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Technical Note No. 40-11

MEAN ELECTRON DENSITY VARIATIONS OF THE QUIET IONOSPHERE NO. 11–JANUARY 1960

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

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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CONTENTS

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 January are illustrated graphically. This report is the eleventh 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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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 January 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)	$x10^3$ = 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	$x10^3$ = 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	$x10^{10}$ = 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 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 January 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

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AVERAGE ELECTRON DENSITY KP BELOW 4.5

PUERTO RICO 60 W JAN 1960

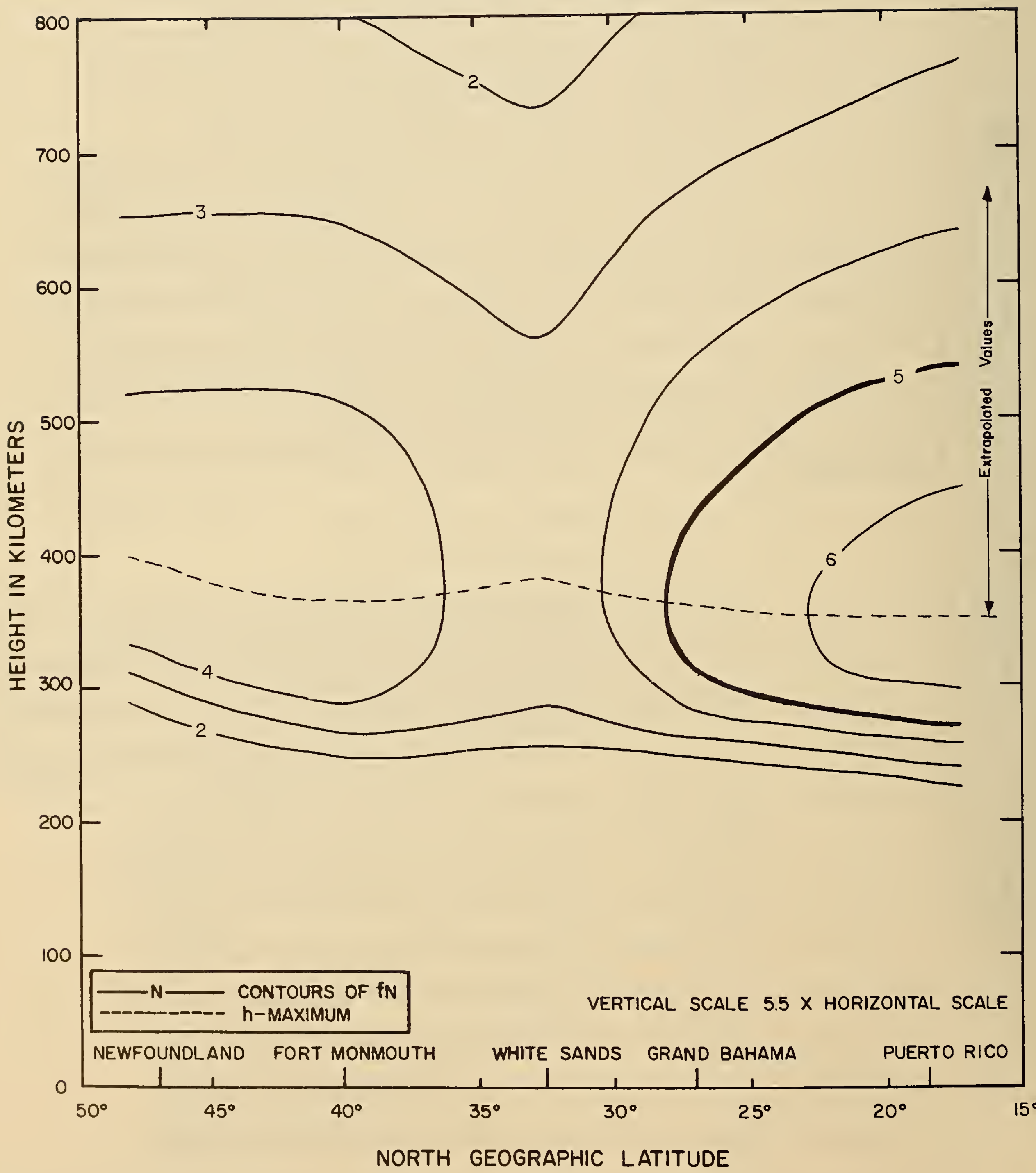
TIME	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100
COUNT	28	28	23	26	23	25	25	25	27	28	24	22
HMIN	229	227	214	210	232	226	214	228	110	110	109	109
RATIO	5.7	6.5	6.6	5.5	4.4	4.7	4.6	6.1	5.4	5.2	5.0	4.2
SCAT	44.3	40.6	39.4	48.9	62.6	56.4	57.4	43.3	42.9	42.8	44.5	57.0
NMAX	552	542	476	317	269	280	267	510	1305	1914	2174	1841
HMAX	332	319	297	315	371	356	342	316	277	283	280	295
SHMAX	334	295	242	204	226	216	209	284	859	1320	1542	1637
SHINF	1890	1823	1584	1098	984	1007	961	1724	4542	6719	7674	6830
KM												
950	41.5	38.9	30.2	22.2	24.3	23.5	21.2	35.3	74.7	113	127	116
900	53.2	49.9	38.7	28.5	31.2	30.2	27.2	45.2	95.9	145	163	149
850	68.2	63.9	49.6	36.6	40.0	38.7	34.8	58.0	123	186	209	190
800	87.4	81.9	63.6	46.9	51.2	49.6	44.6	74.3	158	238	268	244
750	112	105	81.6	60.1	65.4	63.4	57.1	95.2	202	305	343	313
700	143	134	104	76.7	83.4	80.8	72.9	122	259	391	439	400
650	182	171	133	97.8	106	103	92.7	155	331	499	561	511
600	230	216	169	124	133	130	117	197	421	636	715	650
550	289	271	214	156	165	162	146	248	534	805	905	821
500	357	335	267	193	200	198	180	309	670	1010	1137	1027
490	371	349	279	201	207	205	187	322	701	1056	1188	1072
480	386	363	291	209	213	213	194	335	732	1102	1240	1119
470	401	377	303	217	220	220	201	349	764	1150	1295	1166
460	415	391	315	226	227	227	208	362	797	1199	1350	1214
450	430	405	328	234	233	234	215	376	831	1250	1407	1263
440	444	419	341	242	239	241	222	390	865	1300	1464	1313
430	459	433	353	251	244	248	229	404	900	1352	1523	1363
420	472	446	366	259	249	254	235	417	935	1404	1582	1413
410	485	459	379	266	253	259	241	431	970	1456	1641	1462
400	497	471	391	274	256	264	246	443	1006	1508	1700	1511
390	509	482	403	281	258	268	251	456	1041	1559	1758	1559
380	518	492	415	287	259	271	255	467	1075	1609	1815	1605
370	526	499	426	292	258	273	258	477	1109	1658	1871	1648
360	532	504	436	297	255	273	259	487	1142	1704	1924	1689
350	535	508	445	300	250	270	260	494	1173	1748	1974	1726
340	533	510	453	301	242	265	258	501	1201	1788	2021	1759
330	525	509	459	301	231	255	254	504	1227	1824	2063	1787
320	510	503	462	298	217	242	246	504	1250	1854	2099	1808
310	485	491	463	292	199	226	235	498	1270	1879	2128	1822
300	452	472	459	283	178	205	220	485	1284	1896	2150	1826
290	406	443	448	269	155	182	202	458	1293	1904	2161	1814
280	352	401	429	250	131	154	180	415	1292	1891	2152	1781
270	287	345	398	228	107	128	155	354	1276	1841	2111	1722
260	220	271	354	203	85.2	102	128	275	1238	1748	2024	1636
250	156	187	290	174	63.3	74.7	102	187	1169	1605	1885	1519
240	98.7	109	209	141	43.6	52.2	79.6	105	1058	1412	1686	1373
230	55.9	50.2	126	102	28.4	33.6	56.4	47.3	901	1179	1440	1207
220	27.0	17.5	60.5	63.2	18.2	20.2	38.1	16.7	708	920	1156	1030
210	9.8	4.7	23.9	30.3	10.1	10.5	23.1	8.5	520	688	892	850
200	1.0		6.0	11.1	2.2	3.0	10.8	2.1	365	506	661	691
190				1.6	.1	.1	1.0		255	378	490	558
180				.3					185	294	378	448
170									141	235	306	367
160									115	191	254	304
150									99.3	160	212	254
140									90.8	140	181	213
130									84.7	128	162	184
120									75.6	120	151	169
110									20.4	51.8	83.8	94.8

AVERAGE ELECTRON DENSITY KP BELOW 4.5

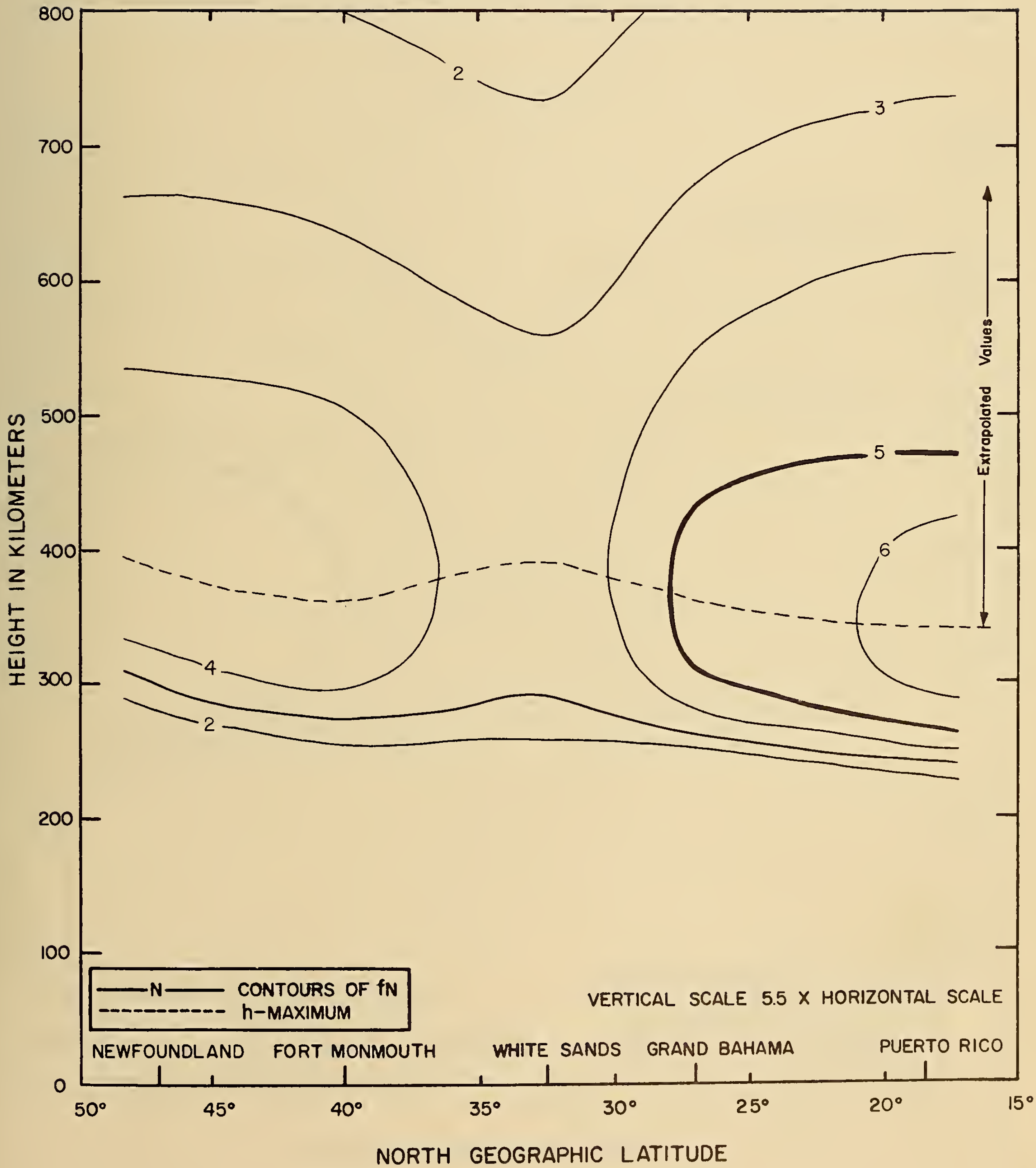
PUERTO RICO 60 W JAN 1960

TIME	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
COUNT	24	19	21	23	22	18	22	26	28	26	26	28
HMIN	109	109	110	109	110	110	211	193	210	230	217	213
RATIO	3.8	3.8	3.7	3.6	3.7	4.1	5.0	4.8	4.9	5.5	5.3	5.0
SCAT	61.2	59.9	64.8	65.6	65.5	60.3	54.6	53.6	52.4	46.8	49.5	52.3
NMAX	1764	1765	1796	1725	1775	1901	1579	1117	915	837	717	618
HMAX	315	320	329	334	335	327	322	326	341	339	333	341
SHMAX	1784	1778	1910	1862	1854	1744	1138	847	675	535	483	431
SHINF	6761	6758	6977	6729	6862	7106	5593	3997	3257	2897	2506	2175
KM												
950	122	125	133	131	136	140	113	81.6	72.9	66.5	54.9	47.6
900	157	160	171	168	174	179	145	105	93.5	85.2	70.4	61.0
850	201	205	219	216	224	229	186	134	120	109	90.3	78.2
800	257	263	281	277	287	294	238	172	154	140	116	100
750	330	337	359	354	367	377	305	220	196	179	148	128
700	421	431	459	452	468	481	390	281	251	229	189	164
650	537	549	585	576	596	613	497	358	319	291	241	208
600	682	697	741	729	755	777	631	454	403	367	304	263
550	859	877	931	914	946	976	793	570	504	460	381	330
500	1069	1090	1153	1130	1169	1210	984	707	621	565	471	406
450	1303	1325	1394	1362	1408	1465	1195	856	743	676	566	487
440	1351	1373	1442	1408	1455	1516	1238	886	766	697	585	503
430	1399	1421	1490	1453	1501	1566	1280	915	789	717	603	518
420	1446	1468	1536	1496	1545	1616	1322	944	811	737	621	533
410	1492	1513	1580	1537	1587	1663	1362	972	831	755	637	547
400	1536	1557	1622	1576	1627	1708	1400	998	850	772	653	560
390	1579	1598	1661	1612	1663	1750	1436	1023	866	787	667	572
380	1618	1636	1696	1643	1694	1788	1469	1045	881	798	679	582
370	1655	1671	1727	1670	1721	1821	1499	1065	891	806	689	590
360	1687	1701	1752	1691	1742	1849	1525	1081	897	810	696	596
350	1714	1726	1771	1705	1756	1871	1545	1094	898	807	700	599
340	1736	1745	1783	1712	1761	1885	1560	1102	892	796	700	600
330	1751	1756	1785	1707	1754	1887	1566	1103	878	775	692	595
320	1757	1758	1773	1688	1733	1874	1562	1093	850	741	673	583
310	1750	1744	1745	1651	1694	1841	1542	1071	810	693	643	562
300	1725	1709	1696	1594	1632	1783	1501	1034	753	629	600	529
290	1678	1648	1624	1516	1548	1700	1432	977	680	554	545	485
280	1607	1562	1531	1420	1444	1592	1335	902	590	468	476	429
270	1512	1455	1419	1308	1325	1461	1212	809	485	373	396	361
260	1394	1324	1290	1184	1192	1307	1057	701	375	275	308	286
250	1259	1178	1150	1049	1047	1136	871	578	268	182	223	212
240	1115	1030	1001	919	899	953	659	450	175	105	153	145
230	971	887	860	792	762	772	425	322	105	51.7	95.0	88.3
220	836	754	732	678	638	599	204	213	57.2	24.3	50.9	47.3
210	717	642	623	581	530	454	43.0	127	26.9	9.4	23.1	20.9
200	612	548	532	496	439	343	2.3	60.5	8.6	3.9	5.0	5.9
190	520	472	455	424	364	262		18.6	1.6	.3	.5	.3
180	441	407	391	361	303	204		5.4				
170	374	351	336	306	254	165		3.9				
160	316	302	288	261	214	138		3.2				
150	267	260	248	224	182	119		2.7				
140	228	223	215	195	158	106		2.5				
130	197	194	192	174	142	98.4		1.9				
120	178	177	176	162	132	91.3						
110	109	96.3	79.0	76.5	59.4	31.6						

