Simulation of Indian Summer Monsoon Circulation and Rainfall using Mesoscale Models

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OBJECTIVES

- To examine the characteristics of mean monsoon circulation and rainfall over India using MM5V3.
- To predict the track of Orissa supercyclone in 1999 over the Bay of Bengal using different convection schemes in MM5V3.
- To evaluate the performance of RegCM3 in simulating the Indian summer monsoon circulation and rainfall using different convection schemes (no-snow experiment).
- To examine the impact of spring Tibetan snow depth on the Indian summer monsoon circulation and rainfall by conducting a series of sensitivity experiments with RegCM3 (snow experiments).

Domain selected (for mean monsoon circulation and rainfall)

Central Lat and Lon- 15°N, 75°E: 141 X 101 Points along XY direction
Extended domain has 155 X 115 Points along XY direction
Domain covers 40°E to 110°E and 10°S to 40°N with Grid distance- 55 Km

Domain selected (for Orissa Supercyclone simulation)

Central Lat and Lon- 15°N, 90°E: 81 X 81 Points along XY direction
Extended domain has 109 X 109 Points along XY direction
Domain covers 80°E to 100°E and 5°N to 25°N with Grid distance- 27.5 Km

Data used

USGS Global 1 degree datasets to create terrain and land-use file.

Monthly SST available from NOAA for integration.

NCEP analysis dataset of 1998 for setting the initial and boundary conditions.

Physics options used

- **Mixed phase or the Reisner scheme is used for the explicit moisture scheme.**
- **MRF scheme is used for the planetary boundary layer.**
- **simple cloud scheme for the atmospheric radiation.**
- **multi-layer soil model has been used.**

MODEL INTEGRATIONS

(for mean monsoon circulation and rainfall)

The model is integrated from 1st August to 30th September 1998.

The experiments are carried out for three cumulus parameterization schemes such as Anthes-Kuo (Kuo), Betts-Miller (BM) and Grell.

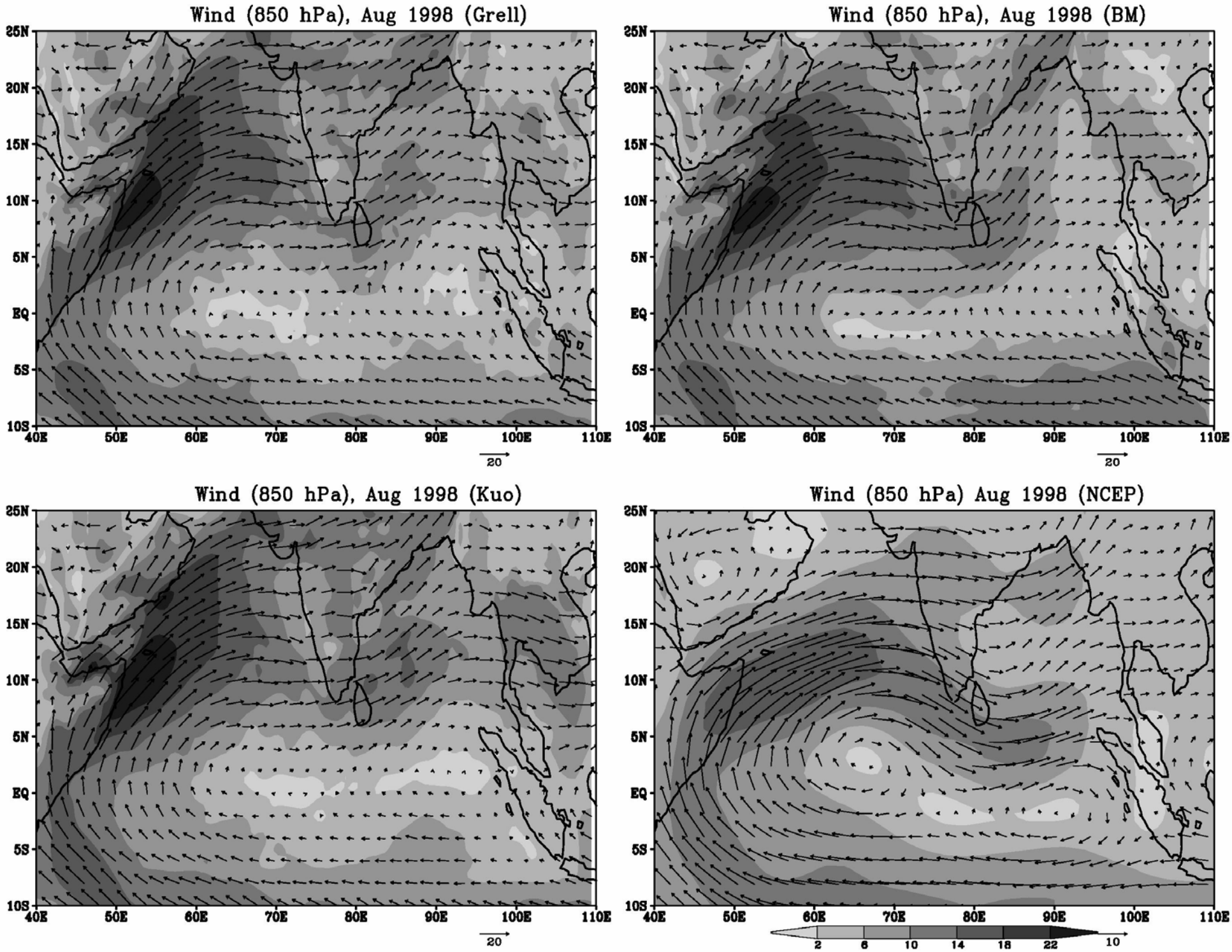
Inter-comparison of rainfall simulated by the model in three different convective schemes are done.

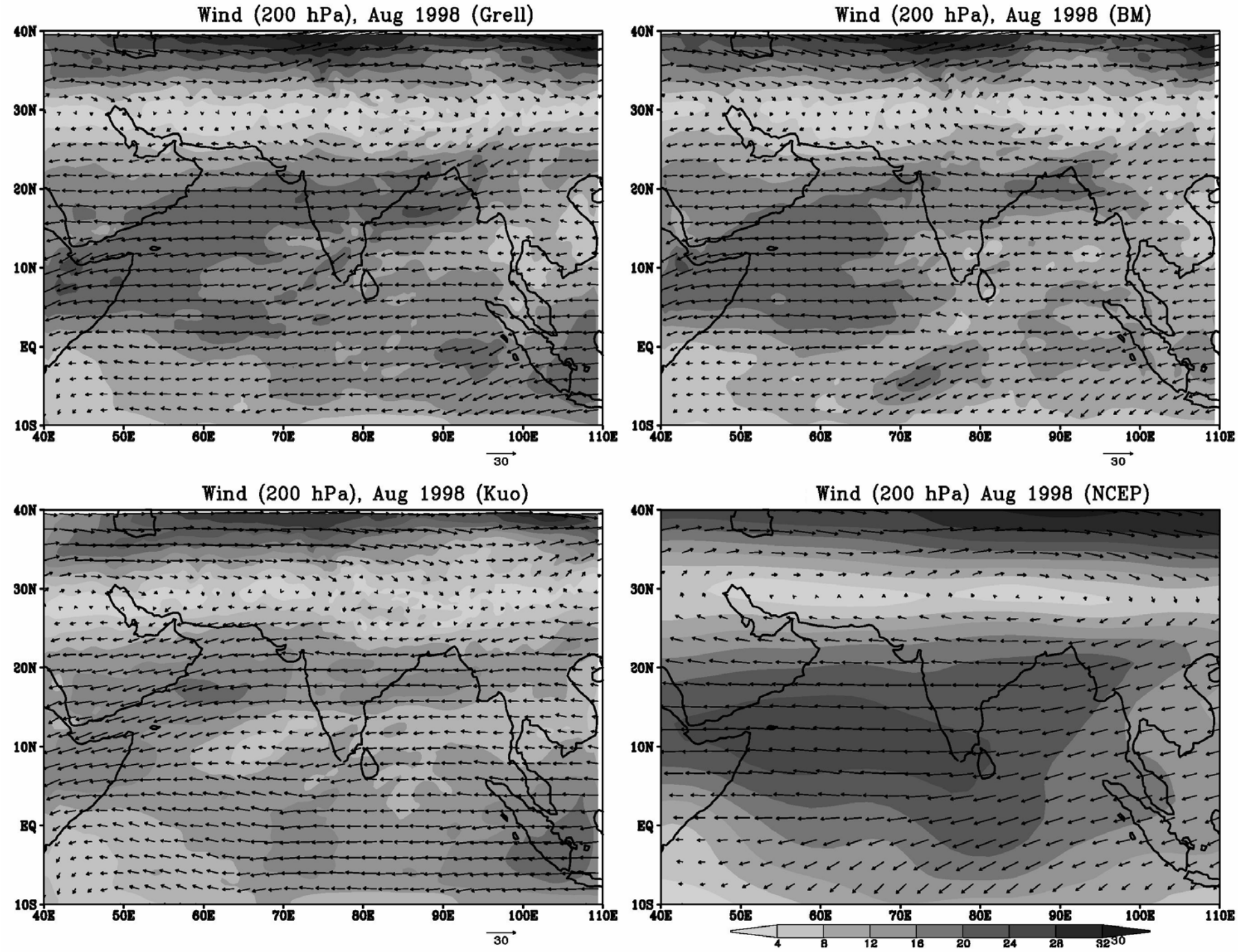
The monsoon circulation features are compared with those of NCEP/NCAR reanalysis and the rainfall with those of IMD observational rainfall data.

(for Orissa Supercyclone)

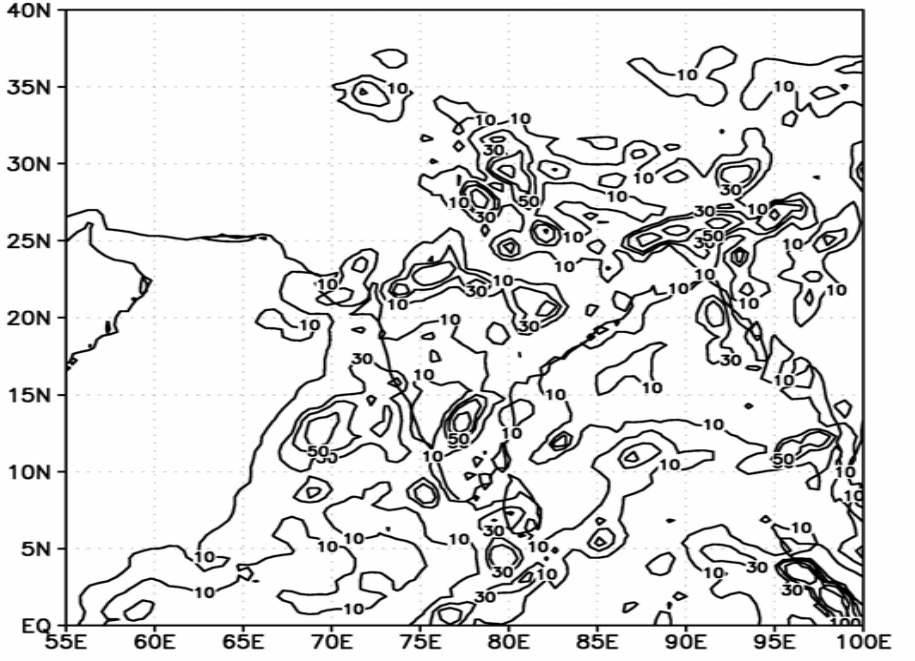
MM5 is integrated from the initial condition of 00Z on 25th October 1999 in three stages of 48 hours each.

The simulations are carried out for three cumulus parameterization schemes.

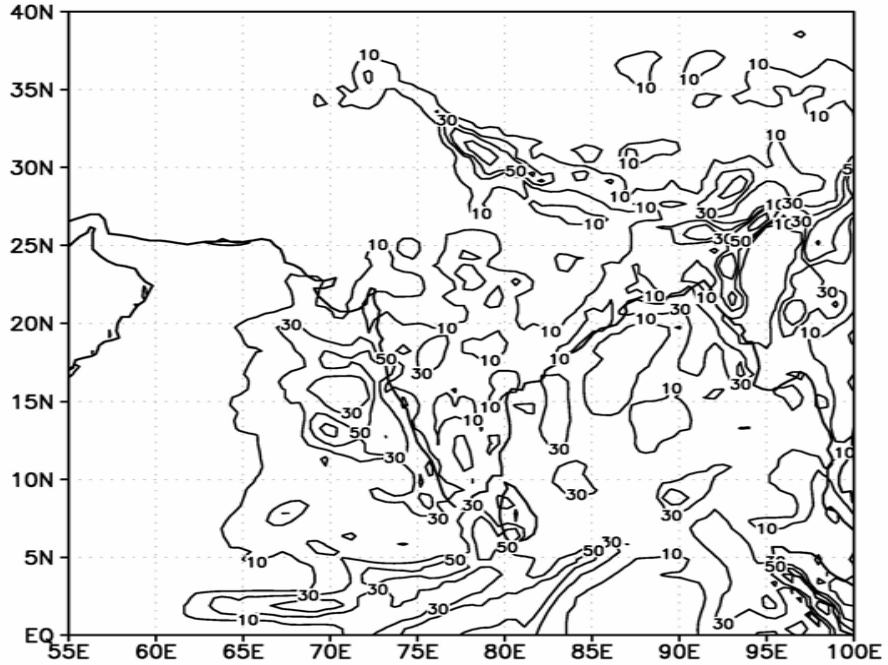

Wind (850 hPa), Aug 1998 (Grell)
Wind (850 hPa), Aug 1998 (BM)
Wind (850 hPa), Aug 1998 (Kuo)
Wind (850 hPa) Aug 1998 (NCEP)
25N
20N
15N
10N
5N
EQ
5S
10S
40E
50E
60E
70E
80E
90E
100E
110E
20
2
6
10
14
18
22
10


Wind (200 hPa), Aug 1998 (Grell)
Wind (200 hPa), Aug 1998 (BM)
Wind (200 hPa), Aug 1998 (Kuo)
Wind (200 hPa) Aug 1998 (NCEP)
40N
30N
20N
10N
EQ
10S
40E
50E
60E
70E
80E
90E
100E
110E
30
4
8
12
16
20
24
28
32

