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CLIMATOLOGICAL BULLETIN

CONTENTS

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CALCULATED AND MEASURED NET RADIATION FOR A SLOPE

by

R.G. Wilson and B.J. Garnier*

Introduction

More than twenty years have passed since C.W. Thornthwaite introduced the word "topoclimate" (1953a) and discussed the ultimate objective of topoclimatology, namely to map geographically the exchanges of heat, moisture, and momentum for local regions (1953b). We have now reached the point where it is possible to foresee methods by which evapotranspiration could be calculated and mapped on a topoclimatological scale (Garnier, 1972a). However one major question which has not been answered adequately concerns the reliability of calculated net radiation values for slopes. Clearly the determination of the net radiation is a major step towards the goal set by Thornthwaite. Methods by which slope net radiation can be calculated have been referred to by several authors (Rouse and Wilson, 1969; Wilson, 1970; Basnayake, 1971; Garnier, 1972a), but there appears not to have yet been a study which compares calculated values with measured values.

The basic operating procedure for evaluating surface variations of the radiation balance is to measure various radiation components at a representative horizontal site and then to calculate values for the surrounding terrain from a knowledge of the local surface characteristics. Provided that the horizontal surface and the sloping surface are covered by the same vegetation, the primary local characteristics which must be known are slope inclinations and azimuths, both of which can be determined from topographic maps in several ways (Basnayake 1970, 1971). The rela-

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tionships between horizontal and slope radiation fluxes clearly are vital elements of the basic procedure but, in the cases of some radiation components, the relationships are not understood well.

The radiation balance of a horizontal surface can be written as:

$$R = (Q+q)(1-\alpha) + L\downarrow - L\uparrow \quad (1)$$

where R is the net radiation, Q and q are direct and sky-diffuse solar radiation respectively, α is the shortwave reflection coefficient or albedo, $L\downarrow$ is incoming longwave (counter) radiation from the atmosphere, and $L\uparrow$ is outgoing longwave (terrestrial) radiation. Using a subscript s to denote a slope value, the balance on a sloping surface can be written similarly as:

$$R_s = (Q_s+q_s+q_r)(1-\alpha_s) + L_s\downarrow - L_s\uparrow + L_r + L_e \quad (2)$$

where q_r and L_r are respectively solar radiation and counter radiation reflected onto a slope from surrounding surfaces, and L_e is terrestrial radiation emitted by adjacent surfaces and absorbed by the slope.

The most progress to date has been made in understanding topographic variations of solar radiation. Using the method of Garnier and Ohmura (1968, 1970), values of Q and q are determined for a base station and then the corresponding components can be calculated for slopes. The value of Q_s is determined as:

$$Q_s = \frac{Q_o}{e^2} \sum_{t_1}^{t_2} p^m \cos(\vec{X} \wedge \vec{S}) \, \Delta t \quad (3)$$

where Q_o is the solar constant, e is the radius vector of the earth, p is the atmospheric transmissivity, m is the optical air mass, $\vec{X}$ and $\vec{S}$ are unit co-ordinate vectors describing the azimuth and inclination of the slope and the position of the sun respectively, the symbol $\wedge$ denotes the angular difference between $\vec{X}$ and $\vec{S}$, and Δt represents the time interval between t_1 and t_2. If it is assumed that sky-diffuse solar radiation is isotropic, then q_s can be calculated simply as a function of the slope inclination, k, from the expression:

$$q_s = q \cos^2 \frac{k}{2} \quad (4)$$

Tests by Garnier and Ohmura (1970) and Basnayake (1971) have shown that calculated values of (Q_s+q_s) using equations (3) and (4) agree to within ± 3 percent of measured values. In the present study, the basic computer program presented by Garnier and Ohmura (1969) has been altered to incorporate the changes suggested by Fuggle (1970), thereby giving a more precise evaluation of n, and to incorporate the calculation of p from the measured values of (Q+q) and q by an iterative process.

Four other terms ($L_s\downarrow$, q_r, L_r, and L_e) in equation (2) can also be estimated if it is assumed that these components are isotropic (Kondratyev, 1965). In all cases, however, small amounts of energy are involved in these terms as long as the slope inclination is moderate: for example a 20° slope would receive 3 percent less counter radiation, and the sum of the other three terms ($q_r+L_r+L_e$) would probably never exceed 14 Wm^{-2} (0.02 ly min^{-1}) for vegetated surfaces during the summer. Since the corrections also are partially self-cancelling, it has been assumed here that they produce a negligible difference between R and R_s.

The remaining two terms ($L_s\uparrow$ and α_s) in equation (2) are surface-dependent terms and therefore the relationships between the horizontal and slope values cannot be calculated by physical laws without having specific measurements on the slope itself.

In the case of terrestrial radiation, topographically-induced variations result from differences in surface temperature, and although relatively large temperature differences between topographic units have been observed, the effect on the difference ($L\uparrow-L_s\uparrow$) is relatively slight. Rouse and Wilson (1969) found a maximum 7°C difference in surface soil temperature between the north and south slopes of a small mountain, but estimated the radiative effect to represent only 7 ly day^{-1} or 2 percent of average diurnal net radiation. Similarly, Garnier (1971, 1972b) performed airborne measurements of surface radiative temperatures and found that the terrestrial radiation from various natural surfaces in sloping terrain was normally within ±5 percent of that measured over short grass at a representative station.

Intuitively one might expect the albedo of sloping land to be different from that of horizontal land since the albedo of a surface is frequently found to depend upon the solar zenith angle. Clearly the difference ($\alpha-\alpha_s$) would be smallest for tall rough vegetation such as forest in which multiple reflections reduce or eliminate the zenith angle dependence (Stanhill et al., 1966), and for cases in which the solar zenith angle is less than about 50° when relatively constant albedos are observed. This latter case generally would apply to moderate slopes during summer months. However the dearth of suitable measurements makes this the least well known component in the radiation balance of a slope, at the present time.

Thus, for practical purposes, the complete radiation balance of a slope as expressed in equation (2) could be reduced to:

$$R'_s = (Q_s + q_s)(1-\alpha) + L\downarrow - L\uparrow \qquad (5)$$

so that the only corrections for the slope involve the global solar radiation. Application of equation (5) requires base station (horizontal) measurements of global, sky-diffuse and reflected solar radiation together with net radiation (so as to calculate the net longwave radiation, $L\downarrow - L\uparrow$).

An alternative to the individual component analysis exemplified by equation (5) is the use of a simple linear regression between solar and net radiation, of the form:

$$R = a + b\ (Q + q) \qquad (6)$$

Such regressions have become common for estimating net radiation when a long-term measurement of only solar radiation is available, and correlation coefficients often exceed a value of 0.9 since the fluctuation of $(Q+q)$ generally is much more significant than the changes in α or in $(L\downarrow - L\uparrow)$ for a specific surface. Since the only difference between equations (1) and (5) is in the global solar radiation term, it could be argued that the same regression constants, a and b, used in equation (6) for a horizontal surface should apply also to a slope, so that:

$$R''_s = a + b\ (Q_s + q_s) \qquad (7)$$

This procedure has two practical advantages in that: (1) it eliminates the need to measure or estimate the surface albedo; and (2) the measurement of R could be terminated after a and b values of the regression constants could be used so that R would not have to be measured. The net effect would be to reduce regular base-station measurements to only global and sky-diffuse solar radiation.

Experimental Procedure

An experiment to test these two techniques of calculating R_s was conducted during July 1972 at Glen Sutton, Quebec (45°02 N, 72°33 W). A base station for horizontal radiation measurements was established over a short grass surface and R_s was measured on a grassy northeast-facing slope (inclination 22°, azimuth 29° east of north) located about fifty meters from the base station. The radiation components measured and the corresponding instrumentation is listed in Table One. Measurements were

TABLE ONE

Radiation Components Measured and Equipment Used

Component	Sensor	Recorder
Q+q	Kipp and Zonen	Inst. Corp. of Amer. (400)
q	Kipp and Zonen	Heathkit (IR-18M)
$(Q+q)(1-\alpha)$	Solar Radiation Inst. (SRI4) radiometer with glass domes	Inst. Corp. of Amer. (400)
R	Solar Radiation Inst. (SRI4) radiometer with poly. domes	Leeds & Northrup (Speedomax H)
R_s	Thornthwaite miniature net radiometer	Thornthwaite net radiation recorder

maintained for approximately a month but a large amount of the data has been disregarded because of unsettled weather conditions and equipment failures. On many days the sky was completely overcast, resulting in very small radiation differences between the horizontal and the slope, while on several other days the frequent passage of small cumulus clouds made it impossible to obtain an accurate integration of the R_s signal. After also disregarding periods in which thunderstorms were experienced and those when the portable R_s equipment failed, it was decided for the purpose of this paper to concentrate the analysis on three consecutive days at the beginning of the month.

Between July 7 and 9 the area experienced a combination of overcast, broken cloud and clear sky conditions, as shown in Figure 1, thus allowing a wide range of radiation conditions for the tests. Since the test slope faced northeast, it tended to receive a greater intensity of solar radiation in the early morning hours and, being a northerly rather than southerly slope, it received considerably less solar radiation during clear mid-day hours. These trends are apparent in Figure 2 where it can be seen that the smallest differences in solar radiation occurred on July 7 during overcast conditions, somewhat larger differences appeared on July 8 in a broken cloud situation, and a maximum difference of 237 Wm^{-2} (0.34 ly min^{-1}) occurred on July 9 with a clear sky. Similar patterns existed in the differences between the measured values of R and R_s as shown in Figure 3, although it is obvious that the absolute differences were not as large as those between (Q+q) and Q_s+q_s).

Hourly values of slope net radiation were calculated both by the component technique as in equation (5) and by the regression technique

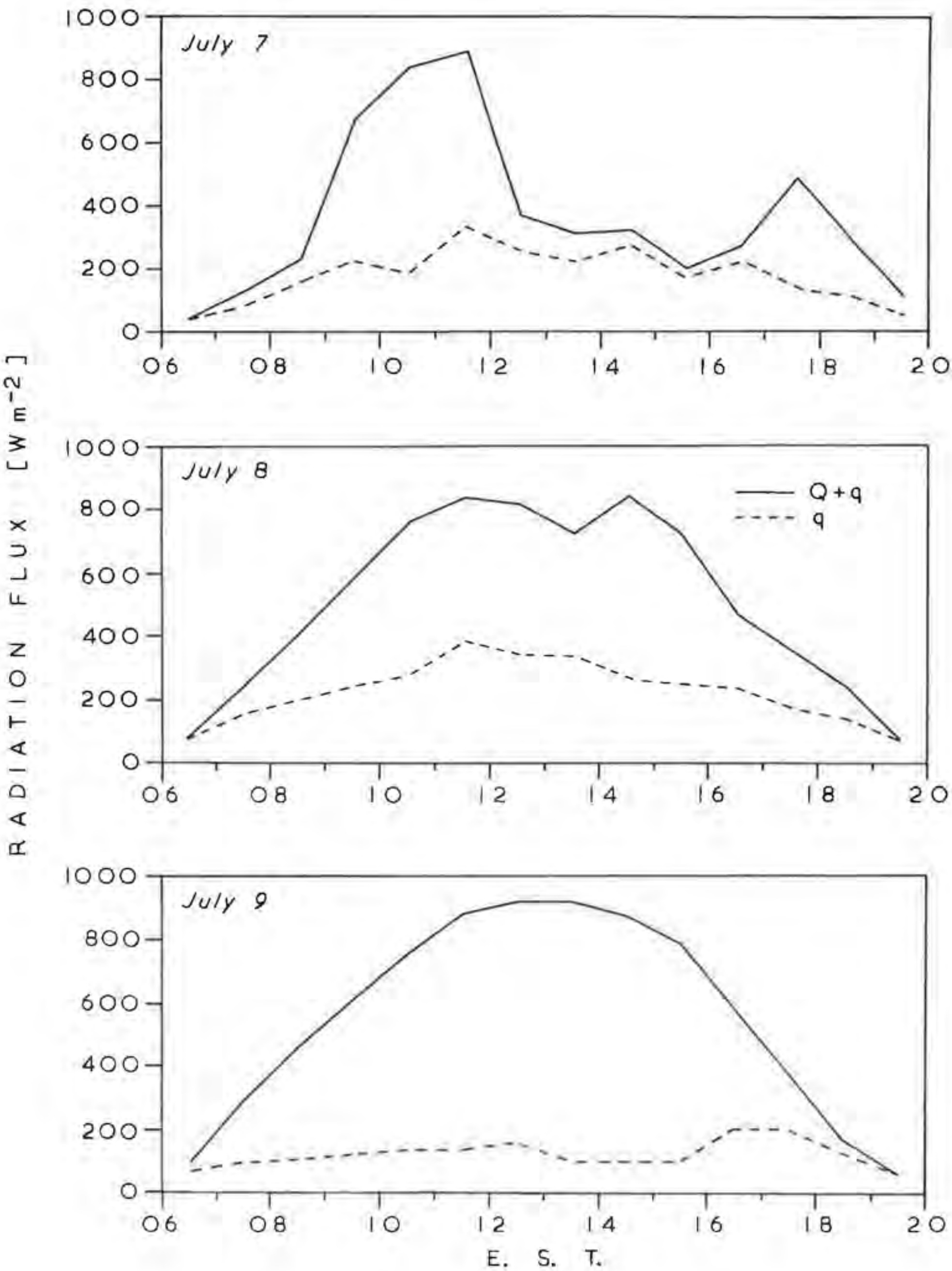

Fig. 1. Global and diffuse solar radiation at Glen Sutton, July 7-9, 1972.

