

REVISED REGRESSION EQUATIONS FOR ESTIMATION OF SOLAR RADIATION OVER AUSTRALIA

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ABSTRACT

Regression equations developed with data to the end of 1961 were recomputed using approximately twice the number of observations. The new equation based on data for six radiation stations using the Robitzsch actinograph is $Q/Q_A = 0.27 + 0.50 n/N$ and is almost identical with the one obtained earlier. The wide spatial and temporal variation of regression equations for particular months for individual stations makes them of little value. Combining all station data for individual months produced monthly regression equations which were in close agreement with one another and with the "all-in" equation.

1. INTRODUCTION

In a previous study (Hounam 1963) of the relationship between sunshine and solar radiation, the regression equation

$$Q/Q_A = 0.26 + 0.50 n/N \quad \dots(1)$$

was obtained using 458 monthly totals for six radiation network stations for all years of record up to the end of 1961;

- where Q = total radiation received at the earth's surface
 Q_A = radiation received on a horizontal surface at the top of the atmosphere
 n = duration of sunshine
 N = maximum possible duration of sunshine.

Years of record for individual months ranged between 3 and 10.

Regression coefficients for individual months showed wide spatial and temporal variation and appeared to be due to the short period of records rather than any climatic or geographical cause.

Radiation was recorded by the Robitzsch actinograph which is not considered to be a high quality actinometer; however, during 1968 the Bureau of Meteorology established a new radiation network comprising 24 stations equipped with Eppley instruments. Robitzsch actinographs ceased operation with the installation of new equipment.

The purpose of this investigation is to compute regression equations using all the Robitzsch data available to the end of 1967 and find out what improvement, if any, results from the longer period of record now available. In all, for the six stations, there are now 890 monthly radiation totals compared with 458 at the end of 1961.

2. REGRESSION ANALYSES

Table 1 shows the results of regression analyses for each of the six radiation stations and for combined data for all stations. Monthly statistics for each station are shown thus:

- a = intercept of regression equation
 b = slope
 σ_s = standard deviation of monthly sunshine ratios n/N
 σ_Q = standard deviation of monthly radiation ratios Q/Q_A
 r = correlation coefficient
 E_Q = standard error of estimates of Q/Q_A
 s = number of months in sample.

Table 1. Monthly values of linear regression coefficients "a" and "b" in equation $Q/Q_A = a + b n/N$

- σ_s, σ_Q = standard deviation $n/N, Q/Q_A$
 r = correlation coefficient Q/Q_A
 E_Q = standard error in estimates of Q/Q_A
 s = No. of months in sample.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	All Months
(i) MELBOURNE													
a	0.28	0.34	0.25	0.16	0.33	0.41	0.36	0.37	0.21	0.39	0.35	0.26	0.28
b	0.47	0.38	0.50	0.71	0.33	0.15	0.21	0.24	0.59	0.25	0.30	0.49	0.45
σ_s	.075	.078	.079	.092	.105	.048	.040	.062	.064	.063	.061	.063	.106
σ_Q	.043	.038	.050	.078	.053	.035	.049	.034	.048	.041	.034	.044	.061
r	.82	.77	.79	.83	.64	.20	.17	.44	.78	.38	.55	.71	.79
E_Q	.025	.024	.031	.043	.041	.034	.048	.031	.030	.038	.028	.031	.037
s	14	15	15	15	15	15	14	14	15	14	14	14	174
(ii) WILLIAMTOWN													
a	0.21	0.24	0.26	0.23	0.22	0.24	0.35	0.32	0.01	0.07	0.14	0.22	0.23
b	0.57	0.54	0.51	0.49	0.53	0.50	0.38	0.40	0.92	0.90	0.73	0.59	0.56
σ_s	.066	.062	.077	.051	.078	.145	.062	.064	.032	.085	.060	.085	.089
σ_Q	.047	.043	.051	.040	.053	.077	.039	.034	.047	.107	.062	.053	.066
r	.81	.78	.79	.62	.79	.95	.60	.75	.63	.71	.70	.94	.75
E_Q	.028	.027	.031	.031	.033	.025	.031	.022	.037	.076	.044	.018	.044
s	8	10	10	10	10	9	9	10	10	11	11	10	118

