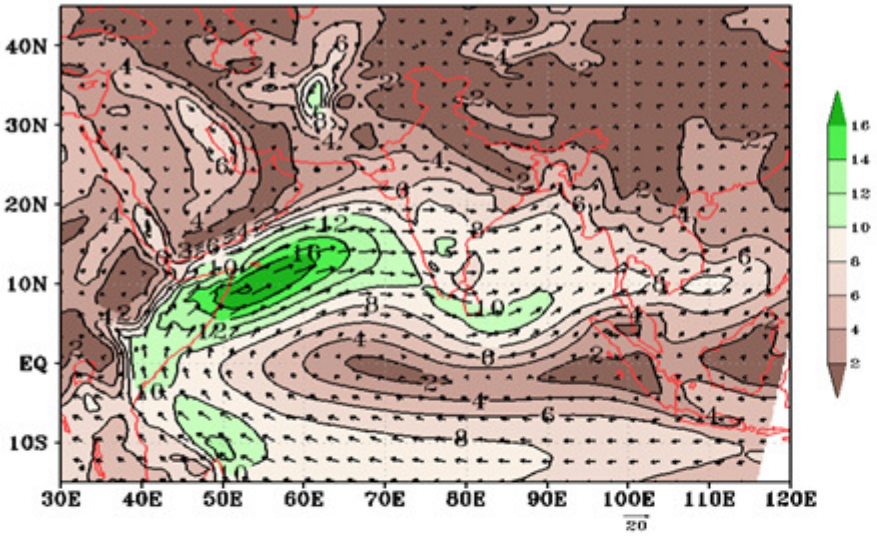


JJAS mean temperature (K) at 500hPa from 1990-2008



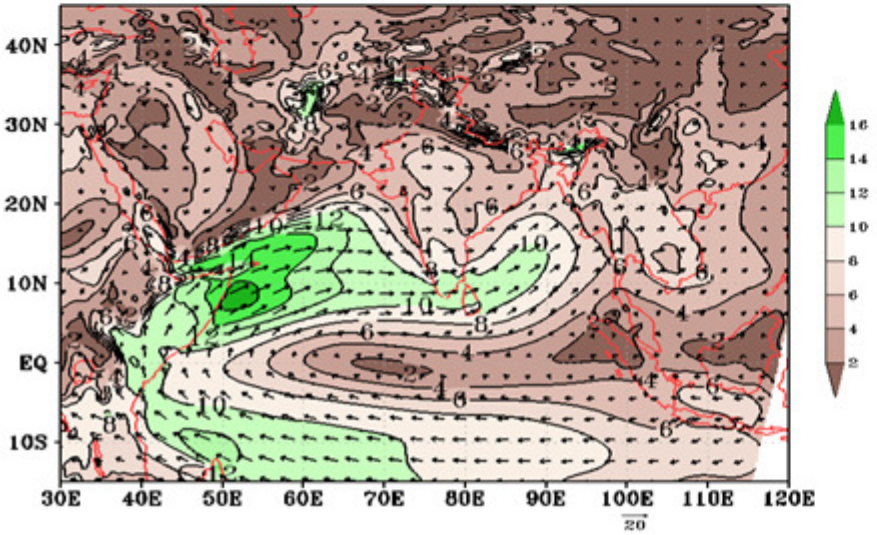


ERIN at 850hPa

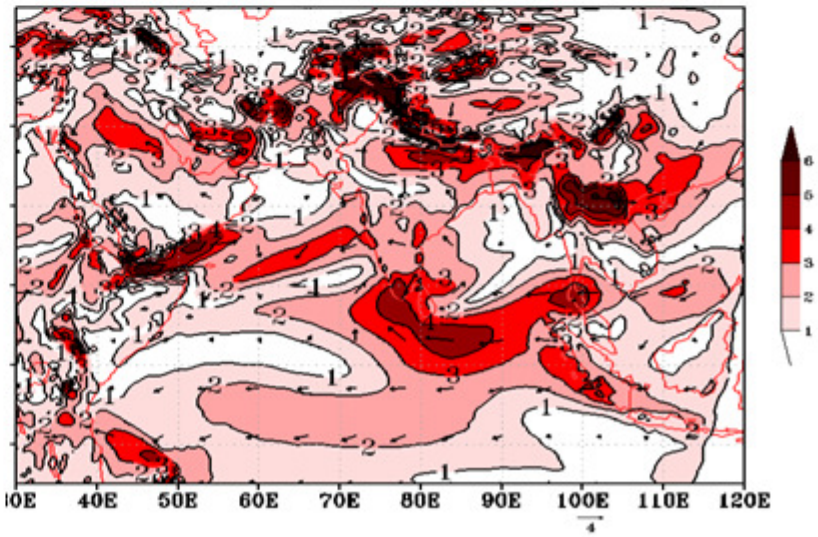


