Perspective Of Progress in Monsoon Meteorology and Prospects in the next two Decades

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Introduction : Phase I

- From Ancient Period to the 19th Century
- Monsoon Meteorology from ancient concepts to the scientific era at he time of establishment of IMD
- March from “From Sun come the rain” (Vedic concept) to “Let us Investigate the Rain (Varhamihra, 6th century AD)
- Little Progress in Medieval Period
- India misses the dawn of the scientific era from 15 to 18 centuries. New concepts began to develop in the 17th century (Halley’s work) and that the rainy season and winds on the sea and related became evident and the basic concept of physical causes of Monsoons (continental scale land-sea temperature contrasts, Influence of rotation of the earth and the role of moist processes became increasingly evident from 17 to 19th century.

Phase II

- Establishment of IMD and Dawn of Scientific Meteorology
- Establishment of surface and upper air networks and early analysis of scientific data
- Work of Pioneers of Indian Meteorology – Blanford, Eliot, Walker and Normand (1875-1945)
- Indian researchers began to be inducted in IMO by the efforts of Sir G.T. Walker from 1920 onward and several of them (S.K. Banerjee, P. Koteswaram, Y.P. Rao, A. Mani and several others in early 1940s joined IMD. Operations and research done at the same time. No specialised training and learning while in profession remained till 1960s.

Phase III (1920-1960)

- India Misses the NWP revolution

- Though weather prediction has been recognized as a deterministic initial value problem in 1904 (V. Bjerkenes), even attempted with grand failure in 1918-20 (Richardson) and phenomenal progress in computational problem and simple modeling solutions formulated during 1920 to 1950 (a revolution was taking place) but IMD researchers mostly remained oblivious of the happening as operational work (Agricultural Met, Aviation Meteorology War Effort) consumed their working time. Synoptic process, phenomenology, climatological tables and atlases dominated Indian Meteorology.

Phase IV (1960-1980:

- IMD establishes IITM (1962) and Participation in International Field Programs

- IMD recognized the need for full-time research effort and established IITM in November 1962. Exclusive recruitment, mostly scientists joined from IMD. In 1970s a few scientists joined from outside IMD.

- Self training program began by review of path making papers. Dynamical diagnostic work began.
- Work began on NWP by using Non-Divergent barotropic model under Dr. K.R. Saha. Work also began at IMD too under Dr. P.K. Das. No computer and hence special zeal and efforts of the scientists kept up the effort

Phase IV .. Contd…

- IMD gets its first computer in 1976 and IITM the premier research organization could get it in 1987
- IIOE, Monsoon Experiments of 1970-1980, FGGE Program brought enthusiasm among scientists and their horizon expanded by foreign visits as well as participation in Field Program.
- IMD made NWP operational O.G. Multi-Layer Model between 1976-1980
- IITM and IMD experimented with P.E. Barogtropic Model. Support from Govt in IMD, IITM passed through difficult period.
- Diagnosis of Monsoon in several important stubs and discovery of northward propagating mode of ISV of Monsoon and Monsoon – ENSO connection in India in 1980
- Establishment of Dept. of Atmos. Sci. in IITD (1979) and centre for ocean-Atmos. Studies in IISc. Bangalore in early 1980s.

Phase V: 1980-2000

- WCRP Programs of WMO / ICSU
- CMMACS established
- Meteorology came under DST and research community received boost
- Growth in Monsoon understanding and Modeling of the Monsoon
- India launches INSAT
- Study of intra-seasonal variability of Monsoon and its modes
- IAV received impetus from scientists in India and abroad
- Global prospective and Monsoon – CLIVAR, Diabatic process, Heat sources
- IITM rainfall series introduced which became a standard reference data
- Monsoon – ENSO connections and Monsoon – Snow relation explored in modeling studies

Phase V

- Early studies on climate change
- NCMRWF established in 1988 and global modeling introduced
- Indian Field Programs using super computer beun under DST Support – MONTBLEX, LASPEX
- Indian Climate Research Program began in 1995 and BOBMEX Implemented
- Several other steps for research promotion such as India's participation in Middle Atmos. Program and INDOEX Aerosol Begin

Phase VI 2000 – 2012

- Meteorology came under MOES
- Aerosol and Monsoon research became another focus
- Role of Barrier layer in ocean processes. Freshwater discharge in Bay of Bengal
- Monsoon Research
- IOD discovered in India
- Atmospheric GCMs adopted at several centres for program on model generated LRF inter-comparison initiated (SPIM Program in IISc.)
- Centre for climate change established in IITM
- Advanced training with assured job opportunity established in IITM
- High speed computing system available under MOES support. IISc and CMMACS also provided advanced computing

Phase VI – Contd.

- High resolution global and regional (meso-scale) models adopted for short-medium range and high impact weather forecast. Climate prediction using LFS (coupled model) began at IITM
- Uncertainty in weather and climate prediction realized and ensemble setup adopted
- Weather Prediction on short-range improve
- LRF still a challenge. India introduces state of the art models for weather and climate prediction
- Extended range prediction becomes another challenge using the predictability through ISOs. Lot of understanding about ISOs and explanation sought through dynamics.

Phase VI – Contd.

- Climate change and monsoon became another important focus of research. Impact of aerosols on monsoon a favourite subject
- Ocean State Forecasting introduced and India became a partner in ARGOS Program
- Repeated Monsoon failures – 2002, 2004, 2009 and near failure in 2012 prompted research in dynamical LRF
- Indian Monsoon Mission conceived and India invited foreign collaborators to participate in improving skills of prediction model on all scales. This was with a view to use to accelerated progress
- High resolution Indian rainfall on gridpoints became available and promoted research
- TRMM Satellite Data usage in monsoon research
- Modernisation of IMD in terms of observational system, Interactive Forecasting tools, Nowcasting, District Level Forecasting and Extension for Agriculture

Phase VI – Contd.

- STORM Program established
- ARMEX Implemented (2002-2004)
- CTCZ conceived (2008-2010) and became operational in 2012
- IMD launched forecast demonstration projects in Tropical Cyclone, Norwesters, Monsoon and Winter Fog.

Prospects

- Immense progress in phenomenology of monsoon during 1875-1950, which continued till 2000. From Active – break cycle of monsoon droughts to variability of monsoon on IS and IA scales and possibility of prediction through models. Discovery of Northward Propagating episodes, ENSO-Monsoon –IOD connection, snow-monsoon and aerosols and monsoon.
- Role of land surface process in high impact. Modernisation of IMD and availability of High Performance Computing, INSAT Program, ARGOS Program, Indian Ocean Buoys Program, Research Ship facilities are credible achievements. Young generation being trained with modern outlook on ocean-atmosphere and coupled processes for weather and climate.
- Tremendous facilities and encouragements. Next two decades would be crucial to stand nearly at par with the advanced countries in respect of monsoon research. All will depend on the dedication of the new generation to make efforts.
- Monsoon science regain its prestige which began with work of Blanford at the establishment of IMD and sustained by the generations which followed. We have the tools but they would deliver through the efforts of young Indian Weather and Climate Science Community.

Concluding Remarks

I was privileged to witness the enormous progress in Indian Meteorology since 1950s (over 6 decades). My only wish is that we strive hard to make new grounds . We now use modern terminology to describe weather and climate phenomena – terminology based on dynamics which is welcome but not enough for new discoveries. Weather prediction on short and medium range has become technology and if computing resource is available, we can adopt any model. Challenge lies in developing models or schemes adopted in them. Data quality of density still is a challenge for 3-dimensional structure of the atmosphere-ocean system and only govt. Organization can meet the challenge. New policies for acquiring instrumentation and sustenance of observational system needed. Research challenges lies in Monsoon Mission, Land Surface data, climate change, Earth System Modeling and societal applications with a clear range of probability of happening. Continuous and upgraded funding needed to support research. Let us hope we begin a new future.

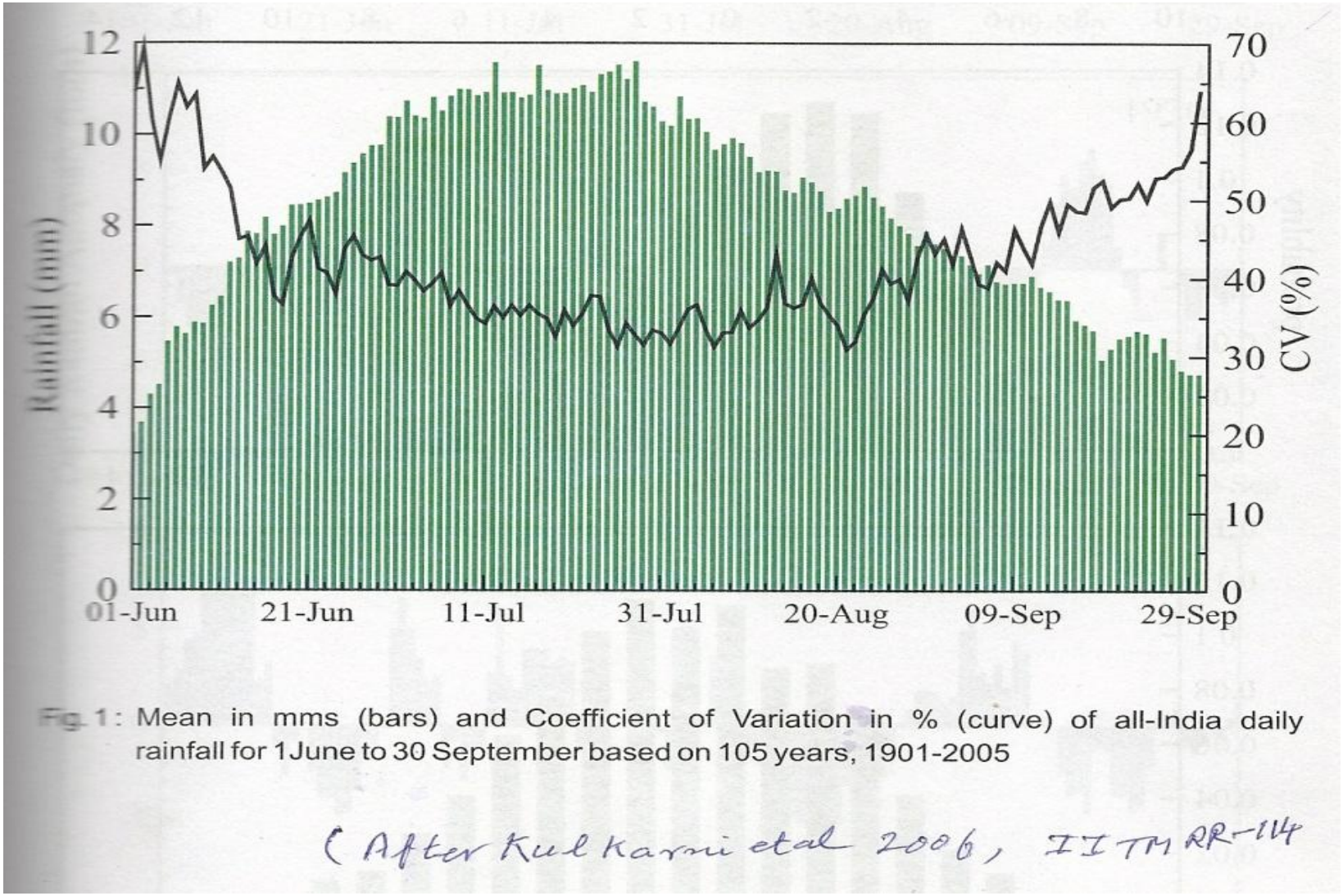


Fig. 1: Mean in mms (bars) and Coefficient of Variation in % (curve) of all-India daily rainfall for 1 June to 30 September based on 105 years, 1901-2005

