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A PRELIMINARY RADIATION CLIMATOLOGY OF WINDSOR, ONTARIO

by

Marie Sanderson*

Introduction

The measurement of various solar and atmospheric radiation fluxes has only recently been added to the program of most national weather offices. In Canada, the Monthly Radiation Summary currently contains data from 46 localities. The most commonly measured flux is that of incoming solar (global solar) short wave radiation. Data on net all wave radiation is published for 20 stations. In Ontario, incoming solar and net radiation are measured simultaneously at only 4 locations: Moosonee, Ottawa, Guelph, and Toronto (Scarborough). None of these locations could be considered representative of an industrial urban environment. Humans are increasingly urban dwellers, and thus it becomes increasingly important to understand the ways in which man has modified the microclimate by the physical fact of the city itself. Probably the major changes caused by the city are the changes in the energy balance. Although our present understanding of the urban energy balance is meager (Peterson, 1970), it is generally accepted that pollutants in the urban atmosphere decrease the incoming solar radiation received at the earth's surface. It is believed that such decreases on a global scale could result in world wide temperature decreases (Davitaya, 1969).

Short term measurements have been made of various aspects of the urban energy fluxes (Terjung, 1970; Oke and Fuggle, 1971; Rouse, Noad, and McCutcheon, 1973) and various models of the urban energy balance have been advanced (Myrup, 1969; Outcalt, 1972). However, many climatologists believe that the ability to model the urban energy balance has

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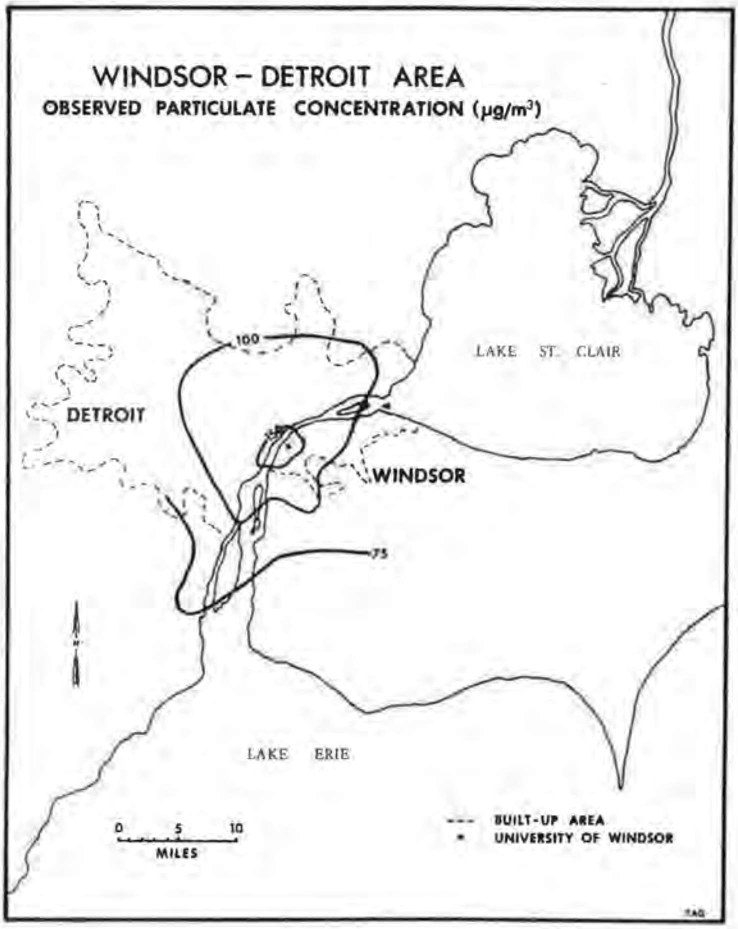

Fig. 1. Particulate concentration in the Windsor-Detroit area.

outstripped the physical data base. Only by continuous measurement of the various radiation fluxes can the effect of man's modification of the urban atmosphere be ascertained, and ground truth for various urban energy balance models be provided. Windsor, Ontario, offers an excellent location for measuring the radiation components in an industrial urban environment, situated as it is adjacent to Detroit's large industrial complex, (Fig. 1). Particulate matter in the atmosphere is known to be especially high in the western part of the city (International Joint Commission, 1972).

The present report presents data on incoming solar and net radiation taken during the three years 1971-1973 at the University of Windsor and a preliminary analysis of some relationships between the two radiation parameters.

The following symbols and equation will be used:

$$R_n = R_s - R_s\ (\alpha)\ + R_L\downarrow - R_L\uparrow$$

where R_n is net all wave radiation, R_s incoming short wave radiation, α the reflection coefficient of the surface (grass), $R_L\downarrow$ long wave radiation downward (atmospheric radiation), and $R_L\uparrow$ long wave radiation upward (terrestrial radiation).

Equipment

An Eppley black and white pyranometer (1969 model), transparent to wavelengths .28 to 2.80μ m was installed on the roof of Essex College, on the University of Windsor campus, in the fall of 1970. It was calibrated by the Atmospheric Environment Service radiation laboratory before installation and again in July, 1972. A Leeds and Northrup strip chart recorder produced a continuous trace of incoming solar radiation, and an integrator and digital indicator provided daily radiation totals. The daily charts were reduced manually to give hourly values of incoming solar radiation until June, 1973 when a Sodeco printing counter was installed, and printed hourly millivolt totals were thus provided. The hemisphere of the pyranometer was cleaned daily, a procedure especially necessary in an area of high air pollution.

Net radiation equipment was installed at the University of Windsor weather station, 600 yards to the south-east of the Eppley radiometer location, in the summer of 1971. The instrument was a C.W. Thornthwaite Associates miniature net radiometer (Model 602). The two hemispherical radiation windows of clear plastic have good transmission characteristics for both short and long wave radiation. The instrument was mounted 3 feet above a permanent grass sod which was kept at lawn height and not irrigated. A portable microvolt recorder with strip chart was operated by a 12 volt DC battery in a nearby small laboratory building. The manufacturer's calibration was accepted. The net radiometer began operation in October, 1971, and the daily charts were reduced manually to give hourly totals of net radiation. Because of injury to the radiometer a new instrument was installed in October, 1972. The system was recalibrated by the manufacturer in August, 1973.

Incoming Solar Radiation

The average daily short wave radiation (R_s) received monthly on a horizontal surface at Windsor for the 3 years of observation is shown

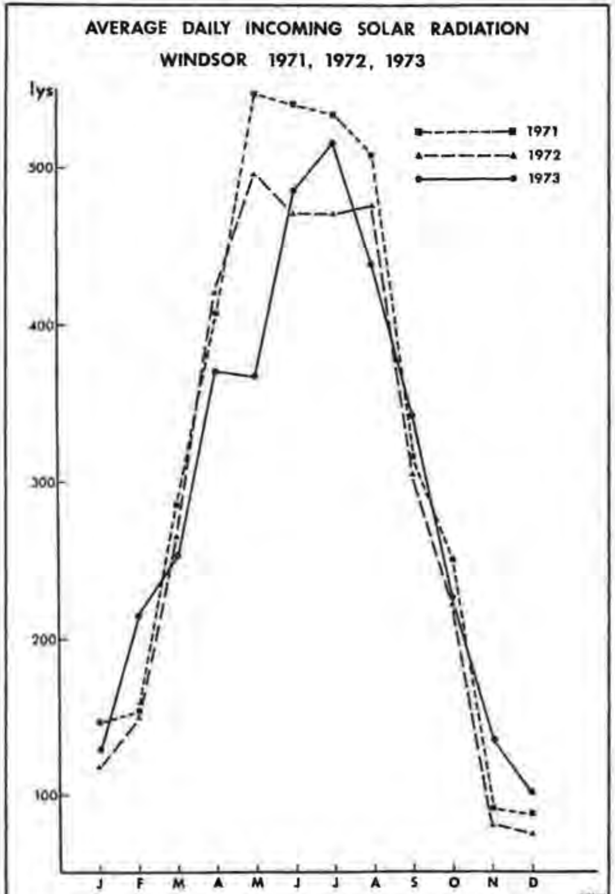

Fig. 2. Average daily short wave radiation at Windsor, 1971-1973.