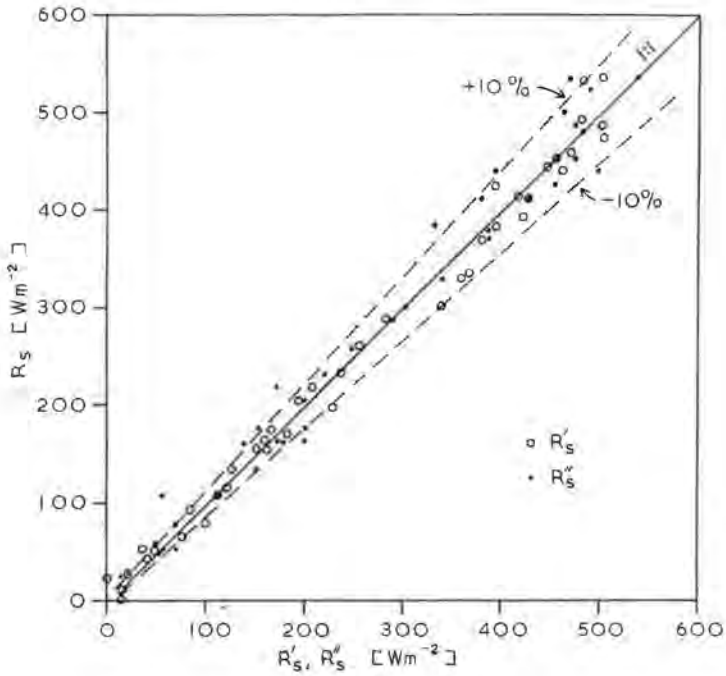

Fig. 2. The difference between global solar radiation measured on the horizontal and that calculated for the test slope.

shown in equation (7). For convenience, the values of slope net radiation calculated by the component analysis will be designated R'_s and those calculated by regression will be designated R''_s. In both cases hourly values of (Q_s+q_s) were calculated according to equation (3) and (4). For the component analysis the albedo of the grass on the slope site was assumed to be the same as that measured at the base station, and the net longwave radiation was assumed to be the same as that derived for the base station:

$$(L\downarrow - L\uparrow) = R - (Q+q)(1-a) \tag{8}$$

For the regression method, the relationship between (Q+q) and R for those hours with positive (Q+q) values was derived by linear regression as:

$$R(Wm^{-2}) = -37.6 + 0.697\ (Q+q) \tag{9}$$

which had a correlation coefficient of 0.993 and a standard error of pre-

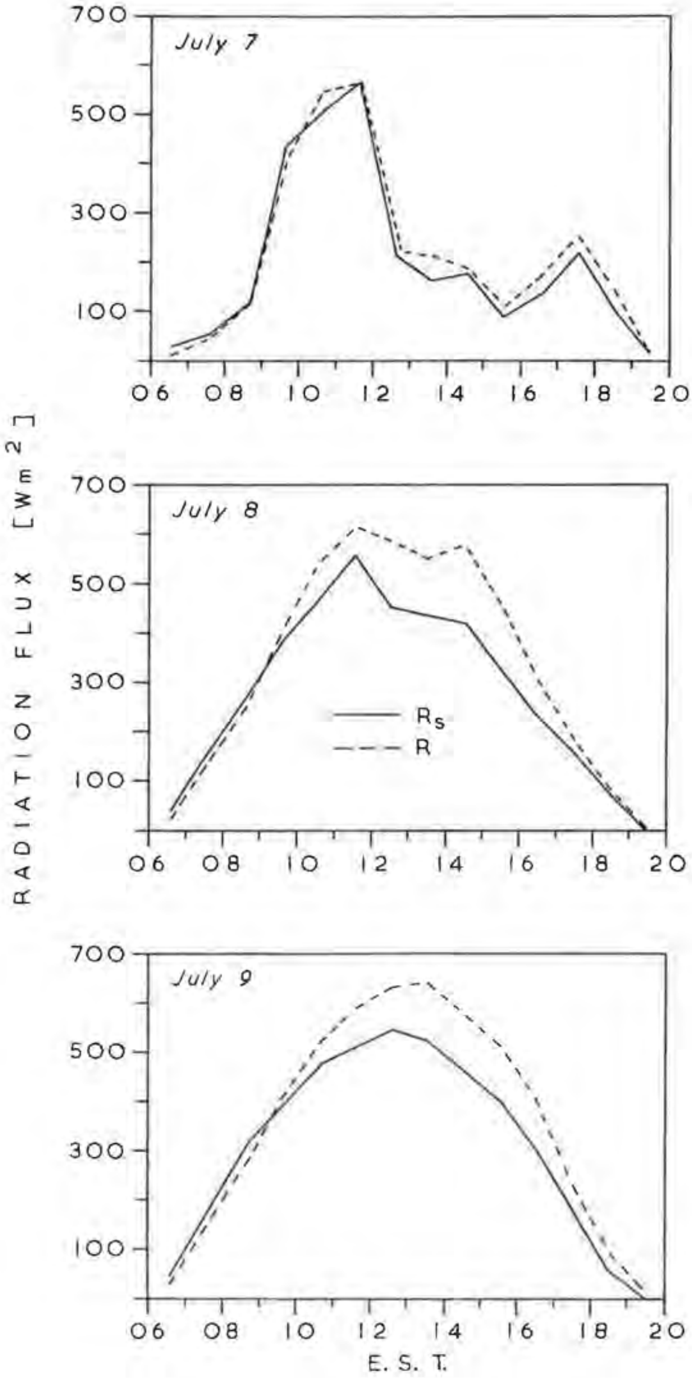

Fig. 3. Comparison of net radiation received on horizontal slope.

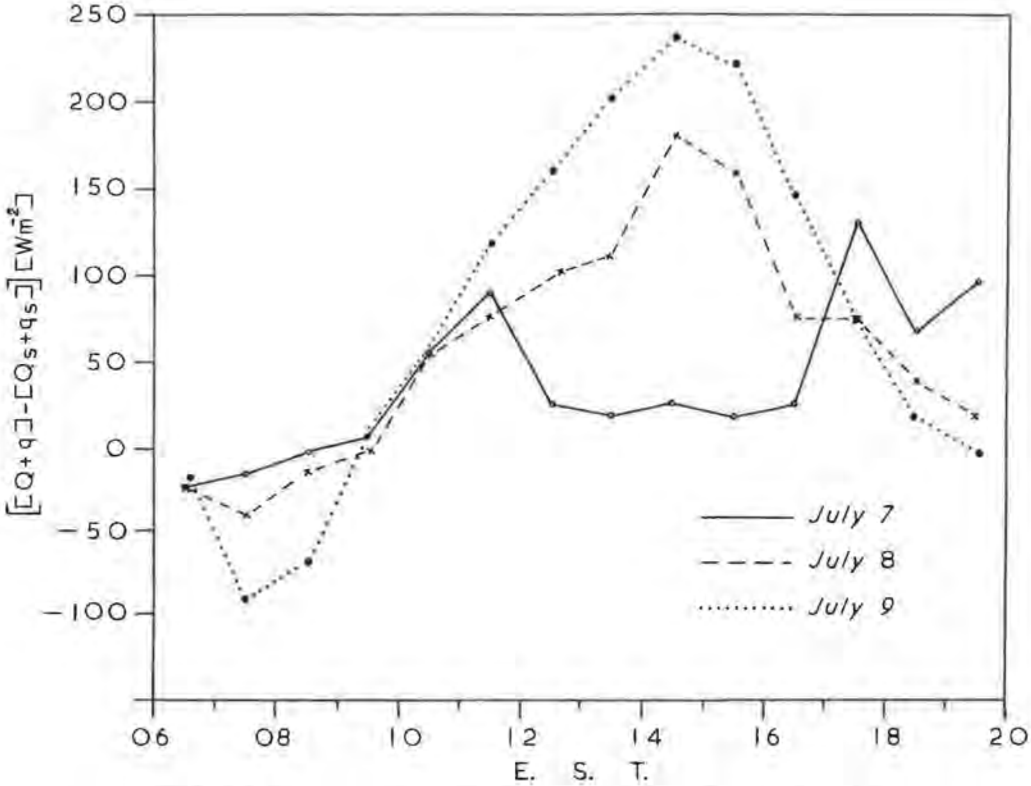

Fig. 4. Comparison of all measured and calculated values of slope net radiation.

diction of 24.4 Wm^{-2} (0.035 ly min^{-1}). The regression estimate, R''_s, was then calculated by substituting the value of (Q_s+q_s), thus:

$$R''_s\ (Wm^{-2}) = -37.6 + 0.697\ (Q_s+q_s) \qquad (10)$$

<u>Results</u>

The good agreement found between the hourly values of measured R_s and calculated (R'_s, R''_s) slope net radiation is illustrated in both the scatter diagram shown in Figure 4 and the graphs of the hourly differences $(R_s-R'_s)$ and $(R_s-R''_s)$ in Figure 5. Out of a total of 42 hours (0600 to 2000) on the three days, the difference $(R_s-R'_s)$ exceeded a value of ±35 Wm^{-2} (±0.05 ly min^{-1}) during 8 hours, while $(R_s-R''_s)$ exceeded that value during only 2 hours. As shown in Figure 6, the calculated values generally were within 10% of the measured values except for the early morning and evening hours. The better agreement during the mid-day hours is significant since this is the normal period of high radiation intensities. Throughout these three days, 83% of the total R_s was received during hours when R_s exceeded a value of 200 Wm^{-2} (0.29 ly min^{-1}). Under these conditions, the difference

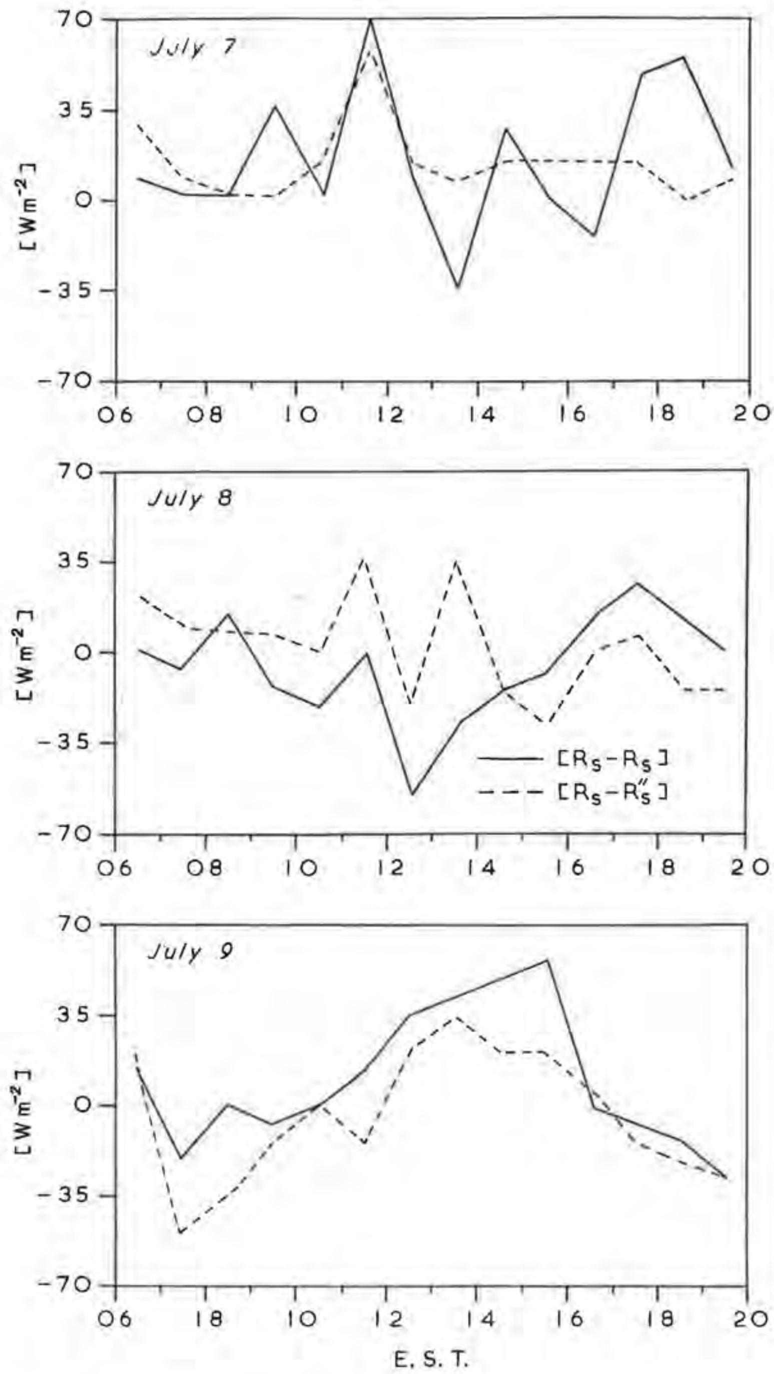

Fig. 5. Hourly differences between measured and calculated values of slope net radiation.