(After Kulkarni et al 2006, IITM RR-114

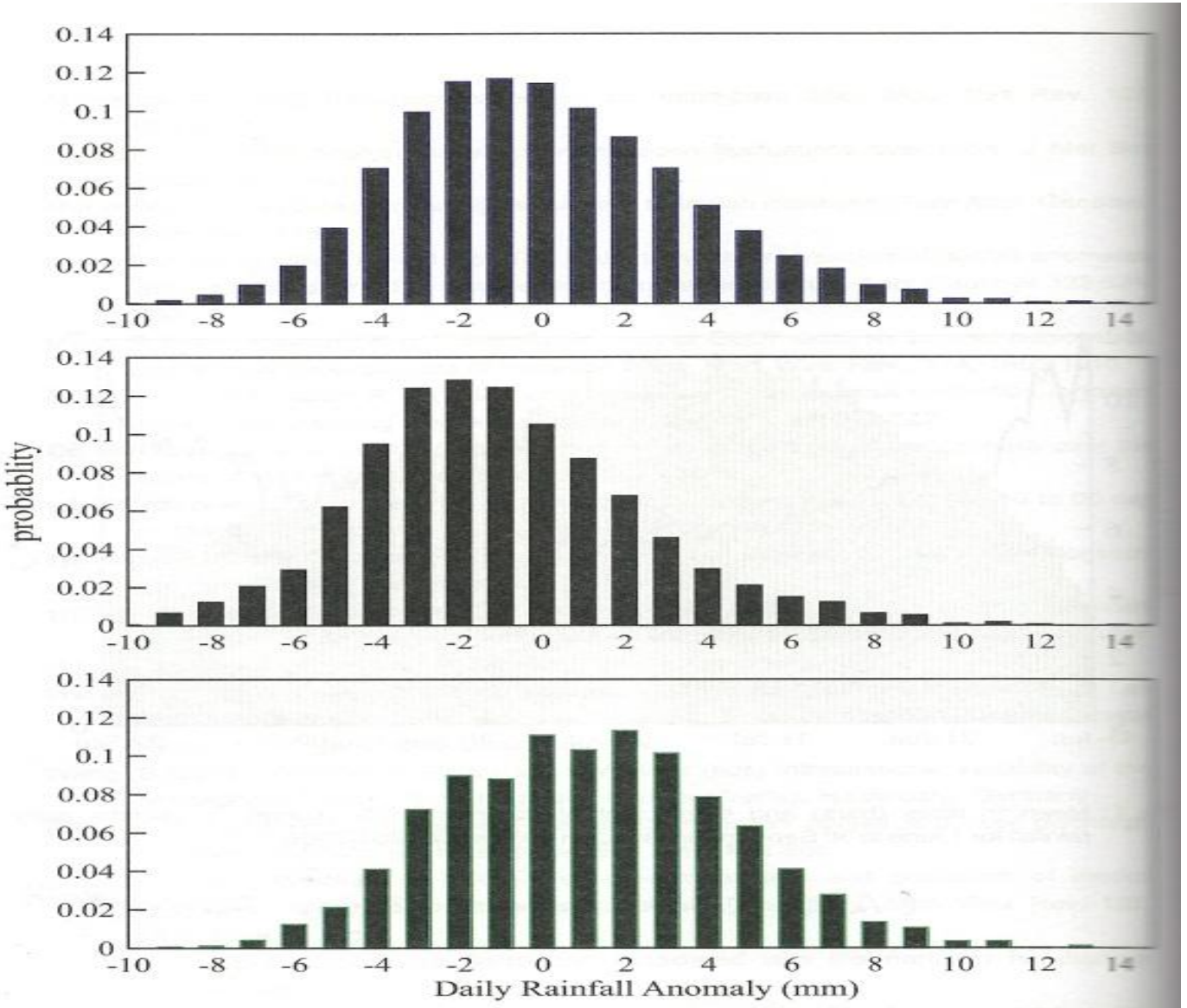
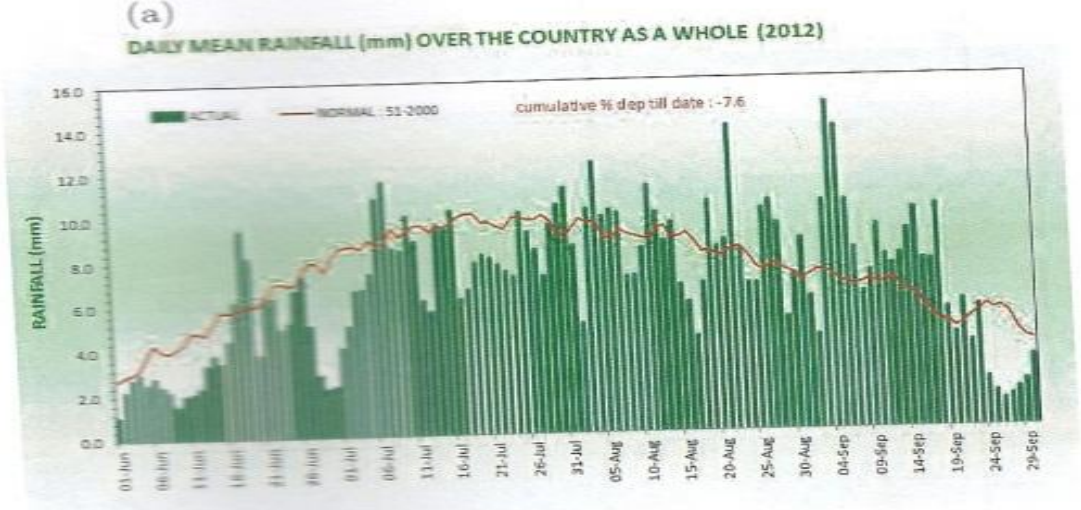


Fig. 2 : Probability density function of all-India daily rainfall anomalies based on 1901-2005 (top panel), all-India droughts (middle panel) and all-India floods (bottom panel)

(a)



(b)

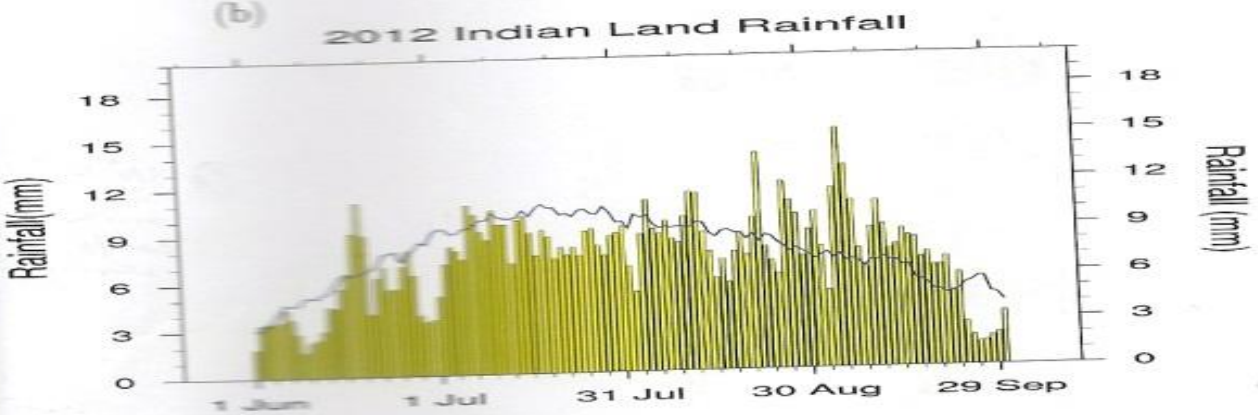


Figure 6: Rainfall bar plot for the year 2012 from IMD(a)and(b)IMD-TRMM Merged data.

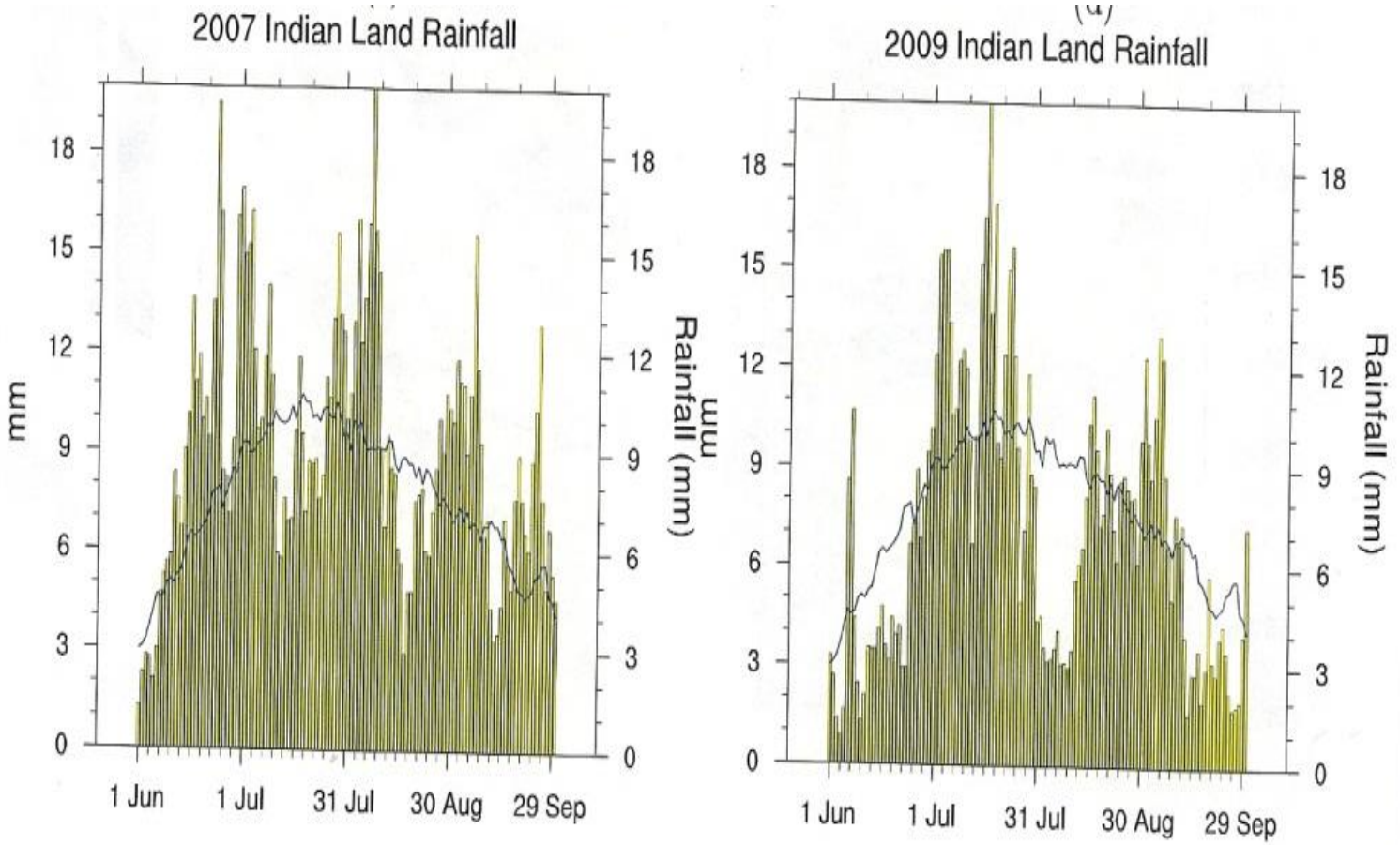
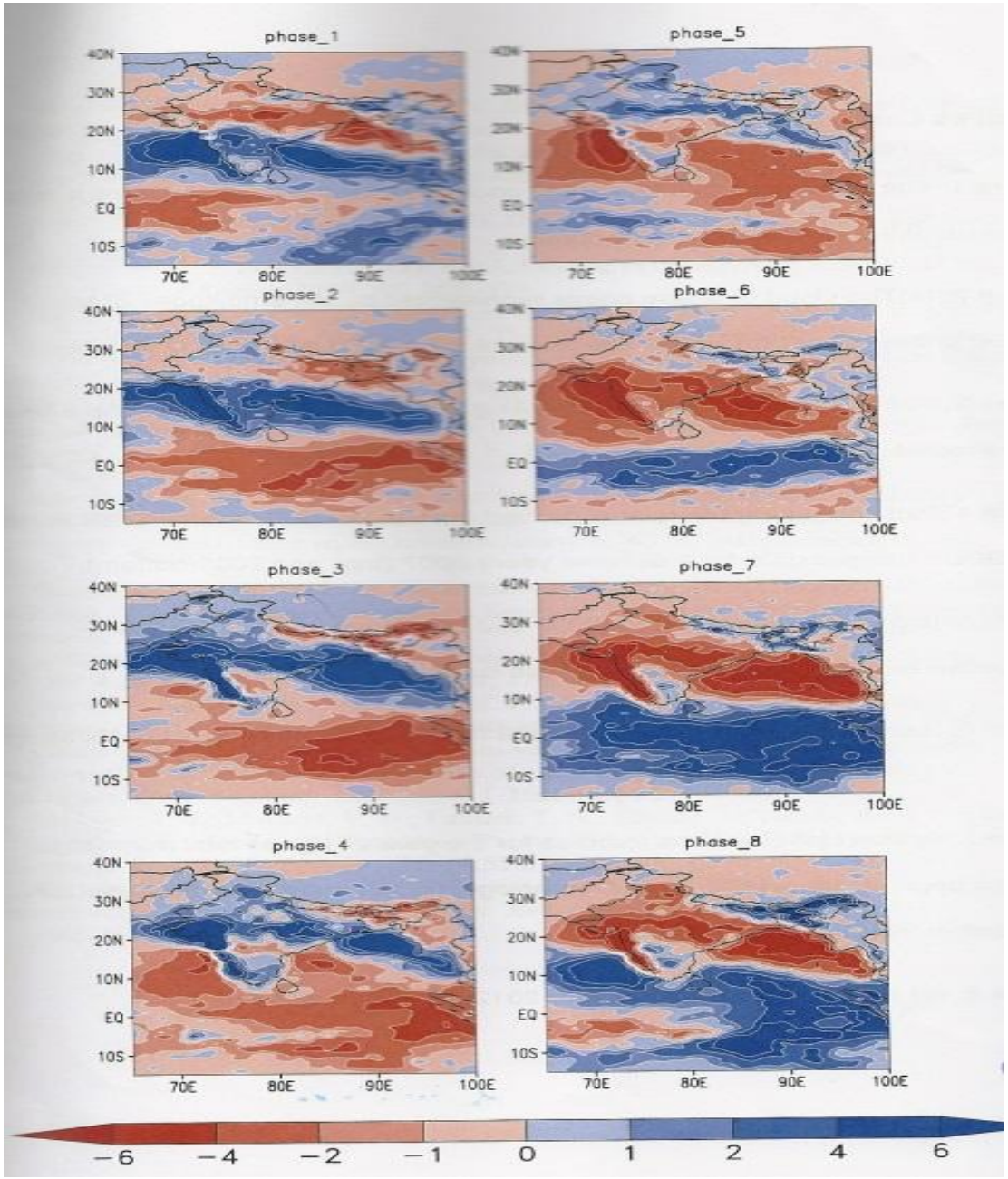


