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PENTAD RAINFALL CHARTS AND SPACE-TIME VARIATIONS OF RAINFALL OVER INDIA AND THE ADJOINING AREAS

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ABSTRACT

Normal pentad rainfall charts for the 73 pentads of the year, for India and the adjoining areas are presented. The salient features of the space-time variations of the rainfall in the course of the year, brought out by the charts are briefly discussed.

1. Introduction

1.1 The Rainfall Atlas of India published by the India Meteorological Department (IMD, 1971) incorporates valuable statistics relating to the space-time variations of monthly, seasonal and annual rainfall, number of rainy days and coefficient of variation of rainfall over the country, depicted in the form of 60 charts. The Atlas also includes tables giving normal rainfall and number of rainy days for the different meteorological sub-divisions of the country.

1.2 The spatial distribution of the annual rainfall of India and the rainfall of the four seasons of the year expressed as percentage of the annual are shown in Figs 1 and 2 respectively. Fig 3 shows the 35 meteorological sub-divisions of the country.

1.3 While monthly and seasonal rainfall diagrams depict the major rainfall characteristics, some of the finer features of the rainfall variation, such as the dates of onset and withdrawal of the monsoon rains, are brought out by the study of long-term rainfall data averaged over time periods shorter than a month. The five-day period (pentad) forms a convenient time unit for this purpose, the annual normal

rainfall of a station being split up into 73 pentad rainfall values instead of 12 monthly rainfall amounts. In a previous publication (Ananthakrishnan and Pathan, 1971) we have presented pentad rainfall patterns for 160 Indian stations based on long-term rainfall normals. One of the new features revealed by this study was the existence of a mid-August minimum in the southwest monsoon rainfall of several north and central Indian stations. This feature is not brought out by the monthly rainfall data and as such had escaped notice.

1.4 Subsequently, we have extended our study of pentad rainfall to include 120 additional stations distributed over India, Burma, Bangla Desh and Pakistan. The net-work of 280 stations provides a fairly good coverage over India and the adjoining areas. It was, therefore, considered to be of interest to prepare a set of normal pentad rainfall charts for the 73 pentads of the year to bring out the sequential changes in the spatial distribution of rainfall in the course of the year.

2. Pentad Rainfall Charts

2.1 The net-work of rainfall stations whose data have been utilised in the present study is shown in Fig 4. The 160 original stations and the 120 stations subsequently added are indicated by separate symbols (dots and open circles) and are designated as A and B respectively. The normals of daily accumulated rainfall published by the India Meteorological Department (IMD, 1965) is the source from which the pentad rainfall data for the Indian stations have been worked out. These normals are mostly based on the rainfall data for the period 1901 to 1950 except for a few stations for which data are available only for a shorter period. In these cases data upto 1960 have been utilised. In respect of the extra-Indian stations the data relate to an earlier set of normals upto the end of 1940.

2.2 On the pentad rainfall charts isopleths have

been drawn for rainfall amounts of 2, 5, 10, 20, 50, 100 and 200 mm to highlight the salient features of the space-time variations in the course of the year. The diagrams are labelled P-1 to P-73 and the interval covered by each pentad is shown on the respective charts. The pentad rainfall diagrams are shown on 19 charts following Fig 4. Each chart gives the rainfall distribution for 4 consecutive pentads. For the sake of cyclic continuity, the diagrams for pentads 1 to 3 are repeated after P-73 in the last chart.

3. Discussion of Salient Features

(a) January - February (P-1 to P-12)

3.1 The central parts of the country are the driest during these winter months with pentad rainfall around 2 mm on the average. Over Jammu-Kashmir, Punjab, Himachal Pradesh and the hills of west Uttar Pradesh which come under the influence of east-ward moving extra-tropical disturbances (western disturbances) in these months, pentad rainfall amounts vary from 5 to 20 mm. Over Assam, Bangla Desh, West Bengal, Orissa and Bihar there is a progressive increase in pentad rainfall from about 2 mm at the beginning of January to 5 to 10 mm towards the middle of February. Detailed examination of the pentad rainfall data shows that over the area comprising Orissa, West Bengal, east Madhya Pradesh and Bihar, the rainfall attains a maximum about the middle of February followed by a decrease (Ananthakrishnan, 1977). It is interesting to note that this winter maximum is separated by six months from the mid-August minimum in rainfall over central and north India already referred to.

3.2 Over the south of the peninsula and the central and south Bay of Bengal, the pentad rainfall increases with decreasing latitude. There is also a gradual decline in rainfall amounts from the beginning of January to the end of February. The declining northeast monsoon activity along the southeast coast of the peninsula and

over Ceylon can also be seen from the diagrams. It may be noted that the isohyetal lines over the south Bay of Bengal run approximately east-west.

(b) March-April-May (P-13 to P-30)

3.3 These are the hot weather months with progressively increasing insolation and increasing thunderstorm activity particularly over West Bengal, Assam and Bangla Desh and also over the south of the peninsula. This feature can be seen from the pentad rainfall charts for April and May (P-19 to P-30). Following the trend of the 2 mm isohyet, it can be seen that a slow increase in the rainfall activity begins to set in over the eastern parts of the Bay of Bengal from the beginning of April and this activity continues to increase. By pentad 18 the 2 mm isohyet no longer runs through the Bay of Bengal but has shifted west-ward and runs across the central parts of the country. The driest areas to the west of this line are Madhya Maharashtra, west Madhya Pradesh, Gujarat, Saurashtra-Kutch and Rajasthan. This situation continues till about the middle of May (P-27).

3.4 After the middle of April, the isohyets over the south and east Bay of Bengal which were more or less oriented in an east-west direction till then, begin to show an increasing north-south orientation with rainfall increasing over the east Bay of Bengal and the Arakan-Tenasserim coasts. By the beginning of May (P-25) the pentad rainfall has reached 20 to 50 mm to the east of 90°E. Over the Kerala coast it is around 20 mm while over northeast India and Bangla Desh the pentad rainfall is between 20 and 50 mm with larger amounts exceeding 100 mm at Cherrapunji.

3.5 The pentad rainfall diagrams for May (P-25 to P-30) show the progressive changes in the space-time variations of rainfall that occur till the onset of the southwest monsoon on the Kerala coast early in June.

The significant features are (i) the progressively increasing rainfall over the east Bay of Bengal and the Arakan-Tenasserim coasts; (ii) the increasing thunderstorm activity and increasing pentad rainfall over south India and also over northeast India and Bangla Desh; (iii) the west-ward shift of the 2 mm isohyet to the India-Pakistan border and decrease of rainfall due to western disturbance activity over the extreme north after the middle of May; and (iv) the development of a dry zone over the Ramnad-Tirunelveli districts of Tamil Nadu, the Palk Strait sea area and the extreme north of Sri Lanka from the middle of May (P-27).

3.6 In a recent study (Ananthakrishnan et al., 1981) we have shown that the onset of the summer monsoon rains over the Nicobar group of islands (around 8°N and 93°E) in the southeast Bay of Bengal occurs towards the end of April while over the Andaman group of islands (around 13°N and 93°E) to the north, the onset occurs about a week later. These dates are a month to 3 weeks ahead of the onset of the southwest monsoon rains over the Kerala coast of south India.

(c) June-July-August-September (P-31 to P-55)

3.7 These are the southwest monsoon months during which most of the country, barring the southeastern parts of the peninsula and the extreme north of India receive 75 to 95% of the annual rainfall. The normal date of onset of the monsoon rains on the Kerala coast is 1 June. A substantial increase in the pentad rainfall along the Kerala coast occurs from P-30 to P-31. The 100 mm isohyet makes its appearance for the first time in P-31 followed by a rapid northward extension over the coastal area during the next 3 to 4 pentads. The dry zone over the Ramnad-Palk Strait-north Sri Lanka region is a prominent features in all the pentad charts during the monsoon months. However, towards the beginning of September (P-49) a gradual increase in rainfall begins to set in over this region.

3.8 The progressive advance of the summer monsoon rainfall over the country can be followed sequentially from the charts commencing from P-31. Along with the north-ward extension of the rains from Trivandrum to Surat on the west coast, a north-westward extension of rainfall also occurs across the Orissa-West Bengal coasts. It is interesting to follow the shift of the 5 mm isohyet across the central parts of the country starting from P-30 (end of May). By the middle of June (P-34) this line lies close to the India-Pakistan border with a progressive increase of rainfall to the south-east. The pentad rainfall over the central parts of the country registers an increase from 5 to 10 mm in P-31 to 20 to 50 mm in P-35. By the middle of July (P-40) when the monsoon is fully established over the country the 10 mm isohyet runs close to the India-Pakistan border with a rapid increase of rainfall to the southeast, the amounts reaching 50 to 100 mm over the central parts of the country.

3.9 The rapid decrease of rainfall to the lee-side of the Western Ghats results in a zone of minimum rainfall over the central parts of the peninsula south of about 20°N. The progressive development of this dry belt can be followed through charts P-31 to P-34. By mid-June the dry zone is fully established and it extends as a tongue from Tamil Nadu and Pondicherry in the south to Marathwada and north Madhya Maharashtra across Telengana, Rayalaseema and north interior Karnataka over parts of which the mean pentad rainfall is less than 10 mm from P-33 to P-45. An increase in rainfall over this region of extreme dryness can be noticed beginning from P-46 (mid-August), coincident with the minimum in the monsoon rainfall over large parts of north and central India.

3.10 The space-time variations of mean south-west monsoon rainfall along the west-coast can be seen by following the configuration of the 100 and 50 mm isohyetal lines. By the end of June (P-36) the 100 mm line extends practically all along the west coast upto Bombay. By mid-

August (P-46) this line has almost vanished except for isolated pockets while the 50 mm isohyet has taken its place. By mid-September (P-52) this line has also vanished except for isolated pockets.

3.11 The weakening of the southwest monsoon activity and its gradual retreat from northwest India can be followed through charts P-50 to P-55. At the beginning of September (P-50) the 10 mm isohyet is close to the India-Pakistan border with a number of pockets of 50 mm isohyetal lines over central and north India. By mid-September (P-52) the 50 mm isohyet can be seen only over northeast India and Bangla Desh while the 10 mm line has shifted a little to the southeast. By the end of September (P-55) the 50 mm isohyet has almost vanished from northeast India. The 10 mm line has moved further southeast while the 2 mm isohyet lies close to the India-Pakistan border. It may be noted that the summer monsoon current does not penetrate into the Kashmir Valley where pentad rainfall amounts range from 2 to 5 mm throughout the monsoon months.

3.12 Over the eastern parts of the Bay of Bengal and the Arakan-Tenasserim coasts where the monsoon rains commence earlier than over the Kerala coast, the rainfall activity is high till mid-August (P-46) after which there is gradual decline. There is a substantial reduction in rainfall over the coastal belt by the end of September (P-55).