$(R_s - R'_s)$ exceeded 10% of R_s in 5 of 23 hours, while $(R_s - R''_s)$ exceeded this limit only once. Combined with the fact that R'_s and R''_s values were both higher and lower than R_s during the course of any one day, thereby producing a partial self-cancelling effect for the differences, this resulted in extremely good agreement between the daily totals shown in Table Two. For the three days, the absolute value of the difference in daily totals averaged 4.2% for R'_s and only 2.5% for R''_s.

TABLE TWO

Daily Totals (Wm^{-2}) of Radiation Components for July 7-9, 1972 at Glen Sutton, Quebec

Date	Q+q	q	(Q+q)(1-α)	α	(Q_s+q_s)	R	R_s	R'_s	R''_s
July 7	209	95	144	0.32	189	123	117	108	110
July 8	303	133	218	0.28	268	196	166	169	165
July 9	335	76	240	0.29	290	207	178	172	180

These results suggest that one is justified in simplifying the radiation balance equation for a slope, as has been done in this paper for the derivation of equation (5). It is possible that the assumptions $\alpha = \alpha_s$ and $L\uparrow = L_s\uparrow$ are not valid, but the data at hand do not disprove them. A clear diurnal trend in albedo was found at the horizontal site, and a difference in this parameter at the test slope should have produced consistently negative values of $(R_s - R'_s)$ during mid-day hours; such a situation existed only on July 8 in these tests. Similarly the positive values of $(R_s - R'_s)$ during mid-day hours on July 9 might be interpreted as the result of higher surface temperatures on the horizontal, resulting in a situation of $L\uparrow > L_s\uparrow$, but this pattern did not occur during similar conditions on July 8.

The relatively random nature of the differences shown in Figure 5 suggests that instrumental error may have been a major factor. Davies et al. (1970) suggests that one can expect an error of 10% in a recorded measurement of net radiation. If this figure is accepted for the R_s measurement, then it is apparent that the majority of the calculated values were within the limits of instrumental accuracy. Certainly this is the case for R''_s. However, as was shown earlier, R'_s was not quite as successful and this may be due simply to the fact that more measurements, and therefore more instrumental errors, were involved in the determination of R'_s than in that for R''_s.

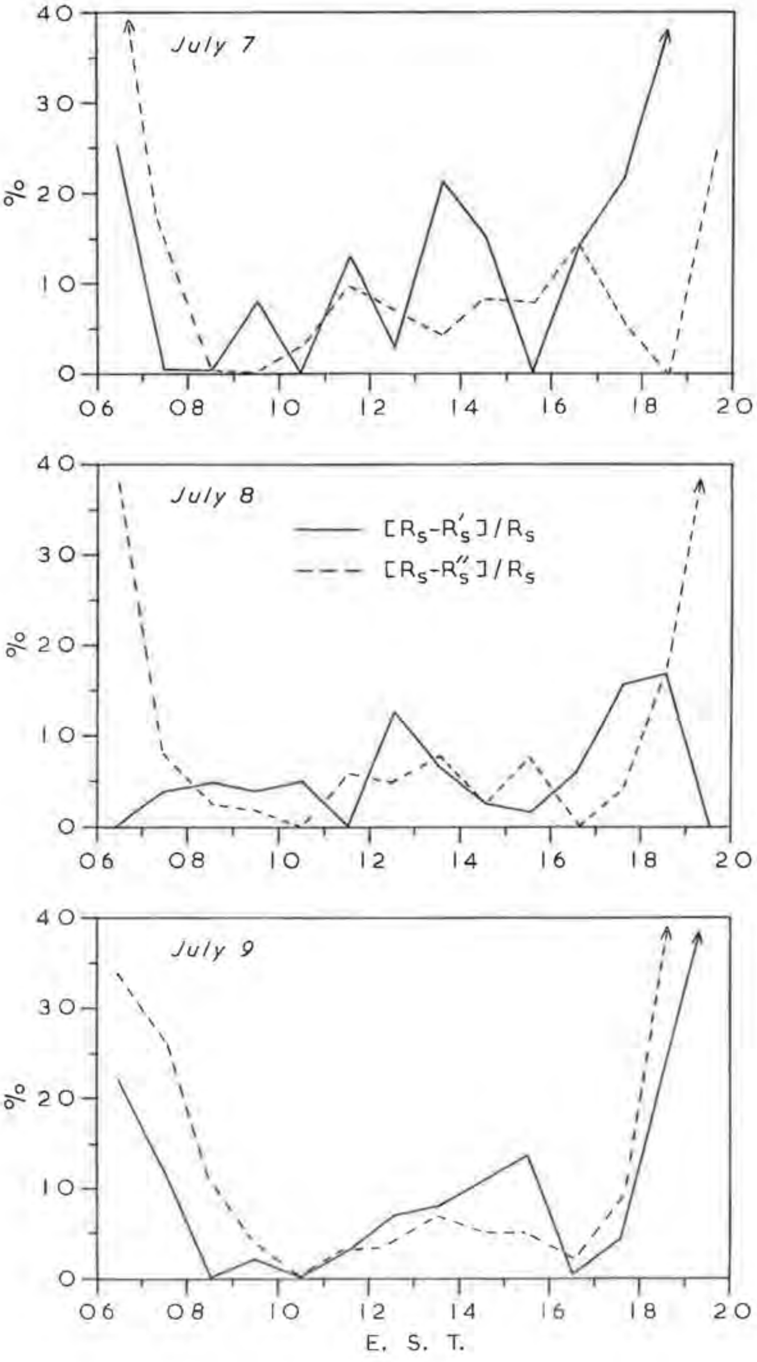

Fig. 6. Hourly percentage differences between measured and calculated values of slope net radiation.

Conclusions

These tests support the validity of both the component analysis and the linear regression techniques of calculating net radiation on sloping surfaces, and they indicate that the slope values can be calculated with about the same accuracy as they can be measured. This result lends support to the conclusions reached in previous papers in which the techniques were used without prior testing, and it makes the suggestion of evaporation mapping even more exciting since we now have evidence that mapping the primary source of evaporative energy is possible in practice as well as in theory. Of particular significance in a practical sense are the good results achieved by the linear regression technique, indicating that only a net radiometer need be added to base station solar radiation equipment to allow the more complex element to be mapped.

ACKNOWLEDGEMENTS

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REFERENCES

Basnayake, B.K., 1970: "Some Problems in Largescale Mapping of the Topographic Variation of Solar Radiation", Climat. Bull., Vol. 8, pp. 1-16.

Basnayake, B.K., 1971: Topography and Solar Radiation in Barbados, Unpub. Ph.D. thesis (McGill University).

Davies, J.A., P.J. Robinson, and M. Nunez, 1970: Radiation Measurement over Lake Ontario and the Determination of Emissivity, Prepared for the Canada Centre for Inland Waters, Great Lakes Division, Burlington, Ontario, 85 pp.

Fuggle, R.F., 1970: "A Computer Programme for Determining Direct Shortwave Radiation Income on Slopes", Climat. Bull., Vol. 7, pp. 8-16.

Garnier, B.J., 1971: "Procedures in Using a Light Aircraft for the Remote Sensing of Surface Radiative Temperatures", Climat. Bull., Vol. 10, pp. 1-12.

Garnier, B.J., 1972a: "A Vierpoint on the Evaluation of Potential Evapotranspiration", Publ. In Climat., Vol. 25, pp. 13-27.

Garnier, B.J., 1972b: "The Remote Sensing of Surface Radiative Temperatures over Barbados", McGill Univ. Climat. Res. Ser., No. 7 52 pp.

Garnier, B.J. and A. Ohmura, 1968: "A Method of Calculating the Short-wave Radiation Income of Slopes", J. Appl. Meteor., Vol. 7, pp. 796-800.

Garnier, B.J. and A. Ohmura, 1969: "Estimating the Topographic Variations of Short-wave Radiation Income: the Example of Barbados", McGill Univ. Climat. Res. Ser, No. 6, 66 pp.

Garnier, B.J. and A. Ohmura, 1970: "The Evaluation of Surface Variations in Solar Radiation Income", Solar Energy, Vol. 13, pp. 21-34.

Kondratyev, K.Y., 1965: Radiative Heat Exchange in the Atmosphere, Pergamon Press, London, 441 pp.

Rouse, W.R. and R.G. Wilson, 1969: "Time and Space Variations in the Radiant Energy Fluxes over Sloping Forested Terrain and their Influences on Seasonal Heat and Water Balances at a Middle Latitude Site", Geografiska Annaler, Vol. 51A, pp. 160-175.

Stanhill, G., G.J. Hofstede, and J.D. Kalma, 1966: "Radiation Balance of Natural and Agricultural Vegetation", Quart. J. Roy. Meteor. Soc., Vol. 92, pp. 128-140.

Thornthwaite, C.W., 1953a: "A Charter for Climatology", W. M. O. Bull., Vol. 2.

Thornthwaite, C.W., 1953b: "Topoclimatology", Proc. Toronto Meteor. Conf., pp. 227-232.

Wilson, R.G., 1970: "Topographic Influences on a Forest Microclimate", McGill Univ. Climat. Res. Ser., No. 5, 109 pp.

A STATISTICAL ANALYSIS OF RAINFALL IN SAMARU, NIGERIA (1928 - 1971)

by

J.O. Ayoade*

Introduction

Samaru (11° 3' N, 7°42' E) has a tropical savanna climate (Koppen's Aw) with distinct wet and dry seasons. The climate can also be described as dry subhumid using Thornthwaite's moisture index. The wet and dry seasons are associated respectively with the prevalence of the moist maritime southwesterly monsoon from the Atlantic Ocean and the dry continental northeasterly Harmattan from the Sahara desert. The fluctuating boundary zone between these two air masses has been called various names of which the Inter-tropical Discontinuity (ITD) appears to be the least ambiguous. As in other parts of Nigeria, the sequence of weather types experienced in Samaru during a given year is determined largely by its location relative to the fluctuating surface position of the ITD (Garnier, 1967).

