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PERSISTENCE OF THE HOURLY-MEAN SURFACE WIND AT TRAWSFYNYDD AND VALLEY

by
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An appendix to

A study of the relation between the surface wind at Trawsfynydd power station and nearby topography

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1. Introduction

The raw data used in this paper is the same as that of the main paper mentioned on the cover*. The number of hours for which the hourly-mean wind direction and speed remained within a direction-speed category is taken as a measure of persistence of wind and if the direction and speed remained within a category for r hours this is called 'a run of length r'. The within-category frequencies of run-lengths are used to calculate various persistence statistics for each category.

It was hoped that a comparison between the Trawsfynydd and Valley persistence statistics would reveal the effects of the mountainous topography near Trawsfynydd on the wind persistence there. Such effects are more likely to be discernible if a paired-comparison between runs is made, but no way of doing this could be thought of. An unpaired comparison was made but this did not expose links between wind persistence and topography at Trawsfynydd. Nevertheless, both Trawsfynydd and Valley persistence statistics are given in this paper.

2. Correction for missing observations

At any particular hour in a sequence of wind observations the direction or speed or both may be missing and we will call this event an 'incomplete observation'. When incomplete observations occur the sequence is broken and the true beginning or the true end of some of the runs will be unknown. The true beginning of the first run and the true end of the last run of a sequence will also be unknown. A run preceded by or followed by an incomplete observation will be called an 'undefined run'.

When run-lengths were being counted undefined runs were 'thrown out' so that some short runs and some long runs were excluded. Since it is reasonable to assume that there is a greater probability of an incomplete observation occurring in a long run than in a short run more long runs than short are likely to have been excluded and the observed frequency distribution of runs is likely to be

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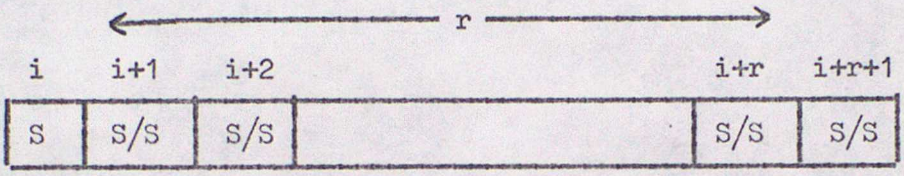
* To be published in Boundary-layer Meteorology

biassed. This biassing effect is illustrated in Figure 1. A correction for biassing was applied as follows:

Let an incomplete observation be denoted by an F (for failure) and a complete observation by an S (for success), and consider a run of length r occurring in the $(i+1)^{th}$ to $(i+r)^{th}$ position in a sequence of hourly wind observations.



The probability of not excluding this run is the probability of an (S) in the i^{th} position and then (S/S (S given S)) in positions (i+1) to (i+r+1). The probability of (S/S) was not assumed, A priori, to be equal to that of (S) since it was felt that the likelihood of an (S) in the $(i+1)^{th}$ position would depend to some extent on whether an S or an F had occurred in the i^{th} position. That is,

prob (S and S) = prob (S) x prob (S/S)

where prob (S) $\neq$ prob (S/S) since (S) and (S/S) are dependent events.

In fact, when estimates of prob (S) and prob (S/S) were made (see later), they were found to be only slightly different.

Let prob (S in i^{th} position) $= t$

and prob (S/S in any of the subsequent (r+1) positions)) $= p$

Then, prob (not excluding a run of length r) $= t\ p^{r+1}$

Hence, if f'_r is the frequency of runs of length r when undefined runs have been excluded and f_r is the frequency which would have been observed had there been no undefined runs, then

$$f'_r = t \cdot p^{r+1} \cdot f_r$$

$$\text{or } \underline{f_r = \frac{1}{t \cdot p^{r+1}} f'_r} \qquad A$$

Since p and t are unknown, estimates $\hat{p}$ and $\hat{t}$ of them were made as follows:

$$\hat{p} = \frac{\text{number of occasions of } (S/S)}{\text{number of occasions of } (S/S) + \text{number of occasions of } (F/S)}$$

$$\hat{t} = \frac{\text{number of occasions of } (S)}{\text{total number of occasions}}$$

If we now make the reasonable assumption that runs occur randomly in a given sequence of observations then for each direction-speed category a correction can be made for the exclusion of undefined runs using Equation A. Run-length frequencies corrected in this way were used to obtain the persistence statistics given in Table 1, 2 and 3. Isopleths were drawn through the mean run-lengths given in Tables 1.1, 2.1 and 3.1 and the results are shown in Figures 2, 3 and 4.

Figures 2 and 3 indicate a variation of persistence with wind direction and speed at Trawsfynydd but it is not clear how the nearby topography contributes to the variations.

3. <u>Distribution of run-lengths within a category</u>

The run-length distributions for the 84 (12 x 7) categories were obtained and a brief description of them will now be given. The distributions were all roughly the same shape; the mode was at r=1 (hour) in all categories and thereafter the run-length frequency tended to decrease with increasing run-length value, but rather irregularly. Most of the frequencies were contained within the region $r \leqslant 4$ (hours) and some distributions had long tails.

The shape of the distributions suggested that an attempt to fit a geometric distribution to each might be worthwhile. Moreover, under certain assumptions, a geometric distribution can be theoretically derived as follows:

Let θ be the probability that a given hourly-mean wind will be in the same category as that of the immediately previous hourly-mean wind. That is, θ is the probability of a 'success'* given that the immediately previous observation

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* This definition of a 'success' should not be confused with that given in Section 2.

was a 'success'. In other words Θ is the 'stay-on' probability for a particular category. Hence $(1-\Theta)$ is the 'switch-off' probability for the category or the probability of a 'failure' given that the previous observation was a 'success'. Writing S for 'success' and F for 'failure' we have

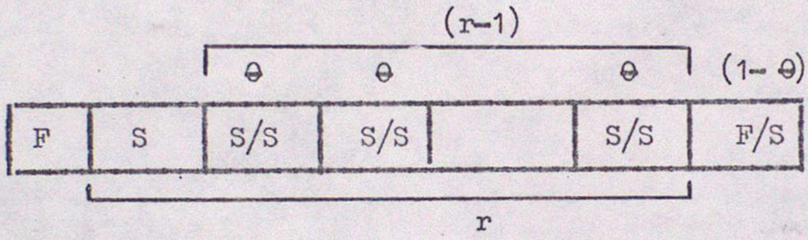
$$\text{prob } (S/S) = \Theta$$

$$\text{prob } (F/S) = 1 - \Theta$$

therefore, the probability of a run of length r is given by

$$\text{prob } (r) = \Theta^{r-1} (1 - \Theta)$$

if, and only if, the 'stay-on' probabilities are independent of each other.



