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Boulder Laboratories

MEAN ELECTRON DENSITY VARIATIONS OF THE QUIET IONOSPHERE

1-MARCH 1959

BY J. W. WRIGHT AND L. A. FINE

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS

Technical Note

40-1

February 1960

Mean Electron Density Variations of the Quiet Ionosphere I - March 1959

by J. W. Wright and L. A. Fine

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MEAN ELECTRON DENSITY VARIATIONS OF THE QUIET IONOSPHERE
I - MARCH 1959

By J. W. Wright and L. A. Fine
Central Radio Propagation Laboratory

Abstract

The CRPL has initiated a program for large-scale computation of electron density profiles from ionospheric vertical soundings. Scaling is performed at field stations permitting computation of hourly profiles at the central laboratory. These profiles are combined to form hourly mean quiet profiles for each station and month. The results of this program for one month are illustrated graphically. This report is the first of a series illustrating the electron density variations in the mean quiet ionosphere between latitudes 15°N and 50°N along the 75°W meridian.

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MEAN ELECTRON DENSITY VARIATIONS OF THE QUIET IONOSPHERE
I - MARCH 1959

by

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Central Radio Propagation Laboratory

I Introduction

Part of the basic responsibility of the Central Radio Propagation Laboratory is to gather ionospheric, solar, or other geophysical data necessary in the pursuit of research leading to improvements in radio communication and knowledge of the earth's upper atmosphere. The existing network of ionospheric vertical sounding stations is an important source of such data. Typically, the radio sounding data directly provide observations of peak electron densities (corresponding to "critical" frequencies foE, foF1, foF2), data on Sporadic E, and certain derived propagation data such as maximum usable frequencies or MUF factors (Smith, 1939).

In fact, the vertical sounding is potentially capable of providing the complete electron density profile of the underside of the ionosphere (i.e., below hmaxF2), and of providing a basis for extrapolation to much greater altitudes. However, because a lengthy and difficult calculation is required, little of this work had been done until quite recently when techniques and computers have become available, and the exigencies of the IGY and satellite programs have made it imperative.

In the course of its development of facilities for electron density profile calculations, the CRPL has succeeded in devising means by which basic data for this purpose may be scaled by the individual field stations, thereby decentralizing and simplifying the most onerous part of the work. Through its own station network and in cooperation with the U. S. Army Signal Ionosphere Stations of the Signal Radio Propagation Agency, the CRPL has initiated an extensive systematic data reduction program, from which hourly electron density profiles are being computed for the following stations:

Puerto Rico (NBS, January 1959)
Grand Bahama Island (U. S. Army Signal Corps, February 1959)
Fort Monmouth, New Jersey (U. S. Army Signal Corps, Feb. 1959)
White Sands, New Mexico (U. S. Army Signal Corps, March 1959)
St. Johns, Newfoundland (U. S. Army Signal Corps, April 1959)
Adak, Alaska (U. S. Army Signal Corps, June 1959)
Okinawa, Ryukus (U. S. Army Signal Corps, June 1959)
Thule, Greenland (U. S. Army Signal Corps, July 1959)

Affiliation and approximate date of initial participation in this program are given in parentheses.

The hourly electron density profiles are extensively used in the research programs of CRPL, and are supplied directly to certain other agencies as part of various research and practical activities. However, in this comparatively early stage, broad dissemination of the computed data is a somewhat difficult problem.

In an attempt to make at least a summary of the results of the program widely and rapidly available, the CRPL has initiated the present series of reports. These provide graphical representations of the monthly mean quiet hourly electron densities from certain of the stations in the preceding list, from which a fairly clear picture of the local ionosphere morphology may be obtained.

This report contains these data for the stations at Newfoundland, Fort Monmouth, Grand Bahama Island, White Sands, and Puerto Rico. Pertinent facts concerning these stations are given in the following table:

Table 1

Station	Geomag. Coordinates fH	Lat.	Dip	Geog. Coordinates	
St. Johns, Newf.	1.38Mc/s	58.5°N	72°N	47°33'N	52°40'W
Ft. Monmouth, N.J.	1.46	51.7°N	71.5°N	40°15'N	74°01'W
White Sands, N.M.	1.30	41.2°N	60°N	32°24'N	106°52'W
Grand Bahama Island	1.30	37.9°N	59.5°N	26°40'N	78°22'W
Puerto Rico	1.15	30°N	51.5°N	18°30'N	67°12'W

II Description of Basic Data

True heights of reflection of radio waves are calculated from the observed or "virtual" heights by the method of Budden (1954); this method need not be described here except to point out that full correction for geomagnetic field effects is made and that the usual restrictions to monotonic profiles apply.

Tabulations of the mean electron density data at 10 km intervals and certain related quantities are the bases for the graphs and charts. A sample for the Puerto Rico March data is given on page 11. The table on the following page identifies the quantities appearing on the tabulation.

Table 2

Quantity	Units	Remarks
Average Electron Density (N)	$x10^3$ = electron/cm^3	Body of table; given at each 10 km of height from the lowest hmin to 950 km.
NMAX	$x10^3$ = electron/cm^3	The mean value of Nmax.
COUNT		Count of the number of profiles entering the the mean.
HMIN	Kilometers	The average height of zero or very low electron density, obtained by linear extrapolation of the electron density of the individual profiles.
HMAX	Kilometers	The average height of maximum electron density, determined by fitting a parabola to the upper portion of the individual profiles.
SHMAX	$x10^{10}$ = electrons/ cm^2 column (10^{-12} on maps)	Obtained by averaging the integration of the individual profiles between the limits HMIN and HMAX.
SHINF	$x10^{10}$ = electrons/ cm^2 column (10^{-13} on maps)	The average total number of electrons in a column to infinity obtained by extrapola- of observed profiles into the region above HMAX. (See text)

The following particular features of the tabulated data should be noted:

A. Averaging process. Eachhour of each day is identified with its magnetic character figure, Kp. For each hour, those days for which Kp is less than 4+ are included in the "quiet" average. The other days are similarly combined to form a "disturbed" average; however, this rarely has physical significance because the number of distrubed periods is usually small and the behavior of the ionosphere during disturbed hours is not consistent. Thus graphs for these latter averages are not presented here.

B. Determination of hmax. The nature of the "true height" process is such that no direct measure of hmaxF2 is obtained, the virtual height at Nmax being immeasurable. A useful procedure is to fit the portion near hmaxF2 with a suitable curve and to determine hmax from this curve. A parabola is quite satisfactory for this purpose; it is fitted to two of the highest true heights and the measured value of Nmax(foF2).

C. Extrapolation of profiles above hmax. Before averaging, the individual profiles are extrapolated above hmax by a Chapman distribution of 100 km scale height. This assumed model seems to agree well with the few published measurements dealing with the profile of the F region above hmax (Wright, 1959). Extrapolation is necessary in order to calculate homogeneous averages near hmax and the average profiles are, in fact, given to 950 km.

D. Integrated Electron Densities. The total number of electrons in a unit column of the ionosphere between the effective bottom (hmin) and hmax is called Shmax; it is obtained by obtained by numerical integration of the observed profiles between these limits. An estimate of the total electron content to infinity, based upon the Chapman model, is called Shinf. It is obtained by adding to Shmax the quantity N_A = 2.82 HNmax where H is an (assumed constant) scale height for the region above hmax. Current evidence

(Wright, 1960) indicates H = 100 km, is an acceptable choice.

III Description of Graphical Representation

The relative smoothness of mean quiet ionosphere data lends itself to various kinds of graphical presentation which offer convenient aids to the visualization of the height, geographic, and temporal variability of the ionosphere. Three such graphical forms are included here, prepared from the tabulations described in Section II.

A. Vertical cross sections of the ionosphere along the 75°W meridian. Pages 12 through 35 give for each hour, a vertical cross section of the mean quiet ionosphere along a meridian section, nominally the 75°W geographic meridian, for the month of March 1959. Contours are parametric in "plasma" frequency (f_N) related to electron density N by

$$12{,}400\ f_N^{\ 2}(\text{Mc/s}) = N(\text{electrons/cm}^3).$$

The height of maximum electron density is represented by a dashed line. Note that the vertical scale is expanded about 5.5 times.

With the exception of White Sands, each of these stations is reasonably close to the 75°W meridian (see Table 1). There is the possibility that some of the anomolies imposed by White Sands on these contours are the result of the well-known longitudinal asymmetry of the ionosphere.

B. Local time vs Latitude Maps. Another form of presentation, useful for indicating the two-dimensional geographic variations of the ionosphere, is that illustrated by the maps of pages 36 through 45. Here, for fixed levels in the ionosphere (150,200,300,350, 400 km), contours of electron density are drawn in the latitude vs. local time plane. To the extent to which longitude variations are negligible, these maps give also the longitude vs. latitude distribution of electron densities at the indicated heights when it is noon over the 75°W meridian. Similar maps for the peak density, Nmax; its height, hmax; the total electron content to nmax, Shmax and the estimated total electron content, Shinf, are also shown.

C. Electron density vs. time curves (N(t) curves). The mean quiet diurnal variation of electron density between 150 and 400 km heights above the sounding stations is illustrated by these curves. Dashed lines are used wherever the electron density at any height falls below the peak density (i.e. when the height hmaxF2 falls below the height for the curve in question.) Such electron densities are the result of the extrapolations by the Chapman model discussed in Section II C.

IV Discussion and Applications of the Data

Mean quiet electron density data over wide geographic areas are essential for application to numerous problems of both practical and scientific interest. For example, the assessment of the radio refraction errors and Faraday rotation effects in satellite tracking require a knowledge of the electron density profile in the direction of the satellite or an estimate of the electron density at the satellite itself. Alternatively these properties of the ionosphere, or estimates of the total electron content in a column, may be measured by observations from rockets and satellites, or from radar moon-echoes, and compared with ground-based observations of the kind shown here.

Frequently it will be necessary to use instantaneous density data because of the considerable variability of the ionosphere about the quiet mean. In such cases, the mean data are of value as a "reference level" in the design of the experiment; for example, in the choice of radio frequencies, satellite heights, antennas, etc.

Since electron density data represent virtually our only source of continuous, widespread data on the earth's upper atmosphere, such data also are essential to geophysical problems involving the electrical, neutral, and magnetic properties of the atmosphere.

For example, data on the vertical cross sections may be compared with theoretical expectations for the meridional height dependence of the quiet ionosphere. Several workers, (Hirono, 1955), and Martyn (1956), have investigated the equilibrium height (of hmax) for an ionosphere controlled by diffusion, height-varying electron loss rate, and uniform (or zero) vertical electron drift. The results are qualitatively in agreement with these observations in predicting a rise of hmax towards the equator in daytime and a reversal of this tendency at night.

The N(t) curves are perhaps the most physically significant representation of electron density data. The strong solar control at all levels and the important perturbations of this solar control in the upper F region may be easily seen.

Acknowledgements

We are indebted to Mr. A. H. Shapley, Assistant Chief of the Radio Propagation Physics Division for guidance in the course of this program, and to Dr. H. H. Howe for the development of the computer programs upon which the whole system heavily depends. The cooperation of the U. S. Army Signal Radio Propagation Agency, in particular, the enthusiastic assistance of Mr. F. H. Dickson (Chief) and Mr. H. F. Busch (Chief, Field Operations), is essential to the success of the program and is gratefully acknowledged.

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AVERAGE ELECTRON DENSITY KP BELOW 4.5

PUERTO RICO 60 W MAR 1959

TIME	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
COUNT	26	26	26	26	26	23	25	25	24	26	24	25	24	25	24	25	24	27	27	27	28	28	28	27
HMIN	251	244	235	224	223	239	265	137	110	109	109	108	108	108	109	109	109	111	200	233	231	247	262	260
NMAX	1260	1146	958	705	479	387	408	855	1511	2039	2406	2505	2529	2525	2429	2326	2231	2146	1968	1772	1464	1316	1312	1374
HMAX	350	335	328	325	357	388	392	304	295	310	318	329	340	352	362	366	368	367	368	367	378	387	388	367
SHMAX	771	667	561	457	411	351	317	638	1231	1830	2219	2505	2673	2770	2829	2742	2628	2457	1774	1469	1240	1074	980	907
SHINF	4326	3900	3262	2445	1762	1442	1468	3048	5494	7582	9007	9570	9807	9892	9682	9303	8921	8511	7327	6467	5370	4787	4681	4782
KM																								
950	104	87.7	69.9	50.7	41.6	38.7	41.0	56.1	94.8	138	169	186	198	210	212	208	200	191	177	159	138	130	130	123
900	133	113	89.6	65.0	53.3	49.7	52.5	71.9	122	177	217	238	254	269	272	266	257	245	227	203	176	166	167	158
850	171	144	115	83.4	68.4	63.6	67.3	92.2	156	227	278	305	326	345	349	341	329	315	291	261	226	213	215	203
800	219	185	147	107	87.6	81.4	86.2	118	200	291	356	391	417	441	447	437	421	403	372	334	289	273	274	260
750	280	237	189	137	112	104	110	151	256	372	456	501	534	565	571	559	539	515	476	427	370	348	351	332
700	358	302	241	175	143	132	140	194	328	476	583	640	682	720	729	712	686	657	607	544	471	443	446	423
650	454	385	307	223	181	167	177	247	418	607	743	816	867	916	925	904	871	834	770	690	597	561	564	537
600	574	487	389	282	228	209	222	314	532	771	943	1033	1097	1156	1166	1139	1097	1050	969	869	749	703	707	676
550	717	610	488	354	283	257	273	397	673	972	1187	1298	1375	1445	1453	1416	1364	1305	1205	1080	928	867	872	841
500	879	753	604	438	344	308	327	495	842	1212	1475	1607	1696	1773	1774	1726	1660	1590	1466	1315	1122	1041	1049	1023
490	913	784	628	456	357	318	338	517	879	1264	1538	1673	1763	1841	1840	1789	1721	1648	1519	1363	1161	1076	1083	1060
480	947	814	653	475	369	327	348	538	917	1317	1601	1740	1832	1910	1906	1852	1781	1706	1572	1410	1199	1109	1117	1097
470	981	845	679	493	381	336	358	561	956	1371	1666	1808	1900	1978	1971	1914	1840	1763	1624	1457	1236	1141	1149	1133
460	1014	876	704	512	393	345	367	584	995	1426	1731	1876	1969	2046	2035	1974	1898	1819	1675	1502	1272	1172	1179	1169
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390	1209	1070	868	632	453	371	396	743	1279	1804	2169	2317	2394	2440	2383	2291	2198	2109	1937	1738	1437	1286	1294	1350
380	1226	1090	886	645	456	367	390	764	1318	1851	2222	2366	2437	2473	2406	2309	2215	2126	1950	1750	1437	1274	1279	1359
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260	177	332	438	440	217	90.2	35.6	681	1335	1598	1733	1686	1530	1335	1226	1131	1095	1083	681	478	309	175	52.5	73.7
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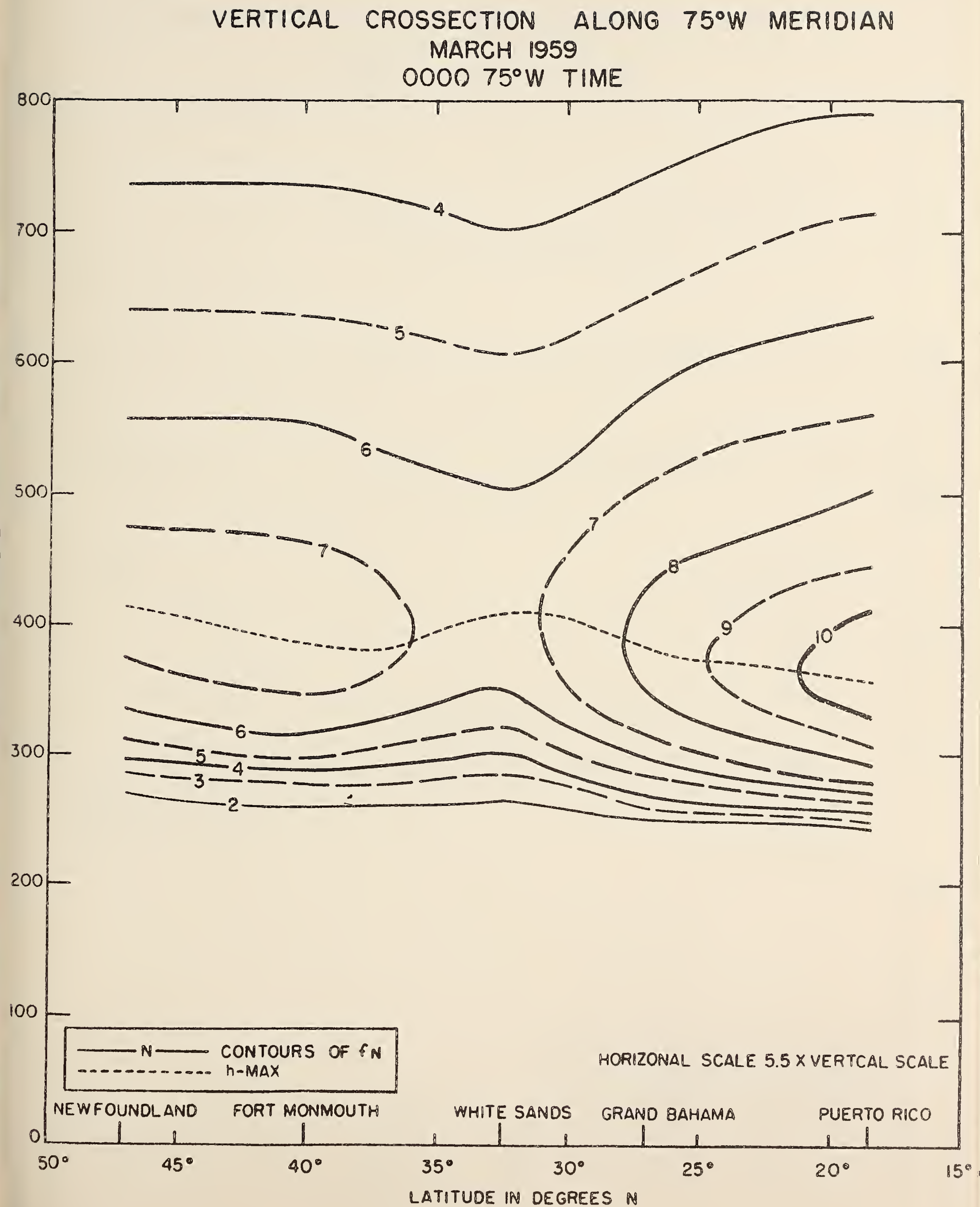
230	2.8	12.2	66.3	119	68.4	27.4	1.8	377	925	1044	1092	1079	994	876	824	760	722	676	132	47.5	49.5	17.9		2.8
220		.4	24.4	52.6	38.5	13.2		272	755	858	901	905	857	768	729	671	631	568	83.2	8.5	23.7	5.4		.8
210			4.5	20.4	18.7	6.3		191	592	696	742	759	737	676	646	595	551	475	57.7	1.8	11.8	1.6		
200				2.7	5.1	2.9		134	451	561	611	638	635	596	572	526	480	393	42.9		5.1			
190					.4	2.0		97.6	340	453	509	540	546	525	503	463	415	324	32.4		1.7			
180						1.7		73.8	259	365	425	460	472	461	439	405	356	266	26.2					
170						.9		59.2	200	297	357	393	411	406	381	352	302	219	22.1					
160						.1		51.5	161	245	304	338	357	356	331	304	257	183	19.5					
150								45.9	136	205	259	293	311	310	288	263	220	156	17.8					
140								41.9	121	177	223	254	270	270	251	227	192	138	16.9					
130								35.7	112	159	197	224	238	239	223	202	173	127	15.9					
120								26.1	103	148	180	204	218	219	205	188	160	115	14.7					
110								5.4	25.6	63.4	90.7	110	120	83.2	77.9	73.1	61.3	25.2	4.2					


VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
0000 75°W TIME
HEIGHT IN KILOMETERS
800
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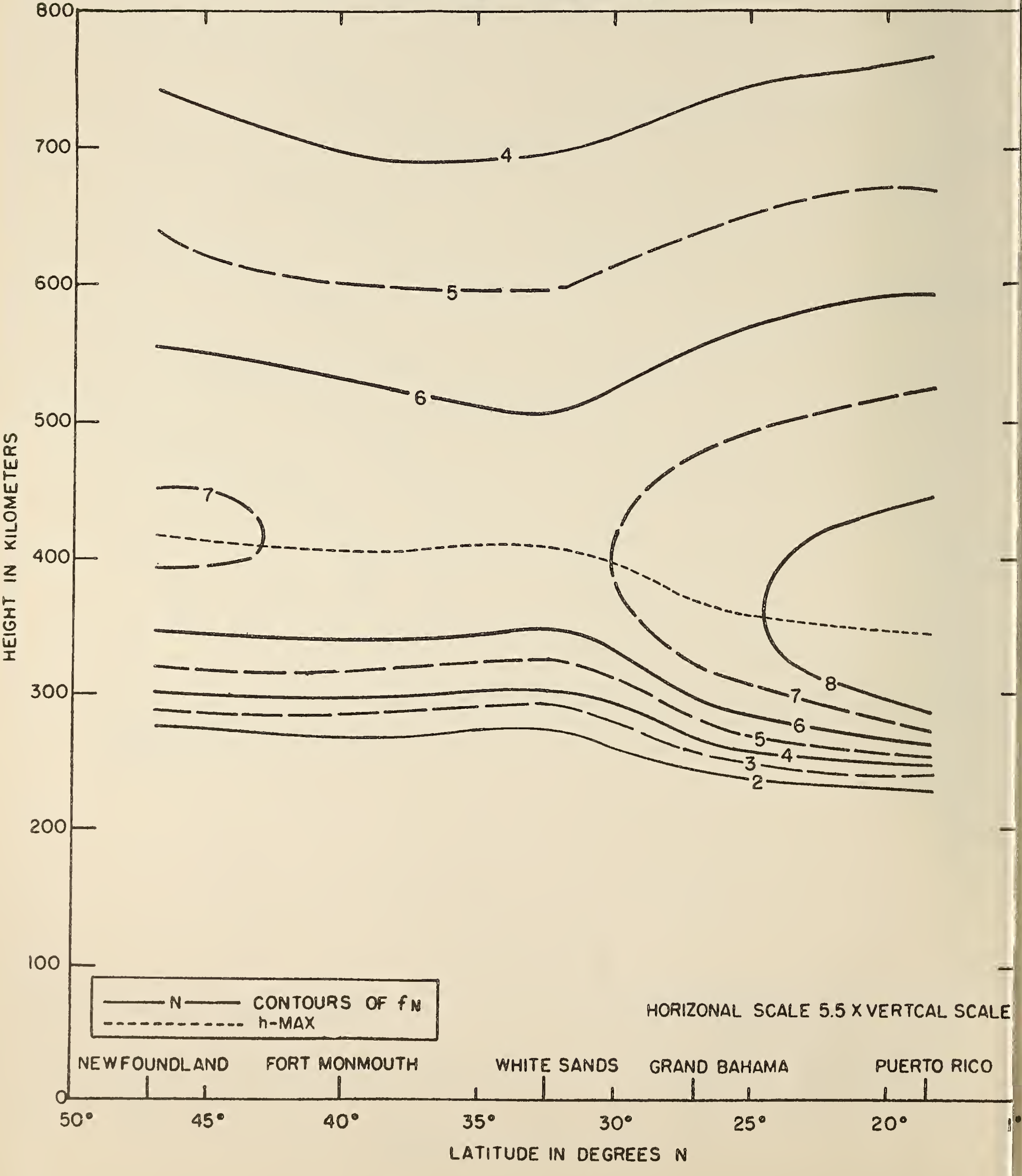
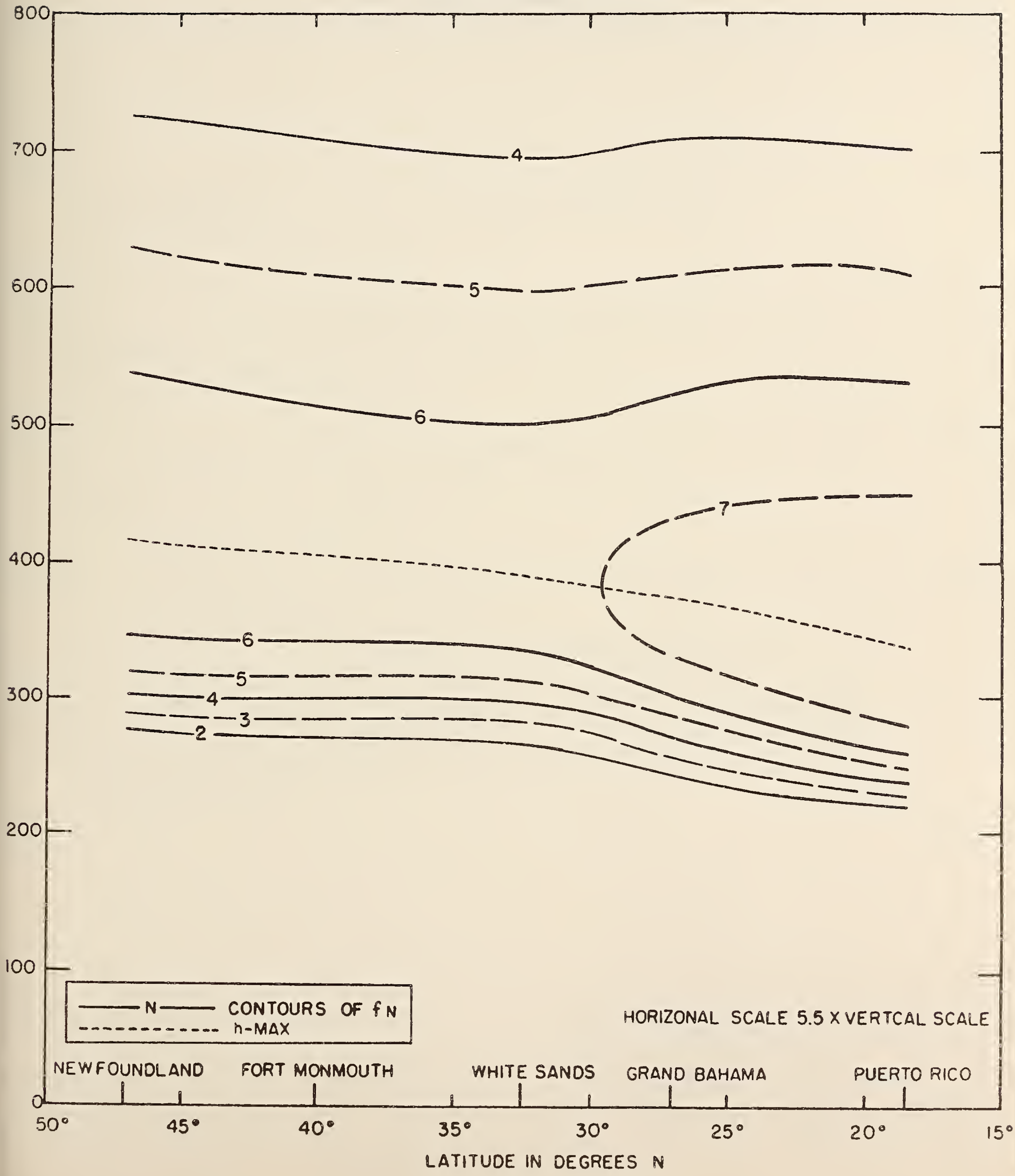
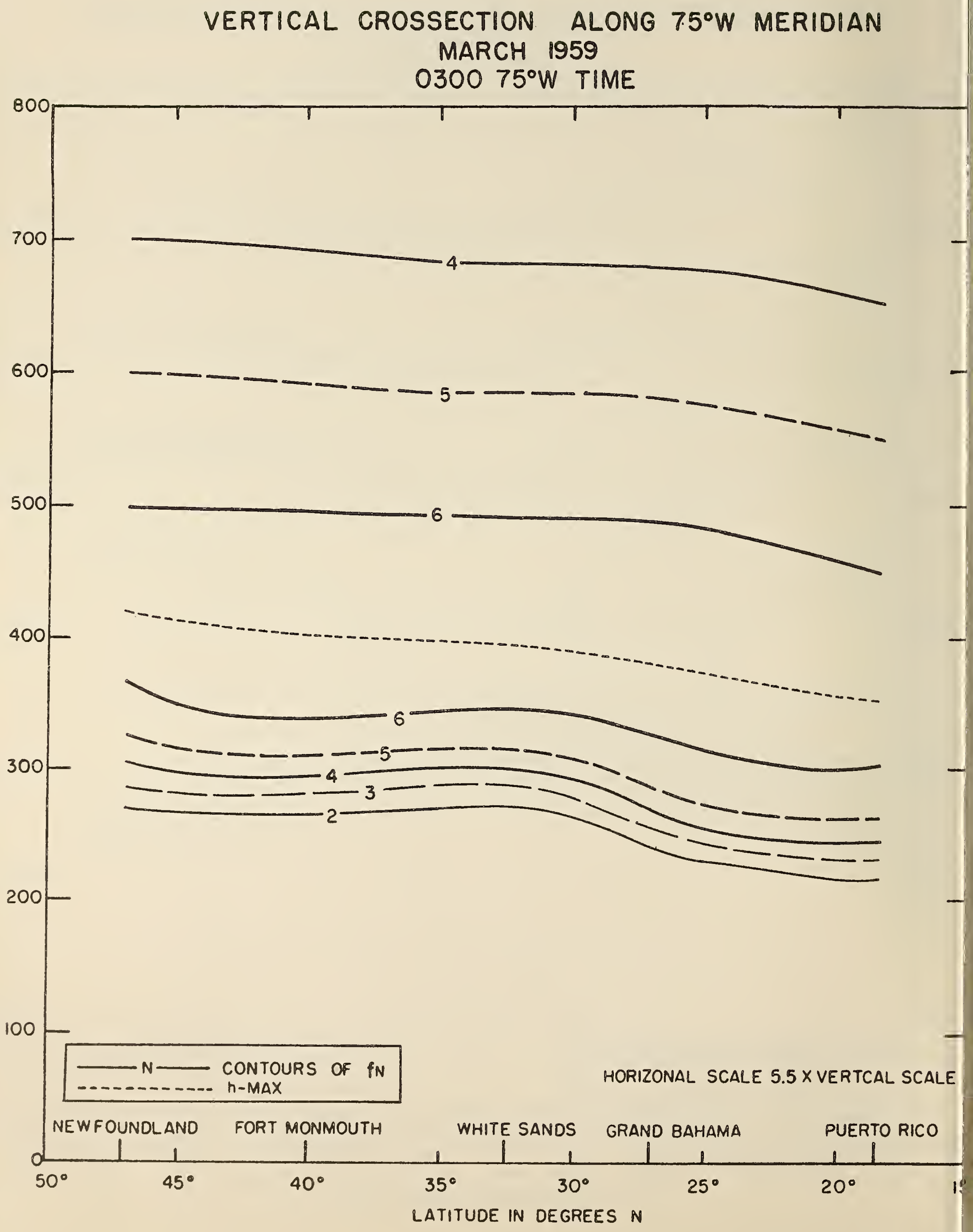
MARCH 1959
0100 75°W TIME



VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
0200 75° W TIME




VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
0300 75°W TIME
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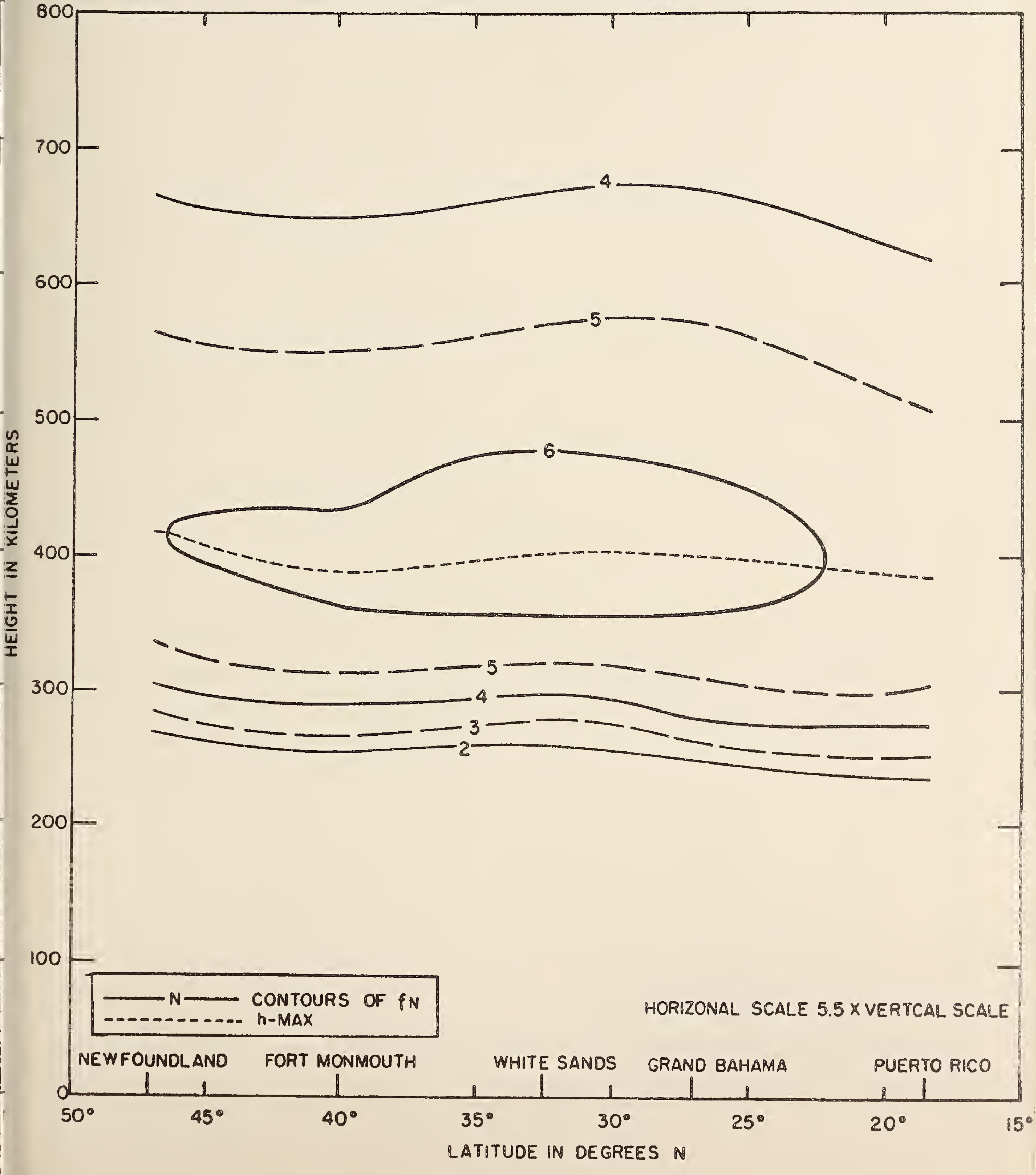
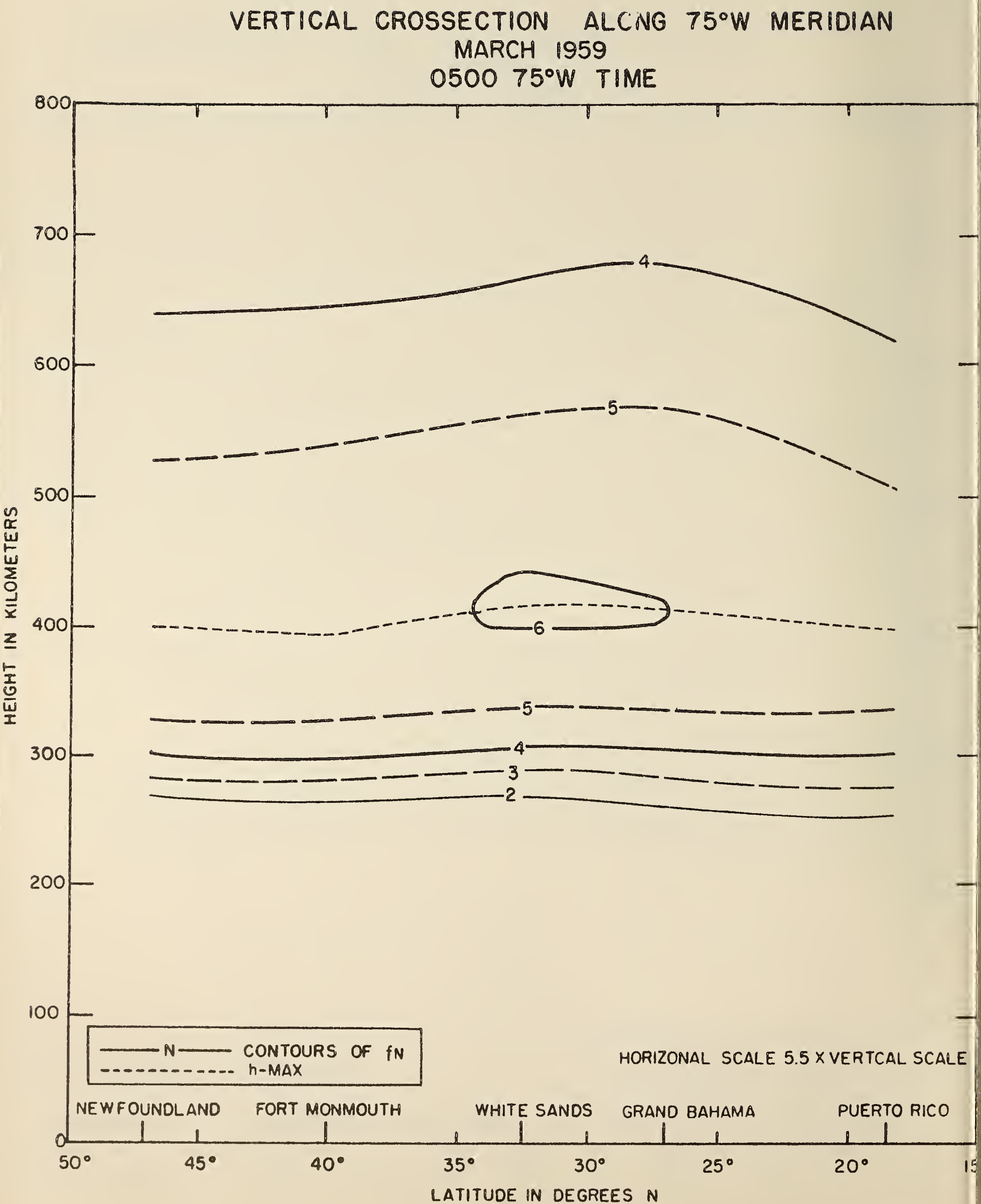
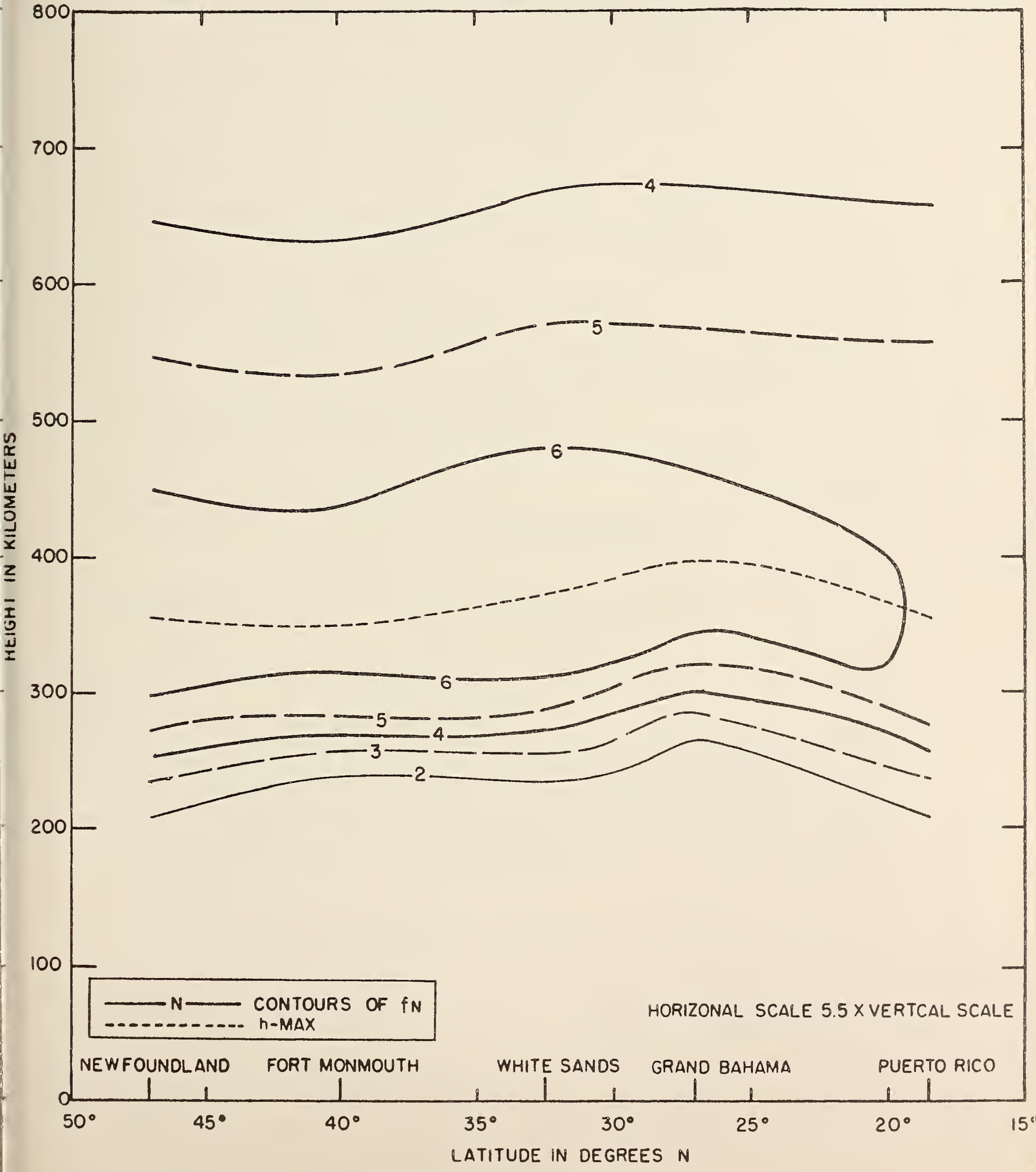
HORIZONAL SCALE 5.5 X VERTCAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
LATITUDE IN DEGREES N

VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
0400 75°W TIME

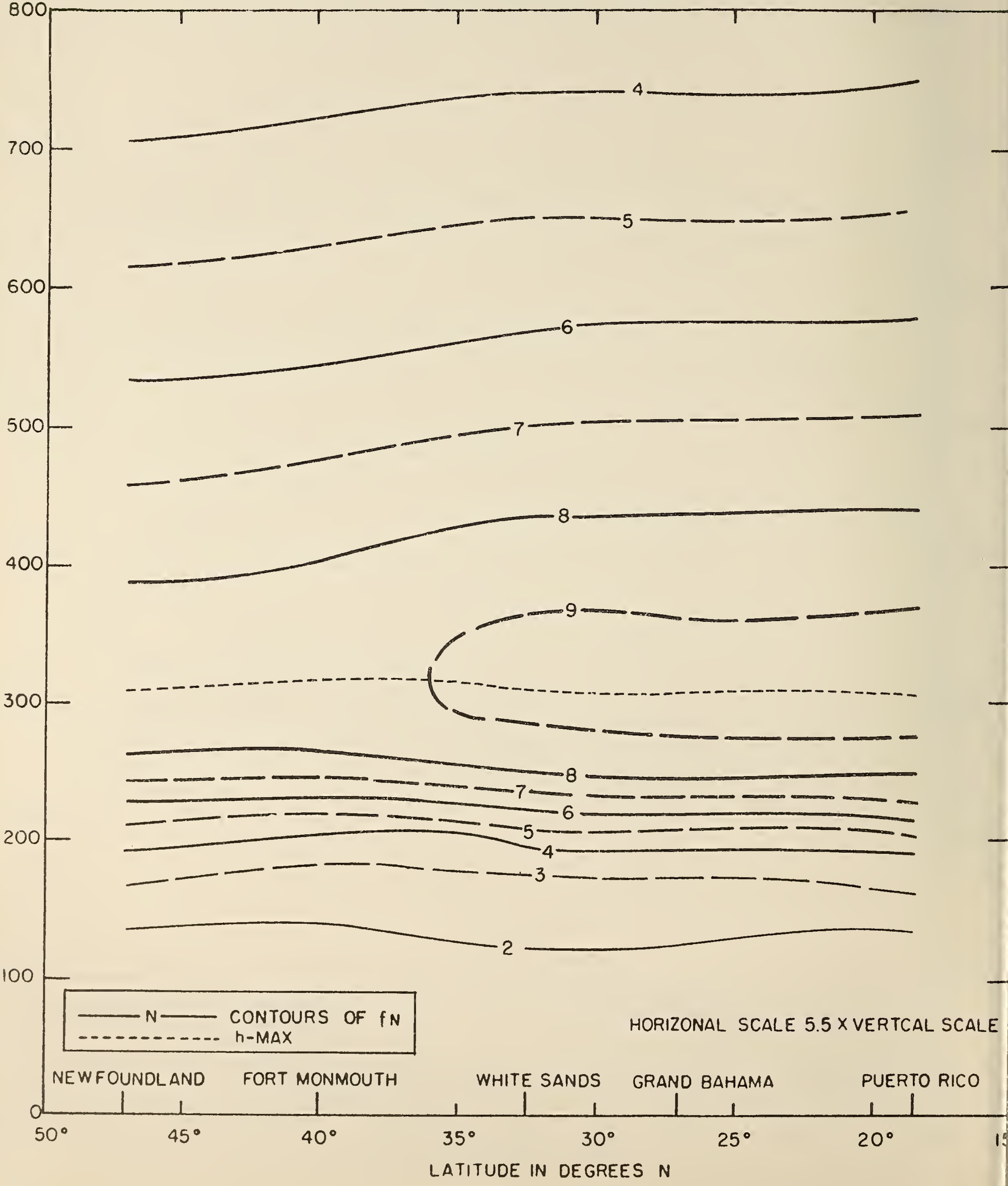


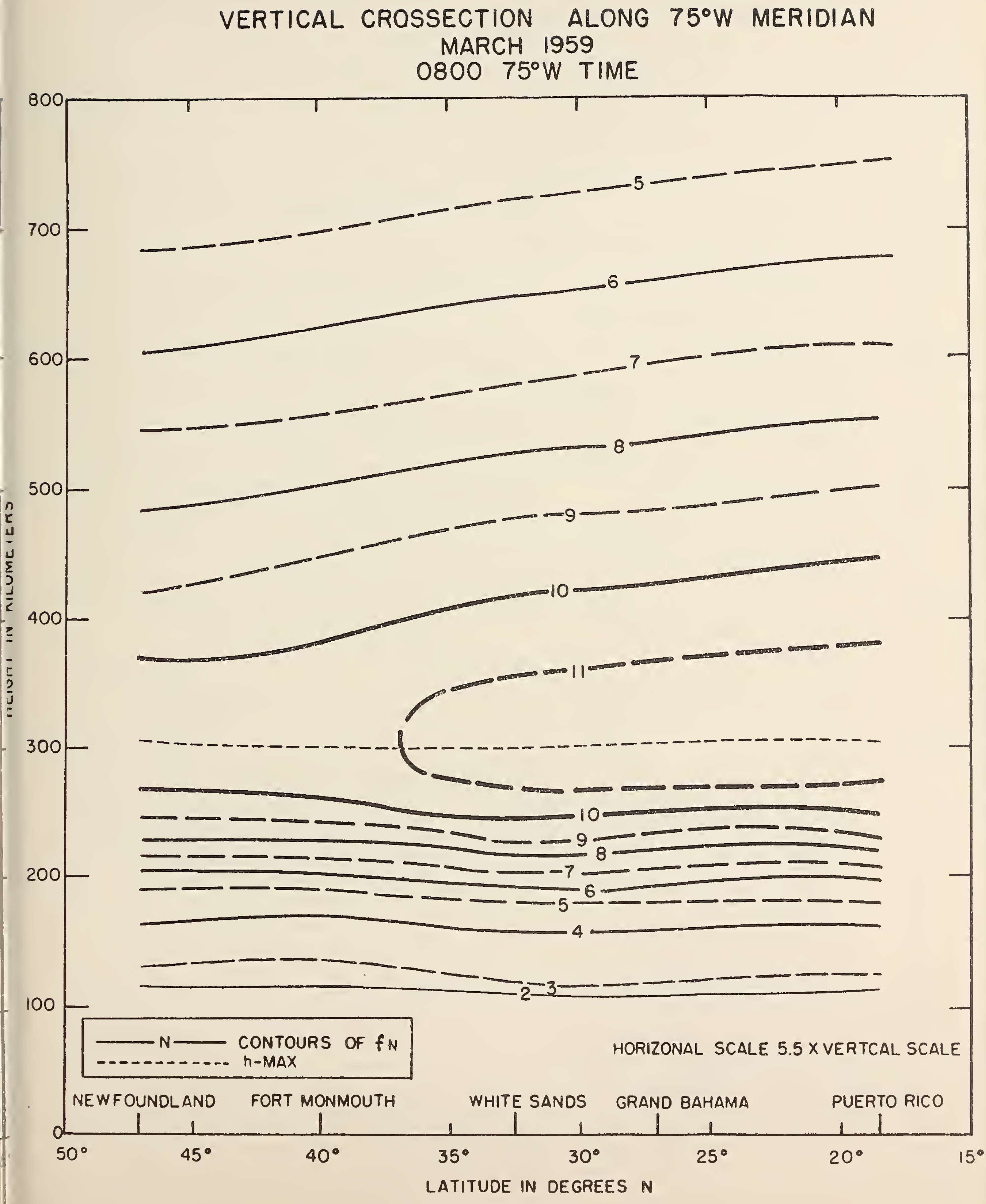

VERTICAL CROSSECTION ALCNG 75°W MERIDIAN
MARCH 1959
0500 75°W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
4
5
6
5
4
3
2
N CONTOURS OF fN
h-MAX
HORIZONAL SCALE 5.5 X VERTCAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
LATITUDE IN DEGREES N

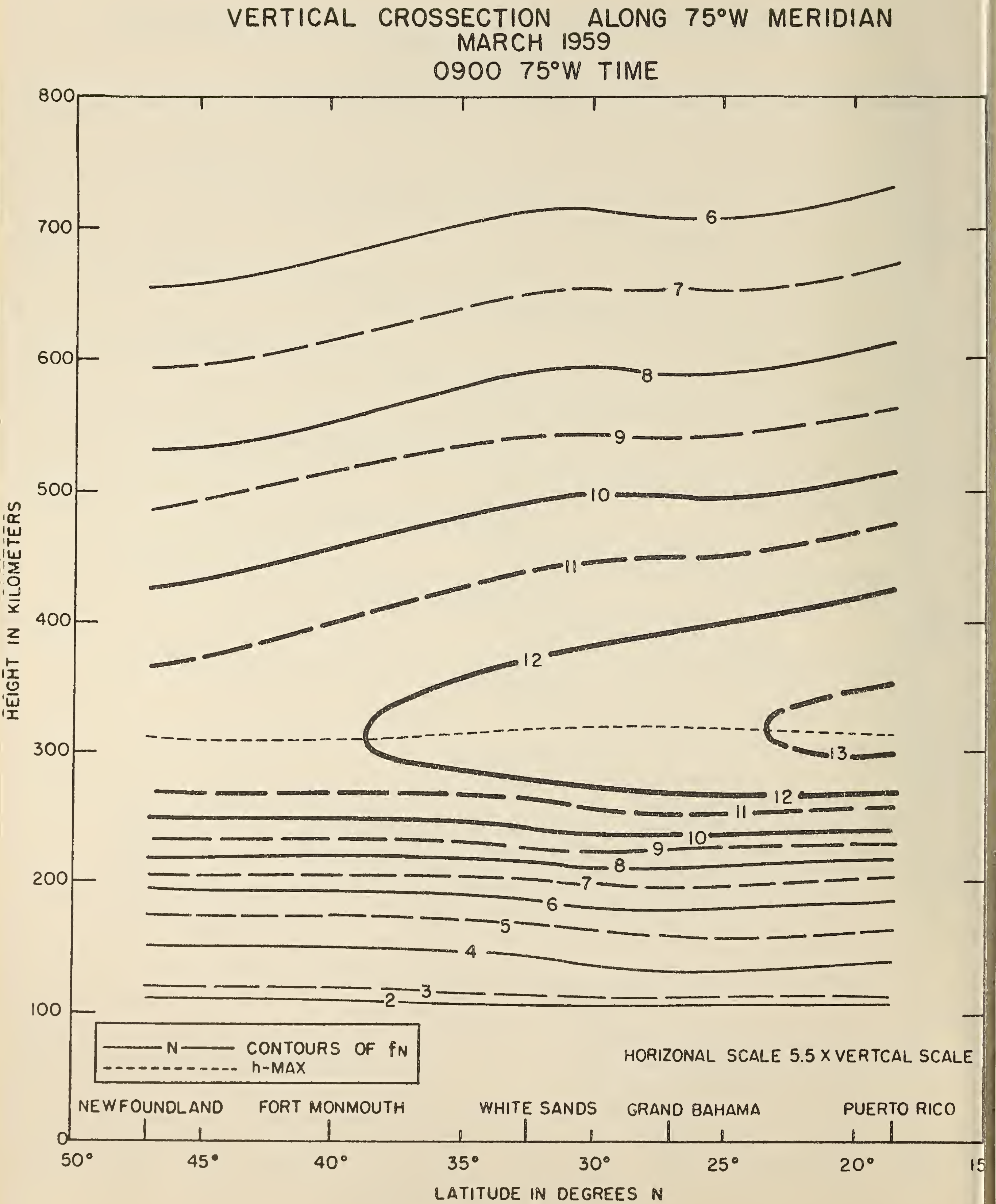
VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
0600 75°W TIME



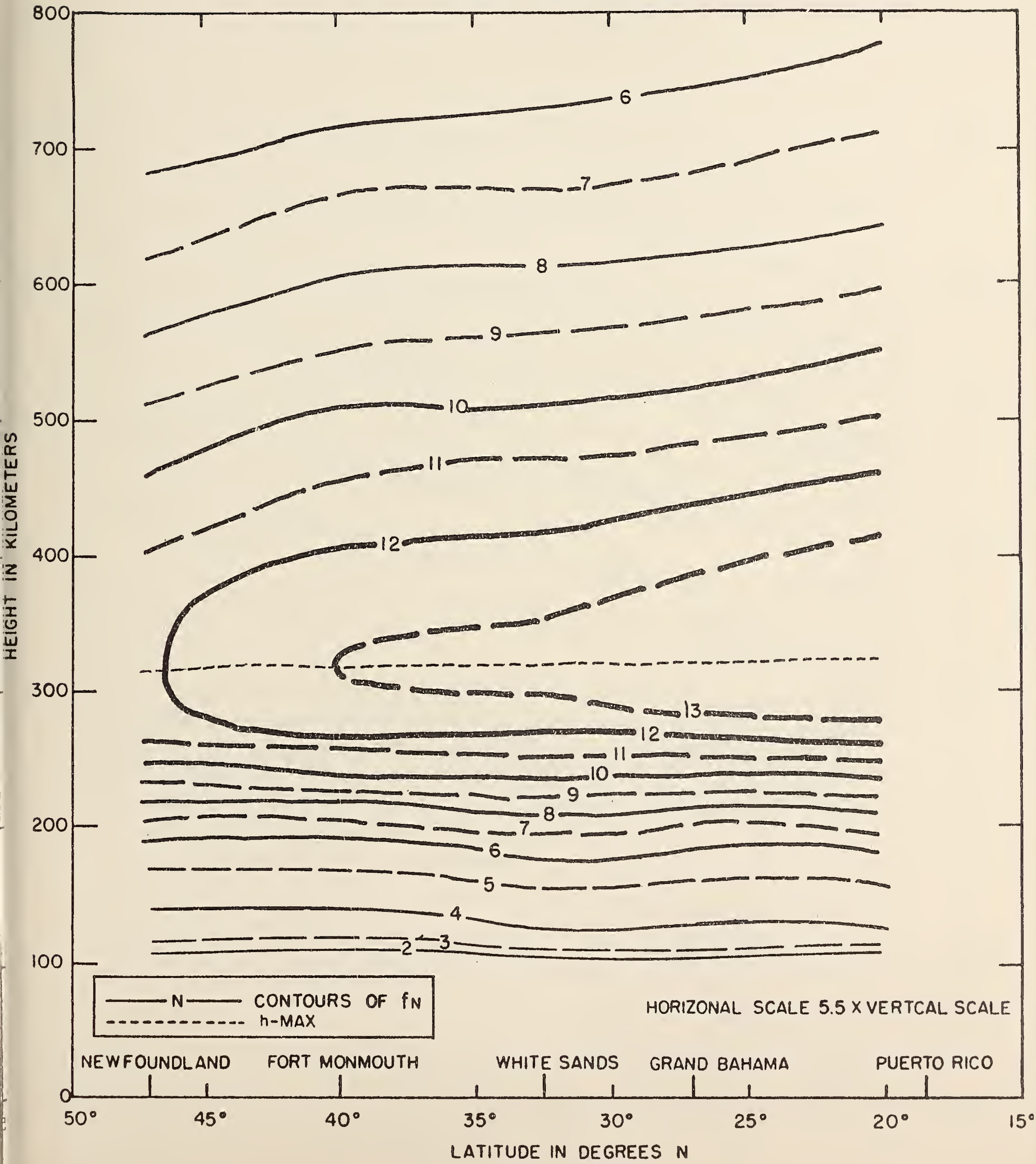
VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
0700 75°W TIME



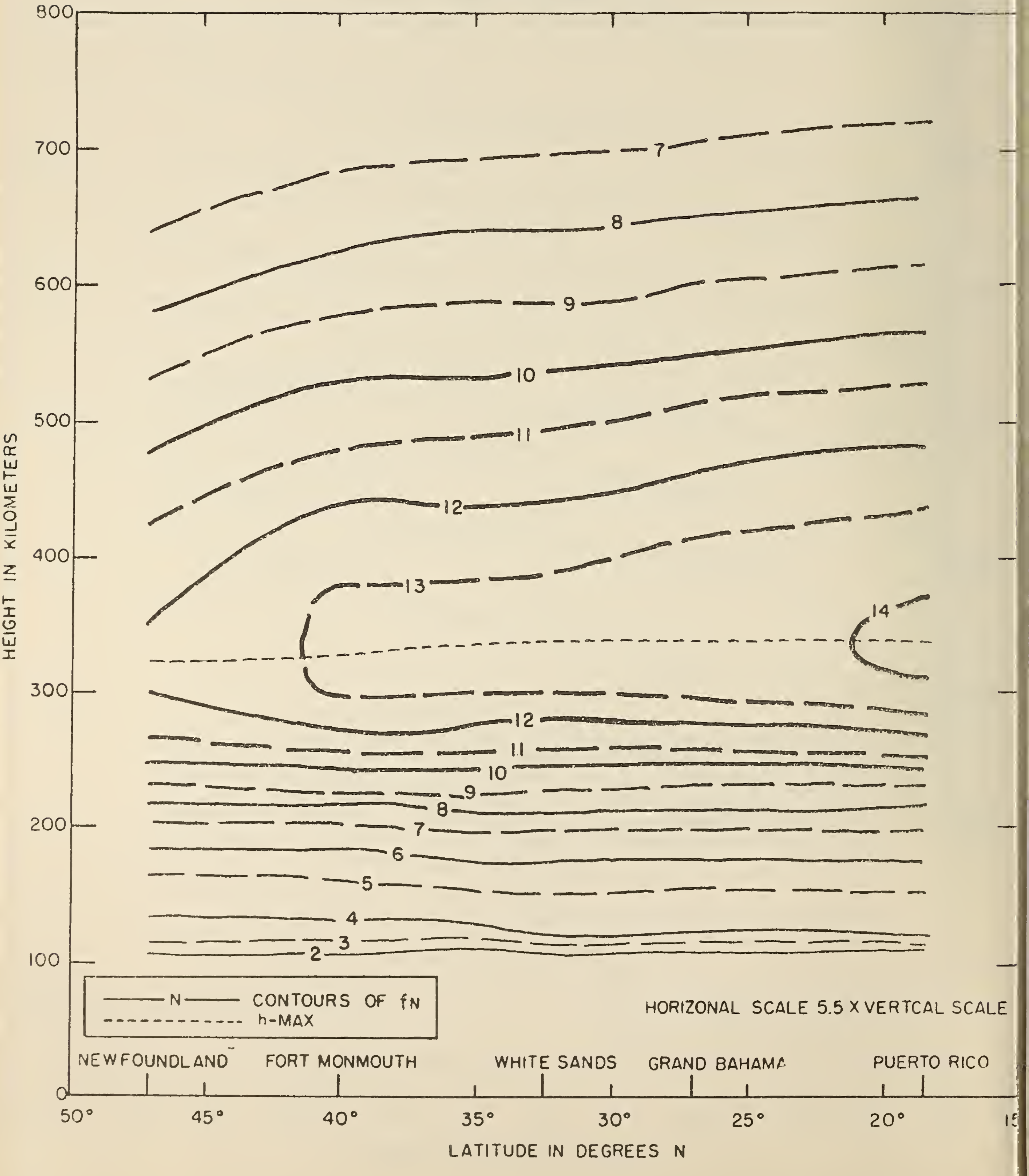

VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
0800 75°W TIME
800
700
600
500
400
300
200
100
0
5
6
7
8
9
10
11
10
9
8
7
6
5
4
3
2
N CONTOURS OF fN
h-MAX
HORIZONAL SCALE 5.5 X VERTCAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
LATITUDE IN DEGREES N


VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
0900 75°W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
6
7
8
9
10
11
12
13
12
11
10
9
8
7
6
5
4
3
2
N CONTOURS OF fN
h-MAX
HORIZONAL SCALE 5.5 X VERTCAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15
LATITUDE IN DEGREES N