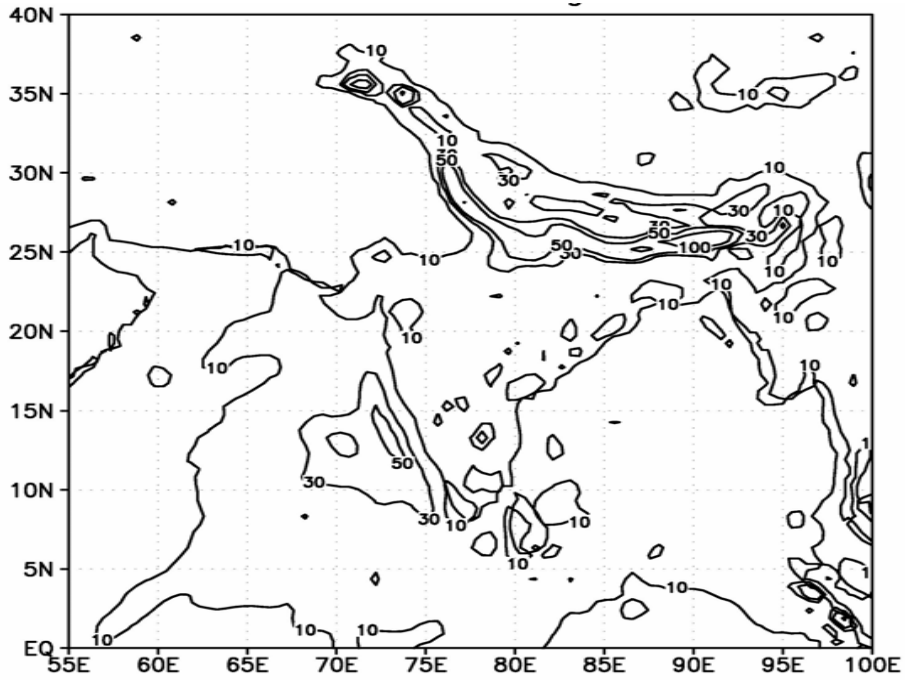
Total rainfall (Cm), Aug 1998 (Grell)



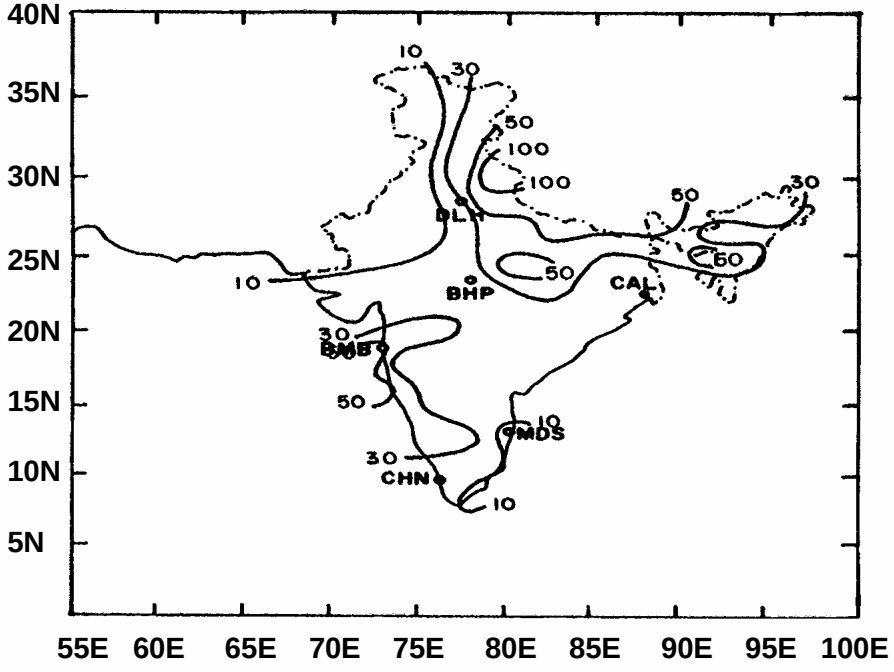
Total rainfall (Cm), Aug 1998 (BM)



Total rainfall (Cm), Aug 1998 (Kuo)

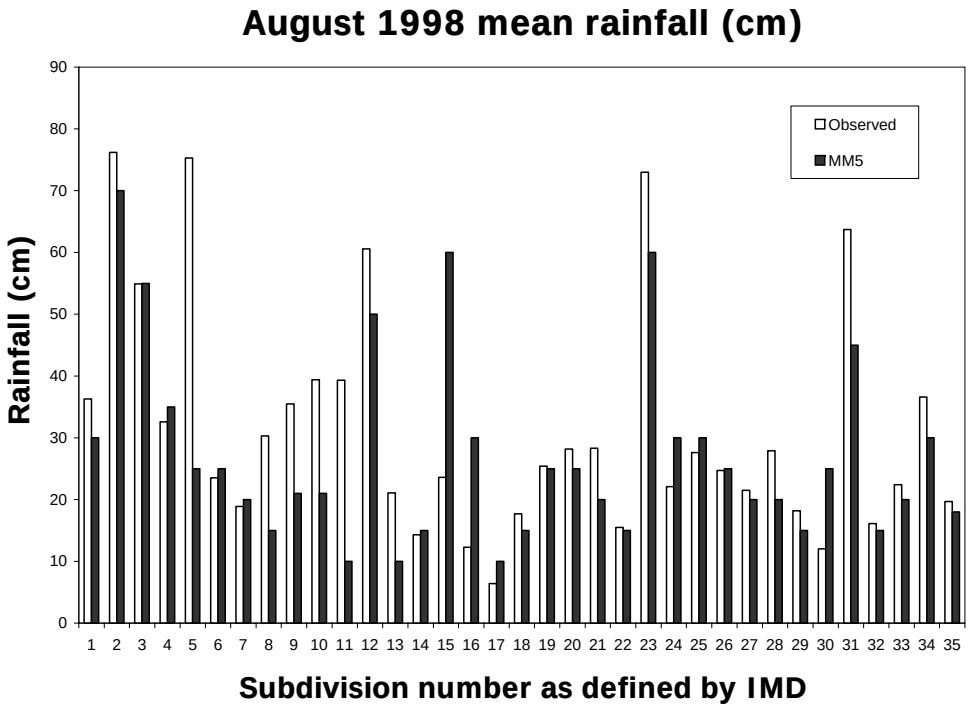


Total rainfall (Cm), Aug 1998 (IMD Obsv.)

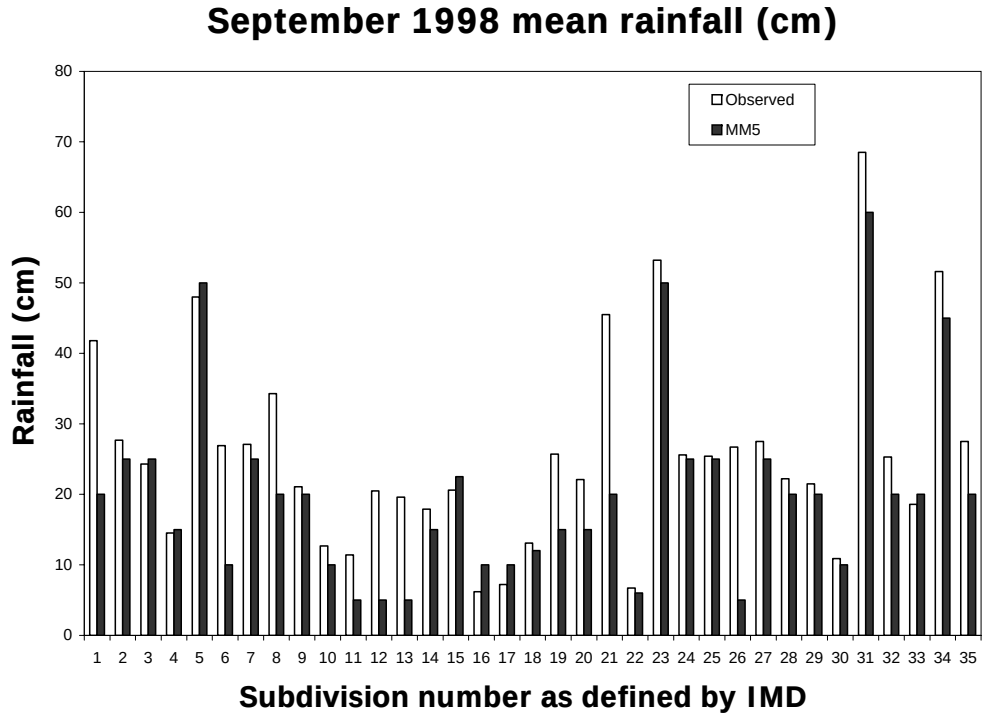


Station	MM5			IMD (Cm)
	Grell (Cm)	BM (Cm)	Kuo (Cm)	
Mumbai	23	50	26	50
Delhi	11	27	80	30
Bhopal	34	31	22	30
Chennai	12	11	6	10
Kolkata	10	10	6	25

August mean rainfall (Cm) simulated by different convective schemes of MM5 and based on observed values of IMD.

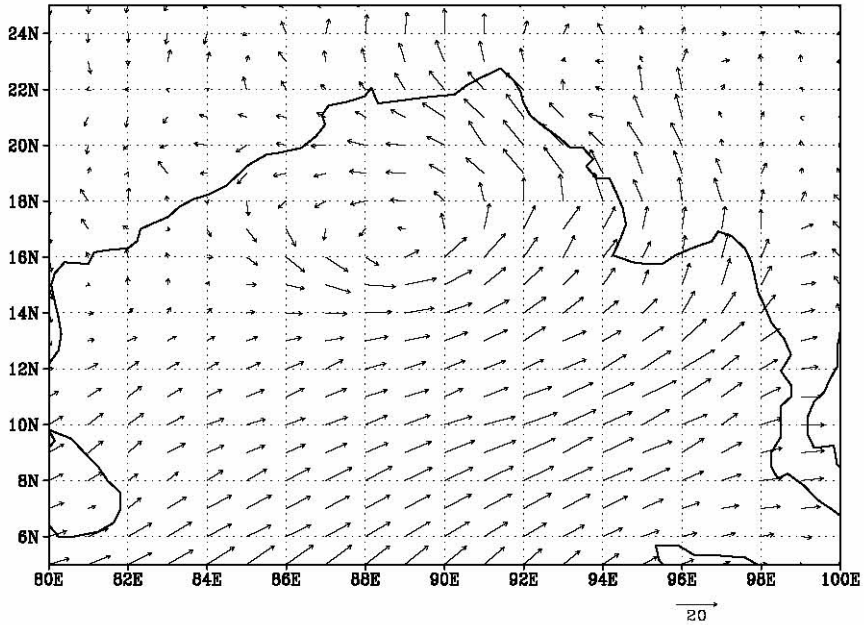


Good agreement for 21 subdivisions (1, 2, 3, 4, 6, 7, 12, 14, 17, 18, 19, 20, 22, 25, 26, 27, 29, 32, 33, 34 and 35).

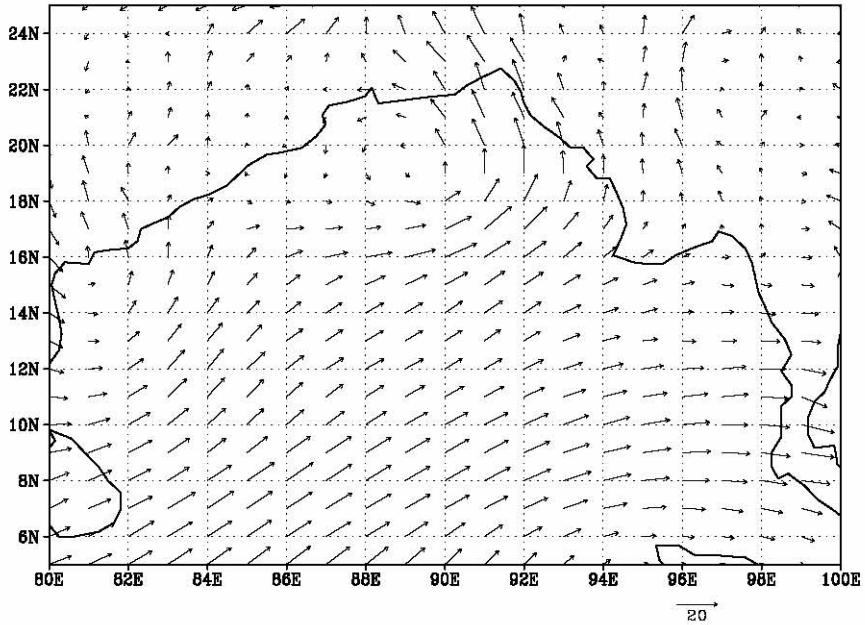


Good agreement for 22 subdivisions (2, 3, 4, 5, 7, 9, 10, 14, 15, 16, 17, 18, 22, 23, 24, 25, 27, 28, 29, 30, 32 and 33)

