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AN ANALYSIS OF EVAPOTRANSPIRATION OBSERVATIONS AT VALENTIA OBSERVATORY AUGUST 1952 – JULY 1956

BY

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INTRODUCTION

Potential Evapotranspiration is defined as the water loss by transpiration and evaporation from a green plant cover growing on a soil whose moisture content is maintained at or near field capacity so that the plant cover never suffers from shortage of water. It can be measured directly in soil-filled tanks covered with growing vegetation, as the difference between applied water (rainfall or irrigation) and percolation, if the tanks are provided with arrangements to permit measurement of the percolating water.

The determination of PE (as we shall, for the sake of brevity, denote Potential Evaporation) has attracted much study in recent years, under the stimulus of growing water shortage in many countries, and because of the necessity to resort to irrigation to increase crop production in many parts of the world. It would be well to emphasize at this stage that Actual Evaporation or Evapotranspiration i.e. water loss to the atmosphere when the natural soil moisture condition is not interfered with, is not the same thing as PE, but a knowledge of PE is regarded as a prime essential in the eventual determination of the actual evaporation.

The present paper presents the results of four years observations at Valentia Observatory, on the South West coast of Ireland, from August, 1952 to July, 1956.

GEOGRAPHICAL AND CLIMATOLOGICAL FEATURES OF VALENTIA

Valentia is a first-order observing station, providing observations for synoptic and climatological use. The station is situated at 51° 56'N, 10° 15'W, and the instrument enclosure is about 30 ft. above M.S.L. The instruments used, and their exposures, conform to a high standard; the anemometer (Dines Pressure Tube) is set at an effective height of 33 ft. above ground level, while the Campbell-Stokes Sunshine Recorder is mounted 42 ft. above ground level. Further details, with a photograph of the instrument enclosure site, are given in reference (1).

The exposure of Valentia is typically maritime. For details of the climate the reader is referred to the "Climatological Atlas of the British Isles" (2) or to Appendix II of this paper, which gives the monthly mean values of various meteorological parameters over the four years in question, with the long-term monthly means of the same parameters. In brief, it may be stated that the monthly mean temperature varies from 45°F in February to 59°F in July; monthly mean maximum temperature from 49°F (January-February) to 64°F in July; annual rainfall is 58 inches spread fairly evenly throughout the year (4 inches per month April-July, 5½ to 6 inches per month August to March), with 250 rain-days per year. Relative Humidity is high throughout the year, attaining a 1300 GMT. mean minimum of 75% in March-May. Cloudiness is high and sunshine low.

THE VALENTIA INSTALLATION

The evapotranspirometer at Valentia Observatory consists of four grass-covered tanks, each about 55 cms. in diameter. As the instrument has been described in full elsewhere (3), it is unnecessary to repeat the details here; suffice it to say that it is of the conventional type, such as has been installed in many regions in recent years.

Apart from two short and unimportant breaks, readings were taken daily from the instrument throughout the period August, 1952 to July, 1956. Irregularities in the readings from individual tanks early in 1954 had hinted strongly that two of them had developed leaks. New copper tanks were prepared and the old ones replaced in pairs. Thus, from January to September 2nd, 1954, the observations are from two tanks only: throughout the rest of the period, four tanks were in operation. The readings from the individual tanks were always taken separately, and have remained consistent except during the period noted above, when the intruding inconsistency revealed the developing leaks. Some differences, due to differing lag in run-off time, were perceptible after heavy rains, but these differences were smooted out when summed over five or ten-day periods. The figures given herewith (in Appendix I) represent the water loss from the whole area of the four tanks.

In view of the normally high rainfall at Valentia, no steps were taken to irrigate a "buffer" area as recommended by Thornthwaite (4). In view of the location of the station, with prevailing SE to NW winds from a warm sea, low humidities are unusual; in fact they occur only when the wind comes from the Northeasterly quadrant. Winds from this quarter occur only in 14% of Valentia observations. Though no observations of soil moisture are available, it may be presumed that it rarely falls to a low level at Valentia. In the 48 months under review, for example, only two (July, 1955 and April, 1956) had less than one inch of rain, and only seven had less than two inches. The readings of PE for these "dry" months were not excessively high, so that dearth of Evapotranspiration from surrounding vegetation cannot be adduced as a factor in these experiments.

RESULTS

In a previous paper (5), the results of the first year's working were presented, together with the run-off figures from the Shannon River catchment area and from the Shannon Airport drainage basin. These three sets of figures indicated that Potential Evapotranspiration agreed fairly well in the Summer months with the estimates deduced from the Thornthwaite formula, but that in the months November to February evapotranspiration losses were far below the Thornthwaite figures.

The discrepancies between the computed and observed values were discussed in some detail (5); it was shown that a better fit to the run-off figures from the Shannon River catchment area and from the Airport drainage basin could be obtained by postulating zero transpiration plus 0.3 cms. evaporation loss per month throughout the Winter. These low evapotranspirative losses are well supported by the observations from the experimental tanks at Valentia and by various evaporation tanks in England. The reason for the high computed and low observed losses appeared to lie in the fact that Valentia Winter mean temperatures are much higher than would be expected at such Northerly latitudes; thus, while growth and transpiration are practically at a standstill, the predictions from Thornthwaite's mean temperature formula remain high. The climate of the West of Ireland is dominated by advection, and the temperature corresponds butweakly to the energy directly available from insolation; thus if growth and transpiration are largely controlled by insolational energy, a formula based on mean temperature alone will yield too high estimates in Valentia.

Broadly speaking, the present results confirm those of the first year. Table 1 and Figure 1 include the fortyeight monthly values obtained, and also the monthly estimates of PE for Valentia from the Thornthwaite and Penman formulae, based on the parameters given in Appendix II.

It will be observed that the observations for October to February fall below the levels predicted by the Thornthwaite formula but agree better with the Penman values. In March, April and May the observations fit both curves well (Figure 1); in June they are much lower than either curve in two years, and in July, August and September agreement is again fair. No convincing explanation for the very low June, 1955 observation emerges from a study of the readings for that month: but sunshine duration was 2.2 hrs. per day lower than normal, and Relative Humidity about 4% above normal. The sums of the squares of the deviations of the computed from the observed values were 68.5 for Penman's and 138.5 for Thornthwaite's figures. About half of the discrepancy between the Thornthwaite computed figures and the observed values arises in the months November-February inclusive.

ANALYSIS OF DATA

A scrutiny of the data suggested that it might be possible to devise a formula of local applicability in the form of a simple regression equation. This has been attempted by other workers, among them Leeper (6) and Clark (7), who reported considerable success. As an initial step, the correlation coefficients of PE on various of the meteorological parameters were computed. In consequence of the method of applying water (i.e. by natural rainfall and supplemental sprinkling), the PE values obtained from day to day are subject to large fluctuations, which arise from the fact that the run-off from a heavy rainfall does not percolate through the soil of the tanks on the day on which the rain occurs, but is delayed until the next day or even for two to three days afterwards. Thus the day in question will show a high PE, while the next day or days will indicate sub-normal or even negative loss. "Smooth" readings are to be expected only during dry weather, when a constant quantity of water is applied daily. To avoid these unrealistic fluctuations, the data were grouped together in five-day periods of pentades, which with the pentade means of daily mean temperature, daily maximum temperature, sunshine (hrs/day), relative humidity, at 1300 GMT., and wind speed (metres/sec.) are presented in Appendix 1. It will be noted that even the five-day grouping does not eliminate the fluctuations, so a further combination into ten-day groups was undertaken. In the Winter, when PE losses are extremely low and rainfall at times very heavy, even a monthly grouping will not guarantee "smooth" readings. Thus observed PE for December, 1954 was actually negative.

