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SPATIAL PATTERNS OF INDIAN SUMMER MONSOON RAINFALL FOR THE PERIOD 1871-1990

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Abstract

This report presents seasonal (June through September) percentage departure from normal rainfall patterns over India for a 120 year period(1871-1990). The normal monsoon rainfall map for India , along with coefficient of variation and the All India Monsoon Rainfall (AIMR) for the country as a whole are also presented.

These spatial patterns reveal that years having similar AIMR values (amounts of rainfall) need not have similar spatial patterns. Even during normal monsoon years, the patterns may be different. However, for majority of drought years or El-Nino years, the patterns and the corresponding AIMR resemble very well.

For each year's spatial pattern, the best three analogues are obtained from the same data set(i.e.1871-1990). It is seen that on 70% of the occasions the first analogue has a correlation coefficient (CC) > 0.5 , suggesting that spatial percentage departure patterns do repeat.

1. Introduction

Abnormalities in the performance of the Indian summer monsoon over different meteorological subdivisions (SDs) for the period 1871 to 1984 has been studied by Parthasarathy et. al. (1987). They have identified the different SDs and years affected by meteorological droughts and floods during the 114 years.Kulkarni et. al. (1992) and Raj(1990) have shown that majority of these spatial patterns of rainfall distribution can be mainly classified into six distinct types . However there is year to year variation in the rainfall anomaly patterns over the country, hence it is desirable to present the spatial percentage departure rainfall pattern maps of India along with AIMR.With the above idea in view we are presenting the departure pattern maps of India along with the AIMR for a 120 year period (1871-1990) in this report.

2. Data

Monthly rainfall data for 306 stations spread over the country for the months June through September for the period 1871-1984 are obtained in a processed form(i.e. scrutinized and error free data without gaps) from Dr.B.Parthasarathy,who obtained the basic rainfall data from National Data Centre, India Meteorological Department (IMD),Pune.From these 306 stations seasonal data , the averages for 51 blocks (Fig.1) are prepared.The number of stations falling in each block are shown in the same figure.The percentage departures from normal are prepared for each of the 51 blocks. Data for the years 1985-1989 have been collected from Mausam and for 1990 from the Weekly Weather Report of the IMD. Therefore the data for the period 1985-1990 are also available for all SDs. From these data sets departure values for each of the 51 blocks have been interpolated for different years.The AIMR for the entire period is obtained from the publication of B.Parthasarathy et.al.(1990).

Fig. 2a shows the spatial normal distribution of rainfall in centimeters(cms) based on the period 1871-1984. This figure reveals that the normal rainfall over northeast India and along the west coast is about 200 cms, whereas over northwest India and the southeast peninsula it is less than 50 cms. Fig. 2b shows the distribution of the coefficient of variation (CV). It is observed that CV is less than 20% over northeast India and along the west coast - the regions with heavy rainfall. The CV lies between 30 to 50% over northwest India and is around 30% over the southeast tip. These are the regions with low rainfall.

The spatial patterns for the entire period are shown in Fig.3. The corresponding AIMR is also shown for each year. It also indicates whether a particular year was El Nino (Gupta and Muthuchami,1991; Quinn et.al.,1978) or La Nina year (Kiladis and Van Loon,1988)

3. Results

3.1 Analogues

To investigate whether a particular anomaly pattern repeats itself we have computed the correlation coefficient for each year's spatial pattern with the remaining 119 years (51 values of one year are correlated with corresponding 51 values of another year). For a sample of 51 a correlation of 0.35 is significant at 1% level. Keeping this value in view and the fact that we are considering the percentage departures,a value of 0.5 should be considered adequate for a good analogue and 0.7 for an excellent analogue. For each year , out of 119 values,the highest three are selected.Table 1 shows these correlations along with the year for which these values are obtained. On visual examination of the year along with its analogue,it is seen that the spatial patterns resemble very well. However,the magnitudes may not match since the correlation measures only the similarity in patterns. This suggests that spatial patterns with similar features do recur , but forecasting these patterns is a challenging problem.

3.2 Best (first) Analogue

To get an idea of the occurrence of a good or an excellent analogue we have determined the frequency distribution (FD) of the CCs of the first analogue. The FD is as follows (Table 2):

Table 2 : Frequency distribution of the first analogue for various correlation ranges.

CC	Frequency
CC < 0.5	35
0.5 < CC < 0.6	31
0.6 < CC < 0.7	39
CC > 0.7	15

This shows that about 70% of the years have an analogue with C >= 0.5, showing that there is a probability of 0.7 for a good analogue to recur. Though the occurrence of an excellent analogue is rare,it is worthwhile to see the years having analogues >=0.7. Table 3 below depicts these years.

Table 3 : Years having CC >=0.7 and their best analogue

Ser No	CC	Year (AIMR)	Best Ana.(AIMR)
1	0.813	1905 (715)	1918 (648)
2	0.794	1899 (628)	1918 (648)
3	0.794	1911 (733)	1939 (789)
4	0.787	1908 (895)	1917 (1003)
5	0.766	1878 (974)	1979 (708)
6	0.743	1877 (604)	1987 (688)
7	0.727	1901 (719)	1911 (733)
8	0.704	1904 (749)	1939 (789)
9	0.702	1922 (867)	1936 (904)

From the above table it is clear that an excellent analogue is available for majority of drought years.From the above table it is also seen that 1877,1899,1905,1911,1918 and 1987 were El Nino years whereas only 1908 and 1922 were La Nina years. Again suggesting that the El Nino years have excellent spatial analogues.

Further to see whether there is a possibility to find when an analogue which is likely to repeat we have examined the difference in years between a pattern and its analogue,a FD is shown below (Table 4):

Table 4 : Frequency distribution of the difference in a year and its analogue.

Difference in Yrs	Frequency
< 10	14
10 - 20	28
20 - 30	22
30 - 40	16
40 - 120	40

From this table we can infer that on 67% of the occasions an analogue can be found within the range of past 40 years.

3.3 Spatial patterns for normal monsoon years

As stated earlier the spatial patterns in normal (normal means when AIMR for the country as a whole is normal) years are quite different. Here we just illustrate a few years of these types,eg. the years (AIMR) 1881(860),1903 (858),19[illegible]4 (862),1927 (849),1940 (850),1963 (835) and 1976 (835) have practically the same AIMR , however their spatial distributions are drastically different (see Fig.3). Hence AIMR and spatial patterns seem to have no relation.

Even during years when the spatial patterns are similar,their AIMR may be different. Table 5 shows 6 such cases.

Table 5 : Years having similar spatial patterns but different AIMR

S.no	Year	AIMR	Year	AIMR
1	1877	604	1938	908
2	1976	855	1917	1003
3	1937	843	1961	1017
4	1982	735	1942	958
5	1965	707	1988	999
6	1941	729	1927	849

4. Conclusions

(i) The year to year percentage departure rainfall patterns are quite different and seem to have no relation with AIMR.

(ii) Spatial patterns for drought or El Nino years have maximum similarity.

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------------------------------ (1987) : ------------ (June-Sept.1986). Mausam,38,372.

------------------------------ (1988) : ------------ (June-Sept.1987). Mausam,39,326.

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Table 1 : A year and its best 3 analogues. CC=Table value$\times 10^{-2}$

YEAR	1ST(YEAR)	2ND(YEAR)	3RD(YEAR)	YEAR	1ST(YEAR)	2ND(YEAR)	3RD(YEAR)
1871	62(1922)	56(1876)	51(1888)	1901	72(1911)	72(1939)	67(1915)
1872	44(1875)	37(1975)	32(1910)	1902	49(1920)	43(1987)	38(1915)
1873	45(1942)	44(1876)	44(1923)	1903	67(1989)	57(1988)	57(1966)
1874	46(1889)	41(1938)	37(1982)	1904	70(1939)	70(1911)	64(1985)
1875	50(1942)	44(1872)	36(1873)	1905	81(1918)	66(1911)	64(1987)
1876	61(1952)	56(1871)	44(1873)	1906	48(1886)	47(1938)	43(1989)
✓1877	74(1987)	62(1901)	61(1905)	1907	43(1882)	42(1929)	42(1896)
1878	76(1979)	66(1970)	62(1954)	1908	78(1917)	62(1893)	61(1975)
1879	44(1916)	43(1976)	37(1871)	1909	46(1983)	45(1916)	44(1897)
1880	42(1918)	39(1984)	37(1928)	1910	55(1903)	52(1895)	52(1966)
1881	62(1884)	58(1894)	48(1944)	1911	79(1939)	74(1918)	72(1901)
1882	43(1907)	42(1932)	41(1873)	1912	43(1878)	43(1979)	38(1961)
1883	51(1954)	47(1928)	44(1969)	1913	68(1941)	49(1927)	44(1926)
1884	67(1894)	62(1881)	61(1967)	1914	45(1983)	42(1959)	42(1878)
1885	50(1968)	47(1943)	43(1967)	1915	67(1901)	67(1938)	60(1911)
1886	48(1906)	44(1979)	43(1953)	1916	65(1892)	50(1917)	46(1975)
1887	52(1891)	48(1969)	46(1963)	1917	78(1908)	65(1975)	63(1893)
1888	66(1936)	64(1923)	62(1904)	1918	81(1905)	79(1899)	74(1911)
1889	46(1874)	40(1903)	36(1935)	1919	40(1942)	31(1876)	30(1871)
1890	58(1898)	51(1899)	49(1911)	1920	49(1902)	40(1924)	35(1885)
1891	52(1887)	47(1969)	41(1934)	1921	35(1913)	33(1922)	32(1905)
1892	65(1916)	53(1976)	52(1983)	1922	70(1936)	62(1871)	61(1888)
1893	63(1917)	62(1908)	59(1976)	1923	64(1888)	59(1904)	58(1948)
1894	67(1884)	62(1970)	58(1881)	1924	44(1923)	42(1974)	40(1920)
1895	52(1910)	50(1989)	49(1915)	1925	65(1911)	59(1936)	55(1980)
1896	54(1937)	45(1959)	42(1907)	1926	59(1959)	54(1884)	52(1944)
1897	44(1909)	37(1966)	35(1924)	1927	49(1913)	46(1941)	46(1926)
1898	58(1890)	55(1939)	54(1938)	1928	47(1883)	41(1965)	37(1880)
1899	79(1918)	72(1987)	70(1911)	1929	42(1907)	41(1940)	36(1876)
1900	57(1933)	50(1970)	46(1967)	1930	43(1969)	33(1943)	33(1891)

YEAR	1ST(YEAR)	2ND(YEAR)	3RD(YEAR)	YEAR	1ST(YEAR)	2ND(YEAR)	3RD(YEAR)
1931	62(1955)	50(1973)	48(1975)	1961	60(1884)	53(1944)	45(1926)
1932	42(1882)	30(1883)	26(1947)	1962	43(1983)	41(1949)	40(1988)
1933	57(1900)	48(1884)	47(1967)	1963	56(1901)	53(1960)	46(1939)
1934	48(1945)	44(1942)	41(1891)	1964	58(1988)	49(1892)	47(1903)
1935	38(1949)	37(1906)	36(1883)	1965	66(1989)	41(1928)	41(1987)
1936	70(1922)	66(1888)	61(1985)	1966	57(1903)	52(1910)	48(1895)
1937	54(1896)	51(1884)	36(1926)	1967	61(1884)	49(1943)	47(1933)
1938	67(1915)	54(1898)	50(1989)	1968	56(1877)	52(1899)	50(1885)
1939	79(1911)	72(1901)	70(1918)	1969	60(1948)	48(1887)	47(1891)
1940	43(1901)	41(1929)	36(1951)	1970	66(1878)	62(1894)	50(1900)
1941	68(1913)	49(1905)	46(1927)	1971	59(1888)	48(1985)	47(1922)
1942	52(1923)	50(1875)	50(1977)	1972	60(1985)	58(1986)	48(1901)
1943	55(1952)	49(1967)	47(1885)	1973	64(1944)	55(1917)	50(1893)
1944	64(1973)	57(1893)	56(1908)	1974	61(1987)	60(1985)	53(1899)
1945	64(1977)	50(1884)	48(1934)	1975	65(1917)	61(1908)	52(1955)
1946	38(1939)	36(1896)	34(1891)	1976	61(1917)	59(1990)	59(1893)
1947	36(1915)	33(1903)	33(1906)	1977	64(1945)	50(1942)	47(1881)
1948	63(1904)	61(1982)	60(1969)	1978	48(1908)	43(1917)	42(1975)
1949	52(1903)	48(1981)	47(1966)	1979	76(1878)	49(1959)	48(1903)
1950	37(1907)	32(1977)	32(1927)	1980	55(1925)	46(1967)	45(1894)
1951	62(1901)	55(1911)	54(1877)	1981	48(1949)	44(1989)	44(1903)
1952	61(1876)	55(1943)	47(1984)	1982	61(1948)	48(1923)	44(1904)
1953	46(1893)	43(1886)	39(1944)	1983	57(1878)	54(1954)	52(1892)
1954	62(1878)	54(1983)	51(1883)	1984	54(1922)	51(1899)	47(1952)
1955	62(1931)	56(1893)	52(1975)	1985	65(1899)	64(1904)	61(1936)
1956	51(1944)	45(1893)	39(1881)	1986	67(1911)	60(1987)	58(1972)
1957	46(1887)	44(1960)	41(1963)	1987	74(1877)	72(1918)	72(1899)
1958	50(1954)	43(1887)	41(1983)	1988	58(1964)	57(1903)	53(1878)
1959	59(1926)	55(1878)	49(1979)	1989	67(1903)	66(1965)	50(1938)
1960	53(1963)	52(1985)	46(1915)	1990	59(1976)	58(1908)	49(1917)

Figure legends :

Fig.1 : Map showing the location of the 51 blocks. Values in square indicate the number of stations in each block.