Figure 5: (top)MISO phase plot for 2007 and 2009.(bottom) Rainfall Evolution(yellow bar) and daily climatology(blue curve).


phase_1
phase_5
phase_2
phase_6
phase_3
phase_7
phase_4
phase_8
40N
30N
20N
10N
EQ
10S
70E
80E
90E
100E
−6
−4
−2
−1
0
1
2
4
6

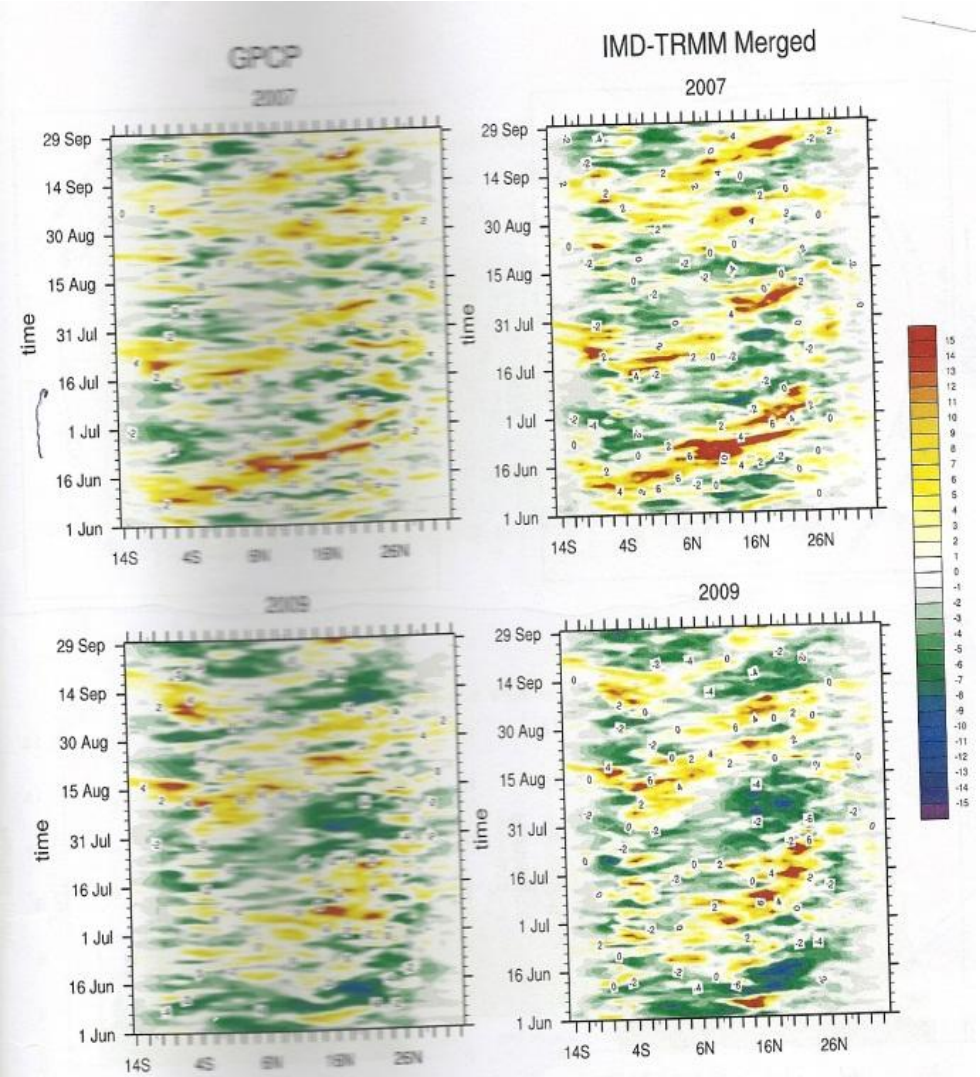


Figure 4: Plot comparing the rainfall derived from IMD-TRMM merged (left panels) and GPCP merged data for 2 extreme years 2007 (top) and 2009(bottom).

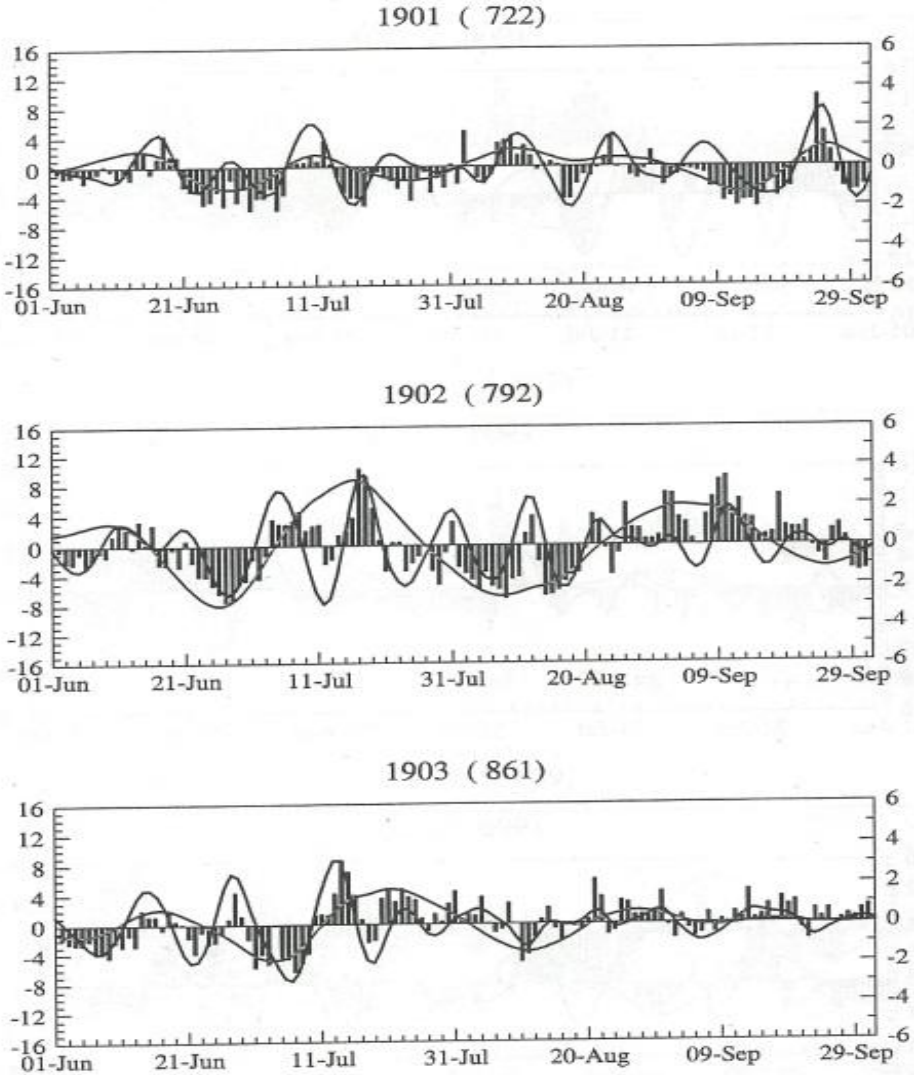
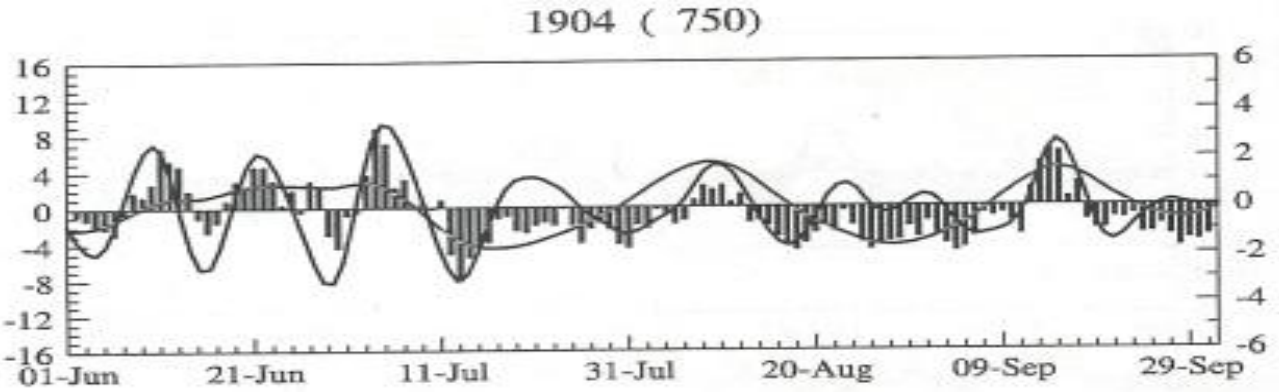
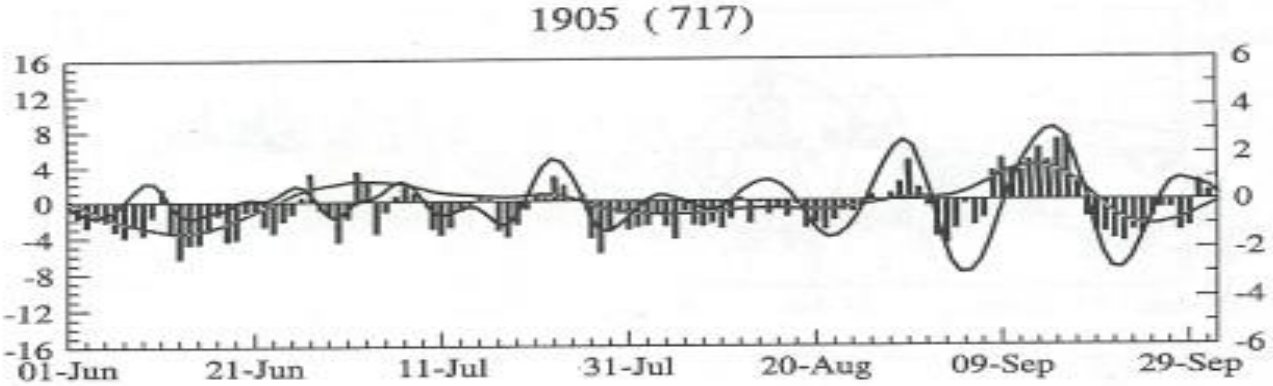


Fig. 5 : All-India daily rainfall anomalies (bars), 30-60 days (red curve) and 10-20 days (blue curve) filtered anomalies for 1 June to 30 September for the period 1901-2005. The scale for daily rainfall anomalies is left Y axis while that of daily filtered anomalies is right Y axis. Figures in the bracket indicate AIMR for corresponding year.