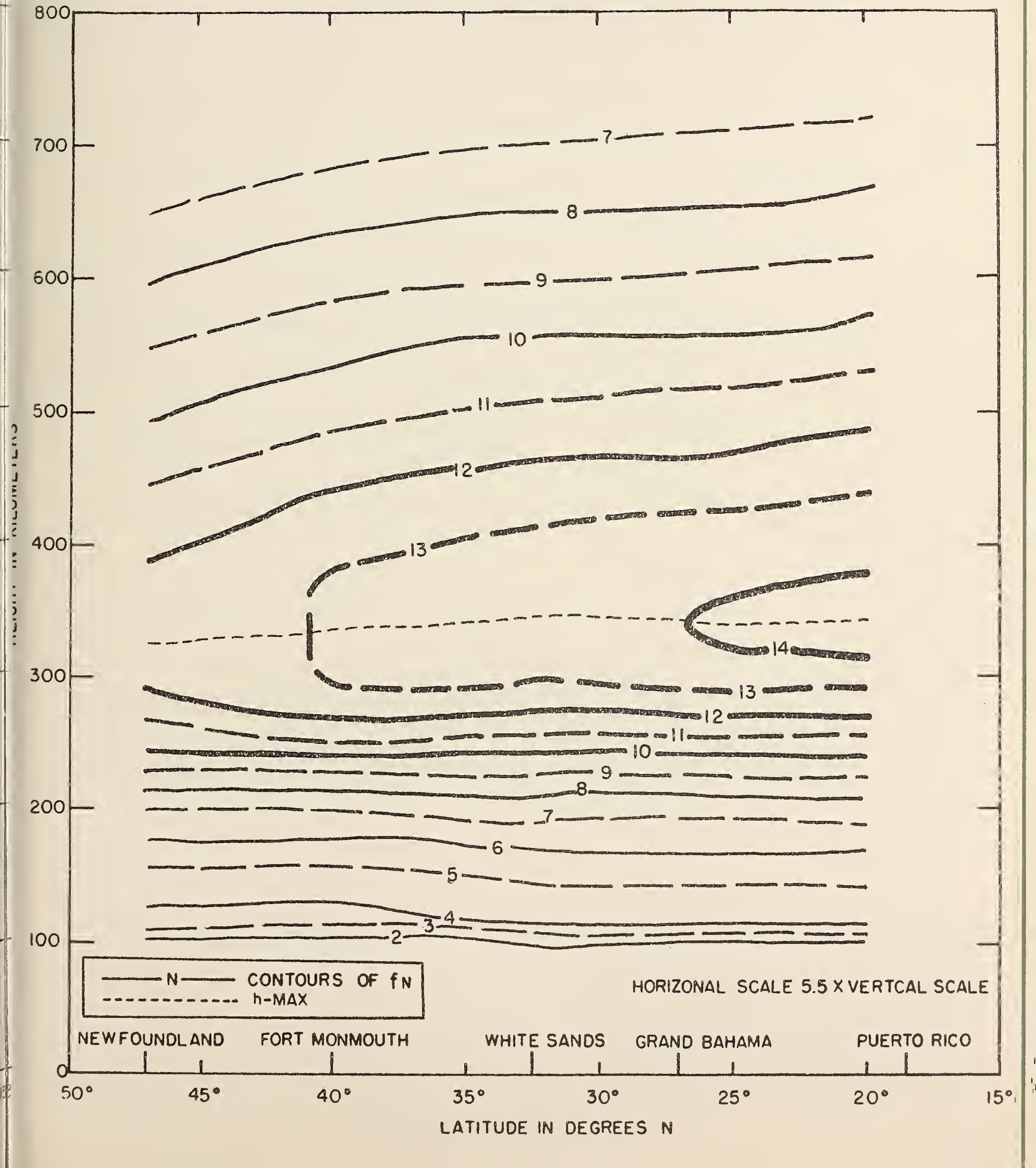
VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
1000 75°W TIME

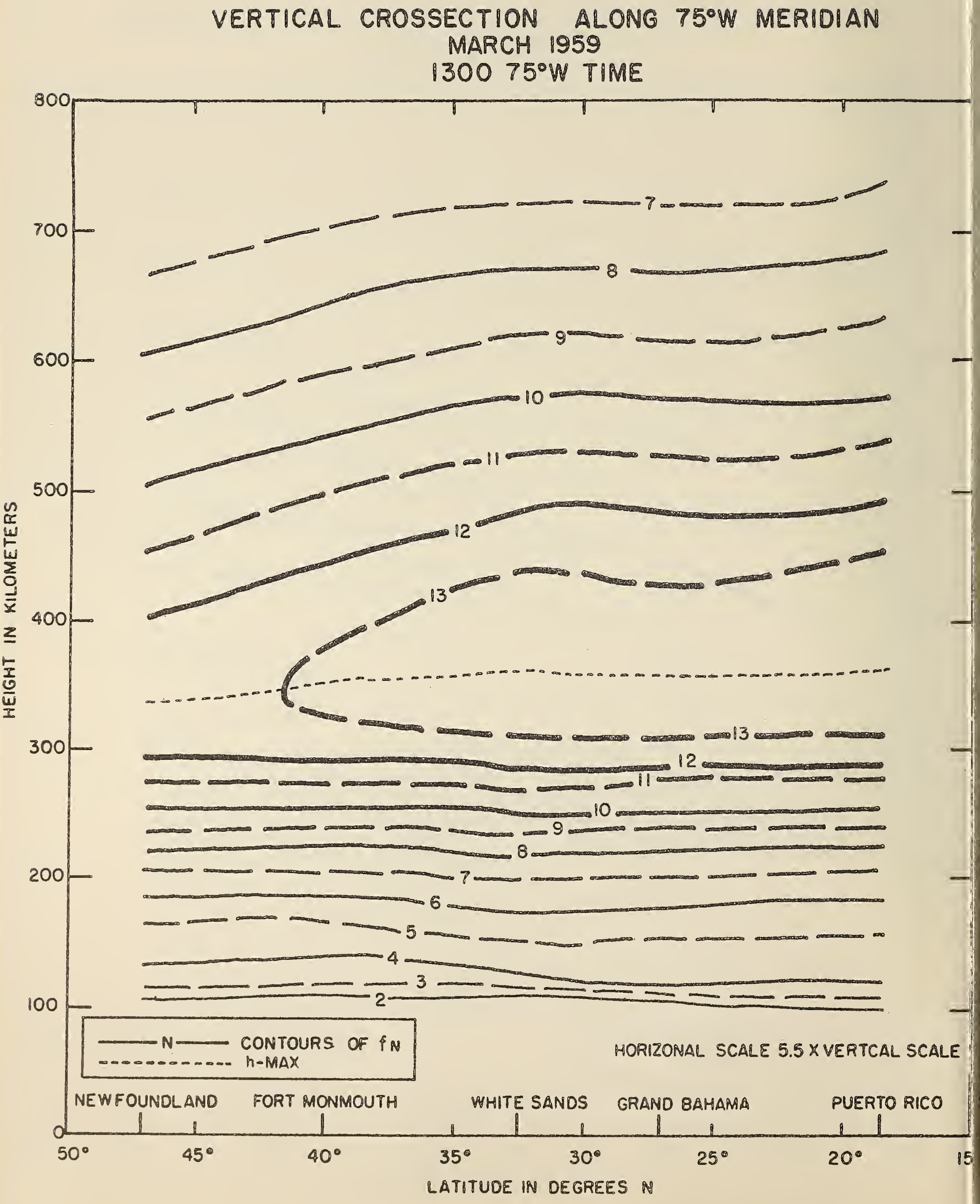


VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
1100 75°W TIME

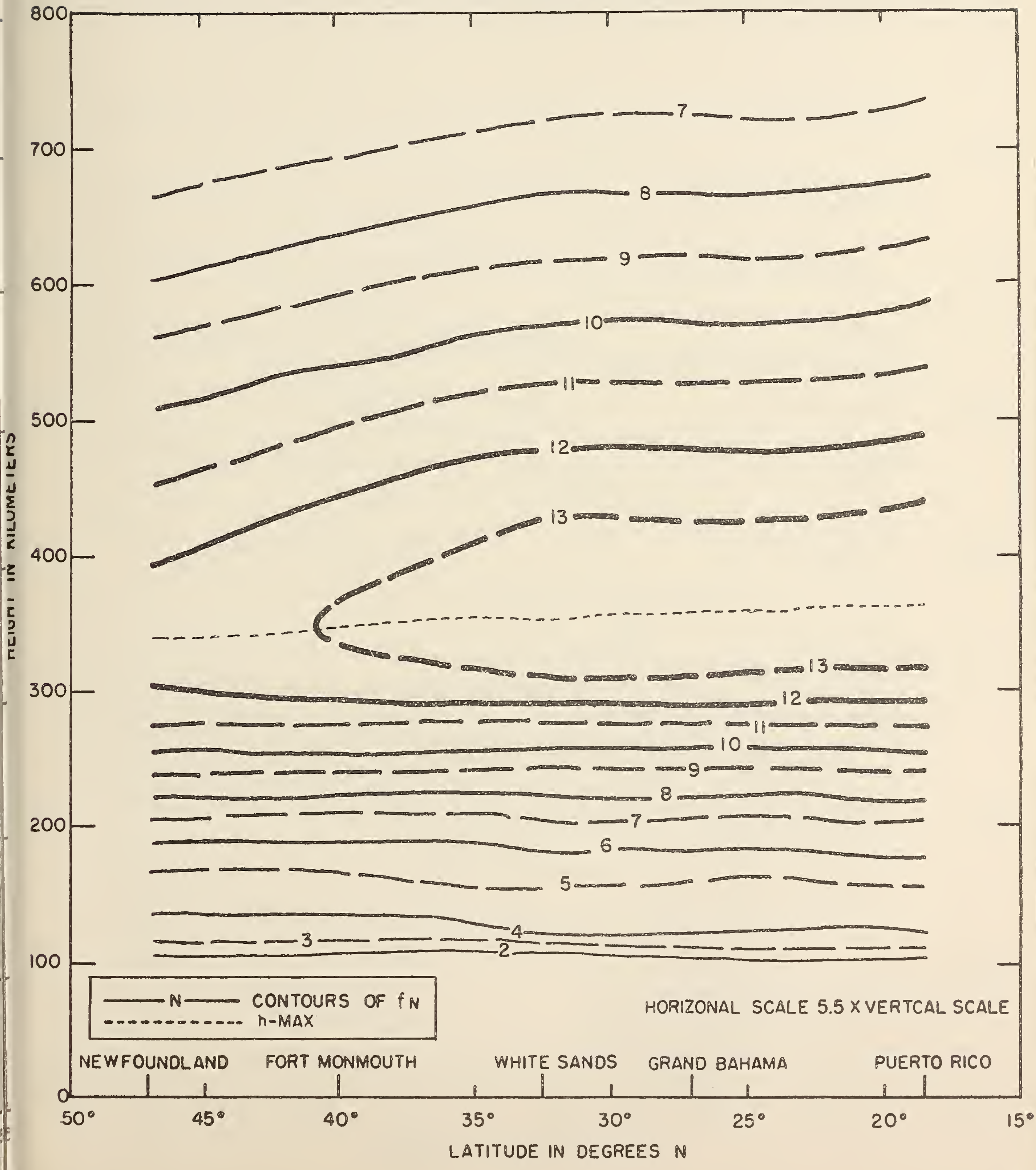


VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
1200 75°W TIME

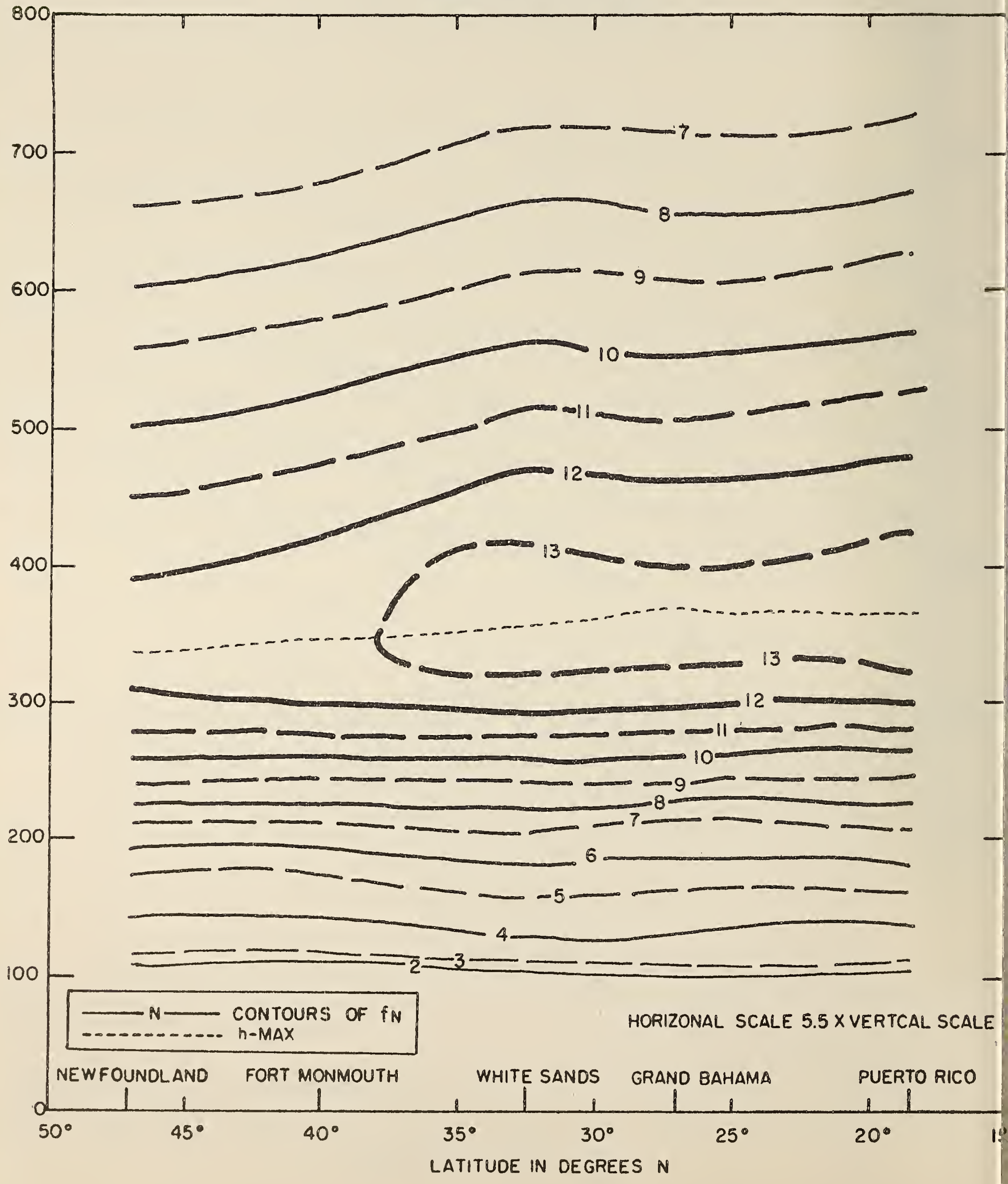



VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
1300 75°W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
7
8
9
10
11
12
13
13
12
11
10
9
8
7
6
5
4
3
2
N CONTOURS OF fN
h-MAX
HORIZONAL SCALE 5.5 X VERTCAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15
LATITUDE IN DEGREES N

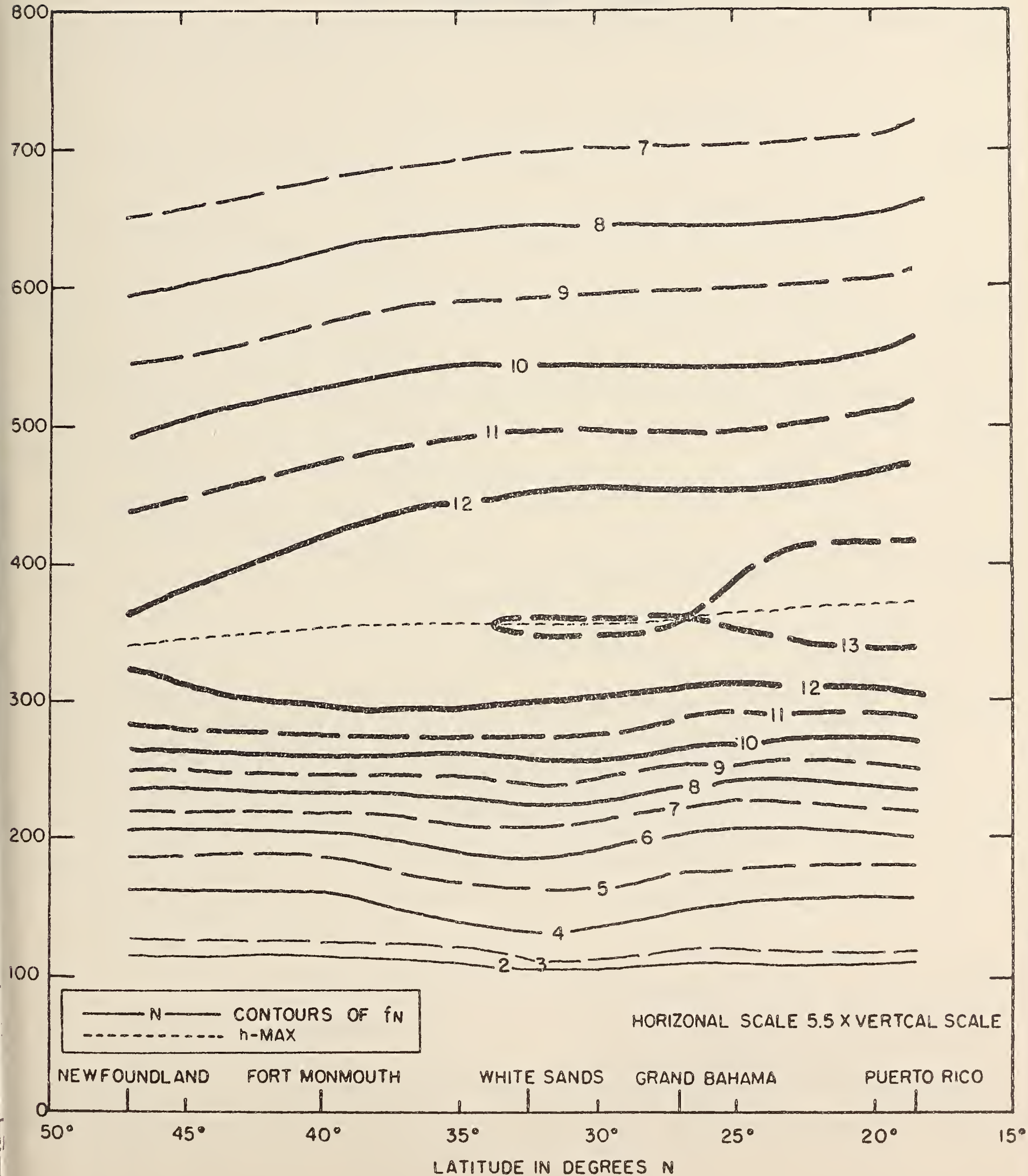
VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
1400 75°W TIME



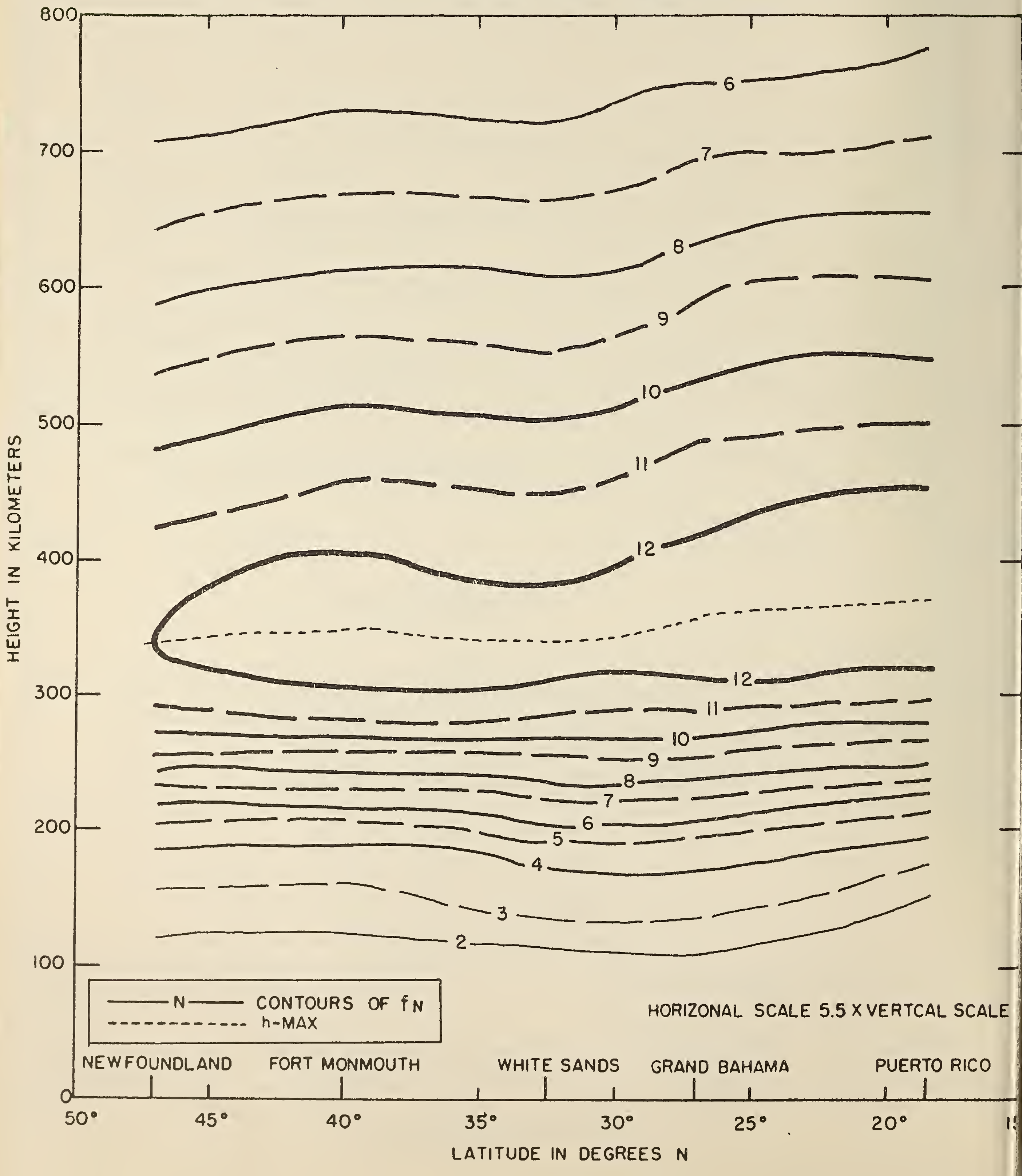
VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
1500 75° TIME



