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METEOROLOGICAL BRANCH - DEPARTMENT OF TRANSPORT - CANADA

AIR MASS VAPOUR PRESSURES OVER THE GREAT LAKES

by

P. D. Jackson*

* This study was undertaken while the author was employed as a student assistant during the summer of 1962 assigned to the Lakes Investigation Sub-section of the Hydrometeorology Section. Mr. Jackson is a Honours Mathematics and Physics undergraduate at the University of Toronto.

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1. INTRODUCTION

1.1. One approach used to determine the amount of evaporation from a large body of water is the mass transfer method based on Dalton's equation

$$E = (e_s - e_{ae})\ f\ (u) \quad 1$$

where E = evaporation

e_s = vapour pressure at the evaporating surface,

i.e. saturation water vapour pressure at surface water temperature.

e_{ae} = vapour pressure of air over the lake.

$f\ (u)$ = function of horizontal wind speed.

1.2. This study is concerned with a method of estimating a value for e_{ae} from a consideration of the vapour pressure at the land stations surrounding the lakes. For this purpose, a humidity ratio H has been defined by Richards and Fortin (1962) and will be used again in this study.

$$H = \frac{\text{Vapour pressure over lake}}{\text{Vapour pressure over land}} = \frac{e_{ae}}{e_{ad}}$$

2. PROCEDURE

2.1. The method for investigating the humidity ratio H is identical to that used by Richards and Fortin (1962). The position of the ship at

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any given synoptic hour was taken as within a triangle with vertices at three land stations as shown in Figure 1. Knowing the dew points at these stations, an interpolated dew point can be found for the ship's position. This is considered to be the dew point which would occur at that point if no lake were present. The corresponding vapour pressure is taken as e_{ad}. Knowing the dew point as measured at the ship for that synoptic hour, a land-lake vapour pressure ratio can be found. By averaging the values of e_{ad} and e_{ae} values of H for each month and for each synoptic hour can be determined. Richards and Fortin (1962) derived values of H for the Great Lakes as a whole for each month and for each of the four major synoptic hours using observations from the research ship Porte Dauphine from 1959 to early 1961. This study is aimed at deriving a monthly value of H for Lakes Ontario, Erie and Huron individually and the value of H for each of the eight synoptic hours over the three lakes taken together. The previous work of Richards and Fortin was taken as a base and supplemented by Porte Dauphine data to mid-1962. Altogether 2014 observations were available, of which it was possible to match 1728.

2.2. Table 1 shows the percentage breakdown of the observations by individual lakes and seasons of the year. The seasons are defined as follows:

Winter	-	January, February, March;
Spring	-	April, May, June;
Summer	-	July, August, September; and
Fall	-	October, November, December.

TABLE 1

PERCENTAGE BREAKDOWN OF

"PORTE DAUPHINE" OBSERVATIONS

USED IN STUDY

	Lake			
Season	Ontario	Erie	Huron	Total
Winter	8.7	0.5	0.0	9.2
Spring	0.8	9.4	18.0	28.2
Summer	6.5	16.5	15.0	38.0
Fall	3.4	10.3	10.9	24.6
Total	19.4	36.7	43.9	100.0%

3. THE RATIO H:

3.1. The results of this study are shown in Tables 2 - 4 and Figures 2 - 4. Figure 2, plotted from Table 3, shows the variation in the monthly values of H using the combined observations on the three lakes. Figure 3, also plotted from Table 3, shows the same variation of H for each lake. Dashes in Table 3 indicate that corresponding Porte Dauphine observations were not made and values marked by an asterisk indicate that very few corresponding observations were available. The curves on Figure 3 are broken at these points. Figure 4 (plotted from Table 4) shows the diurnal variation in the ratio H for Fall and Winter and for Spring and Summer.