1904 (750)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep


1905 (717)
16
12
8
4
0
-4
-8
-12
-16
6
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2
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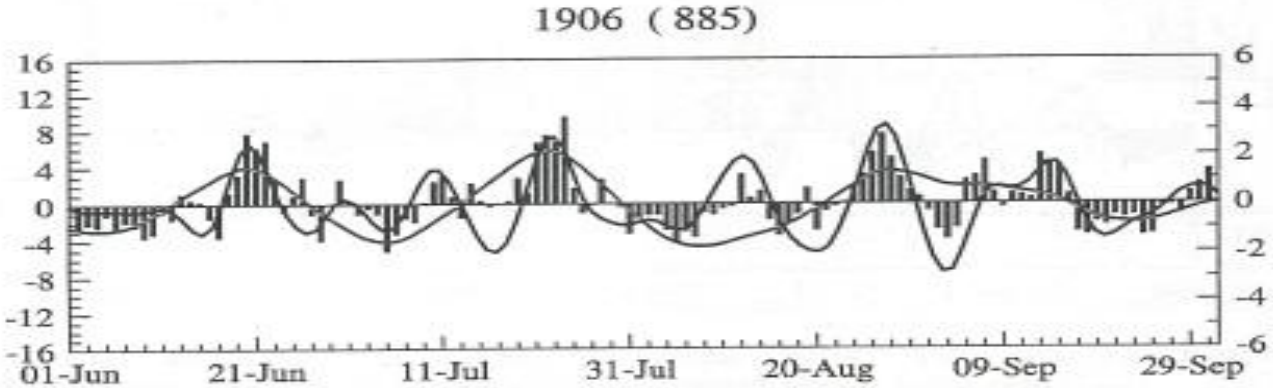
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep


1906 (885)
16
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8
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-4
-8
-12
-16
6
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01-Jun
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11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.

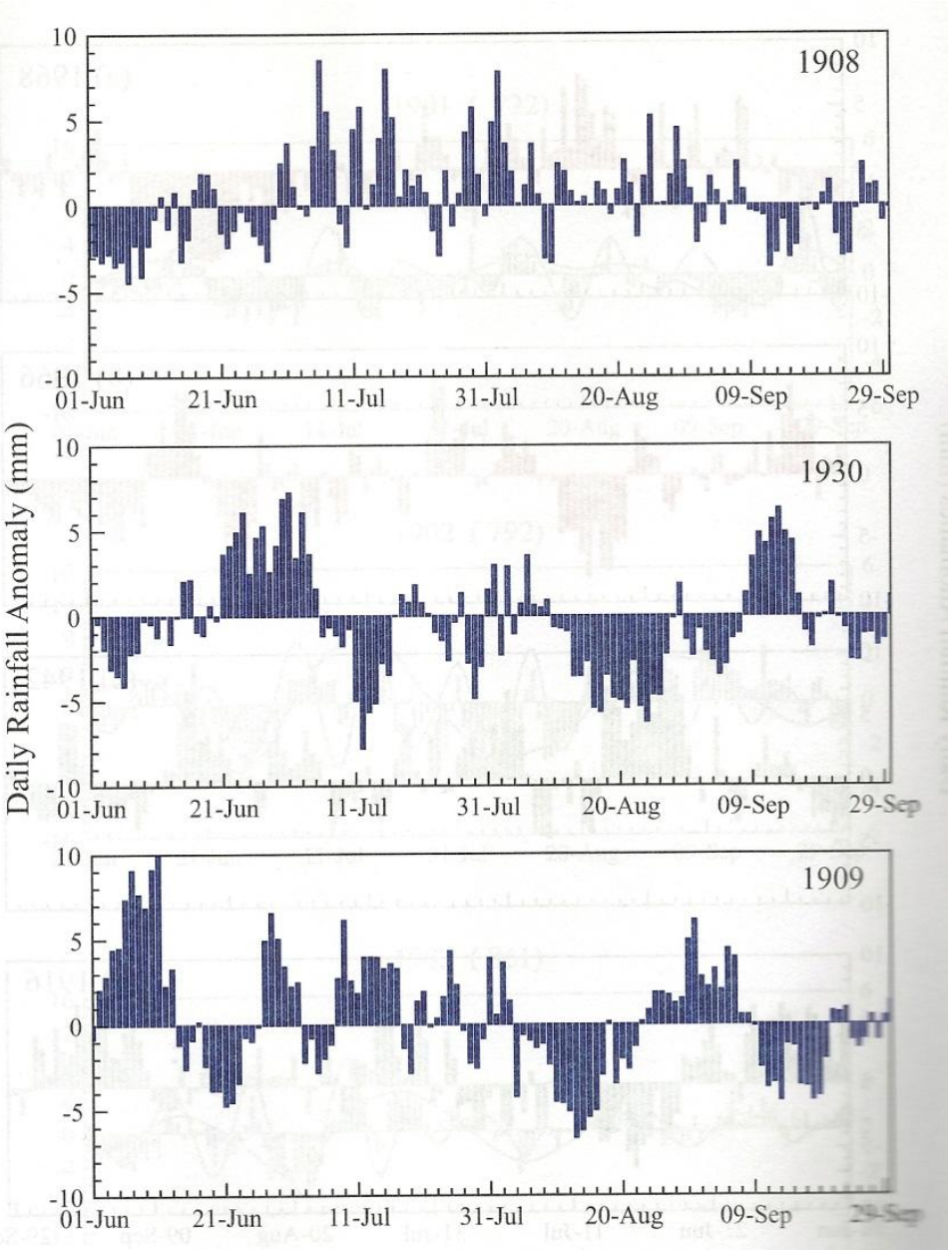
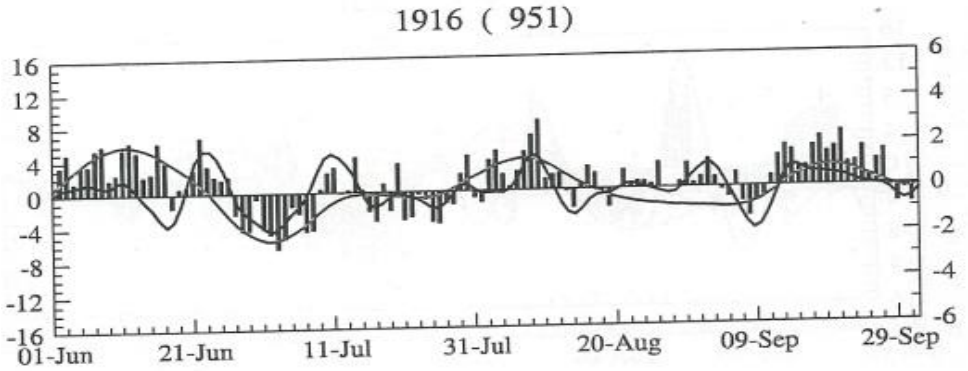


Fig. 3 :Most recurring patterns of all-India daily rainfall anomalies


1916 (951)
16
12
8
4
0
-4
-8
-12
-16
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-2
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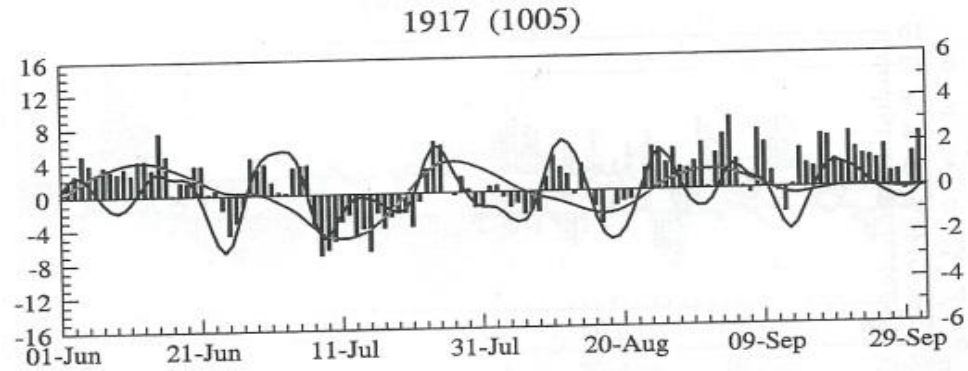
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep


1917 (1005)
16
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-4
-8
-12
-16
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01-Jun
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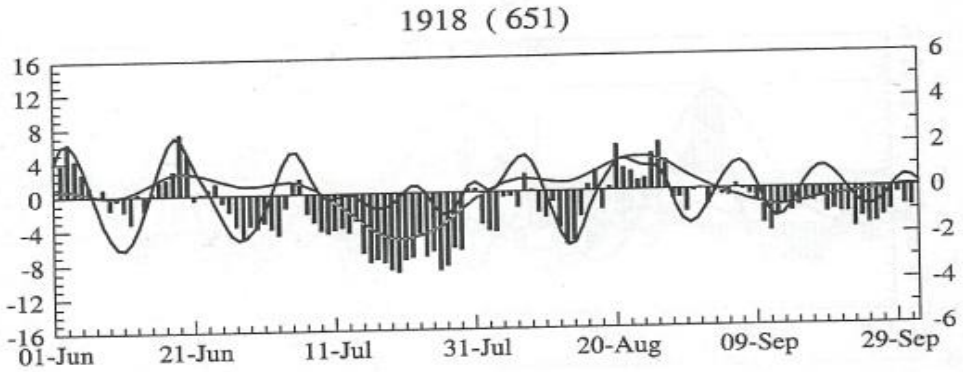
20-Aug
09-Sep
29-Sep


1918 (651)
16
12
8
4
0
-4
-8
-12
-16
6
4
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01-Jun
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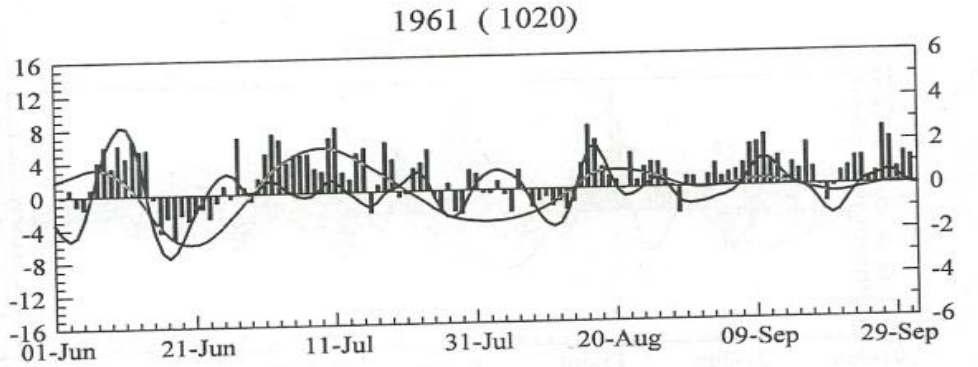
09-Sep
29-Sep

Fig. 5 contd.