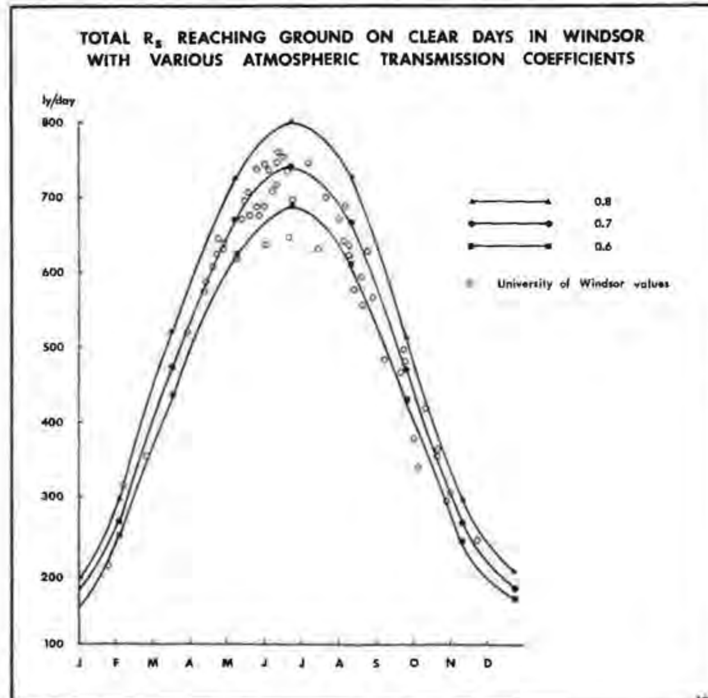

Fig. 3. Daily solar radiation reaching the ground at Windsor under different transmission coefficients.

TABLE ONE

Average Daily Incoming Short Wave Radiation in Windsor

1971-1973 (in langleys)

Month	1971	1972	1973
Jan.	148 (1)	117	129
Feb.	152	201	214
Mar.	284	264	252
Apr.	415	420	369
May	545	495	367
June	540	470	476
July	533	470	515
Aug.	507	— (3)	437
Sept.	317	306	342
Oct.	250	222	225
Nov.	91 (2)	81	134
Dec.	88	74	101
Year	117,900	—	108,500

(1) 15 day average

(2) 12 day average

(3) No record - instrument being re-calibrated

in Table One and Figure 2.

The amount of solar radiation reaching the ground at any locality provides information on the transmissivity of the atmosphere above that location. Atmospheric transmissivity on a clear day depends on the water vapour and the aerosol content of the atmosphere above the measuring instrument. In the present study, a preliminary examination of the transmissivity on 56 cloudless days was made. The Smithsonian tables were used to compute the total radiation (direct plus diffuse) which reached the ground at the Windsor latitude with various atmospheric transmission coefficients. Figure 3 shows these values throughout the year in Windsor, for transmission coefficients of 0.6, 0.7 and 0.8. The measured daily totals of incoming solar radiation for the 56 cloudless days have been added to the graph. None of the days had an atmospheric transmissivity of >0.8; 45% had values between 0.7 and 0.8, 38% between 0.6 and 0.7 and 17% of the clear days had an atmospheric transmissivity of <0.6, giving an average transmissivity of 0.65. This value is similar to that obtained by

Nishizaiva and Yamashita for the highly polluted atmosphere in Tokyo (Nishizaiva and Yamashita, 1967). A previous study of transmissivity values in the Windsor area during clear, dry winter days indicated that atmospheric pollutants caused a decrease of 10% in incoming solar radiation in the western area of the city by comparison with that in the rural areas (Sanderson, et.al.,1973). This reduction on clear days could be due to reflection or absorption of the short wave radiation by pollutants in the atmosphere. Rouse, Noad and McCutcheon (1973) reasoned that in the polluted Hamilton environment, absorption, with subsequent re-radiation were the dominant processes since the decrease in incoming short wave radiation received at the ground was exactly offset by an increase in incoming long wave radiation. This was not found to be the case in Windsor, as will be shown in the following section.

Relationship between Incoming Short and Net Radiation

Net radiation is the total energy available at the ground surface, the balance between incoming and outgoing solar and long wave radiation.

$$R_n = R_s - R_s\ (\alpha) + R_L\ (\text{net})$$

where R_n is the net all wave radiation, R_s is the incoming short wave radiation, α is the albedo of the surface and R_L (net) is the net long wave radiation.

Because of the scarcity of world data on net radiation, many attempts have been made to obtain a relationship between net radiation and incoming solar radiation, so that R_n can be estimated from R_s (Polavarapu, 1970; Selirio, Brown and King, 1971; Davies, 1967). These studies all pertain to the rural environment. The data presented here will provide some information on this relationship in an industrial urban environment.

Using monthly data from rural sites and fitting a regression line of R_n on R_s, Davies obtained for the growing season for pooled data from various parts of the world:

$$Rn = 0.617\ R_s - 24\ (\text{ly/day})$$

Polavarapu found that the following regression lines fitted the 1964-66 data from Guelph and Toronto for clear days for May to October:

$$R_n = 0.59\ R_s - 13.5\ (\text{ly/day})\quad (\text{Guelph})$$

$$R_n = 0.57\ R_s - 14.6\ (\text{ly/day})\quad (\text{Toronto})$$

Figure 4 shows the relationship between R_n and R_s for more than 200 days

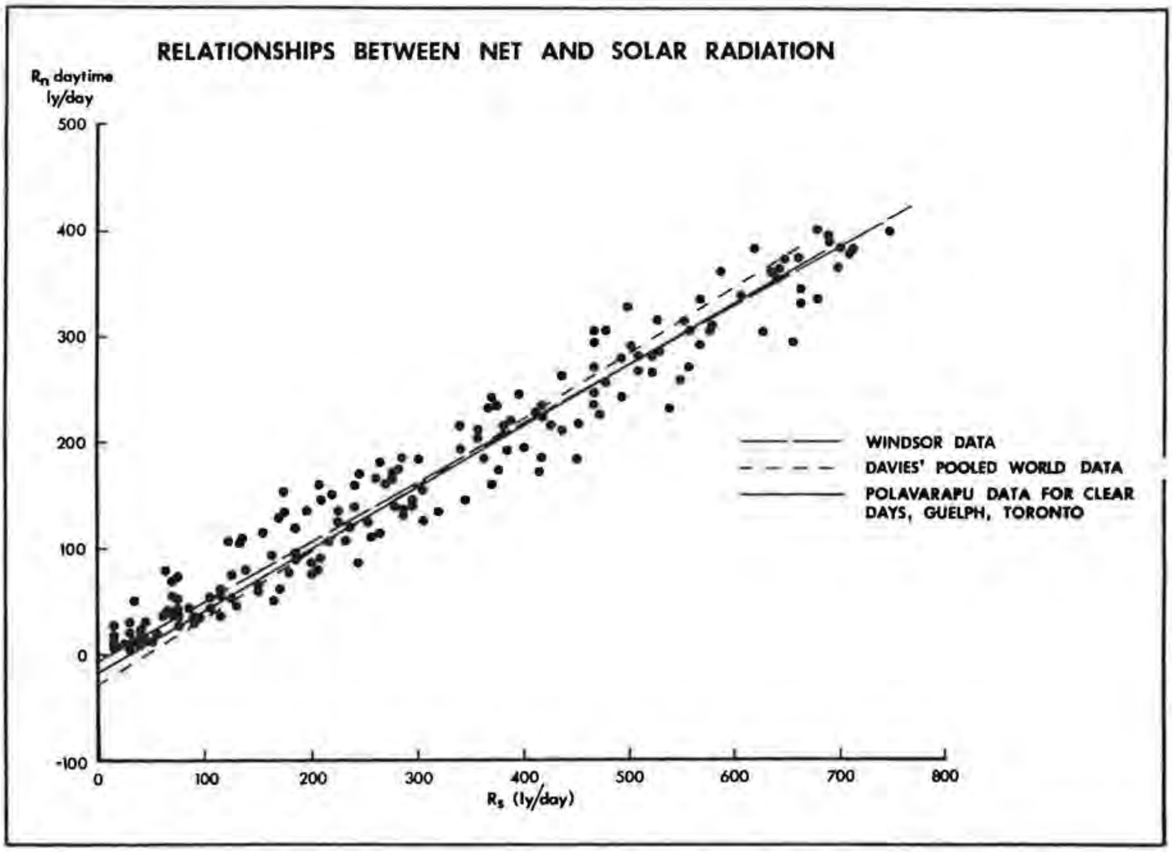

Fig. 4. Some relationships between net and solar radiation.

of data in Winsor. The equation for the regression line fitted to the data is:

$$R_n = 0.56\ R_s - 2.3\ (\text{ly/day})$$

The correlation coefficient r is 0.98 and the standard error of estimate, 24.33 langleys. The regression line for pooled world data obtained by Davies, and the Polavarapu line for clear days in Guelph and Toronto have been added to the graph. Although the Guelph and Toronto instruments are exposed in a rural setting, and the Windsor instruments in a polluted urban environment, the regression lines are similar for the three sets of data. There appears to be little difference in the relationship of R_n to R_s in an urban and a rural environment.

In their Hamilton study, using data from 11 clear days, Rouse, Noad and McCutcheon (1973) found that the polluted urban atmosphere

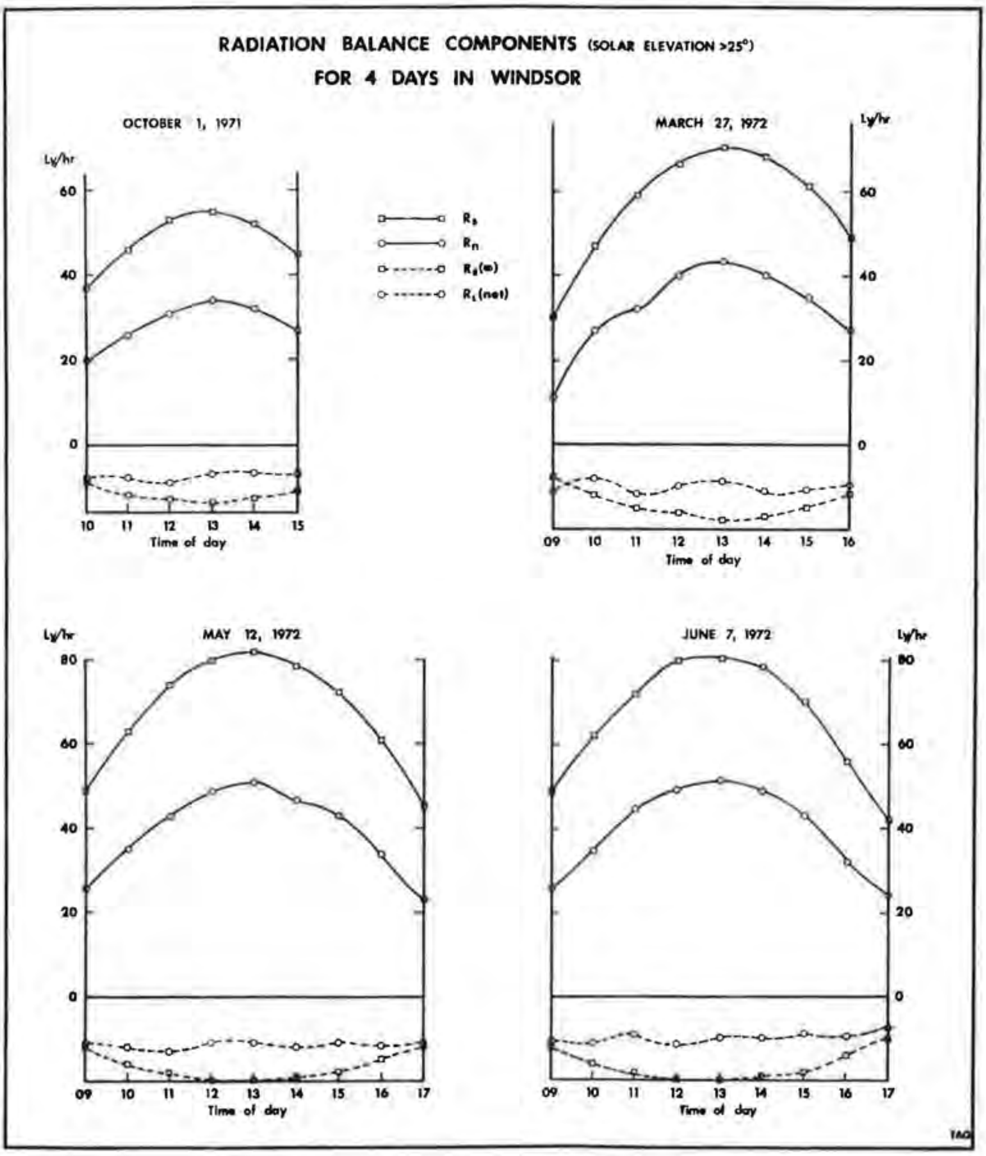

Fig. 5. The radiation balance components for four days at Windsor.

caused a decrease of 12% in incoming solar radiation received at the surface of the urban area and that this decrease was exactly offset by an increase in incoming long wave radiation. They hypothesized that incoming short wave radiation was absorbed by the pollutants in the urban atmosphere thus raising the temperature and increasing downward long wave radiation. The relationship found between incoming solar and net radiation in the polluted urban atmosphere in Windsor does not substantiate this hypothesis. If the 10-12% of the incoming solar radiation which is lost to the surface, and not measured by the pyranometer as short wave radiation, did indeed appear at the surface in the form of long wave incoming radiation, it would be measured by the net radiometer. Thus, for a given R_s value in Figure 4, the corresponding R_n value would be higher than observed, and the regression line would parallel the Polavarapu and Davies' lines, but lie above them. An alternate hypothesis is suggested by the Windsor data. It would appear that the reduction in incoming solar radiation at the earth's surface represents a real loss of energy income because of the increased albedo of the polluted urban atmosphere.

Net Long Wave Radiation

The measurement of incoming short wave and net all wave radiation above a grass site provides a good deal of information about the urban long wave radiation balance for clear days in the absence of actual measurements of long wave fluxes. This is possible since the reflection coefficient of the grass is known to be a conservative element at solar angles greater than 20°, varying only from .23 to .27° (Monteith and Szeicz, 1961; Davies and Buttimor, 1969). Also it is known that the temperature of the soil surface which controls $R_L\uparrow$ behaves in a predictable way on clear days, increasing until solar noon and then decreasing (Chang, 1968).