In this context the assumption of dependence one-back and no further (Markov dependence) infers that the hourly-mean wind has no 'memory' further back than the previous hourly mean wind; that is, persistence is weak.

Since Θ is unknown it was estimated for each category as follows:

$$\hat{\Theta} = \frac{\text{number of occasions of } (S/S)}{\text{number of occasions of } (S/S) + \text{number of occasions of } (F/S)}$$

Since the number of occasions of (S/S) in a run of length r is (r-1) the total number of occasions of (S/S) in a category is

$$\sum_{r=1}^{\infty} (r-1) f_r$$

where f_r is the frequency of runs of length r. Also, there is one occasion of (F/S) per run so the total number of occasions of (F/S) in a category is

$$\sum_{r=1}^{\infty} f_r = N$$

$$\therefore \quad \hat{\theta} = \frac{\sum_{r=1}^{\infty}(r-1)f_r}{\sum_{r=1}^{\infty}(r-1)f_r + \sum_{r=1}^{\infty} f_r}$$

$$= 1 - \frac{1}{\bar{r}}$$

where $\bar{r}$ is the mean run-length for the category.

The chi-square (χ^2) Goodness-of-fit test (see Appendix A) was now used to test the hypothesis of a geometric distribution of run-lengths, for Trawsfynydd and Valley surface winds, and the results are given in Tables 4 and 5. The Trawsfynydd distributions were fitted surprisingly well; only 1 of the 27 values of (χ^2) was significant at the 5% level and this was not significant at the 1% level. The results for Valley were not so good; 7 of the 33 values of (χ^2) were significant at the 5% level and 5 of these were significant at the 1% level (highly significant).

We conclude that, although there will be exceptions, in general a geometric distribution is a good approximate hypothesis for the distribution of run-lengths of hourly-mean surface wind within 30-degree and 5-knot categories.

The Chi-Square Goodness-of-fit test

Let a sample of N observations be drawn from a population whose members have been classified in C ways. Thus, we have a sample of 'observed frequencies', one frequency for each of the C classes. We now make the null hypothesis* that the members of the population are distributed according to some distribution law and we wish to test whether the frequencies with which the C classes have been observed to occur in the sample support this hypothesis with a sufficiently high degree of confidence.

First, we calculate the frequencies with which the C classes would occur in the sample if the hypothesis were correct; these are the 'expected frequencies'. In this paper the hypothesis was that run-lengths (r) were geometrically distributed so the expected frequencies (E_r) are given by

$$E_r = N\,\theta^{r-1}\,(1-\theta) \qquad r = 1, 2, 3, \ldots\ldots C$$

where θ is the parameter of the distribution. Since θ is unknown it must be estimated using the sample frequencies.

Next, we have to determine whether the observed frequencies (O_r) differ from the expected frequencies (E_r) by more than can reasonably be attributed to chance. If the differences cannot be attributed to chance (that is, to random sampling fluctuations), they are said to be 'significant' and the hypothesis is rejected. The decision as to what is attributable to chance depends upon the probability level α (say) at which we decide to carry out our test. α is usually chosen to be 0.05 and when this value is used we are testing at the '5% significance level' or with '95% confidence'.

In order to test whether the differences ($E_r - O_r$) are significant a sample test-statistic which is a function of the differences is defined and its random sampling distribution is derived, under the assumption that the hypothesis is true. When this sampling distribution is known the probability

* an hypothesis we are going to try to nullify

of getting the observed value of the test-statistic can be determined, under the hypothesis, and if this probability is less than α the differences are adjudged to be significant at the 100 α % significance level and the hypothesis is rejected with 100 (1 − α) % confidence.

In the case of the chi-square test the test-statistic is

$$(\chi^2) = \sum_{r=1}^{c} \frac{(E_r - O_r)^2}{E_r}$$

It has been shown by Karl Pearson that for large samples* the discrete variable (χ^2) has very nearly the same sampling distribution as the continuous variable χ^2 (defined later) on (c−b) 'degrees-of-freedom', if the hypothesis is true. The degrees-of-freedom are the number of independent variates in the sum. 'b' is the number of 'linear constraints' (discussed later). Thus although there are c variates in (χ^2) only (c−b) of them are independent.

The χ^2 variable is defined as the sum of ν squared, standardized, <u>independent</u>, Normal deviates:

$$\chi^2_\nu = \sum_{i=1}^{\nu} \left(\frac{x_i - \mu_i}{\sigma_i} \right)^2$$

Thus each x_i has its own independent Normal distribution with mean μ_i and variance σ_i^2 .

A linear constraint arises when we use a linear function of the observed frequencies to calculate the expected frequencies. Two linear constraints arose when using the Chi-square test in this paper. The first was

$$N = \sum_{r=1}^{c} O_r$$

and the second arose when estimating θ from the observed frequencies as follows:

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* Sample size (N) greater than about 50.

$$\hat{\theta} = \frac{\sum_{r=1}^{c} (r-1) O_r}{\sum_{r=1}^{c} (r-1) O_r + \sum_{r=1}^{c} O_r}$$ (see Section 3 and write O_r for f_r)

$$= \frac{\sum_{r=1}^{c} r.O_r - N}{\sum_{r=1}^{c} r.O_r}$$

$$\therefore \hat{\theta}\left(\sum_{r=1}^{c} r.O_r\right) = \sum_{r=1}^{c} r.O_r - N$$

When calculating (χ^2) two rules arise due to treating each cell frequency as a Normal variate when in fact it is a Binomial variate:

Rule 1. The total frequency N should be at least 50.

