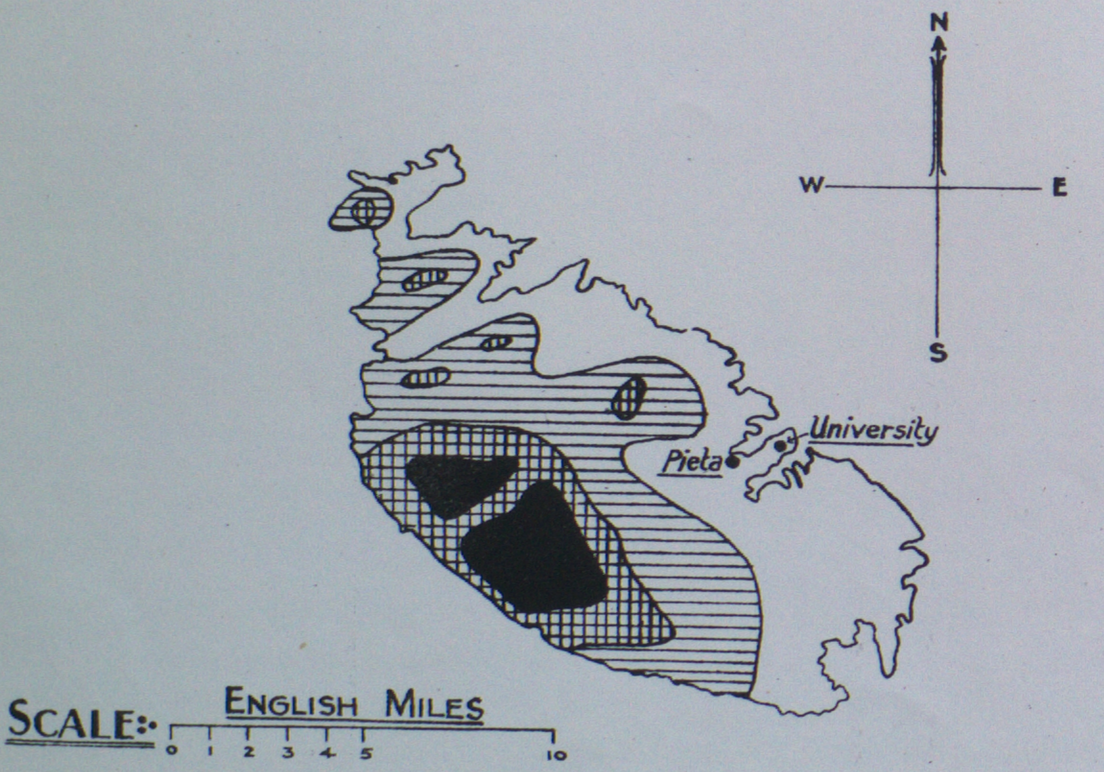
Frontispiece

MALTA

OROGRAPHICAL FEATURES AND POSITIONS OF ANEMOBIAGRAPHS AT PIETA AND THE UNIVERSITY.



OROGRAPHICAL FEATURES SHOWN THUS:-

LAND OVER 200 FEET, ...

" " 400 FEET, ...

" " 600 FEET, ...

P1229^A 5853^A 130/313.625.2/28.

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Studies of Wind and Cloud at Malta

By J. WADSWORTH, M.A.

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STUDIES OF WIND AND CLOUD AT MALTA

INTRODUCTION

The following paper consists of three parts and is based on observations of wind and cloud at the University Observatory, Valletta, and the Meteorological Office, Pietà. The first part deals with the diurnal variation of the surface wind, the second part describes the behaviour of the upper winds and the third part contains information relative to the incidence of cloud and rain.

The island of Malta is situated in latitude 36° N. and longitude 15° E. of Greenwich. It is 17¼ miles long and 9¼ miles broad and rises in the south-west to a height of 800 feet above sea level. Its area is 95 square miles. The positions of the two observatories and the orographical features of Malta are indicated in the *Frontispiece*. The University, which is within the town of Valletta, stands on a promontory separating the Grand Harbour from the Marsamuscetto Harbour, while the Meteorological Office, Pietà, is at the head of the Marsamuscetto Harbour and about a mile and a half distant from the University. The observations discussed in this paper were made on the roofs of the University and Meteorological Office, the exposure and view of the sky being in both cases practically unobstructed in any direction. At both stations the surface wind is taken from the record of a Dines-Halliwell anemobiagraph with its head 20 or 30 feet above the surrounding houses.* The roof of the University is about 200 feet above sea level and the roof of the Office at Pietà about 150 feet. In what follows the two stations will be called University and Pietà respectively.

PART I.—DIURNAL VARIATION OF SURFACE WIND AT MALTA

§ 1.—Existing Theories of Diurnal Variation of Wind

Diurnal variation of wind is observable in all parts of the world, but its intensity varies in different places and it is often masked by other changes of greater magnitude associated with cyclonic disturbances. It is usually more pronounced in the tropics than in the temperate zones. Diurnal changes of wind occur in the South of France and in other parts of the Mediterranean with sufficient intensity to be of practical importance in the management of airships.(7)† A diurnal change of surface wind is also apparent at Malta during the summer(1) and the present investigation indicates its nature and magnitude.

At inland stations the diurnal variation of wind is attributed to the action of convection under insolation during the day-time. (4), (5), (6) The upper winds are normally stronger than the surface winds and when convection is set up the affected layers of air tend to become mixed together. The result is that the surface wind increases at the expense of the upper wind. The effects due to convection extend to a height which varies according to the lapse rate of temperature and the degree of insolation and may be of the order of one or several thousand feet. At night, however, when convection becomes ineffective the surface layers of air remain in contact with the ground and become retarded relatively to the upper layers by friction at the earth's surface, so that the surface wind at night frequently drops to calm or nearly calm. Since the direction of the wind in the upper layers generally differs from the direction of the wind at the surface of the earth it follows that the diurnal increase in the velocity of the surface wind is usually accompanied by a change in direction as well ; and the sense of the change is usually clockwise, i.e., the surface wind veers during the day returning again at night.

The explanation of the diurnal change of wind force is due to Espy and Köppen, and the deduction concerning the diurnal change of wind direction is due to Sprung. It should be noted, however, that the wind direction at inland stations such as Madrid and Nukuss usually tends to follow the sun, i.e., it tends to be easterly in the morning in the northern hemisphere, southerly in the afternoon and westerly in the evening. This effect is also observed on the summits of mountains and is there explained by variations in temperature which take place in the course of the day in

* Estimated surface winds are also used in this paper in cases where great numerical precision is unnecessary.
† The numbers in the text refer to the Bibliography on p. 31.

the layers of air to east, south and west of the point of observation. The changes observed in the surface wind are held to be induced by those occurring in the upper air in a manner which resembles the production of forced or sympathetic vibrations.(6)

At coastal stations the diurnal change is represented mainly by land and sea breezes and these are due to inequalities in temperature which arise between land and sea under the influence of radiation or insolation. The surface of the land warms more rapidly during the day-time than the surface of the sea and a breeze from the sea develops owing to the relative decrease in pressure which occurs over the land. At night the surface of the land becomes colder than the surface of the sea and the flow of air is then directed from the land towards the sea. The land breeze is generally less intense than the sea breeze and may often fail altogether. Apart from land and sea breezes, which may be regarded as phenomena due to convection, the diurnal variation of surface wind at coastal stations is also partly composed of changes similar to those observed at inland stations. On the open sea the diurnal variation of wind is hardly observable at all.(6)

The surface winds used in this investigation are instantaneous values at each hour of the day obtained by inspection from the records of the anemobiagraphs at Pietà and the University. They refer to the period June to August, 1924, and December, 1924, to February, 1925, at Pietà, and May to December, 1922, at the University. Part of the analysis consisted in resolving each observation of wind into two components along mutually perpendicular lines and using the mean components so obtained.

The results of the analysis of the observations at Pietà are given in the following sections.

§ 2.—Diurnal Variation of Wind Velocity at Pieta

Treating first the wind velocity as a scalar quantity, i.e., without reference to its direction, we find that at Pietà during the summer of 1924 the mean velocity of the surface wind was 7·5 mi/hr. and the mean diurnal range 8·5 mi/hr. The mean minimum velocity was 3·7 mi/hr. and occurred at 6h., while the mean maximum velocity was 12·2 mi/hr. occurring at 14h. In winter the mean velocity was 9·1 mi/hr., the mean diurnal range 5·2 mi hr., the mean minimum velocity 7·4 mi/hr., and the mean maximum velocity 12·6 mi/hr. The times of occurrence of the minimum and maximum were 6h. and 14h., respectively, as in summer. The wind was therefore slightly stronger on the average in winter than in summer, but exhibited a smaller mean diurnal range in winter. The times of minimum and maximum velocity were early morning and early afternoon, respectively, and were the same for both seasons. Hence as far as wind velocity alone is concerned the diurnal variation at Pietà closely resembles the diurnal variation at inland stations. The complete results are shown in Table 1 and also graphically in Fig. I.

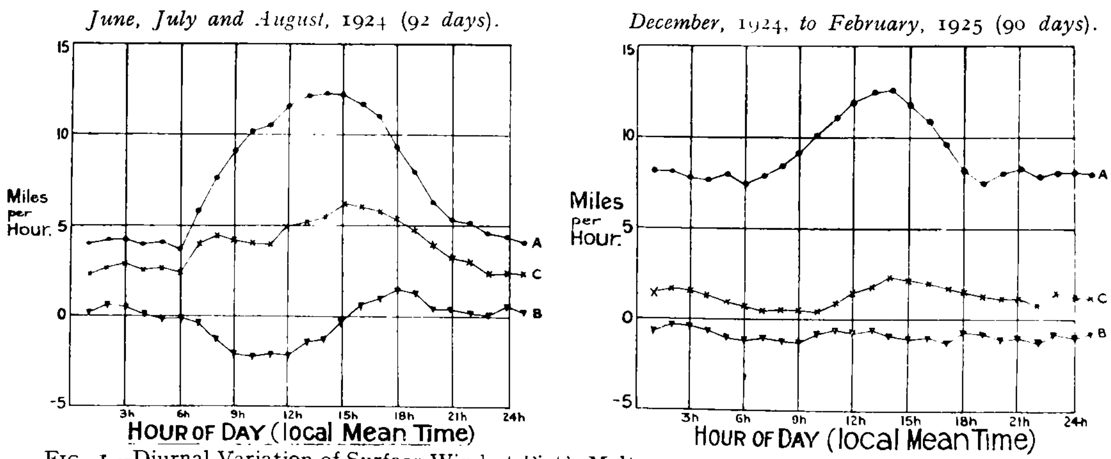

FIG. I—Diurnal Variation of Surface Wind at Pietà, Malta.

A—Mean wind velocity irrespective of wind direction (scalar mean).

B—Algebraic mean component of wind at right angles to the coast. The positive direction is from S.W.—N.E.

C—Algebraic mean component of wind parallel to the coast. The positive direction is from N.W.—S.E.

Table I.—Diurnal Variation of Wind Velocity at Pieta, Malta

(Scalar mean velocities in miles per hour.)

Hour of day (local time).	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	24h.	Mean.
June–August, 1924. (92 days).	4·0	4·2	4·2	3·9	4·0	*3·7*	5·8	7·6	9·0	10·2	10·5	11·6	12·1	**12·2**	12. 1	11. 6	11·0	9·3	8·0	6·3	5· 4	5·1	4·6	4·5	7·5
December, 1924–February, 1925 (90 days).	8·3	8·0	7·8	7·6	7·9	*7·4*	7·9	8·4	9·1	10·1	11·1	12·0	12·4	**12·6**	11·8	10·9	9·6	8·2	7·5	8·1	8·4	7·9	8·2	8·2	9·1

§ 3.—Components of Wind at Pieta Parallel and Perpendicular to the Coast Line

The coast line faces north-east in the neighbourhood of Valletta and Pietà and the winds observed at Pietà were resolved into components along lines running north-east and south-east. Components of wind blowing from north-east and from south-east are regarded as negative, components blowing from south-west and from north-west as positive. The mean components are given in the following table :—

Table II.—Mean Components of Wind in miles per hour at Pieta along the coast (SE.) and across the coast (NE.)

