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CLIMATOLOGICAL BULLETIN

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FACTOR ANALYTIC APPROACH TO A CLIMATIC CLASSIFICATION OF EUROPE

by

G.R. McBoyle*

Classification is such a powerful filter for ordering data that its use in climate has far surpassed the immediate purpose of simplifying unwieldy masses of statistics, and is instead extended to provide means of identifying world regions. To quote Sewell, Kates and Phillips (1968), "Of twenty-six textbooks commonly used in beginning geography courses in the United States, fourteen use climatic variations to regionalize the world." Because of their wide application, then, ideally climatic classifications should be as flexible as possible.

But in classifying climatic data most climatologists have found sharp demarcations between groupings difficult to achieve without resorting to the inclusion of non-climatic variables. For example, Koppen's choice of the isotherm of 10°C (50°F) for the warmest month has considerable relevance to vegetative processes since it coincides with the northermost limit of tree growth, separating boreal forest from treeless tundra, but has little significance for purely meteorological parameters. For this reason an attempt has been made to develop a climatic classification based solely on climatic variables and their interactions; and one which will allow the use of a wide range in the number of variables employed in any one classification to permit variations in the degree of detail required.

Climate is a multivariate phenomenon, and its classification depends upon the degree of affinity between many meteorological parameters from observation point to observation point. Not all members of a grouping can be expected to share all features in common, but the optimum degree of homogeneity internally, and the optimum degree of heterogeneity externally, should be sought. Thus the "regionalization" of climate

* G.R. McBoyle is an Associate Professor in the Department of Geography, Division of Environmental Studies, at the University of Waterloo.

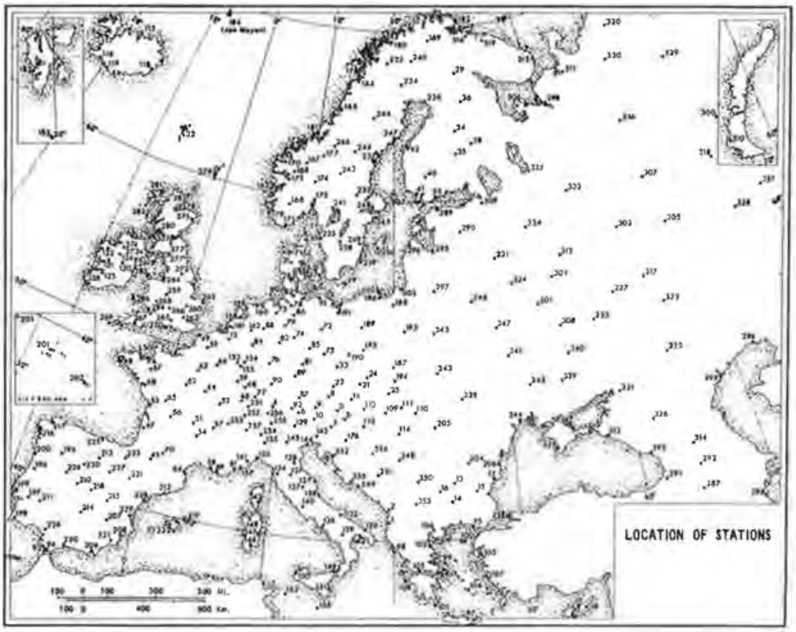

Fig. 1 Location of Climatic Stations

TABLE ONE

Matrix of Simple Correlations Between Input Variables

Variable Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000															
2	0.909	1.000														
3	0.918	0.994	1.000													
4	0.886	0.993	0.973	1.000												
5	0.836	0.549	0.580	0.510	1.000											
6	0.775	0.470	0.516	0.417	0.974	1.000										
7	0.851	0.610	0.619	0.592	0.953	0.862	1.000									
8	-0.484	-0.205	-0.261	-0.145	-0.721	-0.784	-0.580	1.000								
9	-0.073	-0.080	-0.062	-0.056	-0.069	-0.055	-0.085	0.090	1.000							
10	-0.348	-0.079	-0.083	0.026	-0.687	-0.778	-0.513	0.926	0.029	1.000						
11	0.047	0.202	0.180	0.222	-0.224	-0.258	-0.153	0.275	-0.024	0.391	1.000					
12	0.292	0.463	0.439	0.480	-0.016	-0.089	0.086	0.210	-0.022	0.320	0.790	1.000				
13	-0.489	-0.406	-0.426	-0.381	-0.539	-0.499	-0.545	0.340	0.015	0.353	0.586	0.100	1.000			
14	-0.454	-0.778	-0.747	-0.799	0.097	0.170	0.010	-0.294	0.020	-0.479	-0.407	-0.562	0.081	1.000		
15	-0.068	0.216	0.181	0.248	-0.432	-0.549	-0.237	0.620	-0.074	0.840	0.451	0.411	0.210	-0.580	1.000	
16	-0.621	-0.717	-0.713	-0.712	-0.368	-0.300	-0.429	0.074	0.018	-0.004	-0.168	-0.538	0.539	0.580	-0.167	1.000

requires extraction of the various basic underlying patterns which may be controlled by one, or all, of its elements. Since factor analysis allows identification of the underlying independent patterns within a complex set of multivariate data, its application to climate classification seems appropriate.

The theory of factor analysis makes conceptual and mathematical distinctions between principal component analysis and factor analysis (Cattell 1965). Kendal (1957) states the following distinction: "In component analysis we begin with the observations and look for the components in the hope that we may be able to reduce the dimensions of variation and also that our components may, in some cases, be given a physical meaning. In factor analysis we work the other way around; that is to say, we begin with a model and require to see whether it agrees with the data and, if so, to estimate its parameters." In this application of the factor analytic approach principal component analysis was used rather than factor analysis proper.

Using 16 variables from each of 355 stations in Europe (Fig. 1) a matrix of simple correlations between the imput variables was obtained (Table One). This matrix was used as basic imput for the principal component analysis. The variables used were mainly a mix of temperature, relative humidity and precipitation, since heat and moisture are the two dominant climatic controls on our environment. The variables were:

1	Mean annual temperature, °F	T_a
2	Average daily mean temperature, °F, January	T_1
3	Average daily maximum temperature, °F, January	$T_{1, MAX}$
4	Average daily minimum temperature, °F, January	$T_{1, MIN}$
5	Average daily mean temperature, °F, July	T_7
6	Average daily maximum temperature,°F, July	$T_{7, MAX}$
7	Average daily minimum temperature,°F, July	$T_{7, MIN}$
8	Mean annual relative humidity (afternoon), percent	H_a
9	Average relative humidity (afternoon), percent, January	H_1
10	Average relative humidity (afternoon), percent, July	H_7
11	Mean annual precipitation, inches	P_a
12	Average precipitation, inches, January	P_1
13	Average precipitation, inches, July	P_7
14	Temperature range, °F (January-July)	T_r
15	Humidity ratio (July/January)	H_r
16	Precipitation ratio (July/January)	P_r

The data for the 16 climatic variables for each of the stations were obtained from the Meteorological Office Bulletin MO 617c Part III "Europe and the Atlantic Ocean north of 35°N" (1960).

A factor analysis was then carried out on the data set. The unrotated factor solution yielded three factors with eigenvalues greater

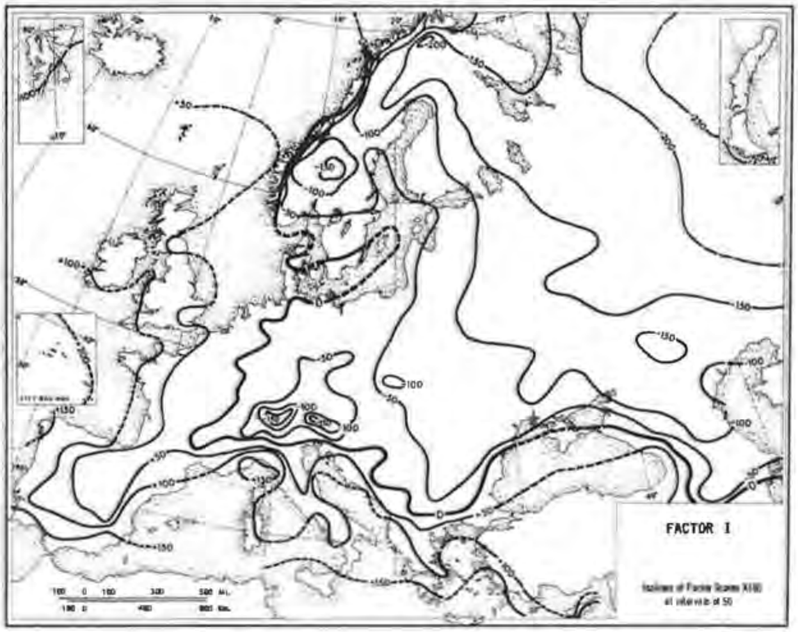

Fig. 2 Factor I - "Mild maritime winter" periphery

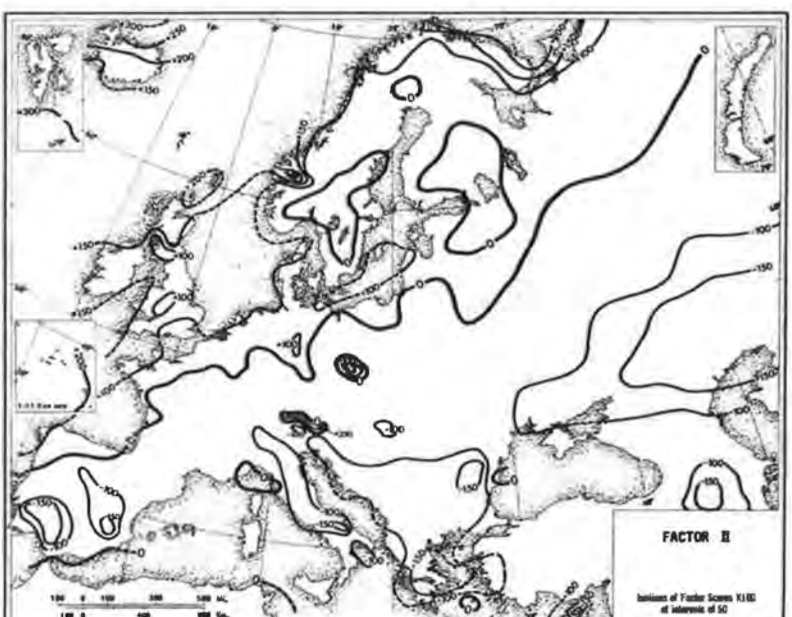

Fig. 3 Factor II - "Cool moist summer" belt

than one, factors which accounted for 90 percent of the original total variance. Because of the complexity of the solution a Varimax rotation was carried out. This rotation simplifies for interpretation the loadings of each factor. The factors, eigenvalues, communalities and rotated factor loadings are indicated in Table Two. The interpretation of the underlying patterns is done with reference to the loadings, those variables with high positive loadings on a factor serving to identify that factor.

Factor I, accounting for 48.98 per cent of the total variance, is the most important. High loadings on this factor are six in number, four positive - January mean, daily maximum and minimum temperatures, annual temperature, and two negative - temperature range and precipitation ration. Factor I appears to be an index of temperature conditions with special emphasis on mild winter temperatures. If the factor scores for each station are mapped and isolines drawn (Fig. 2) the oceanic influence along the Atlantic and Mediterranean fringe is clearly illustrated by high positive figures. The high negative figures of the inland North European Plain indicate the opposite conditions of low winter temperatures - mean and daily minima in particular - with high temperature ranges and high precipitation ratios denoting a summer precipitation season. Also revealed is the fact that stations with a high January mean and minimum temperature generally tend to have a high annual temperature and a low temperature range together with a low precipitation ratio.

