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A PRELIMINARY INVESTIGATION OF SOLAR RADIATION OVER THE GREAT LAKES AS COMPARED TO ADJACENT LAND AREAS

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Abstract. Daily measurements of total solar radiation taken by the Great Lakes research vessel C.C.G.S. PORTE DAUPHINE are compared with simultaneous observations from adjacent shoreline stations. This preliminary investigation includes observations from sectors of Lakes Ontario, Erie, Huron and Superior within 100 miles of Sault Ste. Marie, Cleveland and Toronto during the months of April to December inclusive and presents the comparisons as monthly ratios of total radiation over water to total radiation over land. Results based on data collected since 1960 confirm the physical concept of substantially greater incoming solar radiation over the lakes during the summer (due to less cloud cover over the water areas) with the opposite effect particularly evident in the early spring and late fall.

INTRODUCTION

In Great Lakes energy budget and evaporation studies, one of the least known factors is that of incoming total solar radiation over the actual water areas. Up to the present time, data from shoreline stations have been used almost exclusively in these investigations (Bruce and Rodgers 1962), although it has been suggested that the overland data could be modified through a consideration of the seasonal variation of cloud amounts over water as compared to cloud amounts over land (Rodgers and Anderson 1961).

From basic principals the meteorologist expects on the average: 1) more cloud over land than over lake in the late spring, summer and early fall with the development of cumulus cloud due to daytime heating of the land; 2) more cloud over lake than over land during the late fall and winter with development of cumulus and stratocumulus cloud in cold air as it moves over relatively warm water; 3) frequent formation of stratus and fog over water in the early spring due to the intrusion of relatively warm moist air over the still cold lakes. As yet, however, no quantitative relationship has been established as to the relative values of incoming solar radiation over lake and over land either by month or by season.

Since 1960, the Meteorological Service of Canada, in cooperation with the Great Lakes Institute, University of Toronto, has been measuring total incoming solar radiation on the research vessel C.C.G.S. PORTE DAUPHINE. Although the record is not continuous and carries an understandable bias towards fair weather, there appears to be sufficient data to undertake at least a preliminary evaluation of solar radiation over the Great Lakes, particularly as it compares to simultaneous observations from shoreline stations.

THE DATA

Radiation data were available from the PORTE DAUPHINE and three land stations situated on the shoreline of the Great Lakes—Cleveland, Sault Ste. Marie and Toronto (Scarborough). The observations are in terms of total or global radiation from sun and sky on a horizontal plane and are recorded in

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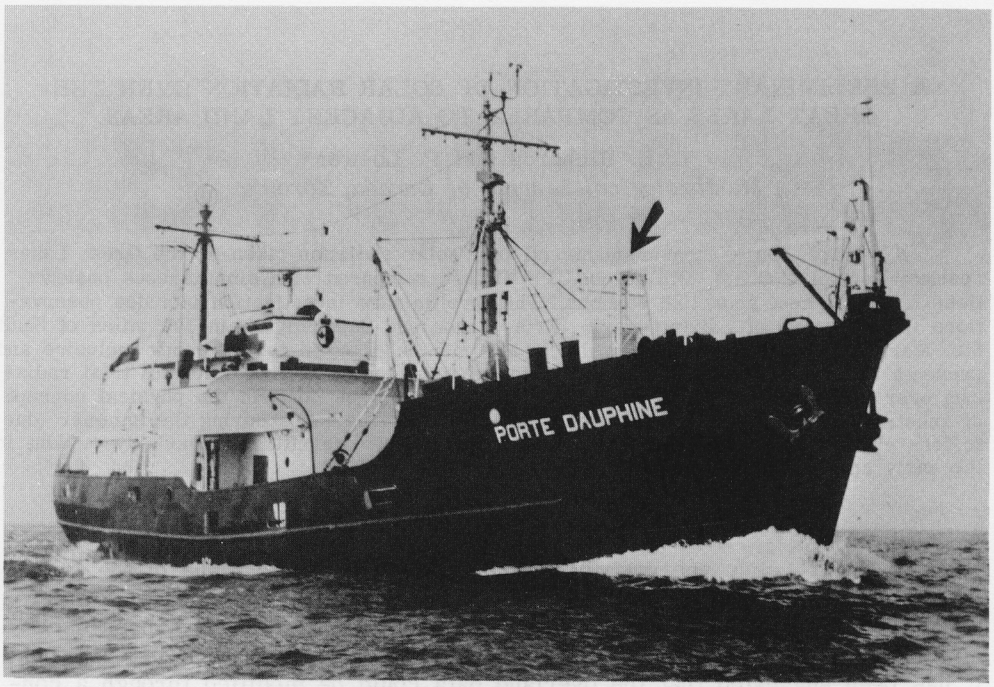