The correlation coefficients found were:-

PE to Maximum Temperature	$= r_{01}$	= 0.744
" " Sunshine Duration	$= r_{02}$	= 0.541
" " 1300 GMT. Relative Humidity	$= r_{03}$	= -0.169
" " Wind Speed	$= r_{04}$	= -0.306
" " Mean Temperature	$= r_{05}$	= 0.620

Relevant statistics of these parameters are:-

	Mean	Standard Deviation
PE	13.8 mm.	11.2 mm.
Maximum Temperature	13.5°C	3.57°C
Mean Temperature	10.6°C	3.45°C
Sunshine Duration	3.9 hrs/day	2.43 hrs/day
Relative Humidity	75.5%	7.40%
Wind Speed	4.94 m/sec	1.24 m/sec.

The parameters were chosen for the following reasons:-
Maximum and mean temperature to determine which was the more effective agent in the control of PE; it was suspected that maximum temperature would be the more effective, and the higher correlation coefficient confirms this. The 1300 GMT. Relative Humidity was preferred to mean daily R.H. as the transpirative process is most active in the afternoon and dormant at night (8, 9). Thus the mean daily R.H., especially in the Winter at our high latitude, is too heavily weighted by the night observations; the same is true for mean temperature as against maximum. Sunshine was introduced as a substitute for measurements of insolation, which were not available at the time, though two short-wave radiation meters have since been installed in Valentia (1).

The remaining correlation coefficients were as follows:-

Maximum Temperature to Sunshine Duration	$= r_{12}$	= 0.456
" to 1300 GMT. Relative Humidity	$= r_{13}$	= 0.034
" to Wind Speed	$= r_{14}$	= -0.368
Sunshine Duration to 1300 GMT. Relative Humidity	$= r_{23}$	= -0.675
" to Wind Speed	$= r_{24}$	= -0.495
1300 GMT. Relative Humidity to Wind Speed	$= r_{34}$	= 0.267

Since the correlation of PE to maximum temperature was higher than that to mean temperature, the latter was not further used.

TABLE 1 - MONTHLY VALUES OF PE OBSERVED AT VALENTIA, WITH PE COMPUTED BY THE METHODS OF PENMAN AND THORNTHWAITE

Month/Year		Observed	Computed	
			Penman	Thornthwaite
August,	1952	9.1	6.2	9.1
September,	"	5.8	3.8	5.7
October,	"	3.5	2.8	4.3
November,	"	0.9	0.9	2.3
December,	"	0.3	1.1	2.4
January,	1953	1.1	0.5	2.4
February,	"	0.6	1.3	2.5
March,	"	3.7	2.8	3.5
April,	"	5.3	5.0	4.2
May	"	3.9	6.3	7.0
June,	"	6.2	7.9	8.3
July,	"	9.1	7.9	9.3
August,	"	5.9	5.7	8.6
September,	"	5.0	3.6	6.8
October,	"	3.0	2.0	4.5
November,	"	0.5	1.0	3.3
December,	"	0.5	0.6	3.1
January,	1954	1.3	0.8	2.1
February,	"	2.0	1.4	2.3
March,	"	3.7	3.4	3.7
April,	"	4.9	5.0	4.9
May,	"	8.3	8.4	6.7
June,	"	7.7	7.1	8.0
July,	"	6.9	6.7	8.6
August,	"	7.7	6.5	7.9
September,	"	4.3	3.9	6.2
October,	"	1.2	2.2	5.2
November,	"	0.4	1.0	2.9
December,	"	-0.9	0.9	2.8
January,	1955	0.5	1.0	1.9
February,	"	2.6	1.3	2.1
March,	"	1.3	3.4	2.3
April,	"	4.5	5.0	5.4
May,	"	6.4	7.9	6.1
June,	"	4.8	6.6	8.3
July,	"	9.9	9.9	10.7
August,	"	9.2	7.0	10.6
September,	"	7.2	4.4	7.3
October,	"	3.2	2.2	4.5
November,	"	2.7	1.0	3.1
December,	"	0.9	1.0	2.8
January,	1956	0.6	0.9	2.0
February,	"	1.0	1.3	1.5
March,	"	1.9	3.3	4.6
April,	"	5.2	4.7	4.7
May,	"	7.2	7.6	7.5
June,	"	7.1	7.4	8.0
July,	"	8.1	7.0	9.7
TOTALS:		196.2	189.6	251.7

