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RESEARCH ESTABLISHMENT
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SELECTED CLIMATOLOGICAL DATA FROM LUCAS HEIGHTS 1958-1966

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E. CHARASH
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ABSTRACT

Routine meteorological observations at Lucas Heights during the years 1958 to 1966 are summarized and presented according to standard meteorological practice. Temperatures and pressure variations are given in the form of averages, extremes and frequency distributions for each season. Surface winds are shown on wind roses. Totals and/or averages of rainfall, days with rain, cloudiness and evaporation for each month are included. Some special meteorological data, such as observations of sea breezes and inversions, are also presented.

PREFACE

This report has been prepared to meet the requirements of workers who need specific local climatological data in research and operations at the A.A.E.C. Research Establishment, and it is to serve as a source book for the kind of information which is likely to be required.

Amendments to this report will be made as the occasion arises, and the authors welcome suggestions from potential users.

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CONTENTS (Continued)

1. INTRODUCTION

Meteorological observations were started at Lucas Heights in March 1958. The observations include:

(a) Dry-bulb and wet-bulb temperature in the screen .

(b) Maximum and minimum temperatures in the screen.

(c) Terrestrial minimum temperature.

(d) Barometric pressure.

(e) Surface wind velocity.

(f) Rainfall.

(g) Cloud.

(h) General weather conditions.

Other observations were initiated at later dates:

(i) Evaporation measurements (since September 1962).

(j) Vertical temperature gradients (since January 1964).

All observed data except vertical temperature gradients are obtained twice daily at 0900 hours and 1500 hours Eastern Standard Time. Vertical temperature gradients are obtained from a continuous record.

The climatological data presented in this report are representative for the nine-year period from 1958 to 1966 with the exception of the evaporation data which cover only four years from 1963 to 1966 and the vertical temperature gradient data which cover three years from 1964 to 1966.

Although a three to four year period is too short for statistical significance these data have been included in view of their particular interest to some users of this report.

2. TEMPERATURES

2.1 Surface Temperatures

Surface temperatures (screen temperatures) are representative for ambient conditions at a height of four feet above ground and inside a louvred instrument screen. Terrestrial minimum temperatures are representative for conditions in the open over a grassy plot at the height of grass tips.

2.1.1 Averages and extremes

Monthly averages of dry-bulb temperatures together with the dew point temperatures and relative humidities at 0900 and 1500 hours E.S.T. are presented in Table 1. A feature of the monthly average temperatures is the large diurnal variation during the winter months as compared with the diurnal variation in the summer months.

The dew points do not exhibit any systematic variation during the day, and remain reasonably constant from 0900 to 1500 hours. Conversely the relative humidity decreases systematically between morning and afternoon except in December when sea breezes prevail.

Monthly averages of screen maximum and minimum temperatures and terrestrial minimum temperatures, together with the observed extremes of these observations are presented in Table 2. The range of temperatures in early autumn and winter is considerably smaller than during other months of the year.

2.1.2 Probability distribution of temperatures

The distribution of temperatures in each season is nearly normal and it is therefore conveniently presented on probability paper (Figure 1).

The standard deviation of temperatures in winter is smaller than in summer, and it is also smaller at 0900 hours than at 1500 hours in each season.

2.1.3 Degree days

The degree day is a measure of the depression of the daily mean temperature below 65°F. It is commonly used as an indicator for the amount of fuel consumed by artificial heating of buildings. Thus if the mean temperature on a particular day is 65°F or more the degree day number is zero and no artificial heating is required. If the daily mean temperature drops below 65°F however, then the fuel consumed to maintain an inside temperature of 70°F varies almost directly with the degree day number. The average degree day totals for each month are presented in Table 3.

2.2 Vertical Gradient of Temperature

Air temperature usually decreases with height. This vertical temperature gradient is on the average 0.6 or 0.7°C per 100 metres in the atmosphere above a few hundred metres from the surface. In the atmosphere near the surface, that is, in the first 100 metres, the vertical gradient is subject to great variations as a result of radiation from the sun, commonly referred to as insolation.

During the daytime the surface of the earth absorbs a large fraction of the short-wave radiation from the sun and as the temperature of the ground increases, the temperature of the air near the ground increases. In these circumstances a vertical temperature gradient two or three times the average value is not uncommon.

During the night however, the surface of the earth receives no insolation, and when the sky is clear the ground cools as a result of long-wave radiation from the earth. The temperature of the air in contact with the ground decreases and this cooling may be sufficient to produce an inversion near the surface, that is, a condition where the temperature increases with height.

Inversions may be caused by other factors, but nearly all inversions observed at Lucas Heights arise in the above way.

2.2.1 Inversions

Temperature differences between 20 and 60 feet, 20 and 100 feet, 20 and 160 feet are measured by means of three pairs of Weston type W55/3 hydrogen-filled platinum resistance thermometers which have a time constant of about 1 minute. Each thermometer is mounted in a heat-reflecting housing and is artificially ventilated by an airstream of about 1.2 m sec^{-1}. A reference temperature is measured by means of a similar unit at the 160 feet level.

In this report an inversion indicates an overall increase of temperature from 20 feet to 160 feet. Temperature profiles taking into account the temperatures at the intermediate levels have not been analysed.

Times of occurrence and peak values of inversions are presented in Figure 2 and Table 4. Inversions occur on 80 per cent of the nights in a year and on the average commence 2 hours 14 minutes after sunset, reach their peak about eight and a half hours after sunset and terminate 25 minutes after sunrise. The average increase of temperature between 20 feet and 160 feet is 2.2°C.

3. BAROMETRIC PRESSURE

3.1 Pressure Corrections

Barometric pressure observations in millibar units are obtained from an M.O. Kew-Pattern station barometer. The observed reading is corrected for the expansion of the mercury and scale due to temperature. A further correction is applied to take account of the latitude variation in gravitational acceleration. The standard conditions for true pressure are a temperature of 0°C and a gravitational acceleration of 980.62 cm sec^{-2}.

3.2 Barometric Pressure Variation

Barometric pressure is observed to follow an approximately systematic daily variation which is usually characterized by two minima occurring near 0400 hours and 1600 hours, and two maxima occurring near 1000 hours and 2000 hours local time. This daily variation is usually masked by larger irregular variations of pressure, which are associated with the changing large-scale synoptic pressure patterns. However in low and middle latitudes this daily cycle is quite apparent and it is commonly referred to as the diurnal variation of pressure.

One of the causes of the diurnal variation of pressure is the alternate heating and cooling of the air by the sun during the day and by terrestrial radiation at night.

The full cycle of the diurnal pressure variation at Lucas Heights is not available as readings are taken only at 0900 hours and 1500 hours. The average pressure variation from 0900 hours to 1500 hours is 2.2 mb. The monthly average of the pressure variation goes through two cycles with a major maximum and minimum in spring and summer respectively, and a minor maximum and minimum in autumn and winter respectively. The annual course of the pressure variation and the frequency distribution are presented in Figures 3 and 4 respectively.

4. SURFACE WIND

The speed of the surface wind is obtained from an anemometer and is an approximate average over a 10-minute interval. Wind directions are specified by sixteen compass points and are estimates of 10-minute averages, obtained either by direct observations or from a vane.

4.1 Wind Roses

The estimates of wind direction contain a bias in favour of the major compass points and this has been removed by the method outlined by Ratner (1950). The resulting distribution of wind velocities in each season is presented in the form of wind roses (Figures 5a, b, c). The length of the line drawn in any direction is proportional to the frequency of the wind from that direction. Lines of different thicknesses are used to indicate different wind speeds.

It can be seen from the wind roses that prevailing winds shift from westerly directions in the morning to easterly directions in the afternoon. North-easterly winds in particular occur with considerably higher frequency in the afternoon than in the morning in all seasons except winter, and this is attributable to the development of sea breezes.

Another feature is that most strong winds blow from southerly and westerly directions.

Wind roses for 2100 hours and 0300 hours are presented in Figure 6, but serve merely as a rough indication of conditions at these hours. They are based on data extracted from the autographic record of a Dines Anemometer over a period of two years.

4.2 Daily Maxima of Wind Gusts

The speeds of the maximum gusts recorded each day have been summarized for each season, and are presented in the form of wind roses in Figures 7a and 7b. The highest maxima and the highest frequency of gusts occur from southerly directions. These gusts reach 63 knots whereas gusts from the north-east which are associated with sea breezes rarely exceed 21 knots. Gusts from southerly directions are observed in all seasons, whereas gusts from the north-east are not observed in winter.

4.3 Sea breezes

In coastal areas, especially in low and middle latitudes, one observes daily the reversal of offshore and onshore winds, called land and sea breezes.

The sea breeze develops, depending on location and season, a short time after sunrise particularly on summer days, when the wind is light and the sky is clear. It continues throughout the day and dies down around sunset. After that the seaward blowing land breeze appears. This phenomenon is due to the difference in the rate of heating between land and water surfaces leading to a thermal gradient between land and sea in a shallow layer of the atmosphere near the ground. A pressure gradient between land and sea is thus established which can be sufficient to affect the flow of air. The sea breeze which is generally stronger than the land breeze is felt up to 25 miles from the coast. The land breeze usually affects only a strip a few miles wide near the coastline.

