551·525 : 551·583·53

Trends in the characteristics of seasonal variation of temperature in the arid and semi-arid regions

P. JAGANNATHAN

Meteorological Office, Poona

(*Received 7 March 1962*)

1. Introduction

The realisation that the earth as a whole is experiencing a minor climatic fluctuation coupled with the fact that the precise modern science of climatology provides objective means of indicating the extent and intensity of such changes, has in the recent years given considerable impetus to the study of climatic changes. In India this problem has been engaging the attention of professional meteorologists for the last four decades and a number of studies have been made largely to answer the public enquiry "Is the climate changing ?"

Willet (1950) found that a pronounced upward trend has been in progress since 1885 of about 2·2° F in the winter mean temperature and 1·0°F in the annual mean temperature; this rising trend has been most pronounced in the higher middle and polar latitudes of the northern hemisphere with no counterpart in the southern hemisphere. Pramanik and Jagannathan (1954) studied the climatic changes in India, in regard to rainfall, maximum and minimum temperatures and pressure for a network of stations in India and neighbourhood for which sufficiently long and unbroken homogenous records are available. The statistical analysis carried out for the detection of long term trends in the temperature series did not reveal any systematic increase or decrease in the maximum and minimum temperatures. However, at some of the stations variations of an oscillatory character with a period of 30-40 years have been noticed.

The relationship between sunspot and air temperature has been the subject of several investigations. Walker (1915) correlated the sunspot numbers with the mean annual temperature of the stations and found a C. C. of —0·2 to —0·5 in respect of Indian stations. Announcing this, he remarked "the marked fall in temperature in the tropical regions calls loudly for an explanation". Willet (1951) studied the relation between the sunspot numbers and air temperatures in the mean latitudes of the northern hemisphere during the last two centuries. He found that after four periods of high solar activity there followed 3 periods of low solar activity and that the mean temperature during the four periods of high solar activity is slightly higher than the mean temperature of the following three periods of low solar activity. Xauthakis (1953, 1955) developed a "new relationship" to represent the annual course of air temperature.

$$\frac{1}{2}\,(T_i + T_{13-i}) = A + C \sin (L_i - V) \quad (1)$$

and
$$\frac{T_{13-i}}{T_i} = \frac{P}{1 - e \cos\,(L_i - w)} \quad (2)$$

$$i = 1, 2, \;\ldots\ldots\; 6$$

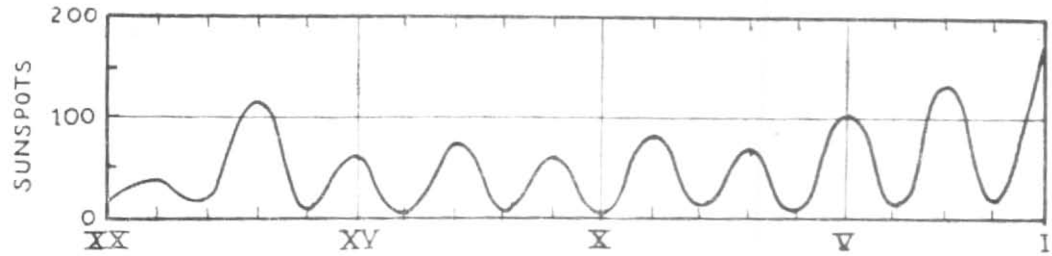

Fig. 1. Mean Sunspot

where T_i and $T_{13\text{-}i}$ represent the mean monthly air temperature in °A during the i^{th} and $(13\text{-}i)^{th}$ month, L_i is the longitude of the Sun during the middle of the i^{th} month and A, C, V, P, e, w are constants. These relationships were verified approximately for many stations in the temperate zones. He studied the variation of the characteristic constants during the successive sunspot cycles—each cycle beginning in the year following that in which the minimum of the annual sunspot number occurs and ending at the year of the next minimum—and found that e and P and hence the range variation of the differences $T_{13\text{-}i} - T_i$, which is related to them, present a correlation with mean annual sunspot numbers one whole period earlier in the case of stations in Europe and near East while in the case of United States stations the relationship was contemporaneous.

2. Annual march of temperature

The annual march of air temperature is primarily dependant upon the variation in the amount of heat received from the Sun. The daily rate of solar radiation received at any point on the earth's surface depends upon the quantity of solar radiation that emanates from the Sun, the duration of the Sun's presence above the horizon and the meridional altitude of the Sun. However, the distribution of land and water in the neighbourhood of the station, its elevation, and the atmospheric and oceanic circulations modify this picture determined by the Sun to a marked extent. Thus the seasonal course of air temperature is a major factor in defining the climate as 'temperate' or 'severe', 'maritime' or 'continental' etc.

This march of temperature of the air at any particular station is to a large extent a systematic oscillation repeating practically in a similar manner year after year. The author (1957) resolved the annual variation in the normal average temperature at a number of stations in India into two harmonic components, the annual and the biannual waves, and studied the regression of the different harmonic constants on the latitude, longitude and elevation of the station. It was pointed out that elevation has no effect on the amplitude as well as the date of maximum in the annual oscillation while the amplitude increases northwards and away from the coast.

3. Scope of the study

The foregoing study has been undertaken essentially for providing answers to the following questions—

(*i*) Are there any long term changes in the characteristic parameters representing the seasonal variation of air temperature particularly over the arid and semi-arid regions ?

(*ii*) Are the characteristic parameters representing the seasonal variation of air temperature dependent upon the sunspottedness ?

With this view the parameters representing the seasonal variations of mean air temperature of representative stations in the arid and semi-arid regions of northwest India as also the semi-arid regions of the Deccan plateau have been calculated separately for each of the 3-year periods of sunspot maxima and sunspot minima, during the entire period for which data are available. The changes in the characteristic parameters from period to period of solar activity have been examined.

The analysis was extended to one or two representative stations in each of the arid or semi-arid regions in the other parts of the world and where sufficient data are available. The stations selected for the purpose are Bikaner, Jaipur, Ajmer, Mount Abu, Rajkot Aurangabad, Poona and Bellary in India; Quetta in Pakistan, Minusinsk and Tashkent in U. S. S. R., Baghdad in Iraq, Helwan in Egypt, Khartom in Sudan, Phoenix in U.S.A., Cardoba and Buenos Aires* in Argentina, O'okiep in South Africa and Alice Springs in Australia.

4. Material for study

The stations selected for the study, the countries in which they are located, their positional co-ordinates and remarks as to the homogeneity of the temperature data as also the availability of the data are given in Table 1.

The sunspot numbers utilised in the analysis are the maximum and minimum value of the 3-year moving averages of mean annual sunspot numbers. The 3-year periods, the values of the mean annual sunspot numbers as well as the mean number of sunspots during the periods are given in Table 2. The variations of sunspot are shown in Fig. 1.

In col. 7 of Table 1 are indicated as to what is meant by the term "mean monthly air temperature" hereafter referred to as "the temperature". In respect of the Indian stations they are uniformly the mean of the mean daily maximum and mean daily minimum temperatures of the month. For the study of the seasonal variation of temperature during the sunspot maxima and minima, the averages of the temperature during the three consecutive years in which sunspot activity as indicated by the 3-year moving average of sunspot numbers was maximum or minimum have been taken.

The data of the Indian stations have been extracted from the Annual Parts maintained by the India Meteorological Department and "corrections"† applied, where necessary to render the series of temperature homogeneous. The data of the other stations have been taken from the *World Weather Records* by Clayton and Clayton (1927, 1934 and 1947) and U. S. Weather Bureau (1959) publications entitled *World Weather Records* and the *Monthly Climatic Data of the World.*

5. Graduation of the seasonal variation of temperature

The seasonal variation of temperature is assumed to be composed of two‡ simple harmonic oscillations one with a period of a year and the other of six months. The

*Buenos Aires is not actually in the arid or semi-arid region; in fact according to Koppen's classification the station is classified as Cfa. However, as the station has a long series of data and owing to its proximity to the semi-arid tracks of Argentina, this station has also been included in the study.