Winds from NE. and SE. are negative (—)
„ „ SW. and NW. are positive (+)

	June—August, 1924 (92 days)		December, 1924—February, 1925 (90 days)	
Hour of day. (local time)	NE.	SE.	NE.	SE.
1	+ ·21	*+2·24*	— ·70	+1·30
2	+ ·59	+2·57	— ·36	+1·72
3	+ ·39	+2·84	— ·47	+1·46
4	+ ·05	+2·49	— ·58	+1·16
5	— ·15	+2·57	—1·04	+ ·97
6	— ·14	+2·33	—1·28	+ ·60
7	— ·48	+3·98	—1·02	+ *·41*
8	—1·35	+4·47	—1·18	+ ·52
9	—2·15	+4·17	**—1·39**	+ ·52
10	—2·19	+3·98	— ·92	+ ·40
11	—2·12	+3·95	— ·58	+ ·93
12	**—2·21**	+5·00	— ·74	+1·59
13	—1·44	+5·15	— ·57	+1·89
14	—1·34	+5·43	— ·90	**+2·34**
15	— ·17	**+6·12**	—1·16	+2·22
16	+ ·54	+5·93	— ·86	+2·11
17	+ ·98	+5·79	—1·23	+1·84
18	**+1·34**	+5·20	— ·57	+1·63
19	+1·24	+4·71	— ·78	+1·33
20	+ ·42	+3·93	—1·06	+1·22
21	+ ·37	+3·17	— ·90	+1·16
22	+ ·11	+2·98	—1·26	+ ·80
23	+ ·05	+2·37	— ·67	+1·45
24	+ ·45	+2·32	— ·91	+1·36

During the summer of 1924 the mean north-east component of wind was found to be positive during the night from 16h. to 4h. and negative during the day from 5h. to 15h. inclusive. The extreme values were 1·3 mi/hr. at 18h., and 2·2 mi/hr. at

10h. and 12h. The mean south-east component was positive throughout the 24 hours and reached a maximum of 6·1 mi/hr. at 15h. Its minimum values were 2·2 mi/hr. at 1h. and 2·3 mi/hr. at 6h. In the winter months the mean north-east component was small and negative throughout the 24 hours and exhibited practically no periodicity; while the mean south-east component was positive and reached a maximum value of 2·3 mi/hr. at 14h. Hence in summer the component of wind across the coast line was reversed twice in the course of the 24 hours. The results clearly indicate a sea breeze‡ during the forenoon and a land breeze at night during summer but no definite land or sea breeze in winter.

§ 4.—Diurnal Variation of Wind Direction at Pieta

The vectors obtained by combining the corresponding north-east and south-east components in Table II are given in Table III. They represent the mean flow of surface air over Pietà at each hour of the day and provide a measure of the diurnal variation of wind direction.

Table III shows that during the summer of 1924 the wind veered during the forenoon up till 10h., when its mean direction was 344°, and then backed again continuously until 19h., when its mean direction was 300°. Thereafter it changed irregularly and began to veer steadily after 2h. In the winter of 1924-5 the changes were more complex. A maximum veer was attained at 9h. when the mean direction was 24°, and again at 20h., when the mean direction was 356° ; while at 13h. and 2h. the mean direction went back to 332° and 327° respectively. The winter results are less significant than those for summer, because the winds are so much more variable in winter owing to irregular changes due to cyclonic disturbances in comparison with which diurnal changes become negligibly small. The variability of the winds in winter is illustrated by the small vector mean velocity.

Table III.—Mean flow of Surface Air over Pieta at each hour of the day

The direction (θ) is given in degrees from North ; the velocity (V) is given in miles per hour.

Hour of day (local time).		1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	12h.	13h.	14h.	15h.	16h.	17h.	18h.	19h.	20h.	21h.	22h.	23h.	24h.	Mean.
June–August, 1924 (92 days).	θ	310	302	307	315	318	318	322	332	342	**344**	343	339	331	329	317	310	305	301	*300*	309	308	313	315	304	319
	V	*2·3*	2·6	2·9	2·5	2·6	*2·3*	4·0	4·7	4·7	4·5	4·5	5·5	5·3	5·6	**6·1**	6·0	5·9	5·4	4·9	4·0	3·2	3·0	2·4	2·4	3·9
December, 1924–February, 1925 (90 days).	θ	343	*327*	333	341	2	20	23	21	**24**	22	347	340	*332*	336	342	337	349	334	345	**356**	353	12 (?)	340	349	349
	V	1·5	1·7	1·5	1·3	1·4	1·4	1·1	1·3	1·5	*1·0*	1·1	1·8	2·0	**2·5**	**2·5**	2·3	2·2	1·7	1·5	1·6	1·5	1·5	1·6	1·6	1·6

The results in Table III are also presented graphically in Fig. *2a*, where only the values for every three hours are used. AO represents the mean wind in velocity and direction for the whole of the 24 hours. BO represents the mean wind at 9h. Hence, BA represents in magnitude and direction the wind which must be compounded with the mean wind for the 24 hours to produce the mean wind BO at 9h. For other hours of the day a similar construction applies. In summer the components such as BA representing diurnal change blow from the sea during the forenoon and early afternoon and from the land during the evening and night. In the course of the 24 hours the point B moves round the polygon in Fig. *2a* in a counter-clockwise direction.*

‡ Or possibly a valley breeze in the Marsamuscetto Harbour.

* At Madrid the sense in which B rotates is, on the contrary, clockwise (6).

In winter the diurnal change is rather restricted and less simple than in summer, but still shows in a general way the counter-clockwise rotation of the point B, and also as in summer a slight irregularity between 24h. and 3h. due to the 12-hour term in the Fourier expressions for the diurnal variation (Fig. 2*b*).

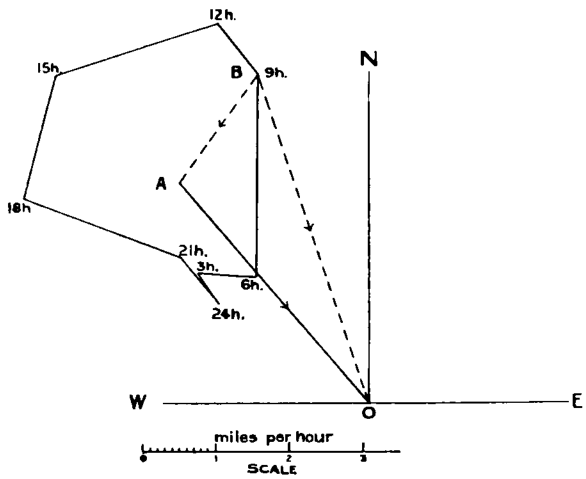

FIG. 2*a*.

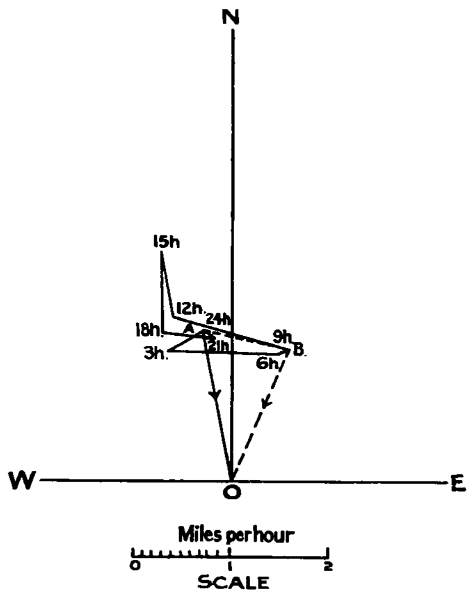

FIG. 2*b*.

Vector Diagrams for Surface Winds at Pietà.
FIG. 2*a*.—June, July and August, 1924 (92 days).
FIG. 2*b*.—December, 1924, to February, 1925 (90 days).

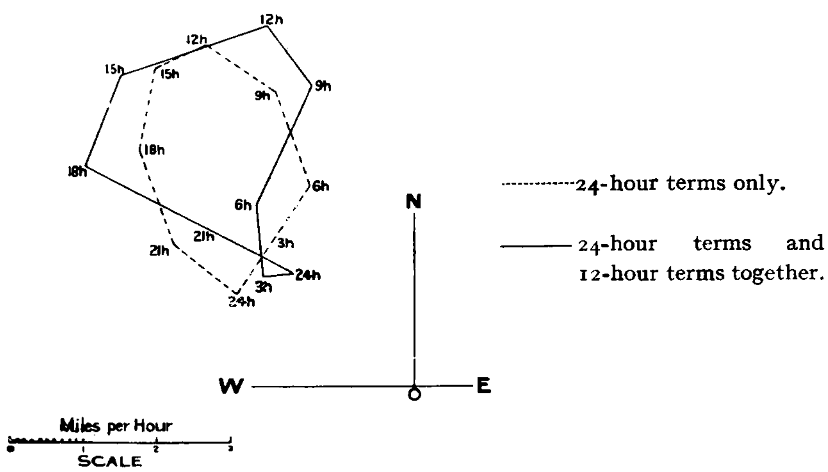

FIG. 2*c*.—Vector Diagrams for Surface Winds at Pietà from terms of Fourier Series. June—August, 1924 (92 days).

An alternative method for isolating diurnal changes of wind direction consists in constructing a table showing the frequencies of various wind directions at different hours of the day. The results for Pietà are shown in Table IV.

TABLE IV.—FREQUENCIES OF WIND DIRECTION AT VARIOUS HOURS OF THE DAY AT PIETA

June—August, 1924 (92 *days*).

Hour of day (local time)	Calm.	N.	NE.	E.	SE.	S.	SW.	W.	NW.
3h.	25	5	5	Nil	Nil	6	10	23	18
6h.	**35**	2	7	2	Nil	4	9	14	19
9h.	1	15	27	**6**	2	7	4	11	19
12h.	Nil	10	**34**	2	4	6	1	15	20
15h.	Nil	10	19	4	4	7	4	22	22
18h.	1	**15**	10	3	**5**	10	2	**32**	14
21h.	12	8	4	2	3	12	**11**	16	**24**
24h.	21	7	3	1	3	**13**	**11**	18	15
Totals	95	72	109	20	21	65	52	151	151

December, 1924—*February*, 1925 (90 *days*).

Hour of day (local time)	Calm.	N.	NE.	E.	SE.	S.	SW.	W.	NW.
3h.	5	7	3	11	6	5	**23**	15	15
6h.	7	8	6	10	**9**	5	**23**	11	11
9h.	**10**	8	7	10	7	9	14	15	10
12h.	1	**12**	16	**11**	7	8	11	13	11
15h.	Nil	9	**20**	**11**	6	10	9	11	14
18h.	7	7	9	10	8	9	11	12	**17**
21h.	5	3	14	6	6	**11**	22	12	11
24h.	5	6	6	9	8	10	17	**17**	12
Totals	40	60	81	78	57	67	130	106	101

In summer the presence of the sea breeze is shown by the increase in frequency of NE. winds during the forenoon to a maximum at 12h. A similar effect is also observable in winter, when the frequency of NE. winds increases during the day-time to a maximum at 15h., while in both seasons SW winds tend to a maximum frequency during the night. The sea breeze thus appears to exist in winter as well as in summer, but reaches its maximum development later in the day.

§ 5.—KATABATIC WIND AT PIETA

The land wind which occurs at night at Pietà may be, in part at least, a katabatic wind, because the land to the south-west and west of Pietà is higher than at Pietà itself. When making observations of cloud at 22h. the author noticed that on calm nights there was nearly always a faint drift of air from about west-south-west ; and the following table confirms this observation. It appears that when the force of the surface wind at 22h. or 23h. (local time) is 0 or 1 on the Beaufort scale there is a pronounced maximum frequency of wind directions between south and west both in winter and summer.

TABLE V —FREQUENCIES OF SURFACE WINDS AT PIETA GROUPED ACCORDING TO DIRECTION AND FORCE

Winter (*November—February*) 1923–24 ; 1924–25.
(223 observations.) 22h. (local time).

Wind force (Beaufort).	NE.	SE.	SW.	NW.
0—1	2	8	**47**	3
2—3	15	23	32	25
4 or greater	15	6	7	28

Number of calms = 12.

Table V.—Frequencies of Surface Winds at Pieta grouped according to Direction and Force—*continued.*

Summer (June—August, 1924) (92 *days*).

22h. (local time.)					23h. (local time).				
Wind force (Beaufort).	NE.	SE.	SW.	NW.	Wind force (Beaufort).	NE.	SE.	SW.	NW.
0—1	6	10	**21**	14	0—1	Nil	7	**27**	11
2—3	1	3	1	9	2—3	3	1	1	10
4 or greater	2	1	1	13	4 or greater	2	Nil	2	11
Number of calms = 10.					Number of calms = 17.				

The two tables for summer show that the night wind from south-west is more strongly developed at 23h. than at 22h. This point was not investigated for winter.

§ 6.—Constancy of Wind Direction at Pieta

The constancy of wind direction may be measured by means of the ratio—(vector mean velocity)/(scalar mean velocity)—and the value of the constancy of direction may therefore be obtained for each hour of the day from the mean velocities given in Tables I and III. The results are shown in the following table :—

Table VI.—Constancy of Wind Direction at Pieta

Values of the ratio (vector mean velocity)/(scalar mean velocity) expressed as percentages.

Hour of day (local time) ..	2h.	4h.	6h.	8h.	10h.	12h.	14h.	16h.	18h.	20h.	22h.	24h.	Mean.
June—August, 1924 (92 days) ..	63	63	64	62	44	47	46	51	58	63	59	53	52
December, 1924—February, 1925 (90 days). ..	22	17	19	15	10	15	21	21	21	20	19	20	18

The mean value of the constancy is 52 in summer and 18 in winter, thus indicating that the winds are much more variable in direction in winter than in summer. The constancy varies in the course of the 24 hours and is generally lowest in the late forenoon and highest in the evening and just after midnight. The increase in the value of the constancy of direction at night corresponds with the development of the katabatic land wind.

§ 7.—Analysis of Observations at the University

The results obtained from the observations at the University* are similar to those obtained at Pietà. They are shown graphically in Figures 3 and 4, in which the broken lines represent the result of smoothing by Fourier series (*see* § 8). In July and August the wind velocity reaches its maximum velocity at 14h. and minimum at 22h. (c.f. Pietà 6h.) ; while the maximum veer which occurs during the forenoon is attained two or three hours before the time of maximum velocity.

