PB 161618

NBS

Technical Note No. 117

Boulder Laboratories

VARIATIONS IN FREQUENCY OF OCCURRENCE OF SPORADIC E, 1949-1959

BY

W. B. CHADWICK

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to government agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. Research projects are also performed for other government agencies when the work relates to and supplements the basic program of the Bureau or when the Bureau's unique competence is required. The scope of activities is suggested by the listing of divisions and sections on the inside of the back cover.

Publications

The results of the Bureau's research are published either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three periodicals available from the Government Printing Office: The Journal of Research, published in four separate sections, presents complete scientific and technical papers; the Technical News Bulletin presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: Monographs, Applied Mathematics Series, Handbooks, Miscellaneous Publications, and Technical Notes.

A complete listing of the Bureau's publications can be found in National Bureau of Standards Circular 460, Publications of the National Bureau of Standards, 1901 to June 1947 ($1.25), and the Supplement to National Bureau of Standards Circular 460, July 1947 to June 1957 ($1.50), and Miscellaneous Publication 240, July 1957 to June 1960 (Includes Titles of Papers Published in Outside Journals 1950 to 1959) ($2.25); available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

NATIONAL BUREAU OF STANDARDS
Technical Note

117

October 1961

VARIATIONS IN FREQUENCY OF OCCURRENCE OF SPORADIC E, 1949 - 1959

by

W. B. Chadwick

NBS Technical Notes are designed to supplement the Bureau's regular publications program. They provide a means for making available scientific data that are of transient or limited interest. Technical Notes may be listed or referred to in the open literature. They are for sale by the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

DISTRIBUTED BY
UNITED STATES DEPARTMENT OF COMMERCE
OFFICE OF TECHNICAL SERVICES
WASHINGTON 25, D. C.
Price $. 75

VARIATIONS IN FREQUENCY OF OCCURRENCE OF SPORADIC E, 1949-1959

By

W. B. CHADWICK
Central Radio Propagation Laboratory
National Bureau of Standards, Boulder, Colorado

ABSTRACT

The question of the dependence of sporadic E on the sunspot cycle has largely been unresolved, with many investigators obtaining conflicting answers. In this report results are given covering daily-hourly values of fEs for eleven years at three ionosphere sounding stations, College, Washington, and Huancayo, chosen as representative of the three main sporadic-E zones. These stations experienced a minimum of equipment changes and changes of location during this period. Scaling procedures were monitored over the eleven years by a data quality-control group at the National Bureau of Standards. The period included the highest average sunspot number for over 200 years.

Correlation coefficients for yearly count of fEs > 5 Mc vs. yearly average sunspot number were found to be: College, -0.68 (daytime only, -0.63); Washington, -0.52 (night only, -0.52); Huancayo, -0.42 (night only, -0.66). Various hourly and monthly correlations were obtained. Of the 153 correlation coefficients listed in the paper, 147 are negative.

Certain correlations of fEs with magnetic index Ap are presented. The remarkably consistent results obtained by use of the Phillips formula $\log_{10}P = a + bf$, are given. (P=probability of occurrence of fEs> f; f=frequency(Mc); a, b are adjustable constants).

An incidental outcome is the confirming of diurnal and seasonal trends at stations in the auroral, north temperate, and equatorial zones, making use of many more data than hitherto available.

Variations in Frequency of Occurrence of Sporadic E, 1949-1959

1. Introduction

Many studies have been made (Wells, 1946; Phillips, 1947; McNicol and Gipps, 1951; Smith, 1951; Matsushita, 1953; Peterson, 1954; Davidson, 1955; Besprozvannaya and Lovcova, 1956; Smith, 1957) in an attempt to decide whether sporadic E is more prevalent at the low or high part of the 11-year cycle of solar activity. In general the results have been inconclusive. For instance, Phillips (1947) reported a negative correlation with sunspot number, at Washington, whereas Wells (1946) found no consistent relationship between sunspot number and sporadic E at Watheroo from 1939 to 1944. Matsushita (1953) obtained at Huancayo a positive correlation of 0.60 between monthly median daytime fEs and sunspot number for the period Aug. 1944 - July 1952. Other reports (*, +) have noted discrepancies in longtime trends of sporadic E between Washington and Watheroo. However, the recent recordbreaking maximum has given an opportunity to compare frequency of occurrence of sporadic E at widely different levels of sunspot number. Furthermore, it has been possible to choose three representative ionosphere stations, in existence for an extended period of time, and presumably somewhat stable in manner of operation over an eleven year period. It was desired also to choose ionosphere sounding stations under the technical control of one organization. Change of equipment characteristics such as relative power emission and sensitivity of reception throughout the frequency range, as well as changes in interpretation of ionograms, would thus presumably be held to a minimum. (**) The three stations selected were Fairbanks (College), representative of a location where the auroral type of sporadic E is prevalent; Washington, a station in the temperate sporadic-E zone; and Huancayo, where equatorial type Es is common in the day hours. Thus all three main sporadic-E zones (Smith, 1957) are represented. Respective geomagnetic latitudes are 64°N, 50°N, and 1°S.

The parameter chosen for study was the count of fEs >5 Mc. By so doing, it was hoped to avoid contamination of the sporadic-E count with scaled values which were really fE rather than fEs, as well as to minimize any possible effect of D-region absorption. (Appleton and Piggott, 1954)

The correlation coefficients given in this report were obtained from comparison of various series of eleven terms each. For example, the values in Table 1 were calculated from the numbers represented graphically in figure 1.

* Report IRPL-F12, O.T.S., U.S. Dept. of Commerce, Wash., 1945

\+ Report IRPL-R35, O.T.S., U.S. Dept. of Commerce, Wash., 1946

** Report IRPL-R34, O.T.S., U.S. Dept. of Commerce, Wash., 1946

2. Uniformity of Data

The equipment was changed at all three stations during the period covered by this report. Therefore, it was felt desirable to go back prior to 1952 for as few years as possible, and still have an eleven-year period somewhat representative of a particular solar cycle.

2.1 Equipment Changes, 1949-1959 (Gladden, 1959)

Fairbanks:	To March 1951, DTM automatic multifrequency ionosonde Since March 1951, CRPL Model C-3
Washington:	To July 1950, CRPL Model C-2 Since June 1950, CRPL Model C-3 Both C-2 and C-3 used in June 1950
Huancayo:	To December 1951, DTM automatic multifrequency ionosonde Since December 1951, CRPL Model C-3

2.2 Change of Location

Washington:	To September 1949, Sterling, Virginia (39.0°N, 77.5°W) Since September 1949, Ft. Belvoir, Virginia (38.7°N, 77.1°W)

There was no indication in the detailed data of any break in the type of scaled results because of the above, except possibly for Huancayo. Because of the necessity for normalization of certain Huancayo data (see next paragraph) it is believed that the Huancayo data are not so uniform in quality as for the other two stations.

2.3 Normalization of Data

Because of an unusual amount of outages attributable to equipment failure, the count for the following months at Huancayo was normalized by multiplying by a factor of proportionality, or, for certain hours, changed to more nearly correspond to average conditions:

September 1949, May 1950, June 1950, August 1951, September 1951, November 1951, February 1959, April 1959

The count for the month of March 1959 was entirely supplied empirically, making use of diurnal and seasonal trends in adjacent months and for other years. The large correlation coefficient for March (Table 3) is thus suspect. However, omitting the month entirely and using only 10 years of March data reduced the coefficient only by -.02 to -.79.