JANUARY 1960
0000 75°W TIME



JANUARY 1960
0100 75° W TIME



JANUARY 1960
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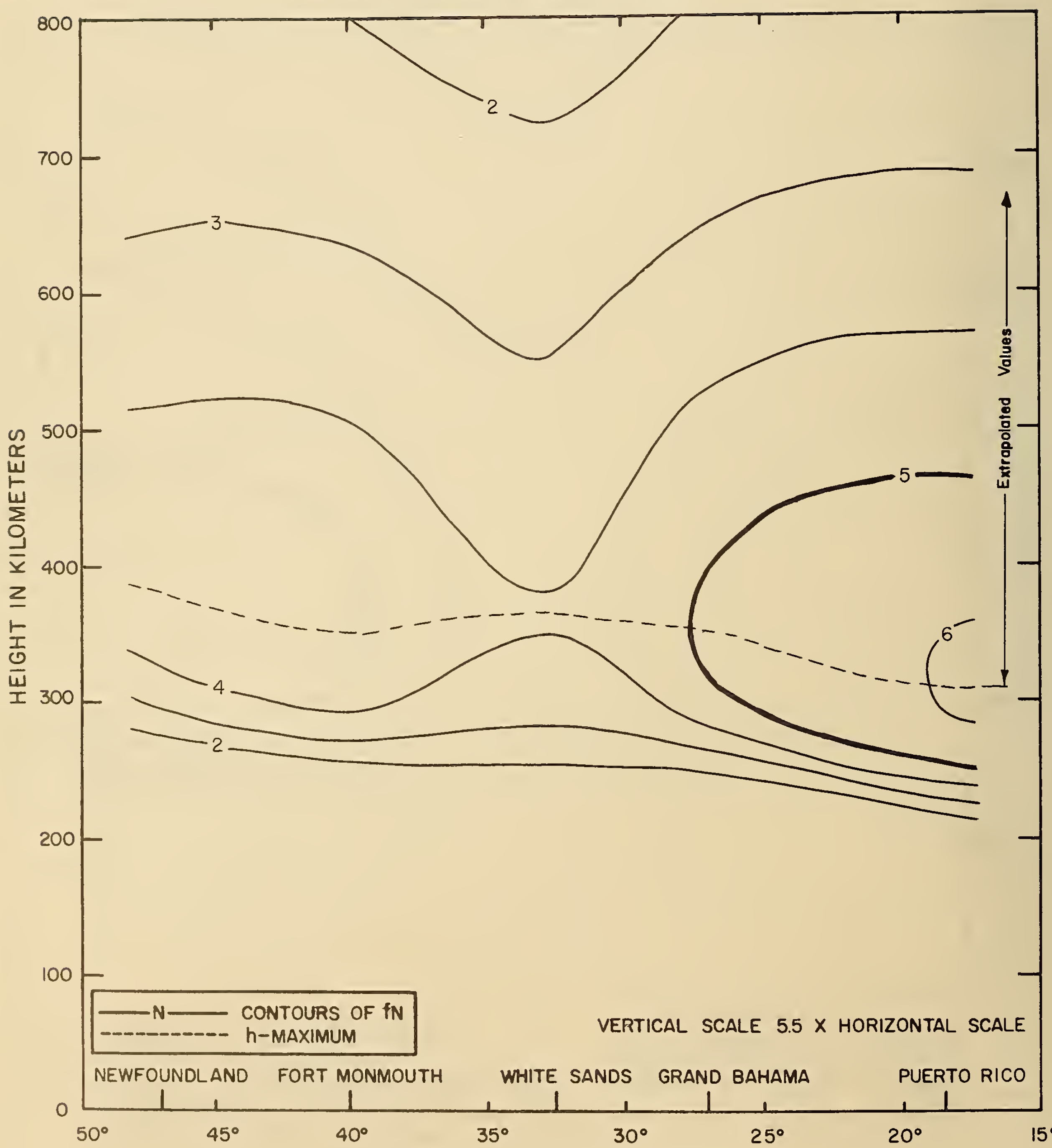
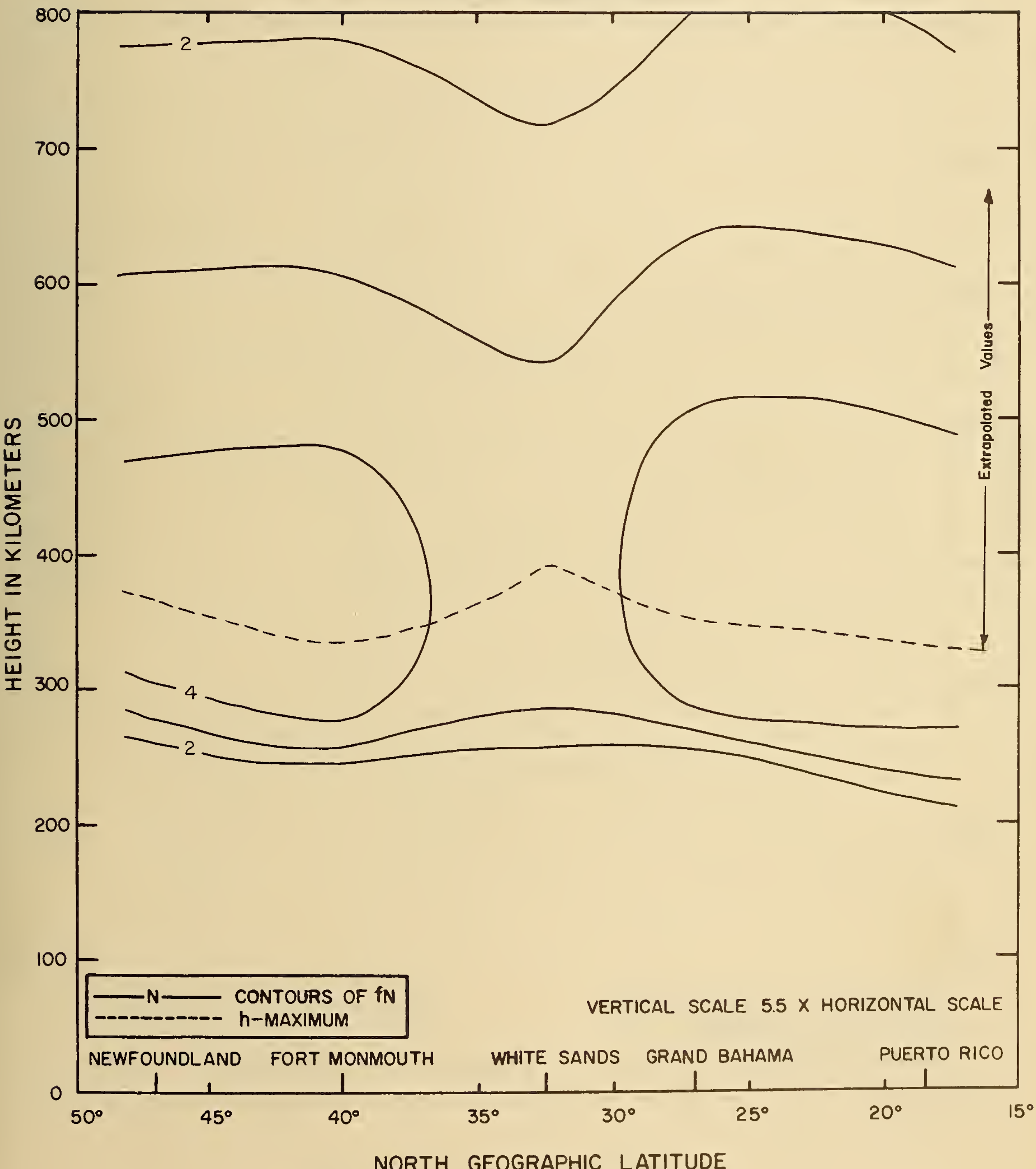


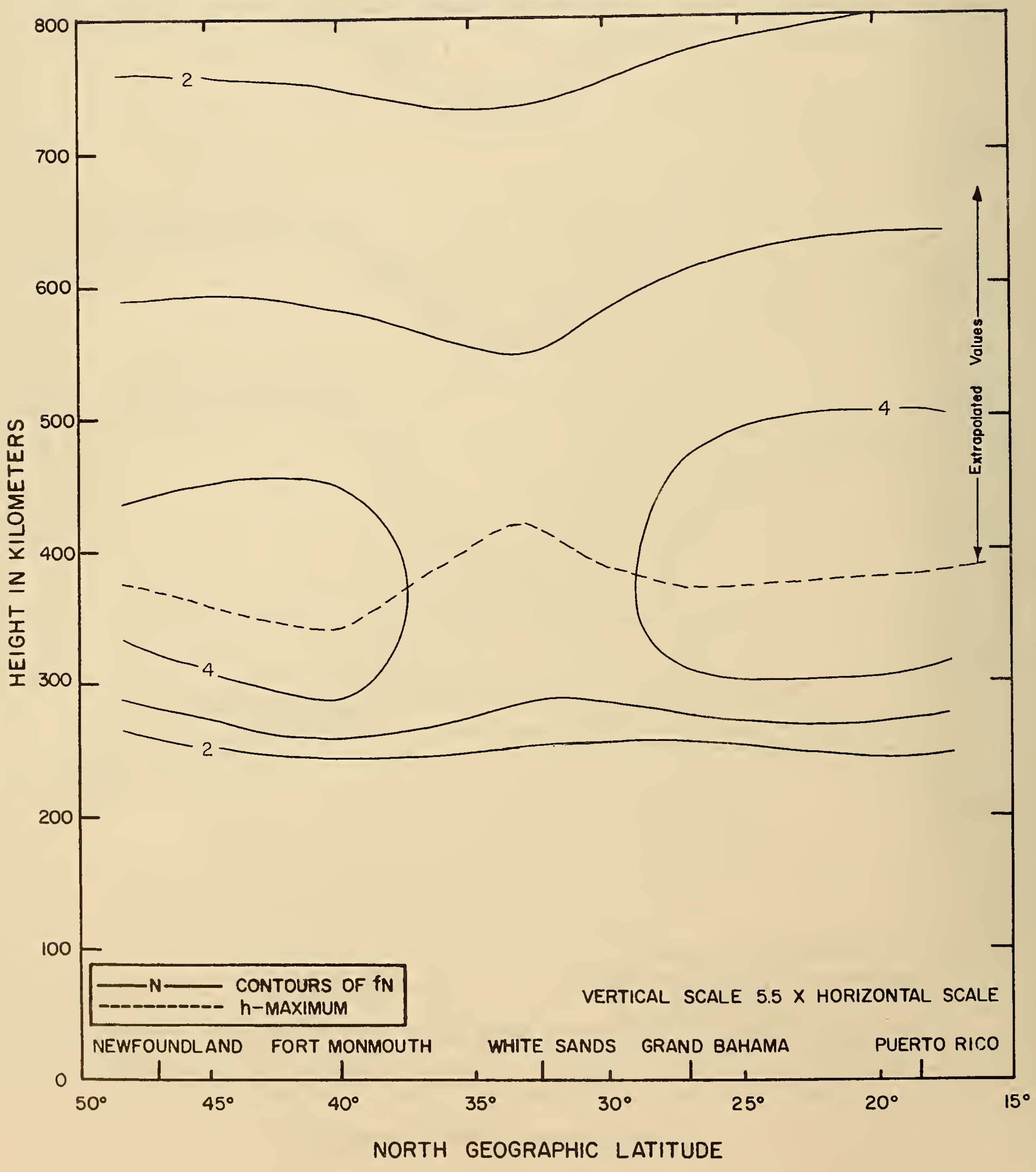
JANUARY 1960

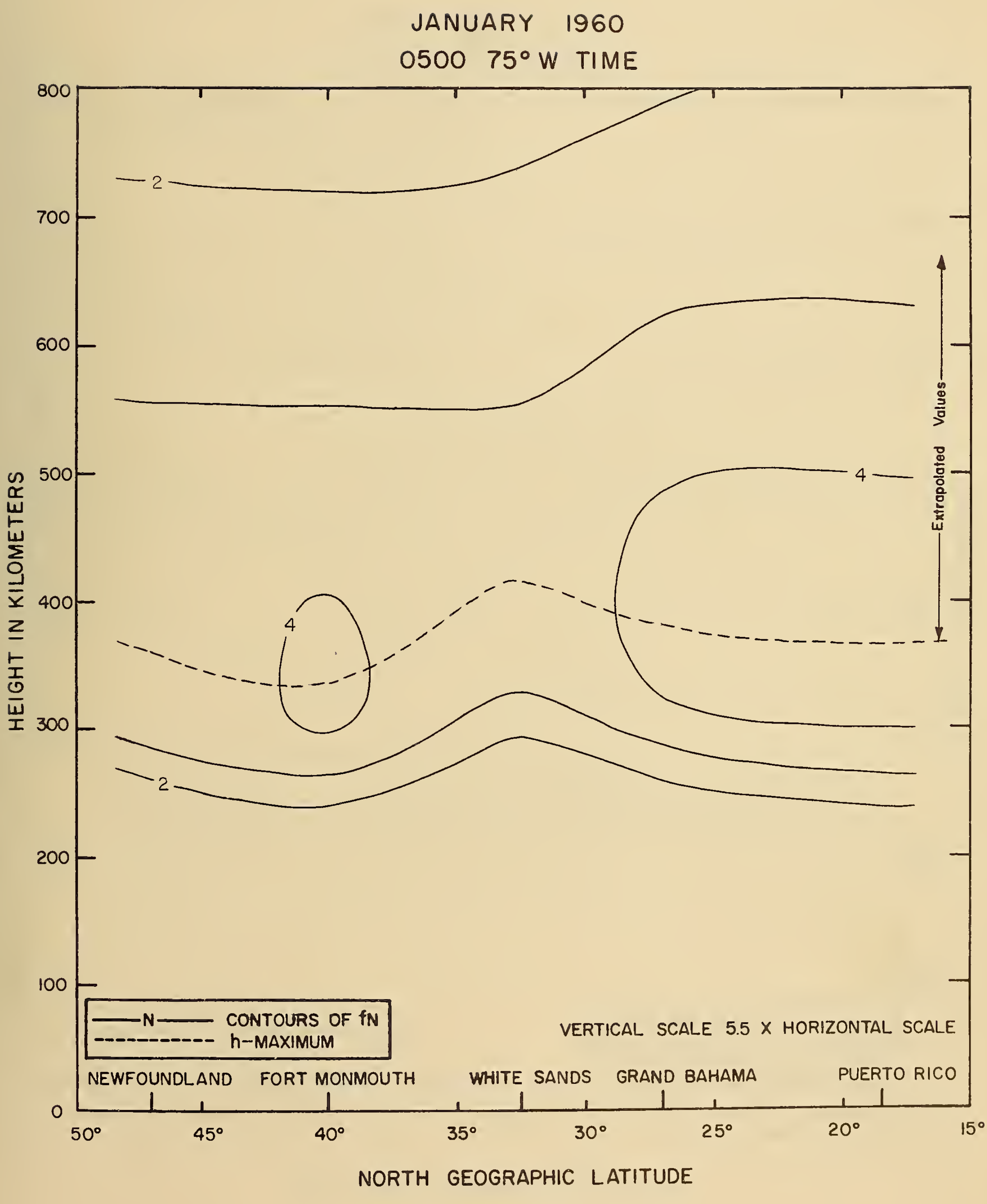
0300 75°W TIME



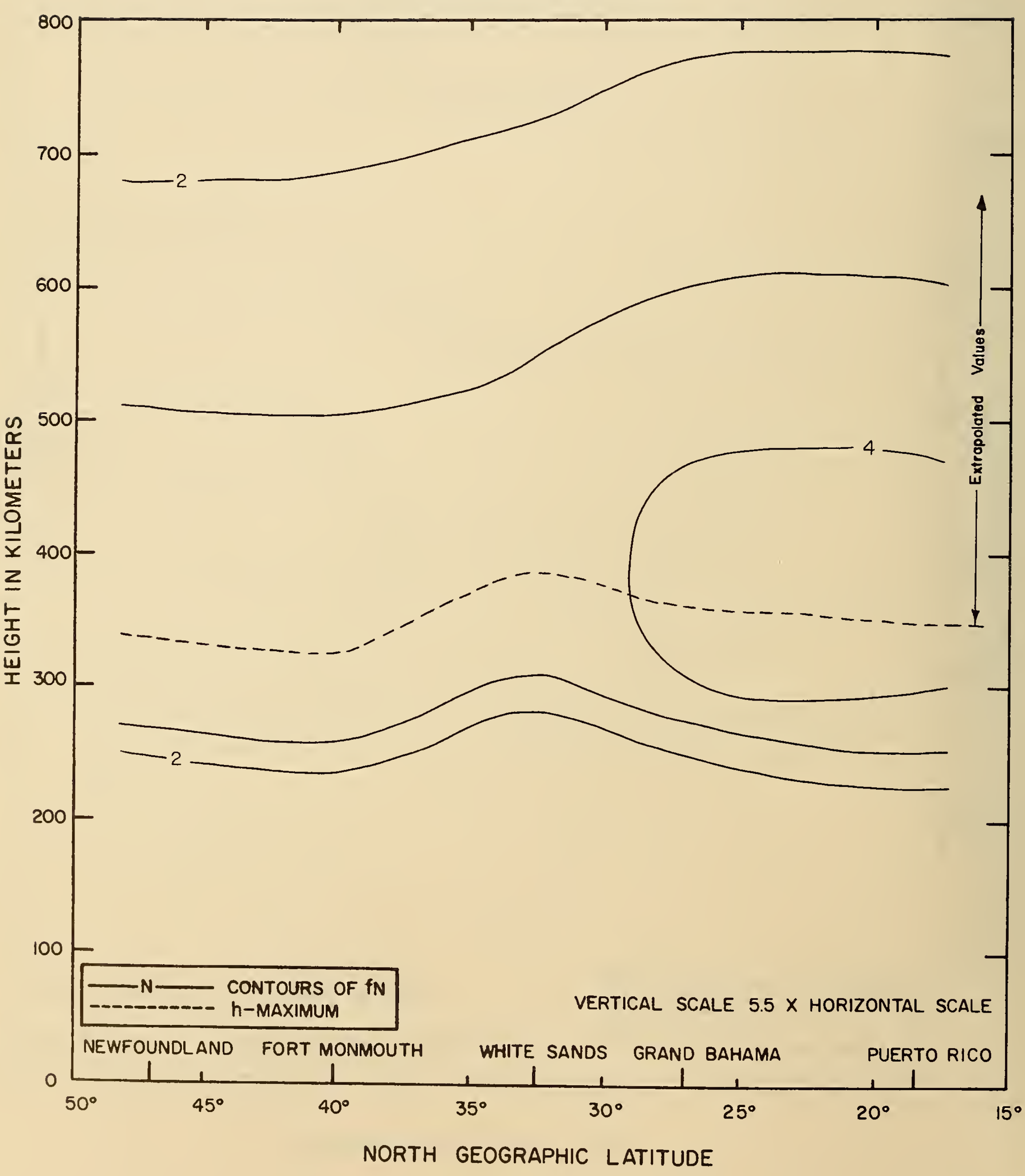
JANUARY 1960

0400 75°W TIME



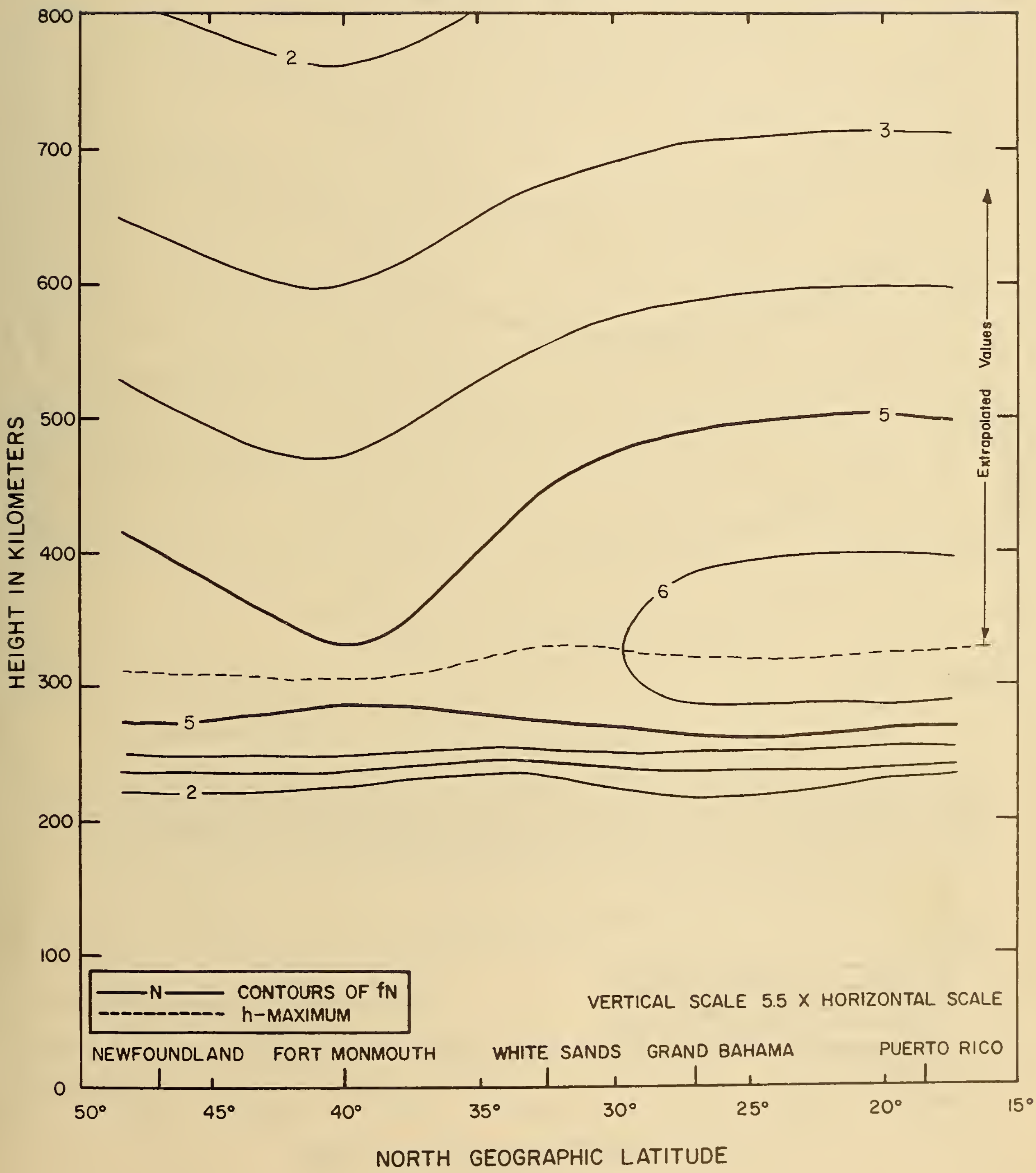

JANUARY 1960
0500 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
2
4
Extrapolated Values
CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