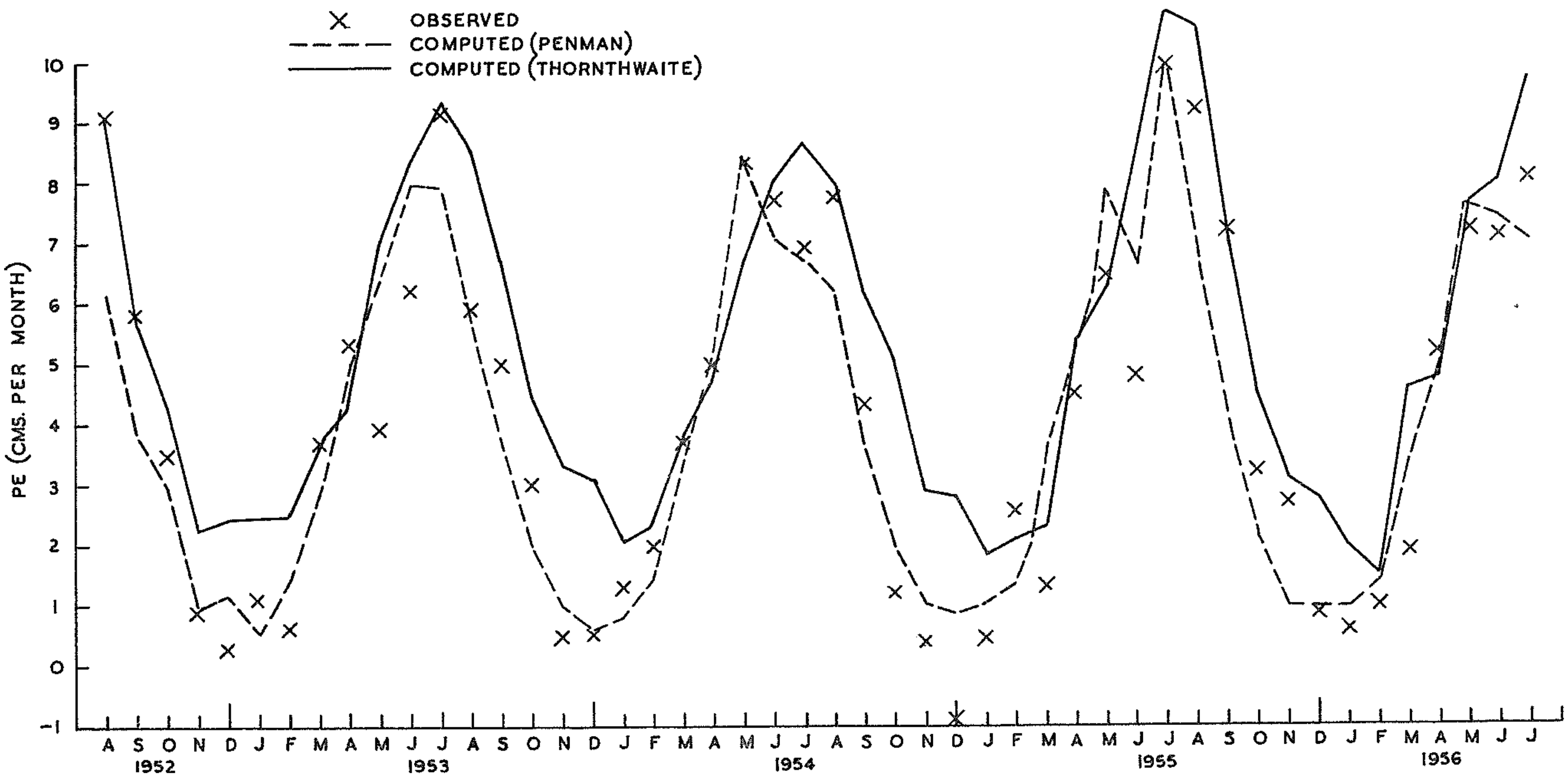

Fig. 1. Monthly values of PE at Valentia, observed and computed by two methods

A linear regression equation for PE in terms of maximum temperature (T_{max}), sunshine duration (SS), relative humidity (R.H.) and wind speed (VV) was derived. This took the form:-

$$PE = 2.04\ T_{max} + 1.02\ SS - 0.09\ R.H. + 0.41\ VV - 12.9$$

where PE is expressed in mms/10 days

T_{max} " " " ^{o}C

SS " " " hrs/day

R.H. " " " %

and VV " " " metres/sec.

The coefficient of multiple correlation R, for PE on these four parameters is 0.792: the standard error of estimate of the regression is $\sigma_{est} = \sigma_o\ (1-R^2)^{\frac{1}{2}}$

$= 6.75$ mms.

The regression was applied to the 141 sets of the variates from which it was derived, and the results are shown in Fig.2, where the predicted values are plotted against the observed. As an independent test, the values for the months of August, September and October, 1956, which had not been used in the formation of the regression, were computed and are shown below in Table 2.

TABLE 2

Pentades	Predicted	Observed
44,45	22.1 mms.	24.5 mms
46,47	20.5	19.7
48,49	20.6	16.2
50,51	15.4	11.9
52,53	17.9	8.3
54,55	19.8	14.4
56,57	14.8	10.3
58,59	16.5	6.2
60,61	10.0	6.3

The measure of agreement is disappointing in at least three of the pentades and the results are inferior to those given by the Penman formula. Nevertheless the formula may have some value for hydrologists, agriculturists and others interested in obtaining a rough estimate of evapotranspiration losses in Ireland by a simple, straightforward method requiring a minimum of computation.

DISCUSSION:

The summarised experience of four years' measurements of Potential Evapotranspiration, as presented in Appendix 1 and Table 1, have been compared with the estimates derived from the well-known formulae of Penman and Thornthwaite. The Penman formula gives satisfactory results over the whole period: Thornthwaite's formula is adequate in the Spring and Summer but yields estimates much too high in the Winter period. The causes of this Winter discrepancy have been discussed before (3), and the extended series of observations now presented confirm the speculations previously made, namely that a formula depending solely on mean temperatures must lead to too high estimates in the Irish Winter. The higher correlation of PE on maximum temperature (0.74) as compared with mean temperature (0.62) might be held to encourage efforts to use the former as a basis for an empirical formula. From a biophysical point of view, the mean temperature is too heavily weighted by the night minimum, because the transpiration process is dormant (or actually reversed by dew deposition) during the night, when the net flux

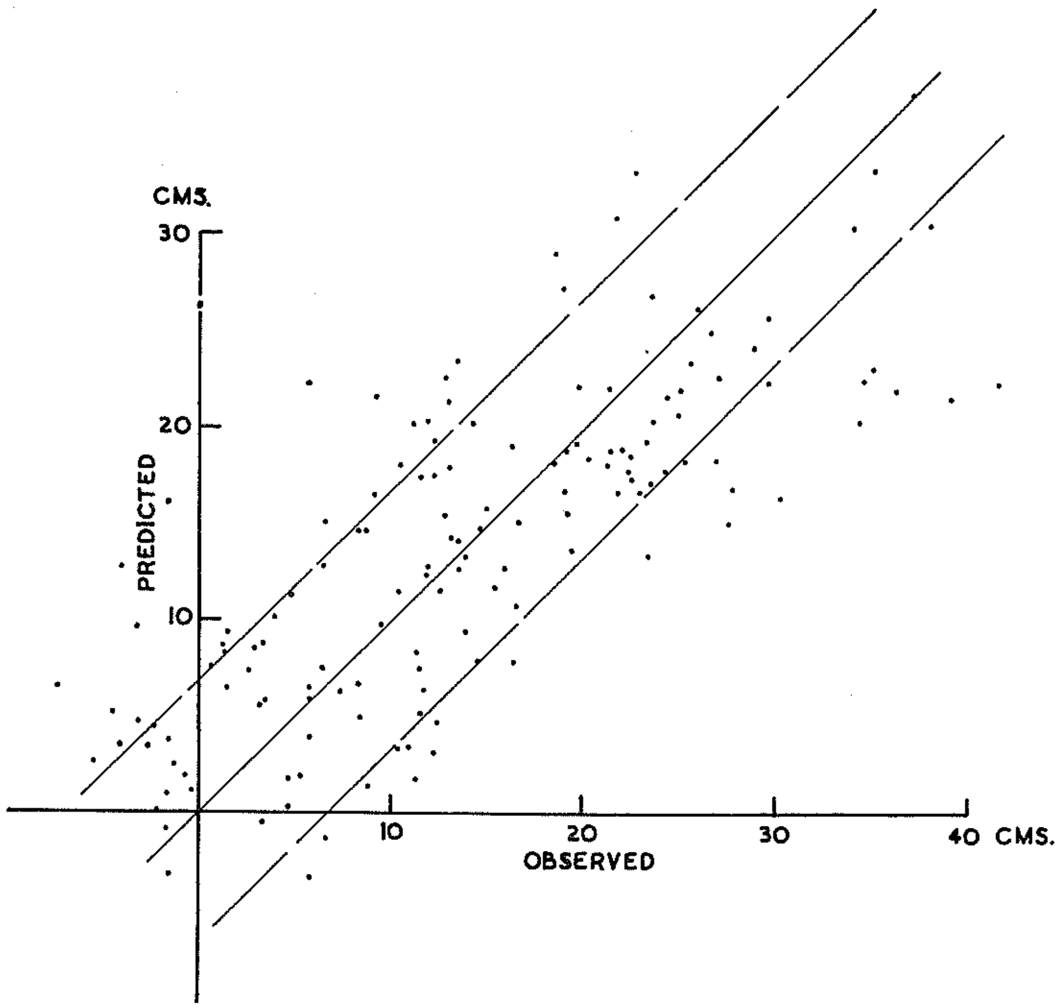

Fig.2. Values of PE observed and those predicted from Regression Equation August, 1952-July, 1956.

of radiational energy is outward. Thus if a simple empirical estimation depending only on climatological parameters is to be used, maximum temperature must be more suitable than mean temperature in high latitudes and advective climates.