These observations again indicate a sea breeze ; for if the diurnal veer of the wind were entirely due to convection, as explained by Sprung, the maximum veer should theoretically coincide in time with the diurnal maximum of velocity.† In this connection the variation of direction between winds at 250 feet and 2,000 feet and between 250 feet and 5,000 feet was examined for July and August, 1922. The

* Exact numerical data for wind velocities at the University cannot be given, because the instrument was for some time defective, its indications of wind velocity being too low.

† This interpretation is due to Dr. W. A. Harwood.

results are set out in Table IX and show that in general the change of direction is clockwise and amounts to an average of 3° between 250 feet and 2,000 feet and 24° between 250 feet and 5,000 feet. The diurnal veer in the surface wind produced by the sea breeze is therefore probably greater than the veer which would be produced by convection alone.

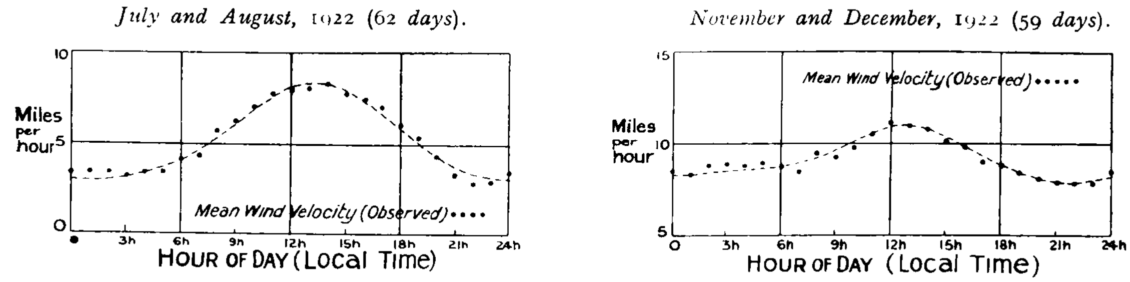

FIG. 3—Diurnal Variation of Wind Velocity irrespective of Direction at the University Malta.

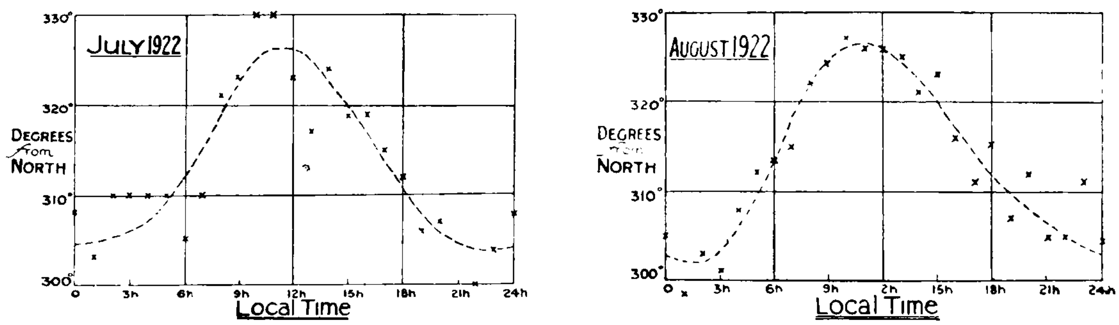

FIG. 4—Diurnal Variation of Wind Direction at the University, Malta.

§ 8.—ANALYSIS BY MEANS OF FOURIER SERIES

The coefficients of the first three terms of the Fourier series which represent the mean hourly values of wind discussed in the foregoing paragraphs are given in Table VII, the form of series used being $a_0 + a_1 \sin (A_1 + x) + a_2 \sin (A_2 + 2x) + a_3 \sin (A_3 + 3x) + \ldots$

The following results emerge from Table VII :—

(1) The period of 8 hours in the diurnal variation of the wind at Malta is practically negligible.

(2) The period of 12 hours is indicated in the diurnal variation of wind velocity. Its amplitude is of the order of 1 mi/hr. and is greater in winter than in summer.

(3) The period of 24 hours is shown in the diurnal variation of wind velocity and is most pronounced in summer when its amplitude at Pietà is of the order of $4\frac{1}{2}$ mi/hr.

(4) The effect of the 12-hour period is exhibited in Figure 2*c* which refers to summer 1924 at Pietà. The dotted curve is the vector diagram given by the Fourier series for the 24-hour term only ; the continuous curve is the vector diagram given by the Fourier series for the 24-hour term and the 12-hour term taken together. This diagram should be compared with the diagrams constructed from the actual observations (Figures 2*a* and 2*b*).*

* Figure 2c was constructed at the suggestion of Mr. M. A. Giblett, who found similar results, not yet published, at Abu Sueir, Egypt.

TABLE VII.—CO-EFFICIENTS OF FOURIER SERIES REPRESENTING DIURNAL VARIATION OF WIND AT MALTA

$$\left\{a_0 + a_1 \sin(A_1 + x) + a_2 \sin(A_2 + 2x) + a_3 (A_3 + 3x) + \ldots\ldots\ldots\ldots\right\};\ x = \frac{2\pi t}{24} \text{ where}$$

t = hour of day (local time).

Pietà.

		a_0	a_1	A_1	a_2	A_2	a_3	A_3
				°		°		°
June–August, 1924	V.	7·54	4·34	240	·70	49	·49	37
	NE.	− ·29	1·26	121	·82	300	·17	48
	SE.	+3·91	1·67	233	·42	306	·27	67
Dec., 1924–Feb., 1925	V.	9·12	1·97	249	1·23	58	·32	186
	NE.	− ·88	·07	91	·21	41	·21	311
	SE.	+1·28	·50	186	·57	14	·04	180

University.

1922.		a_0	a_1	A_1	a_2	A_2	a_3	A_3
May	E.	+1·26	·62	271	·40	312	·43	74
	N.	−1·29	·93	108	·20	93	·18	252
June	E.	+2·22	·71	196	·21	1	·23	70
	N.	− ·55	·33	322	·53	210	·29	303
July	E.	+3·27	·90	227	·46	303	·20	117
	N.	−3·33	2·00	75	·34	203	·25	230
August	E.	+2·64	·18	265	·17	355	·15	17
	N.	−2·71	1·58	91	·27	279	·08	180
September	E.	+2·58	1·09	245	·03	168	·01	315
	N.	−1·36	·34	83	·28	340	·04	11
October	E.	+1·31	·19	131	·54	21	·13	68
	N.	+ ·08	·23	212	·31	211	·27	238
November	E.	+ ·18	·73	246	·54	50	·15	202
	N.	−4·43	·08	322	·66	182	·19	88
December	E.	+1·97	·40	8	·17	29	·09	156
	N.	−1·93	·51	104	·37	242	·14	186
July and August	V.	5·25	2·63	252	·47	35	·32	23
November and December ..	V.	9·32	1·21	271	·61	45	·16	280

V. = scalar mean velocity.
E. = east component (+ if directed towards east).
N. = north component (+ if directed towards north).
NE. = north-east component (+ if directed towards north-east).
SE. = south-east component (+ if directed towards south-east).

§ 9.—SEASONAL VARIATION

A complete account of the seasonal variation in the intensity of diurnal changes is not possible because the spring months are not represented. The mean diurnal range of wind velocity at the University considered apart from wind direction varies as follows : July and August 5 mi/hr.; September and October 4 mi/hr.; November and December 3 mi/hr.

§ 10.—DIURNAL VARIATION OF WIND FORCE IN RELATION TO WIND DIRECTION

It was frequently stated at Malta that easterly winds were less likely to exhibit diurnal variation of wind velocity than westerly winds, and the author considered that this point was sufficiently important to be investigated. But the data hitherto examined do not extend over a period of sufficient length to yield results which would be representative because easterly winds are relatively infrequent in comparison with westerly winds. The author had however prepared some summaries in connection with visibility at Valletta extending over five summers and five winters from which it was possible to obtain information concerning the variation of wind force between 8h. and 14h. (local time) in relation to the direction of the wind. The results are presented in Table VIII (*a*) which follows.

Table VIII (*a*).—Diurnal Variation of Wind Force in relation to Wind Direction

The table gives percentage frequencies of specified wind forces within each quadrant.

Summer (May-August), 1920–24.

Wind force (Beaufort).	NE.		SE.		SW.		NW.	
	8h.	14h.	8h.	14h.	8h.	14h.	8h.	14h.
0–1	59	37	33	29	58	25	25	8
2–3	34	60	53	56	37	70	53	58
4 or greater	8	3	14	15	5	6	22	33

Winter (November–February), 1919–24.

Wind force (Beaufort).	NE.		SE.		SW.		NW.	
	8h.	14h.	8h.	14h.	8h.	14h.	8h.	14h.
0–1	15	21	25	18	40	21	23	7
2–3	45	50	42	53	56	65	50	55
4 or greater	40	29	34	29	4	14	26	38

It will be seen that in summer the force of the wind increases between 8h. and 14h. except in the case of winds from the south-east quadrant, when the percentage frequencies of very light, light and moderate to strong winds remain almost unchanged between 8h. and 14h. In winter westerly winds again show a tendency to increase in strength between 8h. and 14h ; but this tendency is almost absent in the case of easterly winds, while easterly winds, and especially north-easterly winds, of force 4 or more at 8h. even show a tendency to decrease in strength as the afternoon approaches. No allowance has been made in Table VIII (*a*) for the diurnal increase in frequency of north-easterly winds in summer between 8h. and 14h. shown in Table VIII (*b*) which is due to the sea breeze. Hence in addition to a few cases which were calm at 8h. the column for north-easterly winds at 14h. will contain some cases which were found in other quadrants at 8h ; but the latter will generally be light, variable winds, otherwise the weak sea breeze would be ineffective in causing a change of quadrant when compounded with them : or else the change of quadrant will be due to a change in the pressure gradient, in which case any diurnal variation will often be obliterated. Hence the diurnal variation of north-easterly winds in summer is probably a little more pronounced than it appears to be from Table VIII (*a*).

Table VIII (*b*).—Percentage Distribution and Total number of Observations used in Table VIII (*a*)

		NE.	SE.	SW.	NW.	Calm.	Total number of observations.
		%	%	%	%	%	
Summer ..	8h.	20	14	10	52	4	606
	14h.	30	19	7	45	Nil	534
Winter ..	8h.	12	17	21	49	2	596
	14h.	13	16	21	49	1	526

Note.—Local time is used in Tables VIII (*a*) and VIII (*b*).

Table IX.—Change of Wind with Height at Malta during July and August, 1922

The figures in this table are based on the results of about 70 pilot balloon ascents.

Height Interval (feet).	Wind velocity at 250 feet.				Mean Change.
	< 10 mi/hr.		> 10 mi/hr.		
	Clockwise.	Counter-clockwise.	Clockwise.	Counter-clockwise.	
250–2,000	29	17	20	6	3° clockwise.
250–5,000	27	15	17	5	24° clockwise.

§ 11.—Summary and Discussion

The diurnal variation of surface wind at Malta is similar to the diurnal variation observed at an inland station modified by the development of a slight sea breeze. The diurnal variation is more pronounced in summer than in winter. The wind velocity reaches a maximum at 14h., local time, and a minimum at 6h., the mean range being 8·5 mi/hr. in summer and 5·2 mi/hr. in winter. The wind veers during the forenoon until 10h. or 11h. and then commences to back before attaining its maximum velocity. A katabatic wind prevails at night at Pietà from west-south-west.

The diurnal variation of wind force is generally more pronounced with westerly winds than with easterly winds, and hence resembles the diurnal variation of cloud. Both of these phenomena are associated with convection in the lower layers of the atmosphere. The surface wind becomes calm at night when convection ceases, while any low cloud which is present disappears because convection is no longer operative in replacing the cloud dissipated by turbulence or by descent due to loss of heat by radiation. Easterly winds are much less frequent at Malta than westerly winds and their occurrence is therefore generally associated with an abnormal distribution of pressure. They are, therefore, less likely to exhibit normal diurnal changes. The presence of cyclonic cloud which diminishes insolation and radiation, or a difference in the lapse rate of temperature may operate in the case of easterly winds to reduce diurnal convection in comparison with westerly winds.

Note. At Vienna the diurnal variation of surface wind velocity attains its maximum in spring and autumn ; while easterly winds exhibit the diurnal variation to a greater extent than westerly winds, because easterly winds are more often associated at Vienna with fine weather than westerly winds (6).

PART II. UPPER WINDS AT MALTA

§ 12.—The Upper Wind Data

The data used in the present investigation for the discussion of upper winds are obtained from pilot balloon ascents made at Malta by the single theodolite method during the years 1918 to 1924. The earlier ascents were made at the University in Valletta and the series was not at first continuous ; but in July 1922 a regular series of ascents was commenced at the new branch Meteorological Office at Pietà and those at the University were then discontinued. The balloons were used without tails so that a direct measurement of the height of a balloon at any moment

Table X.—The Sea Breeze at Valletta

Wind velocities in this table are in miles per hour.

Date.	Hour of day (local time).							
	3h.	6h.	9h.	12h.	15h.	18h.	21h.	24h.
5–7–22	Calm	NW. 1	N. 2	NE. 4	NNW. 8	ENE. 2	E'S. 2	Calm
11–7–22	Calm	Calm	NE. 2	NE'E. 7	ENE. 5	SE. 2	S. 1	NW. 1
29–8–22	Calm	Calm	ENE. 1	N. 7	NE. 5	SE'S. 3	S. 1	Calm
30–8–22	Calm	Calm	N. 1	ENE. 5	E'N. 6	S. 4	WNW. 1	NW'W. 1

TABLE X.—THE SEA BREEZE AT VALLETTA—*continued.*

Upper winds.

