NBS

Technical Note No. 40-12

MEAN ELECTRON DENSITY VARIATIONS OF THE QUIET IONOSPHERE NO. 12 FEBRUARY 1960

J. W. WRIGHT, L. R. WESCOTT, AND D. J. BROWN

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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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 the month of February are illustrated graphically. This report is the twelfth 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.

MEAN ELECTRON DENSITY VARIATIONS OF THE QUIET IONOSPHERE No. 12 - February 1960

J. W. Wright, L. R. Wescott and D. J. Brown
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 hmax F2) 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 those of the U. S.

Army Signal Radio Propagation Agency, and through cooperation with closely associated stations in other countries, 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 (Def. Res. Tel. Establ. Canada, June 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)
Huancayo, Peru (January 1960)
Talara, Peru (January 1960)
Baguio, Philippines (February 1960)

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.

These reports contain N(h) 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

	Geomag. Coordinates			Geog. Coordinates	
	fH	Lat.	Dip		
St. Johns, Newf.	1.38 Mc/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 her e, but it should be pointed 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 February data is given on Page 11. The table on the following page identifies the quantities appearing on the tabulation.

Quantity	Units	Remarks
Average Electron Density (N)	$\times 10^3$ = electron/cm^3 (10^{-5} on maps)	Body of table; given at each 10 km of height from the lowest hmin to 950 km.
NMAX	$\times 10^3$ = electron/cm^3 (10^{-5} on maps)	The mean value of Nmax.
COUNT		Count of the number of profiles entering 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.
SCAT	Kilometers	One half of the half-thickness of the parabola best fitting the upper portion of the F-region profile. Approximates the scale height near the true HMAX.
SHMAX	$\times 10^{10}$ = electrons/ cm^2 column (10^{-12} on maps)	Obtained by averaging the integration of the individual profiles between the limits HMIN and HMAX.
SHINF	$\times 10^{-10}$ = electrons/ cm^2 column (10^{-13} on maps)	The average total number of electrons in a column to infinity obtained by extrapolation of observed profiles into the region above HMAX. (See text.)

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

A. Averaging process. Each hour 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 disturbed 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 hmax F2 is obtained, the virtual height at Nmax being immeasurable. A useful procedure is to fit the portion near hmax F2 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, 1960). 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 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. Included here are three such graphical forms 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 February 1960. Contours are parametric in "plasma" frequency (f_N) related to electron density N by

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

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 anomalies 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, 250, 300, 350, 400 km), contours of electron density are drawn in the latitude vs. local time plane. To the extent to which longitude anomalies 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; its characteristic thickness, Scat; 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 hmax F2 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 requires 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; 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.

Acknowledgments

We are indebted to Mr. A. H. Shapley for guidance in the initiation of this work, and to Dr. H. H. Howe for the development of the computer programs upon which the whole system heavily depends. This series of reports results from the combined efforts of the NBS Electron Density Profile Group, including at various times L. R. Wescott, L. Hayden, D. J. Brown, F. J. Burmont, I. Ford, N. Moore, M. Durham, G. Lira, under the direct supervision of G. H. Stonehocker. The cooperation of the U. S. Army Signal Radio Propagation Agency is gratefully acknowledged.

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AVERAGE ELECTRON DENSITY KP BELOW 4.5

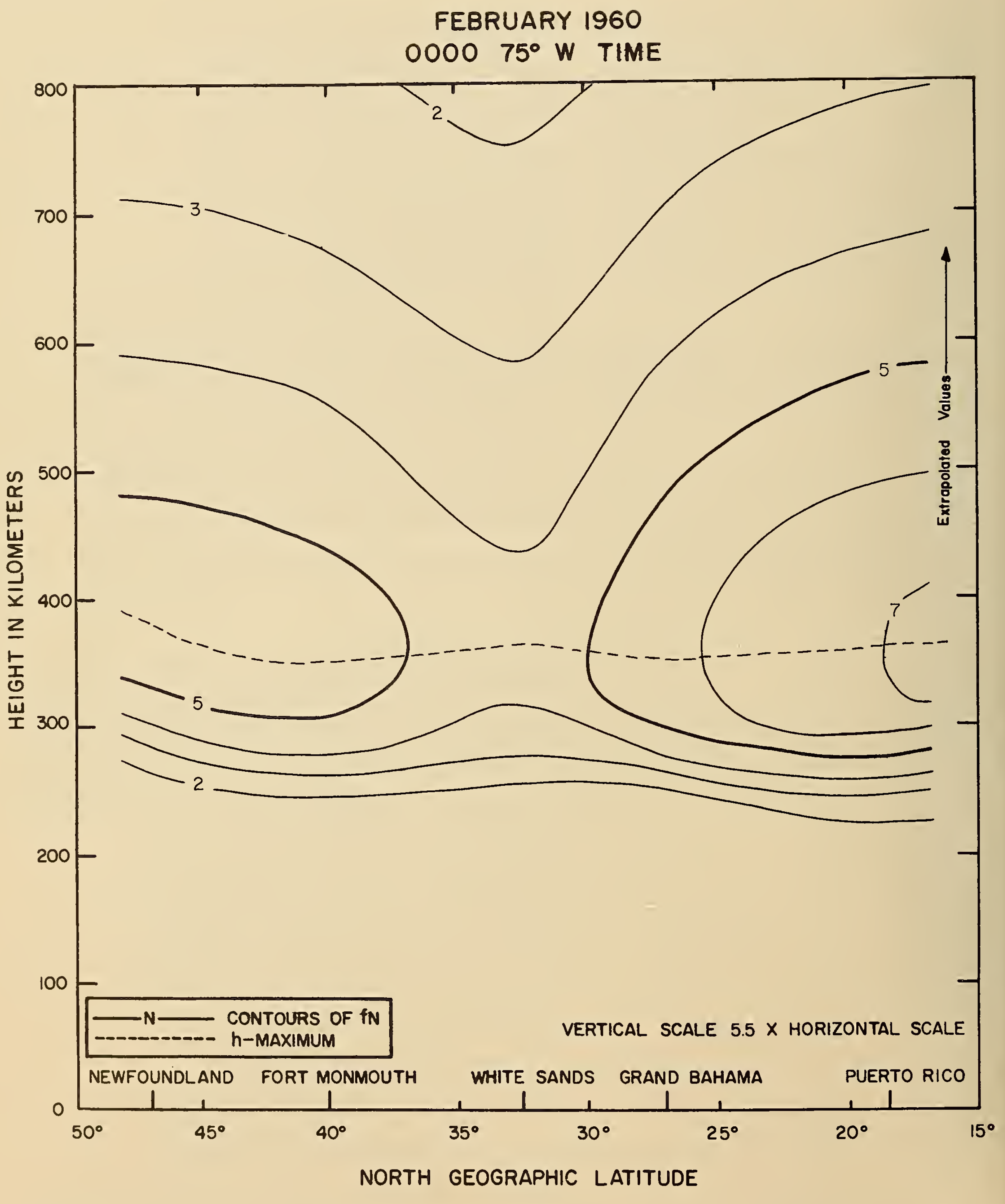
PUERTO RICO 60 W FEB 1960

TIME	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100
COUNT	25	24	26	26	26	25	24	25	26	27	25	26
HMIN	235	228	226	213	201	216	213	219	110	110	109	109
RATIO	5.5	5.8	6.1	7.0	5.6	4.3	4.2	5.9	5.1	4.7	4.5	4.4
SCAT	46.6	43.9	43.5	38.0	55.4	66.0	63.7	45.5	44.4	47.7	49.9	51.9
NMAX	636	592	574	491	308	261	240	470	1110	1610	1979	2099
HMAXF	344	327	320	296	312	357	352	312	277	286	297	299
SHMAX	401	350	324	248	210	231	207	279	776	1236	1608	1777
SHINF	2195	2020	1942	1633	1078	968	884	1605	3908	5778	7190	7697
KM												
950	50.0	43.4	40.5	31.5	21.0	22.3	19.6	32.3	64.1	97.2	125	134
900	64.1	55.7	51.9	40.5	26.9	28.6	25.1	41.4	82.2	125	160	172
850	82.2	71.4	66.6	51.9	34.5	36.7	32.2	53.0	105	160	205	220
800	105	91.5	85.3	66.5	44.3	47.0	41.2	68.0	135	205	263	283
750	135	117	109	85.2	56.7	60.1	52.7	87.1	173	263	337	362
700	172	150	140	109	72.4	76.6	67.3	111	222	336	431	463
650	219	191	178	139	92.2	97.2	85.6	142	283	429	550	591
600	276	242	226	176	117	122	108	180	361	546	700	752
550	346	303	284	222	147	152	135	227	457	691	884	950
500	425	376	352	277	182	186	166	282	574	867	1106	1187
490	442	391	367	289	190	193	172	294	600	905	1155	1239
480	459	407	382	302	197	199	179	306	627	945	1205	1292
470	476	423	397	314	205	206	185	319	654	986	1256	1347
460	492	439	413	327	213	213	191	331	683	1027	1308	1402
450	509	454	428	339	221	219	198	344	711	1070	1361	1459
440	525	470	443	352	229	225	204	356	741	1113	1415	1515
430	541	486	458	365	237	231	210	369	770	1156	1468	1572
420	556	501	473	378	244	236	215	381	800	1200	1522	1629
410	570	515	488	390	252	241	220	393	830	1244	1576	1686
400	583	529	502	403	259	245	225	405	861	1287	1629	1741
390	594	542	515	414	266	248	229	416	890	1329	1680	1796
380	602	554	527	426	272	250	232	426	920	1371	1730	1848
370	608	564	537	436	278	250	235	436	948	1411	1777	1897
360	610	572	546	445	283	249	236	444	976	1449	1822	1943
350	608	577	553	453	287	247	236	452	1002	1484	1862	1984
340	601	580	558	458	290	242	234	457	1026	1516	1898	2020
330	587	577	559	461	292	235	230	459	1048	1545	1928	2050
320	564	567	555	461	292	227	223	458	1067	1568	1951	2073
310	532	547	543	458	291	215	213	454	1083	1586	1967	2086
300	490	514	522	449	287	200	200	442	1094	1597	1973	2086
290	437	468	488	436	280	185	183	422	1100	1597	1960	2063
280	374	406	438	416	269	168	164	391	1098	1577	1915	2008
270	301	327	372	389	254	148	142	348	1081	1532	1829	1913
260	226	249	290	350	234	128	120	291	1042	1458	1703	1782
250	151	174	203	297	207	106	97.5	231	977	1347	1538	1610
240	84.3	104	124	234	174	85.8	77.2	159	882	1196	1338	1409
230	42.2	55.0	65.2	162	136	64.3	57.6	96.3	760	1018	1122	1190
220	16.5	22.0	25.4	91.5	94.7	42.3	37.3	51.8	623	827	898	970
210	3.5	7.2	7.3	42.7	57.2	22.5	24.4	18.1	485	649	705	780
200	1.7	.8	.2	12.9	21.1	8.4	10.3	5.4	365	506	557	625
190				2.1	3.5	1.8	1.4	.6	271	397	449	504
180					.6				201	317	370	417
170									153	256	311	352
160									123	210	263	302
150									104	175	223	260
140									93.9	150	191	224
130									86.6	134	168	195
120									77.8	124	155	177
110									17.7	62.7	82.2	108

AVERAGE ELECTRON DENSITY KP BELOW 4.5

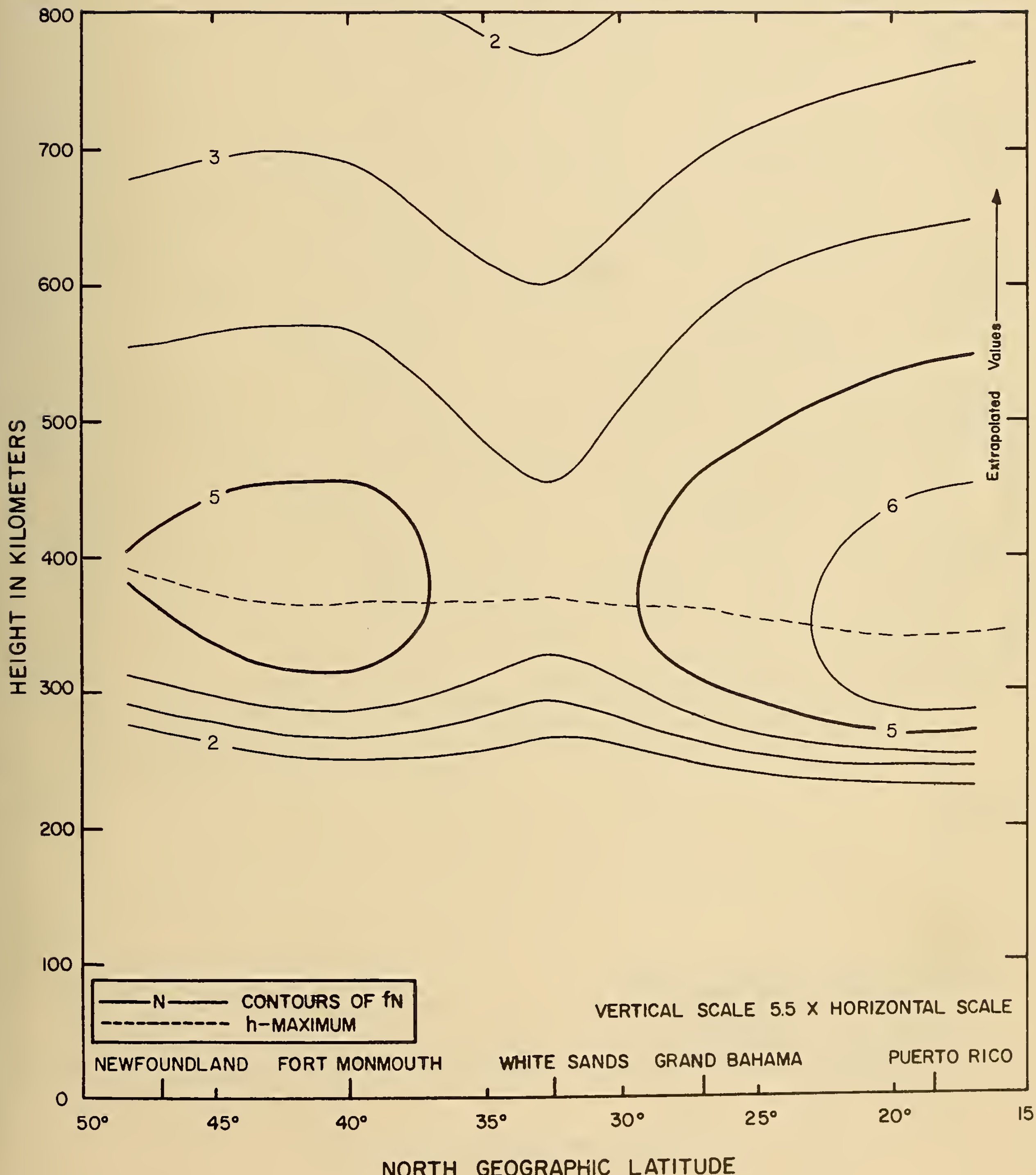
PUERTO RICO 60 W FEB 1960

TIME	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
COUNT	24	25	21	21	23	19	24	24	22	24	24	25
HMIN	109	109	109	109	109	110	211	201	196	210	224	222
RATIO	4.1	3.9	3.8	3.7	3.8	4.1	5.1	5.5	5.1	4.7	5.0	5.2
SCAT	55.3	58.6	60.8	63.6	62.2	58.0	52.7	52.4	50.6	55.2	50.9	49.4
NMAX	2066	2071	1988	1914	1903	1850	1857	1507	1069	856	792	704
HMAXF	309	320	325	331	333	324	325	323	323	346	351	339
SHMAX	1884	2017	2003	1986	1922	1676	1309	1080	759	666	565	478
SHINF	7711	7857	7611	7386	7291	6896	6547	5332	3774	3080	2800	2464
KM												
950	139	148	145	143	144	134	136	108	77.2	70.6	66.4	54.9
900	178	189	186	184	185	172	174	139	98.9	90.6	85.1	70.4
850	228	243	239	236	237	221	223	178	127	116	109	90.2
800	293	311	306	302	304	283	286	228	163	149	140	116
750	375	398	392	387	389	362	366	292	208	190	179	148
700	479	509	500	495	496	463	468	374	266	243	228	189
650	611	649	637	630	632	590	596	476	339	308	290	240
600	777	823	808	798	800	747	755	604	430	389	366	304
550	979	1035	1015	1001	1004	940	949	760	540	485	456	381
500	1221	1285	1258	1239	1241	1165	1176	943	669	594	559	470
450	1492	1560	1524	1497	1497	1413	1425	1144	810	705	664	564
440	1548	1616	1577	1548	1548	1463	1475	1185	838	726	684	583
430	1604	1671	1630	1599	1598	1512	1524	1225	866	746	702	601
420	1660	1726	1681	1647	1646	1561	1572	1265	893	765	720	618
410	1715	1778	1731	1694	1692	1607	1618	1303	920	782	736	634
400	1768	1829	1778	1738	1735	1652	1662	1339	945	797	750	649
390	1819	1876	1822	1779	1775	1693	1703	1374	968	810	762	663
380	1867	1920	1862	1816	1810	1731	1741	1405	989	819	771	675
370	1912	1959	1897	1847	1840	1765	1774	1433	1008	824	776	684
360	1952	1993	1927	1873	1864	1794	1802	1457	1024	825	774	691
350	1987	2021	1950	1892	1881	1816	1823	1477	1036	821	764	693
340	2017	2040	1964	1902	1887	1831	1836	1490	1042	808	746	691
330	2038	2049	1968	1900	1881	1837	1838	1496	1040	786	716	681
320	2051	2046	1957	1884	1857	1828	1825	1489	1029	755	673	660
310	2051	2025	1927	1845	1813	1801	1790	1466	1007	713	618	627
300	2031	1981	1874	1783	1744	1750	1728	1420	971	659	550	579
290	1985	1910	1796	1697	1653	1671	1631	1347	918	596	472	517
280	1905	1809	1692	1588	1537	1564	1500	1246	850	524	390	441
270	1793	1679	1562	1460	1406	1434	1334	1118	764	446	305	357
260	1647	1524	1413	1315	1260	1279	1134	962	666	365	220	268
250	1470	1346	1254	1159	1103	1103	887	781	558	283	152	182
240	1272	1161	1085	1001	944	920	601	576	441	204	99.4	108
230	1071	984	924	852	793	745	314	373	321	135	58.2	56.0
220	884	817	778	717	662	585	120	196	201	72.9	31.7	26.3
210	722	675	653	604	549	458	40.5	87.4	100	35.0	12.9	7.7
200	592	562	549	510	457	360	6.8	28.9	35.7	10.7	4.9	2.2
190	494	475	465	433	380	286	.5	4.0	4.0	2.0		1.0
180	421	408	397	369	318	228						
170	362	353	342	315	267	185						
160	314	308	295	269	225	152						
150	271	267	254	231	191	129						
140	233	229	219	198	165	113						
130	203	202	194	173	146	104						
120	187	186	180	160	136	97.1						
110	105	111	105	94.0	79.7	25.3						

