ΠΡΑΚΤΙΚΑ ΤΗΣ ΑΚΑΔΗΜΙΑΣ ΑΘΗΝΩΝ

ΣΥΝΕΔΡΙΑ ΤΗΣ 3ΗΣ ΙΟΥΝΙΟΥ 1976

ΠΡΟΕΔΡΙΑ ΝΙΚ. Κ. ΛΟΥΡΟΥ

ΑΣΤΡΟΝΟΜΙΑ.— **Analytical expression of the mean annual variation of the precipitation within various latitude zones of the Earth,** *by J. Xanthakis and B. Tritakis**. Ἀνεκοινώθη ὑπὸ τοῦ Ἀκαδημαϊκοῦ κ. Ἰ. Ξανθάκη.

In an extensive previous paper (5) we have studied the variation of the mean annual precipitation $\overline{R - R_0}$ in various latitude zones of the Northern and Southern hemispheres of the earth.

In the present paper we mainly revise the third part of (5) which refers to the analytical expression of the variation of the mean annual zonal precipitation $\overline{R - R_0}$ as a function of the following three components:

a) Solar activity expressed by the area index I_α, which is defined by the relation,

$$I_\alpha = \frac{1}{2}\left[\sqrt{A} + \sqrt{f}\right]$$

where, A and f represent respectively the areas of the sunspots and faculae corrected for foreshortening, as published by the Royal Greenwich Observatory.

b) The long-term periodic variations L_t defined by the relation:

$$L_t = \alpha_n \sum \sin \frac{2\pi}{\Omega_n} (T_i - T_o), \quad \Omega_n \geqslant 12 \text{ years.} \tag{1}$$

* Ι. ΞΑΝΘΑΚΗ καὶ Β. ΤΡΙΤΑΚΗ, Ἀναλυτικὴ ἔκφρασις τῆς μέσης ἐτησίας μεταβολῆς τῆς βροχοπτώσεως ἐντὸς διαφόρων ζωνῶν πλάτους τῆς γῆς.

c) The short-term periodic variations W defined by the relation:

$$W = b_n \sum \sin \frac{2\pi}{\Psi_n} t, \quad 4 \leqslant \Psi_n \leqslant 6 \text{ years.} \tag{2}$$

We assume that the influence of the solar activity on the variation of the mean annual zonal precipitation $\overline{R - R_0}$ is defined by the linear relation:

$$S_\alpha = \alpha \pm b I_\alpha . \tag{3}$$

Where α and b are constants calculated by the least-square method from the observational equations:

$$\alpha \pm b I_\alpha = (\overline{R - R_0}) - L_t . \tag{4}$$

Particularly, in the present paper we were concerned with specifying the short-term periodic variations W. Thus, in each latitude zone of both Northern and Southern hemispheres we calculate the values of the residues:

$$(\overline{R - R_0}) - L_t - S_\alpha .$$

In the following by the power spectrum analysis we search for statistically significant periodicities.

The results of this investigation are shown in figures 1 to 9 for the zones of the Northern hemisphere and in figures 10 to 17 for the Southern hemisphere. Table 1 gives for each zone of both the Northern

TABLE 1.

Zones	Northern Hemisphere Periodicities (in years)	Ranges in mm	Southern Hemisphere Periodicities (in years)	Ranges in mm
0° - 10°	4 6	20 - 70	4	20 - 100
10° - 20°	4 - 4.5 5	20 - 100	4 5 6	20 - 90
20° - 30°	4 6	20 - 80	4	20 - 50
30° - 40°	4 5	20 - 60	5 6	20 - 50
40° - 50°	4 5	10 - 30	5 6 8	20 - 60
50° - 60°	8 *	10 - 30	4 * 6 8 *	20 - 60
60° - 70°	6 * 8	10 - 30	6 - 6.5	20 - 70
70° - 80°	6 8 *			

* Non-significant periodicities.

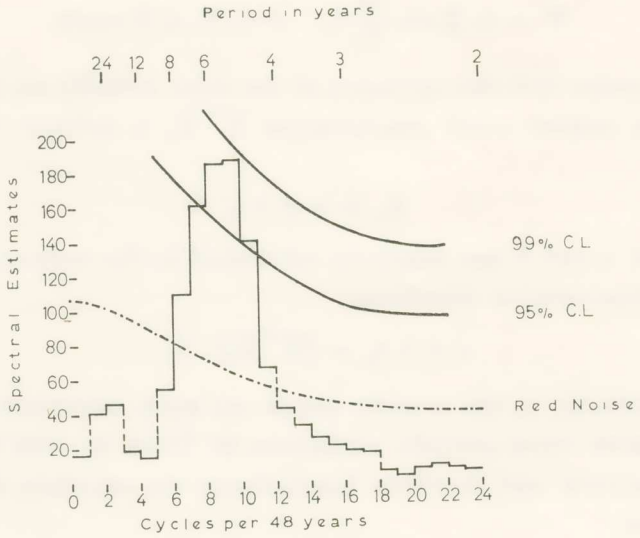

Fig. 1. Zone 0° - 10° N.

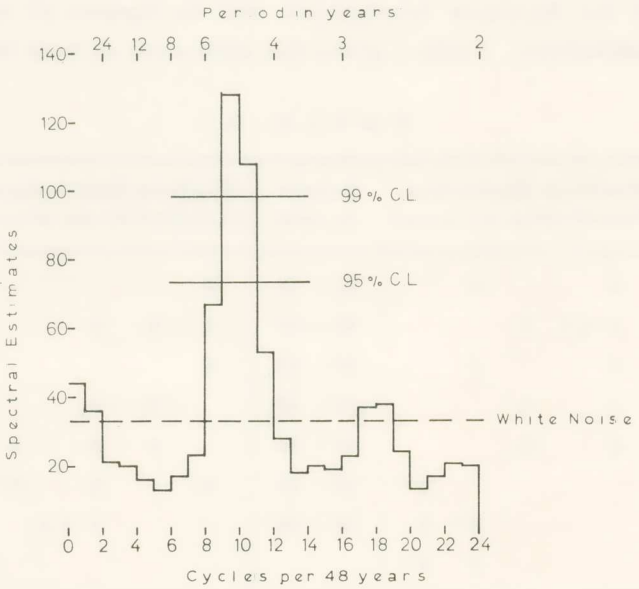

Fig. 2. Zone 10° - 20° N.

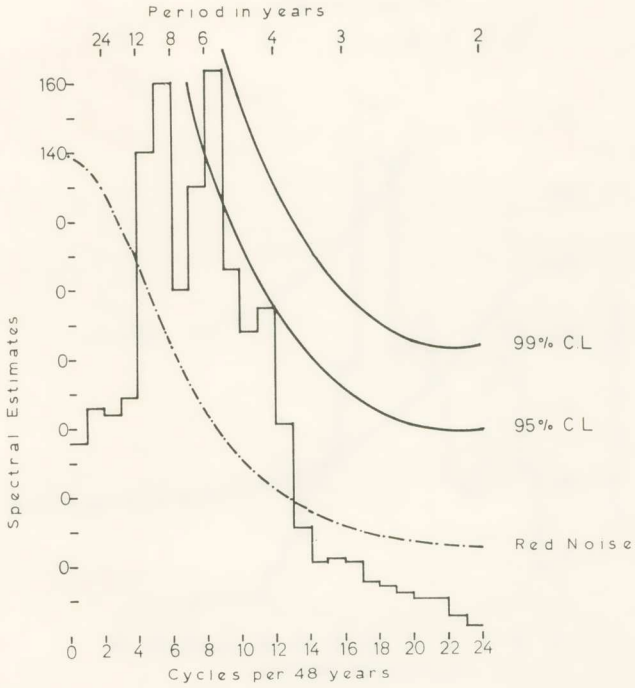

Fig. 3. Zone 20° - 30° N.

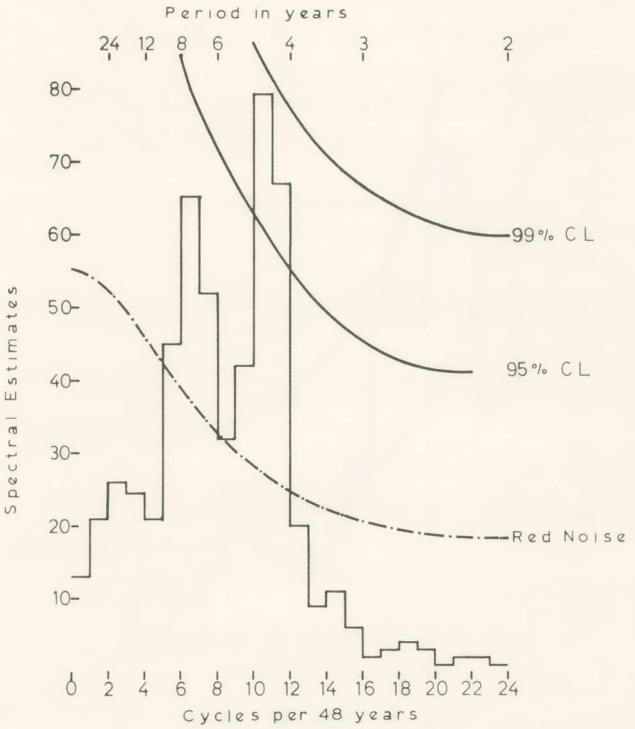

Fig. 4. Zone 30° - 40° N.

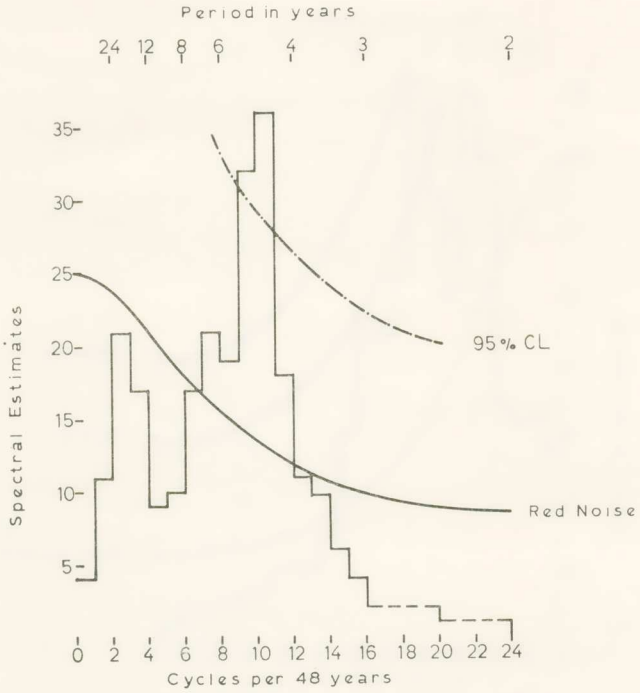

Fig. 5. Zone 40° - 50° N.