2.4 Change of Scaling Practice

Up until the year 1957, values of fEs* were recorded; in 1957, 1958, 1959, values of foEs** were scaled. (At Huancayo, foEs was scaled for the first 4 months of 1949 as well). It was considered better to obtain values of correlation coefficients for unweighted and weighted counts of fEs and foEs >5 Mc, rather than to attempt the formidable and extremely time consuming task of deciding whether each individual value displayed on the original records really was foEs or fEs for the period during which foEs was scaled. In fact, a large number of values on the tabulation sheets were qualified by M+.

3. Conventions Used in Obtaining Correlation Coefficients

In obtaining coefficients such as in Tables 1 and 2, the count for the period when foEs was scaled, was obtained for foEs >4.2 Mc at Fairbanks and Washington, and for foEs >4.6 Mc at Huancayo. The count was also obtained for foEs >5 Mc at the respective locations. Three sets of coefficients were obtained, (1) using the count for foEs >4.2 (or 4.6) Mc, (2) assigning the count for foEs >4.2 the weight 3, the count for foEs >5 Mc the weight 1, and (3) using an unweighted average. The coefficients became larger in absolute value (in the negative direction) in proceeding from (1) to (3). The coefficients shown in Tables 1 and 2 are those obtained from process (2).

For Tables 3, 4 and 5, two sets of coefficients were obtained, using process (1) and process (3). The coefficients shown are those obtained from process (3).

* fEs: Highest frequency on which echoes of the sporadic type are observed from the lower part of the E layer. (CCIR, Sixth Meeting, Geneva 1951)

** foEs: The ordinary wave top frequency corresponding to the highest frequency at which mainly continuous trace is observed. (First Report of the Special Committee on World-Wide Ionospheric Soundings (URSI/AGI), Sept. 1956).

\+ Measurement questionable because the ordinary and extraordinary components are not distinguishable. (Second Report of the Special Committee on World-Wide Ionospheric Soundings (URSI/AGI), May 1957).

In addition, for Tables 3 and 4, comparison was made using smoothed 12-month running average sunspot numbers as well as monthly numbers, for both process (1) and process (3). There was little difference in results from the values shown in Tables 3 and 4, and no conclusions of this paper would be changed as a result of the use of average numbers.

4. Estimation of Sunspot Numbers for the Latter Half of 1959

At the time of writing this paper, Zurich provisional numbers were available for July and August 1959. The following estimated numbers were used for September thru December 1959:

145, 139, 135, 130.

The Zurich provisional numbers, when available, turned out to be

146, 140, 136 and 132 respectively.

5. Diurnal, Seasonal, and Yearly Variations of Count

Figure 1 shows the total count and percentage of fEs >5 for each year for each station. Also plotted is the yearly Zurich sunspot number.

In figures 2 and 3, which show the diurnal variation in count and percentage for the period for each of the three stations, the shaded portions represent hours of minimum count. For Washington and Fairbanks, they are the hours for which the count is less than half the maximum count for any hour; for Huancayo, one-fifth is used. They do not necessarily correspond to day or night hours.

Figures 4 and 5 show percentages by months, both for all hours and for hours of minimum count. In figures 6 - 8 percentages by hours are given. The hours chosen are representative ones for the individual stations. It is seen that the peaks in the graphs do not always correspond to the years of minimum sunspot number. Thus it is clear that the overall variation shown for the entire eleven year period has considerable variation within itself when smaller blocks of data are used.

6. Correlation Coefficients and Their Variations

In Tables 1 through 5 the relationship of sporadic E occurrence to solar activity is described by presenting correlation coefficients of count of fEs >5 Mc vs. sunspot number. Each coefficient was obtained from 11 pairs of data by the use of automatic machine computation.

In Tables 1 and 2 the fEs count refers to the number of hours throughout the entire year that Es occurred, and the yearly sunspot number used is the mean number for the whole year. In Tables 3, 4, and 5 these totals are broken down into time intervals. Table 3 refers to Es occurrences and sunspot numbers in each individual month of the year. Table 4 does the same except that only data for selected hours are included. Table 5 shows how the correlation coefficient varies with hour of the day during the

11-year period under consideration.

A word of caution concerning the coefficients given in Tables 3, 4, and 5. There is a question as to whether it is proper to obtain correlation coefficients by comparing a series of values (sporadic E) subject to seasonal and diurnal effects, with a series of values (sunspot numbers) not subject to such effects. However, the coefficients listed in these tables were readily obtainable. Furthermore, the prevailing types of sporadic E at Fairbanks at night (auroral and retardation types) are not believed to be subject to seasonal variations in frequency of occurrence. Nor is the prevalent daytime type at Huancayo (equatorial sporadic E). The attempt to classify sporadic E into nine types according to the appearance of the trace on the ionogram, is of comparatively recent origin.* Perhaps when a large body of data on types of sporadic E has been accumulated there will be more justification for obtaining correlation coefficients between frequency of occurrence of certain specific types and sunspot numbers month by month or hour by hour. Again, it is possible that the abrupt change between 1800 and 1900 for Huancayo, Table 5, reflects a change from the equatorial type sporadic E to the flat type, and perhaps also the well-known change in the shape of the ionospheric layers at Huancayo from daytime to evening (Wright, 1959).

---

* First Report of the Special Committee on World-Wide Ionospheric Soundings (URSI/AGI), Sept. 1956. Second Report, May 1957.

7. Application of the Formula $\log_{10}P = a + bf$

Figure 9 gives the results of applying the Phillips (1947) formula to certain series of data. It is noted that the value of the slope, b, which is negative, is higher in absolute value at the maximum part of the solar cycle, thus confirming the main conclusion of this paper. This was also found to be true in every one of fourteen additional comparisons made in the same manner: 1957 vs. 1954; 1957 day vs. 1954 day; 1957 night vs. 1954 night; high (count) month 1957 vs. high month 1954; low month 1957 vs. low month 1954. There was also the same relative consistency in the position of the points of intersection. This consistency became less, as might be expected, as the periods of comparison became shorter. Of course, fEs must be $\geq$fE before this formula can be applied, regardless of the position of the point of intersection.

8. Correlation of Sporadic E Occurrence at Fairbanks with Yearly Average Ap

Correlation coefficients are given in Table 6 for yearly average Ap vs. total yearly count. Total yearly count of fEs >7 Mc at Fairbanks is included. An apparent improvement in negative correlation at Fairbanks for count of fEs >7 Mc vs. sunspot number (-.79, -.70 day and -.82 night) is not borne out for Ap. Two monthly correlations, for September (month of maximum average Ap over the 11-year period) and December (month of minimum average Ap) for Fairbanks, night, gave coefficients of -.23 and -.29. It is interesting to note that when Smith (1957) compared quiet periods with disturbed periods, he found a positive correlation in the auroral zone with magnetic activity and a negative correlation in the high north temperate zone at Washington.

