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Report N.:



\* T E C - 4 9 7 \*

SKP Box Number: 672572426



CANADA

**DEPARTMENT OF TRANSPORT  
METEOROLOGICAL BRANCH**

**ATMOSPHERIC POLLUTION AT SAINT JOHN  
NEW BRUNSWICK**

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**U.D.C. 551.510.42  
551.556.4**

**CIRCULAR 3962  
TEC 497  
JANUARY 13 1964**

ABSTRACT

Smoke data from three air pollution sampling stations in the city of Saint John, N. B. is analysed for the period July, 1961 to February, 1963. A soiling index is obtained from standard A.I.S.I. samples and expressed in units of COH/1000 linear feet of air sampled. COH values based on wind direction, time of day and wind speed and daily maximum values are discussed. A case study of the highest COH values reported at Saint John (December 19, 1962) is presented and discussed.

CANADA - DEPARTMENT OF TRANSPORT - METEOROLOGICAL BRANCH

ATMOSPHERIC POLLUTION AT SAINT JOHN, N.B.

by

H. J. Wilson

1. INTRODUCTION

During July, 1961, three air pollution sampling stations were established in the city of Saint John, N.B. Cooperating in the project were the Medical Officer and members of the Saint John Board of Health and the Environmental Assessment Unit, Occupational Health Division, Department of National Health and Welfare. Hydrogen Sulphide ( $H_2S$ ) and smoke were the pollutants sampled, and the first data were received on July 20th, 1961. This report deals only with the smoke data; a later report provides an analysis of the  $H_2S$  observations. The period of record is from July, 1961 to February, 1963, inclusive.

Figure 1 is a simplified diagram of central Saint John and adjacent Lancaster, showing the sampling stations. The Provincial Building, located in central Saint John, is hereafter designated Station "A", and the Department of Veterans' Affairs Hospital in Lancaster is designated Station "B". A third station "C", is in a shopping plaza  $1\frac{1}{2}$  miles NNW of station A, and was the location of the  $H_2S$  sampling.

2. SAMPLING TECHNIQUES

A.I.S.I. samplers were used at stations A and B to obtain a soiling index. The sampler draws air through a filter paper-tape at a constant flow rate, and suspended particulate matter is deposited on the paper. The relative darkness of the spots on the tape is later evaluated by light transmittance, the spot intensity being expressed in units of COH/1000 linear feet of air sampled. One COH unit is defined as "that quantity of light-scattering solids producing an optical density of 0.01 when measured by light transmission".

An automatic timer shifts the tape forward every two hours so that two-hourly COH values are obtained continuously. The sampling periods are 00-02, 04-06 ....., 22-00 local standard time and the data are entered on documents at hours 01, 03, ..... 23 AST. The information is later transcribed to I.B.M. punched cards by the Data Processing Section of the Meteorological Service of Canada, which provides routine frequency distributions of the data.

A similar sampler is used for  $H_2S$  sampling, except that a chemically impregnated tape, sensitive to  $H_2S$ , is used.

3. THE METEOROLOGICAL VARIABLES

In order to correlate air pollution data with wind observations the hourly winds from Saint John Airport were transferred to the air pollution cards. The airport is located some 10 miles east-northeast of downtown Saint John, and these winds are not likely to be identical to winds in the city, even when broad class limits are used. This is because of the channeling effect of the Saint John River valley and because of local land and sea breezes in spring and summer. However, no wind record was available from the city.

4. AIR POLLUTION TABULATIONS

Table 1 is a sampling of a seasonal frequency tabulation of the Saint John air pollution data, prepared by the Machine Processing Section. The tabulation presents a frequency distribution of COH values within 3 ranges of COH (0.0 - 0.9 light, 1.0 - 1.9 moderate and  $\geq 2.0$  heavy), three wind speed classes (0-4, 5-9 and  $\geq 10$  m.p.h.) and 8 wind direction classes. The data are subdivided into four 6-hour time-of-day intervals, and are grouped seasonally into winter (Dec. Jan. Feb.), spring (March, April, May), summer (June, July, Aug.) and fall (Sept. Oct. Nov.) seasons.

An example from the table will explain its content. During the winter of 1961-62, in the period 06-11 AST, at Saint John A there were 8 occurrences of COH in the range 1.0 - 1.9, when winds were northwesterly between 5 and 9 miles per hour.

5. COH DISTRIBUTION BASED ON WIND DIRECTION

The distribution of heavier COH values according to wind direction, compared with the directional distribution of all classes of COH is of interest. A comparison of this kind enables one to pinpoint pollution sources.

In order to derive this comparison, the frequency distributions of COH values in the 1.0 - 1.9 and  $\geq 2.0$  classes were grouped together and the number of occurrences of COH  $\geq 1.0$  that occurred with N, NE, .....NW and calm winds were expressed as a percentage of the total occurrences  $\geq 1.0$ . These percentages were represented pictorially in conventional wind rose form.

Figures 2 - 8 display the seasonal frequency distributions of COH values  $\geq 1.0$  according to wind direction. The Saint John A distribution is represented by the dashed lines and Saint John B is the solid lines distribution. The light continuous line forming a perimeter for the wind rose display is the wind rose based on all classes of COH. Thus, by noting those directions where the arrows extended beyond the closed perimeter, one is able to determine the directions conducive to producing the heavier COH values at each station. From Figure 5, for example, at station B the only directions showing larger frequencies of heavier COH values than the frequencies of all classes of COH are N and NE.

The three central plotted numbers reading from bottom to top are:

- the percentage frequency of calm conditions for COH  $\geq$  1.0 at station B
- the percentage occurrence of calms with all classes of COH averaged for the two stations
- the percentage occurrence of calm conditions for COH  $\geq$  1.0 at station A.

The percentages listed to the lower right of each figure are the percentages of the time each season that COH values  $\geq$  1.0 occur at each station.

The following points with regard to these figures should be noted:

1. At Saint John A the sector which produces the largest frequencies of heavier COH values is W through N to NE (the wind arrows from this sector extend beyond the perimeter).
2. During all seasons at Saint John A, there are larger frequencies of calm conditions with heavier COH values than there are all-classes frequencies of calms. In fact, calm conditions occur more than twice as often with heavier COH values than with all-classes of COH.
3. At Saint John B, in most seasons N and NE are the directions which produce relatively large frequencies of COH values  $\geq$  1.0 (wind arrows extend beyond perimeter).
4. The frequency of calm conditions with heavy COH values at Saint John B is much greater than the all-classes frequency of calms.
5. A comparison of the percentages listed to the lower right of each figure indicates that Saint John A is a significantly dirtier location than Saint John B.

6. COH DISTRIBUTION BASED ON TIME OF DAY AND WIND SPEED

Using the frequency tabulations illustrated in Table 1, joint frequency distributions of COH values based on wind speed and time-of-day intervals can be obtained. As in the case of the wind direction distributions, COH values  $\geq$  1.0 were of primary interest. Displayed in figures 9 and 10 are the seasonal distributions of heavier COH values based on wind speed and time-of-day, for stations A and B respectively. The figures were derived by expressing the occurrences of COH  $\geq$  1.0 during each time interval as a percentage of the total number of observations in the period. Wind speed classes of 0-4, 5-9,  $\geq$  10 m.p.h. are subdivisions of the distribution for each time interval.

For example, during spring, 1962, at Saint John A, considering the COH values reported during hours 00-005 AST, 12.5% were  $\geq$  1.0 when winds were 0 - 4 m.p.h., 7% were  $\geq$  1.0 when winds were 5 - 9 m.p.h., and 9% were  $\geq$  1.0 when winds were  $\geq$  10 m.p.h.

The significant features of figure 9 are the following:

1. Winter shows the highest frequency of heavier COH values. There is also a significant increase in smokiness from the winter of 1961-62 to the winter of 1962-63. This increase can be partially attributed to higher frequencies of light winds during 1962-63. In addition, a calibration error in the flow rate of the sampler is thought to have occurred during the winter of 1962-63.

2. At all seasons of the year the highest frequency is during hours 06-11. An explanation for this lies with the fumigation process which has been investigated by Hewson (1960). Smoke trapped under the nocturnal inversion is brought down to sampler level when the inversion breaks up shortly after sunrise.

The important features of figure 10 are:

1. Heavier COH values occur most often during hours 06-11.
2. During winter the heavier COH values are fairly evenly distributed within each wind speed class.
3. There is little difference between the distributions for the two winters, in contrast with station A.
4. Summer and fall of 1961 show slightly higher occurrences of heavier COH values than does 1962.
5. Each season shows a secondary modal frequency during the evening hours 18-23. This is an observation commonly noted in the data from other locations.
6. The content of figures 9 and 10 reveals that Saint John A is a much dirtier location than Saint John B.