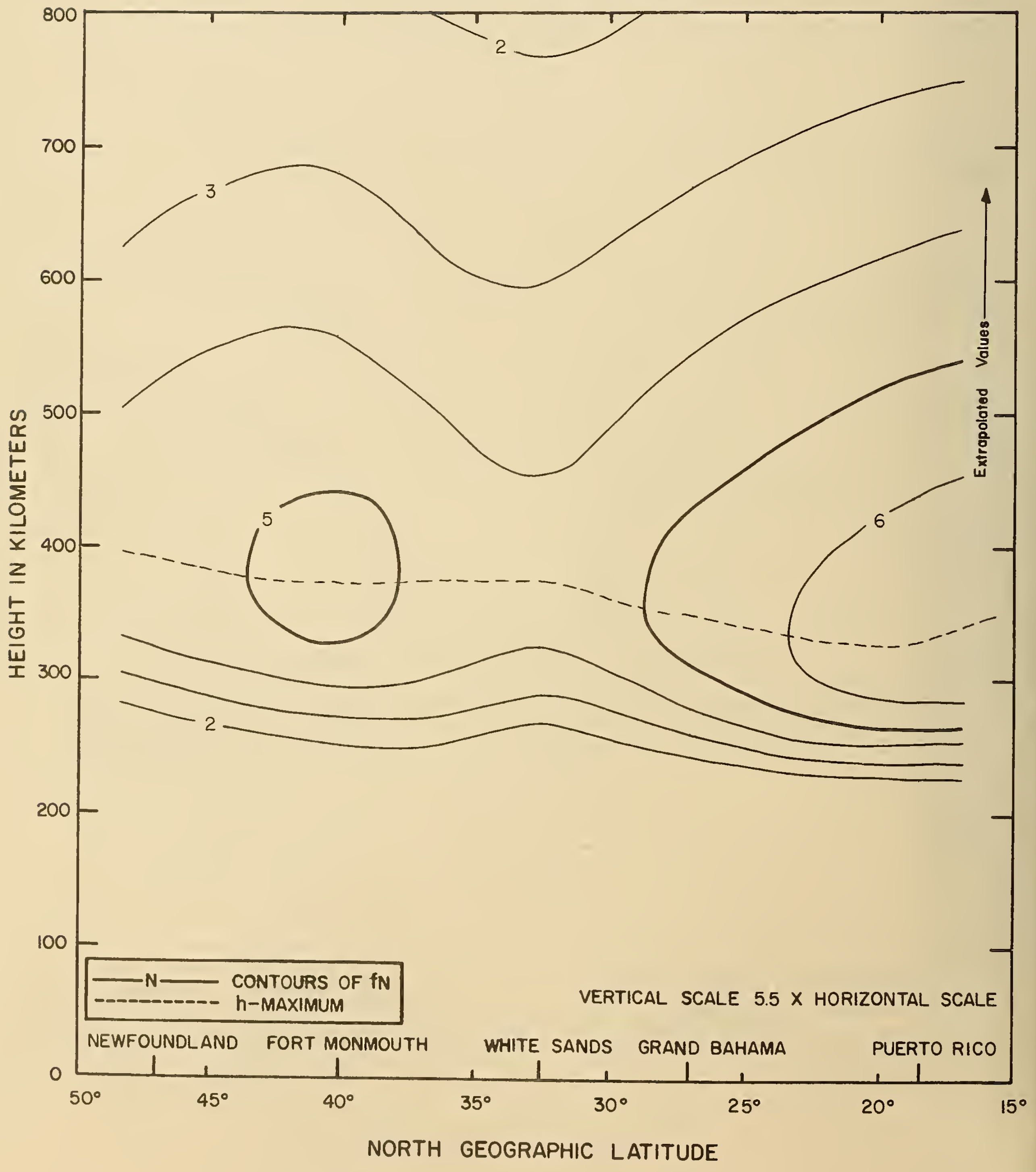


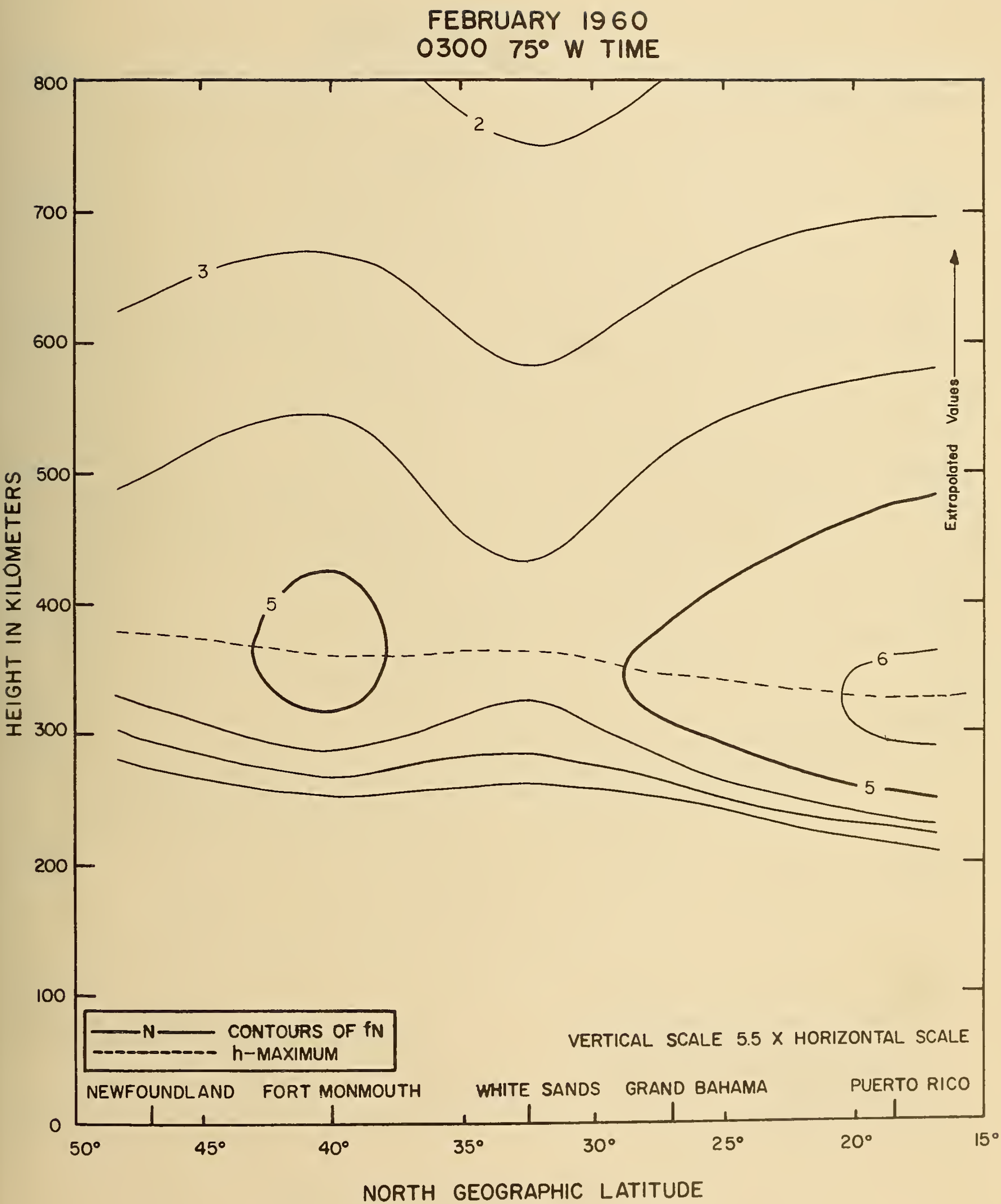
FEBRUARY 1960
0000 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
2
3
5
7
2
5
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

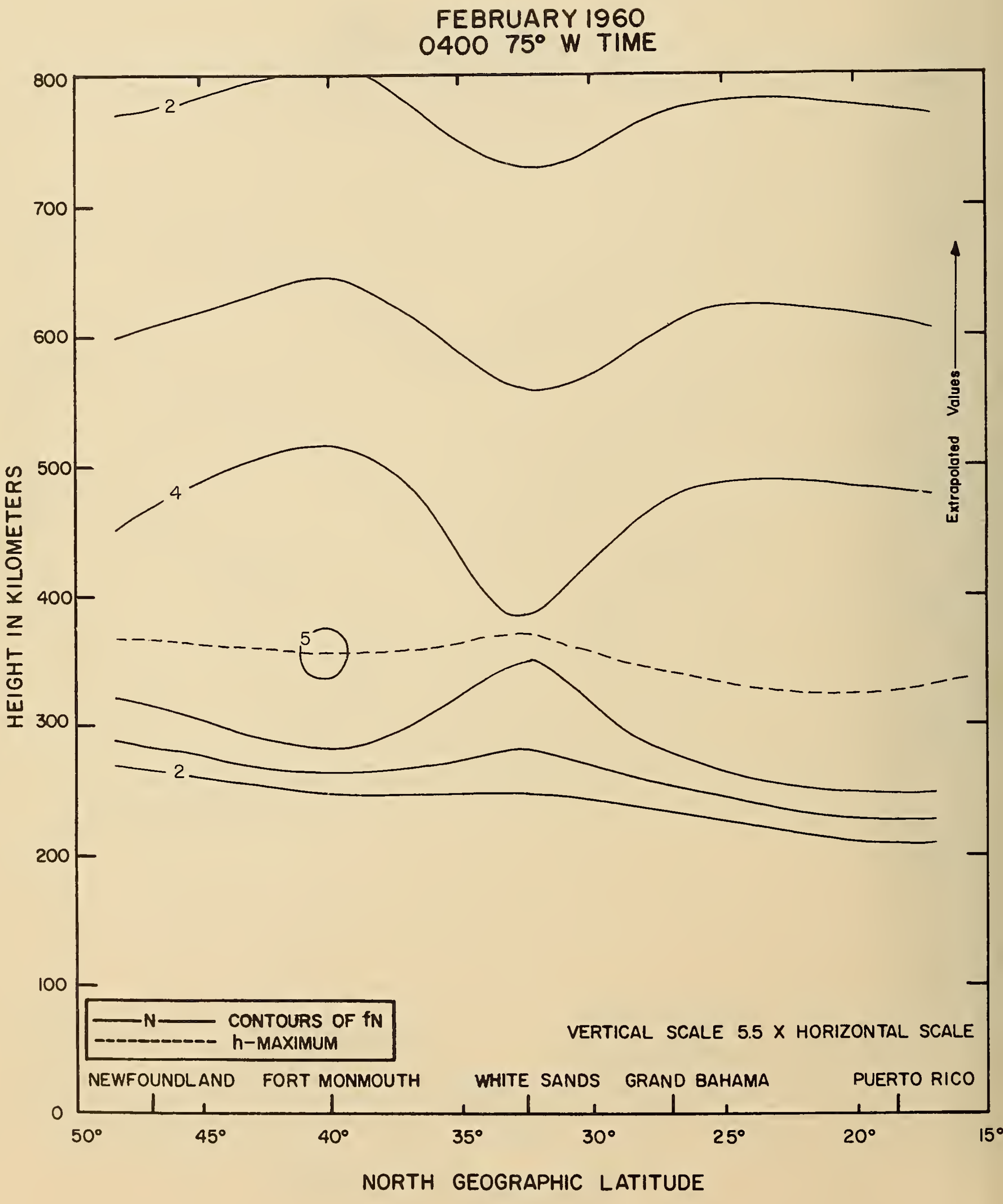
FEBRUARY 1960
0100 75° W TIME

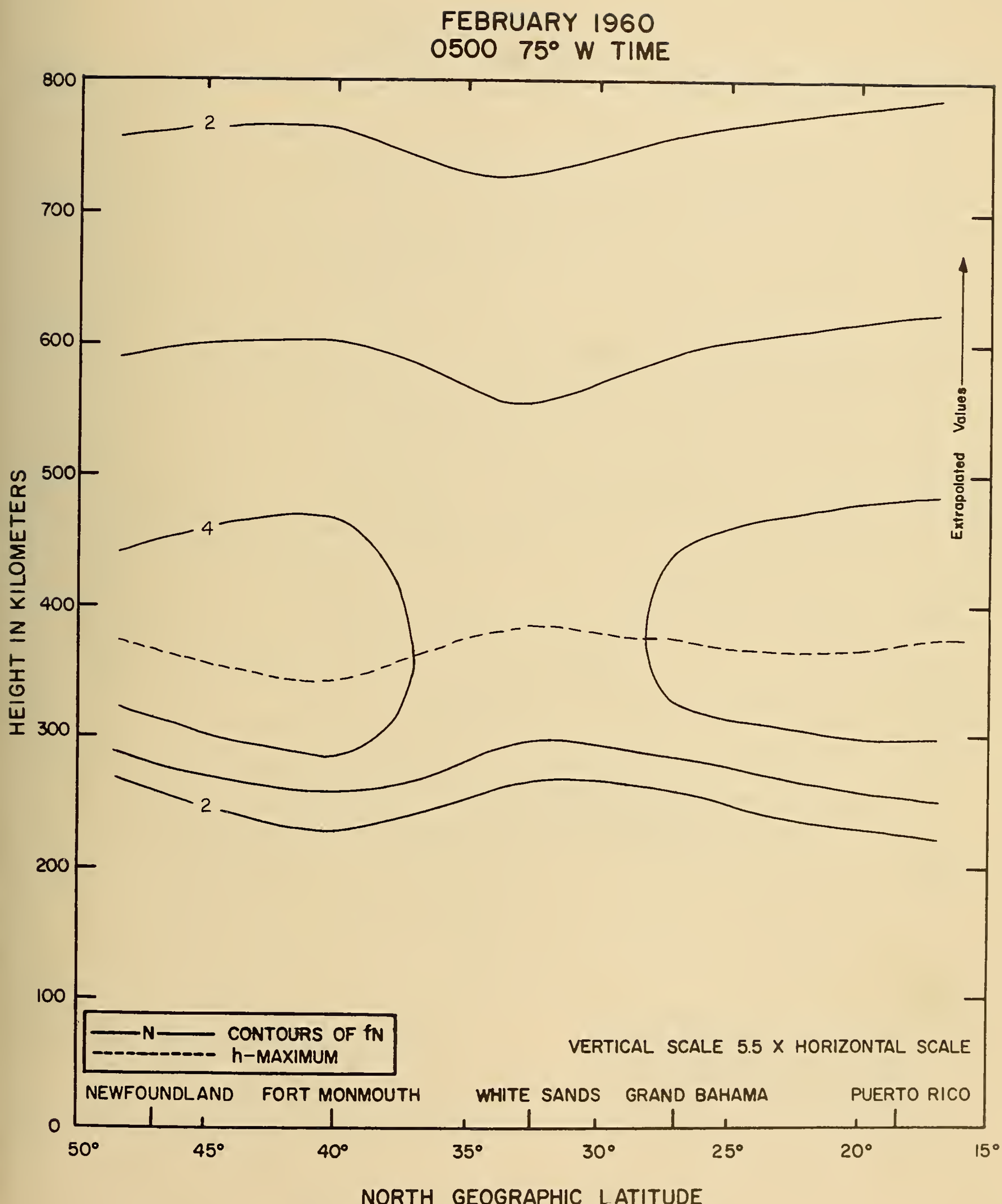


FEBRUARY 1960
0200 75° W TIME

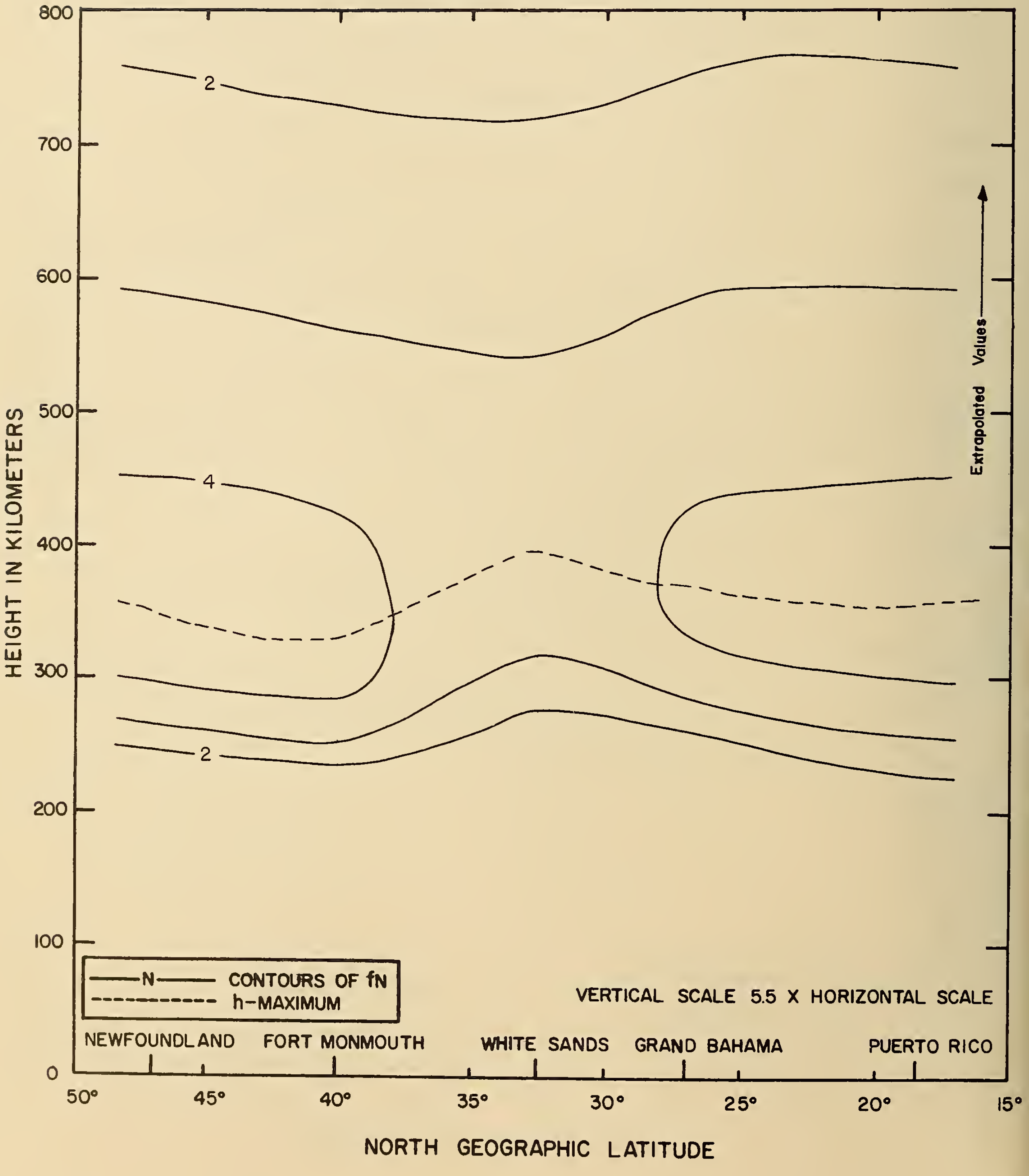


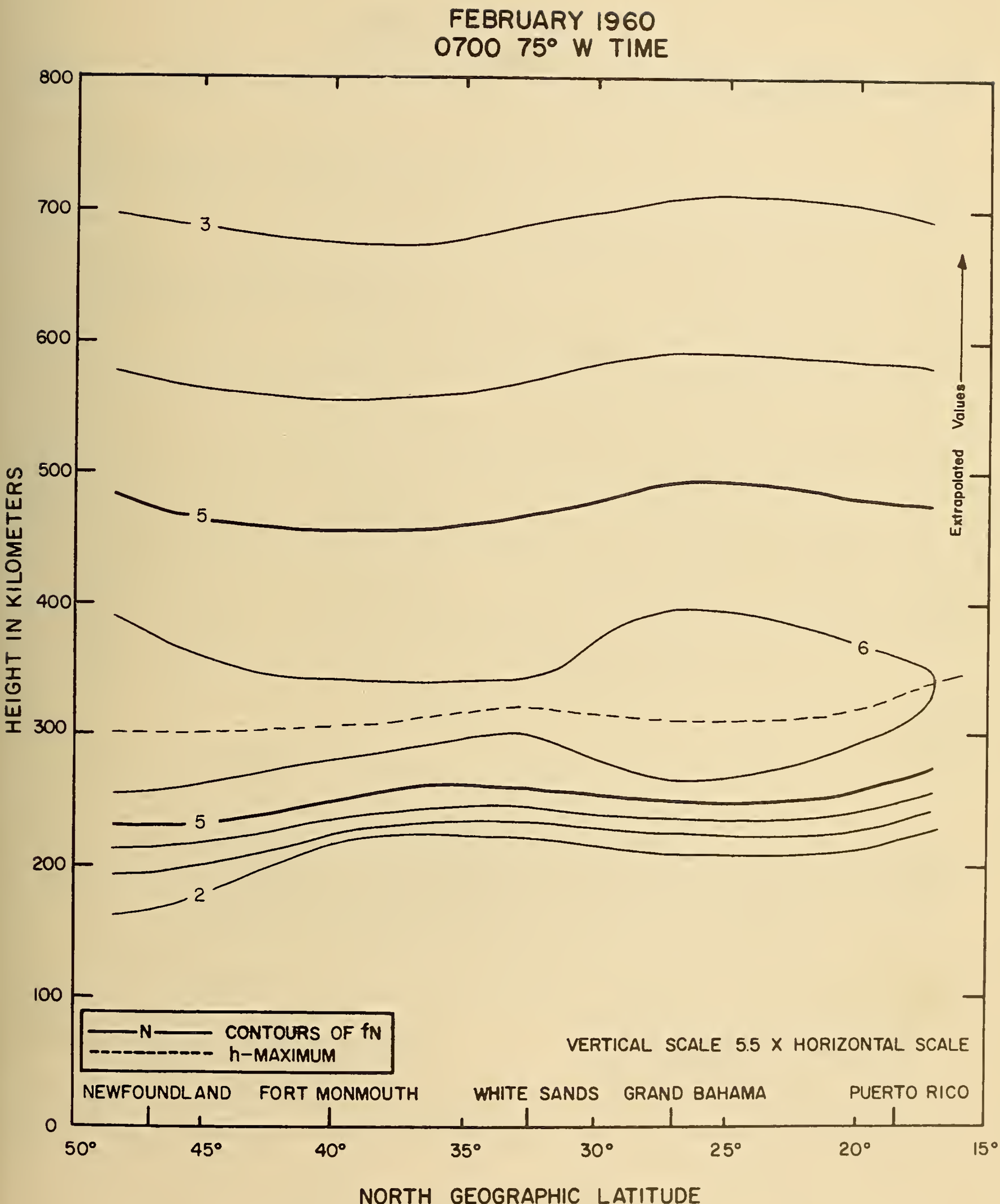

FEBRUARY 1960
0300 75° W TIME
800
700
600
500
400
300
200
100
0
HEIGHT IN KILOMETERS
2
3
5
6
5
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

