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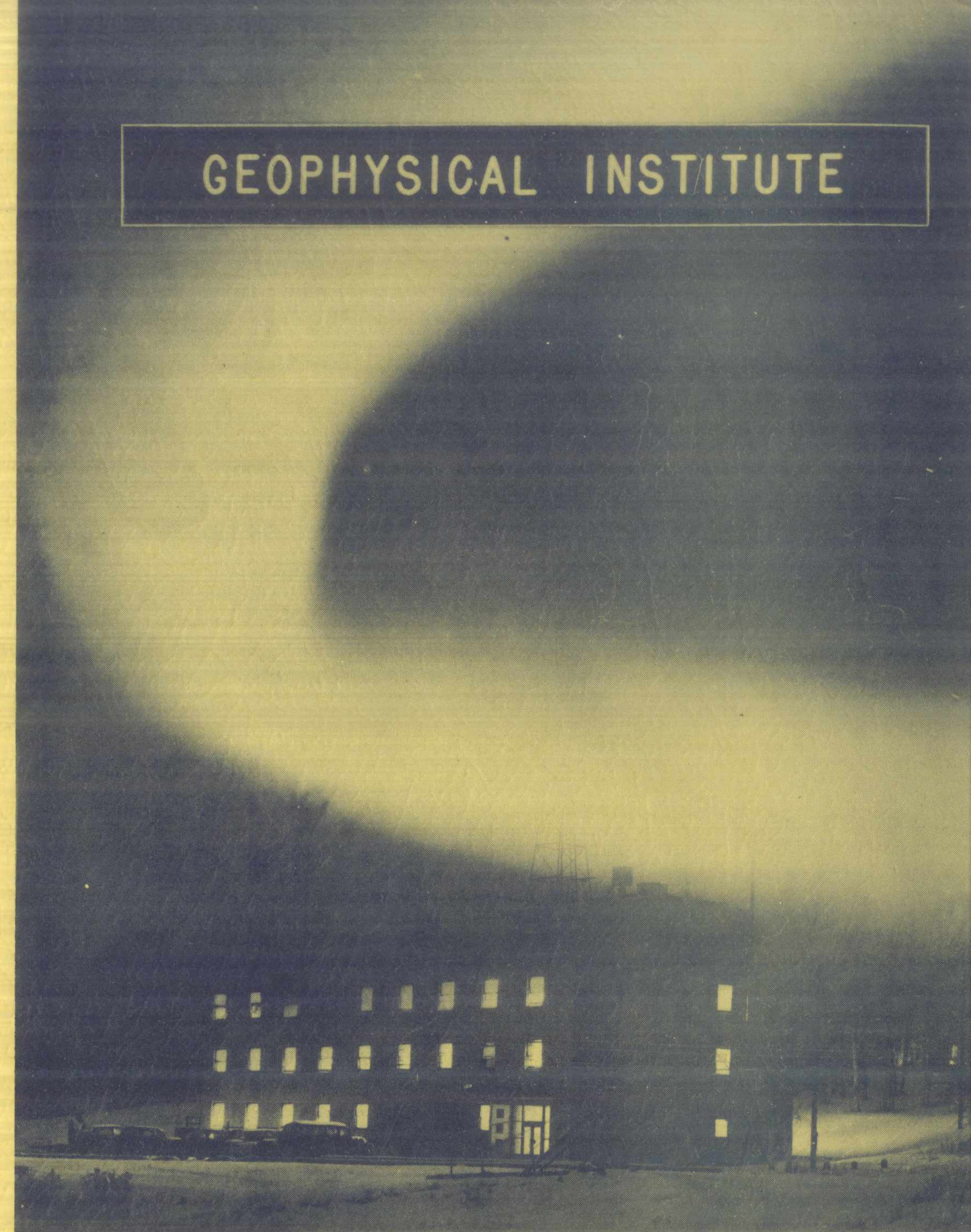

UNIVERSITY OF ALASKA

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ALASKA

AURORAL ZONE ABSORPTION OF RADIO WAVES TRANSMITTED VIA THE IONOSPHERE

Task A and B

Final Report
Covering Period 1 March 1955 to 29 February 1956

Signal Corps Contract	No. DA-36-039 SC-56739
Dept. of the Army Project	No. 3-99-03-022
Signal Corps Project	No. 182B

Laboratory Procurement Office, Signal Corps Supply Agency
Fort Monmouth, New Jersey

GEOPHYSICAL INSTITUTE
OF THE
UNIVERSITY OF ALASKA

AURORAL ZONE ABSORPTION OF RADIO WAVES TRANSMITTED VIA THE IONOSPHERE

TASK A and B

Final Report

Covering Period 1 March 1955 to 29 February 1956

The object of this task was to continue research investigations in connection with the auroral zone absorption of radio waves transmitted via the ionosphere.

Signal Corps Contract No. DA-36-039-SC-56739

Department of the Army Project No. 3-99-03-022

Signal Corps Project No. 182B

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C. T. Elvey, Director
Geophysical Institute

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SECTION I PURPOSE

TASK A:

To conduct research studies of auroral zone absorption of radio waves transmitted via the ionosphere and to provide the services of a supervisory engineer for the stations operated by the Arctic Ionosphere Research Detachment and by the University of Alaska. This task was a continuation of, but over and beyond, Task A under Contract No. DA-36-039 SC-5512.

TASK B:

To perform radio back-scatter observations of direct scatter from aurora-associated E-layer ionization; to observe the aurora visually in the region of scatter, and to correlate these observations with the field intensity measurements obtained under Task A. This task was a continuation of, but over and beyond, Task B under Contract No. DA-36-039 SC-5512.

SECTION II ABSTRACT

TASK A: TRANSMISSION OF HIGH FREQUENCY RADIO WAVES VIA THE ARCTIC IONOSPHERE

The experimental data collected from June, 1949, through October, 1955, under "Experiment Aurora" are summarized in tables and diagrams, and the results discussed.

The monthly percentage of signal in-time is tabulated for all frequencies and paths, and depicted in diagrams which allow a comparison of the values for East-West and South-North propagation at each frequency. The average monthly percentage of signal in-time for the duration of the 6-year experiment is tabulated for each frequency and path. The seasonal variation in signal in-time over short and long paths is shown in diagrams. The relationship found between ionospheric absorption, as measured with a vertical incidence sounder, and signal out-time is summarized.

The average diurnal variation in the hourly median signal strength during the different seasons of the year 1954-55 is given for all frequencies on both short and long paths in the East-West as well as the South-North direction. The diurnal variation in signal strength on the 4 mc short paths and the 12 mc long paths is compared for a year of high solar activity (1949-50) and a year of low solar activity (1954-55).

The discussion of the data reveals that a statistically significant difference in signal in-time for the East-West and South-North paths

exists only for the 12 mc short paths. The larger percentage of signal in-time found in the East-West direction is believed to be due to a preferential orientation of sporadic ionization along parallels to the auroral zone.

A study of the critical frequencies observed for the E and F-layers shows that the difference in daytime variation of median signal strength between the years 1949-50 and 1954-55 may be explained in terms of the normal changes in F-layer ionization and D-layer absorption in course of a sunspot cycle. The results indicate that in Alaska there will generally be F2 propagation during daytime of 4 mc signals over 350 km paths throughout the solar cycle. Regular daytime F2 propagation of 12 mc signals over 1100 km paths may be expected in years of reasonably high solar activity only.

TASK B: PULSE TECHNIQUES. BACK-SCATTER AT 12 MC

A 12 mc radar has been constructed and operated using A-scope and PPI displays. Experimental results obtained during several months of continuous operation are reviewed and discussed. Both direct back-scatter and ground back-scatter echoes, as well as possible combinations of these modes, have been observed.

The echoes are classified in two groups according to their fading rates, those fading rapidly being associated with aurora. Figures show the diurnal, range and range-azimuth distribution of the observed auroral echoes as well as some special types of echoes recorded.

The direct back-scatter echoes at 12 mc associated with aurora show characteristics consistent with those observed at VHF when allowance is made for the frequency difference. At 12 mc the fading rate is proportionally less than at higher frequencies; and aspect sensitivity, although weaker, still exists. The diurnal variation is similar to that found at VHF. Several types of echoes not observed at VHF are mentioned.

TASK B: VISUAL OBSERVATIONS OF THE AURORA

Analysis is made of the visual auroral data obtained at five stations in Alaska during the observing period of 1954-55. Graphs giving the percentage occurrence of aurora at each station as a function of latitude and time of day are presented. Graphs showing the variation of auroral occurrence with geomagnetic latitude as a function of magnetic K index are also given. The conclusions drawn from the 1954-55 data are substantially the same as those based on the 1953-54 data discussed in an earlier report.

SECTION III

PUBLICATIONS, REPORTS, AND CONFERENCES

A. Publications

The following paper dealing with work carried out in part under Signal Corps Contract No. DA-36-039 SC-5512 and published under Contract No. DA-36-039 SC-56739 appeared in the Transactions of the American Geophysical Union:

C. T. Elvey, Harold Leinbach, Joan Hessler and John Noxon, "Preliminary Studies of the Distribution of Auroras in Alaska".
Trans. AGU, 36, 390-394, 1955.

B. Conferences

The following paper was read at the 2nd Conference on Arctic Radio Wave Propagation, Geophysical Institute of the University of Alaska, College, Alaska on 26 January 1956.

R. A. Stark, "H. F. Radio Backscatter".

The following paper was read at the Symposium on "Effects from Low-Energy Particle Bombardment of the Atmosphere", Geophysical Institute of the University of Alaska, College, Alaska, on 1-2 March 1956.

R. S. Leonard, "Radar Auroras".

SECTION IV FACTUAL DATA

TASK A

TRANSMISSION OF HIGH FREQUENCY RADIO WAVES VIA THE ARCTIC IONOSPHERE

(Leif Owren and Harold Leinbach)

1. INTRODUCTION

In 1949 a research program designated "Experiment Aurora" was initiated in which a study of radio wave propagation on several frequencies and over several paths in Alaska was to be made. Two transmitting sites, one at Anchorage (moved to Sheep Mountain in June, 1951), the other at Northway, were established. Each station transmitted a medium power CW signal on each of three frequencies, these being approximately 4, 8, and 12 mc/sec. The Northway signals were received at Nome, and the signals from Sheep Mt. at Pt. Barrow. The signals from both transmitting stations were also monitored at College, which is located approximately one third of the distance from the respective transmitting to receiving sites. Thus there were two short paths of approximately 360 kms length, and two long paths of approximately 1140 kms available for study. Furthermore, one set of paths was oriented roughly from south to north (the Sheep Mt. to College and Barrow paths), and the other set approximately east-west (Northway to College and Nome). Operation of the stations ceased in October 1955. A period of 76 months, covering from near maximum through a minimum of a sunspot cycle, is available for analysis. Details of the equipment and mode of operation can be found in the Quarterly Progress Reports issued under this contract, and its predecessor, SC-5512.

Interim Scientific Report No. 1 (Quarterly Progress Report No. 4, 1 December 1954 to 28 February 1955) describes in detail some analysis of the data obtained through 1954. This report extends the analysis through October 1955. In the Interim Scientific Report emphasis was placed on the relationship of absorption to outage time. In this report, the emphasis is on some observed differences between propagation conditions in 1949-50 and in 1954-55. It is shown that this difference may in part be explained on the basis of variation of normal F2 propagation conditions throughout a cycle of solar activity.

The data discussed here are given in the following order:

Firstly, graphs of the percentage of signal in-time are given for all the paths and frequencies for the six year period of operation. Curves showing the seasonal variation of signal in-time are also presented.

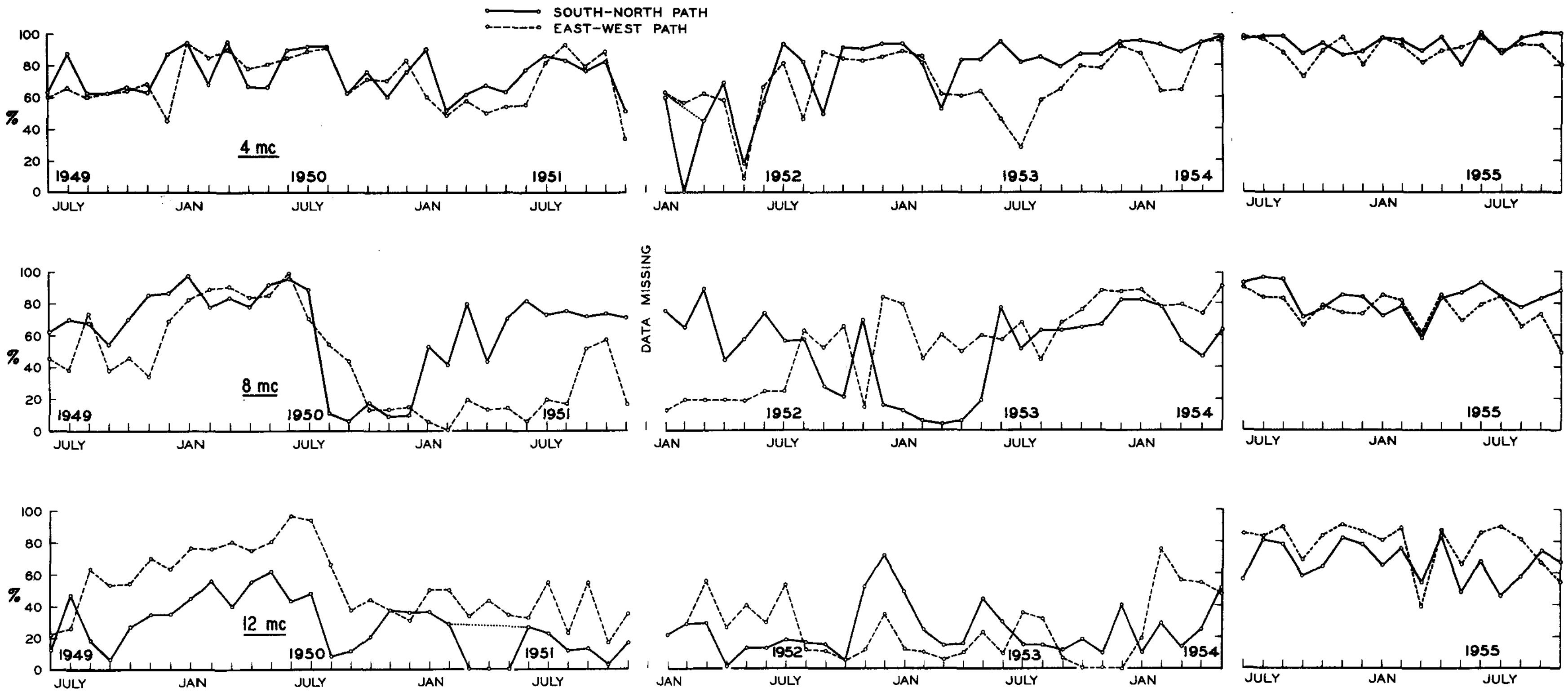
Secondly, a brief summary of the relationship of ionospheric absorption and outage time on the various circuits is given.

Thirdly, the diurnal variation of the median signal strength for the summer, equinoctial and winter periods of 1954-55 is given. Graphs comparing the diurnal variation obtained 1949-50 and 1954-55 for the 4 mc short paths and the 12 mc long paths are also presented.

Lastly, a discussion and interpretation of the results is given. A set of tables (tables 6.1-6.12) is included in this report which give the complete monthly percentage of signal in-time for all paths and frequencies for the period of this experiment.

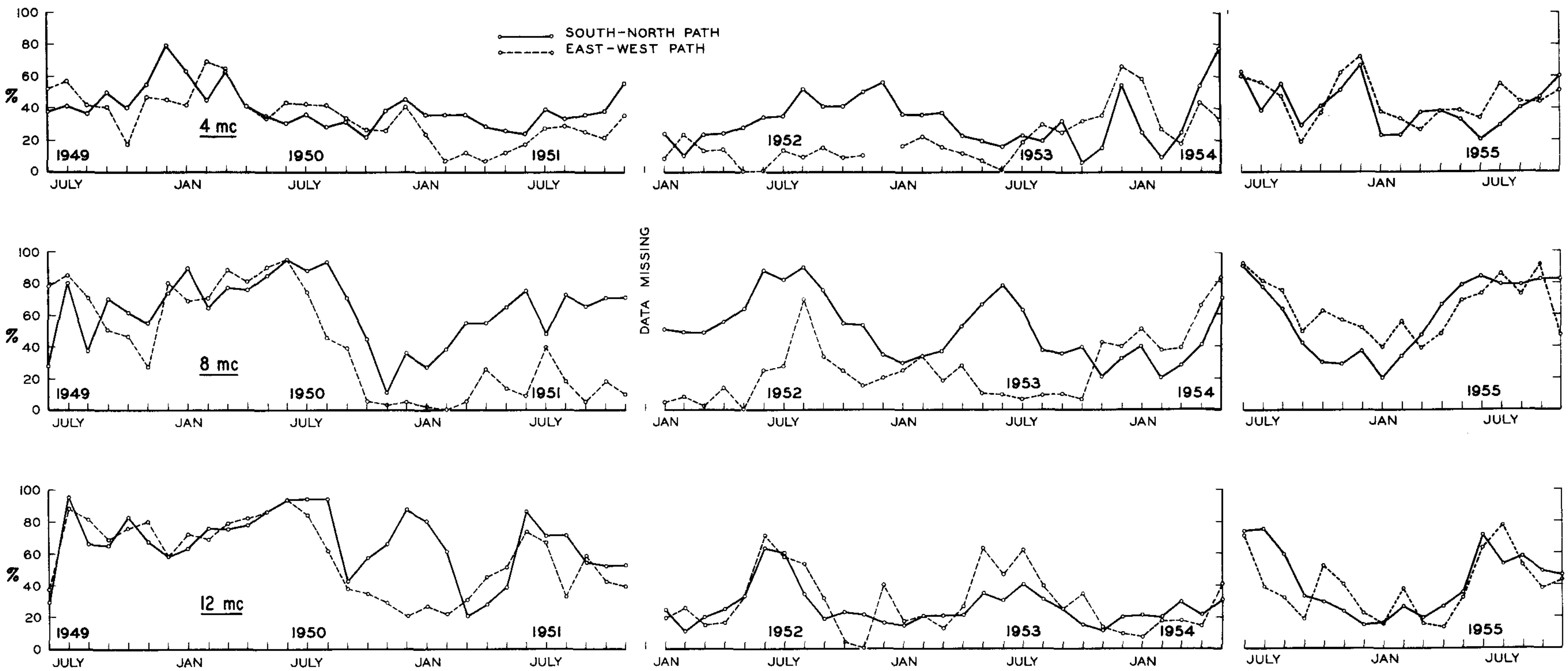
2. SIGNAL IN-TIMES

Figures 1 and 2 show the monthly percentage of signal in-time for the short and long paths respectively, for the period of the experiment. For the purpose of this analysis, positive identification of the periodic keying tags of each transmitter has been used as the criterion of signal in-time. In compiling the data for these graphs, all known "C" time (failure of the equipment) has been taken into account. Even so, two periods of suspiciously low signal in-time have been identified, and dotted corrections have been added to Figure 1 for these cases. As indicated in the Interim Scientific Report, it is felt that values obtained during the period January 1951 through July 1952 for the 8 mc signal from Northway are too low, because of a faulty transmission line on the 8 mc transmitting antenna. Hence, the January 1951 through July 1952 values have been omitted from Table 1, which gives the 76 month averages of the monthly mean percentage of signal in-time. Also given in this table are the maximum percentage signal in-times recorded during the 76 months of the experiment, and likewise the minimum percentage signal in-times. In case there is some question about the validity of the mini-



MONTHLY PERCENTAGE IN TIMES ON SHORT PATHS.