TABLE 2

MONTHLY VALUES OF THE RATIO H FOR EACH SYNOPTIC HOUR FOR LAKES ONTARIO, ERIE AND HURON TAKEN TOGETHER

GMT EST	00 7 PM	03 10 PM	06 1 AM	09 4 AM	12 7 AM	15 10 AM	18 1 PM	21 4 PM
January	1.25	1.30	1.38	1.19	1.14	1.26	1.23	1.24
February	1.21	1.44	1.34	1.47	1.40	1.14	1.14	1.15
March	1.29	1.27	1.39	1.10	1.34	1.13	1.21	1.14
April	1.01	0.99	1.03	1.09	1.12	0.98	1.09	1.06
May	0.85	0.93	0.96	0.94	0.87	0.85	0.86	0.89
June	0.91	0.97	0.95	0.95	0.95	0.92	0.93	0.94
July	1.13	1.09	1.06	1.15	1.07	1.07	1.08	1.13
August	1.07	1.12	1.19	1.16	1.12	1.04	1.06	1.06
September	1.09	1.17	1.12	1.13	1.12	1.04	1.05	1.06
October	1.16	1.18	1.20	1.21	1.18	1.06	1.04	1.10
November	1.12	1.13	1.20	1.20	1.10	1.02	1.12	1.21
December	1.35	1.25	1.20	1.32	1.22	1.33	1.31	1.24
Mean	1.120	1.153	1.168	1.159	1.136	1.070	1.093	1.102

TABLE 3

MONTHLY VARIATION OF RATIO H FOR
LAKES ERIE, ONTARIO, AND HURON

	LAKE				
	Ontario	Erie	Huron	Combined	Richards and Fortin
Jan.	1.33	1.08*	--	1.25	1.33
Feb.	1.24	--	--	1.24	1.30
March	1.22	--	--	1.22	1.21
April	--	0.94	1.14	1.04	1.14
May	0.72*	0.93	0.88	0.89	0.86
June	1.04*	1.02	0.88	0.94	0.94
July	1.13	1.12	1.04	1.10	1.09
August	1.10	1.11	1.07	1.10	1.09
Sept.	1.18	1.13	1.06	1.09	1.11
Oct.	--	1.17	1.13	1.14	1.15
Nov.	1.10	1.14	1.29	1.13	1.15
Dec.	1.23	1.40	1.23	1.28	1.31
			Mean	1.12	1.14

TABLE 4

DAILY VARIATION OF RATIO H FOR THE SEASONS FROM
COMBINED OBSERVATIONS ON LAKES ONTARIO,
ERIE AND HURON (FROM TABLE 2)

GMT EST	00 7 PM	03 10 PM	06 1 AM	09 4 AM	12 7 AM	15 10 AM	18 1 PM	21 4 PM
Winter	1.250	1.337	1.370	1.253	1.293	1.177	1.193	1.176
Spring	0.923	0.963	0.980	0.987	0.980	0.917	0.960	0.963
Summer	1.097	1.127	1.123	1.147	1.103	1.050	1.063	1.083
Fall	1.210	1.187	1.200	1.243	1.167	1.137	1.157	1.183
Mean	1.120	1.154	1.168	1.158	1.136	1.070	1.094	1.101

4. INTERPRETATION

4.1. Figure 2 is similar to the corresponding graph of Richards and Fortin (1961). Winter values of H are slightly lower and the April value is considerably lower. The likely reason for the latter change is the exclusion in this study of Lake Superior on which most of the "Porte Dauphine's" April observations up to 1961 were obtained. From Figures 2 and 3, certain seasonal effects on the value of H are noticeable. One is the great decrease of the value of H in spring. This is the time of year that land dew points, on the average, exceed lake temperatures and there is a period of net condensation. As the spring turns into summer, the lakes become warmer and the over lake vapour pressure increases, raising the value of H past unity.

4.2. The low spring value of H occurs in each lake but is displaced about one month earlier in Lake Erie than in Lake Huron. The reason for this is two-fold. Firstly, Lake Erie is further south in latitude than Lake Huron, thus receiving a slightly earlier spring and, secondly, Lake Huron is a larger and deeper lake than Lake Erie, requiring more time to warm up in summer. A similar, although opposite effect can be seen in the fall.

4.3. Figure 4, showing the diurnal variation of the ratio h, points up a minimum before noon with a secondary minimum towards evening. Assuming very little diurnal variation in vapour pressure over water, the curves then represent the inverse variation of the over-land vapour pressures. In effect then the curves show (i) over-land vapour pressures rising during the morning as increased heating leads to evaporation, (ii) a decrease in vapour pressure about noon as a result of atmospheric mixing in the lower levels due to air-mass instability, and (iii) a secondary rise towards sundown with the development of a stable layer. The wider separation of the minima in the curve for Spring and Summer represents the longer hours of heating at this time of year.