Factor II was found to explain 32.76 per cent of the total variance. When plotted the results gives Figure 3. This factor is composed of positive loadings on summer relative humidity, annual relative humidity, and the humidity ratio, with negative loadings on average summer temperatures and daily maximum temperatures in summer. In other words if the summer and annual humidity is high the summer temperatures (in particular, the daily maximum) will be low. This is the "cool moist summer" belt of Europe delimiting the main pathway for summer depressions moving in from the Atlantic across the North European Plain towards northeast Europe.

Finally, accounting for 8.23 per cent of the total variance, Factor III provided an index of annual precipitation (Fig. 4). The pattern is complicated because of a number of circumstances included within the factor: (1) the maritime nature of western Europe; (2) the mountainous topography of the Scandinavian and the Alpine areas; and (3) the winter inflow of depressions and resulting precipitation in the

TABLE TWO

Matrix of Rotated Factor Loadings

Factor Number			I	II	III
Eigenvalue			6.97	4.66	1.17
Percentage of Total Variance (Communality)			48.98	32.76	8.23
	Variable	Percentage Communality over 3 factors			
1	T_a	97.1	<u>0.856</u>	-0.489	0.004
2	T_1	97.8	<u>0.977</u>	-0.130	0.080
3	$T_{1,MAX}$	96.6	<u>0.964</u>	-0.178	0.068
4	$T_{1,MIN}$	96.9	<u>0.977</u>	-0.080	0.092
5	T_7	93.9	0.482	<u>-0.827</u>	-0.153
6	$T_{7,MAX}$	95.4	0.380	<u>-0.887</u>	-0.156
7	$T_{7,MIN}$	82.2	0.579	-0.686	-0.130
8	H_a	81.1	-0.078	<u>0.891</u>	0.105
9	H_1	0.6	-0.055	0.049	-0.028
10	H_7	89.5	0.092	<u>0.921</u>	0.196
11	P_a	85.1	0.170	0.209	<u>0.882</u>
12	P_1	71.2	0.483	0.173	0.670
13	P_7	71.8	-0.471	0.269	0.650
14	T_r	90.2	<u>-0.801</u>	-0.465	-0.210
15	H_r	71.7	0.321	<u>0.740</u>	0.257
16	P_r	58.4	-0.763	0.035	-0.023

High loadings (over ±0.700 are underlined.)

Key to Fig. 5, p. 8

1 Extreme continental climate
2 Cool maritime rainy climate
3 Maritime rainy climate
4 Mediterranean climate with hot summer
5 Mediterranean climate with warm summer
6 Warm maritime rainy climate
7 Mild continental climate
8 Tundra climate
9 Warm continental climate
10 Alpine climate
11 Mild Mediterranean climate with very moist winter

Mediterranean. It does, however, indicate the forces at play in the study of precipitation in Europe.

The original matrix of 5,680 items of climatic information (an input matrix of 355 x 16) has been reduced to three factors: (a) the "mild maritime winter" periphery; (b) the "cool moist summer" belt; and (c) the overall precipitation scene. Each of these indices can be represented in the form of a linear equation composed of various weightings of all the original imput variables. However because only certain of the loadings are important, the linear equations were compiled using only those loadings that are significant. Values for the indices may be obtained from the following equations:

(a) "Mild maritime winter" periphery

$$= 0.977T_1 + 0.977T_{1,MIN} + 0.964T_{1,MAX} + 0.856T_a - 0.801T_r - 0.763P_r$$

(b) "Cool moist summer" belt

$$= 0.921H_7 + 0.891H_a + 0.740H_r - 0.887T_{7,MAX} - 0.827T_7$$

(c) Overall precipitation scene

$$= 0.882P_a$$

Using the scores of the three factors derived from the 16 variables for each of the 355 stations it is possible to devise groups that could be used as the basis for regionalization. Since three factors have been derived it is possible to construct a 3-dimensional graph, each axis representing any one but only one of the above determined three factors. On this 3-dimensional model each of the 355 stations can be plotted as points in it. Points in this 3-dimensional graph that are close together have similar factor scores and vice versa. Thus it is possible to take the distance between the points as an index of similarity of the climate at these stations. The stations, points on the 3-dimensional graph, are now grouped on the basis of their proximity. Because each station (point on the graph) has a distance measurement with every other station (point) a 355 x 355 distance matrix is obtained. The stations associated with the smallest distance obtained in the matrix are put into one group, the mean for the group calculated, the distance statistics recomputed, and a new data matrix obtained. The smallest distance in the new matrix is determined and the stations put into another group. This step-wise process continues until all stations are

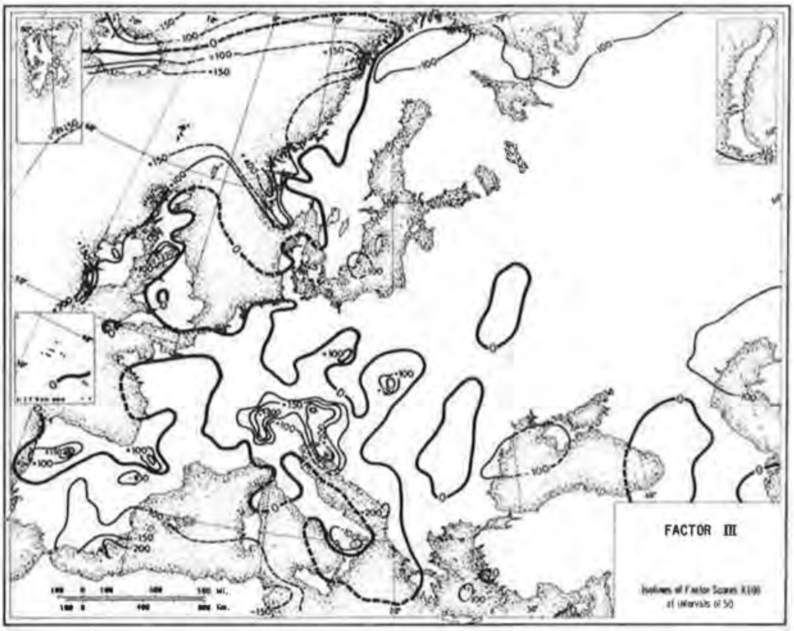

Fig. 4 Factor III - Overall precipitation scene

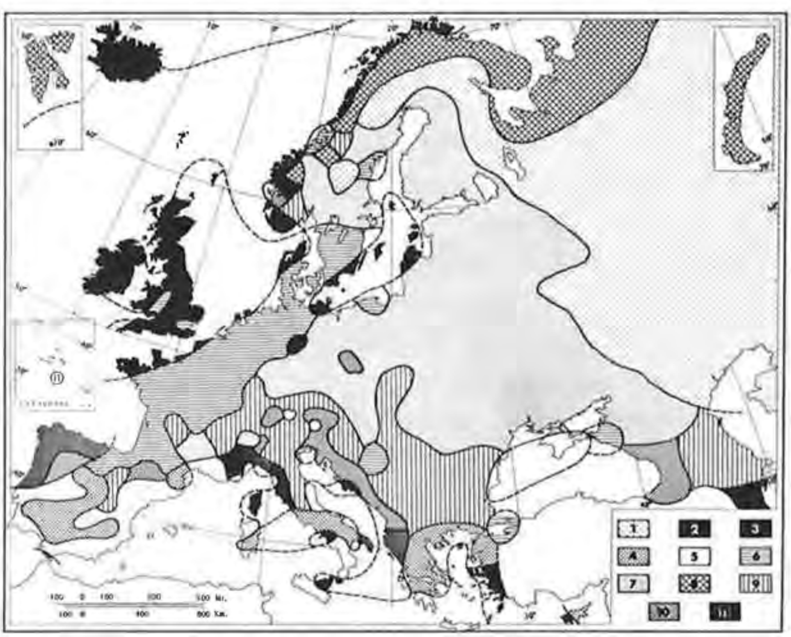

Fig. 5 Climatic Regionalization of Europe
(For key to numbers, see p. 6)

within one group, or, as Berry (1967) notes, the result is "a complete linkage tree", which "proceeds from n outermost branches, through (n - 1) to (n - 2) to i to (i - 1) to 4, 3, 2 and finally the main trunk 1". It should be realized, however, that there is no guarantee with this method that the grouping procedure will yield contiguous regions.

From the grouping analysis program a linkage tree was obtained which reduced 355 individual stations to one group, Europe. The situation of groups at the 344th stage (11 groups) is illustrated in Figure 5. (The choice of 11 groups is simply an arbitrary one, but one which it was felt provided the maximum number of categories easily assimilated by the eye on a map.) Each of the eleven groups or regions has a certain homogeneous internal climate, as is listed in Table Three. These figures were obtained by averaging the climatic data for each of the variables of each station within every group. Each region was identified for simplification and for comparison with other classifications, although it should be borne in mind that the regions are by no means "fixed" and that the boundaries will change depending upon the type and number of input variables and the time period used.

The value of this regionalization technique lies in its great flexibility giving it a wide utility; it does not pretend to provide the definitive answer in an objective sense for it is simply a tool. The meteorological parameters are chosen subjectively according to the individual's basic assumptions regarding significance, or more likely according to data availability!

Not only may the type and number of variables vary, but more significantly the time period over which the data are extracted presents another arbitrary choice. Thus there is little point devising a factor analytic regionalization for a certain time-period and comparing it with a Koppen-type classification of a different time-period.

The technique employed here, viz. factor analysis followed by grouping analysis, lends itself to numerous uses since the individual is presented with a series of groupings, as large as the number of stations chosen, but each subsequent one a stage more generalized than the previous one. Thus, depending on the purpose and preference of the individual using this technique the stage of detail desired is chosen accordingly. In the small group level towards the completion of the grouping procedure a very generalized picture is obtained. For instance, in the example described here the general level of groupings indicated the over-

TABLE THREE

Average Climatic Data for each of the 11 Regions

Region	T_a	T_1	$T_{1,MAX}$	$T_{1,MIN}$	T_7	$T_{7,MAX}$	H_a	H_7	P_a	P_1	P_7	T_r	H_r	P_r
1	36.2	7.9	13.7	2.1	64.9	74.3	67.0	52.9	18.7	1.1	2.4	56.4	0.6	2.3
2	45.0	35.9	39.8	32.0	56.5	62.2	78.0	77.0	48.2	5.1	3.5	20.6	0.9	0.7
3	46.3	36.1	40.1	32.0	58.5	62.6	78.7	76.0	27.8	2.6	2.4	24.9	0.9	1.0
4	61.3	43.8	53.1	38.5	78.1	90.0	55.6	39.5	19.9	2.4	0.4	32.3	0.6	0.2
5	60.1	46.9	53.0	40.7	74.4	83.2	64.0	57.3	19.3	2.2	0.5	27.6	0.8	0.4
6	48.2	34.0	38.6	29.3	63.5	72.3	67.7	59.5	26.9	2.1	2.9	29.1	0.7	1.2
7	43.8	23.6	28.5	19.0	64.7	73.5	66.3	55.4	23.2	1.4	2.8	40.7	0.8	2.1
8	26.4	7.4	12.6	6.7	48.7	55.2	78.4	72.3	23.0	1.4	2.9	41.4	0.9	2.8
9	47.6	30.4	36.5	24.4	68.6	79.4	61.4	50.4	28.8	1.7	3.0	38.1	0.7	2.0
10	50.9	34.9	41.0	28.8	67.1	76.3	66.3	60.8	63.6	5.5	5.5	32.2	0.9	1.3
11	61.0	49.4	54.6	43.9	71.3	81.0	66.3	60.3	38.4	4.7	0.9	24.1	0.9	0.2

all climatic division within Europe, namely the east to west and north to south variations of rainfall and temperature respectively, whereas at the detailed level (i.e. large number of groupings) it elucidates various complex local situations, for example, those within the Mediterranean area. Thus, depending on the purpose of the study and the area covered, a climatic classification can be readily obtained for any of the stages on the linkage tree between the "extremes" of individual station level at one end of the scale and the most general, the one group level, at the other.