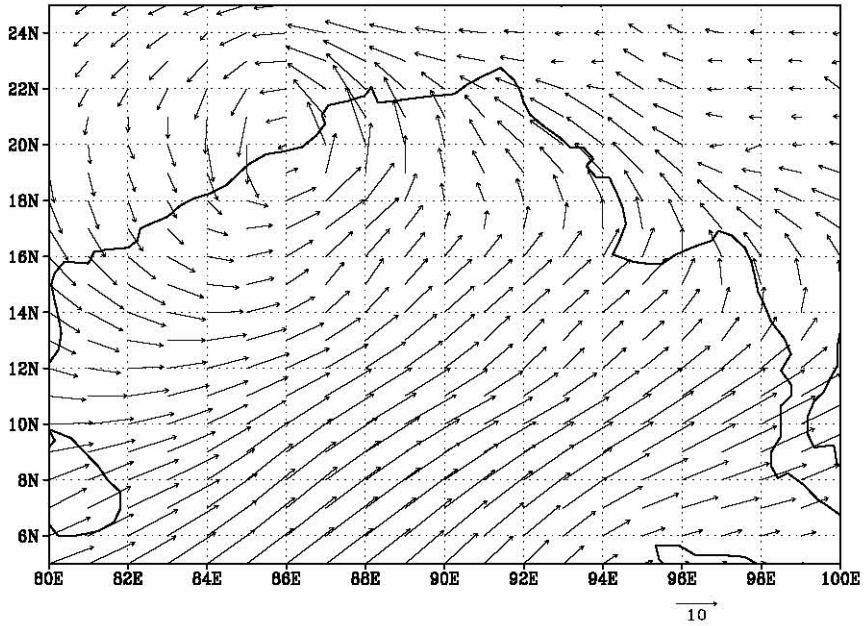
wind (850 hPa), 27 Oct 1999, 1200



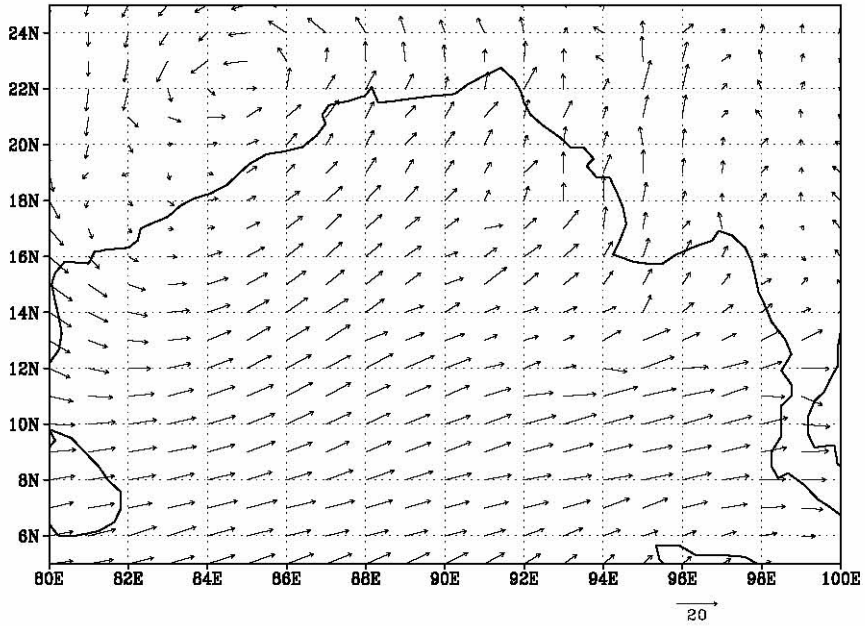
wind (850 hPa), 28 Oct 1999, 1200

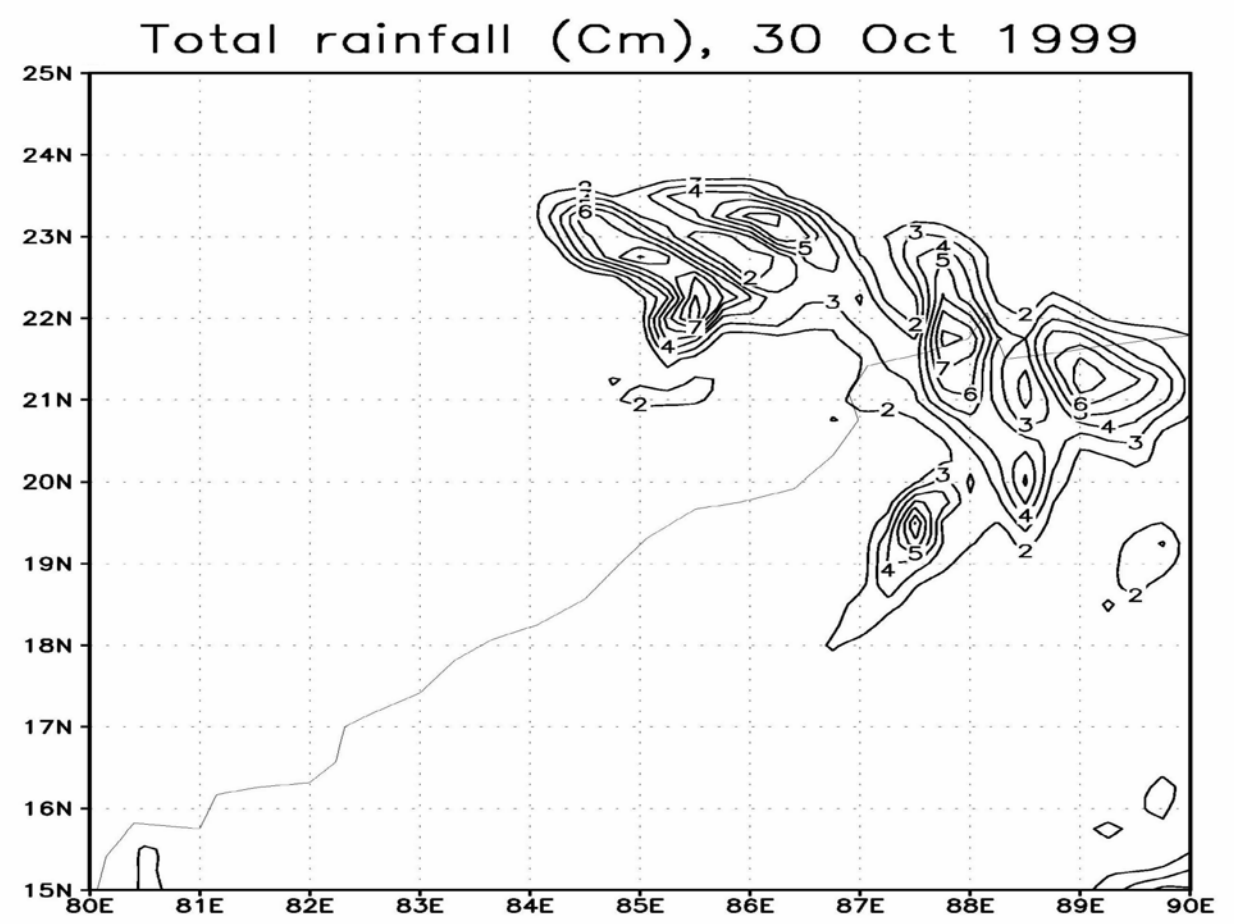


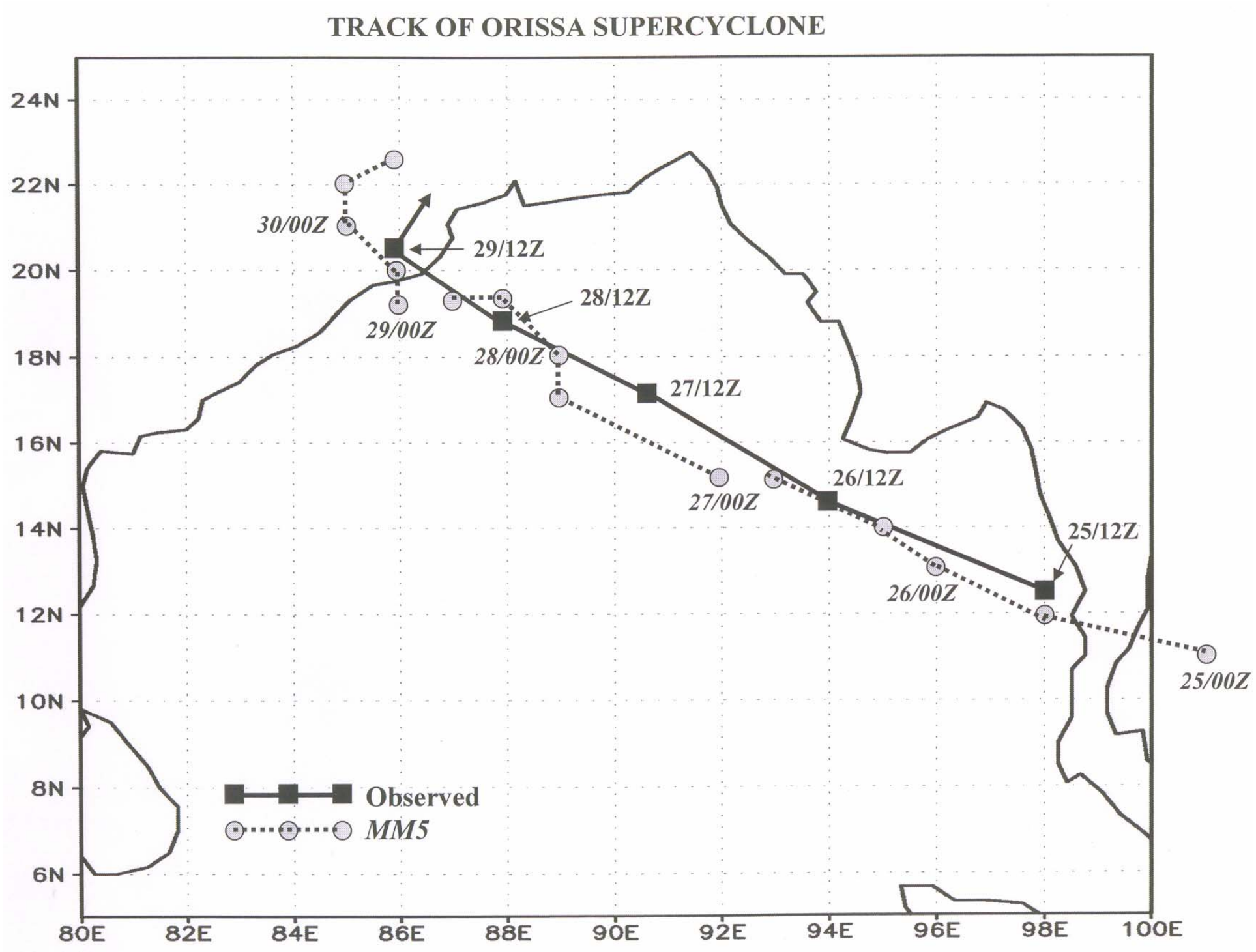
wind (850 hPa), 29 Oct 1999, 1200



Wind (850 hPa), 30 Oct 1999, 1200




Total rainfall (Cm), 30 Oct 1999
25N
24N
23N
22N
21N
20N
19N
18N
17N
16N
15N
80E
81E
82E
83E
84E
85E
86E
87E
88E
89E
90E


TRACK OF ORISSA SUPERCYCLONE
24N
22N
20N
18N
16N
14N
12N
10N
8N
6N
80E
82E
84E
86E
88E
90E
92E
94E
96E
98E
100E
30/00Z
29/12Z
29/00Z
28/12Z
28/00Z
27/12Z
27/00Z
26/12Z
26/00Z
25/12Z
25/00Z
Observed
MM5

OVERVIEW OF RegCM3 MODEL

- 14/18/22 vertical layers, grid point limited area model (LAM) with hydrostatic balance.
- Prognostic variables are u, v, t, q and p
- Map projections are Lambert Conformal, Normal Mercator, Rotated Mercator and Polar Stereographic
- Model Physics:

Cumulus Parameterization- Anthes-Kuo and Grell with Arakawa-Schubert and Fritsch-Chappell as the closure scheme in the Grell scheme

Large scale precipitaion scheme- SUBEX scheme (Pal et. al. 2000)

Planetary Boundary Layer Parameterization- Non local scheme (Holtslag et al. 1990)

Land Surface physics- BATS (Dickinson et al. 1993)

Radiation scheme- NCAR CCM3 scheme (Kiehl et al. 1996)

Ocean Flux Parameterization- Zeng scheme (Zeng et al. 1998)

Pressure Gradient scheme- Direct method and hydrostatic deduction scheme

Lake physics- Hostetler et al. (1993)

Tracer model- Qian et al. (1999)

Domain selected

Central Lat and Lon- 20°N, 80°E with 115 X 101 Points along XY direction

Domain covers 50°E to 105°E and 5°S to 45°N with Grid distance- 55 Km

Mercator Projection

Data used

USGS Global 30 Arc-Sec. elevation and GLCC dataset at 30' resolution to create terrain and landuse files.

Weekly analysis (1981-2002) OISST available from NOAA for integration.

Reanalysis datasets for the period 1993 to 1996 for setting the initial and boundary conditions.

Monthly mean snow depth based on NIMBUS-7 SMMR.

Physics options used

- **SUBEX scheme is used for the explicit moisture scheme.**
- **Holtslag scheme is used for the planetary boundary layer.**
- **Exponential Relaxation for lateral boundary condition.**
- **Zeng scheme for Ocean flux parameterization.**
- **Normal/Directmethod for Pressure Gradient scheme.**
- **simple cloud scheme for the atmospheric radiation.**
- **multi-layer soil model has been used.**

MODEL INTEGRATIONS

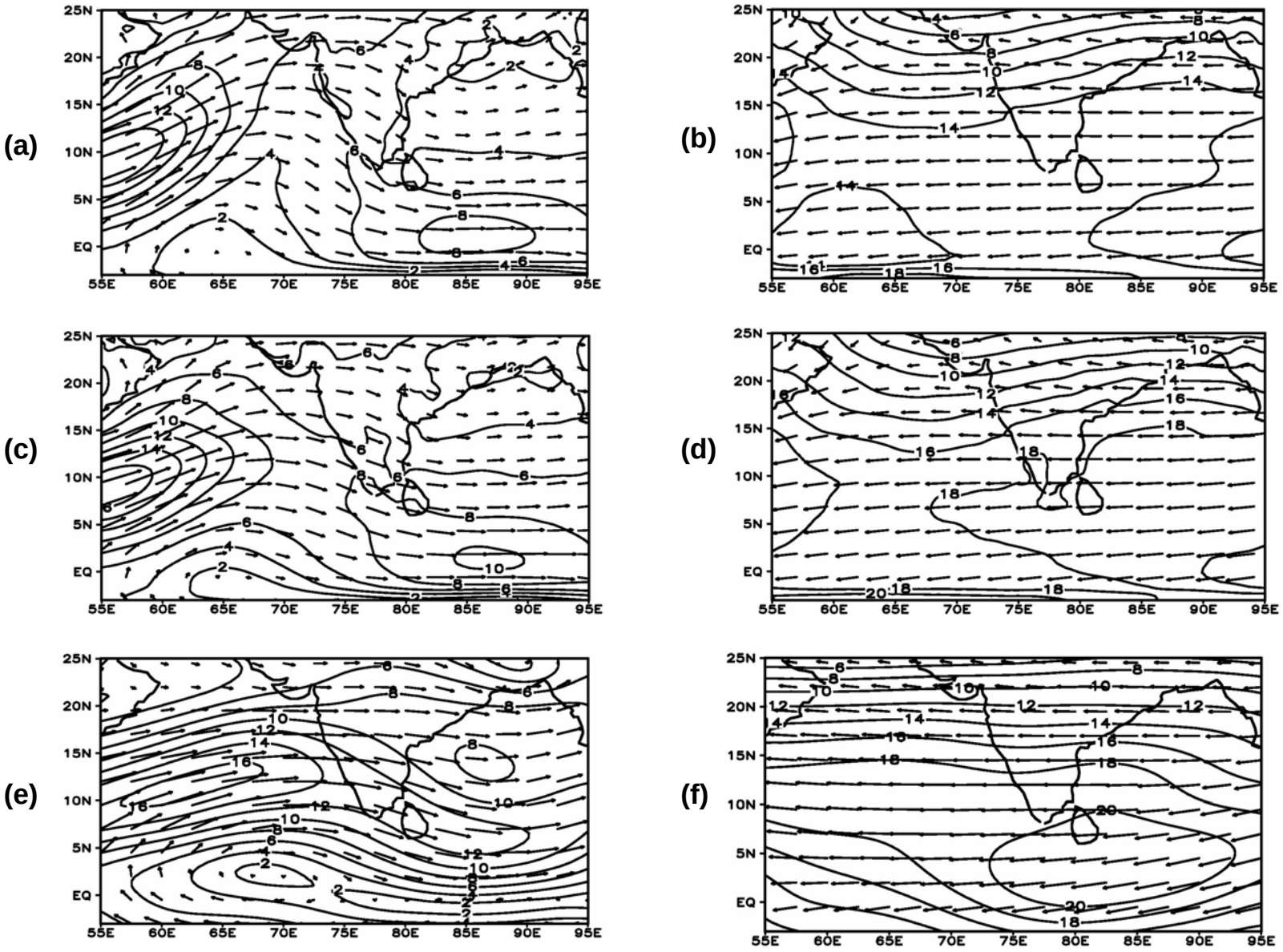
Model is integrated from 1st April to 30th September for each of the years from 1993 to 1996 both for no-snow and snow experiment.

The no-snow experiment is conducted for two cumulus parameterization schemes Kuo and Grell with Arakawa-Schubert as the closure scheme.

Inter-comparison of rainfall simulated by the model in two different convective schemes such as Kuo and Grell are done.