The low correlation of PE with sunshine duration is surprising: this is probably due to the assumption, inherent in the calculation, that an hour of sunshine is of equal effectiveness as a causative agent in evapotranspiration throughout the year.

The best fit to the Valentia observations it that provided by Penman's formula, based on the calculation of the energy available for evapotranspiration. This is primarily a physical method but contains some empirical features - notably the use of Angot's formula for insolational energy in terms of sunshine duration. Presumably the increasing amount of measurements of insolational energy gradually becoming available will enable the future elimination of the Angot formula; but the success of the Penman-computed figures presented herewith argues strongly in favour of the physical approach.

NOTE: It was not possible to discuss details of editorial changes in this paper with the author, who is now working with Pan American Grace Airlines at Santiago, Chile.

REFERENCES

1. McWilliams, S. "Valentia Observatory" Weather, Vol. 11, No.9 (September 1956)

2. M.O. 488, London 1952, H.M.S.O.

3. Irish Meteorological Service Technical Note No.14 "Evaporation and Transpiration in the Irish Climate"

4. "The Measurement of Potential Evapotranspiration", Johns Hopkins University Laboratory of Climatology Publications Seabrook 1954.

5. "A Year of Evapotranspiration in Ireland" in Ref.4.

6. Leeper, G.W. Jour. Aust. Inst. Agr. Sci. (1950) 2-5.

7. Clark, W.E. "Forecasting Dry-weather Flow" Transactions American Geophysical Union 37, 4, Aug. 1956.

8. Montheith, Neth. Jour. of Agr. Sci. Vol.4, No.1, Feb., 1956.

9. Brouwer, do.

APPENDIX I

Observations made at Valentia Observatory from August, 1952, to July, 1956 of Potential Evapotranspiration, Daily Maximum Temperature, Wind Speed, Relative Humidity at 1300 GMT., Sunshine Duration, and Daily Mean Temperature averaged over Pentades and Decades.

PE = Potential Evapotranspiration in mms.

T_{max} = Daily Maximum Temperature in degrees Celsius

VV = Wind Speed in metres per second.

RH = Relative Humidity at 1300 GMT. in %.

SS = Sunshine Duration in hrs/day.

T_m = Daily Mean Temperature in degrees Celsius.

1952

P No.	PENTADES PE	T_{max}	VV	RH	SS	T_m	DECADES PE	T_{max}	VV	RH	SS	T_m
44	21.7	19.4	2.8	76	3.9	15.5						
45	13.4	16.6	4.7	84	5.7	15.9	35.1	18.0	3.7	80	4.8	15.7
46	16.6	15.4	4.4	69	6.8	13.4						
47	10.5	18.0	2.8	74	5.4	15.3	27.1	16.7	3.6	71	6.1	14.3
48	12.1	18.4	3.4	85	1.8	16.1						
49	12.9	18.4	4.1	78	4.4	15.9	25.0	18.4	3.7	81	3.1	16.0
50	10.2	18.8	4.0	74	5.5	12.1						
51	16.6	16.1	4.8	66	7.9	12.4	26.8	17.4	4.4	70	6.7	12.3
52	11.7	18.1	3.0	73	5.6	11.9						
53	4.4	15.3	3.0	87	1.6	11.9	16.1	16.7	3.0	80	3.6	11.9
54	9.4	18.4	6.5	77	4.8	13.2						
55	3.5	13.1	5.0	66	5.3	9.5	12.9	15.8	5.8	71	5.1	11.3
56	5.0	14.1	3.4	74	4.4	9.6						
57	10.0	14.3	4.4	68	4.7	9.9	15.0	14.2	3.9	71	4.5	9.7
58	- 0.6	14.3	8.2	75	1.5	12.2						
59	-	15.0		84	1.2	12.7				79	1.3	12.5
60	-			83	3.1	11.9						
61	-			83	1.5	12.1				83	2.3	12.0
62	-			81	0.3	11.5						
63	-			86	1.7	11.3				83	1.0	11.4
64	- 0.2	11.4	3.6	80	2.5	9.0						
65	11.2	7.8	3.2	75	1.9	4.3	11.0	9.6	3.4	77	2.2	6.1
66	- 1.6	9.6	5.6	75	2.8	6.2						
67	1.0	5.7	6.7	71	3.6	3.8	-0.6	7.7	6.1	73	3.2	5.0
68	13.6	9.8	6.3	72	2.5	7.0						
69	- 7.9	12.0	6.6	89	0.4	10.7	5.7	10.9	6.5	80	1.5	8.9
70	1.8	8.7	7.6	82	1.2	6.1						
71	- 4.5	10.7	6.7	84	1.0	8.1	-2.7	9.7	7.1	83	1.1	7.1
72	4.8	9.8	6.0	84	1.0	8.0						
73	- 5.9	8.1	7.6	77	2.1	5.1	-1.1	9.0	6.8	81	1.5	6.5

