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Technical Note No. 40-3

Boulder Laboratories

MEAN ELECTRON DENSITY VARIATIONS OF THE QUIET IONOSPHERE

3 - MAY 1959

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

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS

Technical Note

40-3

March 1960

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Central Radio Propagation Laboratory

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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 May are illustrated graphically. This report is the third 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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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)
Bogota, Colombia (January 1960)
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

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 May 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, 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. 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 May 1959. 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 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 (150,200,250,300,350, 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^{o}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.

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, in particular the assistance of Mr. F. H. Dickson (Chief), is gratefully acknowledged.

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AVERAGE ELECTRON DENSITY KP BELOW 4.5

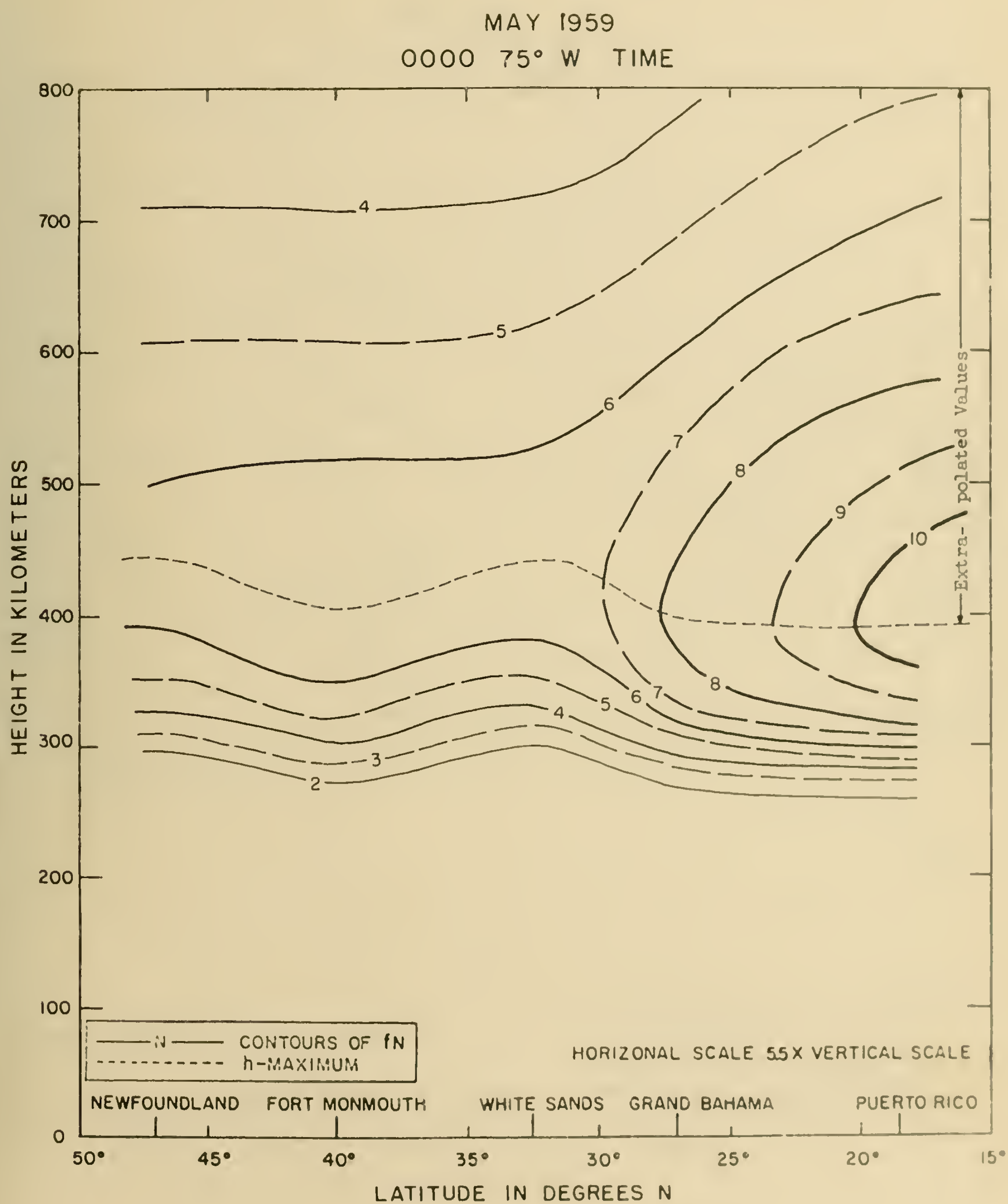
PUERTO RICO 60 W MAY 1959

TIME	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100
COUNT	25	26	27	26	26	27	24	19	22	23	22	22
HMIN	267	250	243	243	251	253	250	111	109	109	109	109
NMAX	1371	1230	999	854	765	693	735	1005	1253	1485	1681	1898
HMAX	384	359	366	376	374	382	363	326	326	346	358	366
SHMAX	922	786	725	650	542	524	531	1057	1361	1792	2110	2331
SHINF	4789	4254	3544	3058	2700	2479	2604	3891	4895	5982	6851	7684
KM												
950	133	105	88.5	80.4	71.0	68.2	64.7	74.7	91.7	120	144	169
900	170	134	114	103	91.1	87.5	83.1	95.8	118	154	184	217
850	218	172	146	132	117	112	107	123	151	198	237	278
800	279	221	186	169	149	143	136	158	193	253	303	356
750	356	282	238	216	191	183	174	202	247	324	388	455
700	453	360	303	275	243	233	222	258	316	413	494	580
650	574	457	385	348	308	294	282	328	403	526	628	736
600	719	576	484	437	386	367	355	415	510	664	792	927
550	888	717	601	540	478	451	441	521	641	830	987	1153
500	1069	875	730	651	577	539	536	644	795	1021	1207	1404
490	1105	908	756	673	597	556	556	671	827	1061	1253	1455
480	1140	940	782	694	616	571	575	697	861	1100	1298	1506
470	1173	973	807	715	635	586	594	724	895	1141	1343	1556
460	1205	1004	832	736	653	600	613	751	928	1180	1388	1605
450	1235	1035	856	755	670	613	630	777	962	1219	1431	1652
440	1261	1065	879	772	687	623	647	804	996	1258	1472	1697
430	1285	1092	900	787	701	632	663	830	1029	1294	1512	1739
420	1304	1118	918	799	712	639	677	855	1061	1329	1548	1777
410	1319	1141	934	809	721	643	690	879	1093	1362	1582	1811
400	1327	1159	946	814	725	644	700	902	1122	1391	1611	1839
390	1327	1174	955	815	725	642	707	922	1150	1417	1635	1862
380	1315	1183	958	811	719	635	711	941	1175	1439	1653	1876
370	1289	1185	956	802	707	622	711	957	1197	1456	1665	1883
360	1246	1178	945	785	690	604	705	970	1216	1468	1669	1877
350	1182	1159	925	759	665	578	691	980	1230	1473	1664	1856
340	1093	1123	895	722	632	545	669	985	1239	1470	1645	1817
330	976	1069	852	672	590	505	637	985	1243	1457	1612	1761
320	836	996	795	613	540	456	593	980	1239	1430	1564	1684
310	676	902	723	543	479	399	539	967	1226	1390	1500	1592
300	505	782	637	464	412	337	470	946	1200	1336	1423	1484
290	340	645	538	381	339	273	394	916	1160	1268	1333	1364
280	195	494	432	300	266	212	312	877	1106	1186	1235	1236
270	95.7	342	321	221	191	160	223	830	1041	1095	1128	1105
260	37.8	207	222	150	121	111	142	772	965	998	1021	978
250	11.0	105	143	94.2	59.6	71.2	78.4	704	876	895	912	857
240	.4	44.5	77.0	50.3	27.0	37.6	36.1	624	781	792	806	751
230		14.4	36.4	22.7	8.4	13.7	13.8	534	683	693	710	661
220		1.4	8.9	7.8	3.5	4.9	6.1	443	587	604	625	591
210			3.1	2.0	1.5	1.5	4.7	353	496	528	551	535
200					.3		4.0	277	414	464	489	486
190							3.4	215	344	406	435	443
180							3.0	168	287	355	387	402
170							2.6	136	239	306	342	361
160							2.3	115	201	262	301	319
150							2.1	101	170	225	262	278
140							1.9	91.7	146	193	228	241
130							1.7	85.8	132	170	203	215
120							1.2	78.4	122	155	185	194
110							.5	17.0	48.0	75.7	61.7	72.4

AVERAGE ELECTRON DENSITY KP BELOW 4.5

PUERTO RICO 60 W MAY 1959

TIME	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
COUNT	24	23	23	24	24	20	14	24	25	24	26	26
HMIN	110	109	109	109	110	109	121	251	267	282	285	276
NMAX	2012	2071	2048	1922	1738	1654	1485	1470	1426	1461	1489	1446
HMAX	365	366	371	369	370	371	378	397	419	420	414	396
SHMAX	2363	2426	2458	2302	2119	1955	1682	1313	1263	1151	1107	995
SHINF	8039	8269	8235	7723	7022	6620	5872	5458	5285	5273	5308	5072
KM												
950	178	184	187	174	158	151	141	152	164	168	167	149
900	229	237	239	223	203	194	181	195	210	215	214	191
850	293	303	307	285	260	249	232	250	269	276	274	244
800	375	388	393	365	333	319	297	320	343	352	351	312
750	480	497	502	467	425	407	379	409	438	449	447	399
700	612	633	640	596	542	519	483	520	555	569	568	507
650	776	804	811	755	687	659	612	657	699	716	715	641
600	978	1012	1021	951	865	829	769	821	869	889	890	801
550	1216	1259	1268	1182	1074	1029	952	1010	1058	1081	1085	985
540	1268	1312	1321	1232	1119	1072	991	1050	1096	1120	1125	1024
530	1320	1367	1376	1282	1165	1116	1031	1090	1134	1159	1165	1063
520	1374	1422	1431	1334	1212	1160	1071	1129	1172	1197	1204	1101
510	1428	1478	1486	1386	1259	1205	1111	1169	1209	1234	1243	1140
500	1482	1534	1542	1438	1306	1250	1152	1208	1244	1269	1280	1178
490	1537	1591	1597	1490	1353	1294	1192	1246	1277	1303	1316	1215
480	1591	1647	1652	1541	1399	1339	1231	1283	1308	1334	1349	1251
470	1644	1702	1706	1592	1445	1382	1269	1318	1337	1362	1380	1285
460	1696	1755	1759	1642	1490	1424	1306	1350	1361	1386	1407	1317
450	1747	1807	1809	1689	1532	1465	1341	1380	1382	1405	1430	1346
440	1795	1857	1856	1734	1573	1503	1373	1406	1398	1419	1449	1371
430	1840	1903	1900	1776	1610	1538	1402	1428	1408	1427	1461	1393
420	1880	1945	1940	1814	1644	1569	1428	1445	1410	1426	1463	1409
410	1917	1982	1974	1847	1673	1597	1449	1456	1404	1415	1455	1416
400	1947	2014	2002	1874	1697	1619	1465	1459	1383	1389	1432	1413
390	1971	2038	2023	1895	1715	1635	1475	1453	1348	1347	1391	1396
380	1986	2055	2035	1908	1725	1644	1478	1433	1296	1285	1329	1360
370	1992	2061	2036	1910	1727	1644	1472	1396	1226	1200	1242	1305
360	1983	2053	2022	1899	1717	1632	1456	1343	1139	1094	1128	1228
350	1959	2027	1988	1871	1694	1606	1424	1272	1039	967	990	1125
340	1914	1977	1933	1823	1653	1563	1376	1185	919	824	834	997
330	1846	1899	1856	1754	1595	1501	1314	1080	782	670	662	844
320	1754	1797	1756	1664	1518	1425	1241	962	636	509	485	675
310	1640	1676	1637	1559	1427	1336	1154	832	488	348	320	502
300	1514	1540	1502	1435	1323	1236	1057	688	345	211	188	339
290	1375	1394	1357	1301	1208	1123	948	535	218	103	90.0	202
280	1230	1242	1207	1167	1088	1010	838	379	116	35.9	29.7	96.0
270	1090	1090	1061	1031	966	895	723	227	52.8	8.8	1.0	33.9
260	960	952	923	899	846	779	610	95.1	19.0	.5		5.4
250	840	829	800	780	734	673	502	31.6	9.0			
240	738	726	698	678	640	579	401	9.0	2.7			
230	655	642	618	597	560	497	327	2.0				
220	587	577	556	534	495	429	267					
210	532	524	505	484	442	372	218					
200	484	481	464	441	396	324	178					
190	444	441	428	402	357	280	145					
180	405	404	394	366	321	241	119					
170	369	367	361	330	287	207	98.9					
160	332	329	325	295	254	178	85.2					
150	296	291	289	262	223	154	76.4					
140	261	256	254	232	196	137	71.0					
130	232	228	227	210	177	127	66.8					
120	211	212	211	195	164	119	62.2					
110	51.1	64.0	66.7	65.6	45.7	29.7	4.4					


MAY 1959
0000 75° W TIME
HEIGHT IN KILOMETERS
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MAY 1959
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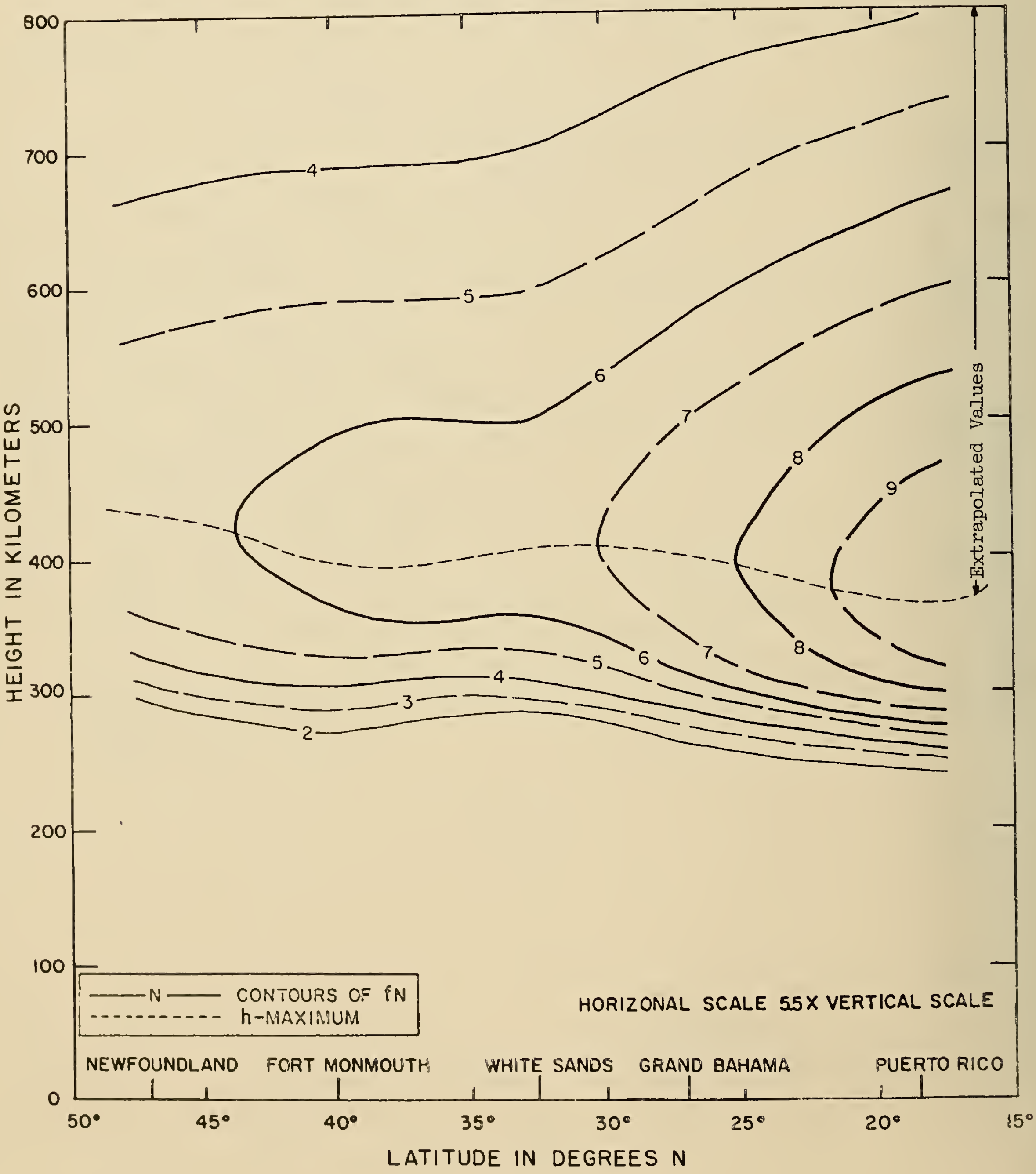
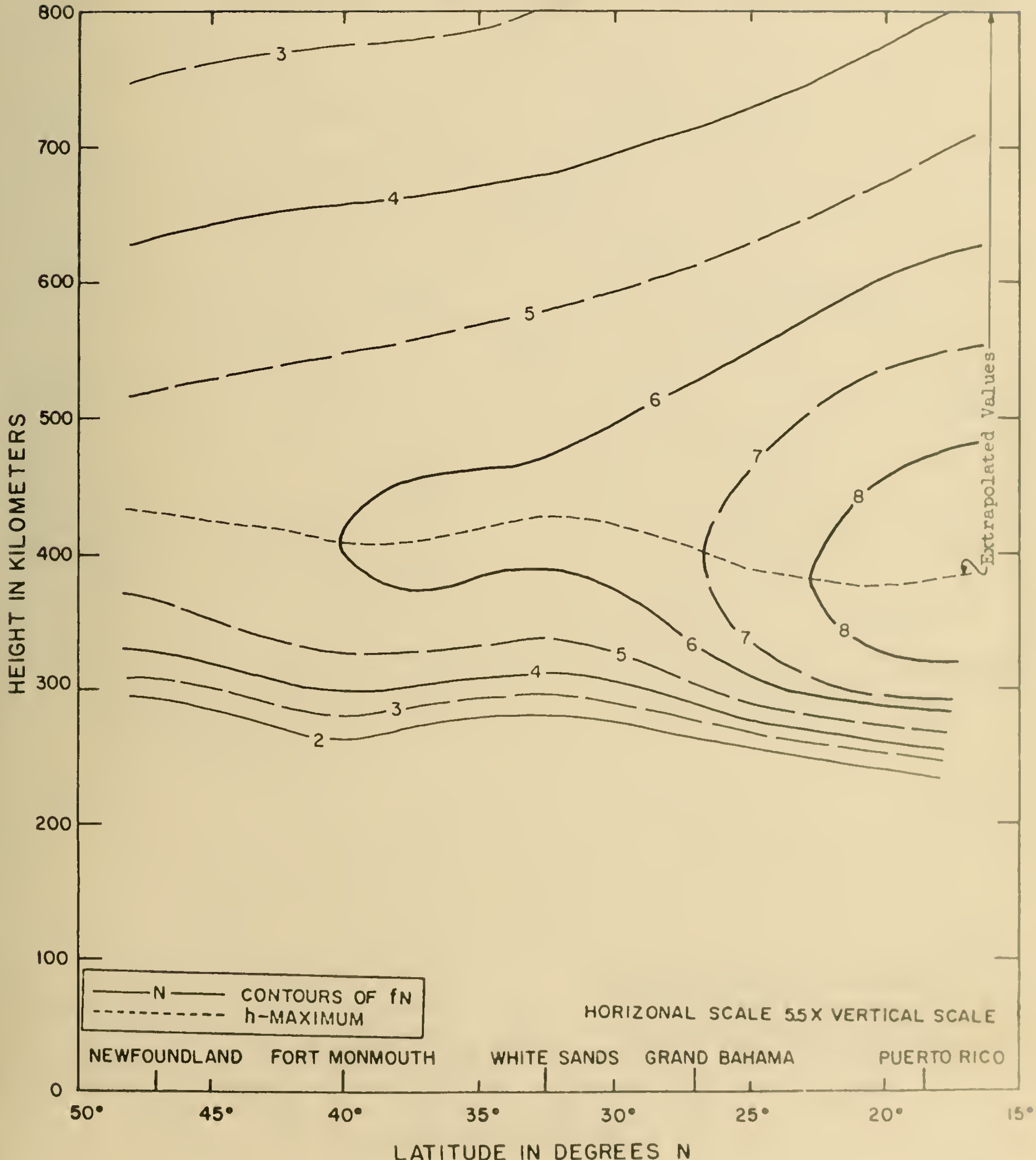
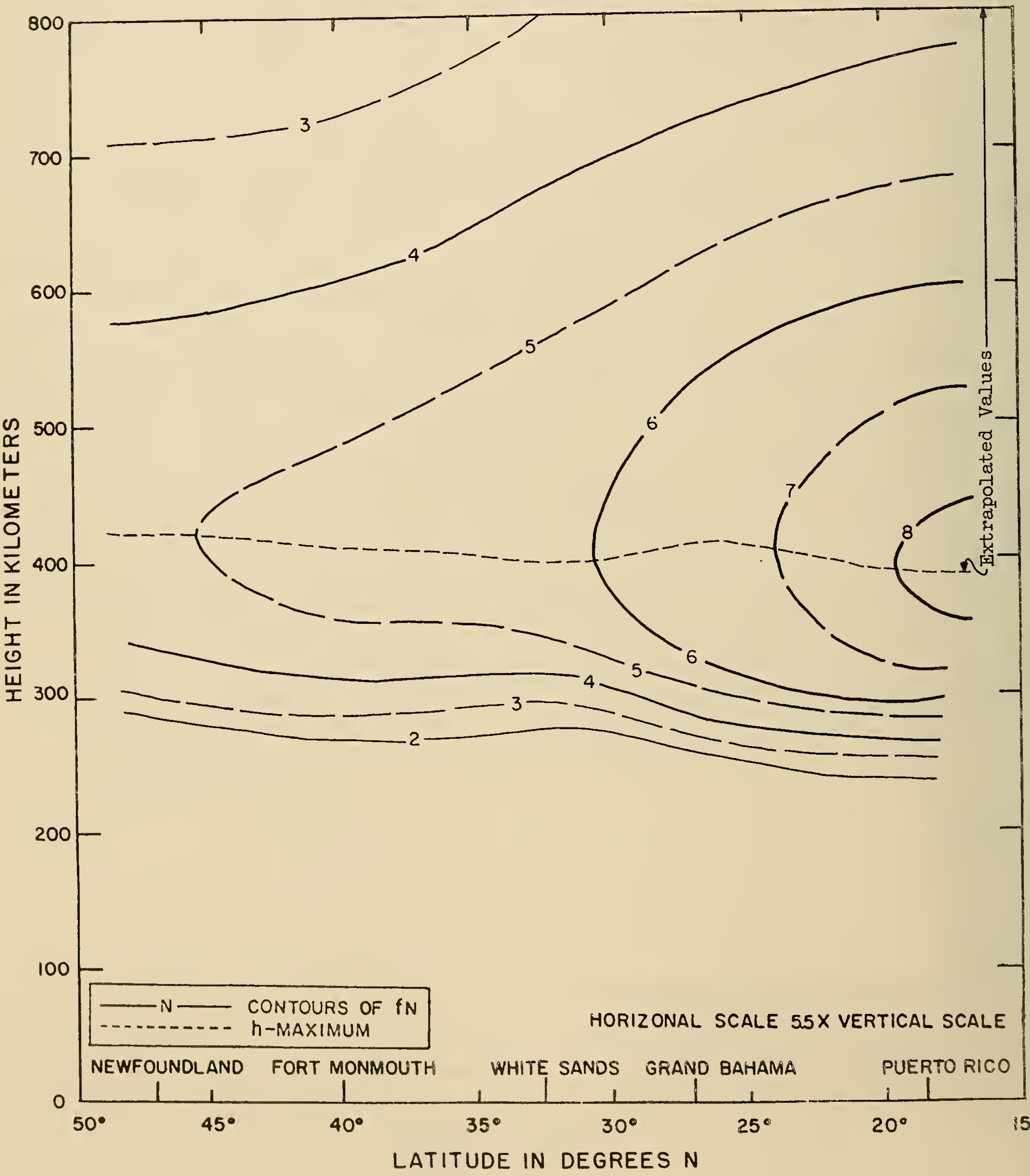