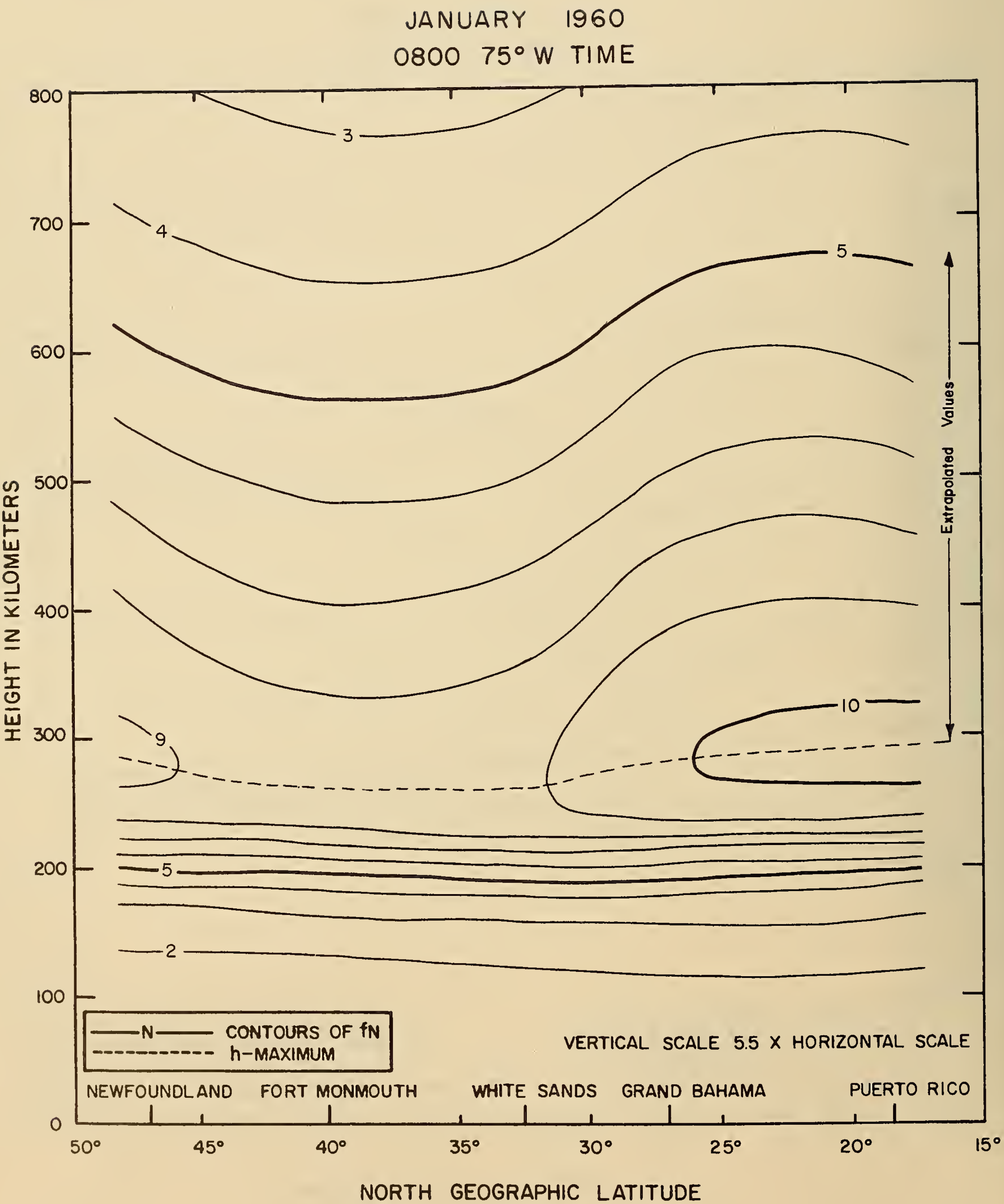
JANUARY 1960
0600 75° W TIME



JANUARY 1960

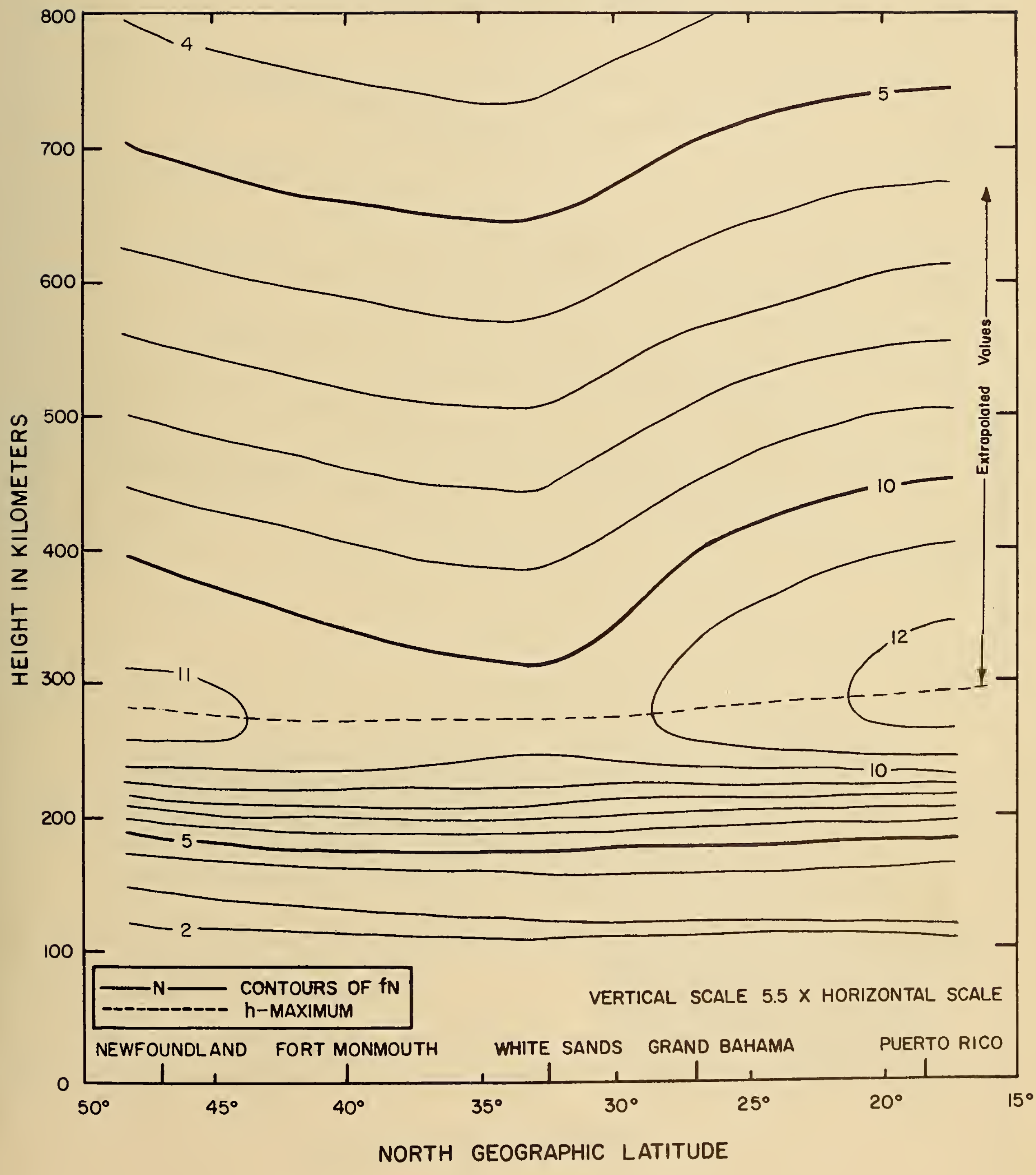
0700 75° W TIME




JANUARY 1960
0800 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
4
5
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