JJAS mean wind (m/s) at 850hPa from 1990-2008

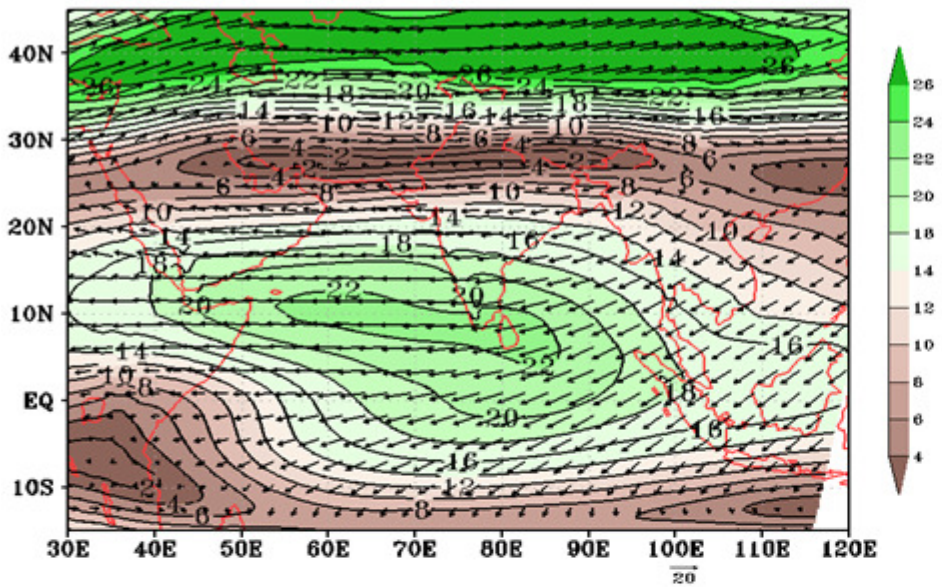
RegCM4.1.1 at 850hPa



Bias between RegCM4.1.1 and ERIN

