M.O. 245p.

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METEOROLOGICAL OFFICE.

PROFESSIONAL NOTES
VOL. 3. NO. 36.

ON THE INTER-RELATION OF WIND DIRECTION WITH CLOUD AMOUNT AND VISIBILITY AT CAHIRCIVEEN, Co. KERRY

BY

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Published by the Authority of the Meteorological Committee.

LONDON:
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1924.

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ON THE INTER-RELATION OF WIND DIRECTION WITH CLOUD AMOUNT AND VISIBILITY AT CAHIRCIVEEN, Co. KERRY.

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Part I.—Wind Direction and Cloud Amount.

In *Professional Notes* of the Metereological Office, Nos. 1 and 14, D. Brunt made an analysis of cloudiness and wind direction for Richmond (Kew Observatory) and several continental stations. His object was to ascertain whether there existed a statistical relation between wind direction and cloud amount of sufficient magnitude to be used effectively in the problem of forecasting the amount of cloud at night from observations made during the afternoon and evening.

In the first part of the present paper an endeavour is made to do the same thing for a locality on the extreme west coast of Ireland, and further, to form an estimate as to how far such relationships can be fairly determined from a series of observations extending over a limited number of years.

The data employed.—The investigation covers a period of ten years from Jan. 1, 1911, to Dec. 31, 1920, and is mainly based on daily eye observations of cloud and wind made at the hours 7h, 13h, 18h and 21h G.M.T. at Valencia Observatory. In the cases of 7h, 13h and 18h an uninterrupted series was available throughout, but at 21h there were numerous gaps during the first four years which were filled up by using cloud observations made at 22h. During the whole of these four years also, the wind direction at 21h or 22h was taken from the published hourly values of the cup anemometer on the Observatory tower, and referred in every case to the hour at which the cloud observation was made. Only about 20 per cent. of the evening observations were made at 22h during the years 1911–1914, so that the 10-year figures may be considered as referring to 21h without appreciable error.

In all the original eye observations the wind direction was estimated to the nearest even point. The cloud amounts were, until June 1915, entered in a code scale 0–4 having the following significance:—

Code figure.	Sky covered.	Code figure.	Sky covered.
0	0 or 1 tenth.	3	7 or 8 tenths.
1	2 or 3 tenths.	4	9 or 10 tenths.
2	4, 5 or 6 tenths.		

From that time they were made in tenths in the usual manner, In dealing with the data all the cloud entries were made in the scale 0–4, and a seasonal grouping was adopted in which winter stands for the three months Dec.-Feb., and the other seasons in rotation.

It was observed that comparatively few cases of 9 tenths covered occurred, so that 4 corresponds closely with a completely overcast sky. Also the number of occasions of 0 and 1 tenth was generally small, so that if 4 be counted as equivalent to 10 the two scales may be treated as proportionally equivalent, and in forming means one may be transformed into the other without appreciable error.

A few cases of fog occurred, but their number was so small that it was not thought worth while to attempt to tabulate them separately and they have been included with overcast sky without distinction. In the tables the wind directions have been grouped under eight heads and calm, instead of the original 17; this was effected by distributing those lying midway equally on either side, and resulted in a great number of entries of ½. To get rid of the ½'s the uniform plan was adopted of writing down the nearest odd figure in each case.

It will be seen that the total number of observations entered under the several hours is not the same; the cause is partly the rounding off mentioned in the preceding paragraph and partly a few errors in transcribing the data. The errors are not numerous and the means and general conclusions reached are not affected thereby.

Valencia Observatory, at which the observations were made, lies in a somewhat sheltered position on the south-east side of a narrow estuary running approximately north-east and south-west. Hills on either side of the estuary form a valley, at the mouth of which the Observatory is situated. The open sea lies about three miles away, and is visible as a short stretch of horizon to the west over low ground on the further side of the estuary. The remainder of the visible horizon consists of higher ground and hills, or islands at various distances, except between SSE and SSW where the land is low.

Table I gives the frequency of occurrence of each cloud figure 0–4 at the four hours, 7h, 13h, 18h and 21h, classified according to each season and wind direction. Tables II, III and IV are further analyses deduced from the material in Table I.

The distribution of wind direction.—Considering first the distribution of wind direction, south winds are on the whole the most common, with south-west and west coming next.

In Table II it is seen that the predominance of south is very marked in winter, spring and autumn, but that in summer west takes its place. This appears to be due to the tendency

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for a sea breeze to blow from the west during the middle of the day and in the afternoon in summer.

Calms need some comment. What is here described as a calm means roughly that the wind at the time of the observation did not exceed about 1 m/s. In the case of the observations at 21h–22h which were taken from *Hourly Values* a calm means that the average wind for the hour did not exceed 1.5 m/s. It is probable that a greater number of calms were thereby recorded than if eye observations at the exact hour had been employed throughout, and therefore the number of calms at 21h in the tables is probably rather greater than it should be in order to be strictly comparable with the other hours.

A reference to Table I shows that when calms occur in winter they do so at any hour but in spring or summer a calm at 13h or 18h is relatively rare, and when it does occur the sky is almost always overcast or nearly so. Autumn also shows rather fewer calms at those hours than at 7h or 21h; no doubt the explanation of the whole matter is that, as Table IV shows, calms normally tend to be associated with a low cloud amount, but when such a thing happens with the sun high in the sky a sea breeze sets in and destroys the calm.