Fig. 1



MONTHLY PERCENTAGE IN TIMES ON LONG PATHS.

Fig. 2

mal value, the next higher value is given in parenthesis.

Table 1. Seventy-six month mean percentage in-times

SHORT PATHS

Frequency mc	South-North			East-West		
	mean	maximum	minimum	mean	maximum	minimum
4	80	100	16 (42)	73	97	8 (28)
8	62	98	4	65*	98	12
12	35	93	0	47	97	0

LONG PATHS

Frequency mc	South-North			East-West		
	mean	maximum	minimum	mean	maximum	minimum
4	37	79	6	31	68	0
8	57	95	11	50*	95	0
12	45	95	11	42	90	1

* The period from January 1951 through July 1952 has been excluded from the data.

The average percentage signal in-time is consistently higher on the south-north long paths than on the east-west long paths. Such a systematic difference is not present in the case of the short paths. South-north propagation on the short 12 mc path is noticeably worse than on the east-west path. Conversely, the average signal in-time is slightly greater for the short east-west 4 mc path than the 4 mc south-north path.

The seasonal variation of in-times, based on all of the data, for the short and long paths are shown in Figures 3 and 4 respectively. The average of both the east-west and the south-north paths has been taken for each month. A pronounced seasonal effect is apparent only for the 8 and 12 mc long paths, where the percentage in-time is greatest during the summer months. No pronounced seasonal effect is in evidence for the other paths and frequencies.

3. REASON FOR OUTAGES

A complete statement of the analysis conducted to determine the reason for outages is given in the Interim Scientific Report. It is pointed out that fifty percent of outages on the short paths during 1954 corresponded to polar blackouts as indicated by the National Bureau of Standards Model C-3 ionospheric sounder in use at College. The percentage increased to 80 when a minimum frequency greater than 1 mc, as measured by the C-3, was used as the criterion of absorption. Absorption measurements of galactic radio noise often show that absorption is non-uniform across the sky. Hence it is concluded that the remaining 20% of outage time not accounted for by absorption measured overhead at College may, nevertheless, be due to absorption rather than lack of the ionization required to support propagation.

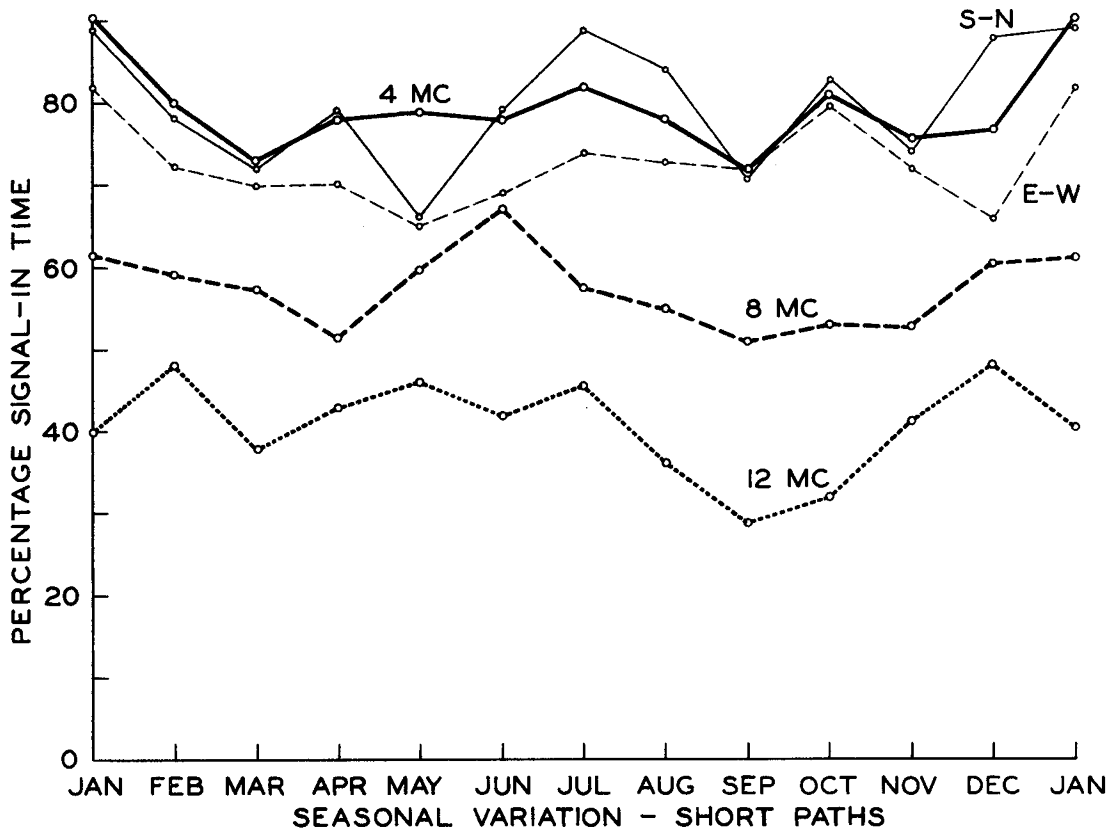

S-N
4 MC
E-W
8 MC
12 MC
PERCENTAGE SIGNAL-IN TIME
0
20
40
60
80
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN
SEASONAL VARIATION - SHORT PATHS

Fig. 3

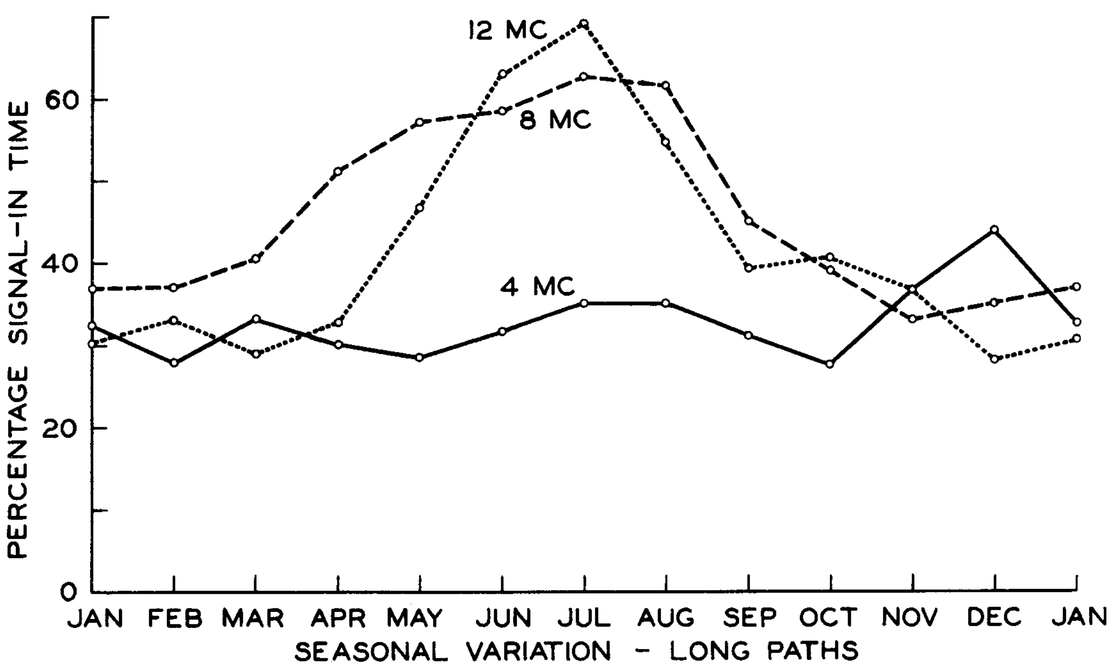

12 MC
8 MC
4 MC
PERCENTAGE SIGNAL-IN TIME
0
20
40
60
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN
SEASONAL VARIATION - LONG PATHS

Fig. 4

4. MEDIAN SIGNAL STRENGTHS

4.1. Daily variations 1954-55

Hourly values of the median signal strength have been scaled for the 76 month period of the experiment. These median values of signal strength have been used to prepare graphs showing the average daily variation for winter months (November through February), summer months (May through August), and the equinoctial months (March-April, and September-October). Figures 5 through 10 give the hourly median signal strengths for the period 1954-55. These graphs are somewhat more extensive than those given in the Interim Scientific Report, in that, wherever possible, data for both paths have been given. This procedure leads to a number of cases where the data are uncertain, but it should be noted that in most such cases the uncertainty arises because of an indeterminate low value of signal strength. Thus the data are still useful in setting an upper limit of expected signal strength.

In all cases where reliable data are available for both the east - west and south-north paths, the two curves have the same shape and generally comparable values of median signal strength. The data for 1954-55 may be summarized as follows:

a. Short Paths

i. A daytime increase of signal strength is very striking during the winter months for the 4 mc short paths. The daytime maximum signal strength is almost 60 times that recorded at the daily mini-

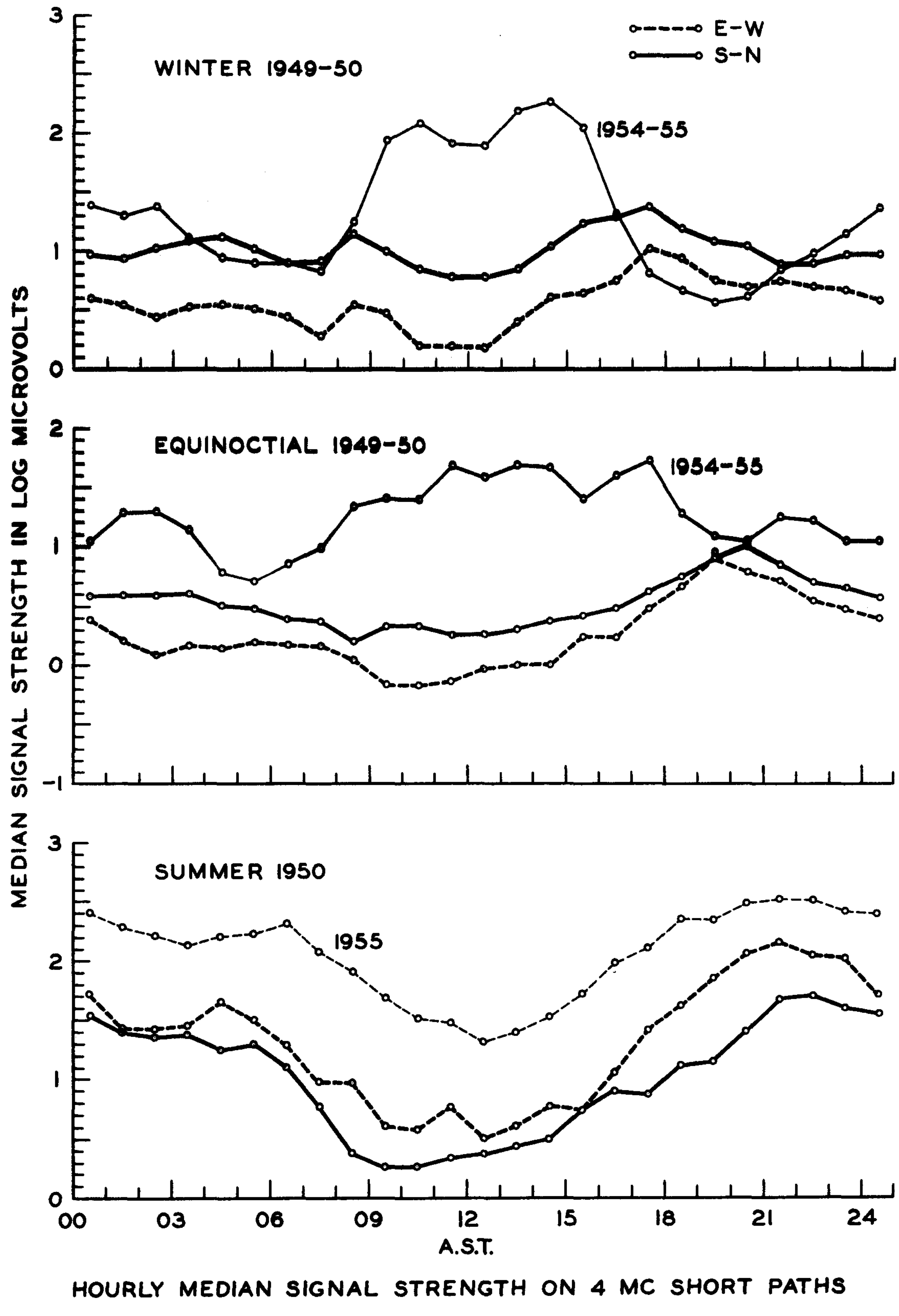
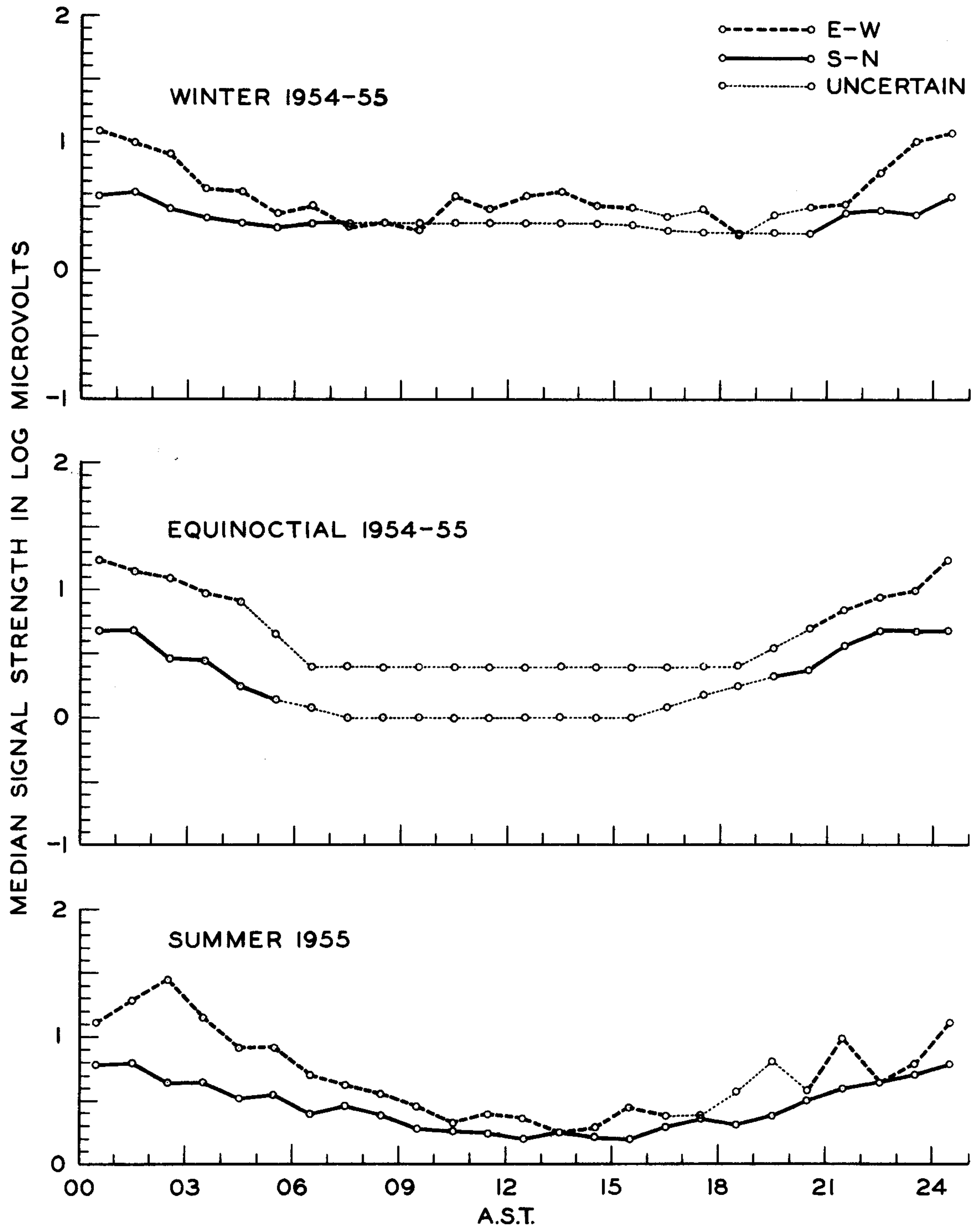
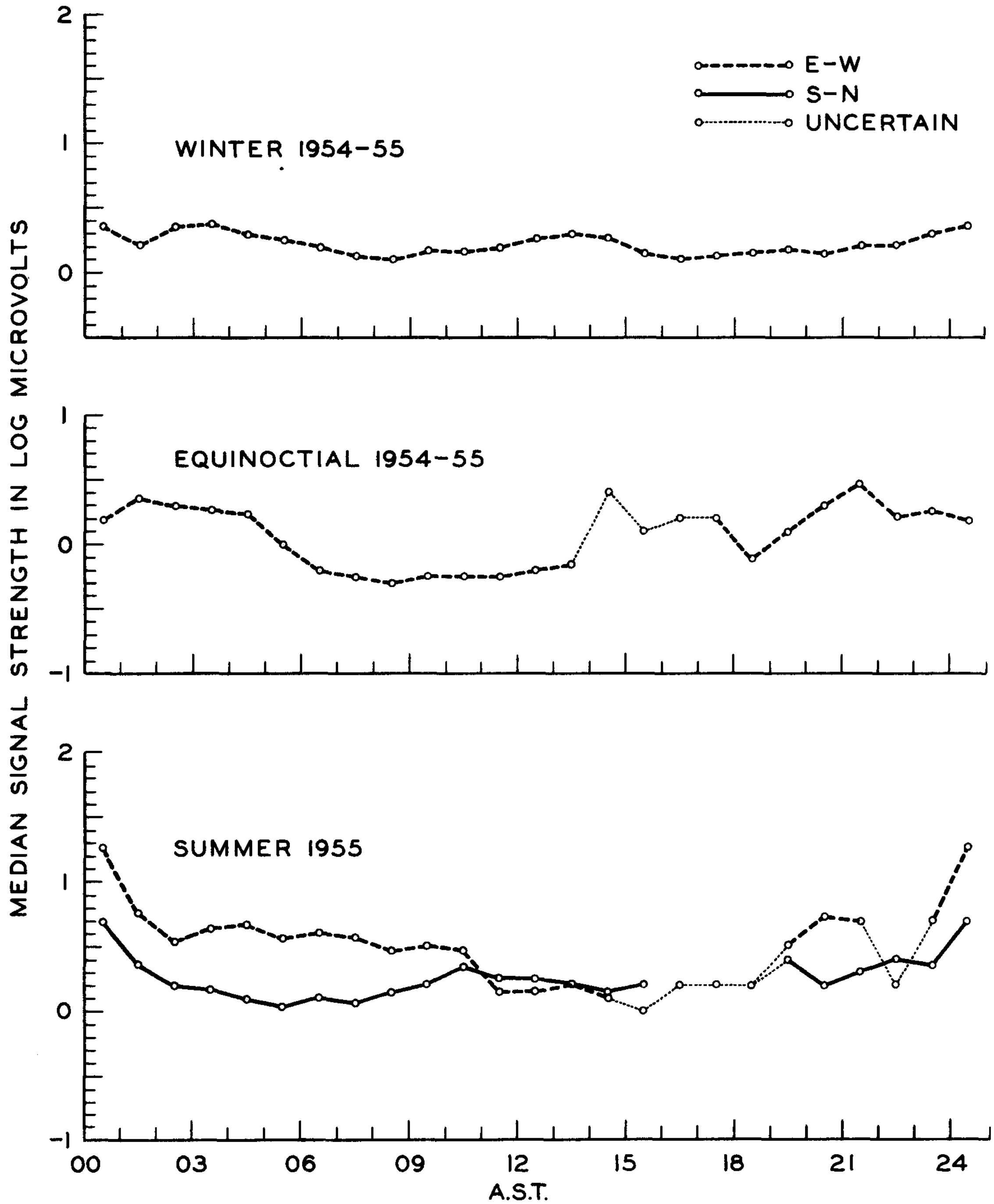