9. Discussion of Results; Conclusions

In obtaining correlation coefficients between eleven pairs of variables, if there is no autocorrelation, a coefficient of ±.602 is significant at the 95 percent level, and one of ±.735 at the 99 percent level. While there may be some autocorrelation in these series, it is believed to be slight, so that certain general statements may be made. Exact values of coefficients undoubtedly have not been found, in view of the above discussion of the quality and uniformity of the data, and the necessity for adopting certain conventions.

(a) From figure 1 and Table 1, it is clear that there is a negative correlation between occurrence of fEs >5 Mc and sunspot number, for these three stations, and for the period 1949 - 1959. The correlation coefficient for Fairbanks may possibly be significant at the 95 percent level.

(b) The diurnal variations, as was expected, followed the pattern previously observed many times for the three main sporadic-E zones - auroral, temperate, and equatorial. (Smith, 1957)

(c) The unshaded portions of figures 4 and 5 represent a nearly constant count in the cases of Huancayo and Fairbanks, (equatorial and auroral types of fEs) but the seasonal variation is clearly shown for Washington. In this connection, it is of interest to compare the coefficients in Tables 1 and 2. The correlation coefficient for the hours of minimum occurrence of fEs, as defined above, at Fairbanks remains possibly significant; at Washington there is no change, while at Huancayo it becomes significant, another indication of the well-known fact that equatorial-type sporadic E is a day-time phenomenon. Tables 3 and 4 give the comparison month-by-month.

(d) It is of interest to apply the critical levels of .602 and .735 to the tables of coefficients. However, there is great uncertainty involved as to the accuracy of results. In Table 5 we find the largest coefficients in absolute value arranged in a pattern for Fairbanks (1800-0200) and Huancayo (1900-2200). For Washington, we have high coefficients at 1700 and 2000, and the ones at 1800 and 1900 are also worth remarking. Finally, there is a minor pattern of high coefficients at 0800 (Fairbanks and Washington) and at 0500-0600 (Huancayo). It is interesting that the hours of 1900-2200 at Huancayo represent the period when the equatorial hump in the ionosphere is present as shown by true-height studies. (Wright, 1959) Note that there is an abrupt change between the coefficient for 1800 (+.07) and for 1900 (-.91). Why there should be this definite pattern of coefficients for these stations is hard to explain.

(e) In Table 3 (totals) the highest coefficients are for the month of March at Fairbanks and at Huancayo (Section 2.3). If smoothed 12-month running averages instead of monthly numbers are used, the respective coefficients are -.87 and -.80. At Washington the highest is for July, the corresponding coefficient using running averages being -.83. No explanation is offered. In Table 4 (selected hours) there is no coefficient significant at the 99 percent level.

(f) There is a high positive correlation (+.77) between the total yearly amount of fEs >5 Mc at Fairbanks and at Huancayo. This is probably due to the large number of occurrences of high values of the auroral type at the former and of equatorial type at the latter station.

(g) The ratio of total occurrence of foEs >5 Mc to (foEs plus $\frac{fh}{2}$) >5 Mc is essentially constant for 1957, 1958, 1959, at each of these three stations.

For Fairbanks, the average ratio is:	0.58	range	0.05
Washington " " " "	0.47	"	0.06
Huancayo " " " "	0.92	"	0.05

This means, for instance, that at Washington for these three years about 53 percent of the values of foEs >4.2 were between 4.3 and 5.0 Mc inclusive. This result indicates that over this range of foEs the value of "b" remained nearly constant in the expression

$$\log_{10} \left(\frac{P_1}{P_2}\right) = b \, (f_1 - f_2) \qquad \text{(Smith, 1957)}$$

REFERENCES

Appleton, E. V., and W. R. Piggott, J. Atm. Terr. Phys. 5, 141 (1954)

Besprozvannaya, A. S., and V. A. Lovcova, Tr. Arctic Res. Inst., Leningrad, 15 (1956), Canadian Translation DRB, T250R

Davidson, David, Tech. Report No. 230, Cruft Laboratory, Harvard University, Cambridge (1955)

Gladden, S. C., NBS Tech. Note No. 28, pp. 91, 93, 105, Washington (1959)

Matsushita, S., J. Geomagn. Geoelect., Kyoto 5, 118 (1953)

McNicol, R. W. E., and G. de V. Gipps, J. Geophys. Res. 56, 17 (1951)

Peterson, A. M., URSI-IRE Spring Meeting, Washington (1954)

Phillips, M. L., Trans. AGU 28, 71 (1947)

Smith, E. K., Tech. Report No. 7, Ionosphere Project, School of Elec. Eng., Cornell University, Ithaca (1951)

Smith, E. K., NBS Circular 582 (1957)

Wells, H. W., Proc. IRE 34, 950 (1946)

Wright, J. W., J. Geophys. Res. 64, 1631 (1959)

TABLE 1

YEARLY COUNT OF fEs >5 Mc vs. YEARLY SUNSPOT NUMBER, 1949 - 1959

Station	Correlation Coefficient
Fairbanks (College), Alaska	-.68
Washington (Sterling, Va.; Ft. Belvoir, Va.). .	-.52
Huancayo, Peru.	-.42

TABLE 2

YEARLY COUNT, SELECTED HOURS, vs. YEARLY SUNSPOT NUMBER

Station	Hours	Correlation Coefficient
Fairbanks	0700-2000, 150°W	-.63
Washington	1900-0600, 75°W	-.52
Huancayo	1900-0500, 75°W	-.66

TABLE 3 MONTHLY COUNT vs. MONTHLY SUNSPOT NUMBER Correlation Coefficients

	Fairbanks	Washington	Huancayo
Jan	-.56	+.37	Jul -.11
Feb	-.60	-.35	Aug -.00
Mar	-.86	-.19	Sept-.47
Apr	-.58	-.48	Oct -.06
May	-.71	-.43	Nov -.17
June	-.71	-.41	Dec -.44
Jul	-.59	-.79	Jan -.25
Aug	-.32	-.04	Feb -.65
Sept	-.51	-.59	Mar -.81
Oct	-.41	-.60	Apr -.55
Nov	-.28	-.51	May -.42
Dec	-.46	-.50	Jun -.19

TABLE 4 MONTHLY COUNT, SELECTED HOURS, vs. MONTHLY SUNSPOT NUMBER Correlation Coefficients

	Fairbanks	Washington	Huancayo
Jan	-.60	+.41	Jul -.45
Feb	-.52	-.44	Aug -.43
Mar	-.67	-.39	Sept-.62
Apr	-.61	-.42	Oct -.08
May	-.65	-.51	Nov -.50
June	-.66	-.35	Dec -.70
Jul	-.46	-.62	Jan -.29
Aug	-.17	-.44	Feb -.69
Sept	-.37	-.28	Mar -.49
Oct	-.26	-.51	Apr -.32
Nov	-.42	-.43	May -.68
Dec	-.59	-.40	Jun -.53

Station	Hours
Fairbanks	0700-2000, 150°W
Washington	1900-0600, 75°W
Huancayo	1900-0500, 75°W