(d) October-November-December (P-56 to P-73)

3.13 These months mark the south-ward retreat of the summer monsoon. This is the main rainy season for Tamil Nadu and the secondary rainfall season for Kerala. Because of the fact that the low level winds are northeasterly over the southern parts of the peninsula this is also known as the northeast monsoon season.

3.14 The dry zone over the Ramnad-Palk Strait-north Sri Lanka region which was a conspicuous feature during

the summer monsoon months disappears by the middle of October and rainfall begins to increase along the Tamil Nadu coast and Sri Lanka. At the same time there is progressive decline of rainfall over north India. By the end of October (P-61) rainfall has considerably decreased over north and central India and the 10 mm isohyet runs from about 15°N on the west coast to south Assam through Calcutta, with a rapid decrease in rainfall to the northwest. At the same time pentad rainfall has increased along coastal Tamil Nadu, south Kerala and the northern parts of Sri Lanka where the amounts exceed 50 mm.

3.15 By mid-November (P-64) the northeast monsoon rainfall begins to decrease while the isohyets over the Bay of Bengal tend to revert to east-west orientation. By the beginning of December (P-68) the mean pentad rainfall over most of north and central India is less than 2 mm. Western disturbances have begun affecting Jammu and Kashmir where pentad rainfall is now 5 to 10 mm.

3.16 With the progressive south-ward retreat of the ITCZ the northeast monsoon rainfall decreases along the Tamil Nadu coast. After the middle of December the 50 mm isohyetal line can be seen as a small pocket only over the northeast coast of Sri Lanka. The 2 mm isohyetal line appears over north Bay of Bengal by P-70 and progressively moves southwards. By the end of the month (P-73) this line lies over the central Bay of Bengal with pentad rainfall increasing to 20 mm over the southern parts of the Bay. The isohyetal lines have become almost identical to P-1 completing the annual rainfall cycle.

Acknowledgements

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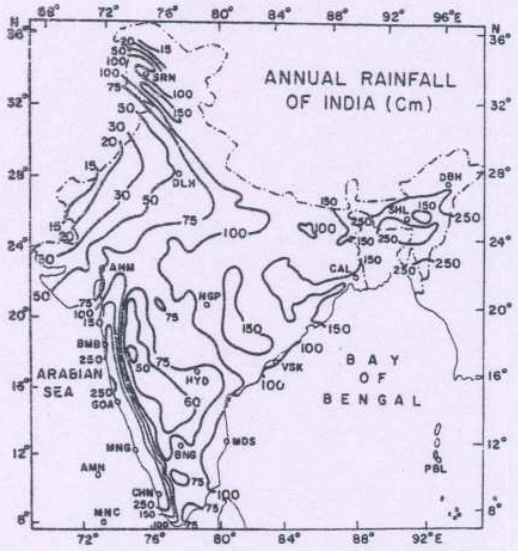

ANNUAL RAINFALL
OF INDIA (Cm)
ARABIAN
SEA
BAY
OF
BENGAL
SRN
DLH
AMM
NGP
BMB
HYD
GOA
VSK
CAL
DBH
SHL
MNG
BNG
MDS
AMN
CHN
MNC
PBL

FIG 1

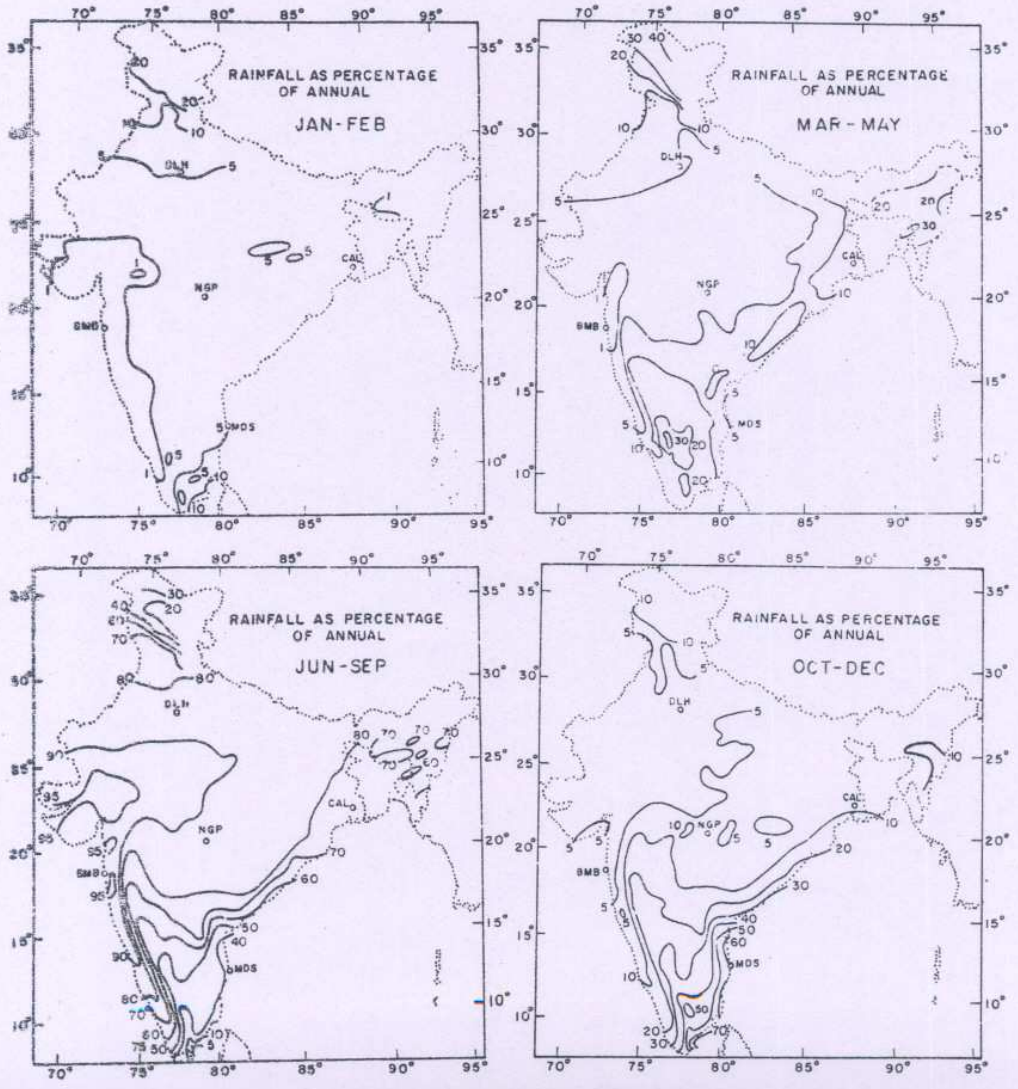

RAINFALL AS PERCENTAGE
OF ANNUAL
JAN-FEB
RAINFALL AS PERCENTAGE
OF ANNUAL
MAR-MAY
RAINFALL AS PERCENTAGE
OF ANNUAL
JUN-SEP
RAINFALL AS PERCENTAGE
OF ANNUAL
OCT-DEC
DLH
CAL
NGP
BMB
MDS

FIG 2

METEOROLOGICAL SUB-DIVISIONS OF INDIA

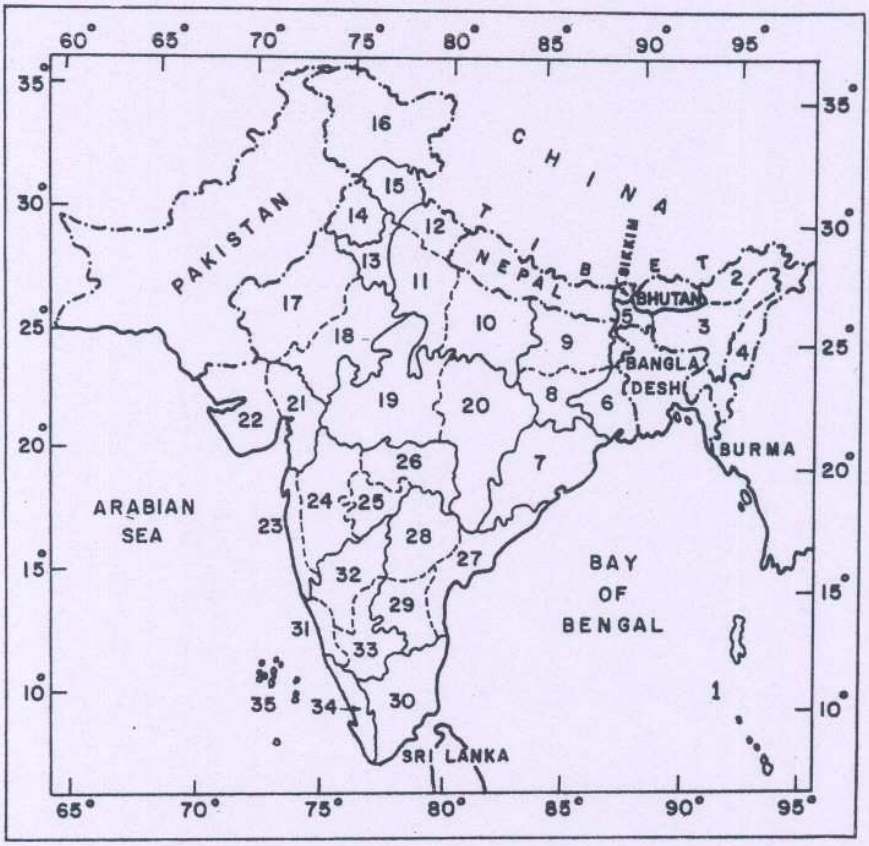


FIG 3

1. ANDAMAN & NICOBAR ISLANDS.
2. ARUNACHAL PRADESH.
3. ASSAM & MEGHALAYA.
4. NAGALAND, MANIPUR, MIZORAM & TRIPURA.
5. SUB-HIMALAYAN WEST BENGAL & SIKKIM.
6. GANGETIC WEST BENGAL.
7. ORISSA.
8. BIHAR PLATEAU.
9. BIHAR PLAINS.
10. EAST UTTAR PRADESH.
11. PLAINS OF WEST UTTAR PRADESH.
12. HILLS OF WEST UTTAR PRADESH.
13. HARYANA, CHANDIGARH AND DELHI.
14. PUNJAB.
15. HIMACHAL PRADESH.
16. JAMMU & KASHMIR.
17. WEST RAJASTHAN.
18. EAST RAJASTHAN.
19. WEST MADHYA PRADESH.
20. EAST MADHYA PRADESH.
21. GUJARAT REGION, DAMAN, DADRA & NAGAR HAVELI.
22. SAURASHTRA, KUTCHH AND DIU.
23. KONKAN & GOA.
24. MADHYA MAHARASHTRA.
25. MARATHWADA.
26. VIDARBHA
27. COSTAL ANDHRA PRADESH.
28. TELANGANA.
29. RAYALASEEMA.
30. TAMILNADU AND PONDICHERRY.
31. COASTAL KARNATAKA.
32. NORTH INTERIOR KARNATAKA.
33. SOUTH INTERIOR KARNATAKA.
34. KERALA.
35. LAKSHADWEEP.