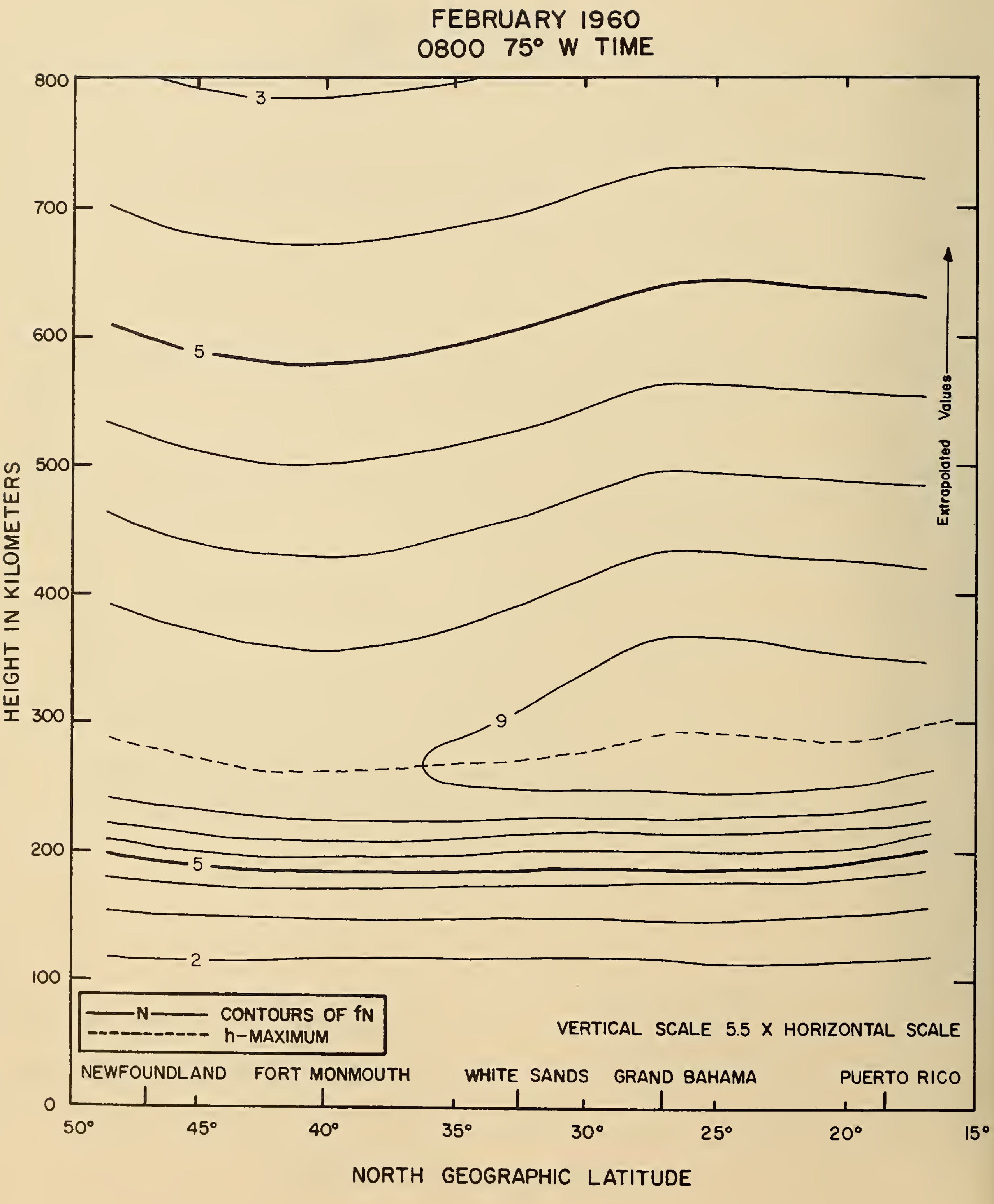

FEBRUARY 1960
0400 75° W TIME
800
700
600
500
400
300
200
100
0
HEIGHT IN KILOMETERS
2
4
5
2
Extrapolated Values
—N— CONTOURS OF fN
------ h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE


FEBRUARY 1960
0500 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
2
4
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

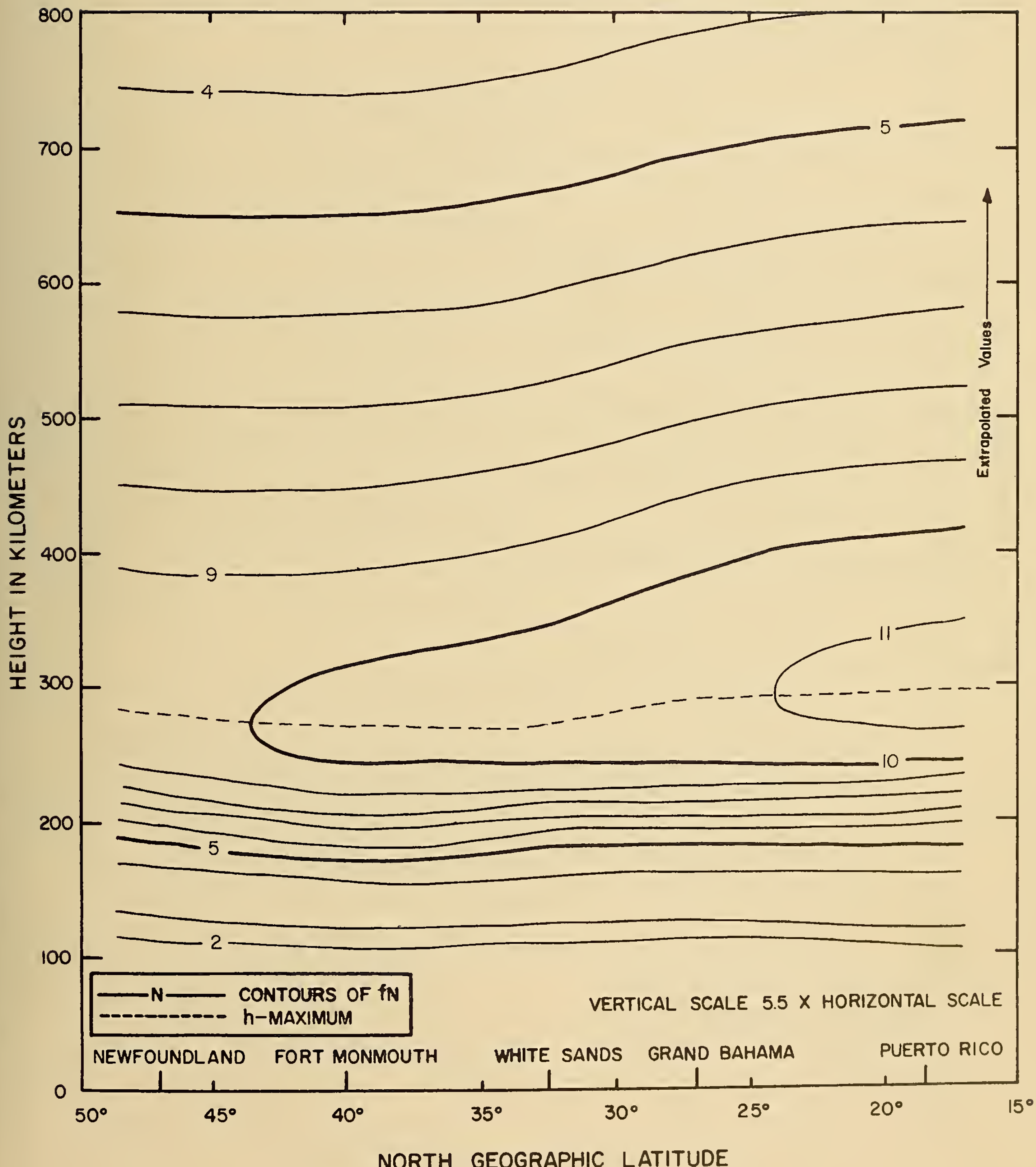
FEBRUARY 1960
0600 75° W TIME

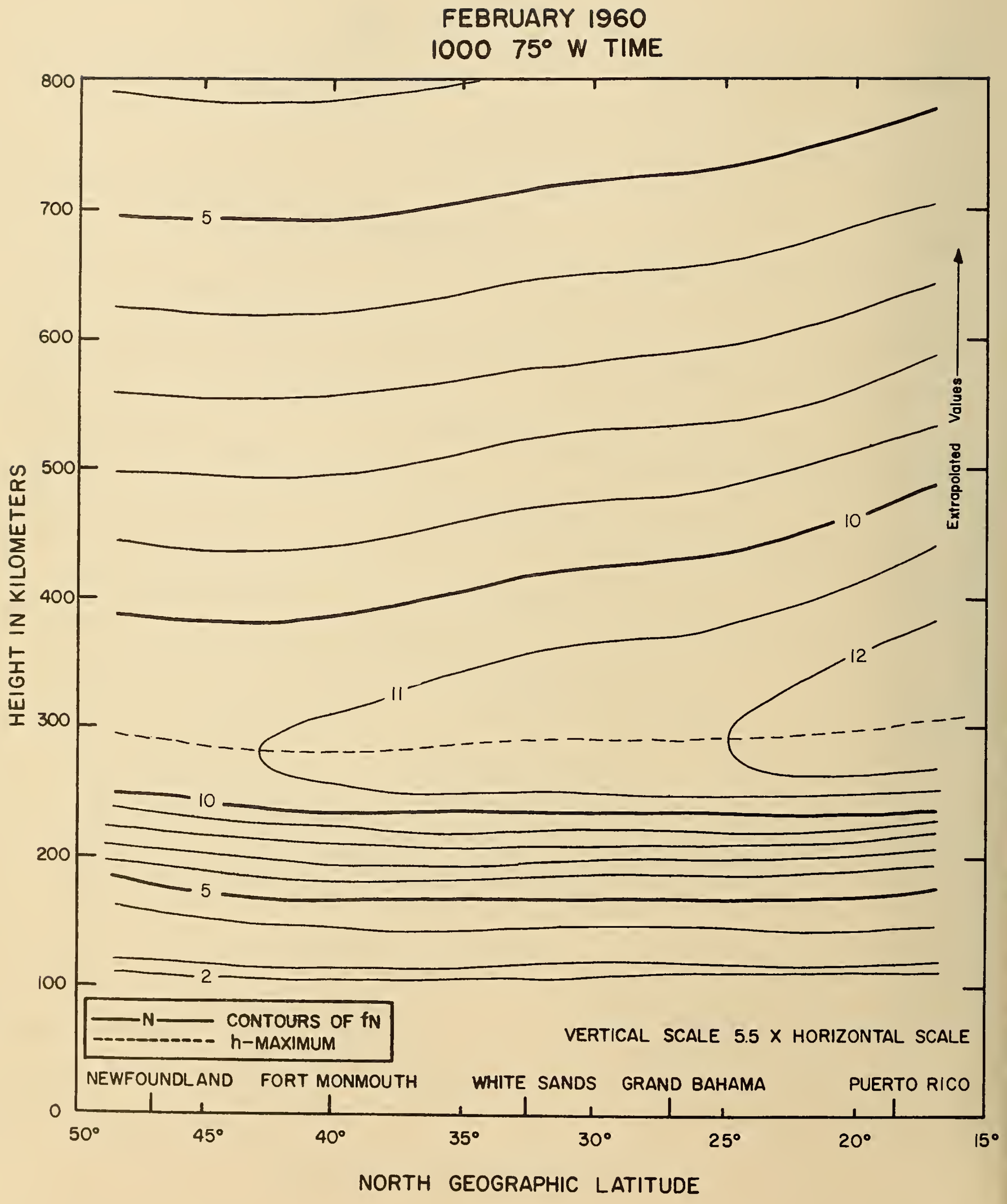


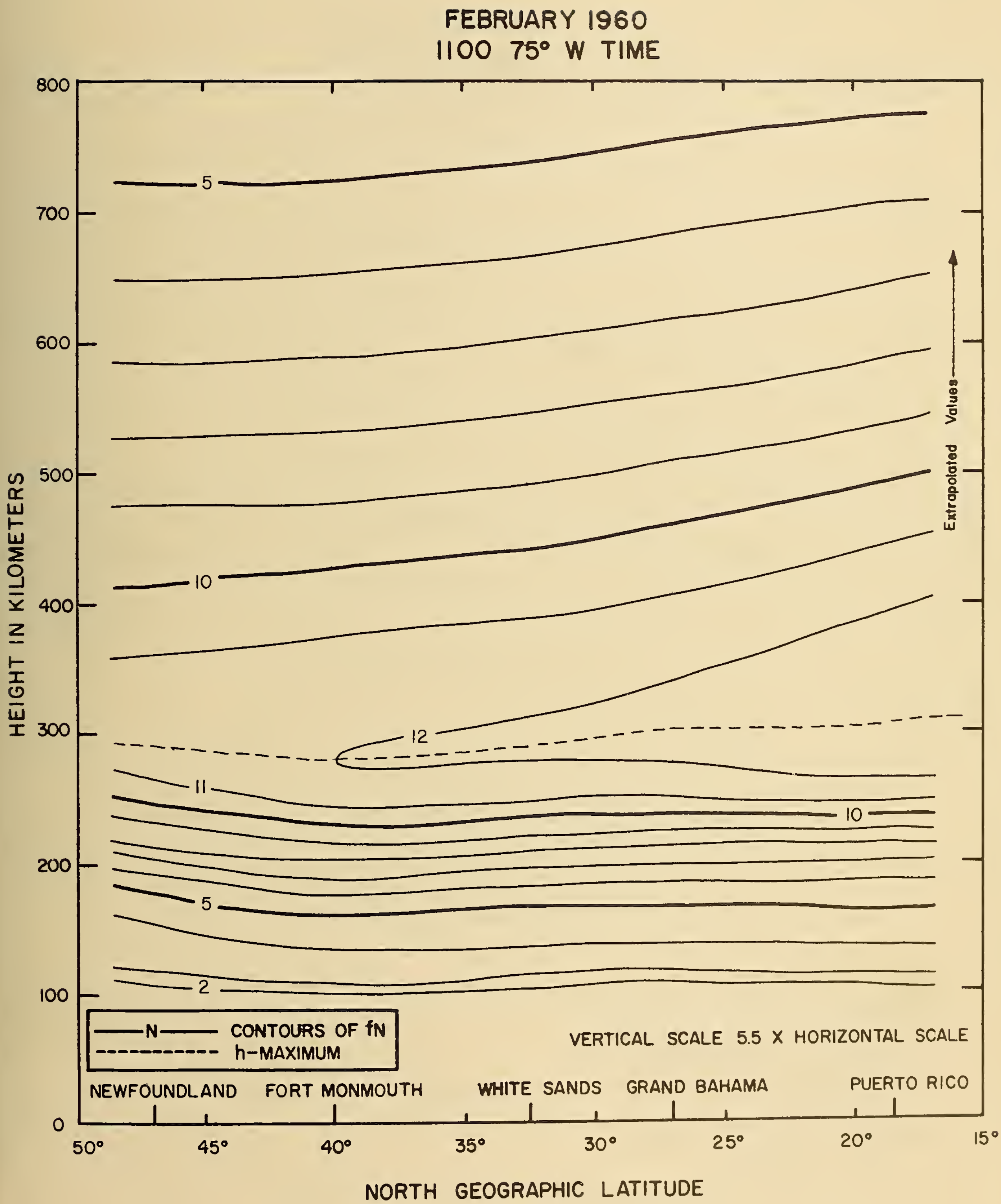

FEBRUARY 1960
0700 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
5
6
5
2
Extrapolated Values
CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

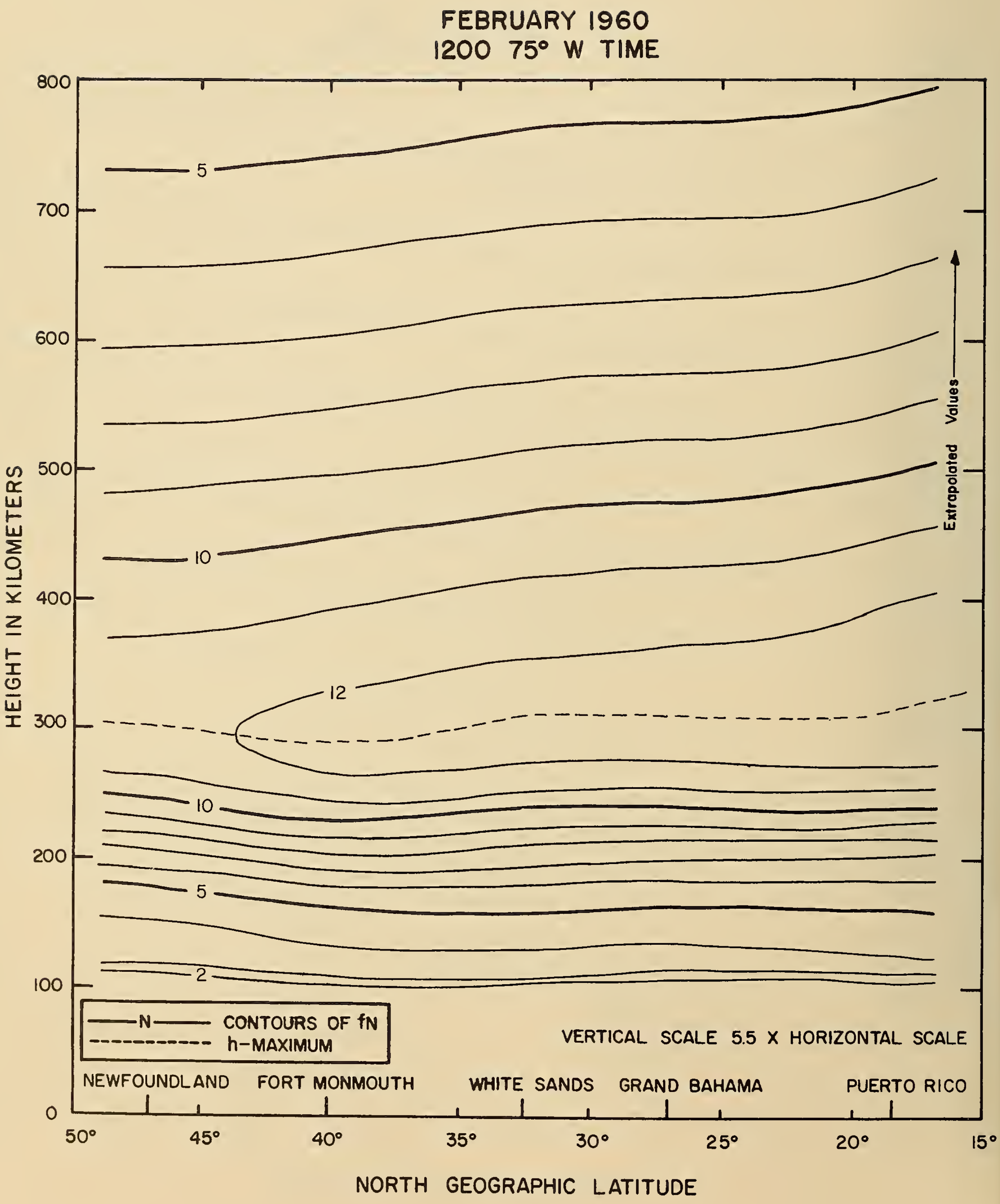

FEBRUARY 1960
0800 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
5
9
5
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