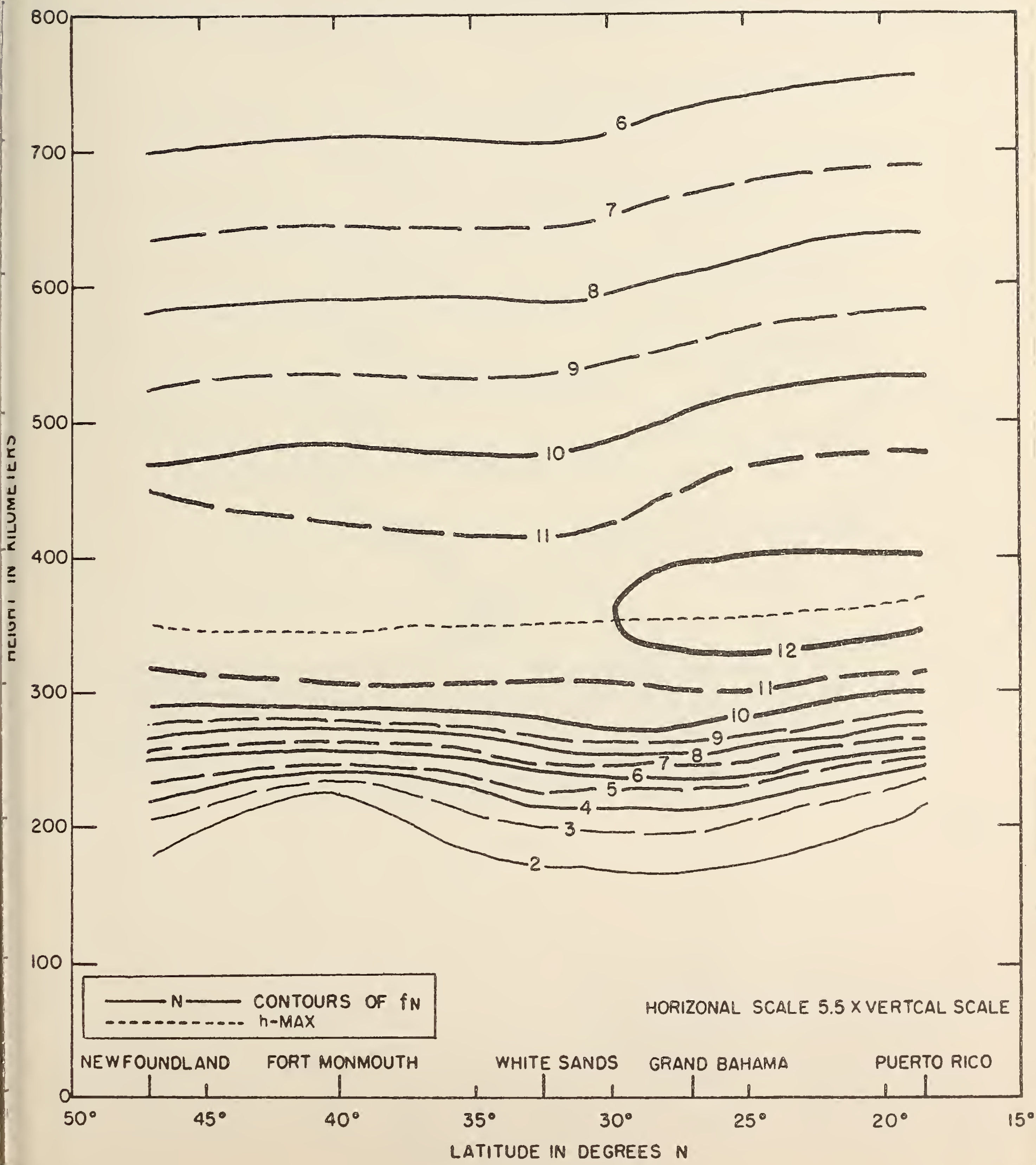
VERTICAL CROSSECTION ALONG 75° MERIDIAN
MARCH 1959
1600 75°W TIME



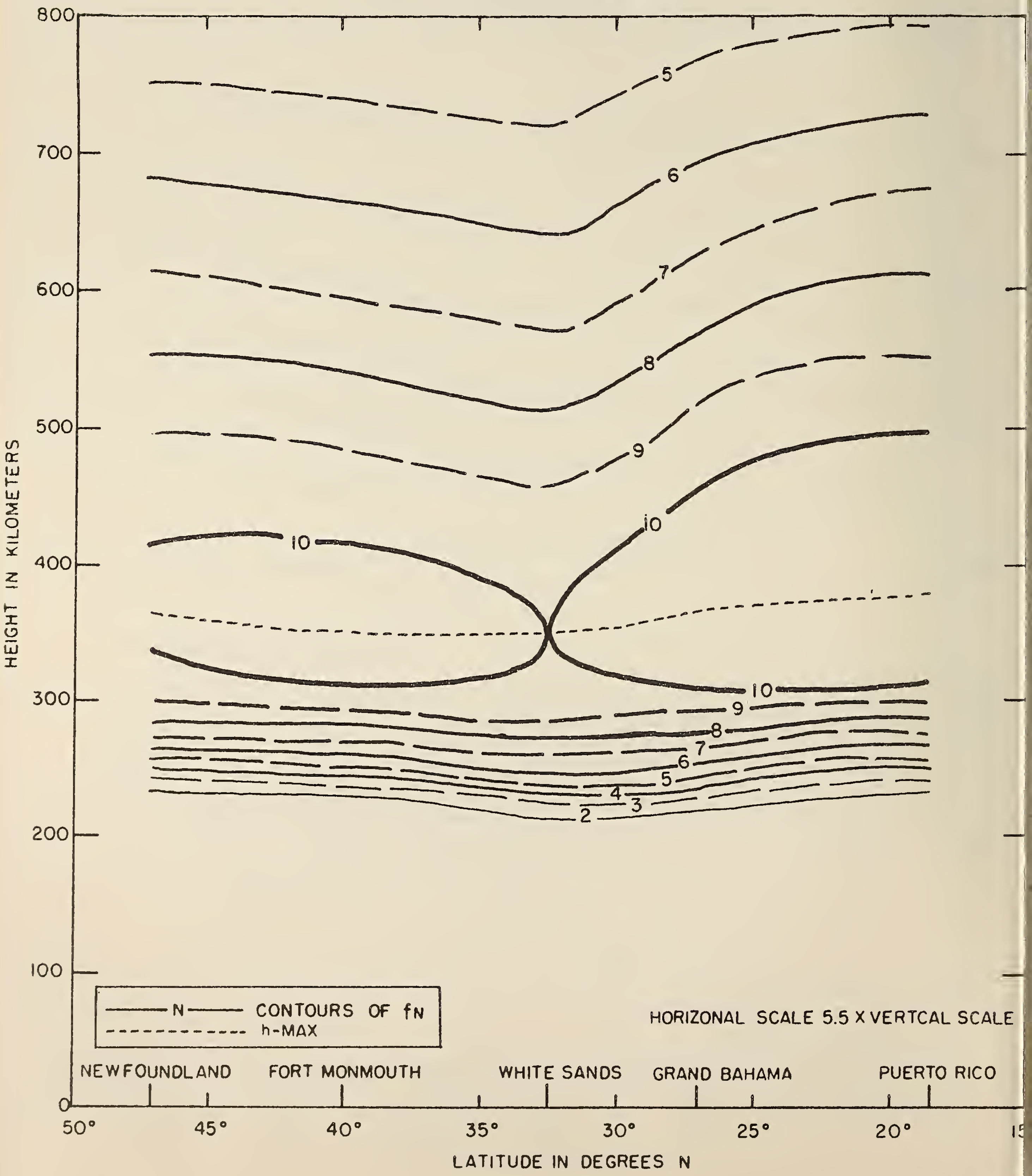
VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
1700 75°W TIME

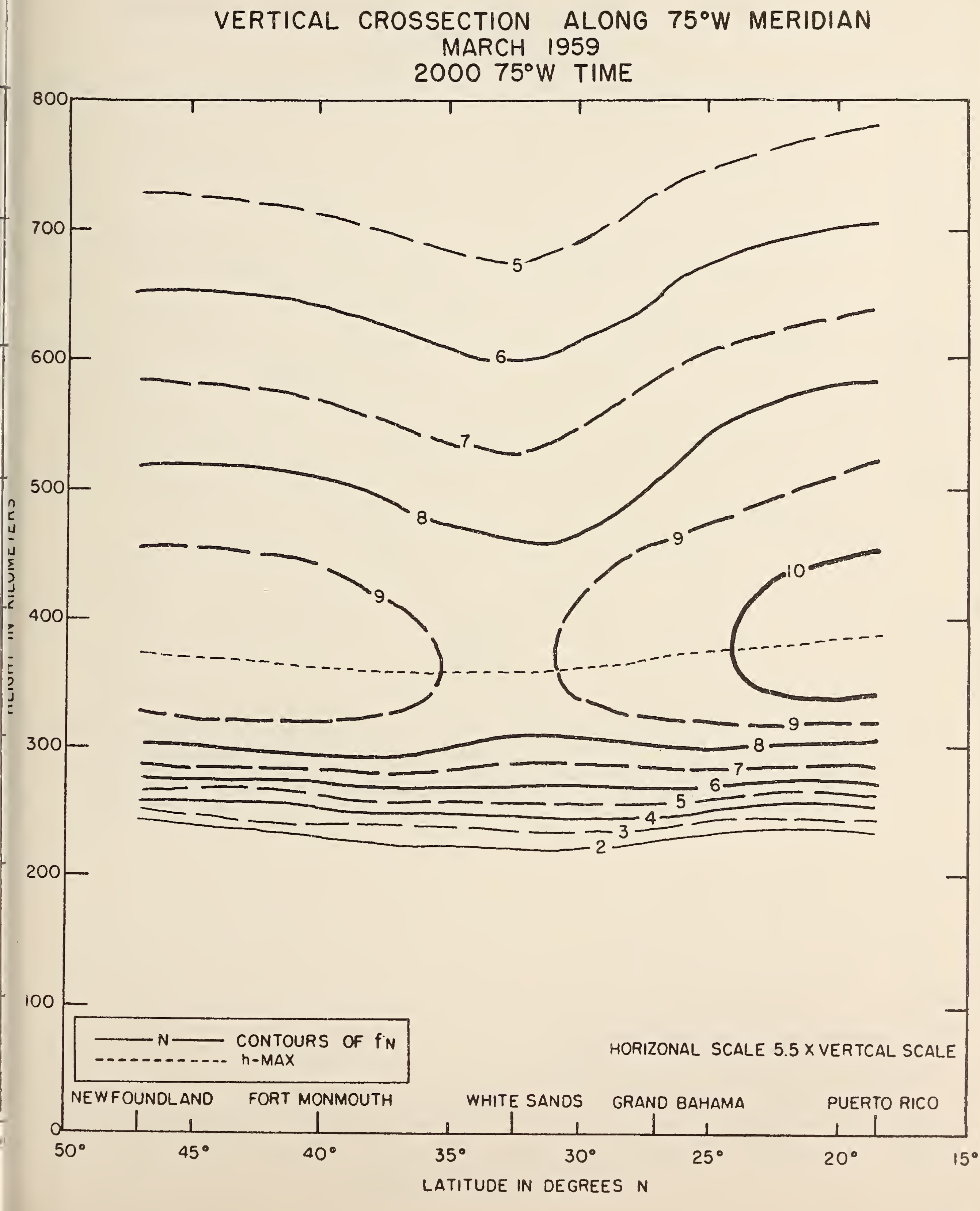


VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
1800 75°W TIME

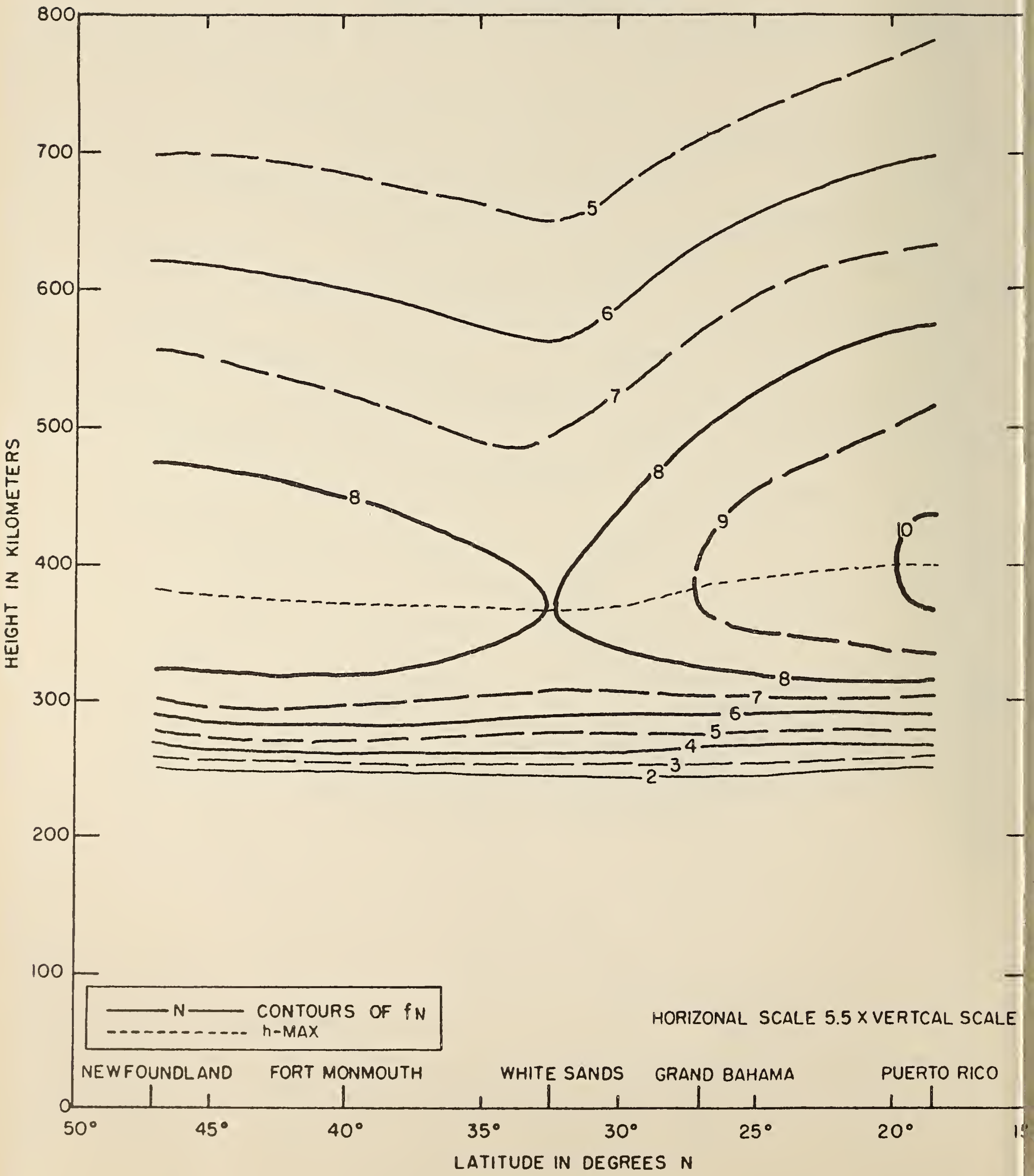


VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
1900 75°W TIME

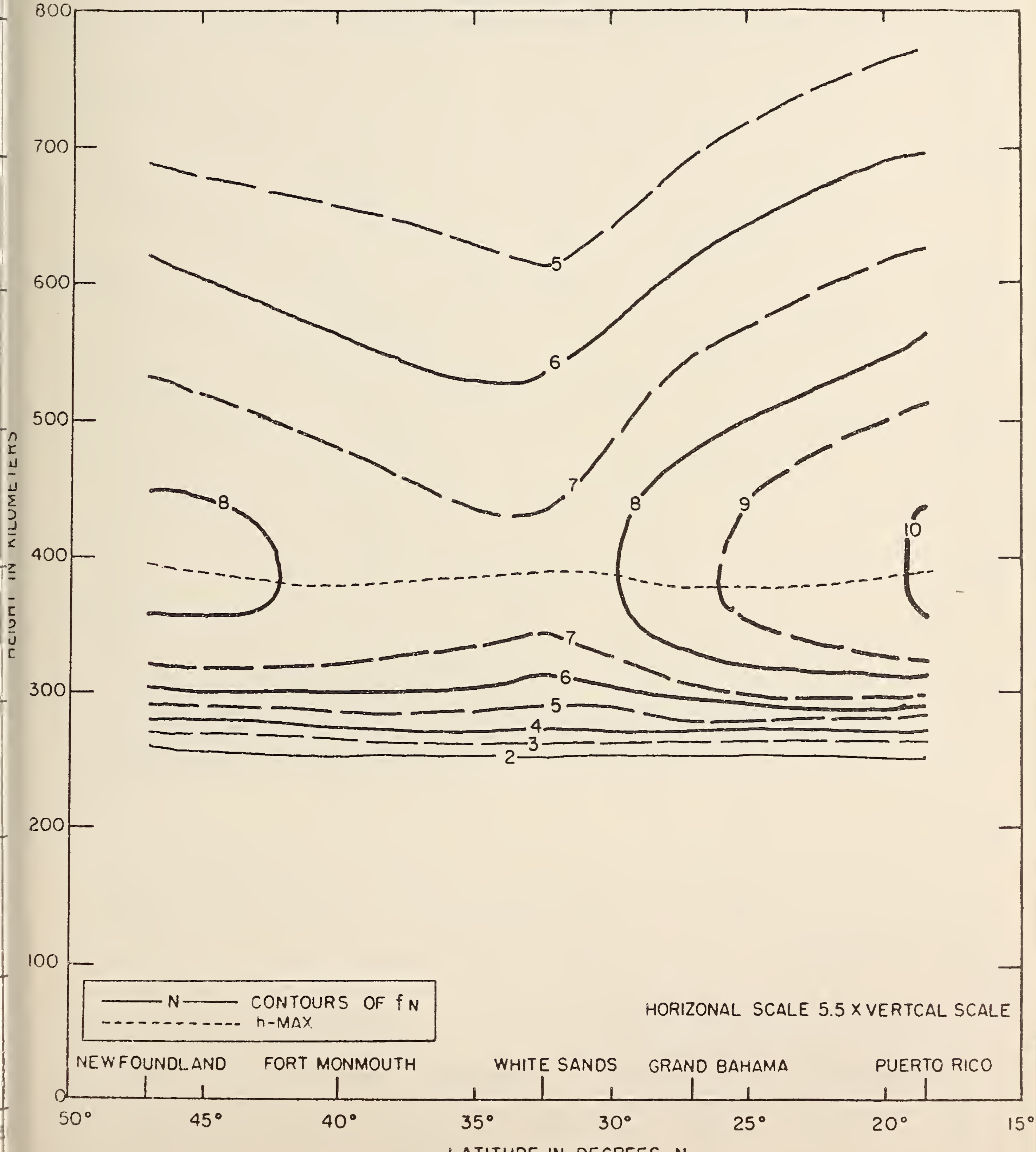


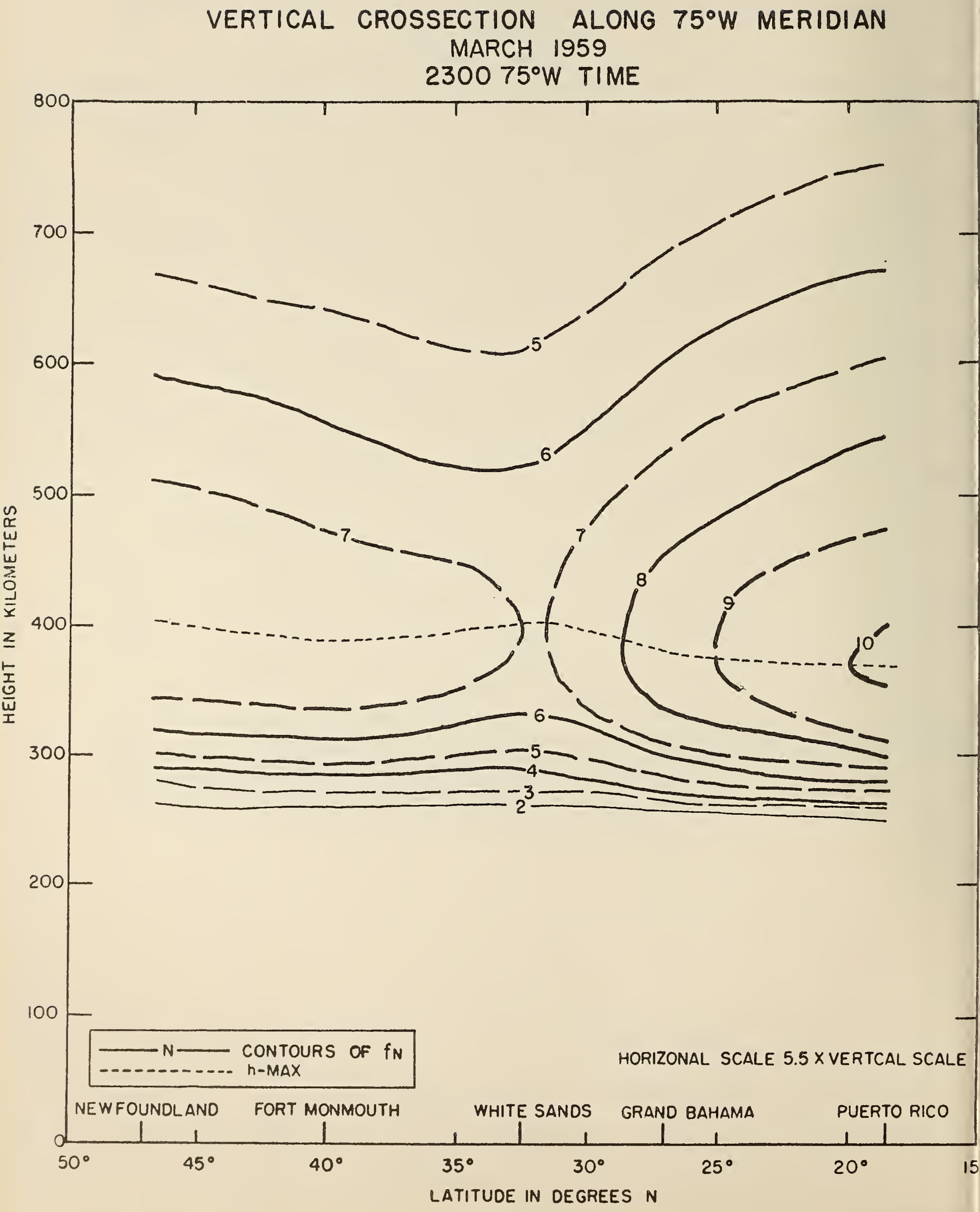

VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
2000 75°W TIME
800
700
600
500
400
300
200
100
0
5
6
7
8
9
9
10
9
8
7
6
5
4
3
2
N CONTOURS OF fN
h-MAX
HORIZONAL SCALE 5.5 X VERTCAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
LATITUDE IN DEGREES N