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SURFACE ALBEDO AND EMISSIVITY FOR LAKE ONTARIO

by

John A. Davies*

1. Introduction

One of the specified tasks of the International Field Year for the Great Lakes is to evaluate Lake Ontario's radiation balance on a daily basis for use in energy balance studies. A network of about 20 stations in and around the lake provides incoming global and longwave radiation data but direct measurement of the radiation balance over water is made only at one location. In order to compute the balance the outgoing fluxes must be evaluated.

Surface temperatures are measured continuously at buoy stations by contact thermometry and once every two weeks by infra-red sensing from aircraft. Daily fields of surface temperature constructed from these are sufficiently accurate for computing emitted longwave radiation from the Stefan-Boltzmann law. The balance can be computed if surface albedo and emissivity can be specified. This paper examines the variability of these parameters as determined from experimental data collected prior to the Field Year and presents numerical values of albedo and emissivity which can be used during the Field Year.

2. Site and Data

The data used in this paper were collected between July and November 1969 at a tower site near the western end of Lake Ontario (Fig. 1). The tower, installed and maintained by McMaster University with the assistance of the Canada Centre for Inland Waters, served as a platform for measuring the radiation balance and some of its components. Standard pyranometers (Eppley Laboratory Inc.) were used to measure incoming global, incoming diffuse and reflected global radiation, with a standard shading

* John A. Davies is Associate Professor of Geography at McMaster University.

Fig. 1 The lake tower used in the McMaster study of radiation fluxes over Lake Ontario in 1969.

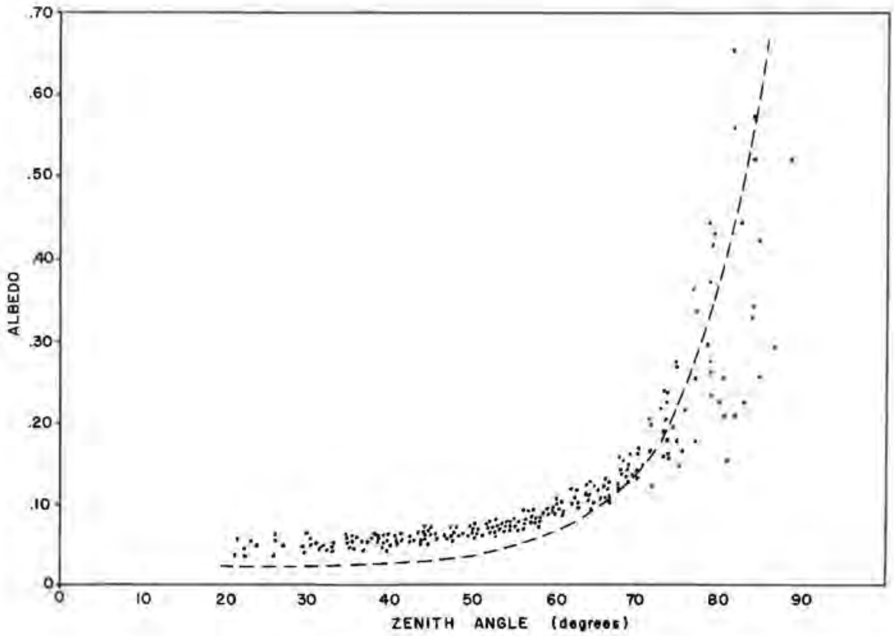

Fig. 2 The relationship between albedo and solar zenith angle for cloudless skies. Calculated values of albedo from Fresnel's formula are given by the dashed lines.

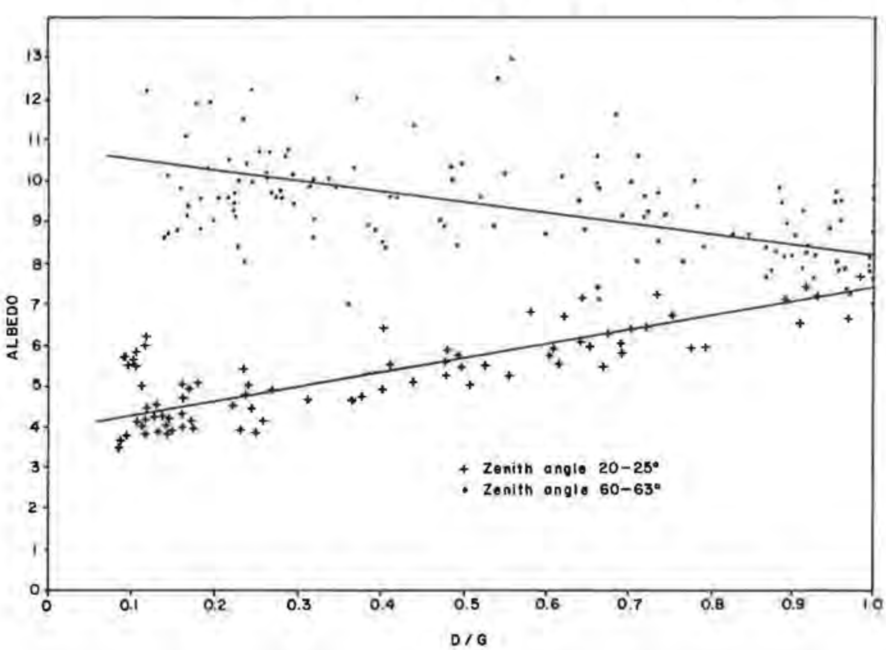

Fig. 3 The relationship between albedo and the diffuse component D of global radiation G for two zenith angle ranges.

ring, as used by the Atmospheric Environment Service in its radiation network, to obtain the diffuse flux. These sensors were linked by lakebed cable with dual-channel, potentiometric recorders (Hewlett-Packard, Model 7100B) at a recording station on shore. Half-hourly flux values were evaluated continuously over the experimental period. An infra-red thermometer (Barnes Engineering Co., Model PRT-5) was used in conjunction with an aluminum cone, as described later, to determine surface emissivity.

3. <u>Albedo</u>

The albedo of a water surface has three components: direct beam reflectivity, diffuse reflectivity and backscatter from the surface water layers. Since all these occur simultaneously, separate observations of each were not made, but estimates were attempted.

Under cloudless skies, the direct beam component is dominant since diffuse radiation is minimal. In accordance with other work we have found that values of reflectivity as a function of solar zenith angle computed from Fresnel's formula (List, 1966), which applies strictly to a plane surface, provide an acceptable fit to the half-hourly field data for cloudless days (Fig. 2). There are two discrepancies. Firstly, at low zenith angles, observed values exceed model values. This feature can be attributed to the effect of waves which has been found to increase albedo at all zenith angles (Nunez, Davies and Robinson, in press). Secondly, at zenith angles above 70° observed values lie below the theoretical curve. With increasing zenith angle, and air mass, diffuse radiation is no longer an insignificant fraction of the global radiation (it may amount to 60% of global) and the diffuse radiation component of albedo has a significant influence. This component, as we shall see, is lower than the Fresnel values at these zenith angles. Any effect of waves is obscured by the increase in this component.

A method by Neumann and Hollman (1961) was used to estimate diffuse radiation albedo (Fig. 3). Albedo is plotted against the ratio of diffuse to global radiation for two zenith angle ranges and the data points fitted by two linear regression lines. Extrapolating these for completely diffuse global radiation gives albedo values of 7.4% and 8.2%. These are slightly larger than Burt's theoretical value of 6.6% (Burt, 1953) due probably to a small backscatter effect.

Accepting the Fresnel relationship for direct beam albedo and Burt's value for the diffuse albedo we have calculated a mean backscatter

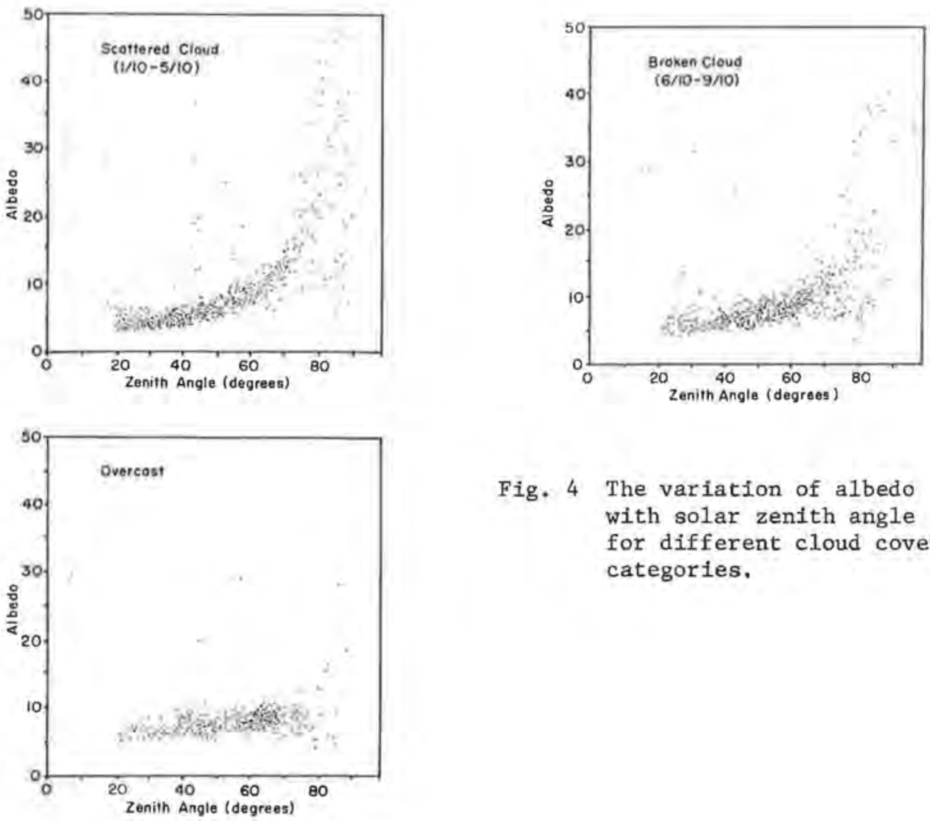

Fig. 4 The variation of albedo with solar zenith angle for different cloud cover categories.