1953

P No.	PENTADES PE	T_{max}	VV	RH	SS	T_m	DECADES PE	T_{max}	VV	RH	SS	T_m
1	- 3.9	7.6	4.3	80	1.2	4.7	- 2.1	8.3	4.2	81	1.7	5.7
2	1.8	9.0	4.1	83	2.2	6.8						
3	- 0.9	10.9	3.8	90	1.7	8.6	- 1.5	10.1	3.6	82	2.2	7.6
4	- 0.6	9.3	3.4	75	2.7	6.6						
5	1.7	9.4	4.5	79	1.2	7.0	10.4	10.4	5.1	86	0.6	8.3
6	8.7	11.3	5.6	93	0.0	9.6						
7	- 2.7	7.3	4.8	59	5.4	4.4	12.2	7.8	4.6	65	3.9	4.8
8	14.9	8.2	4.4	72	2.3	5.2						
9	-10.2	8.1	6.8	81	1.8	6.0	- 5.5	9.5	4.8	84	1.8	7.2
10	4.7	10.8	2.8	86	1.7	8.4						
11	- 4.2	11.7	7.8	95	0.0	10.8	- 3.1	12.3	6.1	85	2.7	9.9
12	1.1	13.0	4.3	75	5.3	8.9						
13	4.2	11.2	1.7	72	8.2	5.9	8.3	11.8	1.8	69	6.9	6.5
14	4.1	12.4	1.9	65	5.6	7.0						
15	7.4	11.6	3.5	64	3.5	7.1	11.8	12.2	3.1	63	5.1	7.3
16	4.4	12.8	2.7	62	6.6	7.5						
17	13.0	14.1	3.3	69	5.0	9.3	15.4	12.5	4.7	73	3.8	8.7
18	2.4	10.8	6.1	77	2.6	8.0						
19	5.5	8.5	4.5	76	5.4	5.0	10.2	10.3	4.1	65	7.4	5.8
20	4.7	12.2	3.7	55	9.3	6.6						
21	8.4	10.7	4.0	70	4.6	7.6	13.1	12.8	4.3	67	5.1	9.0
22	4.7	14.9	4.7	65	5.6	10.3						
23	9.8	15.6	2.3	62	9.3	10.9	30.1	13.5	3.2	65	7.0	9.7
24	20.3	11.3	4.1	67	4.6	8.5						
25	3.3	15.9	2.1	68	10.1	11.2	12.8	16.2	2.9	68	7.4	10.3
26	9.5	16.5	3.6	68	4.7	9.3						
27	19.4	14.9	7.1	75	3.0	12.7	10.4	15.1	5.9	77	4.5	12.9
28	- 9.0	15.3	4.8	78	6.0	13.1						
29	- 1.6	15.6	5.8	85	2.3	13.1	- 1.7	15.2	5.3	87	3.5	12.9
30	- 0.1	14.8	4.8	88	4.6	12.6						
31	5.3	13.6	6.3	72	5.1	11.4	21.3	14.5	4.6	73	5.7	11.7
32	16.0	15.4	2.9	75	6.4	12.0						
33	12.8	15.0	4.2	83	3.6	12.0	19.2	15.1	4.7	80	2.9	11.9
34	6.4	15.1	5.3	76	2.1	11.7						
35	12.6	19.0	4.2	72	7.9	14.7	21.9	19.7	3.7	71	8.4	15.0
36	9.3	20.5	3.2	71	8.9	16.3						
37	8.7	19.6	3.3	80	8.4	15.7	29.6	18.1	4.7	80	7.1	15.3
38	20.9	16.7	6.1	81	5.9	15.0						
39	21.8	16.8	4.6	78	4.3	14.5	41.7	17.3	4.5	79	5.5	14.4
40	19.9	17.9	4.4	80	6.7	14.3						
41	12.8	17.5	6.2	81	5.1	15.2	9.2	17.0	5.5	81	4.7	14.7
42	- 3.6	16.5	4.9	81	4.3	14.2						
43	11.4	18.8	2.3	84	4.0	15.2	19.7	18.8	2.9	87	2.8	15.9
44	8.3	18.8	3.6	91	1.6	16.7						

1953 (Continued)

P No.	PENTADES PE	Tmax	VV	RH	SS	Tm	DECADES PE	Tmax	VV	RH	SS	Tm
45	8.8	17.8	3.7	78	2.9	14.5						
46	12.6	17.8	4.3	78	4.8	15.1	21.4	17.8	4.0	78	3.9	14.8
47	14.2	17.6	5.4	76	5.1	14.5						
48	22.0	17.3	3.6	82	4.1	14.1	36.2	17.5	4.5	79	4.6	14.3
49	- 5.9	17.6	7.2	86	2.2	15.2						
50	5.9	21.1	3.5	72	5.6	17.2	0	19.3	5.3	79	3.9	16.2
51	8.4	16.6	2.9	82	2.7	13.5						
52	13.9	16.7	3.2	80	4.2	13.4	22.3	16.6	3.1	81	3.5	13.4
53	14.4	15.0	7.4	87	1.5	13.3						
54	0.2	15.6	4.2	86	2.3	13.3	14.6	15.3	5.8	87	1.9	13.3
55	3.8	16.2	5.8	86	1.0	14.4						
56	5.2	15.7	2.2	72	3.8	11.2	9.0	15.9	4.0	79	2.4	12.8
57	8.3	15.0	3.5	75	2.3	12.3						
58	0.3	13.5	3.9	70	4.2	9.6	8.6	14.3	3.7	73	3.3	11.0
59	3.8	14.9	5.0	83	2.3	12.7						
60	9.7	13.1	6.1	81	2.3	10.7	13.5	14.0	5.5	82	2.3	11.7
61	7.7	12.1	5.9	77	2.7	9.3						
62	- 6.4	11.8	5.1	77	2.2	9.1	1.3	11.9	5.5	77	2.5	9.2
63	4.7	12.0	5.3	81	1.3	9.6						
64	- 1.6	13.4	6.5	86	0.8	12.1	3.1	12.7	5.9	84	1.0	10.9
65	0.9	12.1	5.1	83	0.7	10.5						
66	10.6	11.9	6.8	82	1.0	10.4	11.5	12.0	5.9	83	0.9	10.4
67	- 6.4	11.2	3.4	84	2.9	7.7						
68	- 1.1	11.9	4.9	84	1.0	9.9	- 7.5	11.5	4.1	84	2.0	8.8
69	1.6	12.3	5.6	88	0.2	11.7						
70	- 1.1	12.7	6.7	81	0.4	10.1	0.5	12.5	6.1	85	0.3	10.9
71	8.7	11.9	4.5	85	0.3	10.4						
72	0.9	11.6	6.2	84	1.6	9.2	9.6	11.7	5.3	85	0.9	9.8
73	- 4.1	10.0	2.1	85	1.2	7.9						

1954

P No.	PENTADES						DECADES					
	PE	T_{max}	VV	RH	SS	T_m	PE	T_{max}	VV	RH	SS	T_m
1	1.3	7.7	2.5	81	1.8	5.0	3.2	8.0	3.3	79	1.9	4.6
2	1.9	8.3	4.0	77	1.9	4.2						
3	4.9	11.5	7.8	78	0.6	8.3	11.1	12.1	7.3	81	0.9	9.1
4	6.2	12.8	6.8	84	1.2	10.0						
5	2.1	11.6	6.6	83	0.5	13.3	5.3	8.6	5.7	76	1.8	7.9
6	3.2	5.6	4.9	69	3.1	2.6						
7	0.6	5.1	2.5	83	1.7	2.0	5.6	7.0	3.2	85	1.7	4.1
8	5.0	8.9	3.9	88	1.8	6.2						
9	4.0	11.3	7.7	83	1.5	9.2	3.1	10.4	5.9	80	2.0	7.9
10	- 0.9	9.5	4.0	77	2.4	6.7						
11	4.0	10.7	6.0	84	1.8	8.2	12.3	9.5	6.9	81	2.5	6.9
12	8.3	8.2	7.9	77	3.1	5.7						
13	10.8	8.9	6.4	78	2.7	5.7	14.6	10.5	6.3	73	3.3	7.3
14	3.8	12.0	6.1	69	3.9	9.0						
15	- 4.3	12.2	7.4	67	3.2	9.1	2.9	11.5	6.7	74	1.9	9.3
16	7.2	10.9	6.1	81	0.5	9.5						
17	4.8	11.6	7.1	76	1.6	9.2	16.2	11.1	6.7	76	2.3	8.8
18	11.4	10.6	6.4	76	3.1	8.5						
19	5.3	11.2	7.3	83	1.4	8.7	9.5	11.7	6.0	77	3.2	8.7
20	4.2	12.2	4.7	70	5.0	8.7						
21	5.4	12.4	3.2	75	4.9	10.1	13.6	13.0	3.7	73	4.6	10.1
22	8.2	13.5	4.1	71	4.2	10.1						
23	13.0	14.9	5.8	59	5.9	11.5	13.0	14.7	4.5	59	7.7	10.2
24	13.0	14.4	3.1	58	9.6	8.9						
25	19.5	11.0	9.6	64	6.7	8.1	27.8	12.5	8.6	65	4.7	9.5
26	8.3	14.0	7.6	67	2.6	10.8						
27	9.9	14.9	4.1	72	9.5	11.5	26.0	15.7	4.1	67	11.2	11.8
28	16.1	16.4	4.0	61	12.9	12.1						
29	16.7	14.0	6.3	74	4.9	11.6	27.0	14.9	5.8	77	5.3	12.4
30	10.3	15.7	5.3	79	5.8	13.2						
31	14.4	16.6	2.5	79	9.5	12.2	34.3	16.3	3.4	76	7.7	12.7
32	19.9	15.9	4.3	73	6.0	13.3						
33	9.8	15.5	4.9	64	4.8	12.1	22.4	15.5	5.6	78	3.2	12.8
34	12.6	15.6	6.3	91	1.6	13.5						
35	5.1	15.6	4.0	81	3.6	13.7	20.1	15.3	5.1	78	4.7	13.3
36	15.0	15.0	6.2	74	5.8	12.9						
37	15.0	15.1	5.2	81	4.7	12.3	27.9	15.1	5.1	81	4.1	12.5
38	12.9	15.1	4.9	81	3.5	12.6						
39	12.6	16.7	4.8	77	4.9	14.3	19.1	16.5	5.2	78	3.0	14.1
40	6.5	16.2	5.6	79	1.1	14.0						
41	19.2	16.8	3.7	84	2.6	14.8	24.4	16.1	5.0	81	2.9	14.3
42	5.2	15.5	6.3	77	3.1	13.7						