†Corrections for changes of site and method of exposure (*e.g.*, prior to 1927 or so the thermometers at the Indian observatories were exposed in thatched sheds and later Stevenson Screens were introduced) were evolved from comparative observations for about two years. These corrections were applied so that series of temperature data relate to the old site or procedure.

‡In the study by the author (1957 *loc. cit.*) it has been shown that the annual and biannual harmonic variation account for 90-95 per cent of the annual variation represented by the 12-monthly values.

temperature at any time t of the year is given by the relationship

$$T_t = \overline{T} + a_2 \sin\left(\frac{2\pi t}{P} + \phi_1\right) + a_2 \sin\left(\frac{2\pi t}{P/2} + \phi_2\right) \quad (3)$$

where $\overline{T} = \sum_{1}^{12} T$ is the mean annual temperature, a_1 and a_2 are the amplitudes of the annual and the half yearly waves and ϕ_1 and ϕ_2 are the respective phase angles. P is the periodic time — here the year.

The different parameters entering in the above relationship have been calculated in the usual manner* by assuming that the mean monthly temperature refer to the midday in each of the months and that the months are all of equal lengths.

The values of the various parameters for the different periods of solar activity are given in the following tables station by station—

Table 3—Mean annual air temperature $\overline{T}$ and the annual range of air temperature, R defined as the difference between the temperature of the hottest month and the coldest month ($T_h - T_c$).

Table 4—Amplitudes and phase angles of the annual and biannual waves.

6. Discussion of the results

(*i*) *Mean annual temperature*—The departures of the average annual temperature during the different periods from the mean annual temperature are given in Table 3 and the variation of $\overline{T}$ from period to period of solar activity at the various stations are shown graphically in Fig. 2. A look at these graphs indicate that at the Indian stations as also the extra-Indian stations there is no systematic tendency for increase or decrease.

In the following table are shown the difference between the average annual temperature during the period of maximum sunspot activity over those of periods of minimum sunspot activity.

$$\triangle T = \overline{T}_{\max} - \overline{T}_{\min}$$

The important feature that is brought out is the decrease of temperature, though small, at practically all stations, during periods of maximum solar activity. The mean decrease is 0·2°C.

Station	$\triangle T$ (°C)
Bikaner	—·3
Jaipur	—·1
Ajmer	—·2
Mount Abu	—·3
Rajkot	—·2
Aurangabad	—·1
Poona	—·2
Bellary	—·2
Quetta	—·2
Minusinsk	—1·6
Tashkent	—·1
Baghdad	—·2
Helwan	—·1
Khartom	+·2
Phoenix	—·2
Cardoba	—·1
Buenos Aires	—·2
O'okiep	+·2
Alice Springs	0
Mean	—·2

(*ii*) *Annual range of temperature*—The variation of R from period to period of solar activity is shown in Fig. 2. An oscillatory tendency with a period of about 2 sunspot cycle is clearly noticeable at most of the Indian stations.

*For details of the method of evaluation of the different parameters the reader may refer to the author's paper 1957 *loc. cit.*) or any text book dealing with harmonic analysis

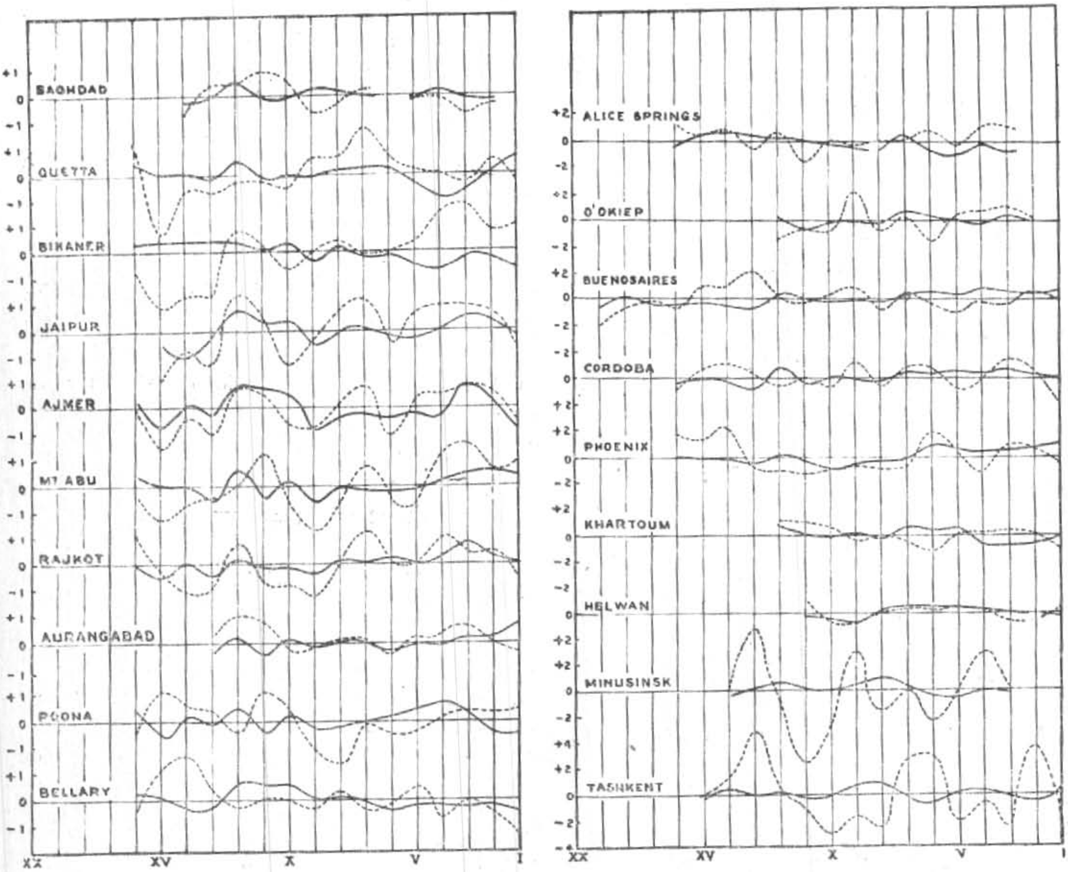

Fig. 2. Fluctuations of temperature and annual range of temperature

— Annual temperature
. . . . Annual range of temperature

The annual ranges of temperature during periods of maximum sunspot activity and those during periods of minimum sunspot activity were separated and their means worked out separately. The difference between the mean ranges are given below:

$$\triangle R = \overline{R}_{\max} - \overline{R}_{\min}$$

Station	$\triangle R$ (°C)	Station	$\triangle R$ (°C)
Bikaner	—·1	Tashkent	—·6
Jaipur	—·3	Baghdad	0
Ajmer	—·1	Helwan	+·2
Mount Abu	+·2	Khartom	—·2
Rajkot	—·4	Phoenix	—·4
Aurangabad	—·4	Cardoba	+·3
Poona	+·3	Buenos Aires	+·2
Bellary	0	O'okiep	+1·2
Quetta	—·4	Alice Springs	—·8
Minusinsk	+·6	Mean	—·1

The positive and negative departures are practically evenly distributed and the general mean works out to —·1°C.

(*iii*) *Annual oscillation*—The amplitudes of the annual wave increases generally polewards. The maximum in the wave occurs about late May at the South Indian stations but are progressively delayed with increase of latitude to about mid July in Minusinsk; Khartom (15°37′N) is an exception, where it is delayed by about one and half month for its latitude. In the southern stations the maximum occurs in the month of January.

The variation of the amplitude and the date of maximum in the annual oscillation during the different periods of solar activity are shown in Fig. 3. It is clear that during the past century there is no systematic increase or decrease in the two components of the harmonic vectors. However, fluctuations have occurred though not in exact sympathy with the fluctuations in the solar activity as represented by the sunspot numbers. At least as far as the Indian stations are concerned in as much as the fluctuations show similar characteristics at a number of stations in the region—and in fact at practically all stations except Bellary, in regard to certain significant fluctuations—we cannot treat them as random fluctuations. For example the amplitude of the annual oscillation which was a maximum at the beginning of the century declined during the next two decades and attained a minimum round about 1918. The maximum of the annual oscillation was very much delayed by about 1906 and advanced by about 15-20 days at most of the stations by about 1923. It may be remarked that in 1906, the maximum sunspot activity was the smallest on record. Again during the late thirties or early forties Poona, Aurangabad, Rajkot and Mount Abu showed a significant advance in the date of maximum in the annual wave.