Fig.2 : (a) Normal rainfall pattern based on 1871-1984.

(b) Map showing the spatial distribution of the coefficient of variation based on 1871-1984.

Fig.3 : Spatial percentage departurefrom normal rainfall patterns for the period 1871-1984.

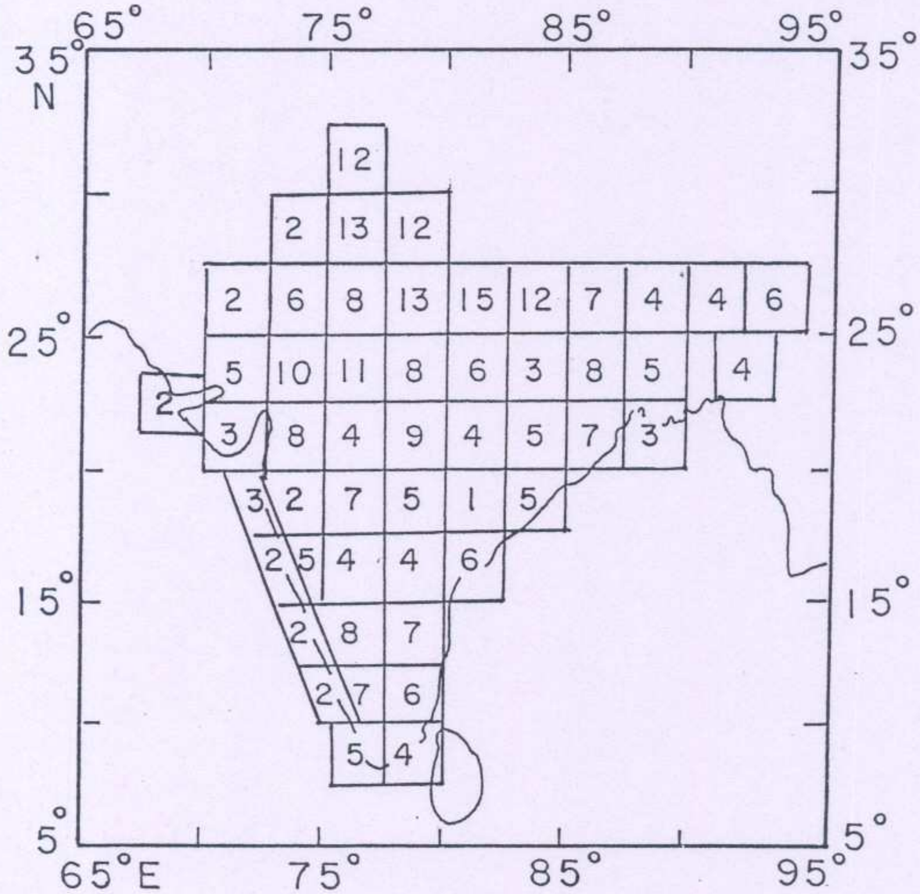


FIG. 1

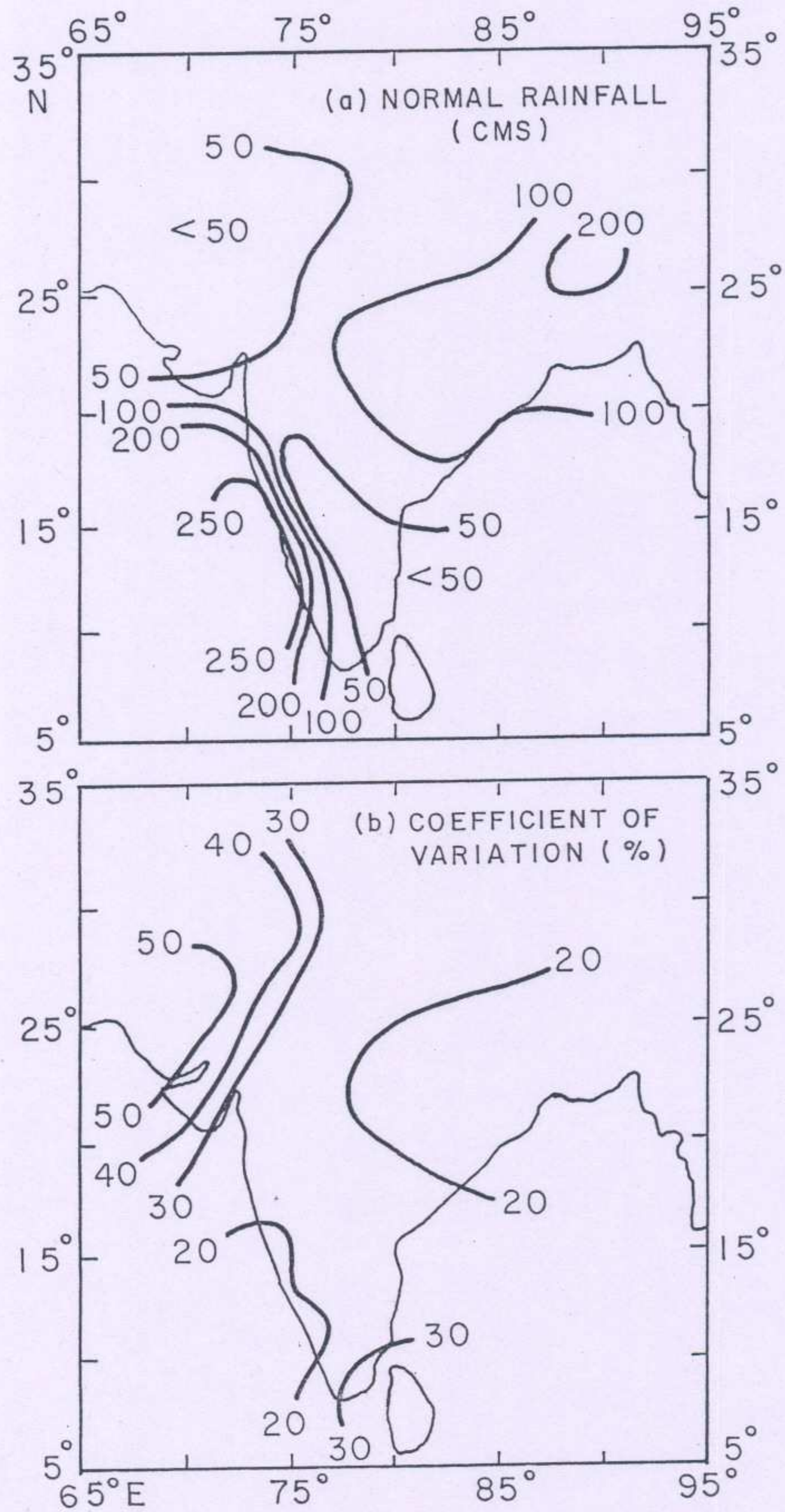

(a) NORMAL RAINFALL (CMS)
(b) COEFFICIENT OF VARIATION (%)
65°E
75°
85°
95°
35° N
25°
15°
5°
<50
50
100
200
250
20
30
40

FIG.2

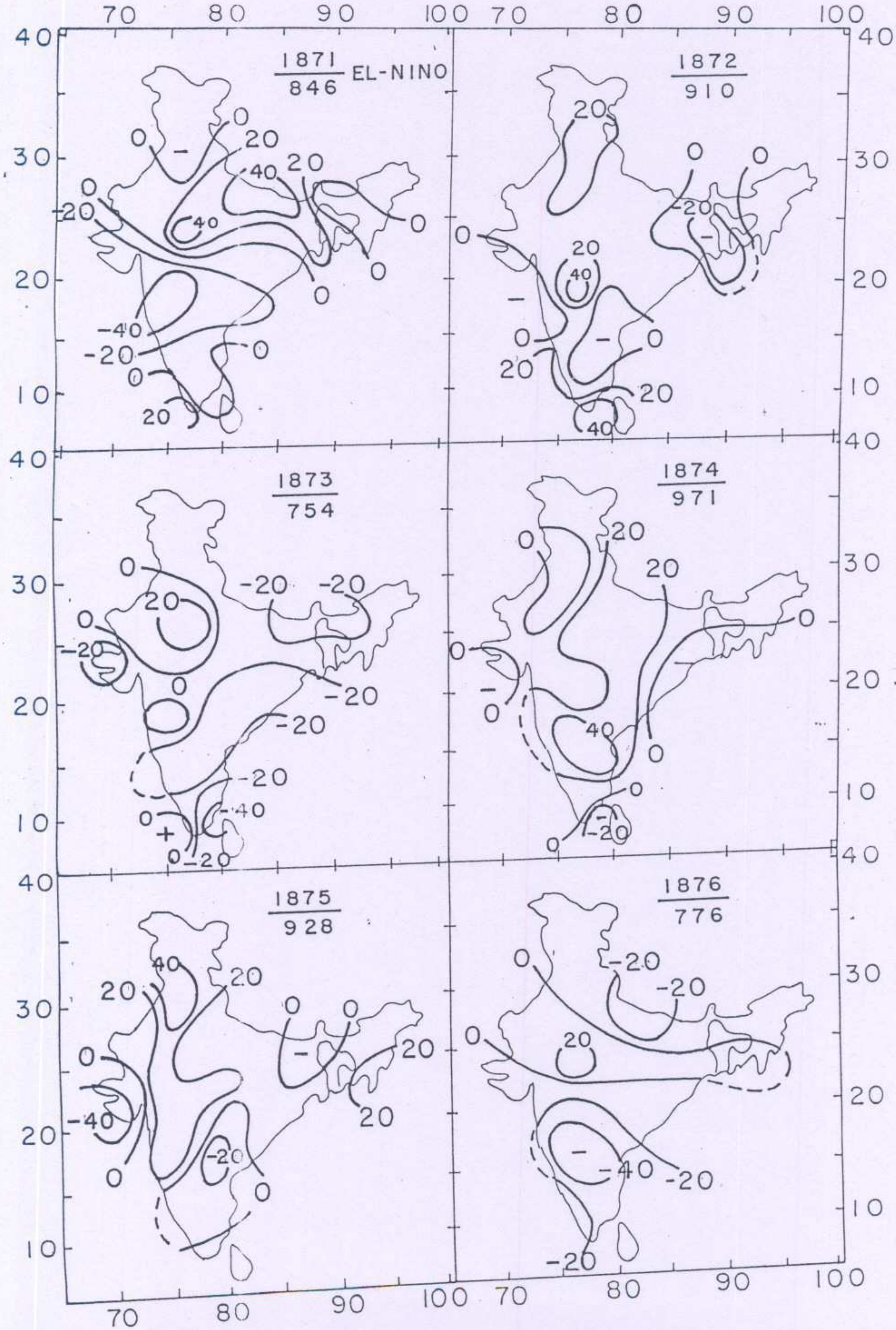
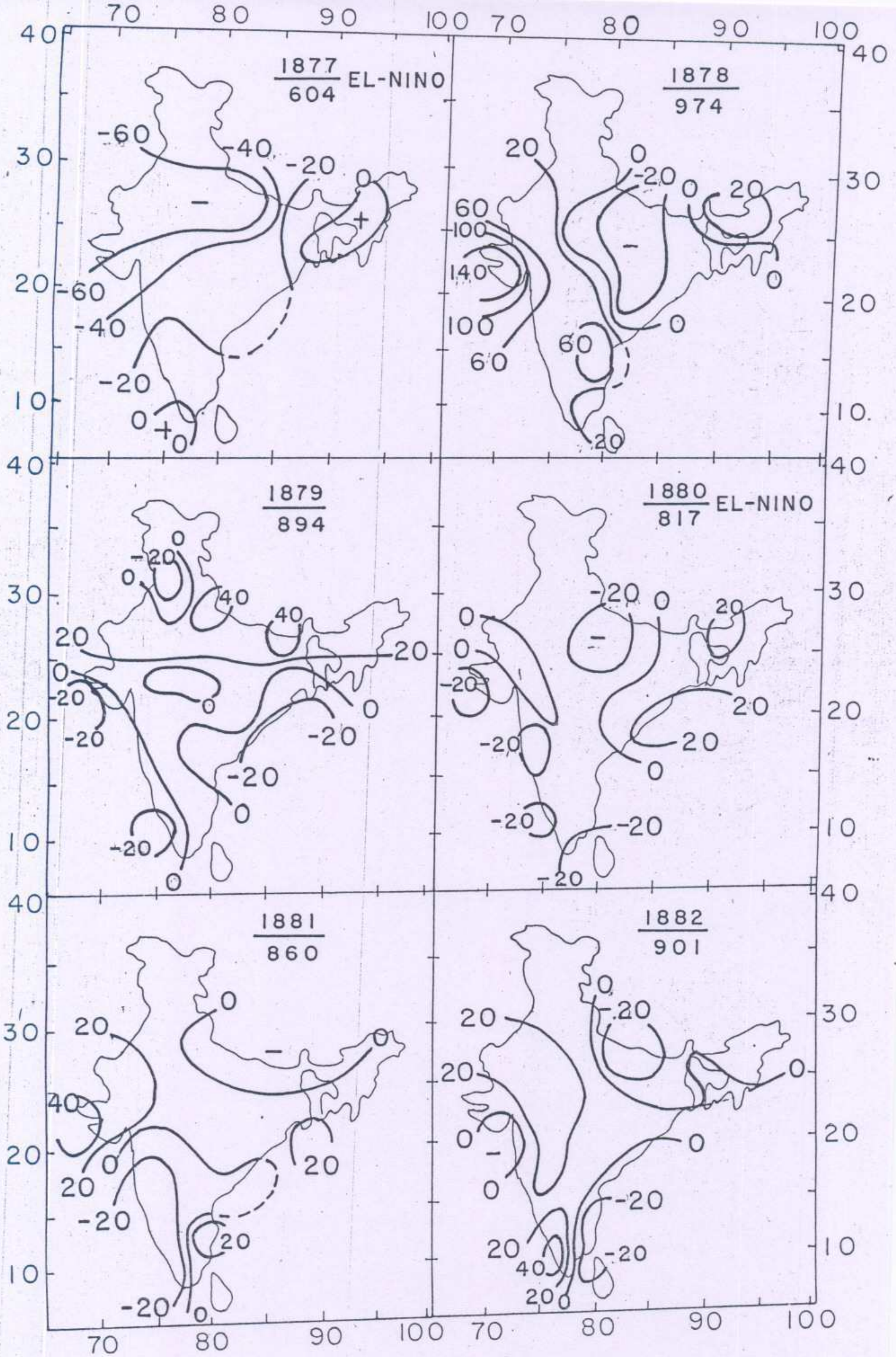