The variation of cloud amount with wind direction.—Turning to Tables I and IV of cloud amount and wind direction, the most outstanding feature is the excessive amount of cloud with south winds in each season and at all hours of the day. At 7h the mean amount of cloud with a south wind throughout the year is as high as 9·1 tenths covered, and the proportion of overcast skies is greater than with wind from any other direction in each season and at every hour. In practically every case the cloudiness is at a maximum with south winds and decreases on either side to a minimum with north-east or north. The clearest skies occur with calms in spring and north-east winds in winter and autumn.

Both calms and north-east winds are associated with a small average amount of cloud at all seasons, and the percentage of clear or nearly clear skies occurring with them is greater than with any other direction. A clear sky may be expected with either once in 5 or 6 times on the whole, as against once in 77 for south-west winds, the direction for which fewest occur.

The general tendency is for the cloudiness to be greatest at 7h and to decrease continuously all day. In some cases, however, it is greater at 13h and 18h than at 7h or at 21h, and others it is less. Of the former, north-easterly winds in winter and easterly winds in spring may be cited, and the cause is probably the formation of convection clouds following a sunny morning; of the latter, west and north-west winds in spring and summer are the best examples and show the tendency in a marked manner, but the cause is unknown.

On clear nights there is a tendency for a gentle katabatic wind to blow down the valley or from off the hill to the east, appearing at the Observatory as a north-east or east-north-east wind. Hence a number of cases of east and north-east winds at night which are associated with a clear sky would otherwise be entered as calm, or even as a wind from some other quarter. The extent of such winds is to be found in the tables in the comparatively large number of clear or nearly clear skies occurring with north-east winds at 7h and 21h. It would not be correct to attribute the whole number of clear skies at night with a north-east wind to this cause as quite apart from it the sky with such winds tends to clear at night at Cahirciveen, but the existence of the katabatic wind is quite definite. Its force does not seem to exceed 2 on the Beaufort scale.

Reliability of the results for the purpose of forecasting.—The question may be asked, how far tables based on 10 years' observations represent true mean values, and what variations may occur from year to year. There is reason to think that the general characteristics noted above would be found in any means based on more than two or three years' observations. It happened that a period of five years from Oct. 1914 to Sept. 1919 was independently tabulated, and the foregoing notes drawn up on the strength of them before the remainder of the work was completed. When tables for the complete 10 years were available it was found that hardly any modification was necessary. It was also found that the mean amount of cloud at each hour agreed to within about 1 per cent. as between the 5 and 10 year periods, but that the mean amount with given wind directions did not agree nearly so closely.

This conclusion is not what would have been expected, but it receives confirmation from another source. On the reverse side of the *Monthly Meteorological Chart of the North Atlantic Ocean* for August 1919 is published an analysis of cloudiness and wind direction at Valencia Observatory based on the three summer months of the 10 years 1901–1910. The same general characteristics appear as in the present investigation and the distribution of wind direction is very much the same, but the mean amounts of cloud with given wind directions again differ, in some cases widely.

In order to form a quantitative estimate of the value to be attached to the 10-year means given here, the total period was broken up into two, and for each set of five summers a table similar to Table III. was drawn up shewing for each wind direction separately, the percentage frequency of each state of the sky on the 0-4 scale. In this way, for the four hours of observation and eight wind directions and calm, 36 differences between the two periods were obtained for each state of the sky. Their root mean squares were determined and are set out below :—

State of sky.	Percentage number of occurrences in the 10 summers, 1911–1920.	Standard value of the difference between the percentages for the two sets of five summers.
0	5·0	6·7
1	11·2	9·9
2	14·7	6·6
3	27·2	11·2
4	41·9	12·4

The left-hand column gives a rough measure of the quantity whose variation is given on the right hand side. The figures refer to every wind direction associated with a particular state of the sky and give no indication of differences which may exist as between different winds. It may be taken on the whole that north-east winds, and especially calms, shew larger differences as betwen the two periods than are indicated by the right-hand column, but winds from south-west and north-west definitely smaller ones, approximately 30 per cent. smaller.

As a further check the same method of procedure was adopted between the 10 summers 1901-1910 dealt with in the Atlantic Chart, and the ten 1911-1920. In this case, owing to the different method of classifying mist adopted in the former set it was not possible to obtain figures perfectly comparable with the latter one; still, the defect is not serious, and does not amount to much more than a slight inflation of the standard difference in the case of overcast skies, which is in fact noticeable. See the table following :—

State of sky.	Standard value of the differences between the percentages for the two sets of 10 summers, 1901–1910, and 1911–1920.
0	4·8
1	4·7
2	5·1
3	9·3
4	11·0

It would normally be expected that the standard differences for 10 years would be ·71 of those for 5, and such a relationship is seen to exist approximately, especially so if it be remembered that the value for overcast sky is too large for the reason given above.

Seeing how great an uncertainty is attached even to a 5-year mean it is clear that any attempt to predict the state of the sky from the wind direction will be liable to a very large casual error indeed.