E-W
S-N
WINTER 1949-50
1954-55
EQUINOCTIAL 1949-50
1954-55
SUMMER 1950
1955
MEDIAN SIGNAL STRENGTH IN LOG MICROVOLTS
A.S.T.
00
03
06
09
12
15
18
21
24
HOURLY MEDIAN SIGNAL STRENGTH ON 4 MC SHORT PATHS

Fig. 5



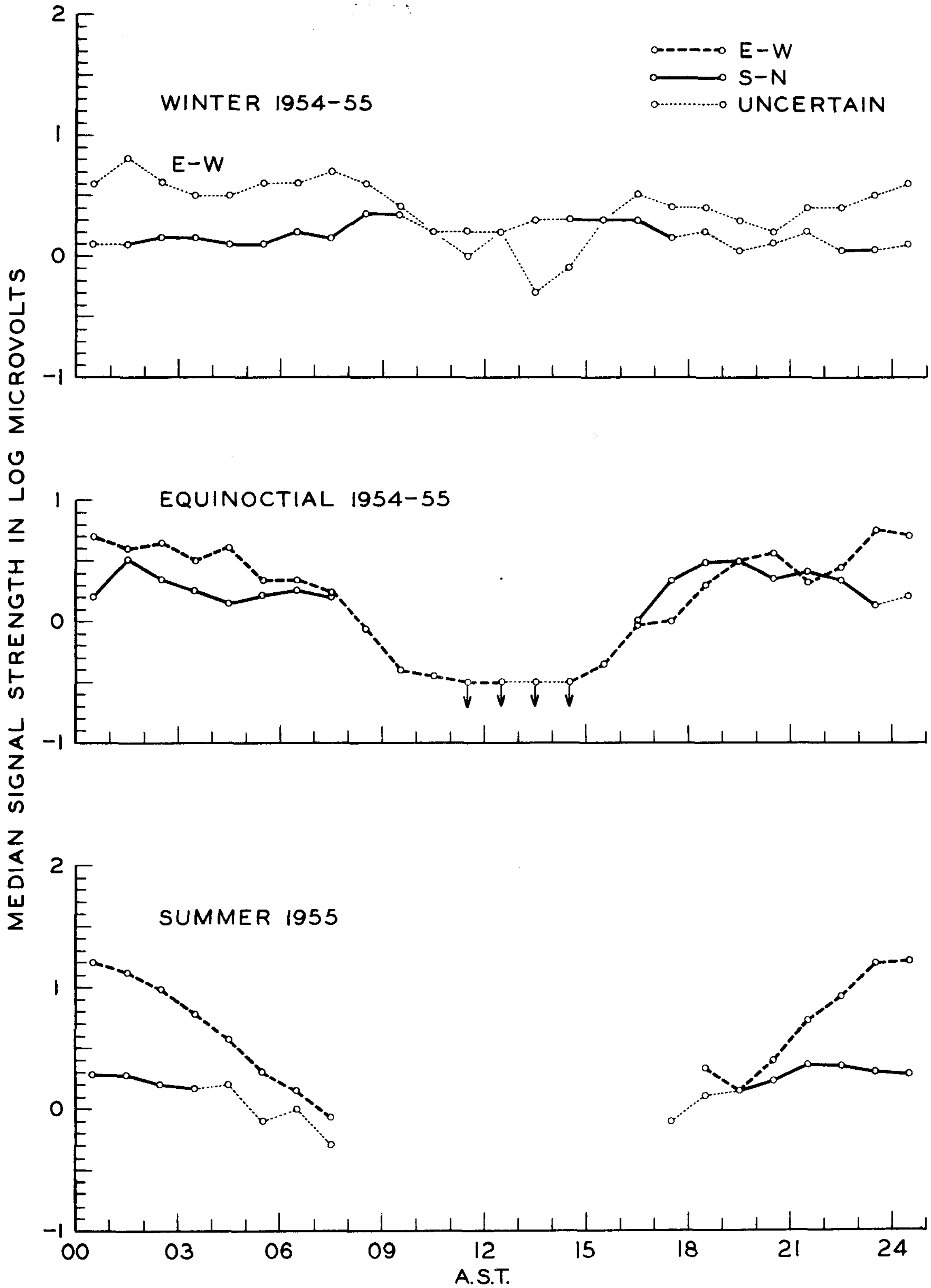
HOURLY MEDIAN SIGNAL STRENGTH ON 8 MC SHORT PATHS

Fig. 6



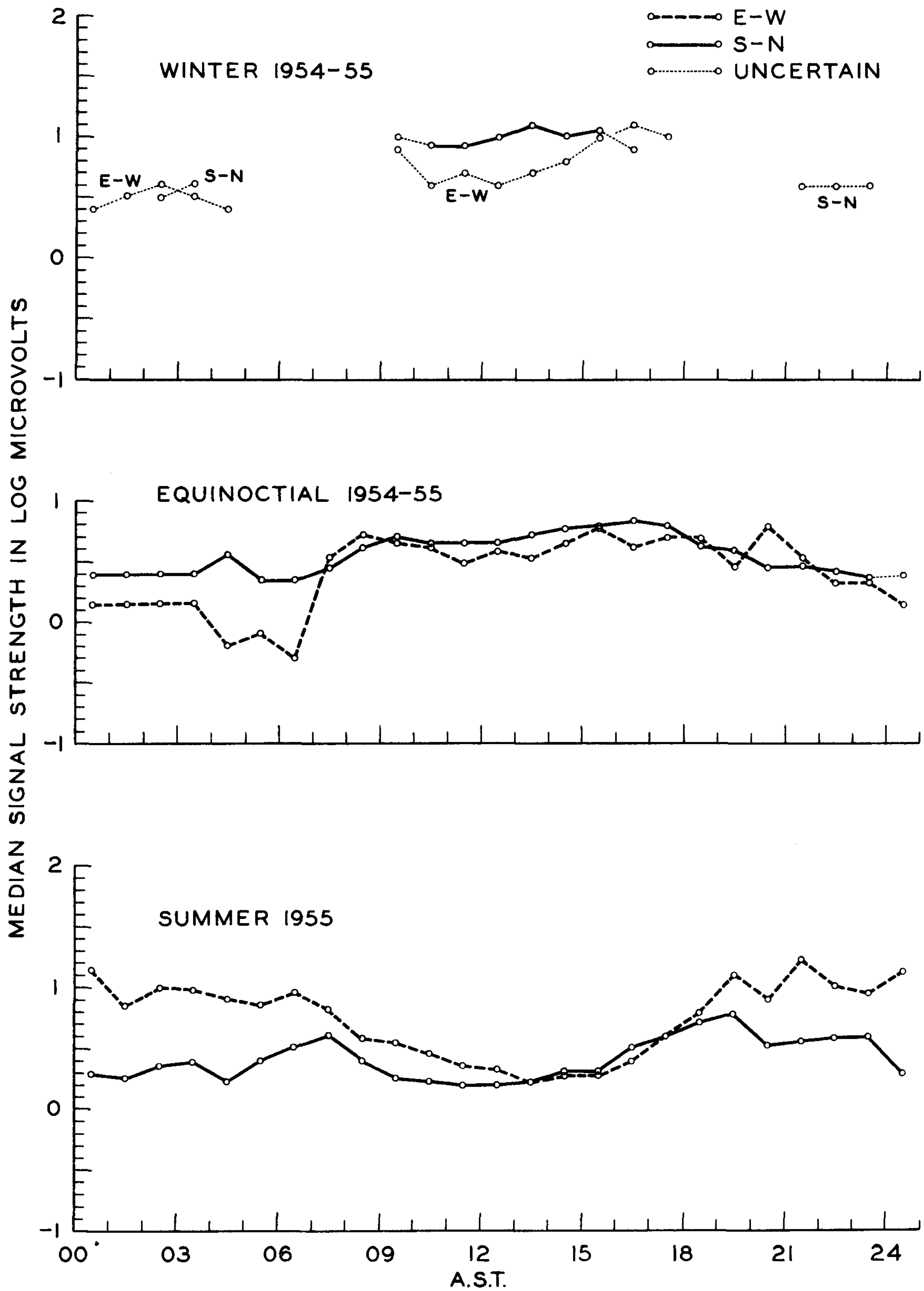
HOURLY MEDIAN SIGNAL STRENGTH ON 12 MC SHORT PATHS

Fig. 7



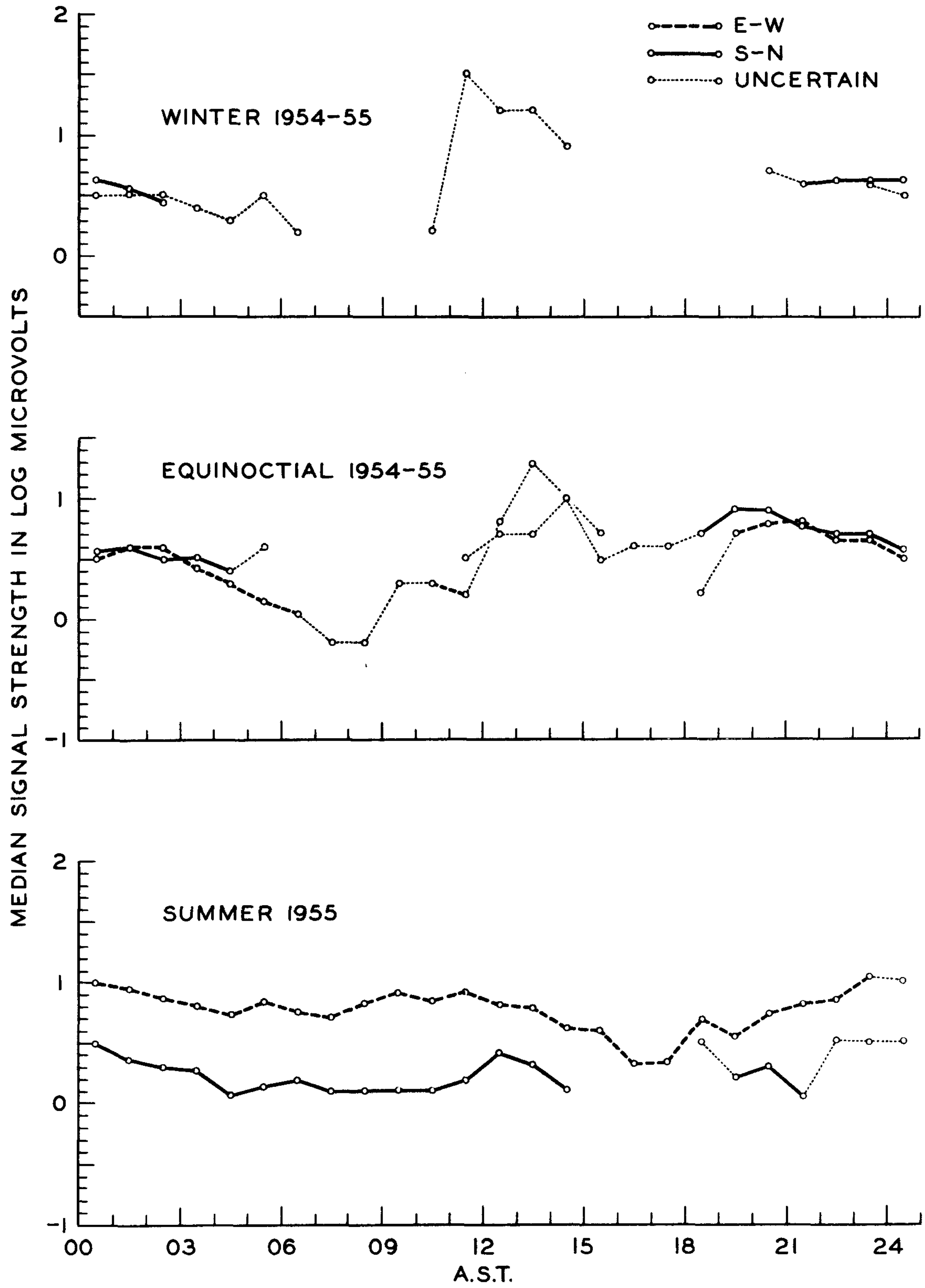
HOURLY MEDIAN SIGNAL STRENGTH ON 4 MC LONG PATHS

Fig. 8



HOURLY MEDIAN SIGNAL STRENGTH ON 8 MC LONG PATHS

Fig. 9



HOURLY MEDIAN SIGNAL STRENGTH ON 12 MC LONG PATHS

Fig. 10

mum at 2000 local time. A less striking increase occurred during the equinoctial months. On the other hand the summer months of 1955 show a slight decrease of median signal strength during the mid-day hours.

ii. The diurnal trend on the 8 mc short paths is toward a decrease of median signal strength during the daytime hours for all three seasonal periods. A numerical value for the relative daytime reduction for the winter and equinoctial months cannot be stated with confidence due to the uncertainty of the lower values of signal strength recorded. The reduction during the summer months is by a factor of about 6.

iii. The 12 mc east-west paths show no pronounced diurnal variation for the winter and equinoctial months. The south-north 12 mc data have been omitted because of the constant low values of signal strength recorded. There is a weak tendency towards lower daytime values of signal strength during the summer months for both paths.

b. Long Paths

i. The median 4 mc signal strength shows a daytime decrease during the summer and equinoctial months. The winter data are uncertain, but that any daytime weakening of the signal appears to be very slight.

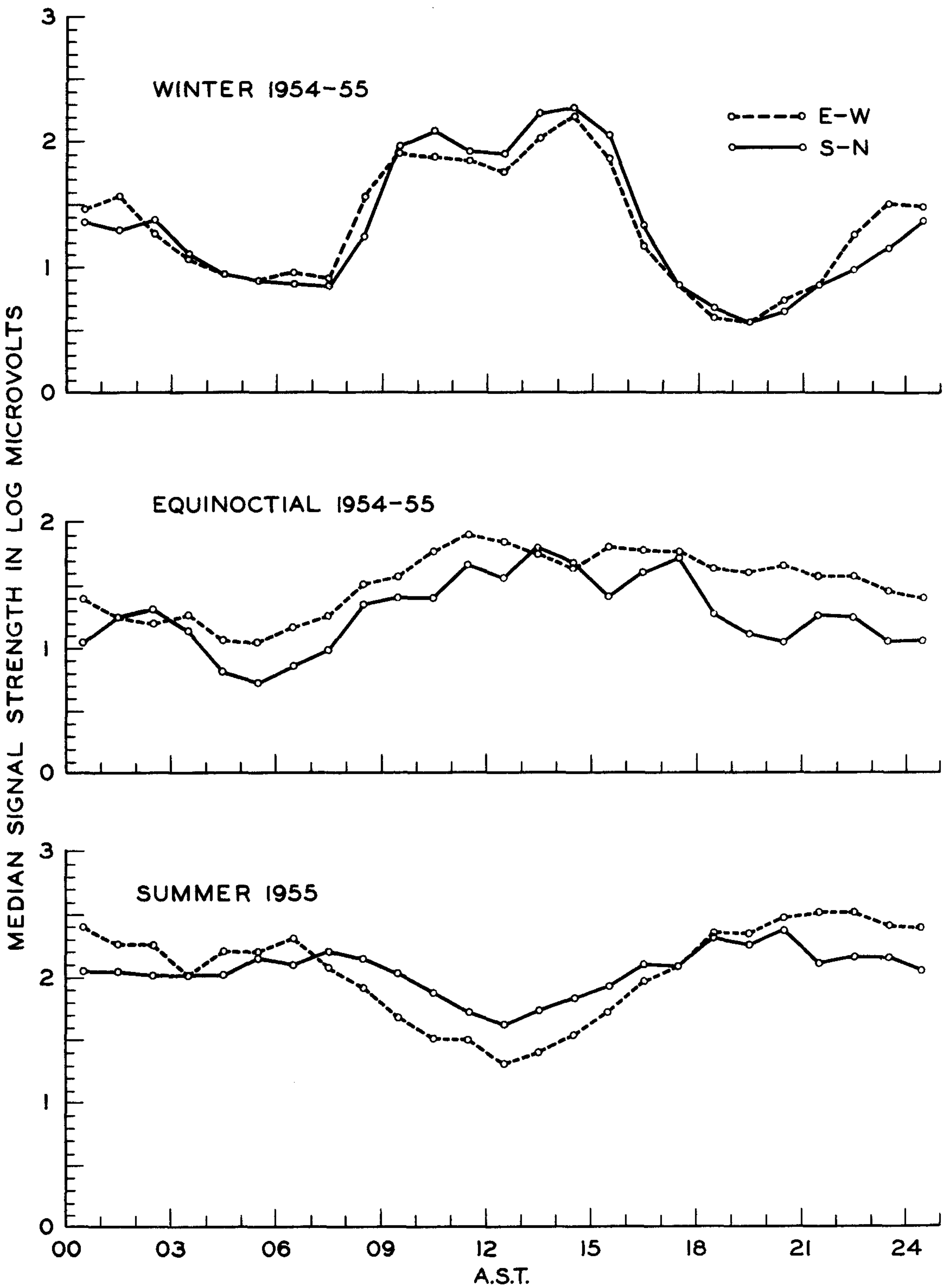
ii. Diurnal effects on the 8 mc path are apparent only during the summer months, when there is a slight daytime decrease of signal strength. The 8 mc winter data are too sketchy to allow any statement to be made.

iii. No diurnal effect is in evidence during the summer months on the 12 mc paths. The 12 mc winter and equinoctial data are too uncertain to allow any conclusion to be drawn.