The ITD and the Weather Zones

The ITD in Nigeria has an approximate WNW - ESE orientation in its surface position which varies not only from season to season but also from one year to another (Clackson, 1957). It assumes its average northernmost position of between 19.6°N and 20.20°N latitude around August while the average southernmost position is reached during February at between 6.2° and 8°N latitude (Obasi, 1965). The movement of the ITD is very irregular and can vary from an average of 1.9° latitude per month to 4.9° latitude, but generally the southward retreat is faster than the

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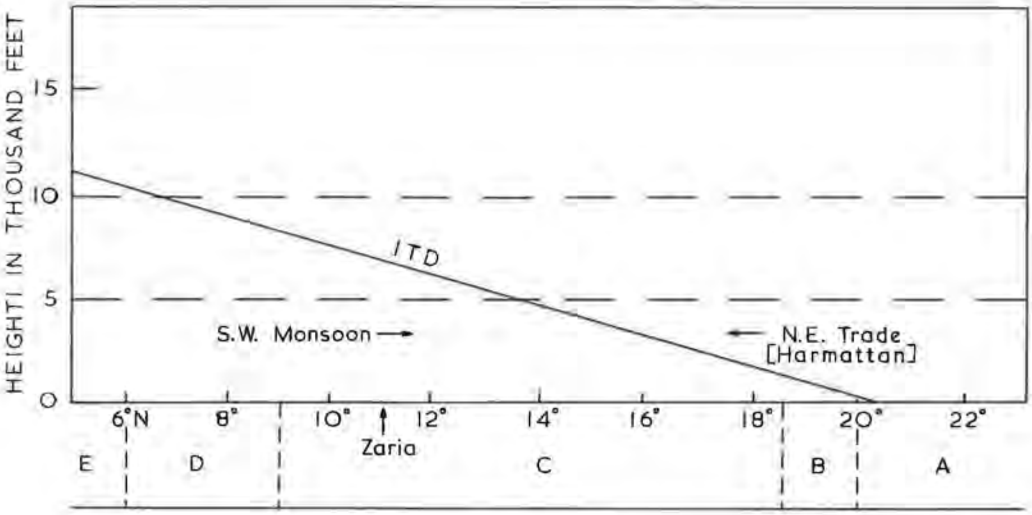


Fig. 1. A cross section across the ITD along the meridian of Zaria in August.
Weather zones: A - dry Harmattan weather; B - dry but humid; C - disturbance line thunderstorms; D - steady rain and drizzles; E - "little dry" season.

northward advance. This explains why the onset of the rains over the country is more gradual than the retreat.

The position of the ITD in Nigeria is very important, not because there is any particular weather activity at this boundary, but because it serves as a reference line for the normal weather system and structure associated with the two-dimensional boundary between the Harmattan and the Monsoon (Clackson, 1957). The characteristics of the various weather zones shown in Figure 1 have been extensively discussed elsewhere (Hamilton and Archbold, 1945; Garnier, 1967). Suffice it to say that the climatic characteristics of any place in Nigeria and the climatic differences over the country as a whole can only be understood in terms of the differing weather types which constitute the basic components of Nigerian climates. Which of these occur at a particular place, their time of occurrence, duration and the intensity with which the weather phenomena are developed are determined mainly by the location of that place relative to the fluctuating surface position of the ITD (Garnier, 1967).

Figure 1 shows a cross section of the atmosphere along the longitude of Samaru in August when the ITD is usually at its northernmost position. It is clear from the diagram that the weather types of zones D and E are only experienced in the southern parts of the country. In the latitude of Samaru, only three of the five weather types are normally experienced, although in occasional years there may be brief spells of the steady monsoonal rain of zone D. In other words, practically all the rainfall in the northern parts of the country is due to the disturbance lines (D/L) whereas D/L rains are experienced in the south only at the beginning and at the end of the rainy season.

The Seasonal Incidence of Rainfall

The rainfall in Samaru is highly seasonal. If we define a wet month as one with an average rainfall of at least 4 ins. (102 mm), we find that only five months (May to September) are wet. This period can then be regarded as constituting the wet season. Over 90% of the mean annual rainfall in Samaru is accounted for by these five months. Rain usually comes in thunderstorms which are either isolated or organised in almost continuous linear belts. The latter are called the Disturbance Lines. They are usually 75 to 150 miles (121 to 241 km) long and move westward across the country at an average speed of 25 - 35 m.p.h. (40 - 56 km). Both the isolated thunderstorms and the Disturbance Lines are formed by convection due to local heating, sometimes triggered off by high ground especially in the case of the Disturbance Lines (Hamilton and Archbold, 1945). Although the rainstorms are of high intensities, they are generally of short duration and those due to isolated thunderstorms tend to be sporadic in occurrence. On the other hand, the rainstorms due to the Disturbance Lines are in the form of belts aligned in a north - south fashion. The isolated thunderstorms are characteristic of weather zone B while the Disturbance Lines are characteristic of weather zone C. We therefore find that the showers at the beginning and the end of the rainy season are sporadic in occurrence since they are due to the isolated thunderstorms. The bulk of the rains received in a given year is due, however, to the Disturbance Lines.

The period from October to April constitutes the dry season. This season could be further subdivided into two on the basis of the relative humidity and temperature (see, for example, Hore 1970). These two subdivisions are the hot season from March to April and the Harmattan season from November to February the month of October being a transitional period between the two seasons. During the hot season the temperatures are highest and the relative humidities are higher than during the Harmattan season although not as high as during the rainy season. The Harmattan season is characterized by both low temperatures and low relative humidities.

The rainfall regime in Samaru is that of the single peak type, the peak occurring on the average in August (Fig. 2). A double peak regime occurs in some years but it is neither frequent nor intense enough for it to show in the average monthly rainfall figures. Over the period studied (1928 - 1971) 20 out of the 44 years showed the double peak rainfall regimes. The highest monthly rainfall usually occurred in August or September (Table One).

TABLE ONE

Number of Occasions in which the Highest Monthly Rainfall in the Year Occurred in Specified Months

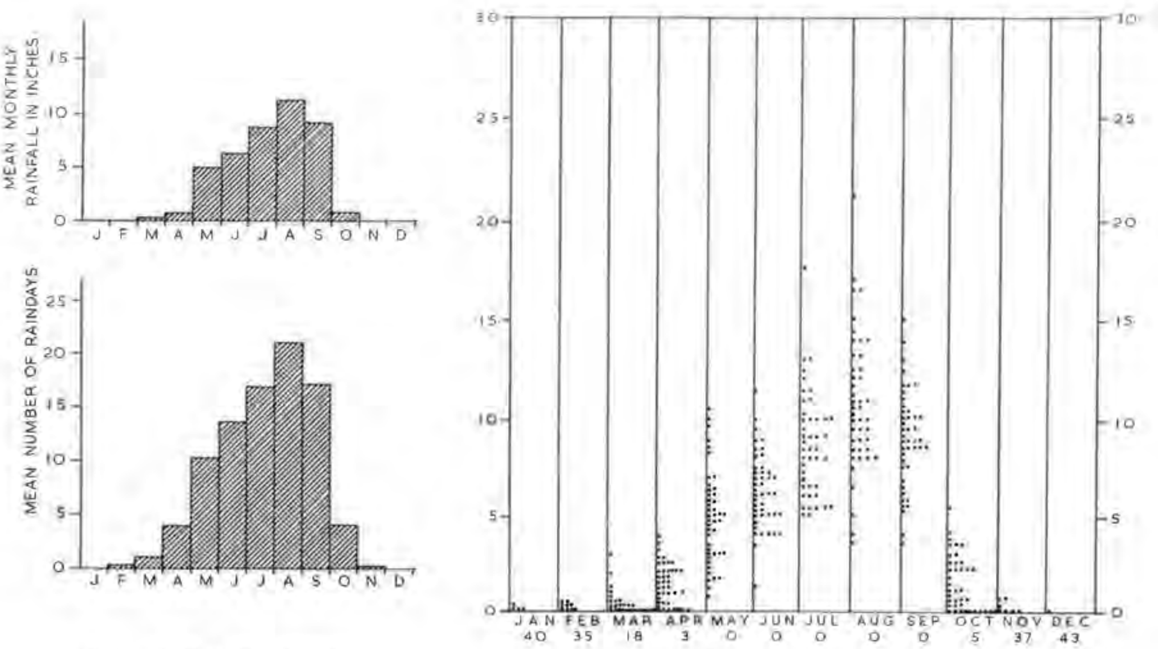
Months	Number of Occasions
May	1
June	4
July	6
August	23
September	10

The Variability of Rainfall

The rainfall amounts vary rather widely from one year to another. Over the period 1928 - 1971, the highest annual rainfall was 58.34 ins. (1482 mm) and the lowest was 32.45 ins. (824 mm) giving an absolute range of 25.89 ins. (658 mm). The coefficient of variation of the annual rainfall over the 44 year period is 18.61%. Monthly rainfall totals are more variable. Since they tend to be nonnormal in their frequency distributions no attempt has been made to calculate the coefficients of variation of the monthly rainfall. The relative variability of the monthly rainfall figures over the period 1928 - 1971 is indicated by the rainfall dispersion diagram in Figure 3.

Rainfall Reliability

The variability of rainfall is relevant to any consideration of the agricultural potentialities of an area. However, for a particular crop it is desirable to know in addition to the variability of rainfall,



(a) monthly totals and rainy days

(b) rainfall dispersion diagram

Fig. 2. Rainfall at Samaru.

the probability of a required amount of rainfall being received during a given period. The theme of probability and reliability follows logically from that of rainfall variability. Provided the frequency distribution of rainfall amounts is normal and we have records for 30 or more years, we can estimate (i) the percentage probability that some specific rainfall amount will be exceeded or will not be reached and (ii) the amount of rainfall that would occur or be exceeded with a specified degree of probability.

In the first case, the procedure is to calculate for a given data series the "z - score" (z) using the formula:

$$z = \frac{x - \bar{x}}{\sigma}$$

where x is the critical rainfall amount and $\bar{x}$ and σ are the mean and standard deviation of the series respectively. The z - score indicates "the extent to which the critical value differs from the mean in terms of 'so many' standard deviations" (Gregory, 1964, p. 60). The percentage probability that the rainfall amount will be more or less than the z - score corresponding to the critical value is obtained from tables of the Normal Distribution Function.

TABLE TWO

Rainfall amount	% Probility of failure to receive the stated amount of rainfall in a given year
20 ins (508 mm)	0.19%
30 ins (762 mm)	5.02%
40 ins (1016mm)	34.29%
50 ins (1270mm)	79.86%
60 ins (1524mm)	98.11%

In the second case, that of the amount of rainfall that would occur or be exceeded with a specified degree of probability, we are no longer interested in the percentage probability with which given critical values can be expected to be exceeded or not. We want to know the value that can be expected to be equalled or exceeded with a given probability. For this, we use a slightly modified form of the formula perviously given, viz:

$$x = z\sigma + \bar{x}$$

where x is the value which can be expected to be equalled or exceeded, $\bar{x}$ is the mean of the observations, σ is the standard deviation and z is the z-score corresponding to the specified degree of probability determined from tables of Normal Frequency Distribution.

Table Two shows the percentage probability of a failure to receive an annual rainfall of 20 ins (508 mm), 30 ins (762 mm), 40 ins (1016 mm) 50 ins (1270 mm) and 60 ins (1524 mm) in Samaru. As one would expect the percentage probability increases as the critical rainfall amount increases. Manning (1956) has defined reliable rainfall as the 5% probability or less of failure to achieve a selected amount of rainfall. Using this criterion the "reliable" annual rain fall in Samaru would be about 30 ins (762 mm). Assuming the annual rainfall series in Samaru approximates the normal frequency curve, the probability of the mean annual rainfall of 43.26 ins (1099 mm) falling in a given year will be 50%. In other words, the mean annual rainfall cannot be described as "reliable" using Manning's definition, since a given amount of rainfall is reliable only if it can be expected to be equalled or exceeded with 95% probability. Other definitions of reliable rainfall are less stringent. For example, Gregory (1964) regards as reliable the amount of rainfall which can be expected on the average nine (9) years out of ten (10), i.e. with 90% probability.

TABLE THREE

The Annual Rainfall Amounts likely to be reached or exceeded in Samaru at Stated Percentage Probabilities

c/o Probability	Annual Rainfall Amount
70	39.03 ins (991 mm)
80	36.48 ins (927 mm)
90	32.94 ins (837 mm)
95	30.01 ins (762 mm)
99	24.52 ins (623 mm)
0.1	68.14 ins (1731 mm)

Table Three shows the annual rainfall amounts likely to be reached or exceeded in Samaru at 70, 80, 90, 95 and 99 per cent probability level.

Assessments of probability characteristics as discussed above are of considerable value in agriculture particularly if critical rainfall limits for crops are known. However, for annual crops, the distribution of rainfall within the year is of great importance. It is therefore necessary to calculate probabilities of obtaining certain specified amounts of rainfall in certain weeks or months. The various probabilities are then multiplied together to give the probability of obtaining a particular distribution of the amount of rainfall required by a given crop during its growth period. Such studies of the relationship between rainfall reliability and crop growth have been carried out in East Africa in respect of cotton and other crops (see, for example, Manning, 1950). In this connection, it must be remembered that monthly and weekly rainfall data, unlike the annual rainfall data, tend to be positively skew and unless they are transformed by appropriate mathematical manipulations to make them normally distributed, the probability estimates obtained would be erroneous and of no use (Ayoade, 1972). It is also worthy of note that the N% probability rainfall does not strictly mean the rainfall that would be obtained N years out of 100. This is because "the percentage probabilities are theoretically related to an infinitely large population, so that there is no necessary reason for them to apply in detail within any shorter finite period" (Gregory, 1969, p. 79). Also, since the data we analyse is a sample drawn from a theoretical infinite population, the probability estimates we obtain either in terms of percentage probability as in Table Two or fiducial limits as in Table Three have some standard errors attached to them owing to sampling variations (see, for example, Gregory, 1969, pp. 77-78).