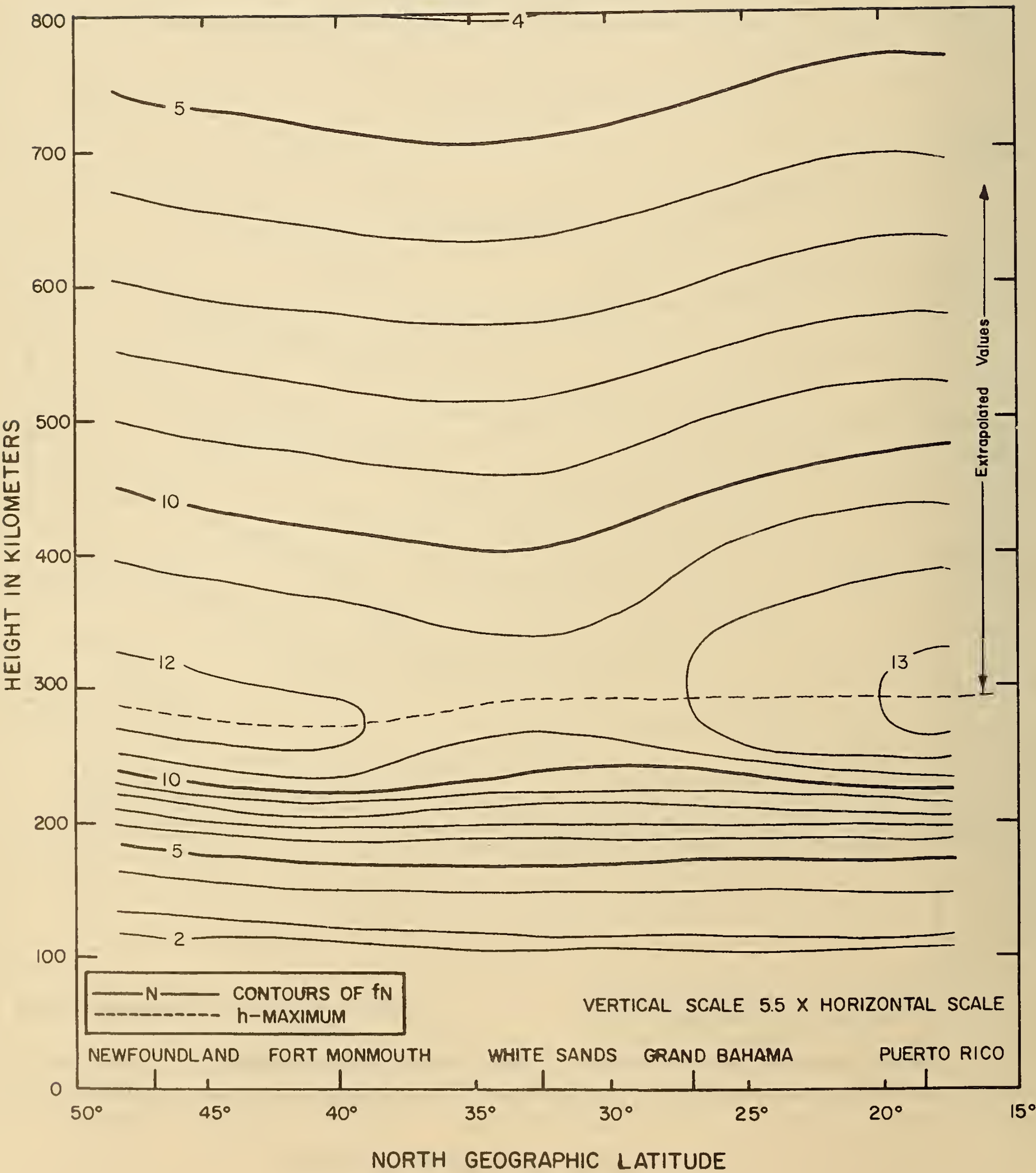
JANUARY 1960

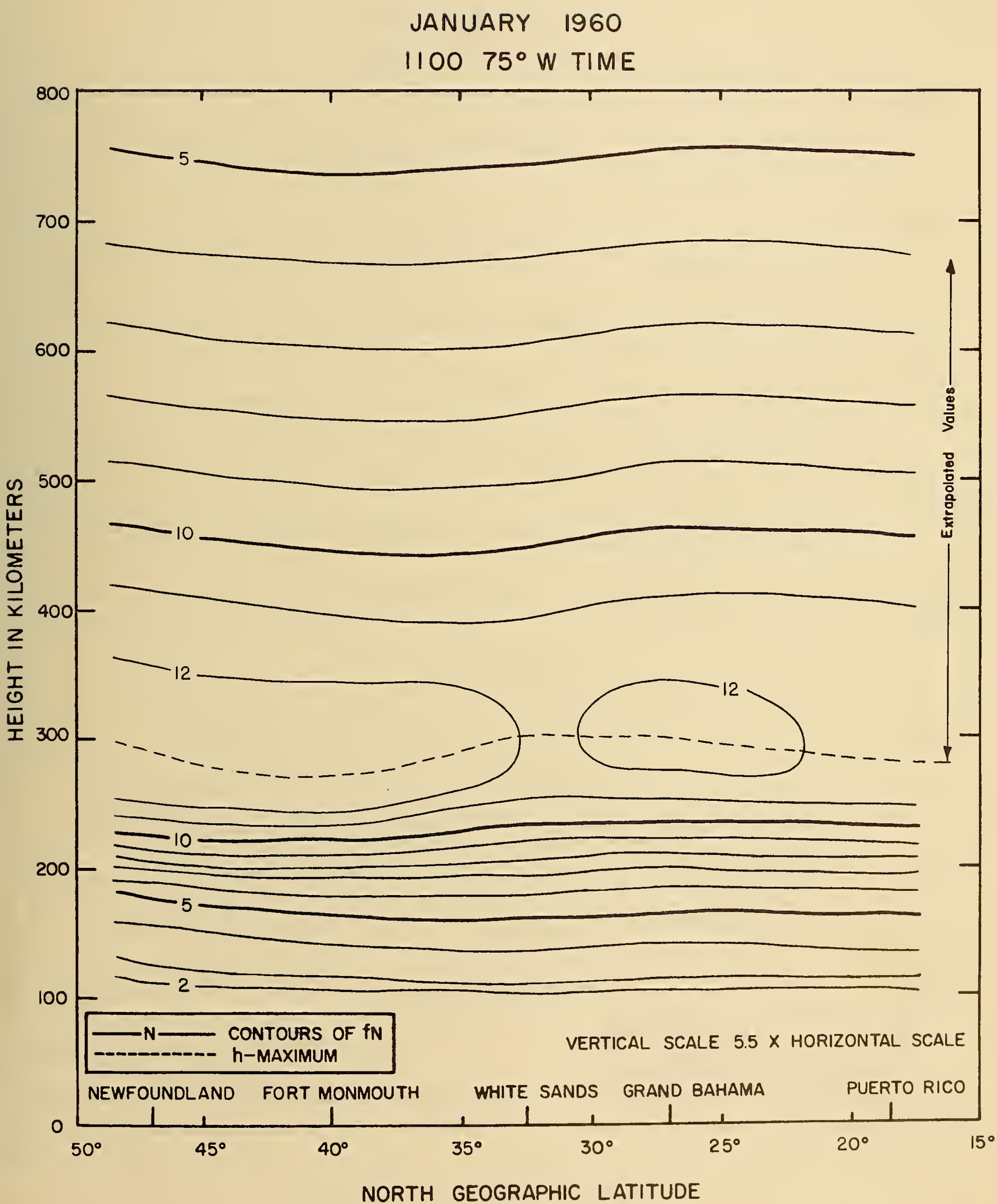
0900 75° W TIME



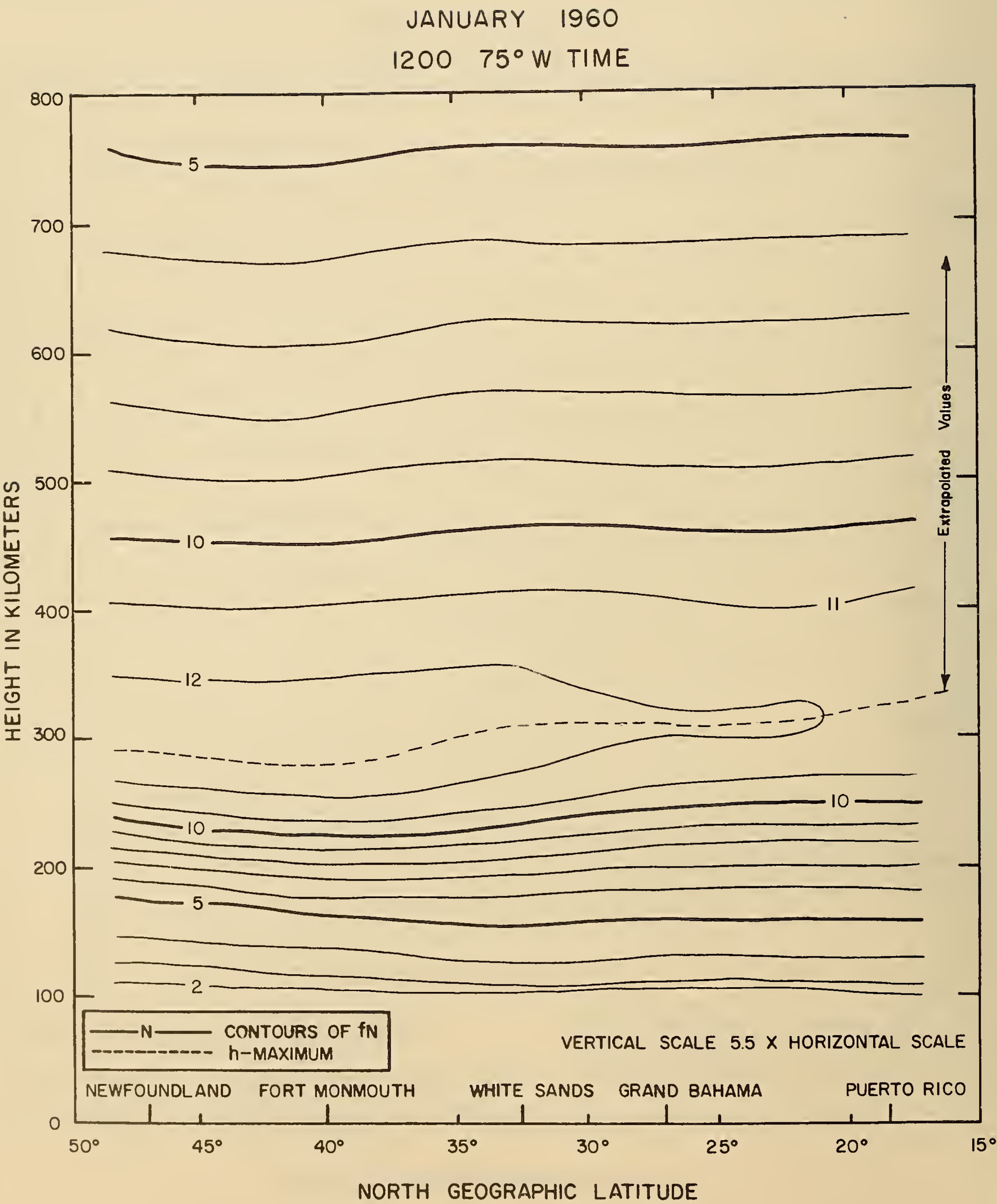
JANUARY 1960

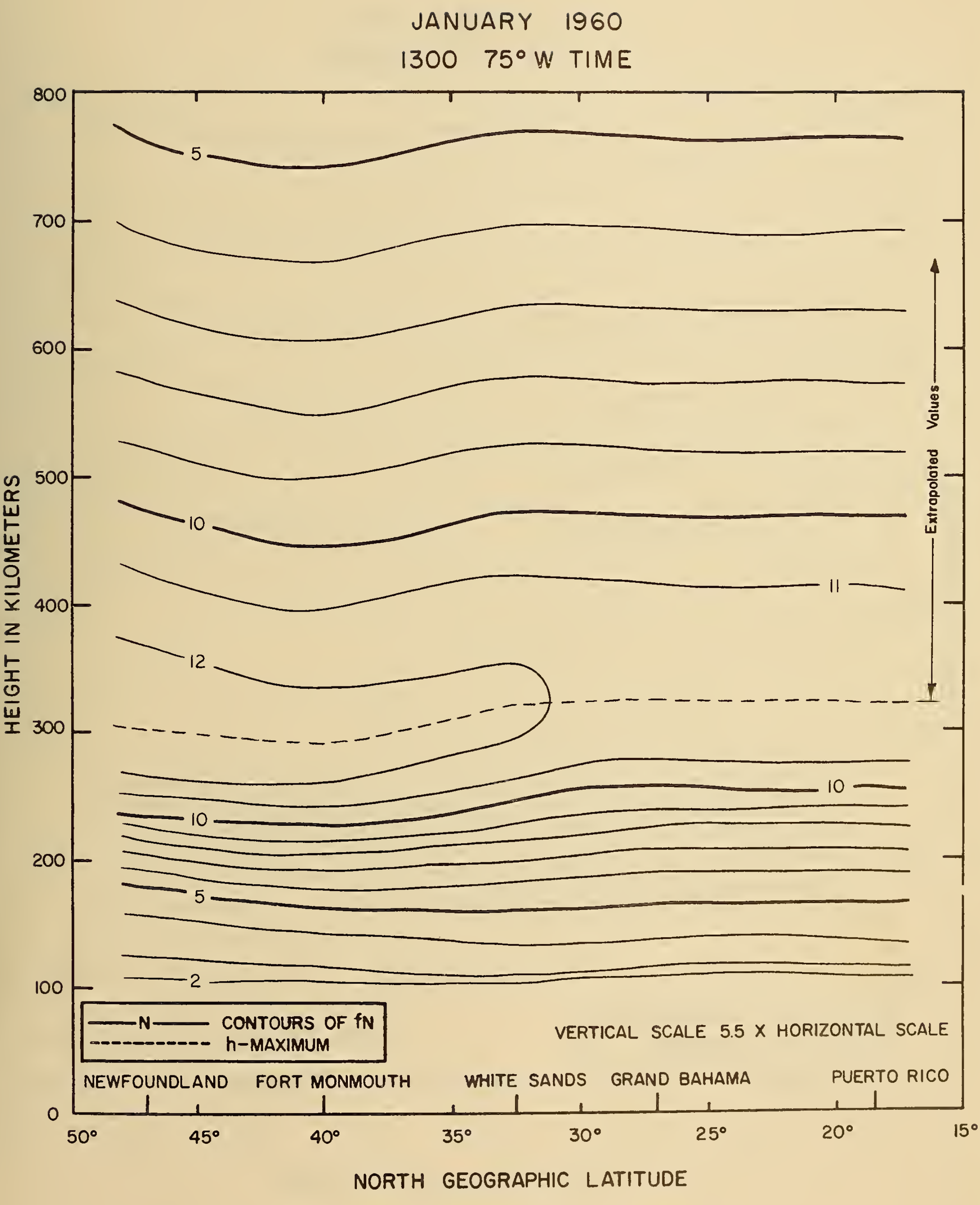
1000 75° W TIME



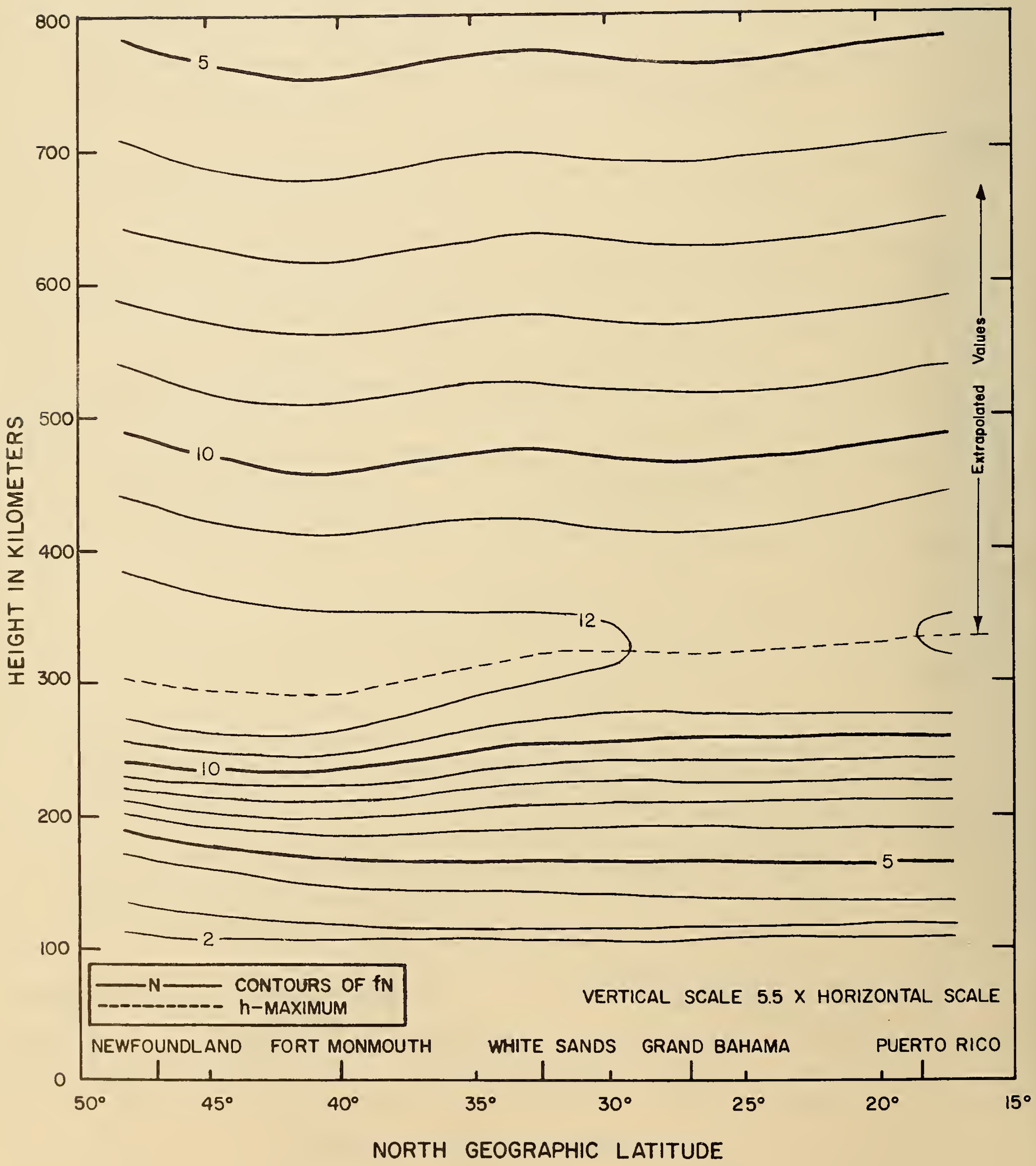


JANUARY 1960
1100 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
5
10
12
12
10
5
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE


JANUARY 1960
1200 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
5
10
11
12
10
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

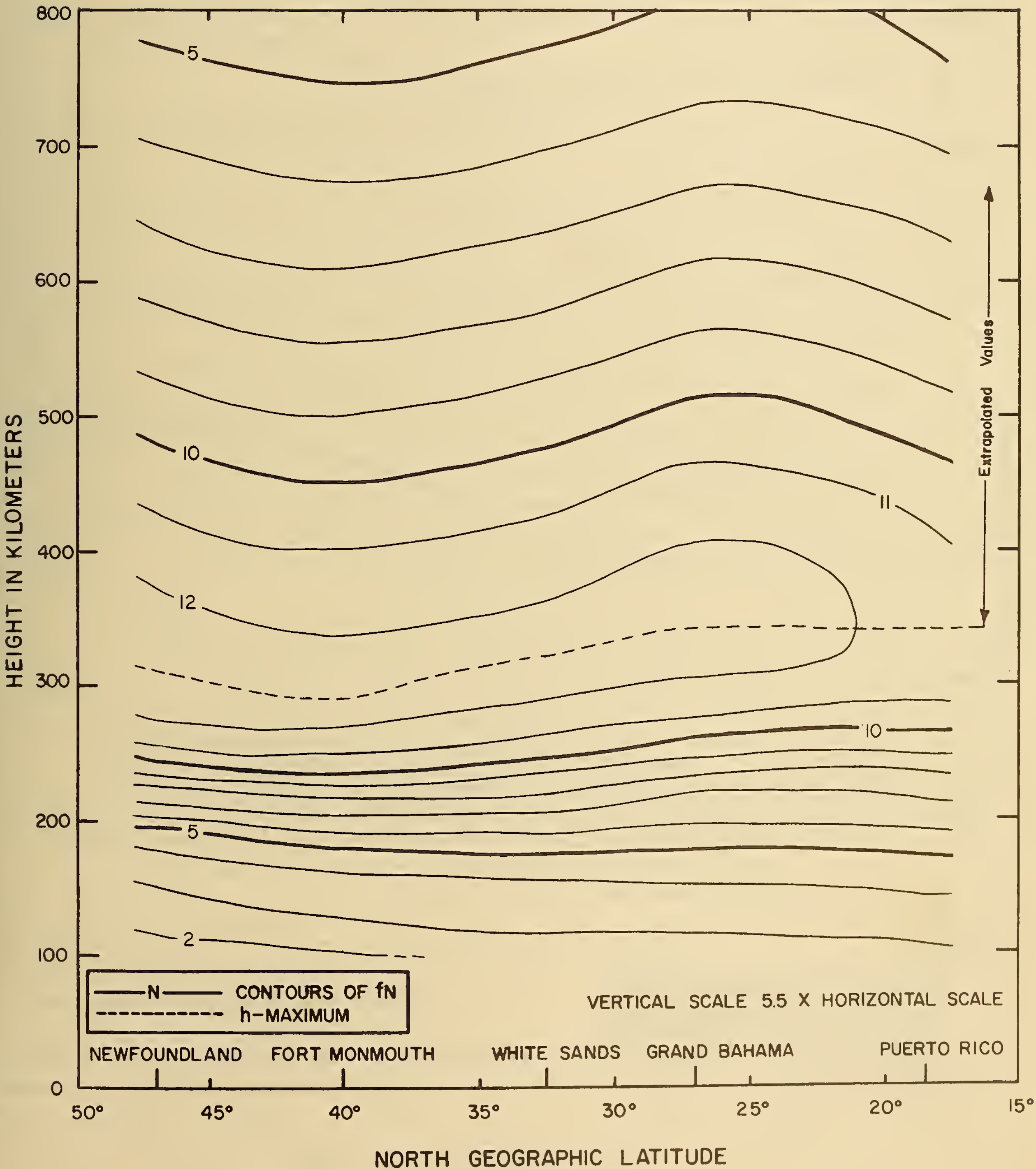

JANUARY 1960
1300 75° W TIME
800
700
600
500
400
300
200
100
0
HEIGHT IN KILOMETERS
5
10
11
12
10
10
5
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC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