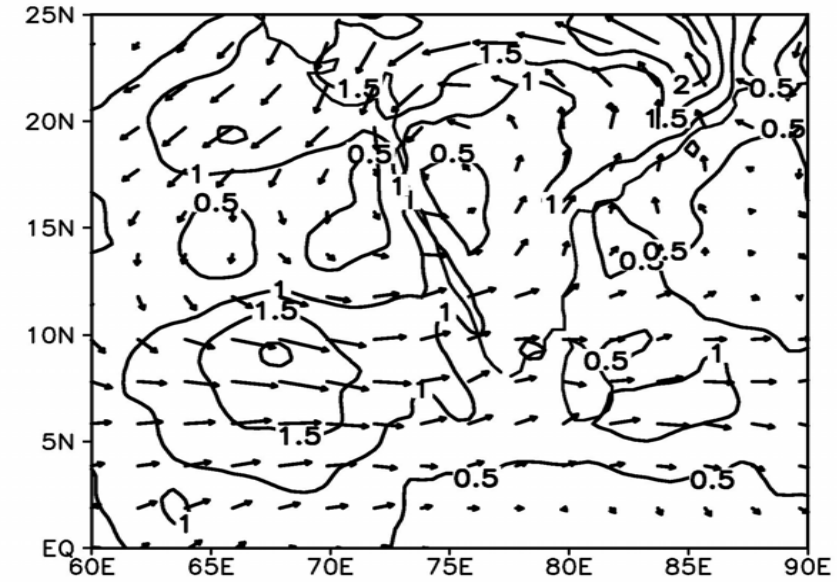
Inter-comparison of rainfall simulated by the model in no-snow as well as snow experiments are also done.

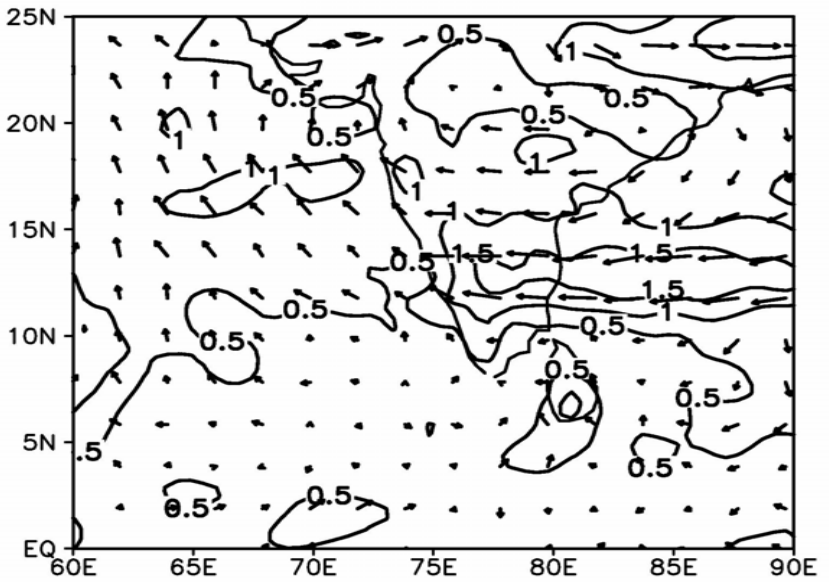
The monsoon circulation features are compared with those of NCEP/NCAR reanalysis and the rainfall with those of IMD observational rainfall data.



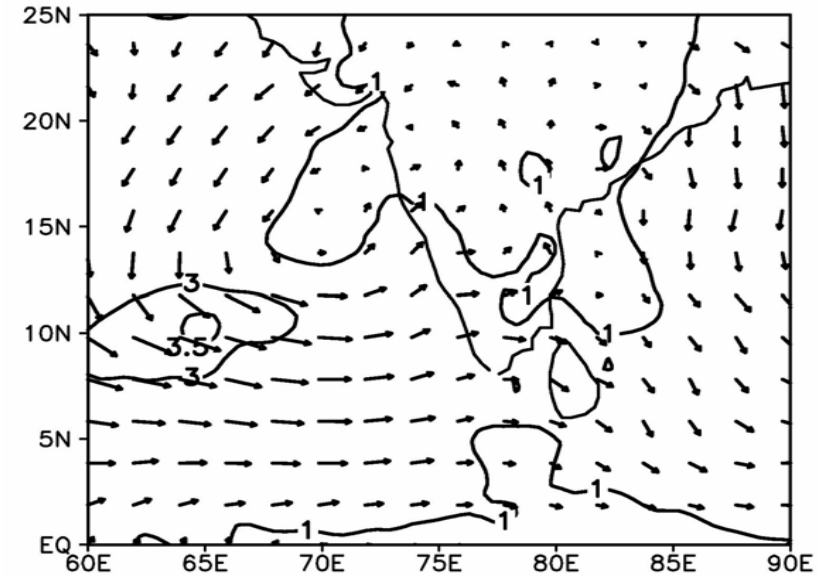
1993-96 average of JJAS mean wind (m/s) for Kuo at (a) 850 hPa and (b) 200 hPa, for Grell at (c) 850 hPa and (d) 200 hPa and for NCEP reanalysis at (e) 850 hPa and (f) 200 hPa

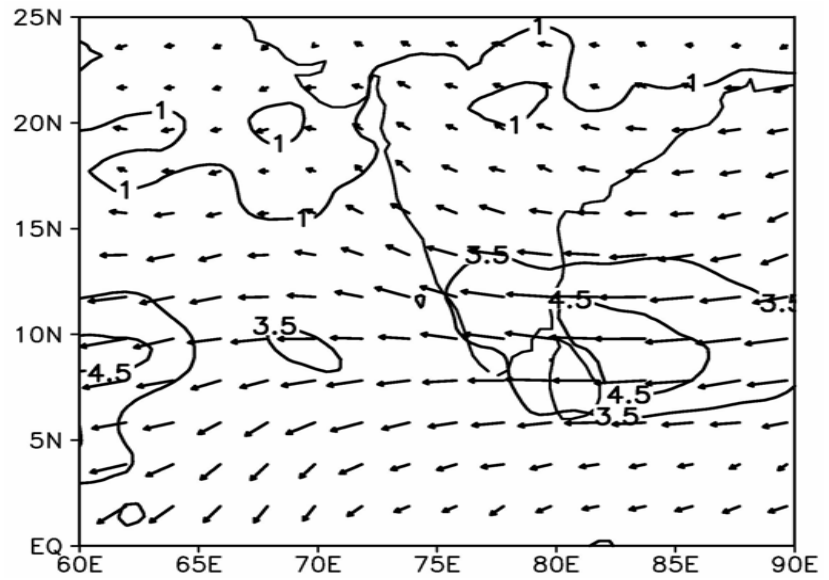
JJAS mean differences (Grell-Kuo) of wind at 850 hPa and 200 hPa





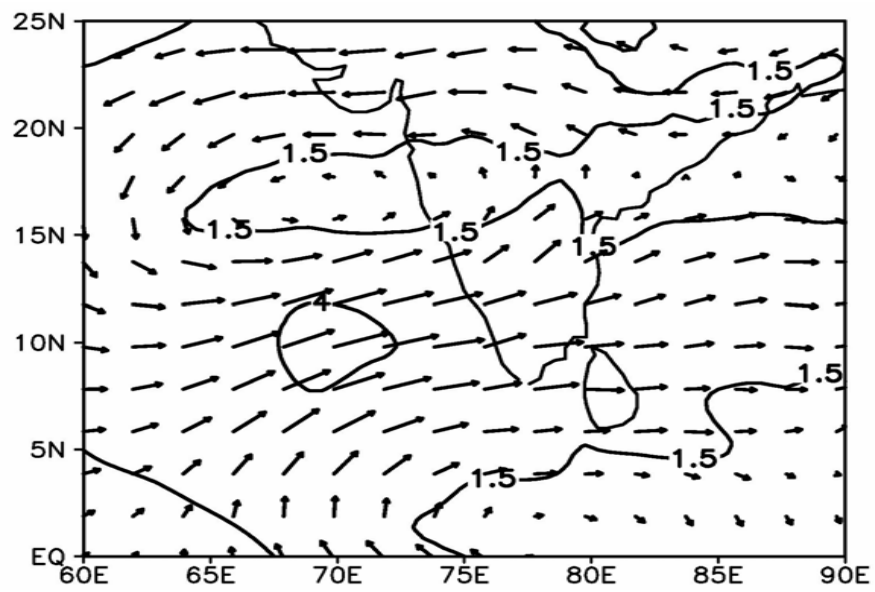
1993

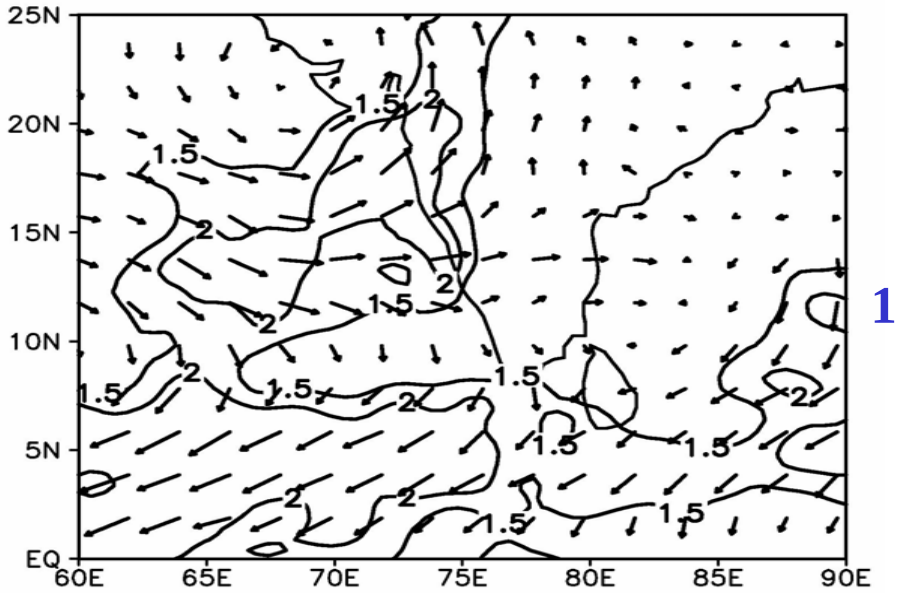




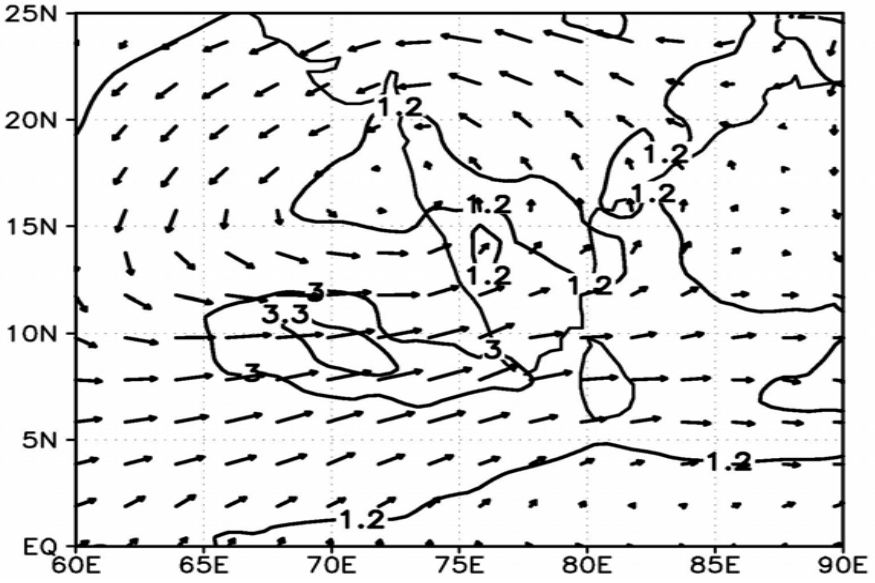
1994

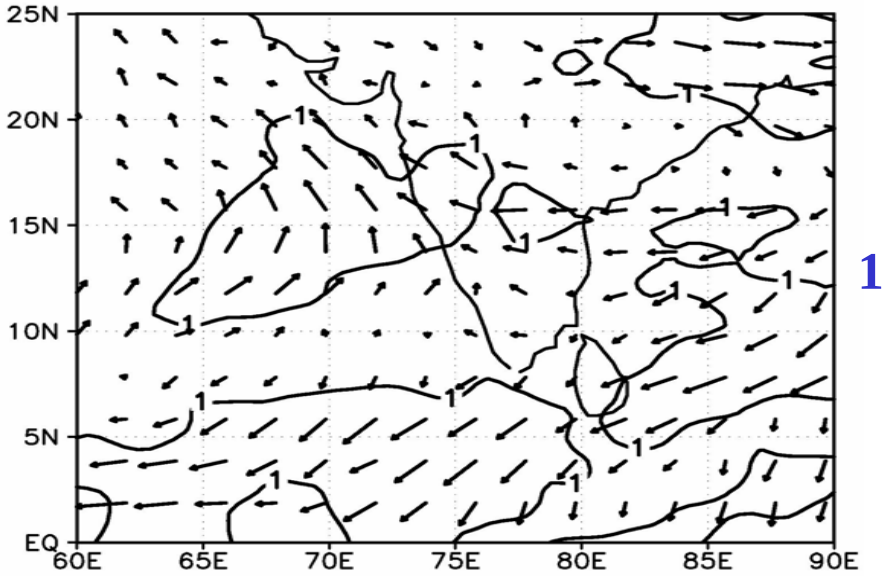
JJAS mean differences (Grell-Kuo) of wind at 850 hPa and 200 hPa