Height in feet.	5-7-22	11-7-22	29-8-22		30-8-22	
	8h.	8h.	8h.	18h.	8h.	18h.
1000	WSW. 6	E'N. 6	S'E. 2	SSE. 12	NE'N. 5	S. 12
3000	WNW. 3	SE'E. 13	S'E. 4	ENE. 8	SW'W. 2	SE'E. 13
5000	W'N. 4	SE. 19	N'E. 2	NE'N 15	E 1	NE'N. 17
7000				N'E. 28	ENE. 6	NNE. 26
10,000						N'W. 34

was not possible. Each balloon usually had an initial free lift which would enable it to rise at the rate of 500 feet per minute in accordance with the formula

$$V = q\frac{L^{\frac{1}{2}}}{(L+W)^{\frac{1}{3}}}$$

where V = upward velocity of balloon in feet per minute
L = free lift of balloon in grammes
W = weight of balloon in grammes
q = constant = 275 if the units are grammes and feet per minute.

Pilot balloon ascents are now made twice a day at Malta at 7h., G.M.T., and 17h., G.M.T. (approximately), the time of the evening ascent varying somewhat according to the time of sunset and state of the sky. It is therefore possible to compare the results of observations made in the morning with those made in the evening.

The results of the analysis are presented in the form of tables of frequencies and mean values referring principally to the summer months May to August and to the winter months November to February. The numbers of observations available at various heights are as follows :—

Height in feet.	1000	2000	3000	5000	7000	10,000	13,000	16,000	20,000
Summer (May–August)	711	699	668	537	427	329	184	104	51
Winter (Nov.–Feb.)	618	592	522	316	229	143	70	29	—

§ 13.—GENERAL RESULTS

In summer north-westerly winds preponderate at all heights. The same preponderance of north-west winds is also observed in winter up to 3,000 feet, but at 5,000 feet and greater heights the preponderating direction in winter is west. Winds

TABLE XI.—FREQUENCIES OF WINDS FROM VARIOUS DIRECTIONS AT MALTA, 1918-24

The numbers given in the table are calculated on the assumption that the number of observations at each height is equal to 1000.

Height in feet.	Summer (May to August).								Winter (November to February).							
	N.	NE.	E.	SE.	S.	SW.	W.	NW	N.	NE.	E.	SE.	S.	SW.	W.	NW.
1000	97	75	73	56	97	67	173	**361**	79	60	47	55	84	149	233	**293**
2000	109	82	76	63	66	99	160	**346**	84	69	29	35	98	162	243	**279**
3000	127	117	63	61	60	84	147	**341**	100	52	25	36	70	180	236	**293**
5000	184	143	45	41	41	73	166	**307**	101	25	16	32	76	193	**310**	247
7000	192	176	23	28	33	56	169	**323**	100	26	4	13	65	210	**314**	266
10000	222	152	15	40	24	49	179	**319**	126	28	—	—	56	266	**301**	224
13000	190	103	49	27	11	71	168	**380**								

from east, south-east and south are comparatively rare at all heights both in summer and winter and so also are north and north-east winds in winter.

The velocities of wind most frequently recorded lie between 11 and 20 mi/hr. at all heights, except in the layers below 5,000 feet in summer when winds below 11 mi/hr. preponderate. Winds of more than 30 mi/hr. are comparatively rare, especially in summer. Except in the lower layers in summer the highest mean velocities occur in general with winds from west.

TABLE XII.—FREQUENCIES OF WIND VELOCITIES WITHIN SPECIFIED LIMITS AT MALTA, 1918-24

The numbers given in the table are calculated on the assumption that the number of observations at each height is equal to 1000.

Height in feet.	*Summer (May to August).* Velocity in miles per hour.						*Winter (November to February).* Velocity in miles per hour.					
	1–10	11–20	21–30	31–40	41–50	Greater than 50	1–10	11–20	21–30	31–40	41–50	Greater than 50
1,000	**471**	351	121	47	8	1	165	**404**	294	112	17	8
2,000	**446**	338	138	46	24	9	136	**378**	280	157	41	8
3,000	**434**	337	135	67	16	10	140	**380**	287	124	49	19
5,000	337	**432**	165	43	13	9	129	**412**	307	120	25	6
7,000	264	**389**	262	61	19	5	175	**366**	310	123	13	13
10,000	158	**438**	264	107	30	3	91	**427**	294	126	56	7
13,000	179	**418**	267	65	59	11						

TABLE XIII.—MEAN VELOCITIES OF WINDS FROM VARIOUS DIRECTIONS AT DIFFERENT HEIGHTS ABOVE THE GROUND AT MALTA, 1918-24

The velocities are expressed in miles per hour.

Height in feet.	N.	NE.	E.	SE.	S.	SW.	W.	NW.
Summer (May to August).								
2,000	11	12	14	**17**	15	14	11	**17**
5,000	13	14	12	11	11	**19**	18	17
10,000	16	17	19	12	12	**23**	22	**23**
13,000	17	16	13	11	8	22	21	**24**
Winter (Nov. to Feb.).								
2,000	17	14	18	19	20	21	**25**	23
5,000	20	22	17	12	17	20	**23**	21
10,000	19	21	—	—	19	**23**	22	22

Numbers of observations.

Height in feet.	N.	NE.	E.	SE.	S.	SW.	W.	NW.
Summer (May to August).								
2,000	76	57	53	44	46	69	112	242
5,000	99	77	24	22	22	39	89	165
10,000	73	50	5	13	8	16	59	105
13,000	35	19	9	5	2	13	31	70
Winter (Nov. to Feb.).								
2,000	50	41	17	21	58	96	144	165
5,000	32	8	5	10	24	61	98	78
10,000	18	4	—	—	8	38	43	32

TABLE XIV.—FREQUENCIES OF WIND VELOCITIES WITHIN SPECIFIED LIMITS AT MALTA GROUPED ACCORDING TO THE DIRECTION OF THE WIND, 1918-24

The numbers given in the table are calculated on the assumption that the number of observations at each height is equal to 1,000.

Summer (May to August)

Velocity in miles per hour.	2,000 *feet.* N.	NE.	E.	SE.	S.	SW.	W.	NW.	5,000 *feet.* N.	NE.	E.	SE.	S.	SW.	W.	NW.
1—10	61	43	30	30	34	52	100	94	84	43	22	22	22	20	49	74
11—20	40	27	31	14	13	26	39	147	75	88	18	13	15	22	54	147
21—30	5	4	11	5	10	10	17	73	25	9	4	6	2	15	43	64
31—40	1	4	1	6	4	6	2	20	2	—	—	—	2	10	15	14
41—50	—	3	1	4	4	2	—	9	—	2	—	—	—	6	2	4
Greater than 50	—	—	—	3	—	1	1	3	—	2	—	—	—	—	4	4

Velocity in miles per hour.	10,000 *feet.* N.	NE.	E.	SE.	S.	SW.	W.	NW.	13,000 *feet.* N.	NE.	E.	SE.	S.	SW.	W.	NW.
1—10	36	27	6	24	15	3	30	15	27	27	22	11	11	32	16	33
11—20	128	83	3	12	6	18	51	137	120	60	16	16	—	5	82	120
21—30	55	36	3	3	—	15	54	98	38	11	10	—	—	11	49	147
31—40	3	3	3	—	3	12	36	45	5	5	—	—	—	5	16	33
41—50	—	3	—	—	—	—	6	21	—	—	—	—	—	16	5	38
Greater than 50	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	11

Winter (November to February).

Velocity in miles per hour.	2,000 *feet.* N.	NE.	E.	SE.	S.	SW.	W.	NW.	5,000 *feet.* N.	NE.	E.	SE.	S.	SW.	W.	NW.
1—10	21	31	8	—	17	12	27	20	12	—	3	12	18	13	34	35
11—20	39	18	10	26	39	70	74	103	38	13	9	15	32	108	104	91
21—30	15	19	5	8	27	58	57	92	41	9	—	3	19	51	101	82
31—40	8	2	3	2	13	20	57	50	6	3	3	—	6	19	57	25
41—50	—	—	2	—	2	3	25	8	3	—	—	—	—	—	12	9
Greater than 50	2	—	—	—	—	—	2	5	—	—	—	—	—	3	—	3

10,000 feet.

Velocity in miles per hour	N.	NE.	E.	SE.	S.	SW.	W.	NW.
1—10	14	—	—	—	7	14	42	14
11—20	56	14	—	—	21	119	105	112
21—30	49	7	—	—	21	77	84	56
31—40	—	7	—	—	7	35	49	28
41—50	7	—	—	—	—	21	14	14
Greater than 50	—	—	—	—	—	—	7	—

§ 14.—DIURNAL CHANGES

The general characteristics of morning and evening ascents are practically the same, but there are slight differences which affect the wind direction. In the lower layers in summer east winds tend to be less frequent in the evening than in the morning and west and north-west winds more frequent; while in winter there is a slight preponderance of west winds in the lower layers in the evening.

No conclusions have been drawn from the results for the higher levels, because the differences are not very regular and it is uncertain how much they are due to the special circumstances in which observations of pilot balloons can be made at great heights.

The mean velocities of wind given by morning and evening ascents are practically the same both in summer and winter.

Table XV.—Diurnal Changes of Wind at Malta 1918-24

(*a*) *Frequencies of winds from various directions at different heights above the ground.* The numbers given in this table are calculated on the assumption that the number of observations at each height both at 7h. and 17h. (G.M.T.) is equal to 1,000.

Height in feet.	N.		NE.		E.		SE.		S.		SW.		W.		NW.	
	7h.	17h.	7h.	17h.	7h.	17h.	7h.	17h.	7h.	17h.	7h.	17h.	7h.	17h.	7h.	17h.
Summer May to August.																
1,000	97	98	97	46	89	52	54	59	87	111	82	49	144	212	351	375
2,000	131	79	91	69	98	46	58	70	70	60	101	96	149	175	302	404
3,000	130	124	124	107	70	54	73	47	70	47	100	64	141	154	292	403
5,000	170	198	125	161	61	29	49	33	49	33	83	62	155	176	307	308
7,000	149	227	170	180	31	17	31	26	46	21	67	47	144	189	361	292
10,000	262	190	138	163	7	22	41	38	48	5	28	65	165	190	310	326
Winter November to February.																
1,000	94	57	64	53	43	53	62	45	88	78	152	143	201	283	297	287
2,000	99	63	73	63	20	42	40	29	104	88	167	155	212	290	285	269
3,000	106	90	48	57	23	28	42	28	84	71	190	165	216	264	290	297
5,000	107	96	25	25	13	19	44	19	88	64	195	191	296	325	233	261
7,000	69	133	26	27	9	—	26	—	60	71	224	195	310	319	276	257
10,000	97	155	28	28	—	—	—	—	69	42	292	239	250	352	264	183

(*b*) *Mean velocities of wind in morning and evening.*

	Summer		Winter	
	7h. G.M.T.	17h. G.M.T.	7h. G.M.T.	17h. G.M.T.
	Miles per hour.	Miles per hour.	Miles per hour.	Miles per hour.
2,000 feet	14·3	14·7	21·6	21·5
5,000 feet	14·7	15·8	20·2	21·0
10,000 feet	19·4	20·0	20·7	22·7

§ 15.—Seasonal Variation

The average velocity of the wind up to 13,000 feet is approximately 20 mi/hr. at all heights in winter, while it varies from 13 mi/hr. at 1,000 feet to 20 mi/hr. at 10,000 and 13,000 feet in summer. The averages for the higher levels are based on a smaller number of observations than those for the lower levels and hence are less representative. Observations at 10,000 feet or more in winter are more likely to be made in quiet weather than in disturbed weather so that the averages given in the table may be too low for the greater heights. The disturbed conditions which prevail in winter over the Mediterranean when the sea is relatively warm would however tend to keep the average wind velocity constant up to a certain height. In summer when the sea is relatively cold the stratification of the air would tend to be more perfect and the velocity of the wind should then increase with height. These conditions in the Mediterranean may be compared with those at a land station where diurnal variation of the surface wind is observable. During the night the ground cools, the surface wind becomes light or calm and the rate of increase of wind velocity with height is greater than it is by day when the surface layers are more turbulent.

In the layers below 7,000 feet the maximum average velocities occur during the period January to February while at 10,000 feet and 13,000 feet the maxima occur in March and April, *i.e.*, later in the year. The period of minimum velocities at all heights up to 13,000 feet is July to October. At 2,000 feet the mean annual range is from 13 to 23 miles per hour; at 10,000 feet 19 to 25 mi/hr.

TABLE XVI.—MEAN VELOCITIES OF WIND AT VARIOUS HEIGHTS ABOVE THE GROUND AT MALTA, 1918-24

The numbers in the table are scalar means expressed in miles per hour.