1954 (Continued)

P No.	PENTADES PE	T_{max}	VV	RH	SS	T_m	DECADES PE	T_{max}	VV	RH	SS	T_m
43	10.6	15.9	3.5	79	3.2	13.2						
44	7.9	17.0	4.9	79	4.3	14.4	19.5	16.5	4.2	79	3.7	13.8
45	9.1	16.2	4.8	78	4.3	13.5						
46	15.8	16.7	5.3	73	5.3	13.9	24.9	16.5	5.1	75	4.8	13.7
47	14.5	16.3	3.8	67	8.6	13.4						
48	Missed		3.8	79	8.8		29.0	16.3	3.8	73	8.7	13.4
49	Missed		5.5	82	3.3							
50	7.1	16.5	5.4	80	5.7	13.7	14.2	16.5	5.5	81	4.5	13.7
51	5.3	16.6	6.0	78	6.0	14.1						
52	5.9	15.5	5.5	80	4.1	13.0	11.2	16.1	5.7	79	5.0	13.5
53	7.6	14.8	4.6	72	6.3	11.5						
54	7.9	15.2	6.0	87	2.3	12.9	15.5	15.0	5.3	79	4.3	12.2
55	1.0	14.7	5.4	85	1.4	13.1						
56	4.5	15.8	4.9	83	3.4	13.0	6.5	15.2	5.1	84	2.4	13.0
57	- 0.1	15.6	4.6	87	2.9	13.0						
58	8.4	15.9	6.3	93	0.0	14.3	8.3	15.7	5.5	90	1.5	13.7
59	- 3.1	14.3	5.3	84	1.3	12.6						
60	- 0.9	14.0	7.0	82	2.5	10.9	- 4.0	14.1	6.1	83	1.9	11.7
61	1.4	12.8	4.7	76	3.5	10.4						
62	- 0.3	10.6	3.9	75	2.0	8.2	1.1	11.8	4.3	75	2.7	9.3
63	6.3	12.2	6.1	74	3.0	9.1						
64	7.4	12.3	3.9	81	1.2	9.9	13.7	12.2	5.0	77	2.1	9.5
65	1.2	11.8	5.2	84	1.1	9.3						
66	4.5	10.7	5.6	78	2.5	6.8	5.7	11.3	5.4	81	1.8	8.1
67	4.6	10.5	8.7	77	1.0	8.1						
68	- 2.2	12.3	7.2	86	0.9	10.7	2.4	11.4	7.9	82	1.0	9.4
69	2.3	7.9	7.6	79	0.9	5.1						
70	- 6.3	11.5	7.6	85	1.2	9.0	- 4.0	9.7	7.6	82	1.1	7.1
71	- 6.6	11.0	5.8	84	0.7	9.9						
72	2.3	11.5	7.6	84	0.3	10.1	- 4.3	11.2	6.6	84	0.5	10.0
73	3.1	11.1	4.7	90	0.8	9.5						

1955

R No.	PENTADES						DECADES					
	PE	T_{max}	VV	RH	SS	T_m	PE	T_{max}	VV	RH	SS	T_m
1	6.4	6.7	6.1	75	0.8	4.7						
2	0.2	8.9	5.2	88	0.6	6.2	6.6	7.8	5.7	81	0.7	5.5
3	- 0.6	6.7	4.8	71	1.9	3.7						
4	- 0.9	8.1	5.7	66	2.8	4.5	- 1.5	7.4	6.2	67	2.4	4.1
5	1.1	10.9	7.1	87	0.3	8.5						
6	4.7	10.6	7.1	83	1.4	8.3	5.8	10.7	7.1	85	0.8	8.4
7	0.4	9.3	5.4	77	1.9	6.5						
8	- 3.4	10.3	5.7	81	2.6	7.3	- 3.0	9.8	5.5	79	2.2	6.9
9	4.7	7.0	4.1	70	6.1	3.2						
10	0.1	6.0	4 4	73	5.4	2.6	4.8	6.5	4.3	71	5.7	2.9
11	4.4	3.4	5.8	74	4.9	1.0						
12	- 5.6	8 0	6.7	80	0.2	5.4	- 1.2	5.7	6.3	77	2.5	3.2
13	- 2.3	9.7	4.1	66	5.8	5.7						
14	4.4	8.4	4.7	55	6.5	4.4	2.1	9.1	4.4	61	6.1	5.1
15	9.1	10.4	3.0	54	8.8	5.2						
16	7.8	7.8	3.0	48	7.6	4.3	16.9	9.1	3.0	51	8.2	4.7
17	6.0	12.0	4.7	64	7.2	7.8						
18	7.6	10.1	3.5	52	8.2	5.4	13.6	11.0	4.1	58	7.7	6.6
19	11.1	13.1	7.9	78	2.9	10.4						
20	1.4	12.3	6.1	85	2.3	10.7	12.5	12.7	7.0	81	2.6	10.5
21	2.3	14.9	2.9	70	4.2	12.0						
22	10.9	17.1	2.6	50	11.6	10.1	13.2	16.0	2.7	60	7.9	11.1
23	19.5	13.7	3.5	76	8.1	9.3						
24	- 0.5	14.1	6.0	79	4.1	11.2	19.0	13.9	4.7	77	6.1	10.3
25	15.1	13.0	9.0	78	6.4	10.8						
26	8.5	13.4	6.6	74	6.5	10.4	23.6	13.2	7.8	76	6.5	10.6
27	6.5	11.6	5.4	70	7.4	8.7						
28	6.4	11.4	5.4	60	9.2	8.0	12.9	11.5	5.4	65	8.3	8.3
29	9.9	15.4	3.5	67	8.8	11.5						
30	15.4	14.9	5.7	83	1.3	12.6	25.3	14.1	4.6	75	5.1	12.1
31	7.2	16.1	4.6	74	3.8	13.0						
32	4.9	16.1	7.0	72	3.3	13.7	12.1	16.1	5.8	73	3.5	13.3
33	13.5	14.8	5.0	79	5.6	11.8						
34	9.7	19.0	2.8	81	2.7	15.2	23.2	16.4	3.9	80	4.1	13.5
35	6.1	16.6	4.8	83	4.5	14.3						
36	6.9	15.9	4.6	89	2.6	14.1	13.0	16.2	4.7	86	3.5	14.2
37	7.6	15.5	4.8	82	4.8	13.2						
38	11.1	22.2	2.4	74	13.5	16.8	18.7	18.9	3.6	78	9.1	15.0
39	18.9	20.7	1.9	81	9.0	16.6						
40	16.4	20.1	3.5	74	11.6	16.5	35.3	20.4	2.7	77	10.3	16.6
41	17.6	21.7	1.7	74	8.6	17.1						
42	19.5	22.2	3.3	66	12.1	17.6	37.1	22.0	2.5	70	10.3	17.3
43	20.8	22.0	2.9	77	7.3	17.9						
44	17.4	20.2	3.8	76	4.6	16.5	38.2	21.1	3.3	77	6.0	17.2