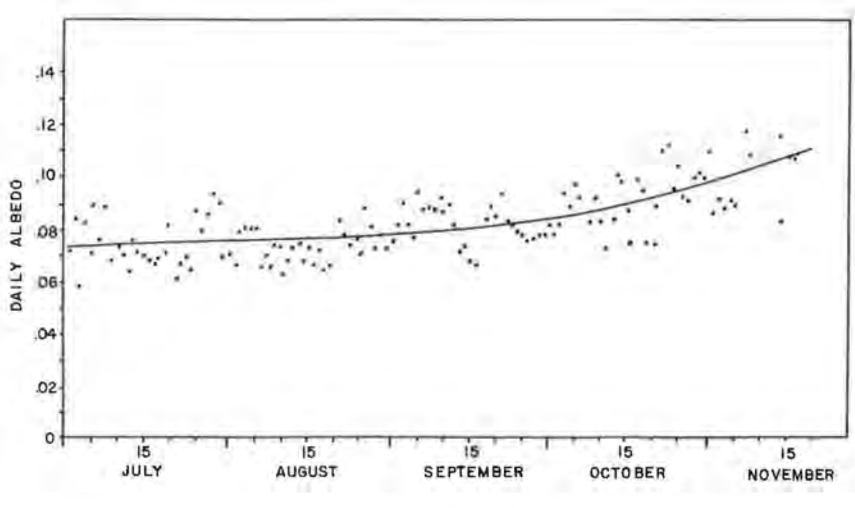

Fig. 5 Daily variation of albedo during the experimental period.

coefficient of 1.7%. There was very little variation around this value. Hence, most of the variability in albedo must stem from variation in the proportions of direct beam and diffuse radiation. This implies a relationship between albedo and cloudiness. This can be shown by grouping the data according to cloud amount categories. Figure 4 shows the variation of albedo with zenith angle for three cloud categories: scattered cloud ($^1/_{10}$ - $^5/_{10}$), broken cloud ($^6/_{10}$ - $^9/_{10}$) and overcast. For scattered cloud cover, the strong dependence of albedo upon zenith angle, which was shown for clear skies, is apparent. Under broken cloud, the dependence is reduced and the data scatter increases. In the overcast case, there is no sign of any dependence and there is little diurnal or seasonal departure from a mean value of 7.5%.

From the nature of the scatter in Figure 4 precise prediction of albedo from a knowledge of zenith angle and cloud amount is unlikely. Obviously, cloud thickness, which is not observed routinely, is also important since it has a bearing upon the magnitude of the diffuse radiation.

Although albedo is sensitive to the type of incident radiation and significant diurnal variation can be expected, daily albedo values are remarkably conservative (Fig. 5). Daily values, computed from daily totals of reflected and global radiation, are shown for the whole experimental period. These range between 7% in early July and 11% in mid-November. The increase, particularly marked from September onwards, is in keeping with the increasing occurrence of higher zenith angles as the sun becomes lower in the sky. The scatter of points around a line fitted by eye is attributed to variation in cloud amount and, to a lesser extent, to wave effects and water turbidity. Since most of the scatter is within 1% of the curve, the total effect is slight and can be safely ignored on a daily basis. In the absence of ice, this diagram can probably be used in studies where daily, weekly or monthly albedo values are required.

4. Emissivity

Surface emissivity ε was determined in the field by the method outlined by Fuchs and Tanner (1968). It uses an infra-red thermometer and an aluminum cone with a highly polished inner surface. Emissivity is obtained from three infra-red thermometer measurements; sky temperature T_k, apparent surface temperature T_r and true surface temperature T_s:

TABLE ONE

Field Emissivity Results

Date (1969)	Local time	Site*	Cloud Type	Cloud Amount (tenths)	Emis- sivity** ε	Dock minus tower ε
15 Sept.	1430	D	Ac Cu	4	0.977	
	1630	D	Ac	4	0.976	
16 Sept.	1240	D	As Ac	9	0.961	
22 Sept.	1130	T	Clear	0	0.977	
	1330	T	Clear	0	0.972	
25 Sept.	1220	D	Sc	10	0.961	
26 Oct.	1660	D	As Ac	10	0.989	
	1650	D	As Ac	9	0.987	
27 Oct.	1230	D	Sc	9	0.984	
	1350	D	Sc	9	0.970	
	1640	D	Sc	10	0.977	
	1770	D	Sc Ac	10	0.976	
28 Oct.	1200	D	Ac	1	0.964	
	1515	S	Ac Cu	2	0.964	
3 Nov.	1210	T	Ac Sc	8	A 0.980)	0.005
	1230	D	Ac Sc	8	0.985)	
	1400	D	As	10	B 0.977)	0.009
	1410	T	As	10	0.968)	
	1505	D	As	10	C 0.952)	-0.020
	1520	T	As	10	0.972)	
4 Nov.	1025	T	As Ac	9	D 0.964)	0.004
	1040	D	As Ac	10	0.968)	
	1330	D	As Ac	9	0.969	
	1610	D	As Ac	9	0.980	
5 Nov.	1010	D	As Cu	9	0.975	
	1315	D	Cc Ac Cu	4	0.579	
	1505	D	As Sc	10	0.956	

* D, dock; T, tower.

** See text for discussion of cases A, B, C, D.

$$\varepsilon = \frac{T_r^4 - T_k^4}{T_s^4 - T_k^4} \tag{1}$$

Sky temperature was taken as the mean of several measurements in various sectors of the sky. Apparent surface temperature was obtained by directing the sensor at the water surface. The radiant flux incident upon the sensor in this measurement includes the portion of the incoming longwave flux that is reflected by the surface. Measurement through the apex of the aluminium cone eliminates this term and gives the true surface temperature. The cone was mounted on styrofoam floats. All measurements were made from a small boat. Since the Barnes PRT-5 measures radiation within the 8-14 μm waveband, emissivity determined by this method also refers to this waveband. The assumption is made that values obtained in this way can be referred to the whole longwave portion of the spectrum.

Spot values of emissivity were made in this way both close to the tower and to the dock (Table One). They show very little variation around a mean of 0.972 although cloud type and amount varied considerably between days. On four occasions (A,B,C,D) measurements were made at both the tower and dock sites within a few minutes of each other. The dock-side water was noticeably more turbid on these occasions but differences in emissivity were insignificant. Nor could any variation with chemical composition be found (Davies, Robinson and Nunez, 1971). Anderson (1954) came to a similar conclusion in his study at Lake Hefner. Our mean value agrees closely with his value of 0.97 and it would seem that 0.97 is a suitable value to apply to all fresh water bodies except where films of foreign substances, such as oil, are present. During the field project there was no opportunity to evaluate such effects. However, these were simulated in a laboratory experiment using an infra-red spectrophotometer (Beckman, Model IR 12) with a reflection attachment. The spectral reflectivity of a water sample was compared with that of a standard (chromium) and the integrated emissivity over the 8-18 μm interval was obtained from

$$\varepsilon = \int_{8\mu m}^{14\mu m} \{1 - Rs_\lambda \ (B_\lambda/A_\lambda)\} \ d_\lambda \tag{2}$$

in which Rs_λ is the spectral reflectivity of a standard sample at wavelength λ, A_λ is the spectrophotometer response in arbitrary units to the reflectivity of the standard and B_λ is the response to a water sample. The integration was performed from measurements at 14 wavelength intervals.

TABLE TWO

Laboratory Emissivity Results

Water Sample	Emissivity
Distilled	.980
Tap	.980
Dissolved detergent	.984
Surface scum of detergent	.983
Lake Ontario	
(1) Clear	.978
(2) Clear	.979
(3) Dirty, settled	.976
(4) Dirty, stirred	.876
Corn oil, surface film	.966
Corn oil and detergent mixed on surface	.979
Machine oil	
(1) Thin film (<1 mm) dispersed with toluene	.956
(2) Thick film (≈3 mm)	.958
Crude oil (Chedabucto Bay)	.952

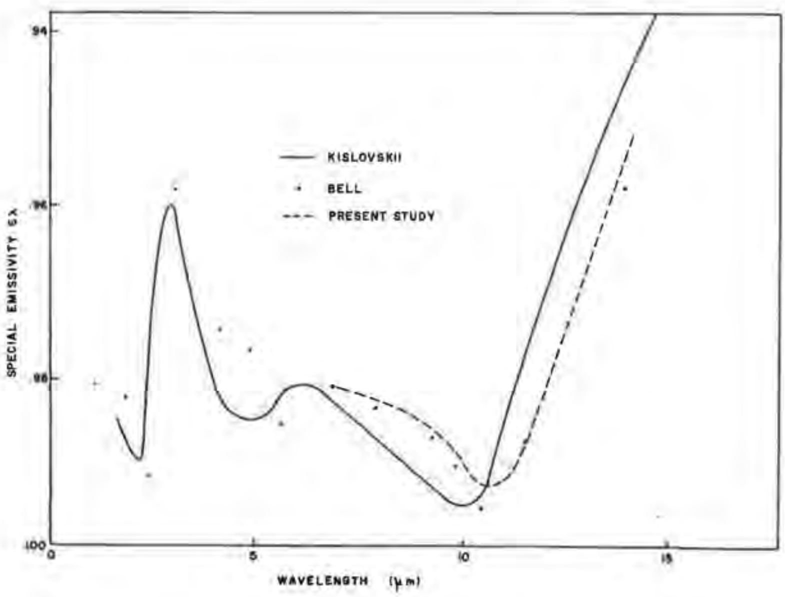

Fig. 6 Spectral variation of emissivity for pure water over the 8-14 μm range as obtained from spectrophotometer measurements. Values from Bell and Kislovskii are also shown.

The emissivity of chromium, assumed constant with wavelength, was taken as 0.95.

As an initial check on the procedure, spectral emissivities for pure water were evaluated and compared with those given by Bell (1957) and Kislovskii (1959) over the 8-14μm range. The results are very similar to those previously published values (Fig. 6).

The emissivities of water with various additives and surface contaminants were then examined (Table Two). These not only confirm the field result that emissivity is independent of water composition but show that it is virtually independent of surface contamination. The presence of surface oil lowered the emissivity by about 3%, but the type of oil was of little importance: differences between crude and machine oil were less than 1%.

5. Conclusion

Since both surface albedo and surface emissivity are conservative quantities on a daily basis, the accuracy with which the surface radiation balance can be determined at a point, when the incoming radiation fluxes and surface temperature are known, depends only on measurement accuracy. The accuracy with which the radiation balance field for the lake can be constructed will depend mainly on uncertainties in evaluating incoming fluxes between measurement points. In turn, these will depend on the spatial variation in cloud amount and type. Uncertainties in constructing the lake surface temperature field on a daily basis are not so crucial to the radiation balance because fluxes computed by the Stefan-Boltzmann law are relatively insensitive to temperature error (Davies, Robinson and Nunez, 1971).

6. Acknowledgements

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CLIMATOLOGY AT THE INTERNATIONAL GEOGRAPHICAL CONGRESS

MONTREAL, 1972

by

Marie Sanderson

A great event in the history of geography in Canada was the hosting in Montreal, August 10-17, of the 22nd International Geographical Congress. Since there are some 70 member countries of the sponsoring organization, the International Geographical Union, and Congresses are held at four-year intervals, the meeting in Canada was a once-in-a-lifetime event for Canadian geographers.

The Centennial of the first Congress held in Belgium in 1871, as well as the 50th Anniversary of the founding of the International Geographical Union, were celebrated in Montreal. The President of the I.G.U. for the meeting was Stanislaw Leszczycki of Poland. In Canada, the responsibility of the Congress lay with the Canadian National Committee for Geography, whose chairman is Gordon Merrill of Carleton University and the chairman of the Congress was Brian Bird of McGill University.

Planning for the Congress began shortly after the 1968 Congress in New Delhi and John Warkentin of York University was appointed chairman of the program committee. The 13 sections listed below were identified by the committee as the ones around which the program should be built.