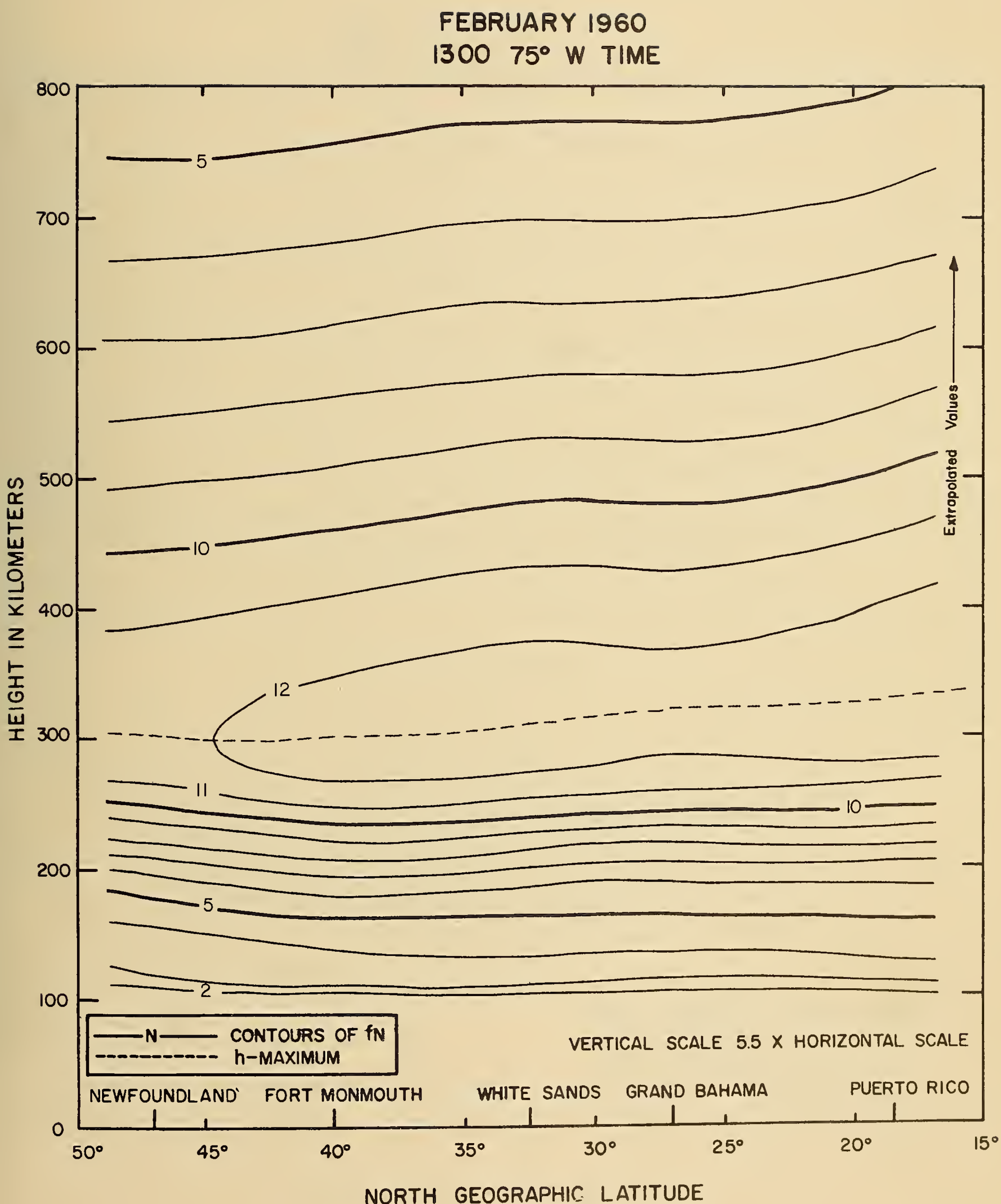
FEBRUARY 1960
0900 75° W TIME

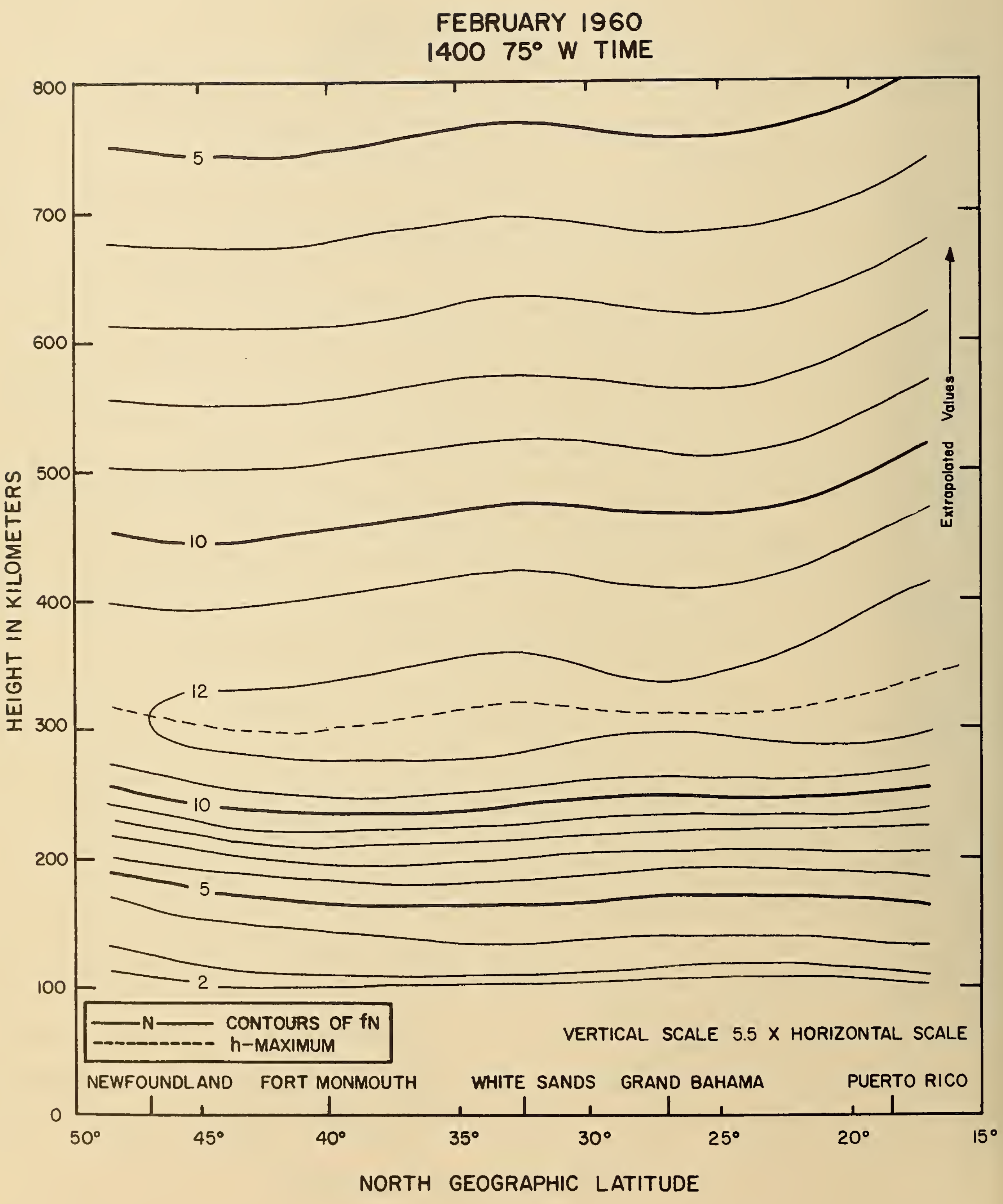



FEBRUARY 1960
1000 75° W TIME
800
700
600
500
400
300
200
100
0
HEIGHT IN KILOMETERS
5
10
11
12
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

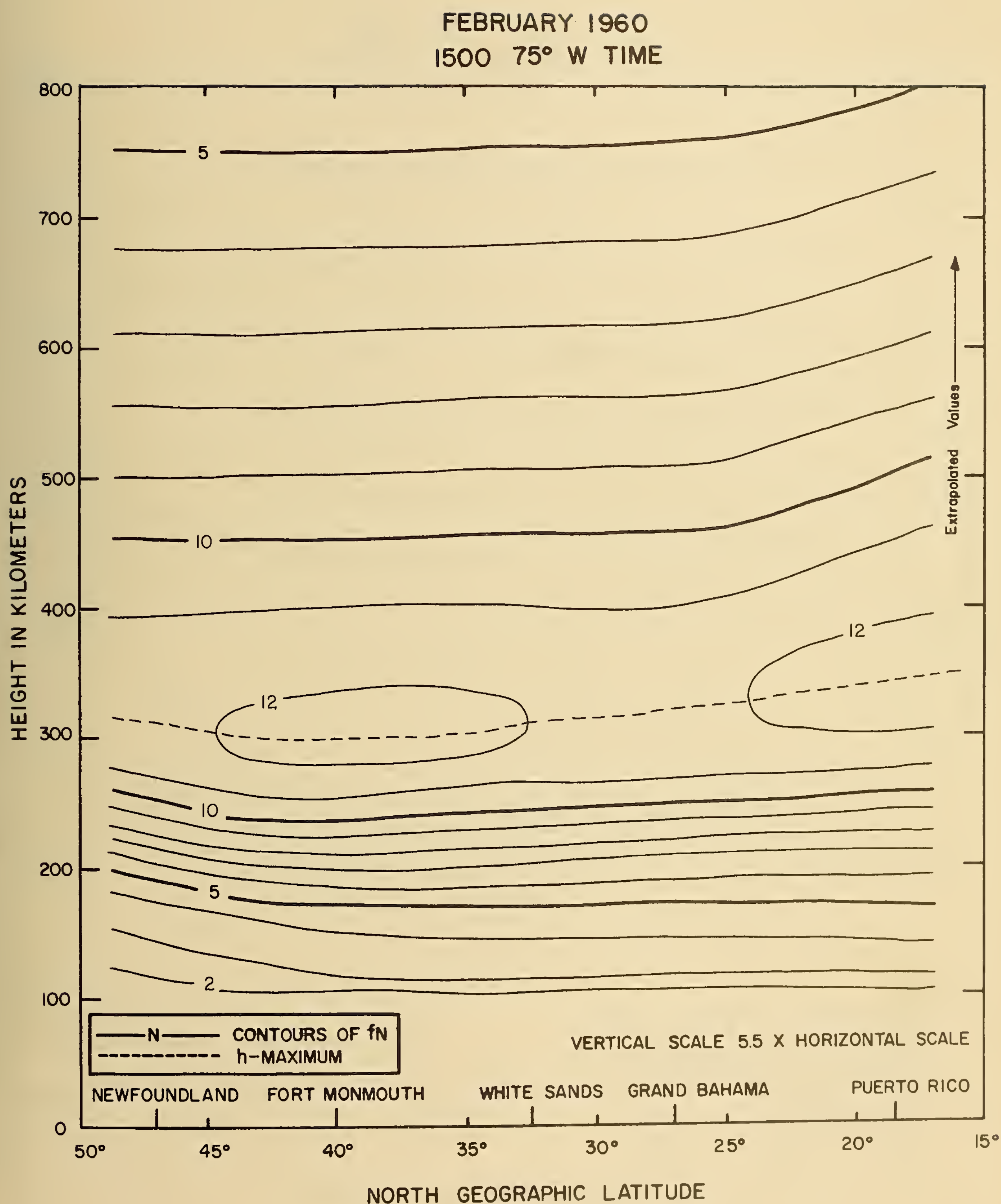

FEBRUARY 1960
1100 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
5
10
12
11
10
5
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

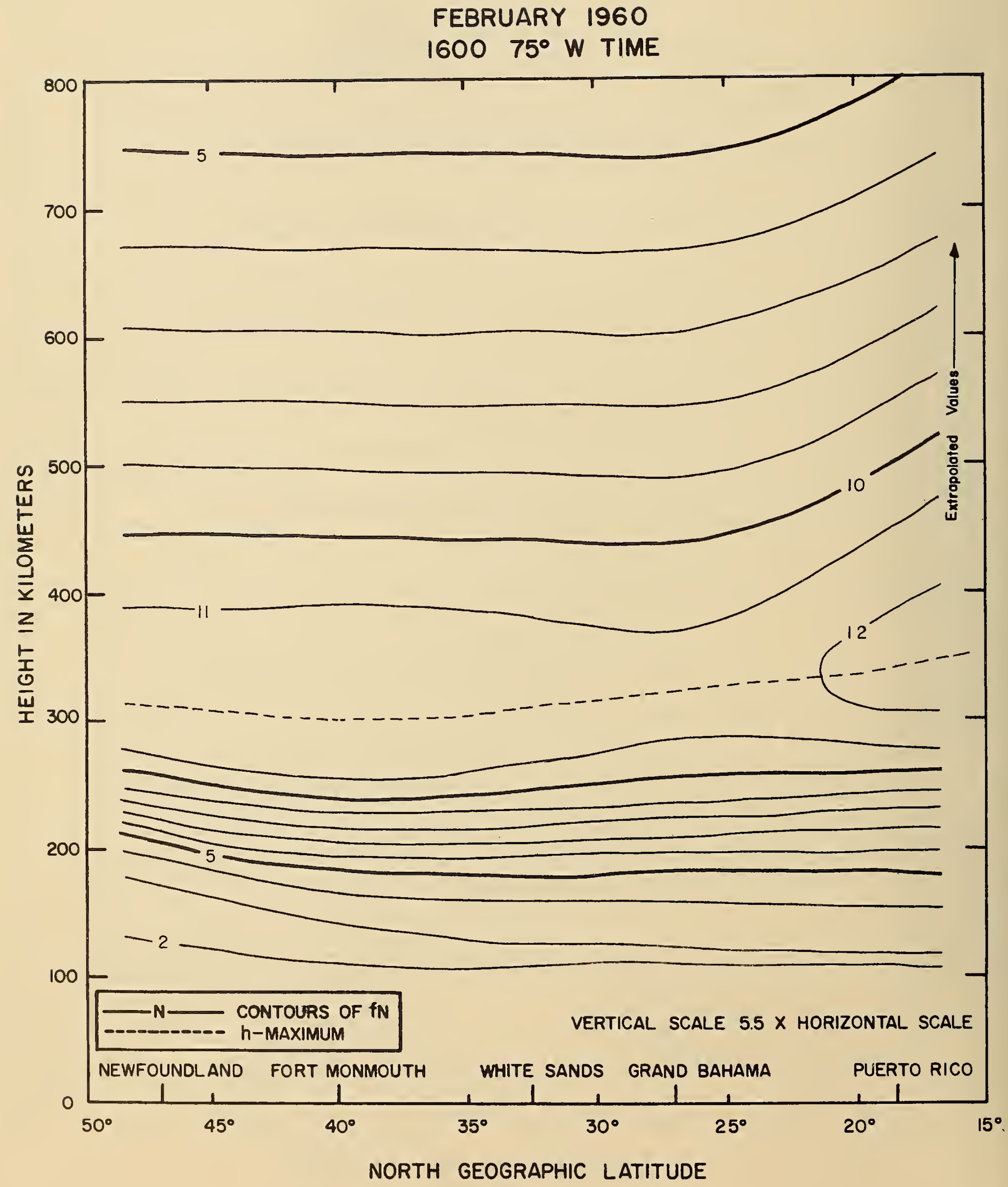

FEBRUARY 1960
1200 75° W TIME
800
700
600
500
400
300
200
100
0
HEIGHT IN KILOMETERS
5
10
12
10
5
2
Extrapolated Values
CONTOURS OF fN
h-MAXIMUM
N
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE


FEBRUARY 1960
1300 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
5
10
12
11
10
5
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

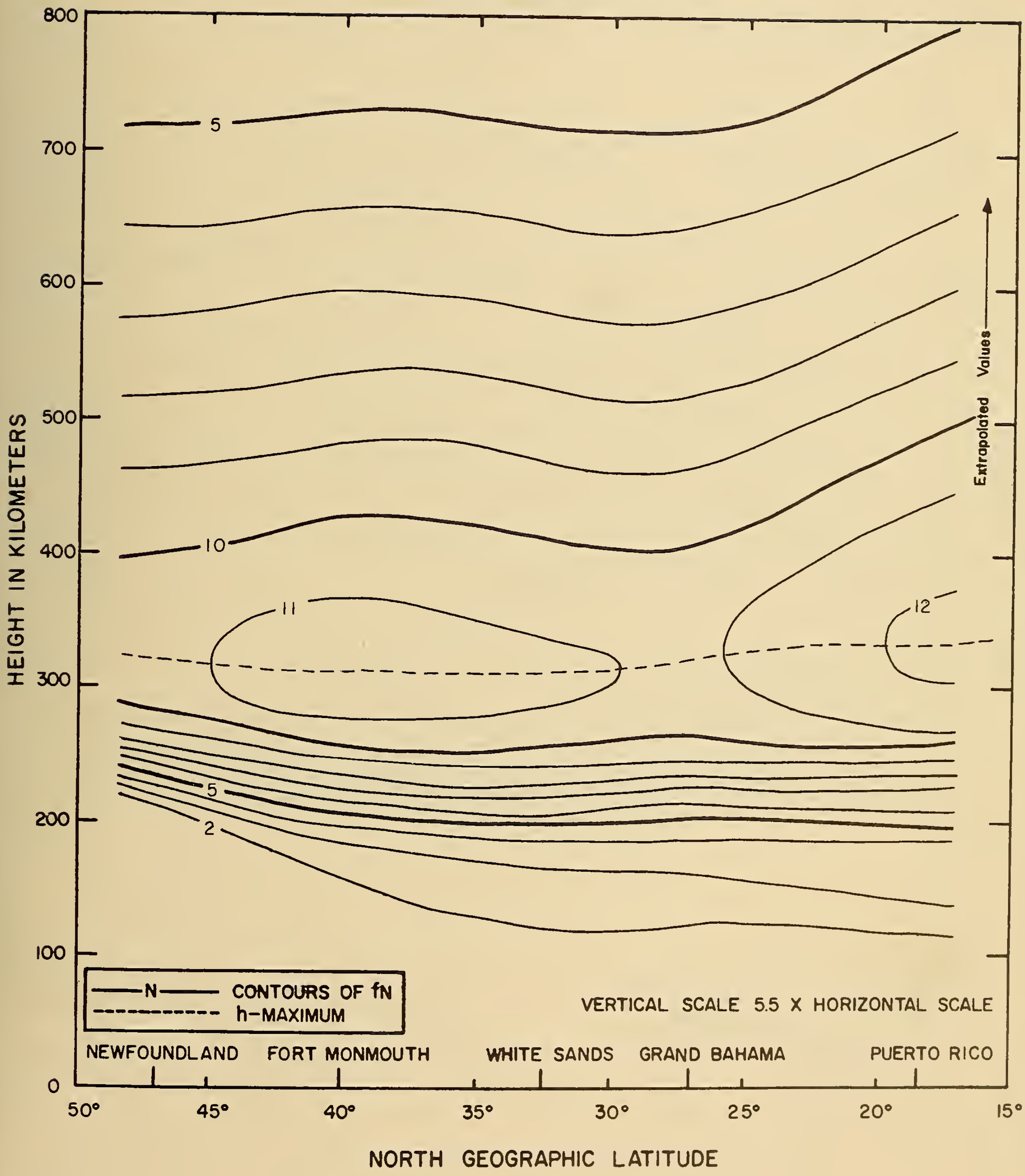


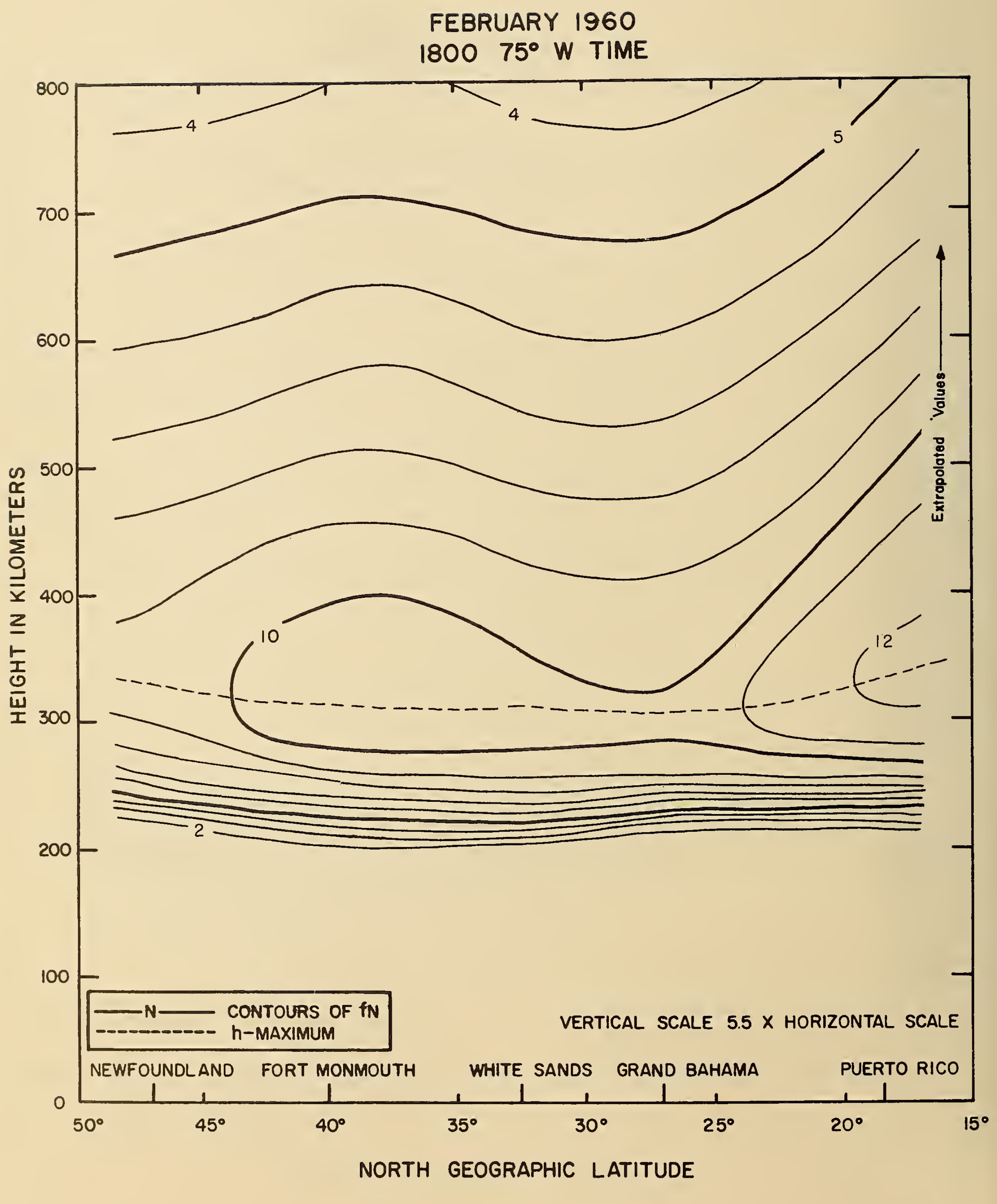
FEBRUARY 1960
1400 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
5
10
12
10
5
2
Extrapolated Values
N
CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