TABLE FOUR

Calculated 0.1% Probability Rainfall	Highest Recorded Rainfall	Calculated 99% Probability Rainfall	Lowest Recorded Rainfall
68.14 ins (1731mm)	58.34 ins (1482mm)	24.52 ins (623mm)	32.45 ins (824mm)

Rainfall Extremes

The 99% and 0.1% probability annual rainfall in Samaru shown in Table Four are estimates derived by fitting the Normal Probability Distributions to the annual rainfall data over the period 1928 - 1971. These estimates can be regarded as indicating the magnitudes of the annual rainfall extremes in Samaru. Table Four however shows that the highest recorded rainfall during the period 1928 - 1971 is much lower than the 0.1% probability rainfall. On the other hand, the lowest recorded annual rainfall over the same period is higher than the 99% probability rainfall estimates. In fact, the probability that the rainfall in any given year will equal or exceed the highest recorded rainfall of 58.34 ins (1482 mm) during the period 1928 - 1971 is 3.06%. Similarly, the probability that the rainfall in any given year will equal or exceed 32.45 ins (824 mm) is 91.02%. An alternative interpretation of these rainfall extremes uses the concept of return period. First, we arrange the annual rainfall totals in descending order of magnitude assigning an order number m, where m = 1, to the maximum value and m = n (the number of years of record) for the minimum value. Each of the annual rainfall totals can then be assigned a frequency position given by the formula:

$$T = \frac{n + 1}{n}$$

where T = return period in years and m and n are as defined above (Bruce and Clark, 1966, p. 136). The return period is then defined as the average number of years within which a given amount of rainfall is equalled or exceeded. The return period for the highest recorded rainfall in Samaru between 1928 and 1971 is therefore 45 years while that for the lowest recorded rainfall is only 1.02 years.

It can be verified that the return period of an event is inversely proportional to the probability of that event occurring (i.e. $T = \frac{1}{P}$). It must be noted however that these events will not necessarily occur at regular intervals of the number of years indicated by their return periods. The probability (P_T) that an event will occur within its

TABLE FIVE

Probability (P_T) that an Event with Return Period (T) will occur within the next T years

T	P_T
2	0.7500
5	0.6723
10	0.6513
20	0.6415
30	0.6380
40	0.6369
50	0.6358
100	0.6340
200	0.6330
500	0.6325
1000	0.6323
α	0.6321

stated return period (T) can be calculated by the formula:

$$P_T = 1 - (1 - \frac{1}{T})^T$$

As the value of the return period (T) becomes larger, the probability (P_T) tends to 0.6321 (Table Five). Since we are often interested in the frequency of rainfall amounts within high return periods and rainfall data are usually available for only short periods, it is necessary to estimate the needed extreme rainfall amounts from the available data. This is particularly the case with extreme daily rainfalls and their frequencies of occurrence. The economic design of bridges, culverts, dams and other structures subject to flooding requires a knowledge of the likely maximum floods which the structures will have to withstand during their estimated economic life (Bruce and Clark, 1966, p. 146).

Three main methods are used for estimating extreme rainfall amounts of various return periods: statistical, physical and empirical methods. It is the statistical approach that has been used here. The approach is based on probability theory. The two distributions most often used are the Normal Distribution Function and the Extreme Value Distribution Function developed by Gumbel (Gumbel, 1968). Both functions assume that the data values are independent of one another, and they give reliable estimates of extreme rainfalls if the sample size is large. But before either is used, the data must conform to the theoretical frequency distribution. The Normal Frequency Distribution is relatively well known

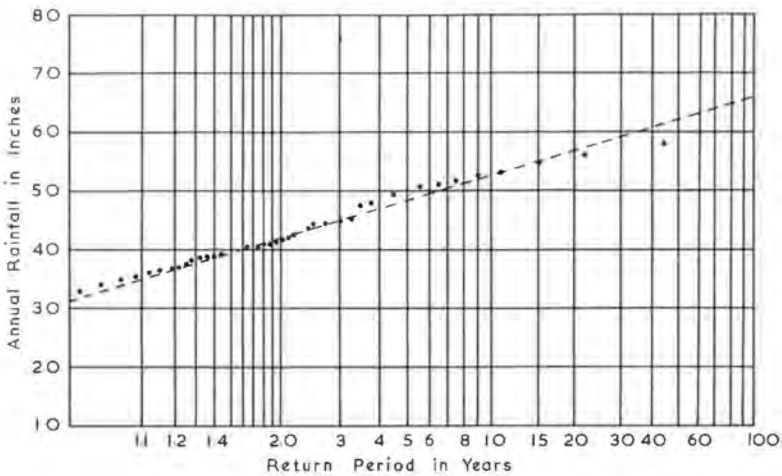


Fig. 3. Samaru: annual rainfall (1928-1971).

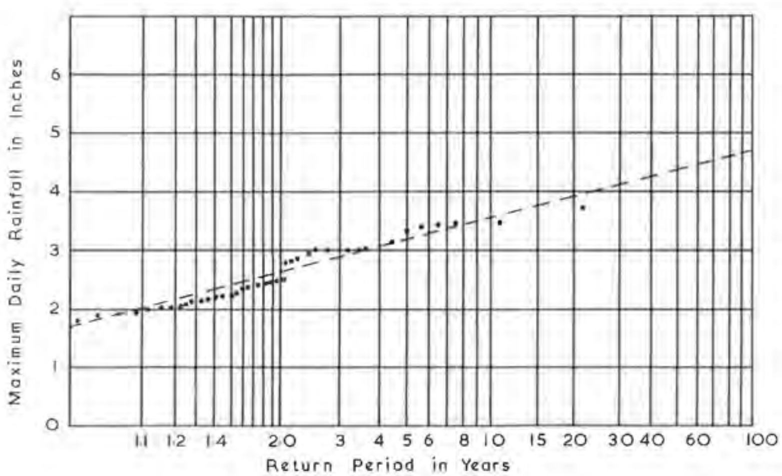


Fig. 4. Samaru: maximum daily rainfall (1928-1971).

and was used in the previous section. The Extreme Value Distribution by Gumbel is increasingly being applied to many hydrological problems with satisfactory results. Although specifically applicable to the distribution of annual maximum rainfalls (i.e. the series of maximum daily rainfalls for each year of the period under investigation), Dury (1964) has demonstrated the applicability of the theory to series of monthly and annual rainfall totals. Details of the distribution function can be found in the appropriate literature (see, for example, Gumbel, 1958). Gumbel has shown that for the assumed distribution, the rainfall amount which may be expected to be equalled or exceeded on the average once every T years is given by the formula:

$$y = \bar{y}_n + \frac{\sigma}{\sigma_n} \quad (\mathrm{Log}_e\ T - \bar{y}_n\ )$$

where $\bar{y}$ and σ are the mean and standard deviation of the observed maximum rainfalls and $\bar{y}_n$ and σ_n are the so-called reduced mean and standard deviation which depend on sample size and can be obtained from published tables. Gumbel's method thus requires the calculation of only the mean and standard deviation of the sample and the estimates of rainfall amounts of various return periods can then be made. Before the method is applied however the data frequency distribution must obey the theory of extreme values. Also, the method applies to only annual maximum series and not a partial duration series which by definition is not a true distribution. A notable characteristic of a distribution which obeys the theory of extreme values is that the mean of the sample values has a return period which approaches 2.33 years for large samples (Bruce and Clark, 1966, p. 151).

A simple way of determining whether a data series conforms to the theory of extremes is to plot it on an extreme probability paper. If the series does not conform to the theory, it will plot approximately as a straight line. Three steps are involved in the plotting:

(1) the observed values are ranked in a descending order;

(2) the recurrence interval of each observation is computed by the formula $T = \frac{n+1}{n}$ where T = recurrence interval in years, n = number of observations in the series and m = rank of a particular observation; and

(3) the rainfall values are then plotted against their computed recurrence intervals and a continuous line fitted to the scatter of points by eye.

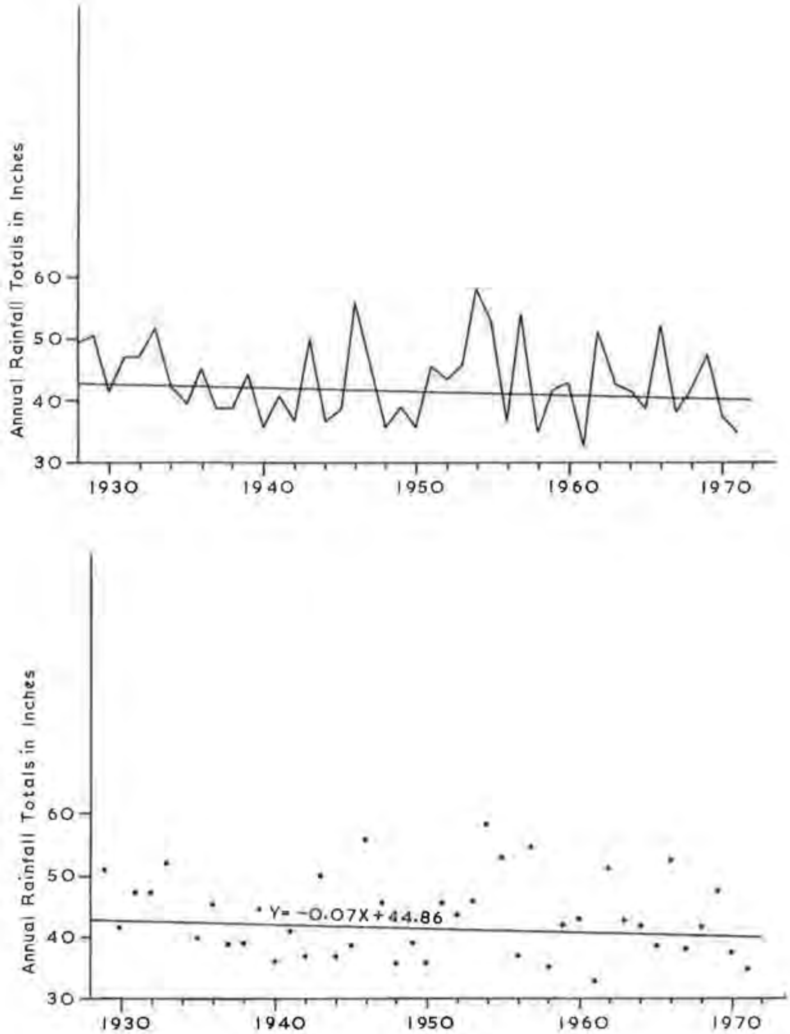


Fig. 5. Variability of rainfall at Samaru (1928-1971).

(a) Upper Diagram: year to year variation
(b) Lower Diagram: linear regression of variability

The reliability of the estimates from the fitted line depends on how close the points are to lying on a straight line. Gumbel (1958) has shown that once a good fit to the plotted points is obtained, the mean value can be read at the recurrence interval of 2.33 years. Similarly, the median and the most probable value are read at recurrence intervals of 2 and 1.58 years respectively. The recurrence intervals for these values are also independent of the duration of records used in the analysis (Dury, 1964, p. 26).

The results of plotting the data for Samaru are presented in Figures 3 and 4 , for the annual rainfall and the daily maximum rainfall respectively. The annual rainfall totals series in Figure 3 conforms better to the theory of extreme values than the daily maximum rainfall series. Estimates of the return period for given amounts of rainfall or of the rainfall amounts with given return periods can be made from the two graphs presented.

<u>Annual Rainfall Fluctuations and Trends</u>

The mean annual rainfall at Samaru from 1928 to 1971 was 43.26 ins. (1099 mm) and the standard deviation 8.05 ins. (204 mm). The wettest year during this period was 1954 which had a rainfall of 58.34 ins. (1482 mm). The driest year, 1961, received a rainfall total of only 32.45 ins. (824 mm). These extreme rainfall annual totals in Samaru represent a range of deviation of from 134.86% to 75.01% by comparison with the mean for the period 1928 - 1971.