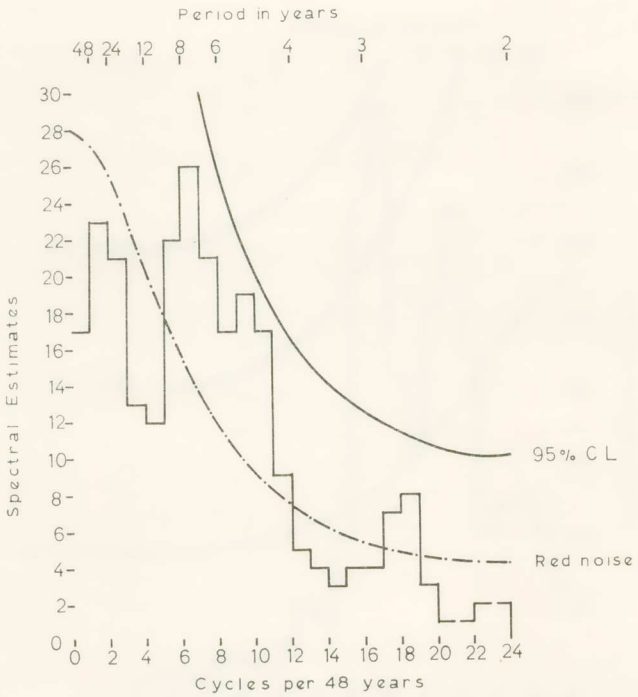

Fig. 6. Zone 50° - 60° N.

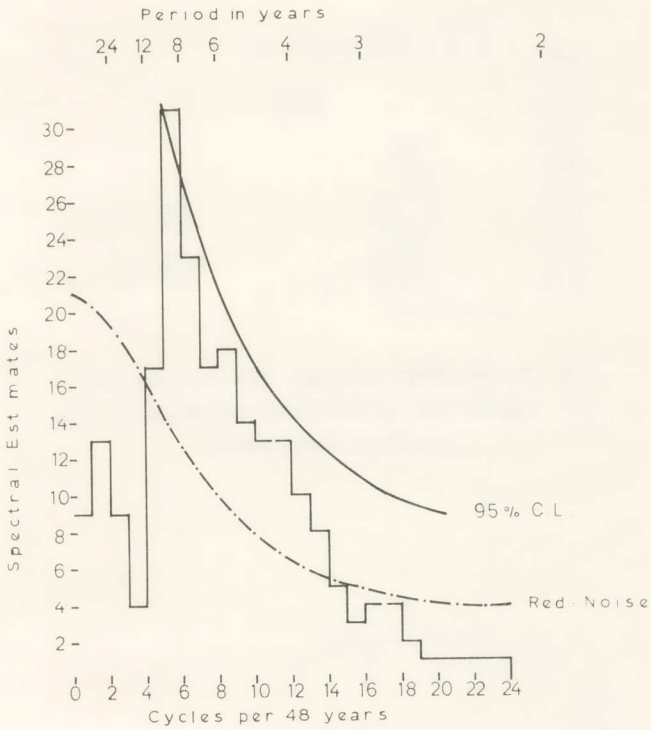

Fig. 7. Zone 60° - 70° N.

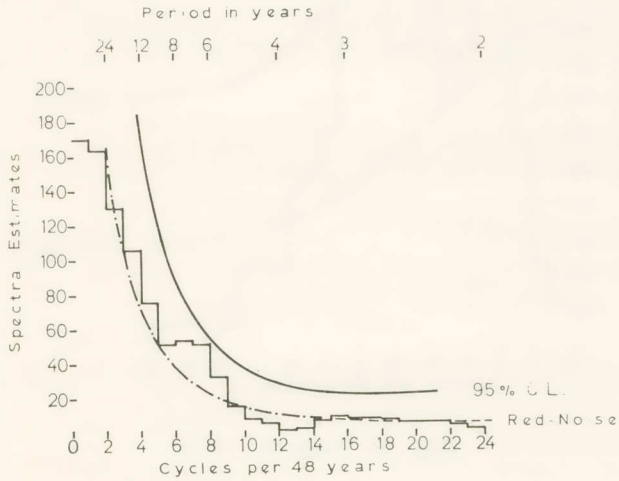

Fig. 8. Zone 70° - 80° N.

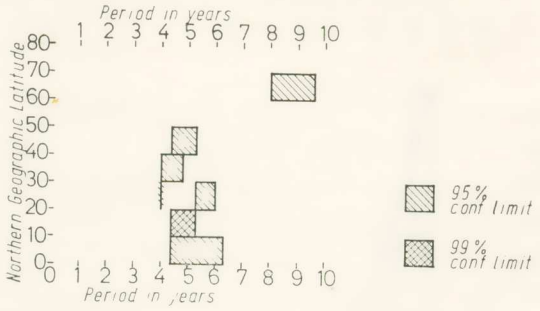

Fig. 9. Shadings indicate the distribution of the significant periodicities throughout the Northern hemisphere.

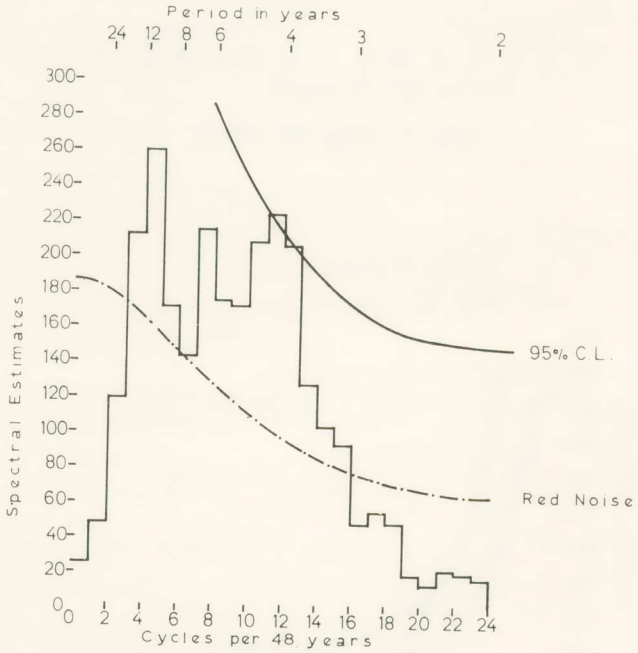

Fig. 10. Zone 0° - 10° S.

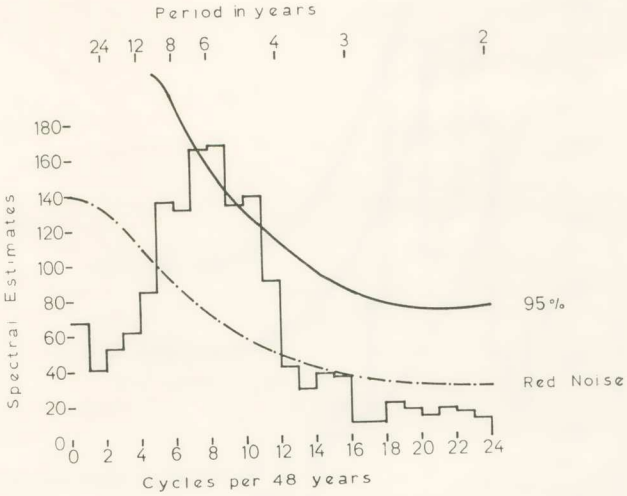

Fig. 11. Zone 10° - 20° S.

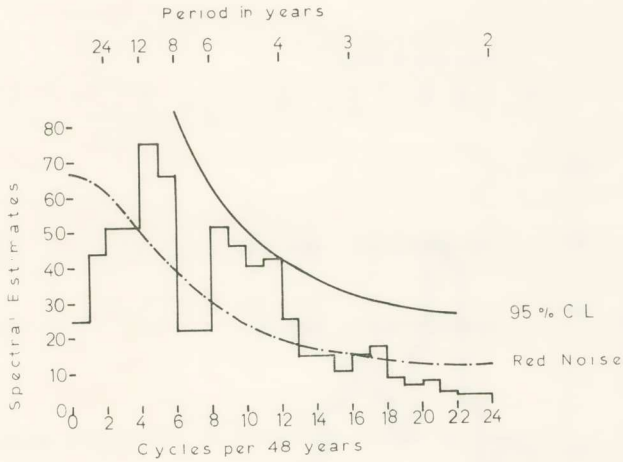

Fig. 12. Zone 20° - 30° S.

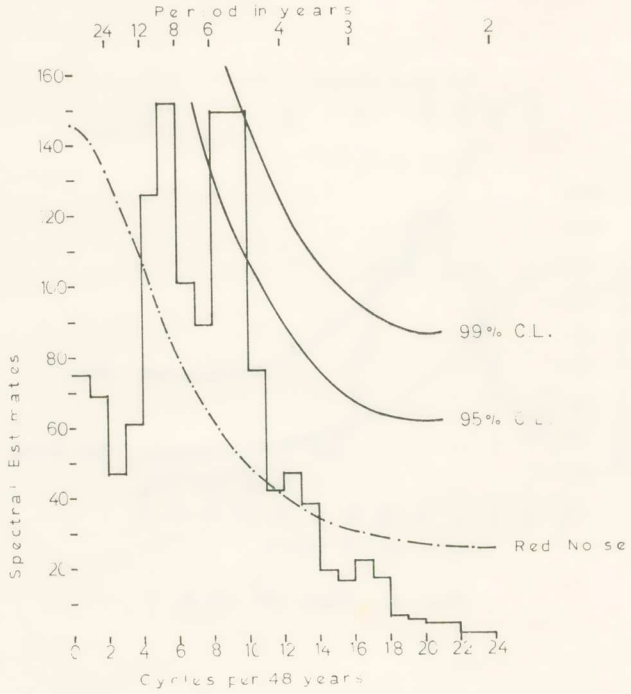

Fig. 13. Zone 30° - 40° S.

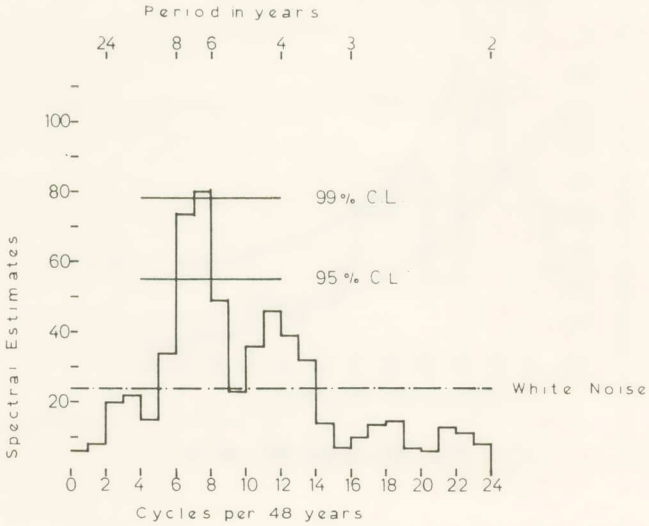

Fig. 14. Zone 40° - 50° S.