To see if the amplitude and the phase angles during the years of maximum sunspot activity differed significantly from the years of minimum sunspot activity the average amplitude and the dates of maximum in the annual oscillations were calculated separately for the period of maximum solar activity as well as periods of minimum solar activity and

$$\triangle\ a_1 = \bar{a}_{1\ \max} - \bar{a}_{1\ \min}$$

$$\triangle D_1 = \overline{D}_{1\ \max} - \overline{D}_{1\ \min}$$

were calculated for all the stations and they are given below :

Station	$\triangle a_1$(°C)	$\triangle D_1$(days)
Bikaner	+·07	+2·0
Jaipur	+·31	+3·0
Ajmer	—·10	+4·0
Mount Abu	+·34	+2·7
Rajkot	+·05	+2·8
Aurangabad	—·13	+4·9
Poona	—·04	+5·3
Bellary	+·03	—0·8
Quetta	+·27	+1·6
Minusinsk	+·54	—0·8
Tashkent	—·03	+0·7
Baghdad	+·37	+0·7
Helwan	+·09	—0·2
Khartom	+·23	+3·2
Phoenix	—·10	—0·5
Cardoba	—·07	+0·4
Buenos Aires	—·13	—1·0
O'okiep	—·09	—0·4
Alice Springs	—·44	+0·3
Mean	+·06	+1·5

The differences in the amplitudes between the years of maximum and minimum solar activity though very small, there is a distinct tendency for the northern hemisphere stations under study here, to be positive with an average of $+\cdot 12$°C (10 positive and 5 negative) and the southern stations to be negative with an average of—·15°C (all negative). For all the stations the average works to $+0\cdot 06$°C.

As far as the date of occurrence of maximum $\triangle D_1$, there is a distinct tendency for practically all the Indian stations except Bellary to attain the maximum delayed by about 3·5 days during years of maximum sunspot activity. Khartom in Sudan and to some extent Quetta in Pakistan also reflect this characteristic. At the other stations the mean differences are small.

(*iv*) *Biannual oscillation*—The amplitudes of biannual wave are of the order of 2-3°C at the Indian stations as also Khartom, while at the rest of the stations they are 1°C or less. The maxima in the wave occur in the months of April and October at all the Indian stations as also Helwan in Egypt and Khartom in Sudan. At the Russian stations the variation is considerable but on the average the maxima in the wave occur in April and October. At the other stations they occur mainly in the months of March and September.

Fig. 3 shows the period to period variations of the components of the biannual harmonic vectors. It is remarkable that at practically all the Indian stations there is an oscillatory tendency with a period of about 2 sunspot cycles with the amplitude and date of maximum increasing in alternate period of high solar activity. Thus in 1906, 1928 and 1948 both the amplitude and the date of maximum wave were practically the same at all the Indian stations; a similar tendency repeating in 1962 is also seen.

The mean difference between the amplitudes and phase angles between the years of sunspot maxima and minima were also calculated.

$$\triangle a_2 = \bar{a}_{2\,\max} - \bar{a}_{2\,\min}$$

$$\triangle D_2 = \overline{D}_{2\,\max} - \overline{D}_{2\,\min}$$

Station	$\triangle a_2$(°C)	$\triangle D_2$(days)
Bikaner	+·06	+2·1
Jaipur	+·20	+0·5
Ajmer	+·29	+1·0
Mount Abu	+·08	—0·7
Rajkot	—·02	—0·3
Aurangabad	+·01	+1·3
Poona	—·03	+1·4
Bellary	+·03	+1·5
Quetta	—·14	+28·6*
Minusinsk	+·38	+16·4
Tashkent	+·03	+7·0
Baghdad	—·40	—2·6
Helwan	+·13	+3·0
Khartom	—·07	+2·3
Phoenix	—·13	—1·2
Cardoba	—·04	+2·0
Buenos Aires	+·07	+3·9
O'okiep	—·08	—4·7
Alice Springs	—·24	—10·0†
Mean	+·01	+1·6

*If the two outlying values in periods XIII and XI are ignored the value of $\triangle D_2$ works to $+7\cdot 3$

†If the outlying value in period XII is omitted the value of $\triangle D_2$ is $+6\cdot 0$

Out of the 8 Indian stations, 6 show a slight increase of amplitude as also a delaying of the date of maximum with increase of sunspot activity. The average for the Indian stations works out to $+\ 0\cdot 08$°C in amplitude and $+\ 0\cdot 9$ days in the date of maximum in the oscillation, but these however are not statistically significant.

7. Summary and conclusions

The study of the available long series of temperature data of representative stations in the arid and semi-arid regions of India as also one or two stations each in the arid

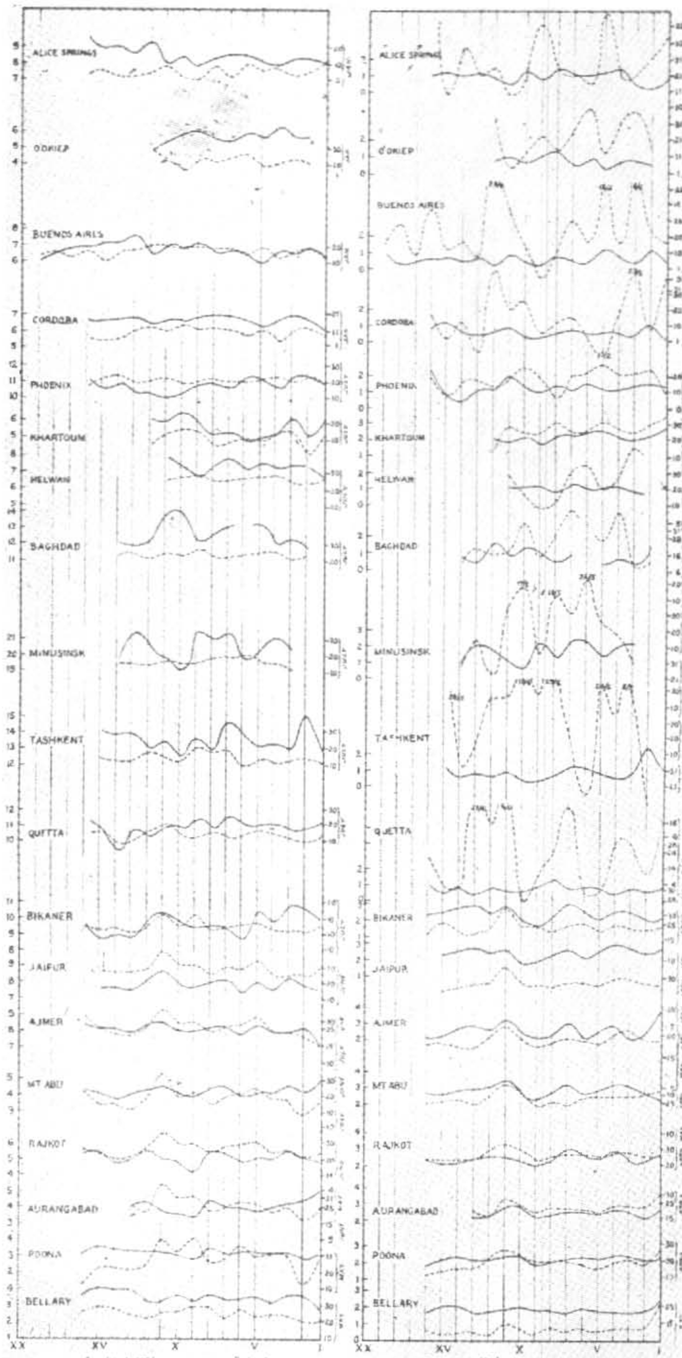

Fig. 3. Harmonic Components

or semi-arid regions of the different continents has revealed the following—

(*i*) The mean annual temperatures do not show any systematic increase or decrease but there is a slight decrease of temperature though small, at practically all stations during periods of maximum solar activity over those of minimum solar activity.