Figures 9 and 10 showed the absolute distribution of heavier COH values within the three wind speed classes. They suggest, in winter at least, that poor air quality is associated with strong winds. This conclusion is somewhat misleading, as can be demonstrated from Figures 11 and 12.

Figure 11 shows the distribution of COH values  $\geq$  1.0 at Station A for the three speed classes, expressed as a percentage of the total observations in each class. The data for each season and each time period are separated. The following example from the figure explains its content. During spring 1962 at Saint John A, COH values  $\geq$  1.0 during hours 06-12 were observed 70%, 45% and 30% of the time with light, moderate and strong winds respectively.

The preceding example and further examination of the figure show that the frequency of heavier COH values decreases as wind speed increases. This effect is evident in all seasons and during each time period.

Figure 12, which displays the data for Saint John B in a manner similar to Figure 11, shows the same inverse relationship between heavy COH frequencies and wind speeds.

The physical explanation for these results is that air quality is a balance between the rate of smoke production and the rate of ventilation of a city. As wind speed increases, air quality will generally improve. However, exceptions may occur when -

- (a) smoke emissions increase during very cold windy weather,
- (b) re-entrainment of deposited soot takes place during strong winds when the streets and roof-tops are dry and bare.

#### 7. THE DISTRIBUTION OF DAILY MAXIMUM COH VALUES

The diurnal variation of smokiness can be demonstrated easily, if one tabulates the hour of occurrence of the daily maximum COH value. Figure 13 shows the results of this tabulation. The data are grouped seasonally, and only include the cases where a clear-cut daily maximum occurs.

From the left hand side of the figure, for Saint John A the highest frequency during each season occurs just after sunrise, at hour 07 in fall and spring and at hour 09 in winter and summer. The fumigation process accounts for the maximum at this time. Each season shows a secondary maximum at hour 21 or 23. The relative minimum occurrence for each season is between hours 13 and 17.

Saint John B, on the right hand side of the figure, shows a diurnal pattern similar to station A. Hour 07 in spring, summer and fall and hour 09 in winter show the modal frequencies. The evening maximum in spring slightly exceeds the maximum at hour 07. The secondary mode for the other three seasons occurs at hour 21, 23 or 01. As with station A the minimum occurrence for each season is between hour 13 and hour 17.

#### 8. A CASE STUDY OF HIGH COH VALUES

The highest COH values reported at Saint John during the 20-month period of record occurred on December 19, 1962. The air pollution observations from the Saint John stations are listed in Table II. Included in the same table are the winds from Saint John airport.

Table II

COH VALUES FOR SAINT JOHN AIR POLLUTION STATIONS,  
DECEMBER 19, 1962 AND ASSOCIATED WINDS

Hour	01	03	05	07	09	11	13	15	17	19	21	23
Stn. A	2.5	3.9	4.7	4.6	6.1	6.9	4.2	1.8	0.9	0.4	0.9	1.3
Stn. B	1.0	0.7	1.3	1.5	5.1	4.1	1.9	0.8	0.3	0.3	0.3	0.5
Wnd	↙03	000	000	000	000	↖03	↑07	↗11	↗18	↑↑18	↑↑18	↗↑17

Munn (1961) has discussed the dependence of high levels of atmospheric pollution on meteorological variables. The two meteorological parameters important to the dilution of atmospheric pollution are the wind speed and its turbulent components.

Examination of Table II illustrates how the maximum COH values reported at Saint John were dependent on wind speed. The high COH values occurred during a period of light winds; when wind speeds gradually increased during the late afternoon and evening, the smokiness decreased significantly.

The degree of atmospheric turbulence depends primarily on the vertical temperature structure of the atmosphere. On a hot summer afternoon the ground is strongly heated, resulting in a decrease of temperature with height. Such a temperature distribution initiates convective currents to considerable heights in the atmosphere and the resultant turbulent mixing effectively disperses atmospheric pollution. An increase of temperature with height (an inversion) suppresses turbulent mixing with the result that pollution is prevented from being diffused vertically. The latter temperature distribution can occur on clear nights with light winds, or when warm air moves over a colder surface. A complete understanding of high pollution intensities therefore depends on a knowledge of the vertical temperature structure of the atmosphere.

Figure 14 is a surface weather map of the Saint John area for 02 AST (06 GMT) for December 19, 1962. The dominant weather feature affecting Saint John is a ridge of high pressure oriented SW - NE along the Atlantic Coast, and through the Bay of Fundy. The pressure gradient at Saint John is extremely weak, which explains the light winds reported in Table II.

A feature of the map, which affects the vertical temperature structure of the air over Saint John, is the Arctic warm front which lies NW - SE through southeastern Quebec. Overrunning warmer air on the frontal surface produces a temperature inversion aloft over Saint John. The effect of overrunning was complemented by a surface-based radiation inversion, created under clear to partly cloudy skies during the preceding night. Thus, a strong temperature inversion to heights greater than 5,000 feet probably occurred at Saint John at the time of the high COH values.

No vertical temperature profiles are available for Saint John, but a regional picture can be obtained by examining the radiosonde ascents from two United States upper air stations located within 250 miles.

Figure 15 shows the temperature profiles from the surface to 12,000 feet at Caribou and Portland, Main on December 19th at 8:00 a.m. and 8:00 p.m., AST. The 8:00 a.m. curves are strikingly similar; there is a surface-based inversion of 7°C surmounted by adiabatic conditions from 500 to 3,000 feet, above which is a shallower and less intense inversion. Smoke emissions are trapped within the inversion layers resulting in the high COH values reported at Saint John.

In the evening, the surface-based inversion had disappeared at both Caribou and Portland, while the upper warm frontal inversion had weakened. The dispersal of atmospheric pollution resulted, and COH intensities returned to more normal values.

9. CONCLUSION

Air pollution data from two sampling stations in Saint John, New Brunswick for the period July, 1961 to February, 1963 have been analyzed. Frequency distributions of heavier smoke values (i.e. COH  $\geq$  1.0) according to wind direction show that:

(a) On an absolute basis heavier COH values occur most often with west, northwest and north winds.

(b) On a relative basis heavier COH values are more prevalent with north and northeast winds.

(c) Seasonal variation is considerable; particularly in summer a sea-breeze effect is evident.

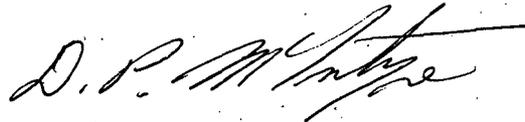
Calm conditions produce nearly twice as many occurrences of heavier than light COH values. This fact, coupled with the data presented in figures 11 and 12, indicates an inverse relationship between wind speed and air quality.

At this point it should be stressed that the wind observations, on which this study is based, are from Saint John Airport. Differences probably exist between winds from the airport and winds from downtown Saint John. In this connection, Munn and Katz<sup>3</sup> based their analysis of air pollution data in the Windsor-Detroit area on winds from the Detroit City Airport. They concluded that the wind data were representative of the Windsor-Detroit urban area when broad class limits were used. Although the topography of the Saint John area is quite different from that of the Windsor area, use of the airport winds should not invalidate the conclusions. It is suggested, however, that it would be useful to operate an anemometer near the Saint John sampling stations for a long enough period of time to determine the degree of correlation between winds from the airport and winds from the downtown area.

Heavier COH values occur most often in the period 06-11 AST. The diurnal variation of smokiness, as revealed by the hourly frequency distribution of daily maximum COH values, shows the highest pollution just after sunrise with a secondary peak in the evening. Minimum COH values are reported during the afternoon.

Finally, a case study of the largest COH values during the period of record reveals that light winds and temperature inversions were the meteorological parameters contributing to the poor air quality.

APPROVED,



J. R. H. Noble,  
Acting Director.

10.

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- (2) Munn, R.E., The Interpretation of Air Pollution Data, With Examples From Vancouver, Canada, Department of Transport, Meteorological Branch Technical Circular CIR-3454, TEC-351, 1961.
- (3) Munn, R.E., and Katz, M., Daily and Seasonal Pollution Cycles in the Detroit-Windsor Area, Int. J. Air. Poll. Pergamon Press 1959., Vol. 2, pp. 51-76.

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- Fig. 15: Vertical temperature profiles at Caribou and Portland, Maine - December 19, 1962.

Table 1 - Frequency Tabulation of Saint John Provincial Building COH Values  
with Saint John Airport winds and time of day. Period of Record - Dec. 1961 - Feb. 1962, incl.