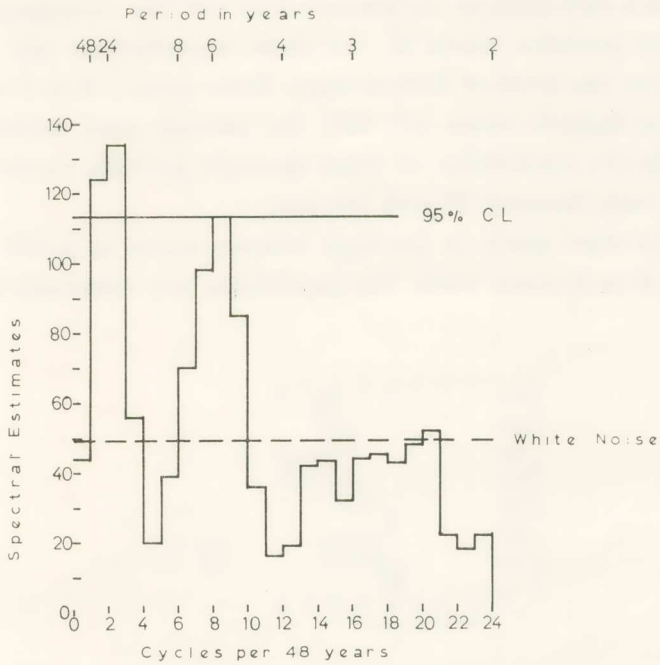

Fig. 15. Zone 50° - 60° S.

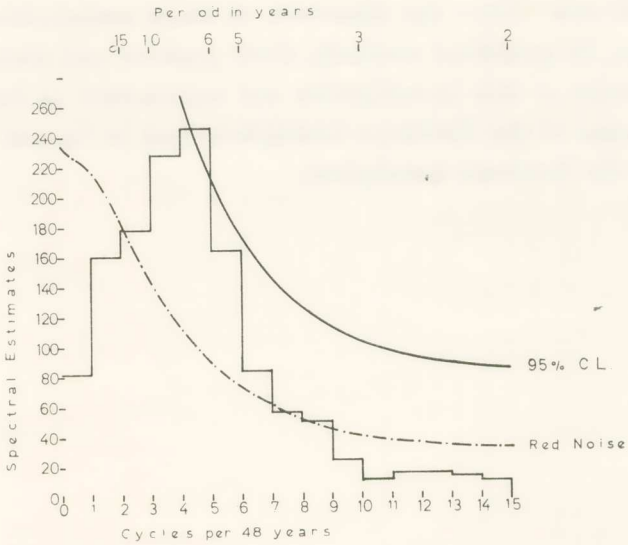

Fig. 16. Zone 60° - 70° S.

and Southern hemispheres the periodicities and the corresponding amplitudes of the periodic terms W. All these periodicities are statistically significant at the level of 0.05 at least. From table 1 it is concluded that in the lower latitude zones (0° - 30°) the periods vary between 4 and 6 years, while the amplitudes of these sporadic periodic terms W, for the most part, vary between 20 and 100 mm.

On the other hand, in the high latitude zones ($\varphi \geqslant 50°$) the periods vary from 6 to 8 years while the amplitudes are relatively low varying

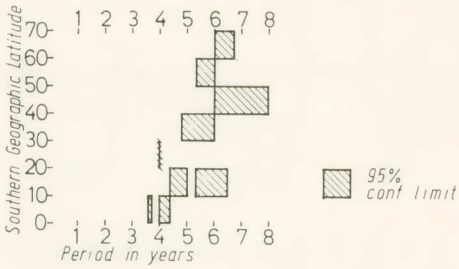

Fig. 17. Shadings indicate the distribution of the significant periodicities throughout the Southern hemisphere.

from 10 to 30 mm. After the discovery of these periodicities we define for each zone, by graphical methods, their position and their amplitude.

The results of this investigation are represented in figures 18 and 19 for the zones of the Northern hemisphere and in figures 20 to 22 for the zones of the Southern hemisphere.

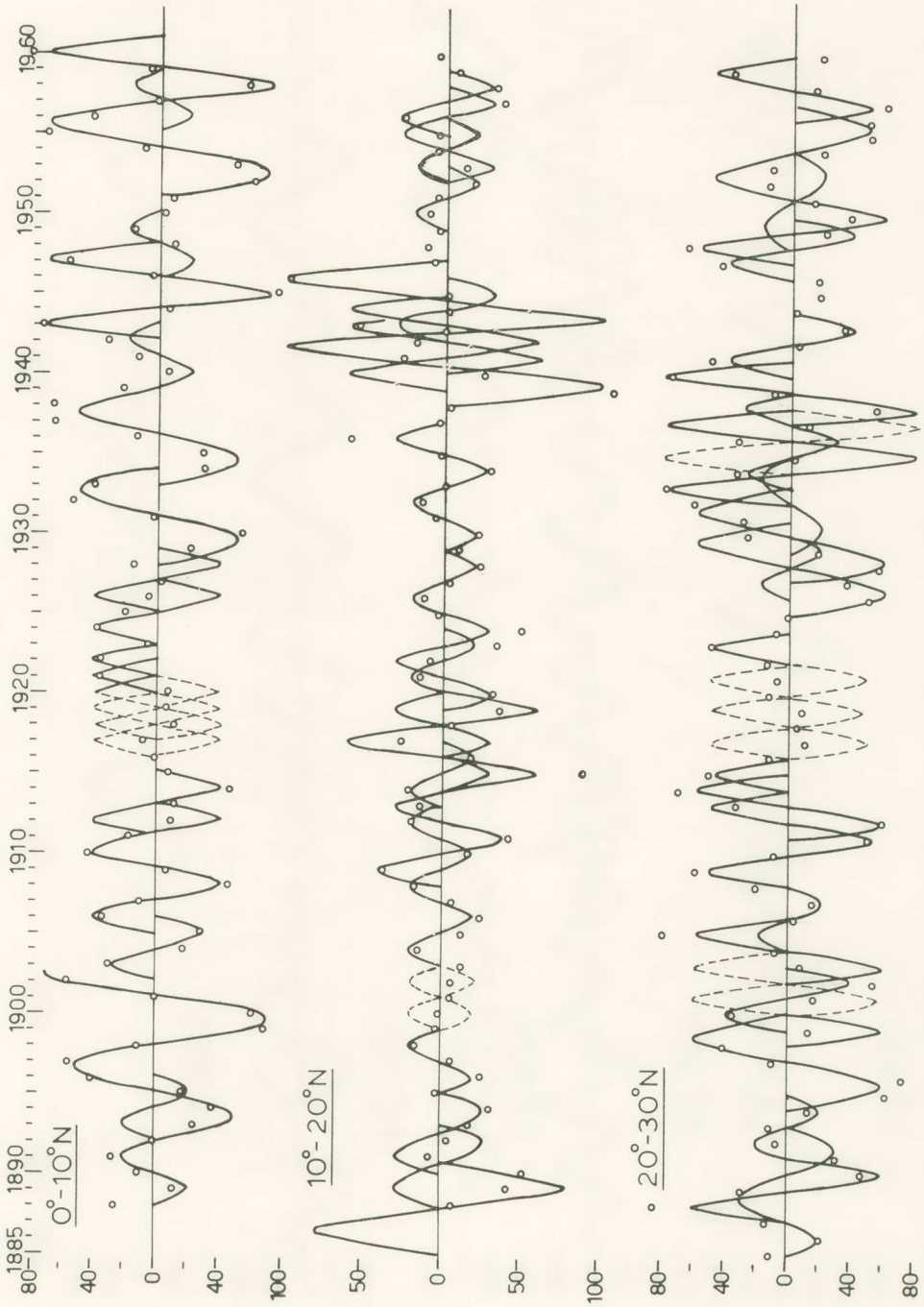
1885
1890
1900
1910
1920
1930
1940
1950
1960
0°-10°N
10°-20°N
20°-30°N
80
40
0
40
100
50
0
50
100
80
40
0
40
80

Fig. 18.

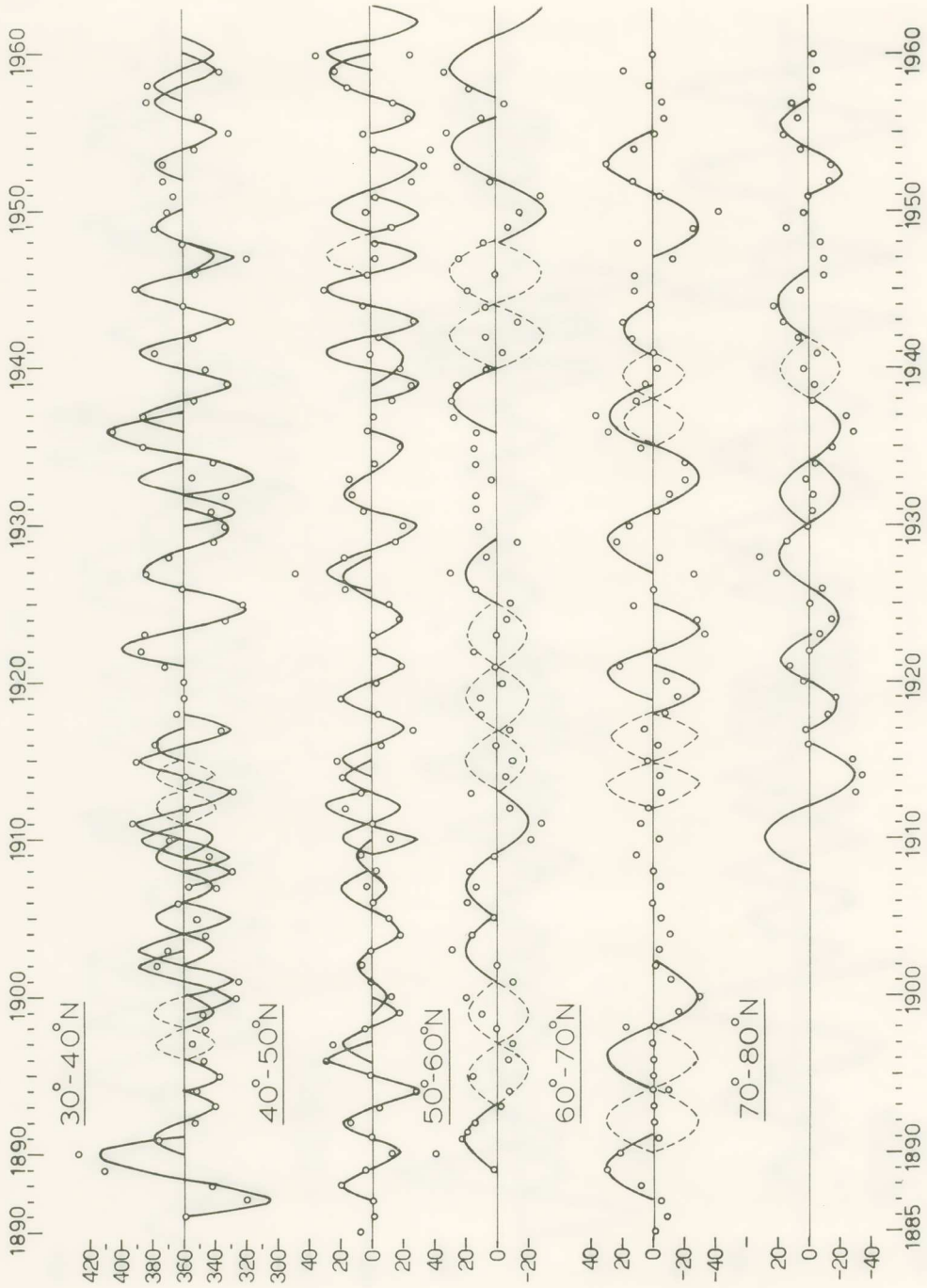
30°-40°N
40°-50°N
50°-60°N
60°-70°N
70°-80°N
1885
1890
1900
1910
1920
1930
1940
1950
1960

Fig. 19.