It is perhaps more practicable to classify the state of the sky under three heads only instead of five, thus :—

A - - -	0—3 tenths covered.
B - - -	4—6 ,, ,,
C - -	7—10 ,, ,,

If now exactly the same procedure be followed as before, the standard values of the differences in the percentages for the two sets of 5 summers will be as follows :—

State of sky.	Percentage number of occurrences in the 10 summers, 1911 -1920.	Standard values of the difference between the percentages for the two sets of five summers.
A	16·2	8·9
B	14·7	6·6
C	69·1	7·5

This last result is a great deal better than the preceding one and indicates, for example, that Table I may be used to predict with some measure of confidence, that with a given wind direction the state of the sky will be C on 69 per cent. occasions, but if it be used to predict that with the same wind the sky will be overcast on 42 per cent. occasions, the risk of error is very much greater.

The evidence warrants the opinion that Tables II and IV have a real value, which lies not so much in the individual figures, as in the shapes of the curves which they yield when plotted. The latter will not vary much in their main features as between different periods, and represent permanent tendencies, whereas Table I has an appearance of precision which may be misleading.

The results of this part of the investigation have to some extent rather a local significance. There is some reason to suppose that the conditions are not quite the same 20 miles or more inland as they are on the coast, and especially it has been noticed that a good deal of the very low cloud experienced at Cahirciveen does not extend very far inland.

It is probably safe to assume that the conditions at Cahirciveen represent well those prevailing along the southern half of the west coast of Ireland, but without further investigation it would not be safe to apply them without modification to the south coast.

TABLE I. FREQUENCY OF WIND DIRECTION AND CLOUDINESS
basis 0 = Clear,

Winter.

State of sky.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Total.
	7 h.									
0	3	26	15	3	2	3	1	1	7	61
1	5	18	17	6	4	13	7	3	4	77
2	9	11	9	7	19	19	23	13	0	110
3	13	15	15	9	31	27	31	21	7	169
4	16	25	53	75	151	91	35	20	15	481
Totals -	46	95	109	100	207	153	97	58	33	898
	18 h.									
0	2	5	11	1	0	0	0	1	8	28
1	13	12	17	6	9	23	13	10	3	106
2	13	13	9	7	16	21	22	9	4	114
3	21	17	15	23	42	35	38	28	3	222
4	16	17	37	64	143	91	23	21	14	426
Totals -	65	64	89	101	210	170	96	69	32	896

Spring.

State of sky.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Total.
	7 h.									
0	1	13	6	3	1	1	1	0	26	52
1	5	19	12	3	1	3	1	1	23	68
2	17	34	21	6	5	13	25	19	22	162
3	25	33	22	13	24	22	29	31	23	222
4	21	28	36	47	107	65	43	37	33	417
Totals -	69	127	97	72	138	104	99	88	127	921
	18 h.									
0	7	9	1	5	6	3	9	11	5	56
1	20	11	1	3	8	9	22	27	3	104
2	27	17	6	9	21	15	30	23	4	152
3	21	18	9	17	37	42	54	53	6	257
4	19	21	19	33	103	63	46	37	6	347
Totals -	94	76	36	67	175	132	161	151	24	916

AT CAHIRCIVEEN, CO. KERRY. Period 1911-1920; on the
4 = Overcast.

Winter.

State of sky.	13 h.									Total.
	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	
0	1	8	8	2	1	0	0	0	7	27
1	5	7	8	7	10	9	9	7	4	66
2	12	13	11	9	17	21	25	11	5	124
3	19	17	24	23	51	54	45	27	16	276
4	11	15	29	63	141	101	29	12	8	409
Totals -	48	60	80	104	220	185	108	57	40	902
	21 h.									
0	2	18	19	4	5	5	3	0	13	69
1	11	11	10	11	13	15	21	7	7	106
2	13	14	11	9	15	13	16	15	7	113
3	11	11	14	18	22	24	16	15	4	135
4	15	19	47	63	163	93	47	17	20	484
Totals -	52	73	101	105	218	150	103	54	51	907

Spring.

State of sky.	13 h.									Total.
0	6	13	3	3	4	4	9	5	1	48
1	12	12	1	3	5	7	28	25	2	95
2	17	21	7	13	21	25	42	39	2	187
3	25	20	15	24	50	33	54	51	3	275
4	13	21	19	41	85	69	38	25	3	314
Totals -	73	87	45	84	165	138	171	145	11	919
	21 h.									
0	15	21	15	5	2	1	3	3	31	96
1	21	14	13	9	19	17	13	19	26	151
2	21	11	11	5	7	15	20	12	10	112
3	16	14	14	9	17	13	21	17	17	138
4	27	29	31	40	115	75	47	35	19	418
Totals -	100	89	84	68	160	121	104	86	103	915

TABLE I.—

Summer.

State of sky.	7 h. N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	Total.
0	3	7	5	1	1	1	3	1	31	53
1	9	13	7	1	5	3	1	3	30	72
2	14	15	7	7	3	8	11	14	28	107
3	27	15	18	12	29	31	37	40	32	241
4	35	18	17	34	95	71	60	58	58	446
Totals -	88	68	54	55	133	114	112	116	179	919

	18 h.									
0	8	3	1	1	2	5	13	13	1	47
1	21	3	1	4	12	9	25	35	1	111
2	17	1	0	3	11	25	41	47	1	146
3	29	8	5	13	28	50	65	66	4	268
4	17	7	8	33	82	77	67	43	9	343
Totals -	92	22	15	54	135	166	211	204	16	915

Autumn.