JANUARY 1960
1400 75°W TIME

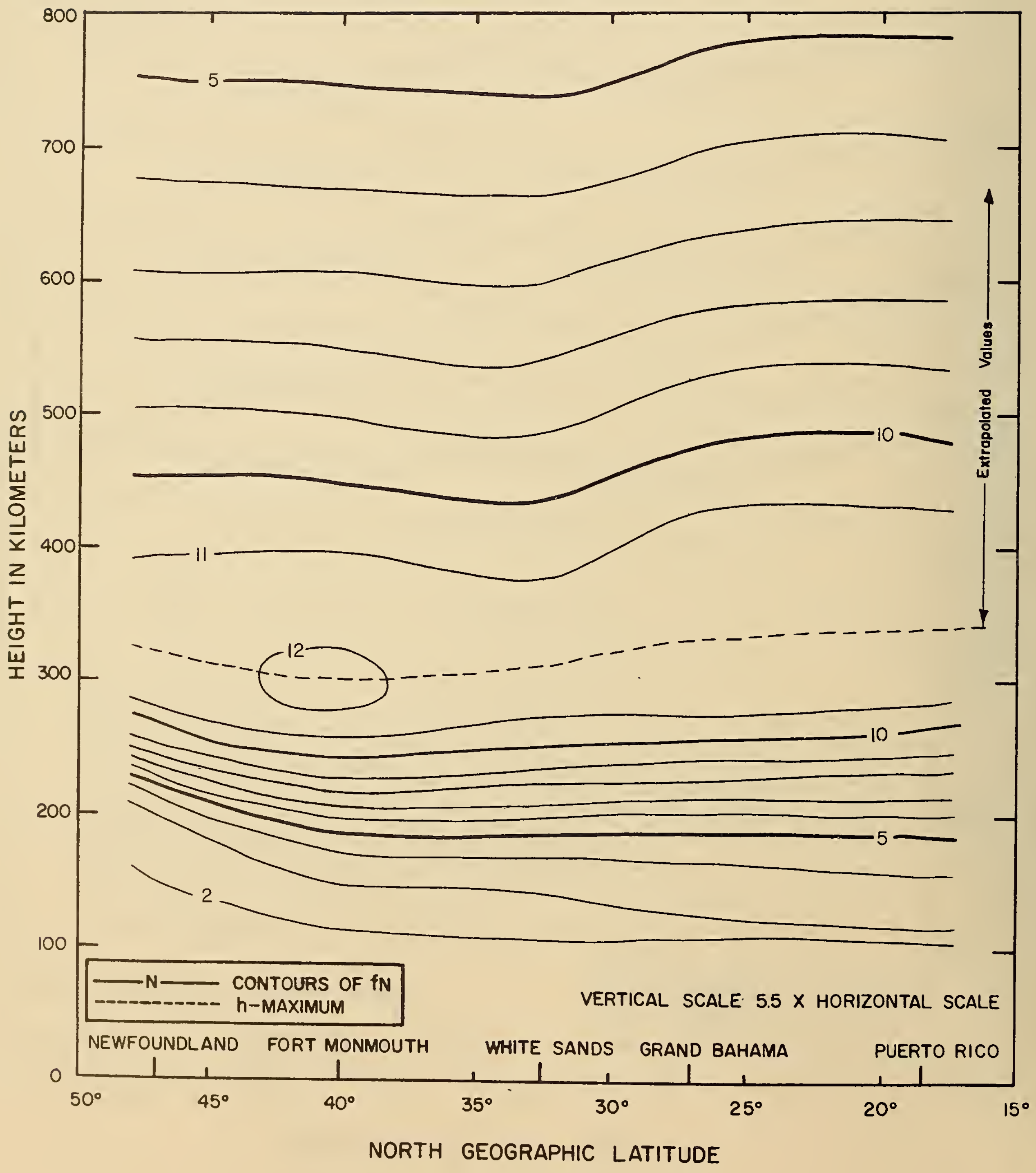


JANUARY 1960

1500 75° W TIME

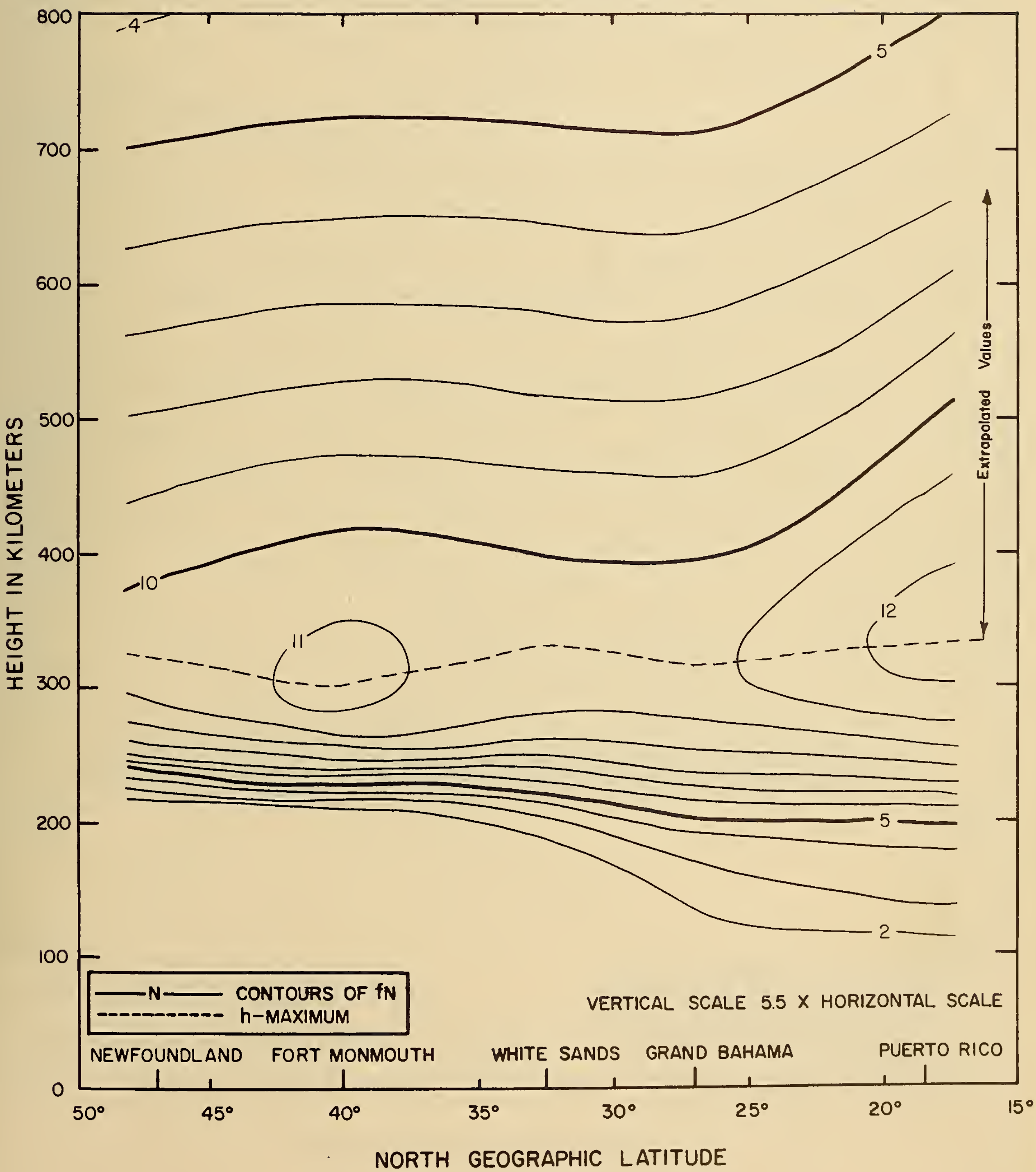


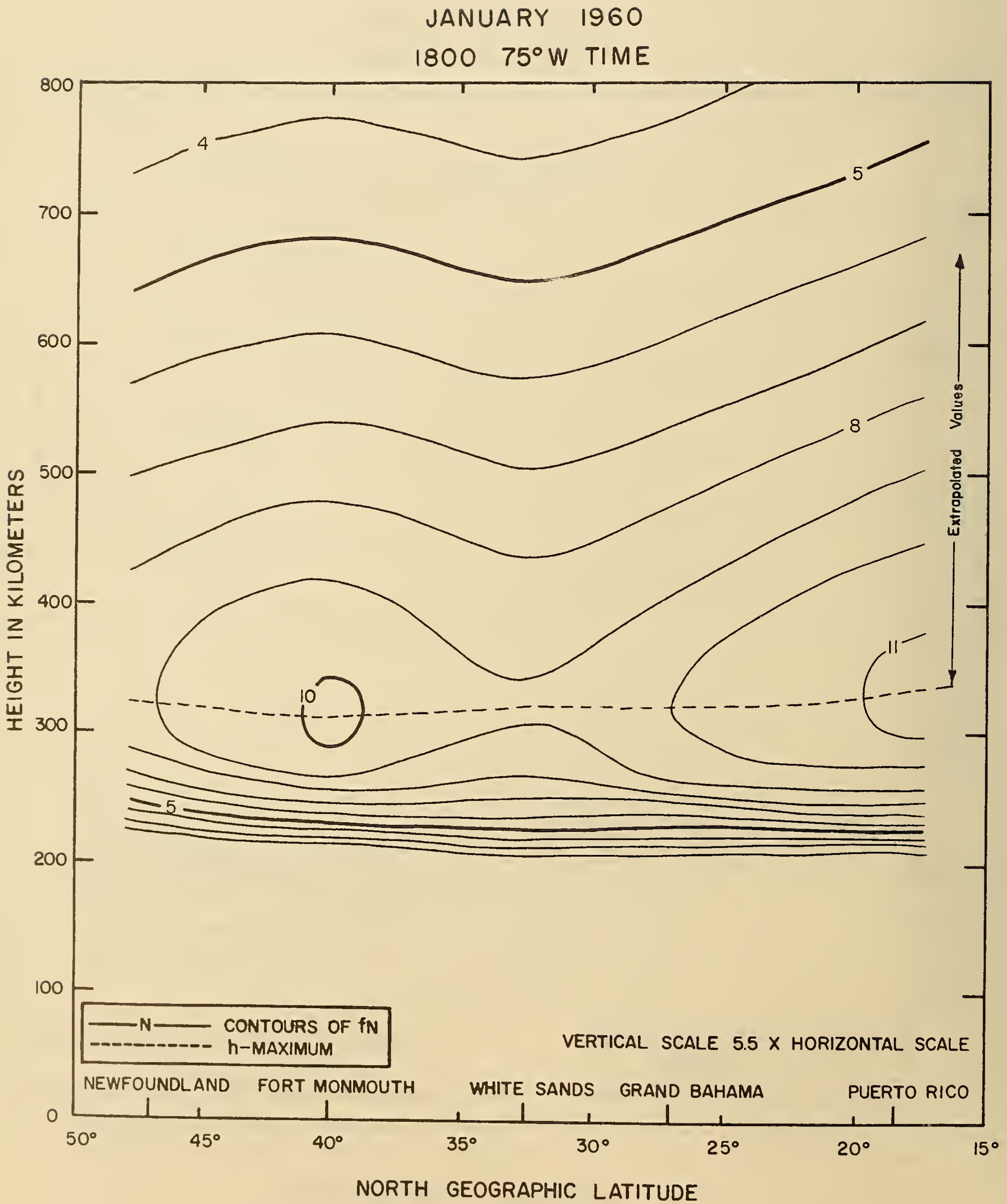
JANUARY 1960
1600 75° W TIME



JANUARY 1960

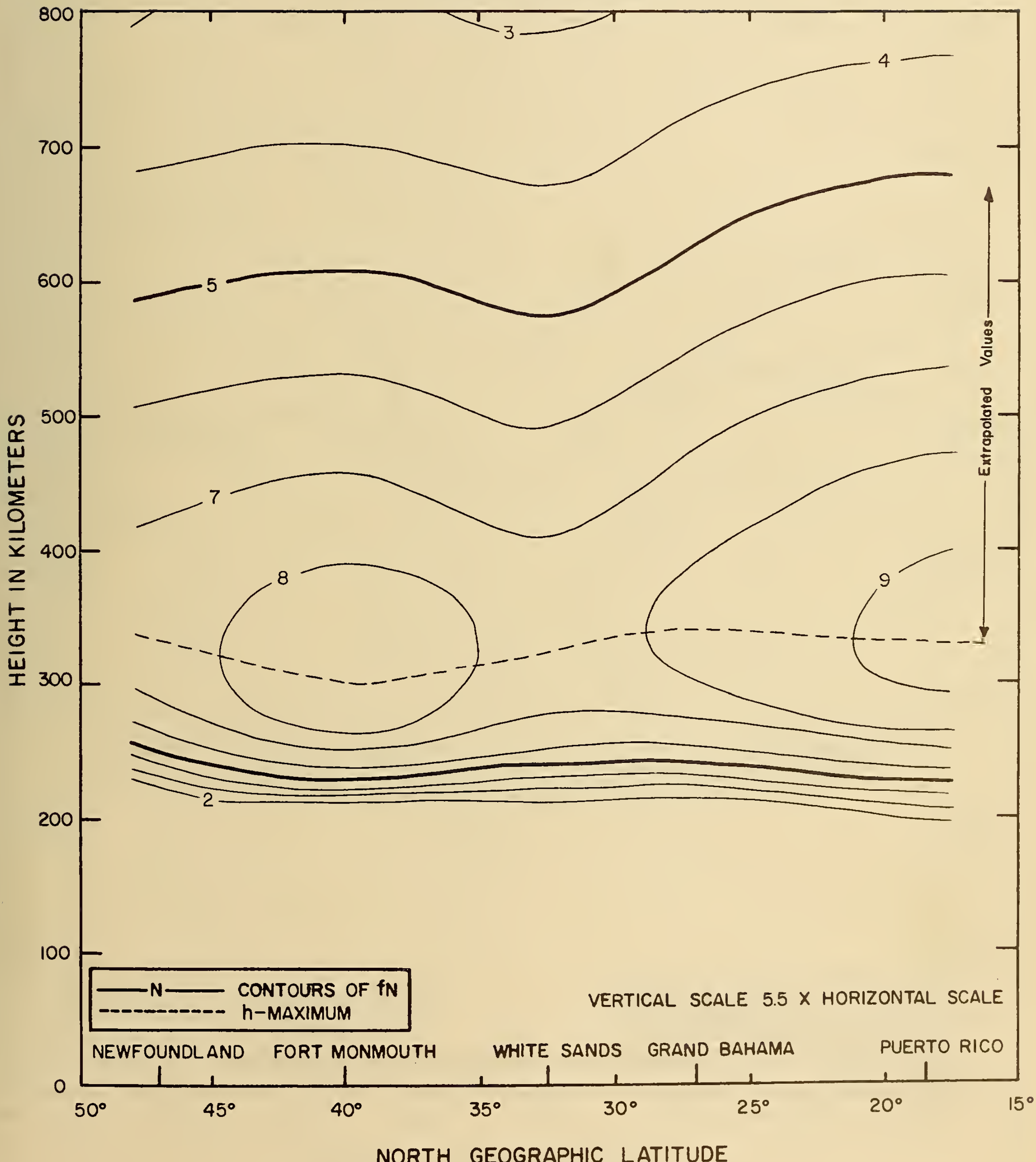
1700 75° W TIME

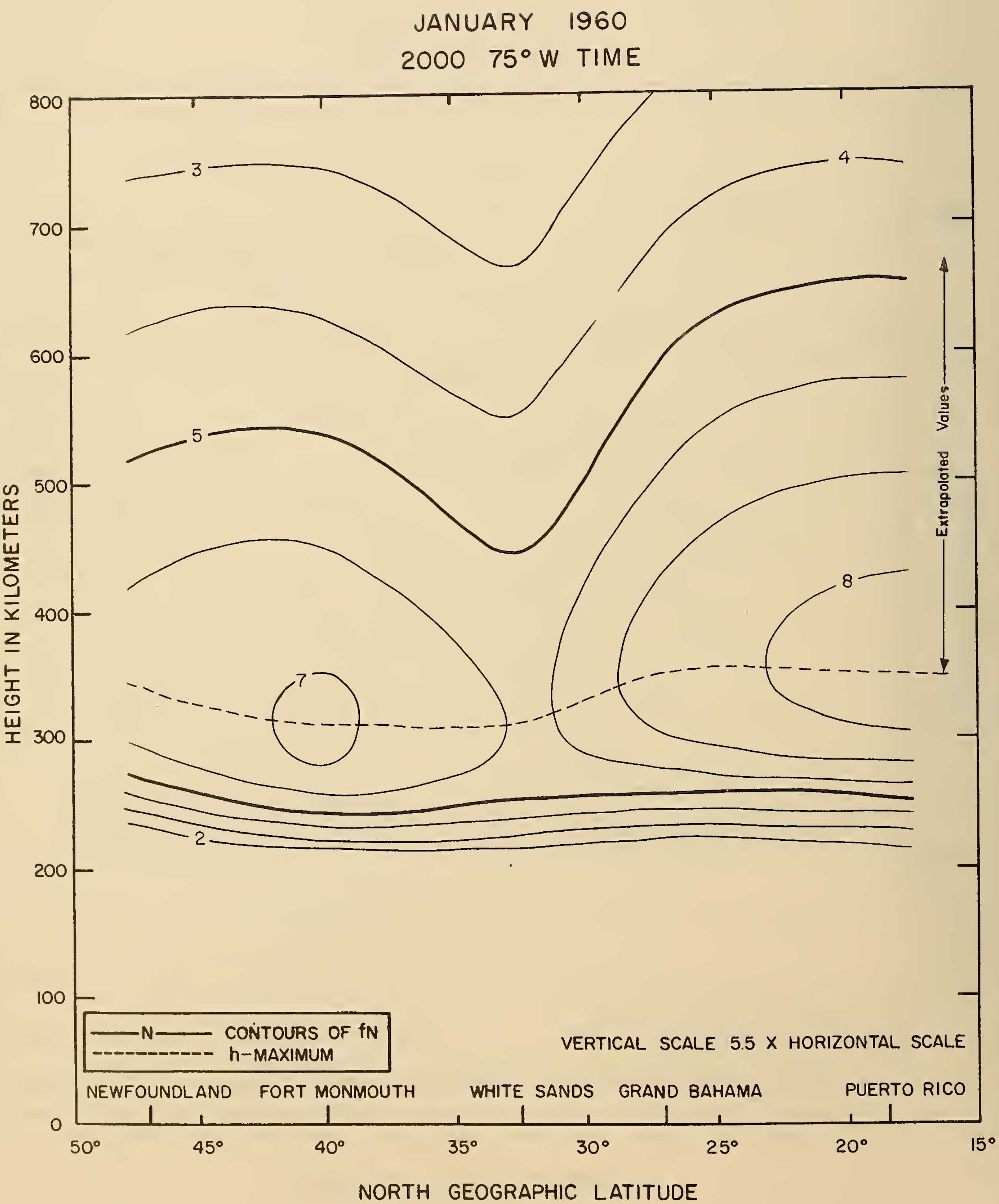



JANUARY 1960
1800 75°W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
4
5
8
10
11
5
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

JANUARY 1960

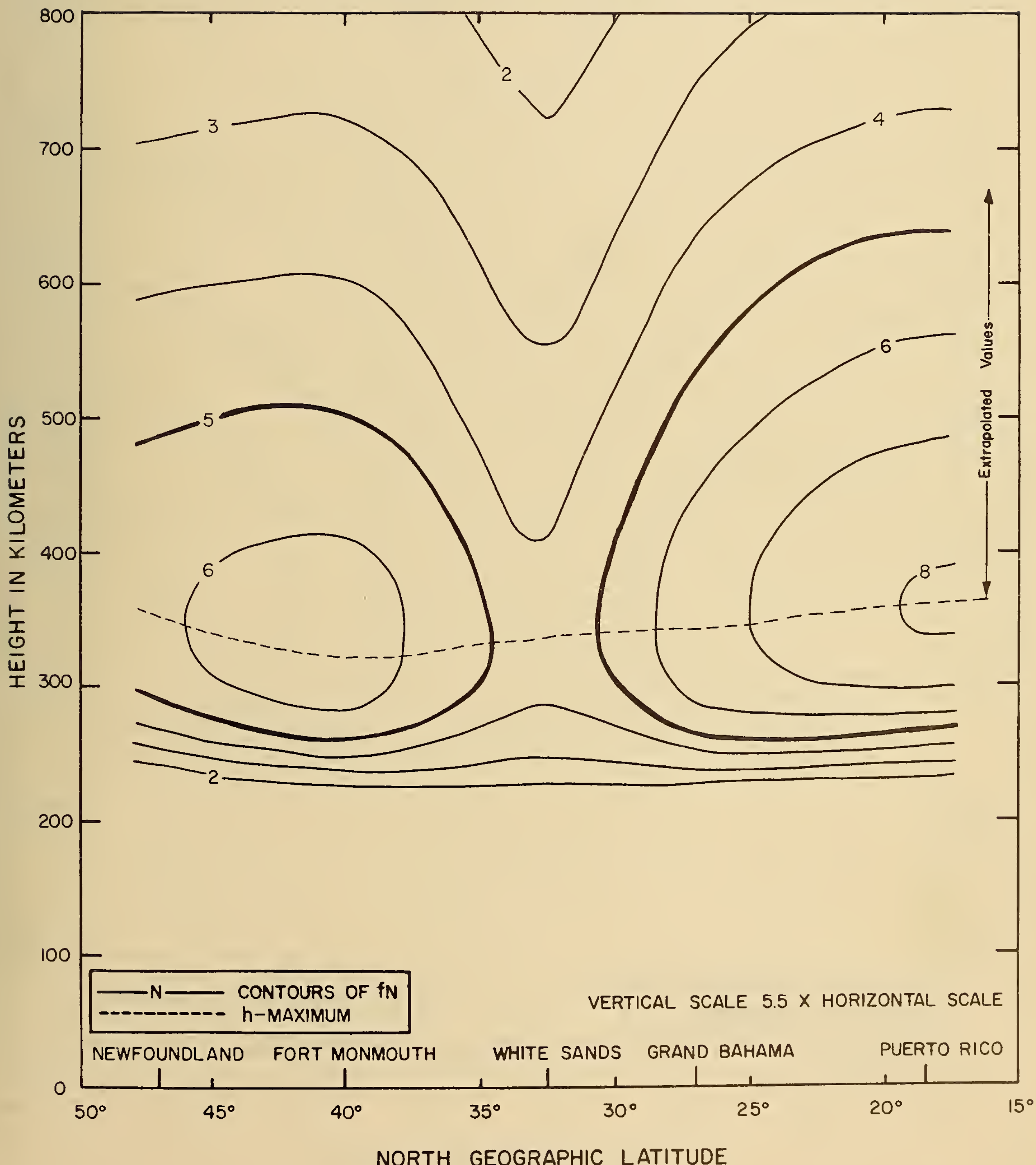
1900 75°W TIME

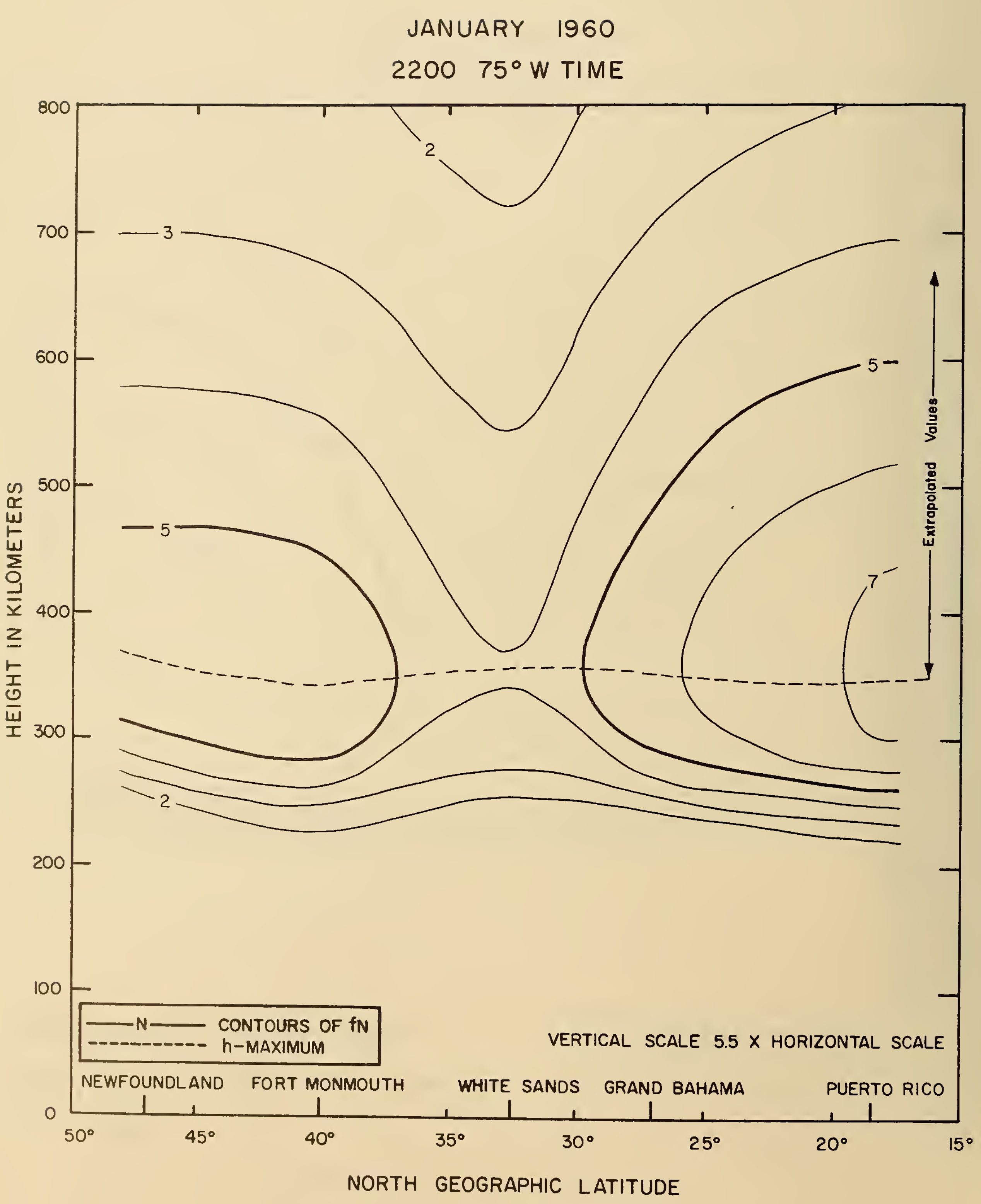


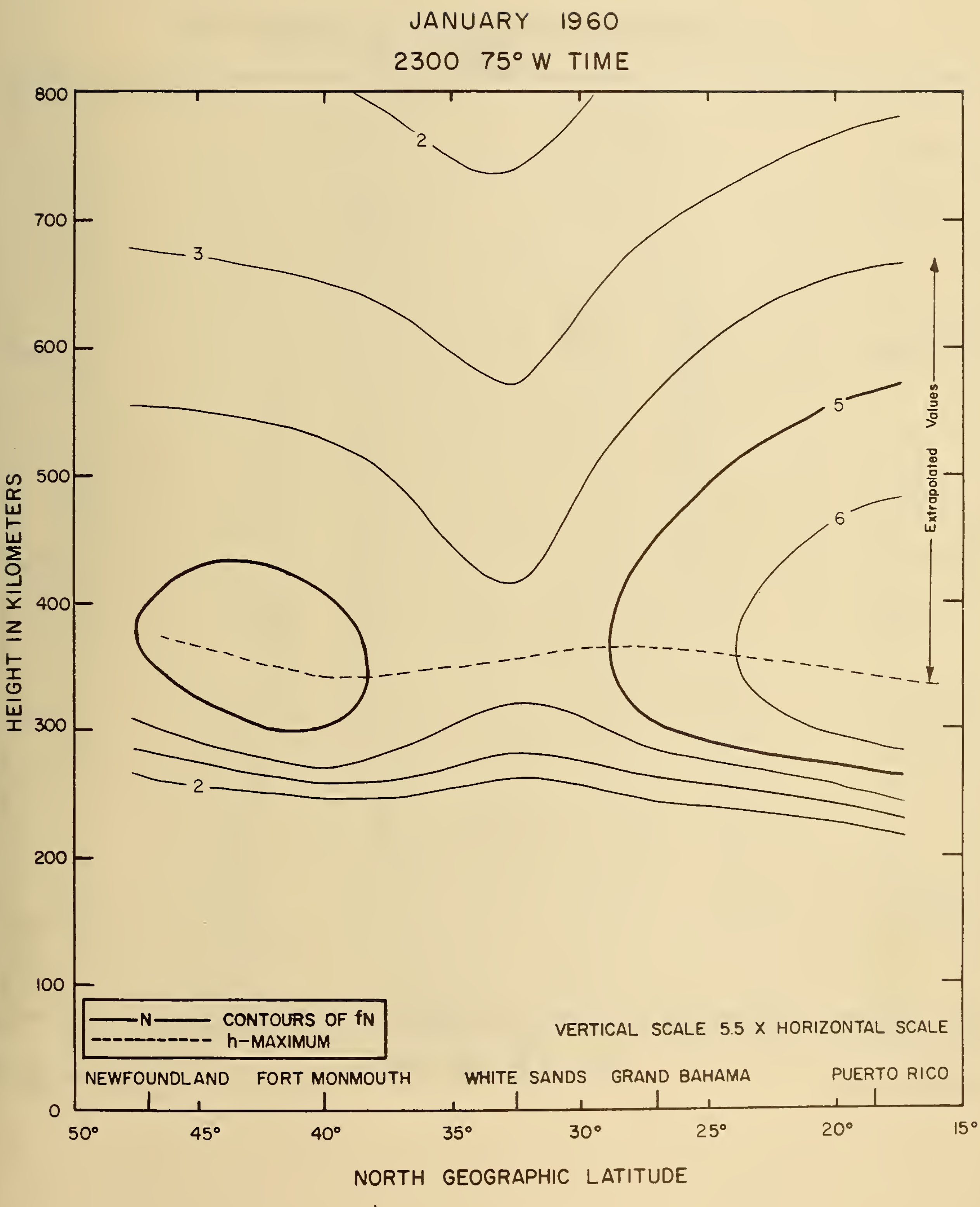

JANUARY 1960
2000 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
4
5
7
8
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