COH 0.0 - 0.9										COH 1.0 - 1.9										COH > 2.0									
Wind Direction	N	NE	E	SE	S	SW	W	NW	CALM	N	NE	E	SE	S	SW	W	NW	CALM	N	NE	E	SE	S	SW	W	NW	CALM		
1. <u>WIND SPEED 0 - 4 M.P.H.</u>																													
00-05 AST	1	1						5	1	4	3			1	2	1		2	3	4	1							1	
06-11	1							1	1	4	1	1		1	1			3		2				1			6		
12-17	2					1	2	1	4	3			1	2		1	2	4	1	1						1	2		
18-23		1	1	1				1		1	2		1	1	6	2	12		2	2	1	1				1	2		
2. <u>WIND SPEED 5 - 9 M.P.H.</u>																													
00-05 AST	7	1		1		3	5	8		10	4		1	2		6	1		1		2				1				
06-11	3					1		2		8	4	1	1		5	2	8		9	2	3	3	2		1	1			
12-17	2		1	1		1	2	4		2	4	1		1	3	4	3							1					
18-23	1		2		1	1	3	5		11	1	1	1	1	1	8	8		2	2						2			
3. <u>WIND SPEED &gt; 10 M.P.H.</u>																													
00-05 AST	24	8	3	14	12	26	22	26		14	2	1	1		4	10	11												
06-11	16	1	7	7	2	10	12	18		16	4	3	2	3	7	37	27		3		2				4				
12-17	13		4	7	5	12	27	29		13	4	8	8	1	13	29	21		3			1	1			1			
18-23	10	4	5	7	12	12	28	20		16	5	2	1	5	4	12	24		2	1						2			

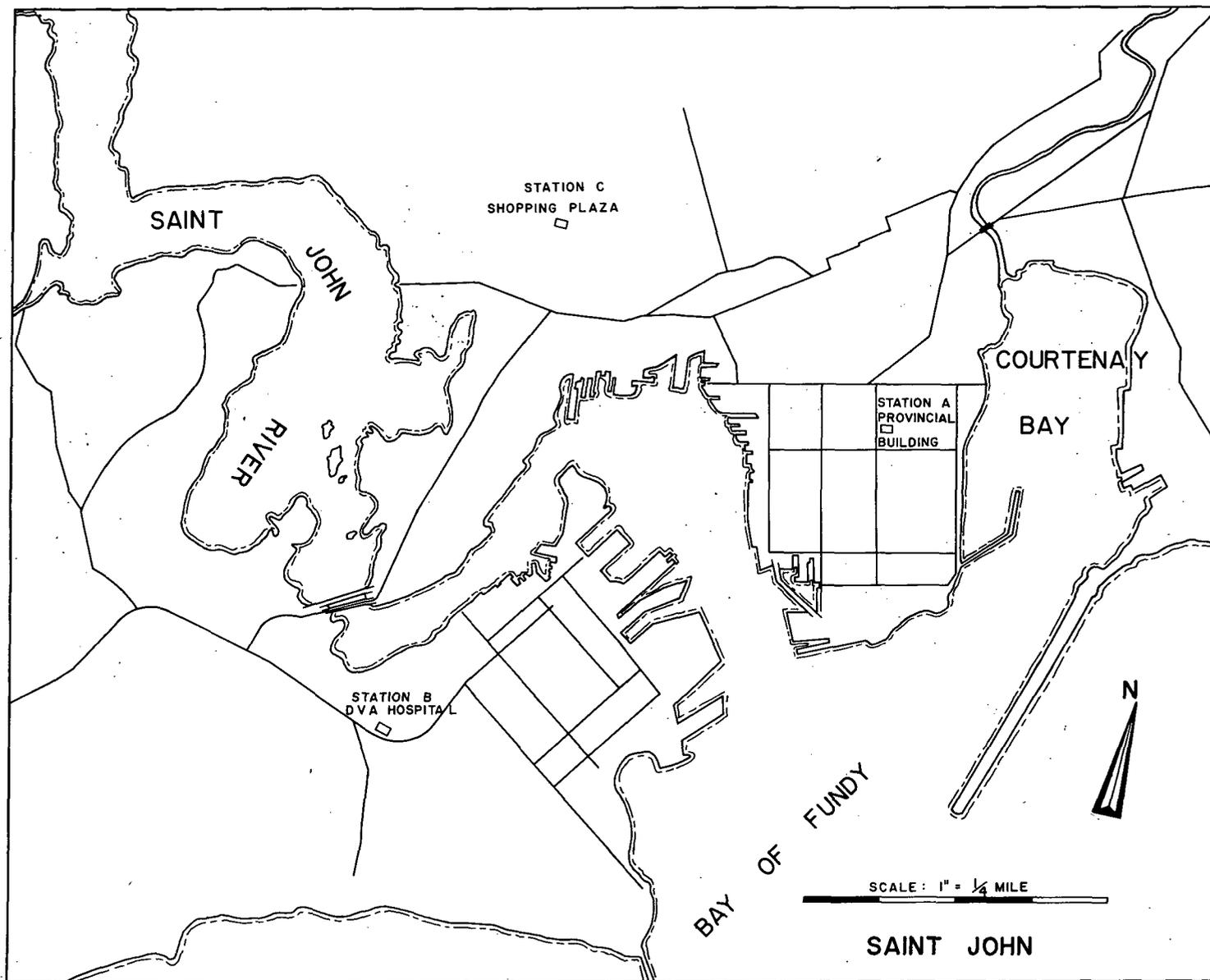


Fig. 1: Map of Saint John, N. B., showing the location of the pollution sampling stations.

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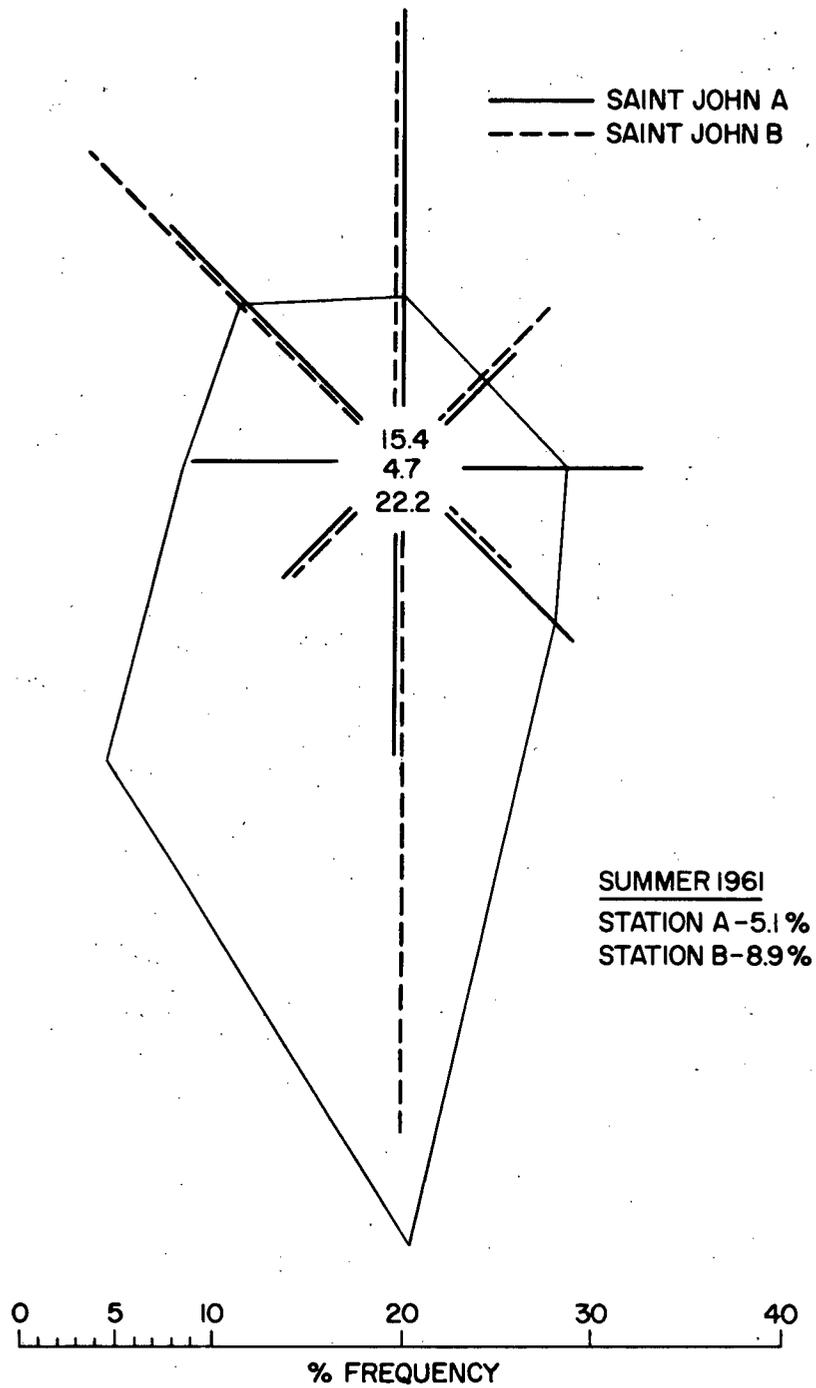


Fig. 2: Frequency distribution of COH values > 1.0 according to wind direction - Summer, 1961.