	7 h.									
0	1	13	9	1	1	1	0	0	7	33
1	7	23	19	3	1	5	3	6	7	74
2	13	35	16	15	7	20	23	17	23	169
3	27	29	19	20	20	19	25	27	18	204
4	21	24	26	57	117	80	39	35	32	431
Totals -	69	124	89	96	146	125	90	85	87	911

	18 h.									
0	3	15	7	3	3	1	2	2	8	44
1	13	13	13	11	9	11	17	17	9	113
2	16	7	15	17	18	20	27	24	6	150
3	29	13	13	27	35	29	41	37	11	235
4	24	11	19	47	111	59	46	25	27	369
Totals -	85	59	67	105	176	120	133	105	61	911

continued.

Summer.

State of sky.	13 h.									Total.
	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	
0	4	9	3	1	1	1	7	7	0	33
1	20	6	3	2	1	16	36	31	0	115
2	17	5	1	5	15	20	45	35	0	143
3	21	9	5	13	39	70	75	69	2	303
4	17	11	11	33	79	66	65	31	9	322
Totals -	79	40	23	54	135	173	228	173	11	916
	21 h.									
0	5	5	3	2	5	1	1	7	22	51
1	19	7	5	6	9	11	9	15	36	117
2	21	5	3	7	14	10	17	33	33	143
3	23	8	5	7	27	27	24	37	28	186
4	25	8	17	36	106	72	68	59	38	429
Totals -	93	33	33	58	161	121	119	151	157	926

Autumn.

State of sky.	13 h.									Total.
	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm.	
0	3	11	5	5	3	1	1	4	6	39
1	9	18	4	6	2	9	11	12	6	77
2	15	17	11	15	21	17	24	26	3	149
3	29	21	23	33	48	41	54	41	11	301
4	15	13	17	44	101	76	47	21	13	347
Totals -	71	80	60	103	175	144	137	104	39	913
	21 h.									
0	4	29	15	3	5	2	3	0	21	82
1	18	21	12	7	9	15	15	11	14	122
2	17	20	13	14	11	10	23	19	11	138
3	15	9	12	21	19	10	15	18	8	127
4	21	23	25	57	128	77	47	24	35	437
Totals -	75	102	77	102	172	114	103	72	89	906

TABLE II.—PERCENTAGE DISTRIBUTION OF WIND DIRECTION THROUGHOUT THE YEAR FOR THE FOUR HOURS TAKEN TOGETHER.

	Winter.	Spring.	Summer.	Autumn.	Year		Winter.	Spring.	Summer.	Autumn.	Year.
N. -	1·4	2·3	2·4	2·1	8·2	SW. -	4·5	3·4	3·9	3·4	15·2
NE. -	2·0	2·6	1·1	2·5	8·2	W. -	2·8	3·6	4·6	3·2	14·2
E. -	2·6	1·8	0·9	2·0	7·3	NW. -	1·6	3·3	4·4	2·5	11·8
SE. -	2·8	2·0	1·5	2·8	9·1	Calm -	1·1	1·8	2·5	1·9	7·3
S. -	5·9	4·4	3·8	4·6	18·7						

TABLE III.—PERCENTAGE FREQUENCY OF DIFFERENT STATES OF THE SKY ON THE BASIS 4 = OVERCAST, FOR EACH SEASON AND EACH OF THE FOUR HOURS.

	Winter.				Spring.				Summer.				Autumn.				Year.			
	7 h.	13 h.	18 h.	21 h.	7 h.	13 h.	18 h.	21 h.	7 h.	13 h.	18 h.	21 h.	7 h.	13 h.	18 h.	21 h.	7 h.	13 h.	18 h.	21 h.
0	6·7	2·9	3·3	7·6	5·6	5·2	6·2	10·7	5·7	3·7	5·1	5·3	3·6	4·2	4·7	9·2	5·4	4·0	4·8	8·2
1	8·6	7·5	11·8	11·8	7·5	10·2	11·3	16·5	7·8	12·4	12·1	12·6	8·2	8·4	12·2	13·4	8·0	9·6	11·9	13·6
2	12·3	13·7	12·7	12·4	17·4	20·3	16·5	12·2	11·7	15·6	16·1	15·4	18·6	16·4	16·6	15·2	15·0	16·5	15·5	13·8
3	18·7	30·5	24·8	14·9	24·0	29·9	28·1	15·1	26·2	33·2	29·2	20·2	22·3	33·0	25·9	14·1	22·8	31·7	27·0	16·1
4	53·7	45·4	47·4	53·3	45·5	34·4	37·9	45·5	48·6	35·1	37·5	46·5	47·3	38·0	40·6	48·1	48·8	38·2	40·8	48·3

TABLE IV.—MEAN CLOUD AMOUNT ON THE BASIS 10 = OVERCAST FOR EACH WIND DIRECTION IN EACH SEASON, AND THE WHOLE YEAR.