FIG. 3


1877
604 EL-NINO
1878
974
1879
894
1880
817 EL-NINO
1881
860
1882
901

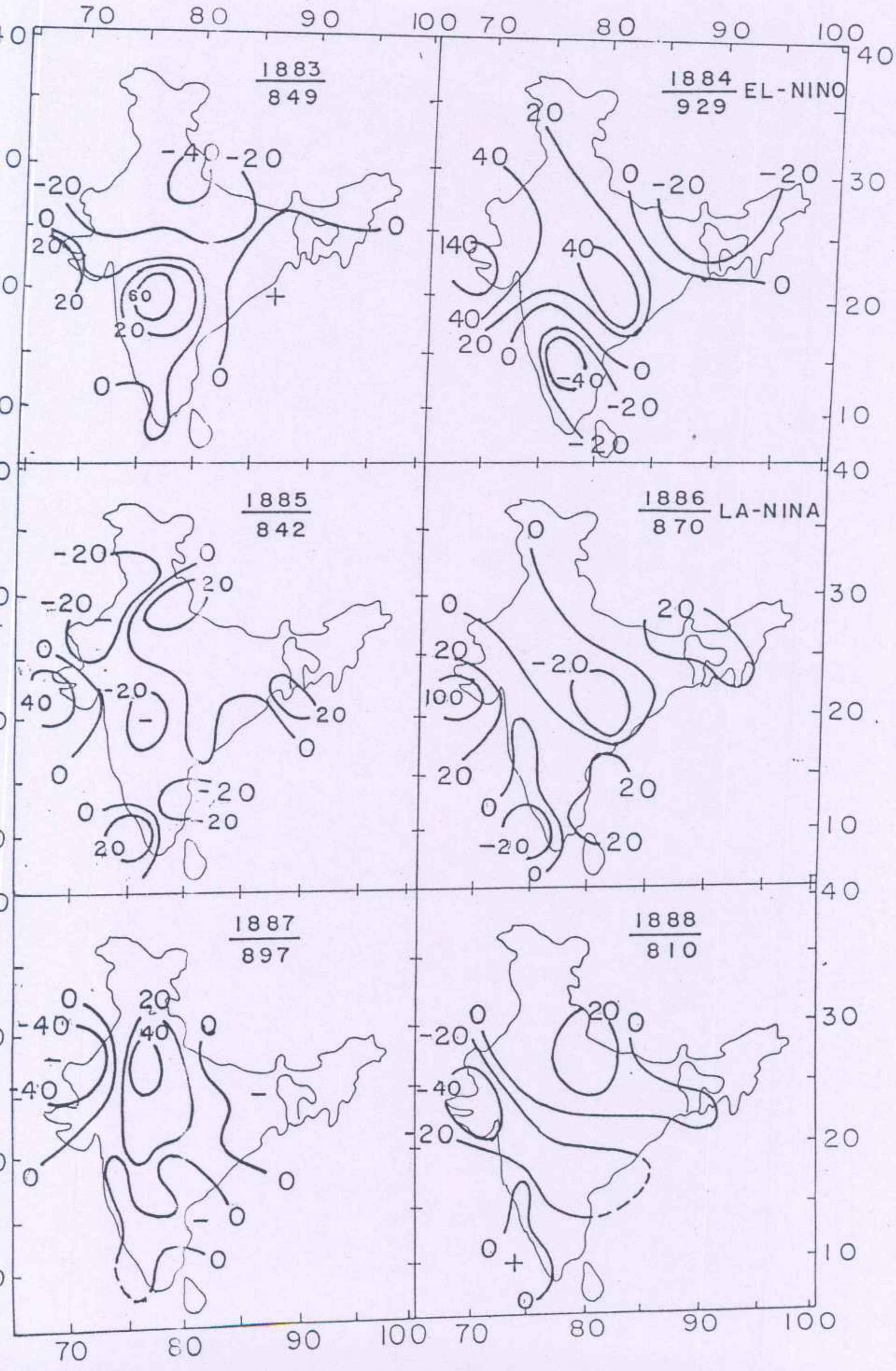
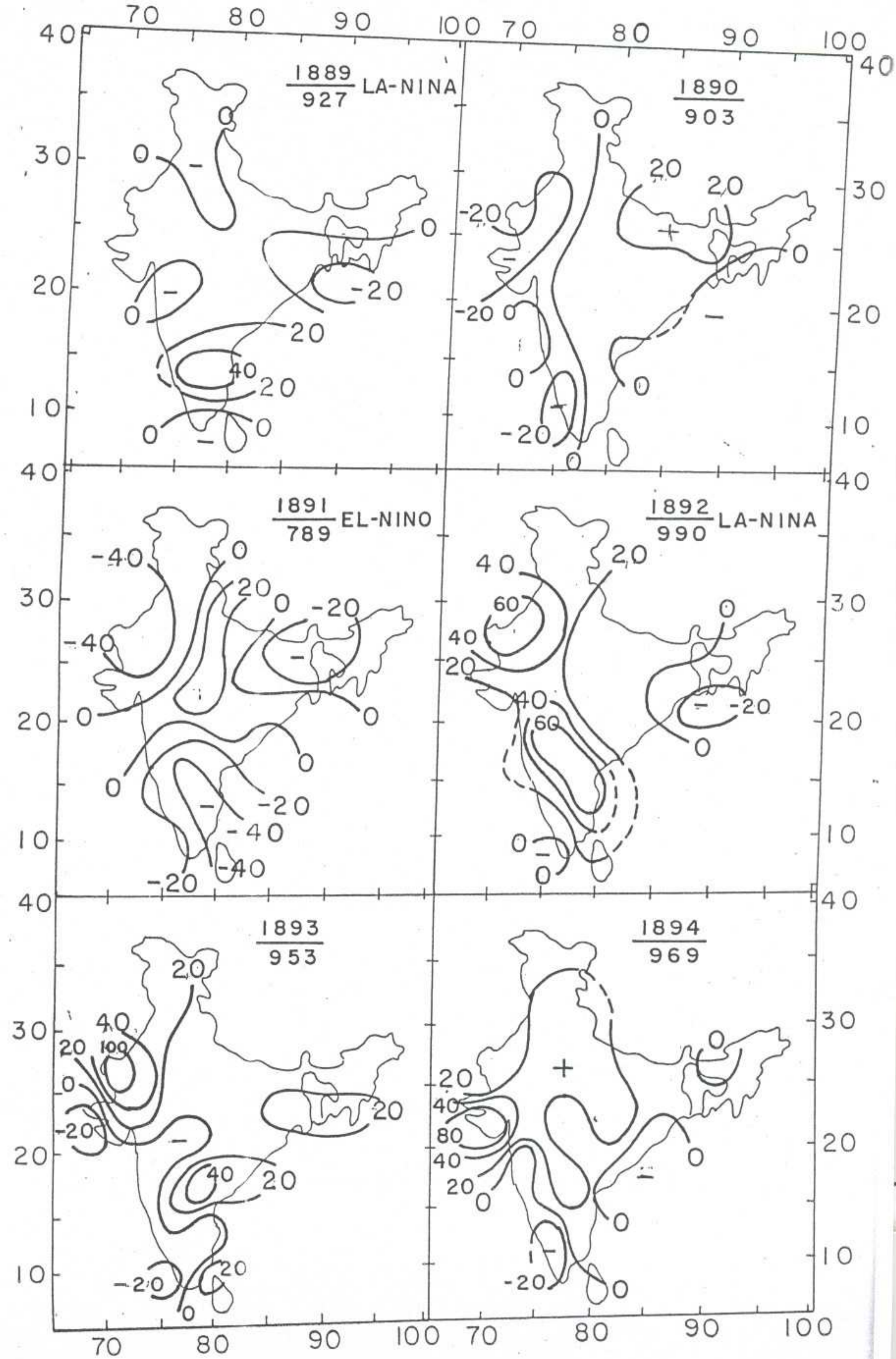

1883
849
1884
929
EL-NINO
1885
842
1886
870
LA-NINA
1887
897
1888
810

FIG. 3 cont.