To obtain some information on the long wave radiation fluxes, and especially on the controversial long wave radiation downward, radiation balances were computed for 20 clear days when R_s and R_n measurements were complete. Hourly totals of the radiation fluxes were used and only those hours considered when the solar elevation was above 25°. A mean reflection coefficient of .25 was used to estimate R_s (α). The hourly values of R_s, R_n and R_L(net) are shown for four selected days in Figure 5. For Windsor, the net long wave balance is a very conservative parameter averaging

-12 ly/hour and not varying from season to season nor diurnally. Monteith and Szeicz (1961) found that net long wave radiation above agricultural crops at Rothamsted reached its maximum at mid-day and stated that the probable reason was the relatively constant incoming long wave radiation during the day and the increase in outgoing long wave radiation at mid-day due to increased surface temperatures.

The long wave radiation balances for the 20 clear days in Windsor show no such diurnal pattern. Net long wave radiation seems to be remarkably uniform during the hours when the sun's elevation was above 25°. Since $R_L\uparrow$ over grass, being directly related to surface temperature, follows a curve which peaks at mid-day; then $R_L\downarrow$ must also follow a curve which peaks at mid-day, since R_L (net) remains uniform.

This conclusion agrees with one of the observations made by Rouse, Noad and McCutcheon (1973) in Hamilton, that atmospheric radiation reached a maximum at solar noon. This could be due to the absorption and re-radiation of terrestrial radiation by particulates in the atmosphere.

Conclusions

A beginning has been made in the continuous measurement of solar and net radiation in an industrial urban environment. Only in this way can models of the effect of the urban environment on various radiation parameters be evaluated, and the degree to which cities affect the macro-climate be assessed. Data from the first three years of measurement show that the relationship between net radiation and solar radiation is similar to that in rural areas, indicating that the surface reduction in solar radiation in a city represents a real loss of energy, which is not made up by increased incoming long wave radiation. A diurnal variation in incoming long wave radiation is observed in the urban environment, unlike that in rural areas, with a maximum occurring at every season of the year at solar noon. It is hypothesized that this increase is due to absorbed and re-radiated long wave radiation.

ACKNOWLEDGEMENT

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PLANT SHAPE AND THE ESTIMATION OF STANDING CROP

by

P. G. Holland*

The above ground tissues of a perennial plant are not distributed at random but are located and presented in a fashion determined by its genetic make-up and environment. A tree's leaves, for example, tend to be restricted to a surface, the complex topography and density of which forms the perimeter of the crown. With practice, one may identify many tree species on the basis of their profiles, therefore it should be possible to predict where in the crown a tree's branches, buds, fruits, and leaves will be situated.

Although a formal statement of the growth behaviour of an entire tree has yet to be published, the lines of study are well documented (Horn, 1971 and Wilson, 1970). A plant's shape is the three dimensional arrangement of its peripheral points. Plant structure is, then, the packing of tissues into the volume defined by the envelope of those points. In most plants, the peripheral points are buds, the growth of which varies with their position in the crown. Thus, plants with buds able to grow at comparable rates usually assume a spherical form, but plants with strong apical dominance appear elongated. Many plants go through a sequence of shapes as they age. Oak trees pass from a somewhat conical form in their sapling stage to an almost flat-topped form at maturity. Competition for light, however, can force trees to retain the elongated growth habit long after other individuals of the same age and species have taken the shallow curved profile of their early maturity.

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Climatological study of the water balance of a forested area depends upon access to a range of plant morphological information: the presentation and arrangement of leaves, the degree of branching in the crown, and the three dimensional arrangements of twigs, branches and trunks. If the emphasis is on the energetics of forested stands then details will be required of the forms and locations of leaves, as well as of their transmissivity. Clearly, what is needed is a series of equations to describe the dynamic geometry of plants. Allometric equations of the form:

$$y = ax^b$$

where a and b are constants, are known to describe many aspects of plant structure: for example, both numbers of branches and numbers of leaves in relation to the age of citrus trees (Wilson, 1970), and the numbers of branches in the different branching orders of three species of *Eucalyptus* (Holland, 1969). The growth behaviour of buds, relative to their locations in the crown, can also be described mathematically. Wilson (1970) outlines a linear programming technique whereby these, and other relationships, can be combined to give an account of the adaptive geometry of a tree. Wilson and Petzold (1973), in their study of the flux of solar radiation to a melting snow pack in an area of spruce-dominated woodland, make use of an attractively simple description of plant shape and structure.

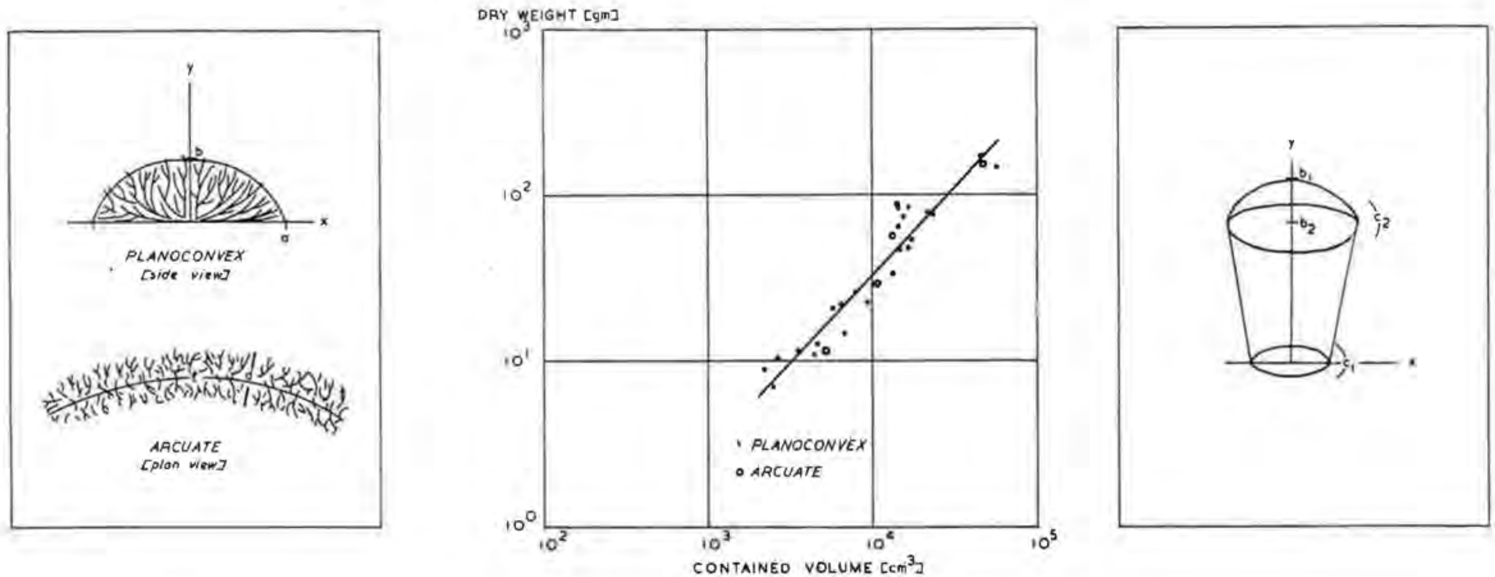
While many of the plant morphological parameters of interest to climatologists reflect age in plants growing in optimum conditions, the relationship is made an imperfect one by the vagaries of environment. In the hardwood forests of southern Quebec one can find low saplings and tall trees of about the same age and, outside areas of mesothermal climate, it is not always possible to date woody plants on the basis of either growth rings or nodes. Experience in the mallee vegetation suggests that the contained volume of a plant is more easily measured and useful, as an independent variable, than is age. It is also an excellent starting point for a number of interesting research problems. For example, do trees take the most efficient shape for their moisture and radiation environment? A good test for this hypothesis would be to consider the shapes of tree species of a wide-ranging genus such as *Acacia*. One might expect a strong tendency towards flat topped plants in the tropics and steeply convex profiles in middle and high latitudes. Jahnke and Lawrence (1965) present a stimulating account of this question by reference to cone shaped trees, of which only the height may change, at different latitudes.