	Winter.					Spring.					Summer.					Autumn.				
	7 h.	13 h.	18 h.	21 h.	All Hours.	7 h.	13 h.	18 h.	21 h.	All Hours.	7 h.	13 h.	18 h.	21 h.	All Hours.	7 h.	13 h.	18 h.	21 h.	All Hours.
N.	6·8	6·8	6·4	6·2	6·6	7·2	5·9	5·6	5·5	6·0	7·4	5·9	5·7	6·2	6·3	7·2	6·6	6·7	6·0	6·6
NE.	4·9	6·0	6·1	5·0	5·4	5·8	5·7	6·1	5·4	5·7	5·9	5·4	6·2	5·4	5·7	5·5	5·2	4·8	4·4	5·0
E.	6·7	6·8	6·4	6·5	6·6	6·8	7·6	8·0	6·0	6·8	6·6	6·8	7·8	7·2	6·9	6·0	6·8	5·9	5·6	6·1
SE.	8·7	8·3	8·5	8·0	8·4	8·4	8·0	7·5	7·6	7·9	8·4	8·4	8·4	8·0	8·3	8·3	7·6	7·5	8·0	7·8
S.	8·9	8·7	8·8	8·7	8·8	9·3	8·1	8·2	8·5	8·5	9·0	8·6	8·3	8·4	8·6	9·3	8·5	8·5	8·7	8·7
SW.	8·1	8·3	7·8	8·1	8·1	8·6	7·8	7·9	8·0	8·0	8·7	7·6	7·8	8·3	8·0	8·4	8·2	7·8	8·2	8·1
W.	7·6	7·2	6·8	7·0	7·1	7·9	6·2	6·7	7·3	6·9	8·4	6·7	6·8	8·2	7·3	7·8	7·4	7·1	7·1	7·3
NW.	7·4	6·9	7·0	6·9	7·1	7·9	6·1	6·3	6·7	6·6	8·3	6·3	6·1	7·1	6·8	7·7	6·5	6·6	7·0	6·9
Calm	6·4	5·9	5·9	5·5	5·9	5·3	6·1	5·5	4·2	4·9	5·8	9·5	8·0	5·4	5·8	6·8	6·2	6·6	5·6	6·3
All Dirns.	7·6	7·7	7·5	7·3	7·52	7·4	6·9	7·0	6·7	7·00	7·6	7·1	6·8	7·3	7·20	7·5	7·3	7·1	7·0	7·22

	Whole Year.				
	7 h.	13 h.	18 h.	21 h.	All Hours.
All Directions	7·52	7·25	7·10	7·07	7·25

Part II.—Wind Direction and Visibility.

The data employed.—The following notes deal with an analysis of wind direction and visibility, also based upon observations made at Valencia Observatory.

The main part of the investigation covers a period of about two years from Feb. 1919 to Dec. 1920, during which time regular observations of visibility on a definite scale were made daily at 7h, 13h and 18h. The scale of visibility employed was that in which the extreme distance is taken at which a small object on the skyline can be seen and distinguished, the object being supposed to have a width of $2\frac{1}{2}'$ of arc and a height of $10'$.

The use of the scale is explained by the following table :—

Visibility No.	0 V	1 V	2 V	3 V	4 V	5 V	6 V	7 V	8 V	9 V
The object can be seen at	·2k	·5k	1k	2k	4k	7k	12k	20 k	30 k	Above 30k and at the same time Beaufort letter "v."
The object cannot be seen at	·5k	1k	2k	4k	7k	12k	20 k	30k	—	

The variation of visibility with wind direction and wind force.—Table V gives all the observations of visibility arranged according to wind direction, and expressed as percentages of the total number for each respective wind direction. The column headed "mean" gives the mean value of all the visibility numbers observed with each wind direction.

TABLE V.—PERCENTAGES OF EACH RANGE OF VISIBILITY WITH DIFFERENT WIND DIRECTIONS.

Visibility No.	9 V	8 V	7 V	6 V	5 V	4 V	3 V	2 V	1 V	0 V	No. of observations.	Mean.
	Percentage.											
N	9	**40**	31	12	7	1	—	—	—	—	77	7·3
NNE	9	**35**	27	19	4	4	—	—	—	2	68	7·0
NE	5	31	**33**	18	8	3	—	—	—	2	112	6·8
ENE	2	31	**33**	24	10	—	—	—	—	—	67	6·9
E	3	**29**	25	**29**	10	4	—	—	—	—	59	6·7
ESE	4	20	**33**	27	16	—	—	—	—	—	45	6·7
SE	1	21	18	**40**	8	11	1	—	—	—	83	6·3
SSE	2	10	25	**33**	12	8	7	2	1	—	126	5·9
S	0	13	21	**29**	15	13	6	3	—	—	290	5·8
SSW	1	12	19	**24**	22	13	5	3	1	—	86	5·7

Visibility No.	9 V	8 V	7 V	6 V	5 V	4 V	3 V	2 V	1 V	0 V	No. of Observations.	Mean.
				Percentage.								
SW - - -	1	11	**25**	24	19	14	4	1	1	–	191	5·8
WSW - -	2	18	**28**	24	15	6	4	3	–	–	201	6·2
W - - -	4	**26**	25	**26**	7	5	3	3	1	–	174	6·5
WNW - -	3	27	**35**	20	11	4	–	–	–	–	101	6·8
NW -	8	23	**40**	20	5	1	2	1	–	–	158	6·9
NNW - -	10	32	**36**	15	5	1	1	–	–	–	122	7·2
Calm - -	0	27	**31**	25	11	3	1	–	1	1	91	6·5
All directions and calm - -	4	22	**28**	24	11	7	3	1	0	0	2,051	6·5

Tables VI and VII give the same observations classified further according to wind force, and expressed as percentages of the total number occurring with that wind force and direction.