JANUARY 1960

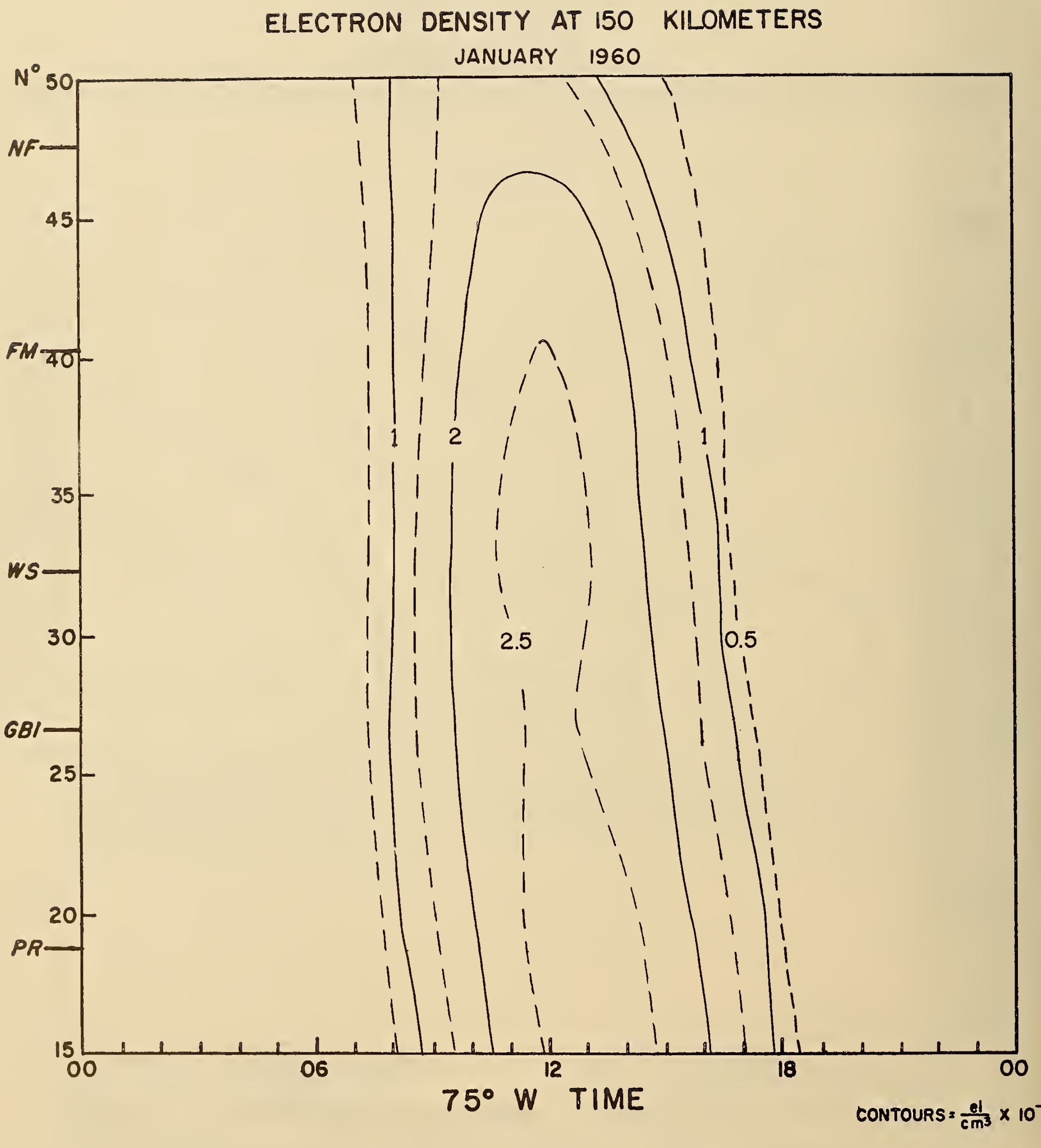
2100 75° W TIME

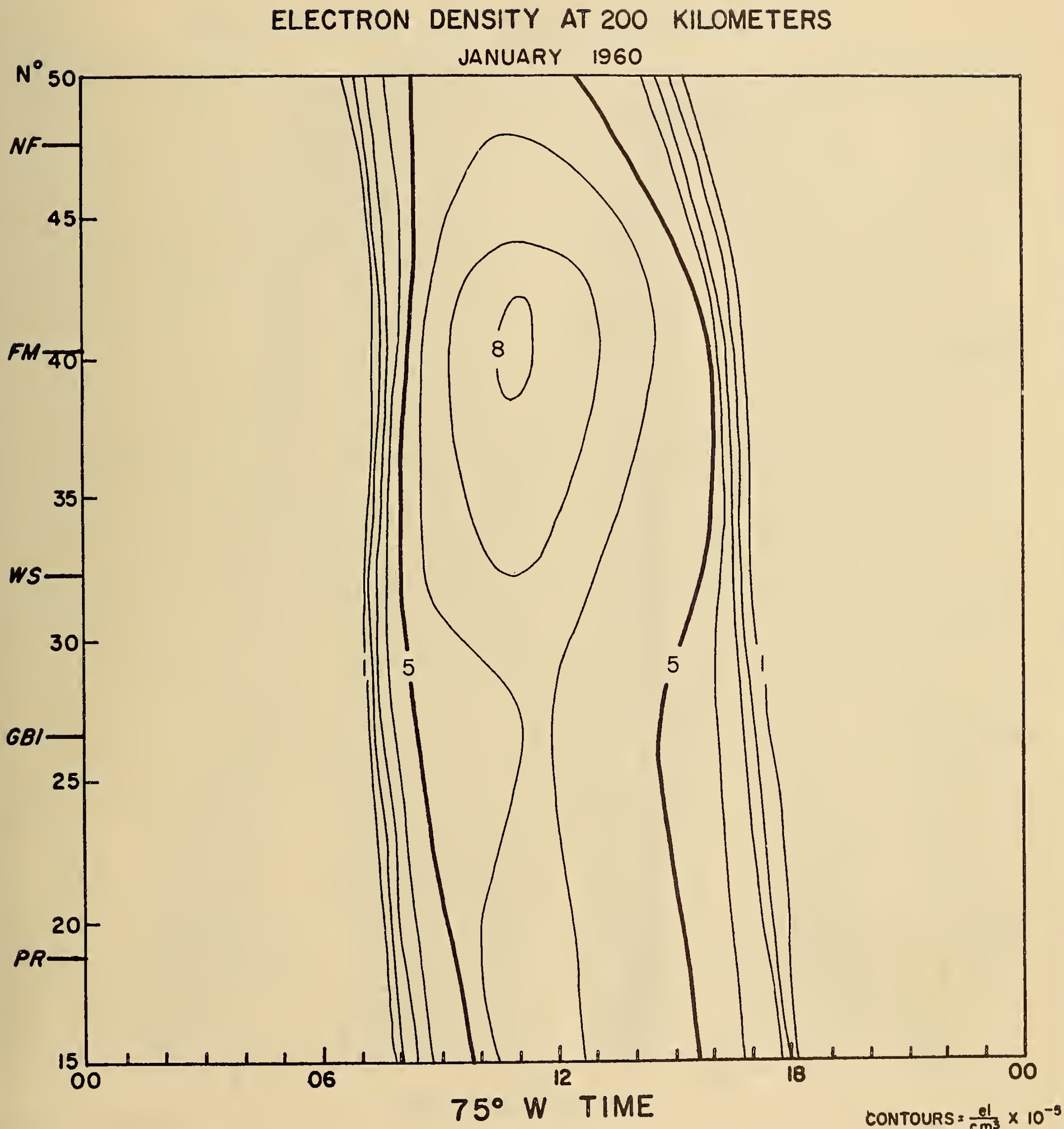


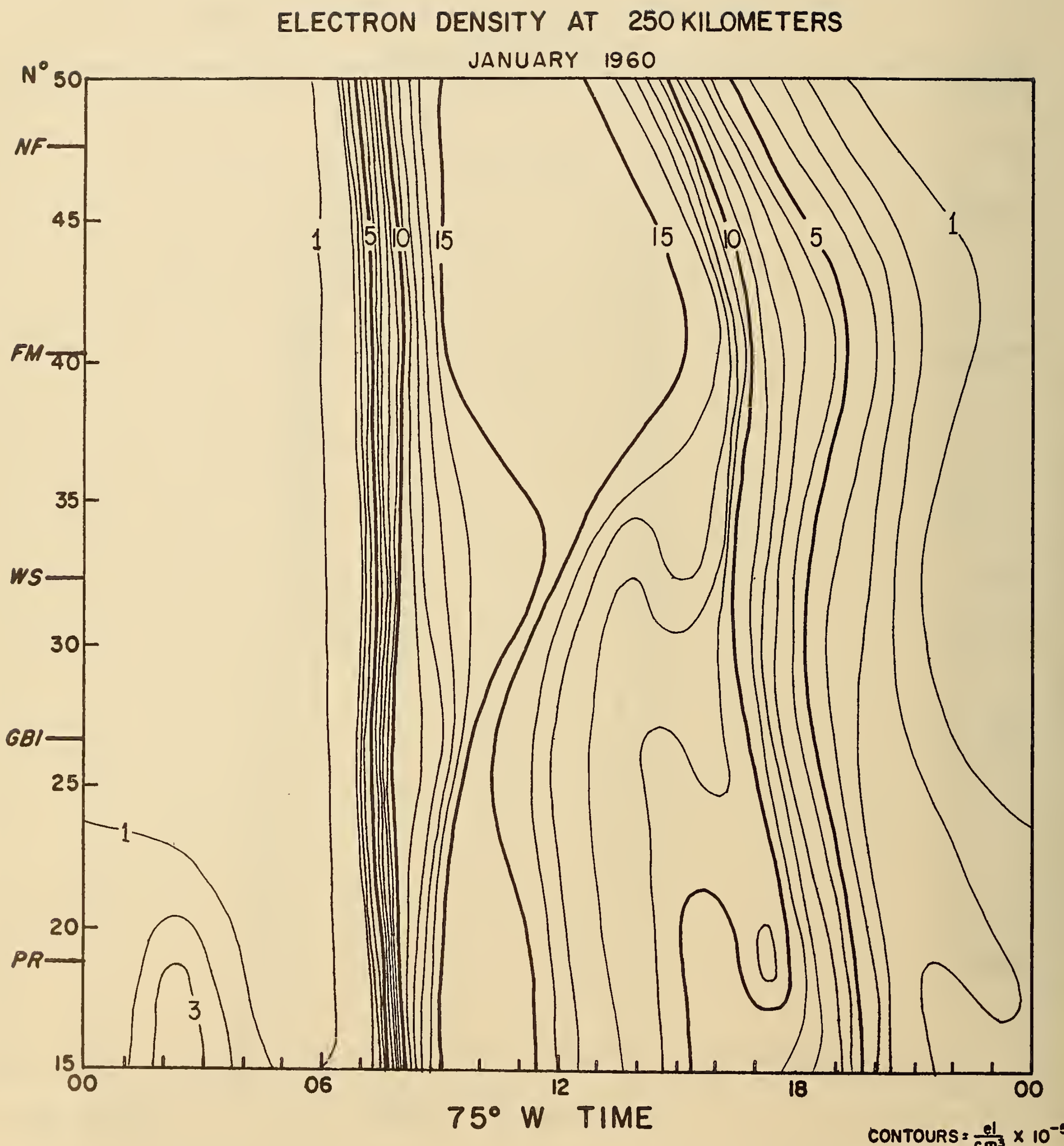

JANUARY 1960
2200 75° W TIME
800
700
600
500
400
300
200
100
0
HEIGHT IN KILOMETERS
2
3
5
5
7
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE



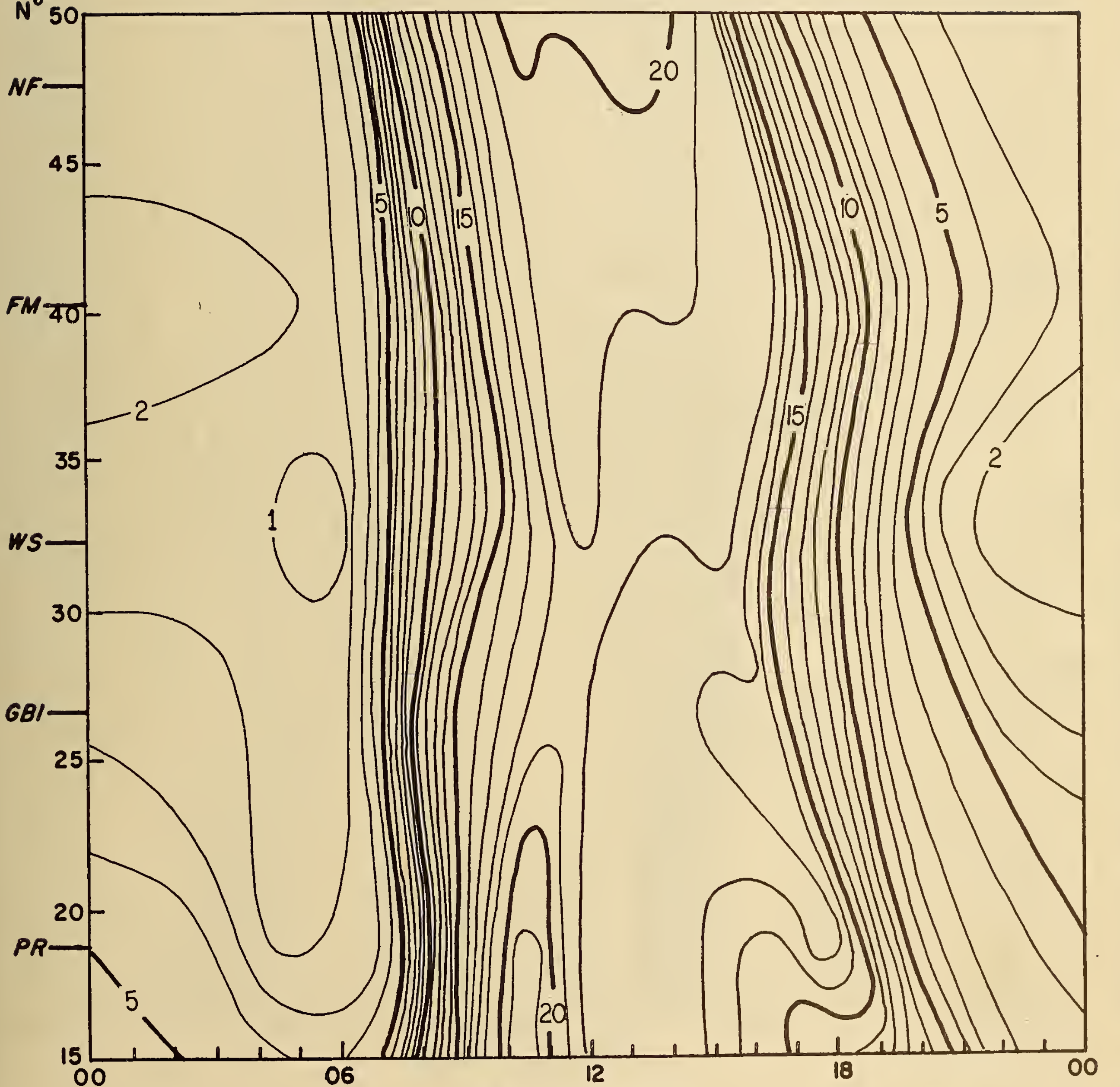
JANUARY 1960
2300 75° W TIME
800
700
600
500
400
300
200
100
0
HEIGHT IN KILOMETERS
2
3
5
6
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE


ELECTRON DENSITY AT 150 KILOMETERS
JANUARY 1960
N°
50
NF
45
FM
40
35
WS
30
GBI
25
20
PR
15
00
06
12
18
00
75° W TIME
1
2
2.5
1
0.5
CONTOURS = el/cm3 X 10


ELECTRON DENSITY AT 200 KILOMETERS
JANUARY 1960
N°
50
NF
45
FM
40
35
WS
30
GBI
25
20
PR
15
8
1
5
5
1
00
06
12
18
00
75° W TIME
CONTOURS = el/cm³ x 10⁻⁵