Land breezes are not observed at Lucas Heights, but sea breezes are frequent. They start with a marked shift in wind direction from the prevailing direction to a north-easterly direction, generally accompanied by an increasing wind speed. The temperature drops slightly and in many cases the relative humidity increases markedly at the same time. Sea breezes in winter are rare and are about half as strong as and approximately one and a half hours later than in summer.

The average time of onset, the frequency and the strength of sea breezes in each season are given in Table 5.

5. RAINFALL

Rainfall totals and raindays (number of days with rainfall) per year are presented in Table 6. The highest 24-hour rainfall recorded in each month is given in Table 7. Monthly totals, average monthly rainfalls and average raindays per month are presented in Figure 8.

The monthly rainfall is less variable in summer than in other seasons. September rainfall is outstanding for its small variability and small average.

6. MISCELLANEOUS

6.1 Cloudiness

Monthly averages of total amounts of cloud at 0900 hours and 1500 hours are presented in Figure 9. Total amount of cloud refers to cloud cover irrespective of type or level of cloud.

Maximum cloudiness occurs in Summer, and between 0900 hours and 1500 hours in the months November to March the cloudiness decreases; during the same period in all other months it increases.

6.2 Evaporation

Evaporation measurements are obtained from a Piché evaporimeter. This instrument consists of a long narrow glass tube, graduated in millilitres, one end of which is ground flat. The flat end is covered with a circular filter paper held in position by means of a small disc and metal clip. The tube is filled with distilled water, closed with the filter paper and hung up in an inverted position in the instrument screen. Water soaks the filter and evaporates from it.

Observations on this type of evaporimeter may be used for comparisons of evaporation at different times at a given place. It is very sensitive to air speed, and in making comparisons between similar measurements in different places it must be assured that similar exposures have been used. No simple relationship exists between evaporation from a Piché evaporimeter and evaporation and transpiration over grassland and other specified surfaces.

Monthly averages of hourly rates of evaporation during the period 0900 to 1500 hours and 1500 to 0900 hours and average 24-hour evaporation during each month are given in Table 12. The annual variation is marked, with a minimum in winter and a maximum in summer. The rate of evaporation in the evening and night hours is on the average about half as great as in the morning hours.

7. ACKNOWLEDGEMENTS

Mr. B. G. O'Brien assisted in the processing of data used in this report.

8. REFERENCES

Ratner, B. (1950). - A Method for Eliminating Directional Bias in Wind Roses, Monthly Weather Review, 78 : 10.

APPENDIX

EXPLANATIONS OF METEOROLOGICAL TERMS AND METHODS

Dry-bulb temperature

Dry-bulb temperature is recorded by means of an ordinary (mercury-in-glass) thermometer.

Wet-bulb temperature

Wet-bulb temperature is obtained from an ordinary thermometer, with the bulb covered by a sheath of muslin kept moist by means of an attached wick dipping into a reservoir of water.

Maximum temperature

Maximum temperature is the highest reading recorded during the 24-hour period from 0900 hours to 0900 hours. The thermometer (mercury-in-glass) used for this purpose is so constructed that the expanding mercury passes from the bulb through a constriction into the tube. The constriction acts as a valve, and as the temperature falls only the portion of mercury below the constriction recedes into the bulb; the column of mercury remaining in the stem thus indicates the highest point to which the temperature has risen since the column was unbroken.

Minimum temperature

The minimum temperature is recorded by means of an alcohol-in-glass thermometer. A coloured glass index is situated in the stem of the thermometer, immersed in the alcohol. The index can move freely within the alcohol and will not emerge readily from it owing to surface tension. When the index is situated at the top of the column of alcohol and the alcohol contracts with decreasing temperature, the surface tension of the alcohol carries the index down the tube towards the bulb. As the index remains stationary when the alcohol expands again the lowest temperature which has been reached will be indicated by the index. The thermometer is in a position slightly tilted from horizontal with the bulb at the lower end, when exposed for operation.

Terrestrial minimum temperature

The terrestrial minimum temperature indicates the minimum temperature of the air near the surface of the ground. This temperature is recorded by means of a minimum thermometer, which has been described above. The thermometer is exposed only during night hours, unsheltered and within a few inches of the ground

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in a grassy plot, and it is read at 0900 hours.

Dew point

The dew point of a sample of air is the temperature to which the air must be cooled at constant pressure and constant water vapour content in order to become saturated. The dew point is a single-valued function of the amount of water vapour per unit volume, and any process changing the amount of water vapour per unit volume changes the dew point. Thus the dew point of a sample of air is not conservative for evaporation and condensation, nor for turbulent mixing with air of different water vapour content. It is conservative for radiational heating or cooling to the point of saturation, or for turbulent mixing when the mixing masses of air differ only in temperature.

Relative humidity

Relative humidity is defined as the ratio, expressed as a percentage, of the actual vapour pressure to the saturation vapour pressure at the same temperature. Since the saturation vapour pressure is a function of temperature and the actual vapour pressure may undergo changes as a result of evaporation and of turbulent mixing processes, it follows that the relative humidity varies with radiation evaporation, condensation, pressure change and turbulent mixing.

Millibar

The millibar is the unit of barometric pressure generally used in meteorology and it is equal to 10^3 dynes cm^{-2}. Other units of barometric pressure frequently used are millimetres and inches of mercury. The various units are related as follows:

1,000 millibars = 750 mm of mercury = 29.53 in. of mercury .

TABLE 1

MONTHLY AVERAGES OF TEMPERATURE, DEW POINT AND RELATIVE HUMIDITY AT 0900 AND 1500 HOURS (E.S.T.)

	Temperature (°F)			Dew Point (°F)		Relative Humidity (%)		
	0900	1500	Diurnal Variation	0900	1500	0900	1500	Lowest
January	72.8	75.1	2.3	58	60	62	57	9
February	71.1	74.7	3.6	61	60	68	60	17
March	69.4	73.6	4.2	59	59	70	59	20
April	64.3	68.7	4.4	55	53	70	60	21
May	57.5	63.8	6.3	48	46	71	56	25
June	53.2	59.2	6.0	45	47	75	63	17
July	51.2	58.4	7.2	42	41	69	53	11
August	53.7	59.8	6.1	41	41	67	53	8
September	58.4	63.9	5.2	46	44	65	52	5
October	62.9	66.3	3.4	50	51	66	57	10
November	67.9	70.5	2.6	54	53	54	53	14
December	69.4	72.1	2.7	57	59	57	59	11

TABLE 2

SCREEN MAXIMUM, SCREEN MINIMUM AND TERRESTRIAL MINIMUM TEMPERATURES (°F)

	Averages				Extremes						Range
	Screen			Terrestrial	Screen				Terrestrial		Extreme Max. to Extreme Min.
	Max.	Min.	Mean*	Min.	Max.	Year	Min.	Year	Min.	Year	
January	77.9	62.8	70.4	59.1	107.0	1960	51.7	1966	42.5	1965	55.3
February	78.3	62.9	70.6	59.4	99.5	1965	51.9	1964	46.5	1964	47.6
March	76.5	61.1	68.8	56.4	104.0	1965	49.0	1961	33.0	1958	55.0
April	70.8	56.3	63.6	52.2	87.3	1966	45.9	1966	38.0	1964	41.4
May	65.6	50.1	57.9	46.1	79.4	1965	40.8	1963	32.0	1964	38.6
June	60.9	46.3	53.6	42.5	74.0	1958	35.3	1966	28.8	1964	38.7
July	59.8	44.6	52.2	40.1	75.0	1960	35.0	1966	29.3	1964	40.0
August	61.9	45.5	53.7	41.1	80.0	1962	34.8	1964	28.4	1964	45.2
September	66.3	49.1	57.7	45.0	94.0	1965	39.0	1958	32.4	1964	55.0
October	70.3	53.2	61.8	49.2	97.0	1958	42.0	1966	35.0	1964	55.0
November	74.7	57.6	66.2	54.1	101.5	1964	46.0	1964	40.0	1966	55.5
December	75.9	60.1	68.0	56.8	99.2	1965	47.0	1960	40.2	1964	52.5
Yearly Average	69.9	54.1	62.0	50.2							

$$* \quad \text{Mean} = \frac{\text{Max.} + \text{Min.}}{2}$$

TABLE 3

AVERAGE DEGREE DAY TOTALS PER MONTH

January	6
February	4
March	16
April	71
May	222
June	308
July	396
August	353
September	217
October	135
November	65
December	28

TABLE 4

AVERAGED DATA ON INVERSIONS AT LUCAS HEIGHTS

	Number of Inversions	Duration of Inversions (hours)	Total Duration of Breaks (hours)
January	21	6.4	1.2
February	20	7.3	0.6
March	24	9.2	1.5
April	24	10.7	0.6
May	27	13.4	2.1
June	27	14.0	0.2
July	27	12.3	0.9
August	29	12.1	0.9
September	26	10.3	1.9
October	24	9.7	1.2
November	21	7.5	0.8
December	21	7.0	1.1
Mean	24.25	10.0	1.1