TABLE VI.—PERCENTAGES OF EACH RANGE OF VISIBILITY WITH DIFFERENT WIND DIRECTIONS.

(Winds of forces 0, 1, 2 and 3 only.)

Visibility No. -	9 V	8 V	7 V	6 V	5 V	4 V	3 V	2 V	1 V	0 V	No. of observations.	Mean.
				Percentage.								
N - - -	5	**42**	26	16	18	3	–	–	–	–	38	7·1
NNE - - -	13	**33**	30	18	3	3	–	–	–	–	40	7·3
NE - - -	7	**35**	32	17	5	2	–	–	–	2	86	7·0
ENE -	2	**37**	31	24	6	–	–	–	–	–	49	7·0
E - - -	5	24	22	**29**	15	5	–	–	–	–	41	6·6
ESE - - -	5	24	28	**29**	14	–	–	–	–	–	21	6·8
SE -	3	30	17	**36**	8	6	–	–	–	–	36	6·7
SSE - - -	6	10	**36**	**36**	3	6	3	–	–	–	31	6·5
S - -	0	17	**26**	**26**	14	7	6	4	–	–	88	6·0
SSW - - -	2	22	22	17	**26**	5	2	2	2	–	42	6·1
SW - - -	5	16	**28**	17	19	9	5	1	–	–	64	6·2
WSW - -	6	**27**	22	21	15	6	1	2	–	–	89	6·6
W - - -	6	**31**	24	20	7	4	4	3	1	–	112	6·6
WNW - - -	4	**35**	31	20	8	2	–	–	–	–	51	7·0
NW - - -	13	24	**30**	18	9	1	3	2	–	–	83	6·9
NNW - - -	**14**	25	**39**	18	2	0	2	–	–	–	44	7·2
Calms - -	0	27	31	25	11	3	1	0	1	1	91	6·5
All directions and calms - -	6	27	**28**	22	10	4	2	1	0	0	1,006	6·7

TABLE VII.—PERCENTAGES OF EACH RANGE OF VISIBILITY WITH DIFFERENT WIND DIRECTIONS.

(Winds of force 4 and upwards.)

Visibility No. -	9 V	8 V	7 V	6 V	5 V	4 V	3 V	2 V	1 V	0 V	No. of observations.	Mean.
	Percentage.											
N - - - -	13	**38**	36	8	5	–	–	–	–	–	39	7·5
NNE - - - -	4	**39**	22	21	7	7	–	–	–	–	28	6·9
NE - -	0	19	**39**	19	19	4	–	–	–	–	26	6·5
ENE - - - -	0	17	**39**	22	22	–	–	–	–	–	18	6·5
E - -	0	**39**	33	28	–	–	–	–	–	–	18	7·1
ESE - -	4	17	**37**	25	17	–	–	–	–	–	24	6·7
SE - -	0	13	19	**43**	8	15	2	–	–	–	47	6·0
SSE - -	1	10	21	**33**	15	8	8	3	1	–	95	5·7
S - - -	1	11	19	**30**	15	15	6	3	–	–	202	5·7
SSW - -	0	2	16	**32**	18	21	7	4	–	–	44	5–2
SW - -	0	9	24	**27**	19	16	4	0	1	–	127	5·7
WSW - - -	0	12	**33**	26	15	6	5	3	–	–	112	6·0
W -	0	18	28	**37**	6	6	2	3	–	–	62	6·3
WNW	2	18	**40**	20	14	6	–	–	–	–	50	6·6
NW - -	3	23	**51**	21	1	0	1	–	–	–	75	7·0
NNW - -	8	**36**	35	14	6	1	–	–	–	–	78	7·2
All directions -	2	16	**29**	27	12	9	3	2	0	–	1,045	6·2

Inspecting Table V it is seen that on the average, and without regard to any specific wind direction, visibility at Cahirciveen is good. On some occasions it is extraordinarily good and from the top of a neighbouring hill cumulus clouds have been seen on the horizon over the sea with perfect distinctness at a distance which was computed to be about 130 kilometres, or even more. The best average visibility occurs with northerly winds, the poorest with southerly, the comparatively bad visibility in the latter case being intimately connected with the frequent low cloud, light mist, rain and generally damp conditions prevailing with such winds. It follows from Table V that it is an even chance whether the standard small object can or cannot be distinguished at about 22 kilometres (14 miles).

Tables VI and VII do not differ much from each other; it is noticeable that the exceptionally good visibility denoted by Beaufort letter "v" mostly occurred with light winds, but was never observed in a calm. The stronger winds between south-south-east and south-west have the worst visibility of all, not only for the reason given above, but also owing to the prevalence of haze with strong south-south-east winds.

The columns headed "mean" are of value only as a comparison on an empirical basis between different directions and forces, they do not represent the mean limits of visibility in the different cases. It may be gathered from them that the visibility is nearly always better with light winds than with strong, and especially so with southerly winds.