TABLE 5 YEARLY COUNT, BY HOURS, vs. YEARLY SUNSPOT NUMBER

		Station	
Hour	Fairbanks	Washington	Huancayo
	Correlation Coefficients		
00	-.78	-.36	-.30
01	-.75	-.50	-.29
02	-.74	-.43	-.27
03	-.73	-.35	-.39
04	-.72	-.44	-.42
05	-.59	-.50	-.70
06	-.57	-.44	-.63
07	-.46	-.57	-.51
08	-.61	-.78	-.51
09	-.60	-.52	-.50
10	-.54	-.24	-.48
11	-.56	-.60	-.48
12	-.57	-.40	-.44
13	-.55	-.38	-.23
14	-.56	-.41	-.13
15	-.48	-.41	+.11
16	-.65	-.46	+.22
17	-.67	-.88	+.39
18	-.76	-.72	+.07
19	-.84	-.69	-.91
20	-.88	-.78	-.90
21	-.77	-.53	-.92
22	-.79	-.07	-.83
23	-.83	-.51	-.44

TABLE 6 YEARLY AVG. MAGNETIC ACTIVITY INDEX, Ap, vs. TOTAL YEARLY COUNT

Correlation Coefficients

Station	fEs >5 Mc			fEs >7 Mc		
	All Hours	Day	Night	All Hours	Day	Night
Fairbanks	-.48	-.62	-.30	-.47	-.58	-.32
Washington	+.31	+.34	+.23			
Huancayo	-.50	-.32	-.52			

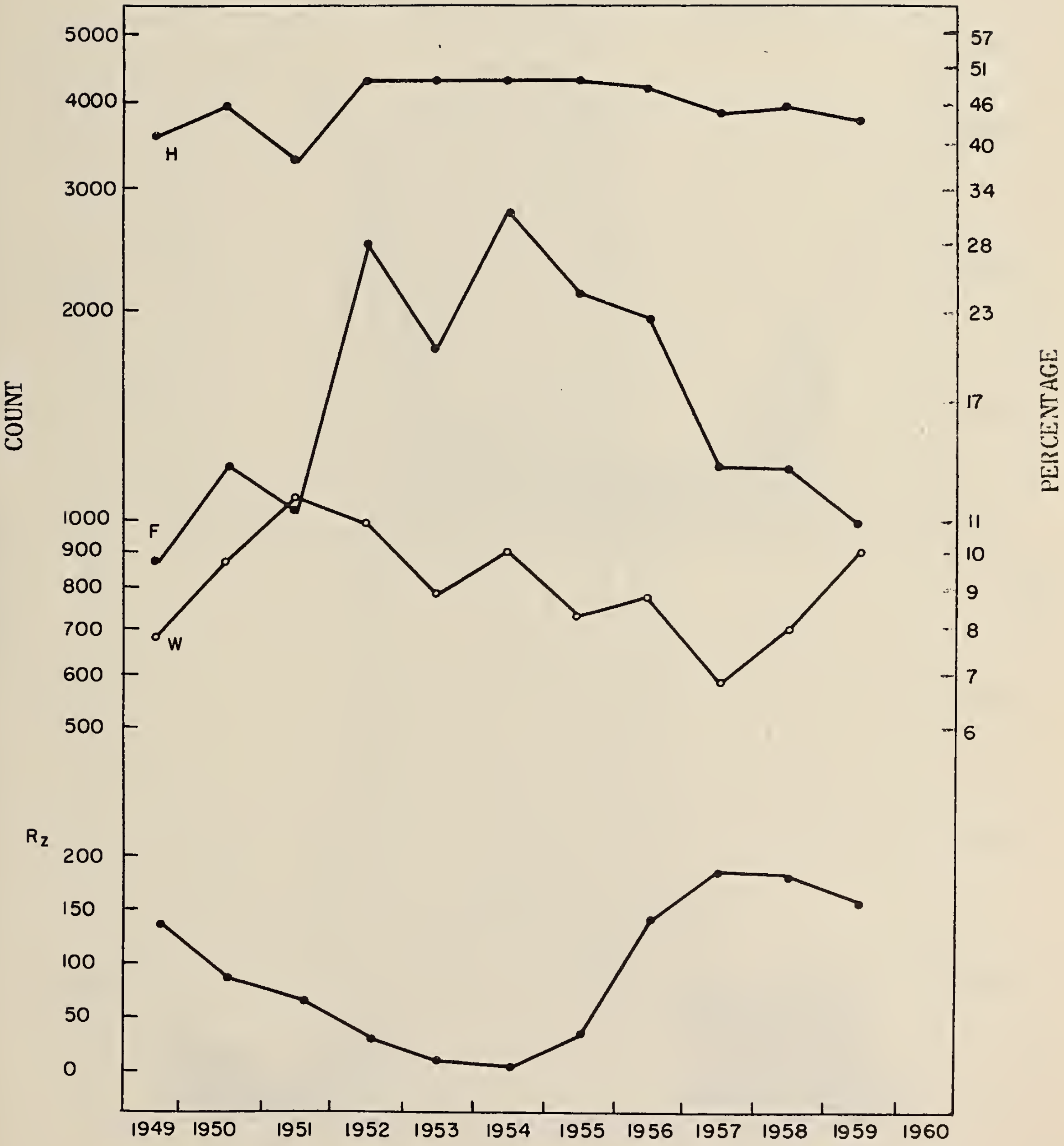


Figure 1 Yearly Count and Percentage of fEs>5 Mc vs Yearly Sunspot Number, 1949-1959.