1961 (1020)
16
12
8
4
0
-4
-8
-12
-16
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01-Jun
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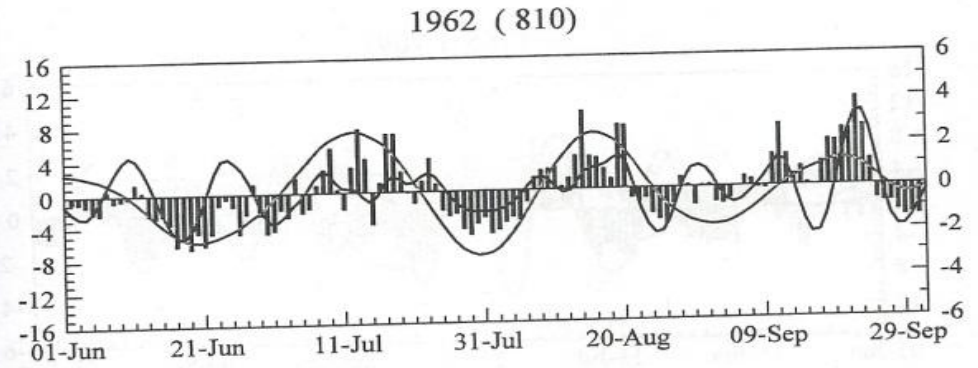
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep


1962 (810)
16
12
8
4
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-4
-8
-12
-16
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-2
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01-Jun
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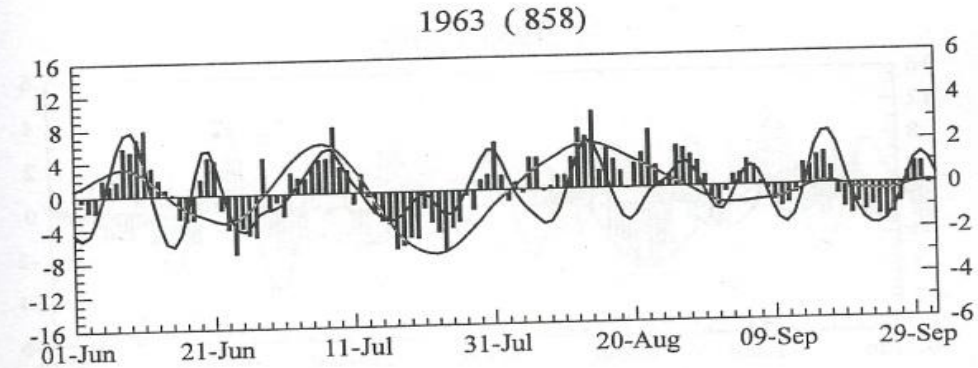
20-Aug
09-Sep
29-Sep


1963 (858)
16
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-4
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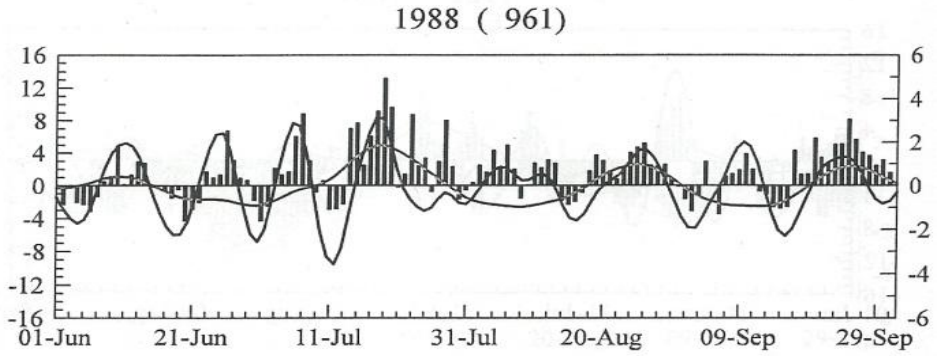
Fig. 5 contd.


1988 (961)
16
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-4
-8
-12
-16
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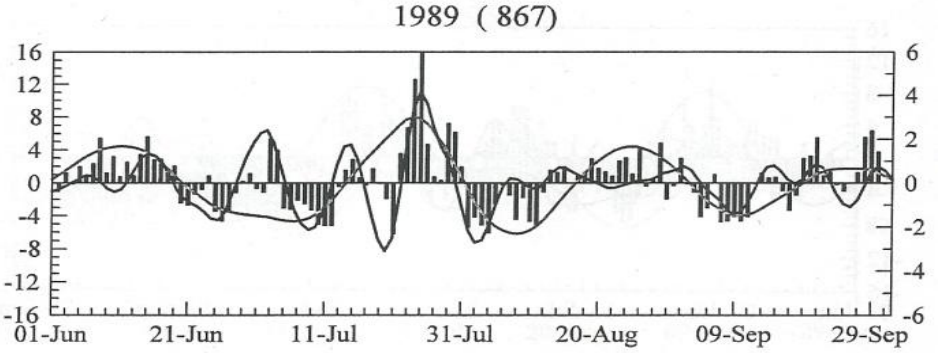
09-Sep
29-Sep


1989 (867)
16
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-8
-12
-16
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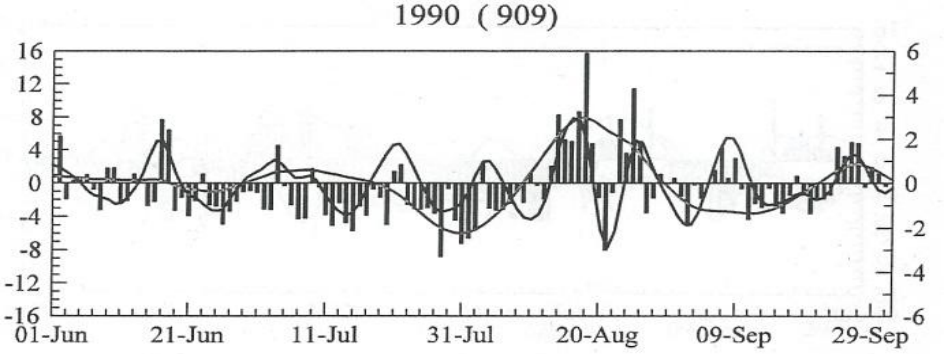
09-Sep
29-Sep


1990 (909)
16
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-8
-12
-16
6
4
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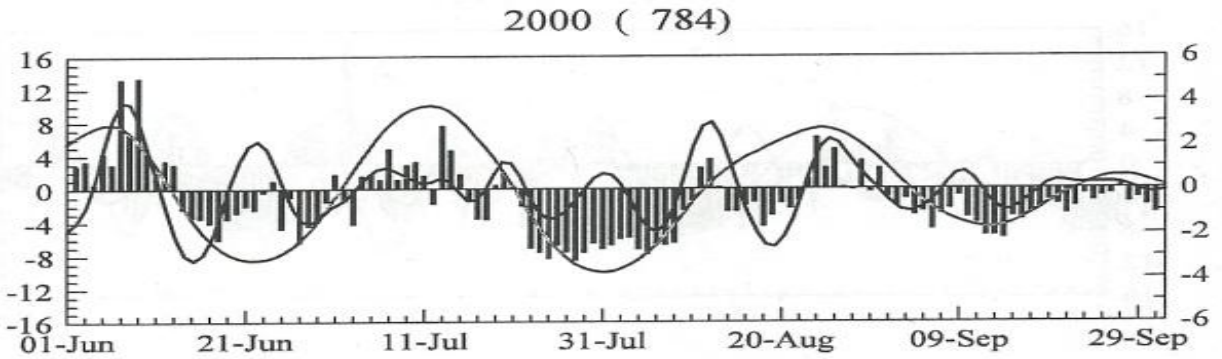
09-Sep
29-Sep

Fig. 5 contd.


2000 (784)
16
12
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0
-4
-8
-12
-16
6
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-2
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01-Jun
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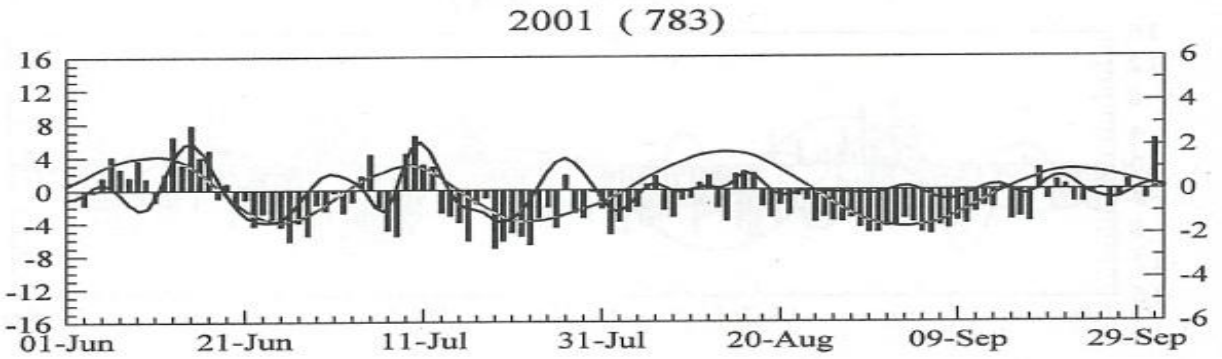
20-Aug
09-Sep
29-Sep