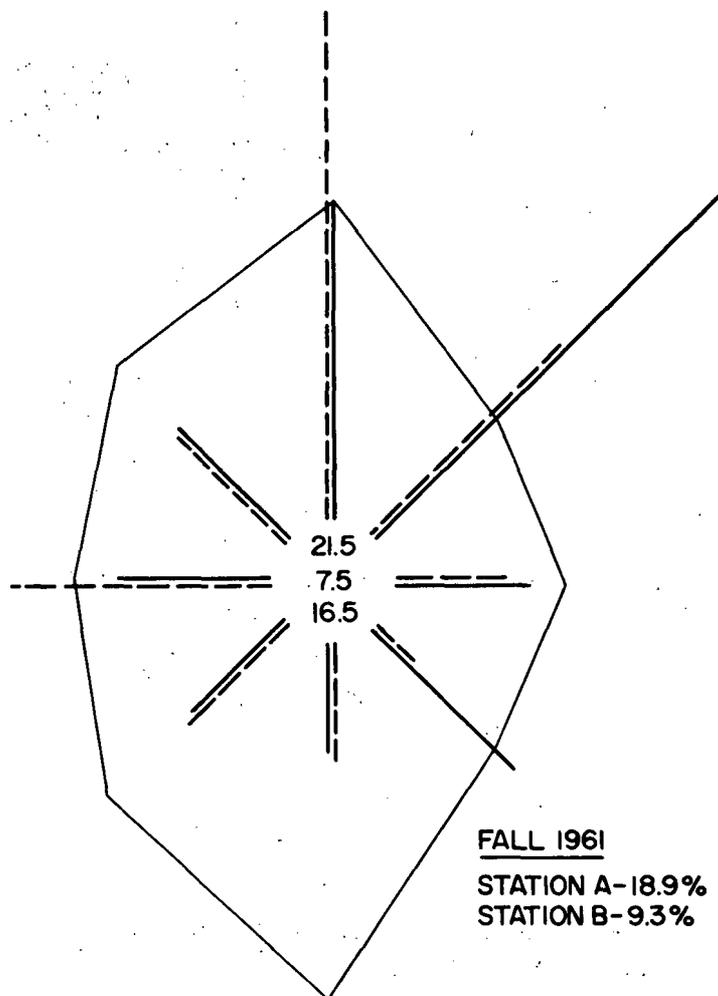


Fig. 3: Frequency distribution of COH values  $> 1.0$  according to wind direction - Fall, 1961.

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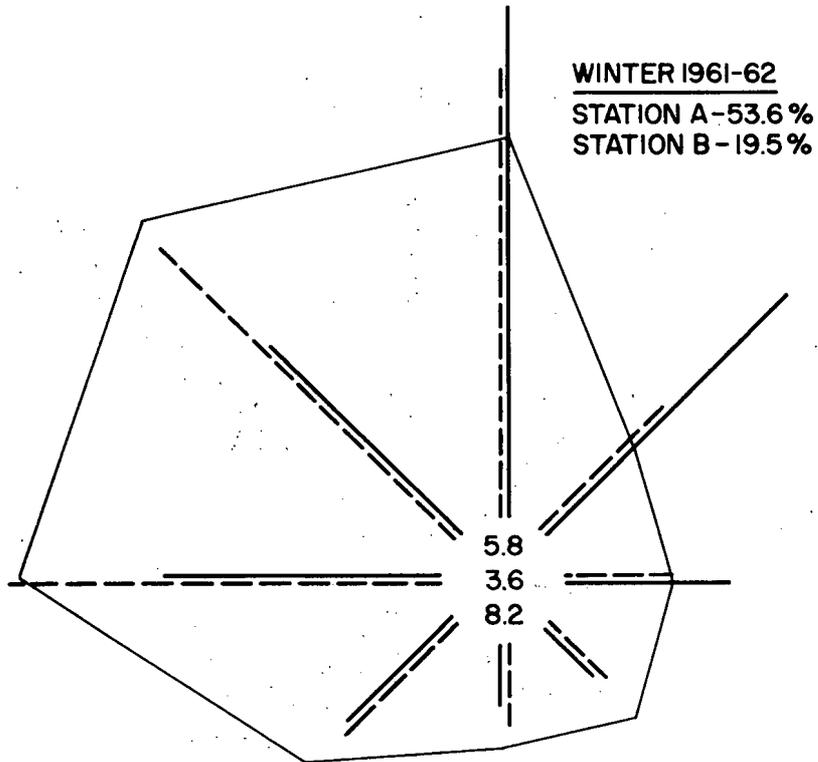


Fig. 4: Frequency distribution of COH values  $\geq 1.0$  according to wind direction - Winter, 1961 - 1962.

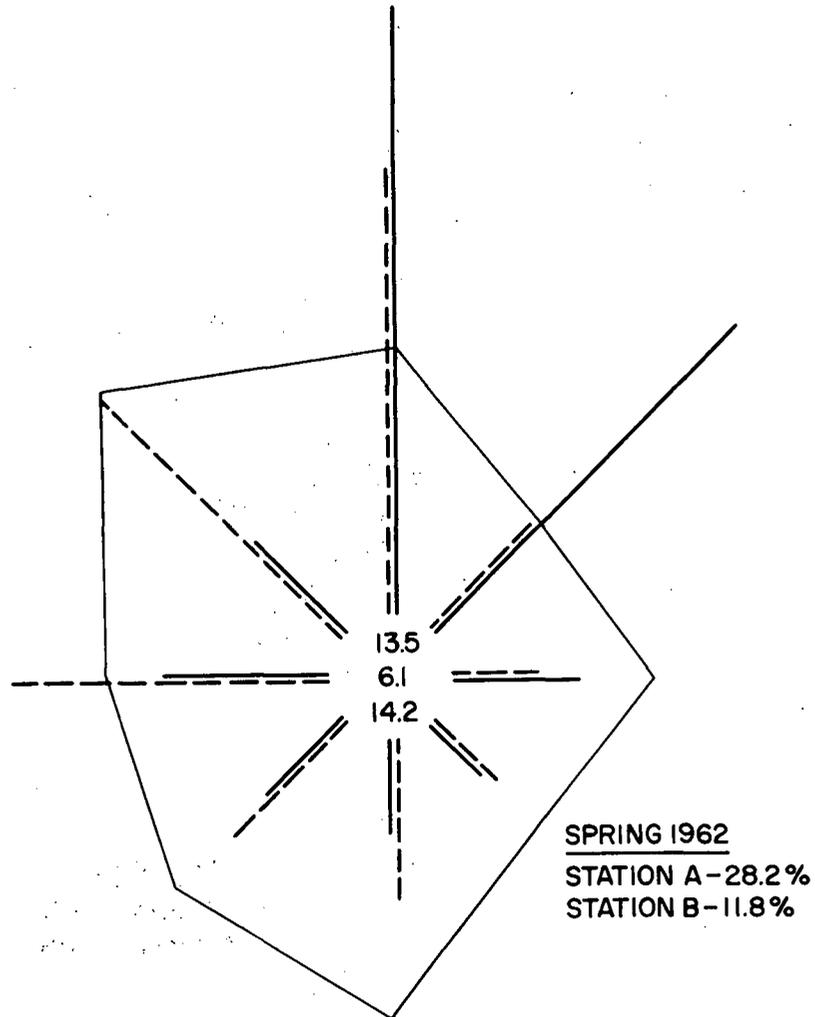


Fig. 5: Frequency distribution of COH values  $\geq 1.0$  according to wind direction - Spring, 1962.