(*ii*) The annual ranges of temperature exhibit oscillatory tendency with a period of about two sunspot cycles and consequently the aggregation of periods of maximum and minimum solar activity does not show any significant difference between themselves. The variations at different stations in the same region, *e.g*, the north Indian stations show considerable agreement in phase while they get out of phase when different regions are considered. Thus it indicates that the solar fluctuations observed should be associated with the fluctuations in the subtropical high pressure centres and on the general circulation patterns.

(*iii*) The components of the harmonic vectors of the annual oscillation do exhibit significant fluctuations though not in exact sympathy with the fluctuations in the sunspots. The date of maximum in the annual wave had the largest lag in 1906 and again in 1938. There is a distinct tendency, though small, for the amplitude of the annual oscillation to increase with maximum solar activity in the northern hemisphere stations while in the southern hemisphere the reverse is true. Another interesting finding is that the peak in the annual wave, at least at the Indian stations, get delayed by about 3·5 days during years of maximum sunspot activity. It is known that the lag in the date of maxima is least in the most continental locations and increase at more maritime ones. If we extend this idea, it can be concluded that in years of maximum solar activity, the soil humidity is slightly increased due probably to slight increase of precipitation or at least to increased relative humidity. This, however, needs further study.

(*iv*) The biannual wave is significant at the Indian stations, in particular with amplitudes of the order of 2-3°C and the maxima occurring in April and October. At the other stations the amplitude is less than 1°C but the maxima systematically occur in March or April (and September or October) in most cases; at Phoenix (U.S.A.) they occur in February and August. The occurrence of the significant biannual wave over the globe in general, should in all probability be associated with the change in the atmospheric general circulation. The amplitude of the biannual wave exhibit oscillatory tendency with a period of about 2 sunspot cycles with the amplitude and date of maxima increasing in alternate periods of high solar activity.

It is well known that the variations in the solar constant occur primarily in the ultra violet increasing with increase of solar phenomena. Much evidence exists of highly erratic fluctuations in the ultra violet roughly paralleling the sunspot cycle. The marked variations in the ultra violet radiation cause large variations in temperature in the higher atmosphere. The temperature increase in the higher atmosphere is propagated downward with marked lag (Haurwitz 1946). The increase in the amplitude of the annual wave observed here is in consonance with this.

Hanzlik (1930, 1931) found important pressure changes of world wide distribution particularly during the winter. In high latitudes these pressure changes give decreasing zonal index as a major sunspot maximum commences and an increasing zonal index as a minor sunspot maximum commences. Willet (1949) further found that these alternating high and low index patterns at successive sunspot maxima, are reflected in the anomaly patterns of temperature and precipitation also.

It is known that the polarity of sunspot changes over each sunspot period and in fact the sunspot cycle has to be regarded as one with a period of about 22 years, during which the number of sunspot and their polarity are restored. The findings here point to the possibility of the biannual wave of temperature oscillations linked up with the pattern of general circulation which get differentially affected during periods of different polarity. These appear to deserve further research.

8. Acknowledgement

The facilities afforded by the Director General of Observatories, New Delhi, and the Deputy Director General of Observatories (Climatology and Geophysics), Poona, were very valuable and are gratefully acknowledged. Thanks are also due to Sarvashri M. L. Khandekar and B. H. Godbole for help in the computational work.

REFERENCES

Clayton, H. H. and Clayton, F. L.	1927	*World Weather Records*—Smithsonian Met. Collections, 79.
	1934	*Ibid.*, 90.
	1947	*Ibid.*, 105.
Hanzlik, S.	1930	*Beitr. Geophys.*, **28**, pp. 114-125.
	1931	*Ibid.*, **29**, pp. 138-155.
Haurwitz, B.	1946	*Trans. Amer. geophys. Un.*, 27-II, pp. 161-163.
Jagannathan, P.	1957	*Indian J. Met. Geophys*, **8**, 2, p. 155.
Pramanik, S. K. and Jagannathan, P.	1954	Climatic Changes in India—IUGG 10th General Assembly, *Sci. Proc. Int., Ass. Met.*, Rome.
U. S. Weather Bureau	1959	*World Weather Records and Monthly Climatic Data of the World.*
Willet, H. C.	1950	Temperature trends of the past century—*Cent · Proc. Roy. Met. Soc.*, London, pp. 195-206.
	1951	*J. Met.*, **8**, 1, pp. 1-6.
	1949	Final Report of Weather Bureau—MIT extended forecasting project in the fiscal year July 1, 1948 to June 30, 1949, Cimb. Mass.
Xauthakis, J.	1953	New relations between the mean monthly the temperatures—*Publ. Univ. Thessaloniki.*
	1955	Study of mean monthly air temperature during the successive sunspot cycles—*Ibid.*

TABLE 1

Patirculars of stations selected for study

Country / Station	Latitude	Longitude	Height	Year from which data available	Mean Temp. obtained from	Remarks
India						
Bikaner	28°00′N	73°18′E	734 ft	1877	$\frac{1}{2}$(Max + Min)	Shed 1-10-1877 to 27-3-1929; S.S. from 1-1-1926; changed in the same compound on 20-8-1937 and 1-3-1942
Jaipur	26°55′	75°50′	1431 ft	1879	Do.	Shed 1-1-1879 to 7-12-1929; and S.S. from 8-11-1925
Ajmer	26°27′	74°37′	1593 ft	1866	Do.	In jail compound 1-4-1866 to 31-12-1879; in court compound 1-1-1880 to 29-7-1927; S.S. 30-7-1927 to 10-3-1930; Commissioner's office in the same compound frcm 11-3-1930
Mount Abu	24°36′	72°43′	3945 ft	1876	Do.	1-5-1876 to April 1929; changed in the same premises and S.S. from May 1929
Rajkot	22°18′	70°50′	432 ft	1877	Do.	Shed 18-6-1877 to 27-7-1929 and S.S. from 28-7-1929
Aurangabad	19°53′	75°20′	1905 ft	1891	Do.	Shed 6-10-1891 to 1-2-1928; S.S. from 2-2-1928
Poona	18°32′	73°51′	1834 ft	1856	Do.	1856 to 19-6-1879 compound of European hospital; 20-6-1879 to 12-7-1905 Yeravada Jail; in the same premises 13-7-1905 to 5-1-1927; S.S. from 6-1-1927 to 31-10-1930; 1-11-1930 onwards in Meteorological Office, Poona
Bellary	15°09′	76°51′	1473 ft	1867	Do.	Changed in April 1885; S.S. from 4-11-1925
Pakistan						
Quetta	30°12′	67°00′	5502 ft	1878	Do.	S.S. from 26-9-1928; correction applied
U.S.S.R.						
Minusinsk	53°42′	91°42′	250·7m	1886	$\frac{1}{3}(7h+13h+21h)+e_{24}$	Upto 1931 station at 53°43′, 91°41′E, 248 m
Tashkent	41°20′	68°18′	478·3m	1881	Do.	*

*No mention in *World Weather Records* as to changes in observations

TABLE 1 (*contd*)