In this paper, a method for estimating standing crop, based on the description of plant shape, is described and reference is made to the estimation of another parameter of interest to climatologists.

Standing crop (the average weight of plant tissues per unit of surface area, gm m^{-2}) is a difficult parameter to estimate under field conditions. Most of the published methods (e.g. Baskerville, 1965; Ovington, 1956 and Ovington et al., 1963) involve clipping live tissues from a known density of sample quadrats and drying them to constant weight at 100°C. These so-called harvest methods work well for physiognomically simple plant communities with few species, such as agricultural crops and range grasslands, but require modification before being applied to areas of woody vegetation. Many alpine and semi-arid shrub communities, for example, comprise several species distributed irregularly over the area. To achieve a useful estimate of standing crop with the harvest method could involve clearing, drying and weighing all plant tissues from at least 30 large quadrats. This is unacceptable on the grounds of the work involved and the destruction of large tracts of vegetation.

The method described here was developed for perennial plant species in the semi-arid mallee vegetation of southern Australia and, in particular, for long-lived compact shrubs and tussocks whose ages could not be estimated with the conventional morphological routines. First, a random sample of between 15 and 30 individuals of each species was drawn. After the appropriate volume determining measurements were made, the plants were cut off at ground level and individually bagged. Later, all "dead" tissues were removed and the plants were washed and dried to constant weight at 100°C. These are the only destructive steps in the routine. Correlation and regression coefficients for the allometric equations relating contained volume and dry weight for each species were computed. A second, and larger, random non-destructive sample of plants was drawn and, in the field, the appropriate measurements for contained volume determination were made. The dry weight of each plant was then estimated from the appropriate regression equation.

A widespread and common plant in the mallee vegetation is the perennial grass, Triodia irritans, which has a distinctive growth habit (Fig. 1a). In places with fertile soil it forms large tussocks (planoconvex shape), the diameters of which frequently exceed 1.5 meters. Elsewhere,



(a) (b) (c)

Fig. 1: (a) growth habits of Triodia irritans; (b) correlation of dry weight (W gm) and contained volume (V cm^3) for tussocks of T. irritans ($r_{W.V} = 0.96$); (c) measurements required for estimation of the contained volume of compact shrubby plants.

and particularly on the thin red soils of central New South Wales, the plant shows a sequence of growth stages. The planoconvex tussocks grow to a maximum diameter of about 0.5 m before dying back in the center, leaving an annulus of live shoots. Those culms in contact with the soil set down adventitious roots and continue to grow out along the radii of the tussock. In this fashion, the diameter of the annulus increases to about two meters before severing into discrete arcuate segments which later condense into planoconvex tussocks and repeat the process.

The contained volume of a clump is calculated as follows (Fig. 1b):

<u>let</u> a be the radius of a circle with circumference the same length as the perimeter of the plant,

b be the maximum height of the plant,

c be the length of the plant's perimeter,

d be the mean width of the arc,

e be the curving length of the arc;

<u>assume</u> any centrally located vertical profile of the plant can be given by an equation of the form:

$$y = -Kx^2 + L \qquad (1)$$

$$x^2 = \frac{(b-y)a^2}{b} \quad ;$$

<u>then</u> the contained volume of a planoconvex tussock is given by:

$$V = \pi \int_0^b x^2 dy \qquad (2)$$

$$= \frac{\pi a^2 b}{2}$$

$$= \frac{c^2 b}{8\pi} \qquad (3)$$

<u>and</u> the contained volume of an arcuate segment can be estimated by treating it as an assembly of curved ends and a central prism:

$$V = 2(e-d) \int_0^{d/2} y dx + \pi \int_0^b x^2 dy \qquad (4)$$

$$= \frac{bd}{24} \{16(e-d) + 3\pi d\} \qquad (5)$$

A comparably simple model can be derived to describe the shape of a shrubby plant with densely packed leafy shoots (Fig. 1c):

<u>let</u> c_1 be the length of the plant's basal perimeter,

c_2 be the length of the plant's longest perimeter in the horizontal plane,

b_1 be the maximum height of the plant,

b_2 be the height of the plane of longest perimeter;

<u>assume</u> the contained volume of any individual can be estimated by treating it as an assembly of a basal frustum of a cone and a cap whose vertical profile is given by equation (1); after substitution:

$$y = \frac{-4\pi^2(b_1 - b_2)x^2}{c_2^2} + (b_1-b_2) \;;$$

<u>then</u>

$$V = \frac{\pi b_2}{3} \{(c_1/2\pi)^2 + (c_1/2\pi)(c_2/2\pi) + (c_2/2\pi)^2\} + \pi\int_0^{(b_1-b_2)} x^2 dy \tag{6}$$

$$= \frac{b_2}{12\pi}(c_1^2 + c_1c_2 + c_2^2) + \frac{c_2^2}{8\pi}(b_1-b_2). \tag{7}$$

Horn (1971) has proposed a generally applicable equation for describing the vertical profiles of plants:

$$x^\alpha + (\beta y)^\alpha = \gamma^\alpha$$

where α, β, and γ are constants and x and y are Cartesian coordinates. It was my experience, however, that equation (1) was satisfactory for plants in the mallee vegetation.

Once contained volume has been computed, it is possible to make estimates of other structural parameters, one of which, leaf area index (LAI), is of particular interest in climatology. First defined by Watson (1947), this index is a dimensionless number relating total leaf area to the vegetated area. Its values range from less than 1.0 in many desert woodland communities to a high of about 9.0 in managed pastures. Pearsall (1954) observes that fields of sunflowers have, on average, about three leaf layers. Their transmissivity is such that leaves in each of the layers can receive sufficient insolation during times of bright sun for photosynthesis to proceed at near-optimum levels. A fourth leaf layer would receive insufficient light, and the third would be under-illuminated at times of diffuse radiation. For these reasons, most agricultural crop plants with thickened leaves have a LAI of about 3.0 (potatoes 2.5 and mangolds 3.0) and grass crops have larger values (wheat 4.3 and a perennial rye grass/white clover pasture 8.9)(Donald and Black 1958).

There are few comparably accurate estimates of LAI for stands of forest vegetation. One method deals with newly fallen leaves on the forest floor (MacArthur and Connell, 1966). A random sample of about 100 points is taken and, at each, a long needle is plunged vertically into the litter and the number of leaves of the current year's crop which are touched by the needle are counted. If the following assumptions are accepted, the mean number of contacts is the LAI value for the stand. First, there must be one only complete turnover of leaves each year. Secondly, all leaves should be shed at about the same time. Thirdly, the leaves should stay roughly where they fall. And, fourthly, it must be possible to distinguish between newly fallen leaves and those of previous years. These assumptions virtually limit application of this method to the deciduous forest formation.