MAY 1959
0200 75° W TIME

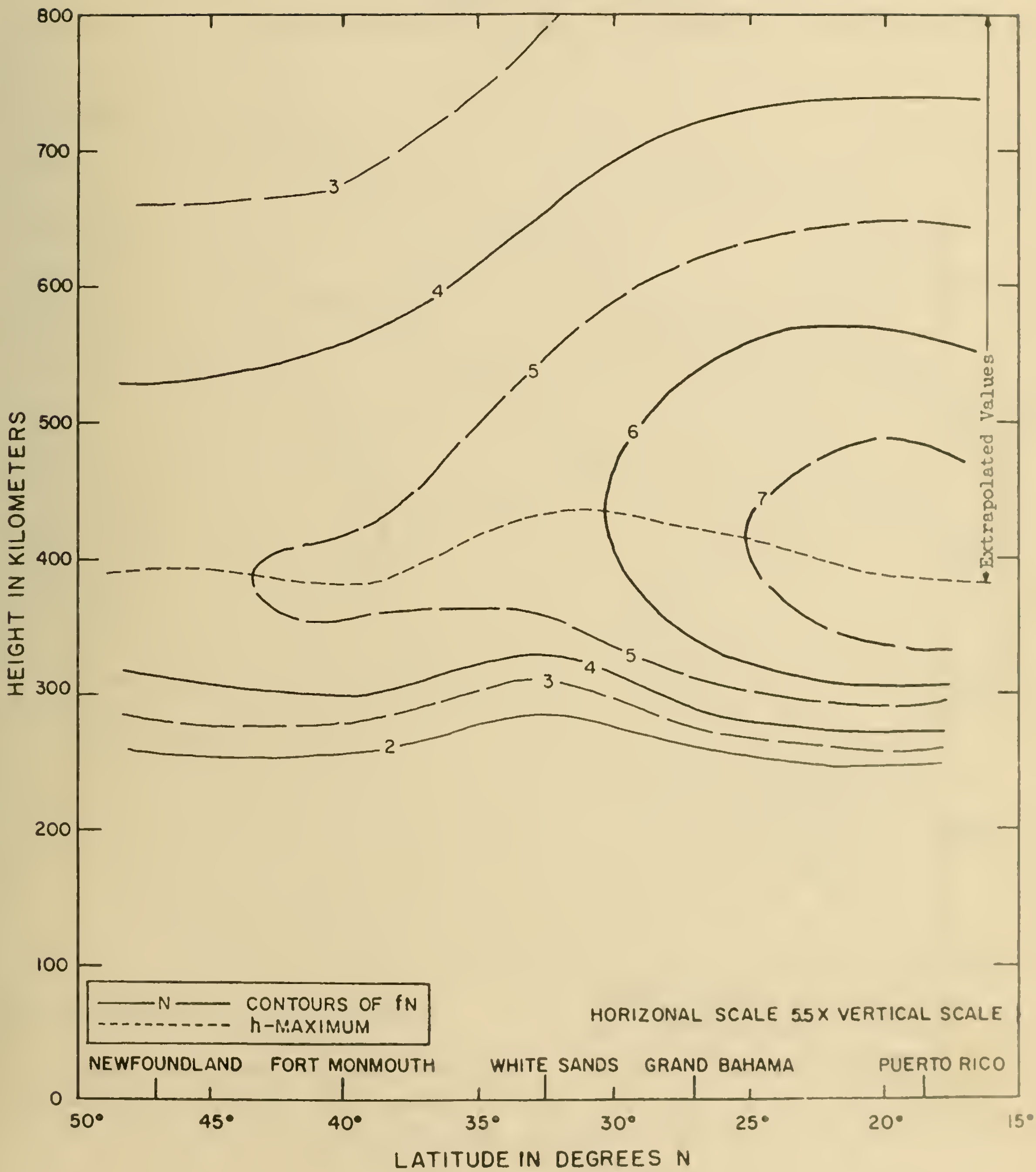


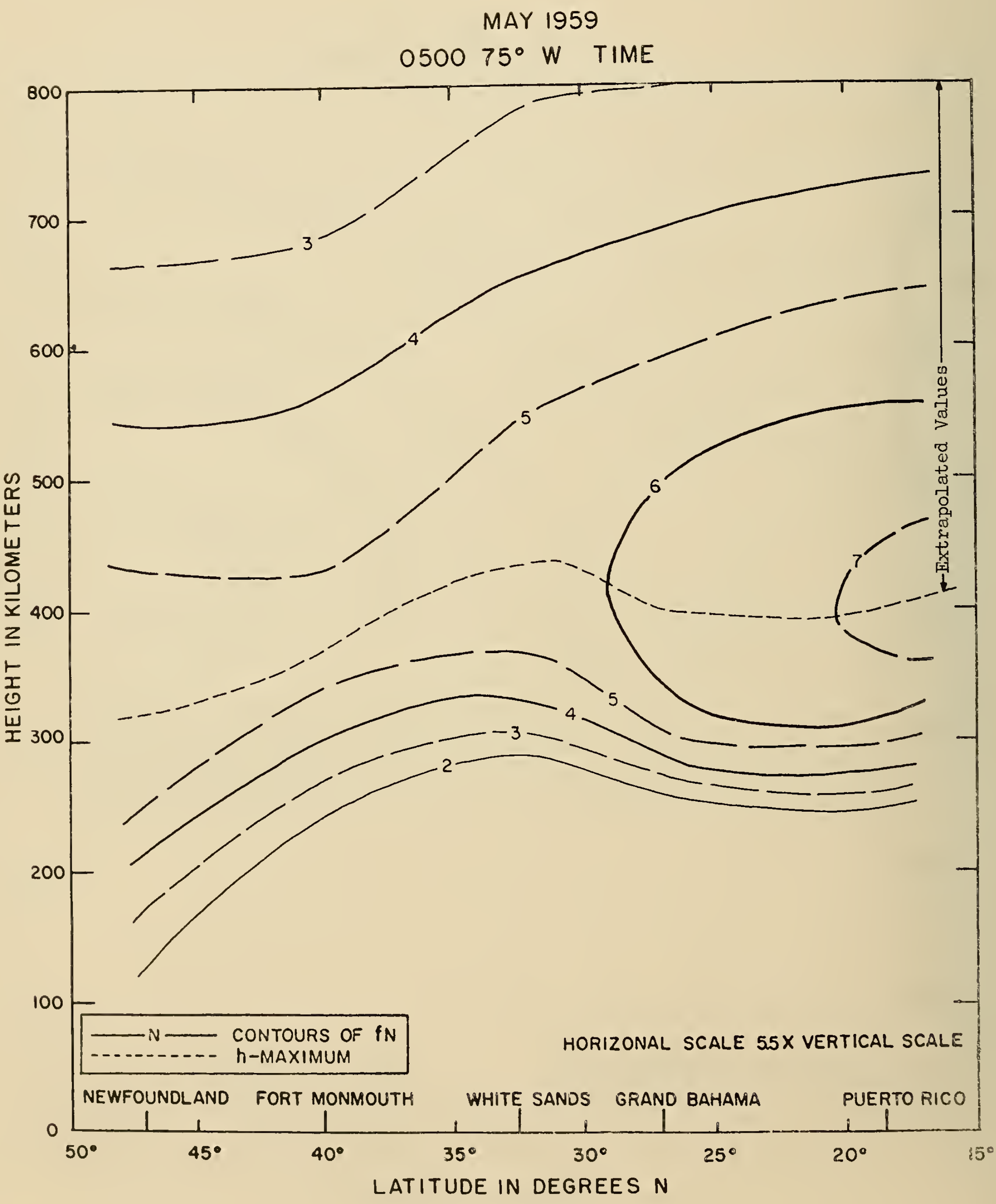
MAY 1959

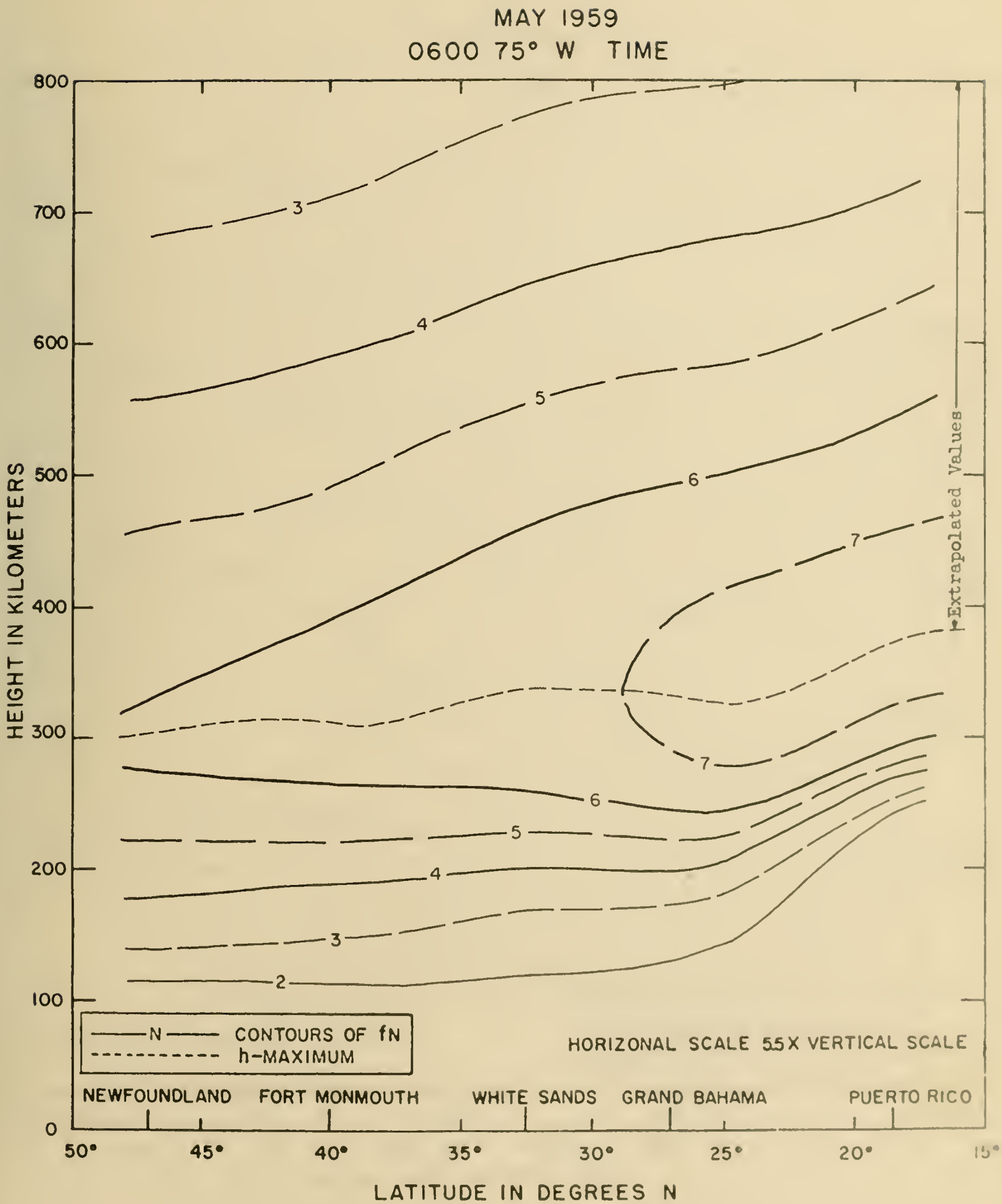
0300 75° W TIME



MAY 1959
0400 75° W TIME

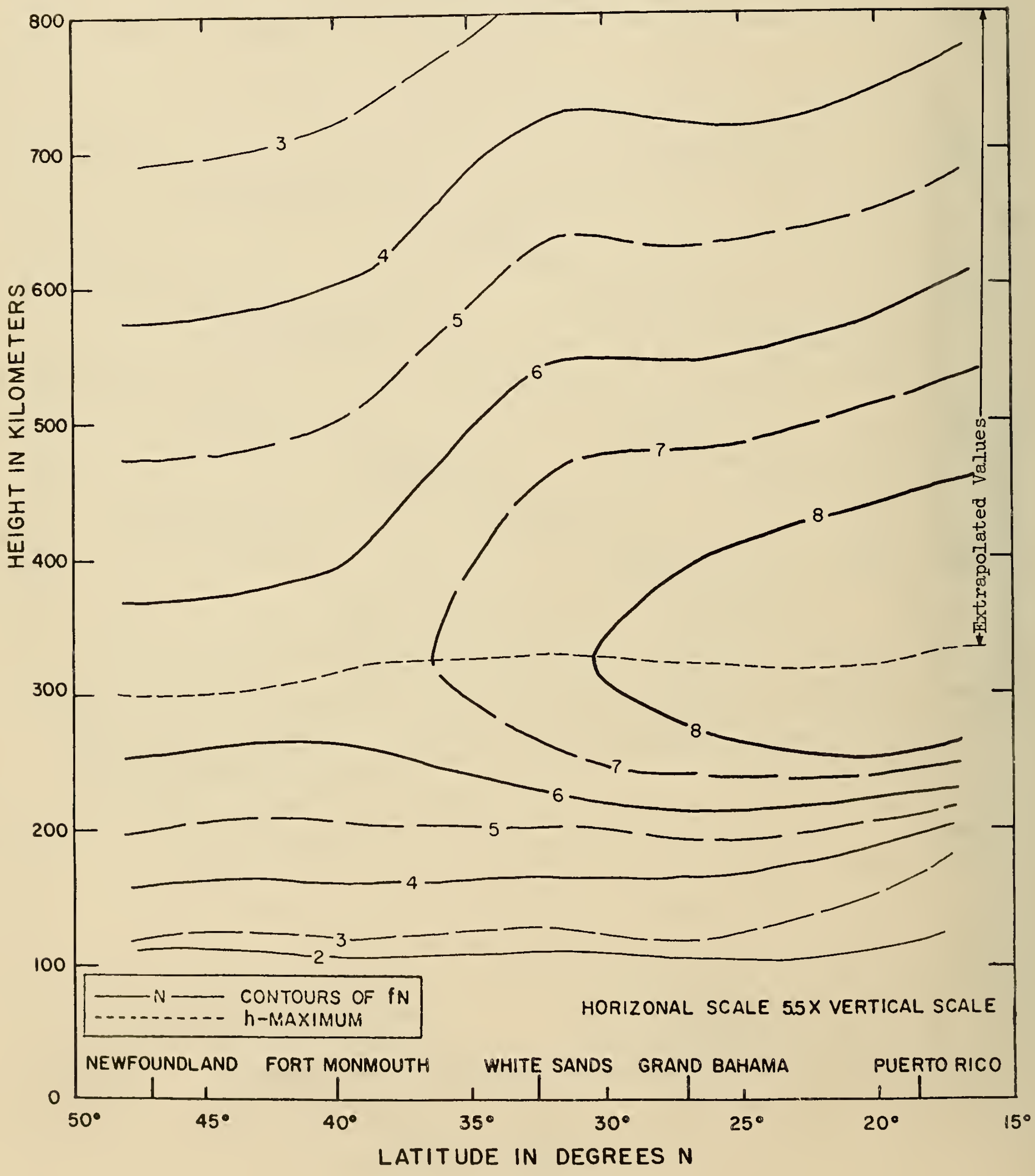



MAY 1959
0500 75° W TIME
800
700
600
500
400
300
200
100
0
HEIGHT IN KILOMETERS
3
4
5
6
7
5
4
3
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
LATITUDE IN DEGREES N