2001 (783)
16
12
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0
-4
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-12
-16
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01-Jun
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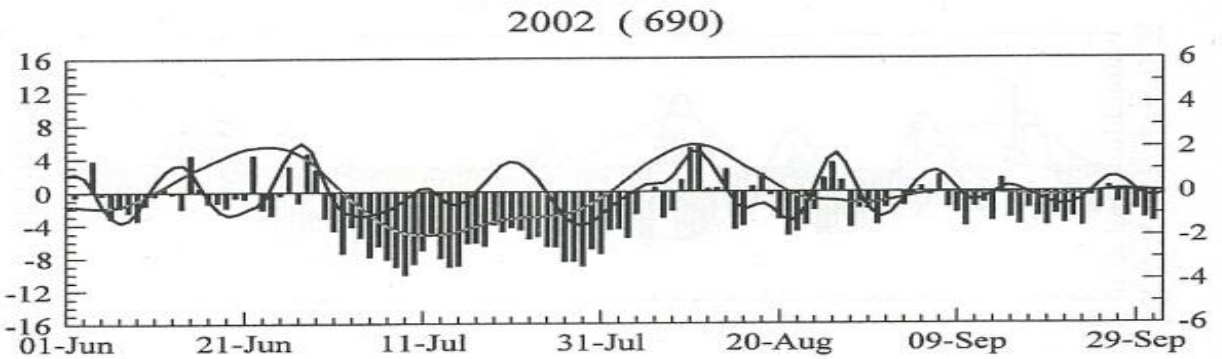
2002 (690)
16
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-16
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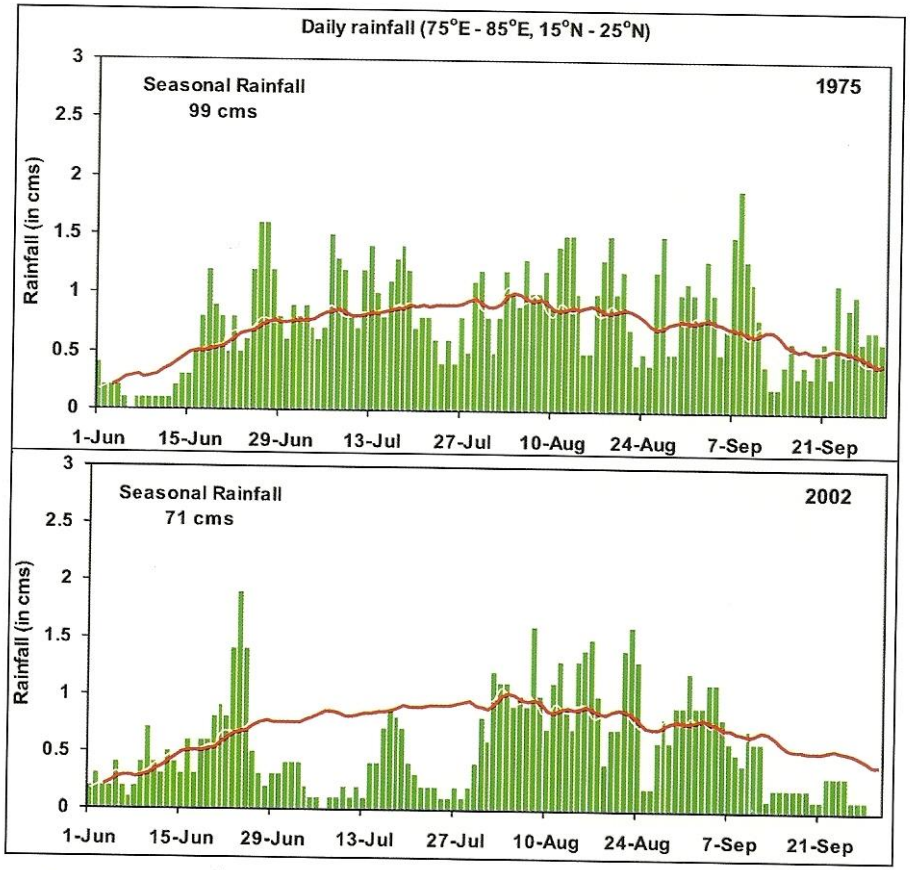
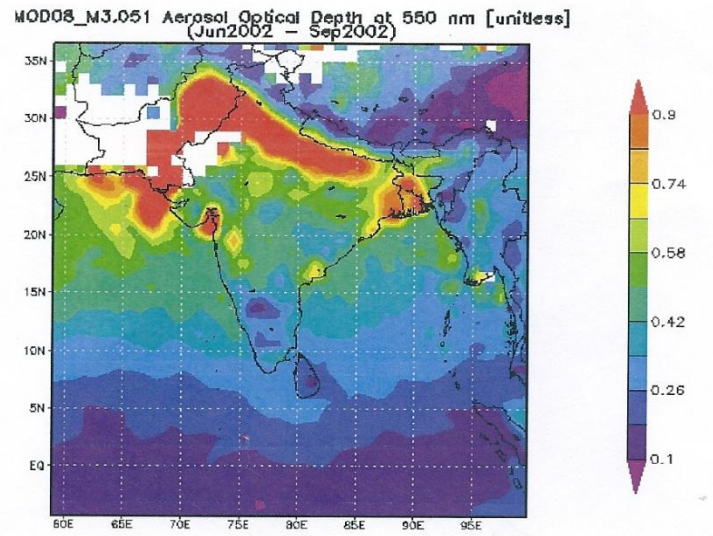
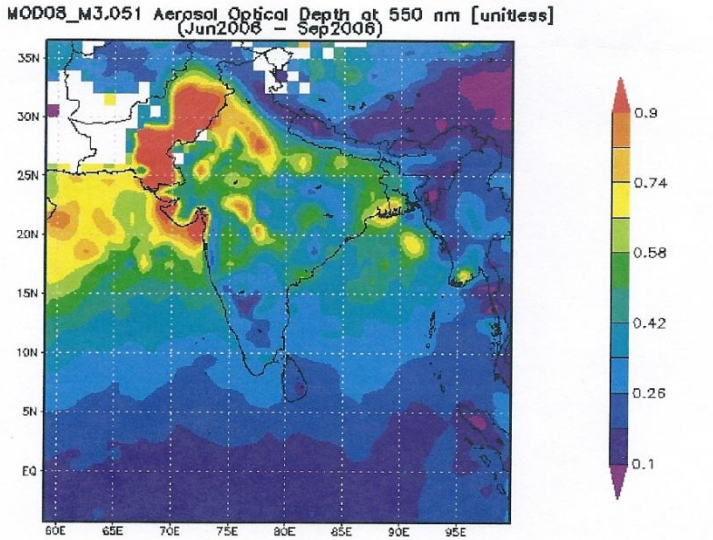
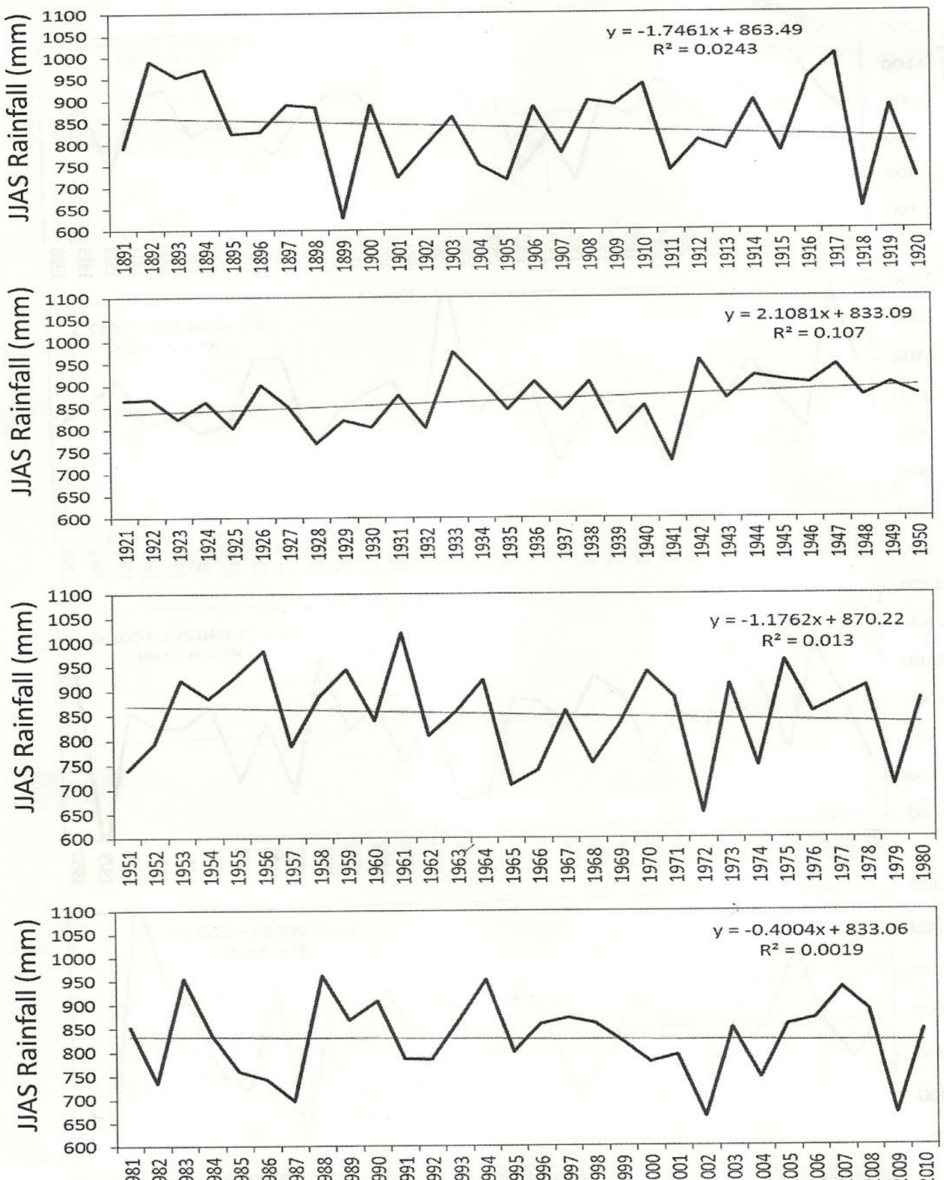


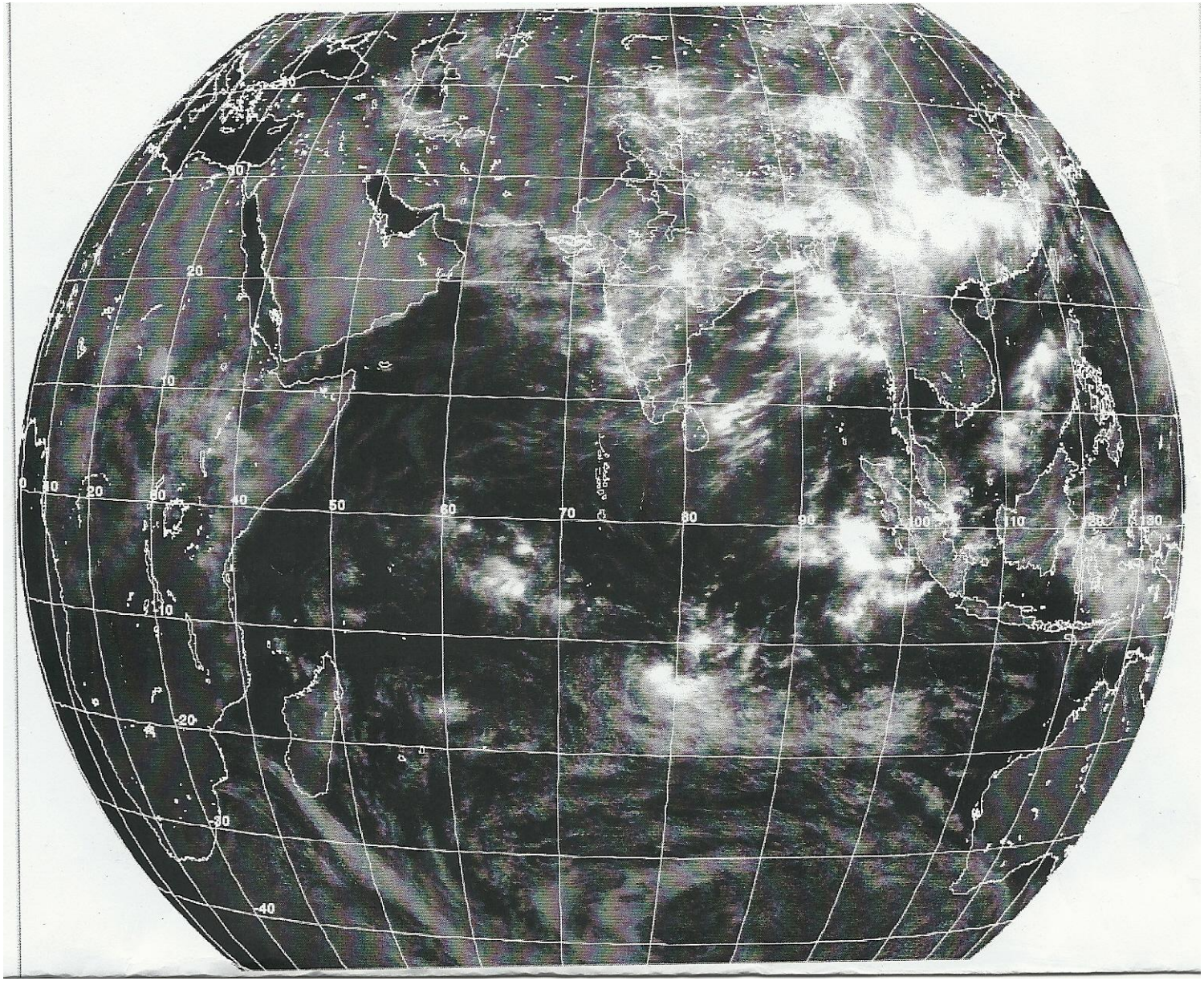
Fig. 2.4: Variation of the daily rainfall over central India during June - Sept. 1975, 2002