Country / Station	Latitude	Longitude	Height	Year from which data available	Mean Temp. obtained from	Remarks
Iraq						
Baghdad	33°20′N	44°22′E	125 ft	1887	$\frac{1}{2}$(Max+Min)	*
Egypt						
Helwan	29°52′	31°20′	115·6m	1904	$\frac{1}{4}(8h+14h+20h+N)+e_{24}$ 1906-1920 actual mean of 24 hrs	*
Sudan						
Khartom	15°37′	32°33′	390 m	1901	Do.	1901 to 1909 Military hospital 1910 to 16-1-1933 Gordon College; 17-1-1933 Stack Laboratory and new type screen installed; correction 0.0 ; 19-1-1941 to 19-5-1941 at site 15°36′N, 32°32′E and June 1941 to June 1944 at site 15°33′N, 32°29′E
U.S.A.						
Phoenix	33°28′N	112°00′W	1108 ft	1877	$\frac{1}{2}$(Max+Min)	Ht. 1879-82: 4 ft; 1895-1901 47 ft; 1902-12: 50 ft; 1913-15: 76 ft; 1916-22: 11 ft
Argentina						
Cardoba	31°25′S	64°12′W	424 m	1873	24-hr mean	At Astronomical Observatory upto 1885 and later Meteorological Observatory
Buenos Aires	34°36′S	58°22′W	25 m	1856	Do.	1st series 1856-75; 2nd: 1873-97 3rd: 1893-1902: 4th: 1901-06 and 5th: 1906 onwards. The different series were compared and reduced to uniform series
South Africa						
O'okiep	29°36′S	17°52′E	3035 ft	1900	$\frac{1}{2}$(Max+Min)	*
Australia						
Alice Springs	23°38′S	133°37′E	1926 ft	1879	Do.	S.S. position changed on 2-2-1932 to a position 2 miles distant and 25 ft lower

*No mention in *World Weather Records* as to changes in observations

TABLE 2

Mean sunspot numbers

Period	Middle year in the 3-year period	Yearly sunspot numbers			Mean number of sunspot	
		Previous year	Middle year	Next year	Minimum	Maximum
XX	1855	20·6	6·7	4·3	10·5	
XIX	1860	93·8	95·7	77·2		88·9
XVIII	1866	30·5	16·3	7·3	18·0	
XVII	1871	139·1	111·2	101·7		117·3
XVI	1878	12·3	3·4	6·0	7·2	
XV	1883	59·7	63·7	63·5		62·3
XIV	1889	6·8	6·3	7·1	6·7	
XIII	1893	73 0	84·9	78·0		78·6
XII	1901	9·5	2·7	5·0	5·7	
XI	1906	63·5	53·8	62·0		59·9
X	1912	5·7	3·6	1·4	3·6	
IX	1918	103·9	80·6	63·6		82·7
VIII	1923	14·2	5·8	16·7	12·2	
VII	1928	69·0	77·8	65·0		70·6
VI	1933	11·1	5·7	8·7	8·5	
V	1938	114·4	109·6	88·8		104·3
IV	1943	30·6	16·3	9·6	18·8	
III	1948	151·6	136·3	134·7		140·9
II	1953	31·5	13·9	4·4	16·6	
I	1958	189·8	184·6	158·7		177·7

TABLE

Mean annual temperature and
Means are given at the bottom

	Bikaner		Jaipur		Ajmer		Mount Abu	
	T	*R*	*T*	*R*	*T*	*R*	*T*	*R*
XX								
XIX								
XVIII								
XVII								
XVI	+·3	—·7			+·3	+·1	+·4	—·4
XV	+·3	—2·1	—·5	—2·0	—·7	—1·5	0	—1·3
XIV	+·4	—1·7	—1·0	—·7	+·1	—·4	0	—·7
XIII	+·4	—1·7	—·3	—1·3	—·2	—1·0	—·6	—·4
XII	+·4	+·8	+·8	+1·4	+·9	+·9	+.7	0
XI	+·1	+·3	+·3	+·6	+·8	+·6	—·5	+1·3
X	+·4	—·7	+·4	—1·3	+·6	—·6	+·2	—·6
IX	—·3	0	—·5	—·4	—·8	—·7	—·6	—1·7
VIII	+·2	+·4	0	+·8	—·3	+·2	0	—·6
VII	—·2	—·1	+·1	+1·2	—·2	+·8	—·2	+·8
VI	—·1	0	—·2	—·5	—·4	—1·1	—·2	—·6
V	—·5	+·3	+·4	+·6	—·1	+·4	—·2	—·6
IV	—·7	+1·5	0	+·9	—·3	+·5	+·1	+1·3
III	—·2	+1·8	+·5	+·9	+·9	+·8	+·5	+1·6
II	—·2	+·9	+·3	+·7	+·3	+·8	+·5	+·6
I	—·6	+1·0	—·2	—·7	—·8	—·6	+·4	+1·0
Mean	26·6	20·9	25·5	17·9	24·8	18·4	20·6	12·0

	Minusinsk		Tashkent		Baghdad		Helwan	
	T	*R*	*T*	*R*	*T*	*R*	*T*	*R*
XX								
XIX								
XVIII								
XVII								
XVI								
XV			—·4	0				
XIV	—·6	0	+·3	+1·1	—·5	—1·5		
XIII	+·1	+4·7	—·1	+3·7	—·2	+·8		
XII	+·7	—·9	+·1	+·3	+1·2	+1·0		
XI	0	—5·7	—·4	—1·2	0	+1·8	—·3	+·9
X	0	—3·0	—·1	—3·0	—·2	+1·4	—·6	—·8
IX	+·3	+2·9	+·6	—1·8	+·4	—1·3	—·7	—·8
VIII	+1·0	—1·6	+·9	—2·5	+·2	—·6	+·2	—·1
VII	+·2	—·1	—·1	+2·7	—·1	+·3	+·5	+·4
VI	—·5	—2·5	—·6	+2·9	—	—	+·5	+·2
V	—·5	0	+·2	—2·0	—·3	—·2	+·4	+·4
IV	0	+3·0	+·4	—·5	+·2	—·2	+·2	+·2
III	—·2	+·3	0	—2·5	—·2	—1·4	0	—·7
II	—	—	—·6	+3·8	—·2	—·3	—	—
I	—	—	+·3	—1·5	—	—	—·1	+·1
Mean	0·2	41·8	13·2	28·8	22.7	25·3	21·4	15·2

3
annual range of temperature
and departures against the periods

Rajkot T	Rajkot R	Aurangabad T	Aurangabad R	Poona T	Poona R	Bellary T	Bellary R	Quetta T	Quetta R
0	+1·2			+·4	—·5	+·2	—·5	+·4	+1·3
—·5	—·3			—·6	+1·1	+·1	+1·2	0	—2·3
+·1	—1·3			+·2	+·6	—·4	+1·7	0	—·6
—·4	—·9	—·4	+·3	—·1	+·4	—·4	+·4	—·2	—·7
+·2	+·8	+·2	+1·1	+·5	—·4	+·7	—·3	+·5	—·3
—·1	—·7	—·4	+·8	—·4	+1·1	+·6	0	—·2	+·3
—·1	—·8	+·1	—·3	+·2	+·4	+·6	0	—·1	—·5
—·4	—1·2	—·1	—2·0	—·3	—1·1	0	—·3	—·1	+·6
+·2	+·2	0	+·1	—·2	—1·6	+·2	+·3	+·1	+·6
+·1	+1·3	0	+·1	—·1	—·1	—·1	—·4	+·2	+1·8
+·2	0	—·3	—·4	—·5	+·2	—·4	—·2	+·2	+·6
0	+·1	—·1	+·2	—·4	+·4	—·2	+·5	—·5	+·2
+·2	+1·1	—·1	+·4	+·1	+·7	—·2	—·7	—1·0	0
+·9	+·5	+·2	+·6	+·4	+·4	—·2	0	—·7	—·3
+·3	+·5	+·2	0	+·3	—·5	—·2	—·5	+·1	+·6
+·1	—·6	+·6	—·4	+·5	—·5	—·4	—1·5	+·6	—·4
26·5	12·9	25·8	11·1	25·1	8·8	27·7	9·1	14·9	22·4