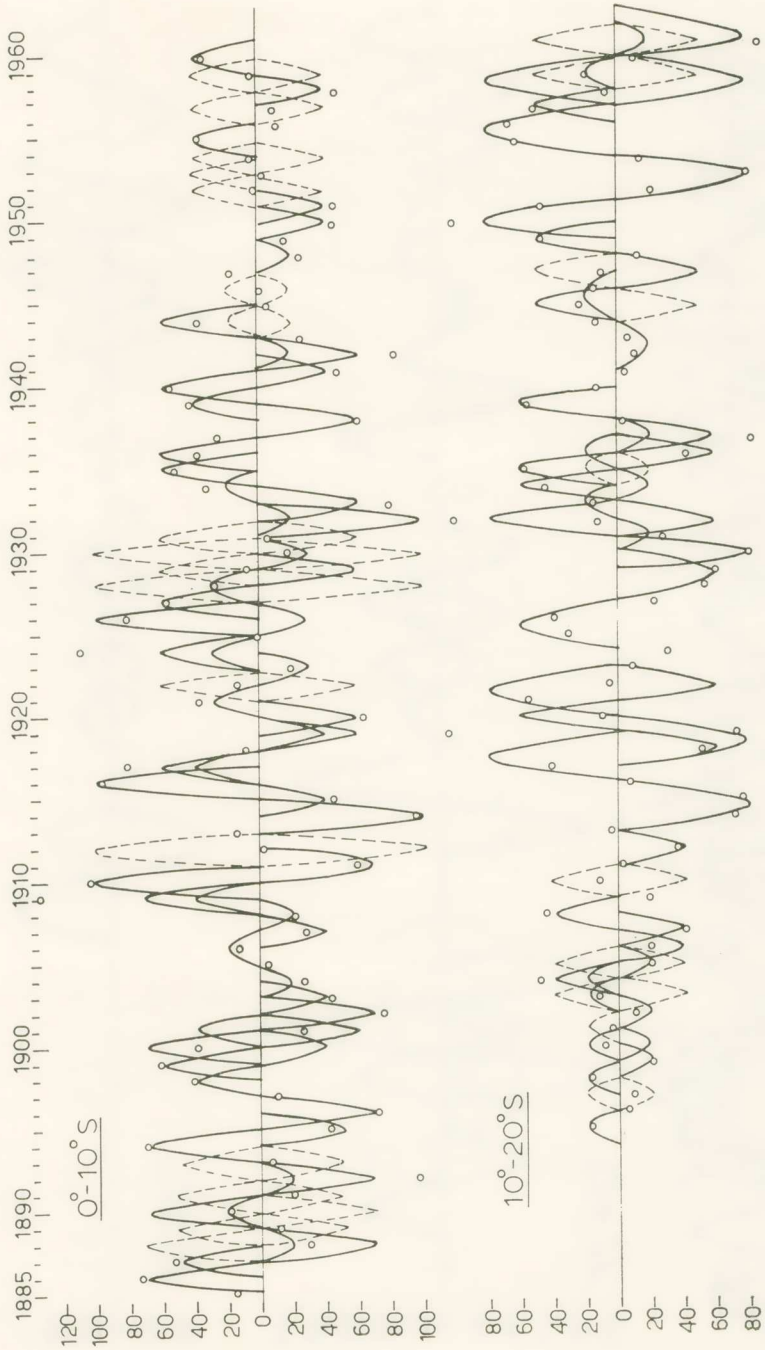
0°-10°S
10°-20°S
1885
1890
1900
1910
1920
1930
1940
1950
1960
120
100
80
60
40
20
0
20
40
60
80
100
80
60
40
20
0
20
40
60
80

Fig. 20.

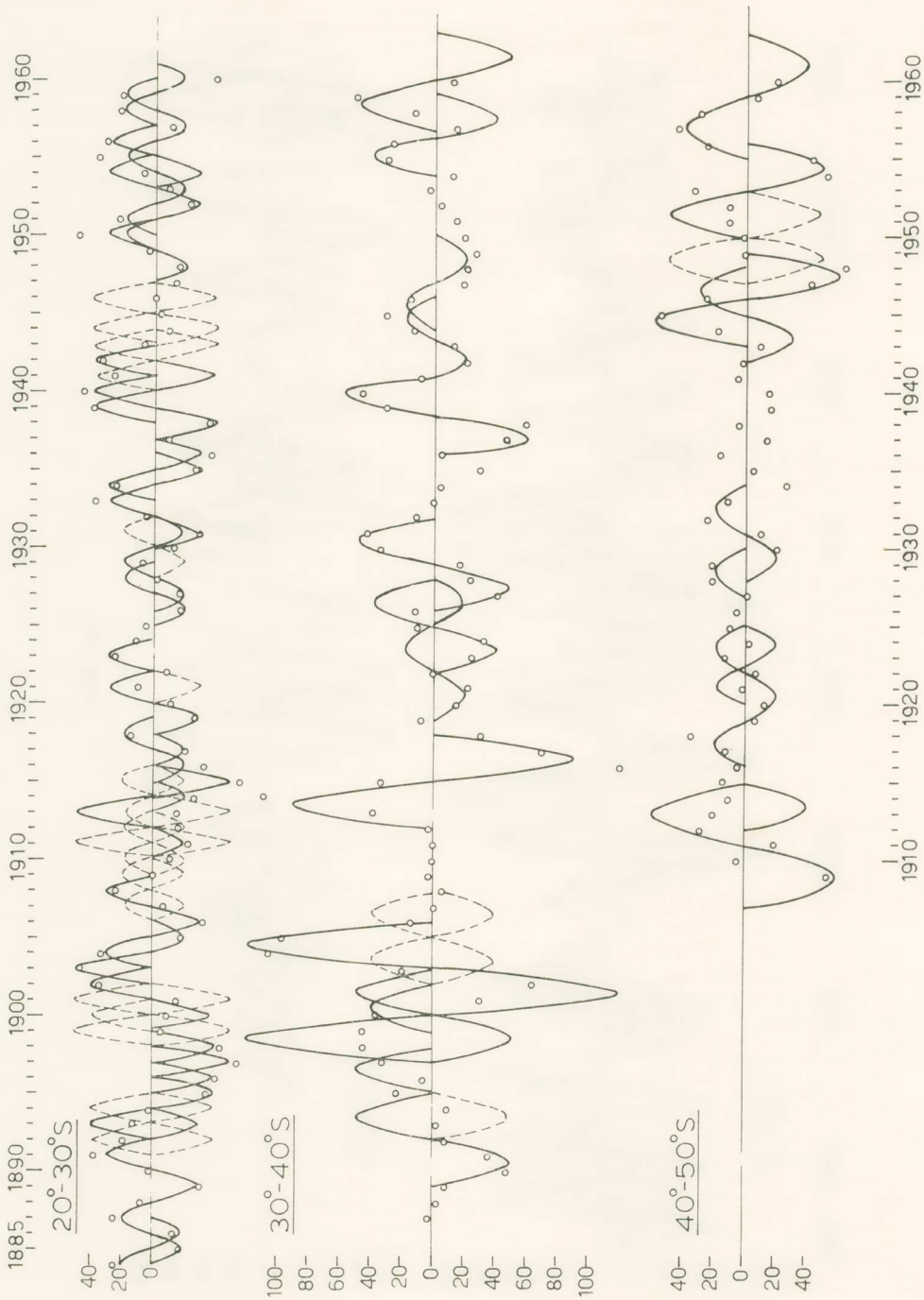
1885
1890
1900
1910
1920
1930
1940
1950
1960
20°-30°S
30°-40°S
40°-50°S
40
20
0
100
80
60
40
20
0
20
40
60
80
100
40
20
0
20
40

Fig. 21.

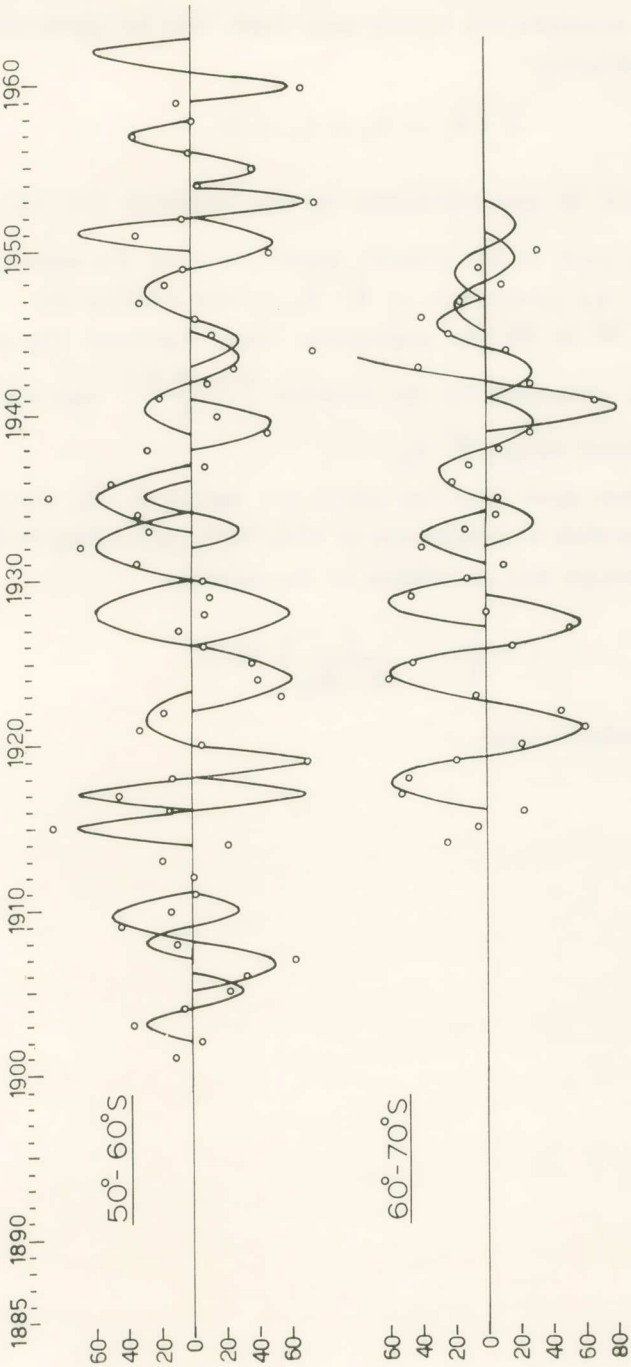
1885
1890
1900
1910
1920
1930
1940
1950
1960
50°-60°S
60°-70°S
60
40
20
0
20
40
60
60
40
20
0
20
40
60
80

Fig. 22

From the above discussion we can conclude that the mean annual variation of the precipitation within each zone may be represented analytically by the relation:

$$\overline{R - R_0} = S_\alpha + L_t + W \tag{5}$$

where S_α, L_t and W are calculated by the relations (1), (2) and (3).