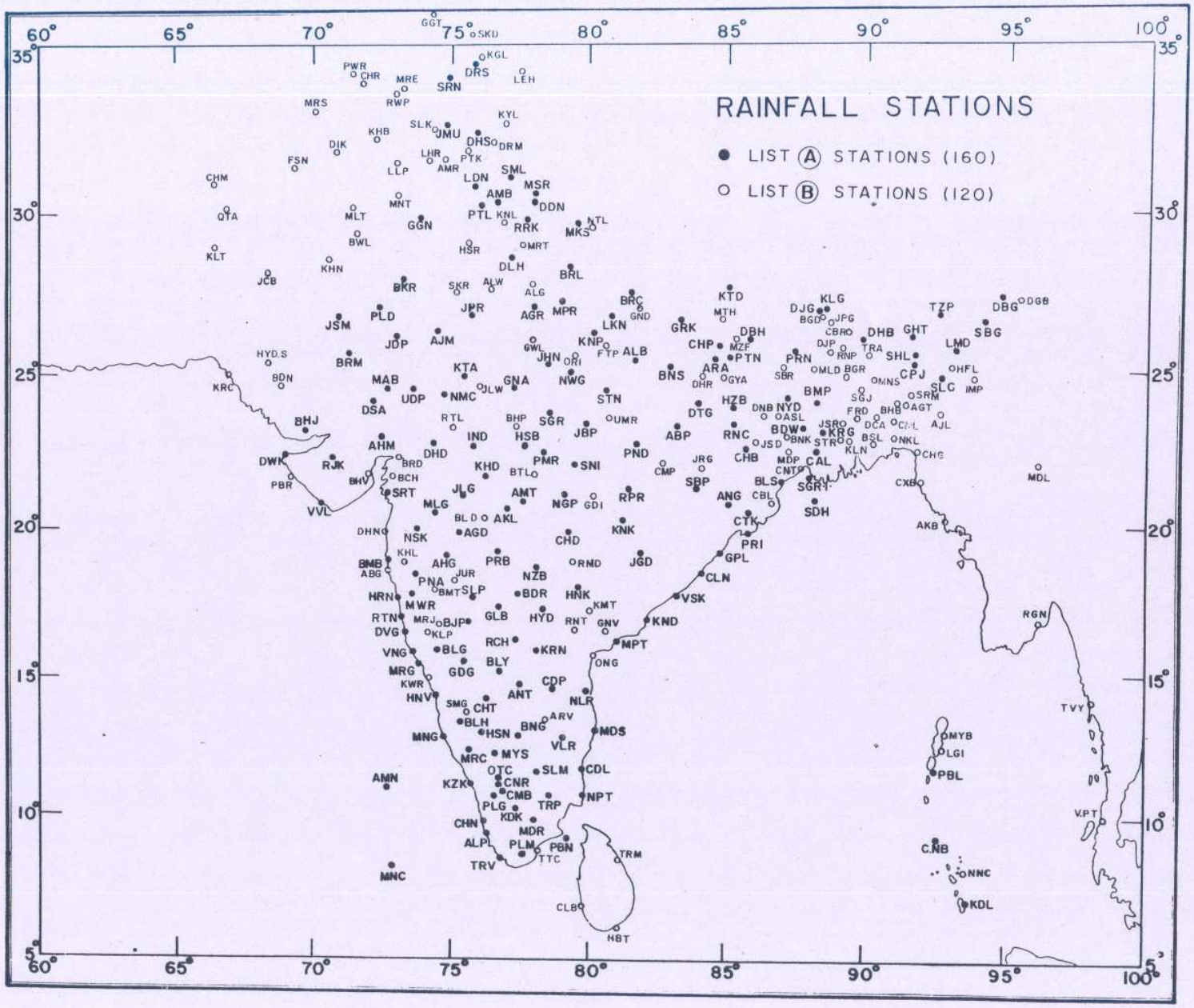
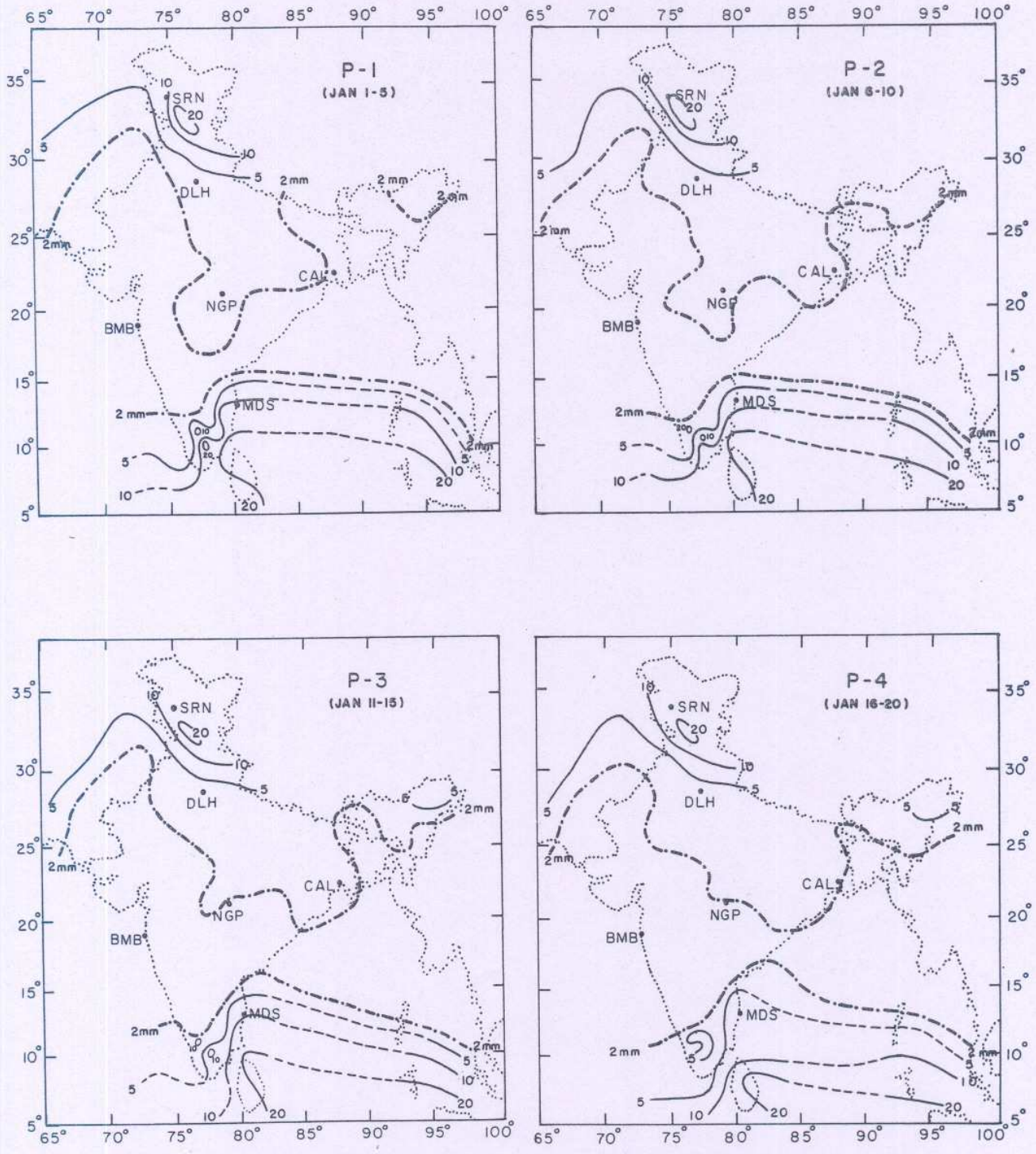
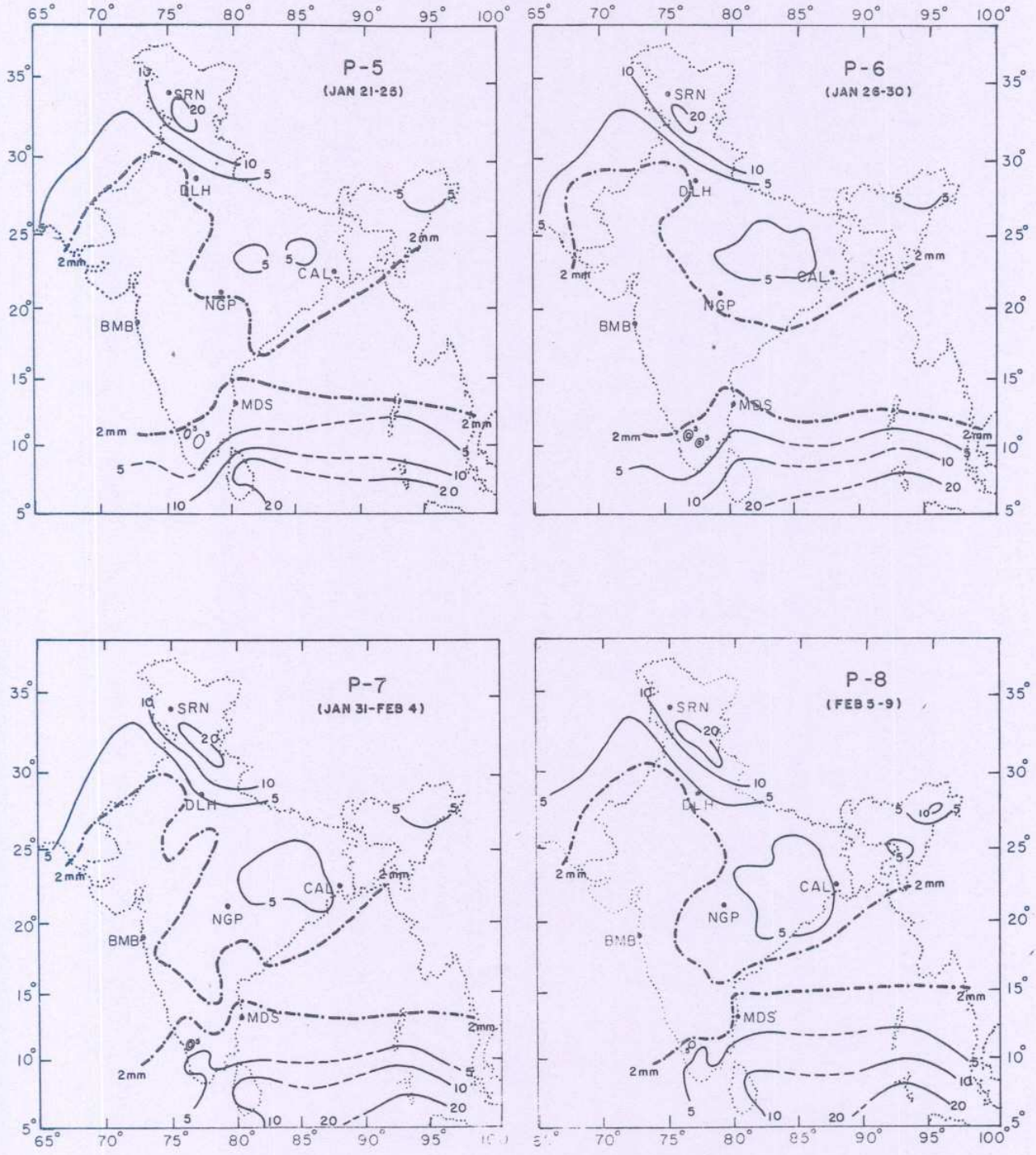