1955 (Continued)

P. No.	PENTADES						DECADES					
	PE	T_{max}	VV	RH	SS	T_m	PE	T_{max}	VV	RH	SS	T_m
45	15.4	22.5	2.4	70	6.5	17.8						
46	18.7	19.9	6.8	75	2.4	18.2	34.1	21.2	4.6	72	4.5	18.0
47	8.0	22.4	3.2	65	5.1	17.9						
48	14.7	22.9	2.6	71	4.2	19.3	22.7	22.7	2.9	68	4.7	18.6
49	9.6	19.4	4.1	72	4.2	17.0						
50	9.4	19.8	4.7	71	5.1	16.9	19.0	19.6	4.4	71	4.7	16.9
51	13.5	17.2	6.3	74	3.8	15.2						
52	10.1	15.7	6.3	65	2.9	13.4	23.6	16.5	6.3	70	3.3	14.3
53	23.6	18.4	8.0	79	2.6	15.8						
54	0.8	16.3	4.9	76	4.2	14.0	24.4	17.3	6.5	77	3.4	14.9
55	10.7	16.0	3.5	78	1.5	13.9						
56	12.3	14.9	6.1	76	4.3	11.3	23.0	15.5	4.8	77	2.9	12.6
57	3.9	17.2	5.7	86	0.9	15.0						
58	8.3	14.2	4.0	78	2.8	11.3	12.2	15.7	4.9	82	3.7	13.1
59	0.8	11.6	6.9	72	2.2	8.5						
60	4.1	12.9	2.8	80	3.4	9.1	4.9	12.3	4.9	76	2.8	8.8
61	5.9	11.2	3.4	67	4.0	7.0						
62	5.9	14.7	7.4	76	1.6	11.2	11.8	13.0	5.4	71	2.8	9.1
63	4.2	13.3	5.1	83	2.2	10.9						
64	- 0.2	12.7	4.9	72	4.0	9.2	4.0	12.0	5.0	77	3.1	10.1
65	4.9	11.3	3.2	72	1.6	8.9						
66	2.5	11.1	2.3	74	2.2	6.9	7.4	11.2	2.7	73	1.9	7.9
67	5.2	11.4	4.0	85	1.1	9.5						
68	3.1	12.7	5.3	86	0.2	10.1	8.3	12.1	4.7	85	0.7	9.8
69	6.7	12.0	6.4	84	0.2	10.0						
70	- 0.3	12.1	6.1	87	1.4	10.2	6.4	12.1	6.3	85	0.8	10.1
71	- 1.9	9.3	4.6	80	2.0	6.1						
72	5.3	11.9	8.9	81	1.4	9.7	3.1	10.6	6.7	81	1.7	7.9
73	3.8	11.5	8.5	80	0.7	9.2						

1956

P. No.	PENTADES PE	PENTADES Tmax	PENTADES VV	PENTADES RH	PENTADES SS	PENTADES Tm	DECADES PE	DECADES Tmax	DECADES VV	DECADES RH	DECADES SS	DECADES Tm
1	2.31	10.9	5.1	80	0.6	9.5						
2	9.12	8.0	3.7	78	0.9	5.4	11.4	9.5	4.4	79	0.7	7.5
3	- 4.93	7.9	3.7	84	1.0	4.2						
4	4.75	10.1	5.1	82	1.7	7.3	- 0.2	9.0	4.4	83	1.3	5.7
5	- 0.23	8.9	5.4	80	1.8	5.9						
6	- 2.04	11.3	4.9	81	2.1	9.5	- 2.3	10.1	5.1	81	1.9	7.7
7	- 0.88	5.8	6.7	83	0.9	4.9						
8	- 0.79	9.1	2.2	66	2.6	6.8	- 1.7	7.5	4.5	75	1.7	5.9
9	4.97	5.2	4.3	57	7.3	3.4						
10	- 0.39	5.7	3.9	70	4.5	3.7	4.6	5.5	4.1	63	5.9	3.5
11	6.73	4.0	5.0	61	5.4	2.1						
12	2.07	10.0	5.4	92	3.5	6.9	8.8	7.0	5.2	77	4.5	4.5
13	0.16	11.4	6.8	83	1.3	9.2						
14	1.18	11.3	7.9	82	1.4	9.6	1.3	11.3	6.3	83	1.3	9.4
15	10.74	10.1	7.1	75	1.7	8.4						
16	0.86	11.0	6.3	73	1.9	8.2	11.6	10.5	6.7	74	1.8	8.3
17	4.41	12.0	6.5	76	2.0	9.6						
18	2.11	13.0	4.4	53	5.6	10.4	6.5	12.5	5.5	65	3.8	10.0
19	11.49	12.4	4.4	66	5.8	9.1						
20	8.1	13.4	5.0	71	3.3	10.7	19.6	12.9	4.7	69	4.5	9.9
21	5.6	12.8	5.3	70	3.5	10.4						
22	11.2	12.8	2.9	61	8.3	7.1	16.8	12.8	4.1	65	5.9	8.7
23	9.1	11.9	4.0	74	3.7	8.5						
24	6.9	12.8	5.0	70	6.2	9.0	16.0	12.3	4.5	72	5.0	8.7
25	12.0	14.6	6.2	76	6.5	11.8						
26	10.3	14.6	7.2	77	2.9	12.3	22.3	14.6	6.7	76	4.7	12.1
27	9.2	14.1	5.0	73	6.2	11.7						
28	12.2	13.5	3.2	70	9.7	9.9	21.4	13.8	4.1	71	7.9	10.8
29	16.3	13.7	6.8	70	7.0	11.1						
30	9.5	18.5	2.7	70	8.4	13.0	25.8	16.1	4.7	70	7.7	12.1
31	13.7	14.0	6.0	86	0.6	12.2						
32	9.5	13.5	6.4	74	5.2	11.3	23.2	13.7	6.2	80	2.9	11.7
33	12.1	14.8	3.1	76	8.8	12.0						
34	9.8	14.1	6.0	84	1.7	12.1	21.9	14.5	4.5	80	5.3	12.1
35	9.9	19.7	2.4	84	9.3	15.4						
36	13.7	17.4	4.2	73	6.2	14.1	23.6	18.5	3.3	78	7.7	14.7
37	28.3	17.3	5.2	80	4.6	14.4						
38	10.8	16.7	4.5	83	5.6	15.0	39.1	17.0	4.9	81	5.1	14.7
39	18.8	17.6	5.1	73	4.5	14.3						
40	10.8	17.2	4.1	82	5.0	14.2	29.7	17.4	4.6	77	4.7	14.3
41	15.3	17.7	2.7	85	5.4	15.0						
42	19.2	17.3	3.9	80	2.1	15.0	34.5	17.5	3.3	83	3.7	15.0