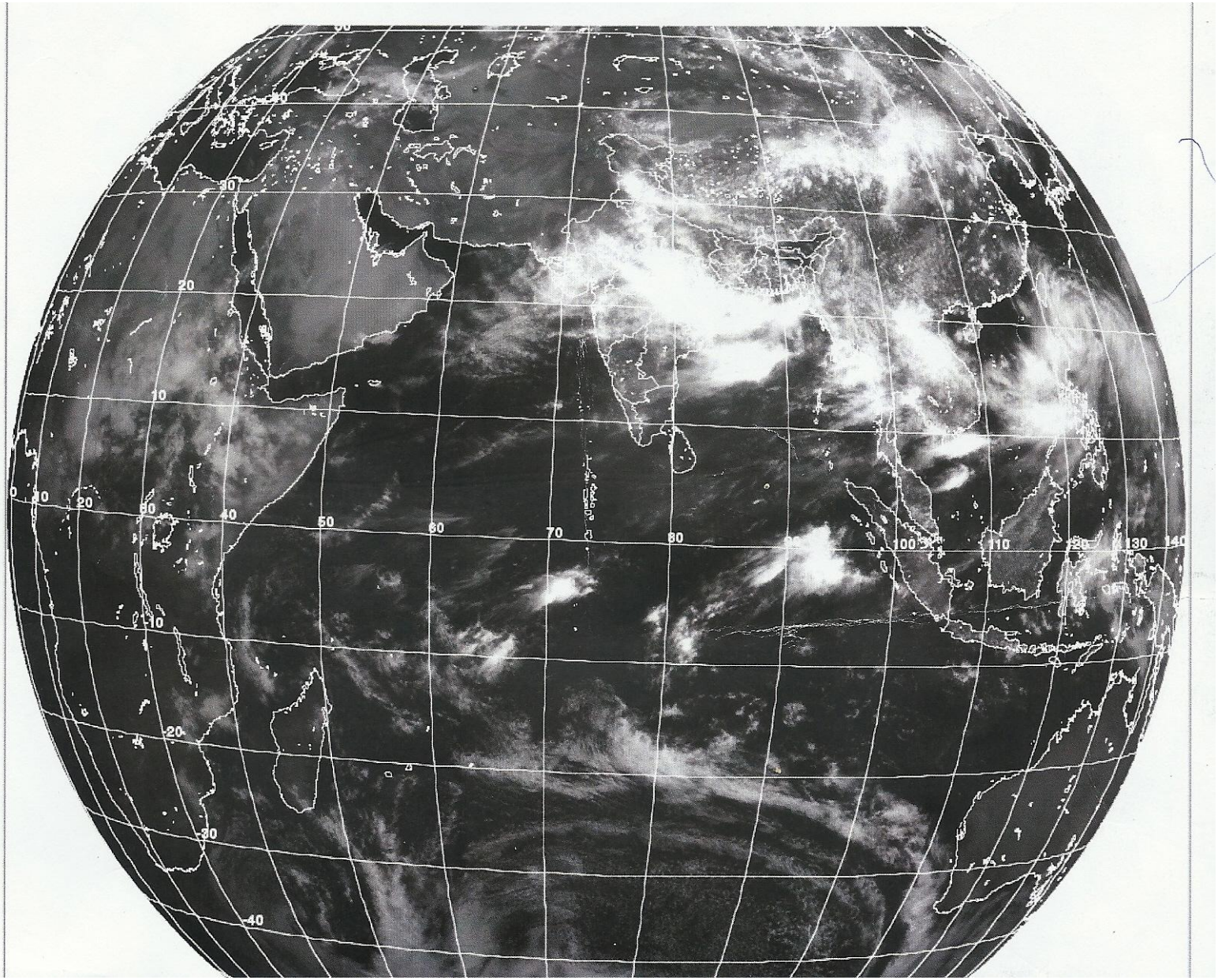

MOD08_M3.051 Aerosol Optical Depth at 550 nm [unitless]
(Jun2002 - Sep2002)
35N
30N
25N
20N
15N
10N
5N
EQ
60E
65E
70E
75E
80E
85E
90E
95E
0.9
0.74
0.58
0.42
0.26
0.1

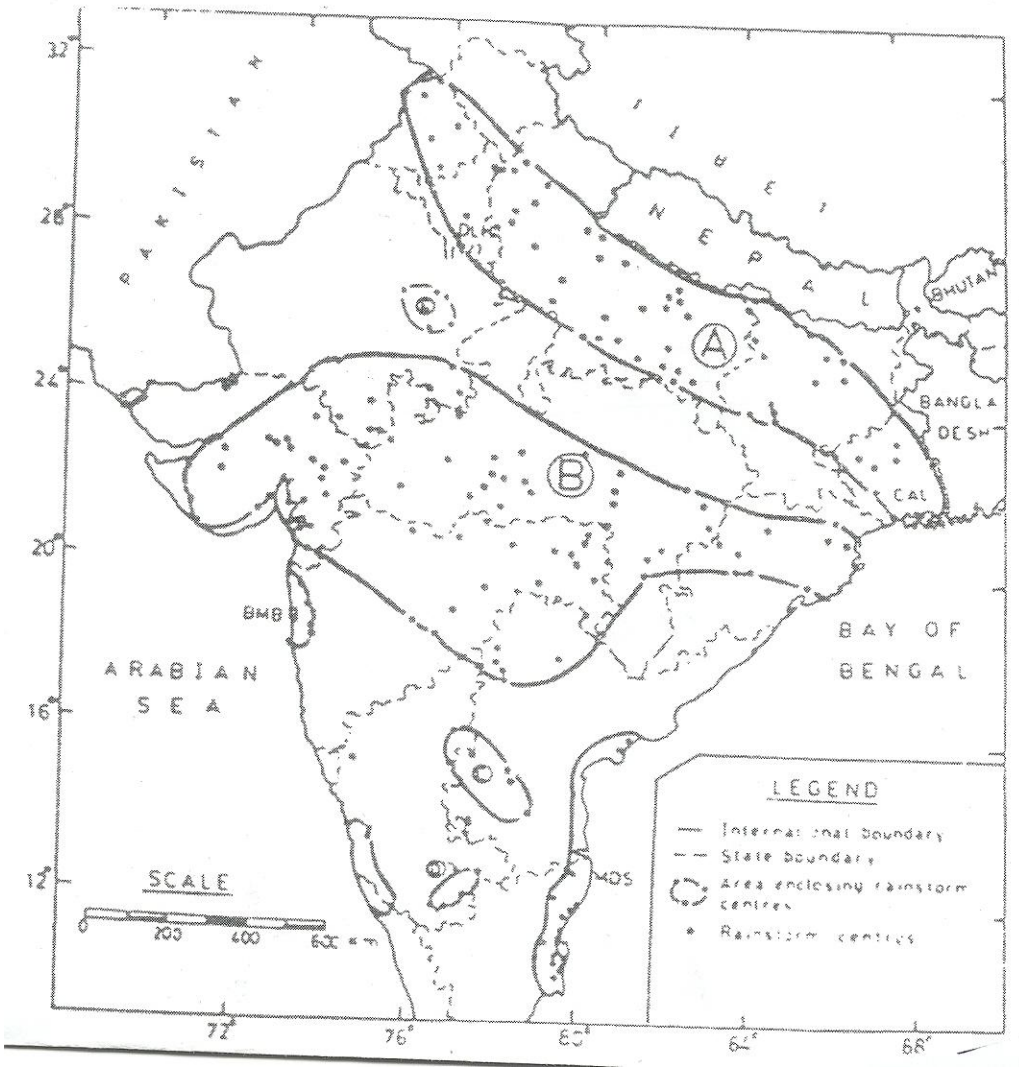

MOD08_M3.051 Aerosol Optical Depth at 550 nm [unitless]
(Jun2006 - Sep2006)
35N
30N
25N
20N
15N
10N
5N
EQ
60E
65E
70E
75E
80E
85E
90E
95E
0.9
0.74
0.58
0.42
0.26
0.1

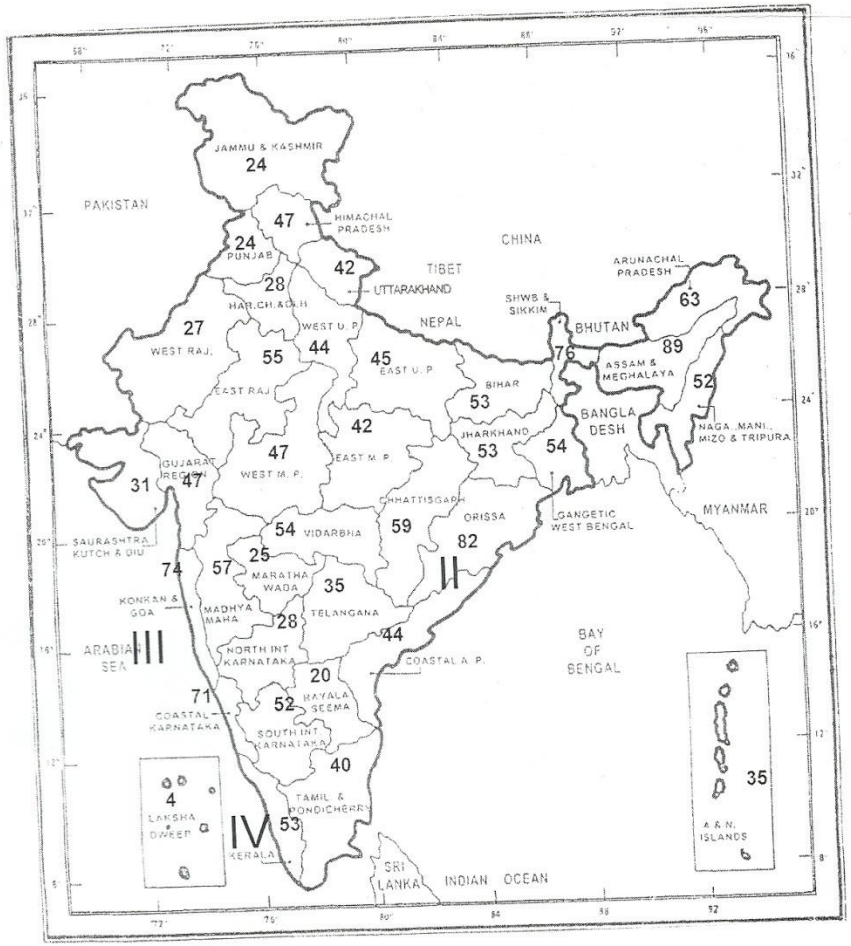
All India


JJAS Rainfall (mm)
y = -1.7461x + 863.49
R² = 0.0243
y = 2.1081x + 833.09
R² = 0.107
y = -1.1762x + 870.22
R² = 0.013
y = -0.4004x + 833.06
R² = 0.0019


10
20
10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
10
20
30
40


30
20
10
0
10
20
30
40
50
60
70
80
100
110
120
130
10
20
30
40


32°
28°
24°
20°
16°
12°
72°
76°
80°
84°
88°
PAKISTAN
TIBET
NEPAL
BHUTAN
BANGLA DESH
CAL
BMB
MDS
A
B
ARABIAN SEA
BAY OF BENGAL
SCALE
0
200
400
600 Km
LEGEND
International boundary
State boundary
Area enclosing rainstorm centres
Rainstorm centres