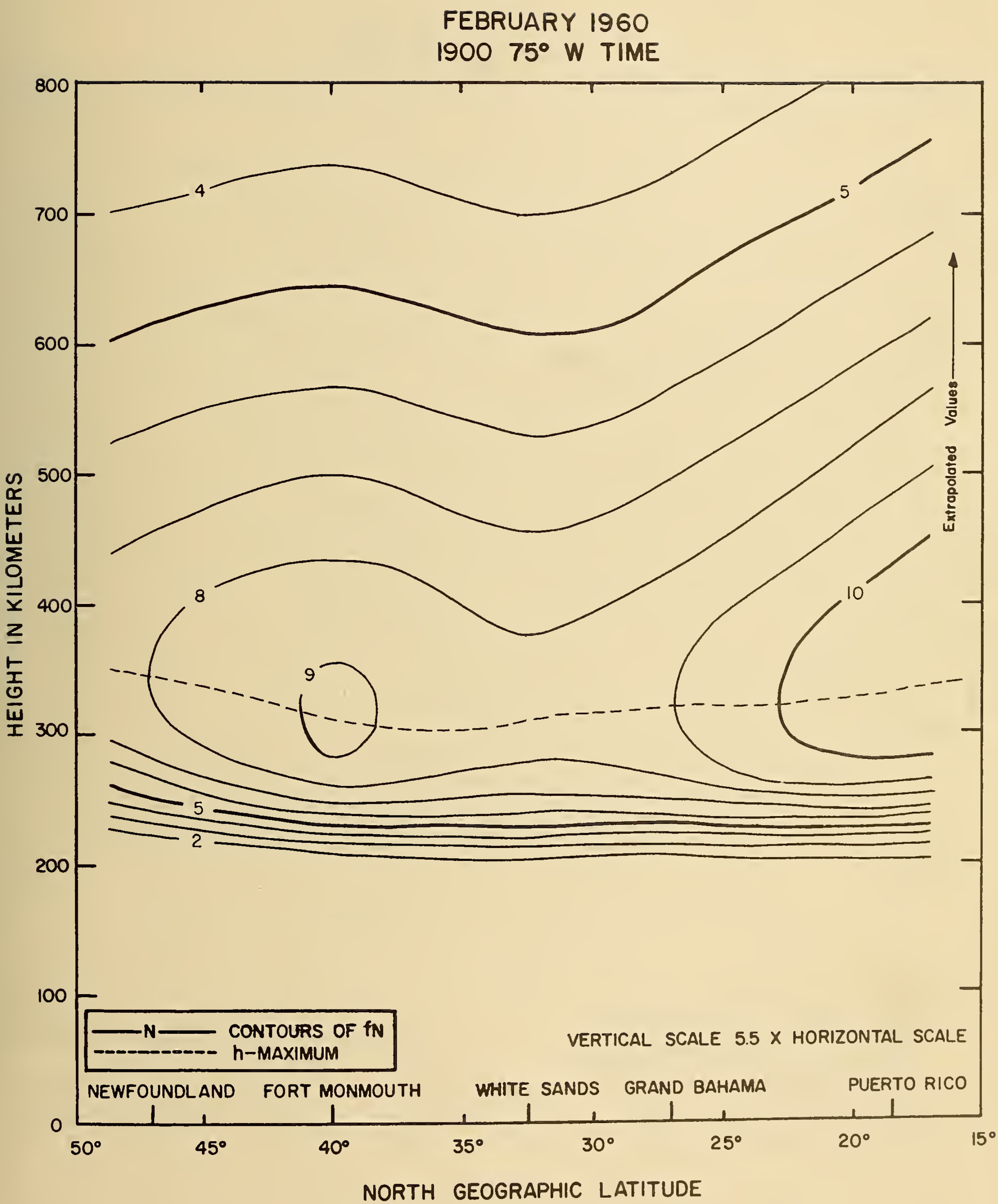

FEBRUARY 1960
1500 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
5
10
12
12
10
5
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE


FEBRUARY 1960
1600 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
5
10
11
12
5
2
Extrapolated Values
CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

FEBRUARY 1960
1700 75° W TIME

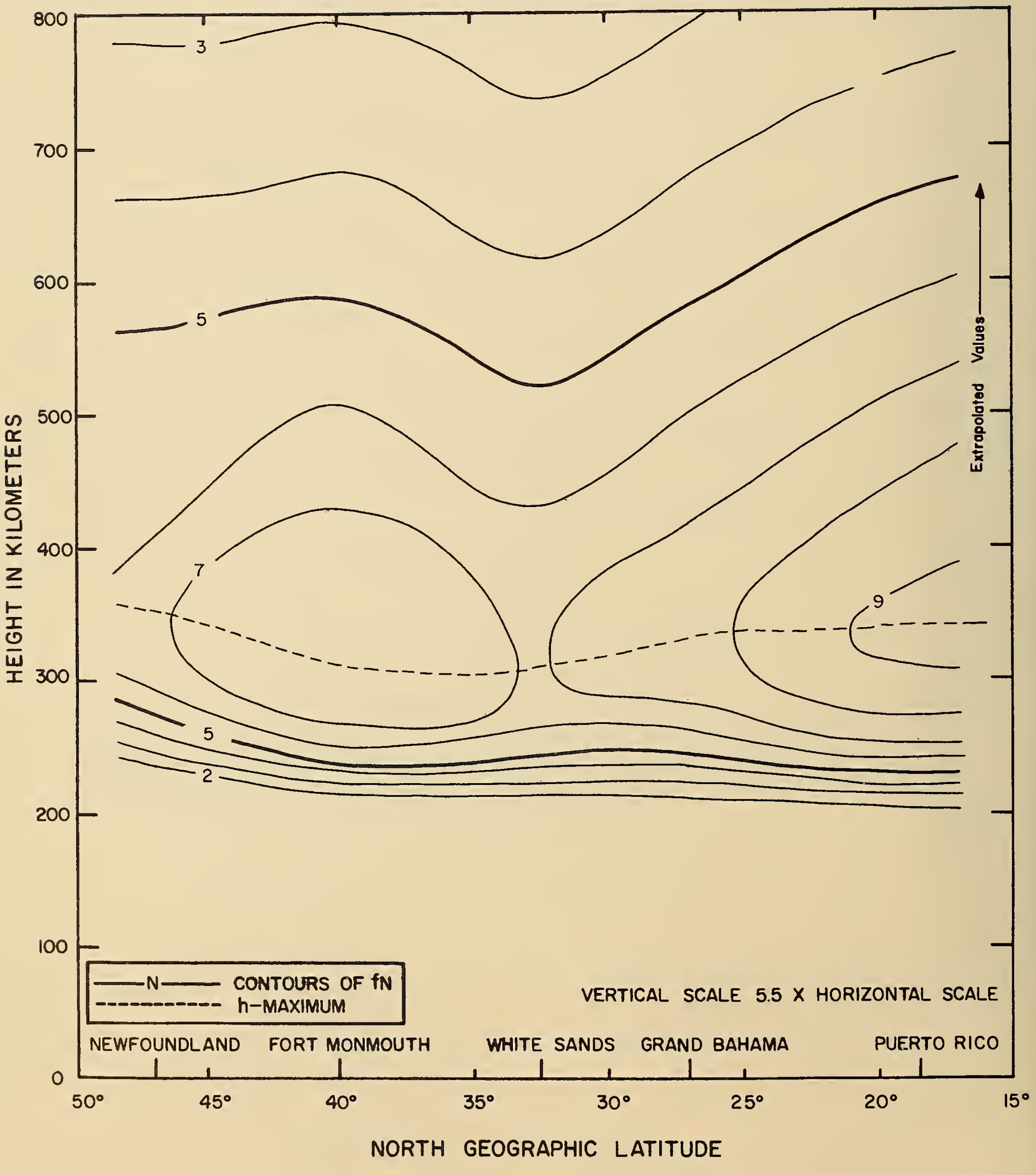


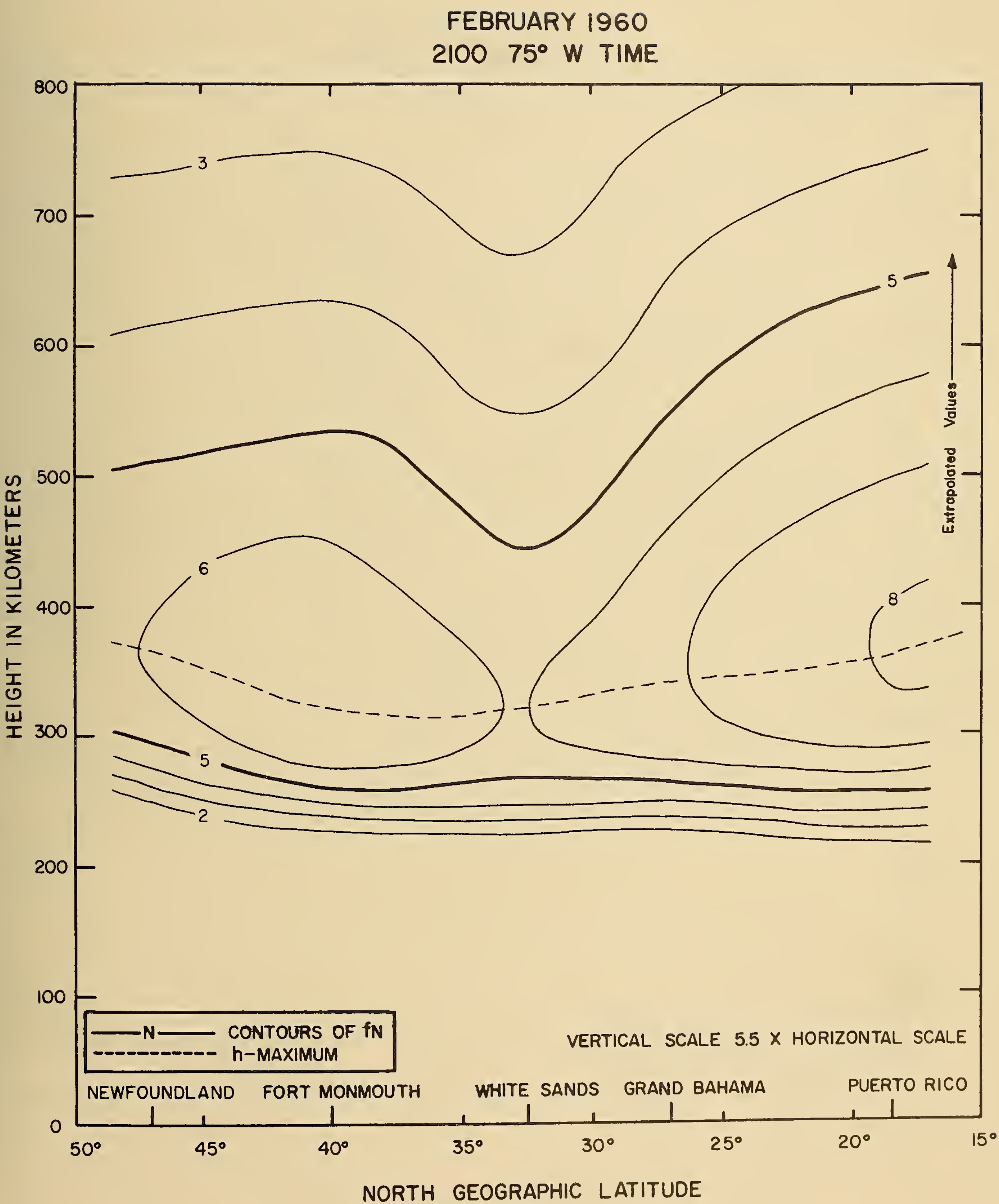

FEBRUARY 1960
1800 75° W TIME
800
700
600
500
400
300
200
100
0
HEIGHT IN KILOMETERS
4
4
5
10
12
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

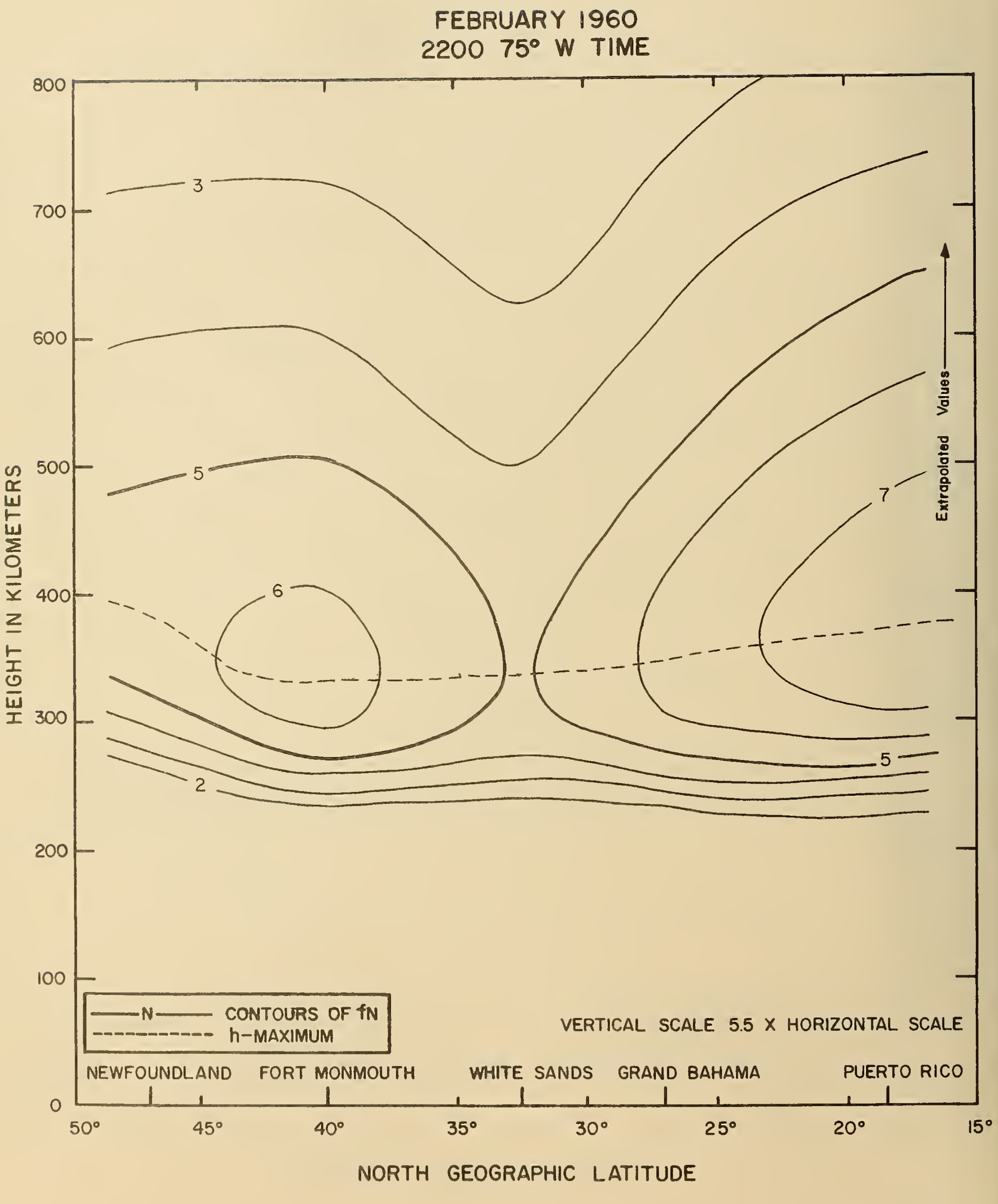


FEBRUARY 1960
1900 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
4
5
8
9
10
5
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

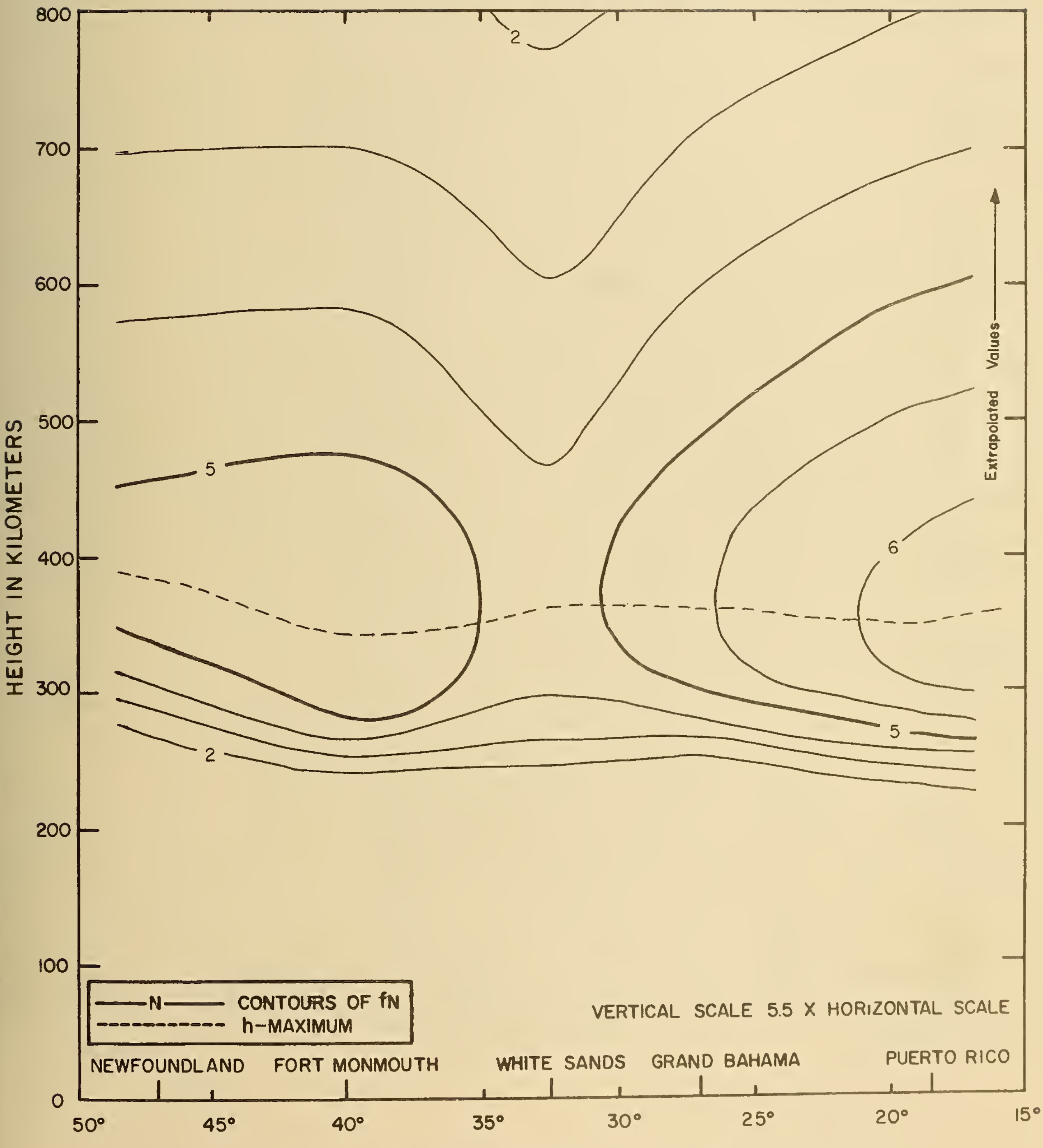
FEBRUARY 1960
2000 75° W TIME



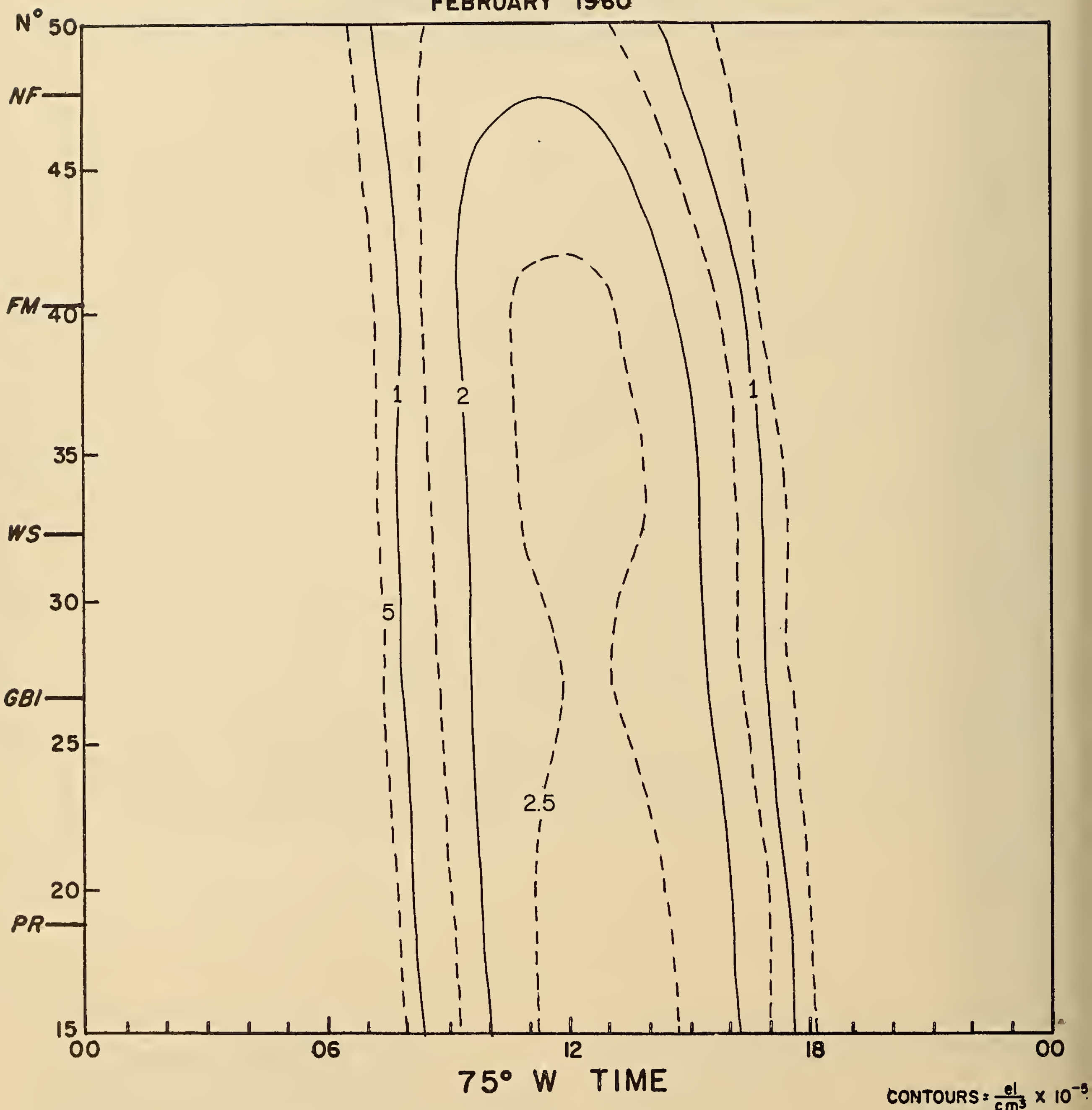

FEBRUARY 1960
2100 75° W TIME
800
700
600
500
400
300
200
100
0
HEIGHT IN KILOMETERS
3
5
6
8
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