TABLE 5

AVERAGED DATA ON SEA BREEZES AT LUCAS HEIGHTS

	Time of Onset (hours E.S.T.)	Time After Sunrise	Number	Wind Speed (knots)	
				Before	After
Dec. - Feb.	1251	7 h 50 min	27	4.5	8.4
March - May	1358	7 h 50 min	24	4.2	7.3
June - Aug.	1424	7 h 24 min	12	4.0	4.4
Sept. - Nov.	1344	8 h 15 min	18	5.1	7.1
Year	1344	7 h 50 min		4.5	6.8

TABLE 6

RAINFALL AND RAINDAYS PER YEAR

Year	Rainfall (points)	Raindays
1958	3434	98
1959	4907	124
1960	4072	135
1961	4989	126
1962	4206	147
1963	7101	167
1964	3784	105
1965	2534	115
1966	3383	112
Average Annual	4268	127

TABLE 7

MAXIMUM 24-HOUR RAINFALL FOR EACH MONTH

Month	Rainfall (points)	Day and Year
January	400	16 - 1963
February	443	19 - 1959
March	398	10 - 1958
April	371	29 - 1963
May	540	14 - 1962
June	478	12 - 1964
July	478	21 - 1959
August	669	30 - 1963
September	98	18 - 1962
October	314	6 - 1959
November	516	19 - 1961
December	370	6 - 1959

TABLE 8

AVERAGED EVAPORATION RATES AND TOTAL EVAPORATION

	0900 hours to 1500 hours (ml/hour)	1500 hours to 0900 hours (ml/hour)	Daily Total (ml/day)
January	0.20	0.09	2.8
February	0.20	0.08	2.7
March	0.20	0.09	2.9
April	0.17	0.08	2.5
May	0.13	0.07	2.1
June	0.12	0.06	1.8
July	0.17	0.08	2.5
August	0.15	0.08	2.3
September	0.20	0.10	2.9
October	0.18	0.08	2.5
November	0.22	0.10	2.9
December	0.20	0.09	2.8
Total			30.8
Average	0.17	0.08	
Extremes and Date	0.92 16-11-65	0.36 6/7-3-65	11.4 16/17-11-65

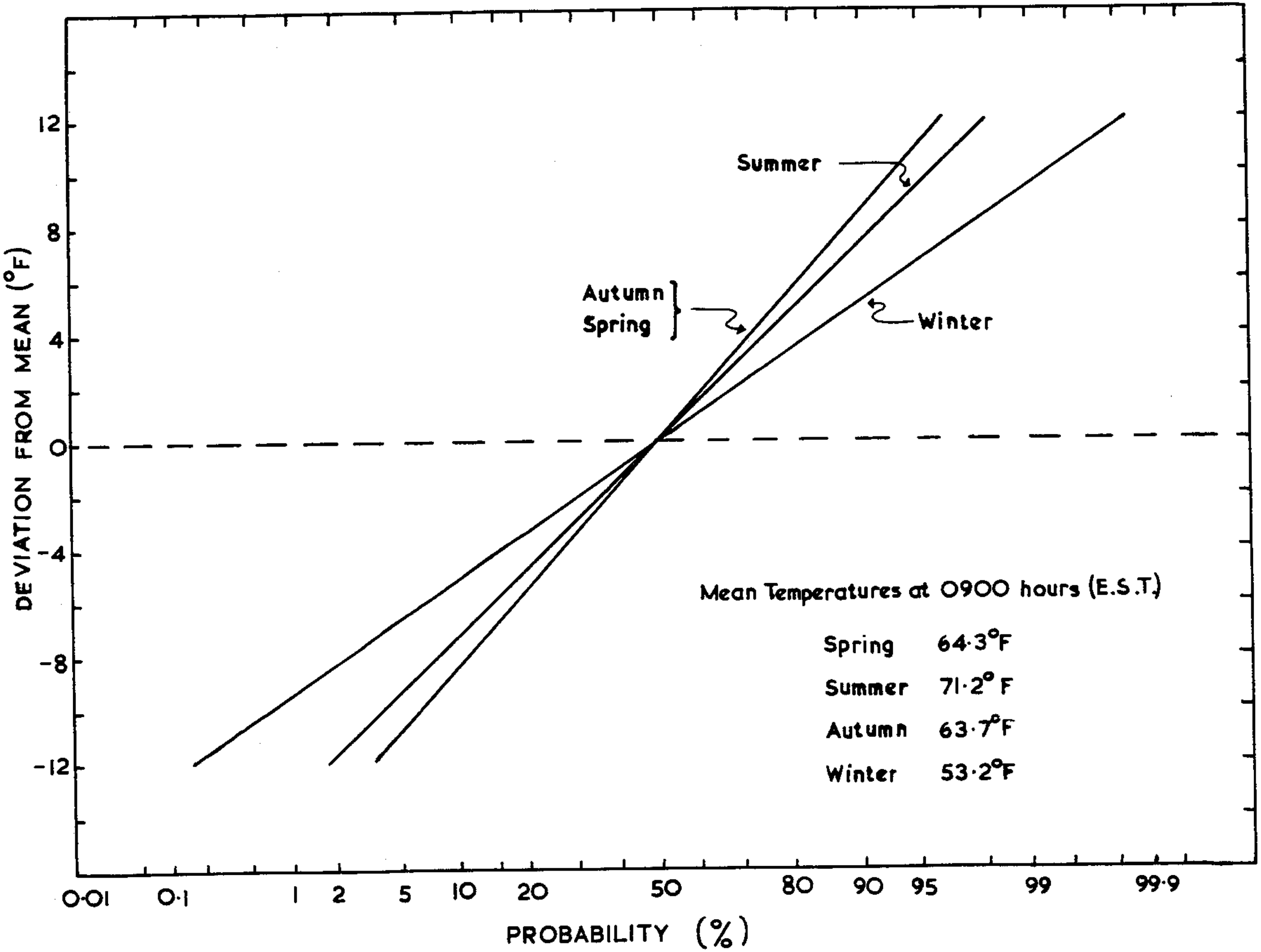


FIGURE 1a. TEMPERATURE VARIATION PROBABILITIES AT 0900 HOURS (E.S.T.)

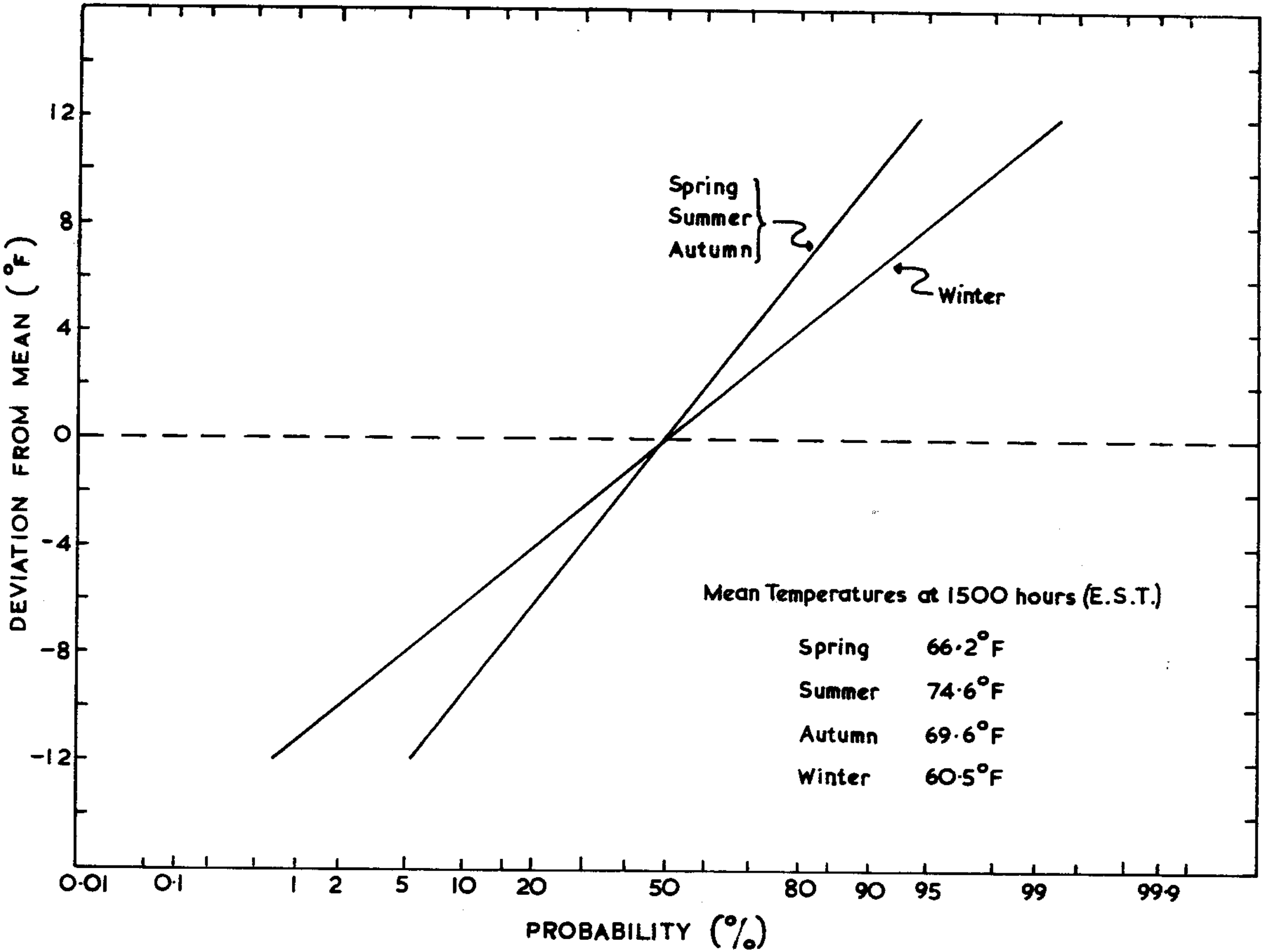


FIGURE 1b. TEMPERATURE VARIATION PROBABILITIES AT 1500 HOURS (E.S.T.)