The year to year variability of rainfall totals in Samaru is shown in Figure 5a. This annual rainfall series is characterised by so much "moistness" that it is difficult to determine any trend or periodicity by mere visual inspection of the graph. The variations in the series are of various wavelengths and it is necessary to remove the more rapid variations in order to determine the trend over time in the fluctuations of the values in the series. There are various methods of smoothing or removing the more rapid variations in a time series. These methods vary in their statistical rigour and the degree to which they generalise the fluctuations in a time series. Only the linear regression analysis has been used here since we are interested only in the overall trend in the annual rainfall fluctuations.

The equation of the line of best fit shown in Figure 5b has been computed using the least squares criterion by which the sum of the squares of the deviation of each observation in the series from the trend is minimised. The correlation coefficient between the annual rainfall totals and time in years is -0.11 which is insignificant at the 5% probability level. In other words, the apparent downward trend in the annual rainfall totals in Samaru from 1928 to 1971 might have been due to chance or sampling variations, and does not necessarily reflect a long-term trend.

REFERENCES

Ayoade, J.O., 1972: A Review of the Assumption of Normality in Statistical Analysis, Unpublished Seminar Paper.

Bruce, J.P. and P.H. Clark, 1960: Introduction to Hydrometeorology, Pergamon Press, Oxford.

Clackson, F.R., 1957: "Seasonal Movement of Boundary of Northern Air", Nigerian Met. Serv. Tech. Note, No. 5.

Dury, G.H., 1964: "Some Results of a Magnitude-frequency Analysis of Precipitation", Australian Geog. Studies, Vol. 2, pp. 21 - 34.

Garnier, B.J., 1967: "Weather Conditions in Nigeria", Climat. Res. Ser. (McGill University), No. 2, 163 pp.

Gregory, S., 1964: "Annual, Seasonal and Monthly Rainfall over Mozambique", Steel, R.W. and R.M. Prothero (eds.), Geographers and the Tropics, Longmans, London.

Gregory, S., 1969: "Rainfall Reliability", Thomas, M.F. and G.W. Whittington (eds.), Environment and Landuse in Africa, Methuen, London.

Gumbel, E.J., 1958: Statistics of Extremes, Columbia University Press, N.Y.

Hamilton, R.A. and J.W. Archbold, 1945: "Meteorology of Nigeria and Adjacent Territory", Quart. Journ. Roy. Met. Soc., Vol. 71, pp. 231 - 262.

Hore, P.N., 1970: "Weather and Climate", M.J. Mortimore (ed.), Zaria and its Region, Ahmadu Bello Univ. Department of Geography, Zaria, Nigeria.

Manning, H.L., 1950: "Confidence Limits of Expected Raintall", Journ. of Agric. Sci., Vol. 40, pp. 169 - 176.

Manning, H.L., 1956: "The Statistical Assessment of Rainfall Probability and its Application to Uganda Agriculture", Proc. Roy. Soc., B, Vol. 144, pp. 460 - 480.

Obasi, G.O.P., 1965: "Atmospheric, Synoptic and Climatological Features over the West Africa Region", Niger. Met. Serv. Tech. Note., No. 28.

A BRIEF REVIEW OF FINDINGS AND THEORIES CONCERNING SEASON OF BIRTH

by

Simon M. Kevan*

The belief that one's time of birth can influence one's personality and one's way of life has been held by astrologers for many years, but, the idea that one's abilities may be limited because of one's month or season of birth is of more recent origin. It is, in fact, a philosophy that has been developed within the twentieth century. Research concerning the effects of one's season of birth has followed various paths: 1) its relation to intelligence; 2) its relation to personality; and 3) its relation to mental illnesses. These relations have been explained in terms of pre- and post-natal theories. The pre-natal theories suggest that the formation of the brain and its subsequent functioning is affected indirectly by the atmospheric environment. It is argued that the mother's physiological adaptations to climate affect the formation and development of the foetus in such a way as to be reflected by the abilities of the offspring. The post-natal theories assume that the climatic conditions to which a child is exposed after birth affect the development of the person's cerebral processes. It is of interest to point out that in general, the advocates of pre-natal theories have been those investigators who have studied season of birth and mental illness; whereas, the research workers who have studied season of birth and intelligence have tended to support post-natal theories.

Season of Birth and Intelligence

One of the first research workers to discover that the mental aptitudes of people vary according to their season of birth was

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M. McCallum Fairgrieve (1921). He made an empirical study of the relation between month of birth of 368 young men and their scores obtained from American Army Intelligence Tests. He found that boys born in the late spring had a tendency to be less intelligent than the boys born in late autumn and early winter. He suggested that "some effect of environment may possibly be indicated" from his data.

The theory that this relation was the product of bioclimatic factors can be credited to Lawson (1922) and his critic Allen (1922). Lawson thought that Fairgrieve's data showed that "the weaklier members have been weeded out by the severity of winter in the first few months of life." Allen criticized Lawson's theory on the grounds that summer is a much more unhealthy season than winter and that the annual variation of intelligence was a result of the reproductive organs "especially the germ cell" being more active during the early spring than at any other time of year. This increase in the vigour of the "germ cell" accounted for his own findings, that eminent men are born more frequently during late autumn and early winter. It can be seen therefore, that both pre- and post-natal theories concerning season of birth were advanced very early in its study.

Initially there was not a great deal of interest exhibited in these findings. It was not until 1929, when Blonsky reported his findings, that interest in season of birth and intelligence was renewed. Blonsky, apparently unaware of the works cited above, found that scores for I.Q. tests given to 453 backward Russian children showed that children born in spring had a tendency to be more intelligent than children born during the other seasons. Blonsky thought that his data, the results from which are not in accordance with the findings of Fairgrieve, could be accounted for by the influence of such beneficial spring climatic conditions as increasing amounts of sunlight and more readily available fresh air upon the growing child.

It was Rudolf Pintner who brought about the English speaking world's interest in the matter of season of birth. In 1931 he produced a paper in which he reviewed Blonsky's work and added his own data which supported Blonsky's findings. Over the next several years Pintner and his associates (see bibliography) re-examined the relation between season of birth and intelligence many times. Their samples consisted of data collected from many thousands of subjects, who lived in Northeastern United States. In general their studies showed that people born during the warmer months have a slightly higher intelligence than those born during the colder months; specifically, they found that spring-born people have higher I.Q.s and winter-born people have lower I.Q.s than people born during summer or autumn. They pointed out, however, that the differences in the scores were not statistically reliable even though these same trends often appeared from the data. This seasonal birthdate trend to intelligence levels, as well as this lack of statictical significance, has been reported by most research workers. One's position concerning the reality of the relation between season of birth and intelligence inevitably depends upon one's belief in meaning of continually recurring trends or in the meaning of statistical reliability.

Goodenough (1941), drawing from her own data as well as those of Pintner and Forlano (1933), showed that the seasonal variation in I.Q. scores could be attributed to the preference of higher socio-economic classes, the classes which are most likely to reproduce children of above normal intelligence, to give birth to their children during spring. According to her this particular preference could account for the lack of difference in the intelligence scores of people born during the other seasons as well.

Orme (1962, 1963) discovered that a statistically significant number of British intellectually subnormal people, I.Q. values of less than 54, are born during the colder months of winter and spring. He suggested that the ambient air temperature regime may be at the root of such a distribution. McEwan's (1955) study, in which it is shown that European children living in Rhodesia exhibit a general deterioration in I.Q. with increasing ancestral span in Africa, has been believed to prove that intelligence is affected by ambient air temperature. Such a finding would have been used by Ellsworth Huntington (see bibliography) to support his contention that the optimum temperature for the conception of the normal child occurs when the diurnal temperature averages 62^{o}F. Huntington (1937) was quick to point out that this ideal temperature will occur at different times of the year for different geographical locations; consequently, data should be examined taking geographical aspects into consideration.

Not all studies have shown a relationship between season of birth and intelligence, or if a relationship has been found sometimes it has been found to be opposite to the norm. Berglund (1967) found that a reliable relationship appeared for the season of birth of Swedish intellectually subnormal children, but that no statistically reliable relationship could be determined for normal Swedish children. Lewinski (1954) did not even find any trend to the variations of I.Q. scores with month of birth. Williams (1964) found that from a sample of 265 children attending special schools in Wales a disproportionately higher number of the students were born during the summer.

Season of Birth and Personality

Huntington (1938) devoted a complete book to the subject of "Season of Birth: Its Relation to Human Abilities". His conclusions were based on an analysis of a tremendous volume of data, which yet has to be matched. His findings may be summarized as follows: people born in January and February, the coldest months, are not likely to be normal, they have a greater chance of becoming geniuses, idiots or lunatics, and, for their occupations they are likely to become criminals, artists or intellectuals; those born in June and July, the warmest months, are least likely to succeed in any field of endeavour; those born in September and August, warm months, have a good chance of becoming good writers, industrialists or technicians, but they too are partial to insanity; people born during the other months of the year, those months that have the optimum thermal conditions, will probably be normal and are therefore not destined to be anything specific.

Other attempts have been made to assess the influence of season of birth upon personality traits. Forlano and Ehrlich (1941) showed that New York City's college freshmen who are born during the summer months have a tendency to be more introverted and to have a greater feeling of inferiotity than students born at other times of the year. A relation between the degree of neuroticism of the "normal" person and season of birth has not been shown to reveal any reliable correlation (Farley, 1968); neither has emotional maladjustment and sociability been shown to be related to season of birth (Davies, 1964). However, it has been shown that in the Netherlands season of birth is related to partner choice in marriage .

Season of Birth and Mental Illness

An excellent review of literature concerning season of birth and mental illness has been given by Barry and Barry (1961). They pointed out that the data produced by six independent investigators (Tramer, 1929;

Lang, 1931; de Sauvage Noltine, 1934; Petersen, 1934; Huntington, 1938; and Pile, 1951) as well as their own data showed that schizophrenics are born significantly more often during the winter-spring trimester (January - April) and significantly less often during the spring-summer trimester (May - August); however, the relationship between manic-depression and season of birth is not so clear. A review of some of the more recent literature has been presented by McNeil, Raff and Cromwell (1971). Most of the more recent studies show the same seasonal relations; however, Barry and Barry's (1964) study of affluent schizophrenics and Dannell's (1973) of schizophrenics did not show the expected seasonal distribution.

The investigators of this subject have been particularly fertile from the point of view of theories. Petersen (1934) argued that environmental stability or instability during gestation, and especially at the time of conception, should affect the potential capacity of the brain. He felt that the reason that schizophrenics tended to be born during spring was that the spring period is dominated by unstable atmospheric environments which overstimulate and fatigue the foetus; on the other hand, manic-depressives are often born during the autumn because that is a season of extreme stability. According to Petersen conditions of atmospheric stability also affected one's life after birth. De Sauvage Nolting (1954) has suggested that the lack of vitamin C during the development of the third and fifth layers of the cerebral cortex could account for the increase in the number of schizophrenics born during the spring months. This lack of vitamin C is a result of the short supply of fresh fruit during that season. Knobloch and Pasamanick (1958) have proposed a somewhat similar foetal theory that accounts for the spring maximum for the birth of schizophrenics. They suggested that in the third month after conception, when the cerebral cortex is being formed, the ambient air temperature is high enough to interfere with the normal protein intake prosesses of the foetus. In a later study (Pasamanick and Knobloch, 1961) they showed that there was a higher incidence of births of schizophrenics after hot summers than there was after cooler summers. Such a finding lends support to their hypothesis. Other pre-natal theories have been put foreward by Hare and Price (1968). They have suggested that it may be possible that parents of schizophrenics, often schizophrenics themselves, may be more likely to conceive in the spring; or that the "increased robustness associated with the schizophrenic genotype may lead to an increased survival of winterborn babies"; or that "some type of intra-uterine loss affecting winter births might also be resited by the schizophrenic genotype, either in the mother or in the foetus."

Hare and Price also suggested some post-natal theories that could account for the seasonal trend in the birth of schizophrenics. "Month of birth often determines whether a child spends his schooldays in a class of children older or younger than himself, and this factor may influence the robustness of the child's future personality." They continue by pointing out that "it is difficult to see how such a process could lead to the facilitation of a schizophrenic rather than a neurotic form of breakdown" - neurotic breakdowns do not seem to be seasonally oriented. One other idea mentioned by them is that it may be possible that for some unknown reason "schizoid maternal behaviour, such as overprotectiveness" may have some relation to winter survival. Pile (1951) showed that in Virginia persons prone to dementia praecox are more likely to be born during the winter. He suggested that the reason for this may be a result of the parents' hostility towards winter born children. Such children are more difficult to feed properly since fresh food is not so readily available and they are generally found, especially in cases where the parents did not want them, to be more of an inconvenience than children born during other seasons. A screaming infant is less appreciated during the winter when the whole family is cooped up than a crying baby is during the other seasons.