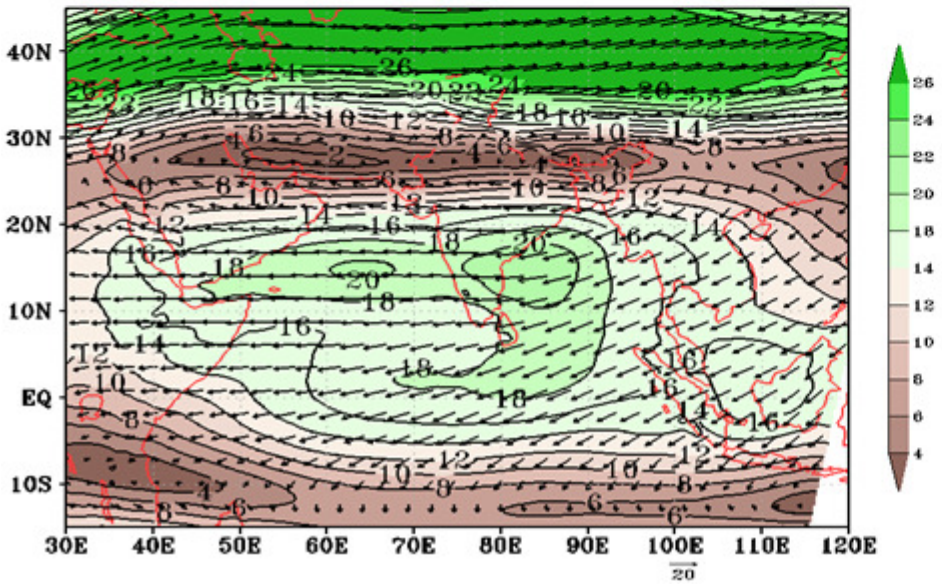


ERIN at 200hPa

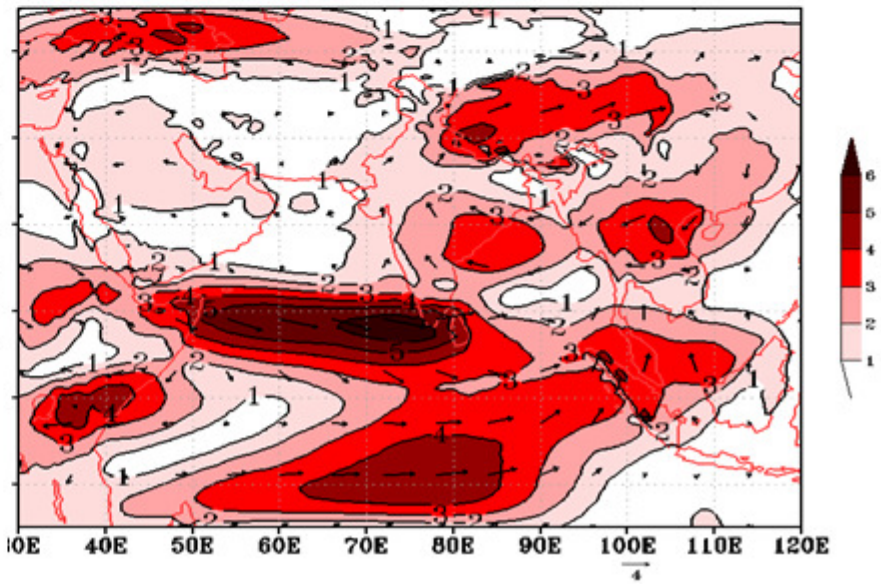


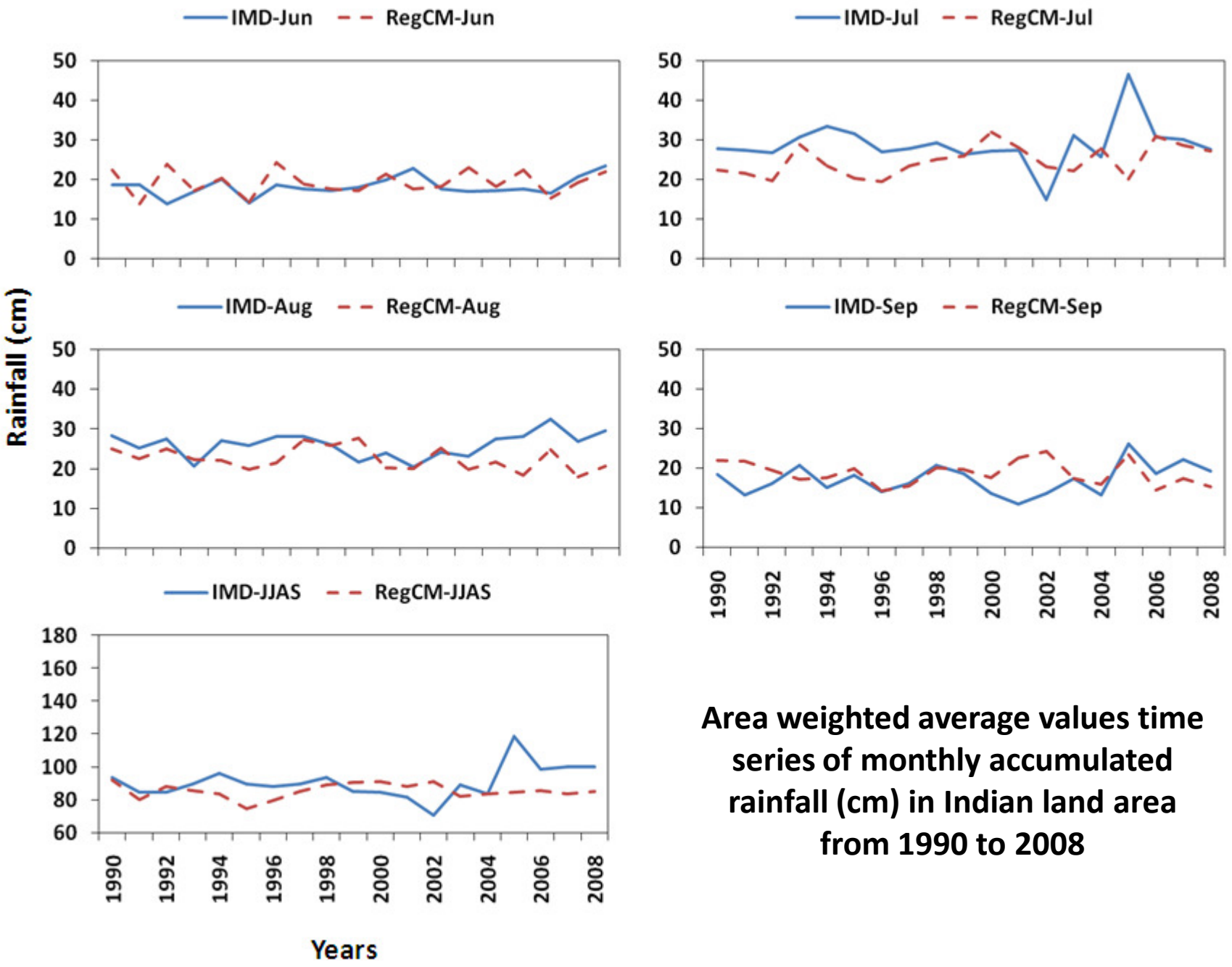
JJAS mean wind (m/s) at 200hPa from 1990-2008