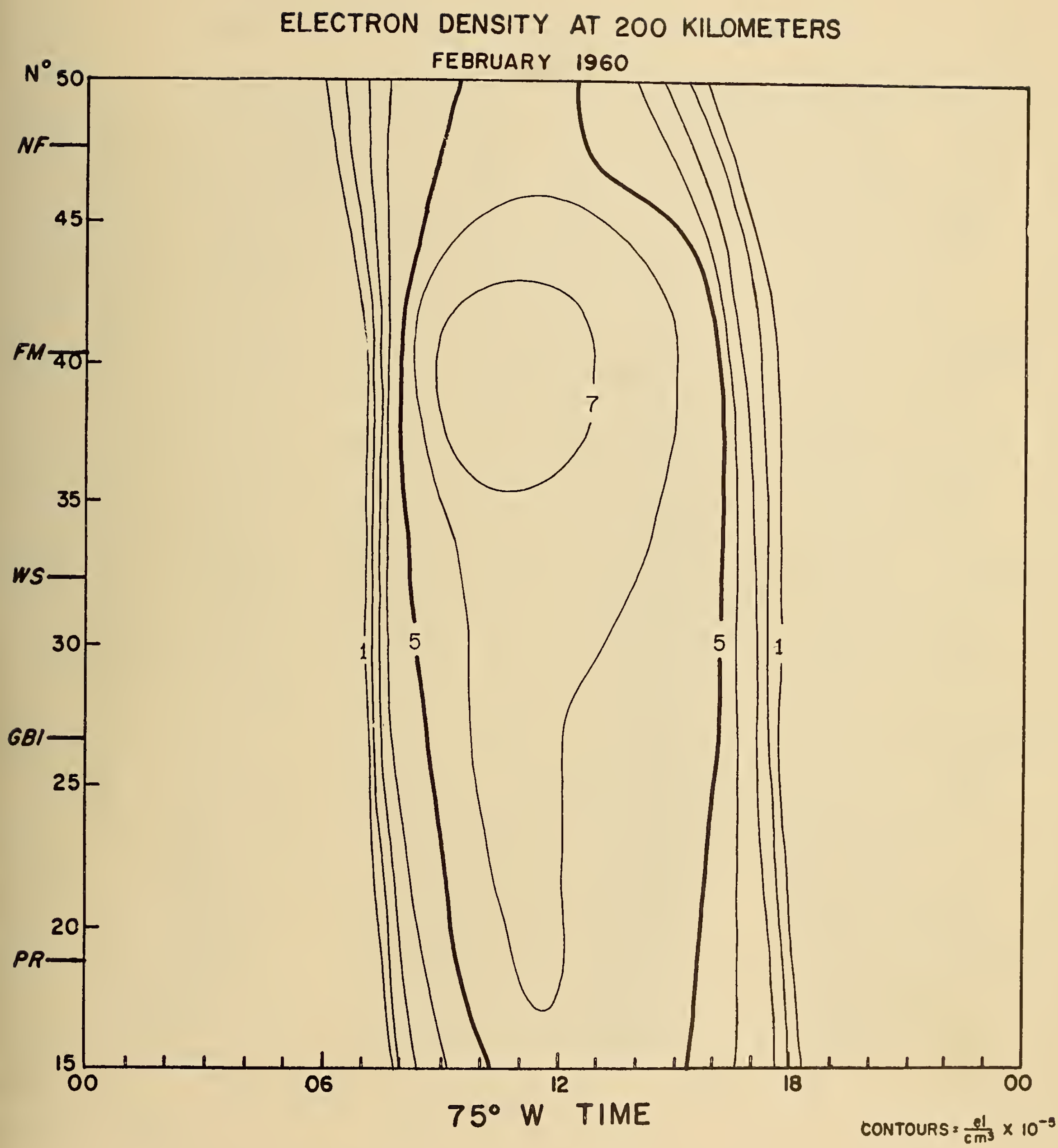

FEBRUARY 1960
2200 75° W TIME
800
700
600
500
400
300
200
100
0
HEIGHT IN KILOMETERS
3
5
6
7
2
Extrapolated Values
—N— CONTOURS OF fN
------ h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

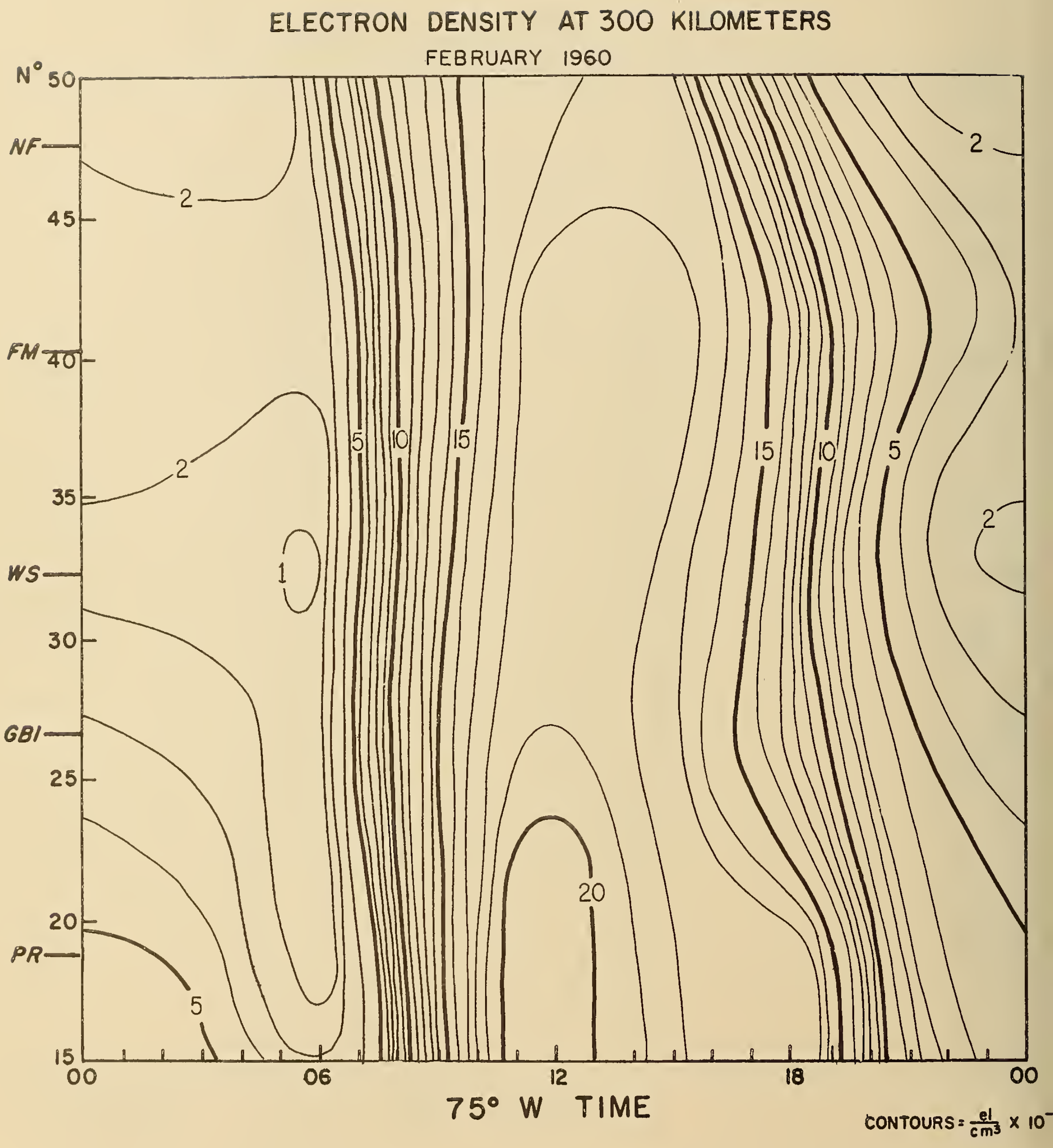
FEBRUARY 1960
2300 75° W TIME



ELECTRON DENSITY AT 150 KILOMETERS
FEBRUARY 1960



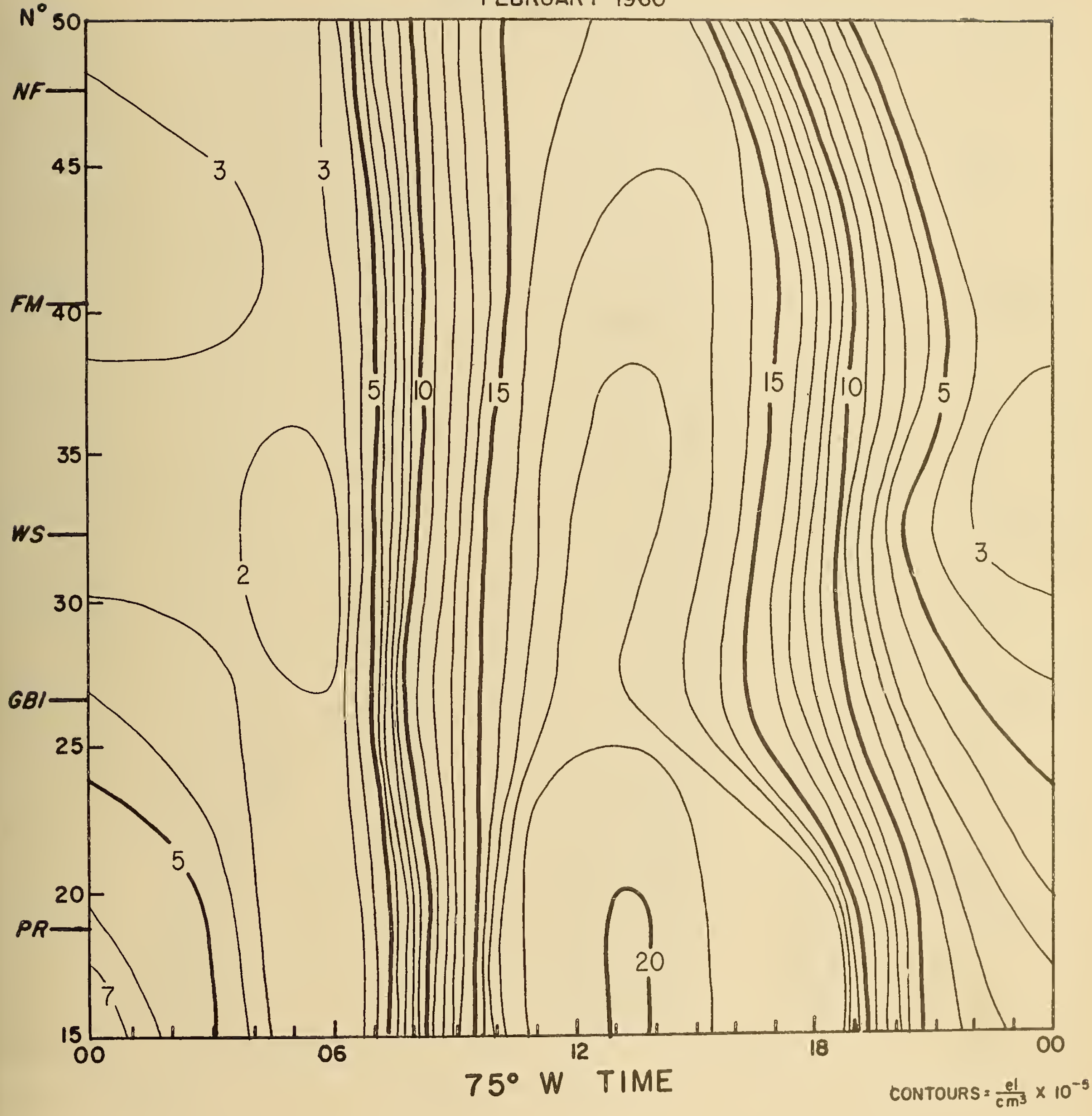

ELECTRON DENSITY AT 200 KILOMETERS
FEBRUARY 1960
N°
50
NF
45
FM
40
35
WS
30
GBI
25
20
PR
15
00
06
12
18
00
75° W TIME
1
5
7
5
1
CONTOURS = el/cm³ x 10⁻⁵



ELECTRON DENSITY AT 300 KILOMETERS
FEBRUARY 1960
N°
50
45
40
35
30
25
20
15
NF
FM
WS
GBI
PR
2
2
1
5
5
10
15
20
15
10
5
2
2
00
06
12
18
00
75° W TIME
CONTOURS = el/cm³ x 10