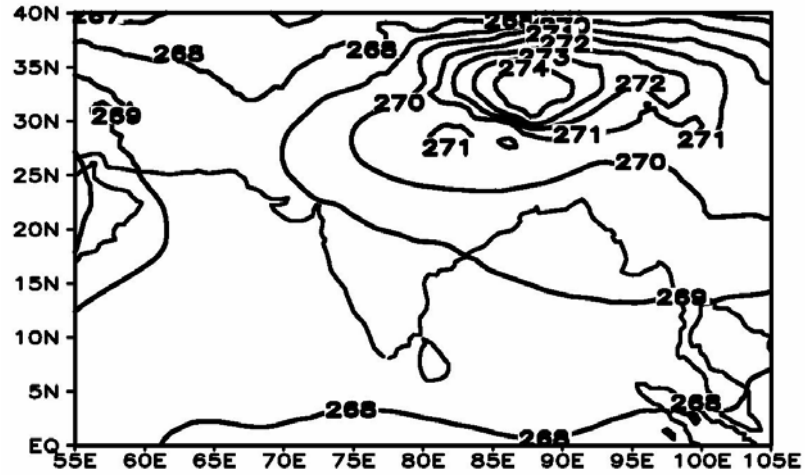
1995



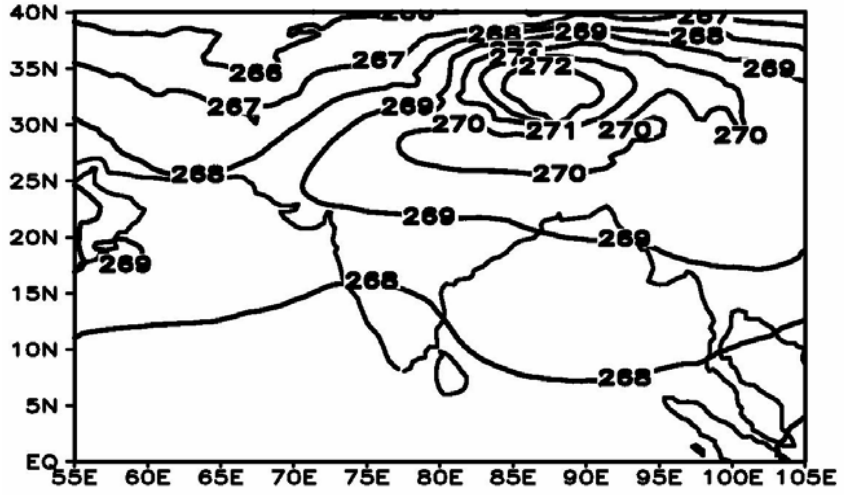


1996

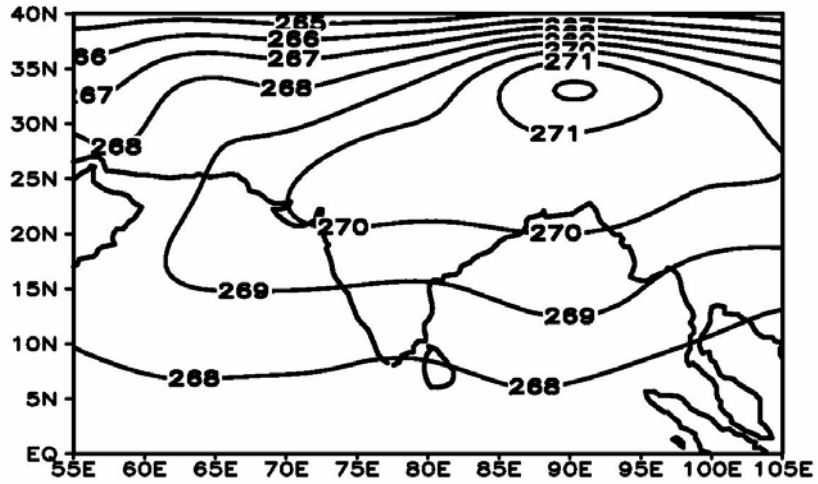
(a)



(b)

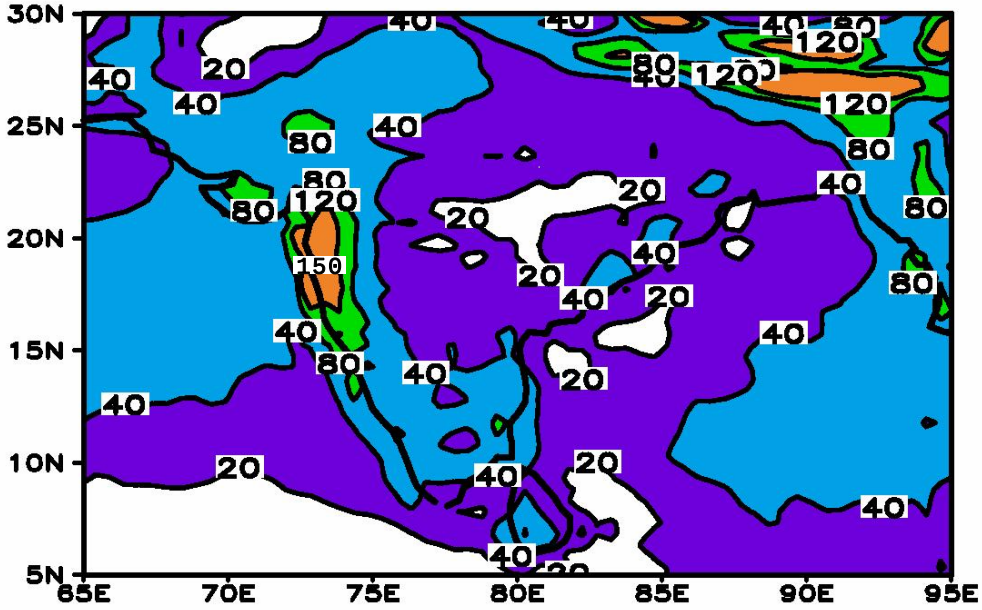


(c)

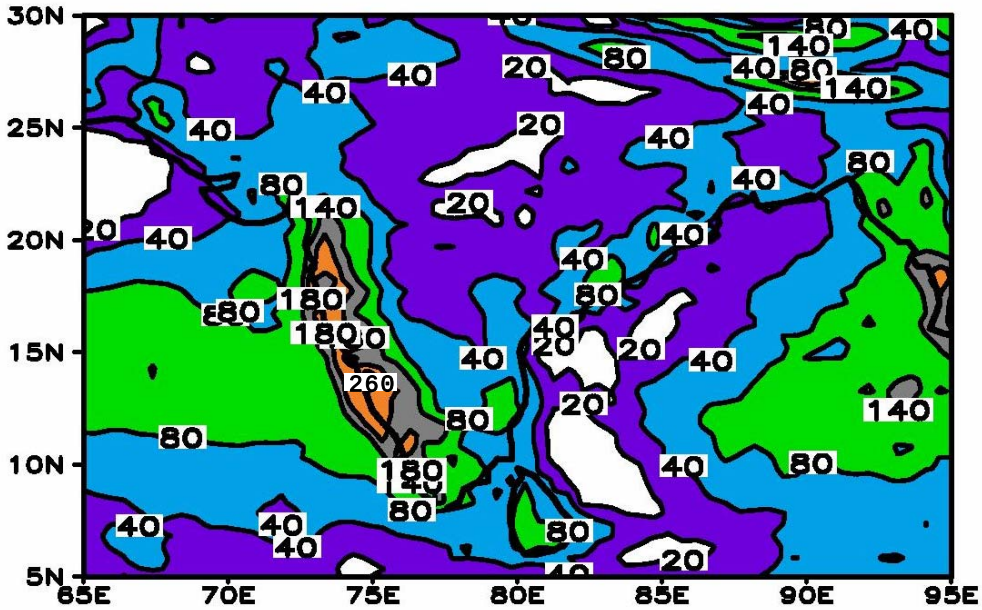


1993-96 average of JJAS mean Temperature at 500 hPa in (a) Kuo, (b) Grell and (c) NCEP Reanalysis.

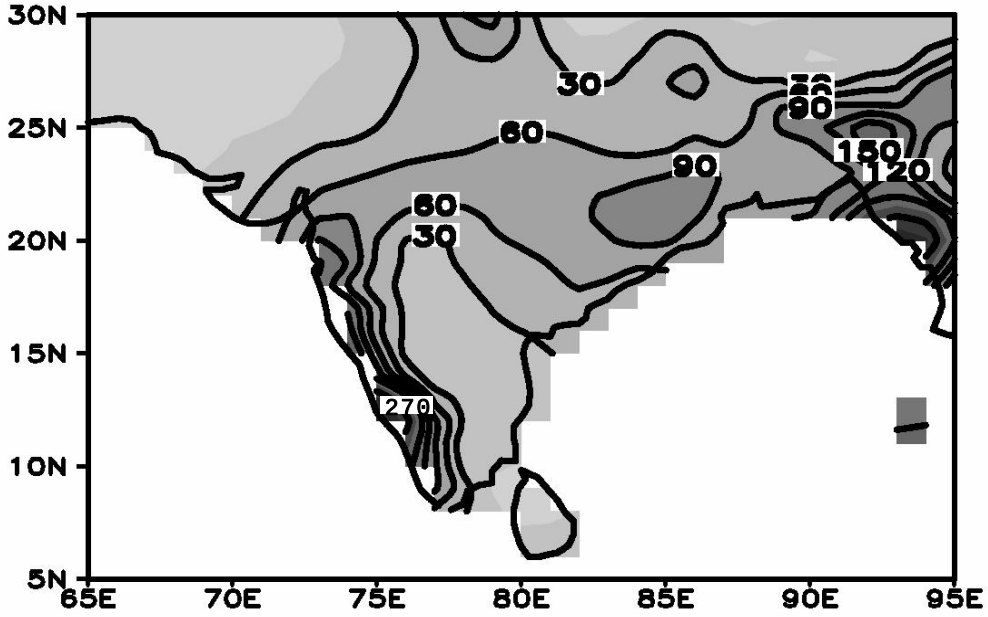
1993-1996 average of JJAS accumulated rainfall (cm) in Kuo convection scheme.



1993-1996 average of JJAS accumulated rainfall (cm) in Grell convection scheme.

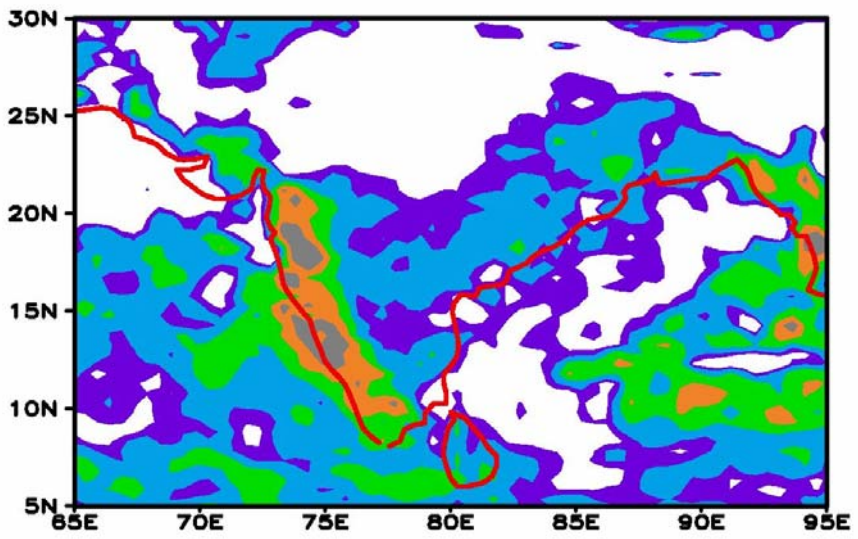


1993-1996 average of JJAS accumulated rainfall (cm) of GPCC

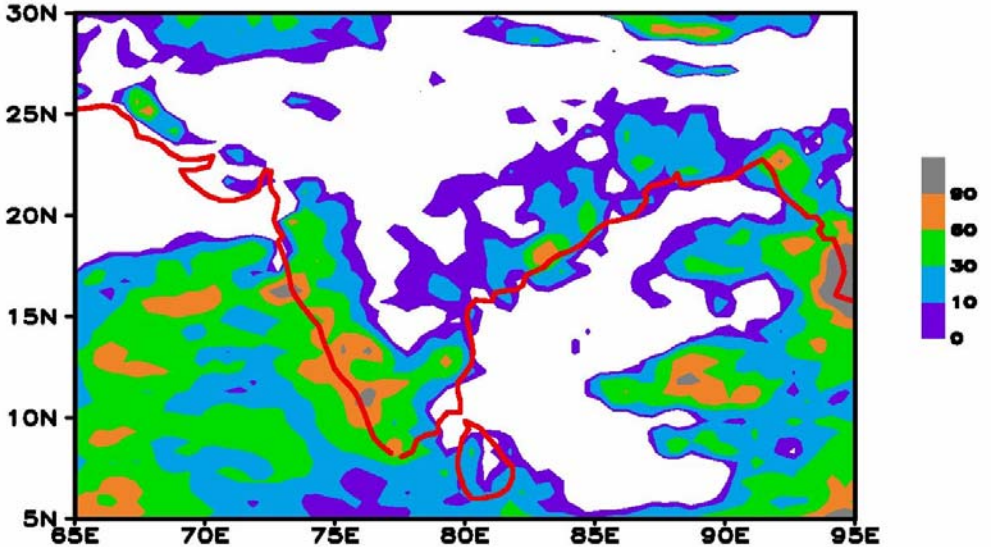


JJAS total rainfall differences (Grell-Kuo)