Height in feet	Jan.–Feb.	Mar.–April	May–June	July–Aug.	Sept.–Oct.	Nov.–Dec.	Summer (May–Aug.)	Winter (Nov.–Feb.)
1,000	**21**	20	16	12	14	19	13	20
2,000	**23**	21	17	13	14	20	15	21
3,000	**23**	20	17	13	15	20	15	22
5,000	**21**	19	16	15	16	20	15	21
7,000	**21**	**21**	18	17	17	19	18	20
10,000	23	**25**	21	19	19	20	20	22
13,000	22	**23**	22	19	18	21	20	21
16,000	—	20	21	18	15	—	19	—
20,000	—	—	23	19	—	—	21	—

The results for the seasonal variation of wind direction may be briefly stated as follows. In July and August the mean direction in the lower layers is north-west and the winds veer with increasing height; in November and December the lower winds are westerly and back with increasing height. The average horizontal gradient of temperature in the layers up to 13,000 feet is therefore reversed in the course of the year over Malta, warm air being to the west in summer and cold air to the west in winter.

TABLE XVII.—MEAN VECTOR WINDS AT VARIOUS HEIGHTS ABOVE THE GROUND AT MALTA, 1918-24

	January–February		March–April		May–June		July–August		September–October		November–December	
Height in feet.	Degrees from North	Miles per hour	Degrees from North	Miles per hour	Degrees from North	Miles per hour	Degrees from North	Miles per hour	Degrees from North	Miles per hour	Degrees from North	Miles per hour
1,000	284	12	264	8	298	4	309	6	283	3	278	8
2,000	283	13	273	9	294	4	312	7	277	4	275	10
3,000	288	15	278	10	302	5	317	7	288	6	275	11
5,000	286	13	279	12	291	8	331	8	291	9	270	12
7,000	284	15	280	14	295	10	334	11	292	9	265	12
10,000	279	16	276	19	300	13	335	12	292	11	266	12
13,000	277	12	279	17	300	15	330	12	292	15	255	13
16,000	—	—	—	—	—	—	326	11	—	—	—	—

§ 16.—Constancy of Wind Direction

The ratio $\frac{\text{vector mean velocity}}{\text{scalar mean velocity}}$ gives a measure of the constancy of wind direction, because the vector mean velocity becomes more nearly equal to the scalar mean when the winds used in calculating the mean velocity become more and more similar in direction. This ratio has been used recently by German and Austrian writers. The values of this ratio are usually expressed in percentages. The lower winds at Malta are very variable in some months but become more steady at greater heights, the smallest variability occurring in late winter and early spring at heights of 7,000 to 10,000 feet. The factor for steadiness of wind direction does not give a definite idea of the extent of the variability of the wind direction but enables comparisons to be made. Perfect steadiness of wind direction would give a factor of 100 per cent, but complete variability in which all directions occurred with equal frequency would not necessarily give a zero factor unless the distribution of wind velocity were quite independent of the direction.

Table XVIII.—Constancy of Wind Direction at Malta at various Heights above the ground, 1918-24

The numbers given in the table are the values of the ratio $\frac{v}{V}$ expressed as a percentage, where v = vector mean velocity of wind and V = scalar mean velocity.

Height in feet	Jan.–Feb.	Mar.–April.	May–June.	July–Aug.	Sept.–Oct.	Nov.–Dec.
1,000	57	40	25	50	21	42
2,000	57	43	24	54	29	50
3,000	65	50	29	54	40	55
5,000	62	63	50	53	56	60
7,000	71	67	56	65	53	63
10,000	70	76	62	63	58	60
13,000	55	74	68	63	83	62
16,000	—	—	—	61	—	—

§ 17.—The Variation of Wind with Height

The preceding work represents a general survey of the data in which all the ascents were treated together. The ascents were afterwards classified according to the direction and force of the surface wind and the mean scalar and vector velocities were evaluated for heights of 500 feet, 1,000 feet, 2,000 feet, 5,000 feet, and 10,000 feet.

In winter most of the increase of wind velocity which occurs with increasing height takes place in the layers below 1,000 feet. If the surface wind is north-easterly the increase of wind with height is much smaller than with other directions. In summer if the force of the surface wind is four or more the greatest increase of velocity occurs when the direction is south-westerly; if the surface direction is north-east or south-east the velocity decreases again above 2,000 feet, while north-westerly winds remain constant above 1,000 feet. But if the surface wind is light the differentiation is not very strong although south-westerly winds still show a greater tendency to increase with height than other winds.

TABLE XIX.—MEAN VELOCITIES OF WIND IN MILES PER HOUR AT VARIOUS HEIGHTS ABOVE THE GROUND AT MALTA, SHOWING VARIATION ACCORDING TO THE DIRECTION AND FORCE* OF THE SURFACE WIND

Winter (October to March, 1922–23 ; 1923–24 ; 1924–25, *except February and March,* 1925.)

Height in feet.	Surface wind in NE. quadrant.			Surface wind in SE. quadrant.			Surface wind in SW. quadrant.			Surface wind in NW. quadrant.		
	Surface wind force 0–1	Surface wind force 2–3	Surface wind force 4 or more.	Surface wind force 0–1	Surface wind force 2–3	Surface wind force 4 or more.	Surface wind force 0–1	Surface wind force 2–3	Surface wind force 4 or more.	Surface wind force 0–1	Surface wind force 2–3	Surface wind force 4. or more.
Surface	2	7	16	3	7	16	3	6	13	3	7	16
500	6	11	18	9	13	20	8	15	23	9	16	23
1,000	7	12	20	11	14	24	9	17	25	10	15	28
2,000	8	12	20	12	16	28	10	19	27	11	17	30
5,000	12	15	20	15	15	—	12	18	27	14	19	29
10,000	18	15	19	19	17	—	17	22	—	19	19	25
Summer (April to September, 1923 *and* 1924.)												
Surface	3	6	15	3	7	15	3	7	13	3	7	17
500	6	9	20	7	12	22	7	12	24	7	10	20
1,000	7	10	26	9	14	27	10	12	27	9	12	23
2,000	7	11	27	9	14	30	12	14	30	9	12	23
5,000	13	13	21	11	12	17	14	16	29	11	14	22
10,000	17	19	—	15	17	—	19	18	—	16	20	26

* Beaufort scale.

The changes of wind direction which occur with increase of height are as follows. The wind backs above surface winds from north-east, veers decidedly above surface winds from south-east, veers slightly above surface winds from south-west and remains constant in direction above surface winds from north-west. In the layers below 1,000 feet there are slight irregular differences between the various quadrants.

TABLE XX.—MEAN VECTOR WINDS AT VARIOUS HEIGHTS ABOVE THE GROUND AT MALTA, SHOWING VARIATION ACCORDING TO THE DIRECTION AND FORCE* OF THE SURFACE WIND

Winter (October to March, 1922–23 ; 1923–24 ; 1924–25, *except February and March,* 1925).

Height in feet	Surface wind in NE. quadrant						Surface wind in SE. quadrant						Surface wind in SW. quadrant						Surface wind in NW. quadrant					
	Surface wind force 0–1		Surface wind force 2–3		Surface wind force 4 or more		Surface wind force 0–1		Surface wind force 2–3		Surface wind force 4 or more		Surface wind force 0–1		Surface wind force 2–3		Surface wind force 4 or more		Surface wind force 0–1		Surface wind force 2–3		Surface wind force 4 or more	
	Degrees from North	Miles per hour	Degrees from North	Miles per hour	Degrees from North	Miles per hour	Degrees from North	Miles per hour	Degrees from North	Miles per hour	Degrees from North	Miles per hour	Degrees from North	Miles per hour	Degrees from North	Miles per hour	Degrees from North	Miles per hour	Degrees from North	Miles per hour	Degrees from North	Miles per hour	Degrees from North	Miles per hour
Surface	41	2	51	7	53	16	135	3	128	6	114	16	225	3	225	6	225	13	309	3	308	7	309	16
500	51	5	54	11	46	18	145	7	131	12	117	20	221	6	228	14	234	22	307	7	308	13	308	23
1,000	54	5	55	12	49	20	155	9	137	14	120	22	222	7	231	16	236	26	304	8	309	15	307	28
2,000	56	4	57	11	49	20	180	9	152	13	130	26	228	8	238	17	244	27	293	9	308	16	307	30
5,000	340	3	28	11	33	20	222	7	191	8	—	—	247	9	253	15	249	27	288	11	305	16	311	28
10,000	202	6	354	11	18	18	262	12	236	10	—	—	270	11	249	19	—	—	295	11	314	14	317	23
Summer (April to September, 1923 *and* 1924).																								
Surface	45	3	47	6	46	15	135	3	135	7	128	15	227	2	215	7	218	13	317	2	309	7	306	17
500	38	4	51	8	46	19	144	7	141	11	147	21	239	7	223	10	219	23	318	7	310	10	307	20
1,000	21	3	58	7	50	25	150	8	150	13	151	26	245	8	229	11	219	26	315	8	313	11	310	23
2,000	2	3	55	7	58	25	168	6	164	10	152	29	247	9	242	11	228	27	317	8	309	11	314	22
5,000	347	7	10	7	54	16	318	2	225	6	191	15	279	10	275	14	235	24	330	8	315	11	303	21
10,000	323	11	328	9	—	—	325	9	286	13	—	—	300	13	291	14	—	—	332	11	321	15	288	24

* Beaufort Scale.

Figure 5.

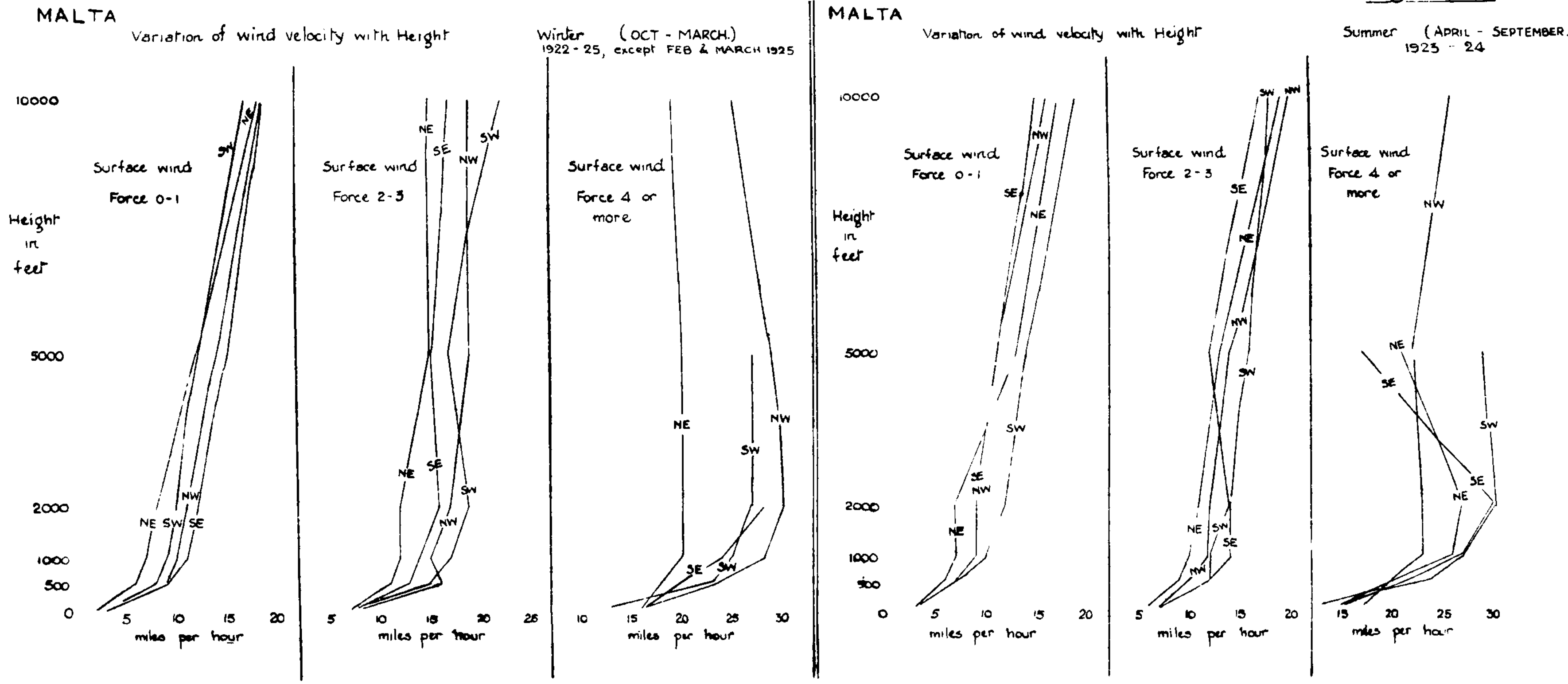

Figure 6.