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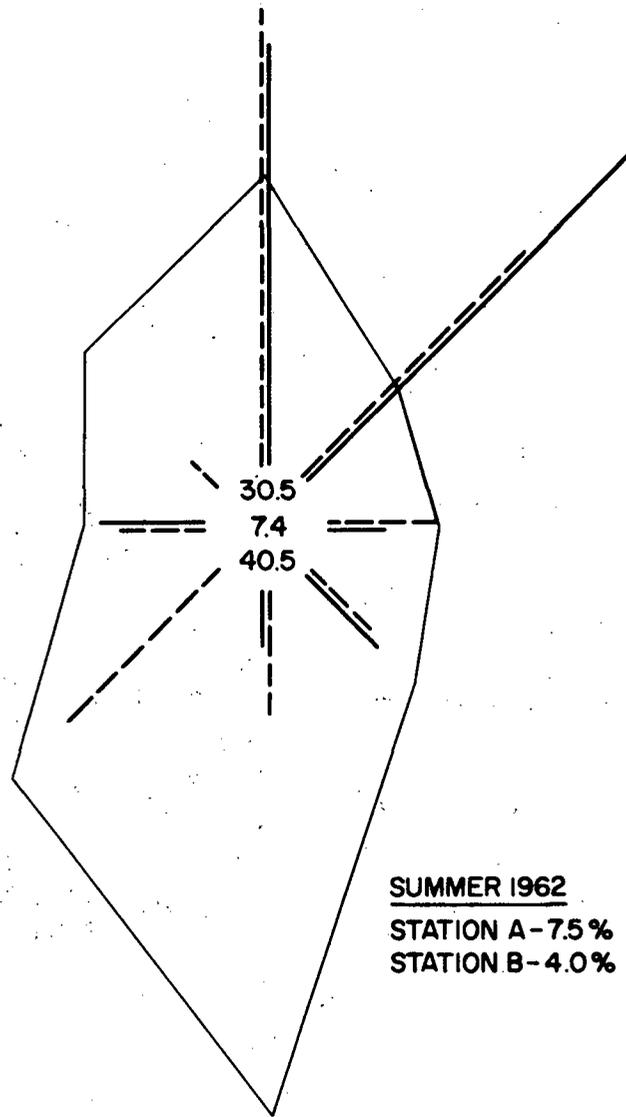


Fig. 6: Frequency distribution of COH values  $\geq 1.0$  according to wind direction - Summer, 1962.

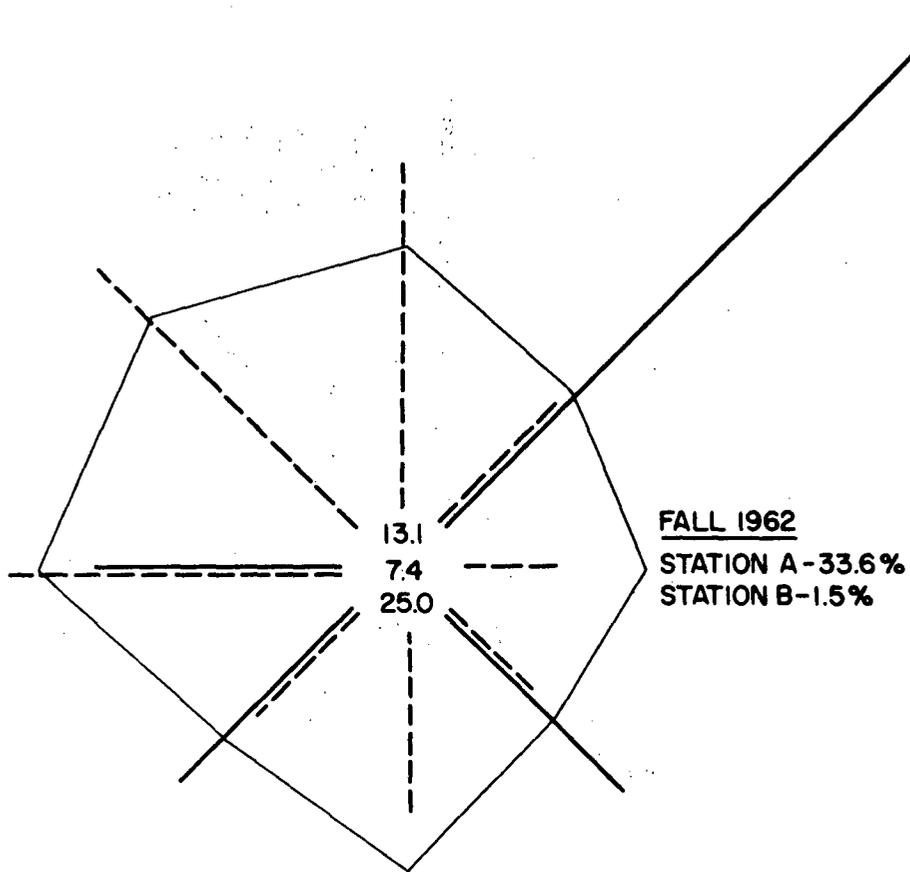


Fig. 7: Frequency distribution of COH values  $\geq 1.0$  according to wind direction - Fall, 1962.

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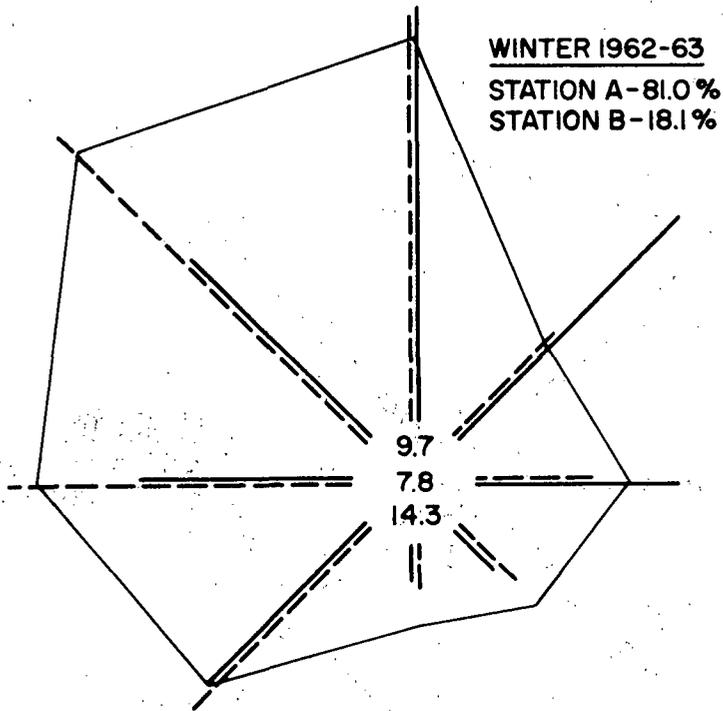


Fig. 8: Frequency distribution of COH values  $\geq 1.0$  according to wind direction - Winter, 1962 - 1963.