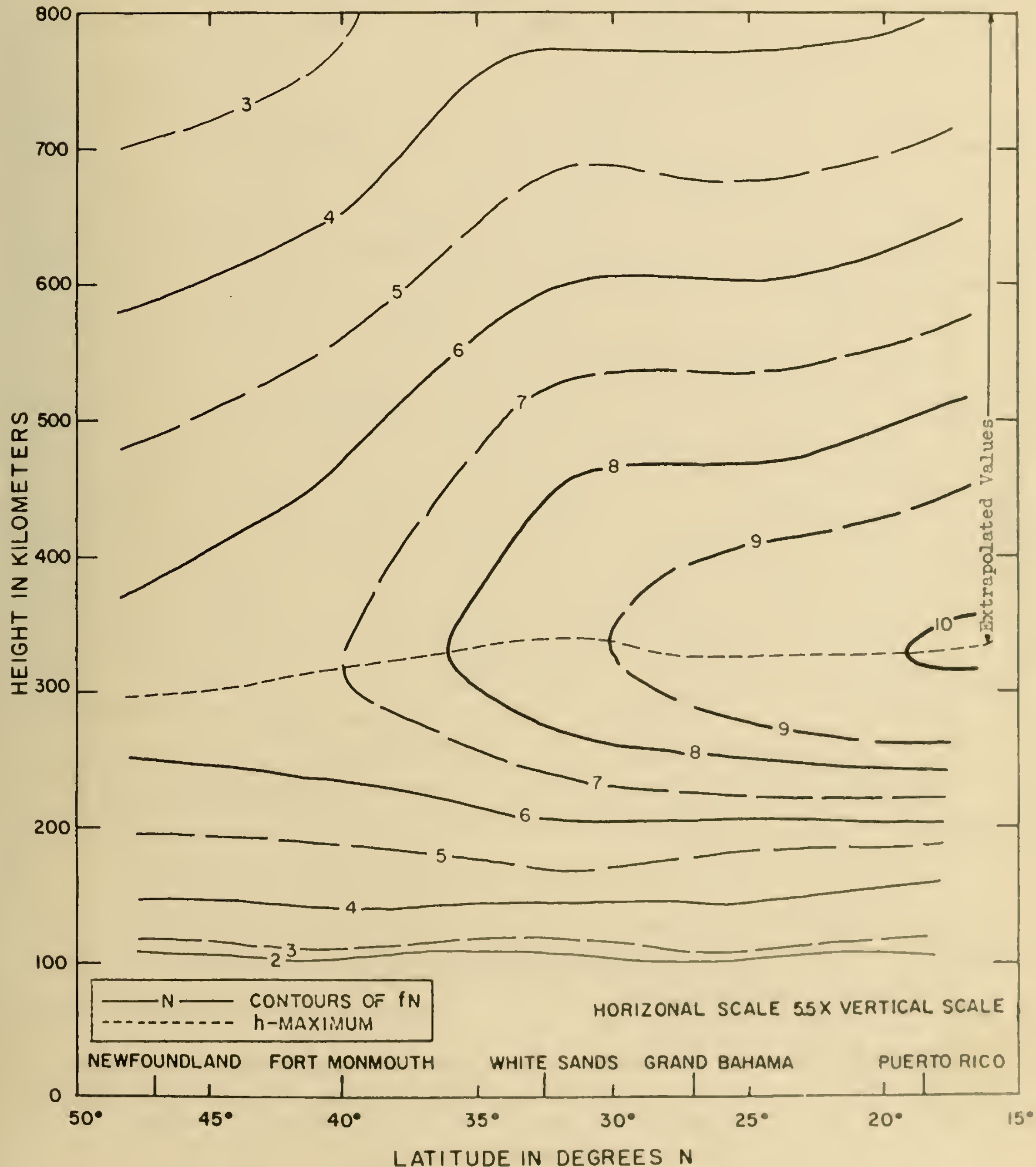

MAY 1959
0600 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
4
5
6
7
7
6
5
4
3
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
LATITUDE IN DEGREES N