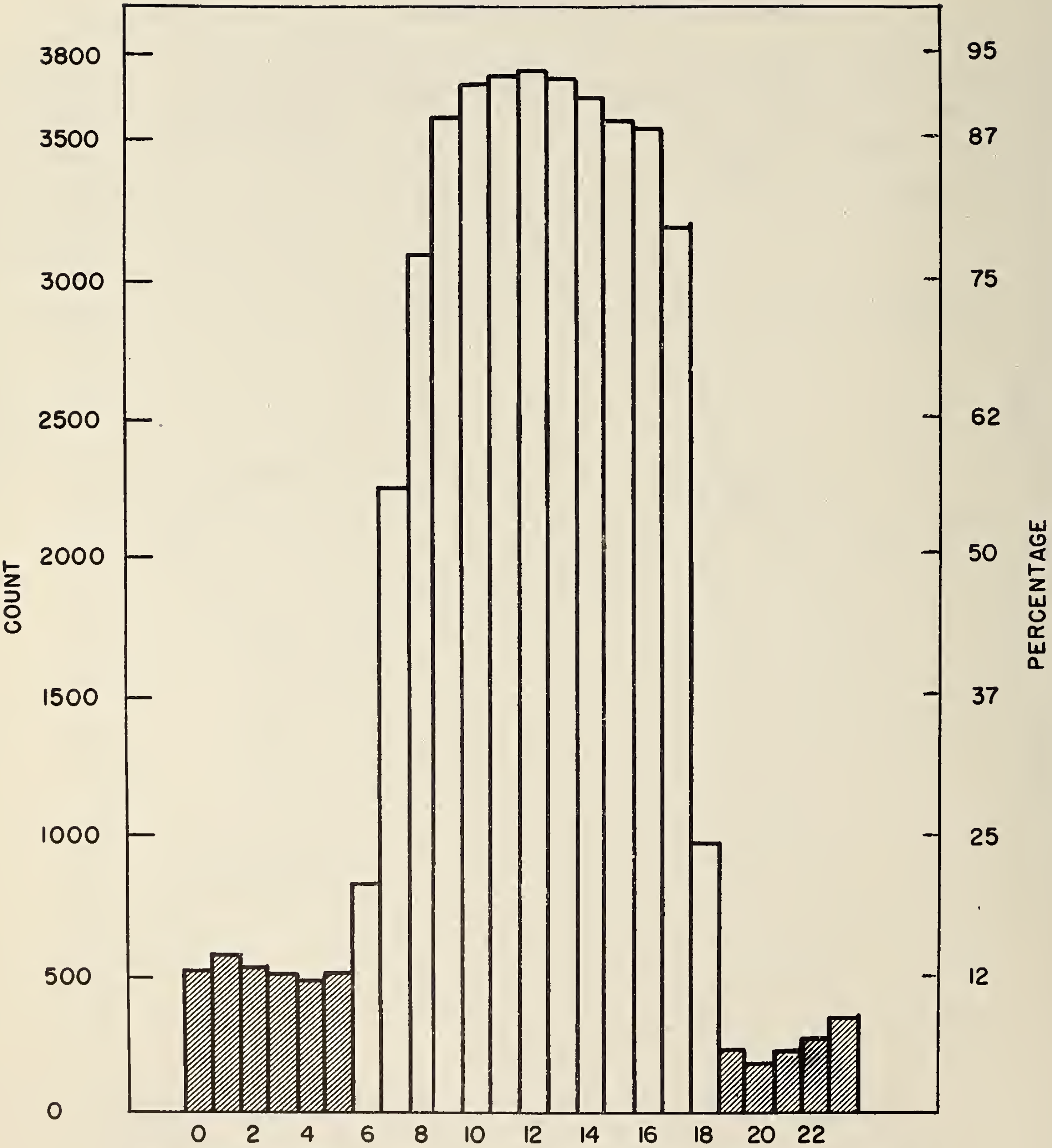


Figure 2 Diurnal Variation, Count and Percentage of fEs>5 Mc, Huancayo, 1949-1959.

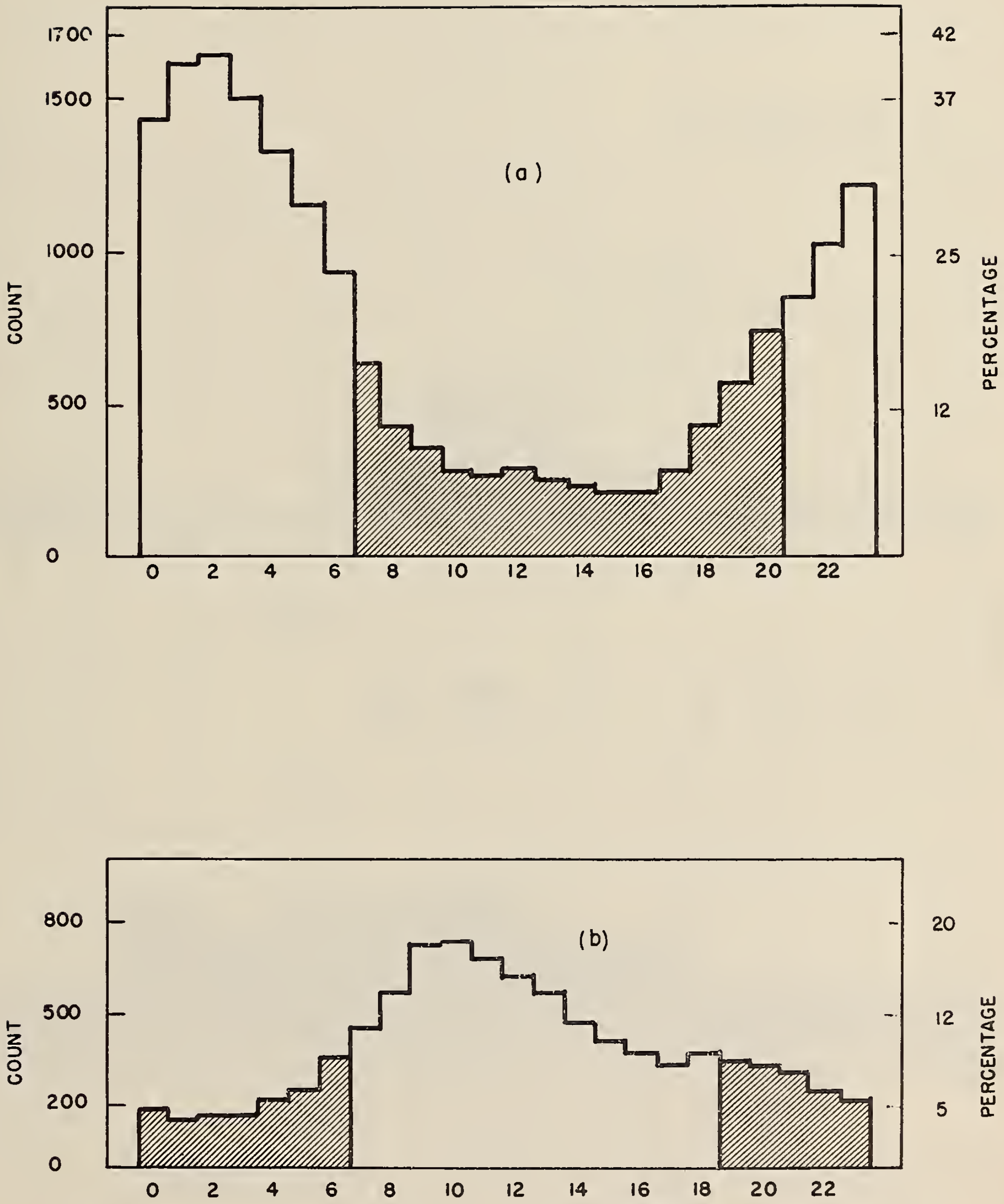


Figure 3 Diurnal Variation, Count and Percentage of fEs>5 Mc, (a) Fairbanks and (b) Washington, 1949-1959.