Khartom T	Khartom R	Phoenix T	Phoenix R	Cardoba T	Cardoba R	Buenos Aires T	Buenos Aires R	O'okiep T	O'okiep R	Alice Springs T	Alice Springs R
						—·7	—2·0				
						+·1	—·8				
						—·4	—·2				
		—·1	+1·7	—·3	—·9	—·3	—·8			—·3	+1·4
		—·3	+1·2	0	+·6	—·3	+·9			+·4	+·5
		—·2	+2·1	—·3	+1·0	—·5	+1·0			+·8	+·9
		—·6	—·9	—·9	+·4	—·7	+2·2			+·5	—·6
+·7	+1·0	+·1	—1·1	+·8	—·6	+·3	0	+·2	—1·6	+·4	+·8
+·1	+·8	—·4	—1·3	—·5	0	—·3	—·1	—·7	—·7	+·1	—1·5
—·1	+·5	—1·1	—1·1	0	—·8	—·2	+·3	—·3	—·7	—·1	+·1
+·1	—·4	—·7	—·7	—·1	+1·2	—·1	+·9	—·1	+2·2	—·3	—·2
—·3	—·2	—·4	—1·0	—·4	—·7	—·3	—1·0	—·2	—·7	—·6	+·1
+·7	—·5	—·3	—·7	+·4	+·7	+·3	+·3	+·7	+·2	+·5	+·2
+·3	—1·3	+1·0	+1·8	+·2	+·6	+·5	—·3	+·3	—1·7	—·6	+1·0
+·6	0	+·5	+·6	+·6	—·9	+·2	—1·0	+·1	+·4	—·9	—·2
—·8	+·2	+·4	—1·1	+·3	—·1	+·8	—·1	—·2	+·8	—·1	—1·2
—·7	+·3	+·4	+1·0	+·6	+1·3	+·4	—·3	+·3	+1·1	—·7	—1·4
—·6	+·1	+·6	+·5	+·3	+·6	+·4	+·5	—·1	+·4	—	—
—·1	—·8	+1·0	—·6	0	—2·0	+·6	0	—	—	+·9	+·4
29·2	10·8	21·1	22·4	17·1	13·8	16·4	13·8	17·6	11·9	20·9	17·7

TABLE 4

Harmonic parameters of seasonal variation of temperature

Period	a_1*	ϕ_1	D_1	a^*_2	ϕ_2	D_2†	a_1	ϕ_1	D_1	a_2	ϕ_2	D_2
			BIKANER							JAIPUR		
XX												
XIX												
XVIII												
XVII												
XVI	9·62	280° 32′	5 JUL	2·46	268° 30′	17 APR						
XV	8·77	283 21	3 ,,	2·59	252 42	25 ,,	7·66	287° 35′	28 JUN	2·34	261° 07′	21 APR
XIV	9·02	282 14	4 ,,	2·87	263 26	20 ,,	7·69	289 19	27 ,,	2·57	256 06	23 ,,
XIII	8·88	284 05	2 ,,	3·07	265 21	18 ,,	7·55	288 45	27 ,,	2·79	255 33	25 ,,
XII	9·96	279 54	6 ,,	2·65	260 26	21 ,,	8·16	286 34	29 ,,	2·48	250 33	26 ,,
XI	10·45	272 57	13 ,,	2·99	234 24	4 MAY	8·77	275 57	10 JUL	2·82	231 08	6 JUL
X	9·83	279 23	6 ,,	2·18	257 16	23 APR	7·96	284 23	2 ,,	1·93	248 18	27 APR
IX	9·40	272 57	13 ,,	1·75	257 34	23 ,,	7·73	284 44	1 ,,	1·86	253 30	25 ,,
VIII	9·52	281 48	4 ,,	2·38	262 39	20 ,,	8·01	290 05	26 JUN	2·25	255 32	24 ,,
VII	9·39	280 43	5 ,,	3·20	257 25	23 ,,	8·24	285 39	30 ,,	2·96	250 40	26 ,,
VI	8·76	278 36	7 ,,	2·70	253 36	25 ,,	7·42	286 36	29 ,,	2·19	251 27	26 ,,
V	10·55	277 48	8 ,,	2·21	263 33	20 ,,	8·09	282 11	4 JUL	2·56	254 21	24 ,,
IV	9·91	281 33	4 ,,	2·66	254 45	24 ,,	7·58	290 33	25 JUN	2·99	247 17	28 ,,
III	10·89	283 02	3 ,,	2·68	259 20	22 ,,	8·36	290 22	25 ,,	2·76	247 03	28 ,,
II	10·72	284 18	2 ,,	2·19	260 56	21 ,,	7·86	290 13	25 ,,	2·41	251 11	26 ,,
I	9·97	280 06	7 ,,	2·31	257 35	23 ,,	7·54	286 00	30 ,,	2·73	252 33	25 ,,
			AJMER						MOUNT ABU			
XX												
XIX												
XVIII												
XVII												
XVI	8·42	281° 54′	4 JUL	2·08	259° 35′	22 APR	4·31	293° 26′	22 JUN	2·61	252° 17′	25 APR
XV	8·12	289 26	26 JUN	2·20	257 47	23 ,,	4·11	301 55	14 ,,	2·48	250 11	26 ,,
XIV	8·08	292 34	23 ,,	2·74	260 54	21 ,,	3·76	301 41	14 ,,	2·84	249 40	27 ,,
XIII	7·84	293 43	22 ,,	2·87	263 25	20 ,,	4·07	304 41	11 ,,	2·87	253 37	25 ,,
XII	8·35	288 20	28 ,,	2·62	251 25	26 ,,	4·26	297 19	18 ,,	2·98	245 33	29 ,,
XI	8·59	277 59	8 JUL	3·24	234 45	4 MAY	4·51	282 39	3 JUL	3·50	228 52	7 MAY
X	8·08	286 24	30 JUN	2·60	249 13	27 APL	4·06	296 14	19 JUN	2·64	237 41	3 ,,
IX	7·97	285 09	1 JUL	2·13	258 44	22 ,,	3·89	294 47	21 ,,	2·24	255 42	24 APR
VIII	8·18	290 56	25 JUN	2·35	254 58	24 ,,	4·40	302 04	14 ,,	2·67	251 48	26 ,,
VII	8·29	288 23	28 ,,	3·11	251 47	26 ,,	4·54	297 01	19 ,,	3·20	253 57	24 ,,
VI	7·77	286 33	29 ,,	2·18	252 53	25 ,,	3·91	295 09	21 ,,	2·57	247 27	28 ,,
V	8·42	281 42	4 JUL	2·52	257 08	23 ,,	4·17	291 29	24 ,,	2·72	245 51	29 ,,
IV	7·95	290 23	25 JUN	2·87	247 52	28 ,,	4·18	297 43	18 ,,	3·21	244 03	29 ,,
III	7·90	291 29	24 ,,	2·16	241 51	1 MAY	4·64	299 10	17 ,	3·05	244 47	29 ,,
II	8·17	294 00	22 ,,	2·37	252 39	25 APR	4·24	307 24	8 ,,	2·65	243 13	30 ,,
I	7·04	300 20	15 ,,	3·77	249 33	27 ,,	4·88	299 34	16 ,,	2·77	246 35	28 ,,