Table 1. Monthly values of linear regression coefficients "a" and "b" in equation $Q/Q_A = a + b n/N$ (Continued)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	All Months
(iii) GARBUTT													
a	0.39	0.22	0.34	0.58	0.35	0.38	0.16	0.49	0.48	0.54	0.27	0.29	0.26
b	0.24	0.54	0.36	0.06	0.38	0.37	0.66	0.25	0.26	0.14	0.47	0.41	0.50
σ_s	.091	.083	.131	.071	.093	.079	.068	.090	.057	.077	.045	.069	.121
σ_{Q_s}	.028	.049	.057	.040	.037	.038	.047	.027	.020	.043	.027	.033	.071
r	.78	.91	.81	.10	.93	.77	.95	.82	.73	.26	.78	.87	.86
E_{Q_s}	.017	.020	.034	.040	.014	.024	.014	.015	.014	.041	.017	.016	.037
s	8	9	10	8	10	10	9	10	10	10	10	9	113
(iv) ALICE SPRINGS													
a	0.30	0.33	0.34	0.34	0.33	0.23	0.23	0.37	0.32	0.19	0.16	0.09	0.24
b	0.41	0.41	0.40	0.41	0.42	0.59	0.58	0.41	0.44	0.59	0.62	0.770	0.53
σ_s	.077	.121	.090	.099	.087	.101	.087	.066	.056	.060	.058	.062	.093
σ_{Q_s}	.043	.060	.044	.046	.041	.063	.055	.039	.029	.041	.042	.051	.059
r	.73	.82	.82	.88	.90	.95	.92	.69	.85	.88	.85	.86	.83
E_{Q_s}	.029	.035	.025	.022	.018	.020	.022	.029	.016	.020	.022	.026	.033
s	12	12	12	13	14	14	13	13	13	12	12	12	152
(v) GUILDFORD													
a	0.28	0.40	0.26	0.42	0.20	0.33	0.33	0.36	0.48	0.58	0.36	0.28	0.32
b	0.49	0.34	0.51	0.23	0.62	0.40	0.42	0.37	0.19	0.06	0.39	0.50	0.43
σ_s	.058	.066	.063	.102	.071	.098	.085	.085	.068	.062	.095	.055	.119
σ_{Q_s}	.037	.043	.040	.055	.054	.055	.043	.050	.030	.016	.046	.047	.062
r	.77	.52	.80	.43	.81	.72	.83	.62	.43	.21	.81	.59	.82
E_{Q_s}	.024	.036	.024	.050	.031	.038	.024	.039	.027	.016	.027	.038	.036
s	14	14	14	15	14	14	14	15	15	14	14	14	171
(vi) DARWIN													
a	0.34	0.34	0.28	0.29	0.35	0.24	0.42	0.80	0.36	0.47	0.29	0.25	0.24
b	0.27	0.31	0.47	0.41	0.39	0.53	0.33	-0.11	0.37	0.20	0.44	0.45	0.51
σ_s	.089	.115	.102	.076	.048	.039	.069	.022	.044	.033	.097	.097	.171
σ_{Q_s}	.046	.054	.082	.044	.027	.030	.041	.028	.031	.028	.092	.059	.098
r	.51	.67	.58	.71	.71	.69	.54	-.09	.53	.23	.46	.73	.89
E_{Q_s}	.039	.040	.067	.031	.019	.022	.035	.028	.026	.027	.081	.040	.046
s	13	14	14	14	14	14	13	14	14	13	13	12	162
(vii) STATISTICAL VALUES BASED ON ALL DATA FOR SIX STATIONS													
a	0.26	0.27	0.27	0.28	0.27	0.28	0.25	0.27	0.27	0.34	0.28	0.24	0.27
b	0.49	0.48	0.48	0.46	0.49	0.50	0.54	0.50	0.50	0.40	0.47	0.52	0.50
σ_s	.141	.147	.130	.138	.175	.198	.206	.179	.151	.136	.116	.125	.159
σ_{Q_s}	.077	.079	.075	.077	.091	.104	.116	.097	.081	.072	.072	.075	.089
r	.89	.90	.84	.81	.94	.94	.95	.93	.92	.74	.76	.87	.89
E_{Q_s}	.034	.035	.040	.045	.032	.035	.036	.037	.033	.049	.047	.037	.040
s	69	74	75	75	77	76	72	76	77	74	74	71	890

3. DISCUSSION

The regression equation derived from 890 monthly pairs is

$$Q/Q_A = 0.27 + 0.50 n/N \quad \dots (2)$$

which is practically identical with equation (1) obtained from half that number of observations.

In the case of Williamtown and Guildford equations based on all observations for each station lie closer to the general relation (Eq. 2) than the earlier ones (based on less data) but very little change is noted for the other stations.

In the case of individual months for each station the increased number of observations results in improved regression equations, but in most instances they are not reliable enough for use as estimators.

Values of the regression coefficients for particular months based on all stations (Table 1 (vii)) show little variation from those in Eq. (2) with the exception of October. Therefore, in the absence of more refined parameters, e.g. turbidity, equation (1) or (2) should be used generally for the estimation of monthly solar radiation rather than use regression equations for each particular month.

Standard errors of the estimates of Q/Q_A in Table 1 may be compared with the standard deviation of this term. This difference, which indicates the usefulness of the regression equations, varies approximately with values of the coefficient "b". When "b" is small the regression equation becomes physically unsound and $\sigma_Q - E_Q$ approaches zero; under these circumstances the mean value would be almost as good an estimator. Equations are more reliable when "b" is between 0.4 and 0.6.

4. SUMMARY

Although data from the new radiation network should be used wherever possible because of the better equipment in use, it will be many years before reliable regression equations can be established. Equation (1) will serve a useful purpose in the meantime. There is a strong indication that the same equation can be applied to each month of the year.

A spatial variation in regression coefficients might be expected (Glover and McCulloch 1958) and is still a possibility, but there is no conclusive evidence from this investigation.

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REFERENCES

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