Rule 2. Cell frequencies should be grouped so that no expected frequency is less than 5.

It is also preferable that the number (m) of cells should be neither too small nor too large. $5 \leqslant m \leqslant 20$ is good but values of m less than 5 may have to be tolerated to satisfy Rule 2.

When (χ^2) and its degrees-of-freedom have been determined then χ^2-tables are used to ascertain whether (χ^2) is greater than the $100\,\alpha$ % critical value of χ^2. If it is then the hypothesis is rejected with $100\,(1 - \alpha)$ % confidence. Figure 5 is given to help clarify the procedure.

Table 1.1

MEAN RUN-LENGTH (hours), FREQUENCY & PERCENTAGE FREQUENCY OF RUNS TRAWSFYNYDD LOW-LEVEL WINDS

WIND SPEED (Knots)	N 35-01	02-04	05-07	E 08-10	11-13	14-16	S 17-19	20-22	23-25	W 26-28	29-31	32-34	N 35-01	ROW VALUE
	WIND DIRECTION (tens of degrees)													
>30							3.0							3.0
							1							1
							0.03							0.03
26 - 30							1.7	2.4						2.1
							3	5						8
							0.08	0.14						0.22
21 - 25							2.4	2.0	4.0	1.0	1.0	1.0		2.1
							12	24	2	1	1	1		40
							0.31	0.61	0.06	0.03	0.03	0.08		1.08
16 - 20	2.0	2.0		1.0		4.5	1.6	2.7	3.0	3.7	7.0	5.0	2.0	2.6
	2	3		1		2	42	120	17	6	1	1	2	195
	0.05	0.08		0.03		0.05	1.13	3.24	0.46	0.16	0.03	0.03	0.05	5.26
11 - 15	2.3	2.8	2.1	2.2	2.7	2.5	2.1	2.8	2.2	2.1	2.8	3.0	2.3	2.5
	10	25	9	11	8	21	69	191	118	52	14	8	10	536
	0.27	0.67	0.24	0.30	0.22	0.57	1.86	5.15	3.18	1.40	0.38	0.22	0.27	14.46
6 - 10	1.9	2.9	2.0	1.9	2.5	2.1	2.1	2.6	2.8	3.0	2.4	2.3	1.9	2.5
	61	126	80	60	71	150	98	249	318	238	73	37	61	1561
	1.65	3.40	2.16	1.62	1.92	4.05	2.64	6.72	858	6.42	1.97	1.00	1.65	42.12
1 - 5	1.7	1.7	1.6	1.7	2.3	2.2	1.5	1.9	1.9	1.9	1.8	1.6	1.7	1.9
	43	63	64	127	234	219	79	89	179	163	66	39	43	1365
	1.16	1.70	1.73	3.43	6.31	5.91	2.13	2.40	4.83	4.40	1.78	1.05	1.16	36.83
COLUMN VALUE	1.9	2.5	1.8	1.8	2.3	2.2	1.9	2.6	2.4	2.5	2.2	2.1	1.9	
	116	217	153	199	313	392	304	678	634	460	155	85	116	
	3.13	5.86	4.13	5.37	8.45	10.58	8.20	18.29	17.11	12.41	4.18	2.29	3.13	

Table 1.2 STANDARD DEVIATION OF RUN-LENGTH (hours) & MAXIMUM RUN-LENGTH
TRAWSFYNYDD LOW-LEVEL WINDS

WIND SPEED (Knots)	N 35-01	02-04	05-07	E 08-10	11-13	14-16	S 17-19	20-22	23-25	W 26-28	29-31	32-34	N 35-01	ROW VALUE
>30							(0.0) 3							(0.0) 3
26 - 30							(0.5) 2	(1.0) 4						(0.9) 4
21 - 25							1.8 8	1.2 6	(1.0) 5	(0.0) 1	(0.0) 1			1.5 8
16 - 20	(1.0) 3	(1.4) 4		(0.0) 1		(3.5) 8	1.0 7	2.1 14	2.9 12	(0.9) 5	(0.0) 7	(0.0) 5	(1.0) 3	2.1 14
11 - 15	1.3 5	2.3 10	(1.1) 4	(1.9) 6	(1.9) 6	1.7 6	1.4 6	2.3 17	2.3 19	1.3 6	2.7 11	(2.7) 9	1.3 5	2.1 19
6 - 10	1.6 9	2.6 17	1.5 8	2.1 12	1.9 10	1.9 13	1.7 11	2.1 11	2.5 14	2.7 14	2.3 17	1.6 7	1.6 9	2.3 17
1 - 5	0.9 4	1.3 7	1.2 6	1.3 8	1.7 11	2.0 12	1.0 6	1.6 11	1.3 10	1.3 7	1.1 7	1.5 10	0.9 4	1.5 12
COLUMN VALUE	1.4 9	2.3 17	1.4 8	1.6 12	1.8 11	2.0 13	1.4 11	2.1 17	2.2 19	2.2 14	2.0 17	1.8 10	1.4 9	

( ) LESS THAN 10 OBSERVATIONS

Table 2.1

MEAN RUN-LENGTH (hours), FREQUENCY & PERCENTAGE FREQUENCY OF RUNS
TRAWSFYNYDD HIGH-LEVEL WINDS

WIND DIRECTION (tens of degrees)