5. LIMITATIONS

5.1. More observations will have to be made on the lakes before more consistent values for the ratio H can be determined for all months of the year, for each lake, and for each synoptic hour. The value of the presently available observations is also limited by the nature of their collection. For example, all the March data come from Lake Ontario in 1961 whereas all the April data come from Lakes Erie and Huron in 1962. Obviously a correlation between March and April data will be hampered by the differences between the two lakes and the two years. However, as Porte Dauphine data continue to accumulate, a better statistical sample, covering all lakes for every month over a period of years, will be obtained.

6. APPLICATIONS

6.1. The values of the humidity ratio found in this study should be useful in several fields:

The forecaster can use the ratio to obtain an approximation of the water vapour content over the lake from a knowledge of the water vapour content over land.

The ratio can also be used to obtain meaningful evaporation estimates for each lake using the mass-transfer method as outlined in the introduction.

Finally, the ratio should enable the researcher to better understand the diurnal and annual variations of the over land and over lake vapour pressures, thus leading to a better understanding of the air-water and land-lake transitional zones.

APPROVED,

P. D. McTaggart-Cowan,
Director.

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(1) Richards, T. L. and J. P. Fortin, (1962)
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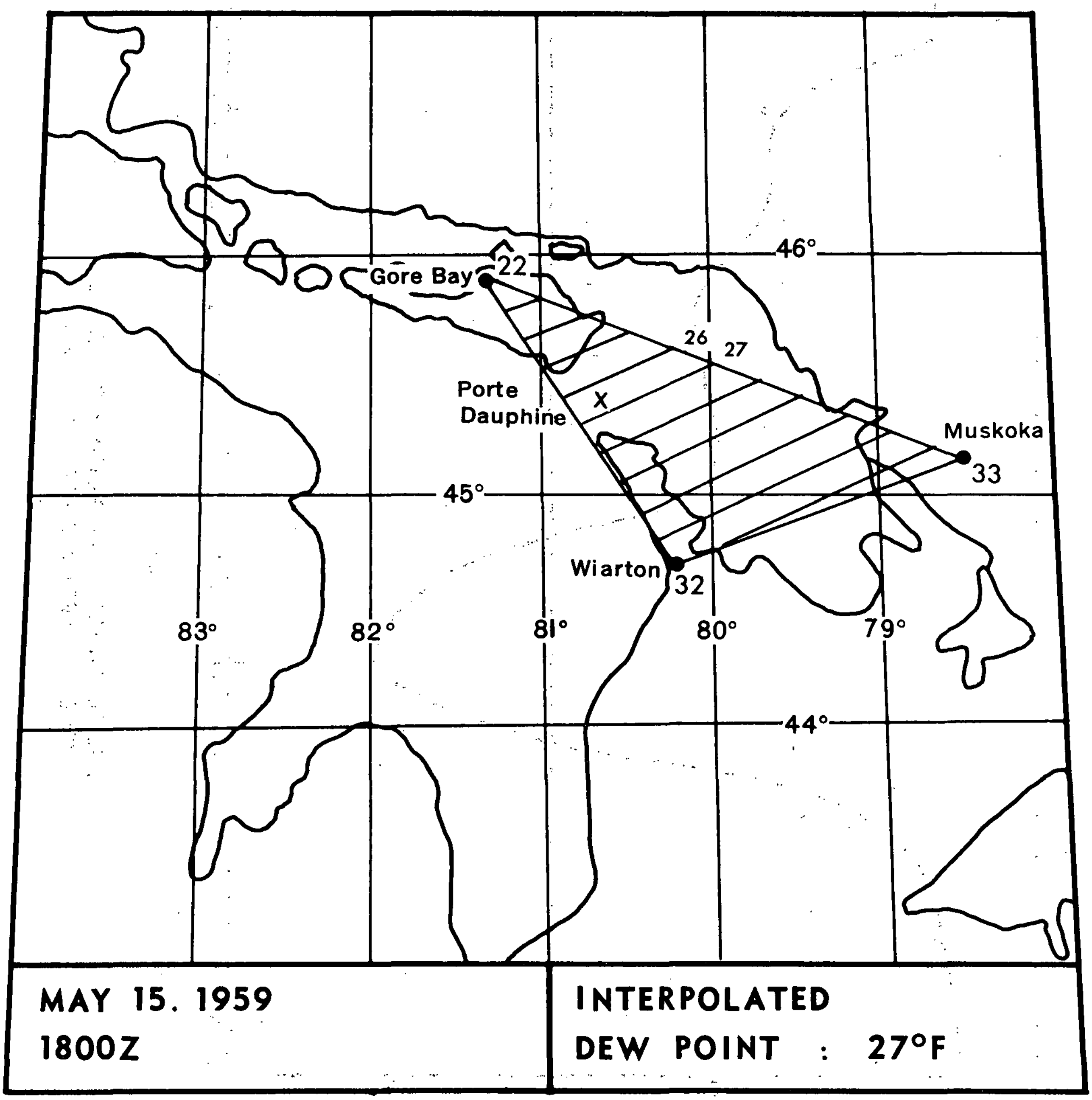
Gore Bay
22
26
27
Porte
Dauphine
X
Muskoka
33
Wiarton
32
46°
45°
44°
83°
82°
81°
80°
79°
MAY 15. 1959
1800Z
INTERPOLATED
DEW POINT : 27°F