MAY 1959

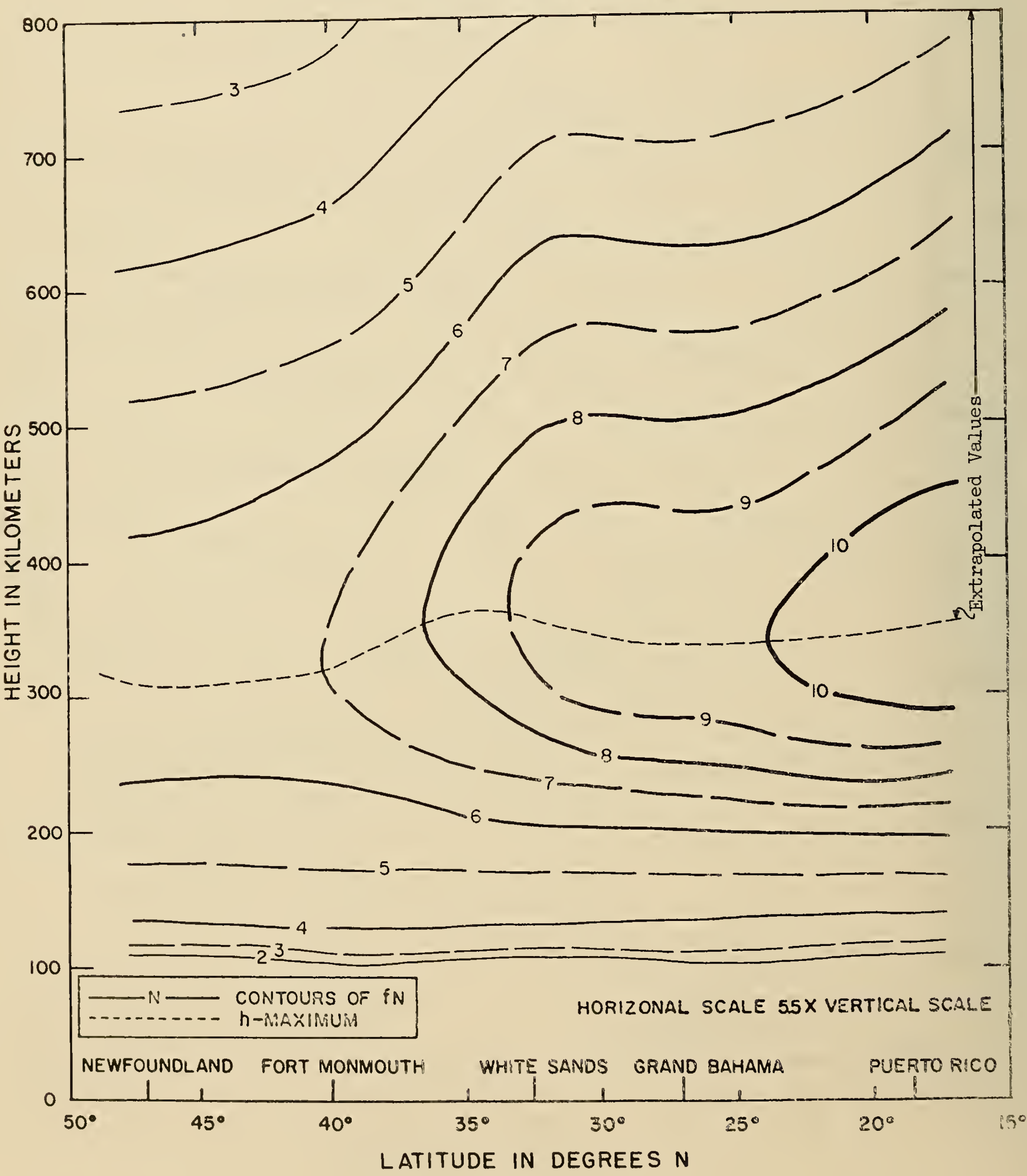
0700 75° W TIME



MAY 1959
0800 75° W TIME

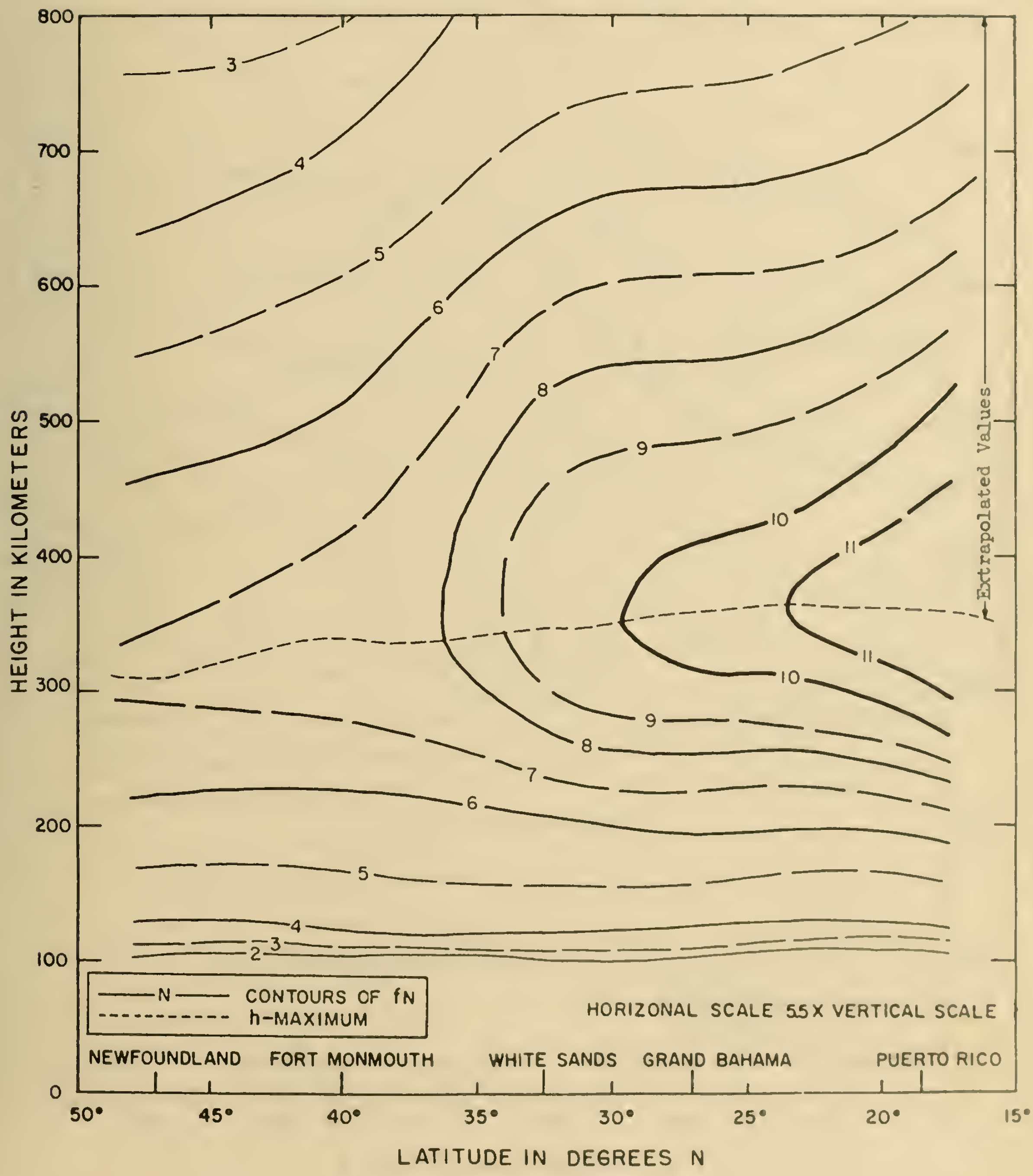


MAY 1959
0900 75° W TIME



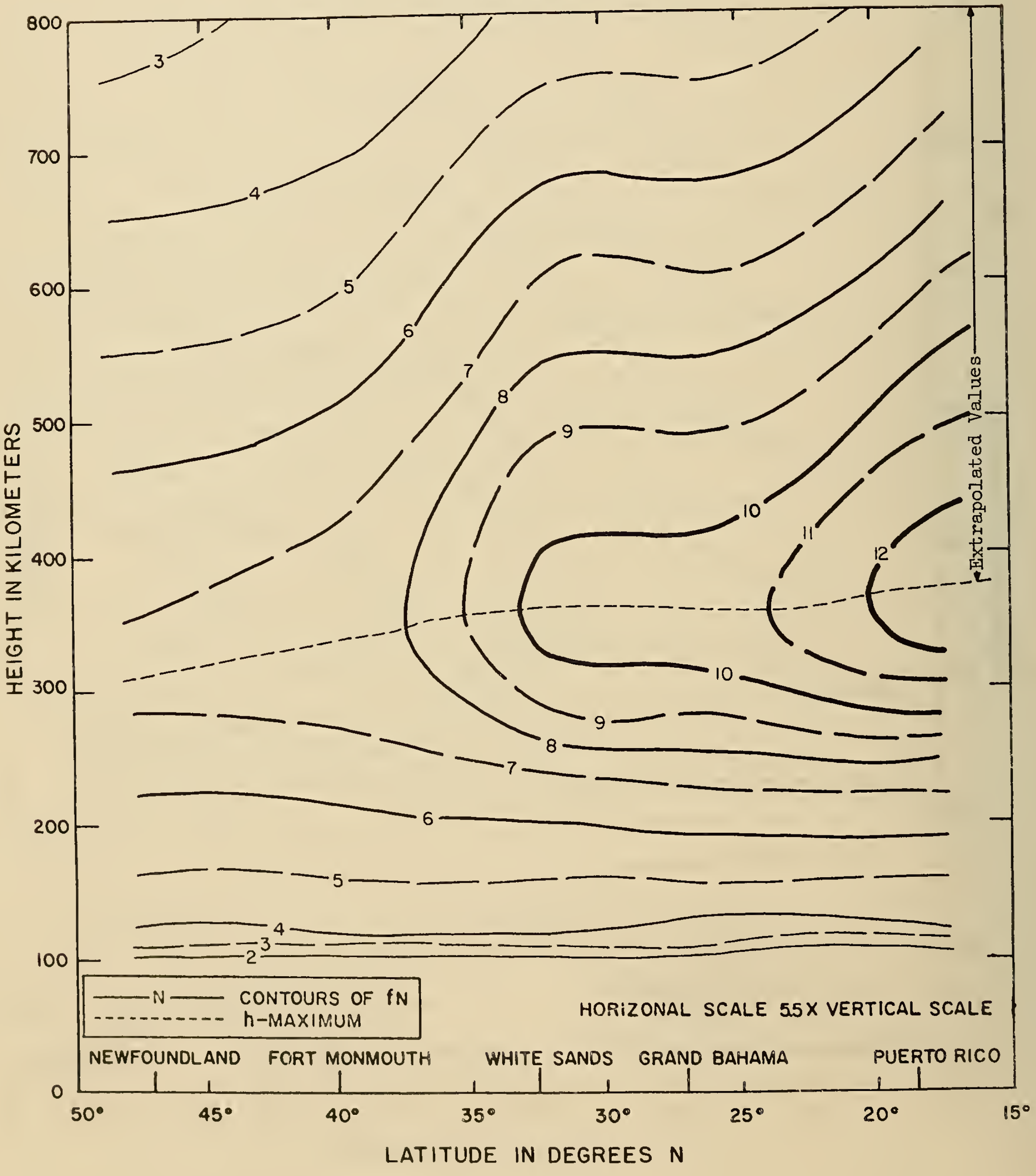
MAY 1959

1000 75° W TIME



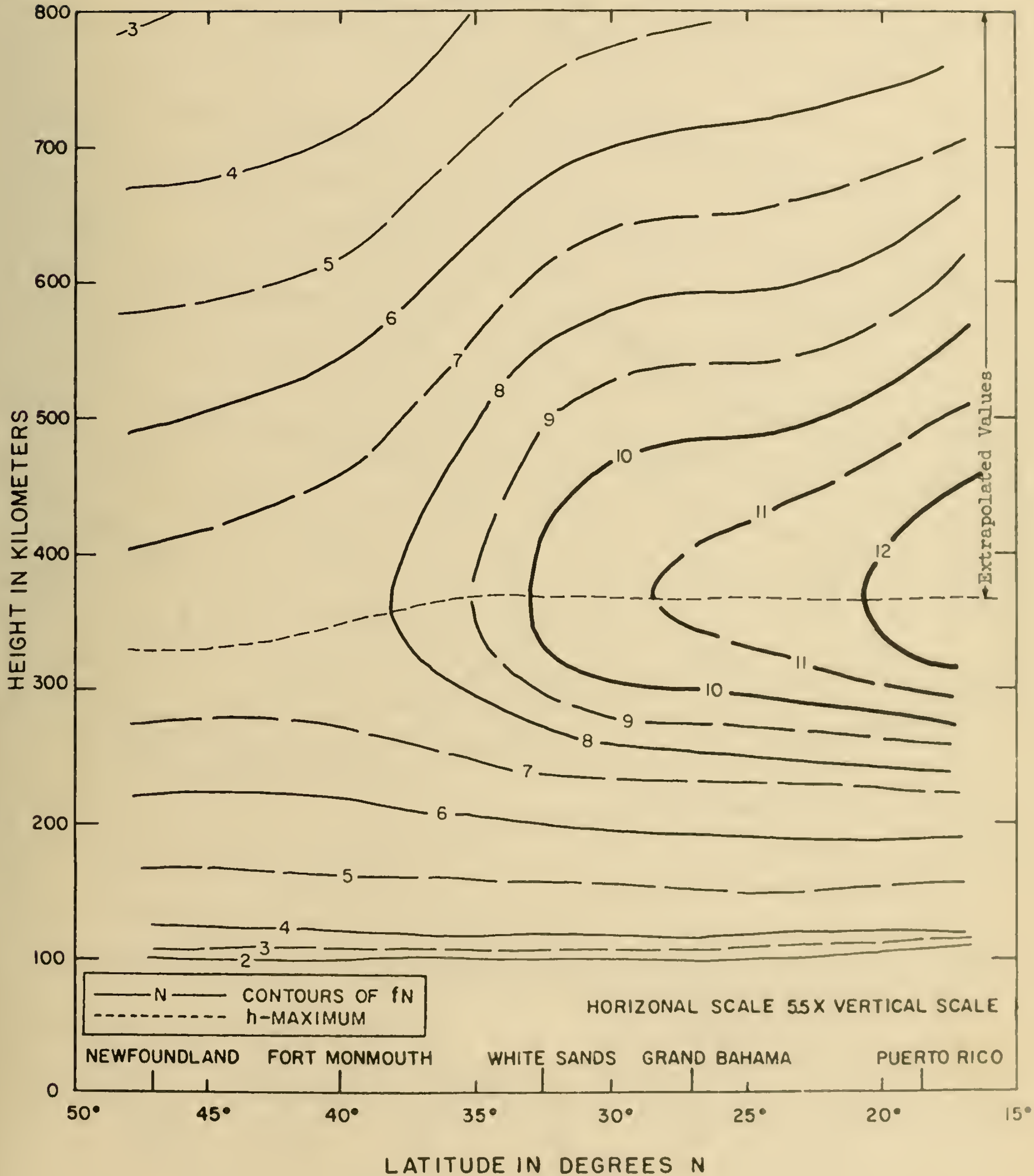
MAY 1959

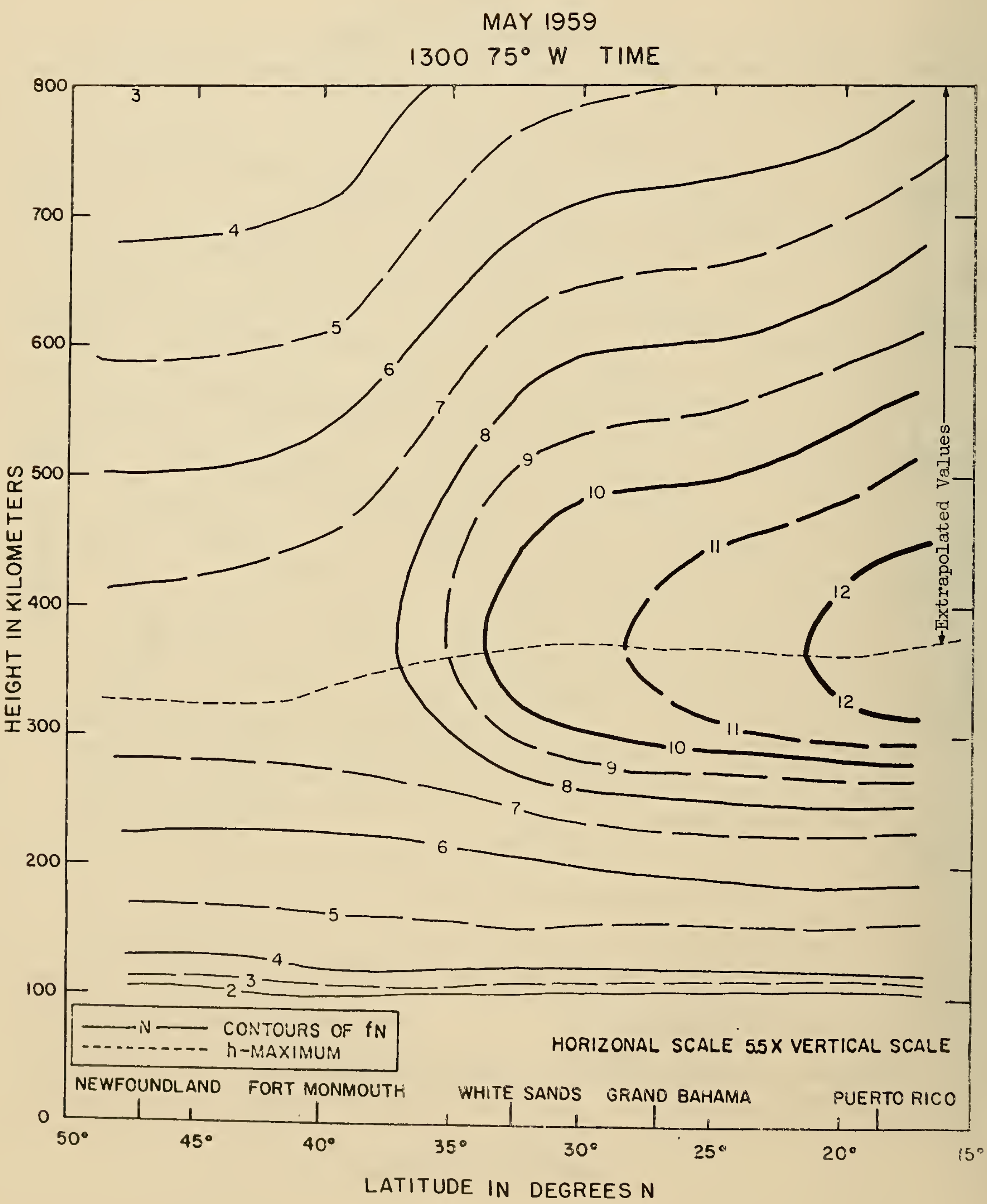
1100 75° W TIME

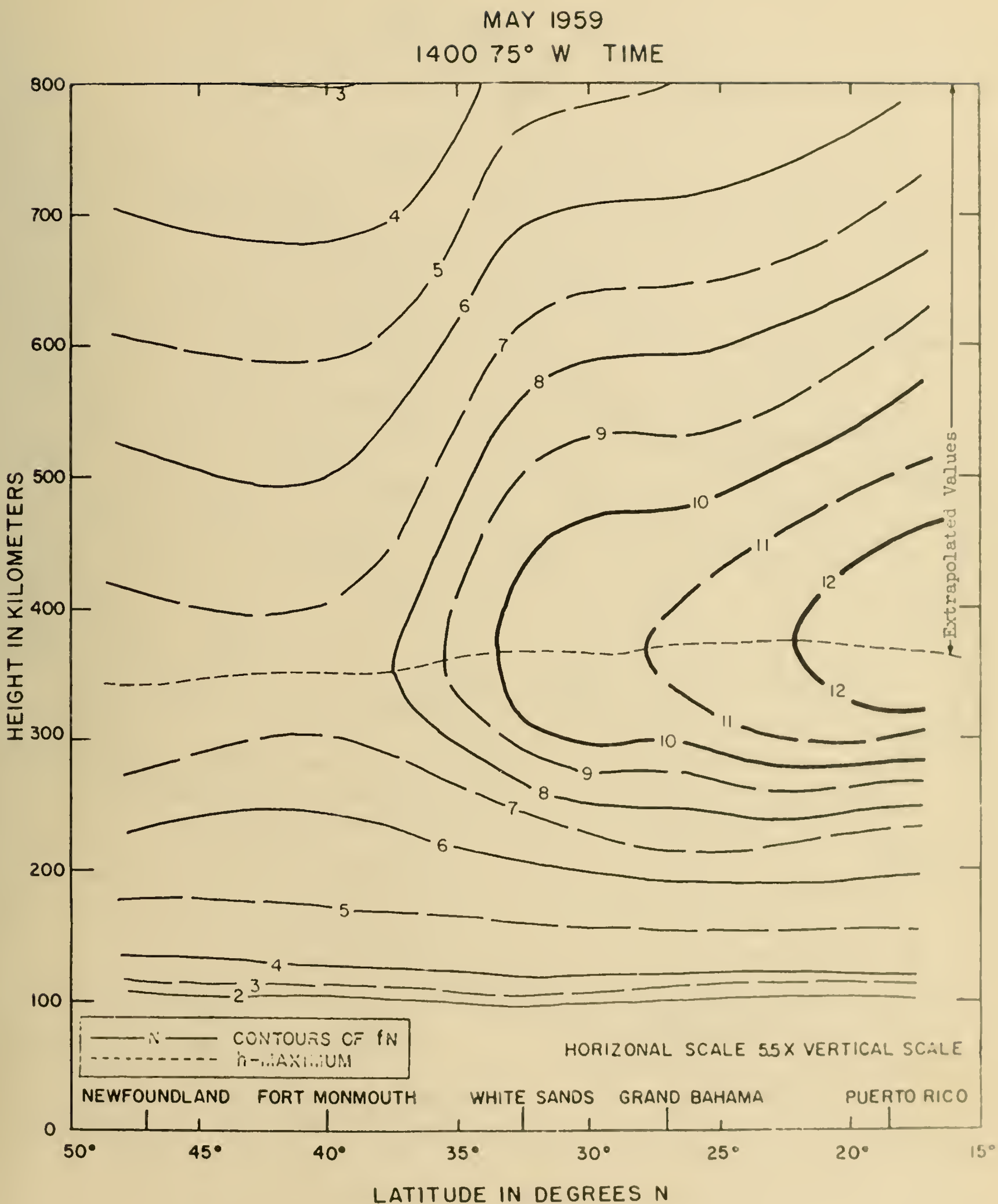


MAY 1959

1200 75° W TIME

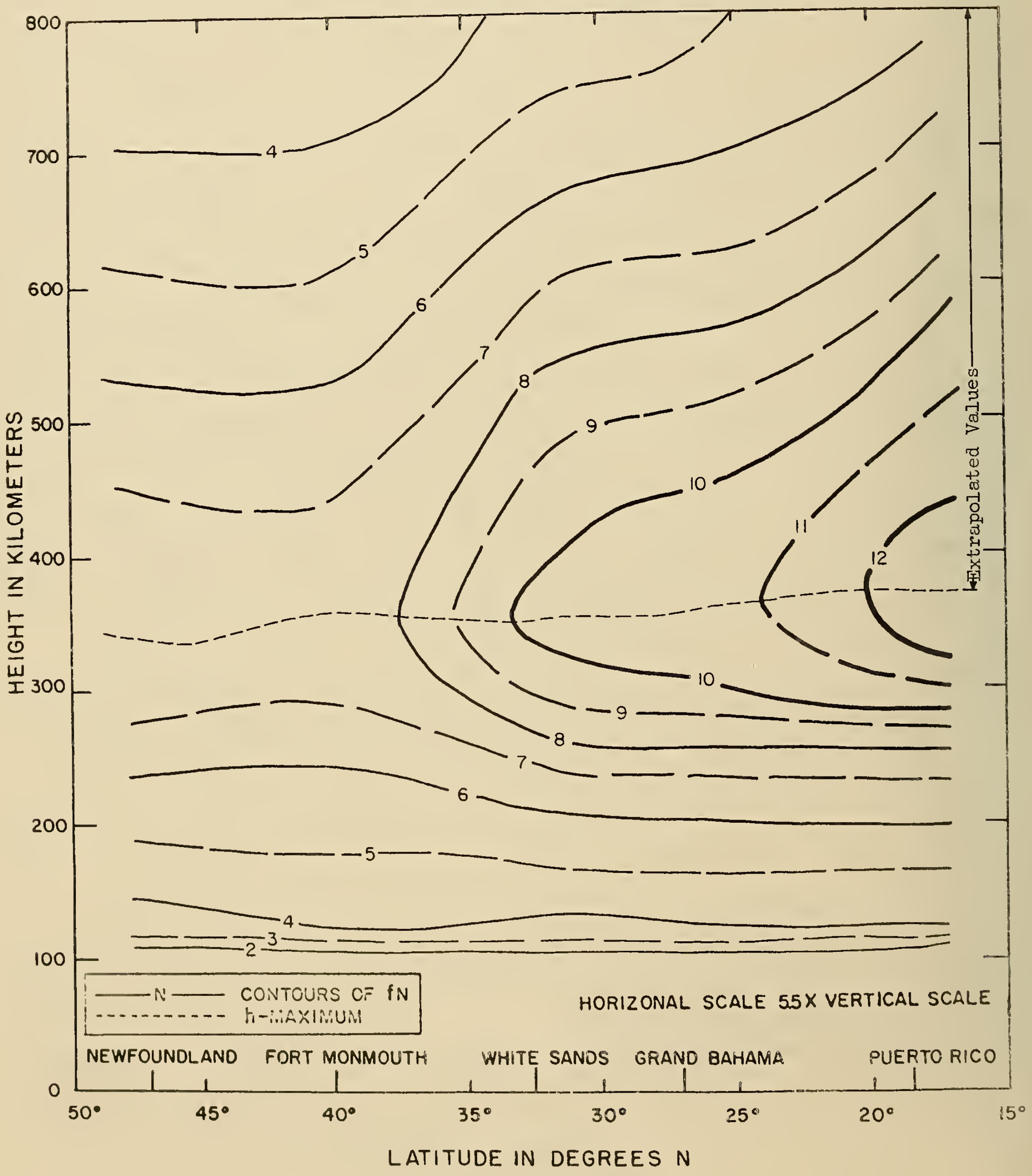


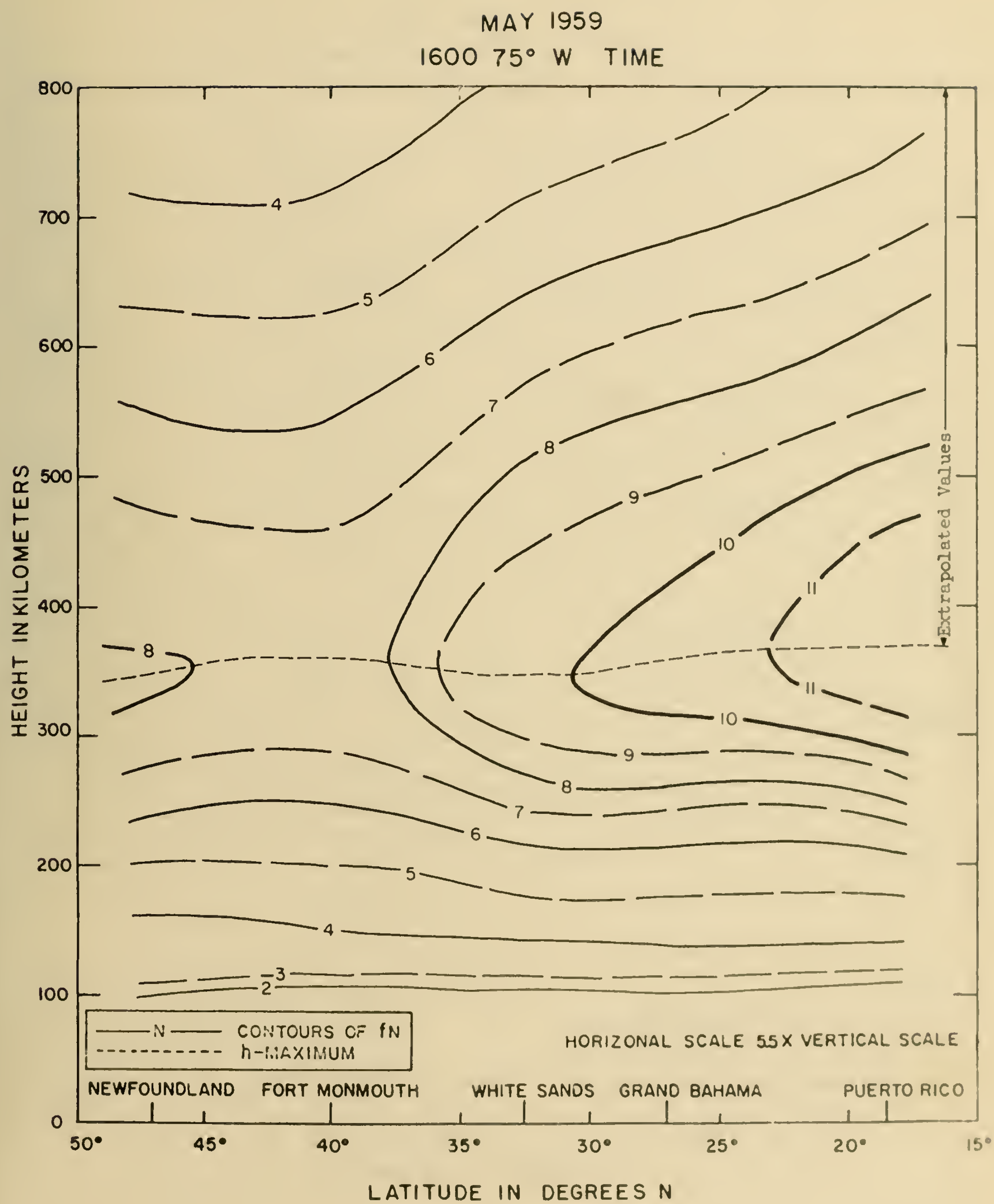

MAY 1959
1300 75° W TIME
800
700
600
500
400
300
200
100
0
HEIGHT IN KILOMETERS
3
4
5
6
7
8
9
10
11
12
Extrapolated Values
CONTOURS OF fN
h-MAXIMUM
HORIZONAL SCALE 5.5 X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
LATITUDE IN DEGREES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


MAY 1959
1400 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
Extrapolated Values
CONTOURS OF fN
h-MAXIMUM
HORIZONAL SCALE 5.5 X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
LATITUDE IN DEGREES N