*Amplitudes are given in Centigrade degrees

†The Second maximum occurs 183 days later

TABLE 4 *(contd)*

Period	a_1	ϕ_1	D_1	a_2	ϕ_2	D_2	a_1	ϕ_1	D_1	a_2	ϕ_2	D_2
			RAJKOT						AURANGABAD			
XX												
XIX												
XVIII												
XVII												
XVI	5·37	289° 25′	26 JUN	2·42	255° 28′	24 APR						
XV	5·45	292 36	23 ,,	2·09	255 08	24 ,,						
XIV	4·77	295 50	20 ,,	2·23	254 05	24 ,,						
XIII	4·88	293 40	22 ,,	2·46	255 41	24 ,,	4·03	317° 06′	28 MAY	2·13	262° 40′	20 APR
XII	5·59	289 01	27 ,,	2·57	243 43	30 ,,	4·40	324 25	22 ,,	2·18	270 0	16 ,,
XI	5·06	280 23	6 JUL	2·53	234 27	4 MAY	3·83	307 5	8 JUN	2·75	248 19	27 ,,
X	4·81	285 38	30 JUN	2·32	241 50	1 ,,	3·62	315 50	31 MAY	2·77	255 36	24 ,,
IX	4·23	287 12	29 ,,	2·03	254 50	24 APR	3·35	314 1	1 JUN	2·06	263 45	19 ,,
VIII	5·42	291 54	24 ,,	2·28	250 58	26 ,,	4·42	323 37	23 MAY	2·15	259 29	22 ,,
VII	5·37	287 44	28 ,,	3·08	249 29	27 ,,	4·01	321 6	25 ,,	2·39	260 45	21 ,,
VI	4·84	286 51	29 ,,	2·71	248 51	27 ,,	4·00	318 3	28 ,,	2·40	261 11	21 ,,
V	5·08	284 30	1 JUL	2·43	250 24	26 ,,	3·67	319 42	27 ,,	2·32	266 3	18 ,,
IV	4·96	291 57	24 JUN	2·94	247 25	28 ,,	3·99	324 17	22 ,,	2·56	255 54	23 ,,
III	5·50	290 10	23 ,,	2·30	247 03	28 ,,	4·16	320 50	25 ,,	2·34	256 45	23 ,,
II	5·04	294 46	21 ,,	2·28	250 03	26 ,,	4·37	329 22	17 ,,	1·96	258 14	22 ,,
I	4·80	291 58	24 ,,	2·65	249 45	27 ,,	4·97	321 30	25 ,,	2·49	242 52	30 ,,
			POONA						BELLARY			
XX												
XIX												
XVIII												
XVII												
XVI	3·10	330° 44′	13 MAY	1·79	277° 12′	12 APR	3·55	320° 11′	26 MAY	1·69	279° 50′	11 APR
XV	3·63	323 33	23 ,,	2·12	274 6	14 ,,	4·06	317 26	29 ,,	2·11	283 50	9 ,,
XIV	3·42	323 24	23 ,,	2·35	268 38	16 ,,	3·95	318 19	28 ,,	2·17	282 47	9 ,,
XIII	3·27	324 13	22 ,,	2·10	268 35	16 ,,	3·95	322 57	24 ,,	1·71	280 47	10 ,,
XII	3·24	322 6	24 ,,	2·11	258 52	22 ,,	3·28	324 54	22 ,,	1·75	284 33	8 ,,
XI	3·22	306 46	9 JUN	2·35	248 58	27 ,,	3·18	321 10	25 ,,	1·80	271 32	15 ,,
X	3·05	313 35	2 ,,	2·36	254 29	24 ,,	3·56	320 37	26 ,,	1·98	277 25	12 ,,
IX	2·73	305 38	10 ,,	1·80	263 25	20 ,,	3·23	317 28	29 ,,	1·79	284 45	8 ,,
VIII	3·53	320 32	26 MAY	1·91	262 18	20 ,,	3·62	311 44	29 ,,	1·82	275 13	13 ,,
VII	3·09	319 51	27 ,,	2·15	262 17	20 ,,	3·39	324 19	22 ,,	1·60	281 49	10 ,,
VI	3·25	310 25	5 JUN	2·23	266 18	18 ,,	3·32	319 58	27 ,,	1·89	277 33	12 ,,
V	3·16	315 31	31 MAY	2·10	270 41	15 ,,	3·52	323 20	23 ,,	1·70	281 57	10 ,,
IV	3·16	314 22	1 JUN	2·36	263 43	19 ,,	3·15	322 50	24 ,,	1·65	277 15	12 ,,
III	3·18	315 15	31 MAY	1·93	260 58	21 ,,	3·52	323 4	23 ,,	1·63	278 11	12 ,,
II	2·84	332 53	13 ,,	2·01	265 26	18 ,,	3·50	326 34	20 ,,	1·70	278 22	12 ,,
I	3·00	319 17	27 ,,	2·21	248 4	27 ,,	2·82	326 13	20 ,,	2·52	248 46	27 ,,

TABLE 4 *(contd)*

Period	a_1	ϕ_1	D_1	a_2	ϕ_2	D_2	a_1	ϕ_1	D_1	a_2	ϕ_2	D_2
			QUETTA						MINUSINSK			
XX												
XIX												
XVIII												
XVII												
XVI	11·27	272° 10′	14 JUL	0·95	15° 17′	21 FEB						
XV	10·53	271 29	15 ,,	0·43	53 10	2 ,,						
XIV	9·43	277 10	9 ,,	0·81	52 7	3 ,,	19·68	271° 4′	15 JUL	0·87	306° 35′	28 MAR
XIII	10·52	274 24	12 ,,	0·36	244 30	29 APR	21·37	271 47	14 ,,	2·05	275 15	13 APR
XII	10·32	270 14	16 ,,	0·73	335 40	14 MAR	20·56	271 53	14 ,,	1·81	314 42	24 MAR
XI	10·93	265 24	21 ,,	0·52	169 46	6 JUN	19·73	269 1	17 ,,	1·12	233 35	5 MAY
X	10·81	273 17	13 ,,	0·50	71 15	24 JAN	19·11	272 21	14 ,,	0·67	210 0	17 ,,
IX	11·47	273 51	12 ,,	0·83	36 5	11 FEB	21·46	271 30	15 ,,	2·29	289 56	6 APR
VIII	10·87	271 31	15 ,,	1·22	10 45	24 ,,	21·00	268 29	18 ,,	1·48	218 57	12 MAY
VII	11·53	274 5	12 ,,	0·69	316 39	23 MAR	21·38	268 36	18 ,,	2·38	241 24	1 ,,
VI	11·01	272 35	14 ,,	0·84	62 50	28 JAN	19·87	265 50	20 ,,	2·36	198 44	22 ,,
V	10·97	270 25	16 ,,	0·68	57 17	31 ,,	20·38	270 15	16 ,,	1·45	251 38	25 APR
IV	10·98	272 29	14 ,,	0·38	359 56	1 MAR	21·14	271 14	15 ,,	2·05	264 45	18 ,,
III	10·60	274 58	11 ,,	0·69	0 28	1 ,,	20.31	275 0	11 ,,	2·24	303 12	30 MAR
II	10·78	277 13	9 ,,	0·56	34 57	11 FEB						
I	11·08	269 53	16 ,,	0·67	340 18	14 MAR						
			TASHKENT						BAGHDAD			
XX												
XIX												
XVIII												
XVII												
XVI												
XV	14·04	271° 38′	14 JUL	1·18	188° 3′	28 MAY						
XIV	13·77	273 22	13 ,,	0·52	298 10	2 APR.	12·07	264° 12′	22 JUL	0·76	347° 16′	8 MAR
XIII	13·91	273 32	13 ,,	0·66	268 45	16 ,,	11·84	261 71	24 ,,	0·44	326 15	18 ,,
XII	13·07	267 44	18 ,,	0·55	213 0	15 MAY	12·19	265 34	21 ,,	1·53	333 19	15 ,,
XI	13·48	272 33	14 ,,	0·85	211 57	16 ,,	13·97	261 50	24 ,,	0·80	314 4	16 ,,
X	12·55	273 45	12 ,,	0·33	145 3	19 JUN	13·97	263 11	23 ,,	1·28	295 13	3 APR
IX	13·68	265 30	21 ,,	0·25	210 0	17 MAY	12·22	259 44	27 ,,	1·00	334 24	14 MAR
VIII	12·96	268 19	18 ,,	0·57	35 49	23 JUN	12·68	263 57	22 ,,	0·44	305 53	29 ,,
VII	14·75	267 18	19 ,,	1·22	260 27	21 APR	13·30	263 45	22 ,,	0·90	279 13	11 APR
VI	13·99	275 55	10 ,,	1·05	333 10	15 MAR	..	.. ..	..	..	.. ..	..
V	13·27	273 15	13 ,,	0·75	95 30	24 MAY	13·21	262 2	24 JUL	0·27	314 10	24 MAR
IV	13·38	274 31	12 ,,	0·36	32 18	5 ,,	12·05	261 32	25 ,,	0·64	282 18	10 APR
III	13·00	273 48	12 ,,	0·75	18 52	2 JUL	12·40	265 15	21 ,	0·23	348 21	7 MAR
II	15·08	271 41	14 ,,	2·32	343 40	9 MAR	11·76	261 18	25 ,,	1·41	342 10	10 ,,
I	12·69	274 49	11 ,,	1·08	23 41	17 FEB						

TABLE 4 (*contd*)