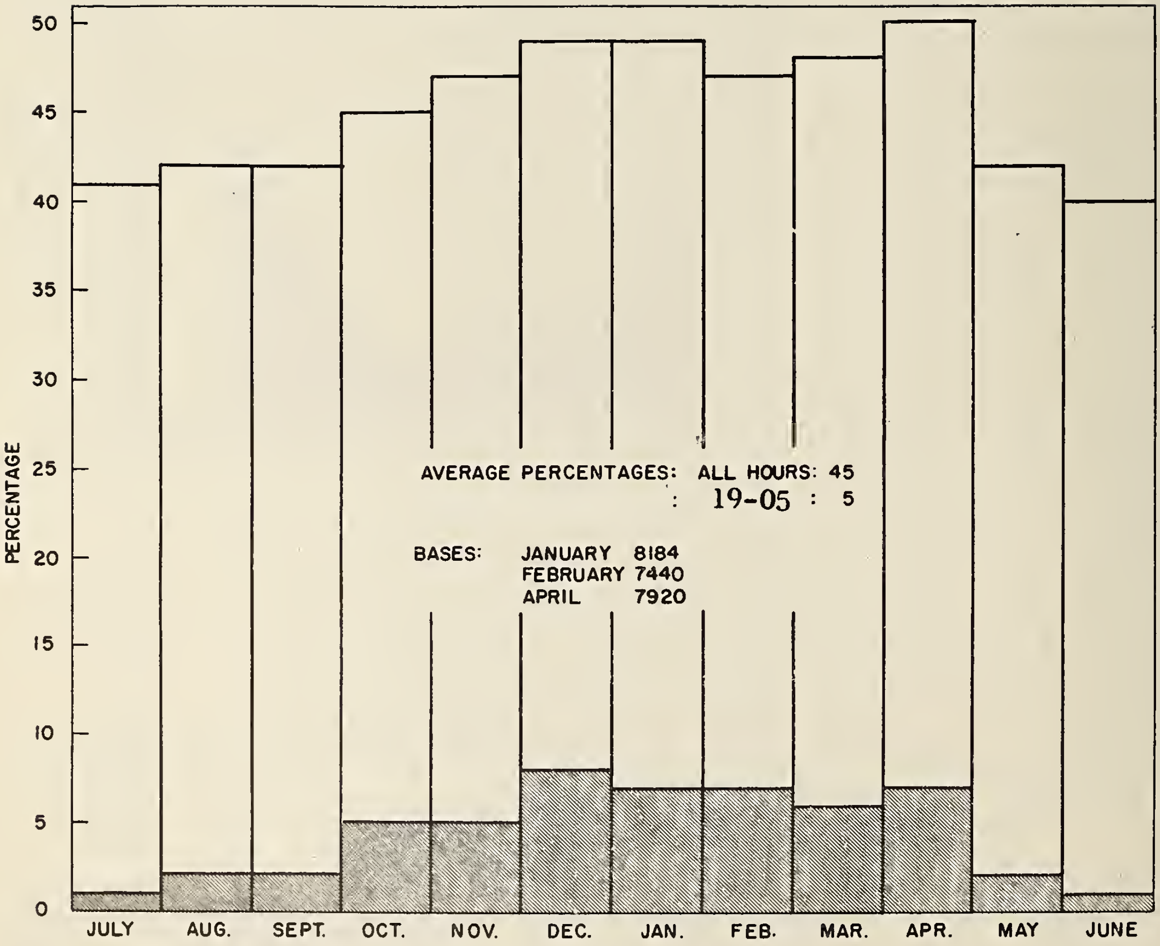


Figure 4 Monthly Percentages of fEs>5 Mc, for All Hours, and for Hours of Minimum Count (shaded) 1900-0500, Huancayo, 1949-1959.

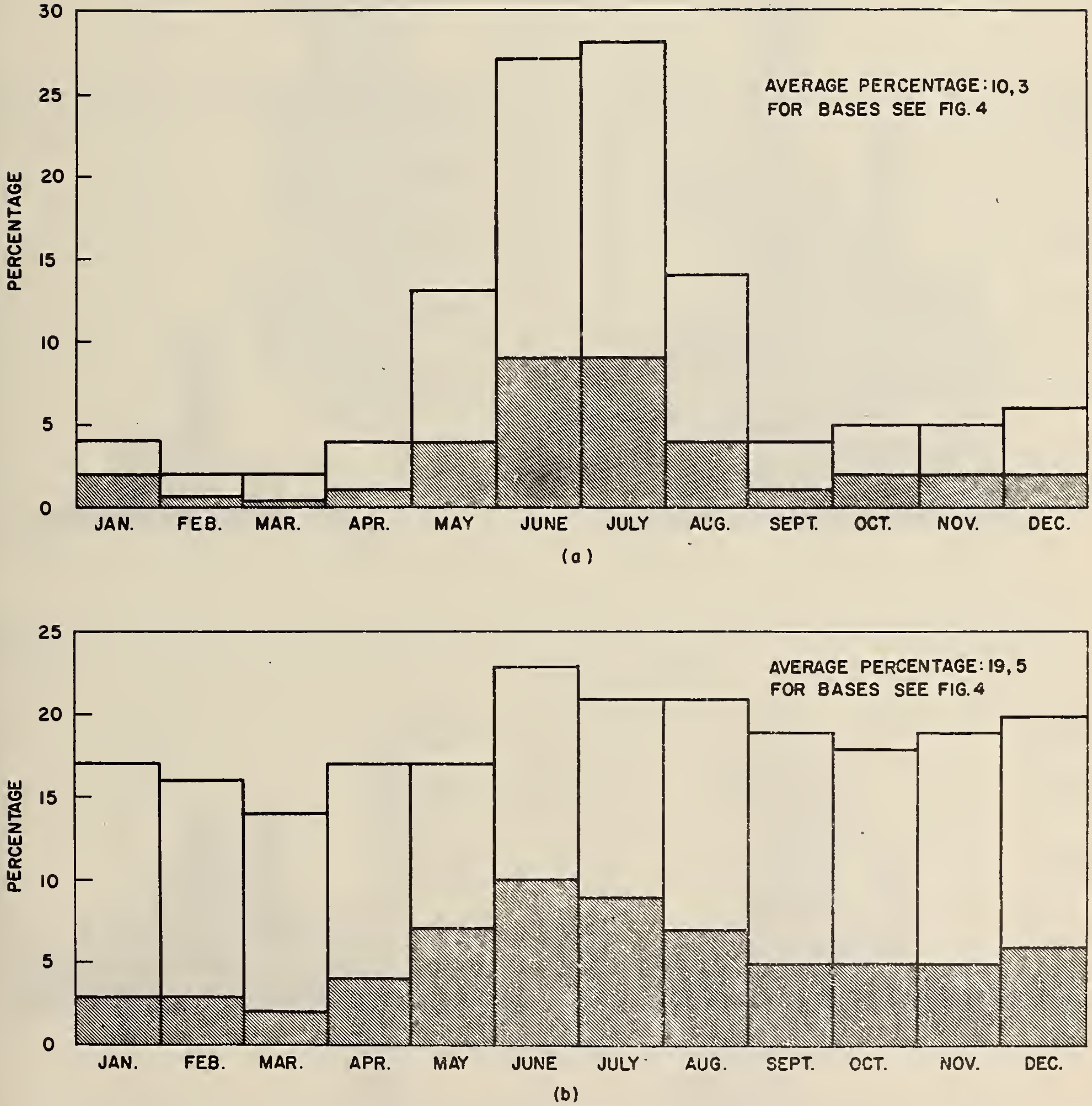


Figure 5 Monthly Percentages of fEs>5 Mc, for All Hours, and for Hours of Minimum Count (shaded) (a) 1900-0600, Washington, (b) 0700-2000, Fairbanks, 1949-1959.