RAINFALL STATIONS
● LIST (A) STATIONS (160)
○ LIST (B) STATIONS (120)
60°
65°
70°
75°
80°
85°
90°
95°
100°
35°
30°
25°
20°
15°
10°
5°

Fig 4-



NORMAL PENTAD RAINFALL CHARTS



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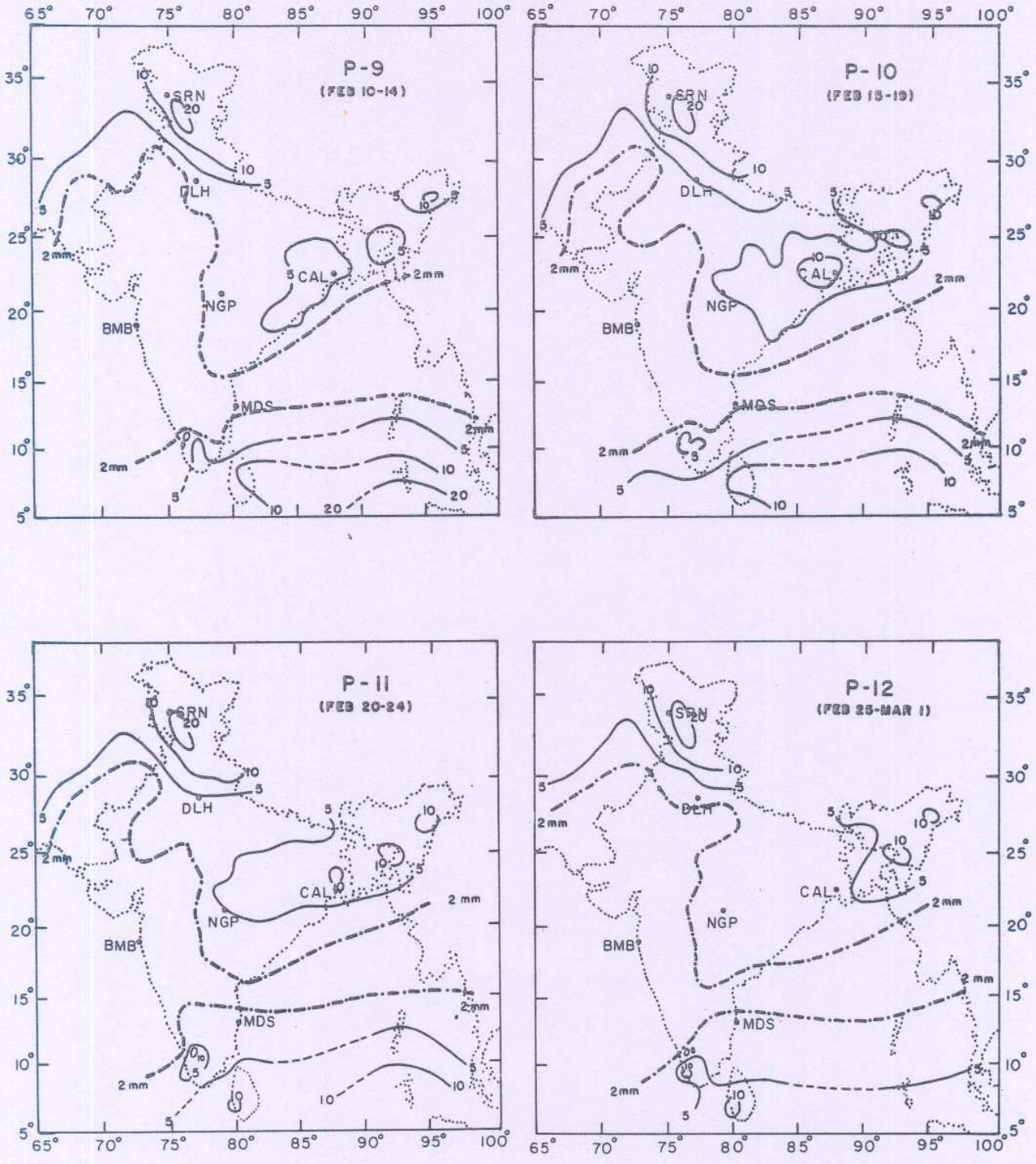

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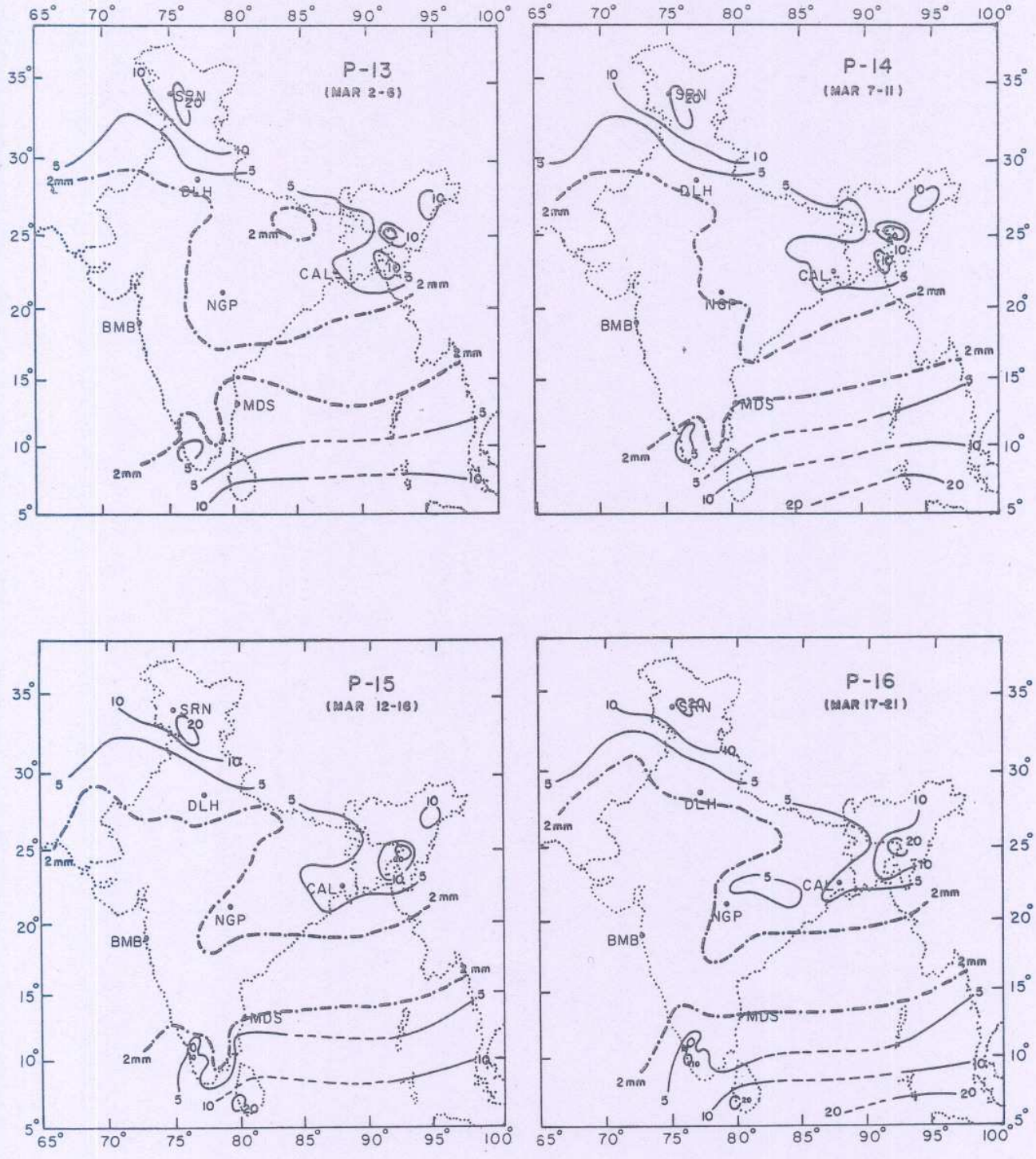

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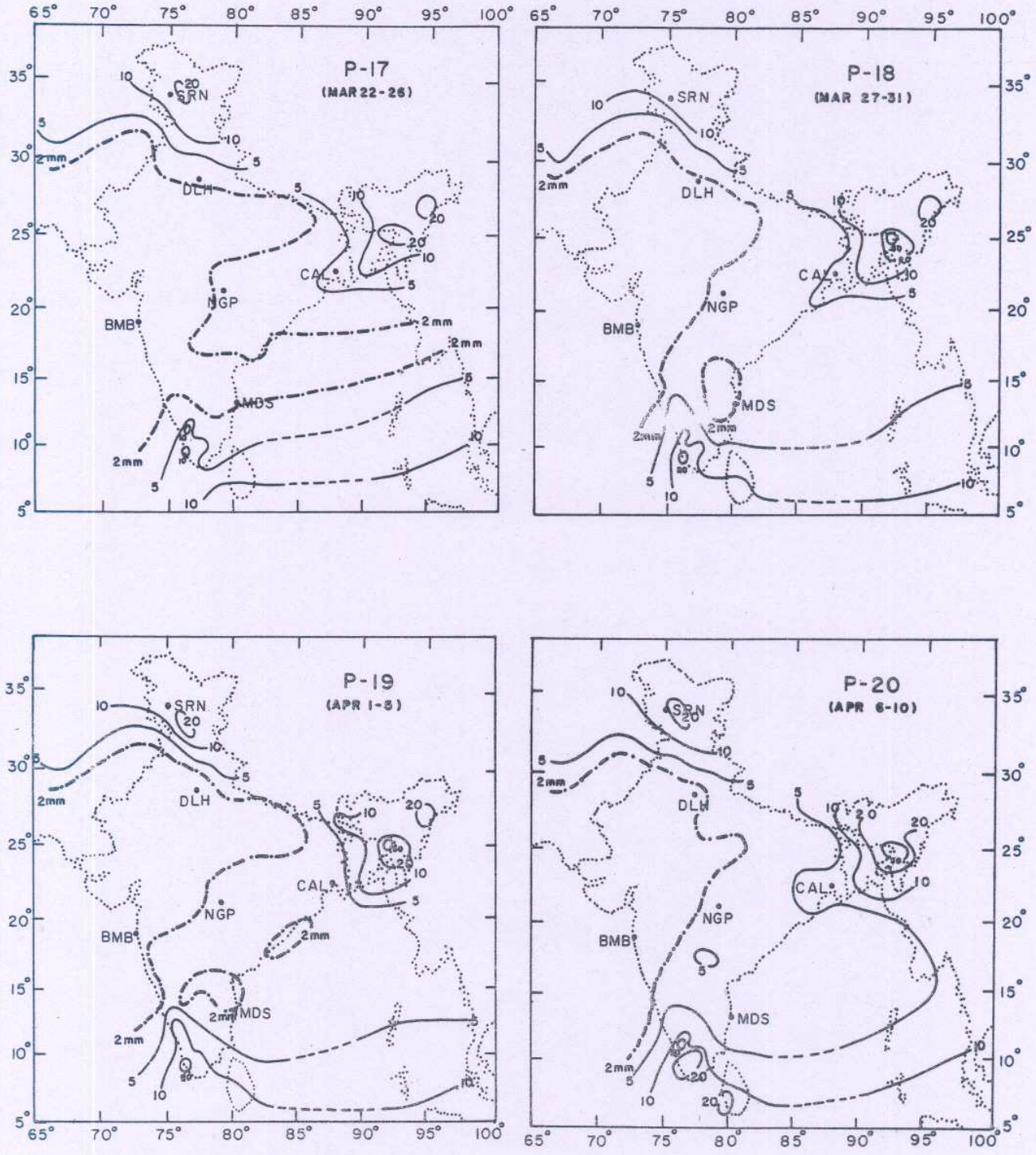