Alternatively, one may define the relationship between numbers of leaves and either contained volume of the leafy crown or plant age. As discussed earlier in this paper, statements of plant age only are worth the effort for trees in managed stands: plantations, orchards, and the like. It is, however, a relatively simple matter to obtain sufficient information with which to define the relationship between crown volume and total leaf area. Given subsidiary observations on the stature and spacing of plants in the study area, it is possible to estimate leaf area index for the stand. In this fashion, LAI for a 4 ha stand of mallee vegetation in Victoria, Australia was computed as 0.4 ± 0.1.

The approach described in this paper works well because plants are systematic in their growth. Ideally, age and not contained volume should be the independent variable but the latter is a satisfactory and simple alternative. Given the resurgence of interest in whole-body morphology, climatologists should soon have available sets of equations to describe the growth behaviour and structure of several species of woody plants. It is likely that these equations will reflect both the intrinsic (genetic and physiological) and the extrinsic (environmental) controls on plant growth, and will express variation in the density of plant tissues in tree crowns.

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TWO APPLICATIONS OF 'SYMAP' AS AN AID TO INTERPRETATION OF SPATIALLY DISPOSED DATA IN MICROCLIMATOLOGY

by

W. J. Kyle*

1. Introduction

Many investigations in microclimatology, particularly those within plant canopies, are made more difficult by the problem that point samples within a crop exhibit considerable variability due to the heterogeneous nature of the canopy. To aid in the interpretation of such measurements it is often useful to map such spatially disposed data using an interpolation and mapping computer program.

SYMAP, a computer program developed by the Laboratory of Computer Graphics, Harvard University, produces maps from any Cartesian system of coordinates. In executing the program, the computer makes a large number of interpolations and then assigns values to all points in the spatial field based on the values in the neighbourhood of each point. A contour map is produced which divides the spatial field into five zones calculated as quintiles from the data range. This procedure tends to smooth the inherent variability in the data. The degree of smoothing is directly related to the range of data and the number of sampling points. A system which has a large range of data values requires a large number of sampling points to avoid smoothing the data so much that it becomes of little value. Conversely, a relatively uniform spatial field requires fewer sampling stations. This note illustrates two applications of SYMAP to microclimatic data. One example is from radiation measurements within apple trees, and the other is from canopy structure measurements in corn.

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2. Radiation field within apple trees

Investigations of radiation distributions within an apple tree (Proctor, Kyle and Davies, 1974) have shown that point samples of radiation within a tree are very variable. Such data are ideally suited to a preliminary analysis using SYMAP. The program was used to obtain maps of the global radiation field within a 10 year-old McIntosh apple tree from 35 sampling stations located in the canopy.

Light, relatively inexpensive pyranometers (Lintronic-Agromet, Ithaca, New York) were used to measure global radiation. According to the manufacturer these instruments are uniformly sensitive in the wave-length range 300 to 3500 mm. The manufacturer's calibrations were verified by field comparison with a precision spectral pyranometer (Eppley Model 2, Newport, R.I.).

Five horizontal wooden tracks, each 4.8 m long, 92 mm wide and with edges 15 mm high were positioned E - W in the tree at 0.10, 0.90, 1.75, 2.60 and 3.45 m from the top of the tree. The sensors, resting on the tracks, were drawn manually eastwards using the signal cable. Return travel was accomplished by taking up, with a fishing reel attached to the end of the track, a string attached to the sensor. Signals were recorded on a multi-point recorder (Esterline Angus, Indianapolis).

Seven positions 0.8 m apart were marked on each of the five tracks. Measurements were started at position 1 (west end) on each track. Three measurements were obtained from each position on all five tracks within 1.5 minutes. The mean for each position was used in subsequent analysis. This procedure was repeated for all seven positions on the five tracks, and took, including movement and positioning of the sensors, about 20 minutes. This sampling period was centered on the hour (mean solar time). Each mean value was corrected for any change in global radiation above the canopy during the sampling period. This was done by multiplying by the ratio of the global radiation above the canopy at the time of sampling measured by a precision pyranometer to that on the hour.

In addition, radiation distribution patterns presented by Heinicke (1963b) for a 17 year-old apple tree (variety Delicious) were reanalysed using this procedure. His patterns were obtained using uranyl oxalate actinometry (Heinicke, 1963a).

A contour map showing five zones of global radiation constructed by SYMAP using data obtained in 1971 is presented in Figure 1. The data

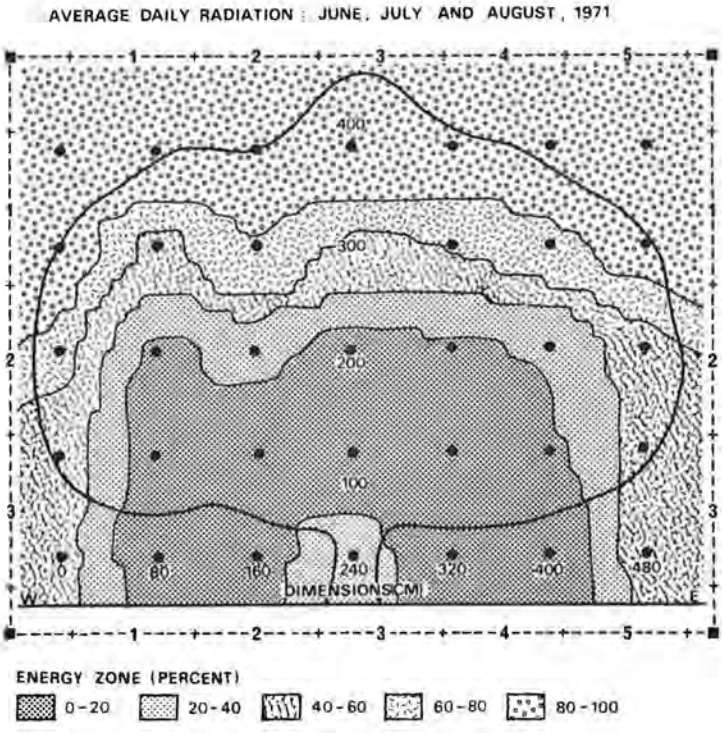

Fig. 1. SYMAP of global solar radiation in a McIntosh apple tree. Sampling locations indicated by ● . Solid line represents approximate outline of tree.

are mean values of percentage of radiation, at each of 35 points, relative to the radiation incident above the tree. Each mean value is the mean of 4 daily averages obtained during the growing season. The canopy outline as obtained from direct measurements is also shown.

The mean data were very similar to those on individual days indicating little variation from day to day. The map indicates that there is a zone of large divergence of global radiation near the periphery of the tree. This zone corresponds to the region of maximum leaf area as found by Heincke (1963b). Inwards from this zone of divergence, the center of the tree is a region of relatively uniform low global radiation.

SYMAP is also useful in investigations of the diurnal variation of the radiation regime in apple trees (Fig. 2). The diagrams derived from SYMAP output, indicate very clearly the diurnal changes in the radiation field within the tree and provide a good representation of the complex environment which is difficult to visualise from point observations.