WIND SPEED (Knots)	N 35-01	02-04	05-07	E 08-10	11-13	14-16	S 17-19	20-22	23-25	W 26-28	29-31	32-34	N 35-01	ROW VALUE
>30						1.0 1 0.03	2.0 3 0.05	1.9 10 0.20		1.0 1 0.03	1.0 1 0.03			1.7 16 0.33
26 - 30						4.0 1 0.03	1.6 7 0.18	2.2 25 0.66	1.3 3 0.08	2.5 2 0.05	3.0 4 0.10	3.0 1 0.03		2.2 43 1.12
21 - 25	1.0 1 0.03	1.3 4 0.10	6.0 1 0.03		3.3 6 0.15	1.7 7 0.18	1.9 16 0.41	2.4 97 2.47	1.9 25 0.64	2.3 4 0.10	1.9 7 0.20	2.6 5 0.13	1.0 1 0.03	2.2 173 4.42
16 - 20	2.4 19 0.48	2.7 22 0.56	2.2 5 0.13	1.1 8 0.20	1.5 16 0.41	2.6 29 0.74	2.5 44 1.12	3.0 178 4.50	2.7 94 2.39	2.7 46 1.17	2.3 32 0.81	2.4 9 0.23	2.4 19 0.48	2.7 502 12.74
11 - 15	3.2 38 0.97	2.6 73 1.86	1.7 26 0.66	2.0 42 1.07	2.1 37 0.94	2.7 85 2.16	2.0 80 2.03	2.9 177 4.50	2.6 232 5.90	2.8 157 3.99	2.7 78 1.98	1.5 19 0.48	3.2 38 0.97	2.6 1044 26.54
6 - 10	1.7 70 1.78	2.2 137 3.48	1.6 57 1.45	1.6 46 1.17	1.8 99 2.52	2.1 187 4.75	1.9 60 1.53	2.1 110 2.80	2.2 268 6.81	2.3 276 7.02	1.6 80 2.03	1.4 32 0.81	1.7 70 1.78	2.0 1422 36.16
1 - 5	1.2 34 0.86	1.2 31 0.79	1.3 27 0.69	1.4 28 0.71	1.5 66 1.68	2.2 174 4.42	1.7 48 1.22	1.6 33 0.84	1.5 92 2.34	1.5 141 3.59	1.1 42 1.07	1.1 19 0.48	1.2 34 0.86	1.6 735 18.69
COLUMN VALUE	2.0 162 4.12	2.2 267 6.79	1.6 116 2.95	1.7 124 3.15	1.8 224 5.70	2.3 484 12.31	2.0 258 6.53	2.6 630 15.97	2.3 714 18.15	2.3 627 15.94	2.0 244 6.23	1.6 85 2.16	2.0 162 4.12	

Table 2.2 STANDARD DEVIATION OF RUN-LENGTH (hours) & MAXIMUM RUN-LENGTH
TRAWSFYNYDD HIGH-LEVEL WINDS

WIND SPEED (Knots)	N 35-01	02-04	05-07	E 08-10	11-13	14-16	S 17-19	20-22	23-25	W 26-28	29-31	32-34	N 35-01	ROW VALUE
>30						(0.0) 1	(1.0) 5	(0.9) 3		(0.0) 1	(0.0) 1			1.2 5
26-30						(0.0) 4	(0.5) 2	1.6 9	(0.5) 2	(1.5) 4	(1.2) 4	(0.0) 3		1.5 9
21-25	(0.0) 1	(0.4) 2	(0.0) 6		(1.8) 5	(1.2) 4	1.0 4	2.0 9	1.5 7	(2.2) 6	(0.7) 3	(1.4) 5	(0.0) 1	1.8 9
16-20	1.3 7	2.2 7	(1.2) 4	(0.3) 2	0.6 3	1.8 6	1.6 6	2.7 19	1.9 9	1.7 9	1.4 7	(1.0) 4	1.3 7	2.1 19
11-15	2.4 9	3.3 20	1.1 6	1.4 6	1.5 6	3.2 21	1.4 6	2.6 15	2.0 13	2.6 12	2.5 14	0.6 3	2.4 9	2.4 21
6-10	1.1 5	1.5 7	1.0 6	1.0 4	1.5 10	1.6 12	1.3 5	2.4 16	1.6 10	2.0 14	1.0 6	0.7 3	1.1 5	1.7 16
1-5	0.6 4	0.5 3	0.5 3	0.9 4	0.8 5	1.9 9	1.4 8	1.0 5	1.0 5	0.9 6	0.3 2	0.3 2	0.6 4	1.3 9
COLUMN VALUE	1.6 9	2.2 20	1.0 6	1.1 6	1.3 10	2.1 21	1.4 8	2.4 19	1.8 13	2.0 14	1.7 14	0.9 5	1.6 9	

( ) LESS THAN 10 OBSERVATIONS

Table 3.1 MEAN RUN-LENGTH (hours), FREQUENCY & PERCENTAGE FREQUENCY OF RUNS
VALLEY LOW-LEVEL WINDS

WIND SPEED (Knots)	WIND DIRECTION (tens of degrees) N 35-01	02-04	05-07	E 08-10	11-13	14-16	S 17-19	20-22	23-25	W 26-28	29-31	32-34	N 35-01	ROW VALUE
>30	1.0					1.3	2.1	2.3	1.9	1.6	2.0	2.5	1.0	2.0
	2					12	49	67	45	19	23	8	2	225
	0.05					0.26	0.76	1.33	0.68	0.42	0.31	0.18	0.05	4.00
26-30	3.0		2.5		3.0	1.9	2.2	2.2	2.5	2.2	2.1	2.3	3.0	2.3
	5		2		1	28	56	98	53	33	15	19	5	310
	0.13		0.05		0.03	0.71	1.46	2.51	1.36	0.86	0.39	0.50	0.13	8.00
21-25	3.6	2.1	1.7		2.5	1.7	2.9	2.5	2.5	2.3	2.3	2.2	3.6	2.5
	15	8	8		8	41	74	149	88	81	45	31	15	548
	0.39	0.21	0.21		0.21	1.10	1.99	3.95	2.28	2.09	1.20	0.81	0.39	14.44
16-20	1.8	2.2	2.0	1.4	1.2	2.1	2.7	2.1	2.0	2.3	2.8	2.0	1.8	2.3
	30	25	25	5	11	40	130	138	122	90	77	38	30	731
	0.78	0.65	0.65	0.13	0.29	1.05	3.37	3.58	3.22	2.33	2.04	0.99	0.78	19.09
11-15	2.4	2.6	2.6	2.3	1.5	2.1	2.3	2.3	2.3	2.1	2.4	2.3	2.4	2.3
	63	54	49	19	20	36	85	110	115	109	117	75	63	852
	1.65	1.41	1.28	0.50	0.52	0.94	2.22	2.88	3.01	2.83	3.03	1.96	1.65	22.23
6-10	2.1	2.3	2.6	1.9	2.2	1.5	1.9	2.0	1.9	1.8	1.8	2.0	2.1	2.1
	105	91	104	56	35	30	50	61	68	106	107	83	105	896
	2.75	2.38	2.72	1.46	0.92	0.78	1.31	1.60	1.78	2.77	2.80	2.17	2.75	23.44
1-5	1.4	1.6	1.6	1.4	1.5	1.1	1.0	1.6	1.1	1.1	1.8	1.3	1.4	1.5
	37	56	53	30	17	13	15	25	13	25	29	23	37	336
	0.97	1.46	1.39	0.78	0.44	0.34	0.39	0.65	0.34	0.65	0.76	0.60	0.97	8.79
COLUMN VALUE	2.1	2.2	2.3	1.8	1.8	1.8	2.4	2.3	2.2	2.1	2.3	2.1	2.1	
	257	234	241	110	92	200	459	648	504	463	413	277	257	
	6.72	6.12	6.30	2.88	2.41	5.18	11.51	16.51	12.66	11.95	10.54	7.22	6.72	

