CALCULATION OF AVERAGE SEASONAL AND ANNUAL SUNSHINE VALUES FOR SCOTLAND

by F. Burns

Introduction.   Formulae for the calculation of average sunshine values in England and Wales have been produced by J. W. Davies for England and Wales and by P. C. Rackliff[1] for Ireland for places where the sunshine is not obstructed or reduced by smoke.   The Davies formulae for England and Wales are given in Table I for seasonal and annual sunshine values, and are expressed in terms of height of the place above m.s.l. (H), its distance from the south coast (C_s), and its distance from the nearest coast (C_n).   It was decided to investigate the use of these Davies formulae for Scotland.

There are 50 Scottish stations with long-term sunshine records. Averages for most of these stations have been published[2].   The sunshine at 14 of these stations was partially obstructed at certain times of the year, and other stations e.g. in the Glasgow and Edinburgh areas, were affected by smoke haze.   However, rather than seriously reduce the number of cases available, all stations have been used in this investigation.

Using the Davies formulae, the average seasonal and annual sunshine were calculated for the 50 stations.   Following a study of these results, modifications in the values of some of the constants and coefficients in the equations were made.

Method.   The distance from the south coast (C_s) was measured as the perpendicular distance from a line joining St. Mawgan to Dungeness to the station in question.   To eliminate coastal inlets judged to narrow to affect cloud, a smoother Scottish "coastline" was used when measuring C_n (see Fig. 1).

Calculation of the annual average sunshine for the 50 stations showed that the formula $(4.77 - 0.04\ C_n - 0.04\ C_s - 0.05\ H\ \text{hrs./day})$ overestimated the effect of latitude.   A study of the results showed that more accurate estimates would be obtained if the latitude effect (expressed by C_s) was halved.   An examination of the distribution of the resulting errors indicated an alteration of the constant from 4.77 to 4.57.   These modifications gave rise to the progressive improvements listed below:-

a. $4.77 - 0.04\ C_n - 0.04\ C_s - 0.05\ H$: 9 out of 50 cases estimated to within ± 0.3 hrs./day

b. $4.77 - 0.04\ C_n - 0.02\ C_s - 0.05\ H$: 34 out of 50 cases estimated to within ± 0.3 hrs./day

c. $4.57 - 0.04\ C_n - 0.02\ C_s - 0.05\ H$: 45 out of 50 cases estimated to within ± 0.3 hrs./day

Inspection of the isohels of the average annual sunshine chart for Scotland suggested that an east/west factor might be introduced into the formula, for stations below 500 feet, to account for the increase in sunshine to the lee of high ground when exposed to a predominantly W-SW airstream.   Stations on the north coast and in Shetland and Orkney are counted as west stations.   Figure 1 shows the east/west dividing line, the positions of the stations used, and (in dotted lines) the smoothed coastline.   A scrutiny of the values so far obtained indicated and adjustment of ± 0.15 hrs./day, this being added to estimates for eastern stations and subtracted from those for western stations.   The final version of the formula, the Davies (modified) formula, thus became $4.57 - 0.04\ C_n - 0.02\ C_s - 0.05\ H\ \pm 0.15$ hrs./day, and resulted in 47 of the

50 cases being within ± 0.3 hrs./day of the long term values. The overall distribution of errors is also considerably improved.

Davies (modified) formulae were then derived for the four seasons, using a procedure similar to that described above. The values of the additive factors were obtained from an inspection of seasonal sunshine charts which had been specially prepared.

Results. Table 1 shows the results obtained for the 50 Scottish stations from the Davies and Davies (modified) formulae.

Table 1

	ENGLAND and WALES	SCOTLAND
	Davies - hrs./day	Davies (modified) - hrs./day
Annual	$4.77 - 0.04C_n - 0.04C_s - 0.05H$	$4.57 - 0.04C_n - 0.02C_s - 0.05H \pm 0.15$ ‡ (47 out of 50)/
Winter (Dec.-Feb.)	$2.19 - 0.03C_n - 0.02C_s - 0.04H$	$2.19 - 0.03C_n - 0.01C_s - 0.04H \pm 0.03$ ‡ (46 out of 50)
Spring (Mar.-May)	$5.84 - 0.08C_n - 0.04C_s - 0.05H$	$5.71 - 0.08C_n - 0.02C_s - 0.05H$ (46 out of 50)
Summer (June-Aug.)	$7.14 - 0.06C_n - 0.06C_s - 0.04H$	$6.50 - 0.06C_n - 0.03C_s - 0.04H \pm 0.15$ ‡ (43 out of 50)
Autumn (Sept.-Nov.)	$3.82 - 0.04C_n - 0.03C_s - 0.04H$	$3.42 - 0.04C_n - 0.015C_s - 0.04H \pm 0.30$ ‡ (47 out of 50)

C_n = distance from nearest "coast" in tens of miles

C_s = perpendicular distance from St. Mawgan-Dungeness line in tens of miles

H = height above m.s.l. in hundreds of feet

/ Figures in brackets are the number of cases within ± 0.3 hrs./day

‡ Add for east stations
  Subtract for west stations $\Big\}$ below 500 feet

The distribution of errors for each Davies (modified) formula is given in Table 2 for unobstructed and partially obstructed sites, separately and together.

/Table 2

Table 2

(Calculated sunshine minus average sunshine) hrs./day

		-0.9	-0.8	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	Total
Annual	(a)					1	1	3	9	4	7	5	6							36
	(b)								2	2	4	3	1	1	1					14
	(a)+(b)					1	1	3	11	6	11	8	7	1	1					50
Winter	(a)						1	1	9	7	12	4	1	1	1					36
	(b)								2	3	5	3	1	1						14
	(a)+(b)						1	1	11	10	12	7	2	1	1					50
Spring	(a)	1					1	2	6	5	8	7	5	1	1					36
	(b)							1	1	2	3	3	2	1	1					14
	(a)+(b)	1					1	3	7	7	11	10	7	2	2					50
Summer	(a)			1		1	1	4	6	5	7	2	3	2	2	1		1		36
	(b)						1	1	1	3	3	4	1		1			1		14
	(a)+(b)			1		1	1	5	7	10	7	2	4	6	2	1		1	1	50
Autumn	(a)						2	4	7	6	9	2	5	1						36
	(b)							2	2		2	4	2	1	1			1	1	14
	(a)+(b)						2	4	7	6	12	6	7	1	1			1	1	50

(a) normal stations

(b) partially obstructed stations

A comparison between the results obtained for Scotland using the Davies (modified) formulae and Davies' results for England and Wales in given in Table 3.

<div align="center">Table 3</div>

	Davies England and Wales	Davies (Modified Scotland
	% Results within $\pm$ 0.3 hrs./day	
Annual	93.1	94
Winter	90.6	92
Spring	89.3	92
Summer	78.6	86
Autumn	93.1	94

Conclusion. The average seasonal and annual sunshine for places at an altitude of 1000 feet or less in Scotland can be calculated, in the great majority of cases, to with $\pm$0.3 hrs./day by use of the Davies (modified) formulae given in Table 1. No similar information is available for the higher land masses.

1. P. G. RACKLIFF   Climatological Memorandum No.36

2. Meteorological Office. M.O.743, Averages of Bright Sunshine for Great Britain and Northern Ireland, 1931-60.

Figure I

Shetland

East/West line

Scale

0 10 20 30 40 50 60 70 80 90 100
Statute miles

Key: ● Station   .... Smoothed Coastline