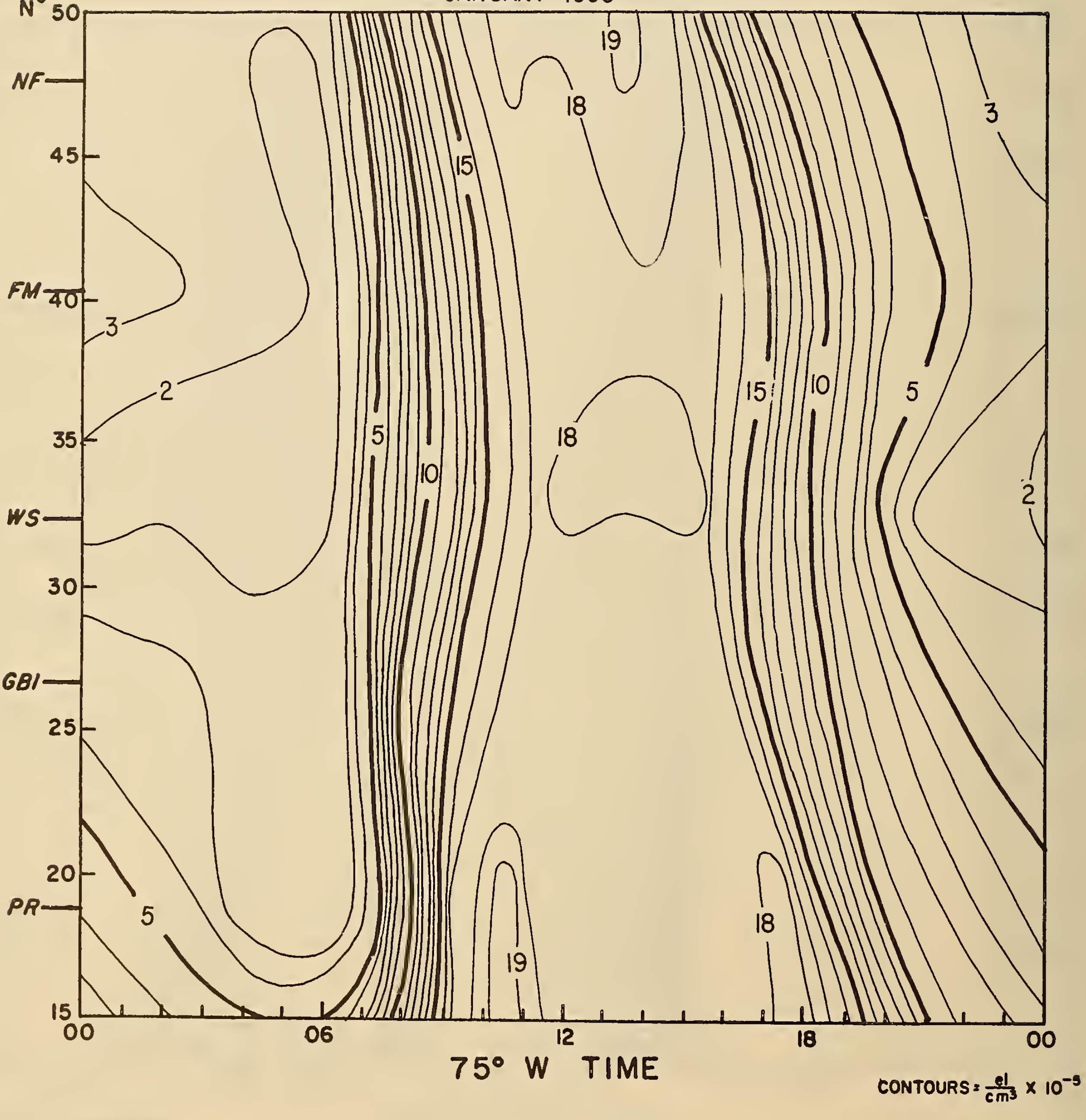

ELECTRON DENSITY AT 250 KILOMETERS
JANUARY 1960
N°
50
NF
45
FM
40
35
WS
30
GBI
25
20
PR
15
00
06
12
18
00
75° W TIME
1
5
10
15
15
10
5
1
1
3
CONTOURS: el/cm³ x 10⁻⁵

ELECTRON DENSITY AT 300 KILOMETERS
JANUARY 1960



ELECTRON DENSITY AT 350 KILOMETERS

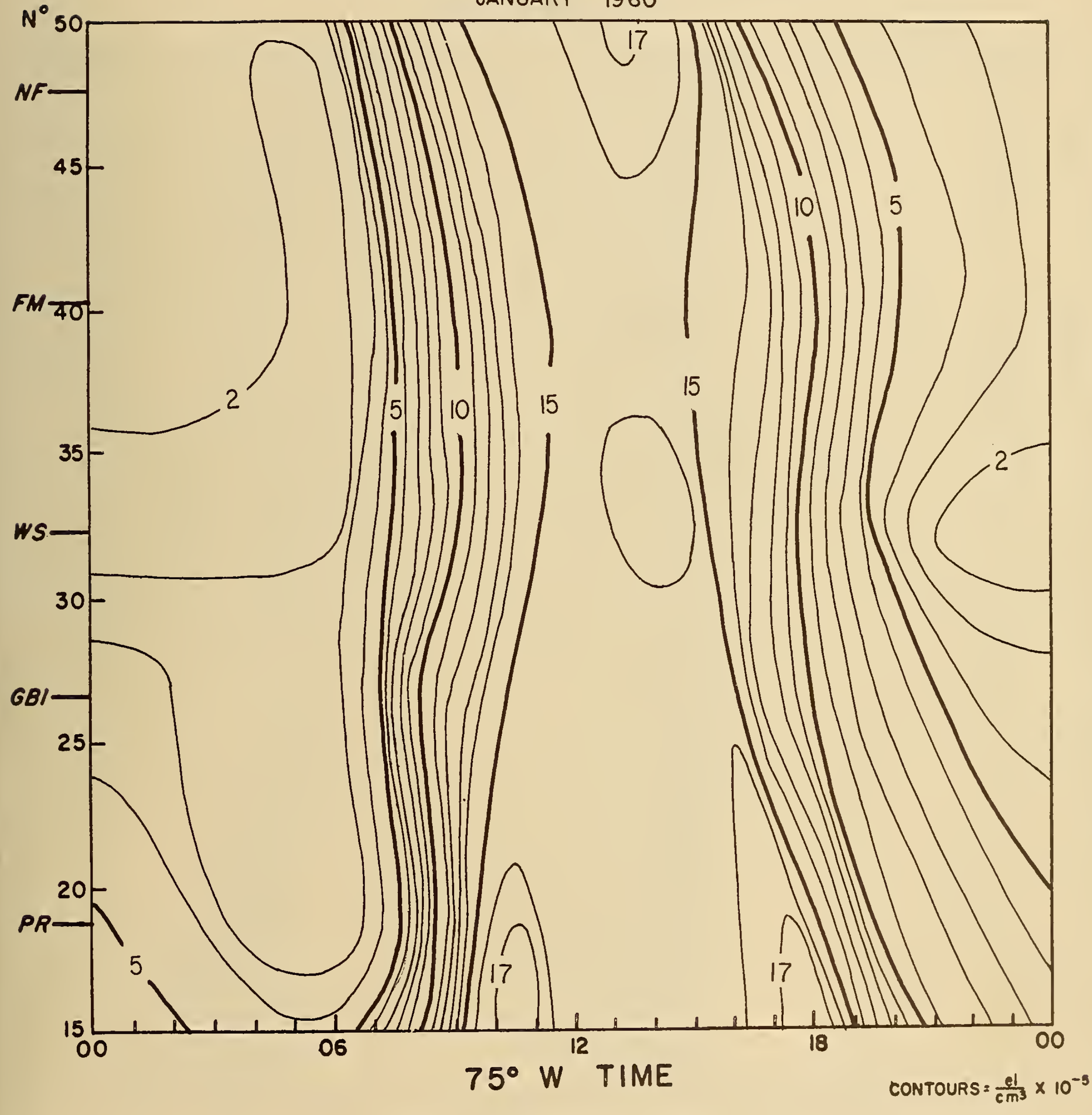
JANUARY 1960



USCOMM-NBS-E

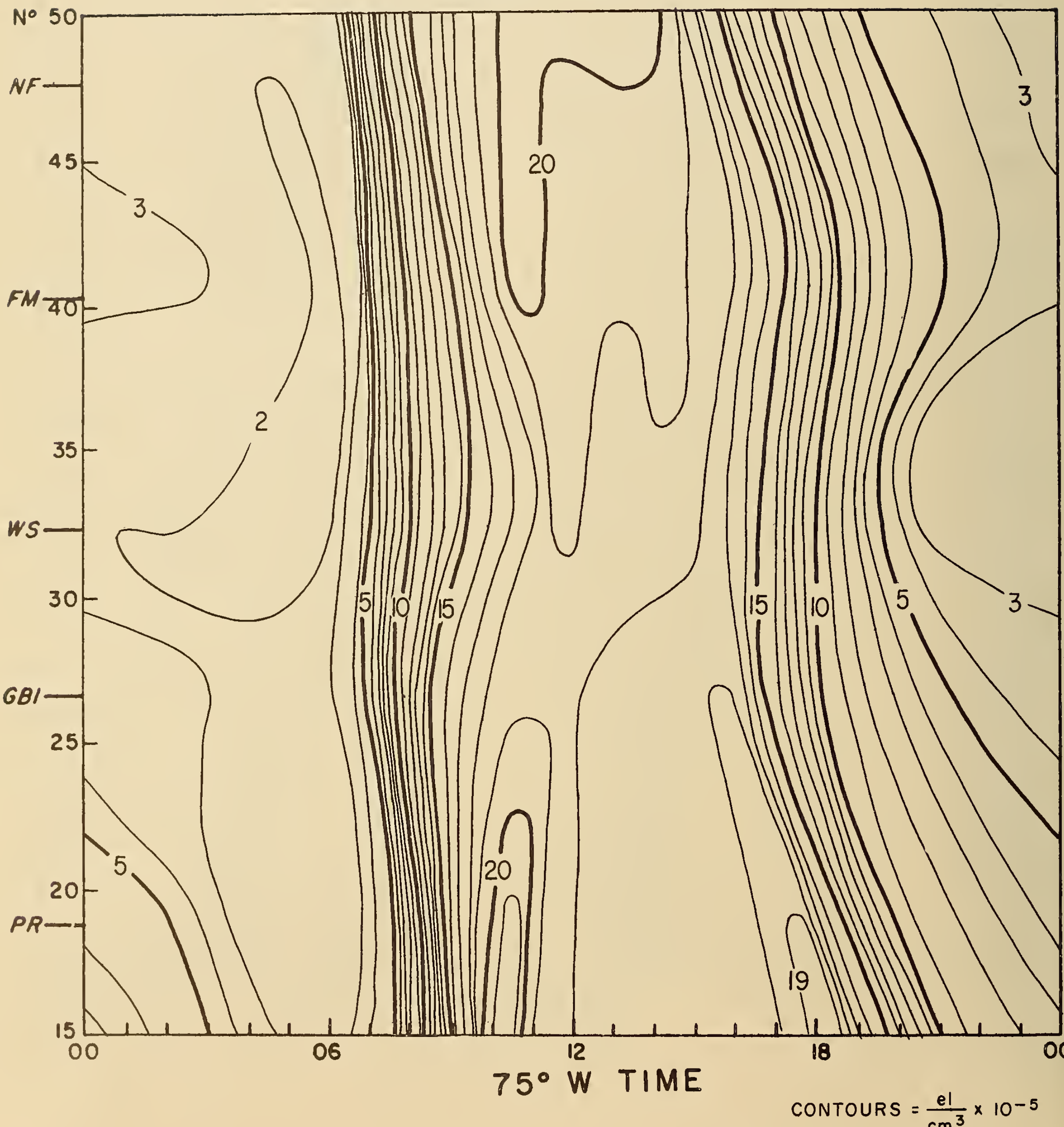
ELECTRON DENSITY AT 400 KILOMETERS

JANUARY 1960



USCOMM-NBS-BL

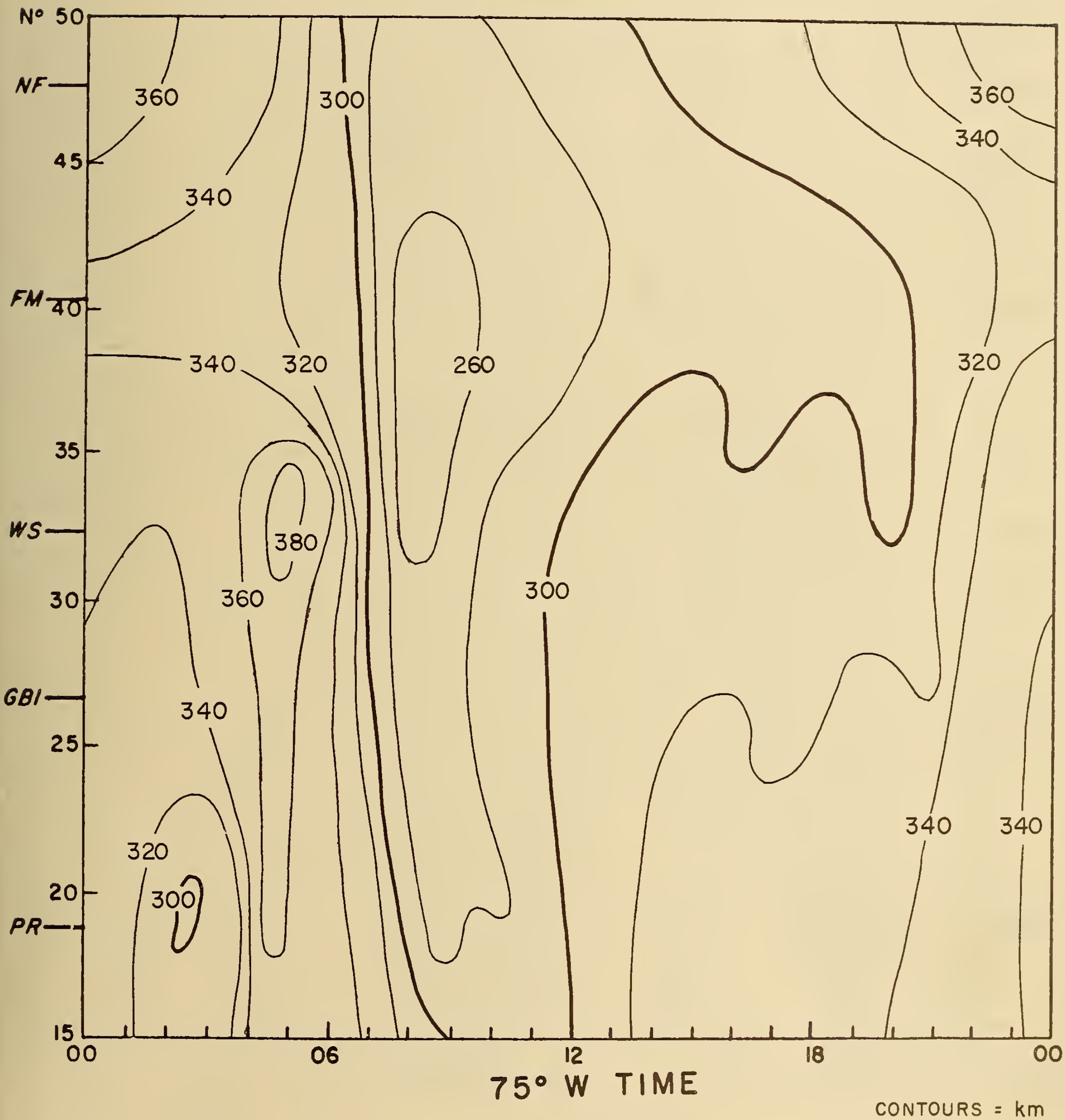
MAXIMUM ELECTRON DENSITY
NMAX
JANUARY 1960