Table 3.2

STANDARD DEVIATION OF RUN-LENGTH (hours) & MAXIMUM RUN-LENGTH VALLEY LOW-LEVEL WINDS

WIND SPEED (Knots)	N 35-01	02-04	05-07	E 08-10	11-13	14-16	S 17-19	20-22	23-25	W 26-28	29-31	32-34	N 35-01	ROW VALUE
						WIND DIRECTION (tens of degrees)								
>30	(0.0) 1					0.9 4	3.9 19	3.2 14	3.5 13	2.0 7	5.9 18	(3.4) 11	(0.0) 1	3.6 19
26 - 30	(2.6) 8		(1.5) 4		(0.0) 3	1.4 8	1.5 8	1.7 9	2.1 8	1.8 9	1.1 5	(2.3) 11	(2.6) 8	1.8 11
21 - 25	3.4 13	(1.6) 6	(1.0) 4		(1.7) 6	1.2 6	2.0 8	2.1 14	1.8 10	1.6 8	1.5 7	1.3 6	3.4 13	1.9 14
16 - 20	1.1 4	1.2 6	2.4 13	(0.8) 3	0.4 2	1.4 7	2.5 12	1.5 12	1.3 8	1.9 11	2.0 7	1.4 7	1.1 4	1.8 13
11 - 15	1.8 10	2.2 11	1.6 7	1.5 6	1.0 5	1.7 8	1.9 11	2.3 15	2.1 15	1.7 12	2.0 13	1.9 10	1.8 10	2.0 15
6 - 10	1.4 7	1.9 10	2.2 15	1.3 6	1.9 10	1.0 5	1.2 5	1.2 5	1.2 7	1.2 5	1.1 5	1.3 6	1.4 7	1.5 15
1 - 5	0.7 4	0.8 4	1.1 6	0.7 4	1.0 5	0.4 2	0.0 1	0.8 4	0.4 2	0.3 2	2.4 14	0.7 4	0.7 4	1.1 14
COLUMN VALUE	1.7 13	1.7 11	1.9 15	1.2 6	1.5 10	1.3 8	2.2 19	2.1 15	1.9 15	1.7 12	2.1 18	1.7 11	1.7 13	

( ) LESS THAN 10 OBSERVATIONS

Table 4

VALUES OF CHI-SQUARE AND DEGREES-OF-FREEDOM
TRAWSFYNYDD LOW-LEVEL (SURFACE) WINDS

Wind speed (Knots)	N 35-01	02-04	05-07	E 08-10	11-13	14-16	S 17-19	20-22	23-25	W 26-28	29-31	32-34	N 35-01
> 30													
26 - 30													
21 - 25													
16 - 20								4.33 5					
11 - 15							5.35 3	5.02 6	4.96 4	1.32 2			
6 - 10	1.01 2	3.62 6	0.44 2	<u>6.50</u> 2	5.54 3	4.19 4	2.36 3	9.80 6	11.95 7	9.35 7	4.48 3		1.01 2
1 - 5		3.48 3	2.94 2	2.99 2	6.19 5	10.99 5	3.66 2	4.27 3	2.82 4	2.95 3	4.49 2		

WIND DIRECTION (tens of degrees)

VALUES OF CHI-SQUARE SIGNIFCANT AT THE 5% LEVEL ARE UNDERLINED

CHI-SQUARE WAS NOT COMPUTED FOR CATEGORIES WITH LESS THAN 50 OBSERVATIONS

Table 5

VALUES OF CHI-SQUARE AND DEGREES-OF-FREEDOM
VALLEY LOW-LEVEL (SURFACE) WINDS

WIND SPEED (Knots)	N 35-01	02-04	05-07	E 08-10	11-13	14-16	S 17-19	20-22	23-25	W 26-28	29-31	32-34	N 35-01
>30								6.20 3					
26 - 30							16.76 2	4.08 3	4.46 3				
21 - 25							13.47 4	4.22 5	4.62 3	12.65 2			
16 - 20							17.59 5	5.80 4	1.89 3	0.99 3	8.99 4		
11 - 15	1.70 3	0.77 3					1.55 3	6.80 4	11.03 4	2.90 3	5.39 4	4.56 3	1.70 3
6 - 10	1.42 3	2.41 3	3.94 4	4.90 2			0.89 2	4.95 2	0.75 2	10.46 2	0.15 3	10.86 3	1.42 3
1 - 5													

WIND DIRECTION (tens of degrees)