Fig. 1

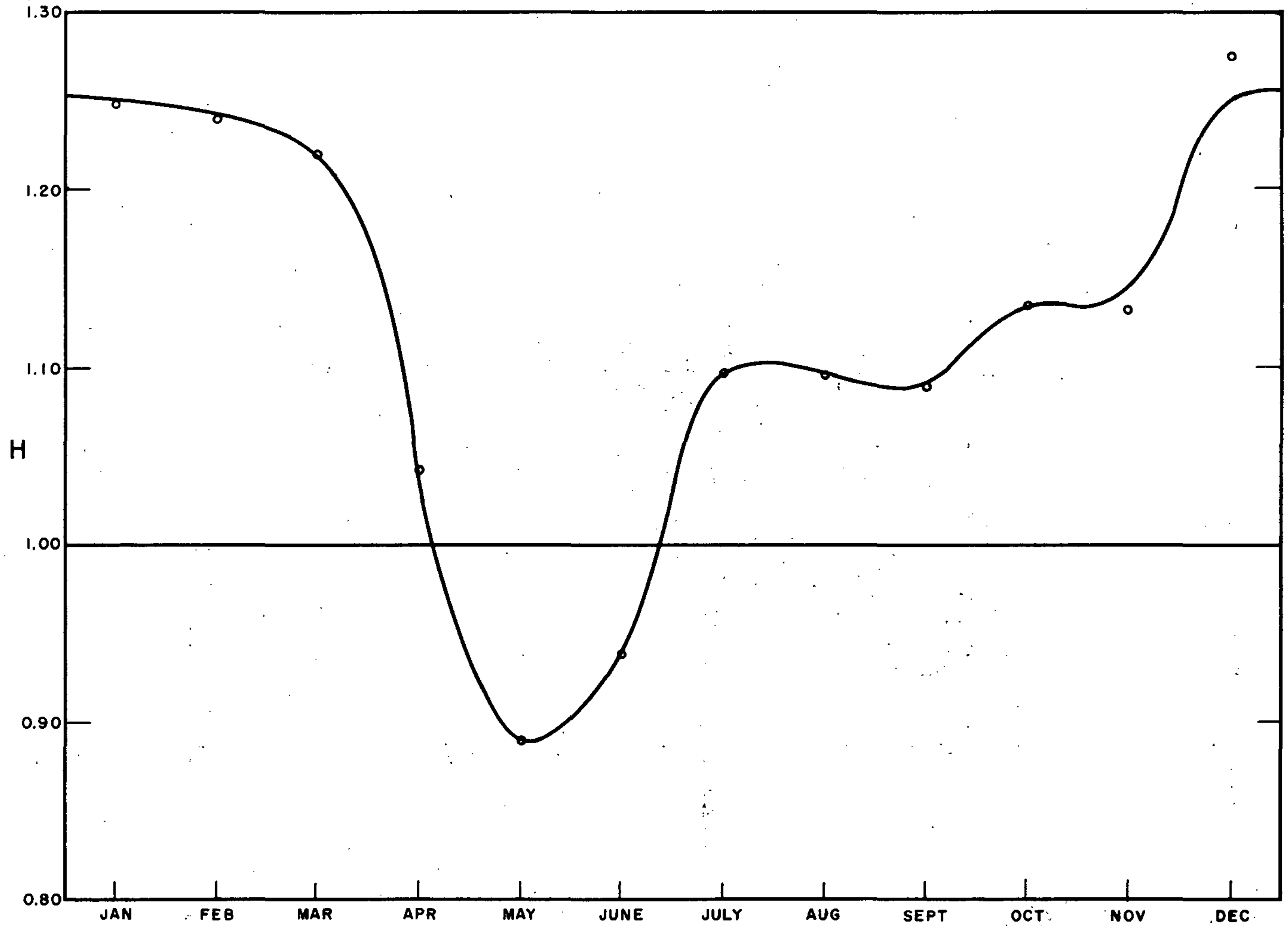

Fig. 2

ANNUAL VARIATION OF RATIO H FOR LAKES