4.2. Comparison of Median Signal Strength for Years of High and Low Solar Activity.

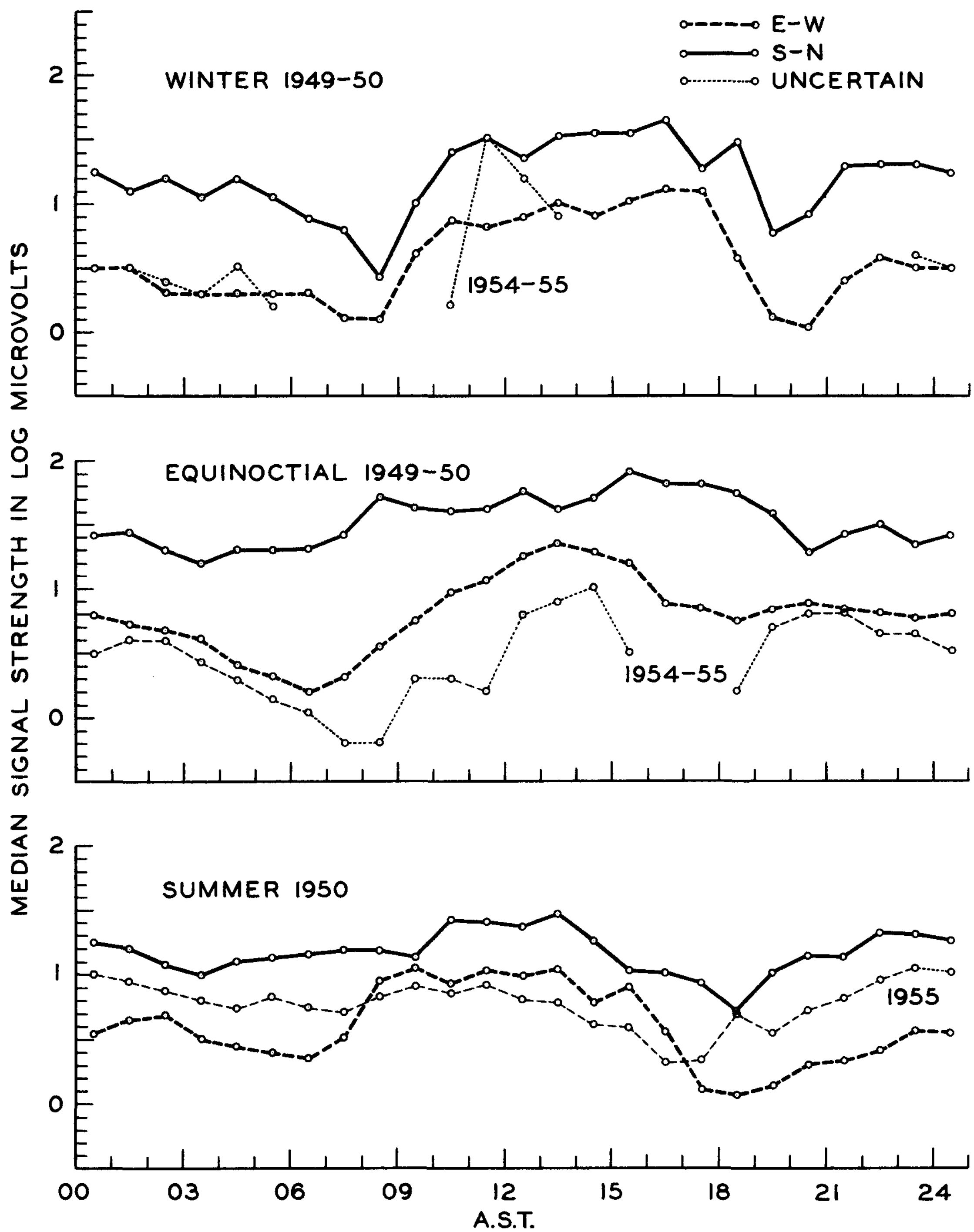
A comparison of the diurnal variation in hourly median signal strength for years of high and low solar activity is of considerable interest. Such comparison may provide an avenue of approach to the study of modes of propagation. The years 1949-50 and 1954-55 together with the 4 mc short paths and 12 mc long paths have been selected for an initial study. During 1949-50 solar activity was still at a high level with mean monthly sunspot relative numbers of the order of 120 as compared with the exceptionally large peak in 1947 reaching the relative number 200. The present sunspot cycle passed through its minimum in 1954 when relative numbers 0 were recorded during the first half of that year. The data for the signal in-times show that 4 mc is by far the best of the three experimental frequencies for point-to-point transmission over the short paths, while 8 mc and 12 mc give the highest percentages of in-time on the long paths (see Table 1). For the particular years considered 12 mc appeared a likely choice for the analysis.

Figures 11 and 12 represent plots of the respective hourly median signal strengths for the years 1949-50 and 1954-55. The following facts are apparent from these graphs:



HOURLY MEDIAN SIGNAL STRENGTH ON 4 MC SHORT PATHS

Fig. 11



HOURLY MEDIAN SIGNAL STRENGTH ON 12 MC LONG PATHS

Fig. 12

a. 4 Mc Short Paths.

The daytime increase of signal strength on the 4 mc short paths during the winter and equinoctial months of 1954-55 is not present for the corresponding intervals of 1949-50. For these seasons there is on the contrary a tendency for a decrease of signal strength in the daytime during 1949-50. The summer months of the years 1954-55 and 1949-50 both show an appreciable decrease of signal strength during the daytime, the relative decrease being about equal for the two years.

b. 12 Mc Long Paths.

On the 12 mc long paths comparison of the average daily variation in signal strength for the years 1954-55 and 1949-50 can be made for the equinoctial and summer months only, the data being incomplete for the winter months of 1954-55. For the equinoctial months of 1949-50 the curves of the daily variation show a tendency toward increased signal strength during the daytime, this increase being somewhat more pronounced in the E-W than the S-N curve. The E-W curve for 1954-55 appears to be similar to that for 1949-50. No great weight can be attached to the apparently sharper and more narrow daytime peak indicated by the 1954-55 curve because of the inherent uncertainty of the data.

The curves for the summer months of 1955 show no marked diurnal variation in signal strength. The corresponding curves for the summer of 1950 indicate a midday increase in signal strength which is most pronounced for the E-W path. This midday increase in signal strength on the 12 mc long paths for the summer of 1950 gains in significance when contrasted with the midday depression which is observed on the 8 mc long paths in the summer months of 1955.

The results of the comparison of the diurnal variation of signal strength for the years 1949-50 and 1954-55 are summarized in the following tables.

Table 2. Midday Signal Strength on 4 Mc Short Paths

Season	1949-50	1954-55
Winter	slight depression	large increase
Equinox	slight depression	some increase
Summer	deep depression	deep depression

Table 3. Midday Signal Strength on 12 Mc Long Paths

Season	1949-50	1954-55
Winter	pronounced increase	possible increase
Equinox	some increase	some increase
Summer	some increase	no increase

The reader should be warned that quantitative comparison of the log microvolt values for the hourly median signal strength over the period from 1949-55 is not warranted by the data. This deficiency in accuracy is due partly to the changes which took place in the experimental facilities during the six years of operation and partly to recently discovered inconsistencies in the procedures adopted by different personnel for deriving the median hourly signal strength values. It is believed, however, that the trends in the diurnal variations of signal strength established above are qualitatively correct.

5. DISCUSSION

a. Signal In-Time.

The percentage of signal in-times given in Table 1 show no appreciable change from the values given in the Interim Scientific Report. In the case of the long paths, the signal in-time is consistently higher on the south-north path than on the east-west path. However, the difference is not large and, hence, probably not of great significance. This difference is also evidenced by the higher minimum percentages for the south-north path.

In order to study quantitatively the difference between east-west and south-north propagation, we have counted the number of months during which the signal was greater on one path than the other. This method of analysis tends to eliminate the effect on the 6 year averages (as given in Table 1) of months in which a large difference in signal in-time between the two paths occurred. Table 4 gives the number of months during which the percentage in-time was greater on the south-north path. It is assumed, on the basis of equal equipment setups for a given frequency for both paths, that the south-north should exceed the east-west percentage in-time half the time, providing that no difference in propagation conditions exist. On this hypothesis the expected number will be one half of the total number of months considered.

Table 4. Number of Months During Which the Percentage In-Time was Greater on the South-North Path than the East-West Path.

Frequency mc	Short Path observed	Short Path expected (1)	Chi Sq.	Long Path observed	Long Path expected (1)	Chi Sq.
4	51	38	4.45	45	38	1.3
8	22	29 (2)	1.7	30	29 (2)	0.3
12	13	38	16.5	33	38	0.7

(1) The expected number is half of the total number of months of data.
(2) The months of January 1951 through July 1952 have been omitted from the count.

A Chi Square test was applied to the observed ratios to determine if there were any cases of significant departure from the working hypothesis. The calculated Chi Square values are also given in Table 4. From a Chi Square table one finds that for n = 1, and a 95% confidence level, Chi Square = 3.84; for the 98% confidence level, Chi Square = 5.41. Thus it is only in the case of the 12 mc short path, and perhaps the 4 mc short path, that any statistically significant difference exists between signal in-times on the two paths.

Calculations of skip distance on the basis of a thinlayer and flat earth model indicate that any F layer propagation on the 12 mc short paths would have been marginal during 1949-50 and impossible during

1954 and 1955. Similarly, examination of E layer critical frequencies shows that 12 mc propagation via the E layer would not have been possible. Thus, the 12 mc short path propagation appears to be highly dependent upon sporadic ionization. Such a difference between east-west and south-north propagation might be expected if there is a preferential orientation of the sporadic ionization along parellels to the auroral zone. Further study is needed on the 12 mc case and in the case of the questionable difference indicated for the 4 mc short paths.

b. Median Signal Strength

The differences noted in the diurnal variation of median signal strengths during 1949-50 and 1954-55 are at least partially due to the change of F2 layer properties between the two periods. Table 5 gives the median daily maximum critical frequency observed during the various seasonal periods of the years in question. These data have been obtained with the C-3 vertical incidence sounder in operation at College. It is immediately obvious that the median critical frequencies in 1949 were nearly double those in 1954 and 1955.

Table 5. Median values of the maximum daily critical frequency of the F2 layer.

Season	1949	1950	1954	1955
Winter (1)	10.1	6.5	5.0	
Equinoctial	8.0 (2)	6.9	4.2	5.1
Summer	6.7	5.9	4.2	4.8

(1) Winter months include November and December of the year noted, and January and February of the following year.

(2) Includes September and October of 1949 and March and April of 1950.

From the critical frequencies observed, the MUF for a given path length can be calculated. The simplest model is that of a thin layer of a flat earth, in which case of MUF factor (in the absence of a magnetic field) is given by:

$$\left(\frac{D^2}{4h_o^2} + 1 \right)^{1/2}$$

where D is the path length, and h_o is the height of the reflecting layer. This formula has been used to obtain a first order estimate of the MUF factor for the short paths. For a path length of 350 km and an F2 layer height of 250 km, one obtains a value of 1.2 for the MUF factor. Applying this value to Table 5, the median daily maximum MUF for the short path was found to be 6 mc during the winter of 1954. During the winter of 1949, however, the MUF for the short path was 12.1 mc.

On the basis of the calculated MUF's, the strong daytime peak of signal strength during the winter of 1954-55 was concluded to be due to F2 propagated signals. Since the MUF's for the summer and equinoctial months of 1954 are also near 6 mc, one would expect to find that the mid-day value of signal strength is of the same order as during the winter. Because of the longer period of daylight, the peak should be broader than during the winter. Examination of Figure 5 shows that the peak is indeed broader in the equinoctial than the winter months. The summer months, however, show a daytime decrease of signal strength on 4 mc. On the basis of the MUF's, one would expect a daytime increase rather than this daytime decrease in signal strength. This depression in signal strength may well be due to an increase of the daytime absorption in the D region, which would not, of course, have any direct effect on the F2 critical frequencies.

During 1949-50, the MUF was approximately 12 mc for the short path, which is considerable above the 4 mc transmitting frequency. Since for a given transmission frequency, non-deviative absorption is proportional to the square of the critical frequency, this implies that the absorption of the 4 mc wave in the F region must have been about 4 times as great in 1949 as in 1954. Near the maximum of the sunspot cycle, one also expects that the general ionization level for all layers will be greater. The expectation is confirmed by the E layer critical frequencies, which averaged about 2.2 mc for the daytime peak during the winter months in 1949-50. These values may be contrasted with those obtained during the winter of 1954-55, when the E layer was essentially absent. During 1949-50, the E layer was seen, however, only about 50 percent of the time, because of (1) complete blackout, or (2) blanketing by sporadic E. Thus all factors point towards large amounts of absorption for the 4 mc short paths during the sunspot maximum years, and consequently, no mid-day peak of signal strength would be expected.

An examination of the 1500 km path MUF factors, which are scaled at College on the basis of the C-3 sounder data, shows that the F2 layer median MUF factor for the 1100 km paths would be between 2 and 2.3.

By comparing these figures with Table 5, we may conclude that during 1954-55, F2 propagation over the long paths was marginal, if present at all. During 1949-50 the MUF would have averaged well above 12 mc, and hence F2 propagation would have been important. An examination of Figure 8 of the Interim Scientific Report, which gives the 12 mc long path data for 1950-51 (the date was inadvertently omitted), indicates that the separation of F2 propagation from other modes is considerably more complex than in the case of the 4 mc short paths. Thus, the weak tendency for a daytime peak of signal strength present during 1949-50 on the 12 mc long path might be ascribed to F2 daytime propagation. During 1950-51, the MUF for these paths should also, on the basis of Table 5, have been above 12 mc; yet no daytime peak of signal strength was observed (except perhaps during the winter months).

The above discussion indicates that the differences of the average daytime propagation conditions found between years of sunspot maximum and minimum can be explained in part on the basis of changes in normal F2 layer propagation. However, many questions have not been answered. For example, nothing has been said concerning the actual values of median signal strength and their variation from year to year, or their diurnal variation. The mode of propagation for any given path and frequency depends on a great number of parameters: for instance, on the presence of the normal ionospheric layers, the sporadic and auroral associated ionization, and the absorption arising from excess ionization in the D region.

6. SUMMARY AND CONCLUSIONS

The Interim Scientific Report stressed the effect of ionospheric absorption in causing outage time on the short paths. It was shown that outages on the short paths during 1954 were primarily due to absorption at levels below the reflecting regions. The absorption was found to be primarily a daytime phenomenon. The absorption correlated well with magnetic activity, in that the magnetic K index was found to be higher than normal during periods of absorption.

In this report, emphasis is placed on the difference of propagation between a year near sunspot maximum and one near sunspot minimum. In the case of 4 mc propagation over a short path, the difference is evidenced by a daytime peak of signal strength during years of minimum solar activity. The 12 mc long path may show signs of a daytime peak in active years, but probably not during years of minimum solar activity. These daytime effects can largely be explained on the basis of variation of the normal F2 layer throughout the different epochs of the solar cycle.

On the basis of the monthly mean signal in-time, it is shown that a significant difference between east-west and south-north propagation may exist in the case of the 12 mc short path. A possible difference also exists in the case of the 4 mc short path. For all other paths and frequencies, no significant difference exists between the east-west and south-north propagation conditions. The analysis to date is not sufficient to determine with certainty whether the observed difference is the result of instrumental differences or due to actual differences of propagation conditions. If the latter is true, the difference probably arises because of some non-normal mode of propagation, such as scatter from sporadic ionization.

The analysis reported in the Interim Scientific Report and this report indicate that similar analyses should be completed for all paths and frequencies. Such analysis falls inside the scope of contract SC-71137, "Arctic Radio Wave Propagation".

TABLE 6. MONTHLY PERCENTAGE SIGNAL IN-TIME

TABLE 6.1 NORTHWAY - COLLEGE 4095 KC (4MC SHORT PATH E-W)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1949	-	-	-	-	-	60	65	60	63	63	66	45	422
1950	95	85	90	78	81	88	90	91	63	72	70	83	986
1951	60	48	58	50	54	55	82	93	79	89	34	-	702
1952	60	57	62	58	8	66	82	47	89	85	83	28	725
1953	89	86	62	61	64	47	29	59	66	80	79	93	815
1954	88	64	64	83	93	97	96	88	72	89	97	80	1011
1955	97	92	81	89	91	97	89	93	92	80	-	-	901
Total	489	432	417	419	391	510	533	531	524	558	429	329	5562

TABLE 6.2 SHEEP MT. - COLLEGE 4240 KC (4 MC SHORT PATH S-N)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1949	-	-	-	-	-	56	84	61	67	67	63	87	485
1950	95	67	95	58	56	89	92	93	63	76	68	77	929
1951	91	52	63	67	63	78	86	82	77	83	51	-	793
1952	63	-	42	70	16	57	93	82	50	92	91	94	750
1953	94	83	53	84	84	96	83	86	80	87	87	95	1012
1954	96	94	89	94	98	96	98	98	87	94	86	89	1119
1955	97	95	89	98	80	100	87	97	100	100	-	-	943
Total	536	391	431	471	397	572	623	599	524	599	446	442	6031

TABLE 6. MONTHLY PERCENTAGE SIGNAL IN-TIME

TABLE 6.3 NORTHWAY - COLLEGE 7580 KC (8 MC SHORT PATH E-W)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1949	-	-	-	-	-	45	39	74	38	46	34	69	345
1950	80	87	89	84	85	98	71	53	43	14	12	14	730
1951	5	-	19	13	14	5	19	16	51	57	16	-	215
1952	12	19	14	19	18	24	24	22	52	66	14	84	368
1953	80	46	60	49	60	57	68	45	68	77	88	87	785
1954	88	77	81	75	89	90	84	83	66	78	74	73	958
1955	85	81	61	85	69	79	84	65	72	49	-	-	730
Total	350	310	324	325	335	398	389	358	390	387	238	327	4131

TABLE 6.4 SHEEP MT. - COLLEGE 7940 KC (8 MC SHORT PATH S-N)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1949	-	-	-	-	-	62	69	67	54	70	86	87	495
1950	98	77	81	77	92	96	88	10	6	16	9	9	659
1951	52	40	79	43	64	82	23	75	72	73	71	-	674
1952	75	64	88	42	57	74	56	57	27	19	70	16	645
1953	10	6	4	6	18	78	52	63	62	95	67	83	544
1954	83	79	57	45	62	92	96	95	71	76	85	84	925
1955	72	78	58	83	86	93	84	77	83	88	-	-	802
Total	390	344	367	296	379	577	468	444	375	437	388	279	4744

TABLE 6. MONTHLY PERCENTAGE SIGNAL IN-TIME

TABLE 6.5 NORTHWAY - COLLEGE 12305 KC (12 MC SHORT PATH E-W)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1949	-	-	-	-	-	22	24	63	53	55	70	64	351
1950	77	76	80	75	81	97	91	65	37	43	27	31	780
1951	50	49	33	43	34	32	55	23	54	17	34	-	424
1952	22	28	55	27	40	28	53	12	11	5	4	39	324
1953	12	10	6	4	23	9	35	31	6	1	0	0	137
1954	19	76	56	55	50	85	83	89	69	84	90	86	842
1955	81	88	39	86	65	85	89	81	66	54	-	-	734
Total	261	327	269	290	293	358	430	364	296	259	225	220	3592

TABLE 6.6 SHEEP MT. - COLLEGE 12072.5 KC (12 MC SHORT PATH S-N)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1949	-	-	-	-	-	12	47	19	7	27	34	35	181
1950	45	57	40	55	62	93	48	9	12	22	35	33	511
1951	33	28	0	0	0	27	22	12	13	3	17	-	155
1952	23	27	24	2	13	12	18	17	16	6	51	72	281
1953	49	24	15	16	44	29	15	15	12	18	10	40	287
1954	4	34	13	24	48	56	81	78	58	64	81	78	619
1955	65	75	54	83	47	67	45	57	69	66	-	-	628
Total	219	245	146	180	214	296	276	207	187	206	228	258	2662