1889
927
LA-NINA
1890
903
1891
789
EL-NINO
1892
990
LA-NINA
1893
953
1894
969
70 80 90 100
10 20 30 40

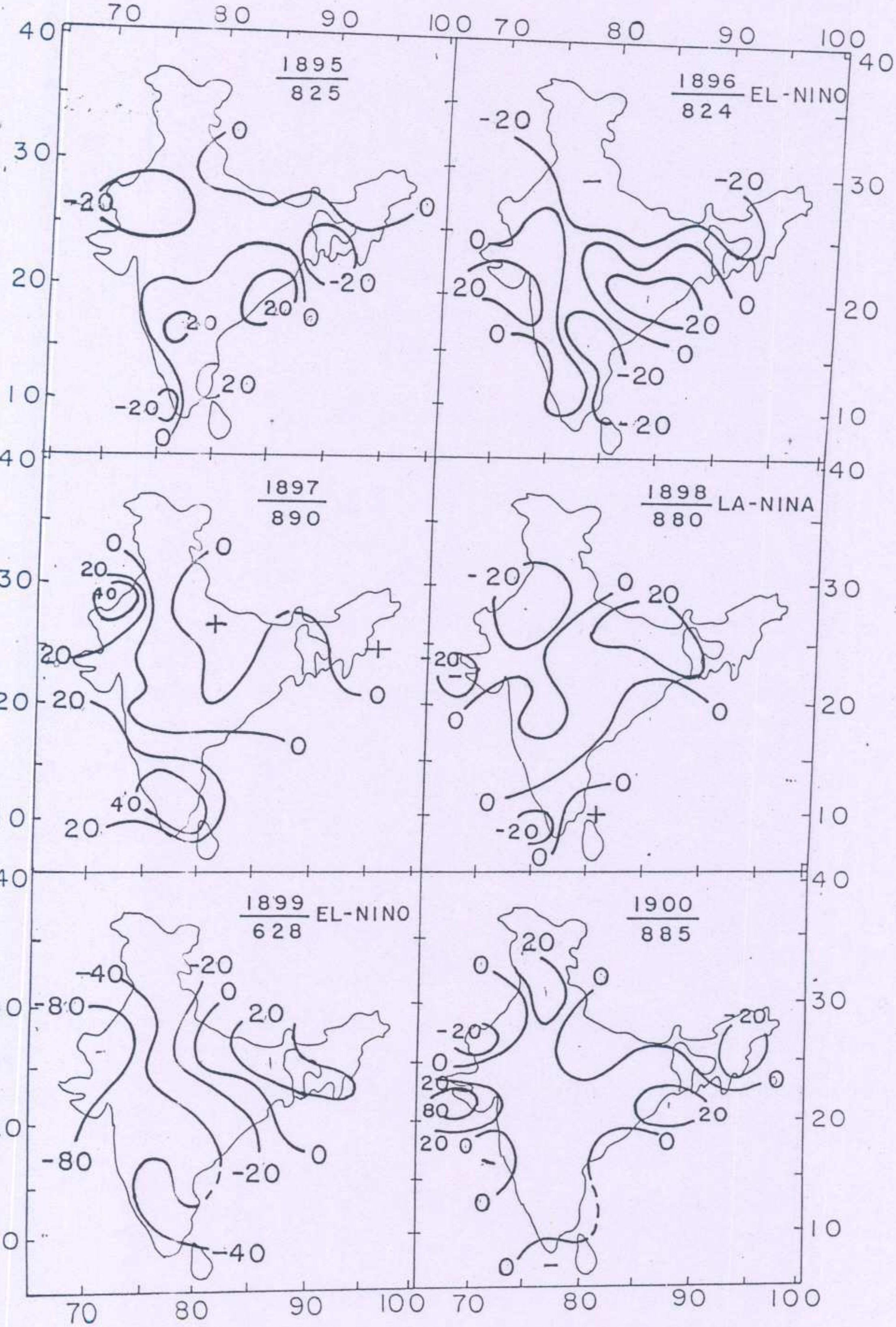
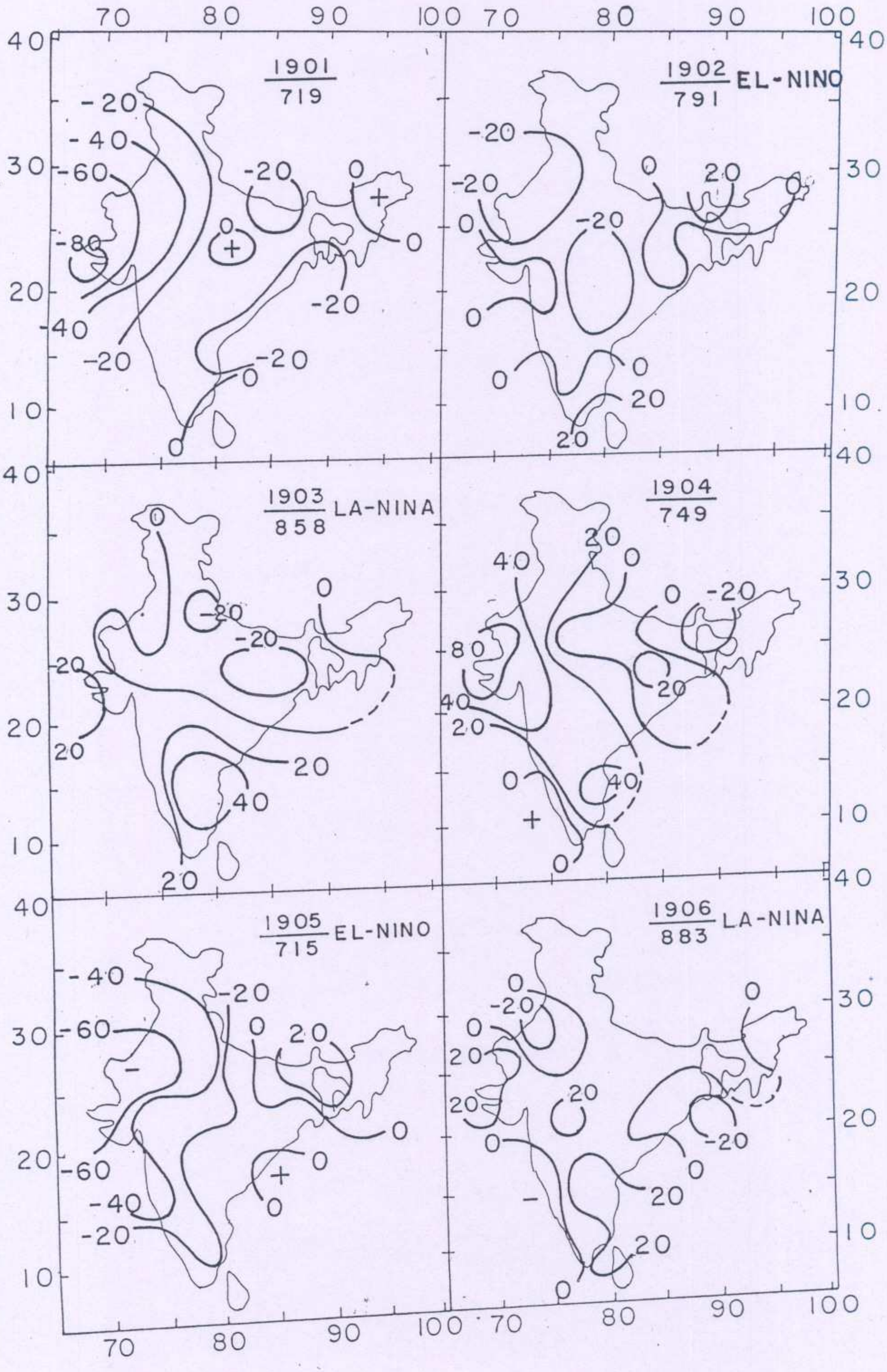

1895
825
1896
824
EL-NINO
1897
890
1898
880
LA-NINA
1899
628
EL-NINO
1900
885
70
80
90
100
10
20
30
40

FIG. 3 cont.


1901
719
1902
791
EL-NINO
1903
858
LA-NINA
1904
749
1905
715
EL-NINO
1906
883
LA-NINA
70
80
90
100
10
20
30
40

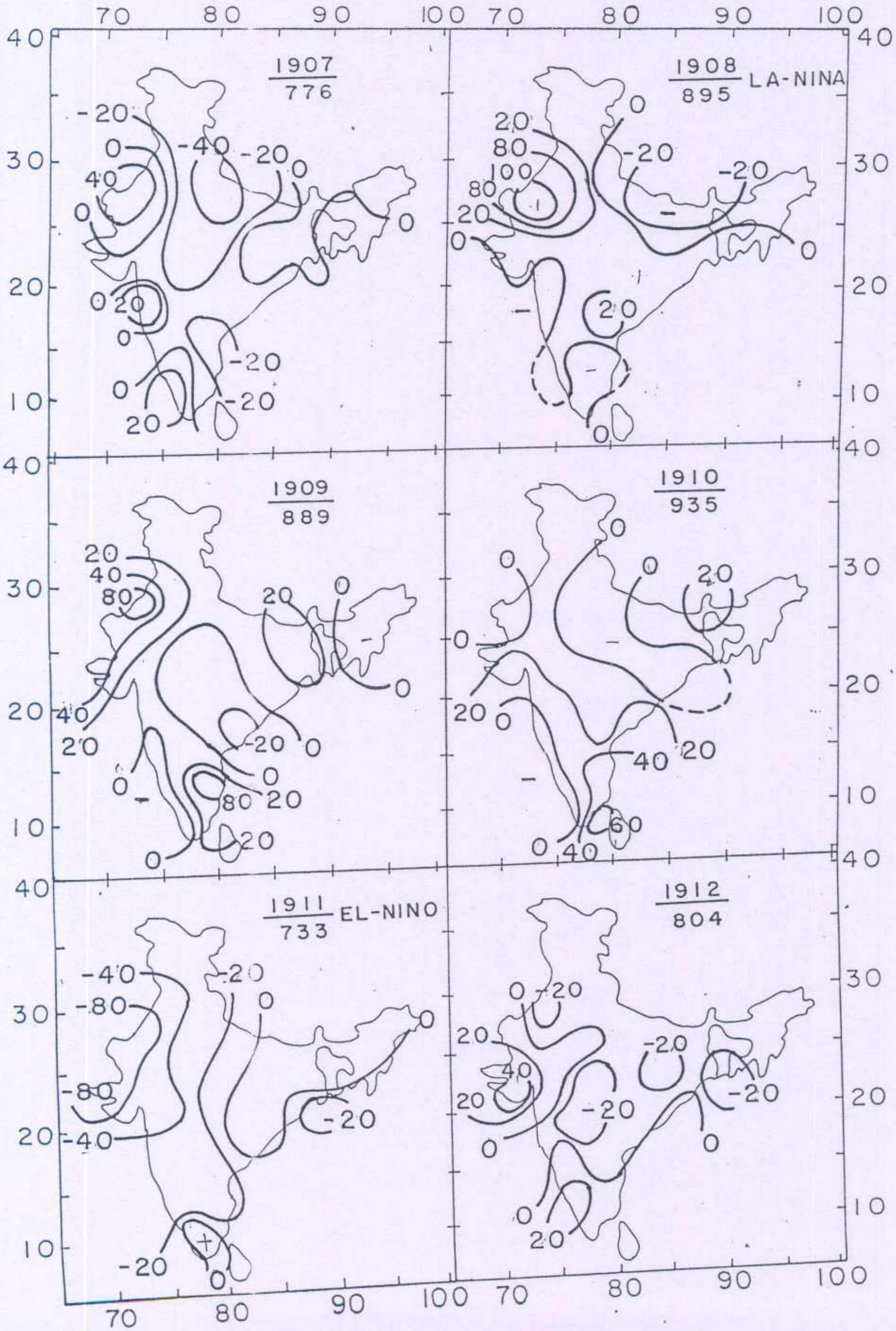
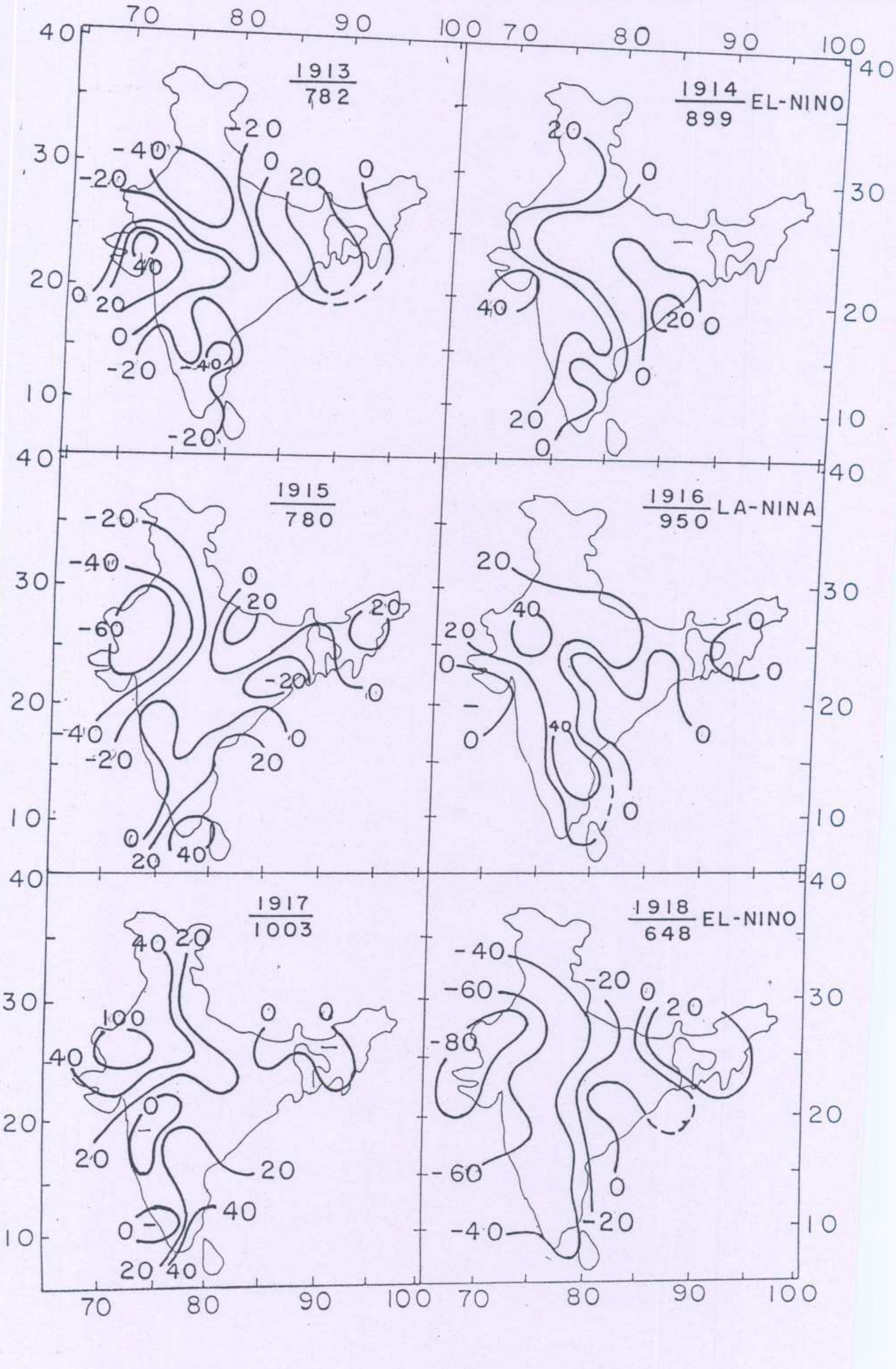