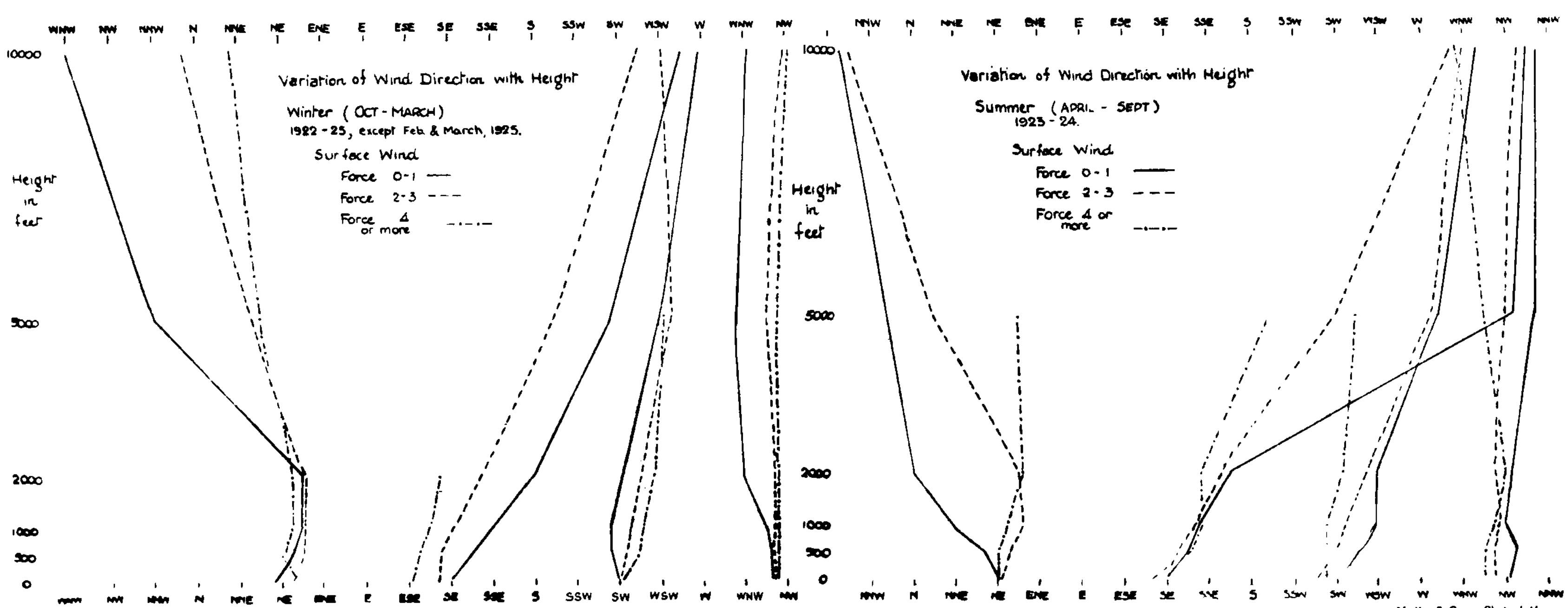

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TABLE XXI—FREQUENCIES OF WIND COMPONENTS AT VARIOUS HEIGHTS

The numbers given in this table are the actual numbers of west, east and zero components on the one hand and south, north and zero components on the other hand of the winds observed at various heights above the ground at Malta. The data are divided up according to the quadrant of the surface wind and further sub-divided according to the force of the surface wind on the Beaufort scale.

Winter (October to March, 1922–23; 1923–24; 1924–25 *except February and March,* 1925.)

Frequencies of west, east and zero components.

Height in feet.	Quadrant of surface wind.	NE.			SE.			SW.			NW.		
	Force of surface wind.	0-1	2-3	4 or more	0-1	2-3	4 or more	0-1	2-3	4 or more	0-1	2-3	4 or more
500	No. of west components.	2	—	—	5	1	—	68	115	32	50	155	115
	No. of east components.	22	58	52	36	65	15	11	2	—	4	1	—
	No. of zero components (E–W).	2	1	—	—	—	—	5	3	1	4	2	—
	Totals ..	26	59	52	41	66	15	84	120	33	58	158	115
1,000	No. of west components.	4	2	—	8	5	—	67	116	33	50	153	115
	No. of east components.	22	57	51	30	60	15	12	4	—	6	3	—
	No. of zero components (E–W).	—	—	1	1	1	—	5	—	—	2	2	—
	Totals ..	26	59	52	39	66	15	84	120	33	58	158	115
2,000	No. of west components.	7	4	1	15	14	1	68	115	33	51	150	112
	No. of east components.	18	53	50	22	49	14	15	5	—	4	4	—
	No. of zero components (E–W).	1	2	1	2	3	—	1	—	—	3	1	1
	Totals ..	26	59	52	39	66	15	84	120	33	58	155	113
5,000	No. of west components.	13	12	4	20	30	1	58	97	21	45	113	54
	No. of east components.	10	33	28	12	21	2	11	2	—	6	12	6
	No. of zero components (E–W).	—	—	—	1	4	1	1	1	—	—	—	1
	Totals ..	23	45	32	33	55	4	70	100	21	51	125	61
10,000	No. of west components.	5	10	5	9	17	1	36	58	8	23	55	16
	No. of east components.	4	13	6	3	8	1	7	4	—	8	16	3
	No. of zero components (E–W).	1	—	—	—	—	—	3	1	—	—	2	—
	Totals ..	10	23	11	12	25	2	46	63	8	31	73	19

Frequencies of south, north and zero components.

Height in feet.	Quadrant of surface wind.	NE.			SE.			SW.			NW.		
	Force of surface wind.	0-1	2-3	4 or more	0-1	2-3	4 or more	0-1	2-3	4 or more	0-1	2-3	4 or more
500	No. of south components.	1	1	1	35	59	13	70	111	31	5	5	—
	No. of north components.	19	54	49	5	4	2	13	6	2	51	150	115
	No. of zero components (N–S).	6	4	2	1	3	—	1	3	—	2	3	—
	Totals ..	26	59	52	41	66	15	84	120	33	58	158	115
1,000	No. of south components.	4	2	2	33	58	13	71	108	32	8	6	—
	No. of north components.	20	54	49	6	5	2	13	11	1	47	151	115
	No. of zero components. (N–S).	2	3	1	—	3	—	—	1	—	3	1	—
	Totals ..	26	59	52	39	66	15	84	120	33	58	158	115
2,000	No. of south components.	7	5	2	32	59	13	64	101	29	13	8	2
	No. of north components.	15	52	50	4	4	2	19	18	2	42	143	111
	No. of zero components (N–S).	4	2	—	3	3	—	1	1	2	3	4	—
	Totals ..	26	59	52	39	66	15	84	120	33	58	155	113
5,000	No. of south components.	6	3	—	21	44	4	52	64	18	15	20	5
	No. of north components.	15	42	32	9	9	—	17	30	3	35	104	55
	No. of zero components (N–S).	2	—	—	3	2	—	1	6	—	1	1	1
	Totals ..	23	45	32	33	55	4	70	100	21	51	125	61
10,000	No. of south components.	4	2	—	7	18	2	26	42	7	10	12	3
	No. of north components.	6	20	11	5	7	—	18	20	—	20	61	16
	No. of zero components (N–S).	—	1	—	—	—	—	2	1	1	1	—	—
	Totals ..	10	23	11	12	25	2	46	63	8	31	73	19

Note.—Components are defined by the direction *from* which they blow.

TABLE XXI—(*continued*).

Summer (April to September, 1923 and 1924.)

Frequencies of west, east and zero components.

Height in feet.	Quadrant of surface wind.	NE.			SE.			SW.			NW.		
	Force of surface wind.	0-1	2-3	4 or more	0-1	2-3	4 or more	0-1	2-3	4 or more	0-1	2-3	4 or more
500	No. of west components.	14	5	—	1	5	2	44	48	10	42	156	104
	No. of east components.	40	68	15	20	49	14	3	1	—	2	1	—
	No. of zero components (E–W).	—	2	—	2	1	—	2	—	—	—	3	—
	Totals ..	54	75	15	23	55	16	49	49	10	44	160	104
1,000	No. of west components.	24	18	—	3	8	2	46	45	10	44	153	105
	No. of east components.	31	53	15	19	44	14	3	3	—	1	5	—
	No. of zero components (E–W).	1	4	—	2	2	—	2	1	—	1	2	—
	Totals ..	56	75	15	24	54	16	51	49	10	46	160	105
2,000	No. of west components.	28	20	1	8	15	1	48	41	10	43	147	99
	No. of east components.	28	52	14	15	33	15	7	6	—	3	12	6
	No. of zero components (E–W).	1	2	—	2	1	—	—	—	—	1	1	—
	Totals ..	57	74	15	25	49	16	55	47	10	47	160	105
5,000	No. of west components.	30	21	1	11	26	7	47	36	10	32	115	91
	No. of east components.	25	43	12	10	17	4	7	4	—	15	35	3
	No. of zero components (E–W).	1	1	—	1	1	1	1	—	—	—	1	1
	Totals ..	56	65	13	22	44	12	55	40	10	47	151	95
10,000	No. of west components	29	29	5	11	29	2	37	25	4	25	78	43
	No. of east components.	16	19	1	7	4	1	7	7	—	16	26	3
	No. of zero components.	—	2	—	—	1	—	1	1	—	—	—	—
	Totals ..	45	50	6	18	34	3	45	33	4	41	104	46

Frequencies of south, north and zero components.

Height in feet.	Quadrant of surface wind.	NE.			SE.			SW.			NW.		
	Force of surface wind.	0-1	2-3	4 or more	0-1	2-3	4 or more	0-1	2-3	4 or more	0-1	2-3	4 or more
500	No. of south components.	5	6	1	23	50	16	37	46	9	—	2	—
	No. of north components	46	67	14	—	4	—	8	3	1	44	151	104
	No. of zero components (N–S).	3	2	—	—	1	—	4	—	—	—	7	—
	Totals ..	54	75	15	23	55	16	49	49	10	44	160	104
1,000	No. of south components.	11	13	1	22	49	16	34	39	8	3	6	—
	No. of north components.	42	60	14	1	4	—	13	7	2	43	151	105
	No. of zero components (N–S).	3	2	—	1	1	—	4	3	—	—	3	—
	Totals ..	56	75	15	24	54	16	51	49	10	46	160	105
2,000	No. of south components.	13	9	2	20	43	16	33	31	8	5	19	2
	No. of north components.	41	61	13	5	6	—	21	15	2	40	135	103
	No. of zero components (N–S).	3	4	—	—	—	—	1	1	—	2	6	—
	Totals ..	57	74	15	25	49	16	55	47	10	47	160	105
5,000	No. of south components.	10	11	3	10	31	11	19	9	8	8	18	11
	No. of north components.	45	54	10	12	13	—	34	29	2	38	130	83
	No. of zero components (N–S).	1	—	—	—	—	1	2	2	—	1	3	1
	Totals ..	56	65	13	22	44	12	55	40	10	47	151	95
10,000	No. of south components.	9	12	3	3	12	3	13	8	3	7	14	13
	No. of north components.	36	37	3	15	21	—	32	24	1	34	89	33
	No. of zero components.	—	1	—	—	—	—	—	1	—	—	1	—
	Totals ..	45	50	6	18	31	3	45	33	4	41	104	46

NOTE.—Components are defined by the direction *from* which they blow.

TABLE XXII.—NUMBERS OF OBSERVATIONS OF UPPER WINDS AT VARIOUS HEIGHTS ABOVE THE GROUND AT MALTA DURING THE PERIOD 1918 to 1924

Height in feet	January February	March April	May June	July August	September October	November December
1,000	321	328	284	427	268	297
2,000	304	320	275	424	254	288
3,000	270	299	257	411	236	252
5,000	167	186	208	329	182	149
7,000	123	131	177	250	139	106
10,000	75	93	133	196	102	68
13,000	35	38	76	108	64	35
16,000	—	25	43	61	37	—

Height in feet	*Summer* (May to August)		*Winter* (November to February)	
	7h. G.M.T.	17h. G.M.T.	7h. G.M.T.	17h. G.M.T.
1,000	404	307	374	244
2,000	397	302	354	238
3,000	370	298	310	212
5,000	264	273	159	157
7,000	194	233	116	113
10,000	145	184	72	71

§ 18.—TYPES OF UPPER WIND STRUCTURE

The following method of classifying pilot balloon ascents was introduced by Cave (3) :—

Type.

A Those which show " solid current " or little change from the direction and velocity at the surface over a large range of height.
B Considerable increase of velocity without much change of direction.
C Decrease of velocity with height.
D Reversal or great change in upper layers.
E Upper wind crossing lower wind (NW. or SW.).

Adding a class F for those ascents which show light variable winds all the way up, the percentage frequencies of occurrence of the various types at Malta are as follows :—

	A	B	C	D	E	F	Number of observations.
Summer (1923-24). *May—August.*	31	23	6	16	13	11	159
Winter (1922-23, 1923-24). *November—February.*	48	24	7	6	13	2	89

Only the layers up to 10,000 feet have been considered in this table.

Type A " solid current " is therefore more frequent in winter than in summer and Type D " reversal or great change " less frequent. Otherwise, apart from light variable winds in summer, the two seasons show similar results.

PART III. THE INCIDENCE OF CLOUD AT MALTA IN RELATION TO THE SURFACE WIND

§ 19.—The Cloud Data

This part of the investigation was suggested by Mr. D. Brunt and is based on observations of cloud at the University Observatory in Valletta. Surface observations at the University are available from July 1901, but there was only one observation a day until October, 1919 and this was made at 7h. G.M.T. (=8 a.m. local time). In October, 1919 afternoon and evening observations were commenced. The time of these was not quite fixed, but they have been treated as 13h. and 18h. observations, although the mid-day ones were sometimes made at 11h. and the evening ones at 16h. There are no records of observations during the night.

The author has also used some observations of cloud made by himself at Pietà and Floriana (in Malta) during the period 1923-25.

§ 20.—Seasonal Variation of Cloud

The mean cloudiness at 7h. G.M.T. for each month of the year is given in the following table :—

Table XXIII.—Mean Cloudiness in Tenths of Sky Covered at 7h. G.M.T. at Malta for the period 1901-24

Jan.	**6·2**	May	4·0	Sept.	3·9
Feb.	5·9	June	3·1	Oct.	4·9
Mar.	5·2	July	*1·7*	Nov.	5·8
April	5·2	Aug.	2·0	Dec.	5·7

The maximum falls in January and the minimum in July, the summer months being almost cloudless.