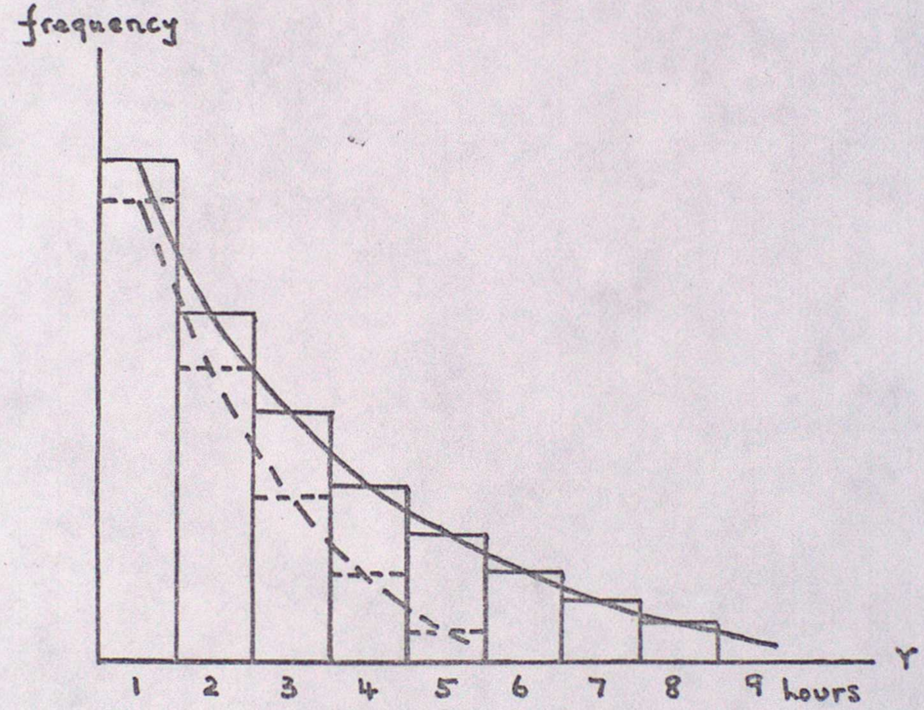
VALUES OF CHI-SQUARE SIGNIFICANT AT THE 5% LEVEL ARE UNDERLINED ONCE

VALUES OF CHI-SQUARE SIGNIFICANT AT THE 1% LEVEL ARE UNDERLINED TWICE

CHI-SQUARE WAS NOT COMPUTED FOR CATEGORIES WITH LESS THAN 50 OBSERVATIONS

Figure 1

BIASSING OF THE OBSERVED DISTRIBUTION OF RUN-LENGTHS



——— distribution of runs in the perfectly complete sequence.

- - - - - distribution of runs when undefined runs have been excluded.

Figure 2

ISOPLETHS OF MEAN RUN-LENGTH (hours)

TRAWSFYNYDD LOW-LEVEL WINDS

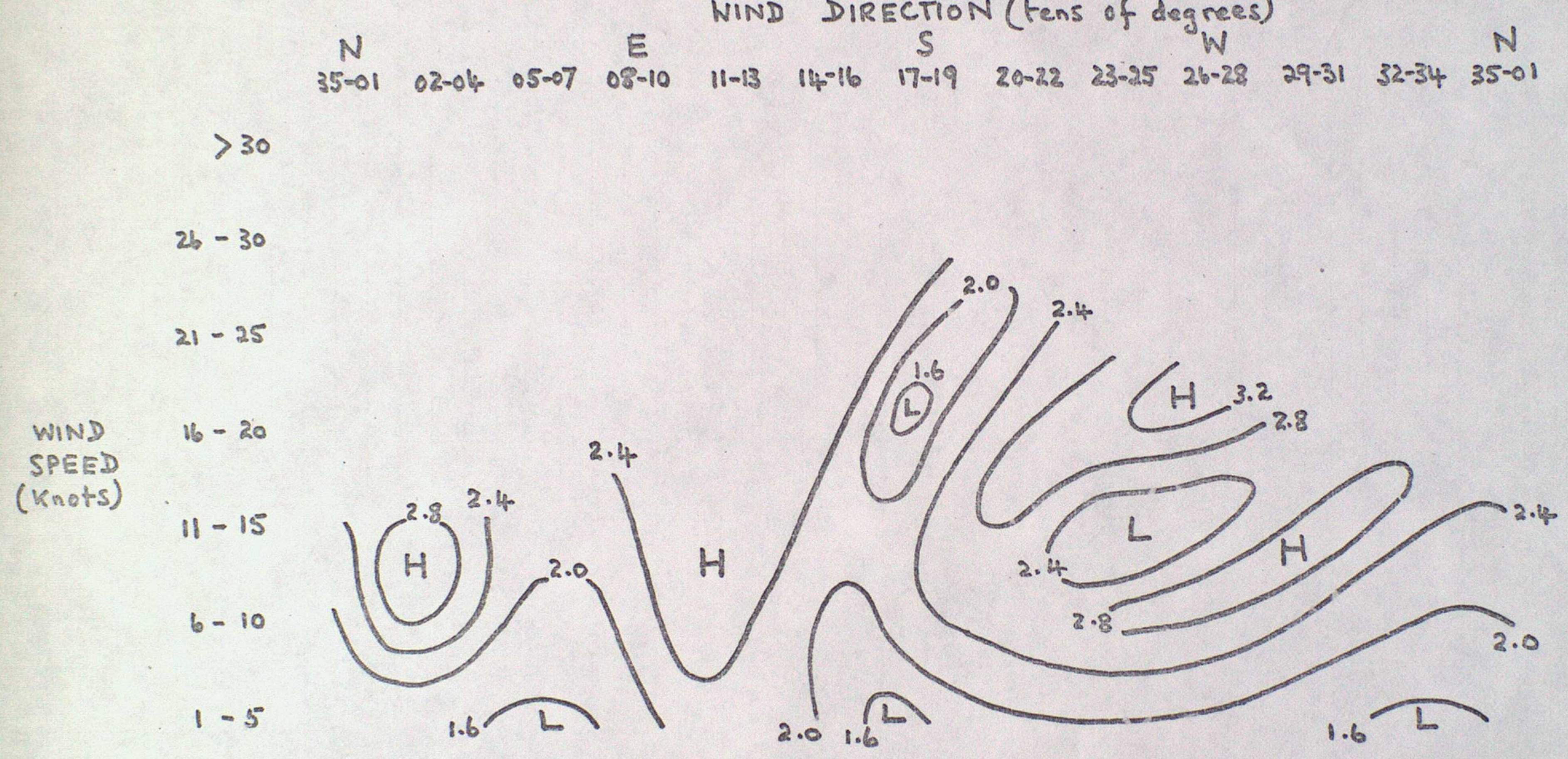


Figure 3

ISOPLETHS OF MEAN RUN-LENGTH (hours)