Season of Birth versus Season of Conception

If one assumes that there is a relationship between the seasons and one's abilities, then the critical question becomes: is mental aptitude related to season of birth or season of conception? As has been pointed out above this was one of the earliest questions to be put foreward by research workers. McNeil, Raff and Cromwell (1971) feel that they have shown that the time of conception rather than the time of birth is the relevant factor. Their findings however, were based on a relatively small sample size (469 emotionally disturbed children). Attempts, using different data, should be made to check their conclusion. Previously published findings could be of use for such a project.

Conclusion

From this review of literature it becomes apparent that: (1) season of birth and intelligence studies reveal, at best, a tenuous relationship; there are seasonal trends to intelligence noted by a winter minimum but that the difference in the scores are by no means statistically significant; (2) there seems to be a significant relationship between season of birth or season of conception and proneness to mental illness especially schizophrenia and that, in general, it is thought that this relationship has something to do with climatic influences upon the foetus; and (3) it is even possible that one's season of birth may affect one's personality.

Is climatology akin to astrology?

BIBLIOGRAPHY

Allen, F.J., 1922: "Seasonal Incidence of the Births of Eminent People", Nature, Vol. 110, p. 40.

Barry ,H. III and H. Barry, Jr., 1961: "Season of Birth: an Epidemological Study of Psychiatry", Arch. Gen Psychiat., Vol. 5, pp. 292-300.

Barry ,H. III and H. Barry Jr., 1964: "Season of Birth in Schizophrenia: Its Relation to Social Class", Arch. Gen. Psychiat., Vol. 11, pp. 385-391.

Berglund, G.W., 1967: "A Note on Intelligence and Season of Birth", Brit. J. Psychol., Vol. 58, pp. 147-151.

Blonsky, P.P., 1929: "Früh- und Spätjahrkinder", Jahrbuch f. Kinder-Heilkunde, Vol. 124, pp. 115-120.

Dannell, R., 1973: "Schizophrenie, Schwachsinn und Jahreszeit der Geburt", Arch. Psychiat. Nervekr., Vol. 217, pp. 37-41.

Davies, A.D.M., 1964: "Season of Birth, Intelligence and Personality Measures", Brit. J. Psychol., Vol. 55, pp. 475-476.

Fairgrieve, M.M., 1921: "The Annual Incidence of Intelligence and its Measurement by the American Army", Proc. Roy. Soc. Edin., Vol. 41, pp. 150-153.

Farley, F.H., 1968: "Season of Birth, Intelligence and Personality", Brit. J. Psychol., Vol. 59, pp. 281-283.

Forlano, G. and V.Z. Ehrlich, 1941: "Month and Season of Birth in Relation to Intelligence, Introversion-Extraversion, and Inferiority Feelings", J. Educ. Psychol., Vol. 32, pp. 1-12.

Goodenough, F.L., 1941: "Month of Birth as Related to Socio-Economic Status of Parents", J. Genet. Psychol., Vol. 59, pp. 65-76.

Hare, E.H. and J.S. Price, 1968: "Mental Disorders and Season of Birth: Comparison of Psychosis with Neurosis", Brit. J. Psychol., Vol. 115, pp. 533-540.

Huntington, E., 1937: "Season of Birth and Mental Stability", Proc. Amer. Assoc. Ment. Defic., Vol. 42, pp. 116-124.

Huntington, E., 1938: Season of Birth: Its Relation to Human Abilities, John Wiley and Sons, Inc., New York, 473 pp.

Huntington, E., 1945: Mainsprings of Civilization, John Wiley and Sons, Inc., New York, 660 pp.

Knobloch, H. and B. Pasamanick, 1958: "Seasonal Variation in Births of the Mentally Deficient", Amer. J. Pub. Hlth, Vol. 48, pp. 1201-1208.

Lang, T., 1931: "Zur Frage Geisteskrankheit und Geburtesmonat", Arch. Rassen Biologie, Vol. 25 (May 15), p. 42 (reference from Barry and Barry, 1961).

Lawson, R.W., 1922: "Intelligence Statistics", Nature, Vol. 109, p. 716.

Lewinski, R.J., 1954: "Variations in Mental Ability According to Month, Season, and Period of Birth", J. Genet. Psychol., Vol 85, pp. 281-288.

McEwan, P.J.M., 1965: "Climate and Intelligence", Brit. J. Soc. Clin. Psychol., Vol. 4, pp. 8-13.

McNeil, T.F., C.S. Raff and R.L. Cromwell, 1971: "A Technique for Comparing the Relative Importance of Season of Conception and Season of Birth: Application to Emotionally Disturbed Children", Brit. J. Psychiat., Vol 118, pp. 329-335.

Mills, C.A., 1941: "Mental and Physical Development as Influenced by Season of Conception", Human Biology, Vol. 13, pp. 378-389.

Orme, J.E., 1962: "Intelligence and Season of Birth", Brit. J. Med. Psychol., Vol. 35, pp. 233-234.

Orme, J.E., 1963: "Intelligence, Season of Birth, Climatic Temperature", Brit. J. Psychol., Vol. 54, pp. 273-276.

Orme, J.E., 1963: "Season of Birth, Psychosis and Intelligence", Dis. Nerv. Sys., Vol. 24, pp. 489-490.

Orme, J.E., 1963: "An Antenatal Determinant of Intelligence", Nature Vol. 200, p. 1239.

Pasamanick, B. and H. Knobloch, 1958: "Seasonal Variation in Complications of Pregnancy", Obstet. and Gyned., Vol. 12, pp. 110-112.

Pasamanick, B. and H. Knobloch, 1961: "Epidemiologic Studies on the Complications of Pregnancy and Birth Process", in Caplan, G, (ed.), Prevention of Mental Disorders in Children, Basic Books, New York

Petersen, W.F., 1934: The Patient and the Weather, Vol. 3: Mental and Nervous Diseases, Edwards Brothers Inc., Ann Arbor, Michigan, 375 pp.

Pile, W.J., 1951: "A Study of the Correlation between Dementia Praecox and Month of Birth", Virginia Medical Monthly, Vol. 78, pp. 438-440

Pintner, R., 1931: "Intelligence and Month of Birth", J. Appl. Psychol., Vol. 15, pp. 149-154.

Pintner, R. and G. Forlano, 1933: "The Influence of Month of Birth on Intelligence Quotients", J. Educ. Psychol., Vol 24, pp. 561-584.

Pintner, R. and G. Forlano, 1939: "Season of Birth and Intelligence", J. Genet. Psychol, Vol. 54, pp. 353-358.

Pintner, R. and G. Forlano, 1942: "Season of Birth and Intelligence", J. Genet. Psychol., Vol. 61, pp. 81-86.

Sauvage-Nolting, W.J.J. de, 1934: "Het Verband Tusschen Schizophrenie en Aanverwante Ziektebeelden en de Geboortemaand", Ned. T. Geneesk., Vol. 78, pp. 528-530.

Sauvage-Nolting, W.J.J. de, 1954: "Viatmin C and the Schizophrenic Syndrome", Folia Psychiat. Neurol. Neerl., Vol 57, pp. 347,355.

Tramer, M. 1929: "Uber die Biologische Bedeutung des Geburtsmonates, Insbesodere für die Psychoseerkrankung", Schweiz. Arch. f. Neurol. u. Psychiat., Vol. 24, pp. 17-24.

Williams, P., 1964: "Date of Birth, Backwardness and Educational Organization", Brit. J. Educ. Psychol, Vol 34, pp. 247-255.

CLIMATOLOGY IN ENVIRONMENT CANADA - 1975

by

Morley K. Thomas*

Introduction

When an earlier report on Climatology in Environment Canada was published in the Climatological Bulletin of April 1972 (Thomas, 1972), it was already out of date. In the 1972 reorganization the name "Climatology Division" disappeared - there is perhaps irony here - the past two or three years have probably seen greater public interest in climate, climatology and climatic change, than ever before! Assuming that the reader has read or can refer to the earlier report, which deals at some length with the history of climatology in Canada, the present report will simply cover the period from 1972 until early 1975.

Along with the disappearance of the name "Climatology" from the organization chart, several veteran climatologists have retired from government service since early in 1972. Rolly Kendall, climatological publications and statistics expert; Roby Titus, quality control and upper air specialist; Harland Thompson, principal Arctic meteorologist, and Clarence Boughner, who was responsible for climatology in the government service for 25 years, all retired in 1972 and 1973. Their responsibilities have been taken over by younger meteorologists, but the loss of 138 years of experience, when four meteorologists retire within a period of a year or so, is a loss which is not readily overcome.

1975 Organization

Most climatological work in Environment Canada is the responsibility of the Meteorological Applications Branch at AES Headquarters in Toronto. Within the Branch the "core" climatological activities of archiving data, answering enquiries, issuing publications and preparing descriptions of the climate of the country are handled by the Climatological Services Division. The actual work of data handling and processing is now largely done by the Computing Centre Division, while the provision of services in applied meteorology and climatology is the responsibility of the Applications Division. Also in the Branch is a Network Standards Division which is responsible for the quality control of all Canadian data issued in publications and put into the archives, and for national data standards and network planning. Basic climatological research is now the responsibility of the Atmospheric Research Directorate, while the operation of the climatolo-

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gical station network is handled by the Regional offices of the Field Services Directorate. To complete the picture of climatological activities within Environment Canada, mention should also be made of research and study into northern climatology which is being carried out in the Glaciology Division of the DOE Environment Management Service.

In today's Atmospheric Environment Service the emphasis is on service, and this is particularly so in the Meteorological Applications Branch. Within the Branch, a relatively broad definition is taken of applied meteorology. In the preparation and issuing of public weather forecasts, AES is providing a general, broad service in meteorology, but where attention is given to the specific and perhaps unique needs of the user and forecasts are drafted with these in mind, such as in the preparation of aviation weather forecasts, a service in applied meteorology is being provided. This is the operational side of applied meteorology which is practiced at numerous weather offices throughout Canada. There are specialized forecasts in different times of the year - frost warnings for farmers, fire weather indices for foresters, temperature forecasts for oil and gas organizations, wind warnings for contractors, forecasts for small boat operators, etc.

The consultative side of applied meteorology is largely based on climatological data and information, and it is here that the Meteorological Applications Branch attempts to play a significant and developmental role in Canadian meteorology. All applications services are not, however, handled in the Toronto based Branch. In each Region of the Atmospheric Environment Service there is a Scientific Services unit where meteorologists and technicians attempt to meet the Regional needs for consultative applications services. Those programs and requests for services that are requested by other federal government departments, that are national in scale, or that are too complex for handling in a Region, are referred to the Meteorological Applications Branch in Toronto. Thus in the provision of services in applied meteorology the Branch attempts to play a dual role of developing, promoting and assisting in guiding activities throughout the country, while at the same time undertaking directly many projects and programs.

Climatological Services Division

Twenty-five years ago this unit was responsible for all climatological work done at the Headquarters of the national meteorological service. As networks were expanded and more services provided to the public, new units were created to become responsible for the new programs. Currently this Division is responsible for all historical and statistical climatic data publications, for reports on the various climates of the country, for maintaining abstracts and summaries of all national climatic data; for provision of an enquiry service to handle those enquiries that are national in scope or too large and complex for handling by Regional weather offices, and for coordinating climatological services throughout the country. A major program is underway to convert all abstracts to microfiche, while the complete revamping of publishing and archiving policies has just commenced.

Computing Centre Division

A new IBM 370 computer, acquired in the spring of 1974, and planned additions to the programming and systems staff in 1975, will provide a better service than it has previously been possible to offer. Over the past few years both the quantity of data being brought into the system and the demand for services have increased at a much faster rate than have resources of staff and equipment. Although the Centre does non-meteorological work for AES units, more than 80% of its resources are still being spent in regular processing, publishing, archiving and project work for the Branch. Major attempts are currently underway to capture all hourly data from the operational networks and to utilize processing done by the Quebec Meteorological Service. This will free resources to process more supplemental data and to better service clients. The government's "user pay" policy frequently causes some concern to students and professors when they learn the cost of acquiring data or of ordering a computer project. It is readily acknowledged that this is a difficult situation, but current policy is to allow the tax payer's dollar to pay for the routine collection and archiving of data, but all clients must pay for any special processing, computing or duplicating services carried out solely for their benefit.