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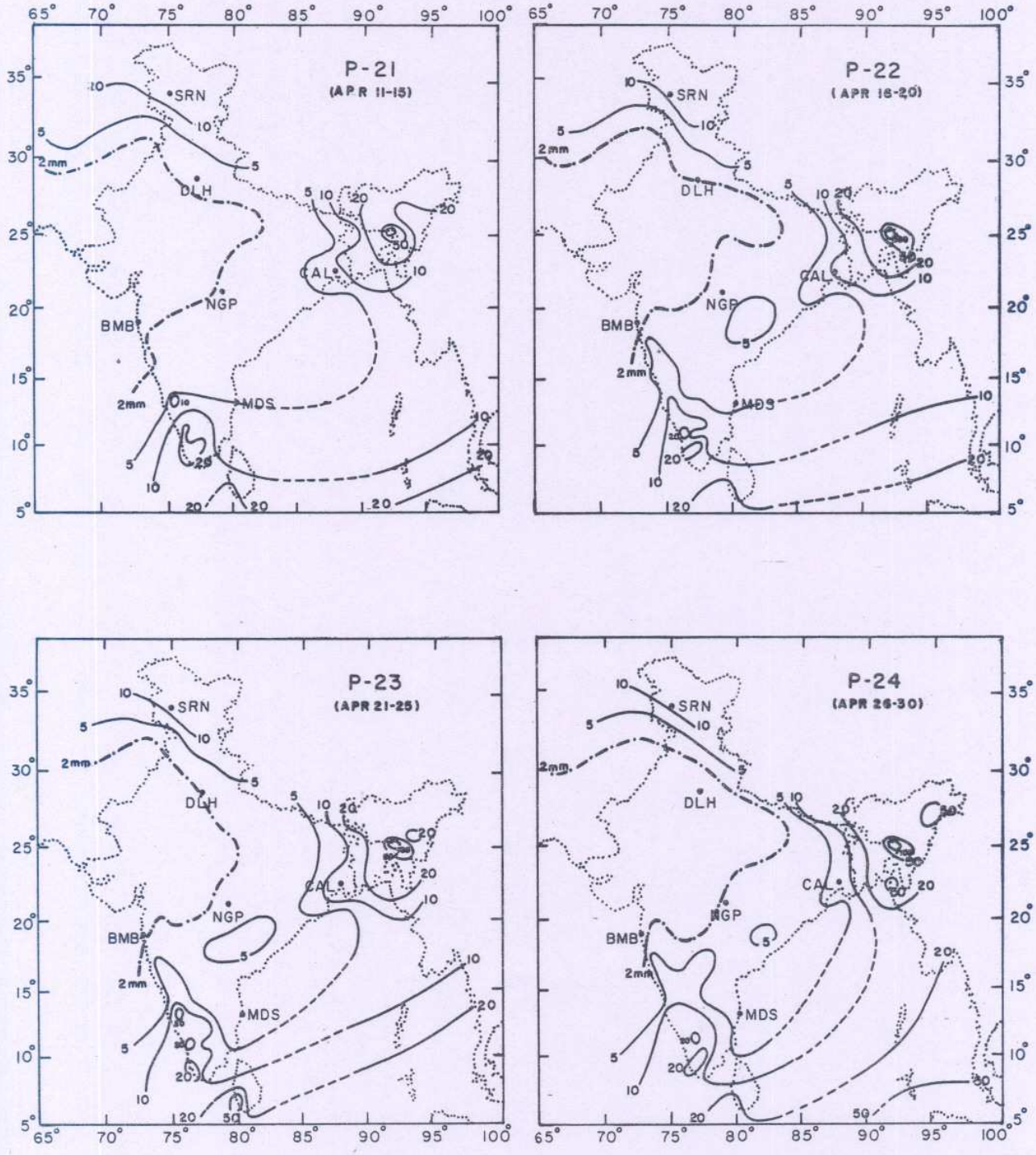
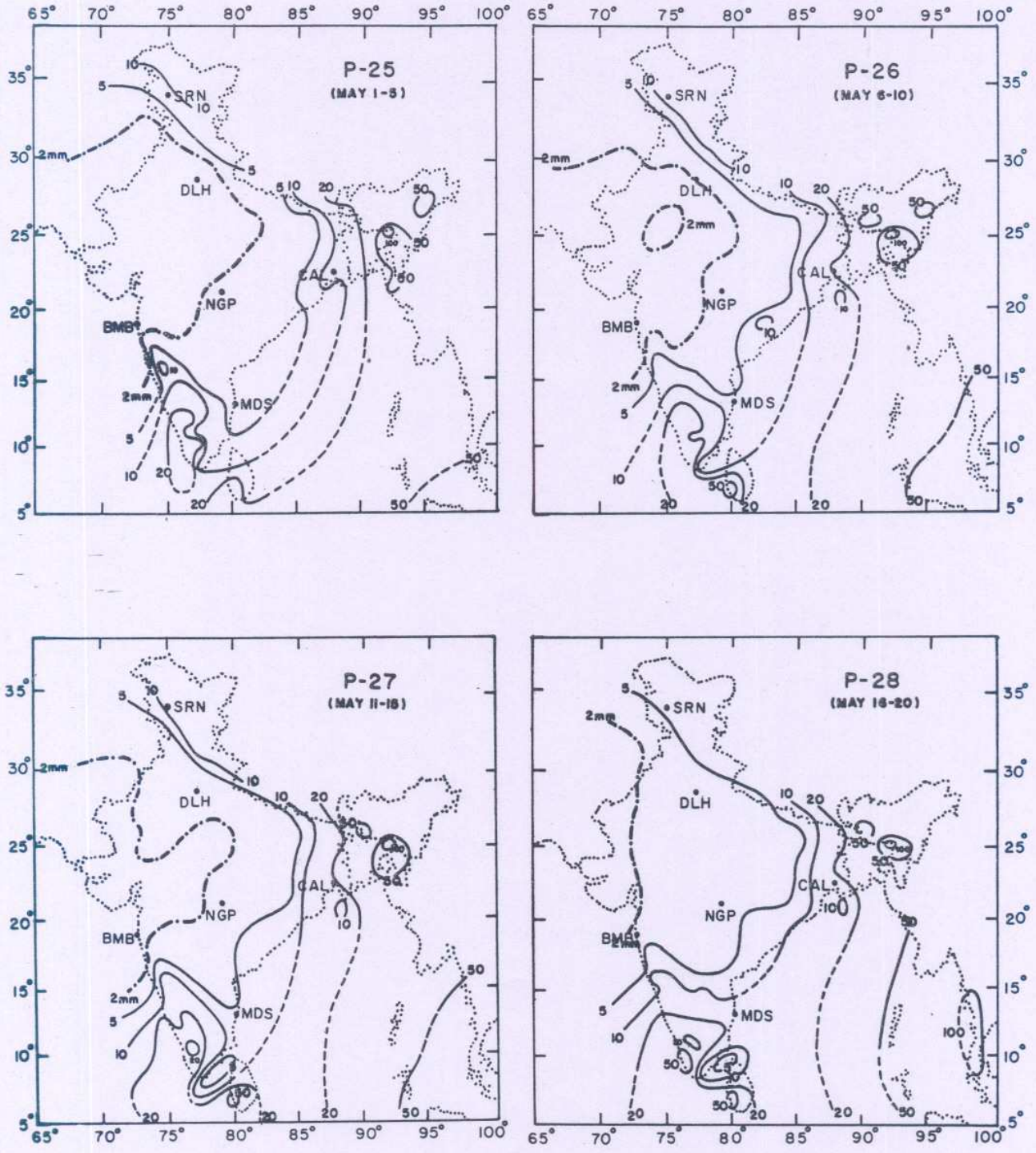