TRAWSFYNYDD HIGH-LEVEL WINDS

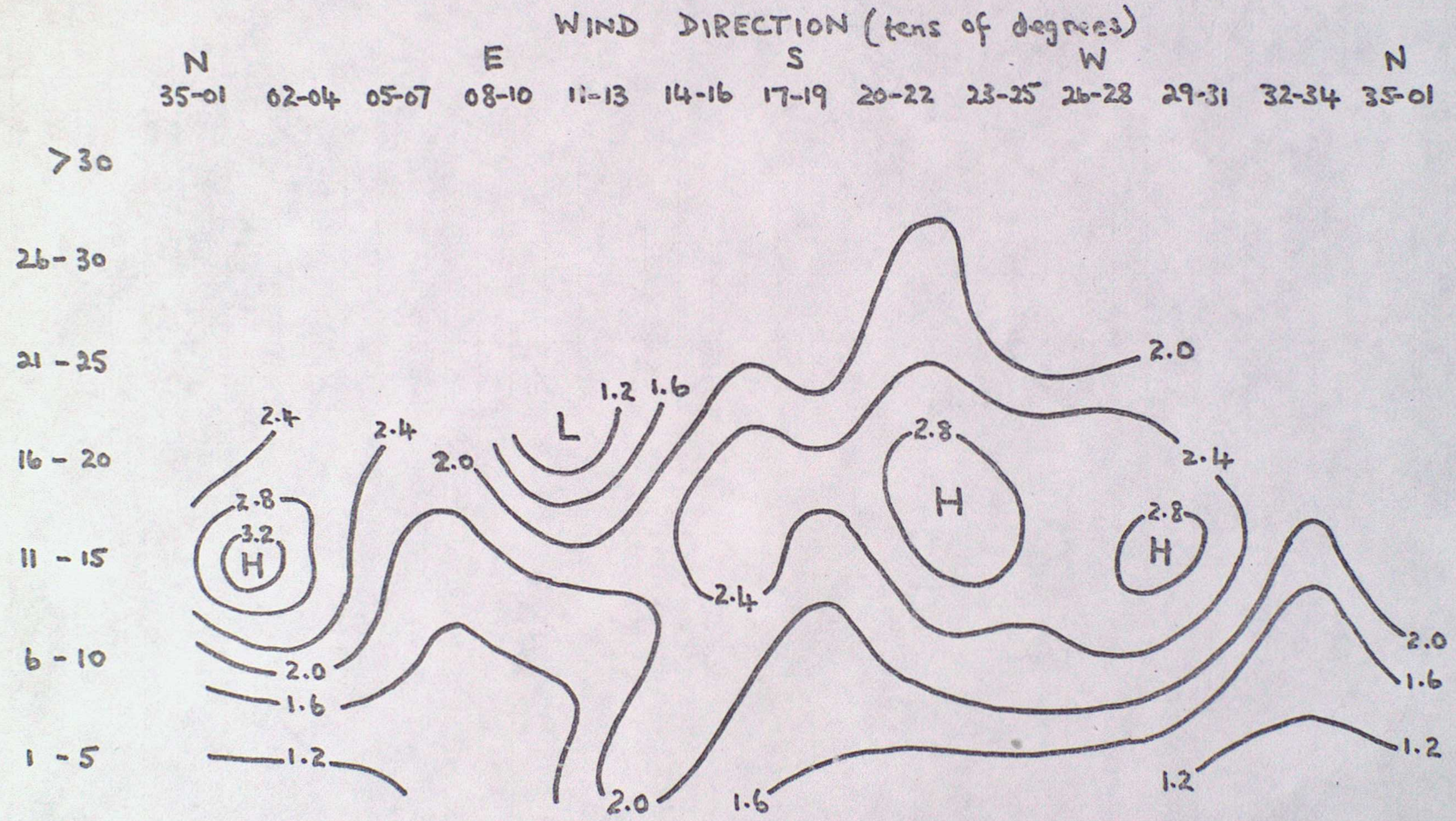
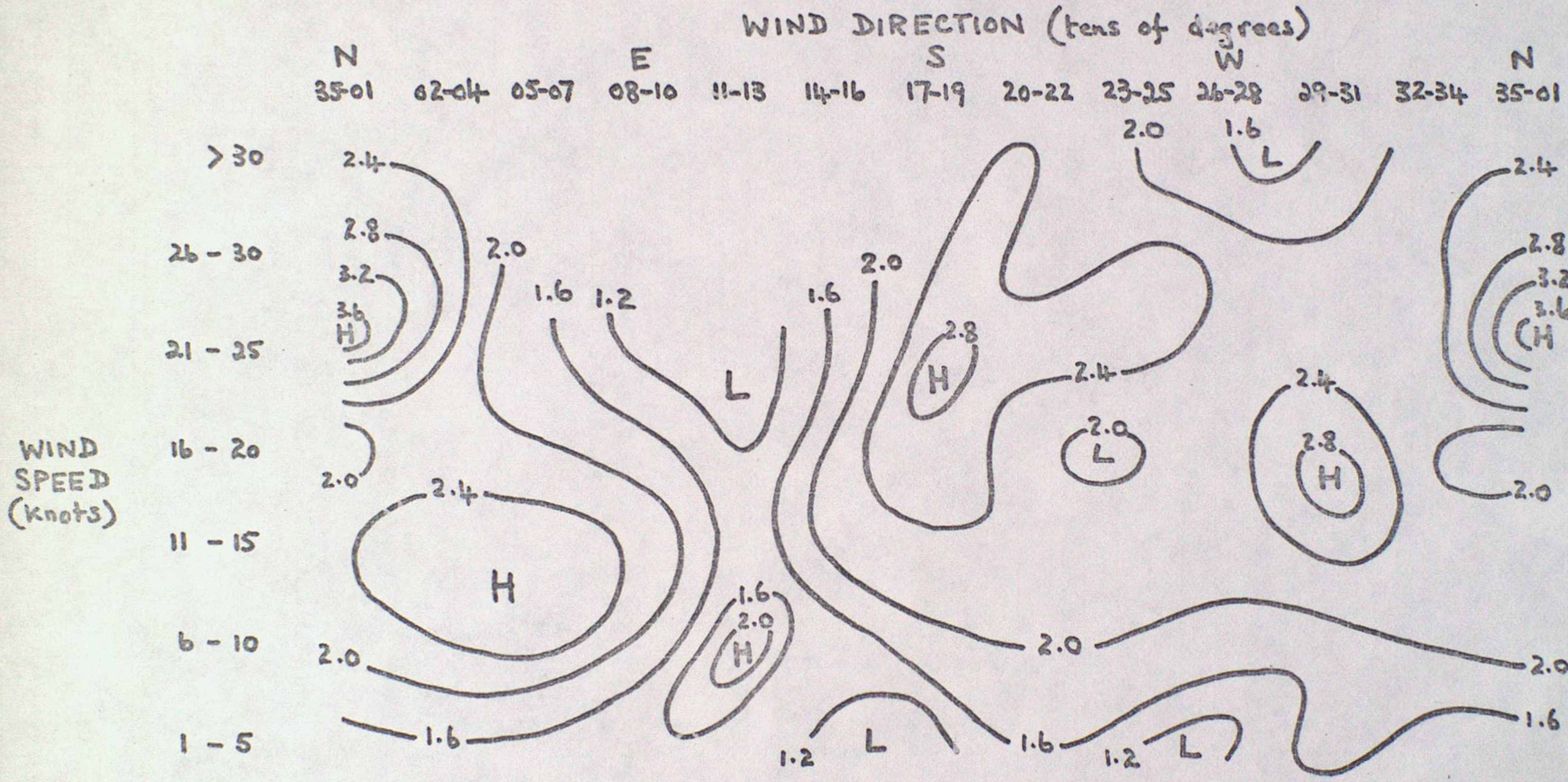