HEIGHT OF MAXIMUM ELECTRON DENSITY

HMAX

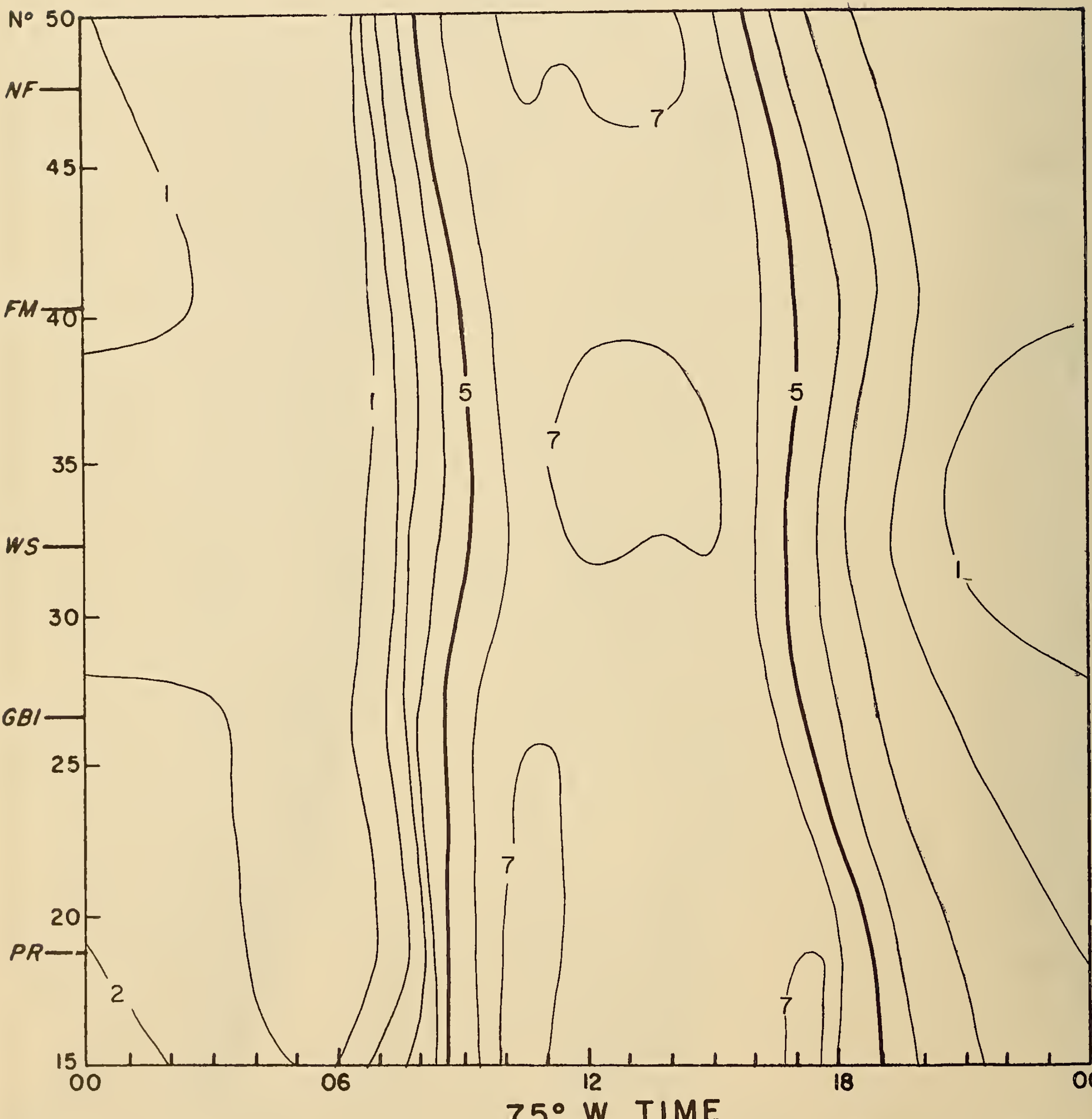
JANUARY 1960



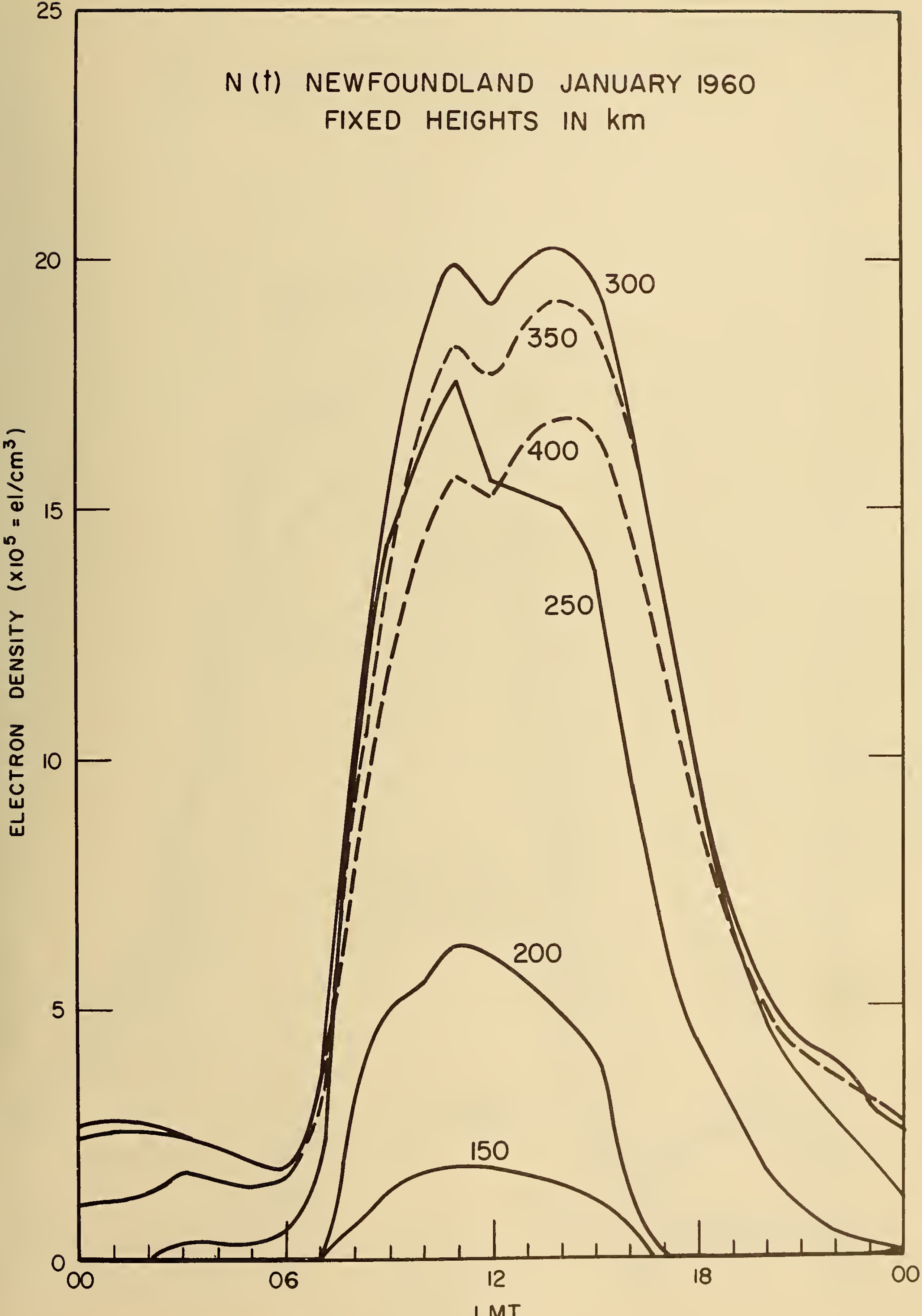
ELECTRON DENSITY INTEGRATED TO INFINITY

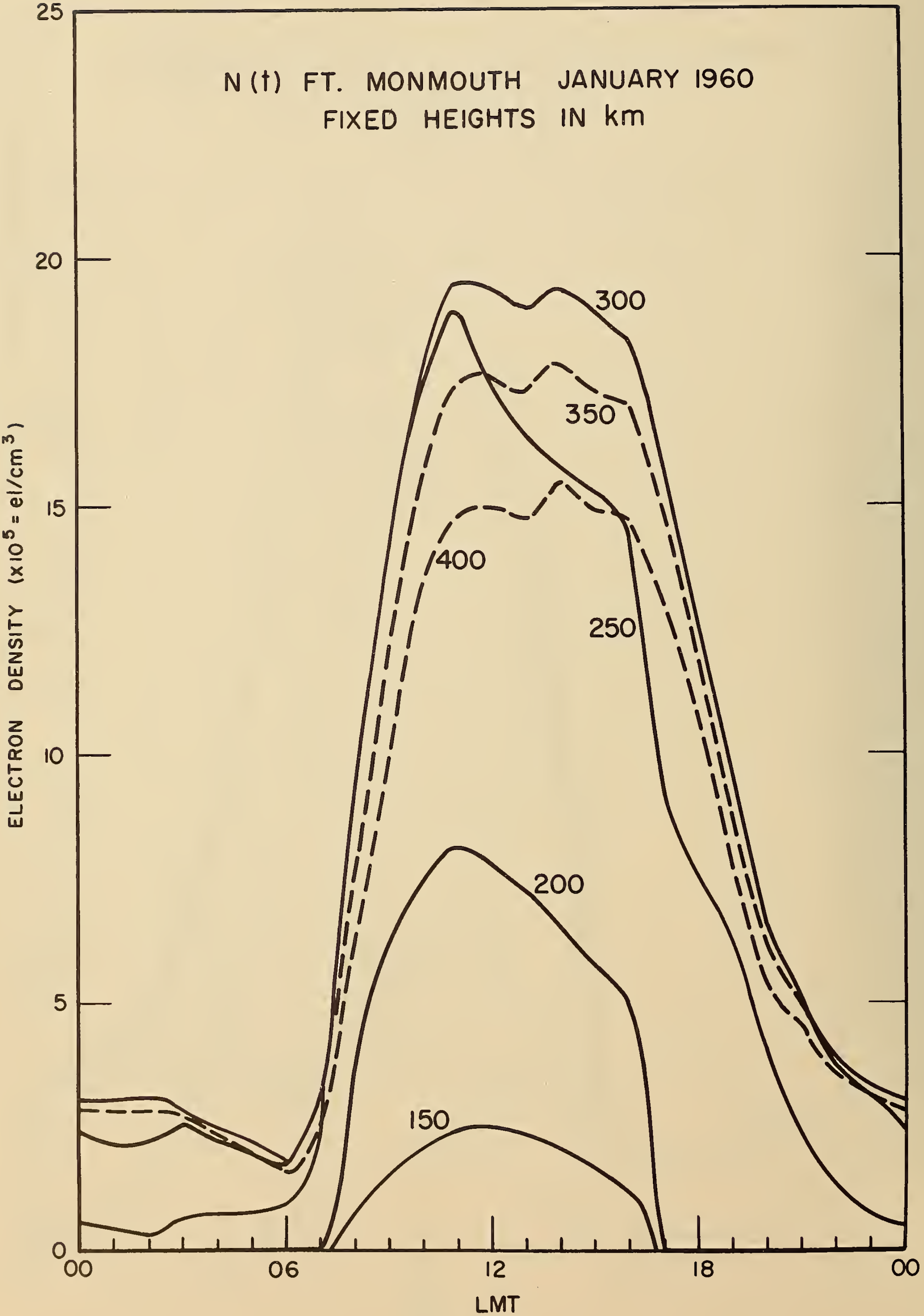
SHINF

JANUARY 1960

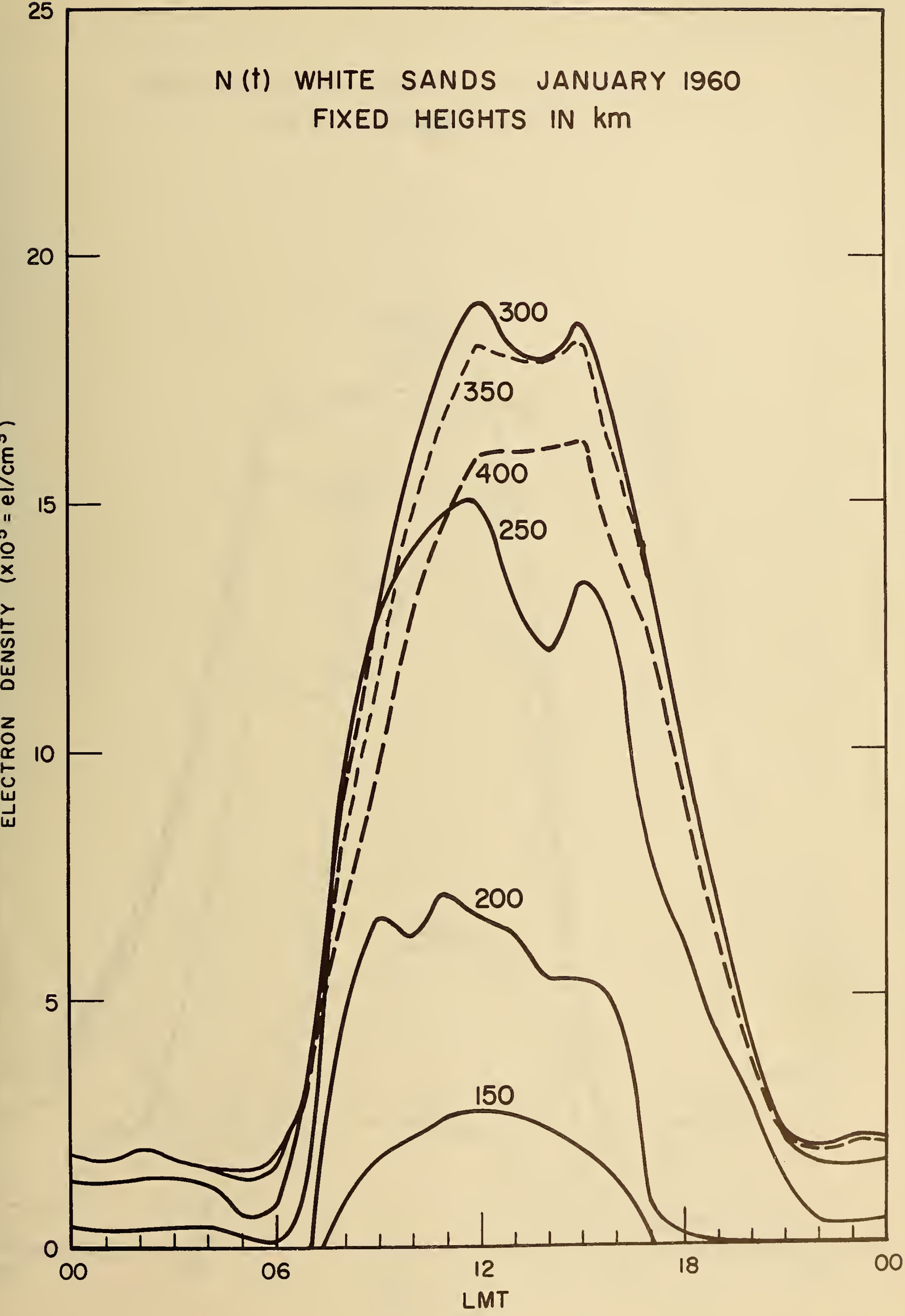


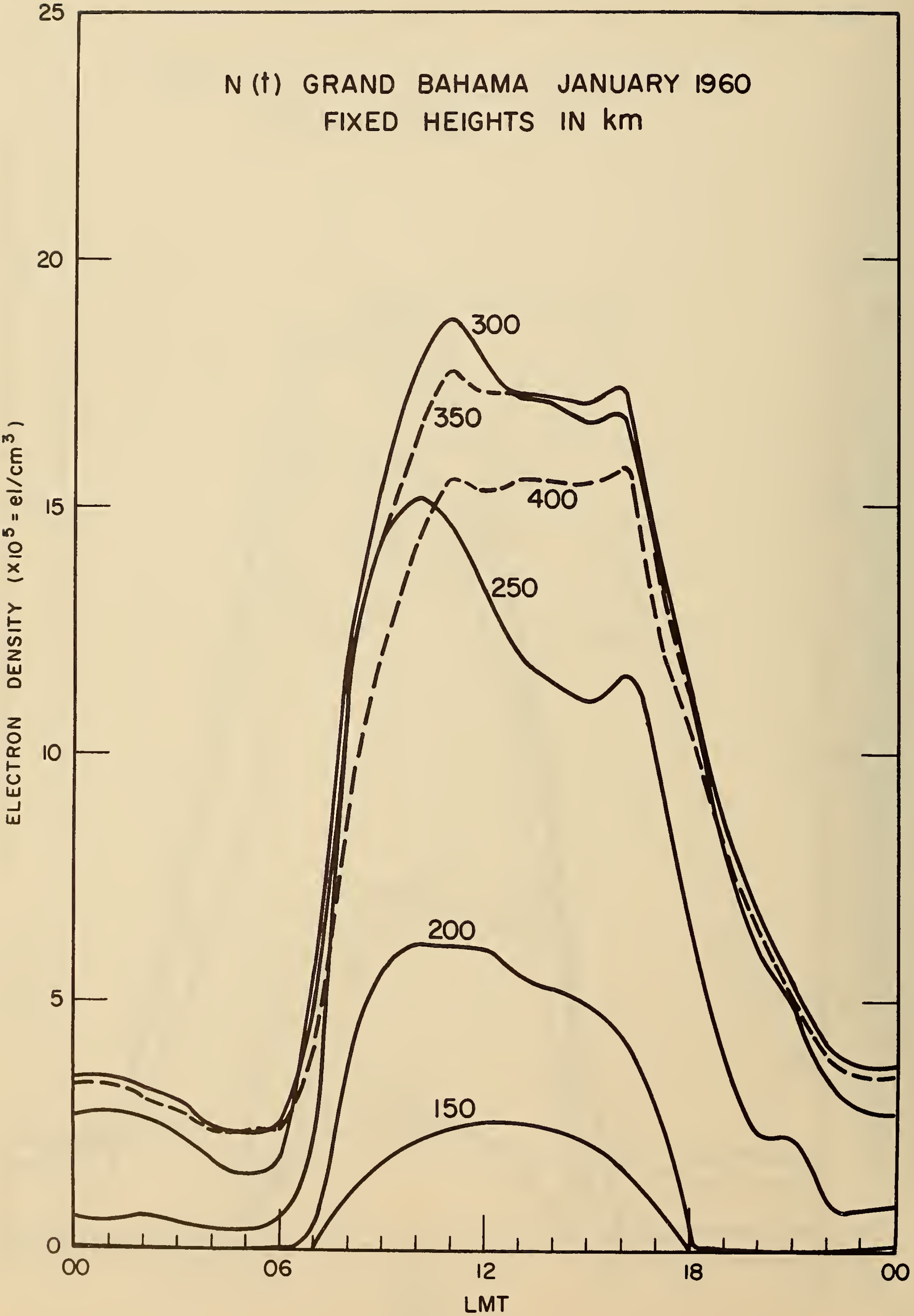
CONTOURS = $\frac{el}{cm^2}$ col. $\times 10^{-13}$


N (t) NEWFOUNDLAND JANUARY 1960
FIXED HEIGHTS IN km
ELECTRON DENSITY (x10^5 = el/cm^3)
25
20
15
10
5
0
300
350
400
250
200
150
00
06
12
18
00
LMT

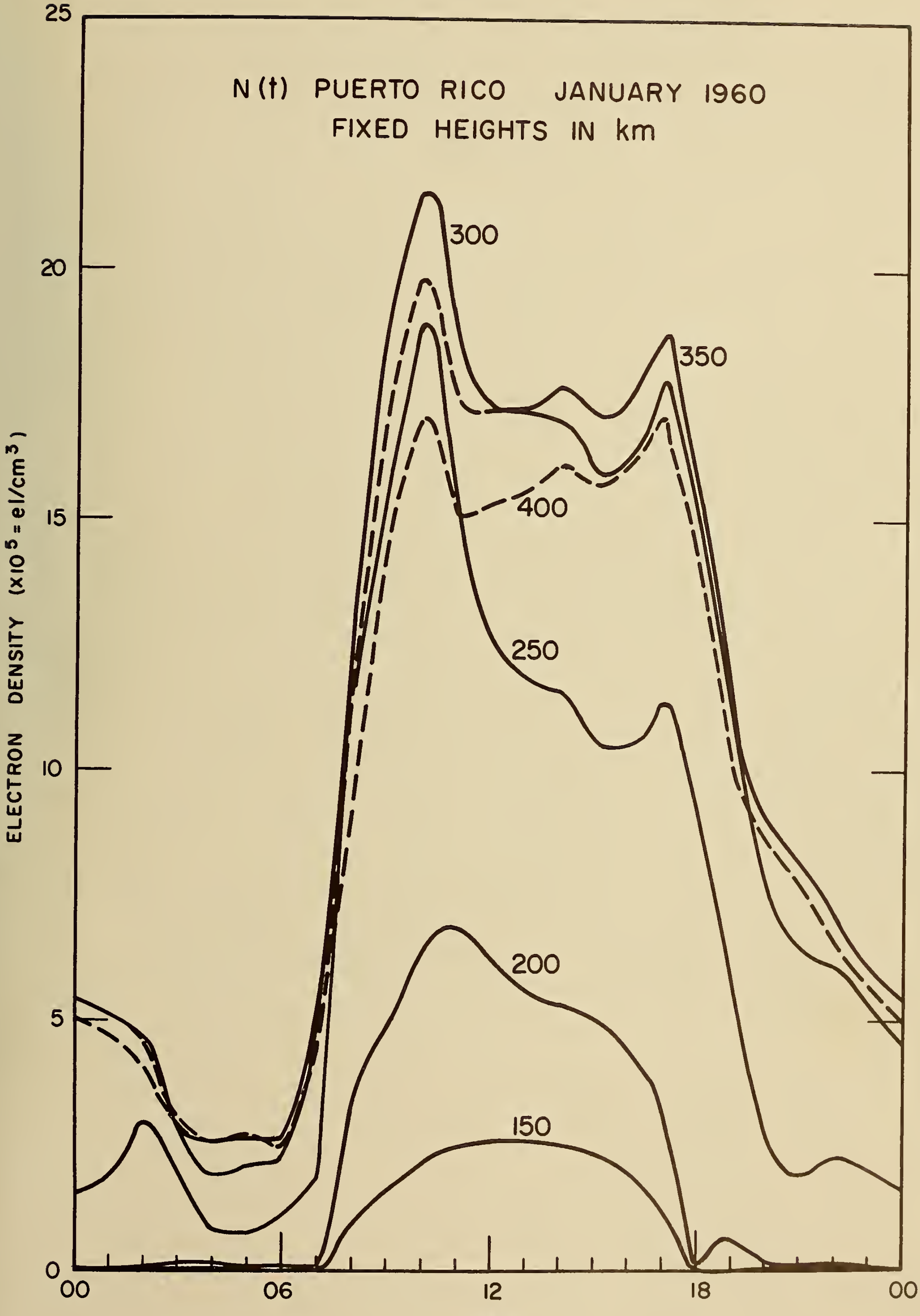


N (t) FT. MONMOUTH JANUARY 1960
FIXED HEIGHTS IN km
ELECTRON DENSITY (x10^5 = el/cm^3)
25
20
15
10
5
0
300
350
400
250
200
150
00
06
12
18
00
LMT


N (t) WHITE SANDS JANUARY 1960
FIXED HEIGHTS IN km
ELECTRON DENSITY (x10⁵ = el/cm³)
25
20
15
10
5
0
300
350
400
250
200
150
00
06
12
18
00
LMT



N (t) GRAND BAHAMA JANUARY 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
06
12
18
00
LMT


N(t) PUERTO RICO JANUARY 1960
FIXED HEIGHTS IN km
ELECTRON DENSITY (x10^5 = el/cm^3)
25
20
15
10
5
0
300
350
400
250
200
150
00
06
12
18
00
LMT

GPO 835-578

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. High Voltage.

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. 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. Microscopy and Diffraction. 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 Equipment. Cryogenic Processes. Properties of Materials. Cryogenic Technical Services.

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.

Radio Propagation Engineering. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. 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 Physics. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time-Interval Standards. Radio Plasma. Millimeter-Wave Research.

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

NBS