In the last part of the present paper we give the necessary data of each zone for the calculation of $\overline{R - R_0}$ by the relation (5).

In figures 23 to 29 the continuous lines represent the observed values of $\overline{R - R_0}$ smoothed by the formula $\frac{\alpha + 2b + c}{4}$ and the dashed curve the calculated values $\overline{R - R_0}$.

These figures show that the calculated values $\overline{R - R_0}$ are closed to the observed ones with a coincidence of 95% - 99%, according to the zone.

This percentage was calculated by the relation

$$\varepsilon = \left(1 - \frac{\sigma}{[\overline{R - R_0}]}\right) 100\,\%$$

where σ the standard error.

NORTHERN HEMISPHERE

Zone $0° \leqslant \varphi \leqslant 10°$ N

Longitude 84°,1 W to 151°,8 E.

$$S_\alpha = 689 + 4{,}19\ I_\alpha, \quad 1887 - 1917$$
$$S_\alpha = 877 - 4{,}84\ I_\alpha, \quad 1918 - 1960$$

$$L_t = 60 \sin \frac{2\pi}{40} (T - 1883) - 60 \sin \frac{2\pi}{12} (T - 1918)$$

1883 - 1943
1943 - 1983

$$W = b_n \sum \sin \frac{2\pi}{\psi_n} t$$

b_n	ψ_n	t			
+ 20	4	1892 - 1896			
— 20	4	1888 - 1892,	1939 - 1943,	1946 - 1950,	1955 - 1959
+ 30	4	1902 - 1906			
+ 40	4	1905 - 1913,	1911 - 1915,	1916 - 1922,	1923 - 1927,
		1925 - 1929			
— 40	4	1916 - 1920,	1917 - 1921		
+ 70	4	1942 - 1948			
— 70	4	1957 - 1961			
— 50	6	1892 - 1898,	1928 - 1934,	1933 - 1939	
— 70	6	1898 - 1903,	1951 - 1957		

Zone $0° \leqslant \varphi \leqslant 10°$ N, Irregular Values (excepted).

Stations	1927	1928	1929	1956	Longitude
Koror, Palau Island	1818	1531	2283	2051	134°,5 E
Sadokan, Borneo		2762			118°,2 E
Calabar, Nigeria	2531				
$\overline{R - R_0}$	781	775	742	663	
N	26	25	26	40	

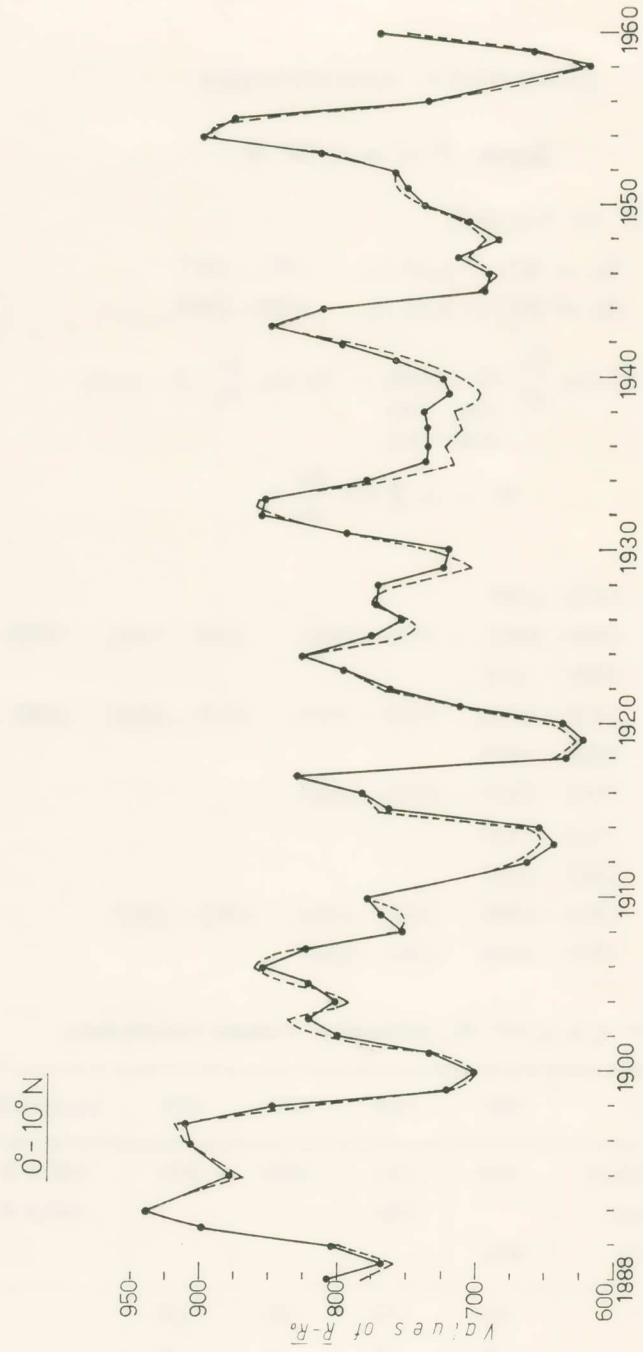

Fig. 23. The continuous curve represents the smoothed values of $\overline{R-R_0}$. The dashed curve represents the calculated values of $\overline{R-R_0}$ by the relation [5].

Zone $10^\circ \leqslant \varphi \leqslant 20^\circ$ N

Longitude 92°,2 W to 166°,6 E.

$$S_\alpha = 814 - 4{,}52\ I_\alpha, \qquad 1888 - 1907, \quad 1918 - 1960$$
$$S_\alpha = 535 + 6{,}71\ I_\alpha, \qquad 1908 - 1917$$

$$L_t = 80 \sin \frac{2\pi}{40} (T - 1878) + 40 \left[\sin \frac{2\pi}{16} \underset{\substack{1905-1929 \\ 1953-1961}}{(T - 1905)} - 3 \sin \frac{2\pi}{16} \underset{\substack{1929-1937 \\ 1939-1947}}{(T - 1929)} + \right.$$
$$\left. + 3 \sin \frac{2\pi}{6} \underset{1936-1942}{(T - 1936)} \right] \mp 40 \sin \frac{2\pi}{10} \underset{\substack{1889-1899 \\ 1900-1905}}{(T - 1889)}$$

$$W = b_n \sum \sin \frac{2\pi}{\psi_n} t, \text{ where:}$$

b_n	ψ_n	t			
+ 20	4	1903 - 1913,	1913 - 1917,	1920 - 1924,	1925 - 1929,
		1949 - 1953,	1952 - 1956		
— 20	4	1895 - 1899,	1929 - 1933		
+ 30	4	1912 - 1916,	1942 - 1946,	1955 - 1959	
— 30	4	1916 - 1920,	1919 - 1925,	1933 - 1937,	1952 - 1958
+ 40	4	1908 - 1912			
+ 60	4	1939 - 1945			
— 60	4	1914 - 1920,	1940 - 1944		
— 100	4,5	1938 - 1947			
+ 30	5	1888 - 1893,	1890 - 1895		
+ 80	5,3	1885 - 1891, 3			

Zone $10^\circ \leqslant \varphi \leqslant 20^\circ$ N, Irregular Values (excepted).

Stations	1890	1899	1900	Longitude
Bombay, India		62		72°,9 E
Belgaam, »		76		74°,6 »
Mangalore, »	345	20		74°,9 »
Madras, »	160		185	80°,2 »
Port Blair, »		90	12	92°,7 »
$\overline{R - R_0}$	669	753	704	
N	8	8	12	
σ	± 365	± 350	± 332	

Zone $20° \leqslant \varphi \leqslant 30°$ N

Longitude 154°,0 W to 177°,7 E.

$$S_\alpha = 677 - 3{,}62\ I_\alpha, \qquad 1885 - 1908$$
$$S_\alpha = 471 + 3{,}48\ I_\alpha, \qquad 1909 - 1960$$

$$L_t = 80 \cos \frac{2\pi}{36} (T - 1886)_{1886 - 1916} - 50 \sin \frac{2\pi}{88} (T - 1918) - 50 \sin \frac{2\pi}{22} (T - 1916)_{1916 - 1938}$$

$$W = b_n \sum \sin \frac{2\pi}{\psi_n} t, \text{ where:}$$

b_n	ψ_n	t			
+ 20	4	1883 - 1887,	1891 - 1895,	1904 - 1908,	1926 - 1930
+ 30	4	1933 - 1939			
+ 40	4	1899 - 1903,	1940 - 1944,	1946 - 1950	
— 50	4	1956 - 1960			
+ 50	4	1908 - 1914,	1914 - 1924,	1916 - 1922	
+ 60	4	1887 - 1891,	1947 - 1951		
— 60	4	1898 - 1906,	1900 - 1904,	1911 - 1915	
+ 80	4	1932 - 1938,	1934 - 1938		
— 80	4	1935 - 1941			
+ 20	6	1948 - 1954			
— 20	6	1929 - 1935			
+ 30	6	1887 - 1893			
+ 50	6	1951 - 1957			
— 60	6	1894 - 1900,	1925 - 1931,	1927 - 1933	

Zone $20° \leqslant \varphi \leqslant 30°$ N, Irregular Values (excepted).

Stations	1893	1894	1957	1958	Longitude
Calcuta, India	1265		248	224	88°,4 E
Shillong, »	1119			130	91°,9 »
Patma, »			159	133	85°,2 »
Allahabat, »	1389	1436	358	220	81°,7 »
Hong - Kong, China		1498			114°,2 »
$\overline{R - R_0}$	581	545	582	559	
N	10	12	18	15	
σ	± 305	± 245	± 214	± 200	

Fig. 24. The continuous curve represents the smoothed values of $\overline{R - R_0}$. The dashed curve represents the calculated values of $\overline{R - R_0}$ by the relation [5].

