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Technical Note No. 40-6

Boulder Laboratories

MEAN ELECTRON DENSITY VARIATIONS OF THE QUIET IONOSPHERE

No. 6 - AUGUST 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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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 June are illustrated graphically. This report is the sixth 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 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)
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, 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 July 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 (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 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. 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 July 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°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 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 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, 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 — AUG 1959

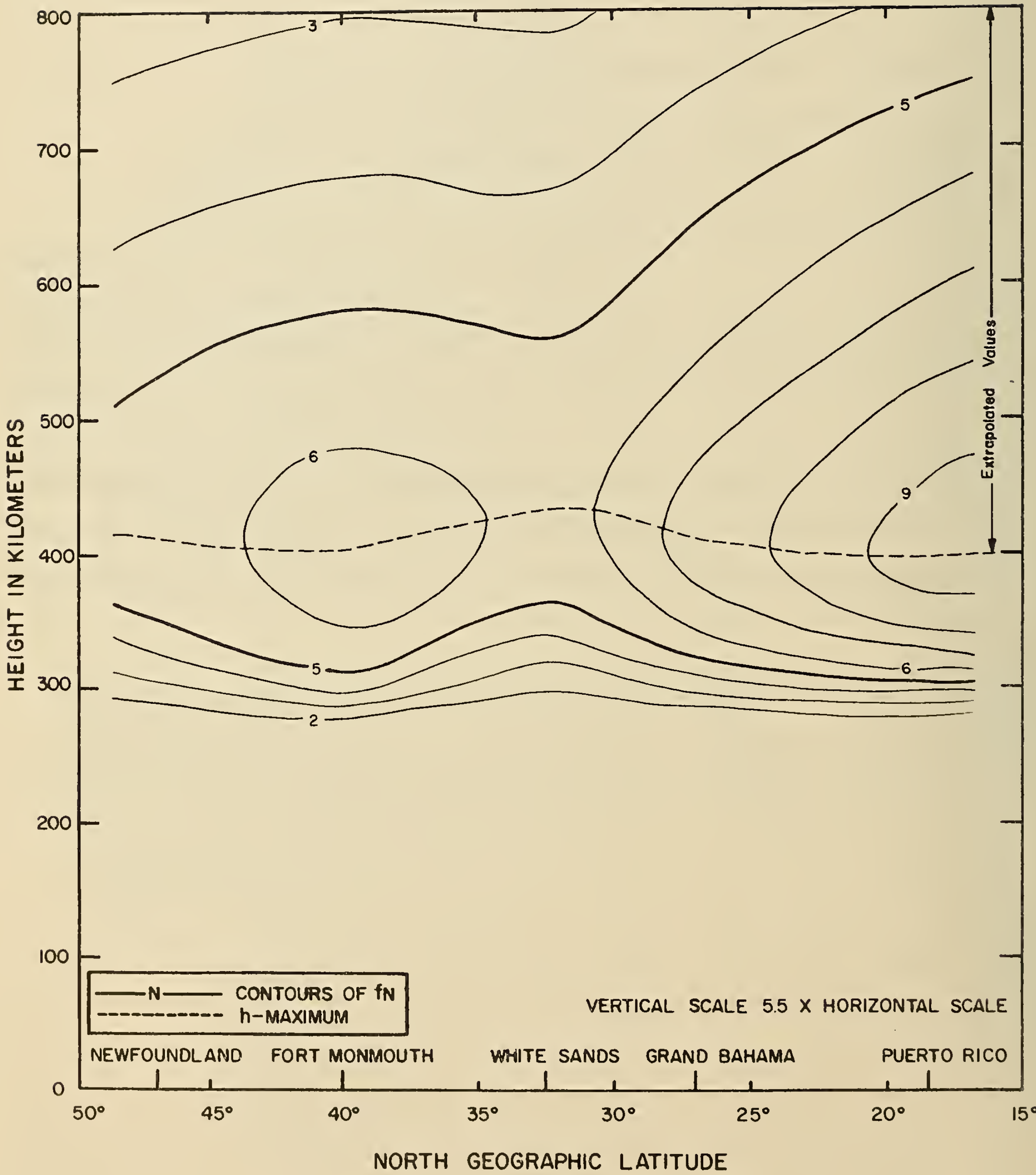
TIME	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100
COUNT	28	28	25	25	25	25	25	21	23	24	19	22
HMIN	280	263	248	247	259	262	266	118	110	110	110	110
NMAX	1076	1021	882	732	671	621	631	881	1092	1240	1392	1578
HMAX	393	375	358	374	383	389	375	302	305	330	388	372
SHMAX	724	700	589	550	500	486	451	744	1059	1442	1879	2107
SHINF	3760	3580	3077	2614	2391	2238	2231	3231	4140	4939	5807	6559
KM												
950	109	94.8	76.2	67.8	65.3	61.4	58.6	57.6	72.0	9205	142	145
900	139	122	97.8	87.0	83.7	78.7	75.2	73.8	92.3	119	156	186
850	179	156	125	112	107	101	96.3	94.7	118	152	201	239
800	229	200	161	143	137	129	123	122	152	195	257	305
750	292	255	205	182	175	165	158	156	195	250	328	390
700	372	325	262	232	223	210	201	199	249	319	418	497
650	470	411	332	294	282	265	255	254	317	406	531	631
600	588	517	418	370	352	331	320	322	403	515	639	793
550	725	640	520	458	434	407	396	407	509	646	832	984