ONTARIO, ERIE AND HURON COMBINED

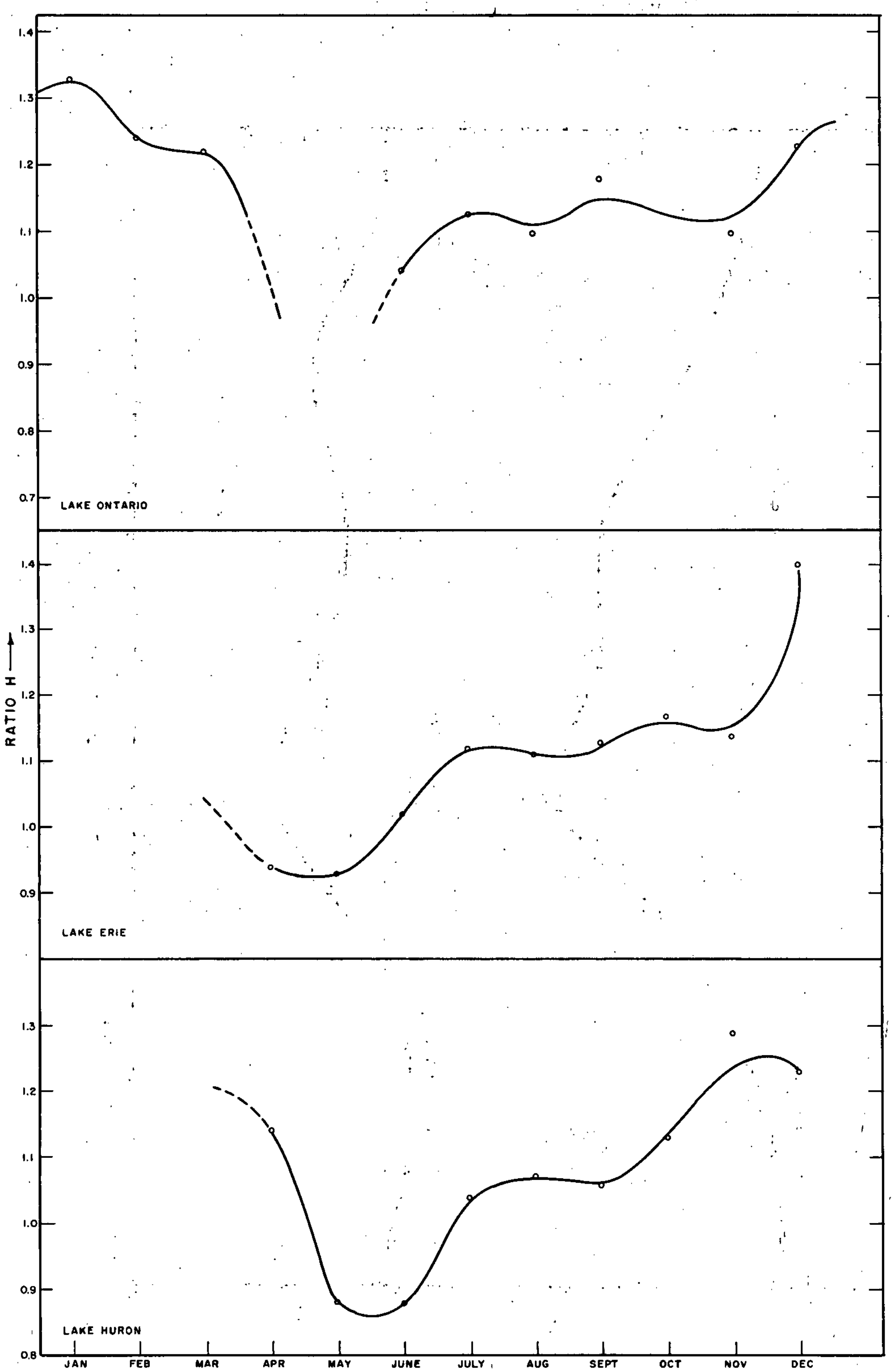

Fig. 3

ANNUAL VARIATION OF RATIO H FOR