APPENDIX 2

Monthly Means of Meteorological Parameters at Valentia

(a) Daily Maximum Temperature °F

	1952	1953	1954	1955	1956	Normals 1921-50
Jan.		49.2	48.4	47.6	49.0	48.6
Feb.		49.5	48.6	44.8	46.0	48.5
Mar.		54.1	51.2	49.4	53.1	50.7
Apr.		53.6	55.6	57.6	54.8	53.1
May		59.9	57.9	56.3	58.7	57.7
June		62.1	60.1	61.4	60.3	61.7
July		63.2	60.4	69.0	62.8	63.6
Aug.	64.9	64.3	62.2	71.0		63.6
Sept.	63.3	62.3	60.2	63.6		60.9
Oct.	57.6	57.7	58.7	56.8		56.4
Nov.	50.6	53.7	52.6	54.2		51.5
Dec.	49.5	53.0	51.5	52.9		49.2

(b) Daily Mean Temperature °F

	1952	1953	1954	1955	1956	Normals 1921-50
Jan.		45.7	44.5	43.2	45.0	45.1
Feb.		45.5	44.4	39.7	40.0	44.8
Mar.		45.1	46.8	42.1	48.8	46.5
Apr.		46.9	49.5	50.8	48.6	48.4
May		53.9	52.3	51.1	53.0	52.5
June		55.7	55.3	56.5	55.2	56.9
July		58.4	56.5	61.9	58.2	59.3
Aug.	59.5	59.0	57.2	63.9		59.4
Sept.	54.5	57.6	55.6	59.2		56.8
Oct.	52.9	52.3	55.1	51.9		52.6
Nov.	46.8	50.0	48.2	49.6		47.8
Dec.	46.2	49.9	48.8	49.3		45.8

(c) Rainfall (mms.)

	1952	1953	1954	1955	1956	Normals 1916-50
Jan.		60.7	142.5	142.7	169.7	170.8
Feb.		87.9	171.2	134.6	49.5	114.8
Mar.		44.6	182.9	59.2	161.9	97.1
Apr.		88.9	43.9	74.1	22.0	77.7
May		94.7	84.6	136.6	66.4	85.8
June		58.0	71.0	95.0	66.7	79.0
July		190.8	106.7	9.1	112.0	105.0
Aug.	70.3	100.1	89.0	30.2		112.2
Sept.	51.9	143.9	136.6	111.5		112.4
Oct.	177.0	131.2	197.8	71.5		144.3
Nov.	92.8	157.8	158.2	121.0		153.4
Dec.	155.0	120.9	164.3	134.8		161.1

NOTE: Monthly mean values of daily maximum temperature and daily mean temperature over the years 1952 to 1956 are based on readings of temperature in a Stevenson Screen standing in the open. Normals for the period 1921-1950 are based on readings in a North Wall Screen.

(d) Mean Relative Humidity (%)

	1952	1953	1954	1955	1956	Normals 1886-1915
Jan.		85.2	82.6	82.0	82.5	86.2
Feb.		83.7	80.6	80.3	77.6	85.5
Mar.		80.2	78.8	72.0	80.6	83.7
Apr.		74.7	77.5	81.4	78.2	82.1
May		83.6	77.4	77.4	81.2	81.2
June		81.5	83.5	85.9	83.5	81.7
July		86.2	84.5	83.7	85.8	82.7
Aug.	85.0	86.5	84.5	82.1		84.7
Sept.	80.9	85.2	84.5	80.7		84.2
Oct.	81.5	84.1	87.8	83.0		84.4
Nov.	82.7	84.5	83.3	81.9		85.8
Dec.	81.3	86.3	85.9	84.2		87.2

(e) Mean Vapour Pressure (mbs.)

	1952	1953	1954	1955	1956
Jan.		8.3	8.3	7.8	8.4
Feb.		8.7	8.0	6.6	6.5
Mar.		8.2	8.6	6.5	9.5
Apr.		8.1	9.3	10.3	9.1
May		11.9	10.3	9.9	11.1
June		12.3	12.4	13.4	12.4
July		13.9	13.1	15.8	14.2
Aug.	14.8	14.7	13.5	16.6	
Sept.	11.7	13.8	12.7	13.8	
Oct.	11.1	11.2	13.0	10.9	
Nov.	9.0	10.4	9.5	9.9	
Dec.	8.6	10.6	10.1	10.1	

(f) Sunshine Duration (hrs/day)

	1952	1953	1954	1955	1956	Normals 1921-50
Jan.		1.46	1.62	1.35	1.42	1.51
Feb.		2.66	2.16	3.69	4.14	2.25
Mar.		5.35	2.54	7.14	2.24	3.66
Apr.		6.46	5.17	5.52	5.16	5.12
May		4.96	7.24	6.54	6.30	6.35
June		6.10	4.81	3.61	5.77	5.85
July		5.35	3.37	9.94	4.45	4.47
Aug.	4.80	3.59	5.71	5.05		4.71
Sept.	4.97	3.10	4.56	3.43		3.89
Oct.	2.95	2.81	1.94	2.92		2.91
Nov.	1.93	1.49	1.97	2.04		2.06
Dec.	1.54	0.76	0.82	1.07		1.28

NOTE: Monthly mean values of relative humidity and vapour pressure are based on readings of wet and dry bulb temperature measured in a Stevenson Screen standing in the open. Normals of relative humidity for the period 1886-1915 are based on readings of wet and dry bulb temperature in a North Wall Screen.

(g) Wind Speed (kts.)

	1952	1953	1954	1955	1956
Jan.		9.0	10.7	12.2	9.3
Feb.		10.1	11.0	10.4	8.9
Mar.		6.3	12.9	7.9	13.1
Apr.		7.8	9.4	9.7	8.9
May		9.5	11.6	11.9	10.4
June		8.5	9.4	9.4	9.2
July		9.7	10.5	5.8	8.3
Aug.	7.5	8.3	9.3	7.1	
Sept.	8.7	9.3	10.6	11.7	
Oct.	12.7	8.6	11.6	9.2	
Nov.	10.3	11.0	10.8	9.1	
Dec.	13.4	10.1	13.6	13.0	