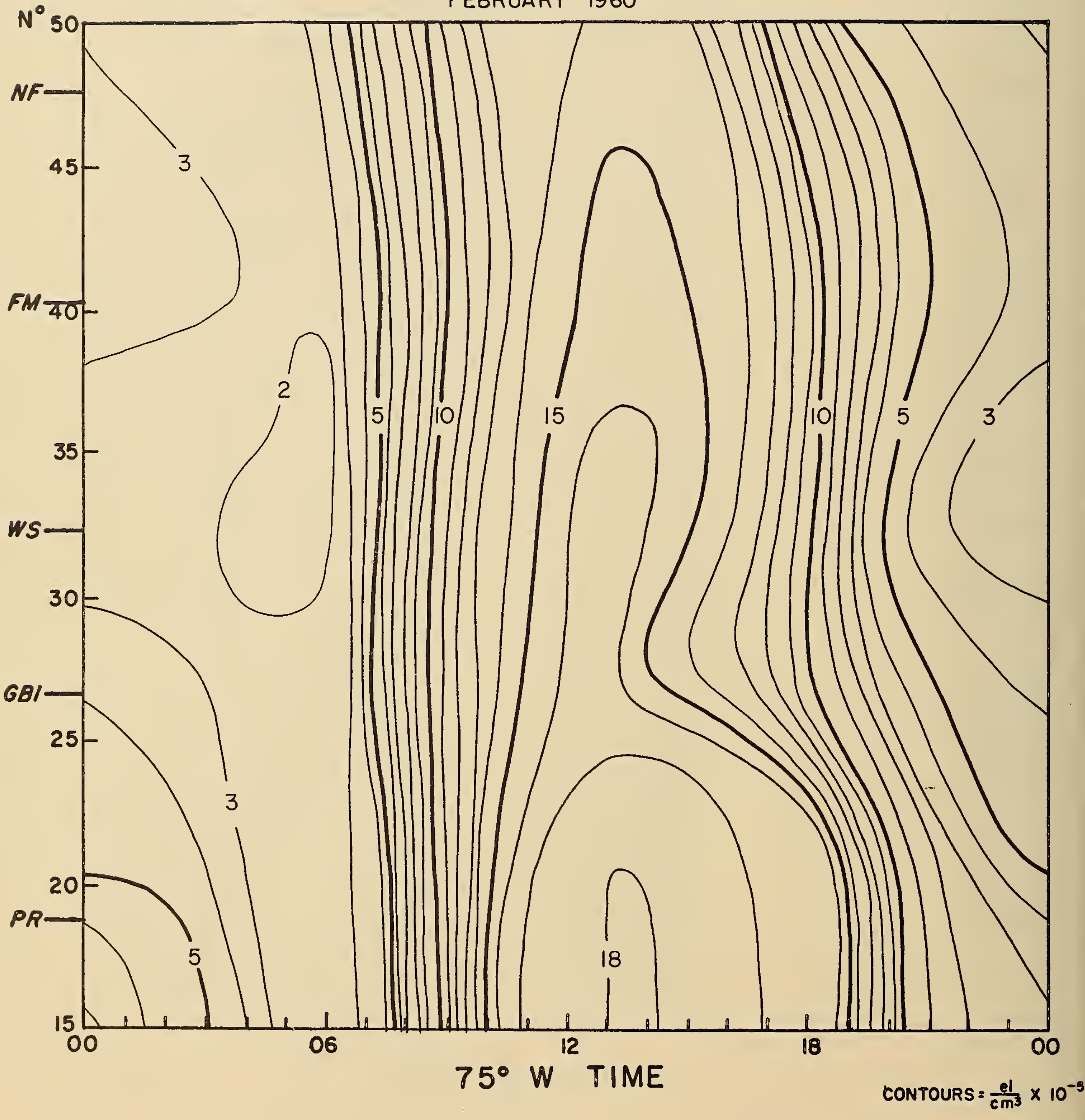
ELECTRON DENSITY AT 350 KILOMETERS

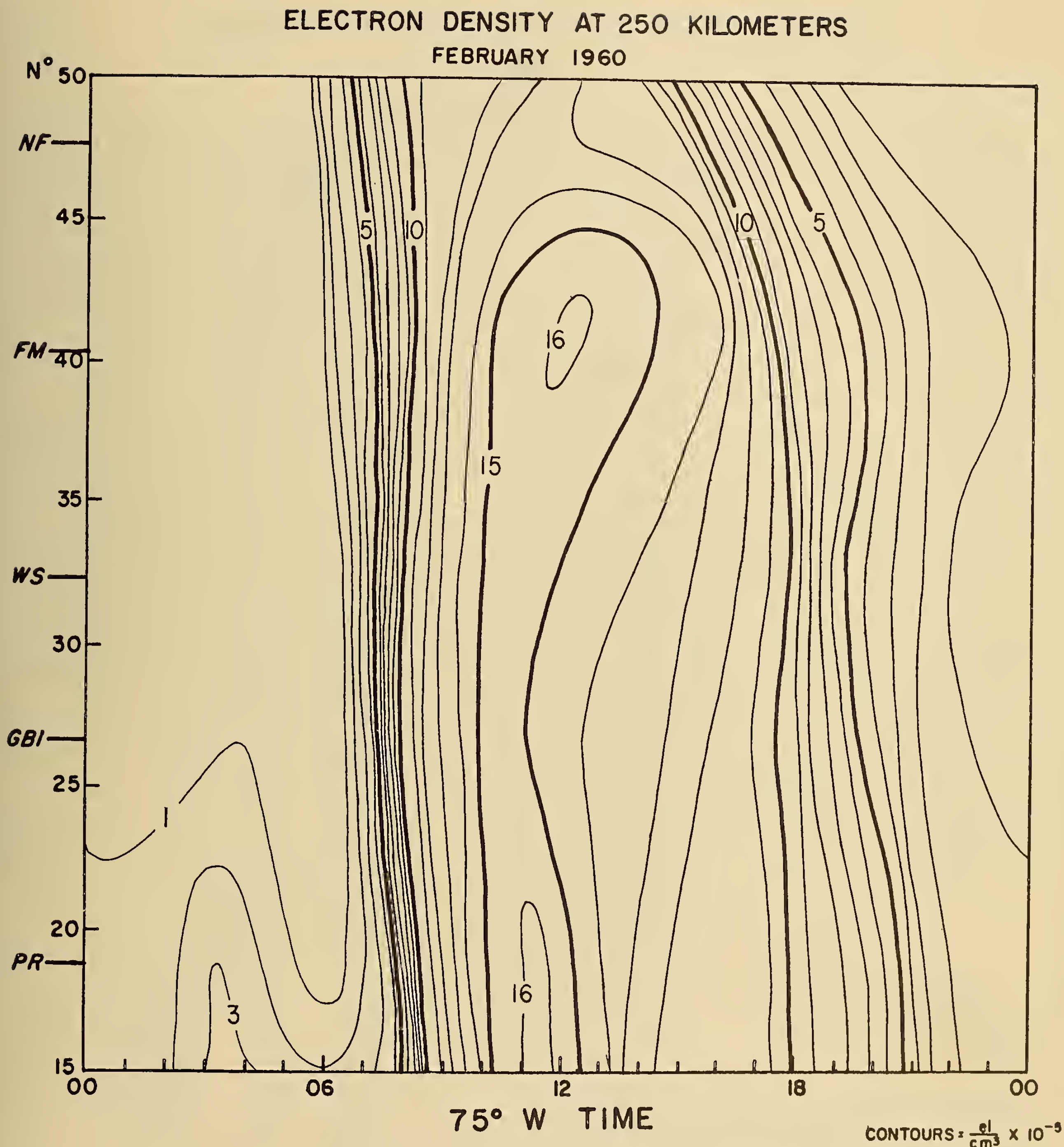
FEBRUARY 1960



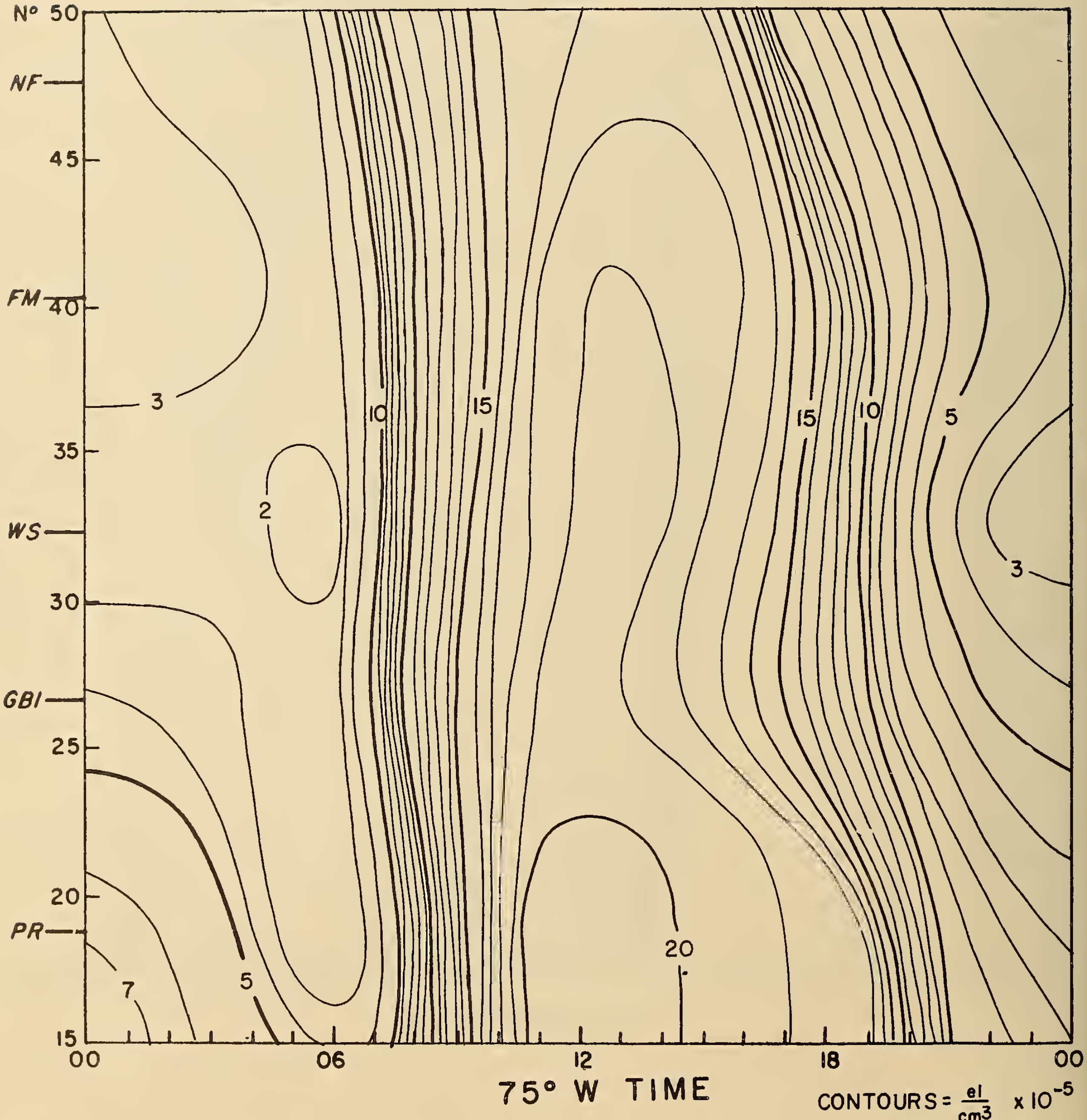
ELECTRON DENSITY AT 400 KILOMETERS

FEBRUARY 1960

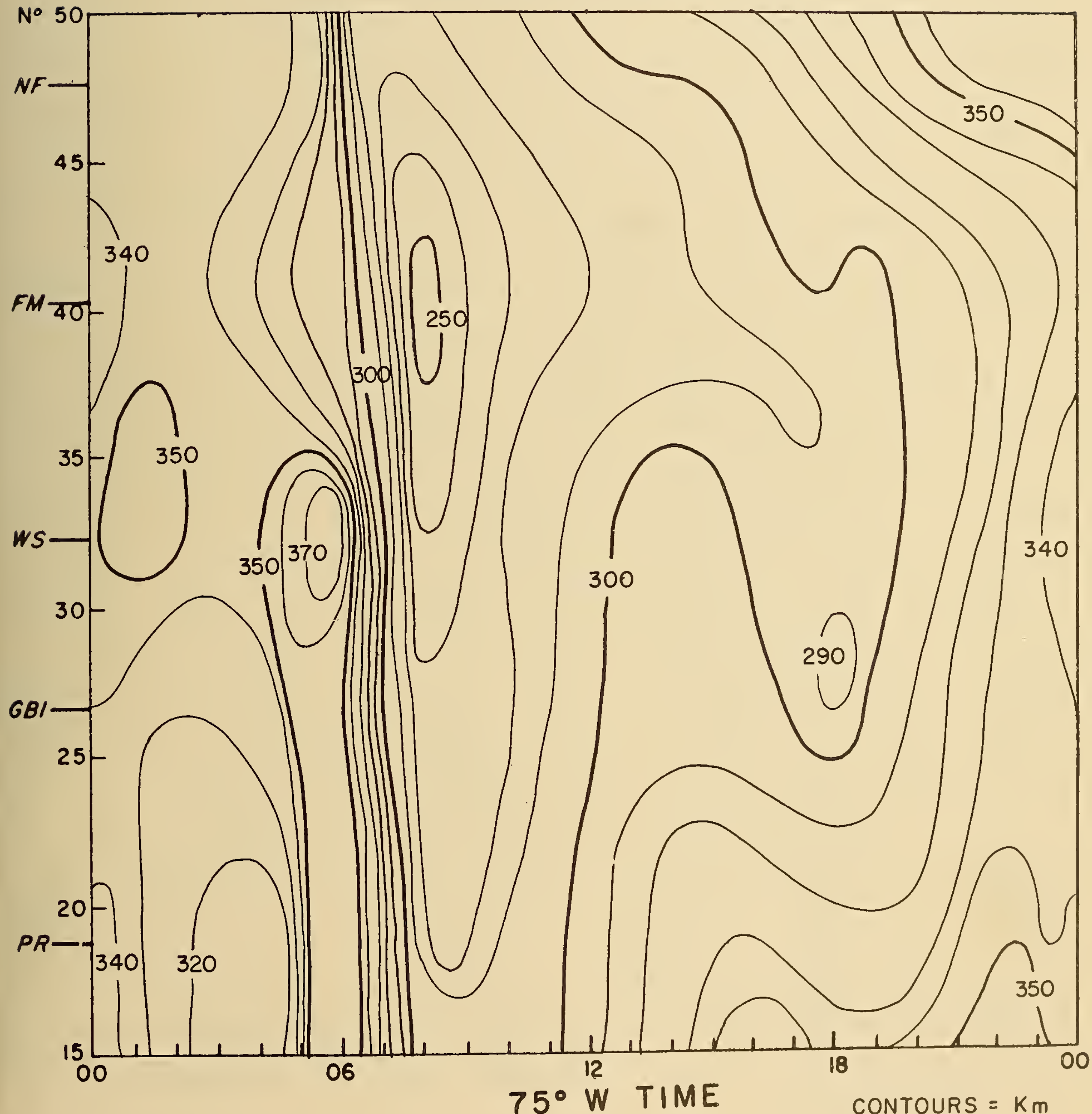



ELECTRON DENSITY AT 250 KILOMETERS
FEBRUARY 1960
N°
50
NF
45
FM
40
35
WS
30
GBI
25
20
PR
15
5
10
10
5
16
15
1
16
3
00
06
12
18
00
75° W TIME
CONTOURS = el/cm3 X 10^-5

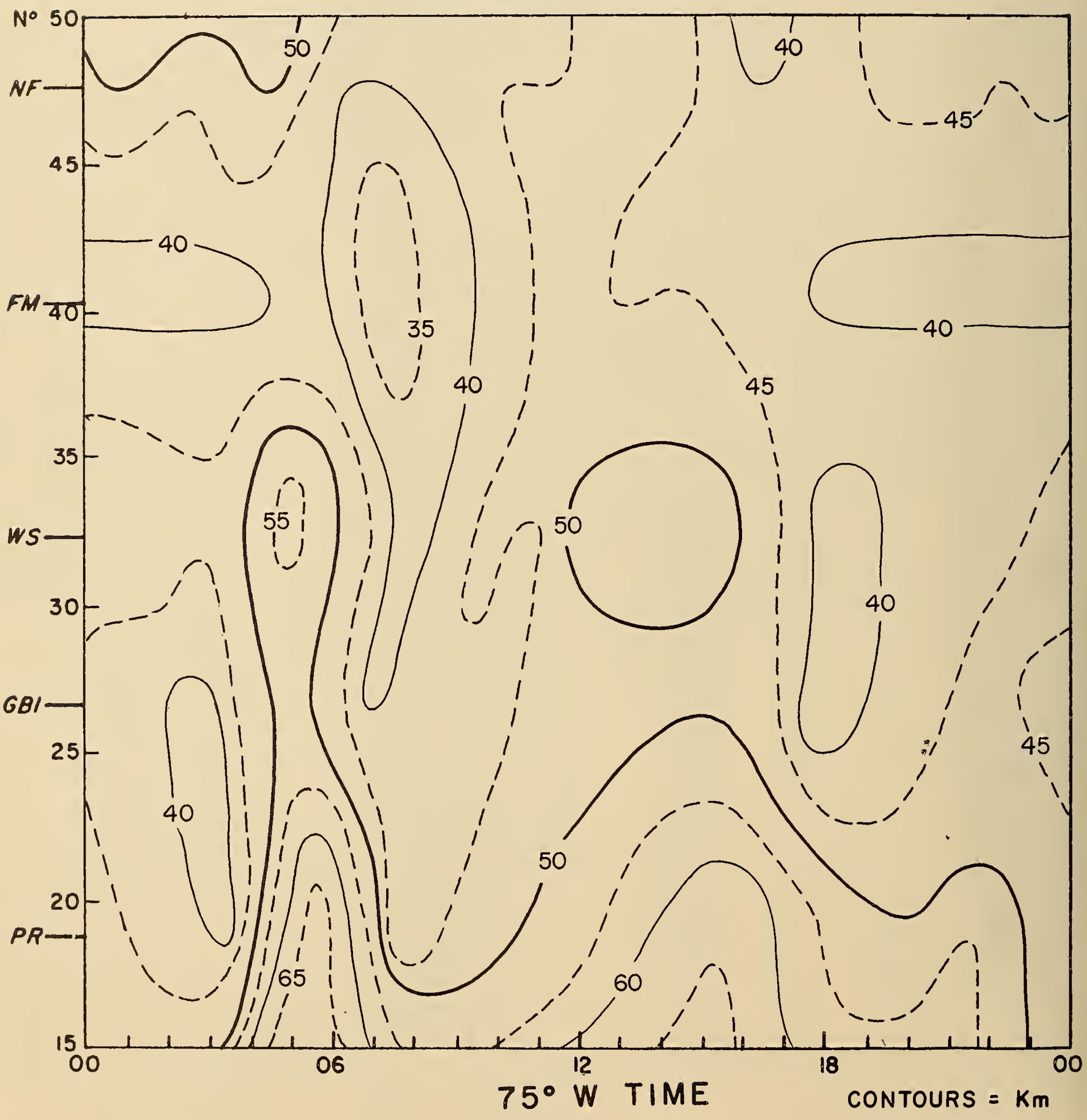
MAXIMUM ELECTRON DENSITY
NMAX
FEBRUARY 1960



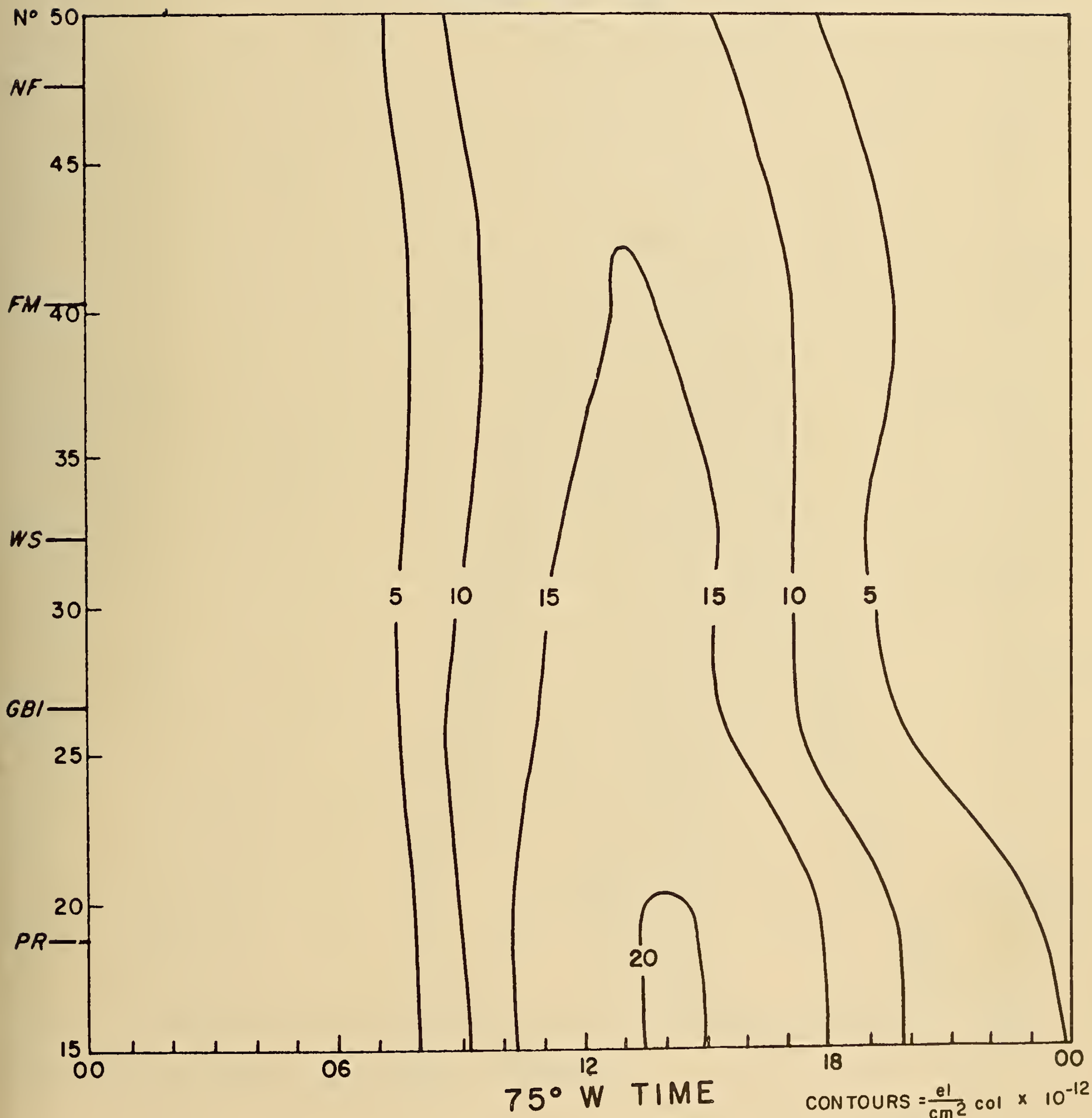
HEIGHT OF MAXIMUM ELECTRON DENSITY
HMAX
FEBRUARY 1960



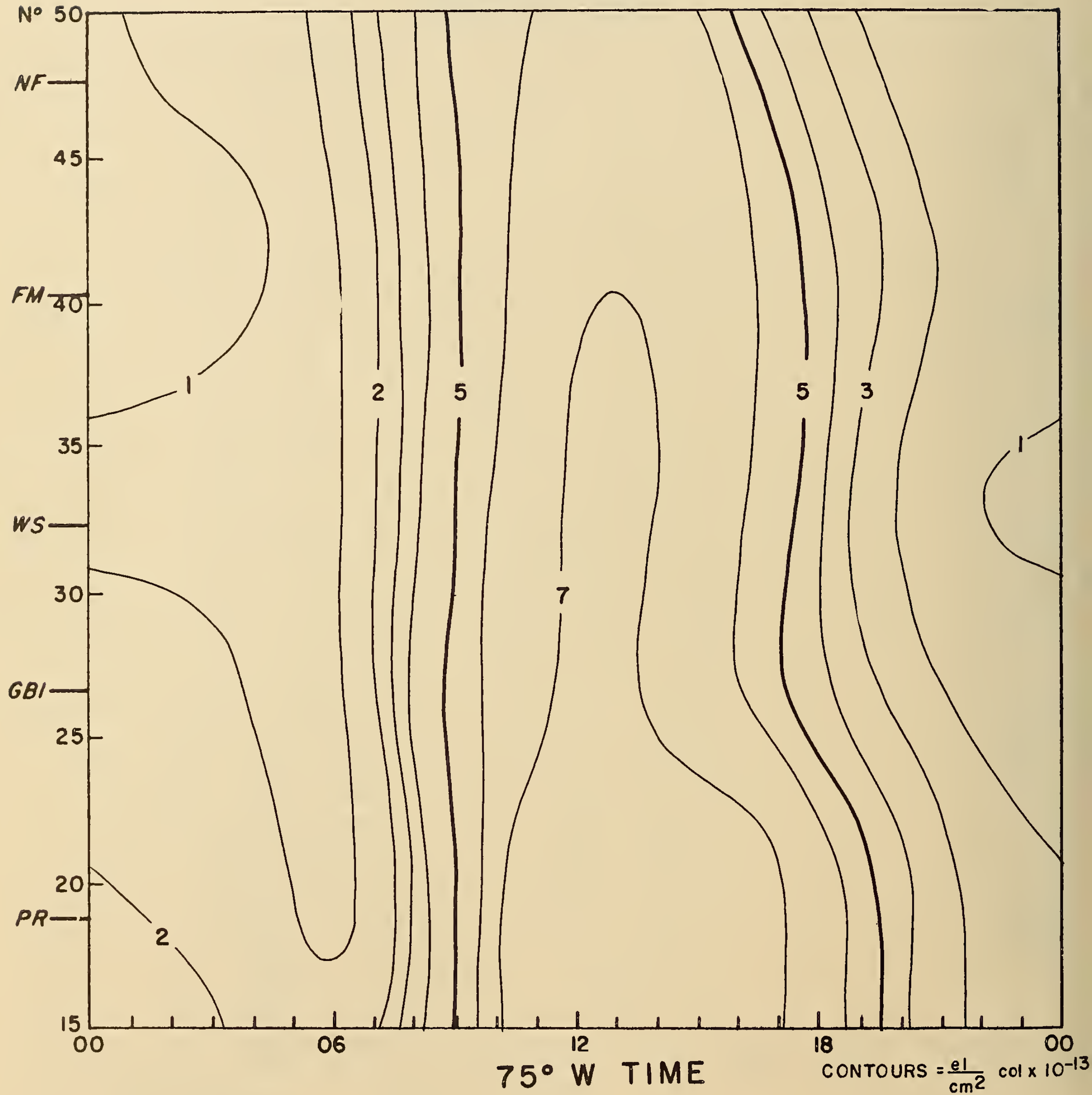
QUARTER THICKNESS OF F- REGION PEAK
SCAT
FEBRUARY 1960