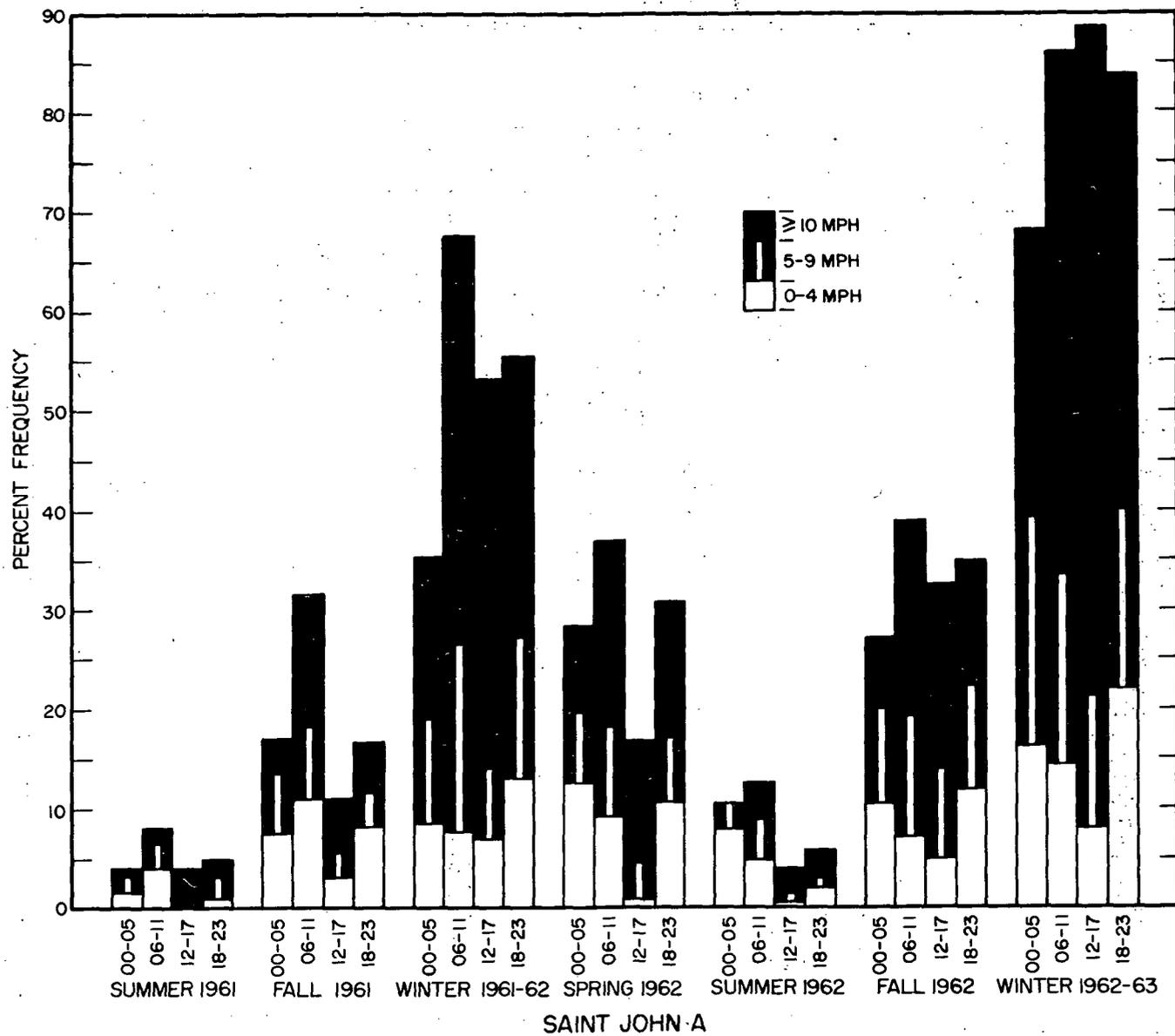


Fig. 9: Frequency distribution of COH values  $\geq 1.0$  according to wind speed and time of day - Saint John A.

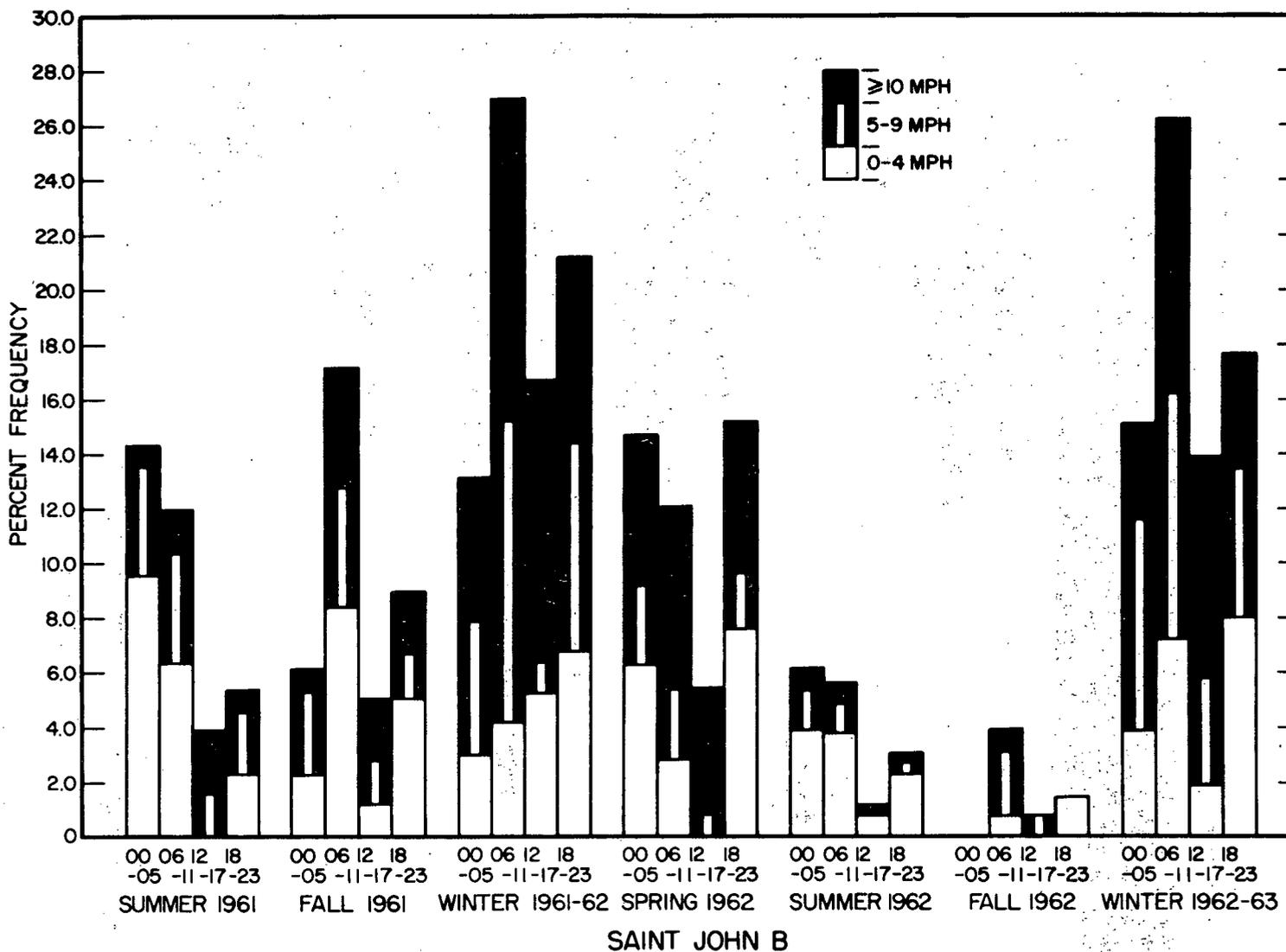


Fig. 10: Frequency distribution of COH values  $\geq 1.0$  according to wind speed and time of day - Saint John B.