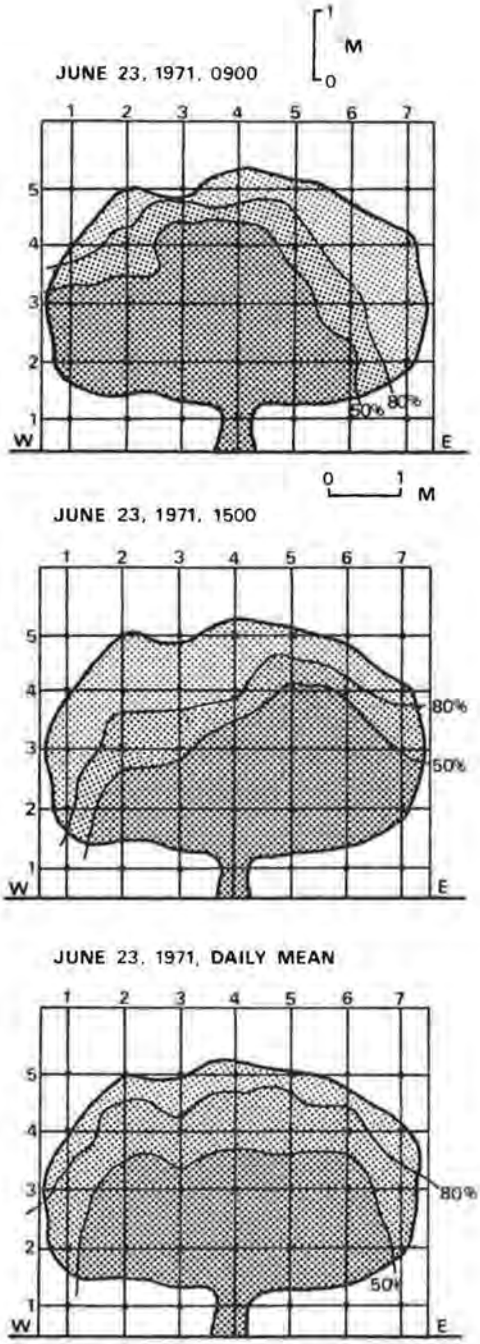

Fig. 2. Diurnal variation of global solar radiation in a McIntosh apple tree.

Re-analysis of the data presented by Heinicke (1963b) using SYMAP resulted in distributions strikingly similar to those originally presented by Heinicke (Fig. 3). Again, three zones, as discerned by him are clearly evident suggesting that this may be a real characteristic of fruit trees with a near spherical canopy. A further observation which is revealed by this technique is the uniformity of the tree as evidenced by the similar distributions obtained using data from both north-south and west-east transects.

3. Canopy structure in corn

Radiation measurements in closed canopies such as corn are dependent on canopy structure. An investigation of the effect of planting procedure on the radiation regime in corn (Kyle, 1974) required considerable information on canopy structure. The relative position of plants to each other in the stand was ascertained with the aid of SYMAP. A grid of 117 sampling stations in each plot formed the data points for the map. Canopy height was measured at each point and formed the imput data for the program. The program divides the data into five equal height intervals using the minimum and maximum data values as boundaries. These classes are assigned the numbers 1 through 5 corresponding to the lowest quintile through to the highest quintile.

Although the above investigation was concerned with the gross structure of corn there is no reason why SYMAP could not be used to study the spatial distribution of leaves and other microstructure elements. Such investigations however, do require a much denser network of sampling stations to obtain the required degree of discrimination.

Figures 4 and 5 present SYMAPS obtained in two plots of corn seeded differently. The equidistant plot was square-sown with plants approximately 0.4 m apart and the row plot was conventionally seeded in north-south rows approximately 0.8 m apart. The usefulness of SYMAP in clarifying the differences in horizontal pattern in the two crops is evident from the maps. There is, of course, no reason other than absence of data, why the radiation field in the two plots could not be plotted in the same way. This would indicate in a preliminary manner the interrelationships between canopy structure and the radiation regime.

AVERAGE DAILY RADIATION: JULY AND AUGUST, 1962

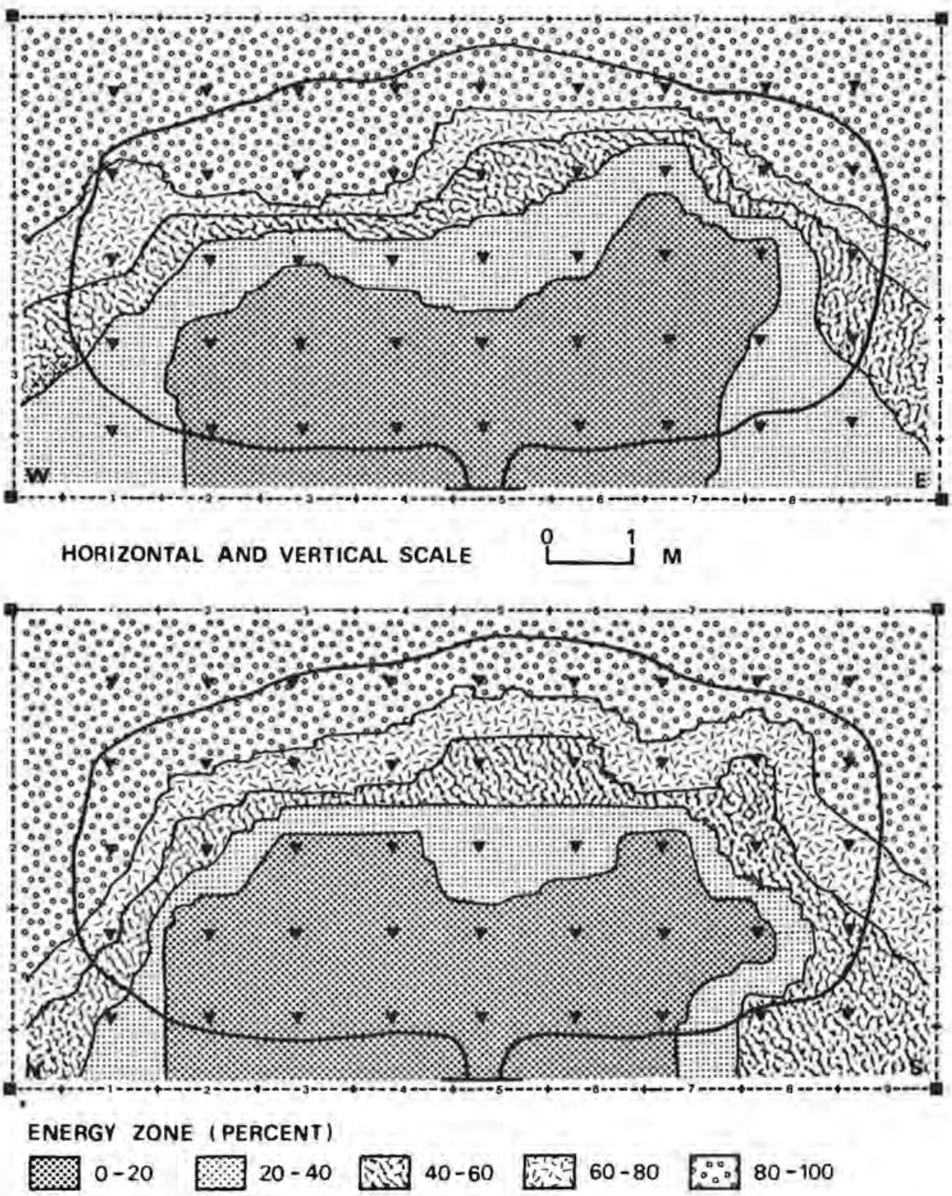

Fig. 3. SYMAP of global solar radiation in a common Delicious apple tree (data from Heinicke, 1963). Sampling locations indicated by ▼. Solid line represents approximate outline of the tree.