Zone $30^\circ \leqslant \varphi \leqslant 40^\circ$ N

Longitude 122°,4 W to 142°,0 E.

$$S_\alpha = 0$$

$$L_t = 357 + 35 \sin \frac{2\pi}{80} (T - 1878) + 20 \sin \frac{2\pi}{22} (T - 1884)_{1884 - 1906}$$

$$W = b_n \sum \sin \frac{2\pi}{\psi_n} t, \quad \text{where:}$$

b_n	ψ_n	t			
+ 20	4	1890 - 1894,	1952 - 1960,	1957 - 1961	
— 20	4	1894 - 1900,	1896 - 1900,	1902 - 1910,	1946 - 1950
+ 30	4	1936 - 1948			
— 30	4	1899 - 1903,	1900 - 1906,	1907 - 1911,	1908 - 1918,
		1930 - 1934			
+ 30	5	1926 - 1931			
+ 40	5	1921 - 1926			
— 50	5	1932 - 1937			
— 60	5	1886 - 1891			

Zone $40^\circ \leqslant \varphi \leqslant 50^\circ$ N

Longitude 122°,3 W to 145°,8 E.

$$S_\alpha = 270 - 0{,}92\ I_\alpha, \qquad 1885 - 1910$$
$$S_\alpha = 217 + 0{,}92\ I_\alpha, \qquad 1911 - 1960$$

$$L_t = -10 \sin \frac{2\pi}{36} (T - 1878) - 30 \sin \frac{2\pi}{18} (T - 1923)$$

$$W = b_n \sum \sin \frac{2\pi}{\psi_n} t, \quad \text{where:}$$

b_n	ψ_n	t			
+ 20	4	1887 - 1893,	1896 - 1900,	1909 - 1915,	1914 - 1922,
		1959 - 1963			
— 20	4	1911 - 1915			
— 10	4	1899 - 1903,	1906 - 1910		

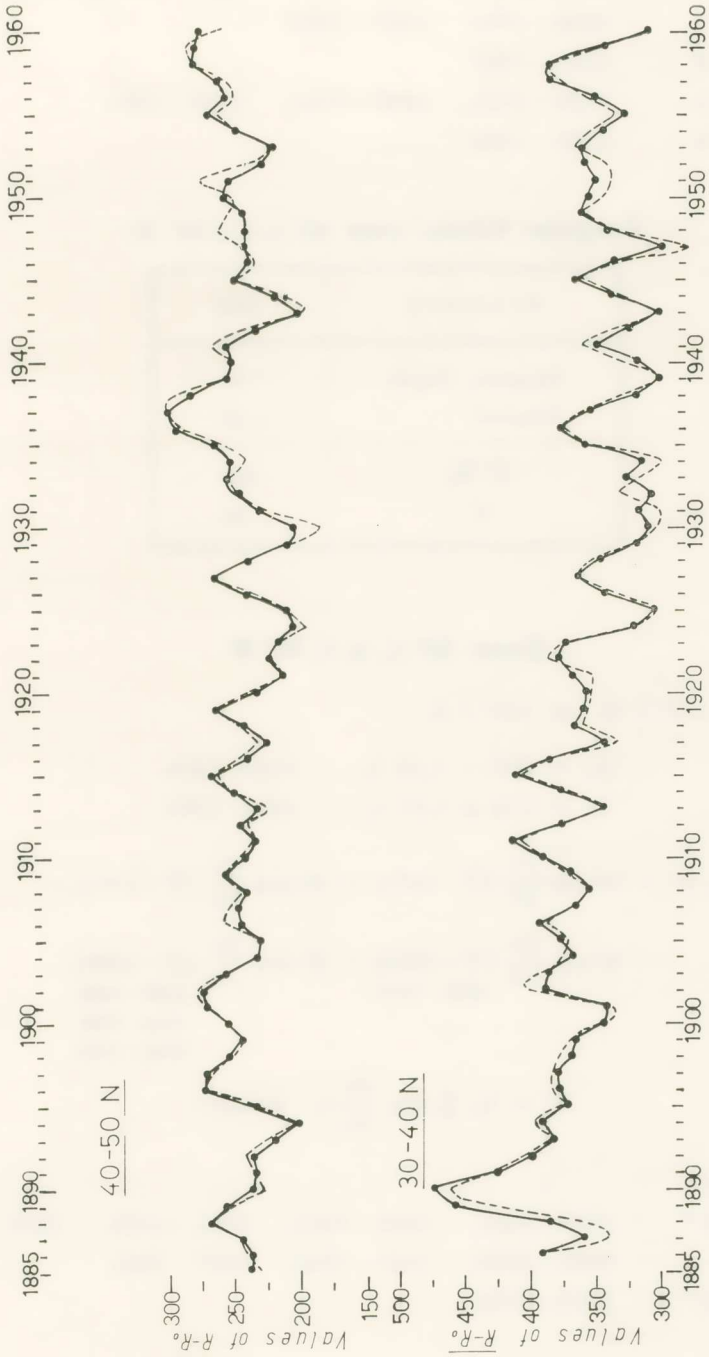

Fig. 25. The continuous curve represents the smoothed values of $\overline{R - R_0}$. The dashed curve represents the calculated values of $\overline{R - R_0}$ by the relation [5].

— 30	4	1893 - 1897,	1909 - 1913,	1938 - 1948,	1939 - 1942
— 20	5	1903 - 1908,	1923 - 1928		
+ 20	5	1931 - 1941			
+ 30	5	1926 - 1931,	1946 - 1951,	1949 - 1954	
— 30	5	1955 - 1960			

Irregular Values, zone $40^\circ \leqslant \varphi \leqslant 50^\circ$ N.

Stations	1900
Sappiro, Japan	44
Nemuro	— 55
$\overline{R - R_0}$	254
N	56

Zone $50^\circ \leqslant \varphi \leqslant 60^\circ$ N

Longitude 176°,7 W to 158°,7 E.

$$S_\alpha = 286 - 1{,}53\ I_\alpha, \qquad 1890 - 1904$$
$$S_\alpha = 174 + 1{,}87\ I_\alpha, \qquad 1905 - 1960$$

$$L_t = -50 \sin \frac{2\pi}{88} (T - 1881) - 40 \sin \frac{2\pi}{44} (T - 1881) -$$
$$- 40 \sin \frac{2\pi}{16} \underset{1902 - 1918}{(T - 1902)} - 30 \sin \frac{2\pi}{8} \underset{\substack{1888 - 1896 \\ 1918 - 1926 \\ 1948 - 1956}}{(T - 1888)}$$

$$W = b_n \sum \sin \frac{2\pi}{\psi_n} t, \quad \text{where:}$$

b_n	ψ_n	t			
+ 30	8 *	1889 - 1901,	1893 - 1901,	1901 - 1905,	1905 - 1925,
		1936 - 1956,	1940 - 1948,	1957 - 1961	
— 30	8 *	1913 - 1929			

* Statistically insignificant.

Zone $60^\circ \leqslant \varphi \leqslant 70^\circ$ N

Longitude 165° W to 149°,8 E.

$$S_\alpha = 316 - 2{,}5\ I_\alpha, \qquad (1885 - 1960)$$

$$L_t = -40 \cos \frac{2\pi}{32} (T - 1882)_{1882 - 1922} + 40 \sin \frac{2\pi}{80} (T - 1918) \pm 40 \sin \frac{2\pi}{12} (T - 1904) \begin{matrix} +1904 - 1910 \\ -1938 - 1956 \end{matrix}$$

$$W = b_n \sum \sin \frac{2\pi}{\psi_n} t, \text{ where :}$$

b_n	ψ_n	t
+ 20	6 *	1935 - 1944
− 20	6 *	1935 - 1941
− 30	6 *	1912 - 1921
+ 30	6 *	1912 - 1918, 1919 - 1925
+ 30	8	1887 - 1891, 1890 - 1898, 1927 - 1939
− 30	8	1890 - 1902, 1947 - 1955

Zone $70^\circ \leqslant \varphi \leqslant 80^\circ$ N

Longitude 156°,3 W to 31°,1 E.

$$S_\alpha = 983 + 1{,}82\ I_\alpha, \qquad 1913 - 1970$$

$$L_t = 40 \sin \frac{2\pi}{22} (T - 1911) + 30 \sin \frac{2\pi}{10} (T - 1935)_{1935 - 1950} - 30 \sin \frac{2\pi}{16} (T - 1955)_{1955 - 1971}$$

$$W = b_n \sum \sin \frac{2\pi}{\psi_n} t, \text{ where :}$$

b_n	ψ_n	t
− 20	6 *	1951 - 1957
+ 20	8 *	1930 - 1942
− 20	8 *	1916 - 1924, 1922 - 1934, 1938 - 1946
+ 30	8 *	1908 - 1916

* Statistically insignificant.

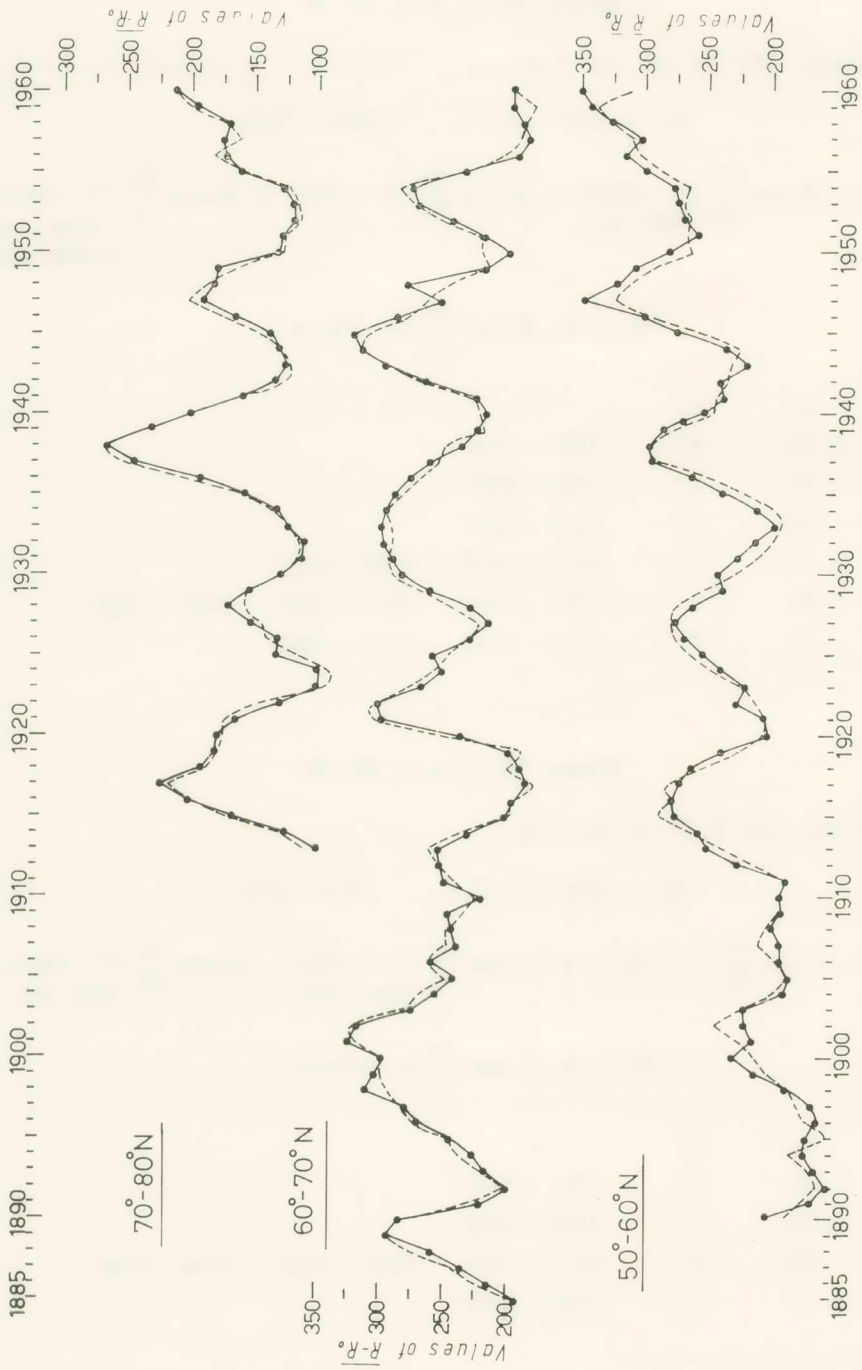

Fig. 26. The continuous curve represents the smoothed values of $\overline{R - R_0}$. The dashed curve represents the calculated values of $\overline{R - R_0}$ by the relation [5].