Hydrometeorology and Marine Applications Division

In recent years this Division has provided Canadian meteorological leadership in the International Hydrologic Decade and the International Field Year on the Great Lakes. As these research programs draw to a close, the Division is becoming increasingly involved in applications studies and in the direct provision of services. The historical storm rainfall series has been completed and short duration rainfall analyses have been updated and recomputed. Developmental work has included Fischer and Porter automatic rain gauge network operation and the radar archiving of precipitation intensity data. Developmental work is underway on a Beaufort Sea project, planning for west coast tanker routes, facilities for Olympic sailing in Lake Ontario, and on lake and ocean weather reporting buoy systems. New work planned for 1975 includes an experimental basin project on the Saint John River in New Brunswick, and some large resource studies in western Canada.

Applications and Consultation Division

In the past two or three years there has been considerable development in the use of meteorology and climatology in the field of tourism and outdoor recreation. A series of publications, ten or more, will be issued dealing with conditions in the different regions of Canada, and specifically for a number of national parks. Requests for information and advice on the meteorology and climatology of Canada's North, particularly in support of oil exploration, pipe line planning and operations and the location of new airstrips and harbours, continue to almost overwhelm the Arctic Section. The Industrial Section is also busy with requests for information regarding the siting of plants, the orientation of airports, etc., while considerable work has been done on the problem of icing on structures and transmission lines. An Agriculture and Forestry Meteorology handbook is under preparation in the Agroforestry Section where special attention is being given to the implications of climatic fluctuations on growing things. The current popular interest in climatic change has led to more extensive analyses of past fluctuations and the development of methods for testing the homogeneity of historical data series.

Network Standards Division

In addition to responsibility for the quality control or validation of all current climatic data, this Division coordinates the preparation of all AES observing manuals, deals with standard instrumentation and observing procedures, provides guidance, on a national AES basis, in the coordination of requirements for observational data, the planning of new networks, etc. The Division also looks after all station documentation and cataloguing work - from its records ready information can be obtained regarding present and past stations, their observing programs, and all observation forms ever received during their periods of operation.

Regional Activities

By the late 1960s there were Regional climatological services offices across the country from which enquirers could obtain data and information - current, historical and statistical. Since that time, Scientific Services units have also been installed in each Region and are all staffed by meteorologists and technicians. The Scientific Services offices are responsible for meteorological applications work on the local, provincial and regional levels. The Headquarters' Meteorological Applications Branch has responsibility for assisting the staff of these offices in every way possible. Guidance is provided in the way of bibliographies, manuals, guides, reading lists and direct consultation, as well as in the provision of Seminars in applied meteorology. Early in 1975 such seminars are being given for 20 meteorologists in February, and for a like number of technicians in April.

Other Activities

Climatological research and development activities are carried out in two Branches of Headquarters' Atmospheric Research Directorate - the Air Quality and Inter-Environmental Research Branch and the Atmospheric Processes Research Branch. Responsibilities for research in hydrometeorology and air quality reside in the former, while general circulation and climatic change research is being tackled by several meteorologists in the latter.

A Challenge

For a long time we considered Canada to be a sparsely populated country with unlimited natural resources. By 1975, the world population explosion, the threat of climatic change, the rapid depletion of our natural resources, the deterioration of our atmospheric environment, and the possibility of an impending food shortage in the world, must tell us that we have to begin using our weather and climate more intelligently than we have in former times. It is here that the utilization of applied meteorology and climatology can benefit Canada and Canadians much more than any of us can readily realize today. By the intelligent use of our climatic resources, by developing better predictive systems to warn of tomorrow's weather and next year's climatic anomalies, by better and more knowledge of the implications of climate on our economic and social activities, and by investment in the support of these activities, both in government and in private business, we can plan for, and hopefully have, a better Canada in the future.

METEOROLOGICAL APPLICATIONS BRANCH

MARCH 1975

Director: Morley K. Thomas

Staff		Division Chiefs	
Meteorologists	31	Applications & Consultation	-G.A. McKay
Technicians	34	Climatological Services	-G.E. Bristow
Geographers	4	Computing Centre	-B.S.V. Cudbird
Data Processors & Programmers	43	Hydrometeorology & Marine Applications	-T.L. Richards
Clerical & Stenographic	33	Network Standards	-J.G. Potter
	145		

Reference:

Thomas, Morley K., 1972: "Climatology in Environment Canada - 1972", Climatological Bulletin (McGill University), No. 11 (April), pp. 1 - 14.

NEWS AND COMMENTS

A conspiracy was perpetrated on the Friends of Climatology concerning their meeting at the University of Toronto-Scarborough on April 4-5. It was the now famous or infamous snow storm of those dates that snarled activities over a quarter of the United States and Canada. Because of the weather, fewer people attended than were expected; however the storm did not deter the lively discussion which occurred.

After dinner on Friday evening (April 4), the group retired to the Faculty Club lounge where Dr. Bennett Lewis talked on "Nuclear Power and the Future of World Climates". Saturday morning the meeting convened at 9:15 A.M., at which time discussion centered around climatic change. The first speaker, Professor J. Terasmae, reviewed indicators of climatic change and world-wide glacial chronology. Professor Roger Barry continued with a talk entitled "Past and Future Ice Ages", which focussed on the fascinating research effort in climatic modelling conducted at the University of Colorado. Morley Thomas, Gordon McKay and Barney Bolville reviewed the efforts of the Atmospheric Environment Service concerning climatic variation, food supply and the numerical studies concerning the stratosphere's ozone layer. During this morning session, the group heard a report from the "Orbiting Climatologist", Professor Marie Sanderson, on her activities visiting various universities in Ontario and Quebec (see below).

The meeting was adjourned at approximately 12:45 P.M. with the strong feeling that not enough time was available for further discussion. The next Friends meeting will be held at Guelph University during the first part of September 1976.

At the meeting of Friends of Climatology Marie Sanderson reported on her activities as "Climatologist in Orbit". Her report is given in full here because of its general interest and entertainment value.

"I think that I was asked to be the climatologist-in-orbit this year because it is International Women's Year, and that I should probably take the advice that Ken Hare gave to a Women's Lib type in an audience he was addressing, "Pray to God and maybe She will help you."

I will begin my report with some statistics. I travelled to 14 campuses in Ontario and Quebec, 4000 miles by plane, 1500 miles by car, 200 miles by train, 200 miles by bus and a few hundred yards on foot. I was an invited guest at 10 dinners, 14 lunches, drank 40 cups of coffee, 30 beers, 20 assorted alcoholic beverages, stayed in 14 of the best hotels from Waterloo to Montreal, and gained 10 pounds. I spoke to some 600 people in first year geography, 2nd year bioclimatology, 3rd year environmental science, 4th year microclimatology and graduate physics classes. On 70% of the days it rained, 5% it snowed, 5% it was foggy and 20% of the time the sun shone.

I was royally entertained at each place I visited, was given a tour of the department, invited to the Faculty Club, visited with old friends and met many new ones. I did my own private survey of faculty clubs, and why females don't ask questions after the lecture, and am now prepared to lecture on these topics. The topic I had chosen to lecture on was "Urban Climatology in the Windsor-Detroit area" - a progress report on my ongoing research at the University of Windsor.

My orbit started in December when Morley Thomas asked me to speak to the Meteorological Applications Branch Seminar in the Downsview headquarters of the AES - to perhaps 100 people - in the beautiful auditorium there. The thing I remember most about that is the introduction I was given by David Phillips, who certainly knows too much about my past.

After Christmas, my orbiting velocity increased. My first stop was the University of Waterloo, where I met Jim Gardner's class of graduate and undergraduate geographers and planners. I had lunch at the Faculty Club with other members of the Department, and a tour of the Department. Later in January, I travelled to Montreal where I spoke at Concordia and McGill. Don Fraser was my gracious host at Concordia and I especially enjoyed the audience of biologists and engineers in addition to Don's class of hydrologists and geographers. I won't mention the fact that most of the engineers left when they found out I was the wrong visiting speaker. But Don won that battle - we stayed and they left! I also enjoyed very much the party he and Erika had at their house that evening. At McGill, it was great to meet old friends - Ben Garnier, Rick Wilson and John Lewis, and I spoke there to a very select group of senior undergraduate and graduate students. Again, a tour of the Department with Ben Garnier and lunch at the Faculty Club.

February was the busiest time of the orbit with visits to 5 campuses, carefully planned around the University of Windsor mid-winter break. The first stop was the University of Guelph, where royal treatment was received from Neil Trivett, of the Geography Department, and Terry Gillespie and Ken King at L.R.S. The large audience I spoke to there was made up of first year geography students as well as 3rd year L.R.S. students, and I won't mention the fact that Ken King almost forgot to pick me up for the 9 A.M. lecture. The next stop was McMaster in Hamilton. After a 6 A.M. arising and a Nordair flight from Windsor, Wayne Rouse gave me a tour of the city and of the Department. I especially enjoyed my lecture at McMaster to 3rd and 4th year as well as graduate students of Wayne Rouse, John Davies and Frank Hannell. There were also many ex-Windsor students present, since we send all the students we want to get rid of to McMaster. I think we scored some sort of achievement there too. Talking to Lloyd Reeds, we made him forget the time and he missed a class - the first in his 30 years of teaching!

The next stop was Toronto where I stayed 3 days, and I visited for the first time the campuses at Erindale and Scarborough. At Erindale I spoke to 2nd and 3rd year climatology students. There was a record-breaking rain storm that day at Erindale but Scott Munro and Peter Duckworth made it a most pleasant day for me. The next day I took the bus ride to the Scarborough campus where Chris Sparrow met me and I spoke to his 2nd year climatology students. The third day there was the thrill of lecturing, for the first time, at my old alma mater, the main campus of the University of Toronto. I enjoyed speaking to Geza Szceicz's 3rd year bioclimatology class at 9 o'clock that morning, lunch at the faculty club, and then Ken Hare's graduate physics class that afternoon. The thought of the physics lecture terrified me, but I think I enjoyed that class, and got more helpful comments from them, than any of my audiences.

March saw me on the last lap of the orbit with visits to 4 campuses. First was Sir Wilfred Laurier, my first visit there and Gerry Hall my host. My audience this time was 3rd and 4th year general and honours geography students. The next week, I was off to Queen's and Carleton, by plane, bus, train and car. First to Queen's, where Harry McCaughey arranged the lecture - to undergraduate and graduate students, and some faculty. I remember that during the question period it became quite hilarious and Dick Ruggles, in thanking me, called me a geographer of the pre-Cambrian era. In Ottawa, Mike Smith and a graduate student called for me and during the drive to Carleton we discovered that we were all Mackenzie River delta rats, so there was no lack of conversation after that! The lecture was given to Mike's 3rd year climatology class - with some graduates. After, there was some interesting talk with the students, lunch at the Faculty Club, and rushing to the airport - the pattern seemed to be repeating itself. That flight was something special too - the roughest flight I've had for several years.

The last stop in the orbit, but not the least enjoyable - was to Brock University in St. Catharines. It was a long drive from Windsor - raining again - and so foggy that I had trouble finding the University. But the Department of Geography's new quarters there are so bright and cheerful - as was my host, Tommy Thompson - and the students, regular and extension students of Dr. Thompson, were so enthusiastic even at 7:30 at night, that it was a pleasant experience. I won't mention the equally pleasant hours spend in the bar with several menbers of the Brock faculty!

In conclusion and seriously, I think the orbiting climatologist idea is a good one. For the students it does, I hope, give them a different viewpoint of climatology, let them know of research being done in another area, and of the problems involved. As for the orbiter, it is a great experience to see different departments, hear what is going on in climatology, meet new students from various disciplines, and hear their comments about one's research. I do thank you for asking me to be the climatologist-in-orbit this year!"

Rick Wilson is leaving his position as Assistant Professor in Climatology at McGill University at the end of May, 1975. He will be taking up an appointment on June 1 as Head of the Climatology Inventory Group, Data Services Division with the Government of British Columbia. His headquarters will be in Victoria, British Columbia.

John E. Lewis, currently of the University of Maryland, has been Visiting Professor in Climatology at McGill University since last January. He has now accepted an offer of appointment as Assistant Professor of Climatology at McGill University and will take up his duties on June 1.

During the first week in February Derek Winstanley visited the Department of Geography at McGill University to give a series of seminars on Climate and Man. His primary concern was with Climatic Change and World Food Production and the climatic aspects and social consequences of the Sahel drought. His visit created considerable interest and his presentation drew large audiences and provoked stimulating discussion.

David Yap has recently accepted an appointment as Senior Meteorologist, Head Meteorology Systems, for the Ontario Ministry of the Environment.

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