NORMAL PENTAD RAINFALL CHARTS



NORMAL PENTAD RAINFALL CHARTS

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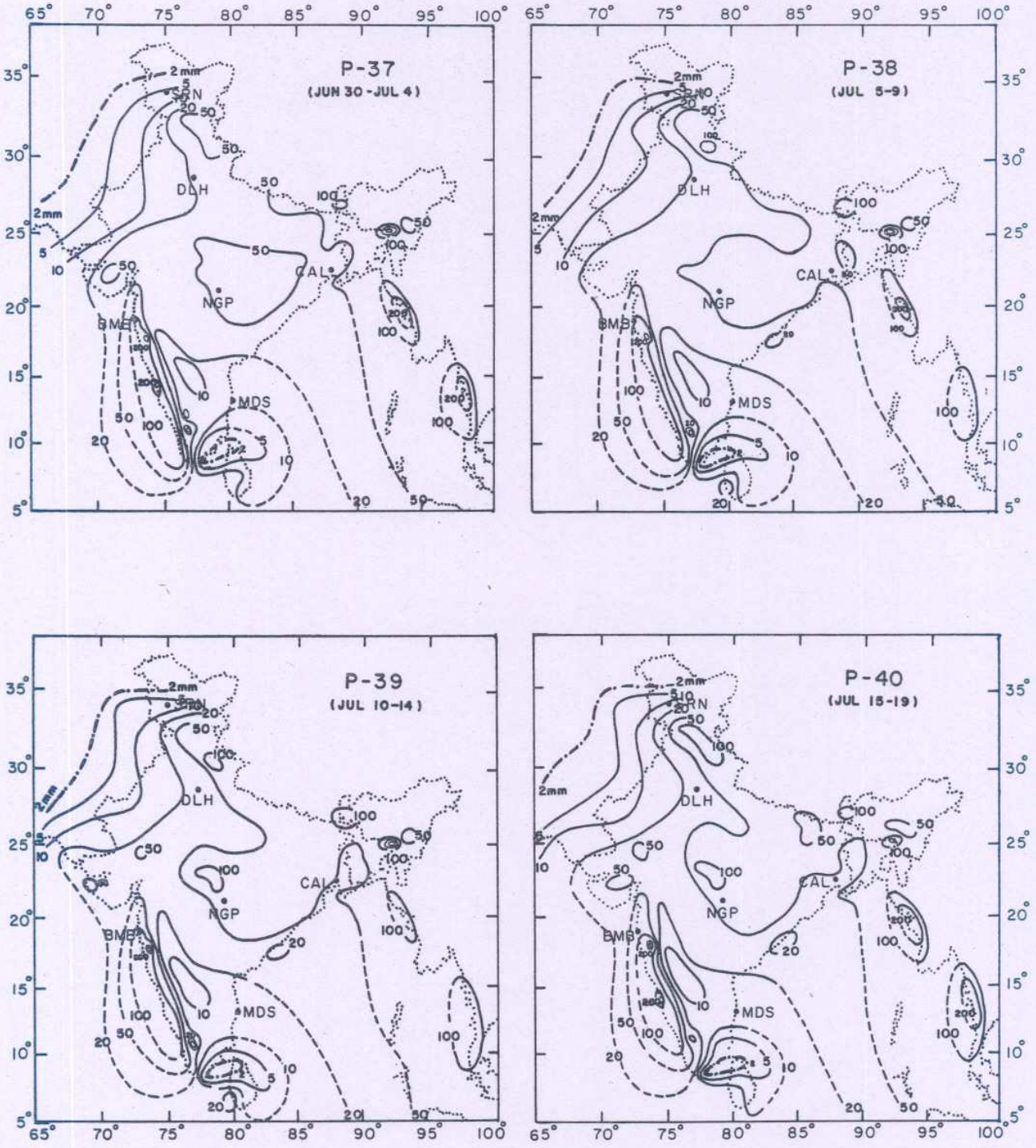
NORMAL PENTAD RAINFALL CHARTS



NORMAL PENTAD RAINFALL CHARTS

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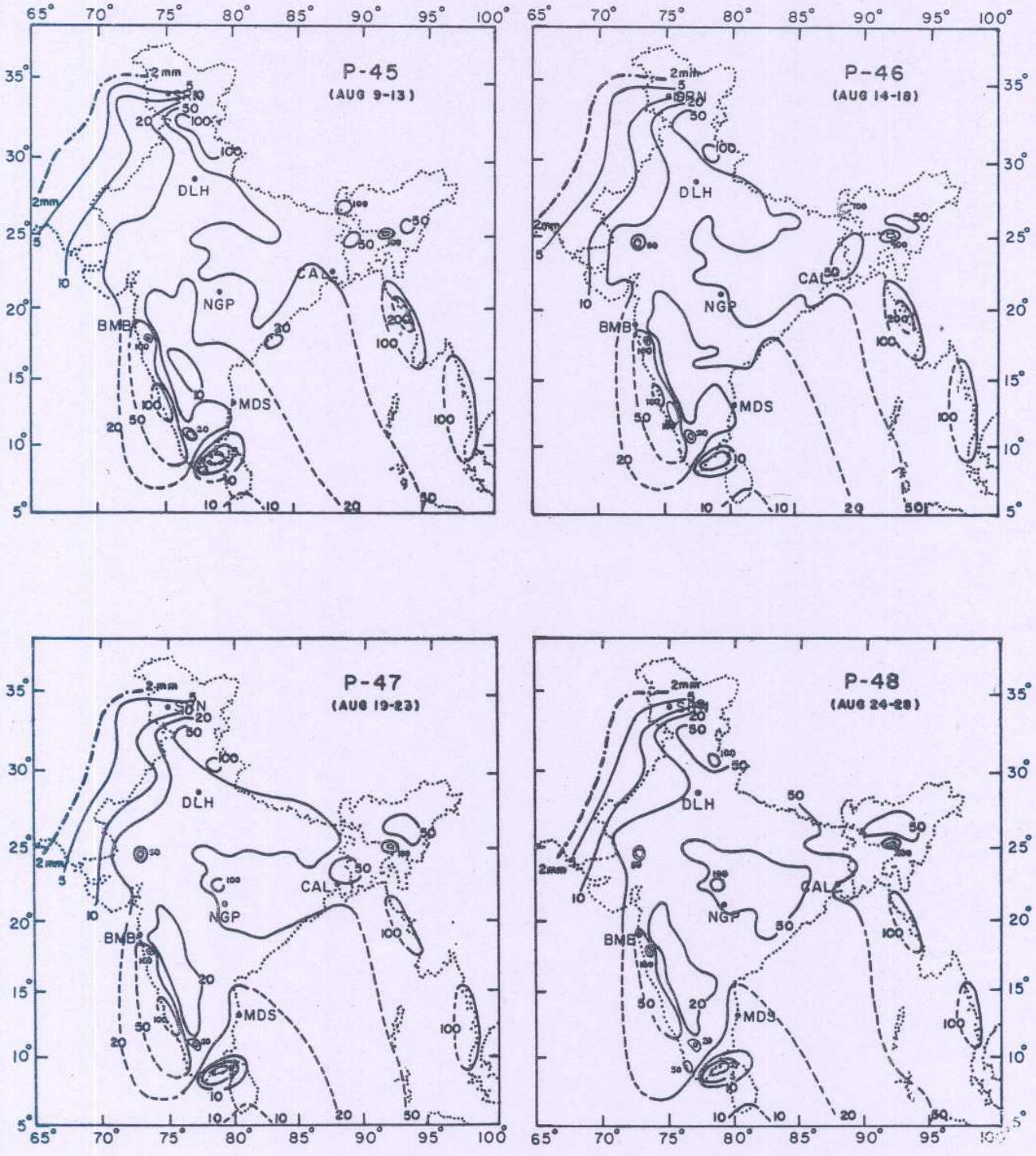

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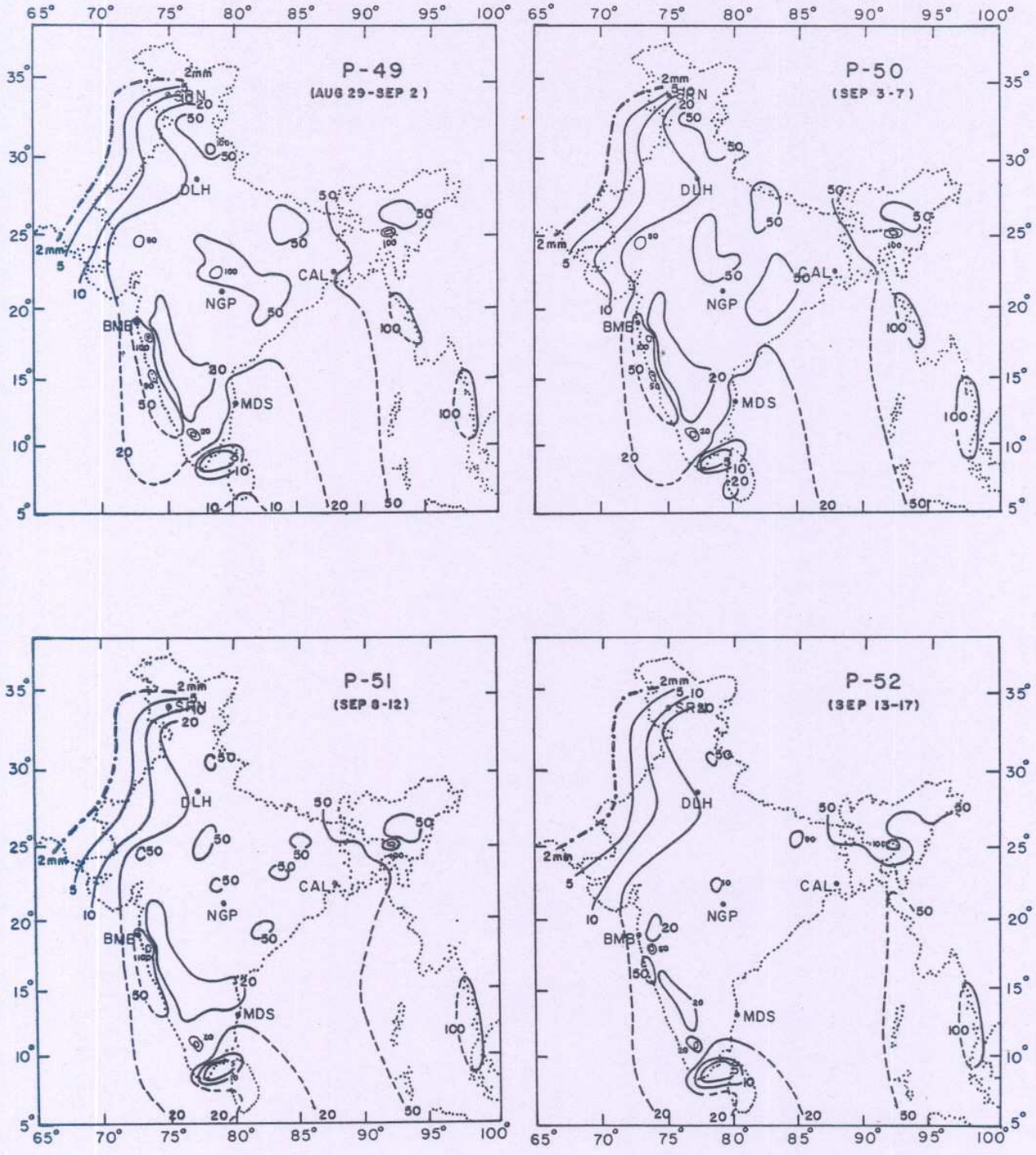