SOUTHERN HEMISPHERE

Zone $0° \leqslant \varphi \leqslant 10°$ S

Longitude 172°,0 W to 179°,2 E.

$$S_\alpha = 787 + 5{,}9\ I_\alpha, \quad (1885 - 1903,\ 1938 - 1939,\ 1916/17)$$
$$S_\alpha = 1093 - 6{,}01\ I_\alpha, \quad (1904 - 1937,\ 1940 - 1960)$$

$$L_t = 40 \sin \frac{2\pi}{44} (T - 1876) - 70 \sin \frac{2\pi}{22} (T - 1876) - 100 \sin \frac{2\pi}{16} (T - 1938)_{1938 - 1954}$$

$$W = b_n \sum \sin \frac{2\pi}{\psi_n} t, \text{ where :}$$

b_n	ψ_n	t
− 20	4	1887 - 1893, 1903 - 1909, 1931 - 1935, 1941 - 1947, 1943 - 1949
+ 30	4	1920 - 1924, 1923 - 1931
+ 40	4	1897 - 1901, 1900 - 1904, 1938 - 1942, 1951 - 1955, 1954 - 1960, 1956 - 1960
− 40	4	1906 - 1910, 1914 - 1920, 1949 - 1955, 1950 - 1954, 1957 - 1961
+ 50	4	1888 - 1896, 1886 - 1894
+ 60	4	1898 - 1902, 1916 - 1920, 1926 - 1936, 1928 - 1932, 1935 - 1945
− 60	4	1919 - 1923, 1921 - 1925
+ 70	4	1885 - 1897, 1887 - 1891, 1899 - 1903, 1908 - 1912
+ 100	4	1909 - 1913, 1911 - 1917, 1925 - 1937, 1927 - 1931

Zone $10° \leqslant \varphi \leqslant 20°$ S

Longitude 156°,1 W to 177°,2 E.

$$S_\alpha = 748 - 2{,}52\ I_\alpha, \quad (1895 - 1899,\ 1903 - 1906,\ 1915 - 1960)$$
$$S_\alpha = 526 + 7{,}21\ I_\alpha, \quad (1900 - 1902,\ 1907 - 1914)$$

$$L_t = 60 \cos \frac{2\pi}{88} (T - 1879) - 70 \sin \frac{2\pi}{28} (T - 1895)_{1895 - 1931} + 70 \sin \frac{2\pi}{10} (T - 1935)_{1935 - 1956}$$

$$W = b_n \sum \sin \frac{2\pi}{\psi_n} t, \text{ where :}$$

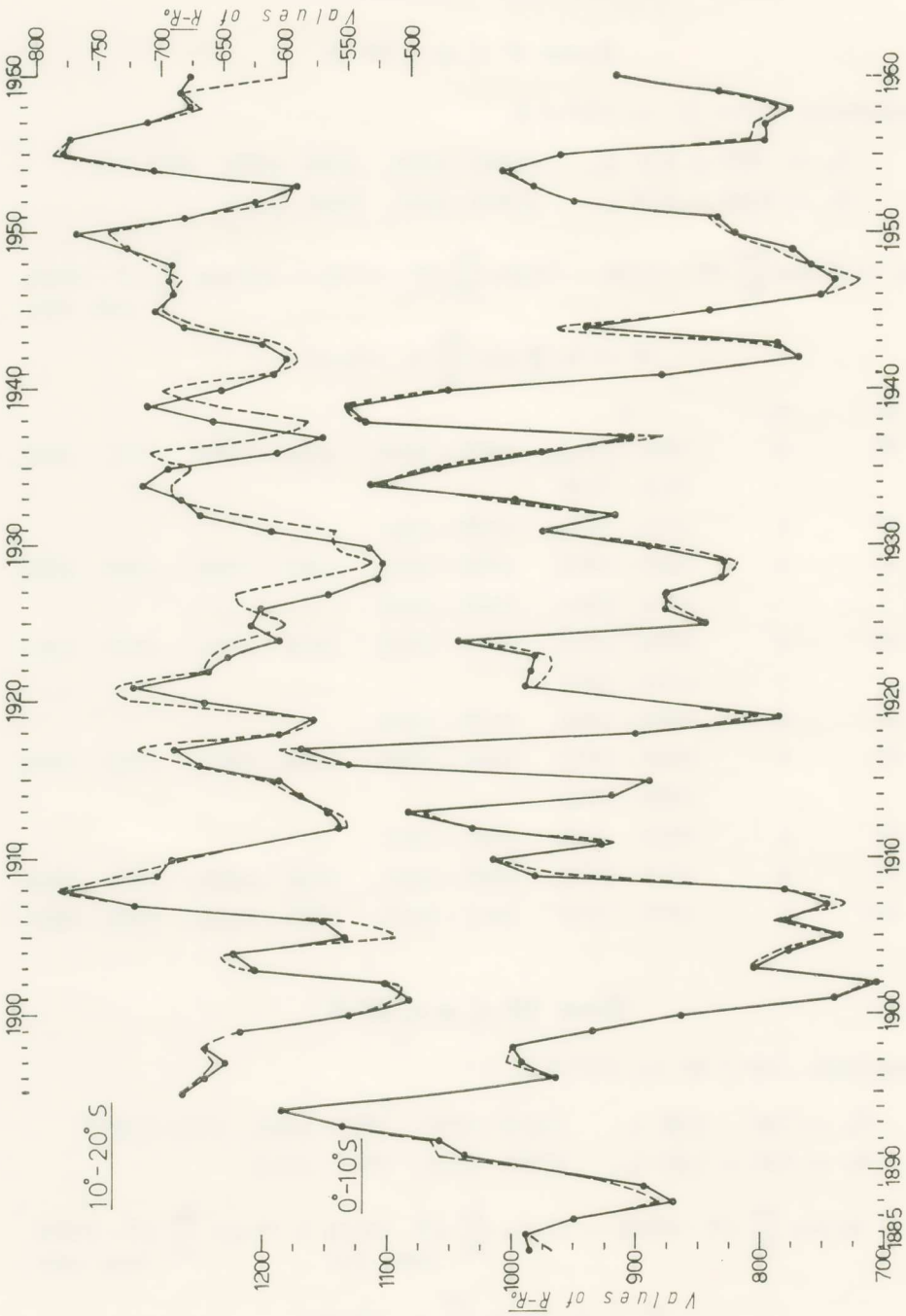

Fig. 27. The continuous curve represents the smoothed values of $\overline{R - R_0}$. The dashed curve represents the calculated values of $R - \overline{R_0}$ by the relation [5].

b_n	ψ_n	t			
+ 20	4	1894 - 1898,	1896 - 1902,	1897 - 1901,	1899 - 1903,
		1902 - 1906,	1934 - 1938,	1958 - 1962	
— 20	4	1930 - 1936			
+ 40	4	1902 - 1906,	1903 - 1911,	1909 - 1913	
— 40	4	1902 - 1908			
+ 50	4	1944 - 1950,	1944 - 1948,	1956 - 1962,	1958 - 1962
+ 60	4	1934 - 1940			
— 60	4	1917 - 1923,	1931 - 1937		
— 80	4	1929 - 1933			
— 20	6	1941 - 1947			
+ 60	6	1924 - 1930			
— 80	6	1913 - 1919,	1917 - 1923		
+ 80	5	1949 - 1954			
+ 80	6	1954 - 1960,	1957 - 1963		

Zone $20° \leqslant \varphi \leqslant 30°$ S

Longitude 178°,7 W to 170°,0 E.

$$S_\alpha = 428 + 3{,}58\ I_\alpha, \qquad (1883 - 1951)$$
$$S_\alpha = 634 - 1{,}89\ I_\alpha, \qquad (1952 - 1960,\ \ 1936/37)$$

$$L_t = 40 \sin \frac{2\pi}{12} (T - 1885) - 60 \sin \frac{2\pi}{80} (T - 1922)$$
$$1885 - 1921$$
$$1916 - 1964$$

$$W = b_n \sum \sin \frac{2\pi}{\psi_n} t, \quad \text{where :}$$

b_n	ψ_n	t			
+ 20	4	1883 - 1887,	1909 - 1913,	1914 - 1918,	1950 - 1960,
		1957 - 1961			
— 20	4	1884 - 1888,	1904 - 1910,	1906 - 1916,	1915 - 1919,
		1925 - 1929,	1926 - 1932,	1928 - 1932,	1947 - 1951
+ 30	4	1903 - 1909,	1949 - 1955		

— 30	4	1888 - 1894,	1918 - 1922,	1920 - 1924,	1930 - 1936,
		1953 - 1957			
+ 40	4	1891 - 1895,	1892 - 1896,	1938 - 1942,	1940 - 1944,
		1941 - 1947			
— 40	4	1891 - 1897,	1897 - 1903,	1894 - 1903,	1937 - 1941
— 50	4	1896 - 1904,	1898 - 1902		

Zone $30^\circ \leqslant \varphi \leqslant 40^\circ$ S

Longitude 73°,2 W to 174°,8 E.

$$S_\alpha = 457 - 2{,}87\ I_\alpha, \qquad (1886 - 1917)$$

$$S_\alpha = 381 + 0{,}39\ I_\alpha, \qquad (1918 - 1960)$$

$$L_t = 30 \sin \frac{2\pi}{32} (T - 1882) - 70 \sin \frac{2\pi}{12} \underset{1882 - 1900}{(T - 1882)} -$$

$$- 30 \left[\sin \frac{2\pi}{16} \underset{\substack{1890 - 1922 \\ 1954 - 1970}}{(T - 1890)} - \sin \frac{2\pi}{16} \underset{1922 - 1954}{(T - 1922)} \right]$$

$$W = b_n \sum \sin \frac{2\pi}{\psi_n} t, \quad \text{where :}$$

b_n	ψ_n	t		
— 20	5	1941 - 1946		
+ 40	5	1954 - 1959		
— 60	5	1936 - 1941		
+ 20	6	1944 - 1950		
— 20	6	1919 - 1928		
— 40	6	1922 - 1928		
+ 40	6	1899 - 1908,	1902 - 1908	
+ 50	6	1889 - 1895,	1957 - 1963	
— 50	6	1892 - 1898,	1897 - 1903,	1926 - 1932
+ 120	6	1897 - 1906,	1912 - 1918	