- I Geomorphology
- II Climatology, Hydrology, Glaciology
- III Biogeography and Pedology
- IV Regional Geography
- V Historical Geography
- VI Cultural Geography
- VII Political Geography
- VIII Economic Geography
- IX Quality of the Environment
- X Agricultural Geography and Rural Settlement
- XI Urban Geography
- XII Geographic Theory and Model Building
- XIII Remote Sensing, Data Processing, Cartographic Data Presentation

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* Marie Sanderson is Associate Professor of Geography at the University of Windsor, and arranged and convened the Section II programme of the 22nd International Geographical Union.

The first task of the section convener was then to identify themes for the program which could be listed in the call for papers in the First Circular (January, 1970). It was noted that climatic problems were discussed at the first Congress meetings in Antwerp in 1871. There, 87 questions were proposed for discussion, among them "Is there an ice free ocean at the North Pole?" and "What are the meteorological consequences of deforestation?" At the last Congress held in North America in Washington in 1952, the section on climatology was co-chaired by Austin Miller (England) and Hermann von Wissmann (Germany) with C.W. Thornthwaite as secretary. One session was held and eight papers presented. By 1964 when the Congress was held in Great Britain, the section of climatology had expanded to include papers in hydrology, oceanography and glaciology since it was realized that all of these fields were concerned with the energy and water balance at the surface of the earth. In new Delhi in 1968, the title was the same and 34 papers were read in Section II, in Climatology, Hydrology and Glaciology, with no papers in Oceanography.

In identifying themes for the 1972 Congress, the opinions of many climatologists throughout the world were sought as to the most important research areas in present-day climatology. The integrated result of the polling was the list below, as published in the First Circular.

1) Heat and moisture balance of the whole earth, including new instrumentation.
2) Climatic models and climatic variation.
3) Heat and moisture balance of the tropical world.
4) Heat and moisture balance of the Arctic and Subarctic.
5) Plant-climate relations.
6) Man-climate relations: Perception and modification of climate.
7) Urban and pollution climatology.
8) Economic and applied aspects of the water balance.

In the circular, it was also stated that "if appropriate papers are received, joint sessions may be held with Biogeography, Quality of the Environment and Geographic Theory and Model Building, or with the Commissions on the International Hydrological Decade, Humid Tropics and Man and Environment."

The deadline for submission of papers was set for August 31, 1971 in order to allow time for the pre-publication of the Congress proceedings. Most of the contributed papers were received by November, 1971, although papers were accepted for presentation up to the time of the Congress. The papers received in time were published in the two volume "International Geography," the Congress pre-publication edited by Peter Adams and Fred Helleiner. Volume I contains 58 papers in Climatology.

A total of 64 papers were submitted to Section II from geographers in 16 countries. Each paper was sent to two referees who evaluated it and recommended that it be read by title only or allowed from 10 to 30 minutes in the program. In addition to the contributed papers, 15 papers by non-geographers were invited, the result of a suggestion by F.K. Hare. "We must invite papers to bring in others than geographers who are in fact doing geographical climatology without knowing it -- meteorologists, oceanographers, soil scientists, ecologists, civil engineers. By geographical climatology, I mean the study of the climate of the earth's surface, not the free atmosphere, considered primarily as an element of the human and biotic environment." The non-geographers who accepted the invitation to take part in the Congress and contributed greatly to the success of the Climatology Section were: meteorologists, Helmut Landsberg, R.E. Munn, Heinz Lettau, T.L. Richards, Murray Mitchell, Wayne Wendland, R.W. Longley, Morley Thomas; oceanographers, R.W. Stewart, Moira Dunbar, R.W. Trites; physicists, J.P. Bruce, Keith Rodgers; engineer, Dave Witherspoon; forest ecologist, Ken Knoerr and soil scientist, Ken King.

When the majority of the papers had been received, it became obvious that they could not be fitted into the narrow eight themes originally identified. In reality, so many good papers were submitted from the world community of climatologists, that i was realized that many more than eight sessions would be required. The themes that finally emerged were the following:

1) Urban Climatology.
2) Water balance - runoff.
3) General energy balance.
4) The energy and water balance of the Arctic and Subarctic.
5) Water balance - precipitation.
6) Bioclimatology.
7) Climatic models and climatic change.
8) Man-climate relationships.
9) General climatology.

In addition, it was decided to arrange several special sessions. The two sessions called the "Thornthwaite Memorial Sessions on the Water Balance" were arranged by Russ Mather and the convener, since they felt that this Congress in North America, 10 years after Thornthwaite's death, would be a fitting occasion to honour the memory of a great climatologist who was also a geographer. The two joint I.H.D. Commission-Climatology sessions on the International Field Year on the Great Lakes were arranged by Arleigh Laycock and the convener in order that this outstanding example of international scientific co-operation in which many geographers are involved and which was in progress in Canada at the time of the Congress, he brought to the attention of the international geographic community. The third arranged session was the session on Oceanography. Since no papers in Oceanography had been submitted, it was decided to rectify this omission, since it is impossible to understand the energy balance of the globe without an understanding of the energy balance of the 70% of the world's surface which is ocean.

In the final published program, 76 papers were scheduled for Section II and 67 were presented. The program as it actually happened is given in the Appendix. Average attendance at the sessions was about 100, and the largest number, over 200, attended the Thornthwaite Memorial session.

A good beginning for Section II was made the opening day with the sessions in Urban Climatology and Runoff. In the former, chaired by the internationally known urban meteorologist Helmut Landsberg, aspects of the energy balance of three cities were presented: Hamilton, Ontario

A Group of Section Chairmen and Speakers discuss the Programme with Marie Sanderson, Convenor of the Climatology Programme.

From left to right: J.R. Mather, C.W. Thornthwaite Associates and University of Delaware; F.K. Hare, Environment Canada; Kenneth King, University of Guelph; Marie Sanderson; Kenneth Knoerr, Duke University; B.J. Garnier, McGill University. Photo: D.B. McGregor.

by Wayne Rouse; Montreal, Quebec by David Yap; and Budapest, Hungary by Ferenc Probald. Two papers dealt with urban pollution: R.E. Munn on particulate pollution in Windsor, Ontario; and Wilfrid Bach on the climatological modeling of urban air pollution, with examples from Cincinnati and Hawaii. Dr. Landsberg, in his brilliant summary, pointed out the need for remote sensing of the urban energy fluxes and the difficulty of truly identifying the urban effect on climate.

The session on Water Balance-Runoff was chaired by F.K. Hare, Director General, Science Policy, Canada's Department of the Environment, and had papers on runoff from four countries; Poland (Irene Dynowska), Mexico (Laura Maderey-Rascon), United States (M.C. Roberts) and Canada (E.S. Spence, Erika Gaerntner and W.E.S. Henoch). Women's liberationists will note that this session had the largest proportion of female speakers (3 of 6) while the total number of papers given by female scientists in Section II was five.

Following the Thursday sessions, a reception was given by the University of Windsor at the McGill Faculty Club for all speakers and chairmen in Section II.

There were two sessions on the second day of the Congress. F.F. Davitaya (Director, Vakhushti Institute of Geography, Tblissi, USSR), new vice-president elect of the I.G.U. was the chairman of the session on General Energy Balance. Papers were given on radiant energy intake research in Australia (David Miller), evapotranspiration in Poland (Janusz Paszynski) and the effect of roughness on evapotranspiration in France (B. Seguin). The session on Oceanography was chaired by A.E. Collin, Director General of the Marine Sciences Directorate of Environment Canada, who stressed the historic lack of interest of geographers in Oceanography and the great possibilities for geographic research in the oceans. The four papers in this session differed in approach and subject matter but all pointed up the problems in research in the oceans. The legal problems of the semi-enclosed seas of the world were outlined by Lewis Alexander, who is one of the few geographers doing oceanographic research, and the organizer of the "Law of the Sea" conference in Rhode Island. The problems of estimating the energy balance of the oceans were enumerated by R.W. Stewart who is Director of Marine Sciences, Pacific Region, and was a participant in the SMIC study of the Massachusetts Institute of Technology. Moira Dunbar and R.W. Trites presented papers on current research in two very important ocean areas in Canada - Nares Strait in the Arctic, for its export of ice southward, and the Gulf of St. Lawrence, soon to be the locale of the "Year of the Gulf" project.

On Saturday, August 12th, there were three scheduled sessions of Section II and a joint session with Geomorphology. The first, entitled "The energy and water balance of the North American Arctic and Subarctic" was notable for the youthfulness of the participants and also its McGill flavour, since the chairman, R.J. Rogerson of Memorial University of Newfoundland, and three of the speakers were McGill graduates: Atsumu Ohmura, who discussed some energy balance studies on Axel Heiberg Island; A.G. Price, snowmelt runoff research in Labrador; and W.P. Adams, the problems of sampling a subarctic lake cover. Tony Brazel spoke of his energy balance studies in the western North American subarctic, in the Chitistone Pass area (Alaska), with the High Mountain Environment Project of the Arctic Institute of North America. A last moment addition to the program of M. Gavilova from the Permafrost Institute at Irkutsk (USSR), added an international flavour to the session with her paper on "Icings radiation and heat balance". Apparent from this session was the excellent calibre of northern climatic research being done by young Canadian Geographers.

W.P. Adams, Trent University, was chairman of the joint Climatology-Geomorphology session on the Canadian Arctic which attracted a large audience. Two climatic papers were given. The results of some subsurface temperature research on Devon Island were described by F.G. Hannell, and of some thermal contrasts between several types of surface in the St. Elias Mountains, Yukon Territory, as part of the Icefield Ranges Research project, by Ray Lougeay.

In the afternoon, the special joint Climatology-I.H.D. Commission sessions on the International Field Year on the Great Lakes took place. This international research program involving hundreds of scientists from both United States and Canada, to learn more about the waters of Lake Ontario and its basin as a basis for beter management of all large lakes, got underway in April, 1972. The research program involves four main areas, lake meteorology, energy balance, terrestrial water balance and water movement. Unfortunately, not many results are yet available, but the basic problems and much background data were presented in the two sessions chaired by Arleigh Laycock, the Canadian representative on the I.H.D. Commission, and Morley Thomas of the Atmospheric Environment Service, which is greatly involved in the Field Year.

An introduction was given by Ira Brown, Secretary of the Canadian National Committee of the I.H.D., on the aims and projects of the I.H.D., and an explanation of the International Field Year program by J.P. Bruce, Director of the Canada Centre for Inland Waters. Three Canadian scientists who have been involved with the planning of the Field Year over the past four years spoke of various aspects of the problems involved. Dave Witherspoon, chairman of the terrestrial water balance work group, discussed the general water balance of the Lake Ontario basin and T.L. Richards, the Canadian co-chairman of the steering committee, of evaporation studies which have been done for the Field Year. Keith Rodgers, the chairman of the energy balance work group, outlined the problems in computing the energy budget of lakes and the picture, as currently known, for Lake Ontario. Four papers were presented by geographers who are actively engaged in the Field Year program: Allan Falconer, on the use of the Earth Resources Technology Satellite data for hydrologic studies; Alan Cole, on hindcast wave heights; and David Phillips, on turbulent heat flux over Lake Ontairo in January. John Davies gave one of the most brilliant papers in the Section, on his current research in albedo emissivity and surface temperature on Lake Ontario.