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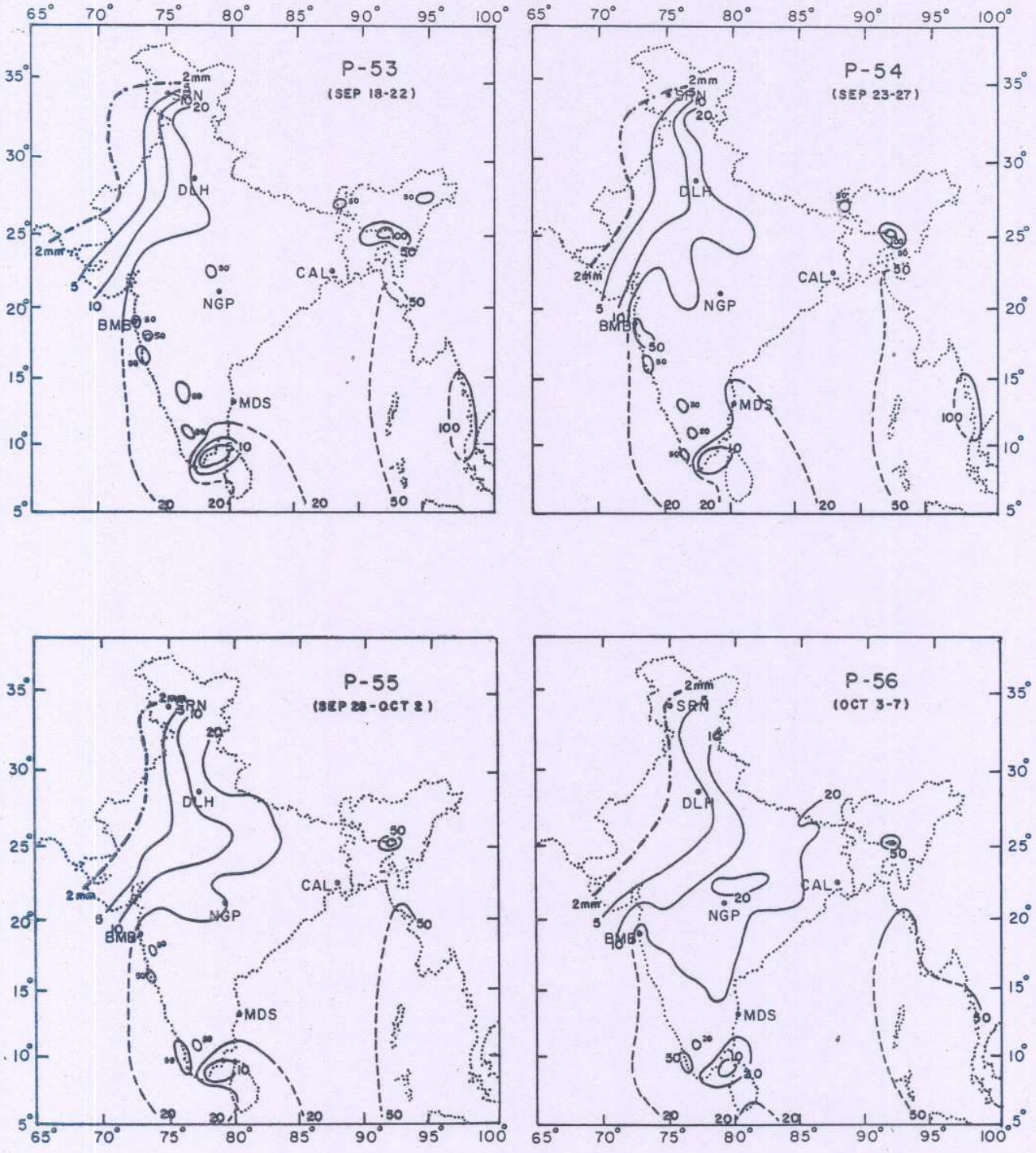

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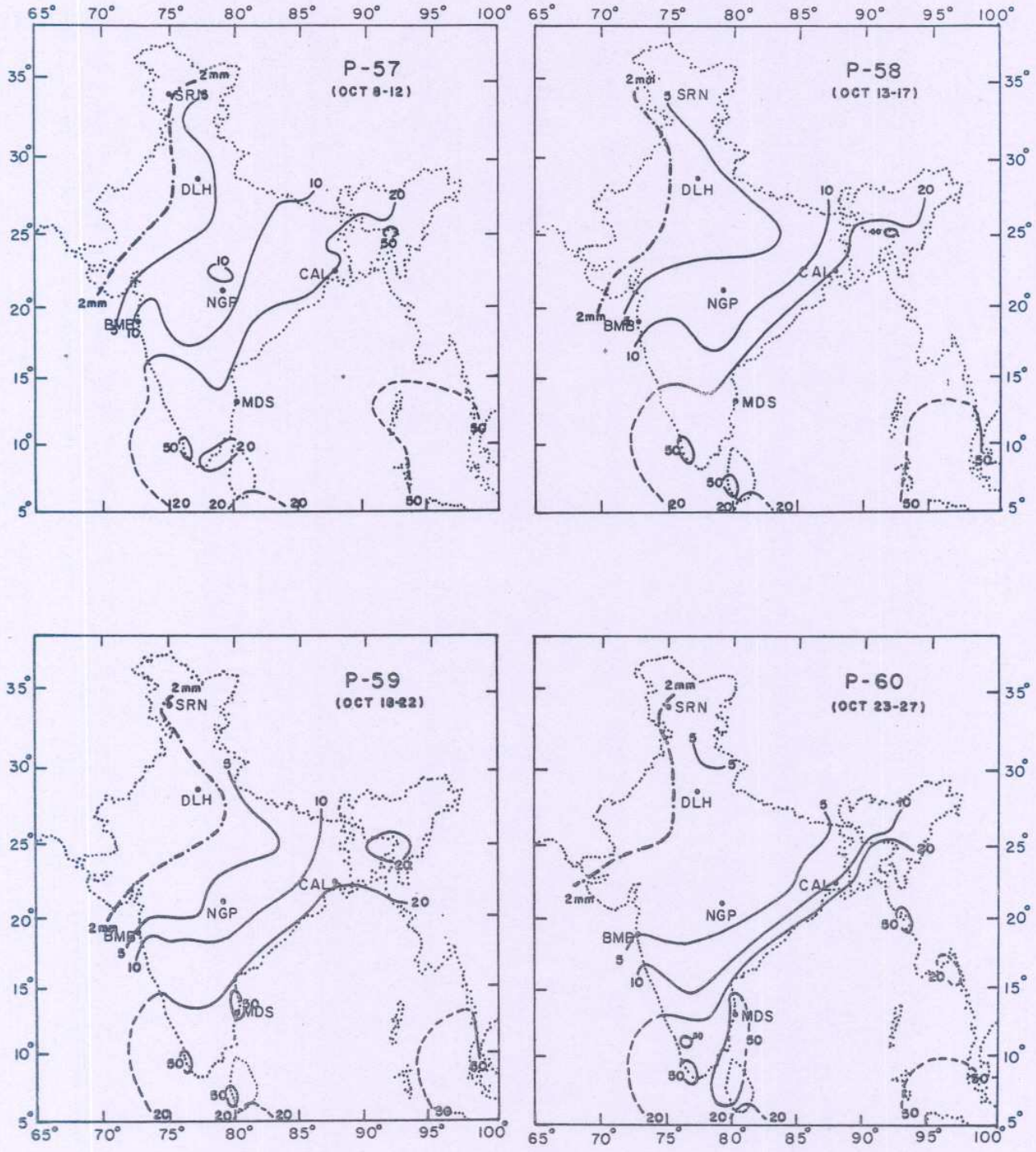

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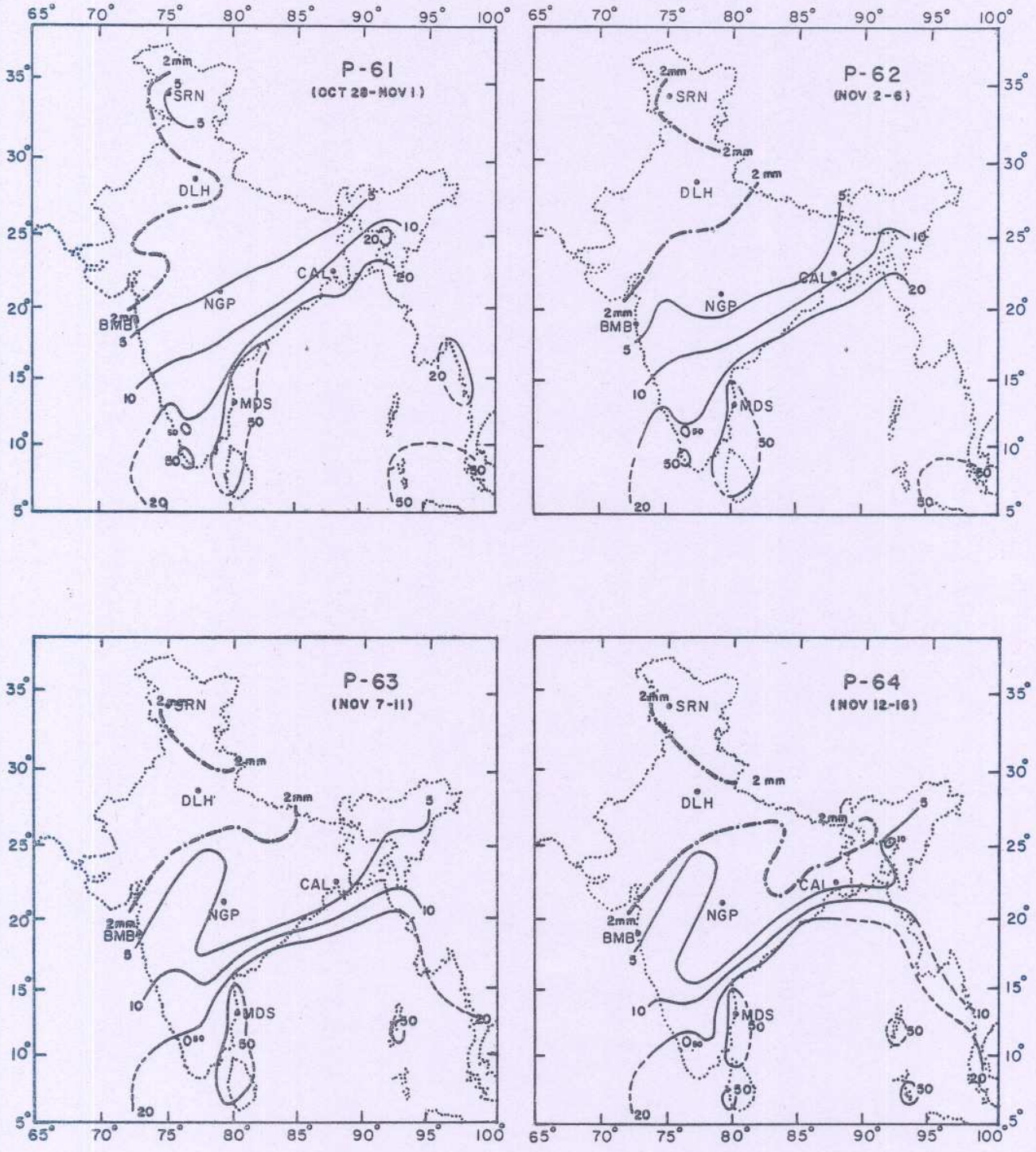