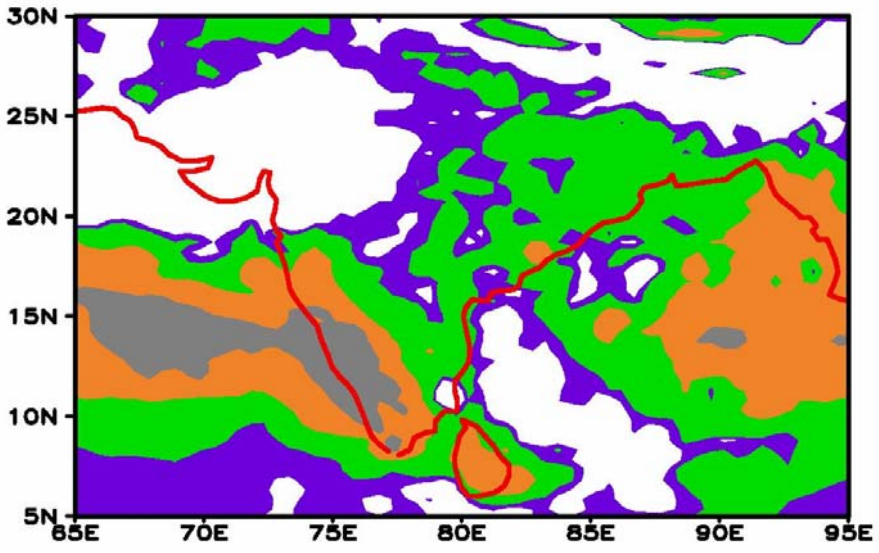
1993



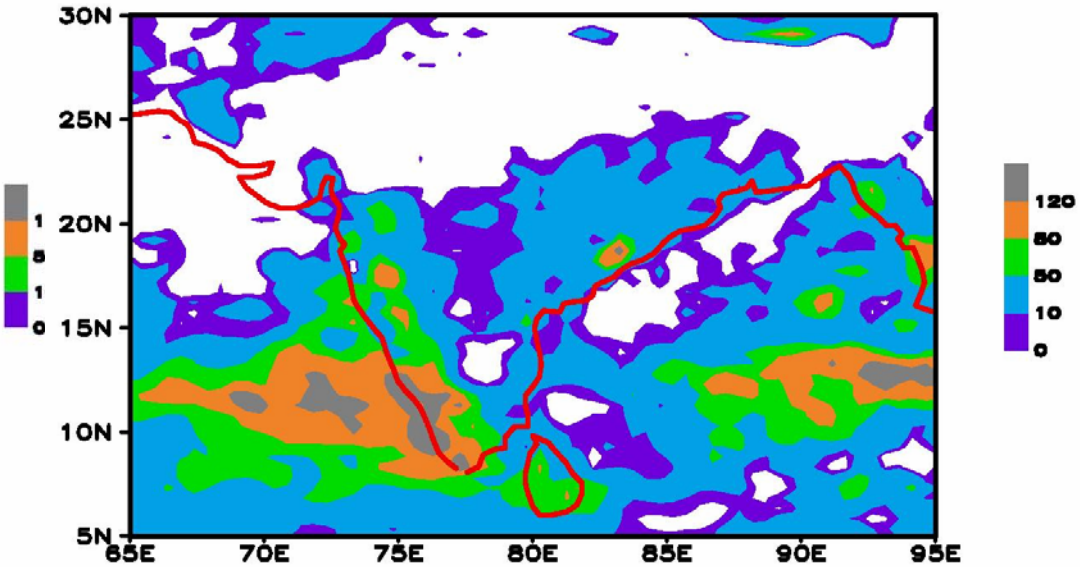
1994



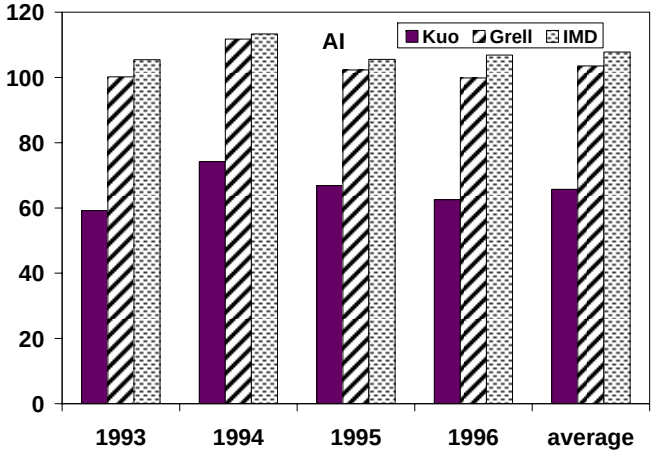
1995

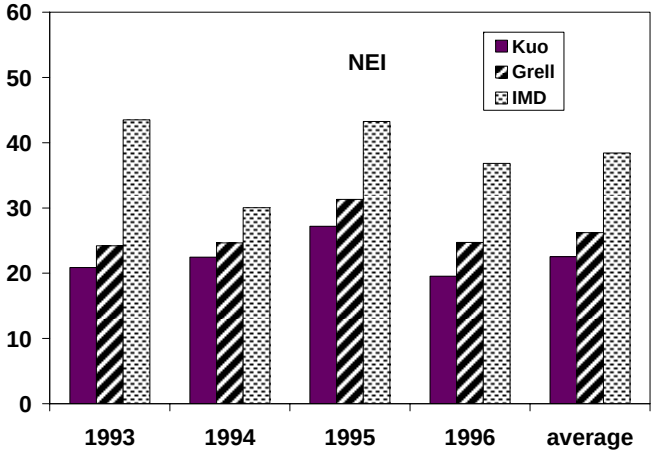


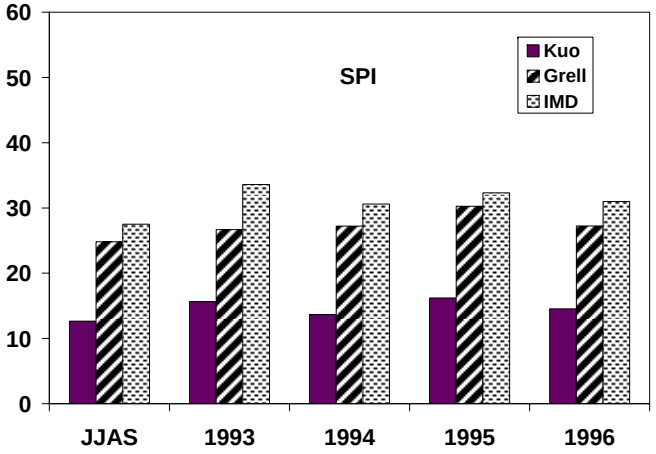
1996

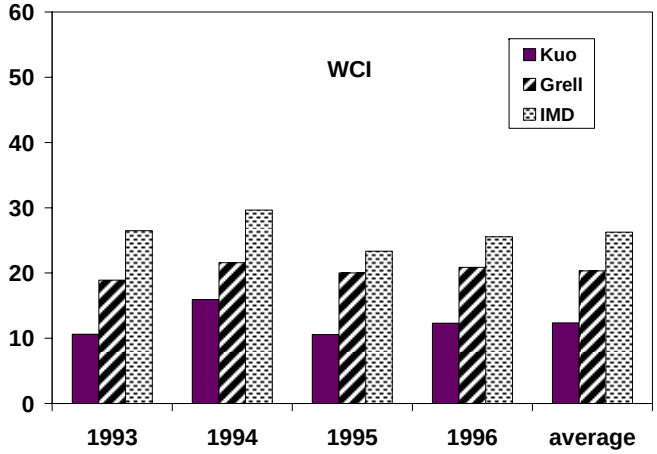


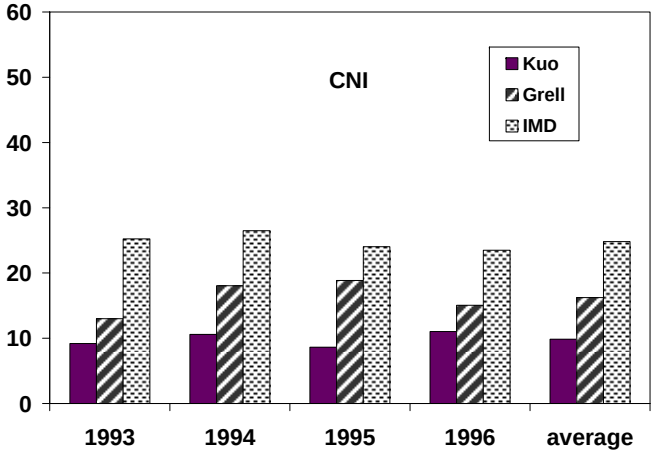
Comparison of rainfall simulated by RegCM3 in Grell and Kuo scheme with IMD observed rainfall

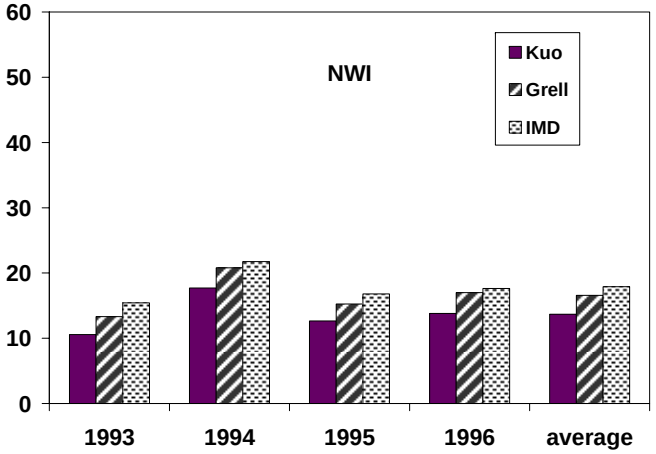


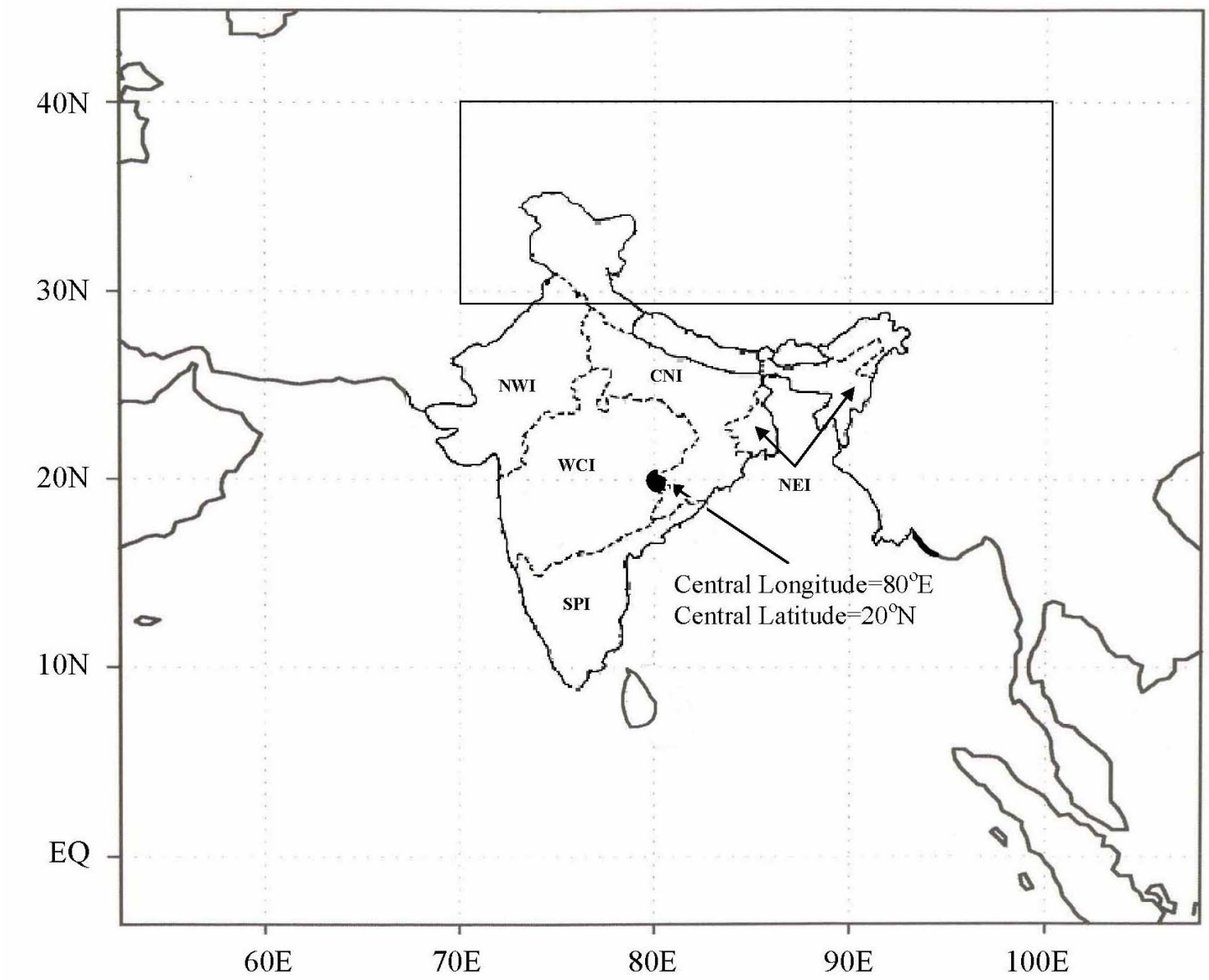






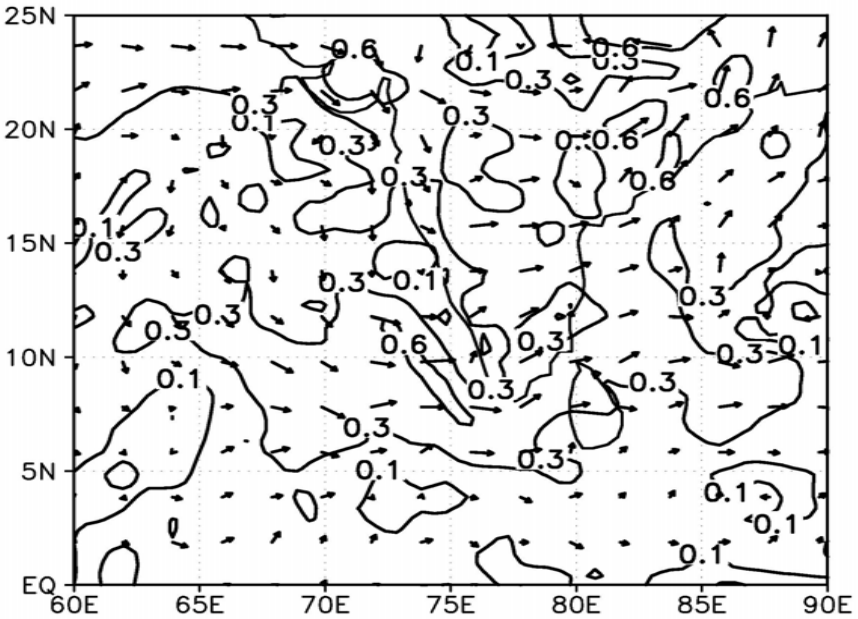


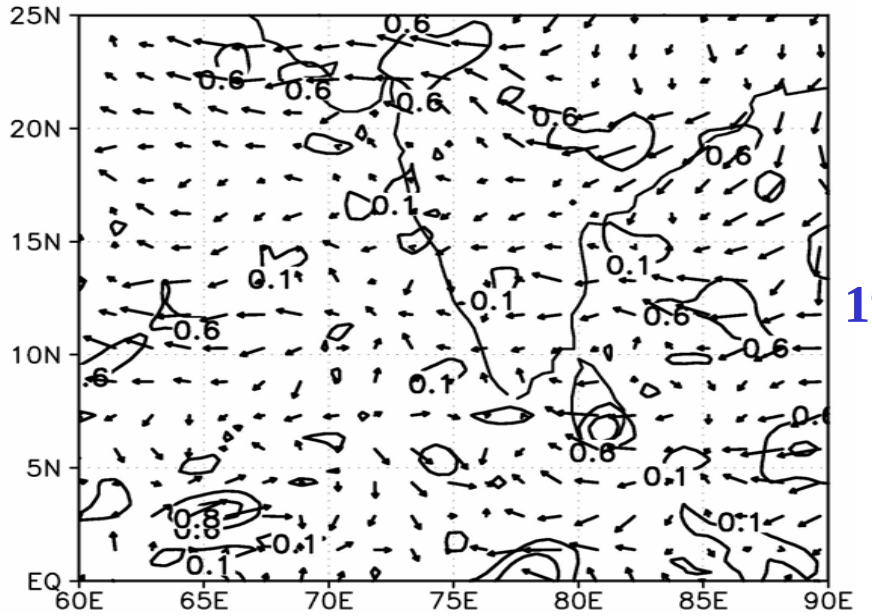




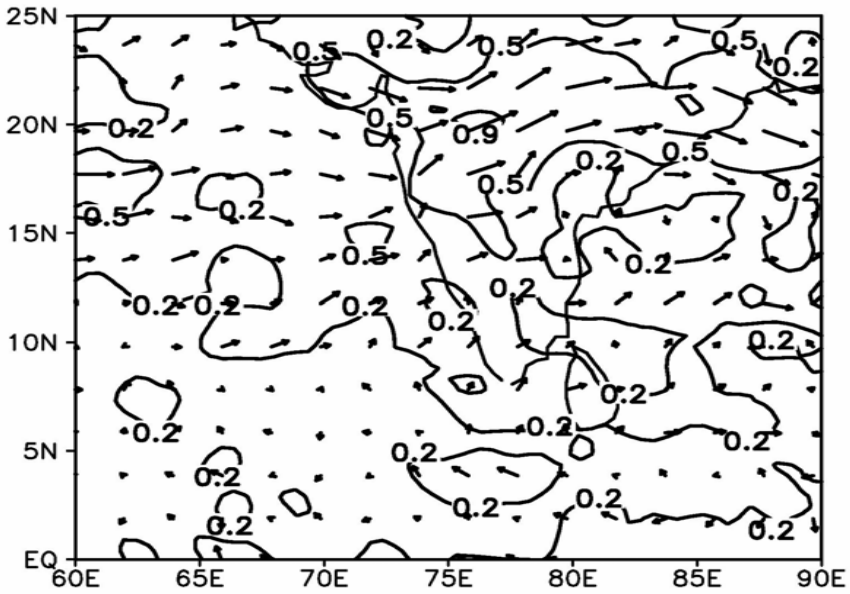
Model domain used in RegCM3, five homogeneous zones of India such as North West India (NWI), West Central India (WCI), Central Northeast India (CNI), North East India (NEI) and South Peninsular India (SPI) and the region over which 10cm of snow has been introduced uniformly in the snow experiment.