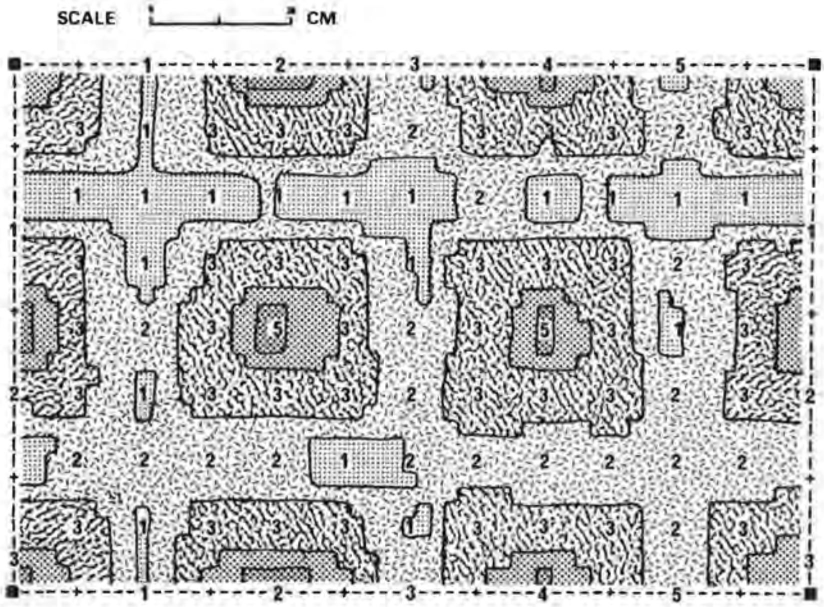

Fig. 4. SYMAP of canopy height in corn (equidistant plot). Numbers at sampling stations indicate sample class.

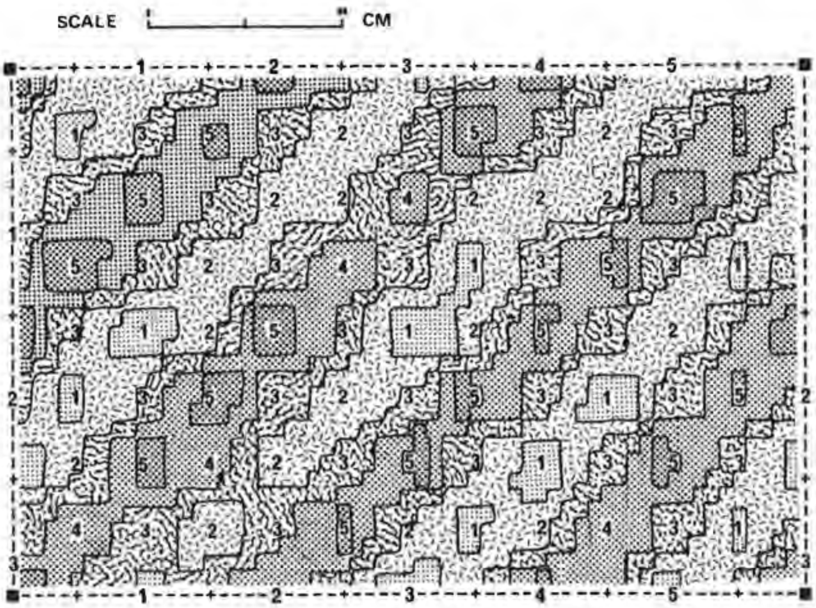

Fig. 5. SYMAP of canopy height in corn (row plot). Numbers at sampling stations indicate sample class.

4. Conclusion

Clearly SYMAP can be of considerable value in interpretation of point sampled data in complex environments such as those commonly encountered in microclimate investigations. This applies not only to radiation and structure data but may also be useful for a wide range of meteorological parameters such as temperature and vapour pressure. The advantage lies in the ability to use fewer sampling stations to characterise the system and the greater objectivity in the presentation of the data.

However, it should be pointed out that the program must be used with an understanding of the physical system for which the data are to be mapped so that irregular and spurious maps can be recognised. For example, Figure 1 shows an anomaly at the base of the tree. A higher energy zone occurs in an area where less energy is expected. In this case the anomaly was due to an open space near the trunk which permitted radiation to be transmitted to the base of the tree.

Further, the user must consider the degree of discrimination which is acceptable for his purposes and plan the sampling procedure accordingly. In a system where there is a large range of data values, considerable smoothing will be generated by SYMAP unless a large number of sampling points are used.

5. Acknowledgements

This project was supported by grants from the National Research Council awarded to Dr. J. A. Davies of McMaster University. The apple tree data were made available by Dr. J.T.A. Proctor, Horticultural Research Station, Simcoe, to whom acknowledgement is made.

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NEWS AND COMMENTS

Mr. Gordon A. McKay of the Atmospheric Environment Service's Meteorological Applications Branch represented the World Meteorological Organization at a Planning Workshop on the Impact of Climatic Change which was held at the Meteorological Institute, University of Bonn, West Germany, in May 1974.

The Workshop, under the auspices of the International Federation of Institutes for Advanced Studies, (IFIAS) was attended by about 25 people drawn from many countries and representing meteorology, medicine, economics, oceanography, law, etc. One product of the Workshop was a manifesto which drew the attention of nations to the serious social consequences which would result from climatic fluctuations in the future, and asked both scientists and governments to take actions aimed at offsetting the stress and suffering that might follow. In addition, related transdisciplinary projects were recommended and these will be undertaken within the IFIAS Climate Project which is headed by Dr. Walter Orr Roberts of the University Corporation for Atmospheric Research, Boulder, Colorado.

The climate studies centered at the McGill Sub-Arctic Research Laboratory were continued during the past spring and summer. These included measurements of radiation and turbulent exchanges over melting snow at woodland sites, a study of albedo of various summer surfaces characteristic of the area, and a study of the effect of woodlands and topography on windspeeds in the local region.

D.E. Petzold has been involved in a study of surface radiative temperatures of lakes in the Schefferville area using a PRT-5 sensor attached to the belly of a single engine Otter aircraft. The first flight was completed on 22 July, 1974, during the period of maximum water surface temperatures. The flight path of about 110 miles sampled lakes in the Knob Lake, Howells River and lower Menihek Lakes basins as well as Dyke, Petitsikapau and Astray Lakes in the upper Churchill River basin of sub-arctic Labrador. Similar traverses will be conducted this fall and throughout next spring and summer as part of a lake evaporation study which will test evaporation estimates by modified equilibrium model.

It is expected that papers based on the Schefferville work will comprise the entire issue of the Bulletin for October, 1975.

B. Singh has commenced his Ph.D. research project which is concerned with the effect of intercepted precipitation on evaporation rates and water shed behaviour at Mont St. Hilaire. Unfortunately the instrument towers in the forest were struck twice by lightning during the summer, so the data collection program was curtailed while repairing and replacing the equipment. However one of the interesting results is that the stomatal resistance of maple trees is considerably more sensitive to weather conditions than that of beech trees, the latter exhibiting much more constant readings than the maples.

Bea Taylor has recently completed her doctorate in meteorology at McGill University with a thesis entitled: "The Energy Balance Climate of Meighen Ice Cap, N.W.T."

Robert Proulx has obtained his Master of Science degree in Geography (Climatology) at McGill University. His thesis was entitled: "L'Evapotranspiration Potentielle et le Bilan de l'eau du bassin de la Rivière Eaton, P.Q."

A recent publication of interest to readers of the Bulletin is "Climate Canada" by F. Kenneth Hare and Morley K. Thomas. The book presents a simple, descriptive account of Canada's climates and their interaction with man. It has been written mainly for College and University students but contains much material for persons involved with the study, development, and utilisation of the Canadian environment. The emphasis is on surface climates and their characteristics. "Climate Canada" is published by Wiley Publishers of Canada Ltd., Toronto.

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