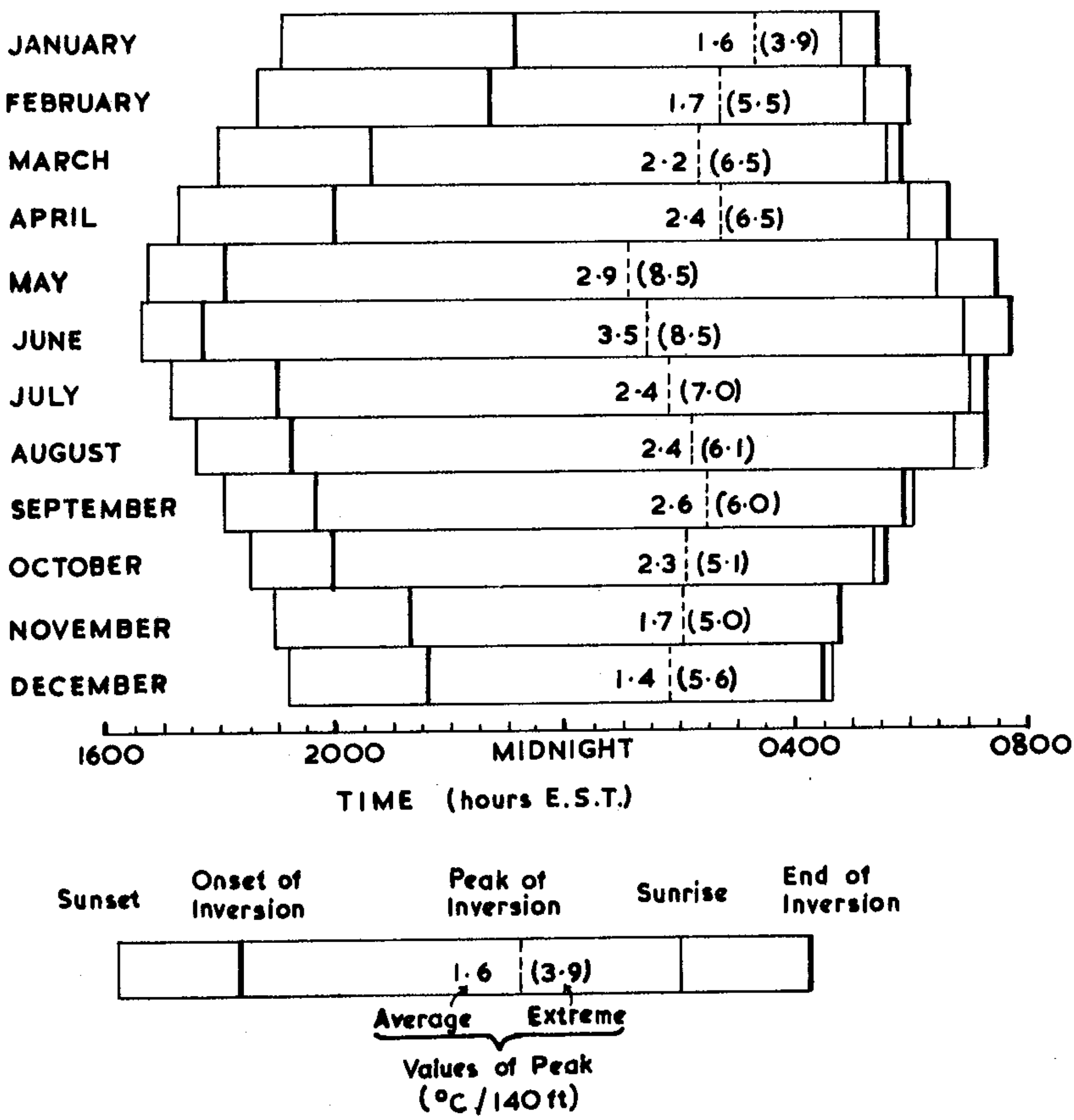


FIGURE 2. MONTHLY AVERAGES OF TIMES OF OCCURRENCE OF INVERSIONS

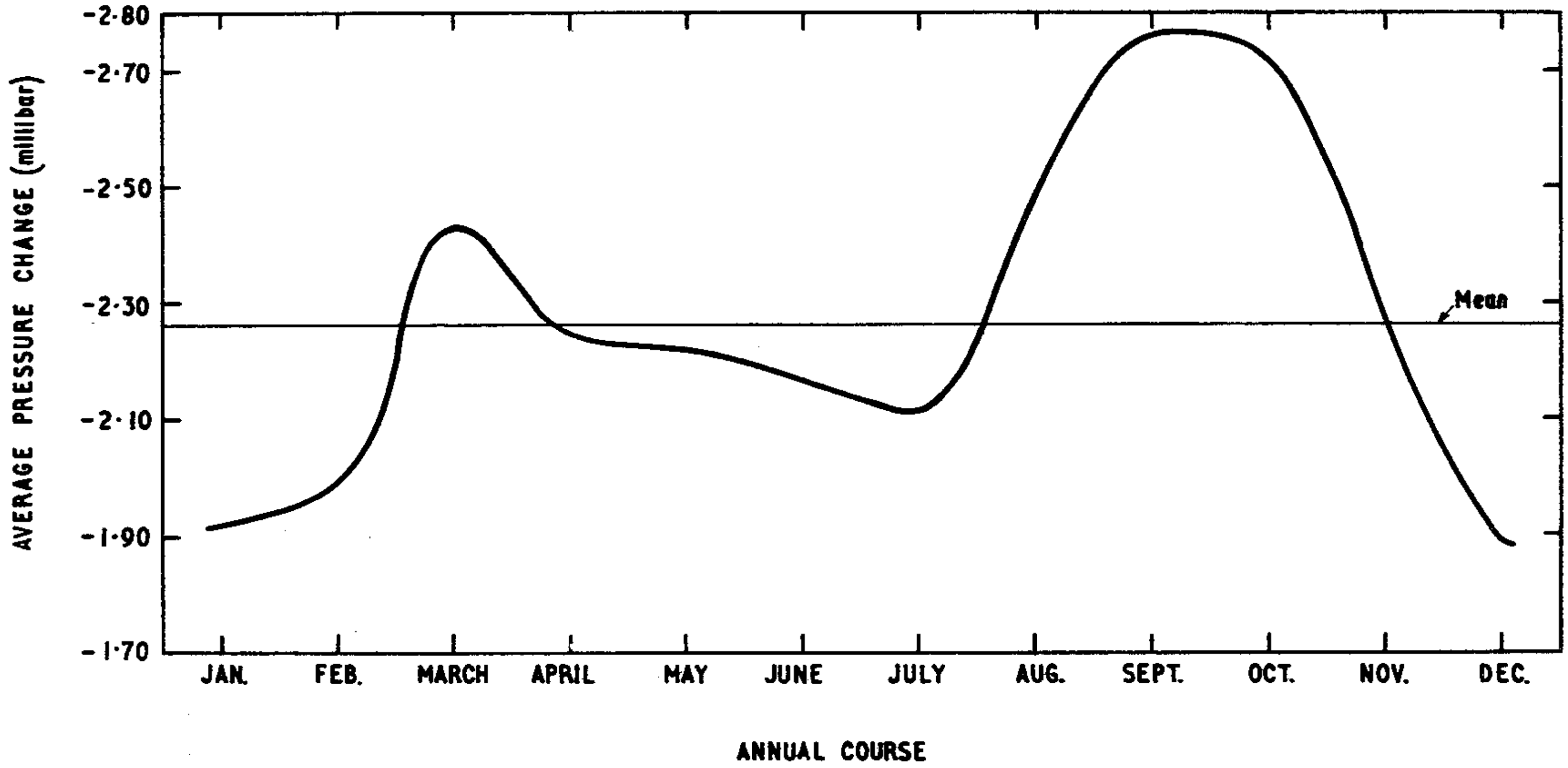


FIGURE 3. AVERAGE CHANGE IN BAROMETRIC PRESSURE BETWEEN 0900 AND 1500 HOURS (E.S.T.)