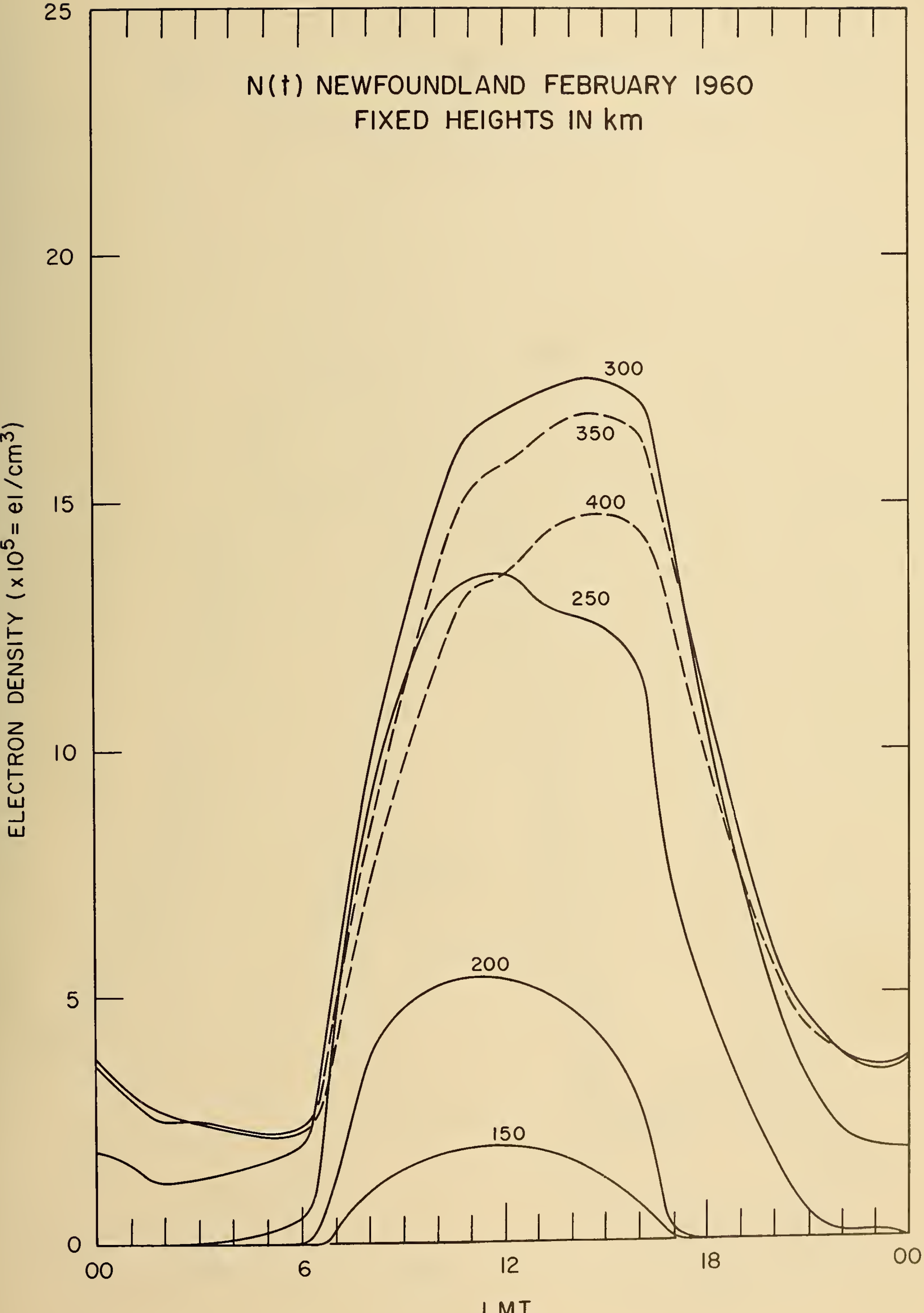


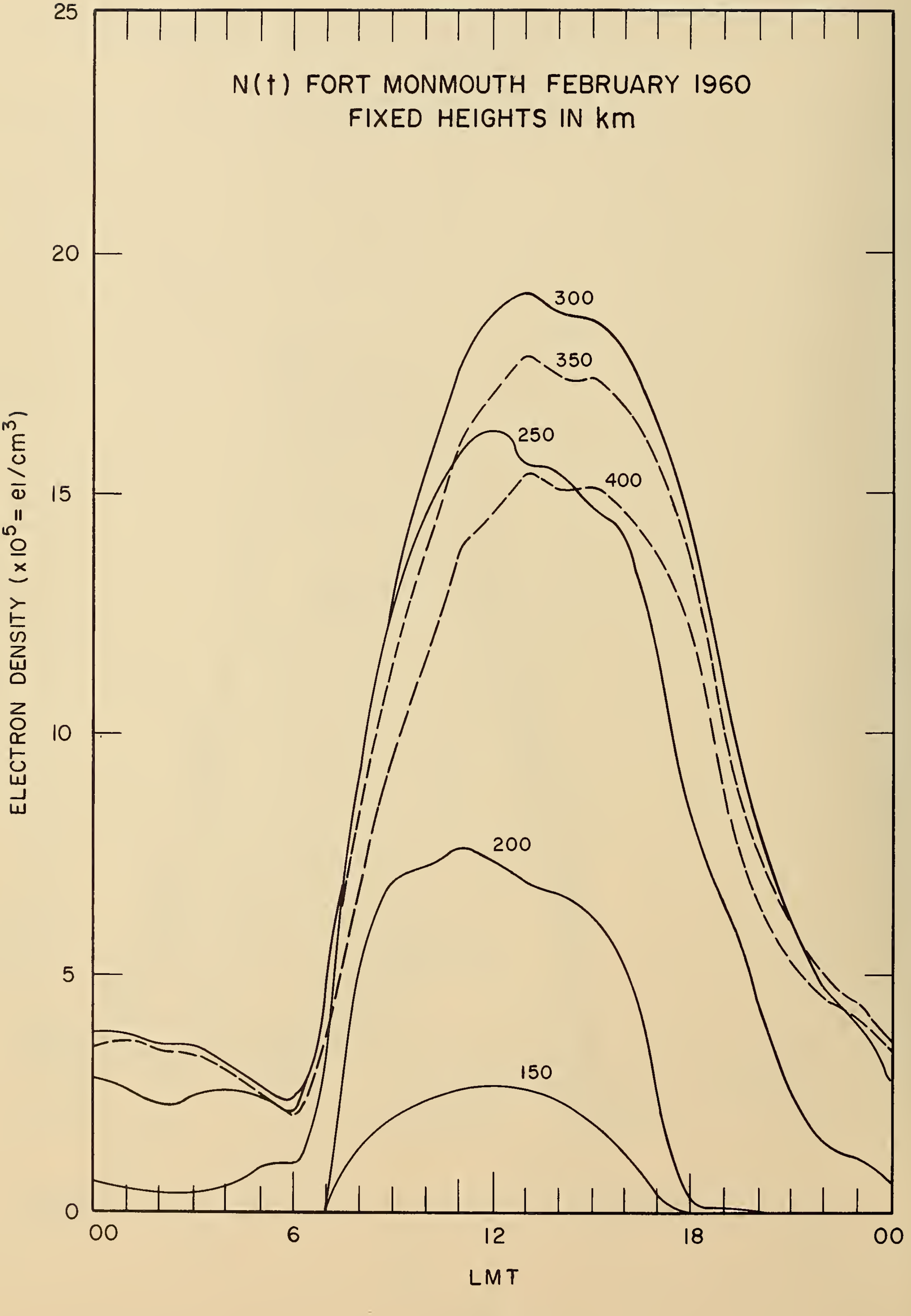
ELECTRON DENSITY INTEGRATED TO HEIGHT OF MAXIMUM ELECTRON DENSITY
SHMAX
FEBRUARY 1960

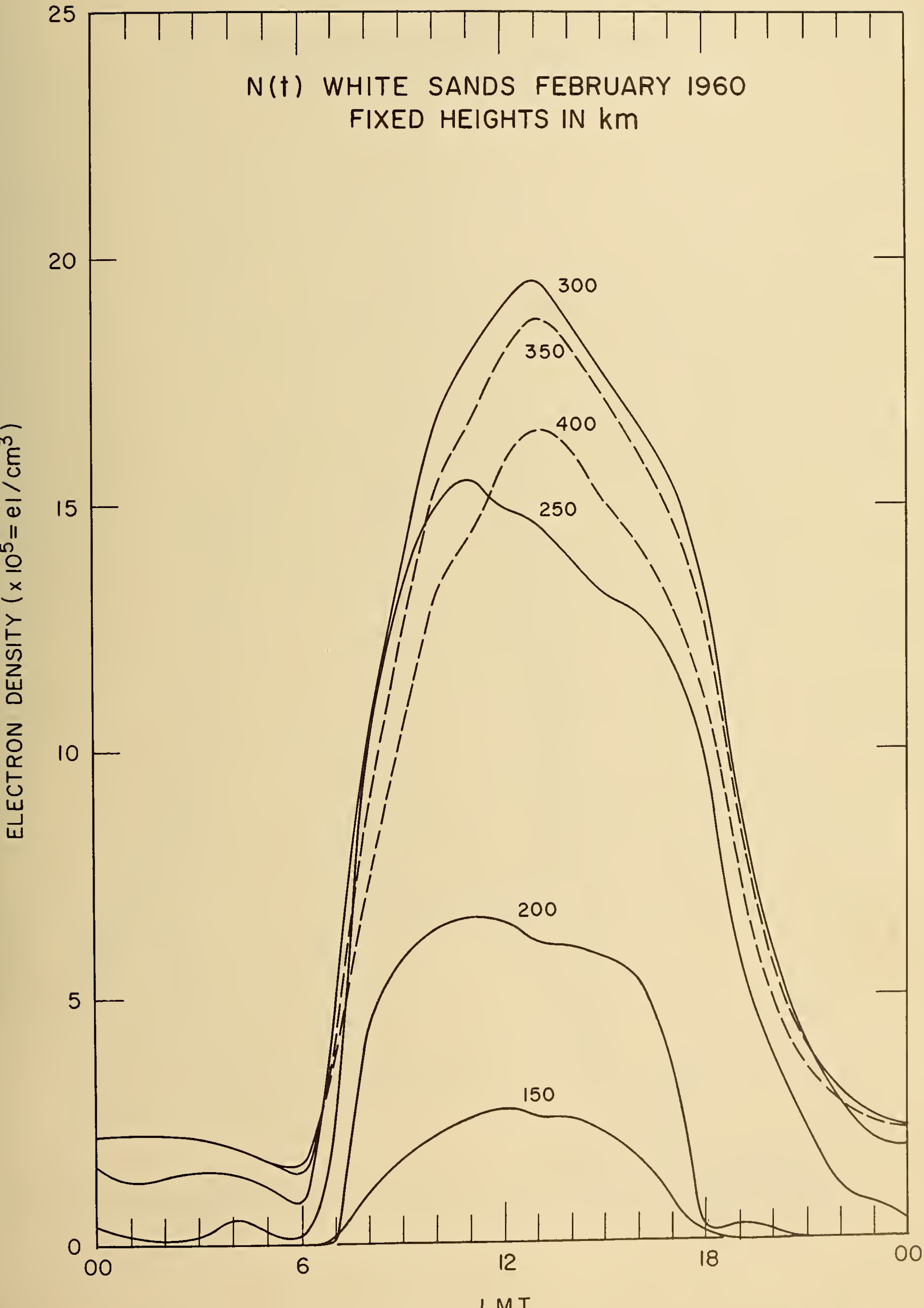


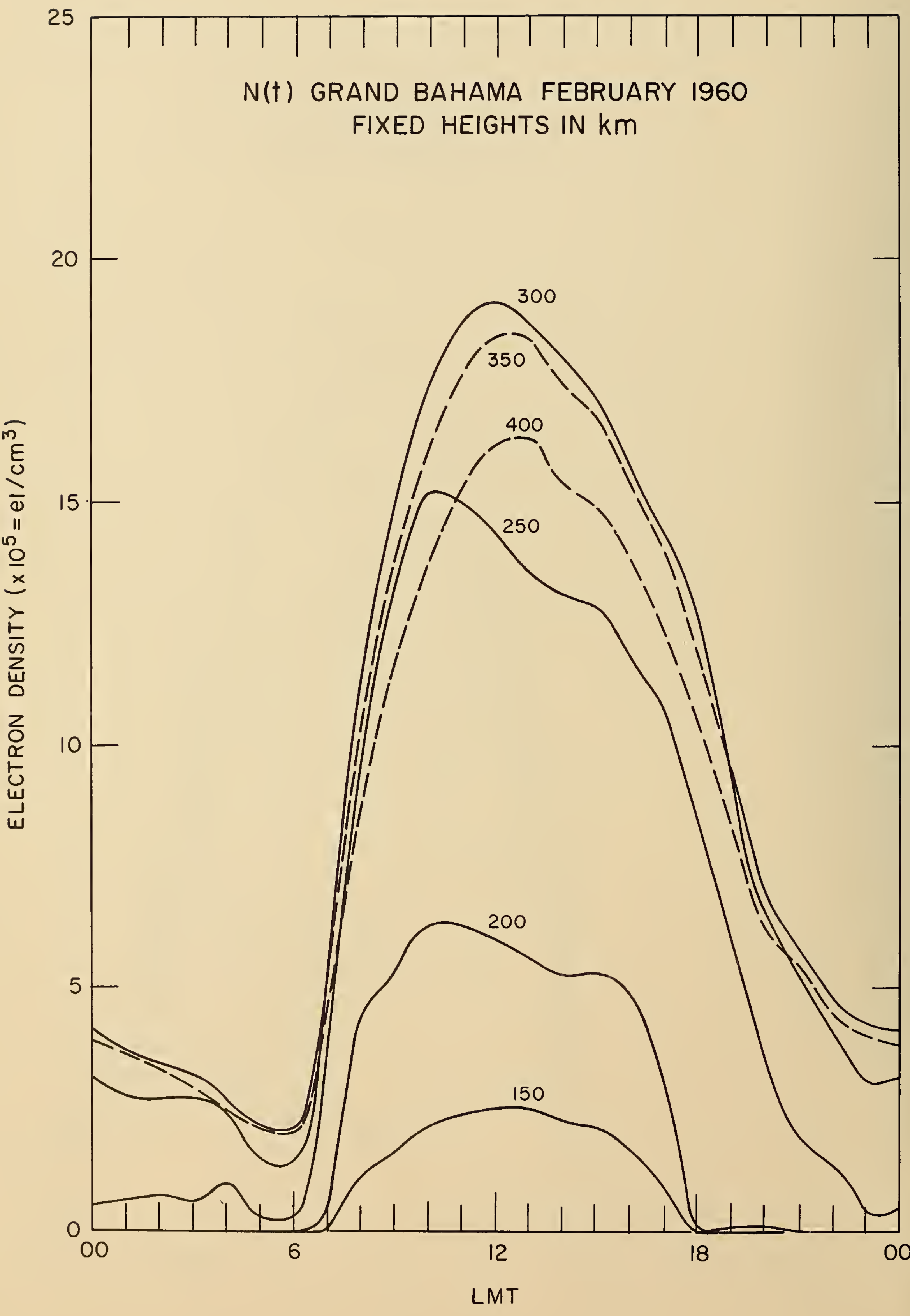
ELECTRON DENSITY INTEGRATED TO INFINITY
SHINF
FEBRUARY 1960



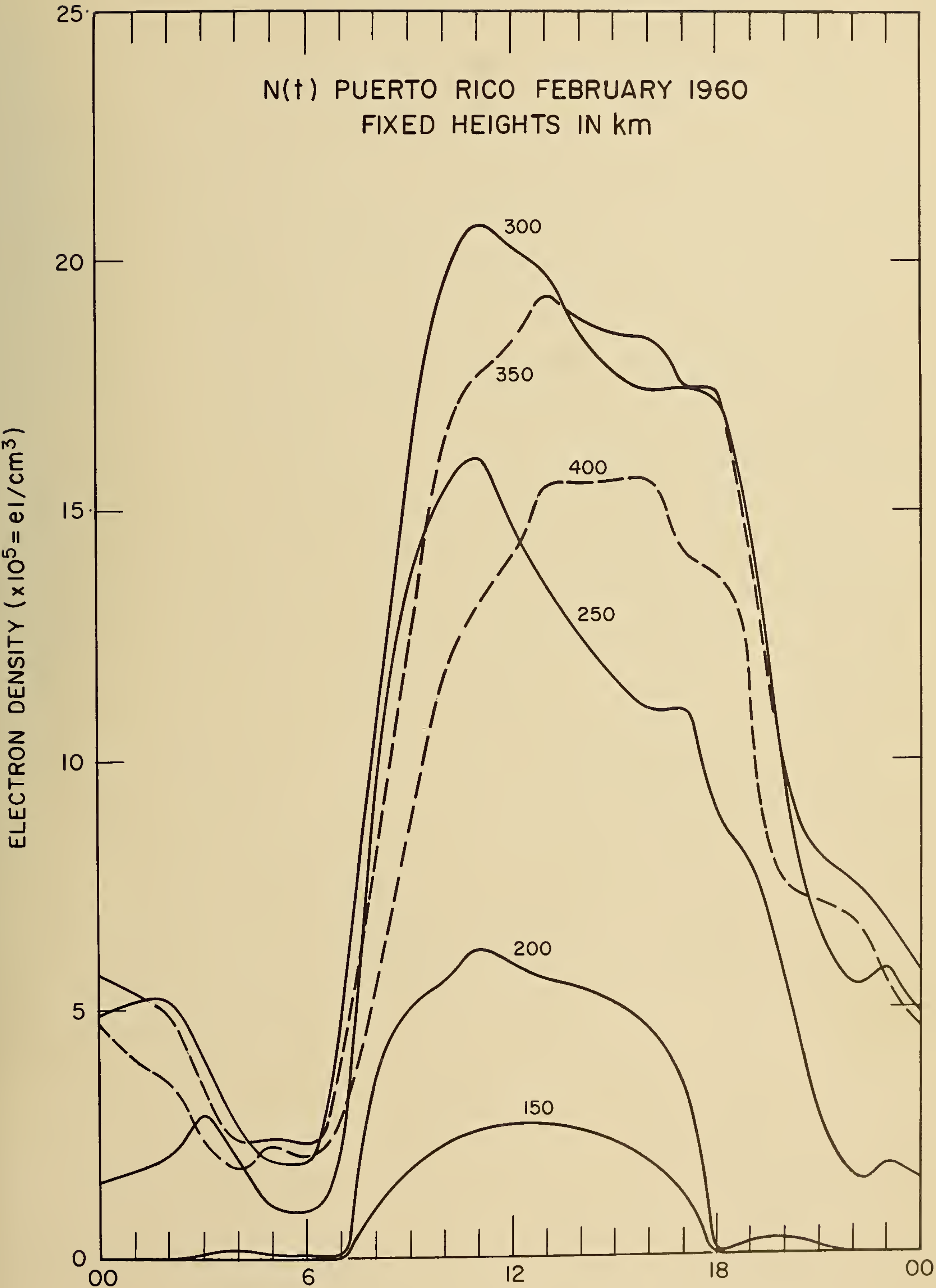

N(t) NEWFOUNDLAND FEBRUARY 1960
FIXED HEIGHTS IN km
ELECTRON DENSITY ($\times 10^5$ = el/cm^3)
25
20
15
10
5
0
300
350
400
250
200
150
00
6
12
18
00
LMT


N(t) FORT MONMOUTH FEBRUARY 1960
FIXED HEIGHTS IN km
25
20
15
10
5
0
ELECTRON DENSITY (x10^5 = el/cm^3)
300
350
250
400
200
150
00
6
12
18
00
LMT


N(t) WHITE SANDS FEBRUARY 1960
FIXED HEIGHTS IN km
300
350
400
250
200
150
25
20
15
10
5
0
00
6
12
18
00
ELECTRON DENSITY (x 10^5 = el / cm^3)
LMT



N(t) GRAND BAHAMA FEBRUARY 1960
FIXED HEIGHTS IN km
300
350
400
250
200
150
ELECTRON DENSITY (x 10^5 = el/cm^3)
25
20
15
10
5
0
00
6
12
18
00
LMT


N(t) PUERTO RICO FEBRUARY 1960
FIXED HEIGHTS IN km
ELECTRON DENSITY (x10^5 = el/cm^3)
LMT
300
350
400
250
200
150
25
20
15
10
5
0
00
6
12
18
00

GPO 837-757

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. High Voltage. Absolute Electrical Measurements.

Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Volume.

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. Crystal Chemistry.

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

Polymers. Macromolecules: Synthesis and Structure. Polymer Chemistry. Polymer Physics. Polymer Characterization. Polymer Evaluation and Testing. Applied Polymer Standards and Research. Dental Research.

Metallurgy. Engineering Metallurgy. Metal Reactions. Metal Physics. Electrolysis and Metal Deposition.

Inorganic Solids. Engineering Ceramics. Glass. Solid State Chemistry. Crystal Growth. Physical Properties. Crystallography.

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

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

Data Processing Systems. Components and Techniques. Computer Technology. Measurements Automation. Engineering Applications. Systems Analysis.

Atomic Physics. Spectroscopy. Infrared Spectroscopy. Far Ultraviolet Physics. Solid State Physics. Electron Physics. Atomic Physics. Plasma Spectroscopy.

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

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Elementary Processes. Mass Spectrometry. Photochemistry and Radiation Chemistry.

Office of Weights and Measures.

BOULDER, COLO.

CRYOGENIC ENGINEERING LABORATORY

Cryogenic Processes. Cryogenic Properties of Solids. Cryogenic Technical Services. Properties of Cryogenic Fluids.

CENTRAL RADIO PROPAGATION LABORATORY

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

Troposphere and Space Telecommunications. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Spectrum Utilization Research. Radio-Meteorology. Lower Atmosphere Physics.

Radio Systems. Applied Electromagnetic Theory. High Frequency and Very High Frequency Research. Frequency Utilization. Modulation Research. Antenna Research. Radiodetermination.

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

RADIO STANDARDS LABORATORY

Radio Standards Physics. Frequency and Time Disseminations. Radio and Microwave Materials. Atomic Frequency and Time-Interval Standards. Radio Plasma. Microwave Physics.

Radio Standards Engineering. High Frequency Electrical Standards. High Frequency Calibration Services. High Frequency Impedance Standards. Microwave Calibration Services. Microwave Circuit Standards. Low Frequency Calibration Services.

Joint Institute for Laboratory Astrophysics - NBS Group (Univ. of Colo.).

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