TABLE 6. MONTHLY PERCENTAGE SIGNAL IN-TIME

TABLE 6.7 NORTHWAY - NOME 4095 KC (4 MC LONG PATH E-W)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1949	-	-	-	-	-	52	57	42	40	17	47	45	300
1950	42	68	62	39	33	43	42	41	33	26	26	41	496
1951	23	7	12	7	12	17	27	29	25	22	35	-	216
1952	8	21	13	13	2	1	13	9	14	9	10	0	113
1953	16	22	48	12	7	0	18	29	24	32	36	67	311
1954	58	27	18	45	34	60	56	48	19	37	62	72	536
1955	38	34	26	38	39	34	55	44	44	51	-	-	403
Total	185	179	179	154	127	207	268	242	199	194	216	225	2375

TABLE 6.8 SHEEP MT. - BARROW 4240 KC (4 MC LONG PATH S-N)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1949	-	-	-	-	-	39	41	36	50	40	54	79	339
1950	60	45	60	41	35	31	36	28	31	21	38	45	471
1951	36	36	36	28	26	23	39	33	35	38	56	-	386
1952	23	10	23	24	28	34	35	52	41	41	50	57	418
1953	36	36	36	20	19	16	22	19	32	6	15	54	311
1954	24	9	24	53	77	63	39	55	29	41	51	67	532
1955	23	23	37	38	33	20	29	40	46	60	-	-	349
Total	202	159	216	204	218	226	241	263	264	247	264	302	2806

TABLE 6. MONTHLY PERCENTAGE SIGNAL IN-TIME

TABLE 6.9 NORTHWAY - NOME 7580 KC (8 MC LONG PATH E-W)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1949	-	-	-	-	-	78	85	71	51	47	27	80	439
1950	64	72	88	81	90	95	74	46	39	6	3	5	663
1951	2	0	6	26	14	8	40	18	5	18	10	-	147
1952	5	8	2	14	0	25	27	70	34	25	16	27	253
1953	25	34	18	28	11	10	7	9	11	7	43	40	243
1954	51	38	40	67	83	92	81	75	49	62	56	51	745
1955	39	55	39	48	69	73	85	73	91	47	-	-	619
Total	186	207	193	264	267	381	399	362	280	212	155	203	3109

TABLE 6.10 SHEEP MT. - BARROW 7940 KC (8 MC LONG PATH S-N)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1949	-	-	-	-	-	28	80	87	70	62	55	73	455
1950	89	64	77	76	85	95	88	93	66	45	11	36	825
1951	27	38	55	55	65	76	48	73	66	71	71	-	645
1952	51	49	48	56	64	88	82	89	76	55	53	35	746
1953	30	35	37	53	57	17	63	38	36	40	22	33	461
1954	41	20	28	42	73	91	78	69	42	30	29	37	580
1955	20	34	47	66	78	84	79	79	82	82	-	-	651
Total	258	240	292	348	422	479	518	528	438	385	241	214	4363

TABLE 6. MONTHLY PERCENTAGE SIGNAL IN-TIME

TABLE 6.11 NORTHWAY - NOME 12305 KC (12 MC LONG PATH E-W)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1949	-	-	-	-	-	33	88	82	68	75	80	58	484
1950	71	68	78	82	86	90	84	61	37	34	28	20	739
1951	26	21	30	45	51	73	67	33	58	42	39	-	485
1952	18	25	14	15	33	71	58	53	32	3	1	39	362
1953	16	20	12	25	63	46	62	39	25	34	12	8	362
1954	6	17	17	13	40	71	39	32	19	52	40	22	368
1955	15	37	15	13	32	63	77	52	38	43	-	-	385
Total	152	188	166	193	305	447	475	352	277	283	200	147	3185

TABLE 6.12 SHEEP MT. - BARROW 12072.5 KC (12 MC LONG PATH S-N)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1949	-	-	-	-	-	29	95	67	64	83	67	58	463
1950	63	75	75	78	86	94	94	93	42	52	66	87	905
1951	79	61	20	27	38	86	70	70	54	51	52	-	608
1952	24	11	19	24	37	63	59	34	18	22	2[illegible]	1	347
1953	14	19	20	20	35	29	40	30	24	14	11	19	275
1954	21	19	29	22	28	74	75	59	33	24	23	15	422
1955	16	26	19	26	35	71	53	58	49	46	-	-	399
Total	217	211	182	197	259	446	486	411	284	292	240	194	3419

TASK B

PULSE TECHNIQUES: BACK-SCATTER AT 12 MC

(B. Nichols and R. Stark)

1. INTRODUCTION

As a result of back-scatter observations using VHF radars made at College and other places (1), a great deal is now known about the character of the echoes obtained at very high frequencies from the aurora. In addition, at lower latitudes, HF radars have been used to obtain echoes back-scattered from the ground after ionospheric reflection (2, 3, 4, 5). During the latter experiments, echoes associated with the aurora have also been seen (6, 7).

During the period of this contract a 12 mc radar was constructed and operated at College. At first the antenna was operated in a fixed position directed toward geomagnetic north. Later the equipment was converted to present a PPI display as well as an A-scope display.

Continuous data have now been obtained for several months, and over two thousand echoes have been included in the analyses that follow. Echoes have been obtained by direct back-scatter, by ground-scatter, and probably by some combination of the two. In separating the echoes into the various modes, we made use of the fading rate as well as the range of the echoes as observed in the A-scope. Echoes associated with aurora are characterized by a high fading rate, roughly 10 to 25 cps at

12 mc, while ground-scatter echoes have fading rates of the order of one cps.

2. EQUIPMENT

A detailed description of the equipment is given in Quarterly Progress Report No. 6 (1 September to 20 November 1955). The usual operating conditions are listed in Table 1.

Table 1. Operating parameters for 12 mc radar at College

Frequency	12.305 mc
Pulse repetition frequency	50 cps
Pulse length	400 microseconds
Antenna	Rotating, three-element Yagi; half-wave above ground; same antenna used for transmission and reception
Peak power	6 kw
Receiver bandwidth	3 kc
Displays	PPI photographed continuously, one frame per antenna rotation on 16 mm film and amplitude-range, (A-scope) observed visually
Maximum range displayed	2500 km
Minimum range displayed	250 km
Operating schedule	24 hours per day

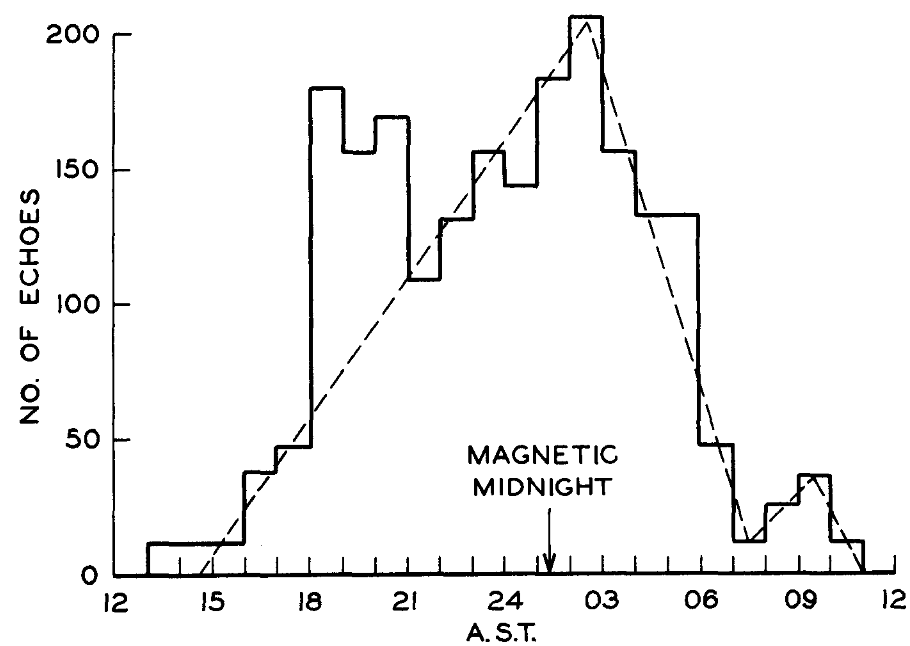
For special observations the pulse length was decreased to 200 microseconds, and the minimum range observable was then decreased to slightly more than 100 km. The maximum range could also be set at 5,000 km for observation of the long range ground-scatter echoes.

Equipment for pulse-by-pulse recording of a gated section of the A-scope presentation was also constructed for fading rate measurements. This equipment is described in Quarterly Progress Report No. 4 (1 March 1955 to 31 May 1955).

3. EXPERIMENTAL RESULTS

All those echoes having auroral fading characteristics were segregated and analyzed separately. The majority of these echoes are obviously direct back-scatter from ionization associated with the aurora. However, a considerable number of echoes require more complicated explanations. These echoes are of two types. One type is most frequently seen in the late afternoon or early evening hours in the northeast at ranges in excess of 2000 km. The second type starts out as an apparent ground-scatter echo, but then suddenly begins to fade much more rapidly. The range of the echo usually remains constant for a few minutes, gradually reduces in range, and then increases again. This phenomenon occurs most often in the early evening hours.

The diurnal distribution of all echoes having auroral fading characteristics is shown in Figure 13. The dashed line shows the curve that



Diurnal Variation of Auroral Echoes

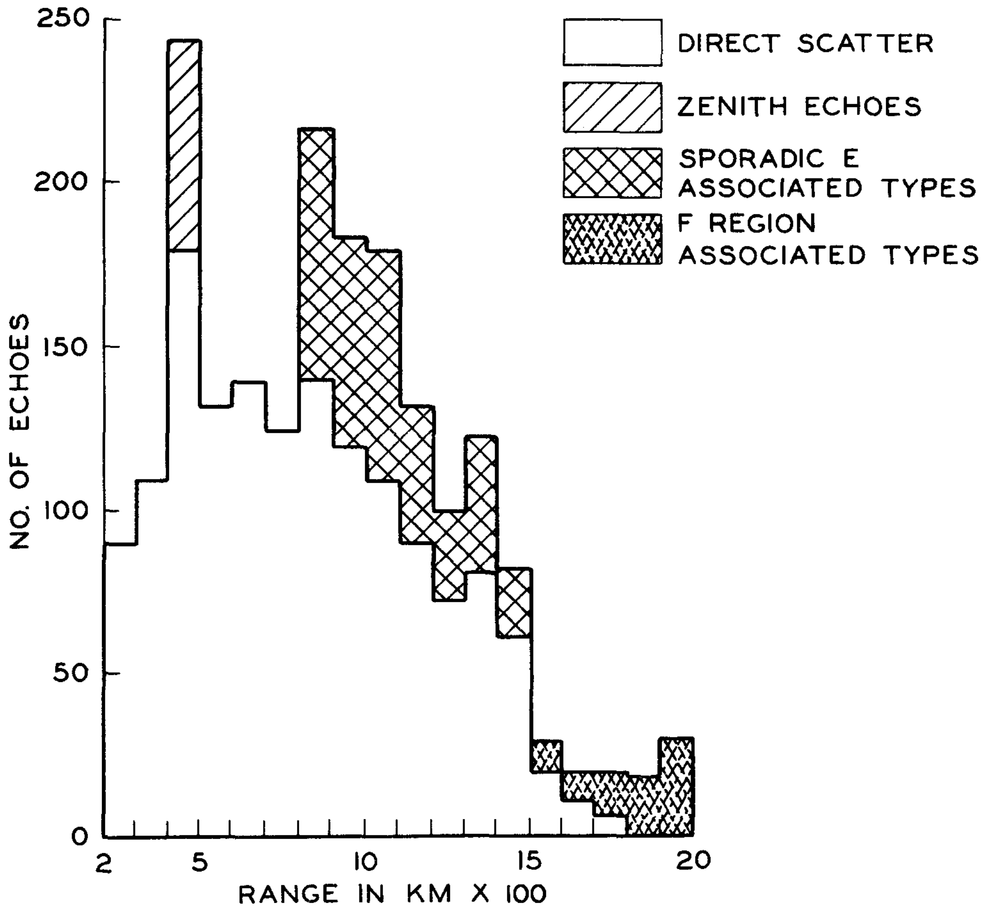
Fig. 13

results if the early evening maximum, caused by the two special-type echoes described above, is left out of the analysis.

Figure 14 is a histogram of the range distribution of all echoes having auroral fading characteristics. The unshaded region shows the range distribution of these echoes believed to be of direct auroral back-scatter origin. The shaded region labeled "zenith echoes" shows those echoes (say, from the west) that are believed to be duplicates of ones already counted (say, from the east). During conditions of aurora in the zenith, simultaneous echoes are obtained symmetrically from the east and west and, therefore, should probably be counted as only one echo. The shaded regions labeled "Sporadic E associated types" and "F-region associated types" show those echoes of the two special types described above. We believe that ground-scatter is part of the explanation of both types.

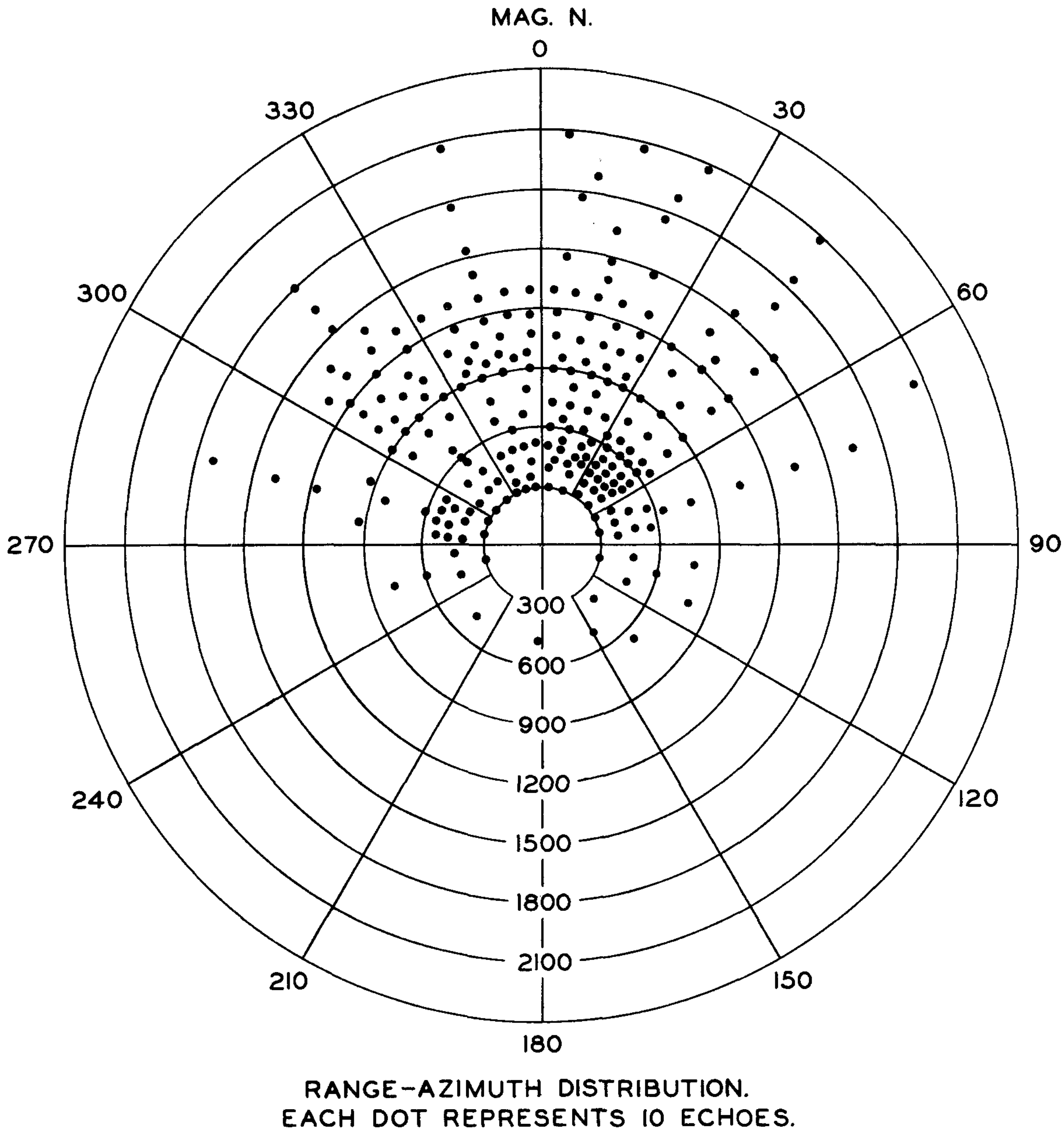
The range-azimuth distribution of all echoes having auroral fading characteristics is shown in Figure 15. Even at 12 mc, the majority of the echoes come from the north. Because the broad horizontal antenna pattern spreads the echo out over 60 to 90 degrees in azimuth, the photographs were divided into 30-degree sectors, and the distribution chart shows only that the origin of the echo was probably in the sector shown.