On Monday, August 14th, the two Thornthwaite Memorial sessions took place under the chairmanship of Russ Mather, who is Director of the C.W. Thornthwaite Assoc. Laboratory of Climatology, N.J., and Professor of Geography, University of Delaware. All visitors to the Laboratory of Climatology during C.W. Thornthwaite's lifetime were invited to attend and take part in the sessions. Some 14 papers were submitted for the sessions and eight were given. The Laboratory of Climatology plans to publish all the submitted papers in a special memorial volume. The topics of the papers given included some that would have been very familiar to Thornthwaite; potential evapotranspiration (H.P. Bailey, F.F. Davitaya, and B.J. Garnier); regional water balance (F.K. Hare, and R.A. Muller) and effluent disposal (W.B. Jackson). They also included topics on which Thornthwaite had never worked; potential productivity (Helmut Leith, and Jen-hu Chang) and subway temperatures (T. Sekiguti). However, all would have been included in Thornthwaite's definition of climatology as the "heat and moisture balance at the surface of the earth".

After the sessions, a memorial luncheon was held for 50 "Thornthwaite associates" at the Hotel Bonaventure. Marie Sanderson was the chairman of the luncheon and introduced special speakers, Wilma Fairchild, editor of the Geographical Review, F.F. Davitaya who spoke on behalf of the foreign scientists who had known Thornthwaite, and Ken Hare who spoke of Thornthwaite as a friend and colleague. The chairman read letters from several foreign scientists who were unable to attend the Congress: Rudolf Geigor (Munich), M.K. Budyko (Leningrad) and V.P. Subrahmanyam (Waltair, India). Everyone present felt that Thornthwaite would have been pleased at the spirit of international goodwill evident at the luncheon and the Congress as a whole.

The session on Water Balance-Precipitation, chaired by Tony Brazel, of the University of Windsor, had papers on wide ranging aspects of precipitation in many parts of the globe. The paper by B.F. Findlay, the only paper dealing specifically with snow, contributed greatly to the knowledge of Canada's snow resources. R.W. Longley described precipitation patterns in Canada's prairie provinces while R. J. Fletcher analyzed synoptic conditions leading up to precipitation in the Southeastern United States, and M. Yoshino described the transport of water vapor and precipitation patterns in summer in Monsoon Asia. A method of using cloud types from satellite photography to estimate water imput in arid low latitude areas was the topic of the paper by Mario Giovinetto.

The final session on August 14th was entitled "Bioclimatology" or more accurately "Plant-Climate relations". The chairman for the session was K.M. King of the University of Guelph who is an international authority in the field. Again, the five papers presented vastly different aspects of plant-climate relationships. Ken Knoerr set the stage by explaining his most recent models, so necessary in all energy balance research, of the energy balance and microclimate of a uniform forest stand. Ken King spoke too briefly of the aims of his microclimatic research with corn at the University of Guelph, while J. Oguntoyinbo described some radiation balance measurements over cocoa in Nigeria. G.D.V. Williams and J.A. Shear spoke of more practical plant-climate problems, the former on weather variability as related to wheat production, the latter on the use of the Thornthwaite water balance method in evaluating drought.

One of the most interesting topics of the whole section was that of Climatic Models and Climatic Change in the two sessions held Tuesday morning, August 15th. Heinz Lettau, of the University of Wisconsin, chaired the first session and Murray Mitchell, Project Scientist, Climatic Change N.O.A.A., Washington, the second. There was a strong international flavour to the sessions with speakers from New Zealand, Switzerland, United States, South Africa, USSR and Chile. Two speakers described climatic models: in New Zealand (D.E. Greenland), and in the Canadian Arctic (A. Ohmura). Three speakers discussed evidence of climatic change: in South Africa (P.D. Tyson), in Chile (Hans Schneider), and in the gas composition of the earth's atmosphere (F.F. Davitaya). Two speakers concerned themselves with the relationship between climatic change and man. Wayne Wendland dealt with the past, identifying climatic change and cultural history during the Holocene period. Murray Mitchell spoke of the future and the probable impact of man's activities on global climate in the most exciting paper, in the convener's opinion, of the entire program of Section II. He summarized the most recent research evidence of the climatic effects of carbon dioxide and particulate loading and concluded that the net thermal effect of both pollutants in combination is relatively small. He re-stated a scientific truth often lost sight of by predictors of doom: that "our climate will continue to fluctuate in the future in response to natural environmental disturbances, and that the amplitute of these naturally induced fluctuations is likely to exceed the climatic changes induced by air pollution until we have arrived well into the 21st century".

The last two sessions of Section II were held on Wednesday morning, Man-Climate Relationships and General Climatology. The chairman of the former was T. Sekiguti of the Tokyo University of Education. The range of topics here was broad. Two speakers dealt with attempts at climate-man measurements: O. Ojo on energy balance of man in Nigeria, and R.B. Batchelder on frigorimeter readings as a measure of human comfort. Jack Villmow spoke of a method of using temperatures to redefine seasons, while K. Mitsui described changes in water characteristics in Kanto district, Japan, as a result of man's activities. An interesting example of applied climatology with, hopefully, expanding future possibilities was described by M. Hirt in his paper on meteorology and land use planning in Southwestern Ontario.

It was perhaps fitting that the last session of Section II of this Congress held in Montreal should be held in French, with chairman, B.J. Garnier, McGill University and two of the speakers from Quebec. J. Litynski spoke of air mass and weather types in Quebec, and A. Hufty of his method of describing weather types. C. P. Peguy of the National Centre of Scientific Research in Grenoble (France) described and showed examples of new climatic maps being produced by this French research centre. Chairman Garnier mentioned that it was unfortunate that the one lady chairman of Section II, Cynthia Wilson, had been unable to attend the Congress, and he also thanked the convener in the French language.

It is hoped that the section on Climatology, Hydrology and Oceanography at the 22nd Intrrnational Geographical Congress was successful in its two main tasks: to bring together the people in the world community of scholars who are doing research on the energy and water balance of the earth's surface, regardless of the title of their disciplines; and to gain an insight into the state of the art in different parts of the world. That the search for climatic truth is being pursued energetically by geographers in many parts of the world is obvious from the number and quality of the papers submitted. That climatologists who are geographers are more aware of climatic research being conducted by other scientists, and vice versa, is an achievement of the Congress which the convener hopes has been accomplished.

APPENDIX

International Geographical Congress

Section II: Climatology, Hydrology, Oceanography

Thursday, August 10

Urban Climatology

Chairman: Helmut Landsberg, University of Maryland (U.S.A.)

Opening Remarks - Marie Sanderson, (Convener) University of Windsor (Canada)

Wayne Rouse* and J.G. McCutcheon, McMaster University (Canada). "The Diurnal Behaviour of Incoming Solar and Infrared Radiation in Hamilton, Canada."

R.E. Munn, Atmospheric Environment Service, Department of the Environment (Canada) "A Study of Regional Particulate Pollution".

Ferenc Probald, Eotvos University Budapest (Hungary) "Deviations in the Heat Balance: The Basis of Budapest's Urban Climate".

Wilfred Bach, University of Hawaii (U.S.A.) "Urban Air Pollution - Climatological Modeling".

T.R. Oke, D. Yap* and R.F. Fuggle, University of British Columbia (Canada) "Determination of Urban Sensible Heat Fluxes".

Water Balance-Runoff

Chairman: F.K. Hare, Director General, Research Coordination Directorate, Department of the Environment (Canada)

Irena Dynowska, Geographical Institute of the Jagiellonian University, Krakow (Poland) "Types of River Regimes in Poland

Laura Maderey-Rascon, Institute of Geography, National University of Mexico (Mexico) "The Research in the Experimental Hydrological Basin of the Tizar River for the International Hydrologic Decade".

M.C. Roberts* and P.C. Klingemen, Indiana University (U.S.A.) "The Relationship of Drainage Net Fluctuation and Discharge".

* Author who presented the paper.

E.S. Spence, York University (Canada)
"The Contributing Drainage Area Variable in the Hydrology of the Canadian Plains".

D.A. Fraser and E. Gaerntner*, Sir George Williams University (Canada)
"The Water Cycle over Two Decades on Several Forest Sites at Chalk River, Ontario, Canada".

W.E.S. Henoch* and M.L. Parker, Glaciology Subdivision Inland Waters Branch, Department of the Environment (Canada)
"Dendrochronological Studies Relating to Climate, River Discharge and Flooding in several Regions of Western Canada".

Friday, August 11

General Energy Balance

Chairman: F.F. Davitaya, Academy of Sciences of the Georgian S.S.R., Vakhushti Institute of Geography, Tblisi (U.S.S.R.)

D.H. Miller, University of Newcastle (Australia) on leave from University of Wisconsin, Milwaukee
"A New Climatic Parameter-Radiant Energy Intake".

Janusz Paszynski, Institute of Geography, Polish Academy of Science, Warsaw (Poland)
"The Role of Evapotranspiration in the Heat Balance of Poland".

G. Guyot et B. Seguin*, Station de Bioclimatologie, Institut National de la Recherche Agronomique, Avignon Montfavet (France)
"Amenagement de L'espace Rural et Rugosité du Paysage".

Oceanography

Chairman: A.E. Collin, Director-General, Marine Sciences Directorate, Department of the Environment (Canada)

Lewis Alexander, University of Rhode Island (U.S.A.)
"Semi Enclosed Seas of the World".

R.W. Stewart, Director, Pacific Region, Marine Sciences Directorate, Department of the Environment (Canada)
"Problems of Estimating the Energy Balance of the Oceans".

Moira Dunbar, Defence Research Board, Ottawa (Canada)
"The Movement of Ice in Nares Strait in Winter".

R.W. Trites, Head of Coastal Oceanography, Bedford Institute of Oceanography (Canada)
"The Physical Oceanography of the Gulf of St. Lawrence".

Saturday, August 12

The Energy and Water Balance of North American Arctic and Subarctic

Chairman: R.J. Rogerson, Memorial University of Newfoundland (Canada)

Atsumu Ohmura, Swiss Federal Institute of Technology (Switzerland)
"Heat and Water Balance on Arctic Tundra".

M. Gavrilova, Permafrost Institute, Irkutsk (U.S.S.R.)
"Icings radiation and heat balance".

Anthony Brazel, University of Windsor (Canada)
"Micro and Topoclimatology: the case of an Alpine Pass, Chitistone Pass, Alaska".

A.G. Price* and T. Dunne, McGill University (Canada)
"Snowmelt Runoff in a Subarctic Area".

W.P. Adams* and A.G. Brunger, Trent University (Canada)
"Sampling a Subarctic Lake cover".

Joint Geomorphology-Climatology Session on the Canadian Arctic

Chairman: W.P. Adams, Trent University (Canada)

Hugh French, University of Ottawa (Canada)
"The Role of Wind in Periglacial Environments with special reference to Northwest Banks Island Western Canadian Arctic".

F.G. Hannell, McMaster University (Canada)
"Sub-Surface Temperature on Arctic Slopes".

Ray Lougeay, State University of New York, Geneseo (U.S.A.)
"Thermal Contrasts between Ice Cored Detrital Surfaces".

Peter Johnson, University of Ottawa (Canada)
"Variations in the Degradation of Neoglacial Ice Cored Moraines".

Joint Climatology-I.H.D. Commission Session on the International Field Year for the Great Lakes

Chairman: Arleigh Laycock, University of Alberta (Canada)

Ira Brown, Secretary, Canadian National Committee, I.H.D.(Canada)
"Canada's I.H.D. Program".

J.P. Bruce, Director, Canada Centre for Inland Waters
Department of the Environment (Canada)
"The International Field Year for the Great Lakes - A Unique Experiment in Scientific Coordination".