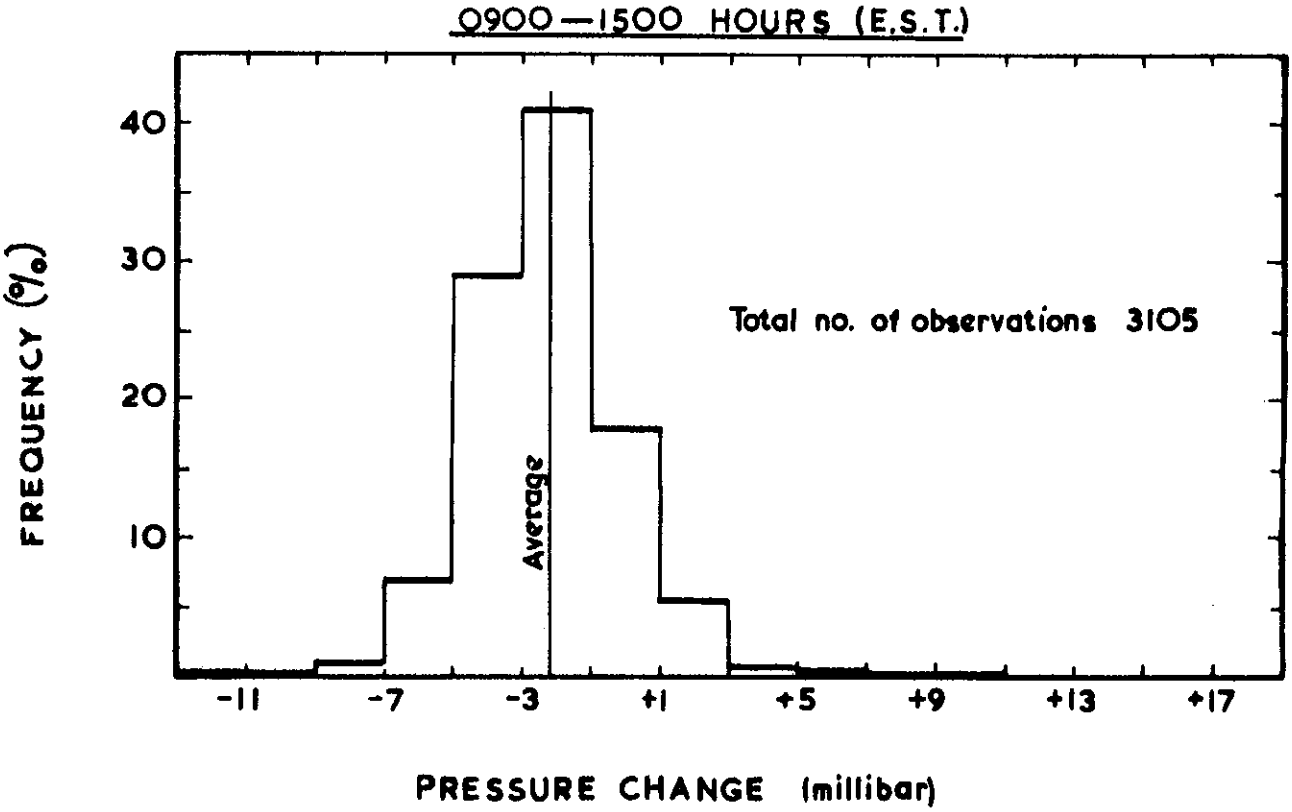


FIGURE 4a. AVERAGE CHANGE IN BAROMETRIC PRESSURE BETWEEN 0900 AND 1500 HOURS (E.S.T.) - FREQUENCY DISTRIBUTION

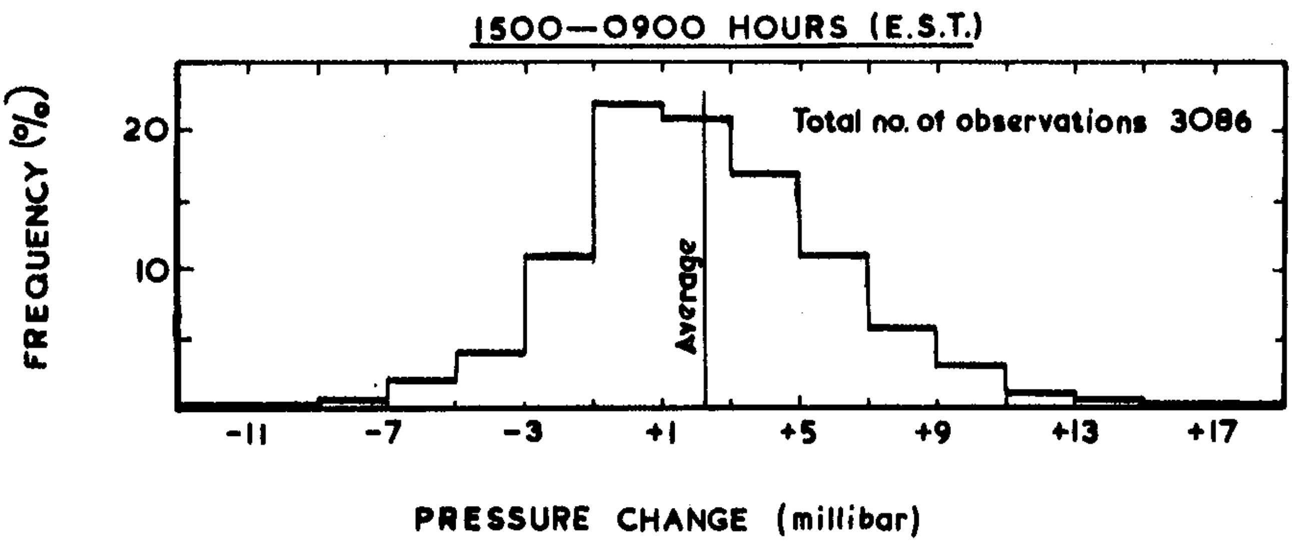


FIGURE 4b. AVERAGE CHANGE IN BAROMETRIC PRESSURE BETWEEN 1500 AND 0900 HOURS (E.S.T.)- FREQUENCY DISTRIBUTION

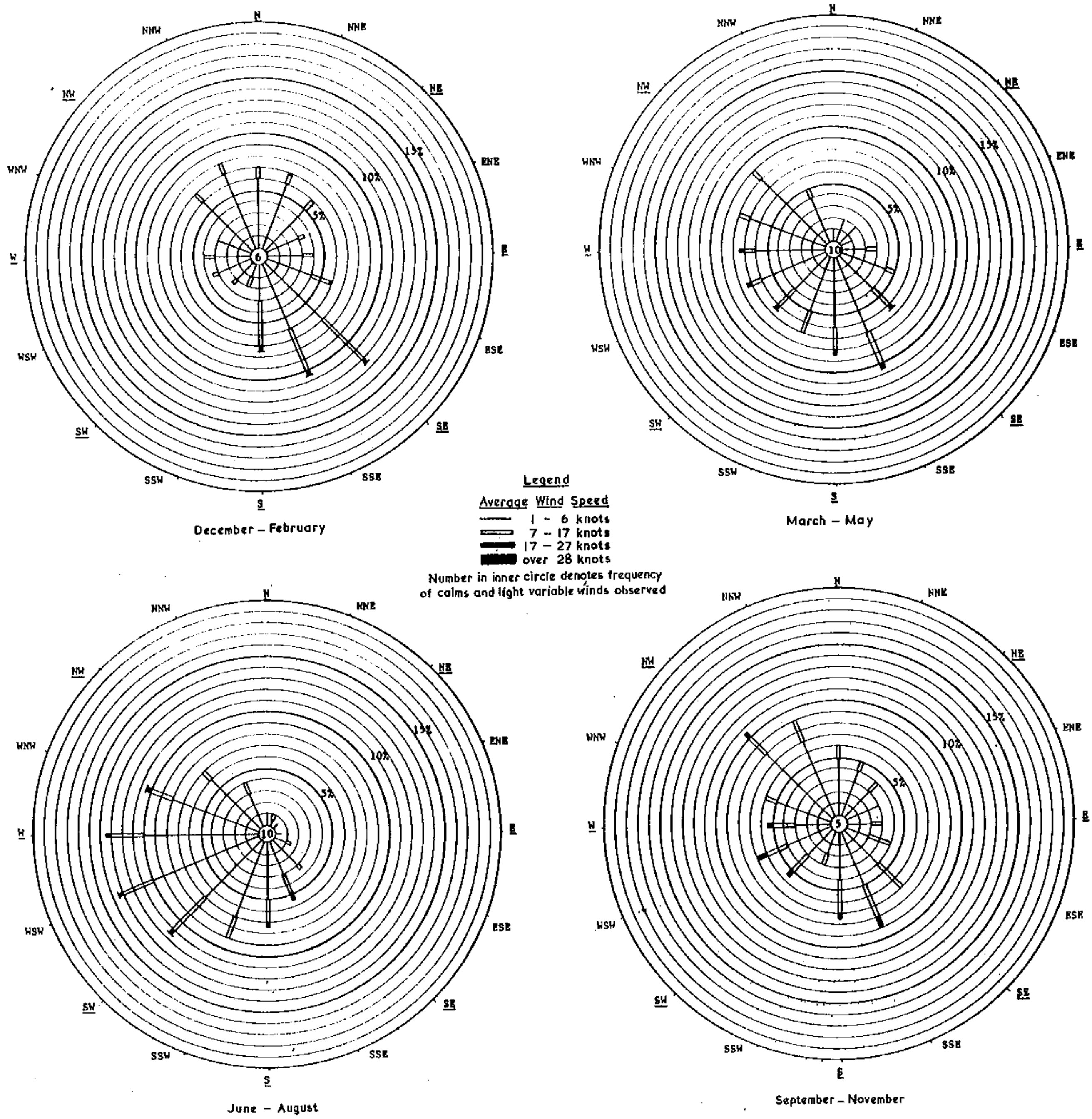


FIGURE 5a. WIND ROSES - FREQUENCY DISTRIBUTIONS AT 0900 HOURS (E.S.T.)