1907
776
1908
895
LA-NINA
1909
889
1910
935
1911
733
EL-NINO
1912
804
70
80
90
100
10
20
30
40

FIG. 3 cont.


1913
782
1914
899
EL-NINO
1915
780
1916
950
LA-NINA
1917
1003
1918
648
EL-NINO

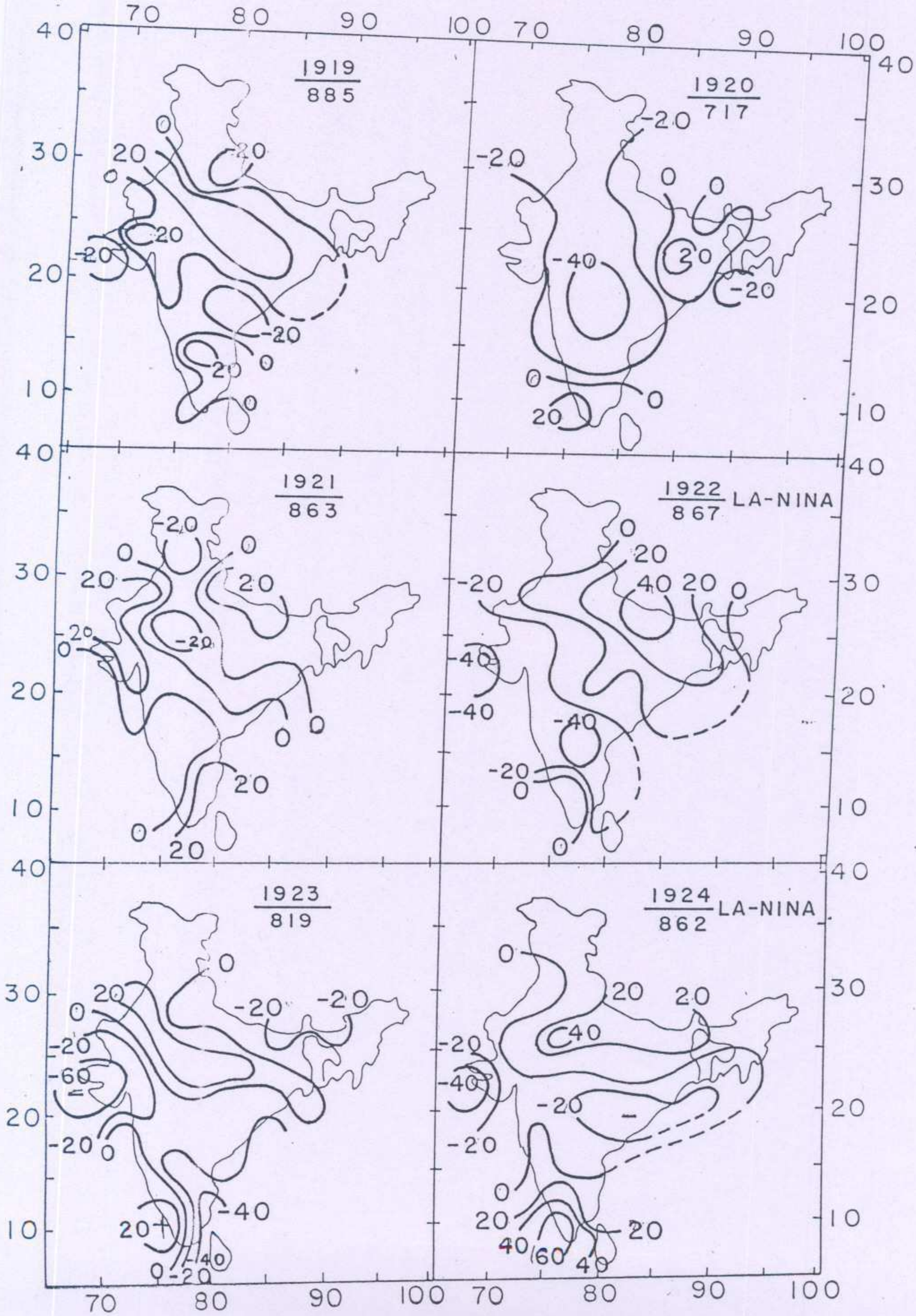
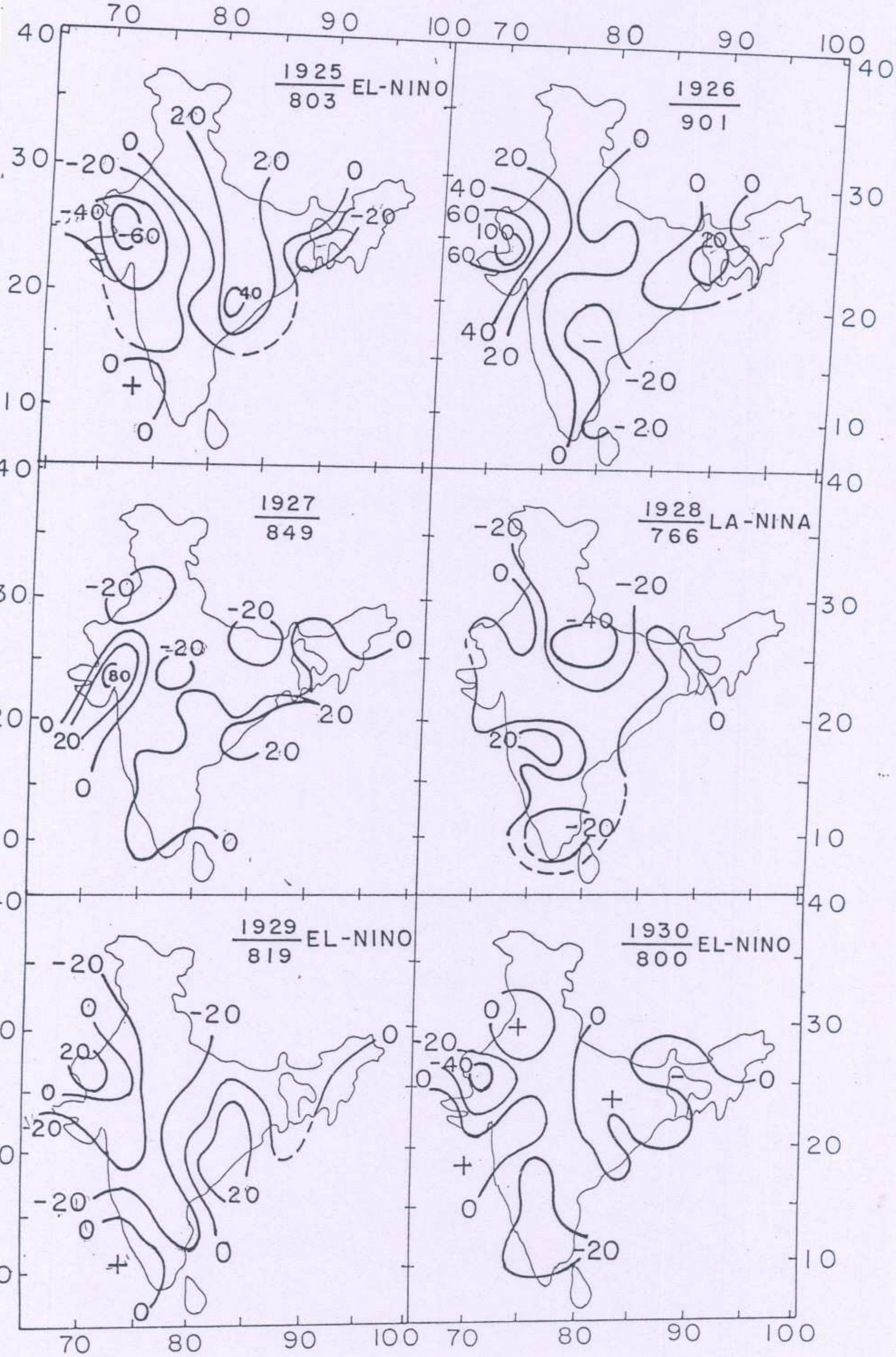

1919
885
1920
717
1921
863
1922
867 LA-NINA
1923
819
1924
862 LA-NINA

FIG. 3 cont.