Figures 16, 17, and 18 show examples of PPI records that have been selected to illustrate some of the special types of echoes observed. In all cases the reference vertical direction is to geomagnetic north. The



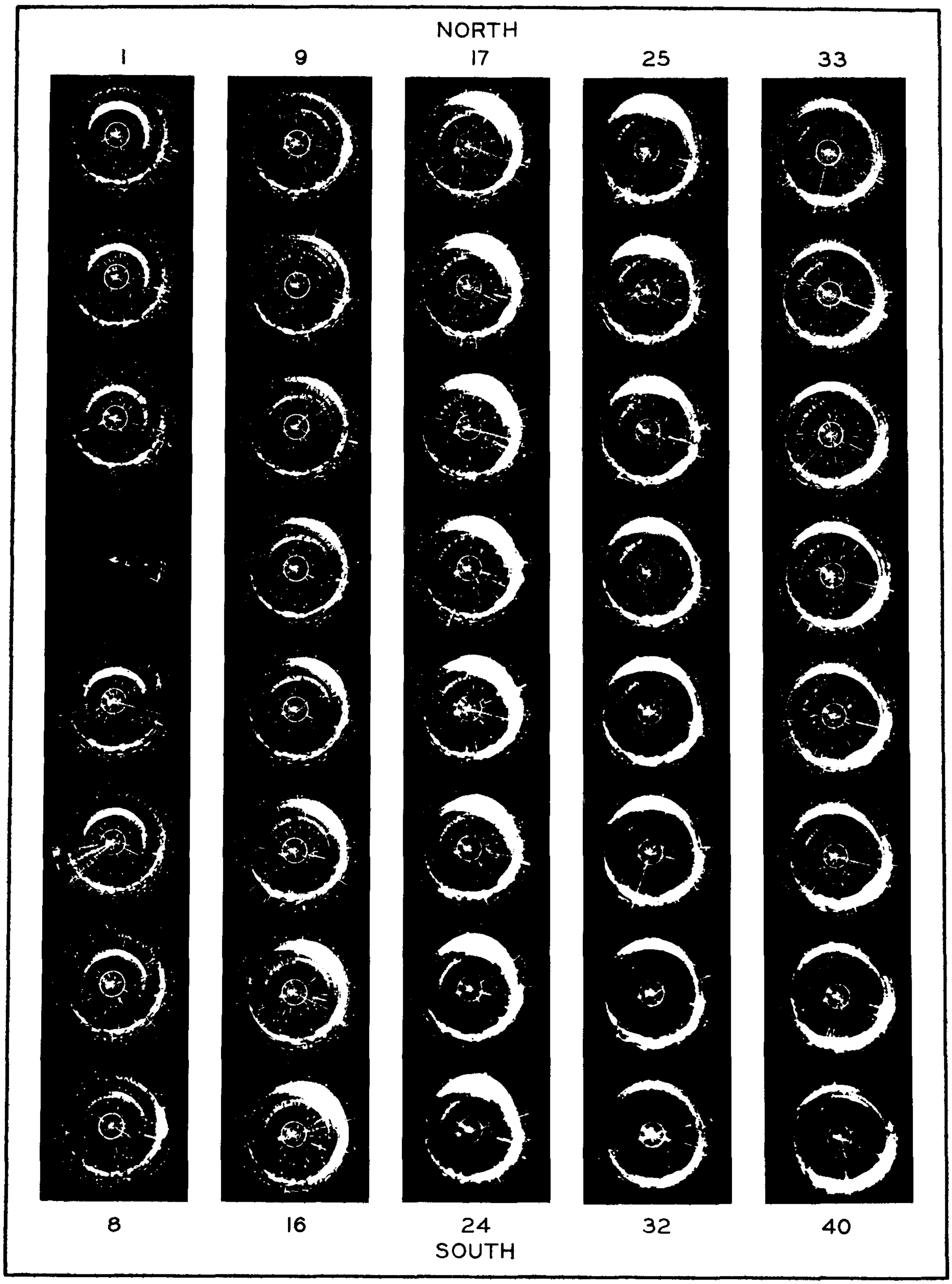
Range Histogram of Auroral Echoes

Fig. 14



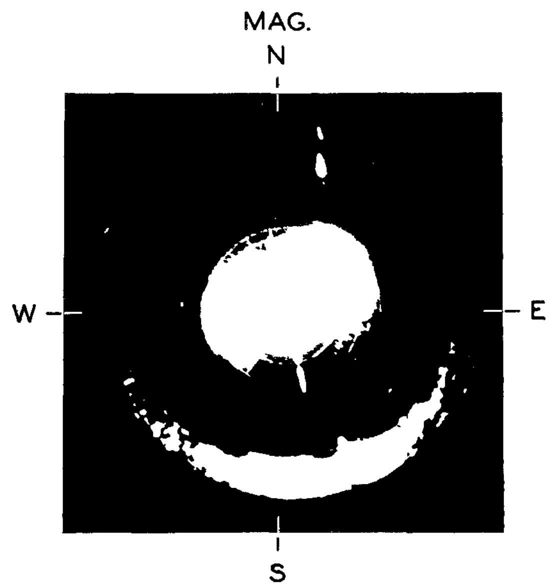
Range-Azimuth Distribution of Auroral Echoes

Fig. 15



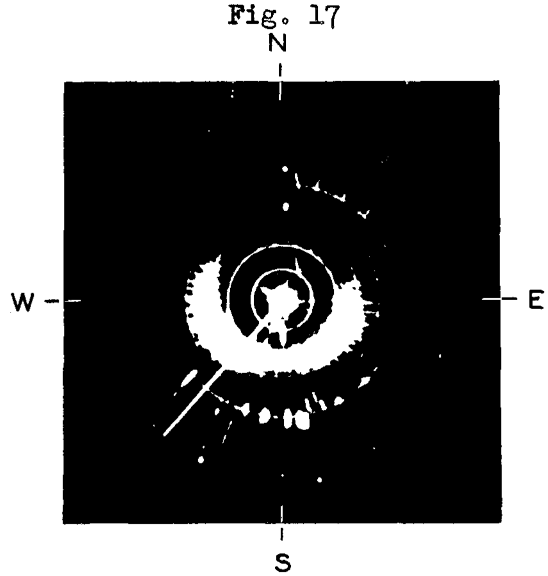
Sequence Showing Development of Auroral Echo From Ground-Scatter

Fig. 16



Echo From Zenithal Aurora

Fig. 17



Auroral Echo From the South

Fig. 18

range circles are separated by 150 km.

Figure 16 shows a sequence of photographs taken at one-minute intervals with the antenna rotating at one rpm so that each rotation of the antenna is presented in the sequence. It is a typical sequence of the phenomenon mentioned previously, in which an echo with all the characteristics of an F-region ground-scatter echo suddenly begins to fade very rapidly. The transition takes place in frame 10 in the northeast quadrant. There is a gradual increase in intensity of the echo together with a range decrease. This sequence is followed by a range increase and shift to the west starting at about frame 25. By frame 40, the echo has begun to fade into F-region ground-scatter in the northwest quadrant. The phenomenon usually lasts for a period of about half an hour. Similar occurrences take place with echoes that appear to start as ground-scatter echoes via Sporadic E.

An example of the "double" echoes obtained from the east and west during zenith aurora is shown in Figure 17. An example of the rarely seen auroral echo from the south is shown in Figure 18. The minimum range of such echoes is around 450 km. (See Figure 3.)

4. DISCUSSION OF RESULTS

The characteristics of the echoes that appear to arise by direct back-scatter from the aurora are consistent with our interpretation of the results obtained from VHF radars (1). For example:

(i) The fading rate is roughly half that observed at 25 mc and roughly a quarter of that observed at 50 mc.

(ii) Aspect sensitivity is still maintained, but to a lesser degree than observed at the higher frequencies. This result is what would be expected from our picture of scatter from short columns of ionization aligned along the earth's magnetic field. The observed minimum ranges are 150 km in the north, slightly under 300 km in the east and west, and 450 km in the south. If we assume a height of reflection of 100 km, we have an off-perpendicular angle of about 30 degrees in all azimuths at these ranges. This angle would correspond to the 7 to 8 degrees seen at 50 mc.

(iii) The diurnal variations of these echoes (see dashed curve of Figure 13) are very similar to that observed at the higher frequencies.

However, other echoes seen at 12 mc were not observed at the higher frequencies. At 12 mc the F-region and Sporadic E may often support reflection resulting in ground-scatter echoes. These echoes are commonly observed but will not be discussed in this report. As stated earlier, the fading rate of these echoes is low.

There are, in addition, the two special types of echoes that have high fading rates. The first type can probably be explained as a combination of F-region ground-scatter and auroral back-scatter. Echoes would reach the receiver by means of F-layer reflection, ground forward-scatter, and scatter from the aurora back over the same path. The echoes are most frequently seen in the late afternoon and early evening hours, when the F-region would have sufficient ionization for reflection. The echoes are seen at ranges in excess of 2,000 km, 30 to 45 degrees east of magnetic north, which would locate the scatterers in or very near the auroral zone, in a region where local magnetic midnight is three or four hours earlier than at College. Because ground-scatter echoes are not seen at the same time from the same direction, this explanation assumes that the combination of forward-scatter from the ground and back-scatter from the aurora is a more efficient mechanism than ground back-scatter.

The second special type of echo, in which a Sporadic-E or F-region ground-scatter echo suddenly develops a high fading rate and decreases in range (as illustrated in Figure 16), also undoubtedly requires an explanation in terms of a combination of ground-scatter and auroral effects. We are not, however, proposing any explanation at this time.

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TASK B

VISUAL OBSERVATIONS OF THE AURORA

(Harold Leinbach and Carol Smith)

The visual auroral observations obtained for the observing period of 1954-55 by Signal Corps personnel at the four field sites of Pt. Barrow, Nome, Sheep Mt., and Northway, as well as by the observers at College, have been analysed. The resulting data supplement those obtained in the earlier years of the auroral observing program, and have been discussed by Elvey et al (1) for the years 1951-1953, and Elvey (2) for the years 1953-54. In general the 1954-55 observations substantiate the conclusions based on the 1953-54 data as given by Elvey (2). However, because the overall reliability of the 1954-55 observations is apparently less than that of the data previously obtained, no conclusions are made based solely on the 1954-55 data.

The method of the auroral observations is summarized by Elvey (2) and will not be dealt with in detail here. The most successful method of observing, adopted in the later years of the program, involved the use of an observing grid so designed as to allow the observer to plot the visual aurora by its occurrence in zones of geomagnetic latitude each having a width of one degree. The essential assumption underlying this method of observation is that the lower border of the aurora is on the average situated at a height of 100 km. The observing grid was oriented along the observer's magnetic meridian. Therefore the observations favored the auroral activity occurring in the region of the sky extending along the magnetic meridian, from horizon to horizon. Because of the dispersal of the five observing stations in geomagnetic longitude, it is possible to build up a picture of auroral activity across Alaska, providing that simultaneous observations from the stations are available.

The 1954-55 auroral data have been analysed through the use of IBM cards and machines. The original auroral data taken at each station were punched on IBM cards in a coding system similar to that proposed by C. W. Gartlein for use by the auroral observers during the International Geophysical Year. The primary object of using the IBM system in the present analysis was to provide a "test" run for the International Geophysical Year covering a moderate amount of auroral data. As anticipated, the actual analysis of the data was greatly facilitated by use of the IBM cards.

The 1954-55 auroral data are summarized and compared with the 1953-54 data in Figures 19 through 28. The percent of observing time during which aurora was seen in the various geomagnetic latitude zones is plotted for each three hour time interval (corresponding to the magnetic K-index periods) in Figures 19 through 23. The following relationships can be established:

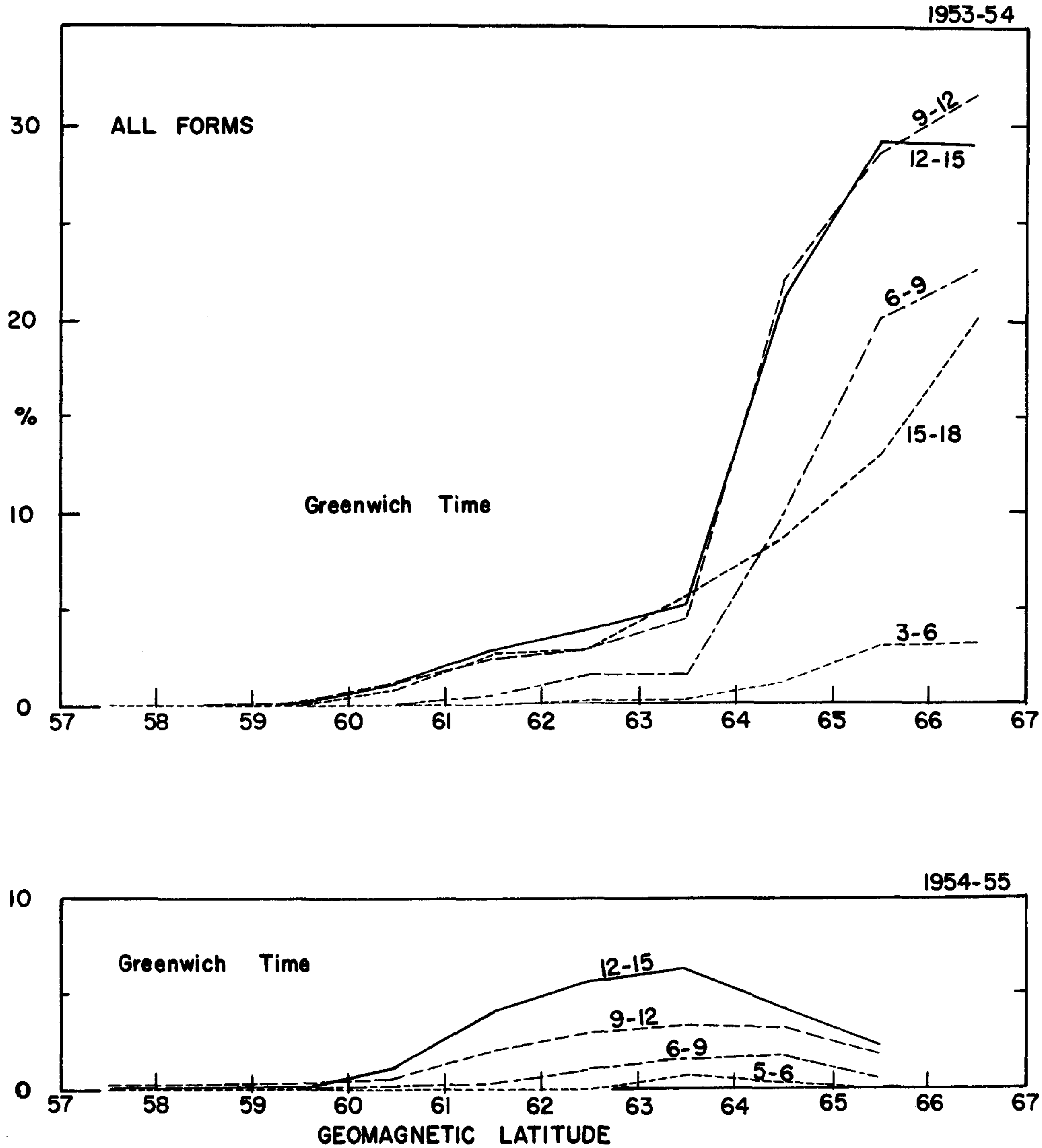
i. The peak auroral activity in a given geomagnetic latitude zone greater than 65 degrees tends to occur in the 09 - 12 GMT interval (23-02

Alaska Standard Time). These latitudes are best observed from College, Northway, and Barrow. For the geomagnetic latitude zones below 65 degrees, which are best observed from Sheep Mt. and Nome, the peak activity tends to occur during the 12-15 period or later for the two seasons.

These graphs, then, indicate that the auroral activity shifts southward during the night.

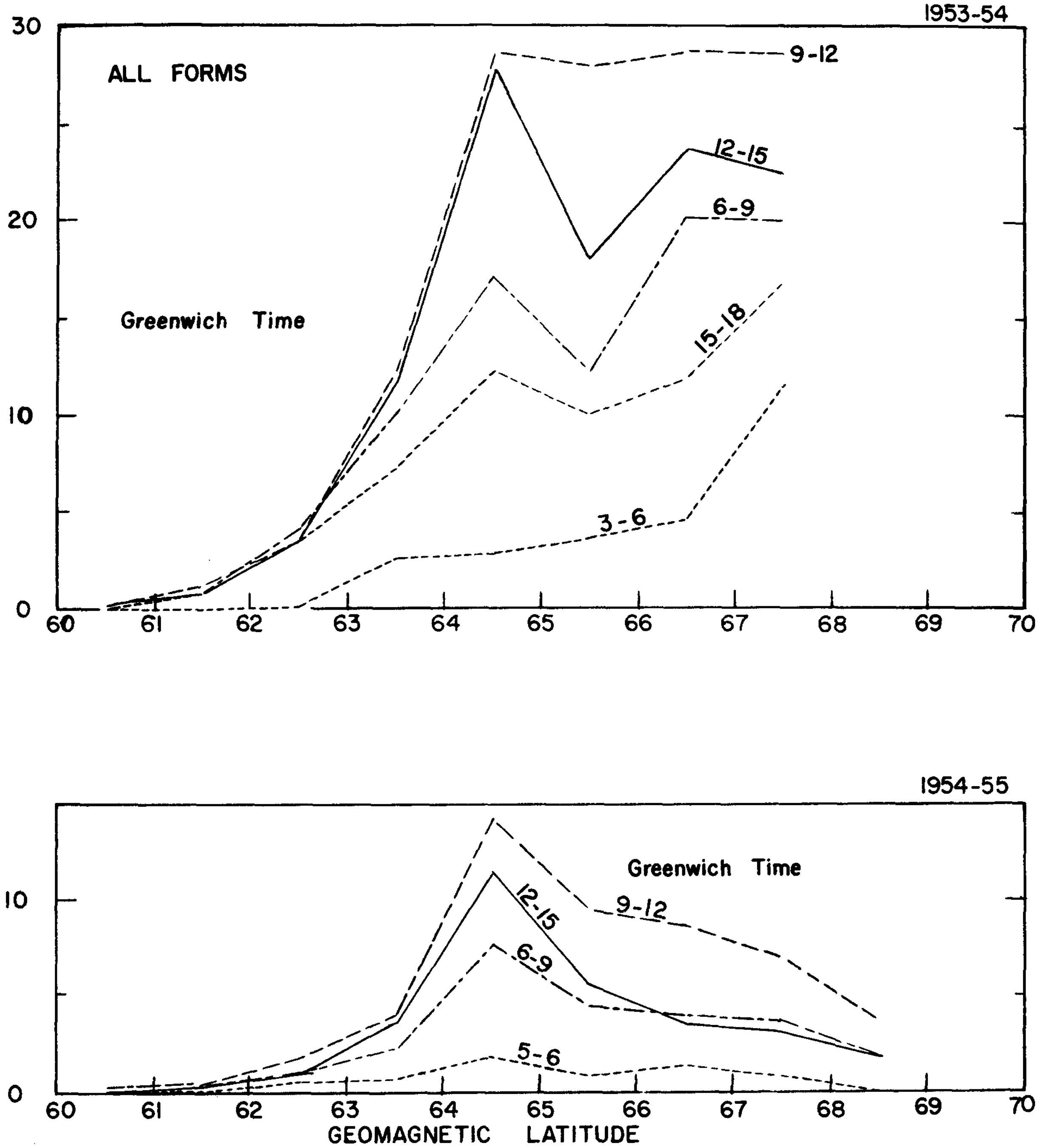
ii. During the early hours of the evening (the 03-06 GMT interval), the largest auroral activity has a pronounced tendency to occur in the northerly latitudes. Even at Barrow, which is well north of the commonly accepted maximum of the auroral zone, the aurora tends to occur in the north during the early hours of the evening.

The variation of auroral occurrence with latitude as a function of magnetic K-index is shown in Figures 24 through 28. The K-indicies determined at the College magnetic observatory were used for comparison with the 1954-55 auroral observations from all stations except Barrow. The K-indicies obtained by the magnetic observatory at Barrow were used in analysing the Barrow auroral observations. In the analysis of the 1953-54 data the K-indicies derived at Sitka were used for the auroral observations made at Sheep Mt. and Northway. Because the Sitka and College K-indicies show a very strong correlation, it is permissible to compare the 1953-54 and 1954-55 data for the Sheep Mt. and Northway stations.