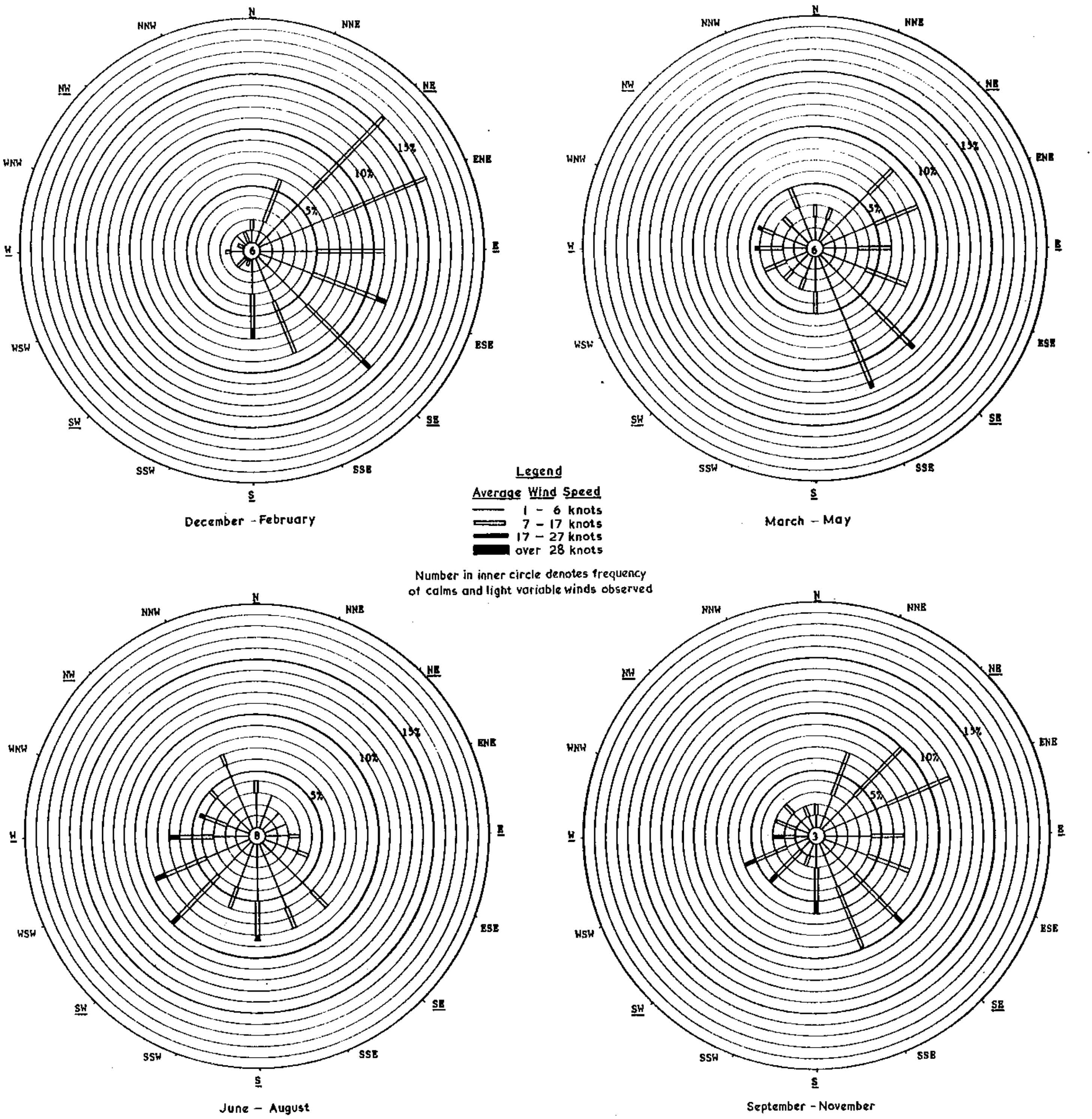


FIGURE 5b. WIND ROSES - FREQUENCY DISTRIBUTIONS AT 1500 HOURS (E.S.T.)

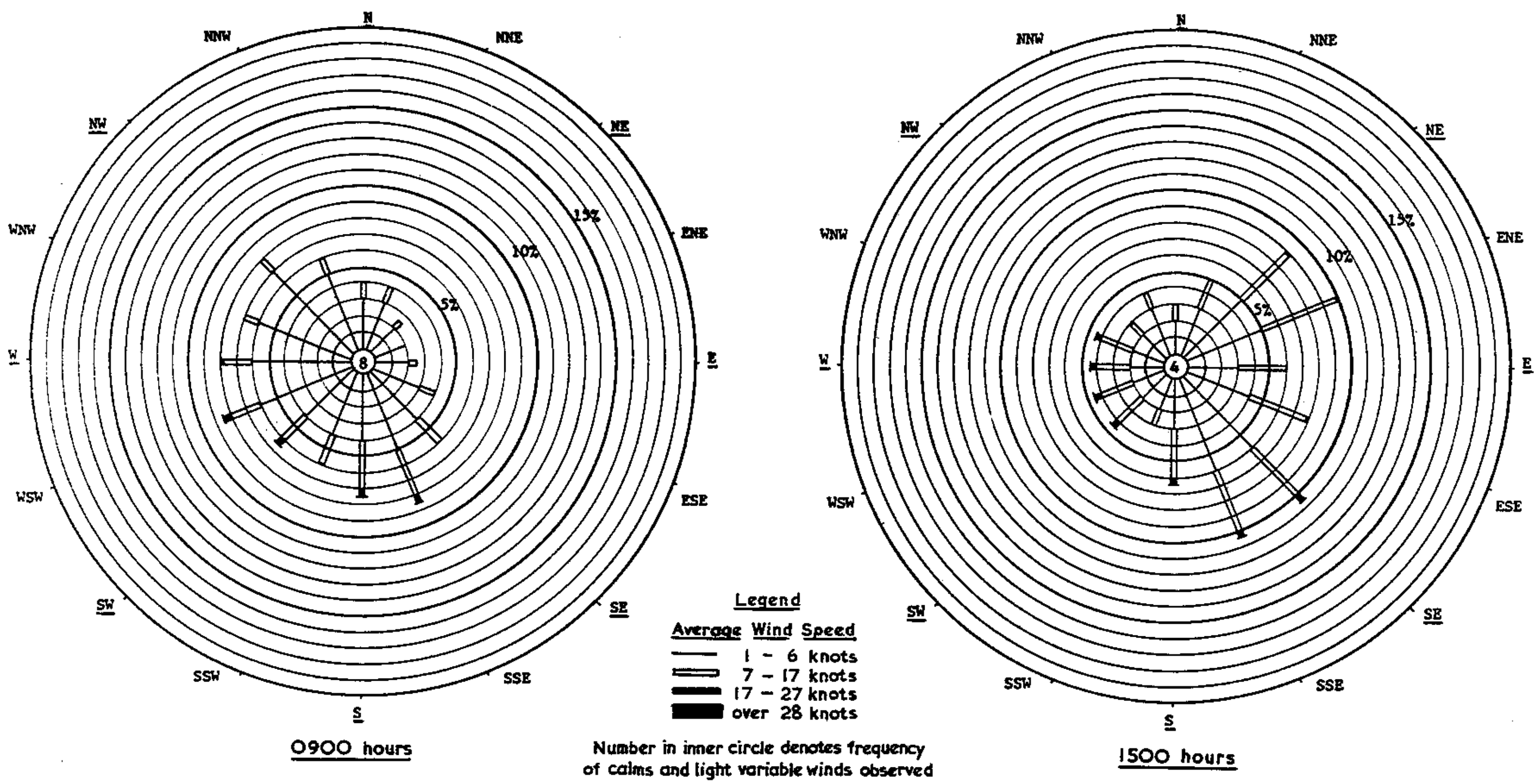


FIGURE 5c. WIND ROSES - ANNUAL FREQUENCY DISTRIBUTIONS AT 0900 AND 1500 HOURS (E.S.T.)