D.F. Witherspoon, Engineer in Charge, Great Lakes - St. Lawrence Study Office, Cornwall (Canada)
"The General Water Balance of the Lake Ontario Basin".

Allan Falconer, University of Guelph (Canada)
"Simulation Studies of ERTS-A and B data for Hydrologic Studies in the Lake Ontario Basin".

A.L. Cole, Northern Illinois University (U.S.A.)
"Climatology of Hindcast Waves on Lakes Michigan, Huron and Superior".

Chairman: Morley Thomas, Atmospheric Environment Service, Department of the Environment (Canada)

T.L. Richards, Superintendent Hydrometeorology, Atmospheric Environment Service, Department of the Environment (Canada)
"Evaporation Studies Associated with the International Field Year for the Great Lakes".

G.K. Rodgers, Institute of Environmental Sciences and Engineering, University of Toronto (Canada)
"The Energy Budget of Lakes".

J.A. Davies, McMaster University (Canada)
"Albedo, Emissivity and Surface Temperatures - Lake Ontario".

D.W. Phillips, Hydrometeorology Section, Atmospheric Environment Service, Department of the Environment (Canada)
"Patterns of Monthly Turbulent Heat Flux Over Lake Ontario in January".

Monday, August 14

Thornthwaite Memorial Session on the Water Balance

Chairman: J.R. Mather, University of Delaware (U.S.A.)

Introductory Remarks: J.R. Mather

F.K. Hare, University of Toronto (Canada)
"The Observed Water Balance of North America".

H.P. Bailey, University of California, Riverside (U.S.A.)
"Potential Evapotranspiration in Relation to Annual Waves of Temperature".

B.J. Garnier, McGill University (Canada)
"A Viewpoint on the Evaluation of Potential Evapotranspiration".

R.A. Muller, Louisiana State University (U.S.A.)
"Application of Thornthwaite Water Balance Components for Regional Environmental Inventory".

F.F. Davitaya, "The Method of Computation and Prognosis of Potential Evapotranspiration in Arid Zones".

Chairman: J.R. Mather

Introductory Remarks: H. Lettau

Helmut Leith* and Eugene Box, Department of Botany University of North Carolina (U.S.A.)
"Evapotranspiration and Primary Productivity: C.W. Thornthwaite Memorial Model".

W.B. Jackson, Environmental Studies Centre, Bowling Green State University (U.S.A.)
"Effluent Disposal in an Oak Woods During Two Decades".

J.O. Juvik and Jen-hu Chang*, University of Hawaii (U.S.A.)
"The Effects of Water Deficit on Length of Growing Session and Potential Productivity".

T. Sekiguti, Tokyo University of Education (Japan)
"Climatic Characteristics of Subway Systems in Tokyo".

Water Balance - Precipitation

Chairman: Anthony Brazel, University of Windsor (Canada)

B.F. Findlay* and G.A. McKay, Atmospheric Environment Service, Department of the Environment (Canada)
"Climatological Estimation of Canadian Snow Resources".

R.W. Longley, University of Alberta (Canada)
"Precipitation over the Prairie provinces of Canada".

R.J. Fletcher, University of Lethbridge (Canada)
"Anomalous Monthly Precipitation Gradients between Florida and Adjoining States".

Mario Giovinetto, University of California-Berkeley (U.S.A)
"Relationships between Cloud Size and the Variability of Precipitation in the Arid Lands with reference to Water Resource Planning"

Masatoshi Yoshino, Hosei University Tokyo (Japan)
"Transport of Water Vapor and Precipitation in Summer in Monsoon Asia".

Bioclimatology

Chairman: K.M. King, Department of Soil Science, University of Guelph (Canada)

Kenneth Knoerr* and C.E. Murphy, Jr., Duke University, School of Forestry (U.S.A.)
"Modeling the Energy Balance and Micro-climate of Uniform Forest Stands".

Julius Oguntoyinbo, University of Ibadan (Nigeria)
"Radiation Balance over Cocoa in Nigeria"

G.D.V. Williams, Plant Research Institute, Canada Department of Agriculture, Ottawa (Canada)
"Weather Variability and Wheat Supply Problems".

James A. Shear, University of Georgia (U.S.A.)
"A Direct Moisture Balance Method of Drought Evaluation".

K.M. King, Department of Soil Science, University of Guelph (Canada)
"Photosynthesis Relations in a Corn Field".

Tuesday, August 15

Climatic Models and Climatic Change

Chairman: Heinz Lettau, University of Wisconsin, Madison (U.S.A.)

D.E. Greenland, University of Canterbury (New Zealand)
"An Application of Lettau's Climatonomy to an Alpine Valley".

Atsumu Ohmura, Swiss Federal Institute of Technology (Switzerland)
"Ocean-Tundra-Glacier Interaction Model".

J. Murray Mitchell, Jr., Project Scientist, Climatic Change N.O.A.A. Silver Spring Md. (U.S.A.)
"The Impact of Man's Activities on Global Climate: A Reassessment".

Chairman: J. Murray Mitchell, Project Scientist Climatic Change, N.O.A.A. (U.S.A.)

Wayne M. Wendland, Center for Climatic Research, University of Wisconsin (U.S.A.)
"Climatic Episodes Identified in Holocene Cultural History".

P.D. Tyson, University of the Witwatersrand (South Africa)
"Rainfall Spectra and Recent Climatic Variation in Southern Africa".

F.F. Davitaya, Vakhushti Institute of Geography, Tblisi (U.S.S.R.)
"The Changes in the Gas Composition of the Earth Atmosphere and the Problems of Biosphere".

Orlando Pena and Hans Schneider*, University of Chile (Chile)
"Quelques Considerations a Propos de la sécheresse Recente dans le Chili Central".

Wednesday, August 16

Man-Climate Relationships

Chairman: Takeshi Sekiguti, Tokyo University of Education (Japan)

R.E. Munn, M.S. Hirt*, and B.F. Findlay, Atmospheric Environment Service, Department of the Environment (Canada)
"The Application of Meteorology to Land Use Planning in Southwestern Ontario".

R.B. Batchelder* and S.N.G. Goward, Boston University (U.S.A.)
"A Single Site Study of Hourly Values of Windchill and Frigorimeter-Recorded Cooling Power".

Oyediran Ojo, University of Lagos (Nigeria)
"Energy Balance Climatology of Man in Ibadan, Nigeria".

Jack Villmow, Northern Illinois University (U.S.A.)
"Temperature: A Measure of Seasons".

Kazuo Mitsui, Hosei University (Japan)
"Changes in Water Characteristics of Rivers in Kanto District, Japan".

General Climatology

Chairman: B.J. Garnier, McGill University (Canada)

A. Hufty, Départment de Géographie, Faculté des Lettres, Université Laval (Canada)
"Méthode Descriptive des Types de Temps".

Joseph Litynski, Université du Québec à Trois Rivières (Canada)
"Classification des Types de Circulation et des Types de Temps Pour le Québec".

Charles-Pierre Peguy, Centre National de la Recherche Scientifique, et Université Scientifique et Médicale de Grenoble (France)
"Les Coupures Gap et Nice de la Carte Climatique Detaillée de la France".

LA CLIMATOLOGIE FRANCAISE ET LE CONGRES DE MONTREAL

par

Pierre Pagney*

Une constatation s'est imposée aux climatologues français ayant participé aux travaux du 22e Congrès de Géographie: leurs préoccupations ne correspondent pas exactement à celles qui ont dominé la plupart des communications. Ici, on s'est surtout intéressé aux bilans radiatifs et aux processus évaporatoires, dans le cadre des bilans hydriques, alors que la recherche française se tourne essentiellement vers l'étude régionale des climats, avec large intervention de l'explication à base de mécanismes majeurs de l'atmosphère (circulation atmosphérique, jeu des masses d'air, etc...). Une telle situation mérite réflexion.

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Il convient de rappeler tout d'abord l'évolution récente de la climatologie française. Avant la seconde guerre mondiale, De Martonne avait préconisé en France une climatologie basée sur la description des éléments du temps et du climat, avec usage de valeurs moyennes (moyennes thermiques, moyennes de précipitations, etc...). Le classement des climats régionaux s'établissait,par conséquent, à partir de critères physionomiques. C'est dans cette attitude que devaient se maintenir, après guerre, des auteurs comme P. Estienne, à propos de son étude sur le Massif Central français (1956); et Ch. P. Péguy, dans la première édition de son "Précis de climatologie" (1961). Face à cette conception "traditionnelle" se manifesta P. Pédelaborde. Cet auteur exprimait en effet, dans le même temps, des vues entièrement nouvelles ("Introduction à l'étude scientifique du climat" 1954 et "Le climat du Bassin Parisien" 1957) desquelles il résultait que la climatologie traditionnelle (appelée encore par lui "analytique" ou "séparative") commettait l'erreur de dissocier artificiellement les éléments du climat. Il convenait, en fait, d'en respecter la combinaison, et ce respect n'était possible que dans le cadre de l'analyse des "types de temps". P. Pédelaborde préconisait donc une méthode synthétique basée sur l'étude de cartes météorologiques exprimant des systèmes de pressions, de vents, de fronts, de masses d'air, etc... et éclairant la combinaison maintenue entre températures, précipitations, turbulence atmosphérique, etc... Le film des types de temps, analysés et maintenus dans leur succession logique aboutissait tout naturellement, au-dessus d'une région, à la description et à l'explication du climat de cette région. Avec P. Pédelaborde, l'orientation de la recherche climatologique et par conséquent la nature de la documentation (cartes synoptiques, cartes de masses d'air, radiosondages) changeaient radicalement vis à vis de la climatologie traditionnelle.

* Pierre Pagney est Professeur de Climatologie dans le Centre de Recherches de Climatologie de l'Université de Dijon.

Les deux orientations extrêmes de la climatologie française ont été récemment réaffirmées par la réédition de l'"Introduction à l'étude scientifique du climat" d'une part, du "Précis de climatologie" de l'autre (1970). A s'en tenir aux travaux de recherche et aux ouvrages de vulgarisation, il apparaît cependant que les auteurs français ont adopté souvent une voie moyenne réservant plutôt à la méthode analytique le soin de décrire et à la méthode synthétique celui d'expliquer. Au demeurant, Ch. P. Péguy a exprimé, il y a fort peu de temps, avec l'auteur de ces lignes ("Recherches géographiques en France" - Montréal 1972) l'idée selon laquelle les deux tendances de la climatologie française ne sont, au fond, que les deux aspects complémentaires d'un même axe d'effort. Il n'empêche que les préoccupations de recherche font actuellement une part importante, mais non exclusive, (P. Pédelaborde porte une partie de ses efforts sur l'analyse des bilans hydriques, de jeunes chercheurs s'attaquent aux problèmes de bioclimatologie humaine) aux mécanismes de l'atmosphère, dans le cadre d'études régionales d'espaces vastes et largement répartis à la surface du Globe (Inde, Philippines, Bassin Méditerranéen, Afrique, Amérique Latine, Groenland, etc...).

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On comprend les raisons pour lesquelles les climatologues français présente à Montréal ne retrouvaient pas, dans la plupart des communications, le sens de leurs propres préoccupations. S'ils peuvent paraître se mal démarquer de la Météorologie, ils ont eu, en effet, un peu le sentiment d'être en présence d'une tendance proche de la physique, où les analyses ponctuelles l'emportent sur la notion éminemment géographique de couverture d'un espace régional.