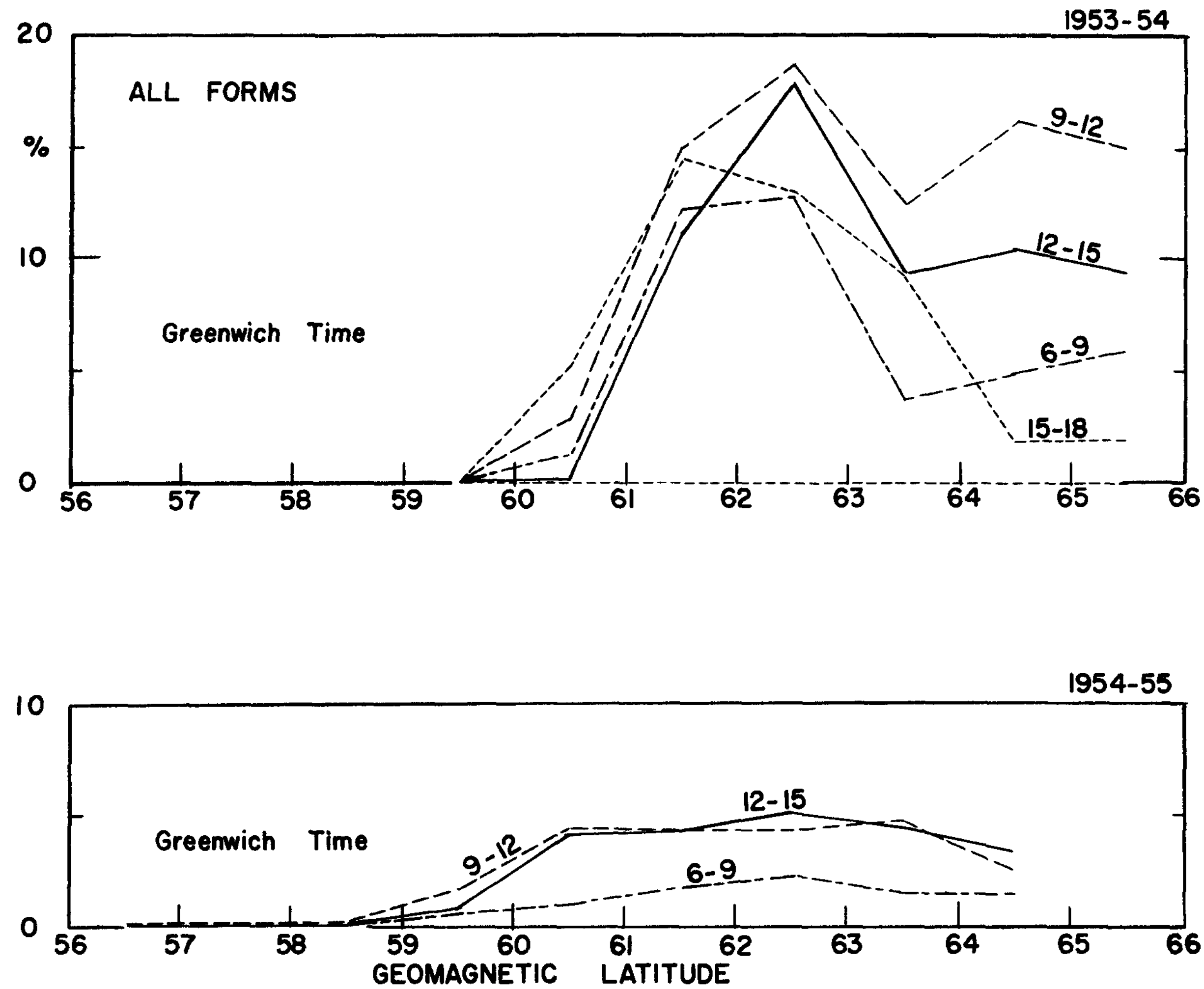
NOCTURNAL VARIATION OF AURORAS WITH GEOMAGNETIC LATITUDE AT SHEEP MT.