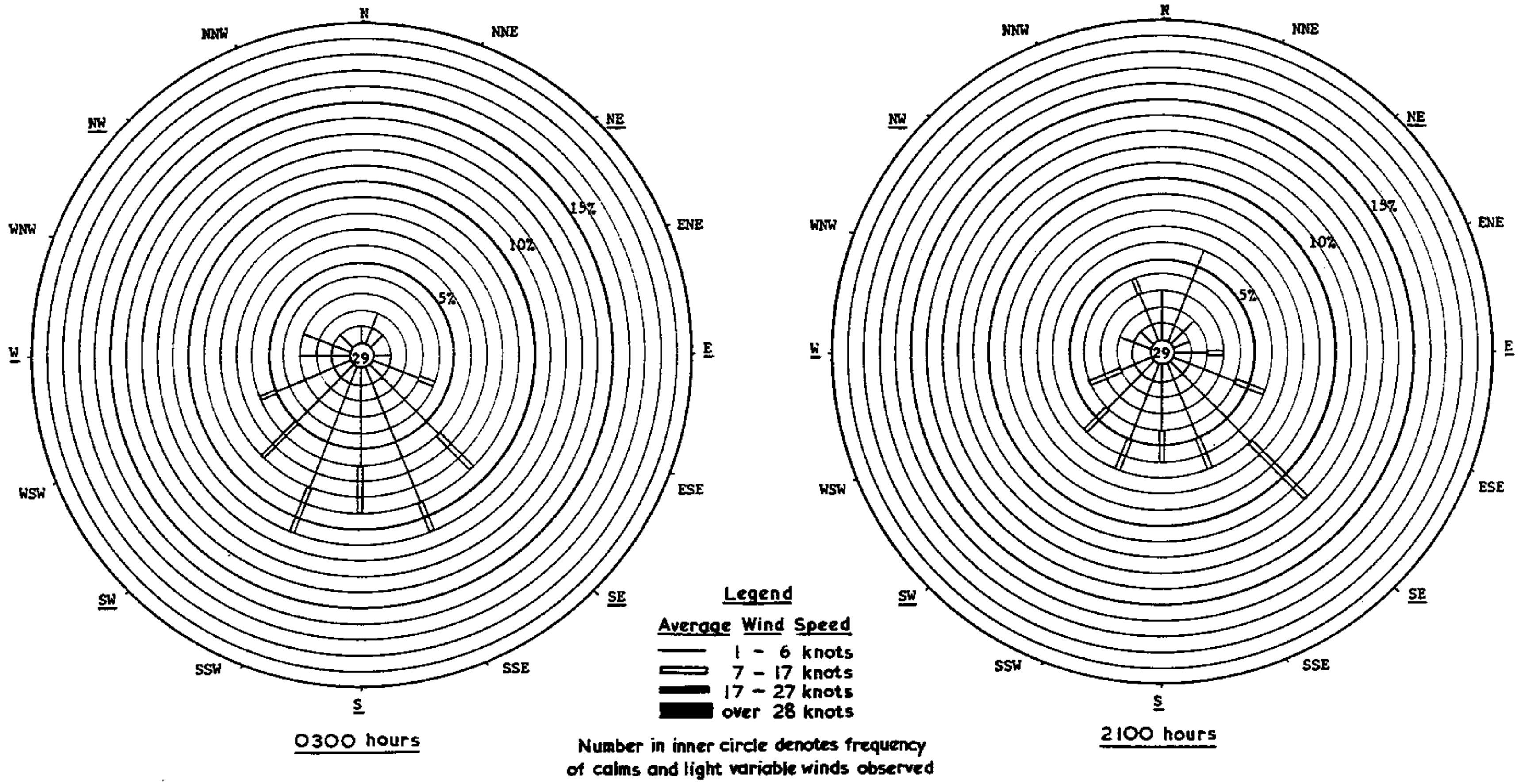


FIGURE 6. WIND ROSES - ANNUAL FREQUENCY DISTRIBUTIONS AT 0300 HOURS AND 2100 HOURS

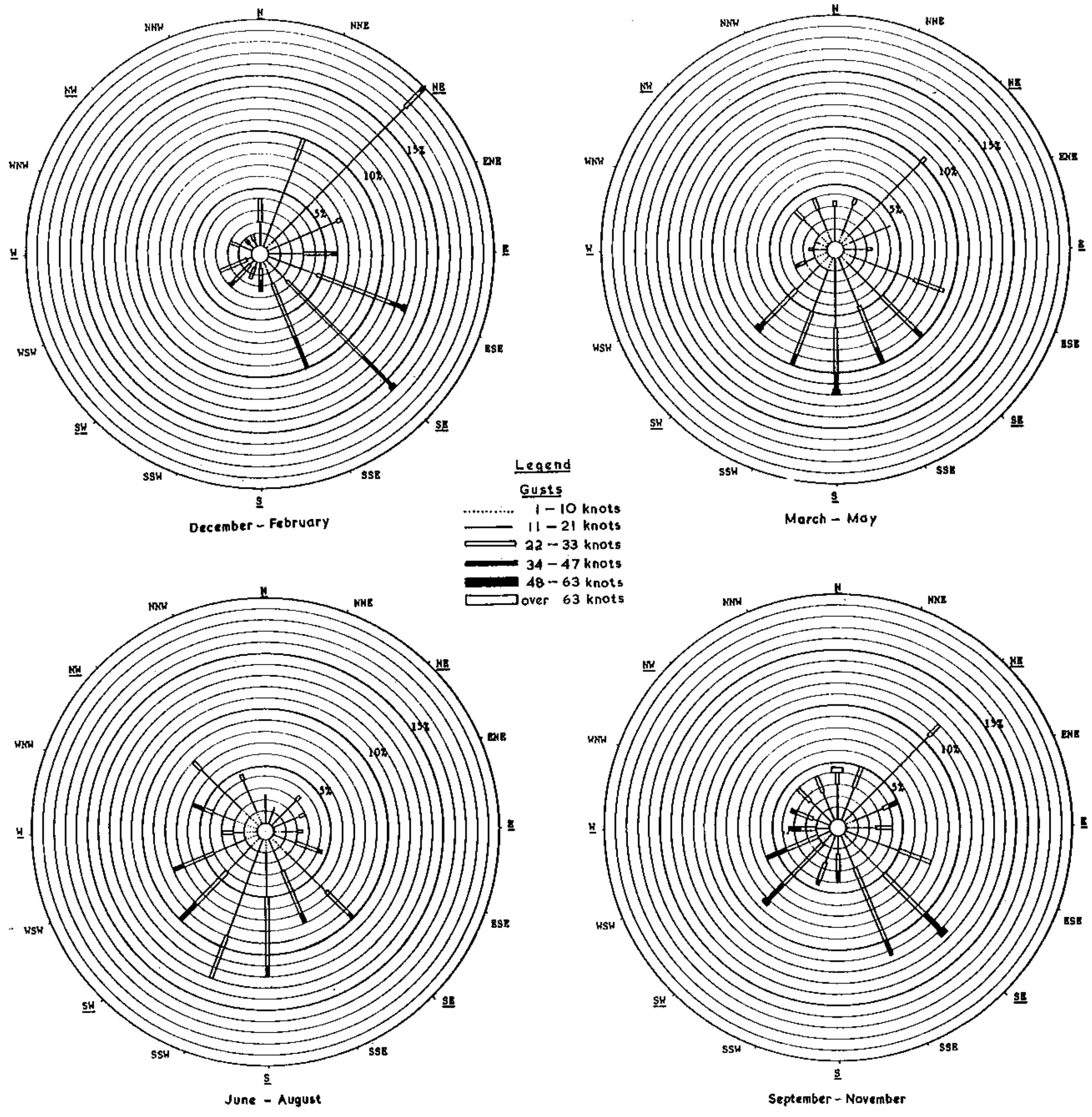


FIGURE 7a. MAXIMUM GUSTS - FREQUENCY DISTRIBUTIONS

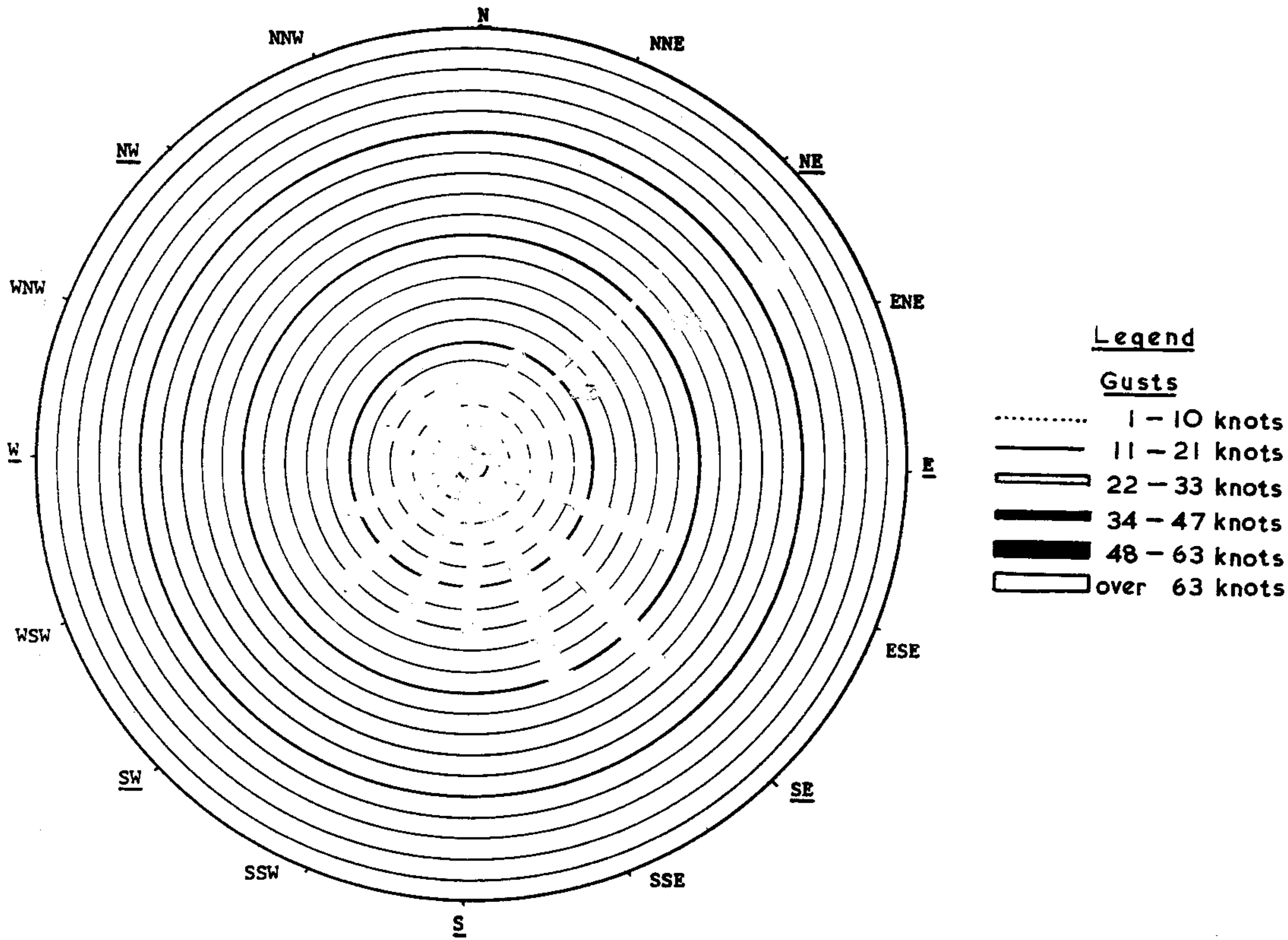


FIGURE 7b. MAXIMUM GUSTS - ANNUAL FREQUENCY DISTRIBUTION