RegCM4.1.1 at 200hPa



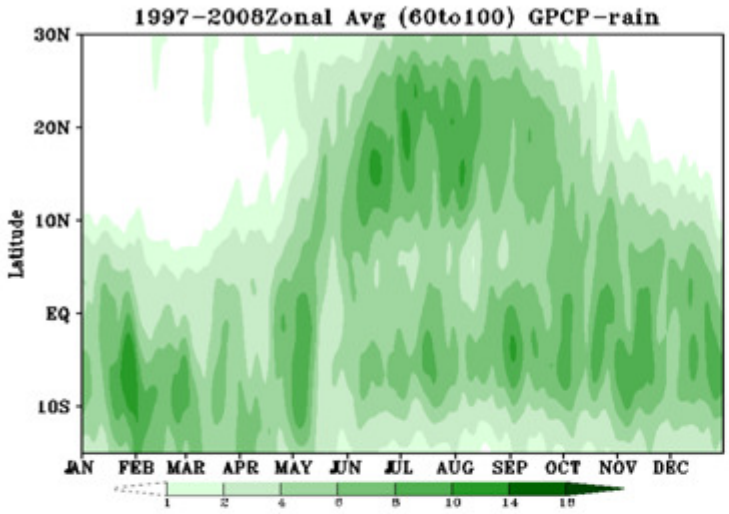
Bias between RegCM4.1.1 and ERIN



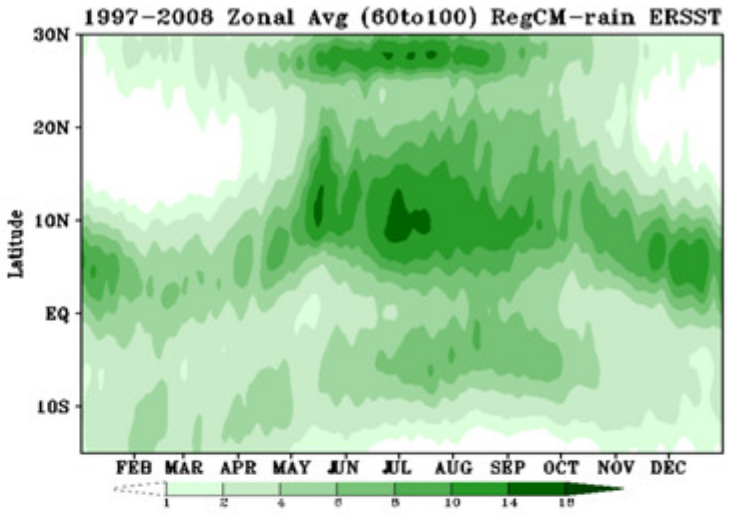


Area weighted average values time series of monthly accumulated rainfall (cm) in Indian land area from 1990 to 2008