Est-il possible, dans ces conditions, de trouver un dénominateur commun à des conceptions d'apparence aussi divergente bien qu'elles se recommandent d'un même but, la climatologie, dans le cadre d'une même discipline d'ensemble, la géographie ? et si incompatibilité il y a, est-il possible de faire la choix le plus géographique parmi les tendances exprimées ou débattues au congrès?* Ces questions peuvent sembler vaines, la recherche s'accommodant mal des limites imposées par les étiquettes (c'est ainsi, par exemple, que les services météorologiques français ont des activités conformes aux préoccupations des climatologues géographes quand ils traitent les mesures d'éléments du climate et qu'ils les cartographient). Elles sont pourtant essentielles dans la mesure où elles englobent tous ceux qui, explicitement géographes ou travaillant selon les normes de la géographie, cherchent à définir le milieu situé au contact de l'atmosphère et de la surface du Globe, dans un cadre régional plus ou moins vaste. Elles vont nous permettre en tout cas de résoudre le dilemme qui nous est posé.

En effet, il est clair qu'il existe une unité de vue fondamentale, parmi les positions choisies, sur l'objet même de notre discipline. Il est évident que les phénomènes radiatifs et que les bilans hydriques représentent des aspects essentiels de la géographie puisqu'ils conditionnent le "substratum" en même temps qu'ils en découlent. Mais il est tout aussi évident que les phénomènes de circulation atmosphérique

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* à la commission de climatologie et lors de contacts privés où s'est plus particulierement exprimé le point de vue de la recherche climatologique en France.

expriment des faits géographiques dès l'instant qu'ils dominent les climats zonaux et régionaux en même temps qu'un effet s'impose à eux par l'intermédiaire des terres, des mers et des reliefs. Ce sont les effets de déflection opérés par le système montagneux de l'Ouest nord-américain sur les flux venue du Pacifique qui imposent, à l'est des Rocheuses, des vallées planétaires déterminantes sur certains aspects climatiques à l'est du continent; c'est l'effet déflecteur des reliefs méridiens de Madagascar sur la circulation d'est, et d'une façon plus générale, la présence de l'île, qui aboutit à la dépression dynamique du Canal de Mozambique et à sa forte cyclogénèse. De même est-ce la présence d'un continent hivernal refroidi au nord-ouest des Grandes-Antilles qui explique les coulées superficielles d'air froid et sec et éclaire la récession pluviométrique alors connue par les îles (dans le même temps, l'air polaire instabilisé par la présence du Pacifique assaille les Hawaii et, en exposition favorable, y impose des chutes d'eau qui sont parmi les plus élevées de l'année).

Ainsi, alors que la plupart semblent travailler aujourd'hui aux échelles fines (encore que l'étude radiative par les bilans énergétique intéresse les phénomènes globaux - échanges thermiques à travers les parallèles) les climatologues français s'intéressent beaucoup à l'échelle des macrophénomènes, avec prise en compte du jeu des circulations de flux et des masses d'air. D'où, une superposition partielle des préoccupations géographiques avec celles de la météorologie, la climatologie générale, celle qui décrit l'ensemble des éléments climatiques et les explique à travers les mécanismes atmosphériques étant très proche de la météorologie, tandis que la climatologie régionale, saisissant les climats dans un cadre spatial déterminé représente plus précisément la synthèse géographique. Au demeurant, l'attitude française n'est pas singulière puisqu'elle rejoint celle des géographes R.G. Barry et R. J. Chorley (Atmosphere, Weather and Climate 1971), A.A. Miller (Climatology, 1965) ou encore P.R. Crowe dont les "Concepts in climatology" (1971) étudient en fait, avec le point de vue du géographe, la matière météorologique (celle-ci étant exposée par ailleurs par des météorologues: F.W. Cole, Introduction to meteorology, 1970; J.P. Triplet et G. Roche, Météorologie générale, 1971).

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La synthèse des positions s'établit donc autour de la notion d'échelle. F. Durand-Dastès a beaucoup insisté sur cette notion, essentielle en climatologie, et d'ailleurs fondamentale en géographie au niveau de l'explication des faits comme à celui de leur classement. En ce sens, on retrouve la distinction des ordres de climate: zonal, régional, local, microclimatique, distinction telle que l'ordre supérieur intègre le suivant et ainsi, de proche en proche. Un climat régional, par example, apparaît comme un faciès de climat zonal.

La question peut se poser, pour les climatologues français, de savoir s'il n'y a pas ambition démesurée à prétendre recouvrir de nombreuses parties du Globe de larges études régionales, dans le temps où la tendance est aux recherches ponctuelles menées en profondeur. La réponse est claire: il y a encore un très gros travail de climatologie à effectuer à l'échelle des méso et des macroclimats et à mener parallèlement aux échelles plus fines (la notion d'échelle étant bien entendu à prendre ici dans son acception courante et non dans son sens cartographique où la petite échelle par exemple intéresse les grands espaces réels). Il apparaît donc souhaitable que les chercheurs, quelle que soit la conception qui les anime, aient présente à l'esprit toute la gamme des échelles de l'analyse climatique et que, sans changer leur axe d'effort, ils pensent à se rejoindre. Une telle attitude peut partir conjointement des échelles les plus extrêmes. Aux latitudes intertropicales, les précipitations ont longtemps été considérées comme reflétant essentiellement l'intervention des phénomènes thermoconvectifs, en accord avec les nouvements saisonniers apparents du soleil. Plus récemment on a mis largement l'accent sur l'action des perturbations cinématiques, CIT, ondes de l'est, cyclones (I. Eaker, H. Riehl). Il apparaît aujourd'hui que les deux séries de phénomènes existent, l'un des grands problèms de la climatologie intertropicale étant de faire la part, en chaque lieu, de l'effet de la thermoconvection et des perturbations cinématiques. Or, la résolution de ce problème passe par l'échelle fine et par celle des macrophénomènes. Il est possible, en effet, de situer la part des perturbations pluvieuses à partir des mouvements généraux et régionaux de l'atmosphère, alors que la thermoconvection sera surtout affaire d'analyses ponctuelles faisant intervenir les bilans radiatifs et évaporatoires. L'explication des précipitations amazoniennes intègre très vraisemblablement cette double position.

Par de telles considérations on débouche sur le classement des climats, c'est-à-dire sur des préoccupations auxquelles ne peut échapper la climatologie. De ce point de vue, De Martonne, Koppen, Thornthwaite, Troll, ont abouti à des classements physionomiques. Il apparaît aujourd'hui souhaitable d'aller plus loin en intégrant aux aspects du climat ses mécanismes, c'est-à-dire de réaliser des classements génétiques. Or, nous retrouvons là un problème d'échelle en même temps qu'un convergence des points de vue discutés ici. Il est évident que les climats s'expliquent et se différencient par les bilans radiatifs et hydriques vus à partir du niveau du sol. Mais il est tout aussi évident qu'ils résultent de l'action des mouvements atmosphériques moins localisés, quitte à ce que les processus radiatifs et hydriques s'intègrent dans l'intervention de ces mouvements. Avec les différences d'échelles, nous voyons apparaître dans les classements, le problème des changements d'echelle (F. Durand-Dastès, Ch. P. Péguy) et le poids relatif des divers mécanismes. Si, au niveau des climats zonaux le bilan radiatif à la surface du Globe est essentiel (jeu du rayonnement solaire sur une sphère assortie d'une atmosphère), il n'empèche qu'à ce niveau interviennent directement les mouvements atmosphériques. On retrouve ces derniers dans l'organisation majeure de l'azonalité (circulations méridiennes des façades orientales des continents - Asie en particulier). C'est à l'échelle des climats plus localisés (climats locaux, microclimats) que la prise en compte des bilans radiatifs et des échanges hydriques devient fondamentale, ceci, sans ignorer que c'est à partir de la multiplication des analyses fines de ce type que l'on arrivera à mieux comprendre les situations régionales de plus grande ampleur.

En somme, il semble bien que chaque échelle comporte ses critères génétiques préférentiels et que l'approche météorologique dans le cadre des grands ensembles régionaux soit souhaitable, en même temps que l'approche plus physicienne dans le cadre intime des mesures stationnelles.

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La distorsion qui est apparue aux Français entre le champs de leurs préoccupations et celui de la plupart des climatologues réunis à Montréal découle finalement surtout de l'échelle à laquelle les uns et les autres travaillent. De sorte que, beaucoup plus que devant des divergences profondes, on se trouve en présence des pôles d'activité d'un même domaine. Il semble souhaitable que tous les chercheurs climatologues, au nom même de la géographie, pour laquelle ils étaient réunis, prennent conscience de ce fait sans qu'aucun ne modifie ses objectifs. Il semble que les français, conditionnés par le renouvellement qu'a constitué pour eux la climatologie synthétique (ou dynamique) aient encore beaucoup à faire dans ce domaine, d'autant que l'ère des satellites leur apporte des images géographiques d'une valeur incomparable. Mais par-dessus tout, les réflexions qui précèdent suggèrent que les contacts réalisés au sein d'un congrès international soient, en même temps que le moyen de faire le bilan des résultats scientifiques, celui de confronter les directions de recherches, et si possible, de les harmoniser.

NEWS AND COMMENTS

Richard F. Fuggle has been appointed to the newly-established chair of Environmental Studies in the University of Cape Town. He will be responsible for the development of an interdisciplinary programme of environmental studies, both for teaching and research, in the University. Richard Fuggle completed undergraduate studies in geography in South Africa and a masters degree at Louisiana State University. After a brief return to his home country, he came to McGill University where he completed his doctorate in climatology in the spring of 1971, presenting a thesis on "Nocturnal - Atmospheric Infrared Radiation in Montreal."

Tim R. Oke has been appointed rapporteur in Urban Climatology for the World Meteorological Organization. He would like to be kept informed of work in this field and interested persons are invited to write to him at the Department of Geography, University of British Columbia, Vancouver, B.C.

B.J. Garnier attended the conference on Urban Climatology and the 2nd International Conference on Biometeorology held in Philadelphia from October 31 to November 2, 1972. He presented a paper, co-authored by Daniel LaFleur and himself, on "A Study of Human Comfort in Montreal, Canada." The conference was sponsored jointly by the American Meteorological Society and the American Institute for Medical Climatology.

The 1973 meeting of Friends of Climatology will be held in Montreal towards the end of March. The programme is being arranged by a group consisting of Conrad East, David Frost, Don Fraser, Ben Garnier, Patrice Paul, and Rick Wilson. It is hoped to develop discussion of two principal themes: climatology and industry; and climatology and the city environment. A general session is also planned for free discussion of any matters relevant to climatology and its development. Interested persons, not already on the mailing list, are invited to write to: Professor B.J. Garnier, Department of Geography, McGill University, P.O.Box 6070, Montreal 101, Quebec, Canada.

The present number of the BULLETIN contains an account of the climatology programme presented at the 22nd Congress of the International Geographical Union held in Montreal in August, 1972. There is also a commentary on the programme by Pierre Pagney. Although climatology has appeared in I.G.U. programmes before, the contribution last August was probably better and more stimulating than at any previous I.G.U. Congress. Much of the credit for this must go to Marie Sanderson who worked untiringly to bring in papers from a variety of sources, to arrange the subsequent programme, and to manage the last-minute changes inevitable at any large international gathering. Climatologists everywhere owe her a great debt of gratitude and it is hoped that her efforts will be reflected in an increasing participation by climatologists in geographical and other environment-oriented congresses and assemblies at all levels.

Mike A. Billelo has been awarded the degree of M.Sc. at McGill University. His thesis was entitled "Air Masses, Fronts, and Winter Precipitation in Central Alaska."

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