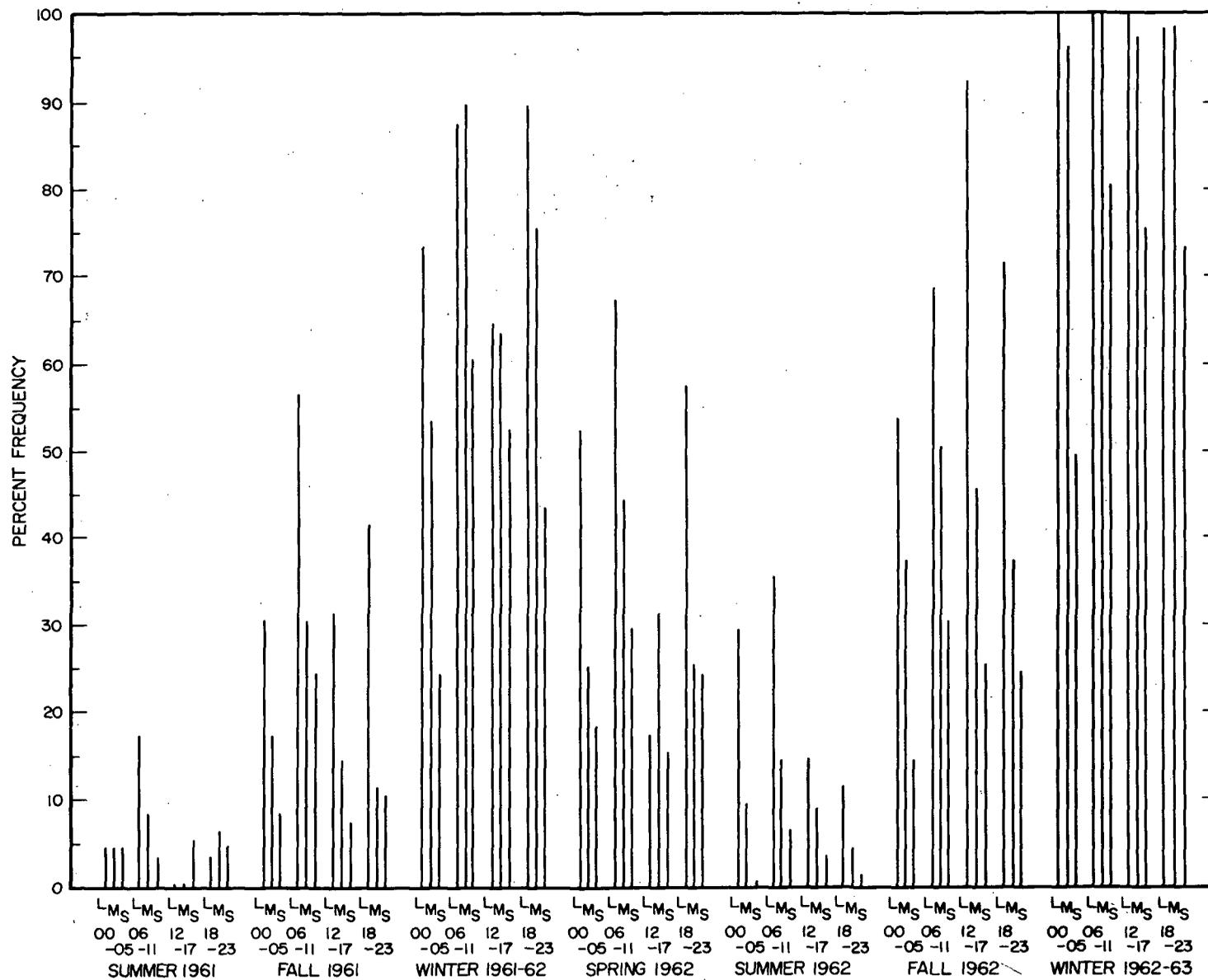


Fig. 11: Percentage frequencies of COH values  $\geq 1.0$  for light, moderate and strong winds - Saint John A.

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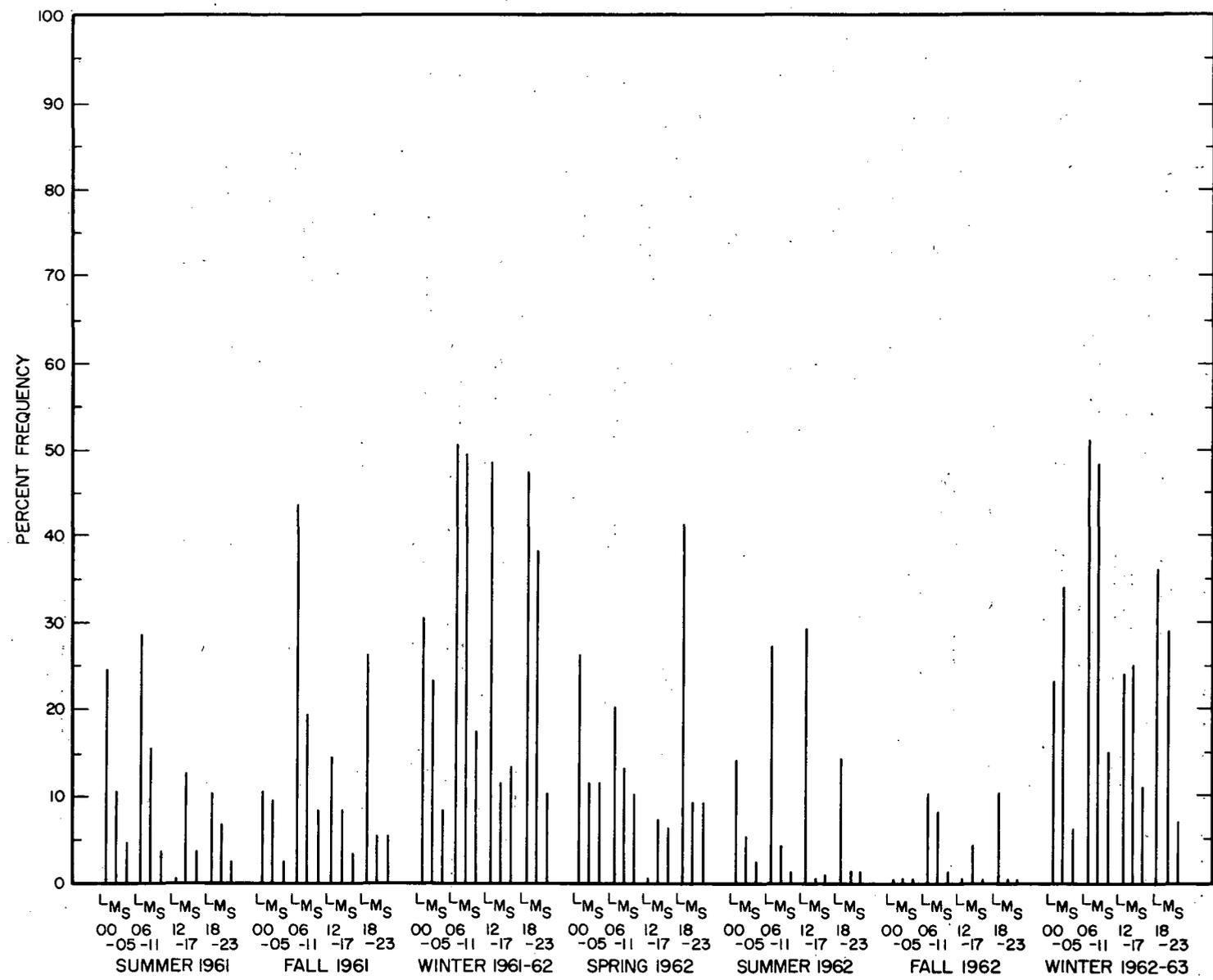


Fig. 12: Percentage frequencies of COH values  $\geq 1.0$  for light, moderate and strong winds - Saint John B.

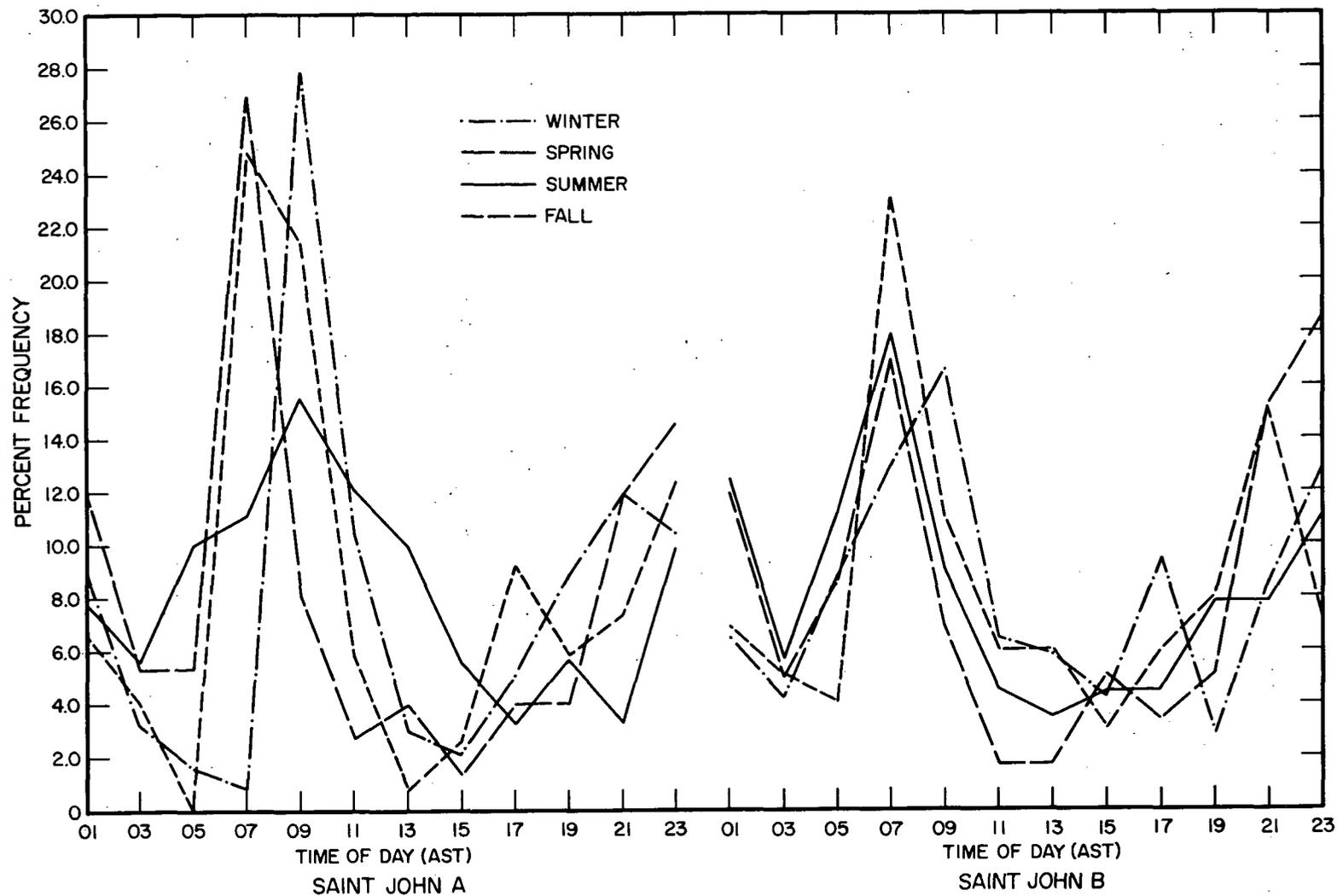


Fig. 13: Frequency distribution of daily maximum COH values by hour of occurrence - Saint John A and B.