The frequencies of occurrence of 9V present an interesting point in all the tables. 9V, as it has been interpreted in this investigation, represents a degree of transparency greatly superior to that ordinarily denoted by 8V, and while it is not possible to assign precise numerical limits to it owing to the absence of sufficiently distant objects, yet observations of distant low clouds have yielded approximate results which suggest that the lower limit is about 100 kilometres.* All the tables show a great preponderance of 9V with northerly winds; in the tables referring to stronger winds there are few entries with any other direction. On the other hand winds blowing off the Atlantic, which are likely to have travelled for a great distance over the ocean, and to be particularly free from dust, show remarkably few cases of 9V.

Unusual visibility as a sign of coming rain.—The meteorological conditions associated with unusual visibility were investigated further by noting entries of Beaufort letter "v" made at Valencia Observatory during the four years 1916–1919 and examining the barograms for the corresponding epochs. Out of a total of 62 cases the barometer was either steady or rising in 50 of them, and of the 12 others only one showed a rapid fall, in most cases the fall was slow and continuous. Another investigation showed that the mean relative humidity of the air on occasions when "v" was entered during the same four-year period was 73 per cent., the distribution being given below :—

Above 89%	89–85%	84–80%	79–70%	69–60%
2%	4%	14%	42%	38%

To serve as a standard the normal humidity for the corresponding hours and dates was determined for the 26-year normal 1886–1910, and found to be 81 per cent. This comparison has the more significance when it is remembered that 74 per cent. is approximately the mean value of the humidity at Valencia Observatory at the driest hour of the driest month of the year.

Exceptionally good visibility has long been widely regarded as a sign of approaching rain† and an enquiry into this belief yielded an interesting result. All the occasions on which Beaufort letter "v" was noted during the period 1916–1919 inclusive were entered, and the number of hours found which elapsed between the first recorded "v" on any particular day and the first appearance of rain. When "v" was noted on several consecutive days each day was considered by itself without reference

* *See* Note on Visibility, *Meteorological Magazine*, Oct., 1921, pp. 250–251.

† *See* Abercrombie—"Visibility." *Q.J.R. Meteor. Soc.*, Vol. 3 (New Series), p. 294.

to those following. The mean was found to be 41 hours. To serve as a standard with which to compare this figure, the year 1916 was chosen as a good representative of a year of normal rainfall both in amount and in number of rain-days, and it was found that on the average 25 hours elapsed between 13h on any particular day and the next appearance of rain; here also each day was considered by itself.

There is some confusion in the use of the Beaufort letter "v" by observers; sometimes it is interpreted as indicating a very exceptional clearness of objects at a moderate distance, sometimes as indicative of an exceptionally long range of vision. The two cases are not quite the same, but it would seem that in both there must be an exceptional degree of transparency in the air through which the observer is looking.

In the present investigation, while a few of the first class may have been included among the entries of "v" made use of, in the vast majority of cases it referred to a long range of vision pure and simple. It would seem that as far as Cahirciveen is concerned there is no truth in the supposed connection between great transparency of the air and coming rain. It would be much more true to regard "v" as a prognostic of fine weather, which is also borne out by the absence of any connection with a rapidly falling barometer.

The variation of haze with wind direction and wind force.— What might almost be called the opposite of the condition noted by "v" is that commonly described as haze. In *The Observer's Handbook** haze is defined as an obscurity due to smoke, dust or other cause when the air is dry. Starting with this definition an observer in a country district quickly notices that a peculiar colour in the atmosphere is associated with it, a dirty dull brownish tint, showing up as a reddish brown when the sun is low. This phenomenon is common at Valencia Observatory, surprisingly so considering the great distance which separates the district from any large manufacturing towns. It is as frequently seen when the air is damp as when it is dry, and as the colour characteristics are very definite and there is little risk of confusing them with anything else, the writers suggest that the limitation of the term haze to occasions when the air is dry is not very satisfactory.†

Treating the phenomenon as chiefly recognisable by its colour, in Table VIII all entries of its occurrence made at 7h, 13h and 18h during the two-year period 1919–1920 have been collected together, arranged according to wind direction, and the totals expressed as percentages of the corresponding wind direction frequency at those hours.

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* 1921 Edition, p. 53.

† See *Professional Note* No. 26. "The Relation between Haze and Relative Humidity of the surface air."—J. Wadsworth, M.A.

TABLE VIII.—PERCENTAGE NUMBER OF OCCASIONS ON WHICH HAZE WAS OBSERVED WITH EACH WIND DIRECTION.

Wind direction.	N.	NNE.	NE.	ENE.	E.	ESE.	SE.	SSE.
Percentage	3·9	7·4	16·1	20·2	22·0	22·2	21·7	11·9

Wind direction.	S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.	Calm.
Percentage	1·7	1·2	0·5	3·5	4·6	7·9	3·8	2·5	22·0

The intensity of the haze included in this table ranges from 4V to 8V but observations of 7V and 8V have not as much value as the others, the obscurity being very faint and less easy to distinguish from mist; their number however is not very large compared with the others.

As would be expected haze occurs principally with winds blowing off the land, and with winds between north-east and south-east is very common; but it is noteworthy that every direction is included in the table, even west and west-north-west, which at first sight would appear to be somewhat remarkable.