Analyzing the morning observations according to the wind direction at the time of observation we get the following table of mean results :—

Table XXIV.—Mean Cloudiness in Tenths of Sky Covered at 7h. G.M.T. at Malta for the period 1901-24, showing Variation according to the Direction of the Surface Wind

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.
May–Aug.	*2·1*	3·6	**4·3**	4·2	2·6	2·3	2·4	2·2	1·8
Nov.–Feb.	*5·0*	6·9	**7·2**	6·6	6·2	5·6	5·9	5·2	5·2

The mean cloudiness of east and south-east winds is therefore greater than that of other winds in summer ; and the mean cloudiness of north and north-west winds least. A calm morning in summer is also generally clear or nearly so. In winter the mean cloudiness of all winds is fairly high ; the maximum occurs with north-east and east winds, the minimum with north and north-west winds or calms.

§ 21.—Cloudiness in Relation to the Direction of the Surface Wind

Tables of frequencies of amounts of cloud in relation to wind direction have been prepared for the five-year period from October 1919 to September 1924 inclusive. They were originally made out for eight principal wind directions but afterwards condensed to four principal directions because the number of observations was not large enough to give smooth results for the less frequent winds. The tables also contain the results for the case in which wind direction is left out of account altogether. Except for a short period when a scale 0 to 4 was in operation, the observations of cloud at the University were entered in tenths of sky covered. The tables in their final form, however, show the frequencies of amounts of cloud on a scale 0-4 obtained from the original scale 0-10 according to the following scheme :—

Scale 0—4.		*Scale* 0—10.
Frequency of grade 0	=	sum of frequencies of grades 0 and 1.
,, ,, ,, 1	=	sum of frequencies of grades 2 and 3.
,, ,, ,, 2	=	(half the sum of frequencies of grades 4 and 6) + (frequency of grade 5).
,, ,, ,, 3	=	sum of frequencies of grades 7 and 8.
,, ,, ,, 4	=	sum of frequencies of grades 9 and 10.

The reason for this procedure is to avoid giving undue prominence to half clouded skies (6).

The tables contain two sets of figures, one referring to low cloud only and the other to all types of cloud taken together (total cloudiness). The term low cloud includes strato-cumulus, cumulus and fracto-cumulus, cumulo-nimbus, stratus and fracto-stratus and nimbus. The general results are shown in Table XXV and may be summarized as follows :—

Table XXV.—Percentage Frequencies of Amounts of Sky covered at 7h., 13h. and 18h. G.M.T. at Malta for the period October, 1919 to September, 1924, showing Variation according to the Direction of the Surface Wind

The table contains two sets of figures, one set referring to all types of cloud taken together, the other referring to low cloud only. The term low cloud includes stratus, strato-cumulus, cumulus, cumulo-nimbus and nimbus.

7h.

	NE.		SE.		SW.		NW.		Calm		All directions	
	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud
Spring (March—April)												
Clear	23	29	5	20	27	52	25	45	40	67	22	40
¼ clouded ..	17	26	11	20	18	13	21	22	20	17	18	20
½ clouded ..	6	9	9	16	9	9	22	14	—	—	13	12
¾ clouded ..	20	12	19	8	18	9	10	6	20	17	15	8
Overcast ..	34	24	55	36	27	18	22	13	20	—	32	20
No. of observations	36	36	55	52	59	58	117	113	5	6	272	265
Summer (May—August)												
Clear	56	68	33	54	54	68	67	76	74	85	59	71
¼ clouded ..	20	16	15	15	12	22	16	12	7	7	16	14
½ clouded ..	9	5	22	15	14	5	9	8	19	7	12	8
¾ clouded ..	5	2	9	6	10	2	3	2	—	—	5	2
Overcast ..	11	9	22	10	10	3	6	2	—	—	9	5
No. of observations	121	120	86	86	63	62	316	314	28	27	614	609
Autumn (Sept.—Oct.)												
Clear	30	32	23	31	27	54	34	44	40	46	31	41
¼ clouded ..	20	25	17	22	18	16	16	20	32	33	19	22
½ clouded ..	23	23	17	14	11	14	24	19	12	13	19	17
¾ clouded ..	16	9	19	14	20	8	11	8	4	—	15	9
Overcast ..	11	11	23	19	23	8	14	8	12	8	17	11
No. of observations	45	45	71	67	44	39	116	105	27	26	303	282
Winter (Nov.—Feb.)												
Clear	10	13	6	17	8	29	9	16	50	67	9	20
¼ clouded ..	13	17	13	19	9	14	19	25	13	11	15	21
½ clouded ..	23	22	7	7	15	17	24	22	25	11	19	17
¾ clouded ..	26	22	18	8	26	10	17	11	—	—	20	11
Overcast ..	29	27	56	49	42	30	32	27	13	11	38	31
No. of observations	75	69	101	91	124	115	288	275	9	9	597	559

13h.

	NE.		SE.		SW.		NW.		All directions	
	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud
Spring (March—April)										
Clear	16	33	15	33	28	42	22	40	20	38
¼ clouded ..	22	21	11	18	9	13	16	21	15	19
½ clouded ..	8	15	6	11	15	7	22	17	13	12
¾ clouded ..	30	13	28	15	17	20	20	12	24	14
Overcast ..	24	19	40	24	32	18	20	11	28	17
No. of observations	51	50	54	56	49	46	102	102	256	254
Summer (May—August)										
Clear	67	81	33	54	46	68	72	81	62	76
¼ clouded ..	12	10	22	14	17	14	12	9	14	11
½ clouded ..	7	2	15	11	11	5	7	5	8	5
¾ clouded ..	7	3	14	10	11	5	6	3	8	4
Overcast ..	7	3	16	10	14	8	3	1	7	4
No. of observations	157	158	96	95	37	38	239	236	529	527
Autumn (Sept.—Oct.)										
Clear	38	47	15	24	19	36	25	40	24	37
¼ clouded ..	20	25	23	29	19	21	21	21	21	24
½ clouded ..	28	23	21	20	19	17	20	22	22	20
¾ clouded ..	12	3	27	19	19	14	21	12	21	13
Overcast ..	2	2	15	9	23	12	12	5	12	6
No. of observations	65	65	81	74	51	44	95	90	292	273
Winter (Nov.—Feb.)										
Clear	2	13	2	19	11	27	7	17	7	19
¼ clouded ..	23	28	10	14	8	13	17	22	15	20
½ clouded ..	19	20	14	13	16	19	22	21	18	19
¾ clouded ..	27	16	15	14	22	13	24	16	23	15
Overcast ..	29	23	58	41	44	27	30	25	38	27
No. of observations	66	65	88	84	110	109	261	253	525	511

18h.

	NE.		SE.		SW.		NW.		All directions	
	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud
Spring (March—April)										
Clear	27	28	25	45	34	48	31	47	30	45
¼ clouded ..	27	31	7	7	17	21	24	20	19	19
½ clouded ..	7	7	16	11	14	10	14	14	13	11
¾ clouded ..	7	3	16	7	14	10	19	8	15	8
Overcast ..	33	31	36	29	22	10	13	11	23	18
No. of observations	32	30	58	57	61	61	112	109	263	257
Summer (May—August)										
Clear	67	79	39	64	59	73	68	81	62	77
¼ clouded ..	13	10	21	19	9	16	16	13	16	14
½ clouded ..	5	4	12	8	9	2	9	4	9	4
¾ clouded ..	5	2	12	3	9	2	4	1	6	2
Overcast ..	9	6	16	6	13	7	4	2	7	4
No. of observations	106	105	101	100	55	55	323	317	585	577
Autumn (Sept.—Oct.)										
Clear	48	65	30	41	34	59	42	57	39	54
¼ clouded ..	21	15	22	23	17	14	21	18	21	19
½ clouded ..	10	8	21	18	22	16	17	11	17	13
¾ clouded ..	12	8	11	8	10	5	9	6	10	7
Overcast ..	10	5	16	10	17	5	11	8	13	8
No. of observations	45	42	83	78	45	40	124	113	297	273
Winter (Nov.—Feb.)										
Clear	14	19	11	22	12	21	20	25	16	23
¼ clouded ..	10	12	13	19	25	23	23	25	20	22
½ clouded ..	21	10	10	7	21	20	22	20	10	18
¾ clouded ..	21	10	18	12	15	12	16	12	10	13
Overcast ..	34	31	47	41	27	23	10	19	28	25
No. of observations	62	61	102	95	108	105	291	279	563	540

Spring (March and April)

North-easterly winds.—Half-clouded skies have the least frequency, while clear and overcast skies occur with almost equal frequency, the former preponderating slightly at 18h., the latter at 7h. and 13h. The similarity of the two sets of figures for total cloudiness and for low cloud only at 7h. and 18h. shows that the morning and evening skies are more likely to contain low cloud than high ; but at 13h. there is a tendency to slight decrease of low cloud, the total cloudiness remaining practically unchanged. The figures show that the tendency for the sky to clear in the evening is not very well marked with north-easterly winds.

South-easterly winds.—The total cloudiness with south-easterly winds is very great at 7h. ; 55 per cent. of the skies are overcast and 19 per cent. are three-quarters clouded. Much of the cloud is low, 36 per cent. of the skies being overcast with low cloud, but low cloud tends to be absent almost as frequently as it is present. The total cloudiness tends to diminish slightly during the day, the low cloud, however, showing the greater tendency to disappear towards evening. At 13h. and 18h. half-clouded skies are the least frequent, the sky tending to be either clear or else overcast.

South-westerly winds.—When the wind is south-westerly the sky tends to be clear of low cloud, especially in the morning and evening. The total cloudiness does not vary much between 7h. and 18h. and exhibits a tendency towards a minimum frequency for half-clouded skies.

North-westerly winds.—With regard to total cloudiness no definite result is shown except a slight tendency to clear in the evening ; but low cloud tends to be absent.

Summer (May to August)

There is very little cloud at all during the summer and low cloud in particular tends to be absent. The tables show that south-easterly winds are the most liable to be associated with cloud.

Autumn (September and October)

North-easterly winds.—The general tendency is to be free from cloud. If cloud is present at 7h. it will generally be low cloud, and low cloud disappears towards evening.

South-easterly winds.—Winds in the south-east quadrant are more liable to be cloudy than other winds, but there is no definite relationship and all degrees of cloudiness appear to be equally probable. If cloud occurs at 7h. it is likely to be low cloud and there is a tendency to clear towards evening, especially with regard to low cloud.

South-westerly winds.—The sky tends to be free from low cloud with south-westerly winds especially in the morning and evening. The total cloudiness tends to decrease towards evening, but during the day all degrees of cloudiness are more or less equally probable.

North-westerly winds.—There is a fairly strong tendency for the sky to be free from low cloud when the wind is in the north-west quadrant. At 13h. all degrees of total cloudiness are almost equally probable, while at 7h. the sky is half clouded or less and at 18h. tends to be clear.

Calms.—A calm morning is generally associated with a clear or almost clear sky.

Winter (November to February)

North-easterly winds.—When the surface wind is north-easterly, the sky tends to be more than half covered, due chiefly to low cloud ; and there is no perceptible diurnal change.

South-easterly winds.—The sky tends to be overcast, chiefly with low cloud, when the wind is in the south-east quadrant and there is no marked tendency to clear in the evening.

South-westerly winds.—The total cloudiness with south-westerly winds tends to be high in the morning and afternoon but shows a tendency to diminish slightly in the evening. No very definite relationship can be traced in the case of low cloud.

North-westerly winds.—With north-westerly winds the tendency is for skies to be half clouded or more in the morning and afternoon with no definite rule in the evening. The figures indicate that the cloudiness is mostly due to low cloud.

§ 22.—Cloudiness in relation to the Force of the Surface Wind.

Tables of frequencies of amounts of cloud have been prepared for the period 1901-24, showing the variation of cloudiness at Malta according to the force of the surface wind. The tables refer to 7h. G.M.T. and show that in certain months (*e.g.* May) an increase in the force of the wind is associated in the case of easterly winds with an increase of cloudiness. The complete results are given in Table XXVI.

Table XXVI.—Frequencies of Amounts of Sky covered at 7h. G.M.T. at Malta during the period 1901-24, showing Variation according to the Direction and Force* of the Surface Wind.

(The figures in this table are relative frequencies, as described in § 21, not reduced to percentages.)