FIG. 1. Research Vessel "Porte Dauphine" showing location of pyrheliometer (arrow).

langleys (gm. cal. $cm.^{-2}$). Data for Cleveland and Sault Ste. Marie were observed and published by the United States Weather Bureau, for Toronto by the Meteorological Service of Canada.

The research vessel is equipped with a standard Eppley 180^{o} pyrheliometer gimbal-mounted on the ship's bow (Fig. 1). The instrument is operated continuously while the ship is at sea except for periods during the winter months when freezing spray makes the record unreliable. The data are abstracted and transferred to punched cards by the Canadian Meteorological Service and are published by both the Meteorological Service and the Great Lakes Institute.

At the time of the study, 4 years of simultaneous observations were available (1960-1963) for the months of April to December inclusive.

Reliability of Ship's Data

Although the ship's pyrheliometer is gimbal-mounted, there has been some concern as to the reliability of the observations due to the motion of the ship under wave action. To check the reliability of the PORTE DAUPHINE data, simultaneous hourly radiation observations from ship and shore were plotted when the ship was close to a shore station. Several such tests under varying wave conditions showed over-water and over-land measurements to be almost identical under similar cloud conditions.

As an example, one such test for 18 July 1961 is shown in Fig. 2. Inspection of the radiation curves for ship and land station reveals them to be identical from dawn to 10.00 Local Apparent Time and from 18.00 to sunset, i.e. when clear skies were reported from both locations. From 10.00 to 18.00

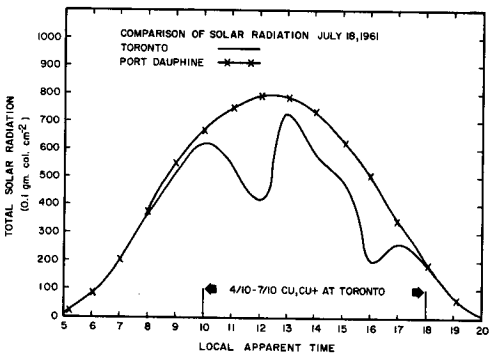

FIG. 2. Comparison of total incoming radiation at ship and at Toronto for July 18, 1961.

the land station curve shows less incoming radiation and major fluctuations apparently associated with the development of 4/10 to 7/10 of cumulus and heavy cumulus cloud. During the same period the ship's curve remained relatively smooth, with only 1/10 of cumulus cloud reported all day, that at 18.00.

On the strength of such comparisons, the ship's radiation data were deemed reliable, at least to the extent of comparing daily totals.

ANALYSIS

For this preliminary investigation a simple method was employed to compare daily over-land and over-water radiation measurements. For all cases where the ship's position was within 100 miles of Saulte Ste. Marie, Cleveland or Toronto (i.e. within one of the 100-mile sectors shown in Fig. 3),