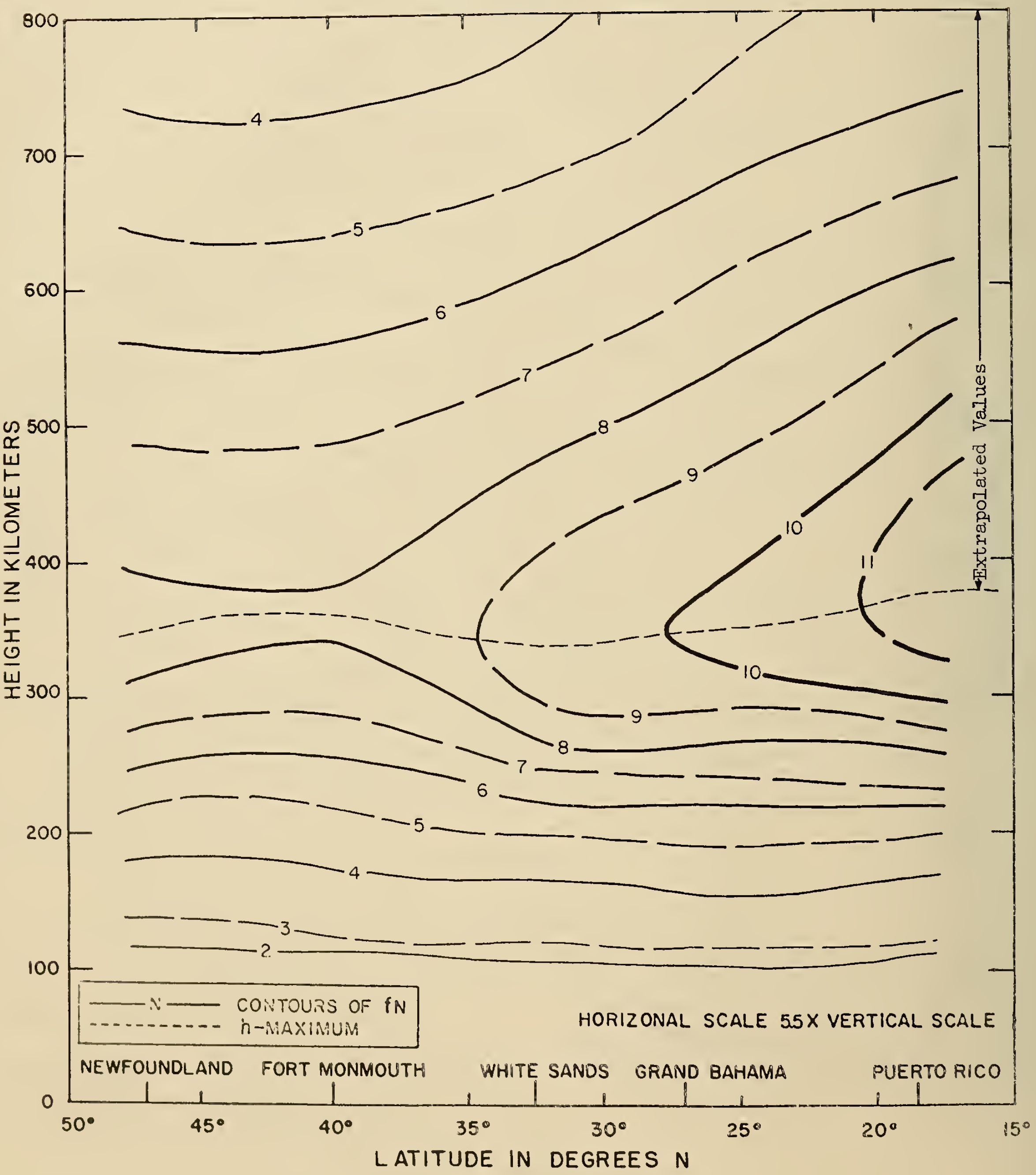
MAY 1959

1500 75° W TIME

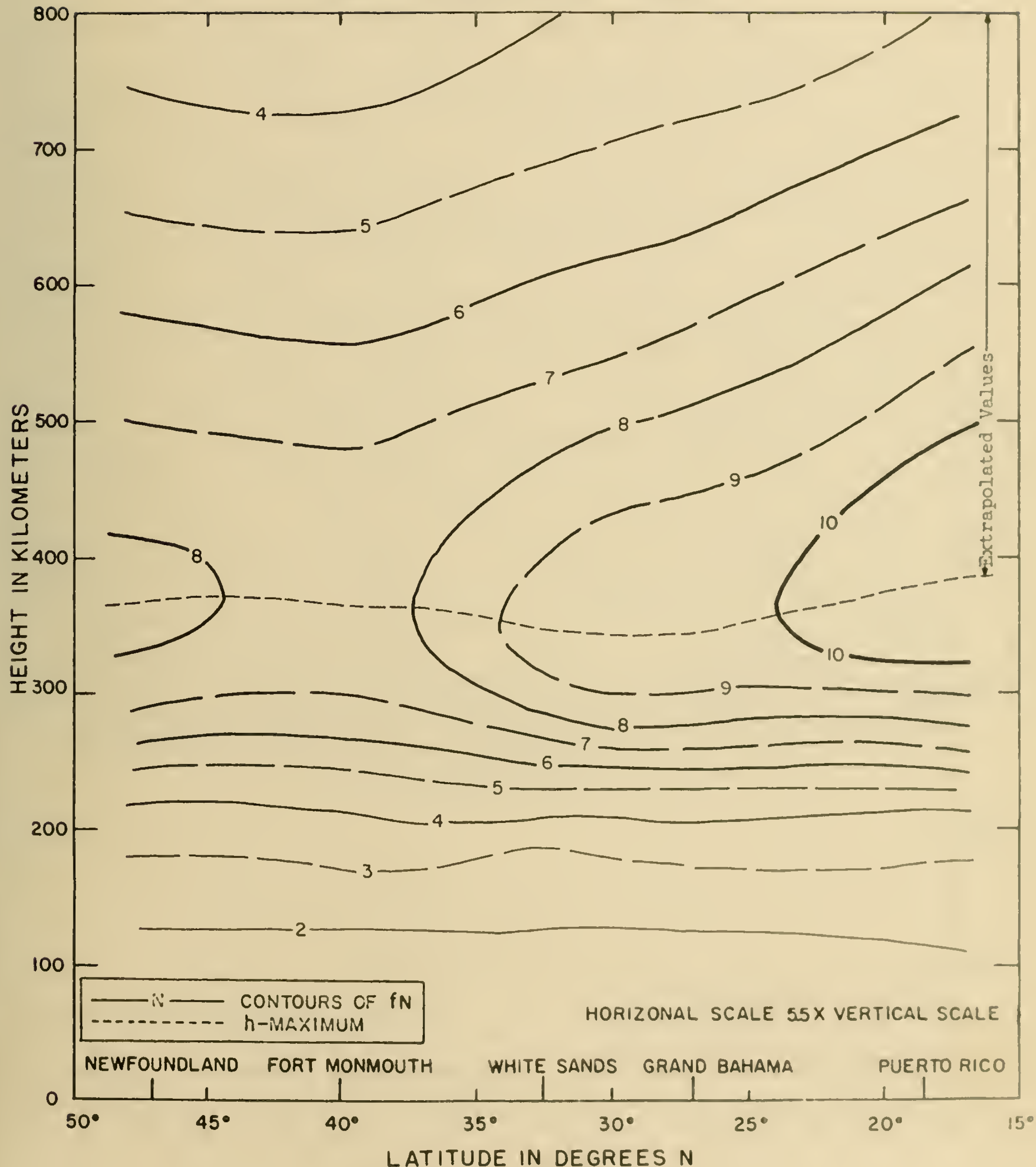


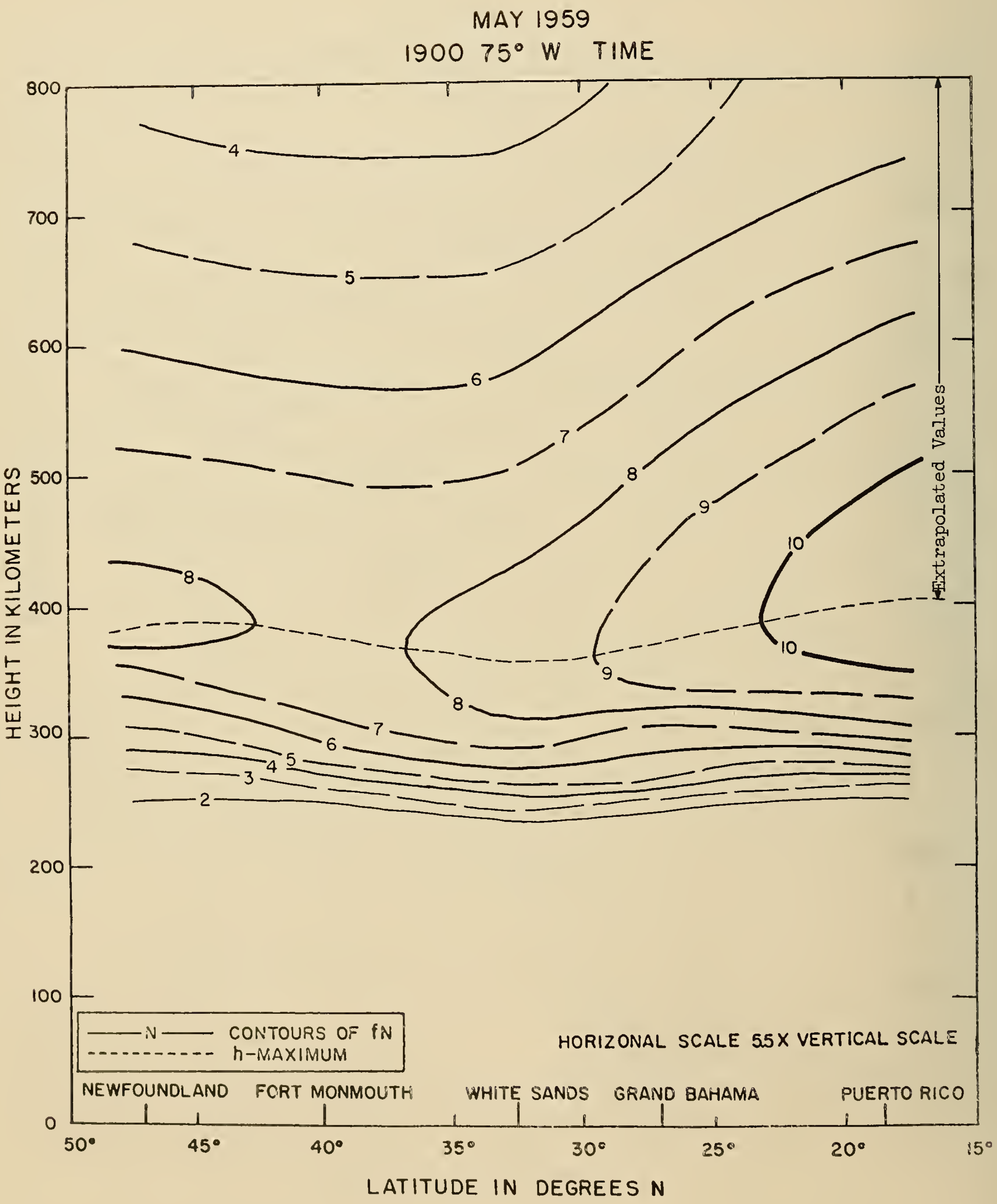

MAY 1959
1600 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
4
5
6
7
8
9
10
11
3
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
HORIZONAL SCALE 5.5 X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
LATITUDE IN DEGREES N

MAY 1959
1700 75° W TIME



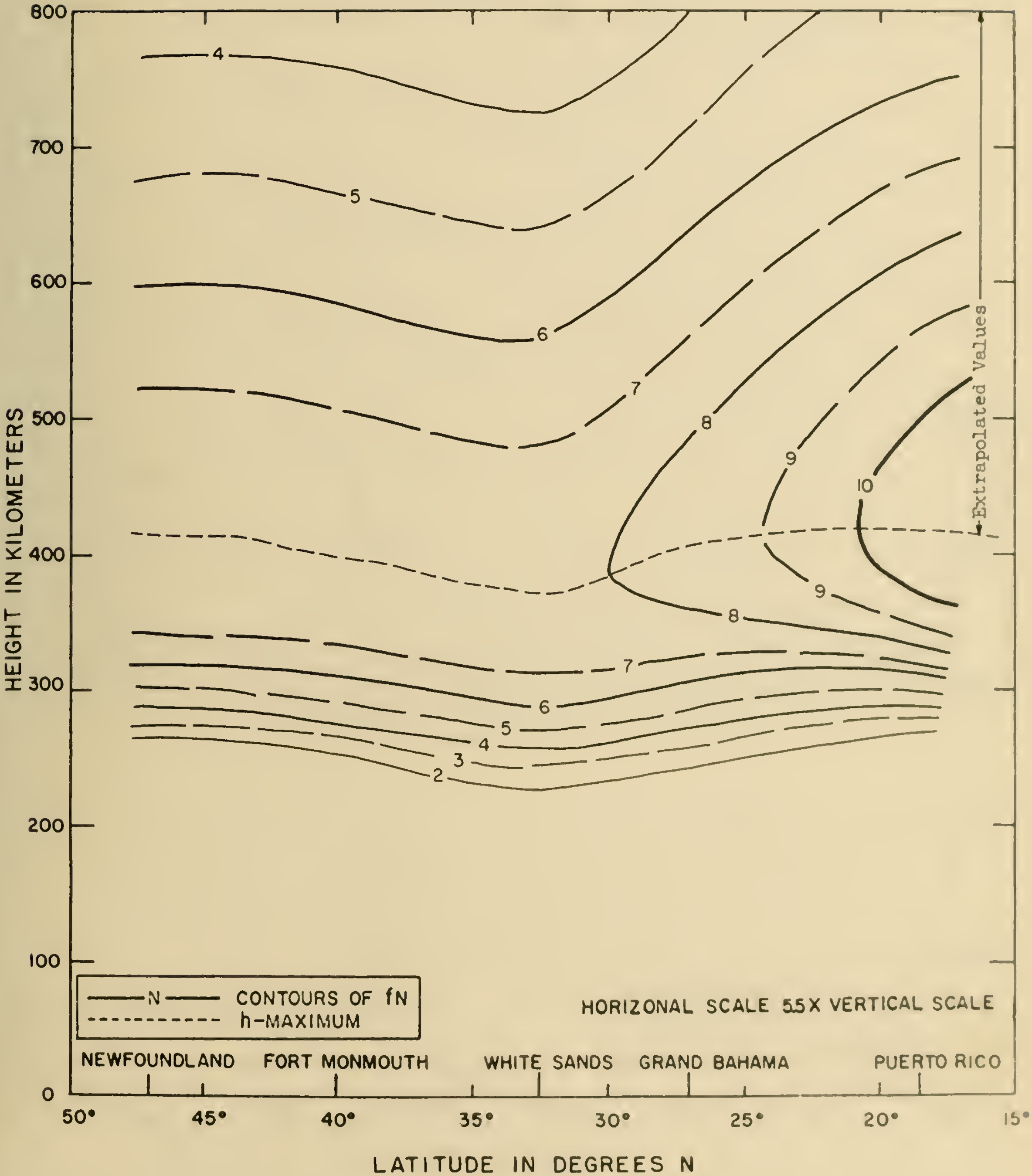
MAY 1959
1800 75° W TIME




MAY 1959
1900 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
4
5
6
7
8
9
10
8
9
10
8
7
6
5
4
3
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
LATITUDE IN DEGREES N