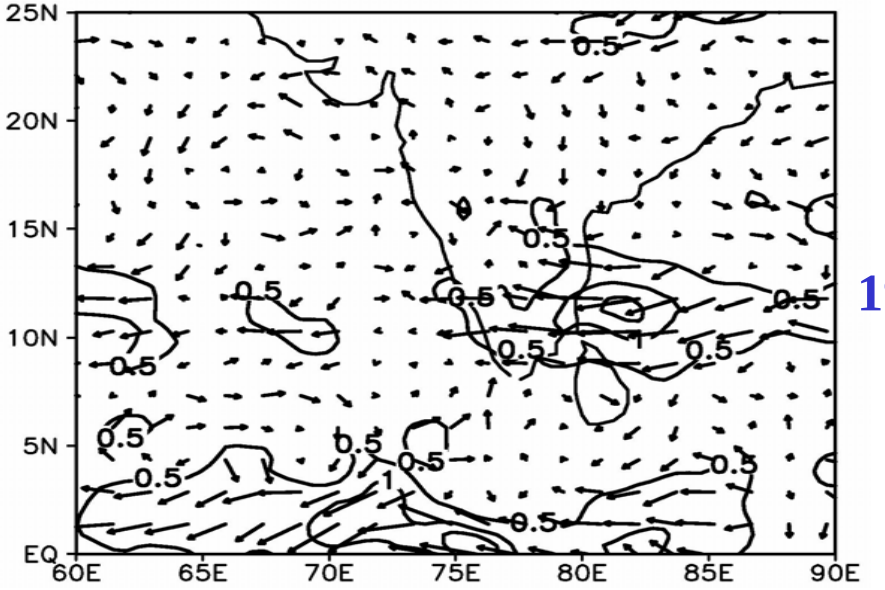
Differences (no-snow minus snow) of wind at 850 hPa and 200 hPa





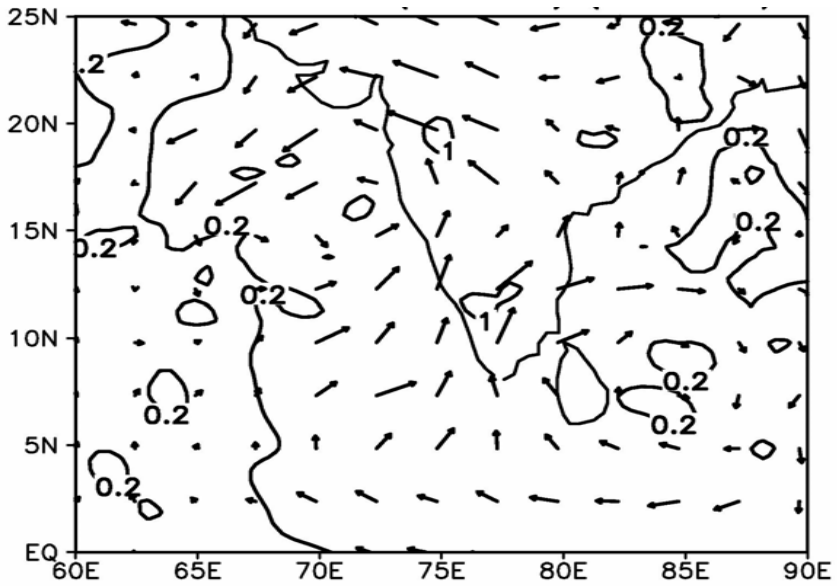
1993

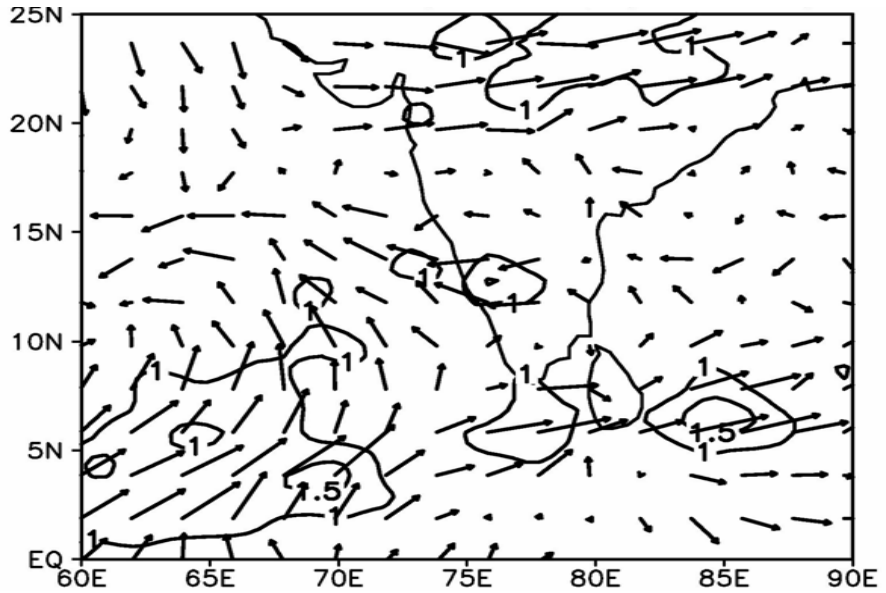




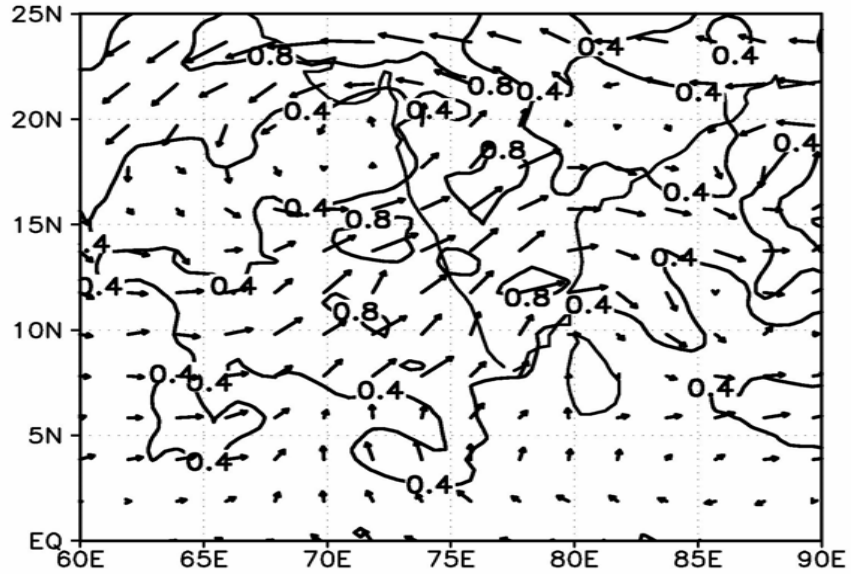
1994

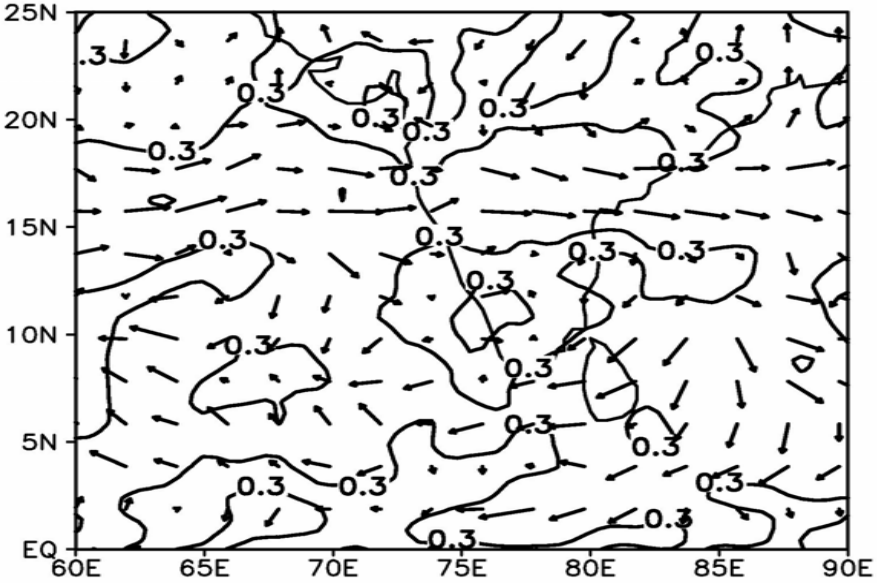
Differences (no-snow minus snow) of wind at 850 hPa and 200 hPa



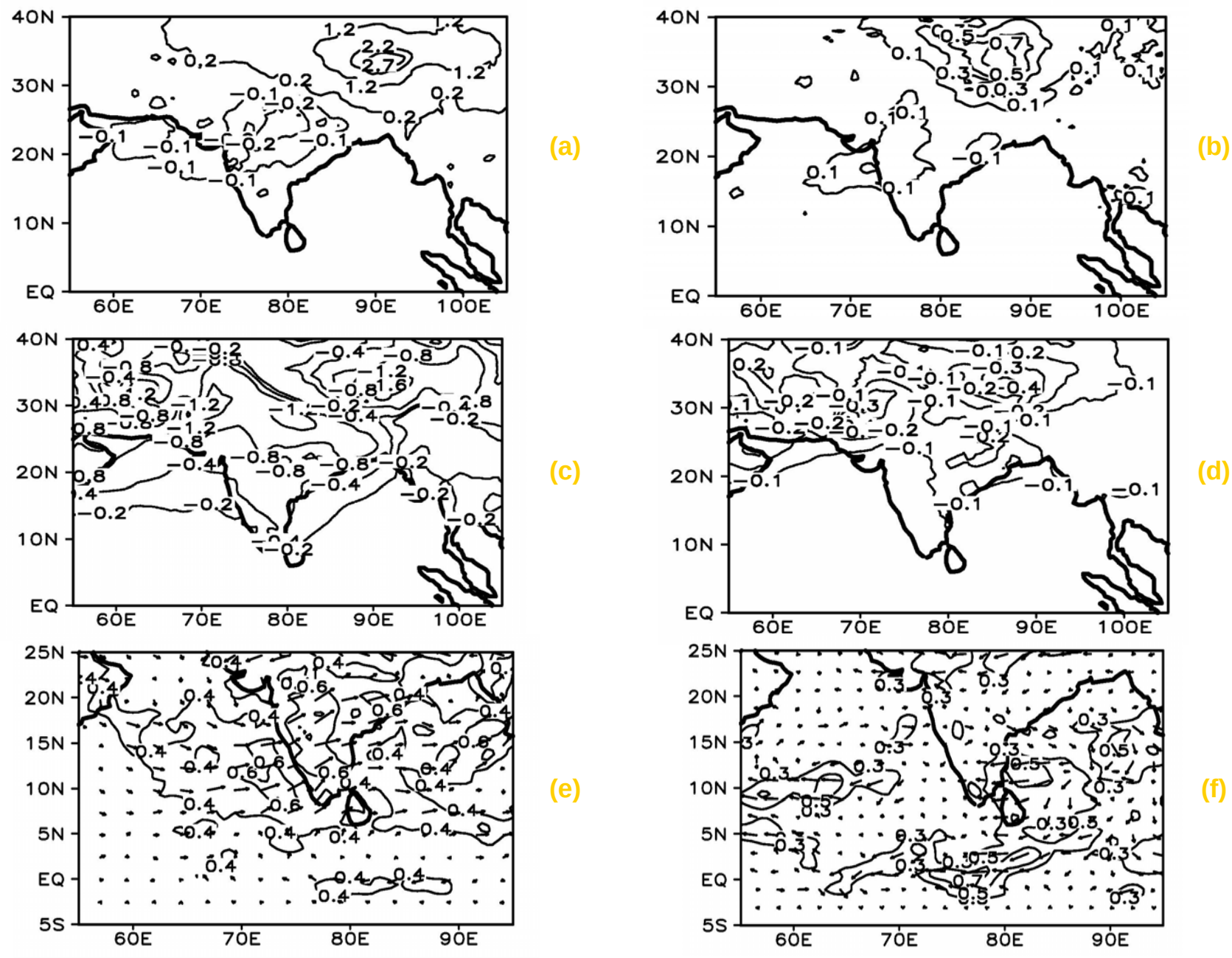


1995





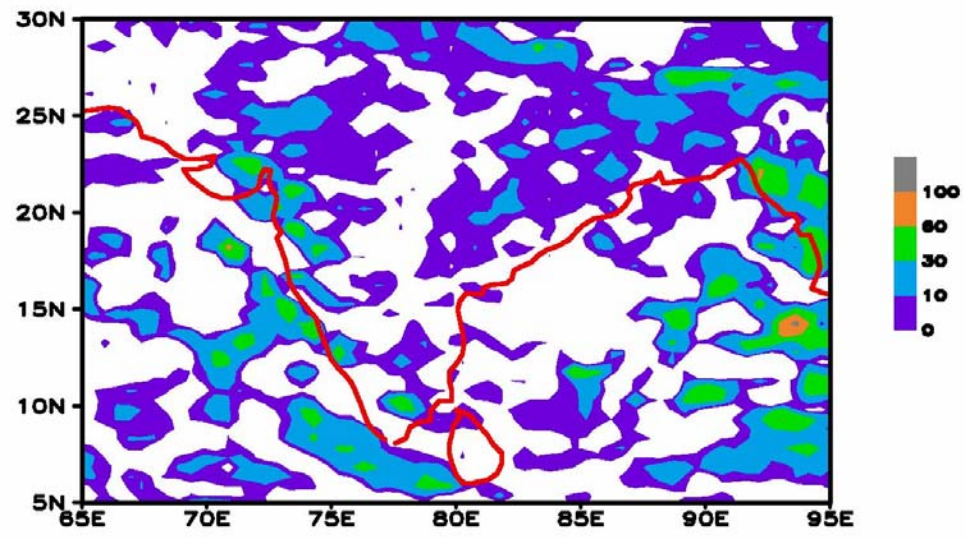
1996



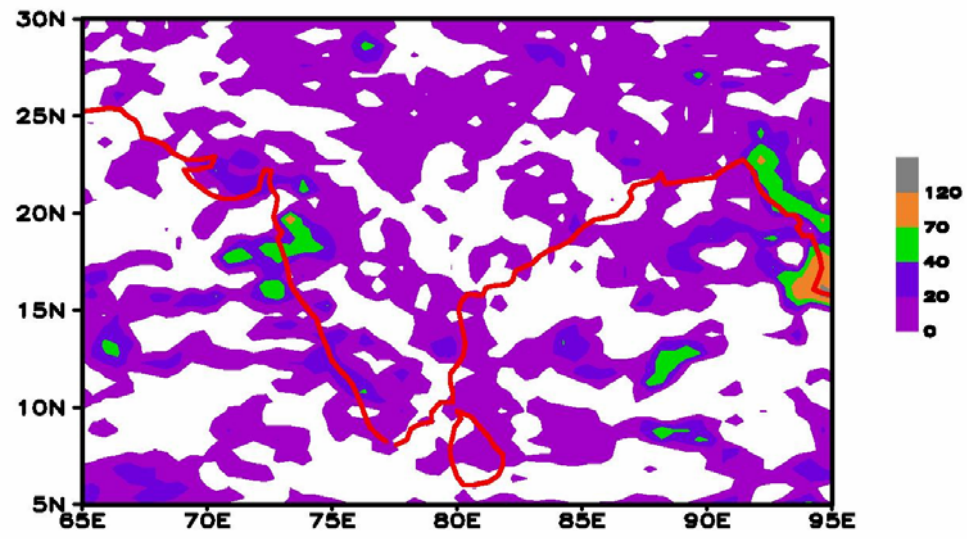
Differences (no-snow minus snow) in the composites of four years (1993 to 1996) of (a) temperature at 500hPa in AM, (b) temperature at 500hPa in (JJAS, (c) surface pressure in AM, (d) surface pressure in JJAS, (e) wind at 850hPa and (f) wind at 200hPa simulated by RegCM3.