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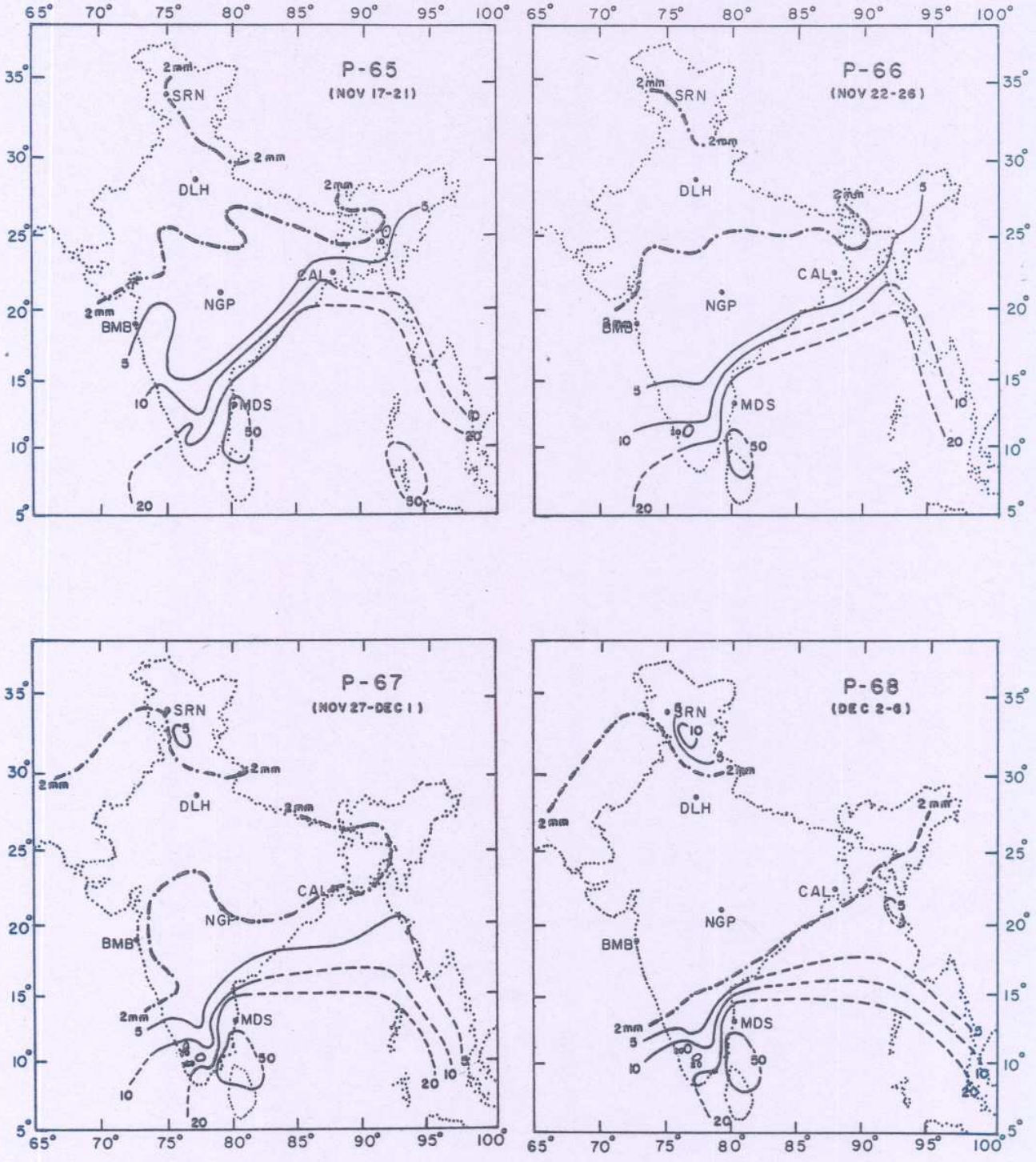

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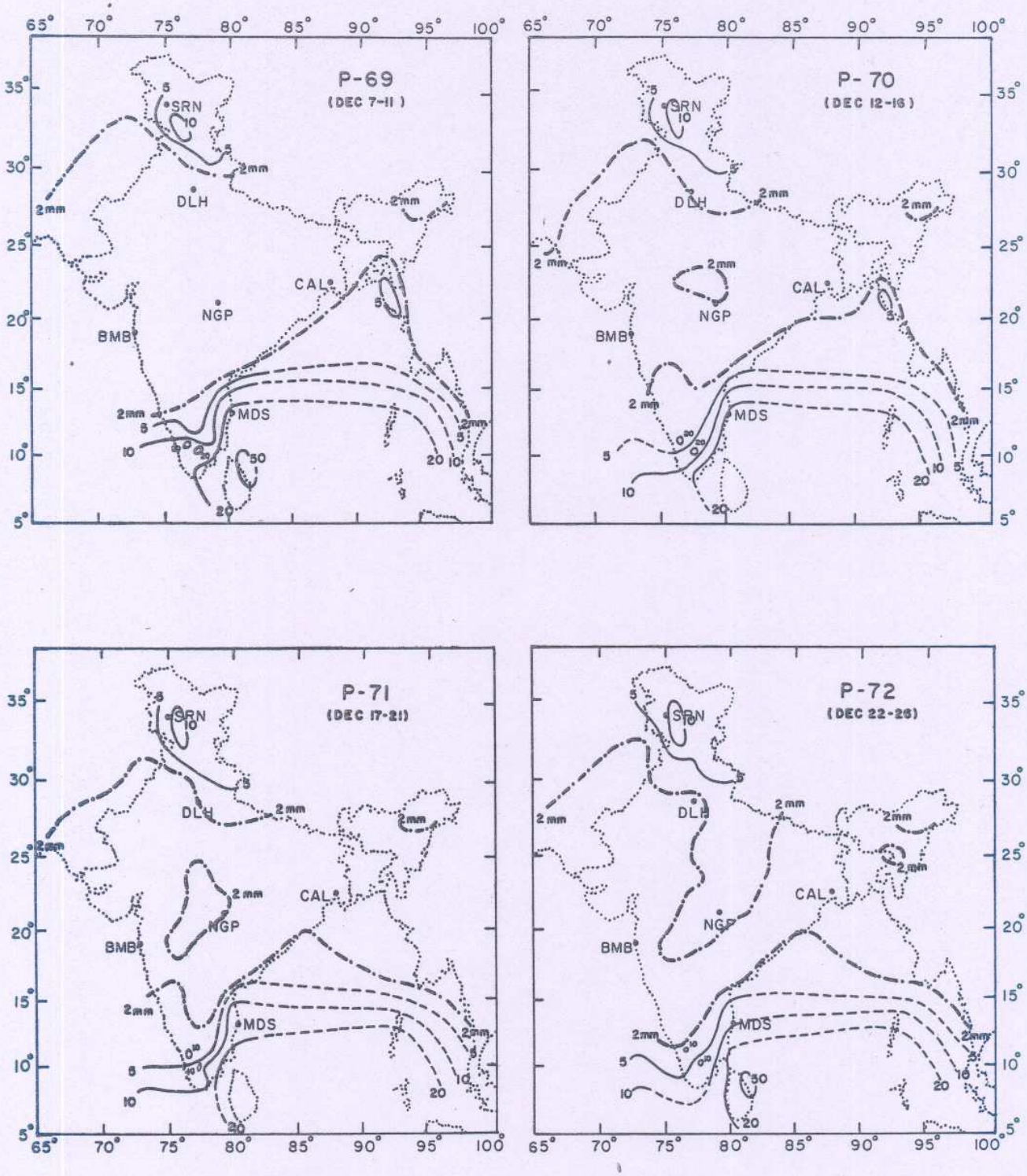

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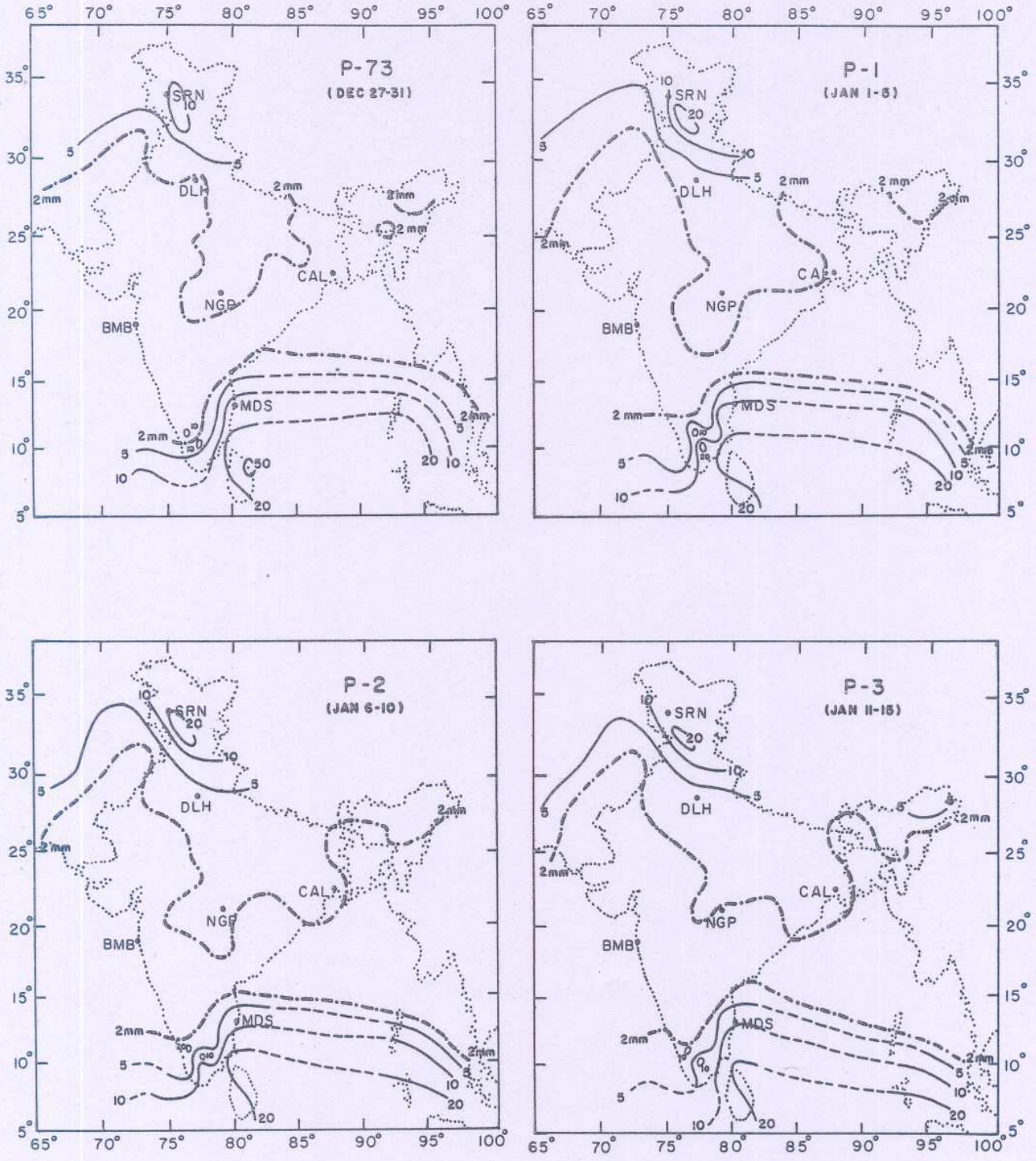

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