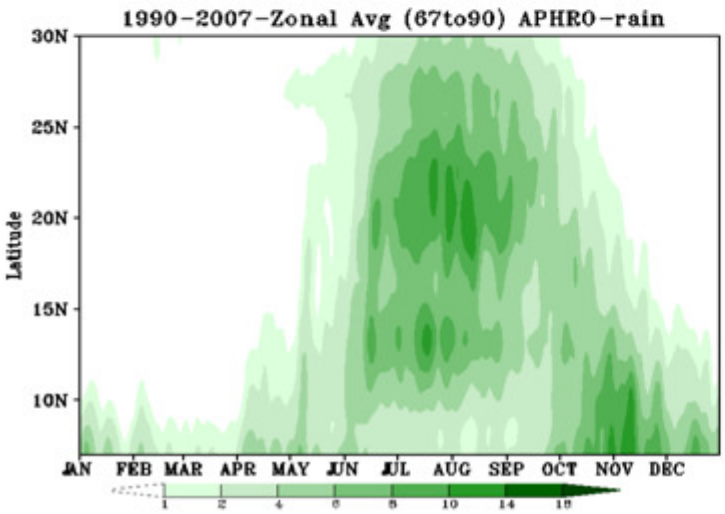
GPCP 1997-2008



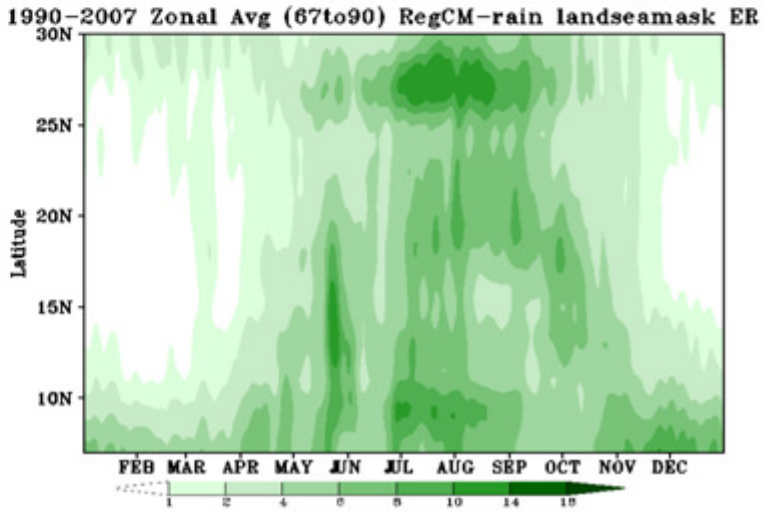
RegCM4.1.1 1997-2008



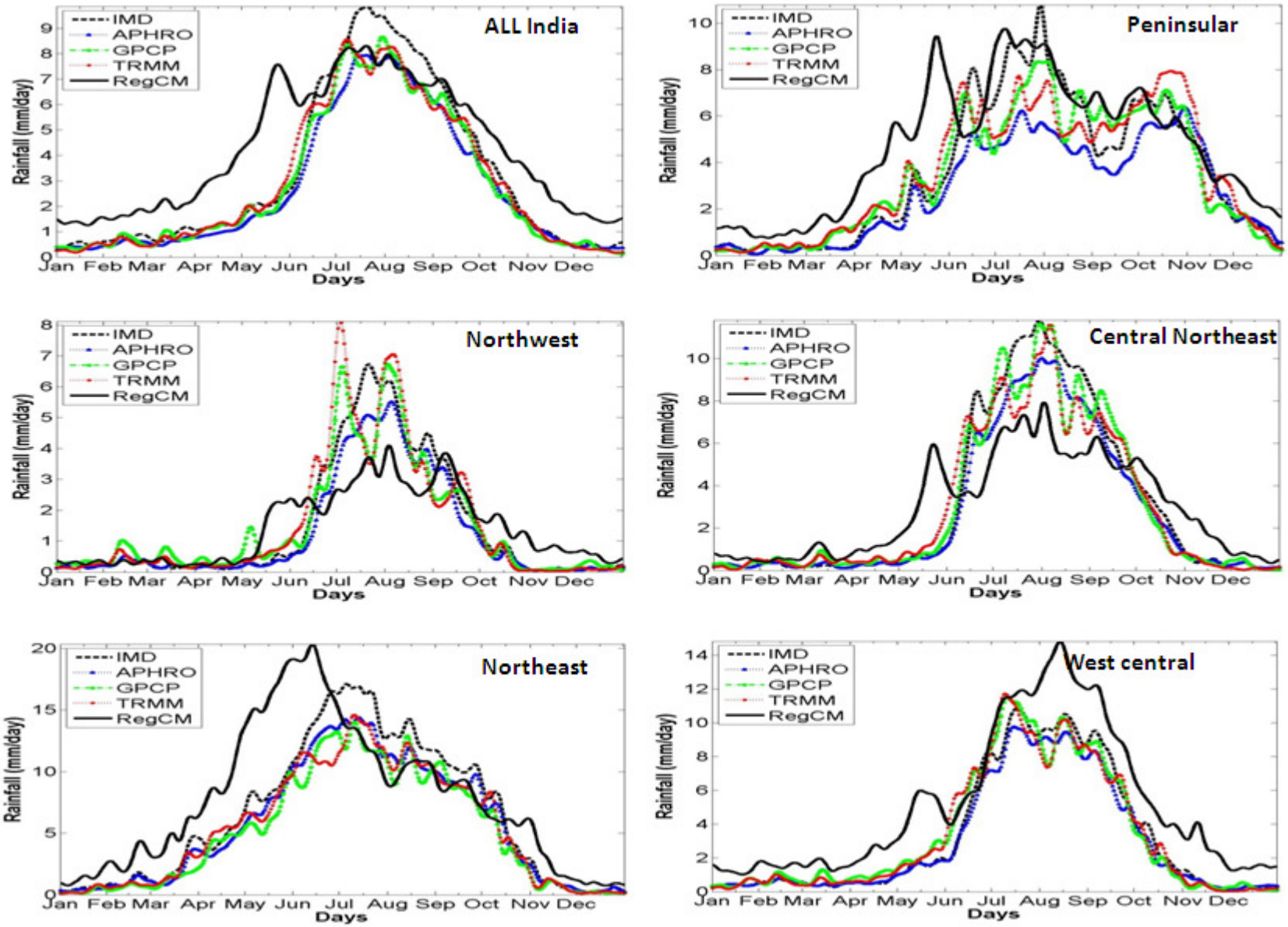
APHRODITE 1990-2007 land-sea mask



RegCM4.1.1 1990-2007 land-sea mask



Hovmöller diagram representation of the mean annual cycle of precipitation (mm/day)



The 1990–2008 mean annual cycle of precipitation(mm/day) in Indian land and in its five homogeneous regions. RegCM4.1.1 simulated precipitation climate (1990-2008) is compared with IMD (1990-2008), APHRO (1990-2007) GPCP (1997-2008) and TRMM (1998-2008)

Results from RegCM4 simulations

- JJAS temperature has a slight cold bias over the mountain and coastline compared with CRU dataset. Indian land area temperature is well represented.
- The monsoon precipitation over the Indian continent is reasonably represented by the use of double convection scheme.
- Comparison of RegCM4.2 precipitation with that of IMD dataset shows good inter-annual variations.

CORDEX Experiment Status

- RegCM4.2 has been integrated for West Asia CORDEX domain using ERA-interim as boundary conditions (1989-2008) using ARGO, ICTP Linux cluster
- RegCM4.2 has been ported on IIT Delhi Linux cluster, Ajaymeru
- One year simulation on 32 processors of Ajaymeru takes about 24 hrs CPU time
- RegCM4.2 will be integrated using HadGEM2 and CanESM2 boundary forcings for both the recent past (RF) and future scenarios (RCP4.5)
- Model is being integrated over the period 1970-2005 for historical experiments and over 2006-2100 for RCP4.5 emission scenario

THANK YOU