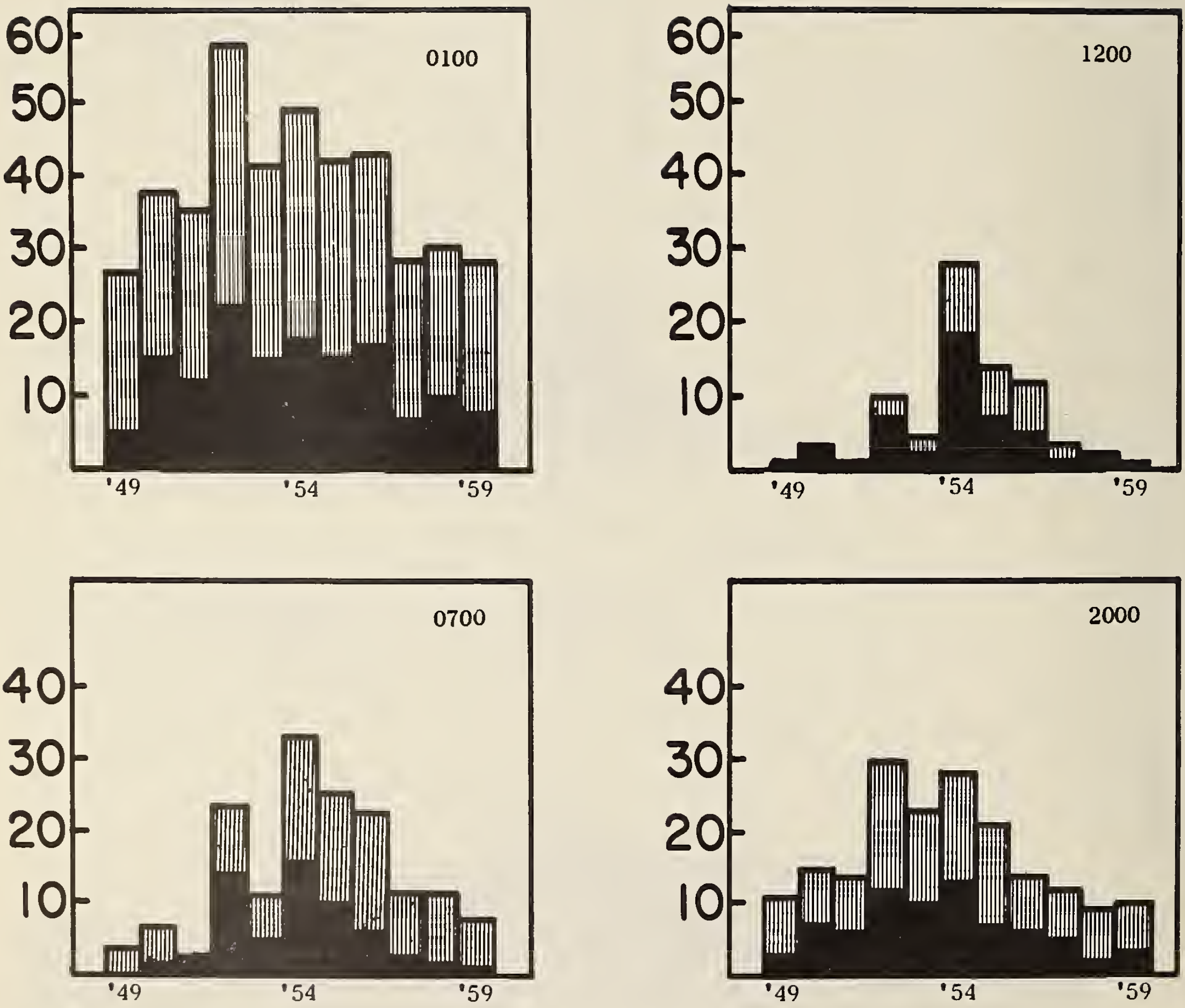


Figure 6 Percentages for Certain Hours, 1949-1959, Fairbanks, fEs>5, 7 Mc.

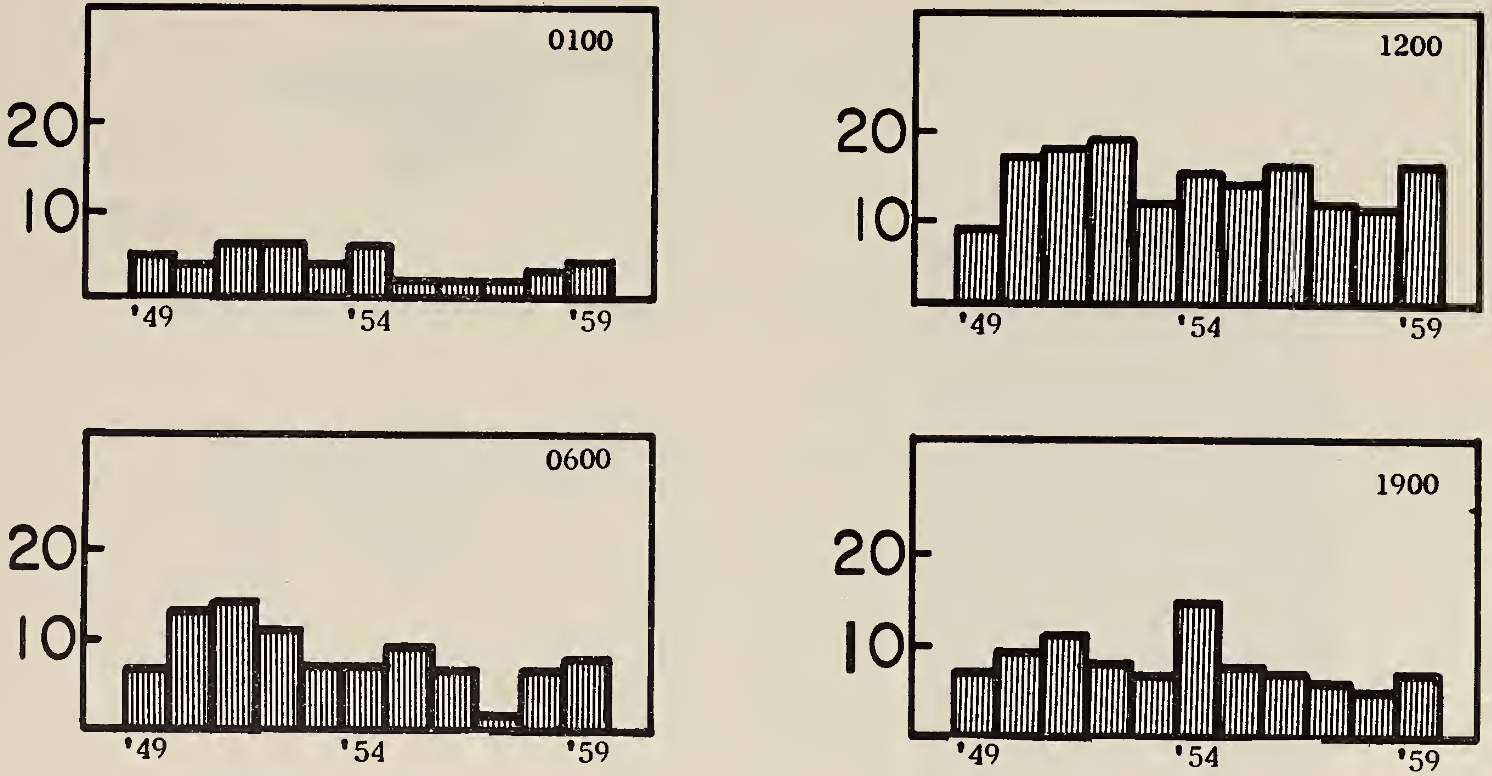


Figure 7 Percentages for Certain Hours, 1949-1959, Washington, fEs>5 Mc.