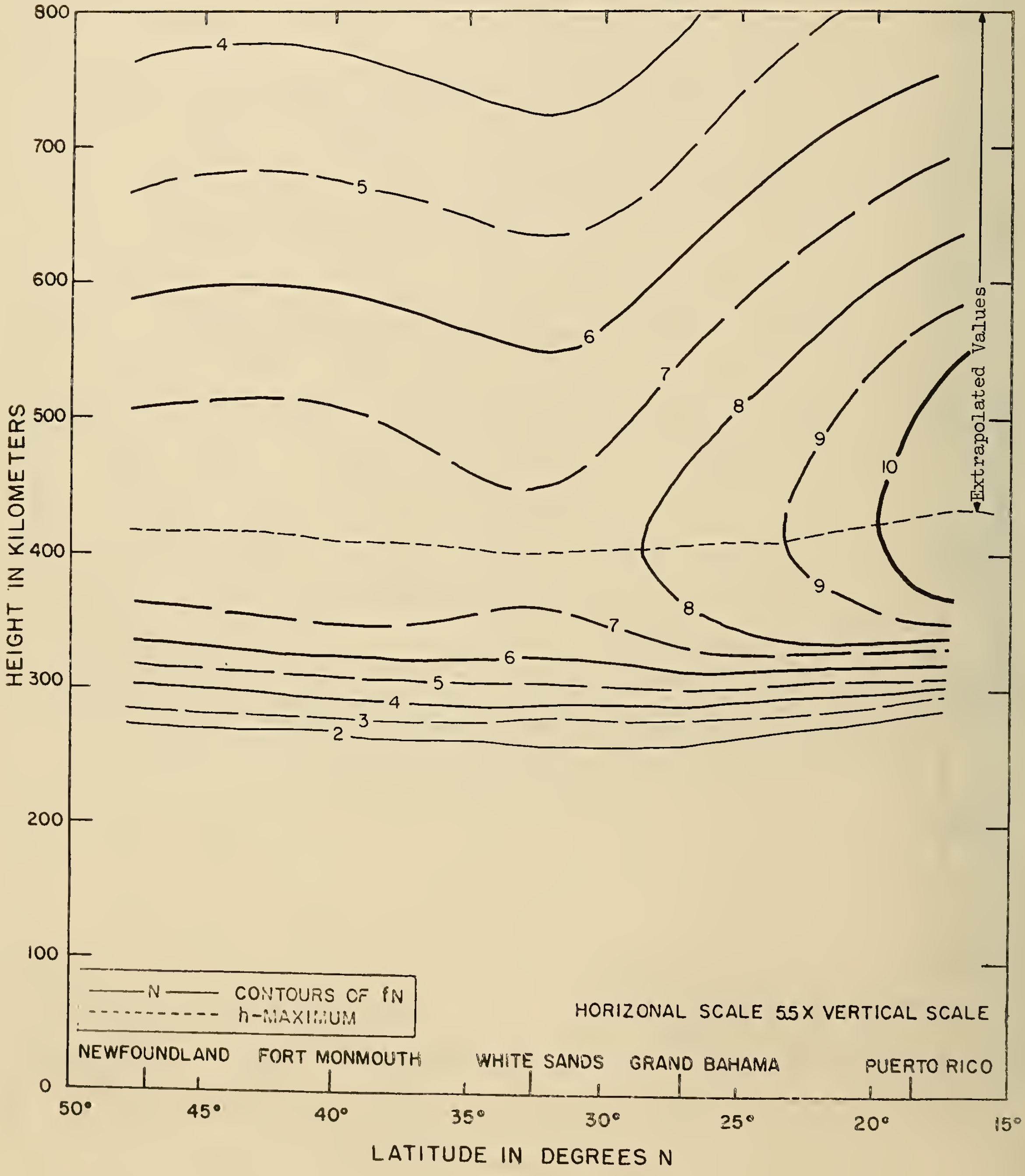
MAY 1959

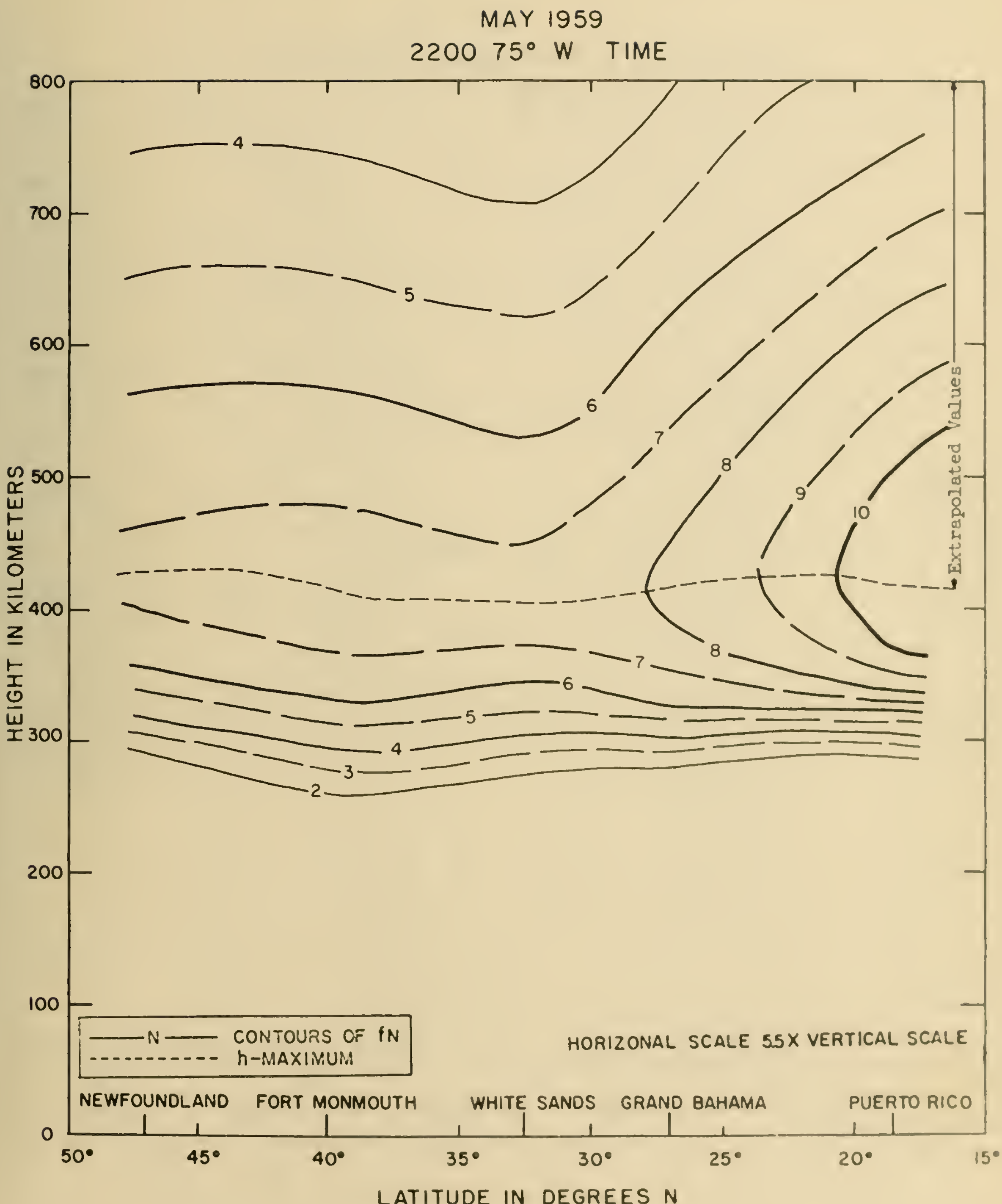
2000 75° W TIME



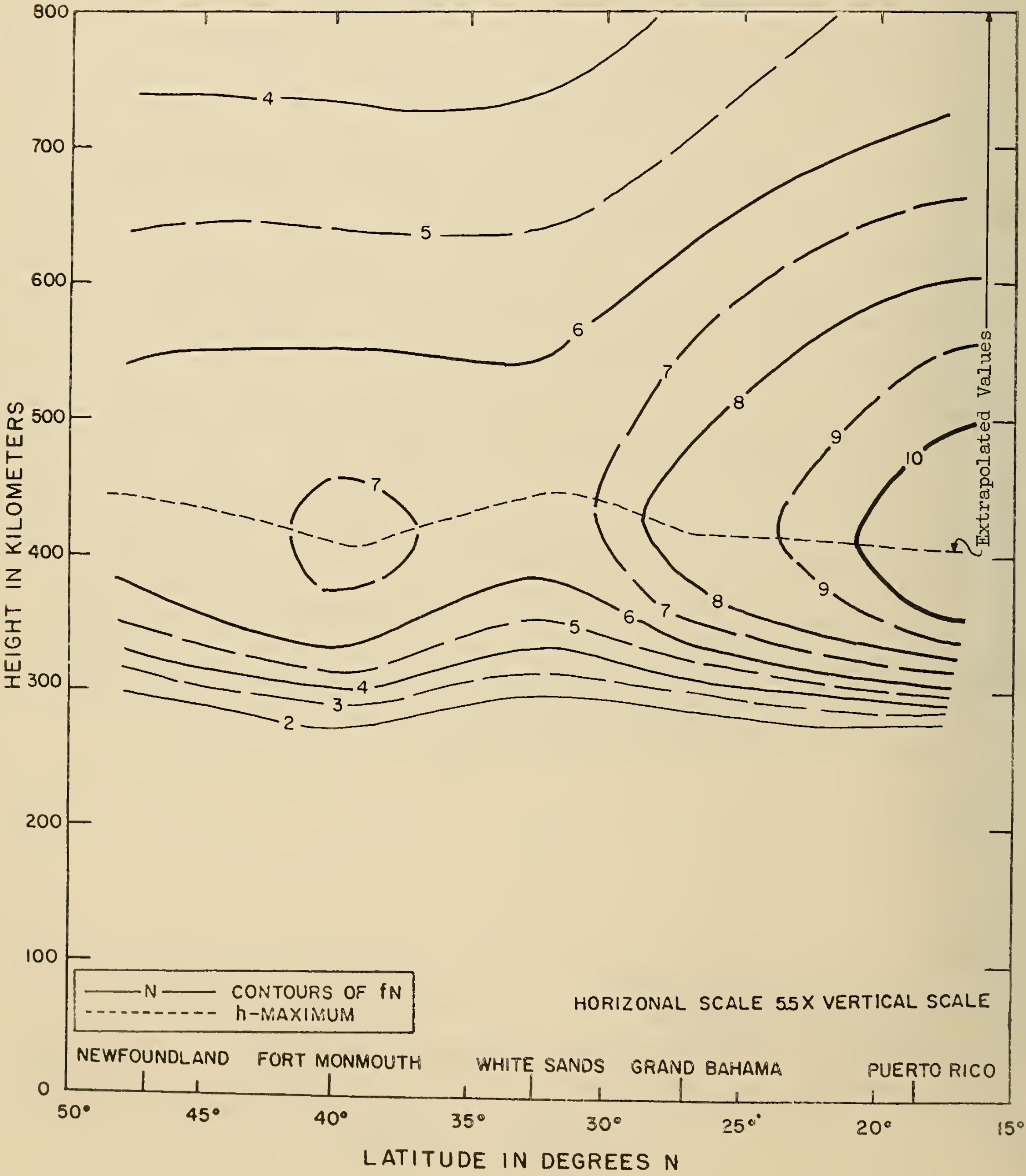
MAY 1959

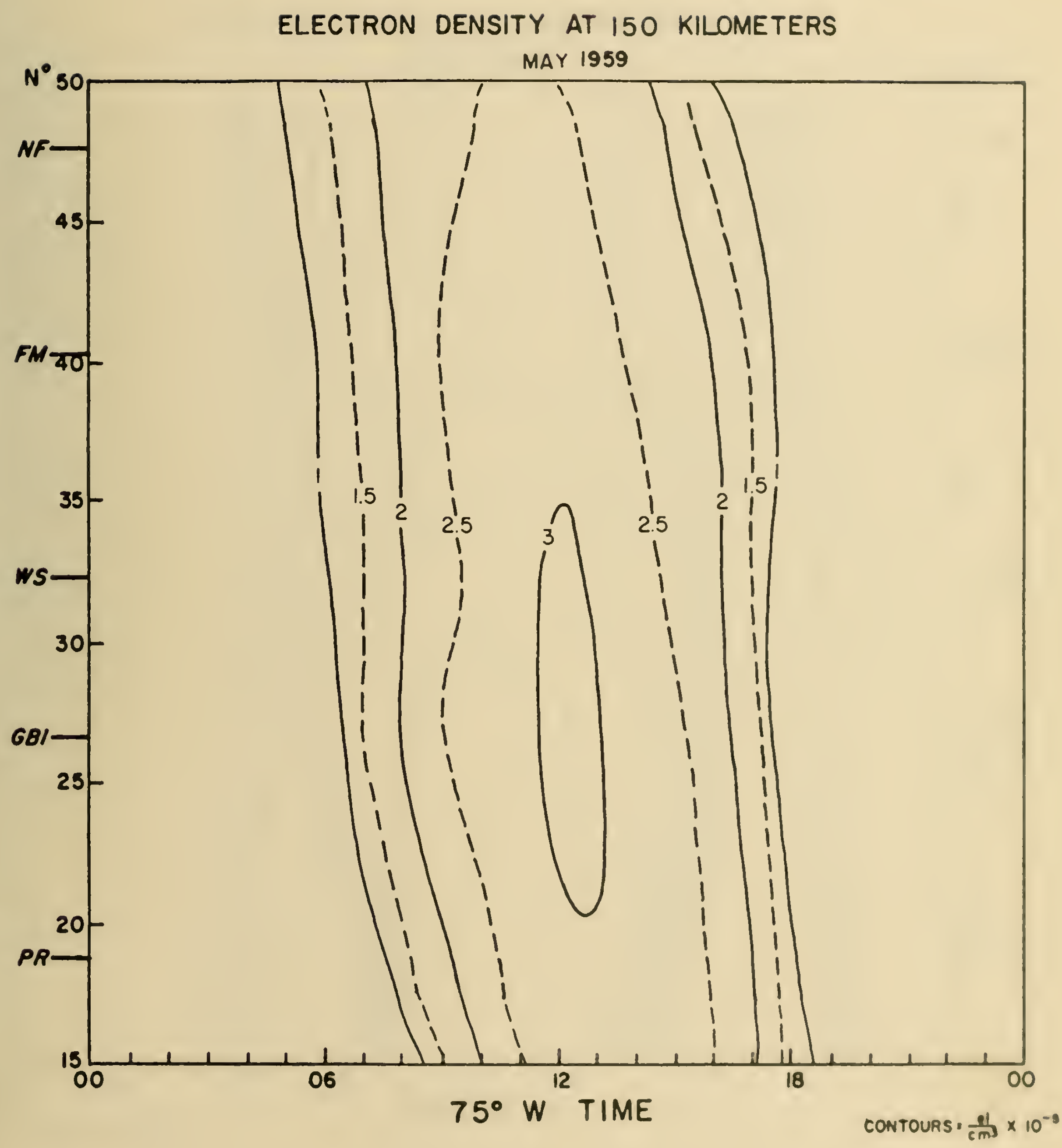
2100 75° W TIME



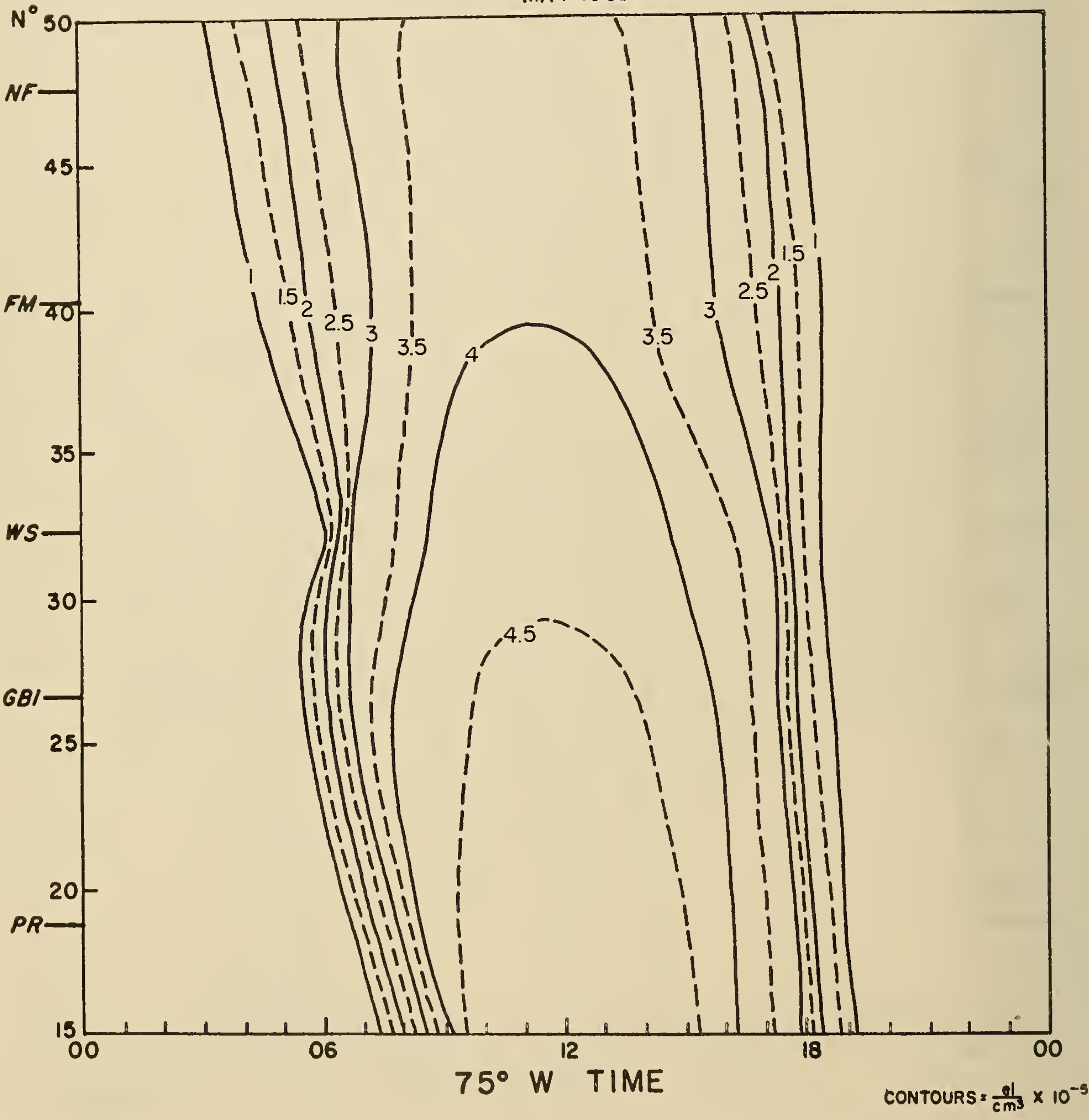

MAY 1959
2200 75° W TIME
HEIGHT IN KILOMETERS
LATITUDE IN DEGREES N
800
700
600
500
400
300
200
100
0
50°
45°
40°
35°
30°
25°
20°
15°
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
N CONTOURS OF fN
h-MAXIMUM
HORIZONAL SCALE 5.5X VERTICAL SCALE
Extrapolated Values
2
3
4
5
6
7
8
9
10

MAY 1959
2300 75° W TIME

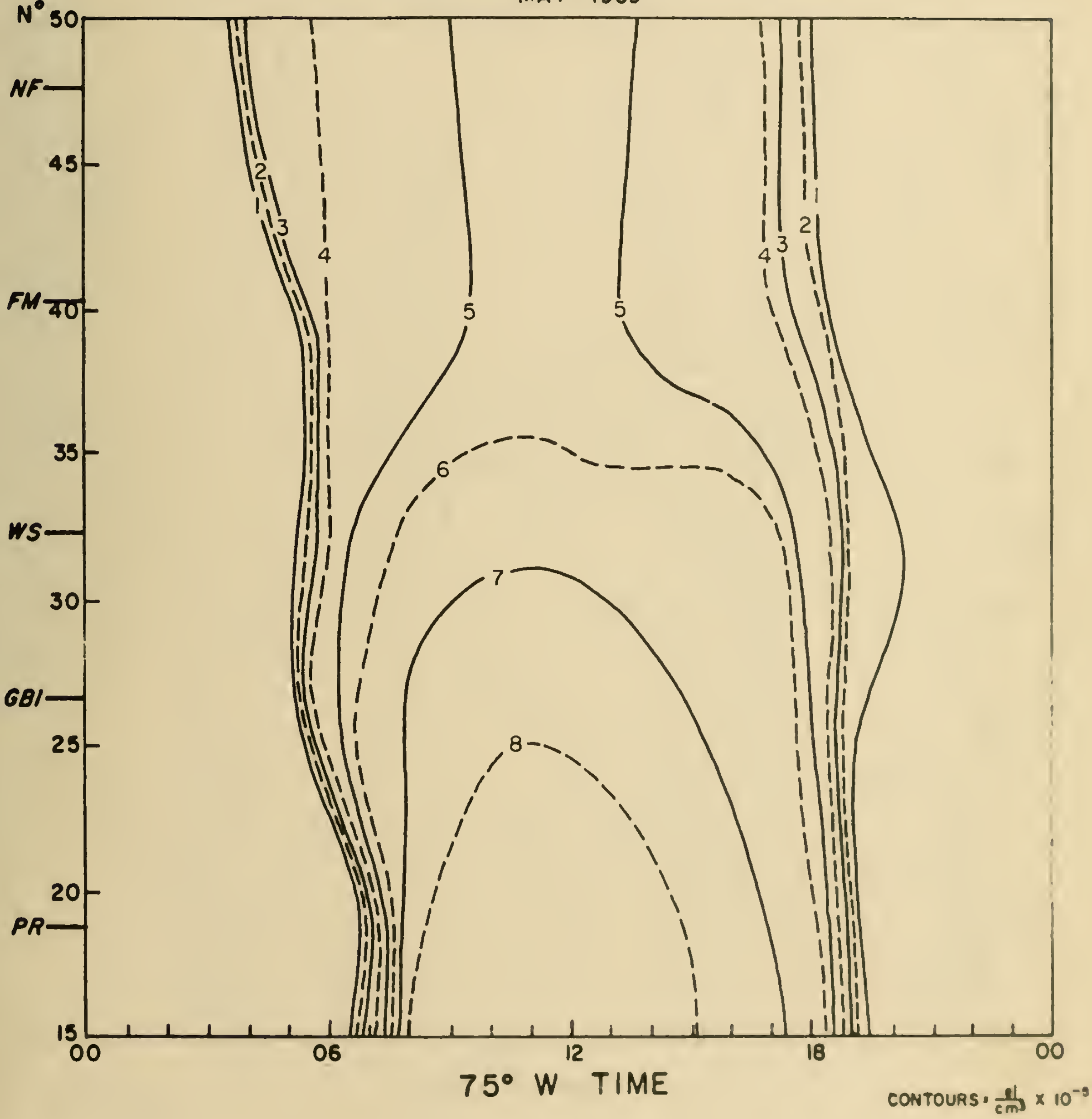


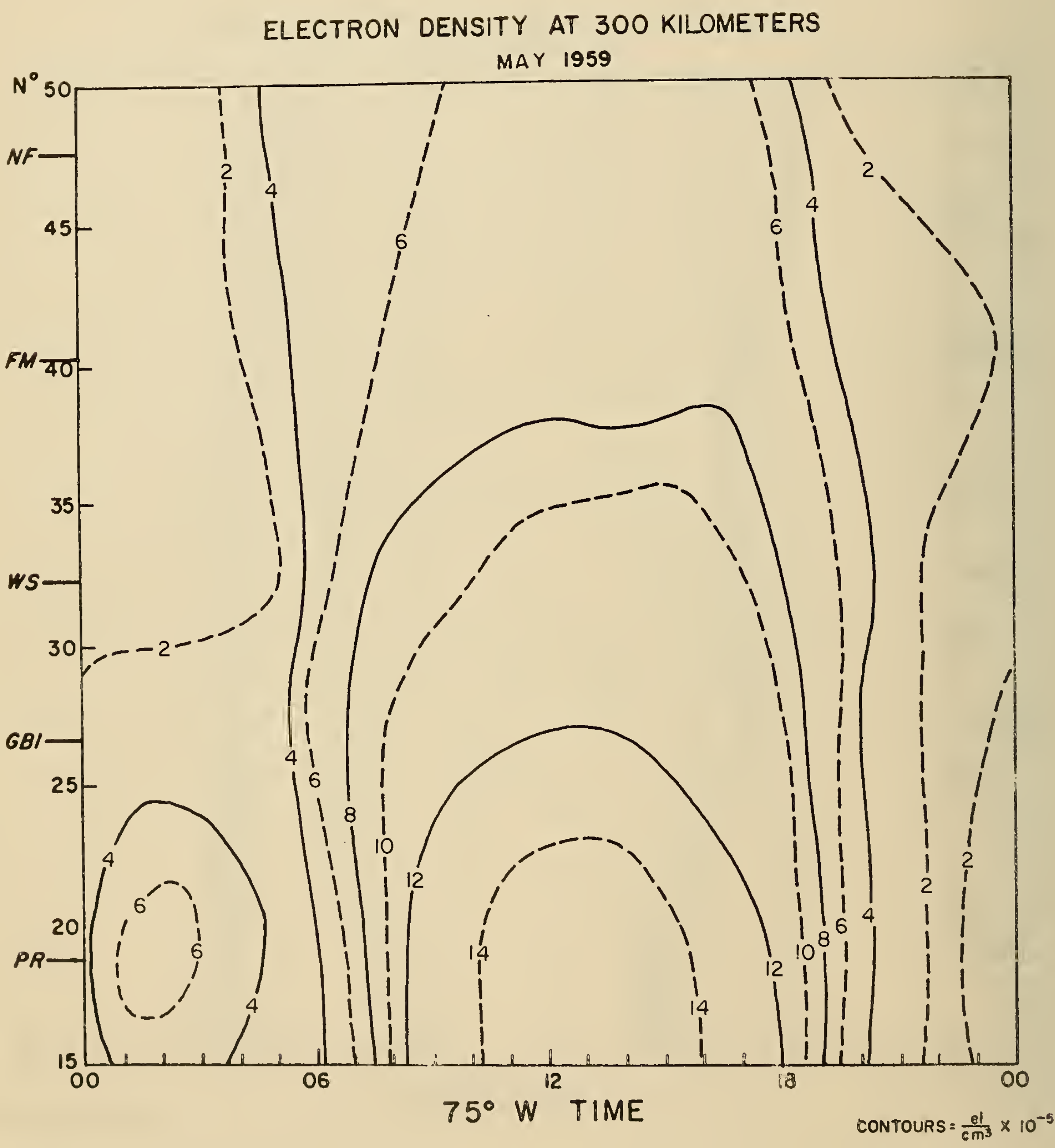

ELECTRON DENSITY AT 150 KILOMETERS
MAY 1959
N° 50
NF
45
FM 40
35
WS
30
GBI
25
20
PR
15
00
06
12
18
00
75° W TIME
1.5
2
2.5
3
2.5
2
1.5
CONTOURS: el/cm³ x 10⁻⁵