LAKES ONTARIO, ERIE, AND HURON

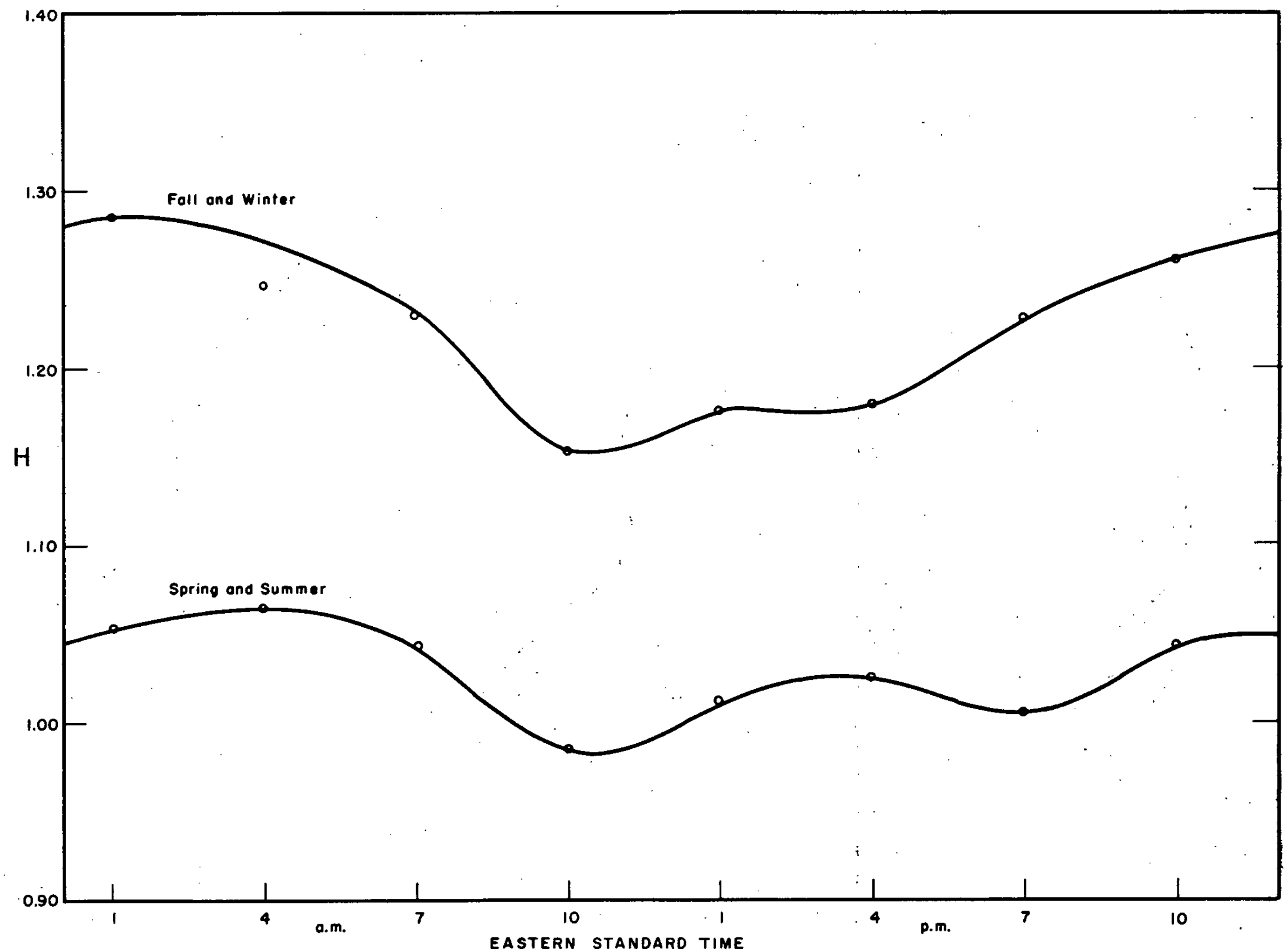

Fig. 4

DIURNAL VARIATION OF RATIO H BY SEASONS