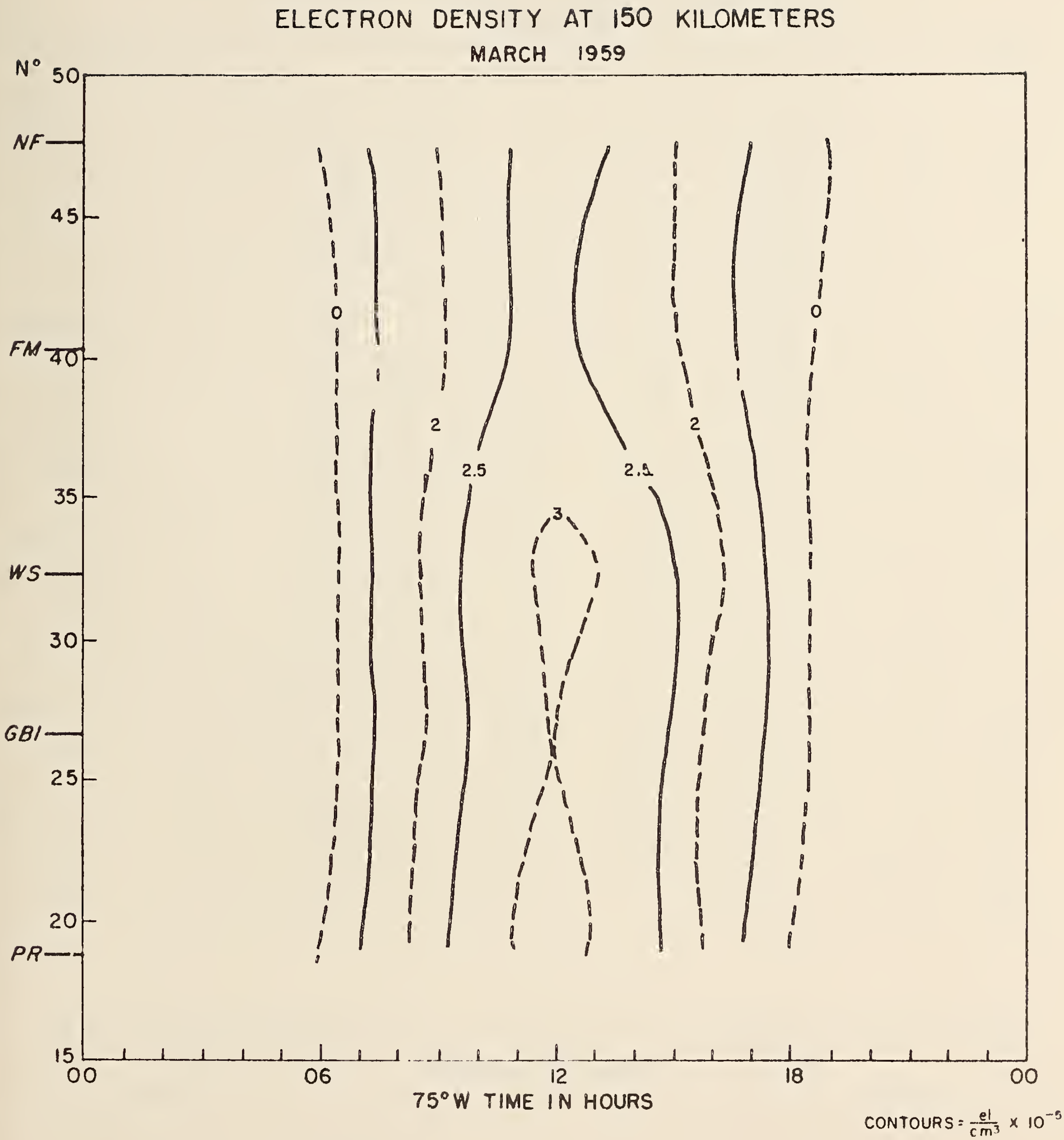
VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
2100 75°W TIME



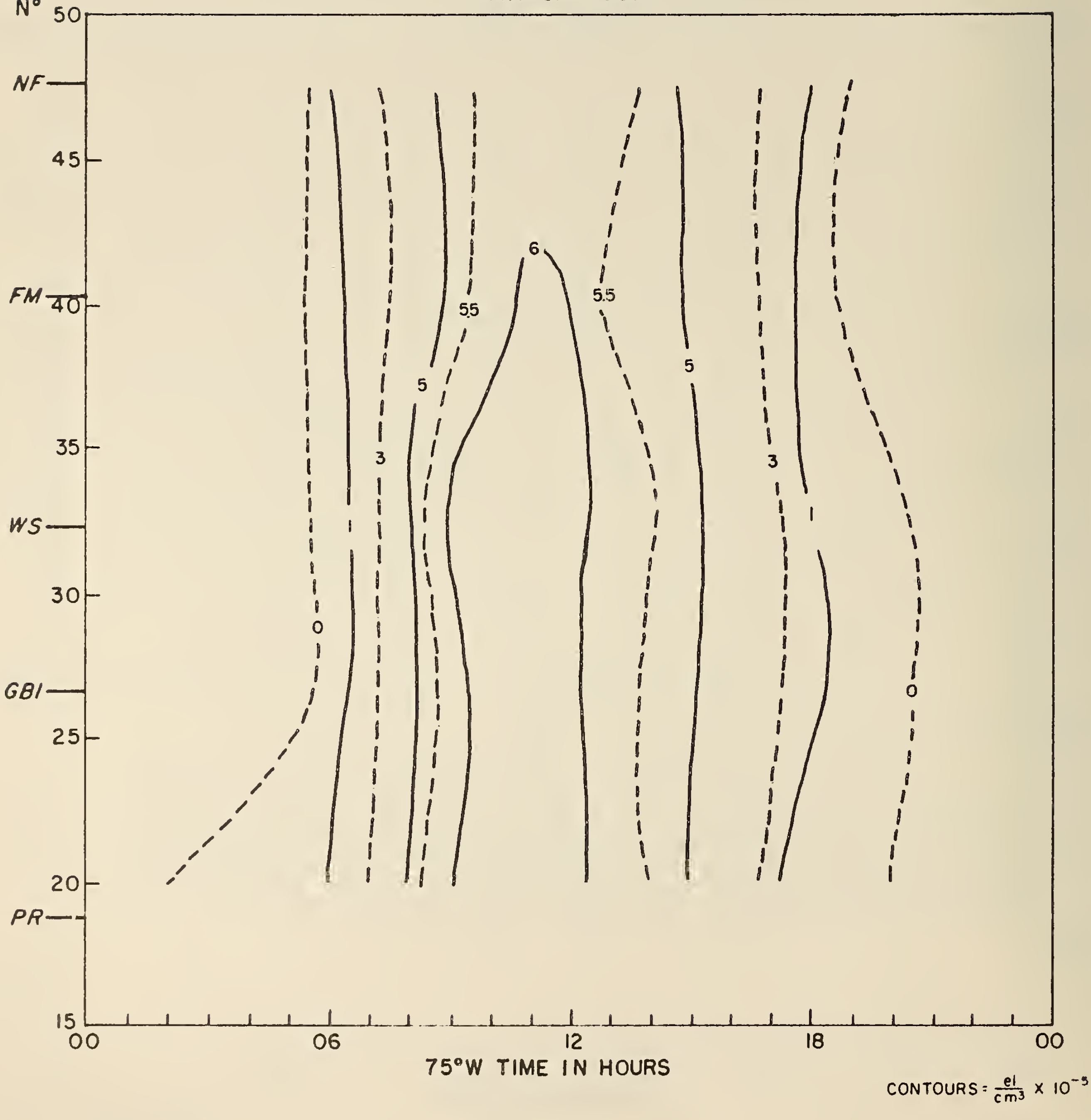
VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
2200 75°W TIME



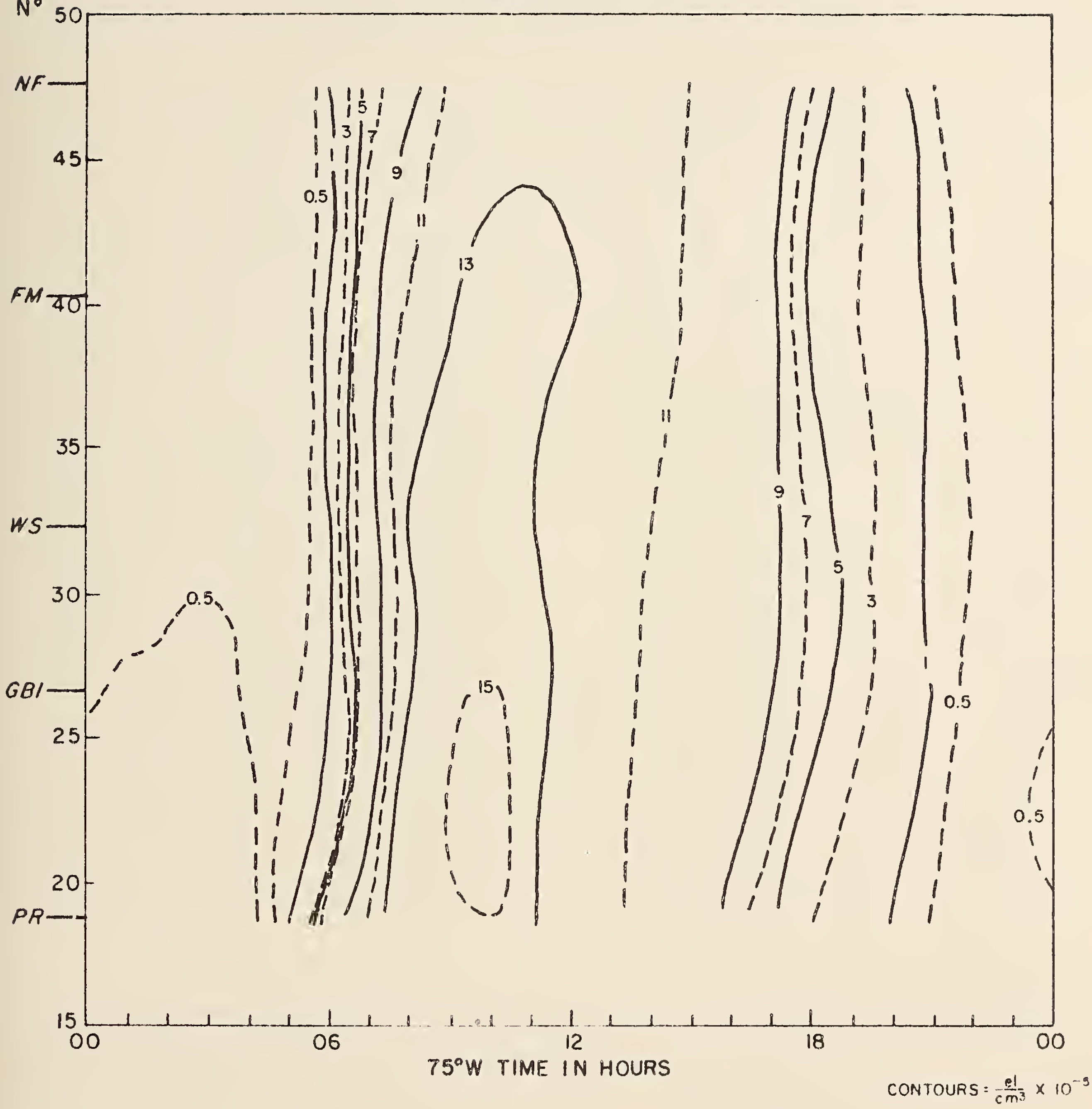

VERTICAL CROSSECTION ALONG 75°W MERIDIAN
MARCH 1959
2300 75°W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
5
6
7
7
8
9
10
6
5
4
3
2
N CONTOURS OF fN
h-MAX
HORIZONAL SCALE 5.5 X VERTCAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15
LATITUDE IN DEGREES N


ELECTRON DENSITY AT 150 KILOMETERS
MARCH 1959
N°
50
NF
45
FM
40
35
WS
30
GBI
25
20
PR
15
0
2
2.5
3
2.5
2
0
00
06
12
18
00
75° W TIME IN HOURS
CONTOURS = el/cm³ x 10⁻⁵

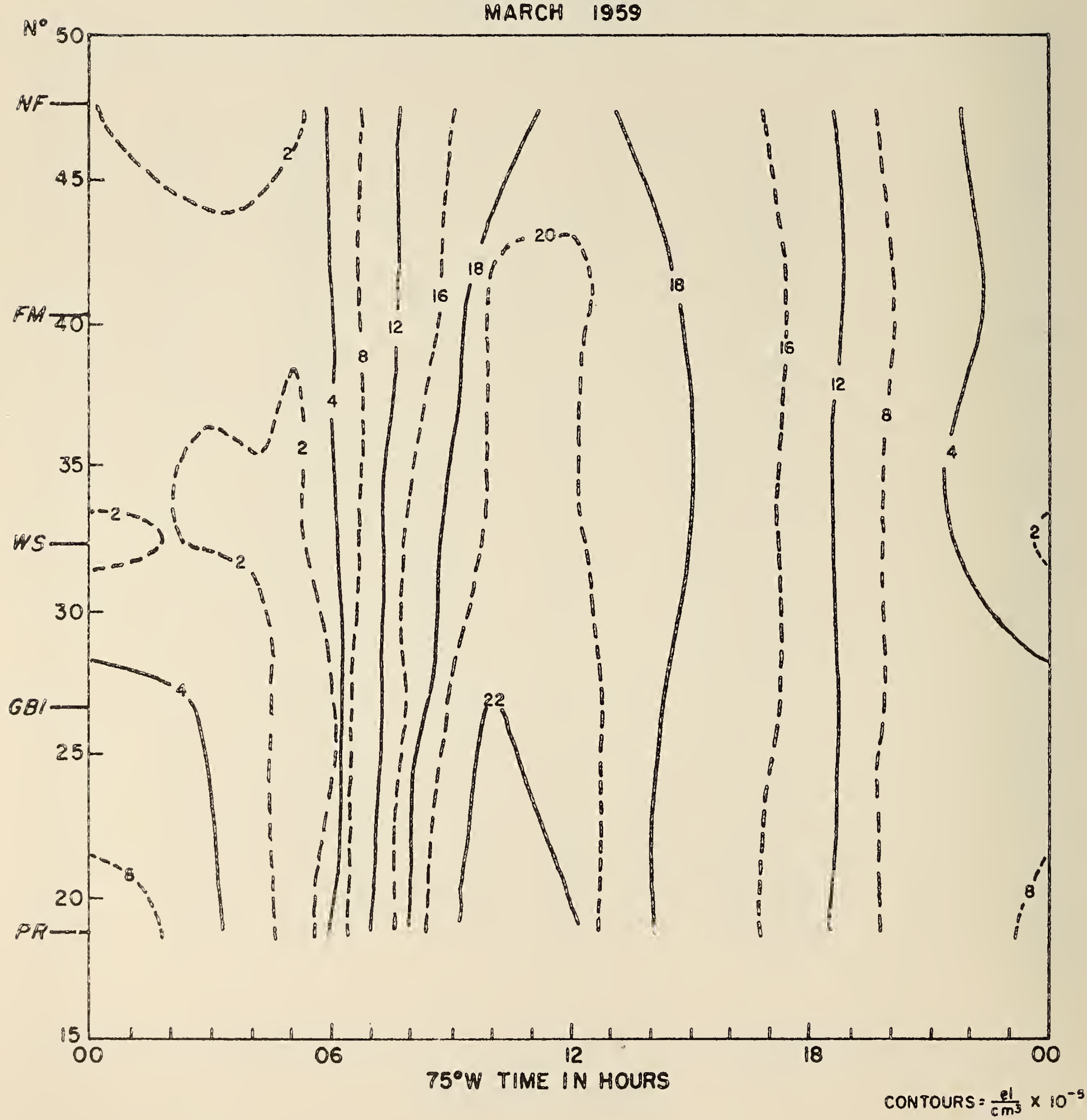
ELECTRON DENSITY AT 200 KILOMETERS
MARCH 1959



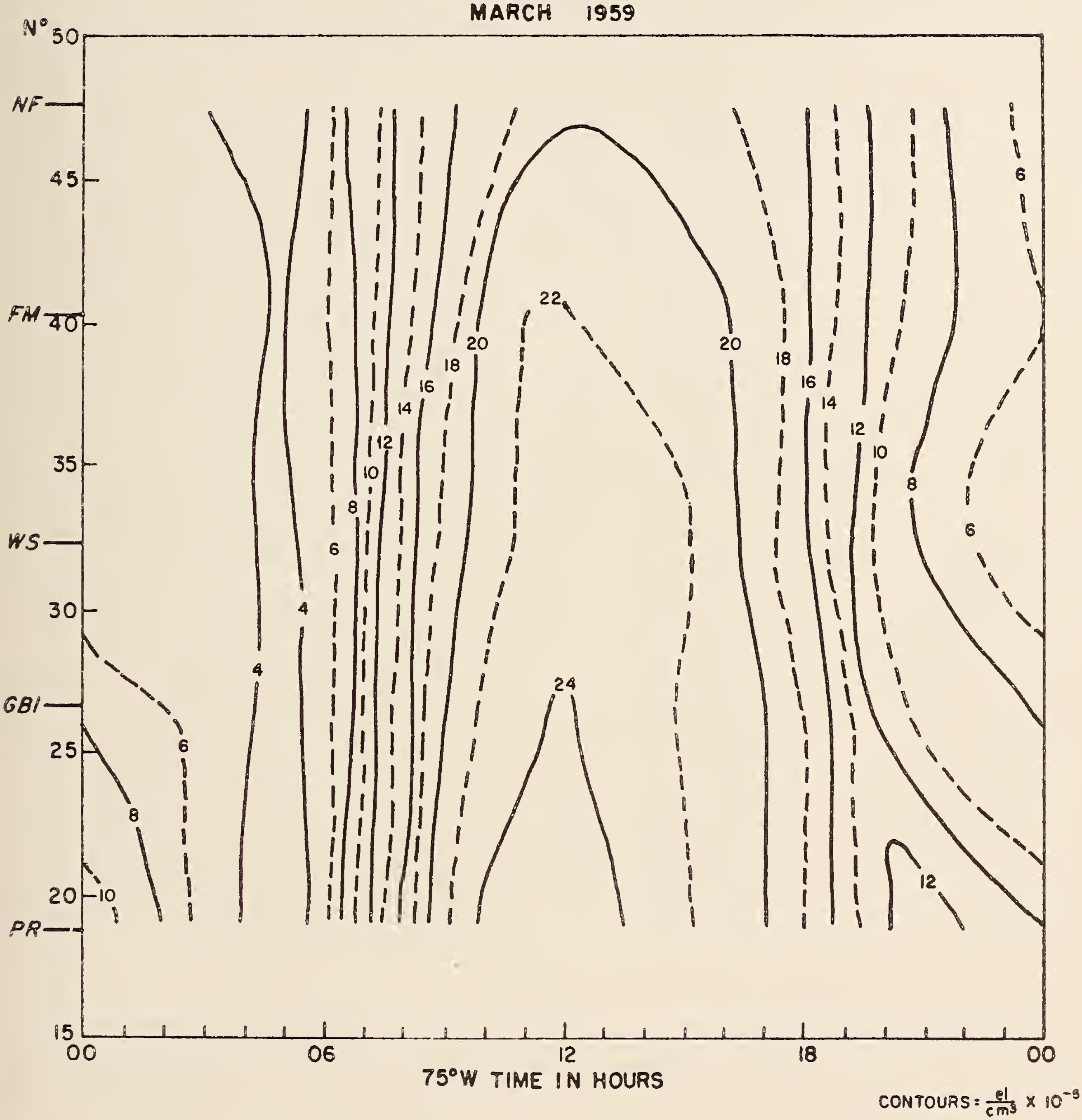
ELECTRON DENSITY AT 250 KILOMETERS
MARCH 1959