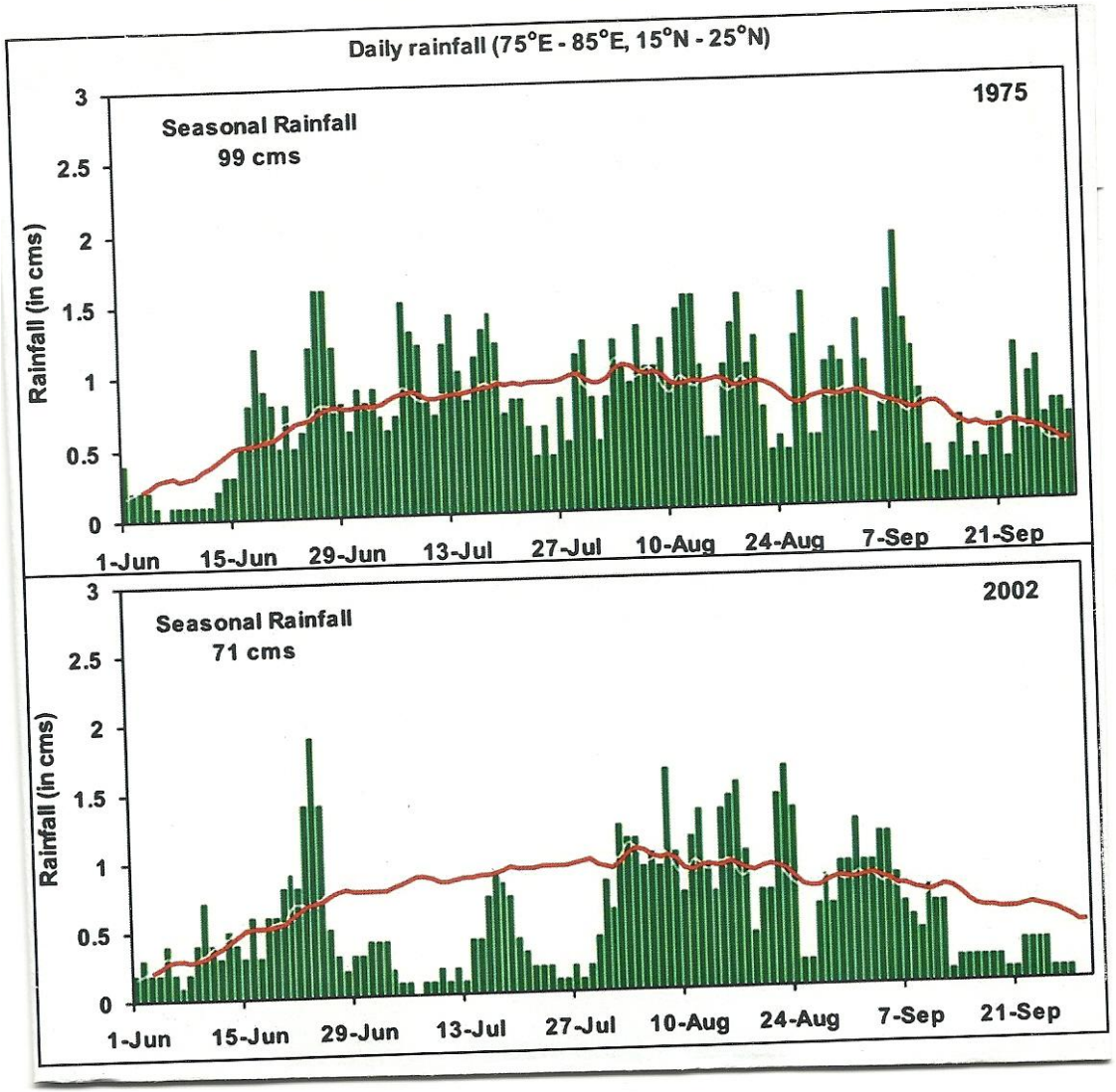
CLUSTER 1- Assam & Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram & Tripura, Sub-Himalayan West Bengal

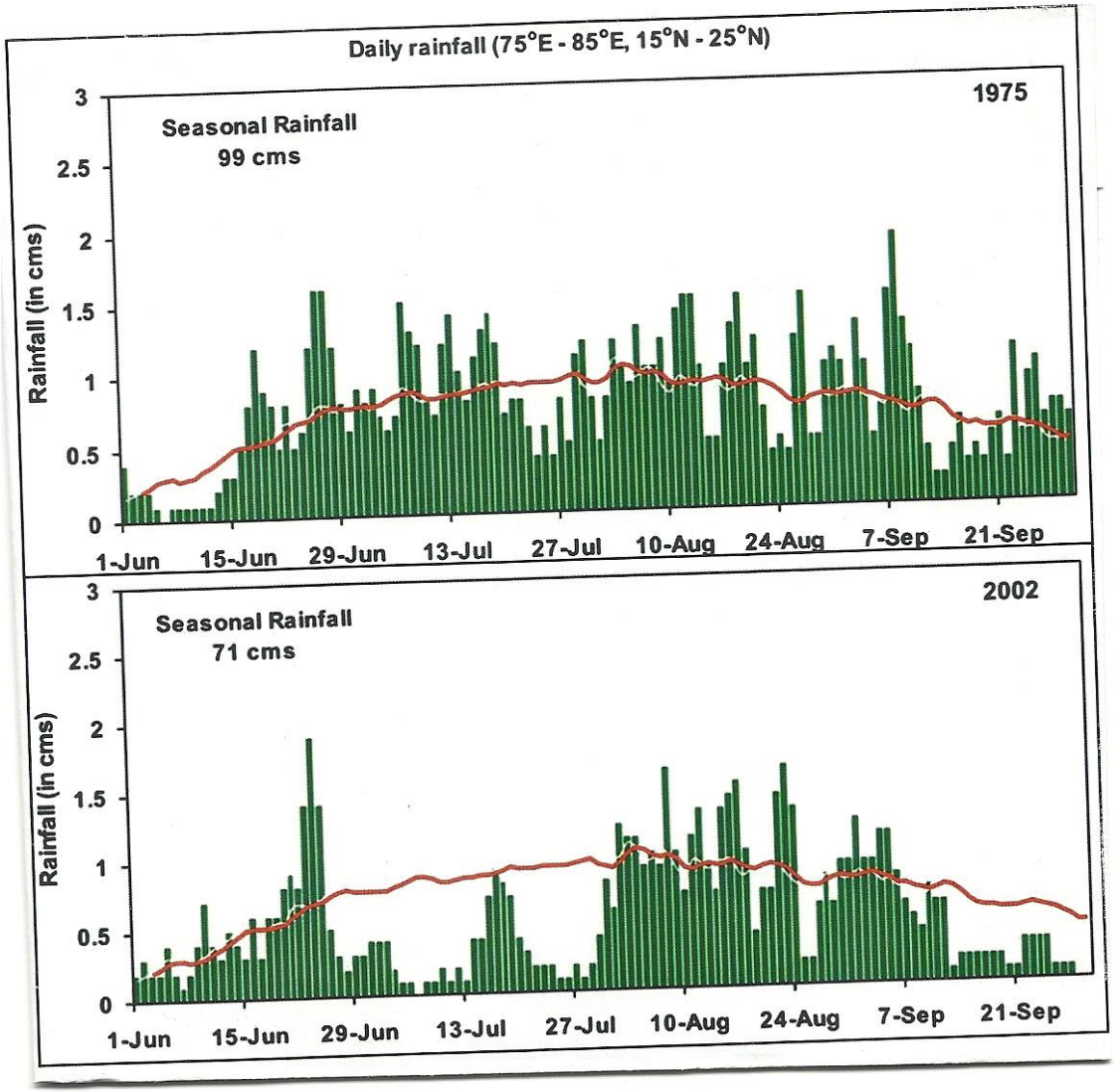
CLUSTER-2- Konkan & Goa

CLUSTER 3-Coastal Karnataka, South Interior Karnataka and Kerala

CLUSTER-4-Orissa, Jharkhand, Bihar, Chhattisgarh, Vidarbha, West Bengal

No. of days during June- September 2012 when the respective Sub-Division experience heavy rainfall over at least one station.


Daily rainfall (75°E - 85°E, 15°N - 25°N)
1975
Seasonal Rainfall
99 cms
Rainfall (in cms)
3
2.5
2
1.5
1
0.5
0
1-Jun
15-Jun
29-Jun
13-Jul
27-Jul
10-Aug
24-Aug
7-Sep
21-Sep
2002
Seasonal Rainfall
71 cms
Rainfall (in cms)
3
2.5
2
1.5
1
0.5
0
1-Jun
15-Jun
29-Jun
13-Jul
27-Jul
10-Aug
24-Aug
7-Sep
21-Sep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Seasonal Rainfall
71 cms
Rainfall (in cms)
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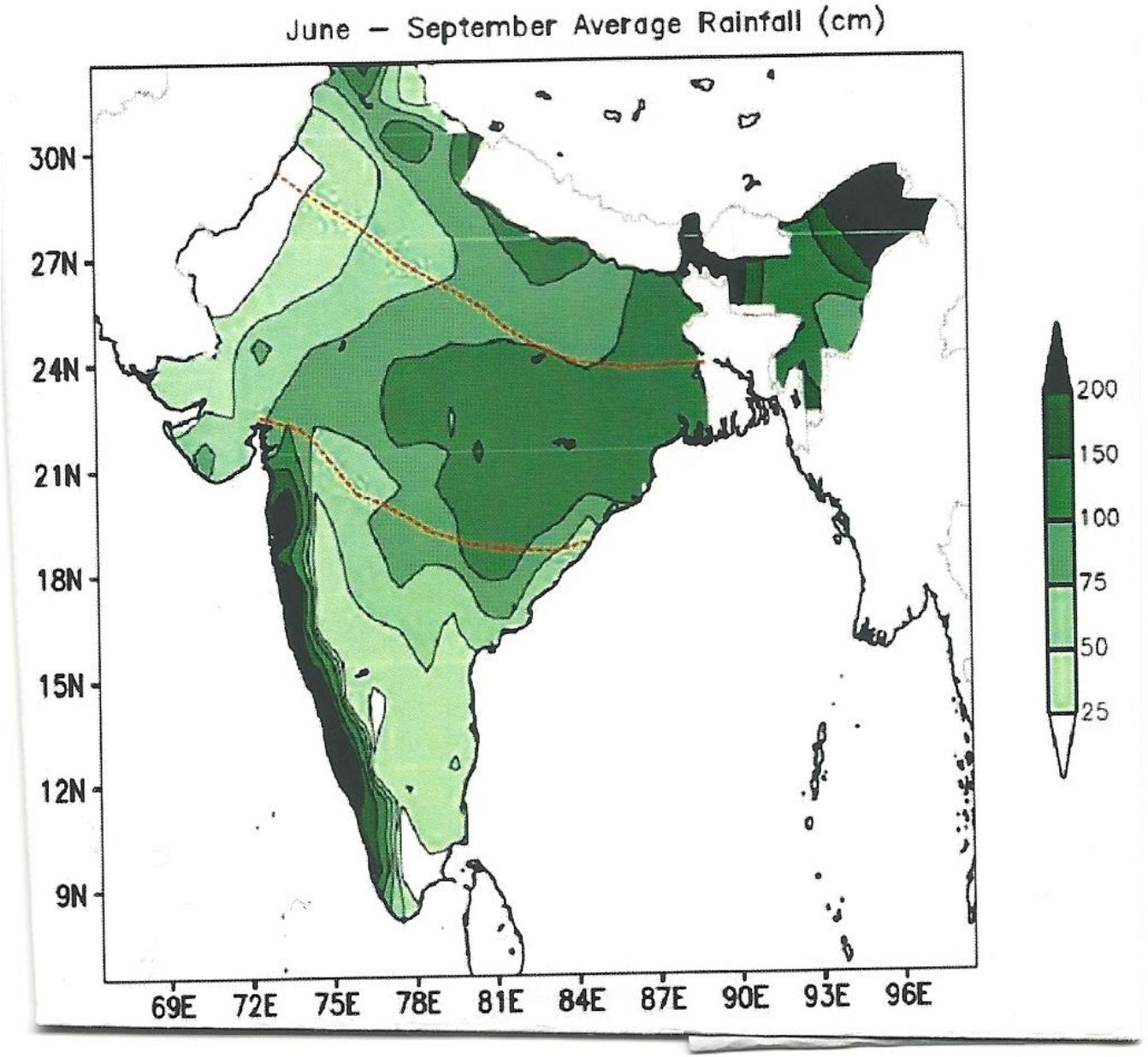
1-Jun
15-Jun
29-Jun
13-Jul
27-Jul
10-Aug
24-Aug
7-Sep
21-Sep


June – September Average Rainfall (cm)
30N
27N
24N
21N
18N
15N
12N
9N
69E
72E
75E
78E
81E
84E
87E
90E
93E
96E
200
150
100
75
50
25