The synoptic charts were examined for all the occasions on which haze occurred with winds between south and north-north-west, and it was found that the weather conditions at the time were in all cases anticyclonic with light or variable breezes, while the gradient was in the majority of cases such as to cause a wind between north-east and south-east.

In a great many cases light breezes were no doubt merely local sea breezes while in some perhaps a local irregularity in the isobars might have given rise to a local wind different in direction from that of the main current. It seems probable in every case that the air which was reaching the Observatory from a seaward direction had only lately curved round from an easterly one.

In Table IX all the observations of haze of degrees of intensity 4V, 5V and 6V only, employed in the formation of Table VIII, have been selected and classified according to wind force; the results have been expressed as percentages of the total number of observations of wind of all forces for the various directions.

TABLE IX.—PERCENTAGE OF TOTAL NUMBER OF OBSERVATIONS OF EACH WIND DIRECTION OF OCCASIONS ON WHICH HAZE OF INTENSITY 4V, 5V AND 6V WAS NOTED, CLASSIFIED ACCORDING TO THE WIND FORCE PREVAILING AT THE TIME.

Wind direction.	N.	NNE.	NE.	ENE.	E.	ESE.	SE.	SSE.
Force 1–3	2·6	5·9	10·7	11·9	**16·1**	6·7	10·8	3·2
Force 4—	1·3	1·5	3·6	4·5	3·4	**13·3**	9·6	7·9

Wind direction.	S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.	Calm.
Force 1–3	1·7	1·2	0·5	3·5	3·4	6·9	3·2	1·6	20·9
Force 4—	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·8	—

It will be seen that with moderate or strong winds appreciable haze never occurs with winds between south and north-west. Its occurrence with a north-north-west wind suggests the possibility that the air had curved round a depression from Scotland.

The origin of the impurities in the atmosphere.—An interesting question arises as to the ultimate origin of the impurities in the air constituting the haze observed in the south-west of Ireland. The smoke of a large industrial district will produce haze for at least one or two hundred miles to the leeward, but Cahirciveen is about 350 miles from any such district in England, and about 260 from Belfast, the only large manufacturing centre in Ireland. It seems, however, almost certain that the origin in this case is in England. Firstly, after the onset of an easterly wind, there is at first no appearance of haze, but if the wind persists from that quarter it appears in the course of a day or two. Secondly, if domestic smoke and dust from the open country in Ireland were the cause there could hardly be so many occasions of Beaufort letter " v " with easterly winds, especially as the air is, as before stated, usually dry when " v " is observed and the dust should then be present in greater quantity than under damp conditions. Thirdly, the large number of occasions of haze shown in Table IX with the stronger winds from east-south-east and south-east practically precludes the possibility of its having arisen anywhere in Ireland.

It would appear that the smoke from the English Black Country and large manufacturing districts extends to a distance of three or four hundred miles with an intensity amounting at times to 4V or 5V.

If Tables V, VI and VII be compared with Tables VIII and IX, it will be seen that directions which yield the cleanest air, as suggested by the absence of haze, are not necessarily those which have a large proportion of 9Vs. From south to west, haze is very rare, and so also is exceptionally good visibility, winds from those directions tend to be damp. From west-north-west to north-north-west haze is still not common, but unusual visibility is at its maximum. The winds from the latter direction are frequently associated with the rear of depressions and are often dry.

The relation between visibility and the dryness of the air.— It will be seen that every condition which has been investigated has either directly associated unusually good visibility with dry air, or with conditions which tend to favour dryness, and there seems good warrant for asserting that as far as the south-west corner of Ireland is concerned it is a factor of primary importance.

It is interesting to observe how well this result agrees with the theory developed by Aitken in connection with visibility. In a paper read before the Royal Society of Edinburgh, Feb. 3rd, 1890*, Aitken showed that water vapour in a cooling atmosphere does not readily condense except there be nuclei of some solid matter present. Further, he points out that when solid nuclei are present water will begin to condense on them at a temperature considerably above the dew point. Air with a fairly large number of solid particles suspended in it may be transparent if it be very dry, but will become progressively less so as its humidity increases and more moisture condenses on the nuclei.

In a district on the western seaboard the atmosphere is much more free from solid impurities of the nature of dust or smoke than in the case of more easterly stations, though there is the possibility of particles of salt being suspended in the air. Low humidities on the other hand are very rare. It would be instructive to obtain data from other stations where the solid impurities are greater but the humidity is less, to determine whether this conclusion is of general application or not.

A good deal of the data in the foregoing investigation were obtained from a period previous to the use of a definite numerical visibility scale, and as has been suggested above, the use of the Beaufort letter " v " in former times was somewhat influenced by the opinions of the individual observer. Under such conditions it is probably not of much use for the purpose of comparing visibility at different stations, or even at the same station over different periods, if the observers have changed in the interval. For the particular purpose to which the observations have been applied in this case the objection does not very much matter, and in addition during the four years covered the use of " v " has been practically consistent throughout at Valencia Observatory.

* Abstracted in *Nature*, Feb. 27th, 1890, pp. 394–396.

Printed under the authority of His Majesty's Stationery Office
By Eyre and Spottiswoode, Ltd., East Harding Street, E.C. 4,
Printers to the King's most Excellent Majesty.