Figure 4

ISOPLETHS OF MEAN RUN-LENGTH (hours)

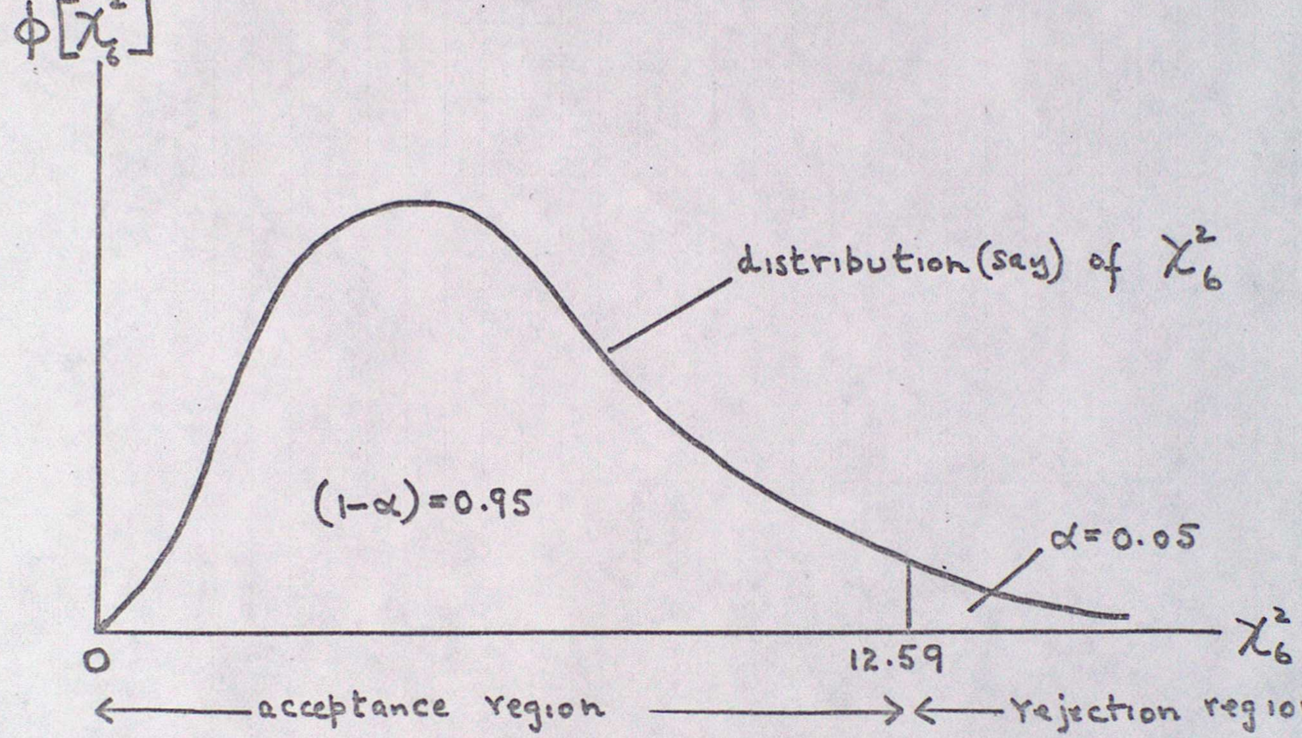
VALLEY LOW-LEVEL WINDS



[20]

Figure 5

THE CHI-SQUARE GOODNESS-OF-FIT TEST



If (χ^2) has 6 degrees-of-freedom and its value is greater than $\chi^2_{6,0.05}$ (which from Tables is 12.59) then the hypothesis is rejected at the 5% significance level