JJAS total rainfall anomaly (Control-Experiment)

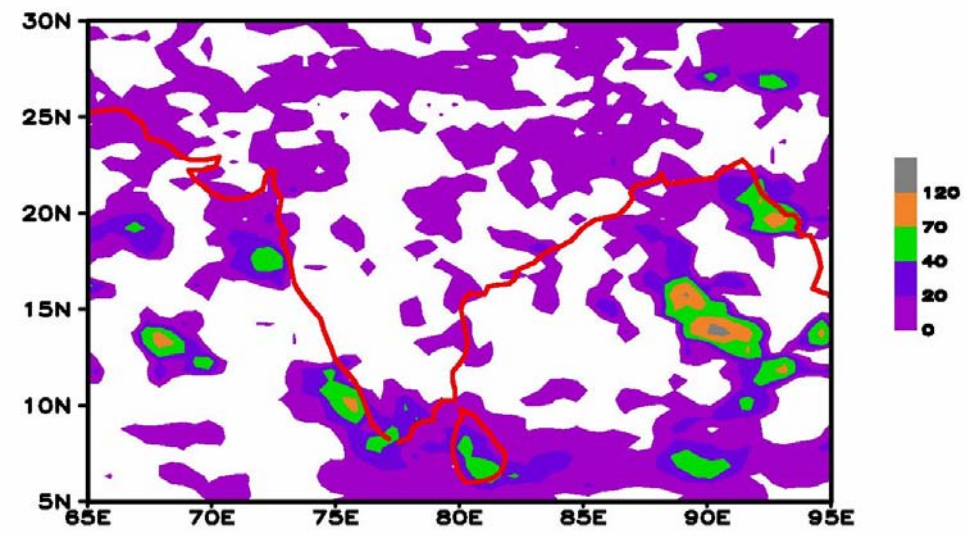
1993



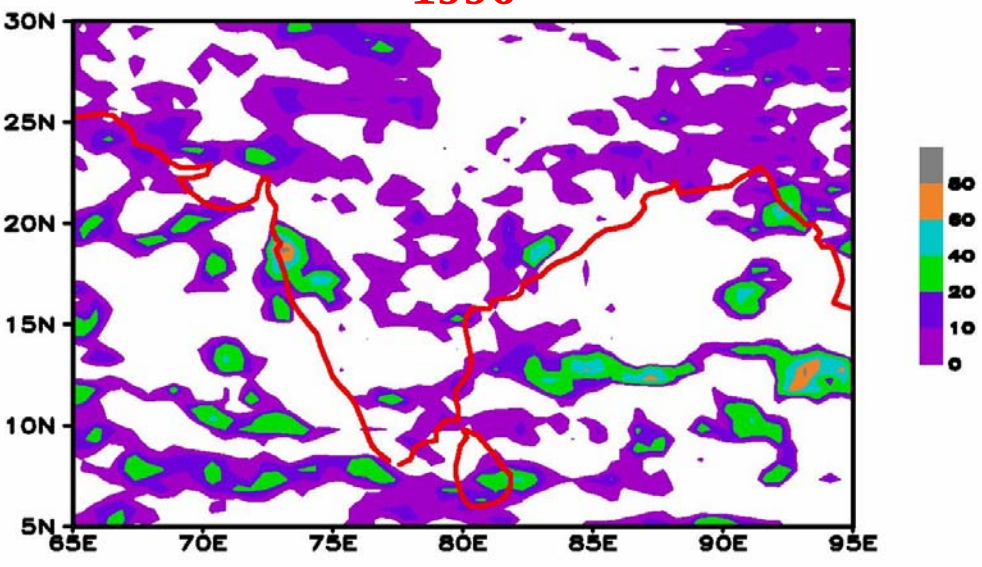
1994

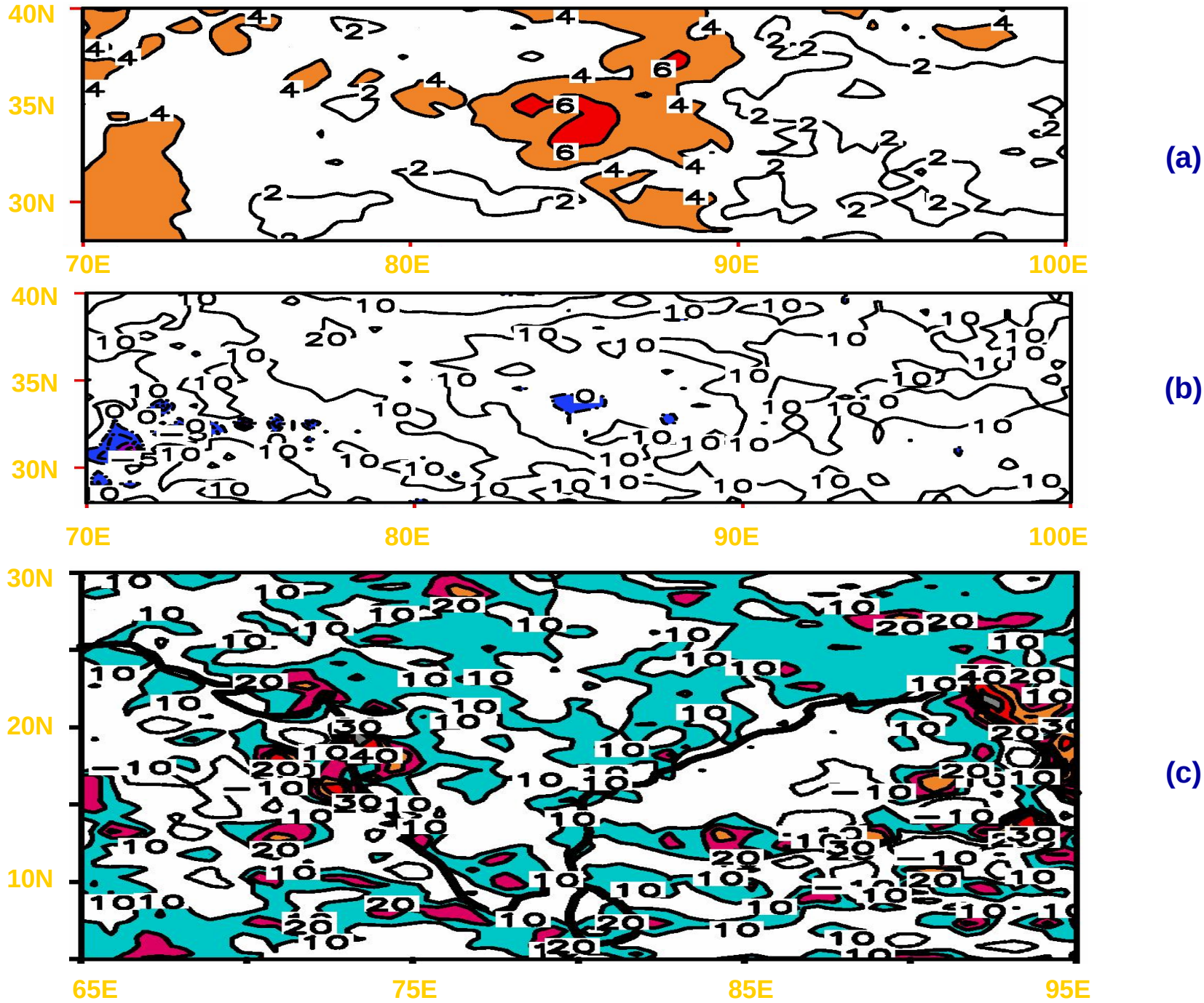


1995

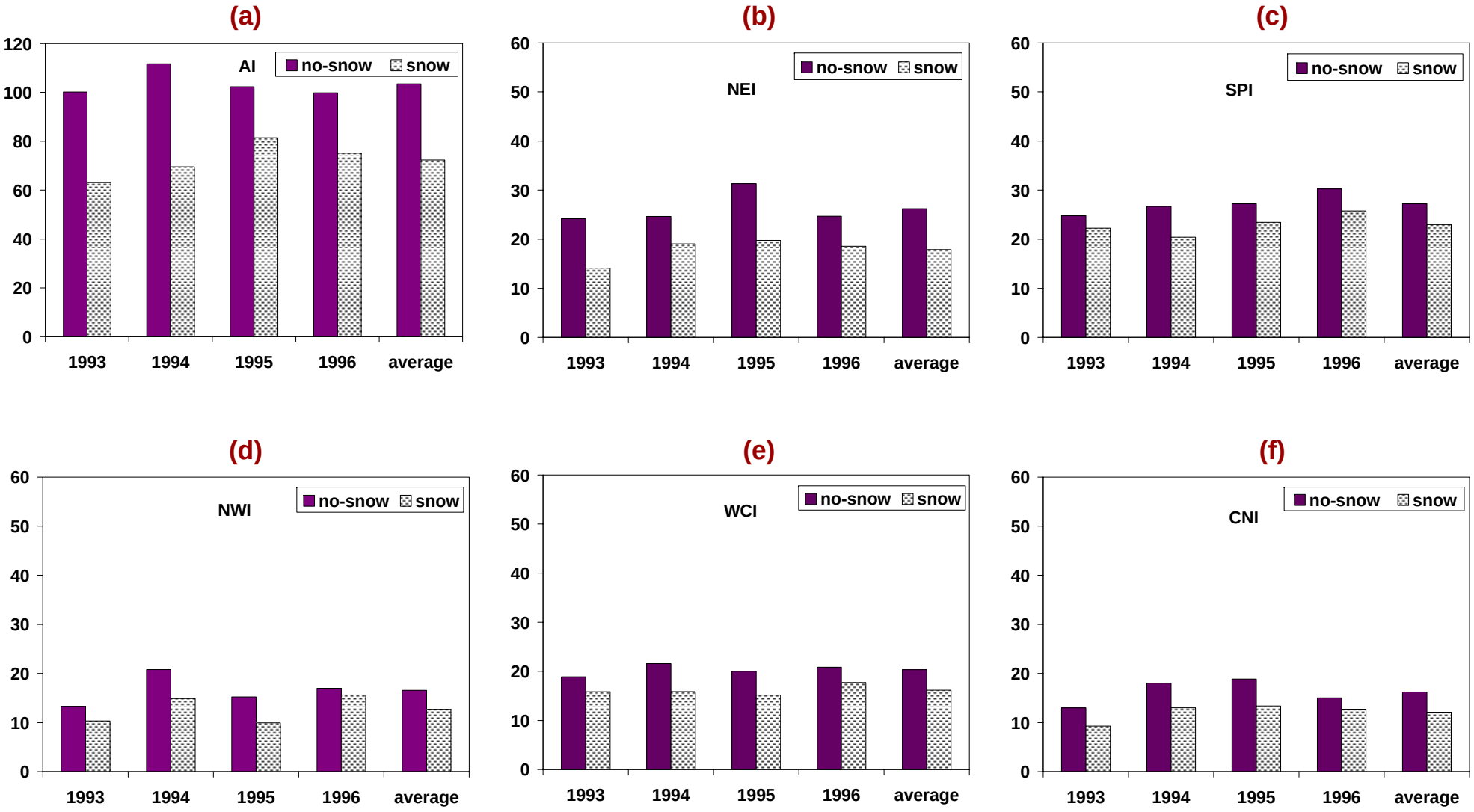


1996





Differences (no-snow minus snow) of the composites of four years (1993 to 1996) of JJAS mean (a) sensible heat flux, (b) latent heat flux and (c) rainfall simulated by RegCM3



Comparison of JJAS mean rainfall (cm) over (a) All India and its five homogeneous zones such as (b) North East India, (c) South Peninsular India, (d) North West India, (e) West Central India and (f) Central Northeast India as simulated by RegCM3 in no-snow and snow experiments

Conclusions (MM5V3)

MM5V3 simulates the monsoon circulation over India reasonably well.

Comparison of wind strengths simulated by different convection schemes in MM5 in the three identified regions such as the region of maximum magnitude, the subtropical region and the Arabian Sea show that, BM scheme gives values close to the reanalysis.

MM5 simulated rainfall with BM scheme compares reasonably well with the observed rainfall of IMD than those by Kuo and Grell schemes.

The track of Orissa supercyclone over the Bay of Bengal has been reasonably well simulated in the MM5 with the Grell convective scheme

Conclusions (RegCM3)

The Regional Climate Model (RegCM3) simulates the monsoon circulation over India reasonably well.

The rainfall simulated in Grell convection scheme is closer to the observed rainfall of the India Meteorological Department compared to the Kuo.

Tibetan snow in April reduces the lower level westerlies and upper level easterlies during subsequent summer monsoon over India.

With the introduction of 10cm of snow over Tibet, the sensible heat flux reduces and the latent heat flux enhances.

When 10cm of snow depth in April is prescribed over Tibet, summer monsoon rainfall in entire India reduces by about 30%.

Indian Summer Monsoon Rainfall indicates a decrease by 30% for the whole of India, 23% for NWI, 20% for WCI, 25% for CNI, 30% for NEI and 15% for SPI.

Future Plan

The performance of different convective schemes depends on the spatial and temporal scale of the weather phenomenon to be simulated in the tropical monsoon atmosphere and dynamics of the model used.

Hence, more sensitivity studies are proposed to be conducted using current generation mesoscale model such as the Weather Research and Forecasting (WRF) model.

Attempts are being made to use WRF in wide range of applications such as the mean monsoon circulation features, precipitation forecasting, extreme weather events, and regional climate studies over India with horizontal grid size of 1 to 10 Km.

THANK YOU