	Calm	N.			NE.			E.			SE.			S.			SW.			W.			NW.		
		light. (0-2)	mod. (3-4)	strong. (5-7)	light. (0-2)	mod. (3-4)	strong. (5-7)	light. (0-2)	mod. (3-4)	strong. (5-7)	light. (0-2)	mod. (3-4)	strong. (5-7)	light. (0-2)	mod. (3-4)	strong. (5-7)	light. (0-2)	mod. (3-4)	strong. (5-7)	light. (0-2)	mod. (3-4)	strong. (5-7)	light. (0-2)	mod. (3-4)	strong. (5-7)
Spring (Mar. & Apr.)																									
Clear ..	12	5	14	6	5	1	1	6	5	2	8	2	2	14	18	2	19	10	1	34	20	6	23	32	19
¼ clouded ..	7	4	5	6	5	4	—	7	7	2	7	12	2	16	10	—	14	5	—	30	19	5	14	25	10
½ clouded ..	5	4	2	1	4	1	3	9	6	9	11	9	4	11	5	1	10	4	—	20	26	14	10	24	17
¾ clouded ..	7	8	2	3	6	5	3	10	10	6	19	11	5	12	13	1	12	3	1	12	25	10	10	17	17
Overcast ..	7	5	7	8	7	12	13	15	34	21	18	25	17	15	6	1	16	2	1	19	16	3	9	25	10
Summer (May–Aug.)																									
Clear ..	71	122	60	8	56	15	—	62	22	—	47	15	1	87	17	5	81	7	1	138	49	2	200	168	32
¼ clouded ..	15	42	30	3	20	14	1	18	15	2	21	15	—	42	1	—	22	2	—	38	31	8	52	76	17
½ clouded ..	12	23	12	2	11	6	4	18	22	2	27	9	4	20	4	—	13	3	—	16	19	7	18	43	18
¾ clouded ..	5	6	5	3	14	9	—	14	18	6	17	14	3	12	4	1	8	4	1	14	16	5	10	25	9
Overcast ..	4	6	8	1	11	8	10	13	23	9	10	14	4	13	4	—	8	—	—	6	6	2	8	23	2
Autumn (Sept. & Oct.)																									
Clear ..	25	18	9	5	9	8	—	14	4	1	26	2	—	30	12	—	21	5	1	29	9	—	26	22	10
¼ clouded ..	28	15	11	2	3	6	1	11	10	1	18	11	1	32	6	—	13	4	1	33	18	1	16	30	11
½ clouded ..	23	9	9	1	9	12	2	17	8	4	16	9	6	18	6	1	15	3	—	24	17	3	15	27	6
¾ clouded ..	10	2	4	—	6	6	—	13	20	4	20	11	3	22	8	2	12	2	1	9	7	4	10	10	3
Overcast ..	6	5	5	1	6	3	3	13	21	10	13	13	2	15	7	2	15	2	—	13	3	1	5	12	6
Winter (Nov.–Feb.)																									
Clear ..	15	11	18	14	5	5	9	9	7	1	15	8	1	20	14	1	33	5	—	33	21	4	27	20	16
¼ clouded ..	18	6	17	11	4	7	1	8	4	4	15	7	3	26	7	4	51	15	1	41	32	7	35	38	15
½ clouded ..	26	8	17	12	5	13	8	10	13	3	17	10	5	43	19	2	47	21	4	44	42	13	23	46	32
¾ clouded ..	27	6	11	22	7	18	20	18	13	7	25	18	4	49	15	2	59	14	—	49	55	17	29	36	14
Overcast ..	17	7	8	24	12	26	30	25	38	33	33	32	20	79	25	6	52	24	4	63	55	24	27	33	32

* Beaufort scale.

§ 23.—Cloudiness at 21h. G.M.T.

In order to obtain some data which would indicate the conditions likely to prevail during the early part of the night the author made a series of observations at 21h. G.M.T. (=10 p.m. local time) during a period extending from the 29th of August, 1923 to the 8th of March 1925. These observations yield the following general results :—

Spring (*March and April*).—Except in the case of north-easterly winds the tendency is for the sky to be clear of low cloud at 21h. Only nine examples of north-easterly winds were available and in these cases the sky was mostly three-quarters covered or overcast with low cloud.

Summer (*May to August*).—The sky is generally cloudless at 21h. The few cases of cloudy or overcast skies occurred principally with north-easterly and south-easterly winds, and the observed cloud was medium or high cloud.

Autumn (*September and October*).—The sky is generally cloudless at 21h.

Winter (*November to February*).—The general tendency in winter is for the sky to be less than half covered with low cloud at 21h. except when the wind is north-easterly, when the frequencies of skies less than half covered are the same as those greater than half covered. No high cloud was observed with north-easterly winds during the period under discussion.

TABLE XXVII.—PERCENTAGE FREQUENCIES OF AMOUNTS OF SKY COVERED AT 21H. G.M.T. AT MALTA DURING A PERIOD EXTENDING FROM THE END OF AUGUST, 1923, TO THE BEGINNING OF MARCH, 1925, SHOWING VARIATION ACCORDING TO THE DIRECTION OF THE SURFACE WIND

The table contains two sets of figures, one set referring to all types of cloud taken together, the other referring to low cloud only. The term low cloud includes stratus, strato-cumulus, cumulus, cumulo-nimbus and nimbus.

TABLE XXVII

	NE.		SE.		SW.		NW.		Calm		All winds	
	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud
Spring (*March–April*)												
Clear	22	22	53	73	59	73	60	67	75	75	55	65
¼ clouded	—	—	12	7	5	5	7	13	—	—	6	6
½ clouded	—	—	6	7	5	5	7	—	—	—	3	3
¾ clouded	11	22	6	7	14	5	7	7	—	—	9	8
Overcast	67	55	24	7	18	14	20	13	25	25	27	18
No. of observations	9	9	17	16	22	22	15	15	4	4	67	66
Summer (*May—August*)												
Clear	67	80	78	100	100	100	86	95	87	92	87	97
¼ clouded	—	—	6	—	—	—	5	2	9	4	4	2
½ clouded	—	20	6	—	—	—	7	2	4	4	4	2
¾ clouded	17	—	6	—	—	—	2	—	—	—	3	—
Overcast	17	—	6	—	—	—	—	—	—	—	2	—
No. of observations	6	5	18	18	29	29	44	43	24	25	121	120
Autumn (*Sept.–Oct.*)												
Clear	39	53	60	80	73	77	67	85	85	94	69	81
¼ clouded	33	29	13	—	4	8	22	11	9	6	15	10
½ clouded	6	12	13	13	—	—	4	—	3	—	3	3
¾ clouded	11	6	13	7	8	4	7	4	—	—	7	3
Overcast	11	—	—	—	15	12	—	—	3	—	6	3
No. of observations	18	18	15	15	26	26	27	27	34	34	120	120
Winter (*Nov.–Feb.*)												
Clear	30	30	29	58	55	63	29	33	38	83	41	52
¼ clouded	13	13	23	19	16	20	27	29	15	—	20	20
½ clouded	13	13	10	13	5	4	12	12	15	—	[illegible]	8
¾ clouded	22	22	19	6	6	4	20	16	—	—	13	9
Overcast	22	22	19	3	18	10	12	10	31	17	18	11
No. of observations	25	25	33	34	84	82	53	54	13	12	208	207

With regard to total cloudiness the tendency for the sky to be clear is strongest in the case of south-west* winds. When the wind is south-east or north-west all degrees of total cloudiness are roughly of equal probability. The cloud which occurs is to a large extent high or medium cloud in the case of south-east winds but low cloud in the case of north-west winds.

The observations during the winter months November to February were also analyzed with reference to the force of the surface wind. If the surface wind is calm or very light the sky is generally clear at 21h., especially with regard to low cloud, while an increase in the force of the surface wind is associated with a tendency to increase of cloudiness. The chances of clear and cloudy skies are almost equal if the force of the surface wind exceeds three on the Beaufort Scale.

TABLE XXVIII.—PERCENTAGE FREQUENCIES OF AMOUNTS OF SKY COVERED AT 21H. G.M.T. AT MALTA DURING THE WINTER MONTHS OF 1923-24 AND 1924-25, SHOWING VARIATION ACCORDING TO THE FORCE OF THE SURFACE WIND.

	Force of surface wind (Beaufort scale)					
	0–1		2–3		4–5	
State of sky	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud
Clear	57	75	40	50	19	28
clouded ..	13	10	20	21	27	28
½ clouded ..	6	4	9	10	10	11
¾ clouded ..	9	4	12	5	21	23
Overcast ..	15	6	19	14	23	11
Number of observations	70	69	89	88	49	49

* It should be observed that when the night is otherwise calm a faint katabatic wind prevails at Pietà from south-west

§ 24.—DIURNAL VARIATION OF CLOUD.

During the period of 150 days extending from the 10th of October, 1924, to the 8th of March, 1925, cloud observations were made every two hours from 5h. till 21h. (G.M.T.). The total cloudiness was found to be three-quarters or overcast during the morning and afternoon on 50 to 60 per cent of the total number of days on which observations were made, decreasing during the evening so that 50 per cent of the days were clear or one quarter clouded by 18h. Analysis of the results for low cloud shows that low cloud at Malta during this particular winter was generally small in amount and tended to disappear altogether after 15h. During the day-time more than 50 per cent of the skies were free from low cloud or only one-quarter covered with low cloud.

The total cloudiness shows a minimum frequency for half-clouded skies.

TABLE XXIX.—PERCENTAGE FREQUENCIES OF AMOUNTS OF SKY COVERED AT MALTA DURING A PERIOD OF 150 DAYS EXTENDING FROM THE 10TH OF OCTOBER, 1924, TO THE 8TH OF MARCH, 1925, SHOWING DIURNAL VARIATION

The table contains two sets of figures, one set referring to all types of cloud taken together, the other referring to low cloud only. The term low cloud includes stratus, strato-cumulus, cumulus, cumulo-nimbus and nimbus.

G.M.T.

	5h.		7h.		9h.		11h.		13h.		15h.		17h.		19h.		21h.	
	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud	All types of cloud	Low cloud
Clear ..	15	36	18	38	16	35	19	31	16	26	20	37	25	45	46	58	**49**	63
¼ clouded ..	22	27	17	21	19	27	12	25	12	26	17	24	25	25	12	15	12	11
½ clouded ..	14	16	8	11	14	10	12	17	12	18	14	13	15	10	8	7	5	5
¾ clouded ..	25	12	20	19	12	11	21	14	21	19	17	15	9	7	13	8	11	9
Overcast ..	24	9	36	12	39	17	36	13	38	12	33	12	27	13	21	12	22	12
Number of observations	149	149	150	150	146	146	145	145	150	150	148	147	145	143	136	134	135	133

Considering now the form of cloud irrespective of the amount of sky covered we find that cumulus was by far the most frequently observed cloud form during the winter of 1924-25. It occurred on 70 to 80 per cent of the total number of days during the morning and afternoon and showed a tendency to disappear at night. The percentage of skies which contained cumulus at 21h. was 33. The other cloud forms were much less frequent than cumulus, but all showed the same tendency to disappear towards evening, except stratus which, though comparatively rare, was found to be more frequent in the early part of the night than during the day, while strato-cumulus showed a secondary maximum in the evening. There is thus a minimum frequency of rainfall at Malta in the evening.

TABLE XXX.—PERCENTAGE FREQUENCIES OF OCCURRENCE OF VARIOUS TYPES OF CLOUD AT MALTA DURING A PERIOD OF 150 DAYS EXTENDING FROM THE 10TH OF OCTOBER, 1924, TO THE 8TH OF MARCH, 1925, SHOWING DIURNAL VARIATION

G.M.T.

Form of cloud	5h.	7h.	9h.	11h.	13h.	15h.	17h.	19h.	21h.	All hours
Ci	9	25	29	24	**36**	31	27	10	11	23
Ci-St	25	24	16	24	**29**	27	10	10	11	20
Ci-Cu	1	7	6	6	**9**	6	5	2	1	5
A-Cu	17	**19**	16	18	15	17	10	5	3	14
A-St	**15**	9	12	10	9	10	11	4	6	10
St-Cu	10	**34**	21	22	19	22	**32**	17	16	21
Nb	**12**	11	11	10	10	10	6	8	6	9
Cu	62	73	73	76	81	**82**	54	35	33	64
Cu-Nb	19	**23**	**23**	17	22	18	11	5	3	16
St	7	7	2	4	3	4	12	**17**	13	7
Number of observations	149	150	146	145	150	147	145	136	135	1,303

There were 33 days on which the sky was overcast at 5h. G.M.T. during the winter of 1924-25 and the following table was made out to show what the prospects of clearing were likely to be in such cases during the day.

TABLE XXXI.—PERCENTAGE FREQUENCIES OF AMOUNTS OF SKY COVERED AT CERTAIN HOURS AT MALTA ON 33 DAYS WHEN THE SKY WAS OVERCAST AT 5h. G.M.T. DURING THE WINTER OF 1924

	9h. G.M.T.	13h. G.M.T.	17h. G.M.T.	21h. G.M.T.
Clear	Nil	Nil	Nil	35
¼ clouded	6	3	8	8
½ clouded	6	16	38	4
¾ clouded	6	19	12	19
Overcast	81	63	42	35

This table shows that the prospects of clearing before 17h. are rather remote, while at 17h. and also at 21h. only about 50 per cent. of the skies are half clouded or less than half clouded.

TABLE XXXII.—PROBABILITIES OF RAIN DURING THE NEXT 24 HOURS AT MALTA, SHOWING VARIATION ACCORDING TO THE DIRECTION OF THE SURFACE WIND AT 7H. G.M.T.

(Probabilities expressed as percentages). Period 1901-11.

	Calm	N.	NE.	E.	SE.	S.	SW.	W.	NW.
Sept.—Oct. ..	17	21	29	32	24	23	31	24	18
Nov.—Dec. ..	33	35	51	47	38	44	49	47	41
Jan.—Feb. ..	33	40	44	40	53	43	50	42	37
March—April ..	9	21	31	34	23	14	25	31	23

The probability of rain during the next 24 hours disregarding other elements varies as follows :—

Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
16	31	43	44	46	41	27	22	9

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