ELECTRON DENSITY AT 200 KILOMETERS
MAY 1959

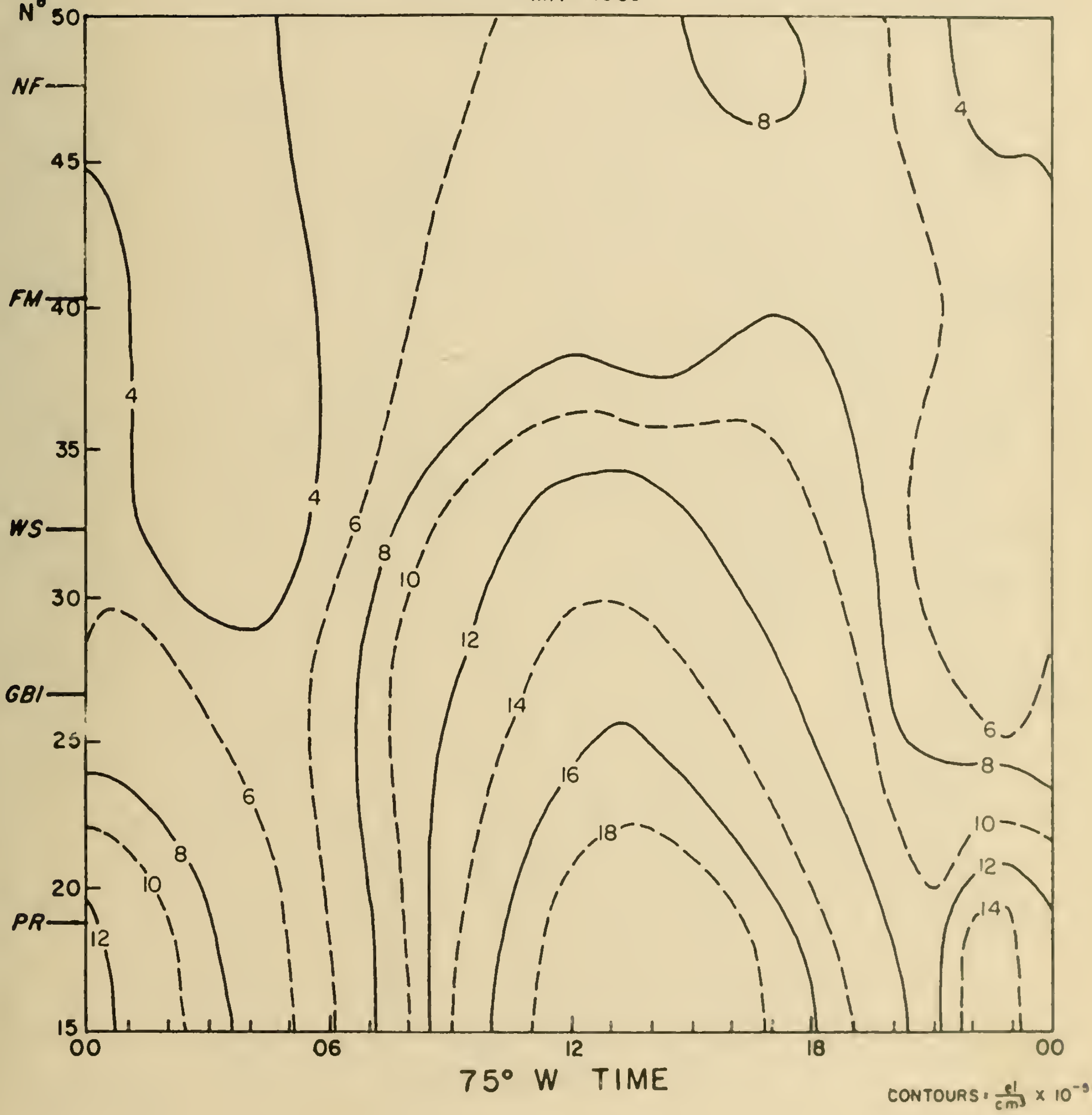


ELECTRON DENSITY AT 250 KILOMETERS
MAY 1959



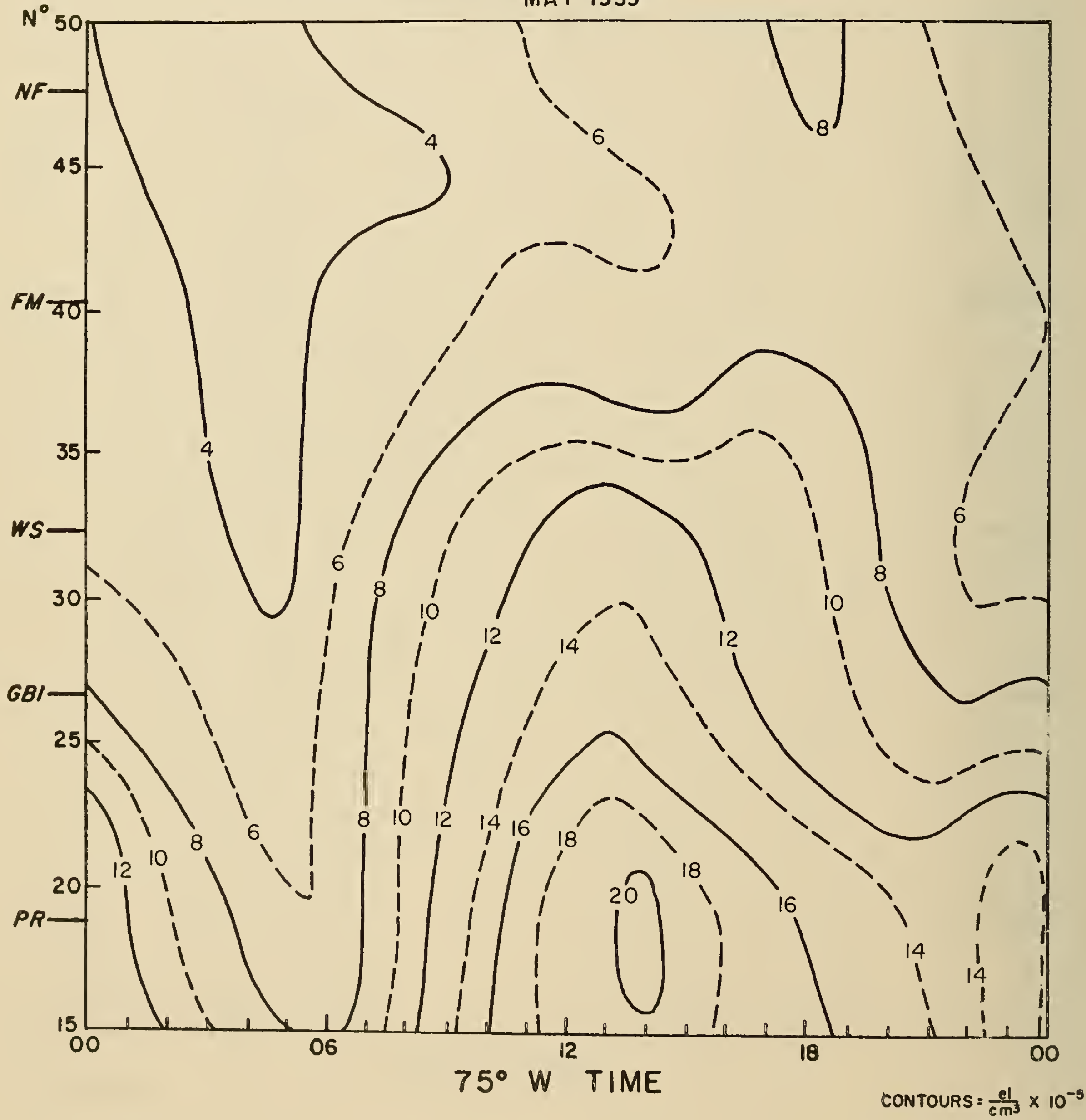

ELECTRON DENSITY AT 300 KILOMETERS
MAY 1959
N° 50
NF
45
FM 40
35
WS
30
GBI
25
20
PR
15
00
06
12
18
00
75° W TIME
CONTOURS = el/cm³ X 10⁻⁵