ELECTRON DENSITY AT 300 KILOMETERS
MARCH 1959

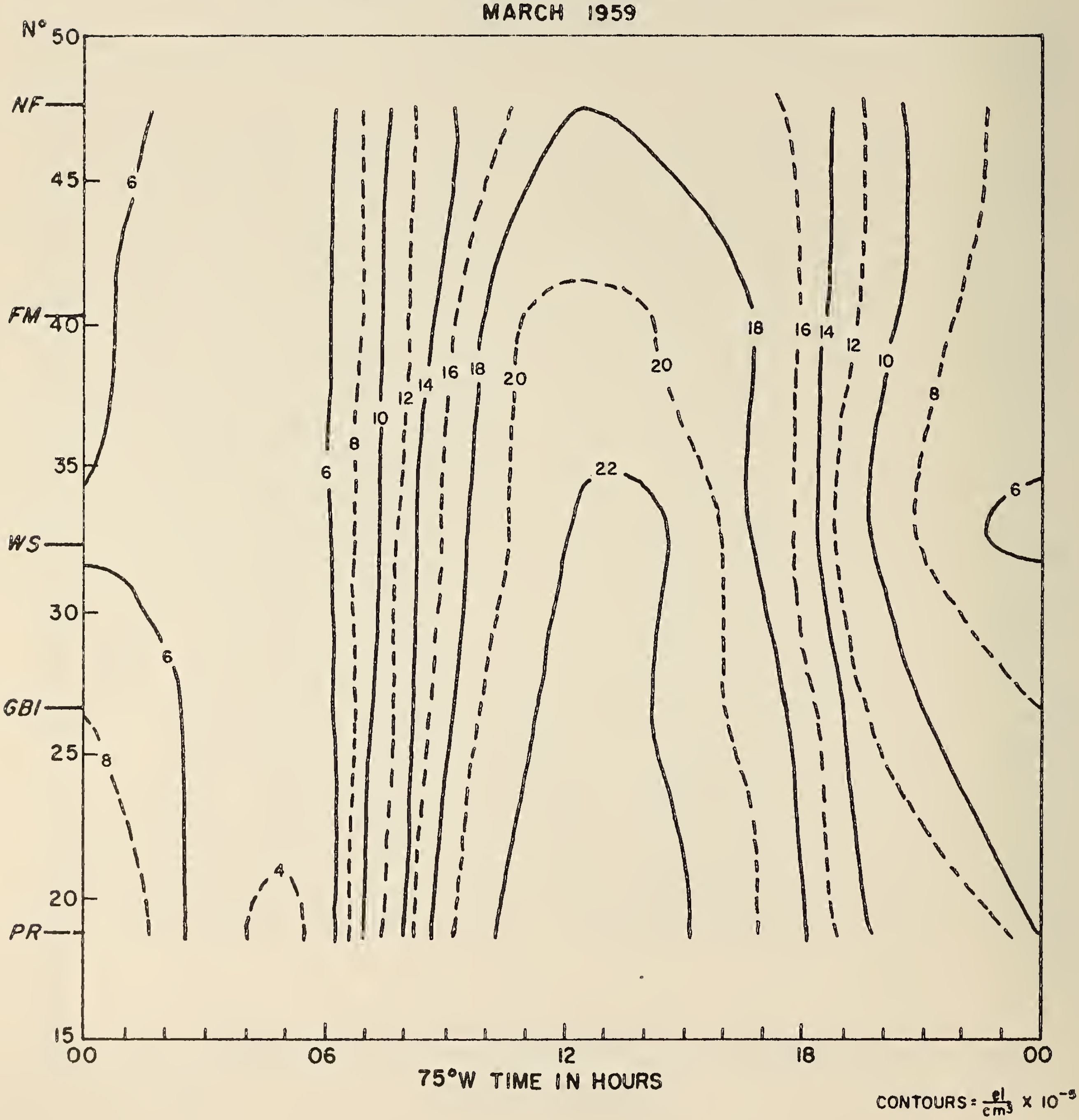


ELECTRON DENSITY AT 350 KILOMETERS
MARCH 1959

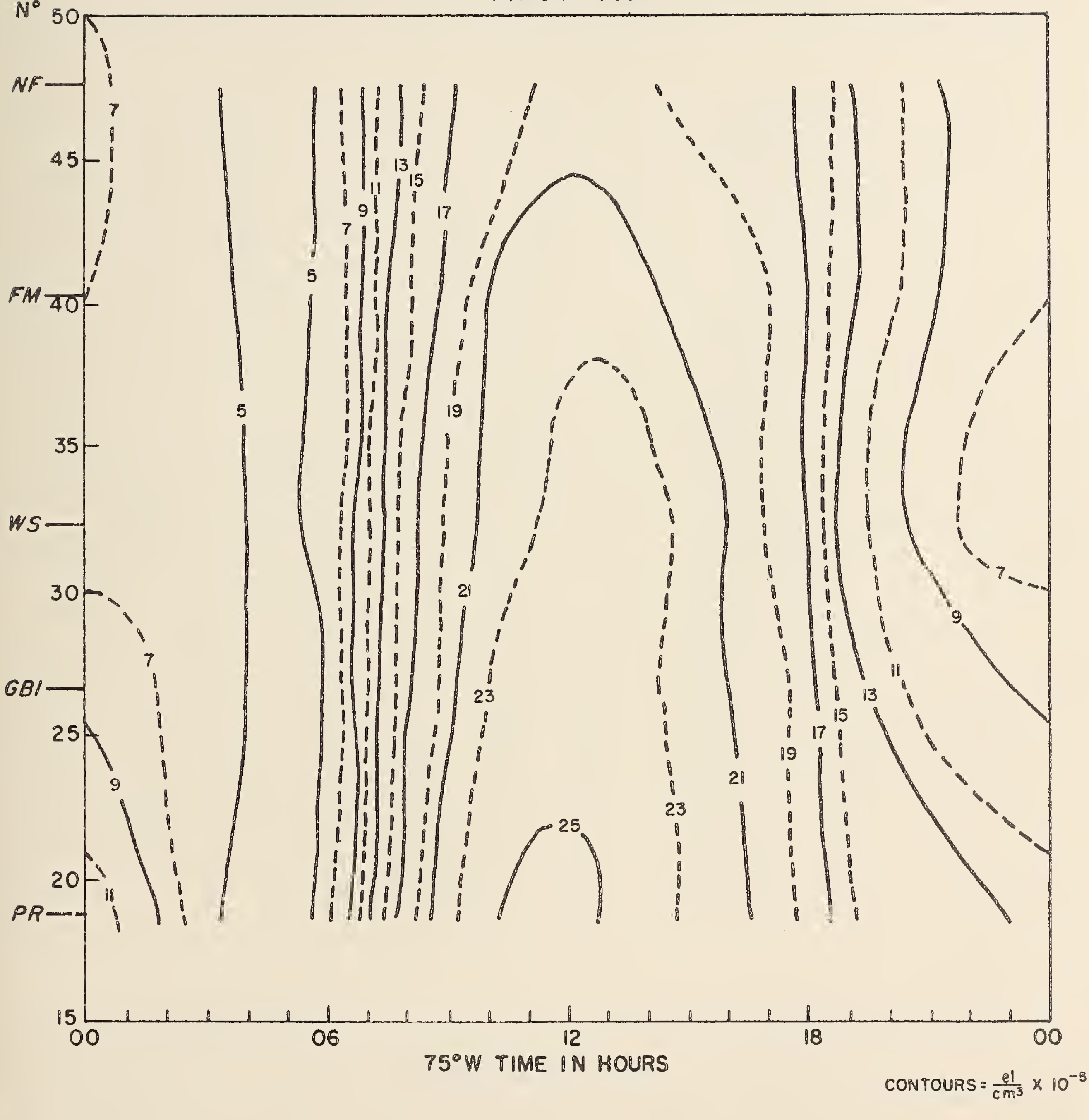


ELECTRON DENSITY AT 400 KILOMETERS

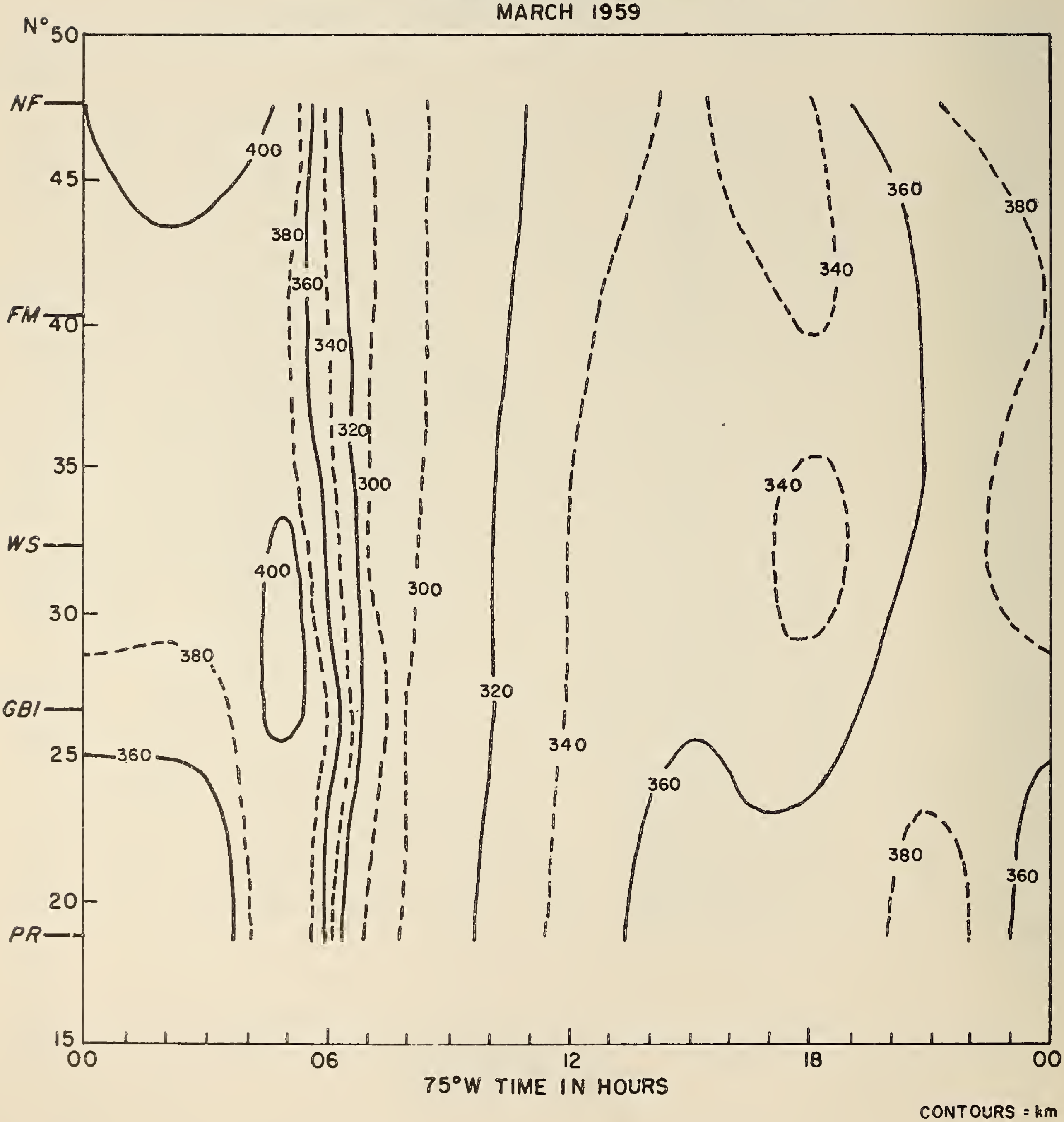
MARCH 1959



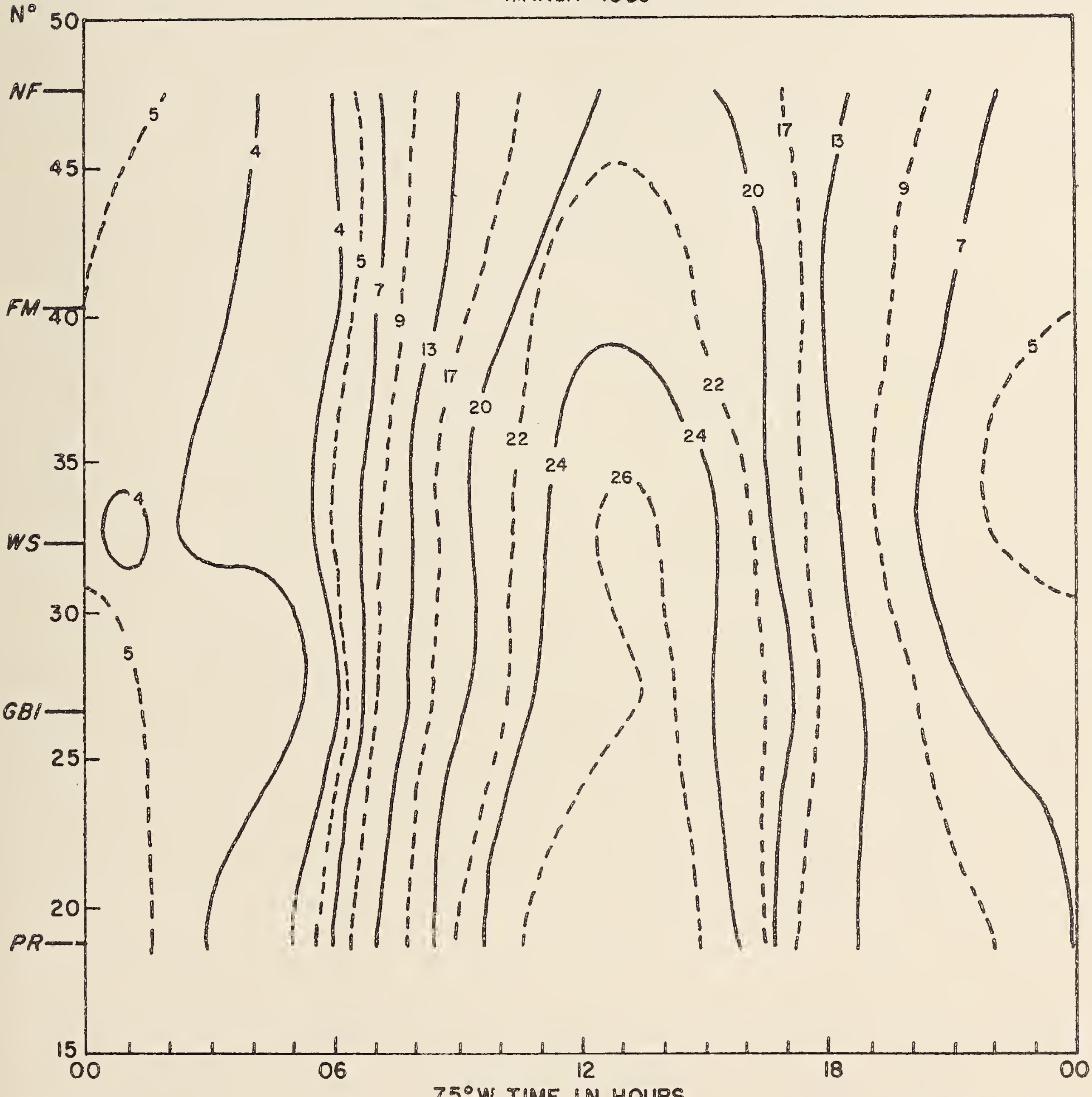
MAXIMUM ELECTRON DENSITY
MARCH 1959



HEIGHT OF MAXIMUM ELECTRON DENSITY
MARCH 1959

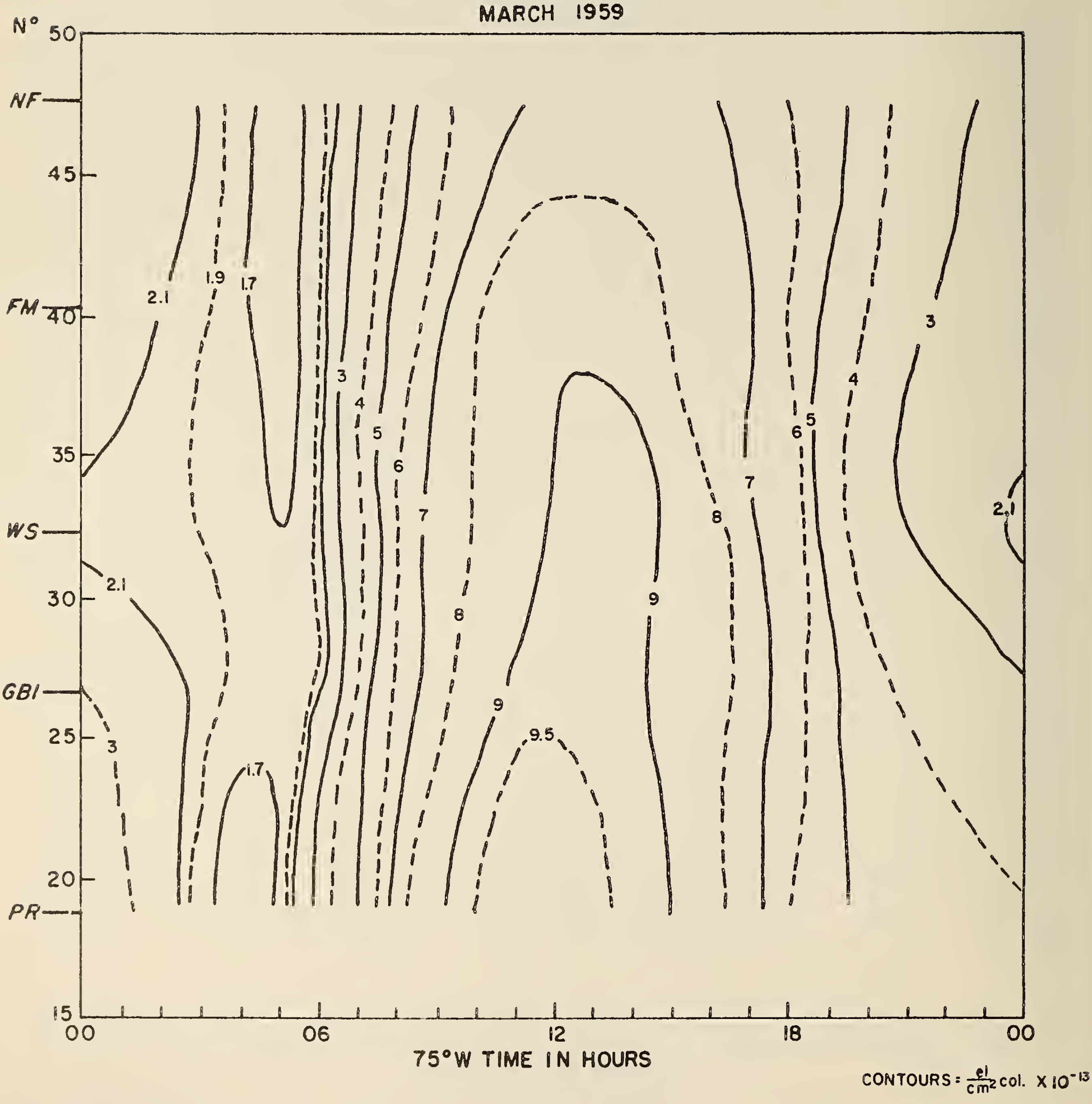


ELECTRON DENSITY INTEGRATED TO HEIGHT OF MAXIMUM ELECTRON DENSITY
MARCH 1959

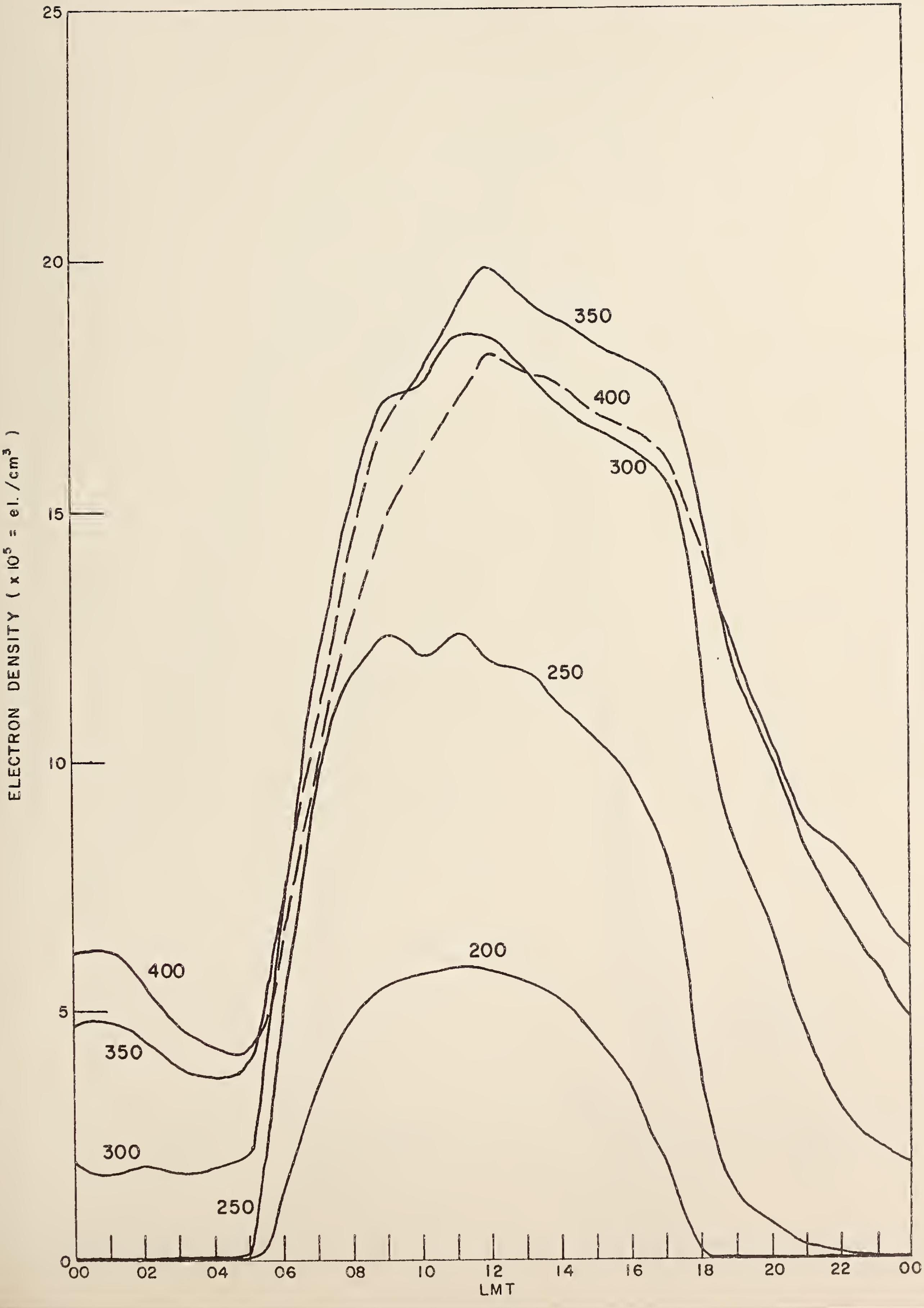


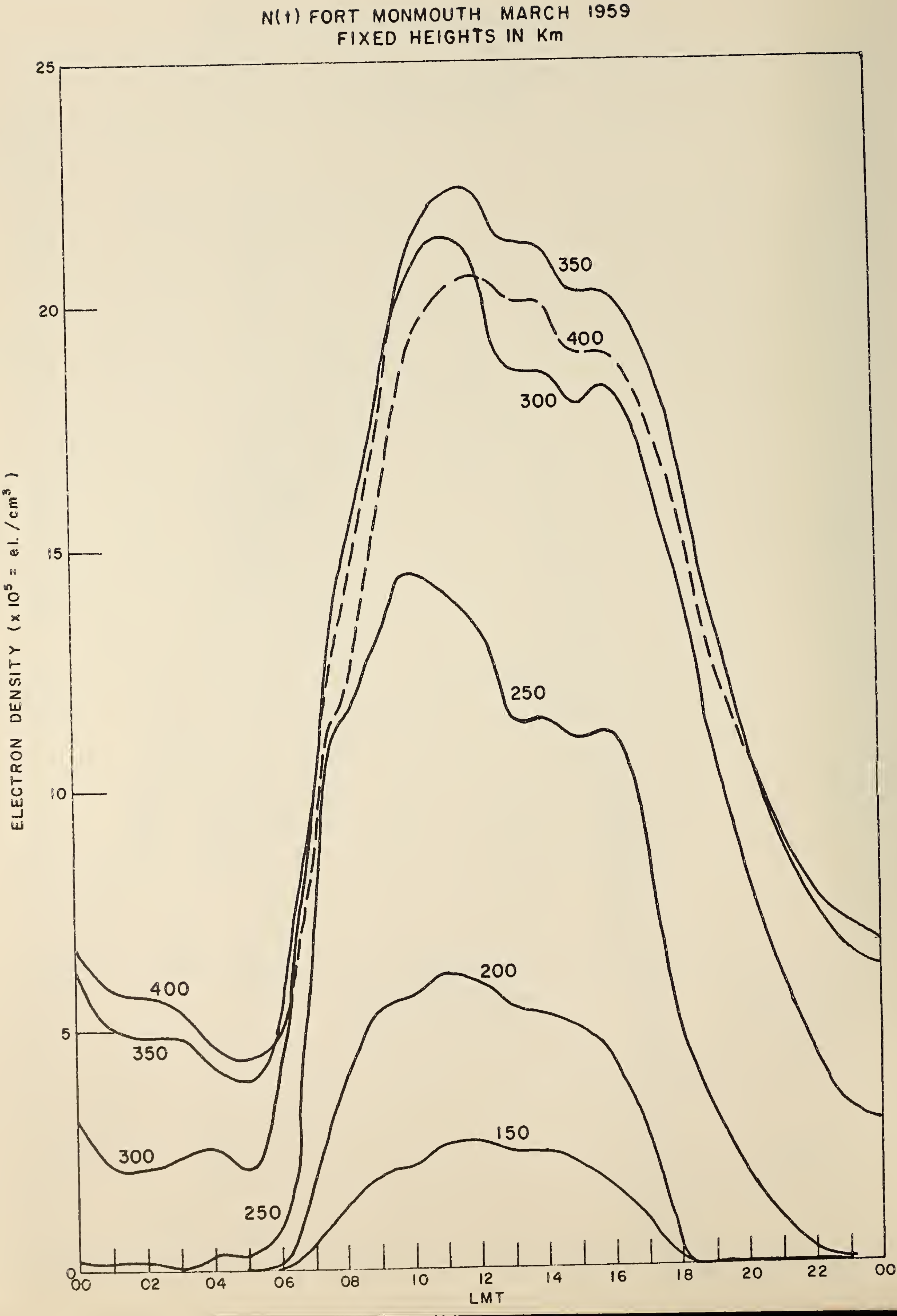
CONTOURS = $\frac{el}{cm^2}$ col. X 10^{-12}

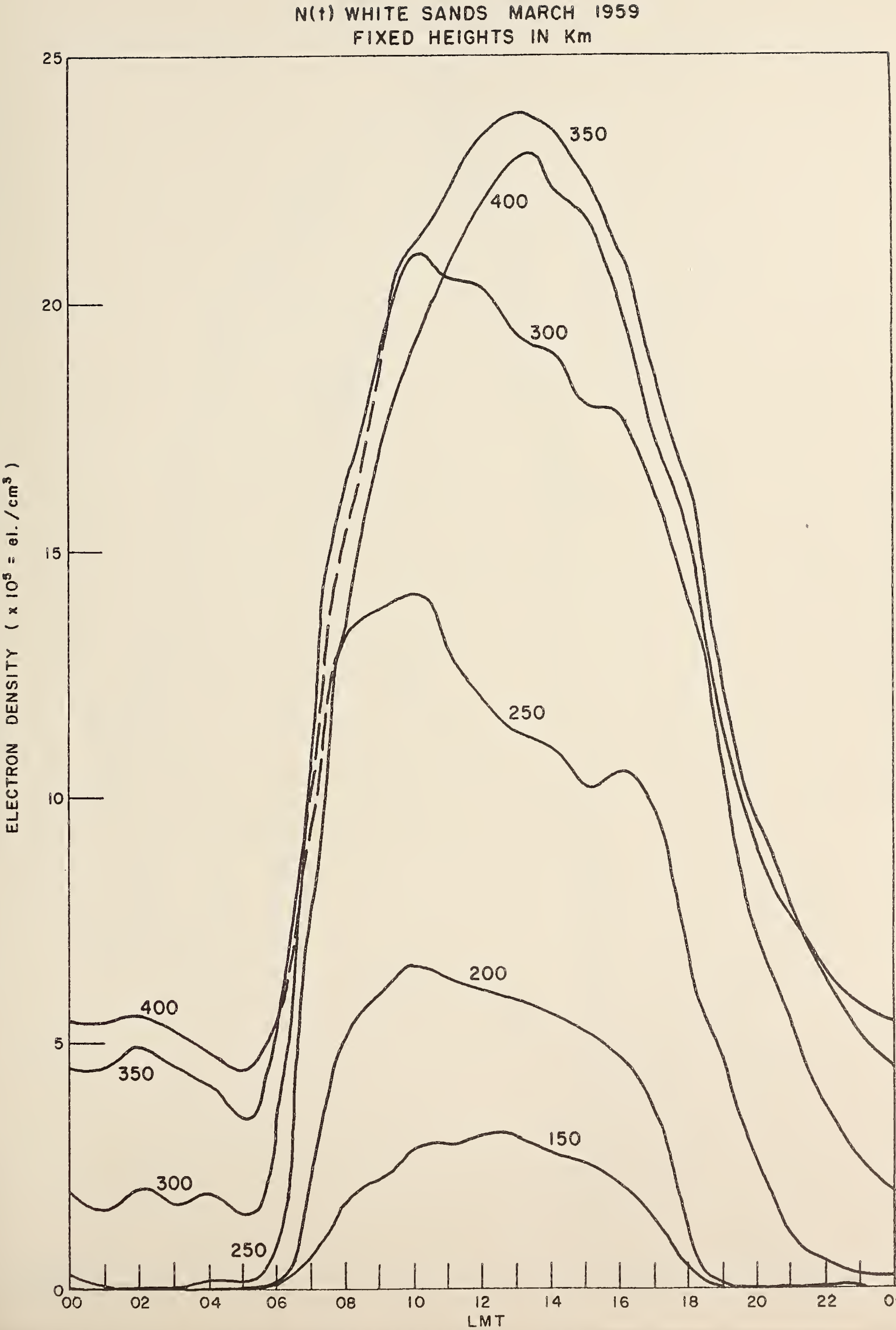
ELECTRON DENSITY INTEGRATED TO INFINITY
MARCH 1959



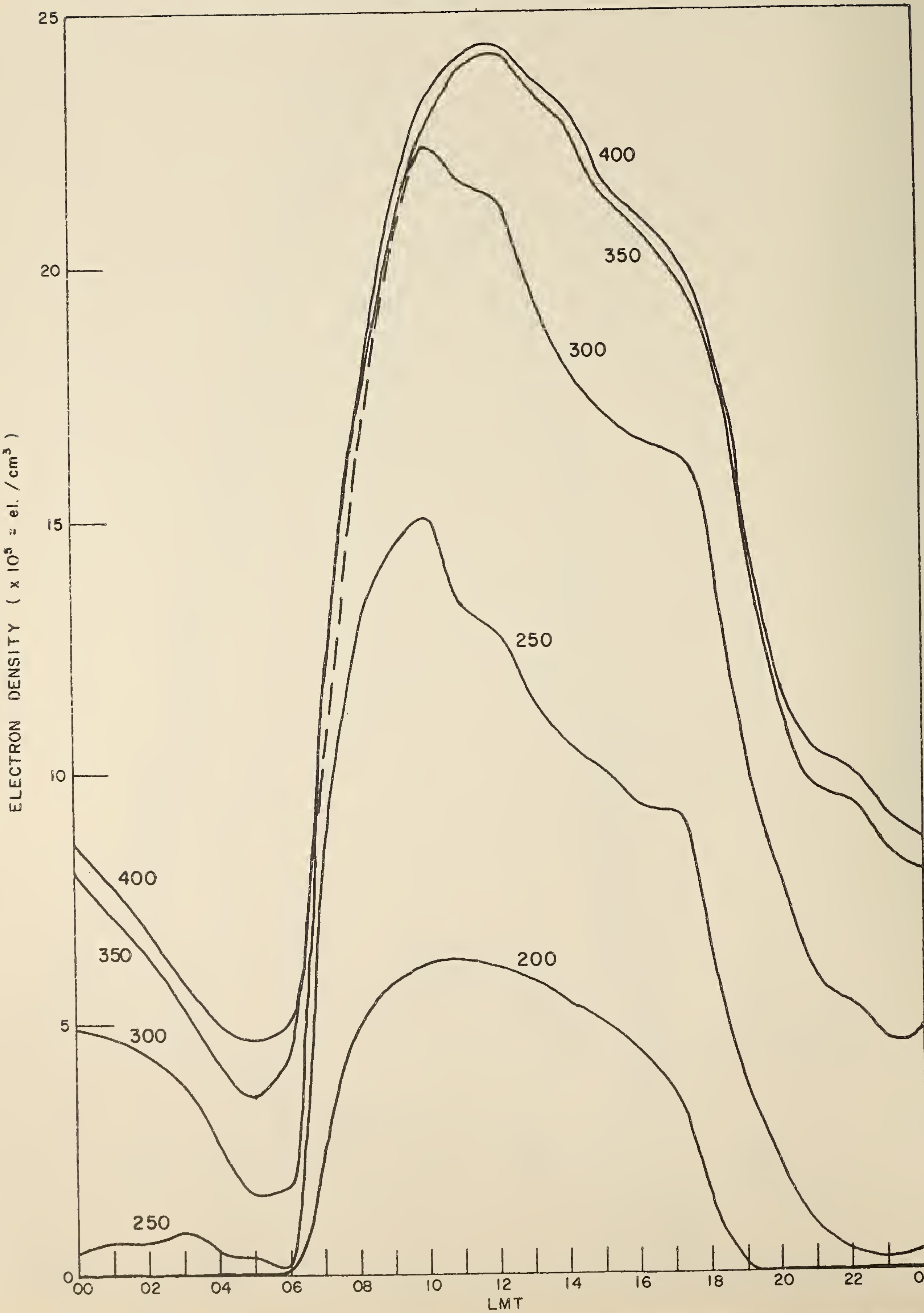
N(t) ST. JOHNS, NEWFOUNDLAND MARCH 1959
FIXED HEIGHTS IN Km

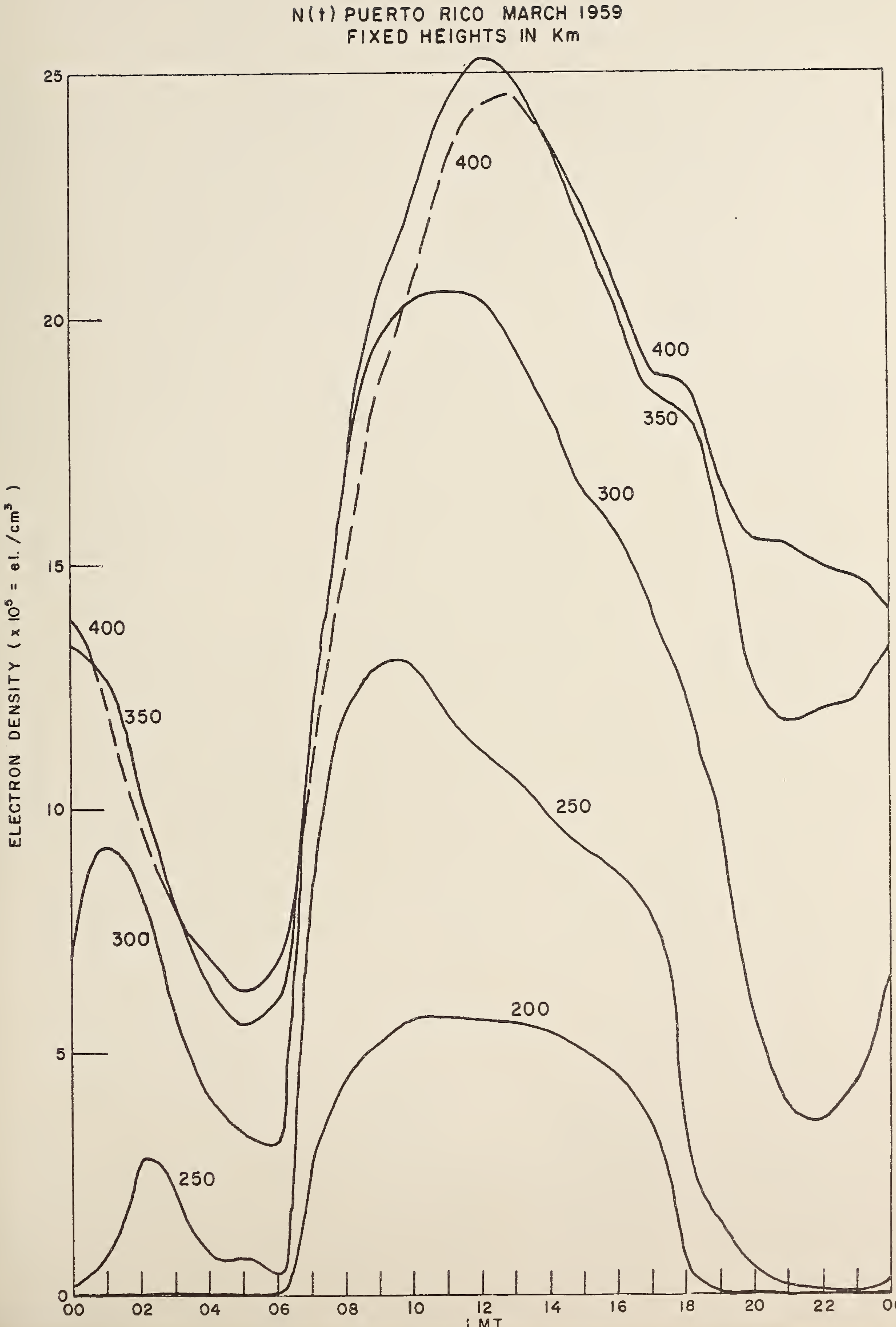



N(t) FORT MONMOUTH MARCH 1959
FIXED HEIGHTS IN Km
ELECTRON DENSITY (x 10^5 = el./cm^3)
LMT
350
400
300
250
200
150
400
350
300
250
25
20
15
10
5
0
00
02
04
06
08
10
12
14
16
18
20
22
00


N(t) WHITE SANDS MARCH 1959
FIXED HEIGHTS IN Km
ELECTRON DENSITY (x 10⁵ = el./cm³)
LMT
0
5
10
15
20
25
00
02
04
06
08
10
12
14
16
18
20
22
00
150
200
250
300
350
400

N(t) GBI MARCH 1959
FIXED HEIGHTS IN Km




N(t) PUERTO RICO MARCH 1959
FIXED HEIGHTS IN Km
ELECTRON DENSITY (x 10^5 = el. /cm^3)
25
20
15
10
5
0
400
400
350
300
250
200
400
350
300
250
00
02
04
06
08
10
12
14
16
18
20
22
00
LMT

U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, *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 and Electronics. Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Photographic Technology. Length. Engineering Metrology.

Heat. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Molecular Kinetics. Free Radicals Research.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Radiation Theory. Radioactivity. X-rays. High Energy Radiation. Nucleonic Instrumentation. Radiological Equipment.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. 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.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer. Concreting Materials.

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

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.

- Office of Basic Instrumentation.
- Office of Weights and Measures.

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research. Radio Warning Services. Airglow and Aurora. Radio Astronomy and Arctic Propagation.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Research. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation Obstacles Engineering. Radio-Meteorology. Lower Atmosphere Physics.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Electronic Calibration Center. Microwave Physics. Microwave Circuit Standards.

Radio Communication and Systems. Low Frequency and Very Low Frequency Research. High Frequency and Very High Frequency Research. Ultra High Frequency and Super High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Systems Analysis. Field Operations.

NBS