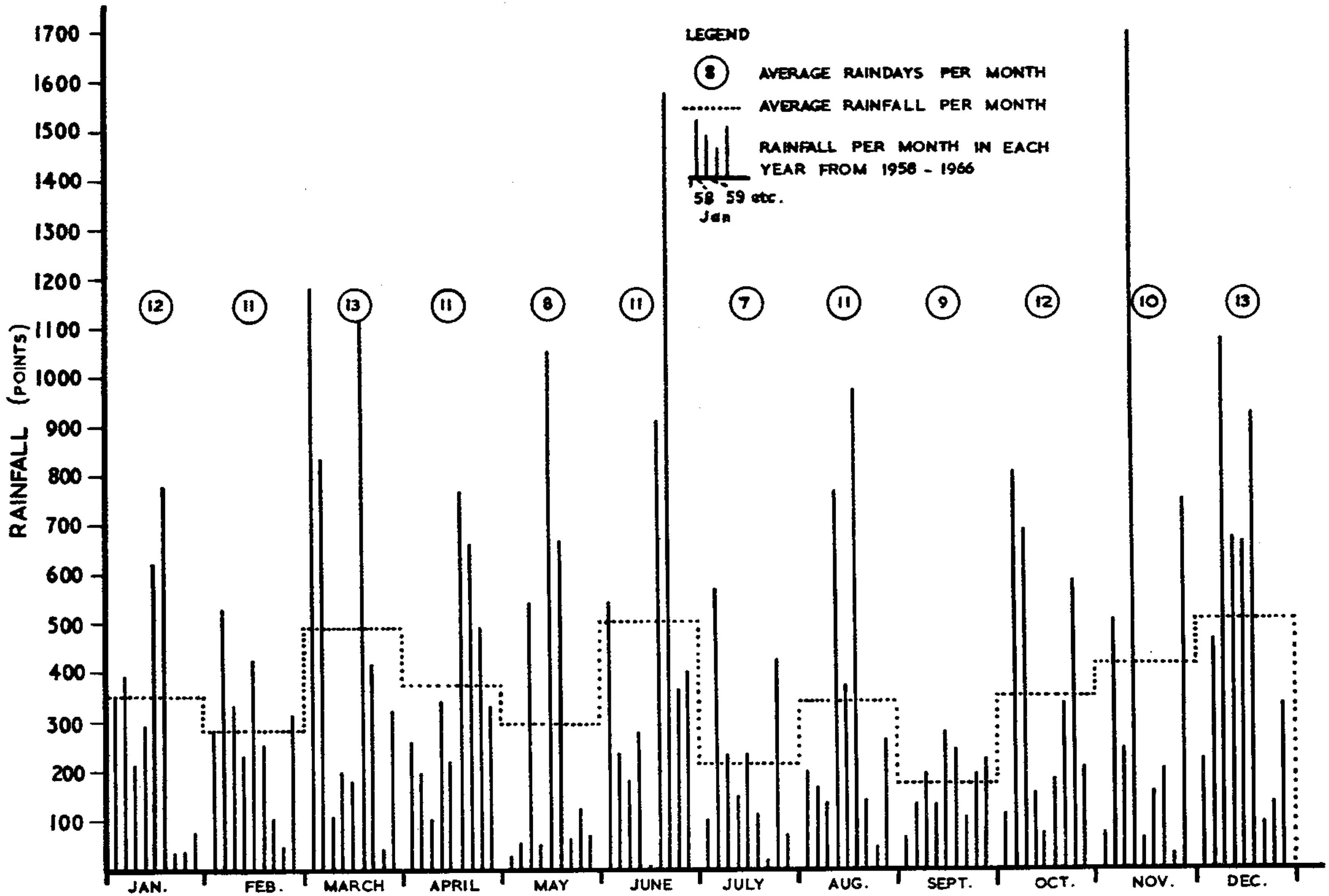
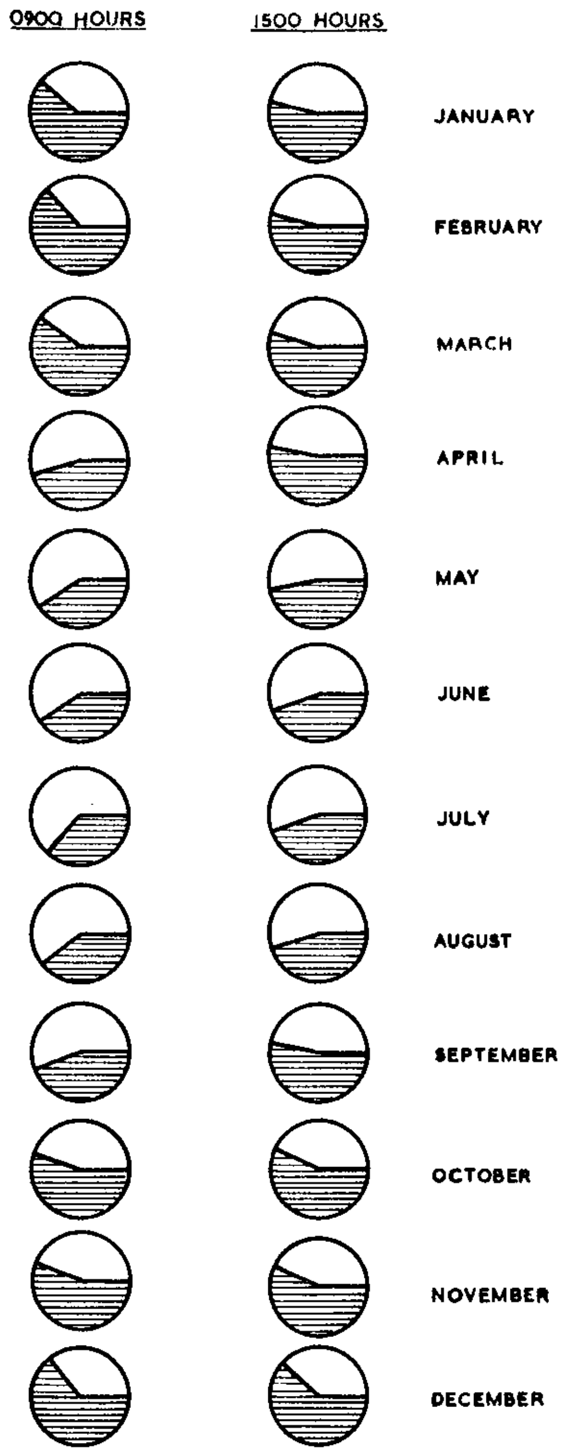


FIGURE 8. TOTAL AND AVERAGE MONTHLY AMOUNT OF RAINFALL AND AVERAGE NUMBER OF RAINDAYS PER MONTH



LEGEND
THE SHADED AREA IS THE PROPORTION OF SKY COVERED BY CLOUD

FIGURE 9. MONTHLY AVERAGES OF TOTAL AMOUNTS OF CLOUD AT 0900 AND 1500 HOURS (E.S.T.)