ELECTRON DENSITY AT 350 KILOMETERS
MAY 1959



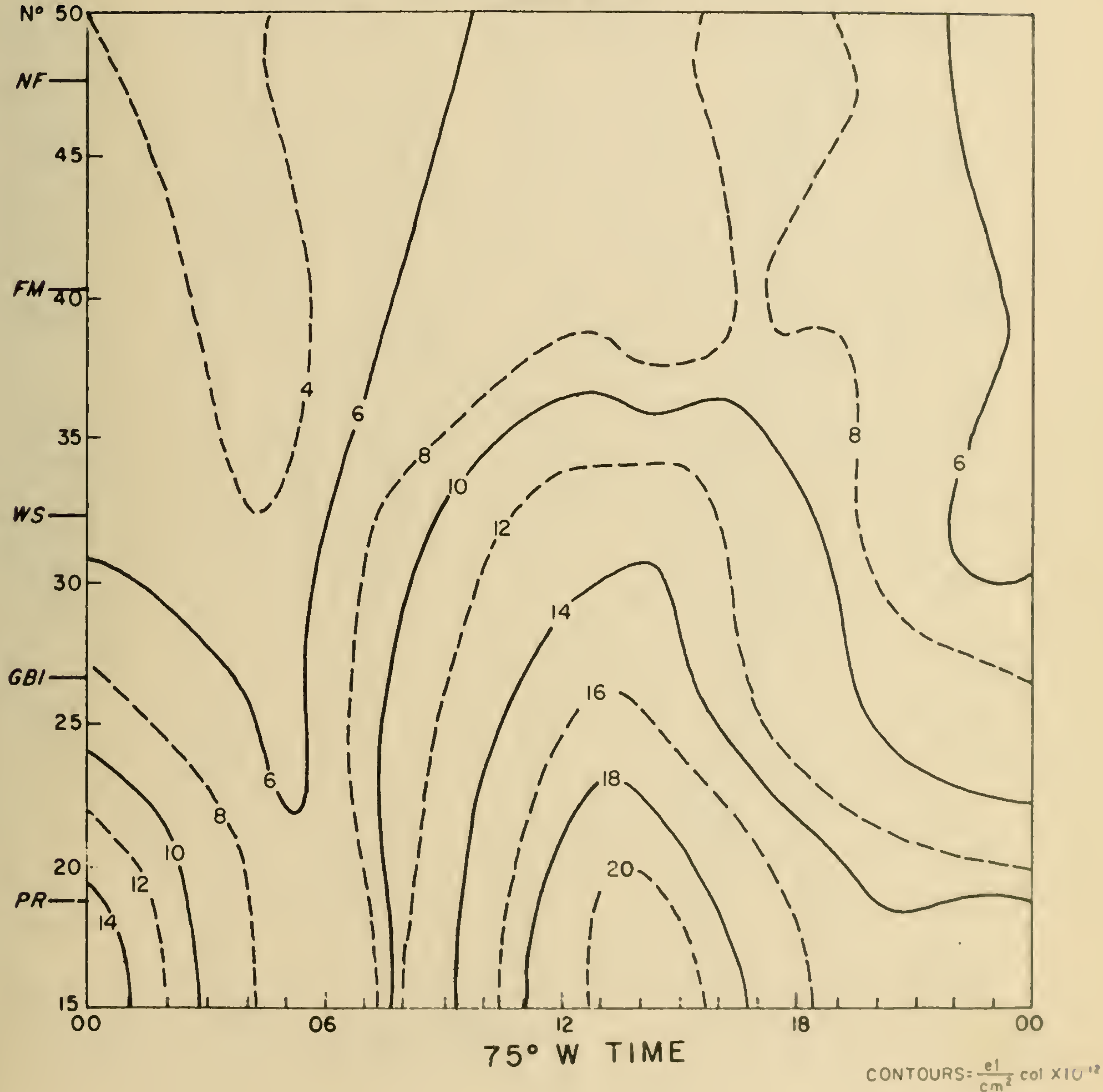
ELECTRON DENSITY AT 400 KILOMETERS

MAY 1959

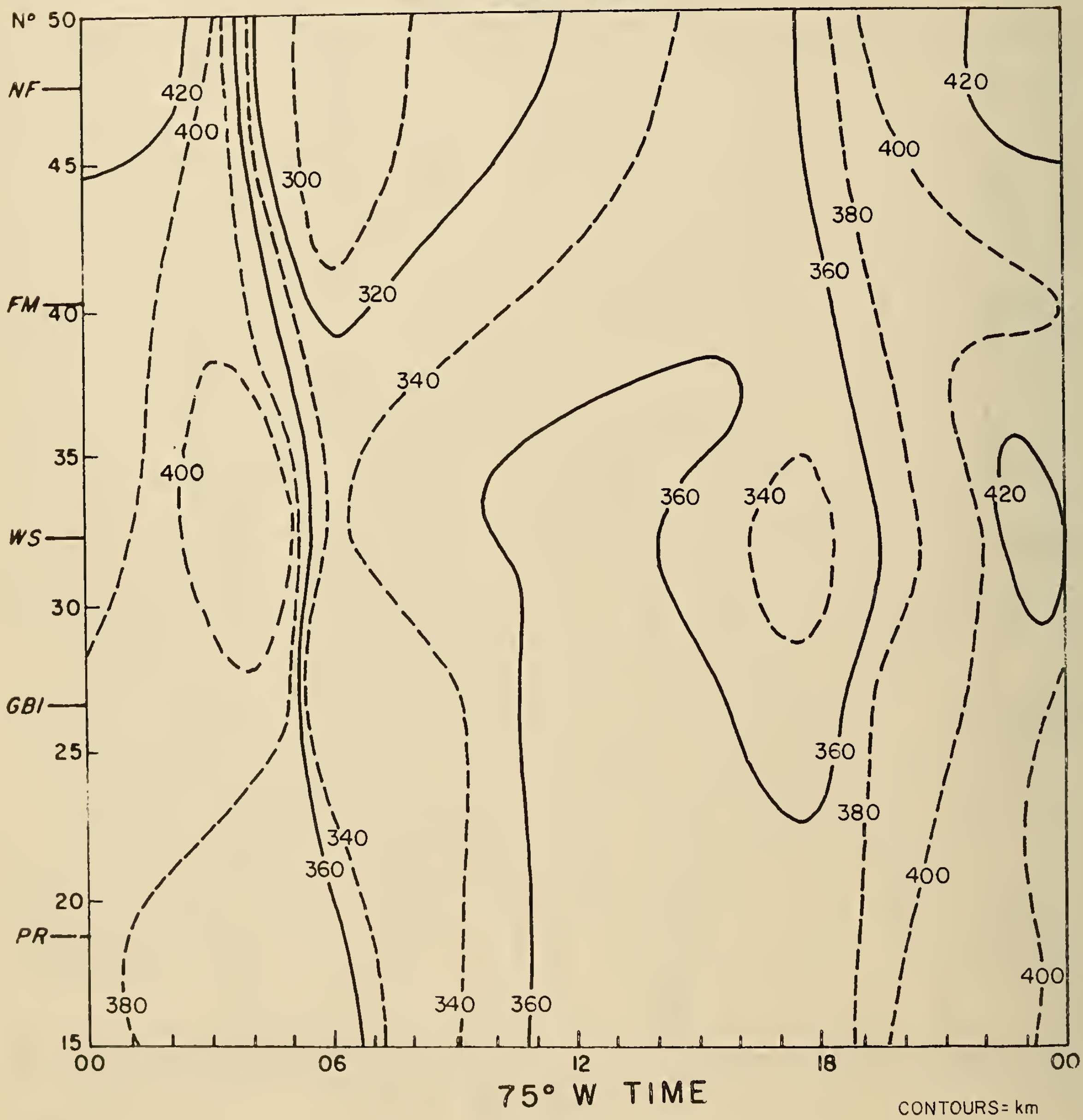


MAXIMUM ELECTRON DENSITY

MAY 1959

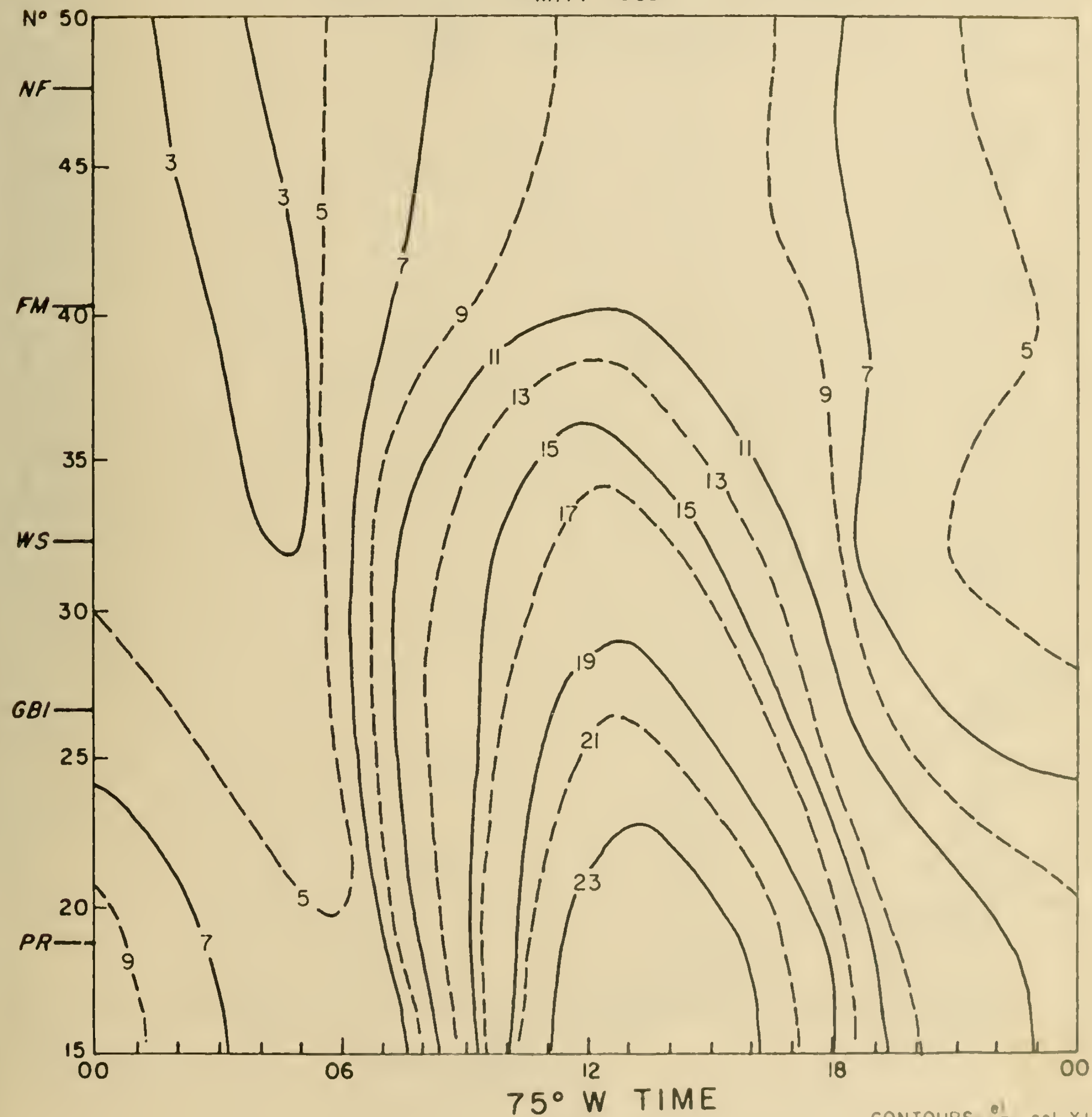


HEIGHT OF MAXIMUM ELECTRON DENSITY
MAY 1959

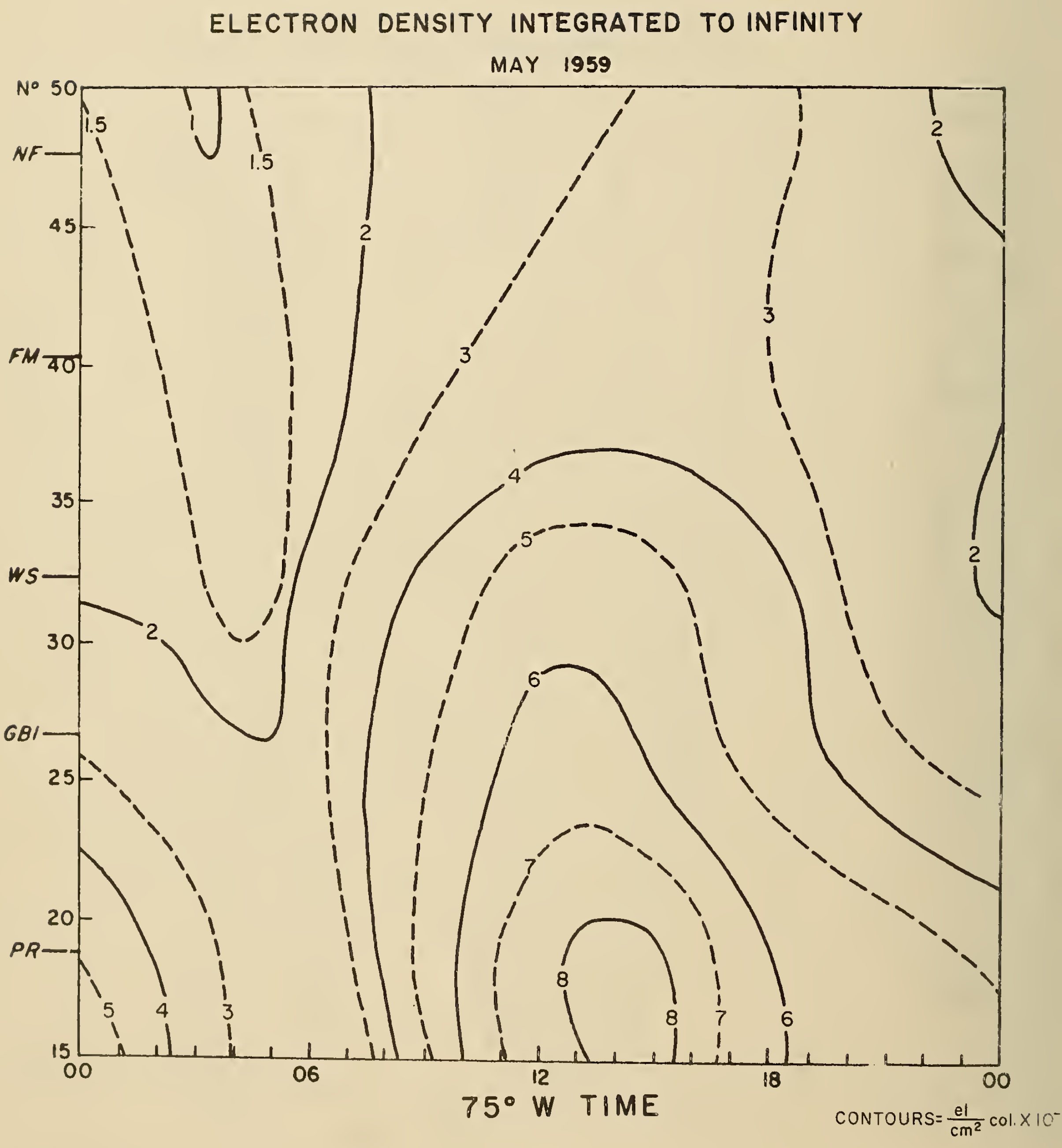


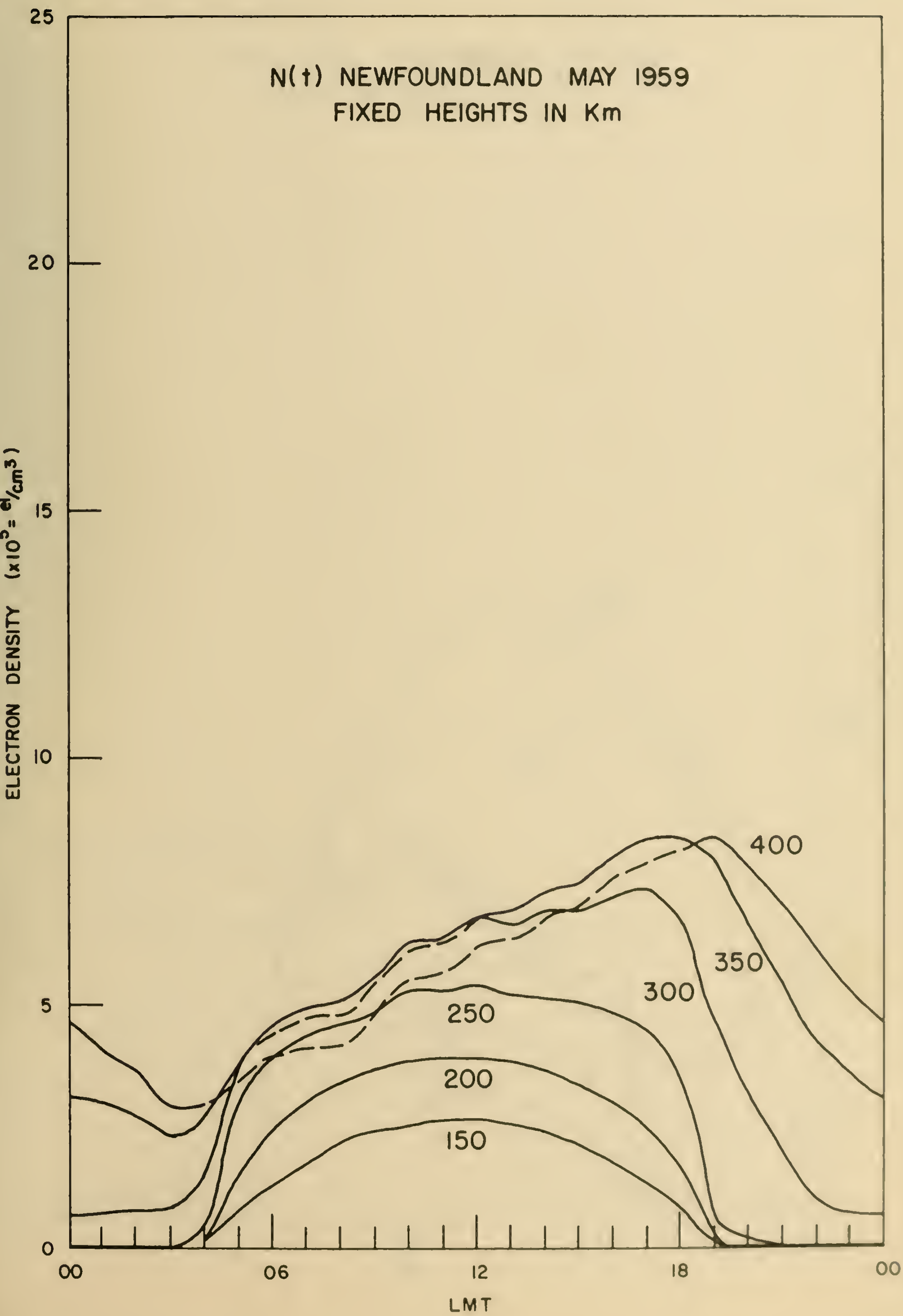
ELECTRON DENSITY INTEGRATED TO HEIGHT OF MAXIMUM ELECTRON DENSITY

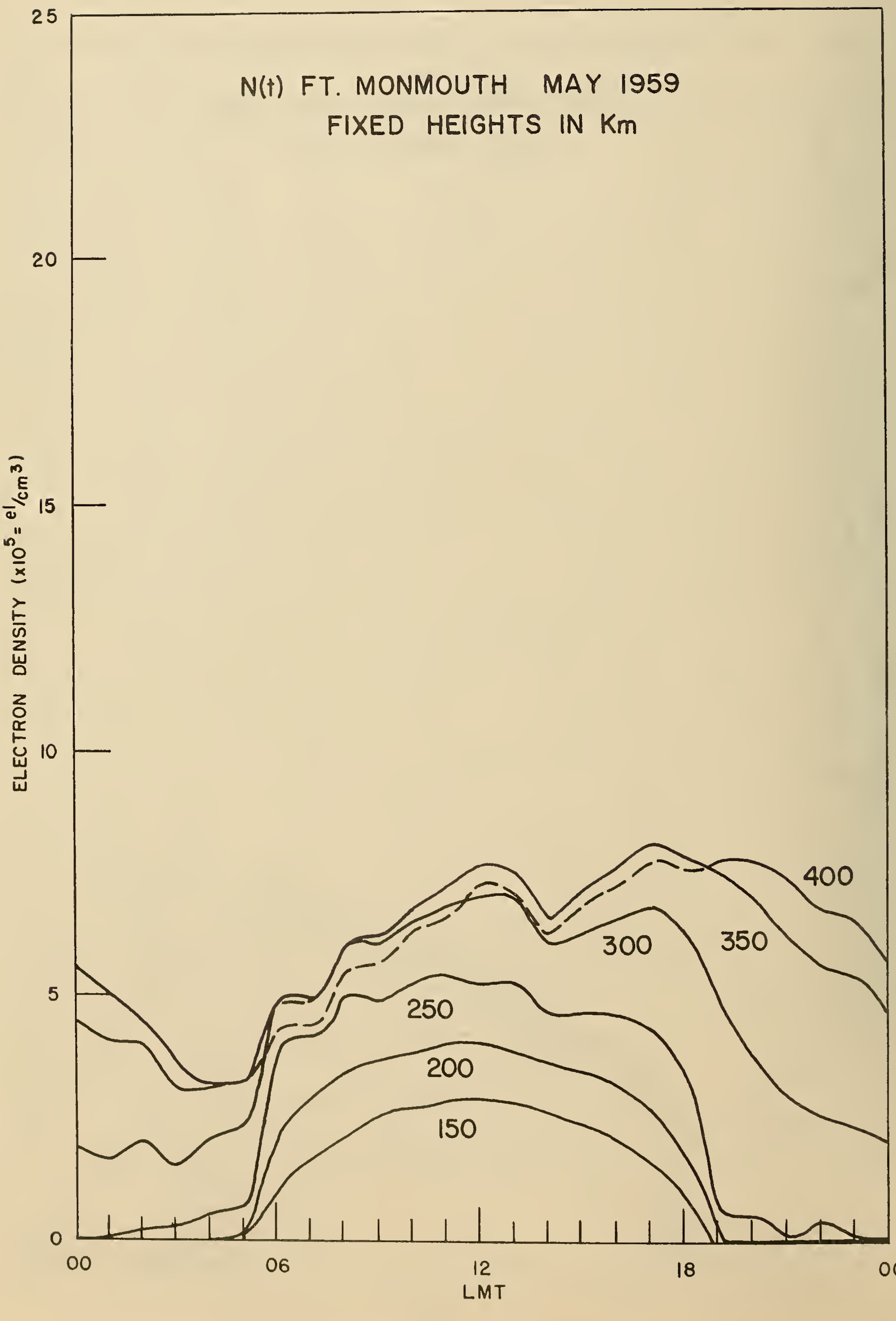
MAY 1959

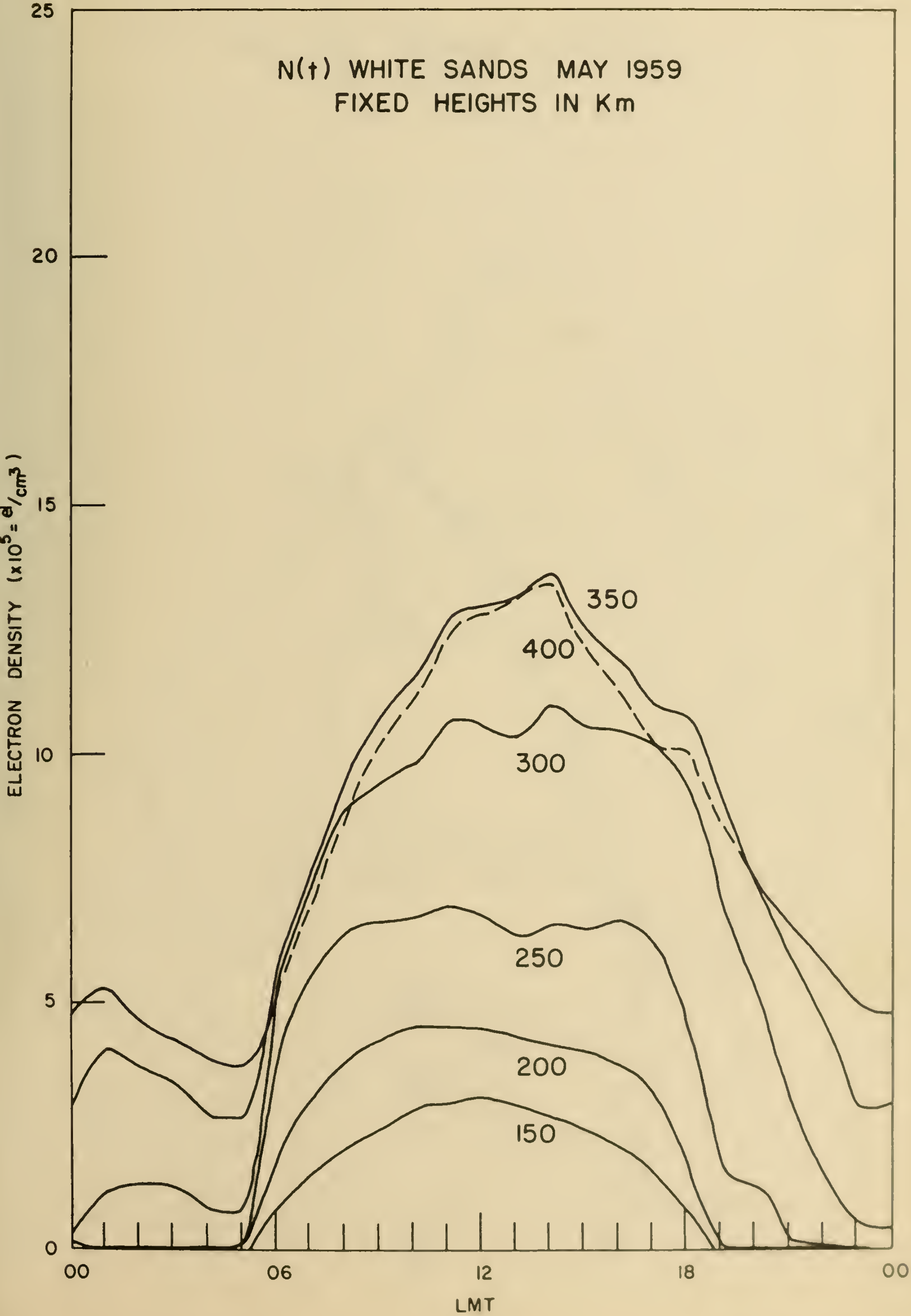


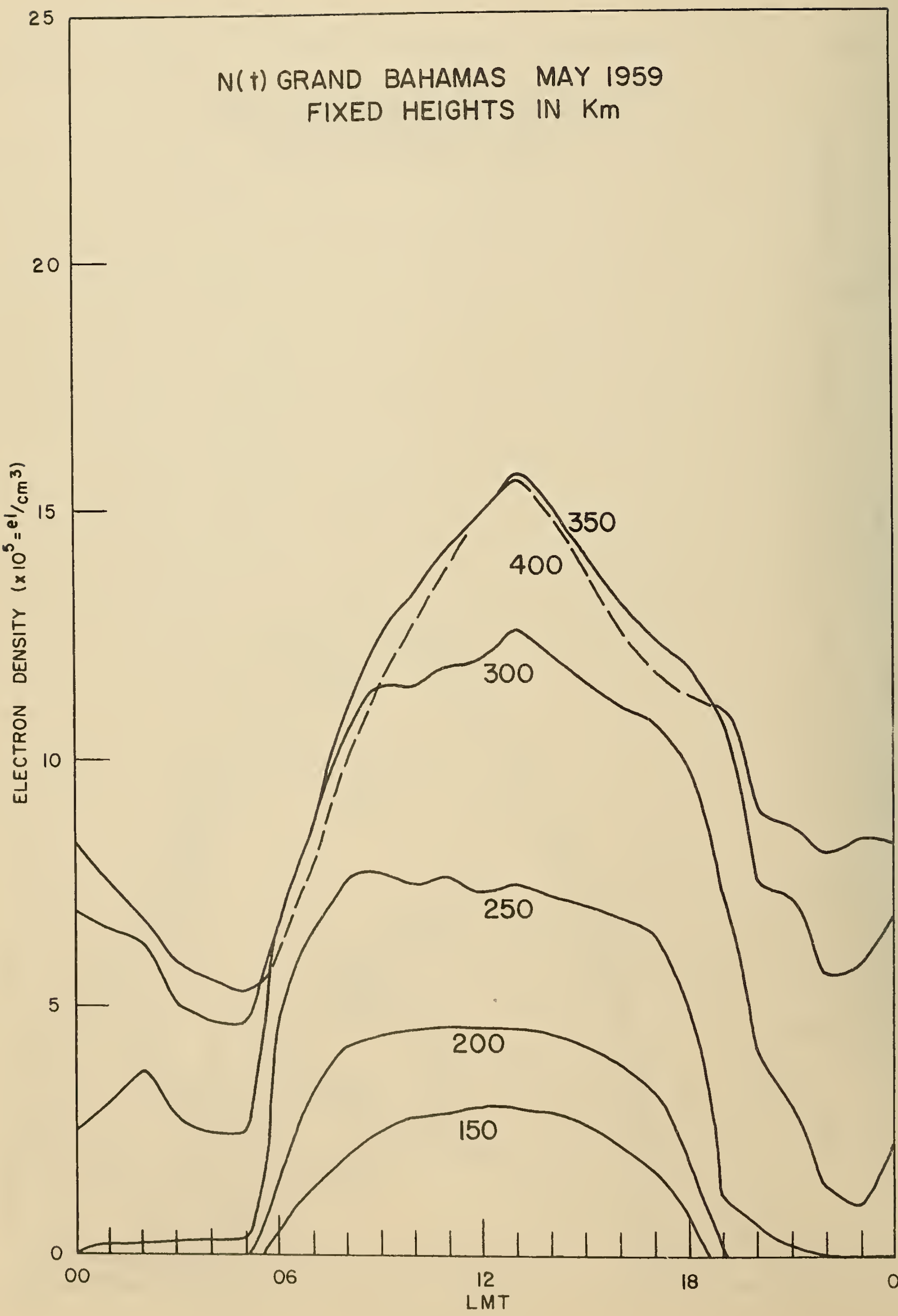
CONTOURS $\frac{el}{cm^2}$ col X10$^{-?}$


ELECTRON DENSITY INTEGRATED TO INFINITY
MAY 1959
N° 50
NF
45
FM
40
35
WS
30
GBI
25
20
PR
15
00
06
12
18
00
75° W TIME
1.5
1.5
2
3
2
3
4
5
2
2
6
7
8
8
7
6
5
4
3
CONTOURS= el/cm² col. X 10

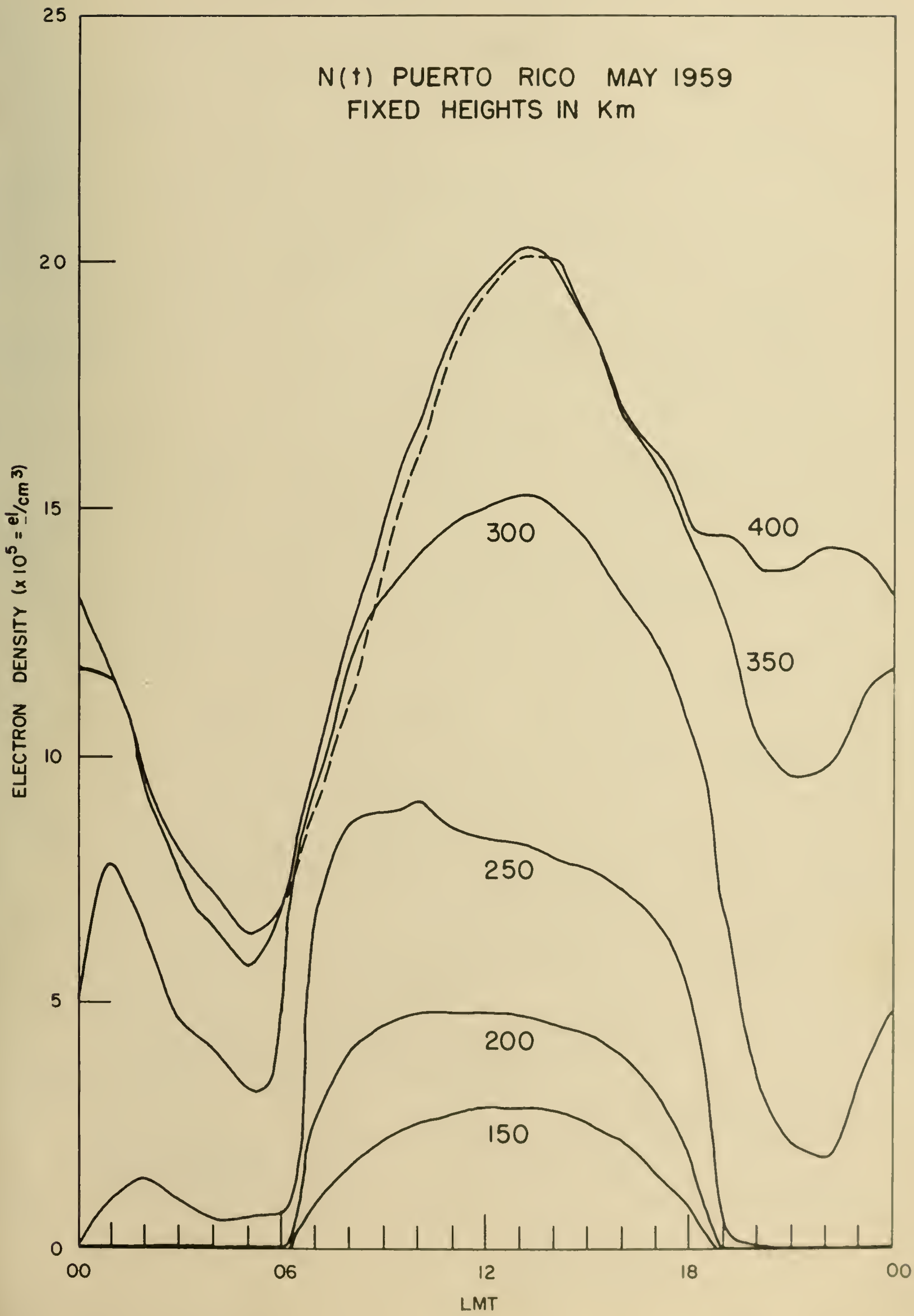

N(t) NEWFOUNDLAND MAY 1959
FIXED HEIGHTS IN Km
ELECTRON DENSITY (x10^5 = el/cm^3)
25
20
15
10
5
0
400
350
300
250
200
150
00
06
12
18
00
LMT


N(t) FT. MONMOUTH MAY 1959
FIXED HEIGHTS IN Km
ELECTRON DENSITY (x10^5 = el/cm^3)
25
20
15
10
5
0
400
350
300
250
200
150
00
06
12
18
00
LMT


N(t) WHITE SANDS MAY 1959
FIXED HEIGHTS IN Km
ELECTRON DENSITY (x10^5 = el/cm^3)
25
20
15
10
5
0
350
400
300
250
200
150
00
06
12
18
00
LMT



N(t) GRAND BAHAMAS MAY 1959
FIXED HEIGHTS IN Km
ELECTRON DENSITY (x 10^5 = el/cm^3)
25
20
15
10
5
0
350
400
300
250
200
150
00
06
12
18
00
LMT


N(t) PUERTO RICO MAY 1959
FIXED HEIGHTS IN Km
ELECTRON DENSITY (x 10^5 = el/cm 3)
25
20
15
10
5
0
400
350
300
250
200
150
00
06
12
18
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, Colo., is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D.C.

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

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

HEAT. Temperature Physics. Heat Measurements. Cryogenic Physics. Rheology. Molecular Kinetics. Free Radicals Research. Equation of State. Statistical Physics. Molecular Spectroscopy.

RADIATION PHYSICS. X-Ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

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

MECHANICS. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. 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 RESEARCH. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials.

APPLIED MATHEMATICS. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

DATA PROCESSING SYSTEMS. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Applications Engineering.

ATOMIC PHYSICS. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics.

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

Office of Weights and Measures.

BOULDER, COLO.

CRYOGENIC ENGINEERING. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

IONOSPHERE RESEARCH AND PROPAGATION. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services.

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

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

RADIO SYSTEMS. High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Space Telecommunications.

UPPER ATMOSPHERE AND SPACE PHYSICS. Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

NBS