1925
803
EL-NINO
1926
901
1927
849
1928
766
LA-NINA
1929
819
EL-NINO
1930
800
EL-NINO
70
80
90
100
10
20
30
40

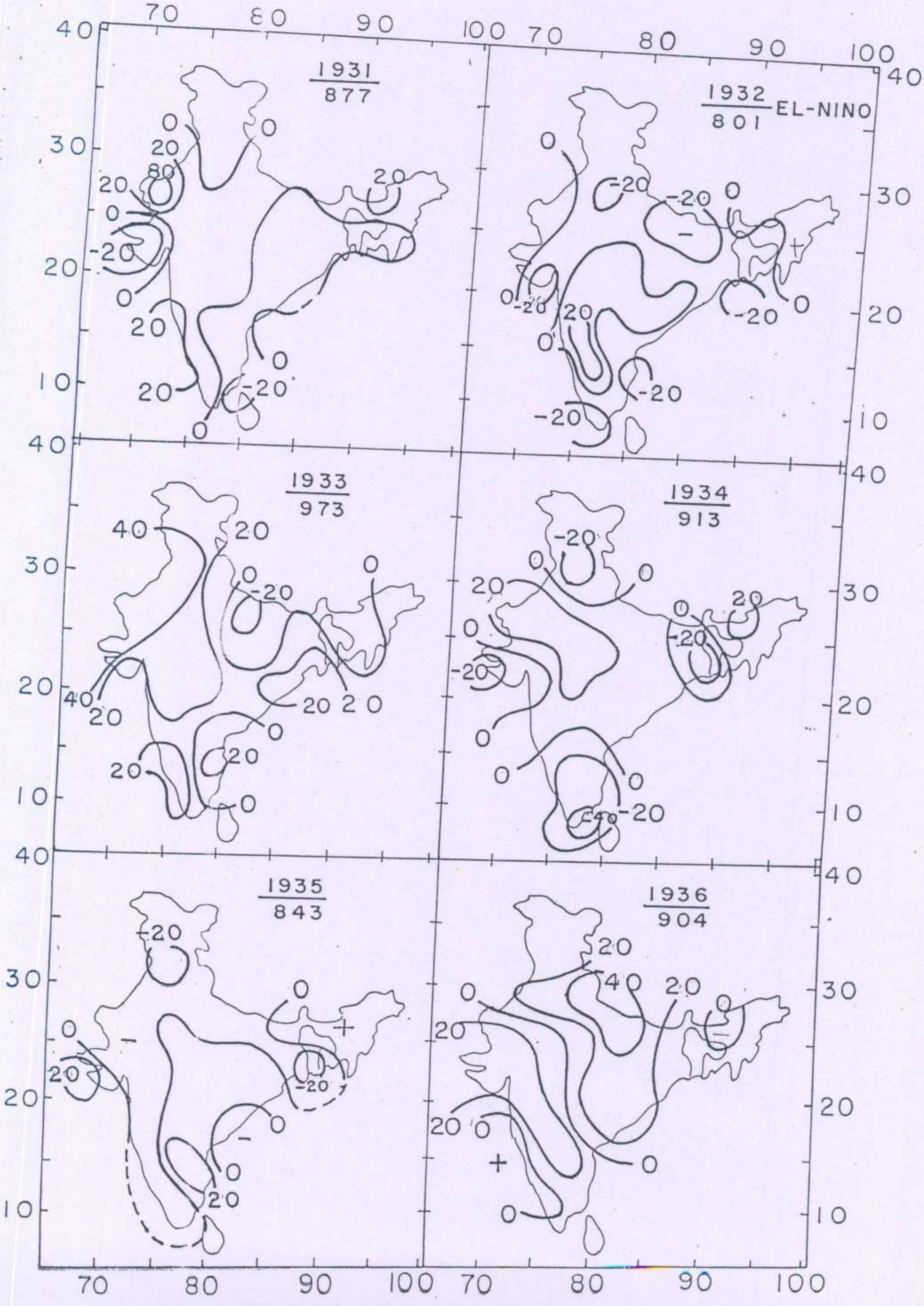
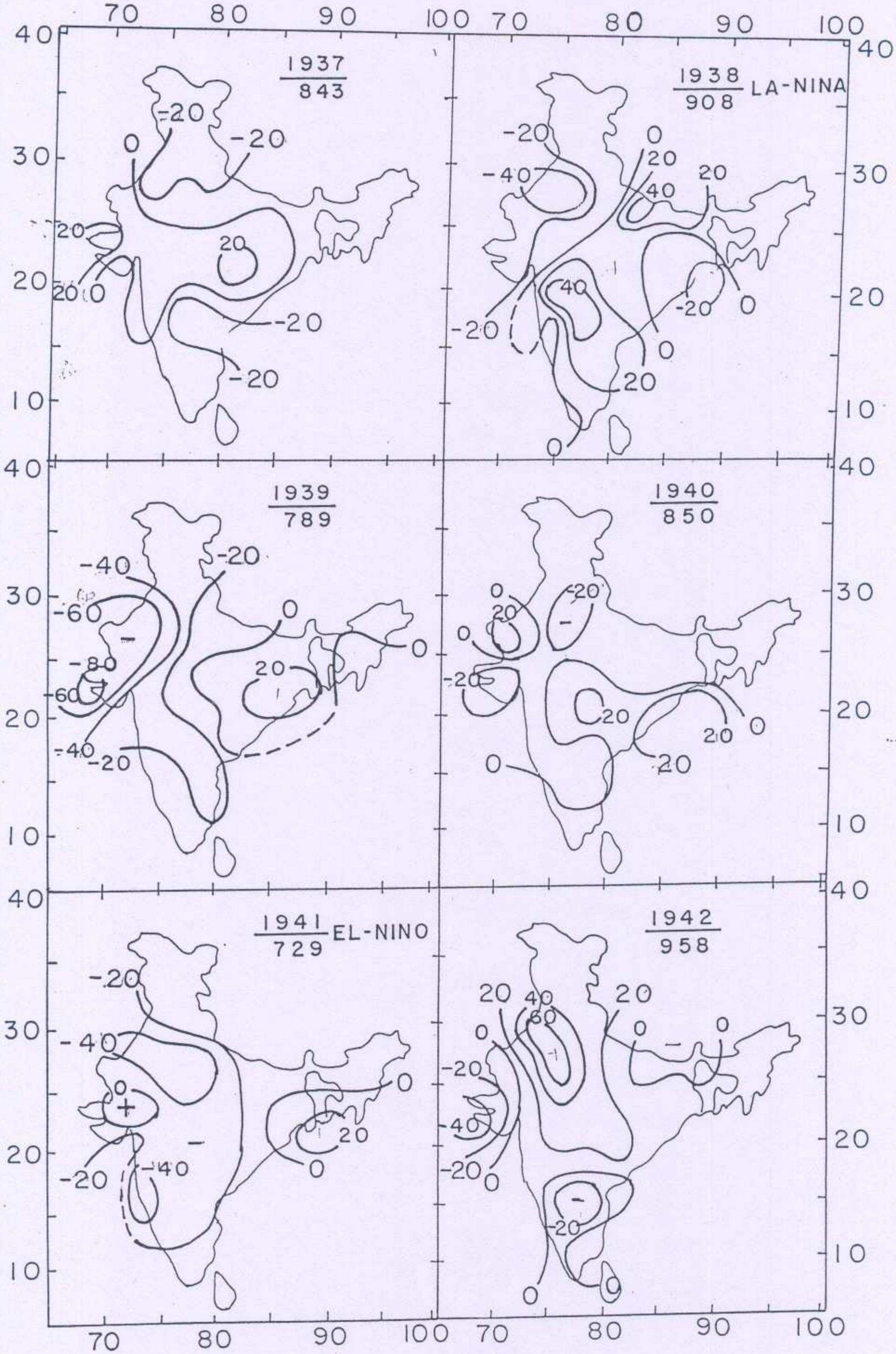


FIG. 3 cont.



1937/843
1938/908 LA-NINA
1939/789
1940/850
1941/729 EL-NINO
1942/958
70
80
90
100
10
20
30
40

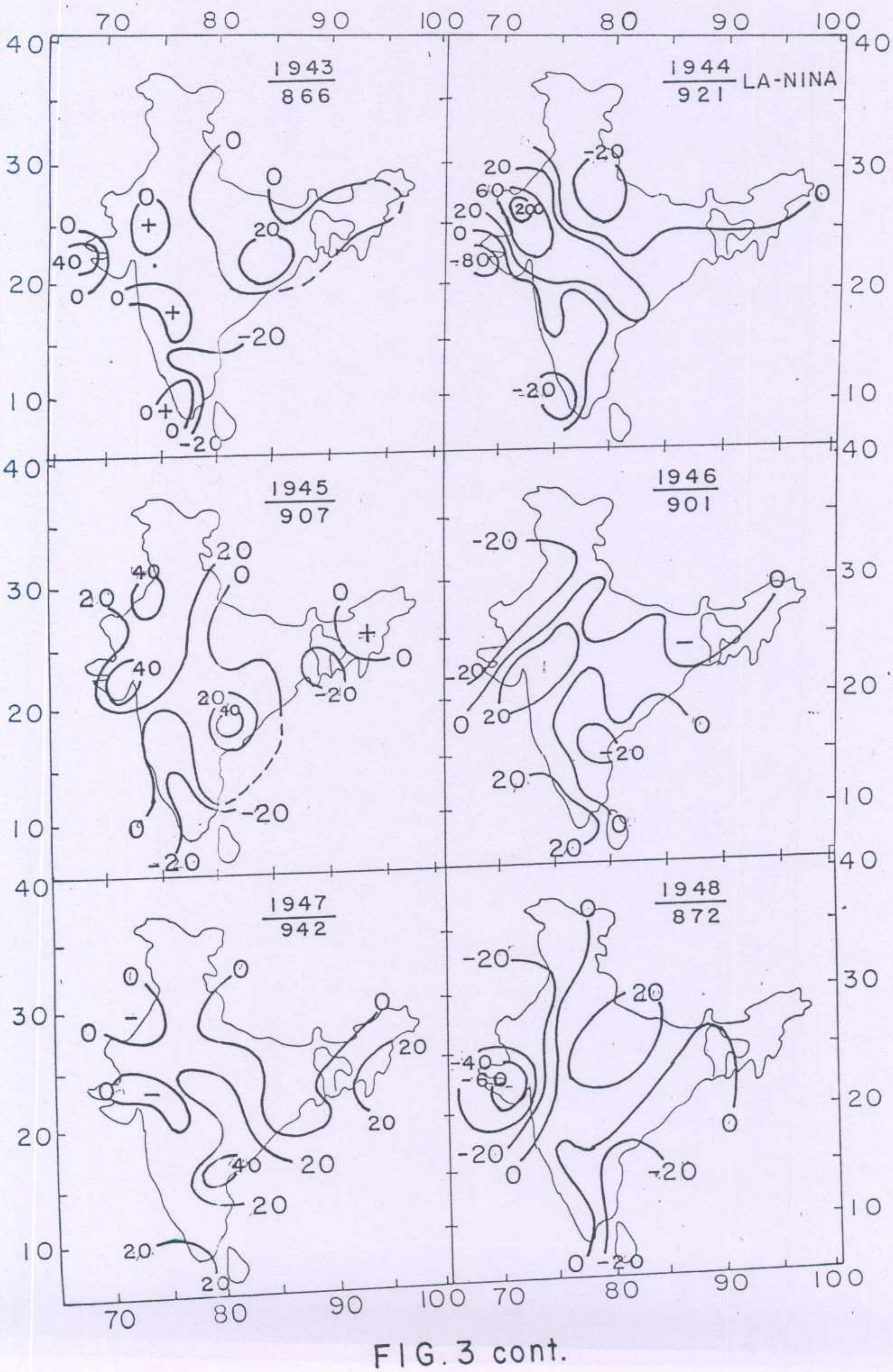
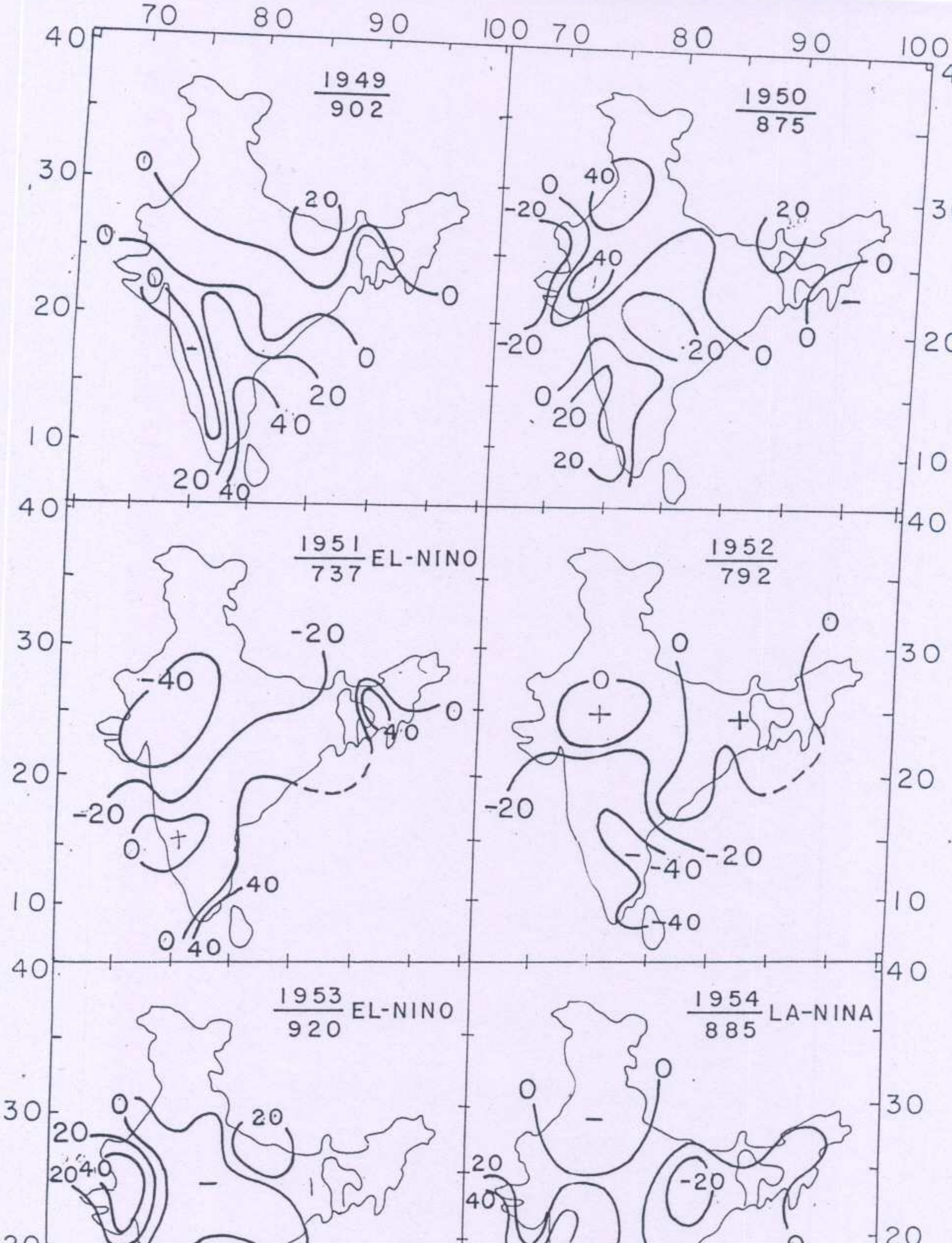

1943
866
1944
921 LA-NINA
1945
907
1946
901
1947
942
1948
872
70
80
90
100
10
20
30
40

FIG. 3 cont.