Period	a_1	ϕ_1	D_1	a_2	ϕ_2	D_2	a_1	ϕ_1	D_1	a_2	ϕ_2	D_2
				HELWAN					KHARTOM			
XX												
XIX												
XVIII												
XVII												
XVI												
XV												
XIV												
XIII												
XII							5·10	281° 15	5 JUL	2·09	275° 57′	13 APR
XI	7·94	261° 12′	25 JUL	1·10	245° 13′	29 APR	4·97	272 58	13 ,,	1·85	244 08	28 ,,
X	7·39	260 51	26 ,,	1·02	268 23	17 ,,	5·53	271 05	15 ,,	2·19	252 79	25 ,,
IX	6·71	258 38	28 ,,	1·15	286 6	8 ,,	4·79	272 45	13 ,,	1·69	258 41	24 ,,
VIII	7·54	262 31	24 ,,	0·81	277 7	12 ,,	4·19	280 28	6 ,,	2·22	241 43	1 MAY
VII	7·92	261 52	25 ,,	1·29	241 27	1 MAY	4·28	279 13	7 ,,	2·23	252 43	25 APR
VI	7·31	260 36	26 ,,	1·01	234 21	4 ,,	3·85	276 52	9 ,,	2·45	250 46	26 ,,
V	7·63	260 24	26 ,,	1·05	262 53	20 APR	3·91	277 51	8 ,,	2·54	241 53	1 MAY
IV	7·37	258 29	28 ,,	1·08	248 0	27 ,,	4·21	273 29	13 ,,	2·21	246 31	28 APR
III	7·48	262 28	24 ,,	0·79	214 13	15 MAY	5·25	271 12	14 ,,	2·02	253 50	25 ,,
II	..	.. ..	..	..	.. ..	..	4·12	286 15	30 JUN	2·28	242 56	30 ,,
I	7·29	259 07	27 JUL	1·27	263 45	20 APR	5·17	273 34	12 JUL	2·70	234 32	4 MAY
				PHOENIX					CARDOBA			
XX												
XIX												
XVIII												
XVII												
XVI	11·26	268° 55′	17 JUL	2·33	17° 45′	19 FEB	6·68	97° 35′	7 JAN	0·83	326° 02′	18 MAR
XV	10·61	263 28	23 ,,	0·73	39 24	8 ,,	6·68	98 21	6 ,,	1·15	357 31	2 ,,
XIV	10·91	261 54	24 ,,	0·43	24 41	16 ,,	6·72	97 18	7 ,,	0·61	338 13	12 ,,
XIII	10·38	265 54	20 ,,	1·07	24 50	17 ,,	6·87	92 51	12 ,,	0·37	14 15	22 FEB
XII	10·33	264 25	22 ,,	1·16	31 11	13 ,,	6·48	91 52	13 ,,	0·44	375 36	13 APR
XI	10·10	263 39	23 ,,	1·98	22 33	18 ,,	6·78	92 48	12 ,,	0·87	323 17	20 MAR
X	10·36	266 21	20 ,,	1·29	8 04	25 ,,	6·68	89 31	15 ,,	0·30	313 0	25 ,,
IX	10·83	264 53	21 ,,	1·00	22 37	18 ,,	6·95	93 12	11 ,,	0·29	350 10	6 ,,
VIII	10·93	263 47	22 ,,	1·39	44 52	7 ,,	7·03	92 25	12 ,,	0·57	338 41	12 ,,
VII	10·76	265 16	21 ,,	1·12	18 50	20 ,,	7·04	93 35	11 ,,	0·73	332 15	15 ,,
VI	11·31	264 47	21 ,,	1·58	11 59	23 ,,	6·77	95 07	9 ,,	0·53	359 6	2 ,,
V	11·22	263 58	22 ,,	1·19	3 36	27 ,,	6·26	92 31	12 ,,	0·62	31 20	13 FEB
IV	10·63	262 22	24 ,,	1·16	14 21	22 ,,	6·85	98 23	6 ,,	0·51	328 22	17 MAR
III	11·45	265 39	21 ,,	1·44	13 11	22 ,,	7·04	98 26	12 ,,	0·35	185 30	29 MAY
II	11·32	261 38	25 ,,	1·57	10 21	24 ,,	6·88	91 12	13 ,,	1·09	346 13	8 MAR
I	10·87	265 44	20 ,,	1·29	39 39	9 ,,	6·09	95 03	9 ,,	0·21	281 35	10 APR

TABLE 4 (*contd*)

Period	a_1	ϕ_1	D_1	a_2	ϕ_2	D_2	a_1	ϕ_1	D_1	a_2	ϕ_2	D_2
			BUENOS AIRES							O'OKIEP		
XX												
XIX	6·20	90° 49′	14 JAN	0·92	28° 12′	15 FEB						
XVIII	6·67	88 19	16 ,,	0·26	3 40	27 ,,						
XVII	6·90	90 16	14 ,,	0·44	41 18	8 ,,						
XVI	6·95	87 21	17 ,,	0·55	346 49	8 MAR						
XV	7·23	93 30	11 ,,	0·61	34 4	12 FEB						
XIV	7·29	87 14	17 ,,	0·47	26 28	16 ,,						
XIII	7·66	80 51	18 ,	0·78	43 54	7 ,,						
XII	6·51	83 26	21 ,,	0·18	136 6	23 JUN	4·93	75° 7′	29 JAN	0·71	291° 47′	5 APR
XI	7·13	84 30	20 ,,	0·82	349 29	7 MAR	5·37	81 54	23 ,,	0·97	353 25	.4 MAR
X	6·98	85 0	20 ,,	0·45	30 0	14 FEB	5·92	87 55	17 ,,	0·64	336 30	13 ,,
IX	7·21	84 31	20 ,,	0·20	64 43	27 JAN	6·08	81 16	23 ,,	1·09	316 27	23 ,,
VIII	6·75	85 19	19 ,,	0·76	35 26	11 FEB	5·63	81 41	23 ,,	1·28	332 53	15 ,,
VII	6·82	86 2	19 ,,	0·48	359 0	2 MAR	5·46	80 44	24 ,,	0·48	309 27	27 ,,
VI	6·49	89 55	15 ,,	0·38	23 25	17 FEB	6·00	77 59	27 ,,	0·88	281 35	10 APR
V	6·01	84 9	20 ,,	1·28	157 26	12 JUN	5·74	84 18	20 ,,	0·19	337 14	13 MAR
IV	6·84	90 58	14 ,,	0·72	25 24	16 FEB	6·44	83 15	21 ,,	0·63	300 0	1 APR
III	6·70	87 17	17 ,,	0·32	150 0	16 JUN	5·81	80 40	24 ,,	0·66	287 39	9 ,,
II	6·97	85 40	19 ,,	1·19	10 6	24 FEB	5·78	82 32	22 ,,	0·44	333 8	15 MAR
I	6·25	91 33	13 ,,	0·33	25 3	16 ,,						
			ALICE SPRINGS									
XX												
XIX												
XVIII												
XVII												
XVI	9·77	100° 37′	3 JAN	0·98	94° 13′	14 JUL						
XV	8·96	97 10	7 ,,	1·19	343 35	10 MAR						
XIV	9·07	101 9	2 ,,	1·03	287 36	7 APR						
XIII	8·66	102 22	2 ,,	1·16	317 59	22 MAR						
XII	9·33	100 39	4	0·82	312 49	25 ,,						
XI	8·03	95 0	9 ,,	0·42	345 25	9 ,,						
X	8·51	102 55	2 ,,	1·23	321 23	21 ,,						
IX	7·94	103 4	1 ,,	0·79	260 7	21 APR						
VIII	8·51	95 29	9 ,,	1·43	312 6	25 MAR						
VII	8·62	100 53	3 ,,	1·15	319 59	21 ,,						
VI	8·62	94 0	10 ,,	1·01	330 54	16 ,,						
V	8·24	97 45	7 ,,	1·13	247 48	28 APR						
IV	8·98	96 23	8 ,,	1·37	324 37	19 MAR						
III	8·46	100 29	4 ,,	0·41	319 51	22 ,,						
II	..	.. ..	..	..	..	..						
I	8·18	91 35	13 ,,	0 88	293 39	4 APR						