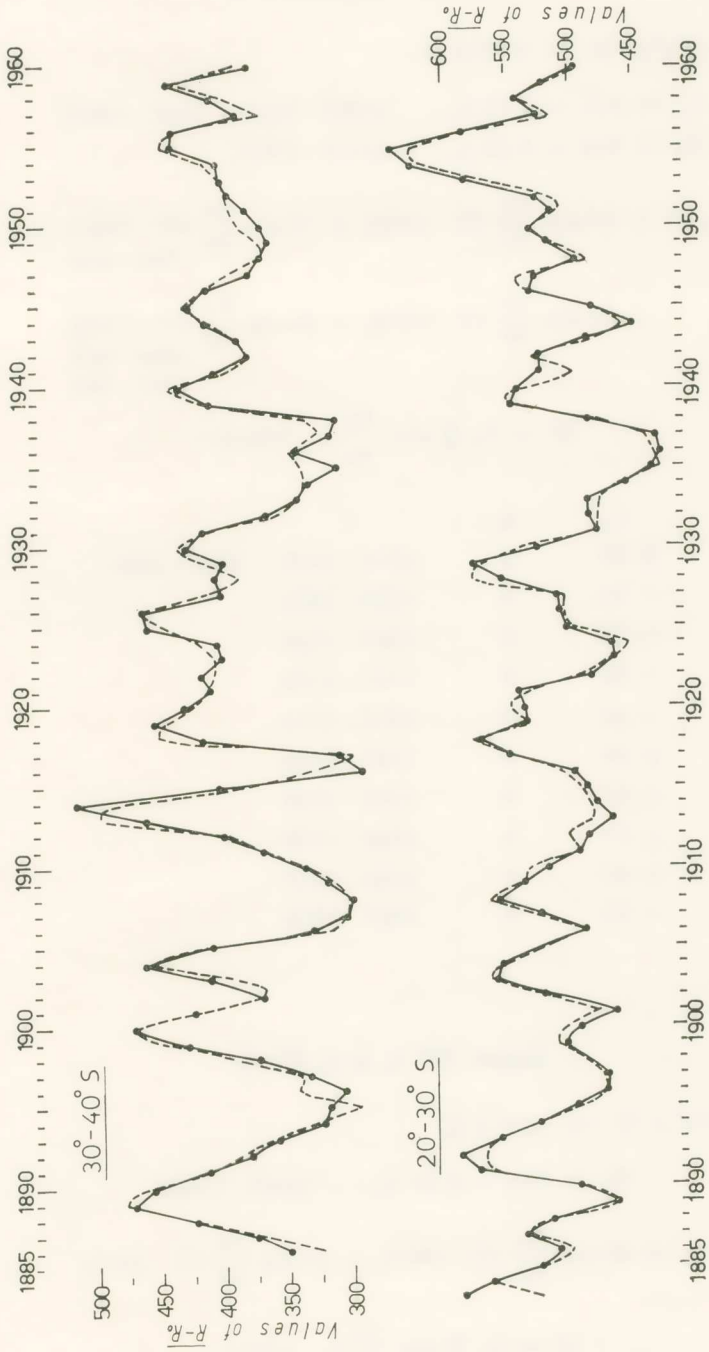

Fig. 28. The continuous curve represents the smoothed values of $R - \overline{R_0}$. The dashed curve represents the calculated values of $\overline{R - R_0}$ by the relation [5].

Zone $40^\circ \leqslant \varphi \leqslant 50^\circ$ S

Longitude 174°,8 W to 176°,6 E.

$$S_\alpha = 525 - 3{,}52\ I_\alpha, \qquad (1909 - 1915,\quad 1940 - 1960)$$
$$S_\alpha = 344 + 2{,}43\ I_\alpha, \qquad (1916 - 1939)$$

$$L_t = -30 \cos \frac{2\pi}{80} (T - 1902) + 70 \sin \frac{2\pi}{18} (T - 1901) + \quad {\scriptstyle 1901 - 1919}$$

$$+ 70 \sin \frac{2\pi}{36} (T - 1904) - 20 \sin \frac{2\pi}{22} (T - 1900) \quad {\scriptstyle 1900 - 1922,\ 1944 - 1966}$$

$$W = b_n \sum \sin \frac{2\pi}{\psi_n} t, \quad \text{where :}$$

b_n	ψ_n	t
+ 20	6	1916 - 1925, 1927 - 1930
− 20	6	1928 - 1934
− 30	6	1942 - 1948
− 50	6	1947 - 1956
− 40	6	1912 - 1915
+ 50	6	1947 - 1953
+ 60	6	1943 - 1949
+ 20	5	1920 - 1925
+ 40	8	1955 - 1963
− 60	8	1907 - 1915

Zone $50^\circ \leqslant \varphi \leqslant 60^\circ$ S

Longitude 74°,1 W to 169°,1 E.

$$S_\alpha = 884 - 6{,}70\ I_\alpha, \qquad (1901 - 1960)$$

$$L_t = 40 \cos \frac{2\pi}{88} (T - 1888) + 40 \sin \frac{2\pi}{18} (T - 1901)$$

$$W = b_n \sum \sin \frac{2\pi}{\psi_n} t, \quad \text{where :}$$

b_n	ψ_n	t
− 20	4 *	1932 - 1936
+ 30	4 *	1902 - 1906, 1907 - 1911
− 40	4 *	1954 - 1958
+ 60	4 *	1914 - 1918, 1916 - 1920, 1950 - 1954
+ 60	8 *	1933 - 1937
− 60	8 *	1922 - 1930, 1926 - 1934
+ 30	6	1939 - 1945
− 30	6	1943 - 1949
− 50	6	1905 - 1911, 1939 - 1942, 1949 - 1952

Zone $60° \leqslant \varphi \leqslant 70°$ S

(One station).

$$S_\alpha = 475 - 5{,}45\ I_\alpha .$$

$$L_t = -30 \sin \frac{2\pi}{18} (T - 1908) - 50 \sin \frac{2\pi}{32} (T - 1910) + 50 \sin \frac{2\pi}{12} (T - 1923)$$

1908 - 1926

$$W = b_n \sum \sin \frac{2\pi}{\psi_n} t, \quad \text{where :}$$

b_n	ψ_n	t
+ 20	6	1945 - 1951, 1947 - 1953
− 30	6	1932 - 1941, 1941 - 1947
+ 60	6,5	1916 - 1929
+ 60	6	1927 - 1930
− 80	6	1939 - 1943
+ 40	6	1931 - 1934

* Statistically insignificant.

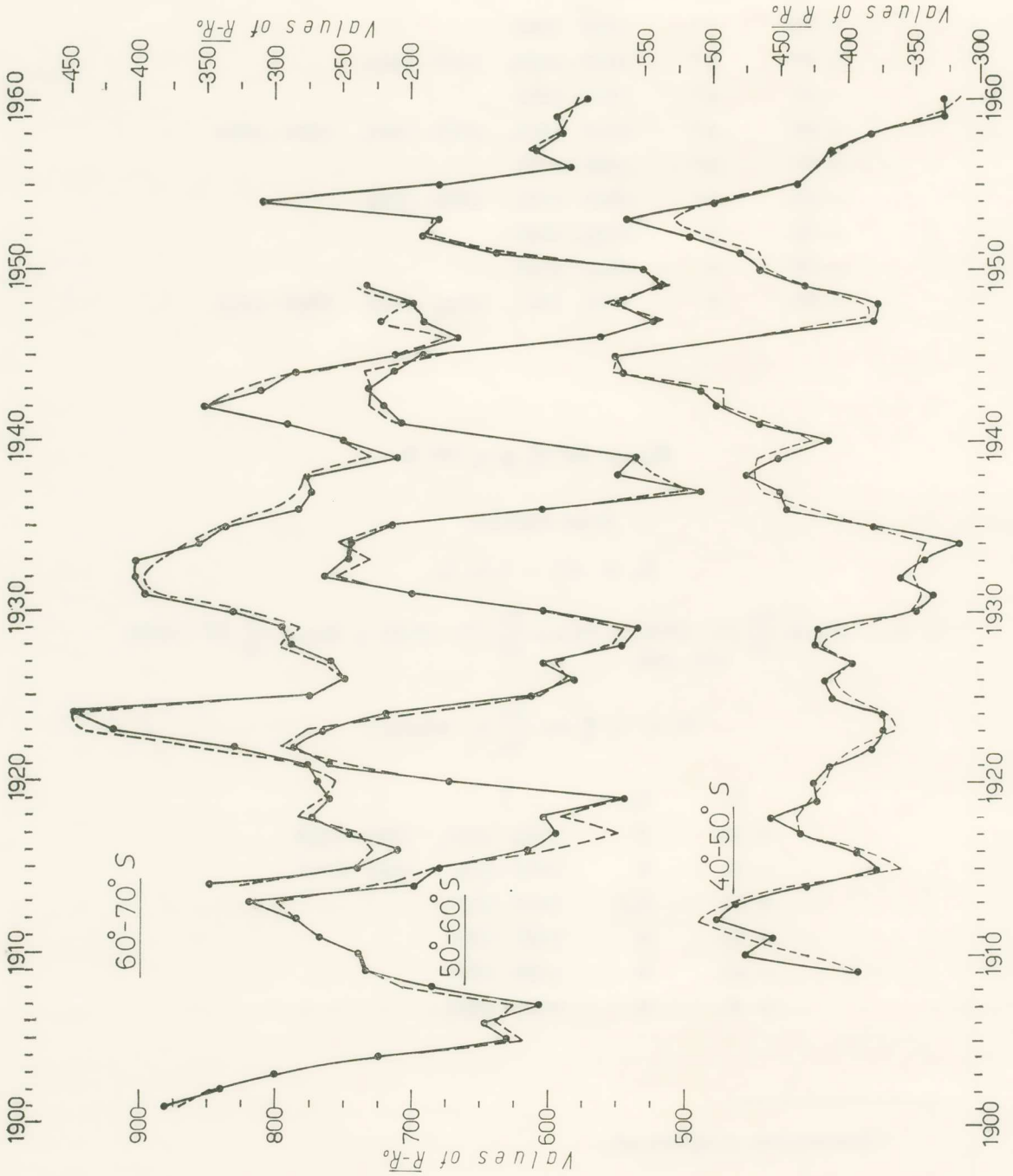

Fig. 29. The continuous curve represents the smoothed values of $R - R_0$. The dashed curve represents the calculated values of $R - R_0$ by the relation [5].

REFERENCES

1. C. Poulakos and B Tritakis, Proceedings of the first European Astronomical Meeting, **1**, 49, 1972.
2. B. Tritakis, Practika of the Academy of Athens, **50**, 478, 1975.
3. J. Xanthakis, Proceedings of the first European Astronomical Meeting, **1**, 20, 1972.
4. J. Xanthakis - C. Poulakos - B. Tritakis, Practika of the Academy of Athens, **49**, 187, 1974.
5. J. Xanthakis, «Solar activity and precipitation», Papers of the Academy of Athens, 1975.
6. C. Zerefos and G. Cosmas, Practika of the Academy of Athens, **50**, 185, 1975.