1949
902
1950
875
1951
737
EL-NINO
1952
792
1953
920
EL-NINO
1954
885
LA-NINA

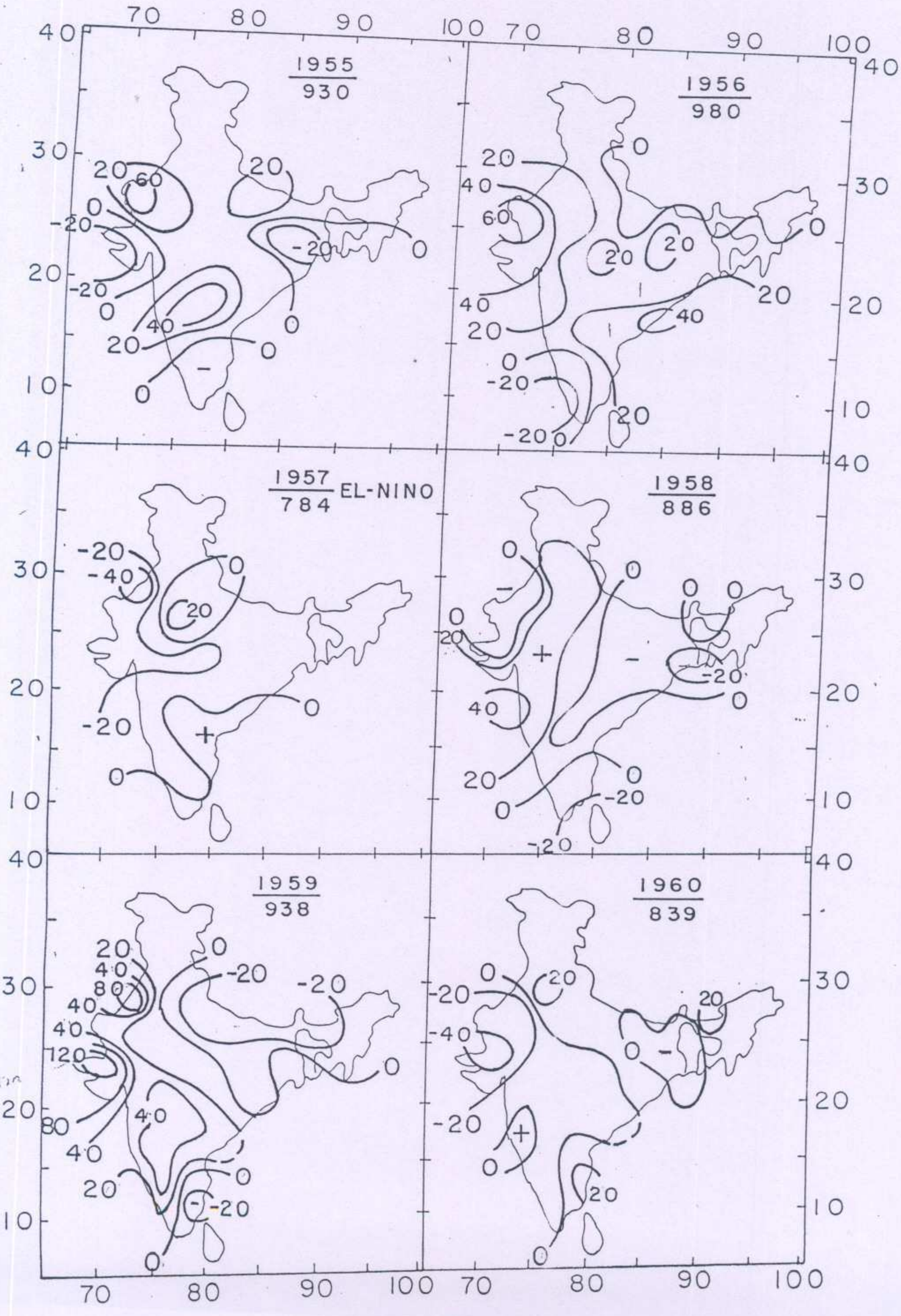
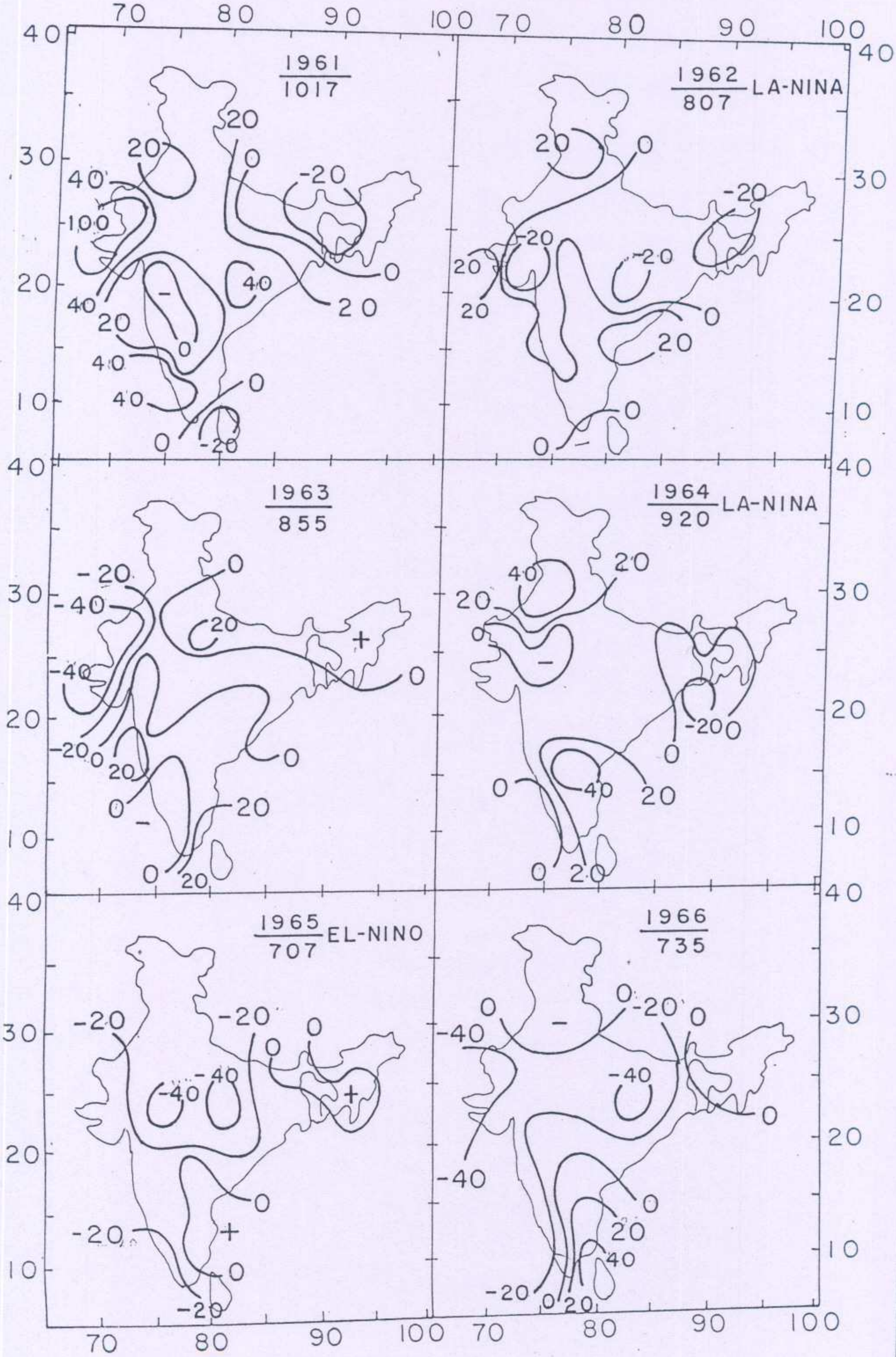

1955
930
1956
980
1957
784
EL-NINO
1958
886
1959
938
1960
839
70
80
90
100
10
20
30
40

FIG. 3 cont.