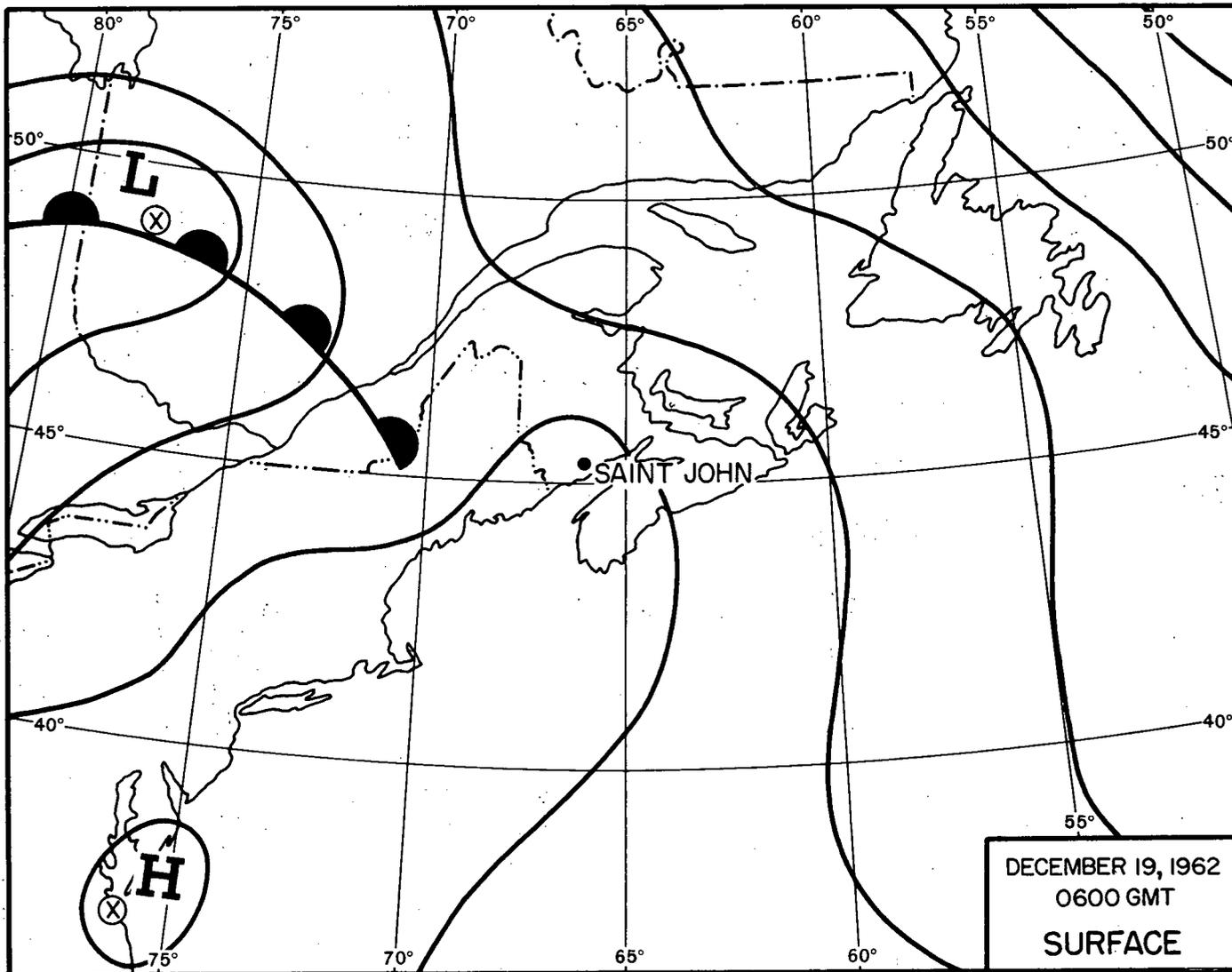


Fig. 14: Surface weather map of Saint John area - 0600 GMT, December 19, 1962.

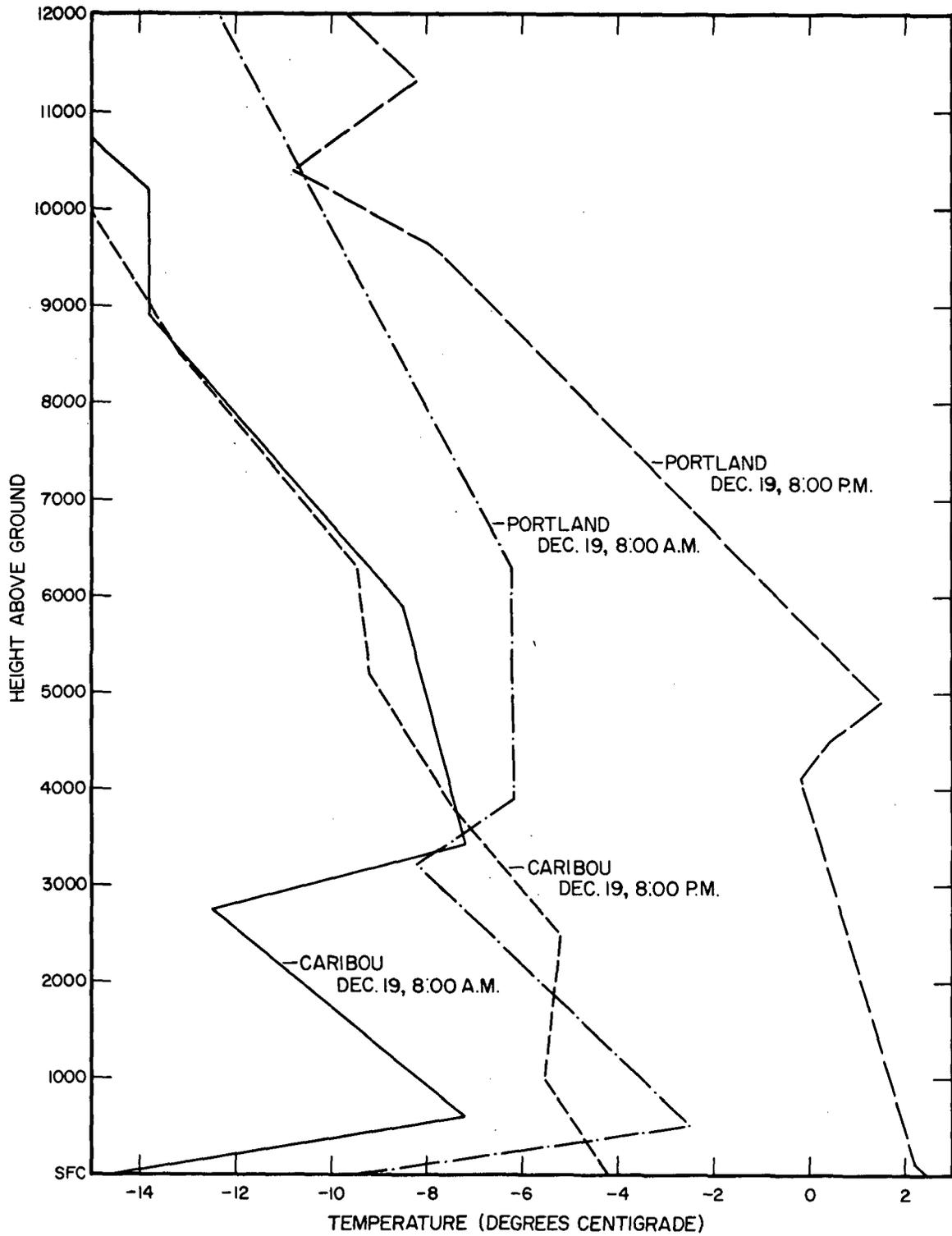


Fig. 15: Vertical temperature profiles at Caribou and Portland, Maine - December 19, 1962.

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7 pp. 15 figures. 2 refs.

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