Fig. 19



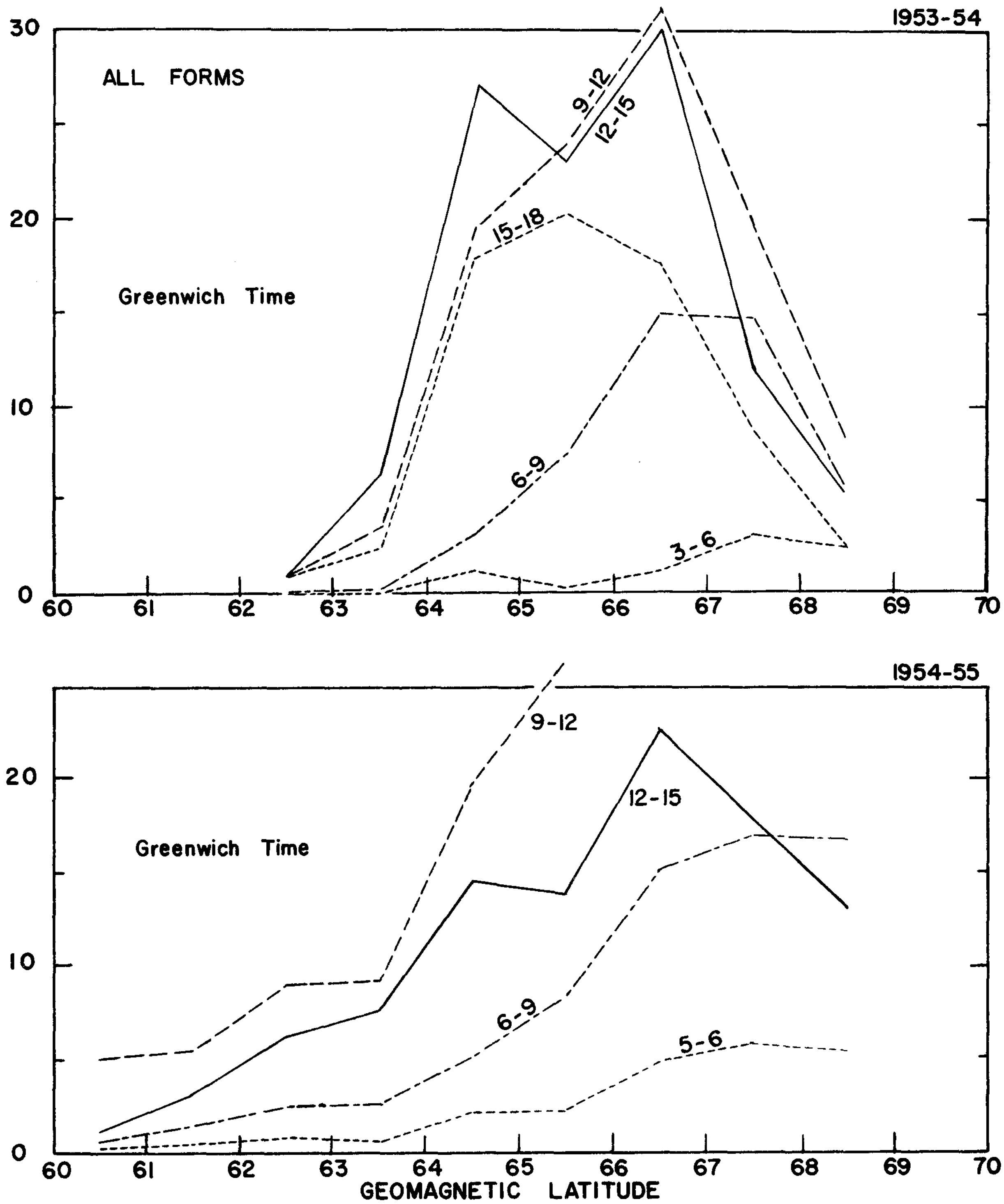
NOCTURNAL VARIATION OF AURORAS WITH GEOMAGNETIC LATITUDE AT NORTHWAY

Fig. 20



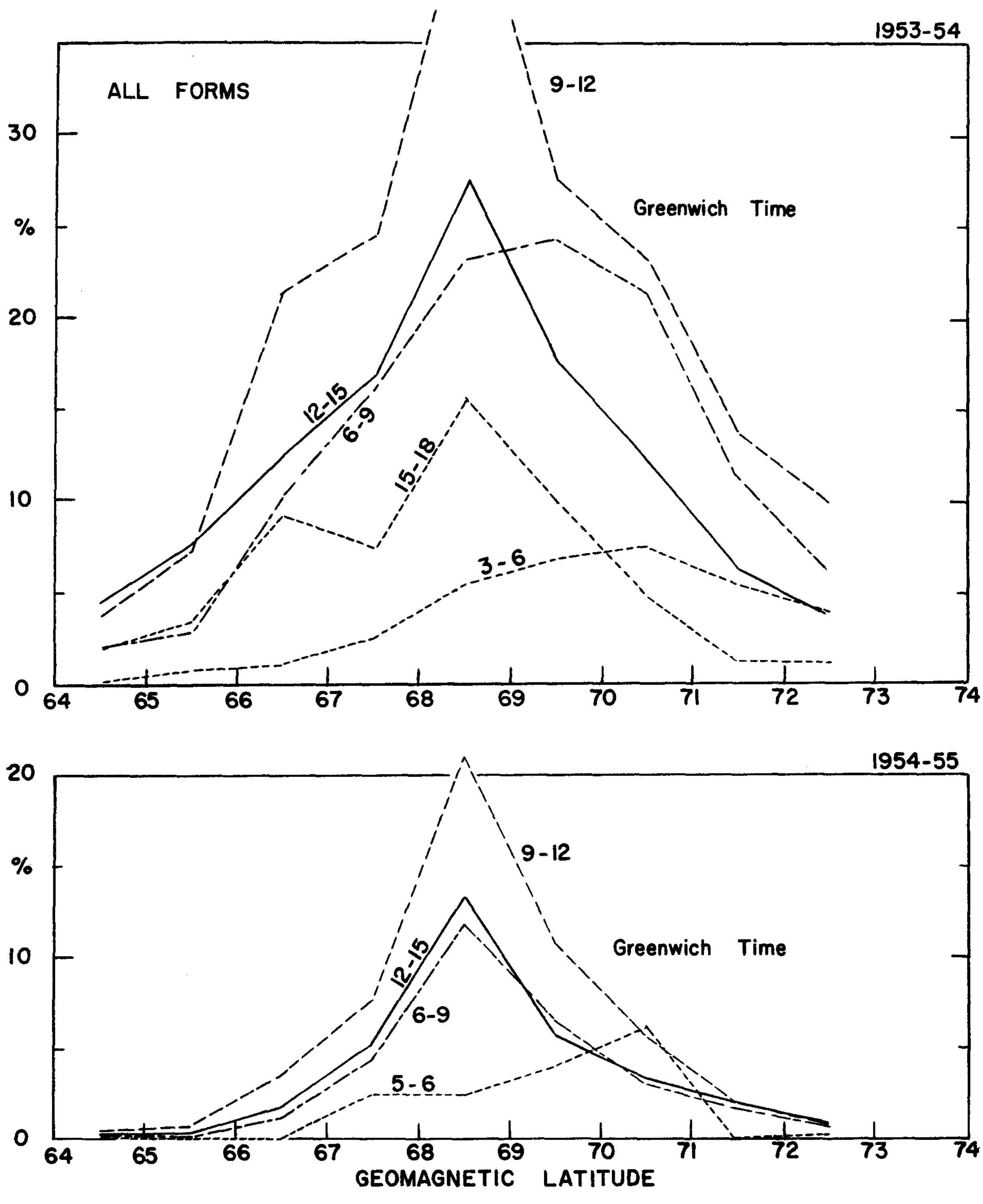
NOCTURNAL VARIATION OF AURORAS WITH GEOMAGNETIC LATITUDE AT NOME

Fig. 21



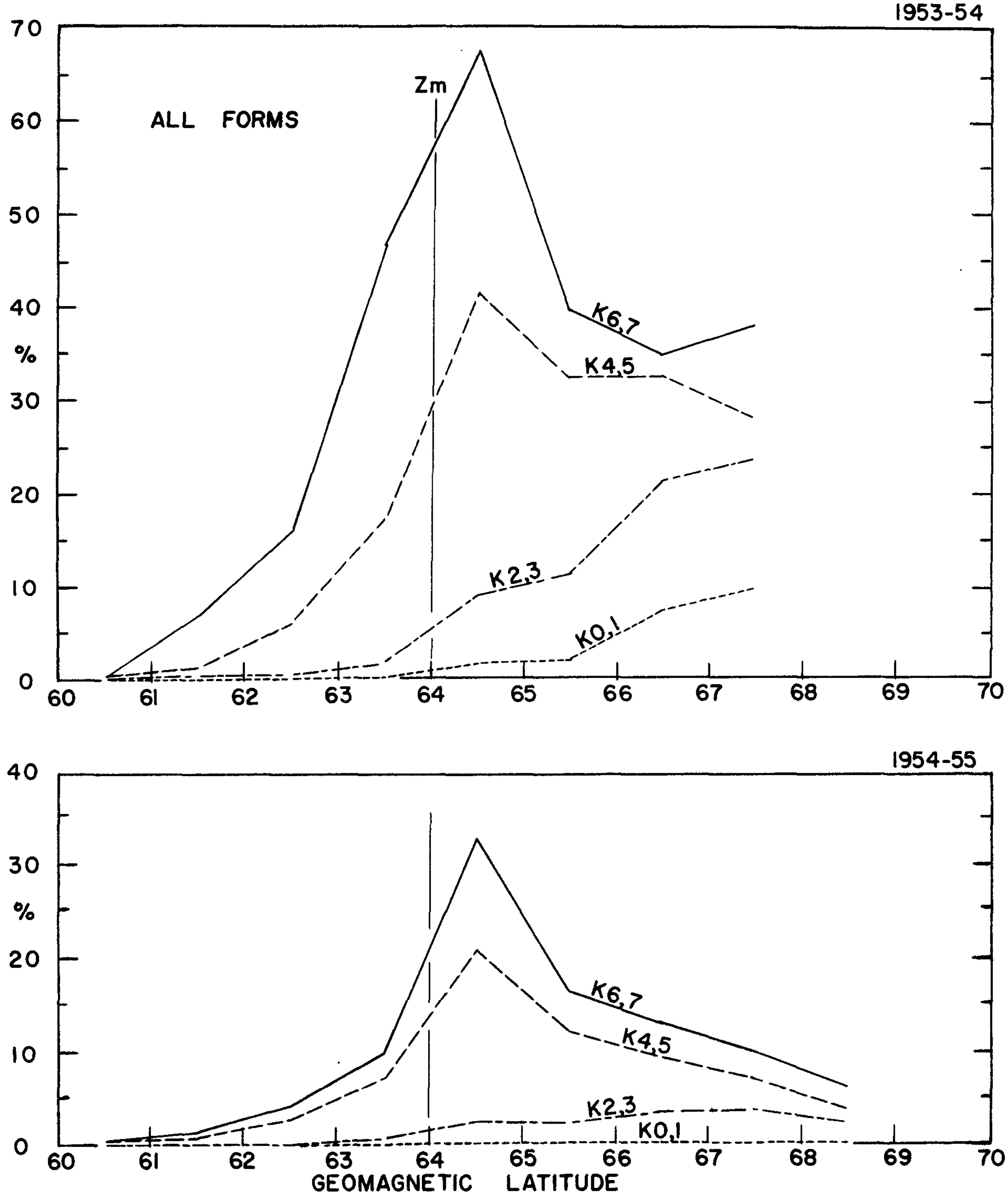
NOCTURNAL VARIATION OF AURORAS WITH GEOMAGNETIC LATITUDE AT COLLEGE

Fig. 22



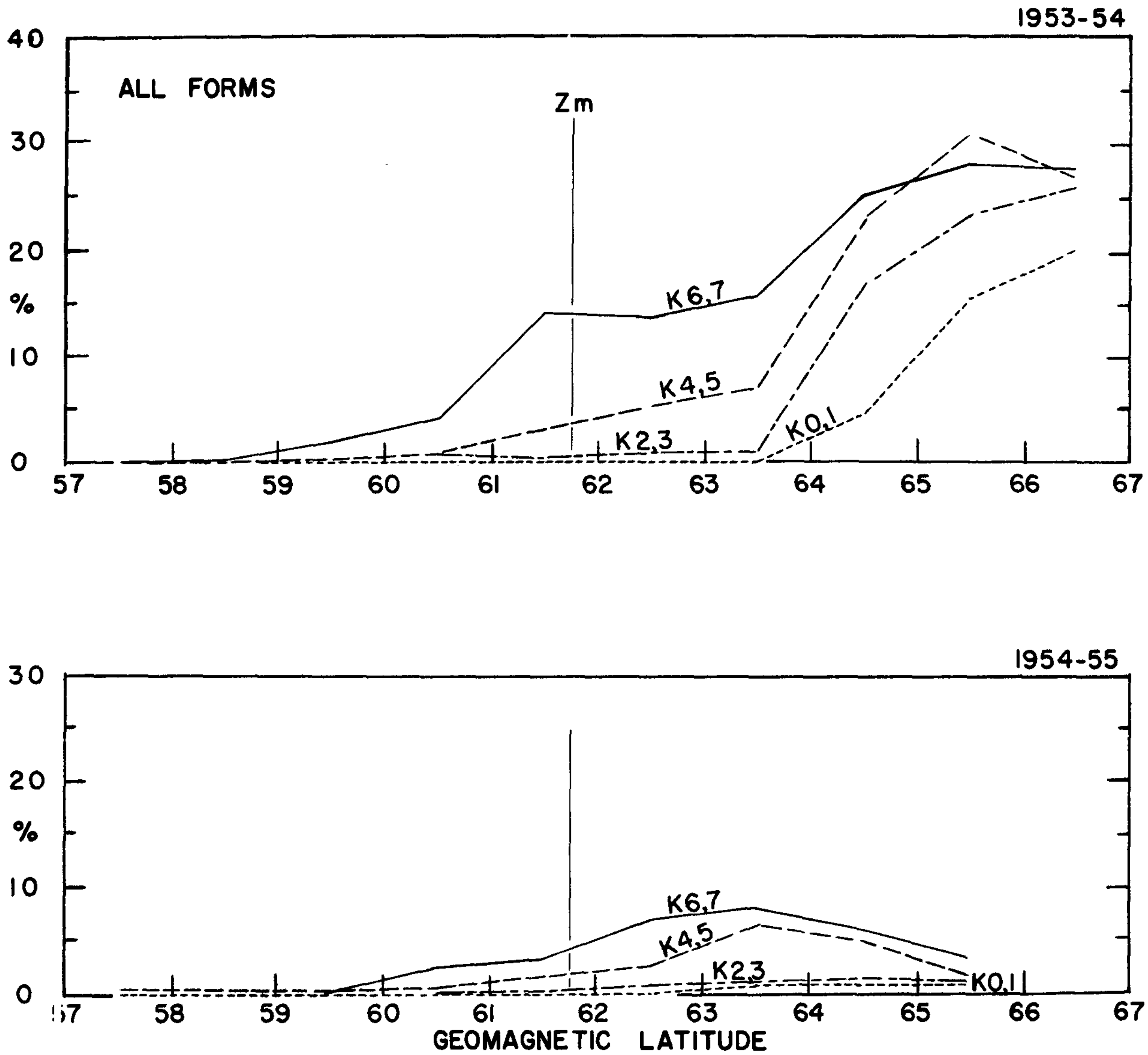
NOCTURNAL VARIATION OF AURORAS WITH GEOMAGNETIC LATITUDE AT PT. BARROW

Fig. 23



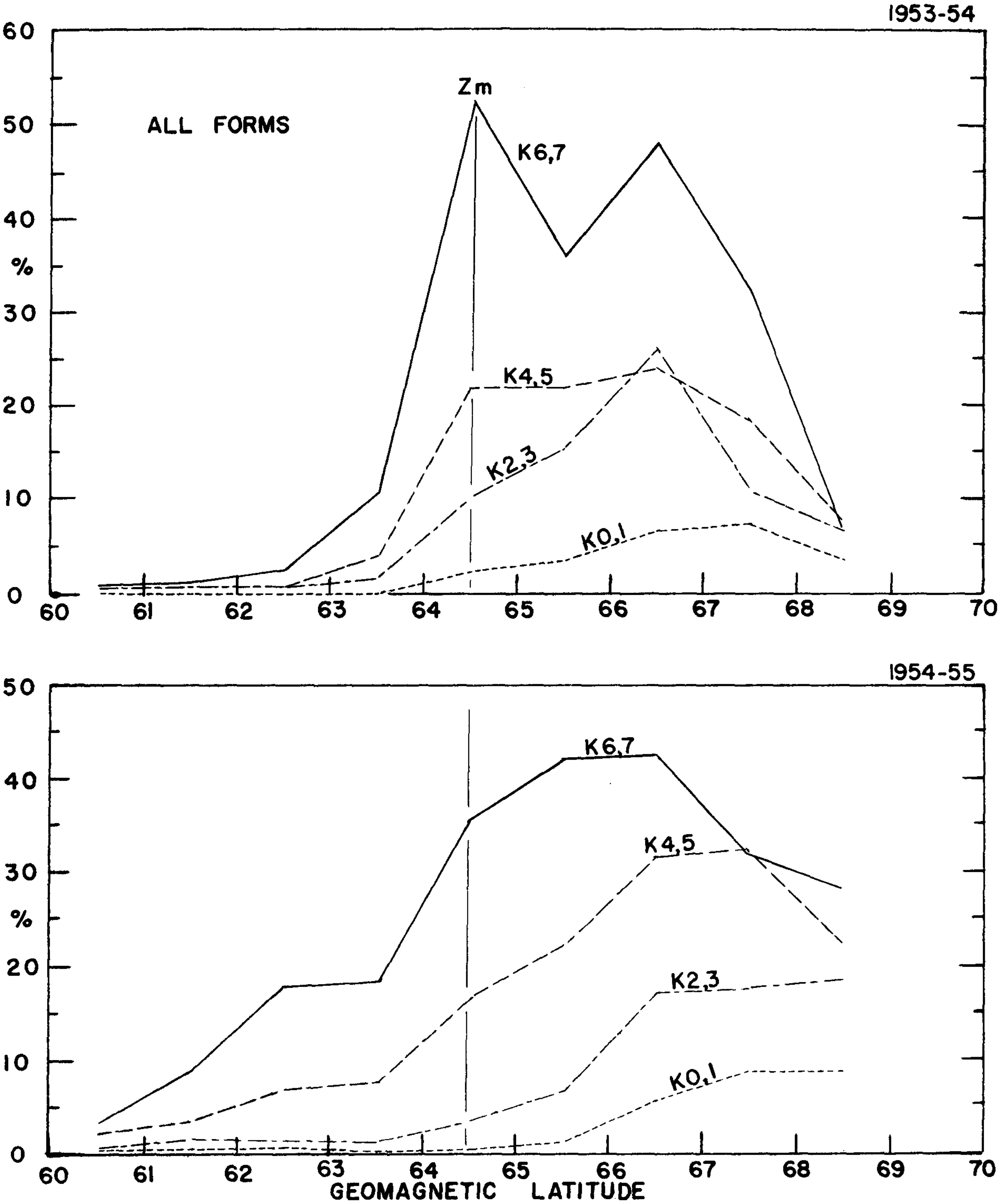
FREQUENCY OF AURORAS SEEN FROM NORTHWAY, ALASKA

Fig. 24



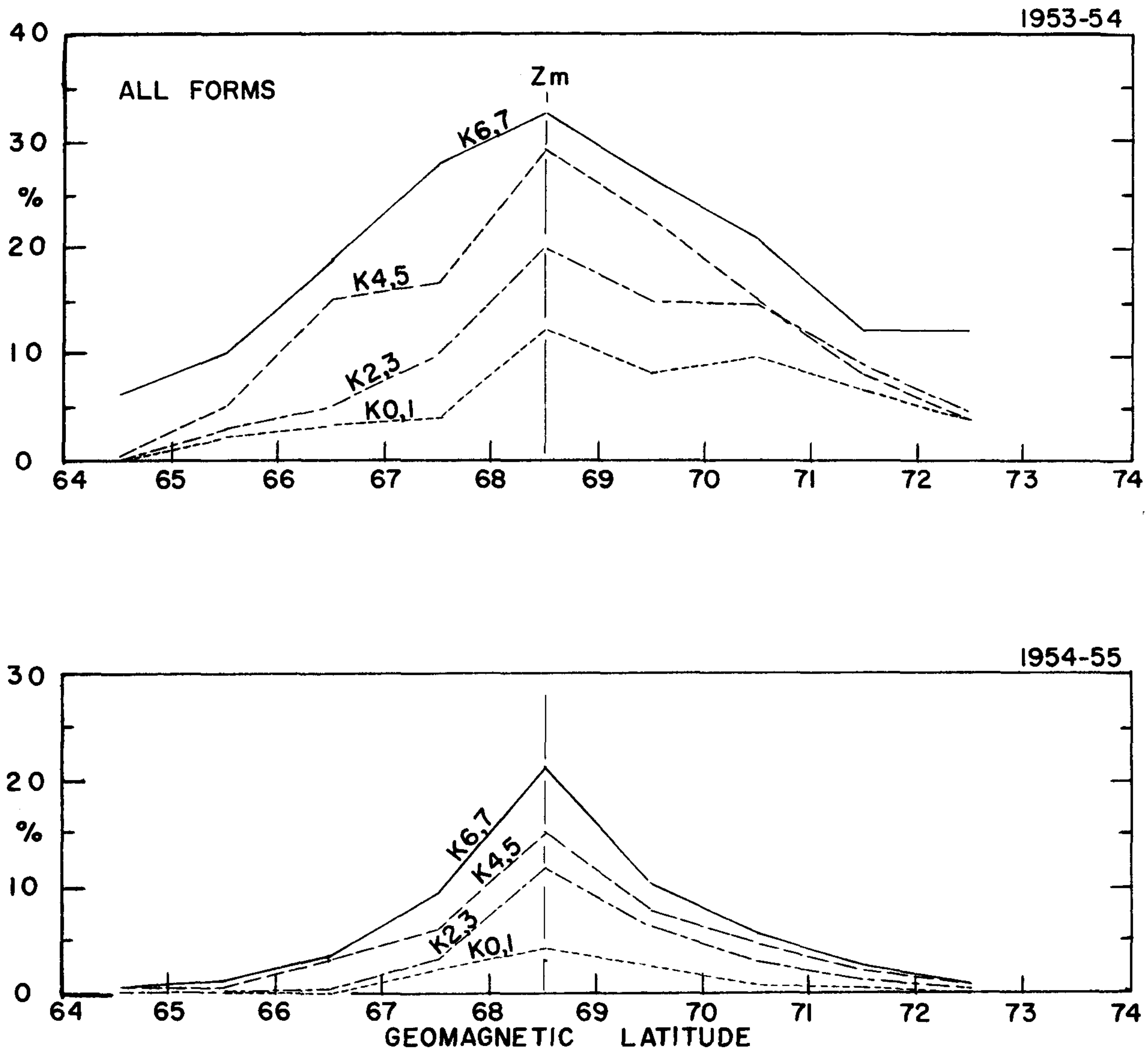
FREQUENCY OF AURORAS SEEN FROM SHEEP MOUNTAIN, ALASKA

Fig. 25



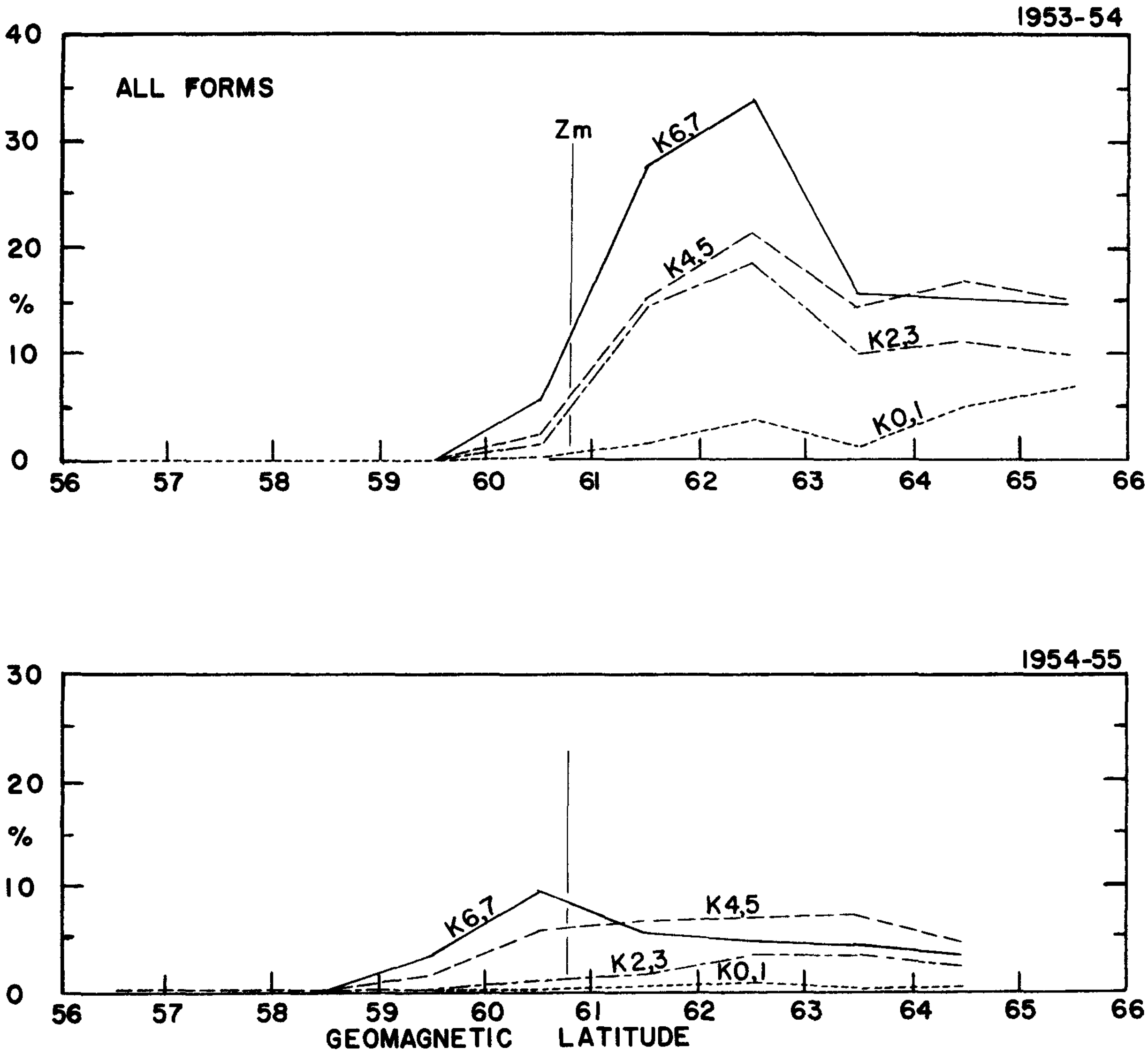
FREQUENCY OF AURORAS SEEN FROM COLLEGE, ALASKA

Fig. 26



FREQUENCY OF AURORAS SEEN FROM PT. BARROW, ALASKA

Fig. 27



FREQUENCY OF AURORAS SEEN FROM NOME, ALASKA

Fig. 28

The following conclusions can be reached by inspection of the graphs:

a. The greatest percentage of auroral occurrence at any latitude is obtained when the K-indicies reach their greatest value.

b. The College observations, which are considered to be the most accurate of those made during 1954-55, indicate a tendency toward a southward expansion of the auroral zone with increasing K-index. The zone of peak activity likewise undergoes a southward shift as the magnetic activity increases.

The data presented in Figures 19 through 28 include all auroral forms. Similar graphs showing the percentage occurrence for homogeneous forms and rayed forms have been prepared. These graphs confirm the results previously obtained on the basis of the 1953-54 observations.

DISCUSSION

The following differences between the 1954-55 and 1953-54 observations are to be noted for the various stations:

1. The percentage occurrence of aurora is appreciably less in the 1954-55 season at all stations except College.

2. The shape of the curves for the two seasons are notably dissimilar for the Sheep Mt. and Nome stations.

The graphs represent the uncorrected visual auroral observations. Elvey (2) points out that there are three corrections which should be applied to the data. The first involves the fact that the northernmost (and southernmost) latitude zones visible from a given station cover a very small angular dimension in the sky. Thus, a very slight error in angle measurement by the observer may result in the aurora being assigned to the wrong zone. On the basis of the 1953-54 data, Elvey finds that there appears to be a tendency to include too much aurora in the farthest north zone seen at the station.

The second correction takes account of the changing aspect of the aurora as a function of zenith distance. The average auroral form has a greater extension in height than in width. When observations are made along the magnetic meridian and the aurora is seen broadside, it appears brighter when near the zenith. This phenomenon is due to the greater optical pathlength when looking in the direction of the zenith. The observer for this reason sees fainter aurora at the zenith than at a large zenith angle. Thirdly, a correction must be made for the increasing extinction at increasing zenith angles. This effect also causes the observer to see fainter aurora at the zenith than at large zenith angles.

Although none of these corrections have been applied to the observations discussed here, the data for the two seasons should be directly comparable, since the method of observing was not changed. The differences recorded are probably due to observer error during the 1954-55 season rather than to an actual difference of percentage occurrence between the two years. At the beginning of the season, only two observers were left at the field sites who had experience from the previous observing period. The other military personnel was new and lacked training in auroral observing. The two trained observers were released from the detachment by the middle of the observing season. During a better part of the period, only one person was present at each of the Barrow and Sheep Mt. stations. Even though these two people were observing only on a limited time basis, it can not be expected that their observations were of a consistently high caliber. This difficulty arises because of the rigors involved in auroral observing during the winter in Alaska, and must be expected from even the most conscientious observer working alone.

The primary fault of the new, untrained observer (and even of some trained observers) is a lack of proper dark adaption of the eye before taking an observation. This lack of adaption has the effect of decreasing the number of faint aurora seen, at the same time increasing the number of "no aurora" observations. The end result is a decrease in the percent occurrence of aurora relative to its actual value, and may explain the greater part of the difference in percentage occurrence noted between 1953-54 and 1954-55 at the field sites.

REFERENCES

1. C. T. Elvey, Harold Leinbach, Joan Hessler, and John Noxon - Preliminary Studies of the Distribution of Aurora in Alaska. Trans. AGU 36 No. 3 390-394, 1955.

2. C. T. Elvey - Visual Observations of the aurora in Alaska, 1953-1954. Appendix A, Quarterly Progress Report No. 5, L March 55 to 31 May 55. S. C. - 56739.

SECTION V CONCLUSIONS

TASK A: TRANSMISSION OF HIGH FREQUENCY RADIO WAVES VIA THE ARCTIC IONOSPHERE

A comparison of the in-times of signals received on 4, 8 and 12 mc over short and long transmission paths (approximately 350 and 1100 km) in Alaska indicates that, in general, 4 mc is the best frequency for point-to-point communication over the short paths, and 8 mc best for communication over the long paths. There is no statistically significant difference in signal in-times between East-West and South-North paths for the two frequencies mentioned. On the 4 mc short paths the average monthly percentage of signal in-time over a 76 month period covering years of both high and low solar activity is 76.5 per cent. On the 8 mc long paths the average monthly percentage of signal in-time over the same 76 month period is 62.5 per cent.

At least 80 per cent of the signal out-time on the short paths are caused by polar black-outs (ionospheric absorption); that the point-to-point transmission over the 4 mc short paths ever fails because of lack of ionization is not indicated.

A study of the transmission of 12 mc signals over the short paths shows that at this frequency and for this pathlength there is a significant difference between East-West and South-North propagation. The propagation appears to be highly dependent on sporadic ionization, and the higher percentage of signal in-time in the East-West direction is believed to be due to a preferential orientation of ionization along parallels to the auroral zone.

A comparison has been made of the diurnal variation in the median signal strength received at 4 mc over the short paths and at 12 mc over the long paths, for years of high and low solar activity. In both cases the daytime variation in median signal strength may be explained in terms of normal F-layer ionization and D-layer absorption; and in Alaska the F-layer will support daytime propagation at 4 mc over the short paths throughout the solar cycle. For daytime propagation at 12 mc over the long paths the situation appears to be less favorable. Only in years of reasonably high solar activity will the F-layer ionization be sufficient to support regular transmission of signals.

The study of the diurnal variation in median hourly signal strength for years of high and low solar activity and the concomitant variation in the mean critical frequencies of the ionospheric layers over the same epoch provides a method for disentangling the propagation modes. This method has so far been applied to the daytime transmission over the 4 mc short paths and the 12 mc long paths. It remains to extend the analysis to all frequencies on both short and long paths.

After completion of the analysis of the daytime variation in median signal strength, it is desirable to undertake a similar investigation of the night-time variations. Investigation of the night-time propagation modes will involve a study of the occurrence of irregular and sporadic ionization, appearing mostly at E-layer height, rather than the regularly formed E and F layers. It is doubtful whether such an analysis can be carried through only on the basis of the transmission data secured under Task A and the ionospheric sounder records obtained during the years "Experiment Aurora" was in progress. The experimental studies of back-scatter being made under Task B by means of pulse techniques are more likely to provide the material required for a full understanding of the different modes of propagation.

The analysis of the signal outages over the short paths during the low solar activity year 1954 demonstrates that ionospheric absorption represents a major obstacle to continuous sky-wave propagation in Alaska. One may expect that the situation will be no better in a year of high solar activity, and possibl, worse, although the analysis required to ascertain the facts still remains to be done. However, the data available from the Task A transmission experiment and the ionospheric sounder records do not provide a sufficient basis for evaluating the properties and effects of the ionospheric absorption; and an adequate analysis can be made only after further, well designed experimental studies of this phenomenon have been made. Measurement of the intensity of incident extra-galactic radio waves provides a direct and powerful tool to this end.

SECTION VI

RECOMMENDATIONS

TASK A: TRANSMISSION OF HIGH FREQUENCY RADIO WAVES VIA THE ARCTIC IONOSPHERE

It is recommended that the Task A data together with available ionospheric and magnetic records be used for some further exploratory analysis of the possible modes of propagation and the factors affecting sky-wave transmission. It appears desirable to make further comparisons of conditions in years of high and low solar activity.

TASK B: PULSE TECHNIQUES. BACK-SCATTER AT 12 MC

It is recommended that the back-scatter observations at 12 mc be continued and a careful analysis made of the different types of recorded echoes.

TASK B: VISUAL OBSERVATIONS OF THE AURORA

The auroral work conducted under this contract and the preceding ones points out the need for auroral observations on a much greater scale; such observations will be undertaken in the near future by an extensive program for the International Geophysical Year.

Because the auroral light is the one direct effect we observe from the bombardment of the atmosphere by charged particles from the sun, visual observations can be made in conjunction with other projects.

SECTION VII PERSONNEL

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