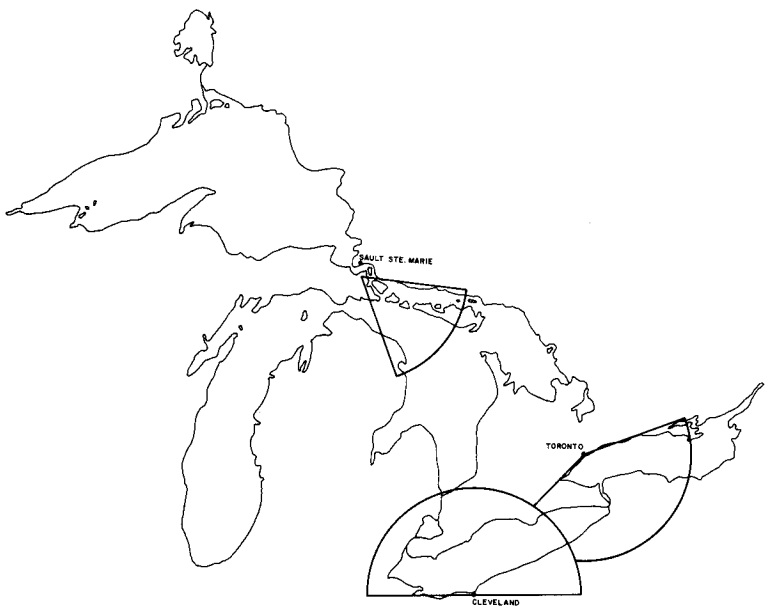

FIG. 3. Map of the Great Lakes showing sectors where comparisons of total incoming radiation were made.

ratios were calculated for daily radiation observed at the ship divided by the daily radiation for the same day at the appropriate land station. In this way a ratio of less than unity indicates less incoming total radiation over the lake than over the land, and conversely a ratio greater than unity indicates greater incoming radiation over the water. The ratios, sorted and averaged by months, are shown in Table 1 for each year and for the 4-year period.

TABLE 1. Monthly ratios of incoming radiation over water/radiation over land for the Great Lakes 1960-1963.

Year	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1960			1.01	1.19	1.28	1.89	1.36	0.96	0.90
1961		1.08	1.20	1.20		0.86	1.48		
1962				0.92	1.15	1.23	1.43	1.26	0.91
1963	0.89	1.10	1.72	1.14	1.42	1.56	1.28	1.22	0.90
No. of cases	5	21	29	41	49	45	63	36	30
Mean ratios	0.89	1.09	1.19	1.15	1.28	1.33	1.37	1.08	0.90

RESULTS AND CONCLUSIONS

The ratios shown in Table 1 represent 319 simultaneous observations of daily totals of incoming radiation over the 4-year period 1960-1963 for the months of April to December inclusive. The number of days of data available for each month is also indicated. April, with a ratio of 0.89, appears to have less incoming solar radiation over the lakes than over land, presumably due to the presence of more stratus over the water at this time of the year, as discussed in the Introduction. Data for the months of May to November indicate greater incoming radiation over water than over land, although the ratios for May and November are close to unity. This is in general agreement with the previously discussed meteorological concept of more cloud over land than over the lake during the late spring, summer and early fall due to daytime cumulus development. It should be noted, however, that the ratios for October and November in particular may be biased towards the high side. This would result from the ship having to take shelter on those days with strong winds from the northwesterly quadrant and thus missing situations when cold air over relatively warm water would produce more cloud over the lake than over the land. The ratio of 0.9 for December is in agreement with the concept of more cloud over water than over land as the air becomes colder than the water, although here again the result may be biased towards the high side for reasons already discussed for October and November.

The monthly ratios as shown in Table 1 are, within the limitations of the previously noted "fair-weather" bias, in agreement with established meteorological concepts of cloud formation over water and over land during different seasons. They give a preliminary quantitative comparison of incoming total solar radiation over lake and over land and could be used to advantage to modify long-term radiation records from shoreline stations for use in energy budget and evaporation studies of the Great Lakes.

PROPOSED EXTENSION OF INVESTIGATION

It has been noted throughout that this has been a preliminary investigation. In addition to being based on only 4 years of data and being limited to those portions of the Great Lakes within 100 miles of Sault Ste. Marie, Cleveland, and Toronto, the general method has been over-simplified. The study is currently being extended to include all the waters of Lake Ontario, Lake Erie, Lake Huron and Georgian Bay and will make use of interpolated radiation data from Sault Ste. Marie, Lansing, Cleveland, Ithaca, Ottawa and Toronto. It is expected that this extended study will be published later this year.

REFERENCES

BRUCE, J. P., and G. K. RODGERS. 1962. Water balance of the Great Lakes system, p. 41-70. *In* H. J. Pincus [ed.], Great Lakes Basin. Pub. No. 71, AAAS.

RODGERS, G. K., and D. V. ANDERSON. 1961. A preliminary study of the energy budget of Lake Ontario. J. Fish. Res. Bd. Canada 18: 618-636.