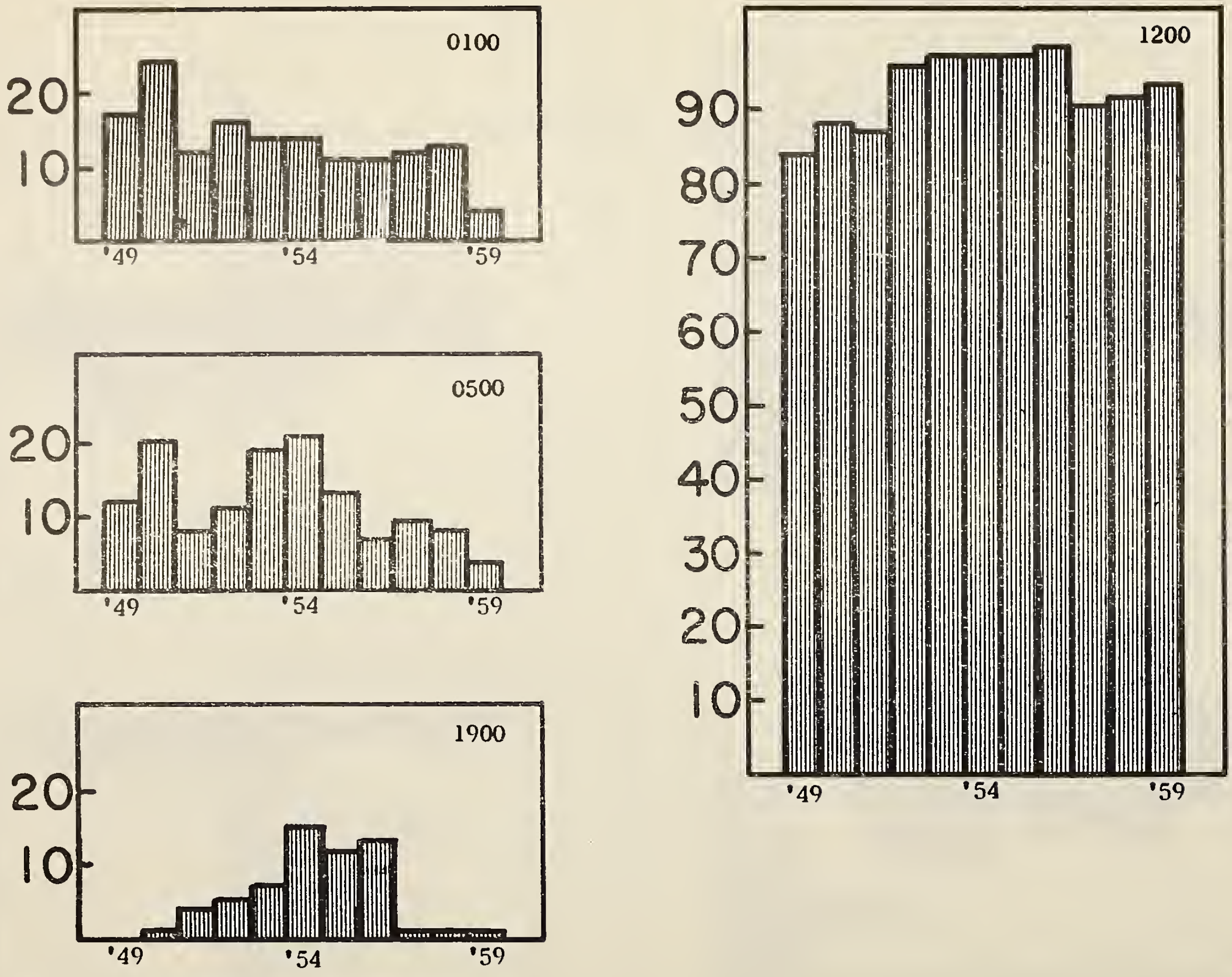
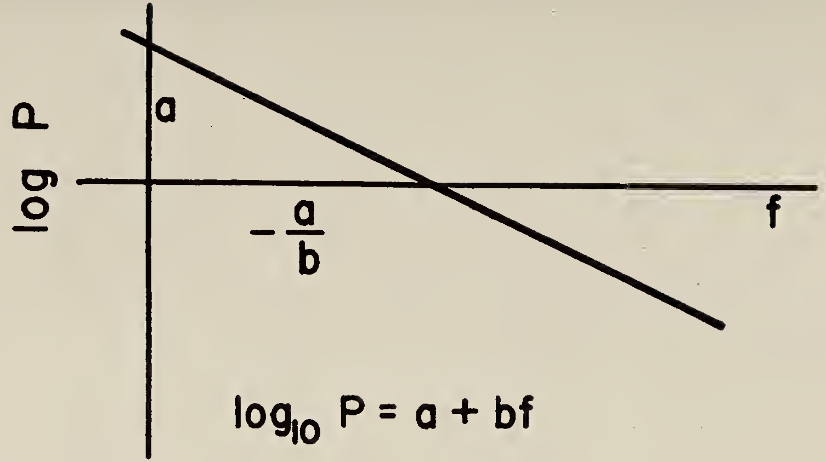


Figure 8 Percentages for Certain Hours, 1949-1959, Huancayo, fEs>5 Mc.



	a	b	$-\frac{a}{b}$	Intersection
F (1)	0.57	-0.33	1.7	f=1.64 Mc, p= 1
F (2)	0.34	-0.19	1.8	
W (1)	0.20	-0.29	0.69	f=2.38 Mc, p=0.32
W (2)	0.01	-0.21	0.05	
H (1)(night)	0.75	-0.41	1.8	f=3.6 Mc, p=0.19
H (2)(night)	-0.22	-0.14	-1.6	

(1)- Years 1957-58-59 averaged
(2)- Years 1953-54-55 averaged

Figure 9 Comparison of the Probability of Occurrence of fEs>f at High and Low Sunspot Number.

U. S. DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D.C.

Electricity. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics.

Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

Heat. Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics.

Radiation Physics. X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

Analytical and Inorganic Chemistry. Pure Substances. Spectrochemistry. Solution Chemistry. Standard Reference Materials. Applied Analytical Research.

Mechanics. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics. Electrolysis and Metal Deposition.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Crystal Growth. Physical Properties. Constitution and Microstructure.

Building Research. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics. Operations Research.

Data Processing Systems. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Applications Engineering.

Atomic Physics. Spectroscopy. Infrared Spectroscopy. Solid State Physics. Electron Physics. Atomic Physics.

Instrumentation. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Molecular Kinetics. Mass Spectrometry.

Office of Weights and Measures.

BOULDER, COLO.

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Cryogenic Technical Services.

Ionosphere Research and Propagation. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services.

Radio Propagation Engineering. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time Interval Standards. Electronic Calibration Center. Millimeter-Wave Research. Microwave Circuit Standards.

Radio Systems. High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems.

Upper Atmosphere and Space Physics. Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

SCOMM-NBS-E


NBS