1961
1017
1962
807
LA-NINA
1963
855
1964
920
LA-NINA
1965
707
EL-NINO
1966
735

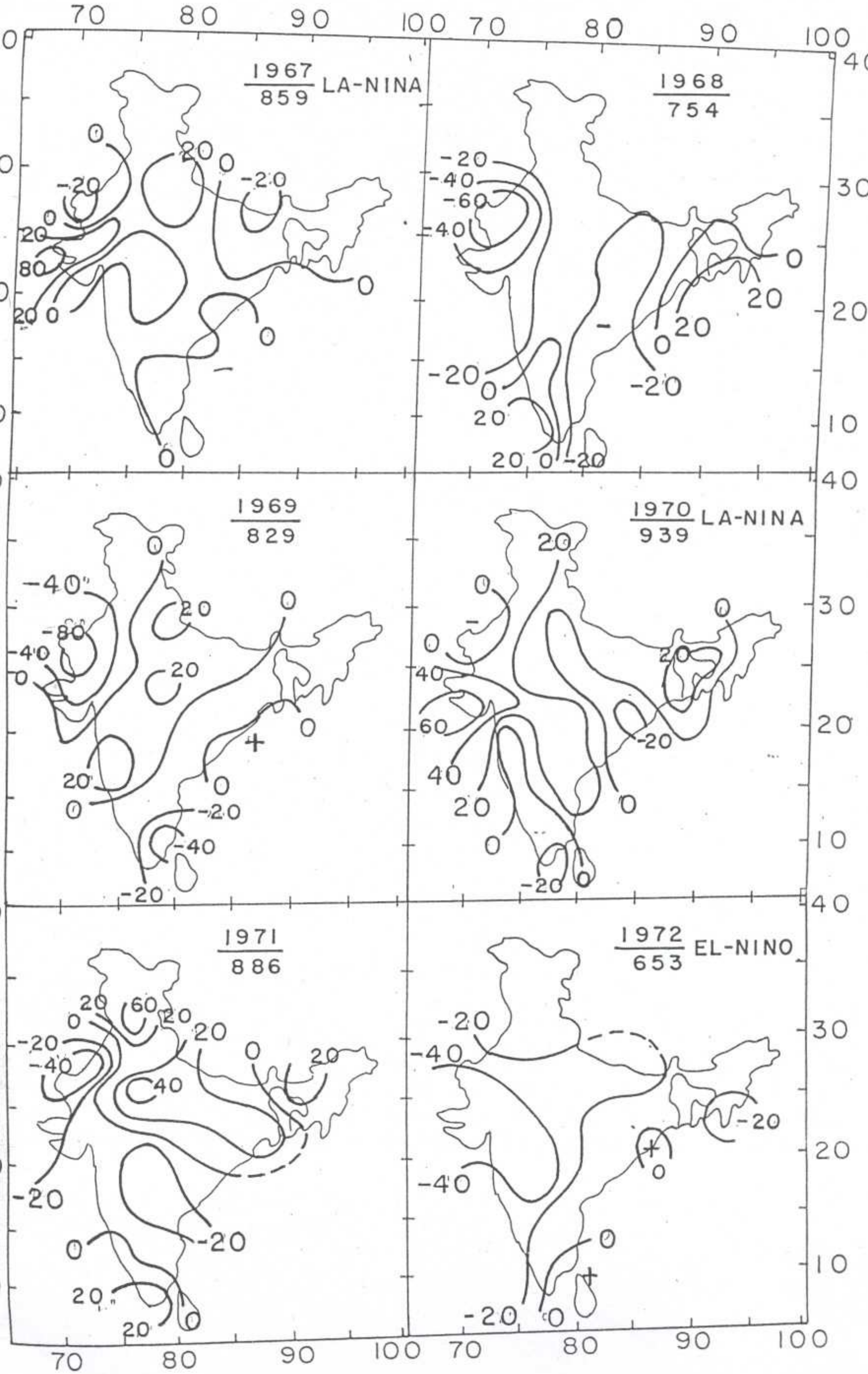
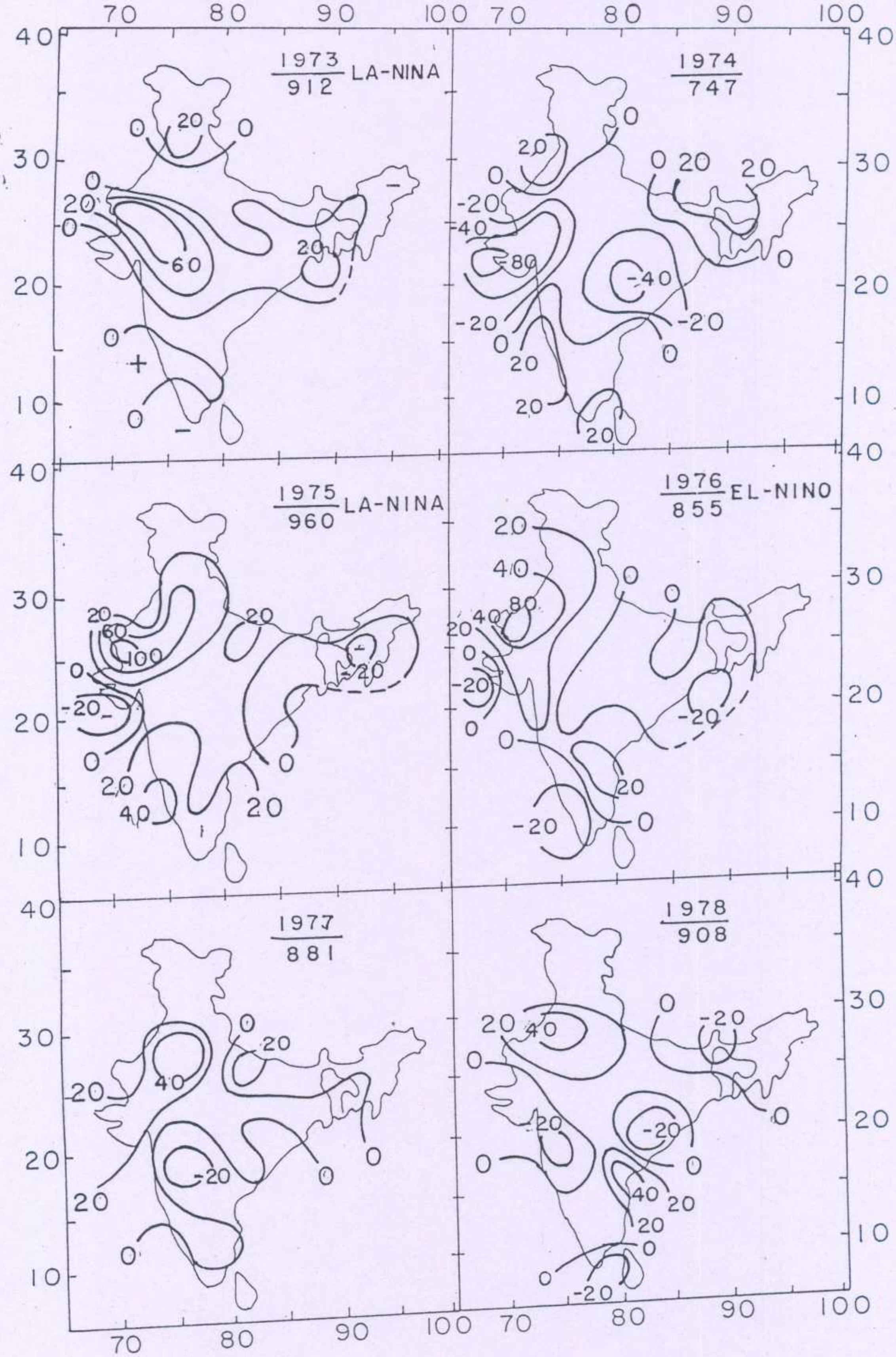

1967
859 LA-NINA
1968
754
1969
829
1970
939 LA-NINA
1971
886
1972
653 EL-NINO

FIG. 3 cont.



1973 / 912 LA-NINA
1974 / 747
1975 / 960 LA-NINA
1976 / 855 EL-NINO
1977 / 881
1978 / 908

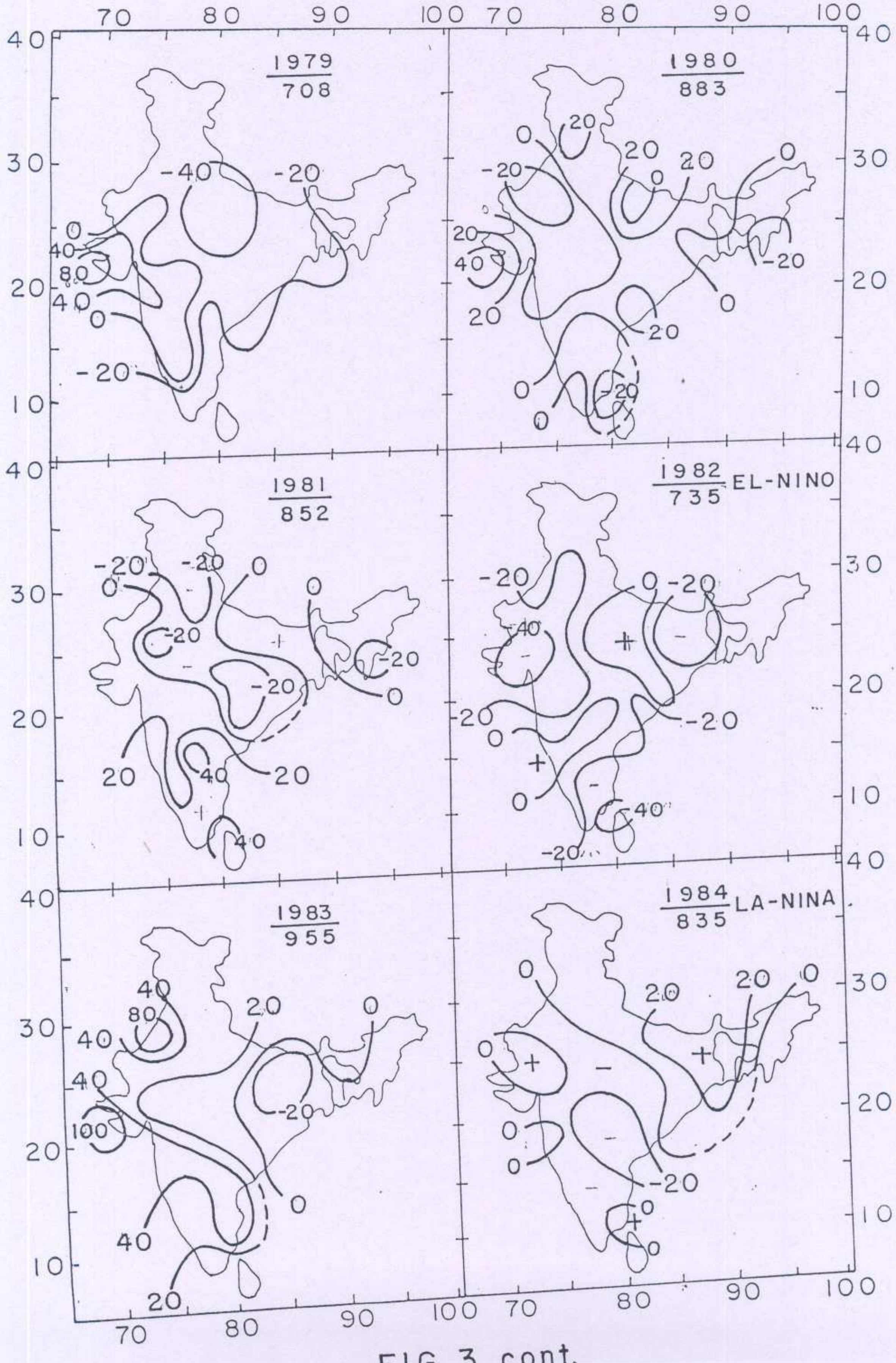
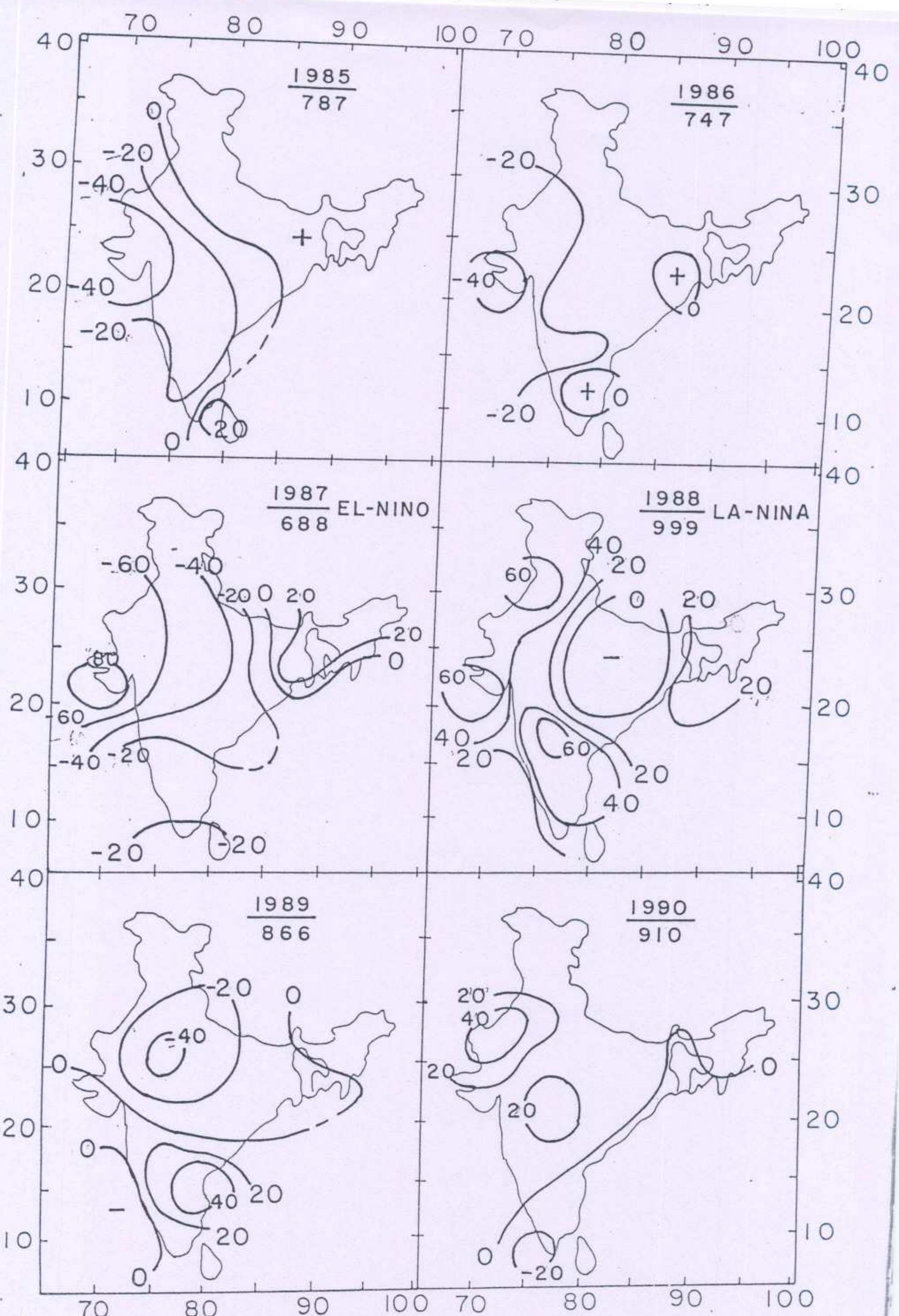

1979
708
1980
883
1981
852
1982
735
EL-NINO
1983
955
1984
835
LA-NINA

FIG. 3 cont.



1985
787
1986
747
1987
688 EL-NINO
1988
999 LA-NINA
1989
866
1990
910