500	869	774	634	554	520	487	479	507	634	799	1014	1195
490	897	801	657	573	537	502	495	529	662	831	1051	1238
480	924	828	680	592	553	517	512	551	690	864	1088	1280
470	951	853	703	611	569	532	527	574	718	897	1124	1321
460	975	878	726	628	583	545	543	597	747	931	1160	1361
450	998	902	747	645	597	557	557	621	776	964	1195	1399
440	1018	924	768	661	610	568	571	644	806	997	1228	1435
430	1035	944	787	675	621	577	583	668	835	1029	1259	1468
420	1040	961	805	688	630	583	594	691	864	1060	1287	1498
410	1056	975	820	698	637	586	602	714	893	1090	1312	1523
400	1061	984	833	706	641	586	608	737	921	1119	1334	1543
390	1054	988	842	709	641	582	611	758	948	1145	1352	1558
380	1035	986	847	707	637	573	610	779	974	1168	1365	1566
370	998	975	847	700	626	560	604	798	998	1188	1373	1566
360	944	952	841	685	609	541	593	816	1020	1204	1374	1556
350	868	916	827	662	584	517	574	832	1039	1216	1367	1533
340	773	864	801	630	551	487	549	845	1055	1223	1352	1498
330	656	795	764	589	506	452	512	855	1068	1224	1325	1448
320	525	711	717	537	454	410	464	861	1076	1217	1288	1386
310	375	609	653	475	389	365	400	863	1078	1202	1239	1313
300	243	490	571	405	315	315	322	859	1074	1176	1179	1228
290	124	378	467	327	242	259	241	849	1060	1138	1112	1133
280	51.1	268	354	255	174	203	171	830	1034	1088	1038	1034
270	14.5	169	244	185	116	143	115	799	995	1028	959	933
260	.6	87.0	147	124	65.2	90.3	73.4	750	941	956	878	836
250		33.4	76.3	73.4	32.[illegible]	49.5	32.1	684	870	877	797	744
240		9.4	39.1	43.0	14.3	22.7	8.9	602	786	791	722	666
230		3.2	18.3	19.3	5.8	12.2	2.7	509	691	700	653	600
220			8.1	9.0	3.1	5.3	.7	408	594	611	591	545
210			2.4	2.7	1.9	1.8		315	500	529	534	501
200				1.3	.2			238	418	456	483	463
190								180	343	395	433	429
180								140	281	342	386	396
170								114	231	295	342	361
160								97.0	191	256	300	325
150								86.2	161	220	262	288
140								80.2	142	191	229	252
130								74.4	131	172	205	223
120								54.5	119	151	181	199
110								4.5	33.7	40.7	54.8	59.2

AVERAGE ELECTRON DENSITY — KP BELOW 4.5

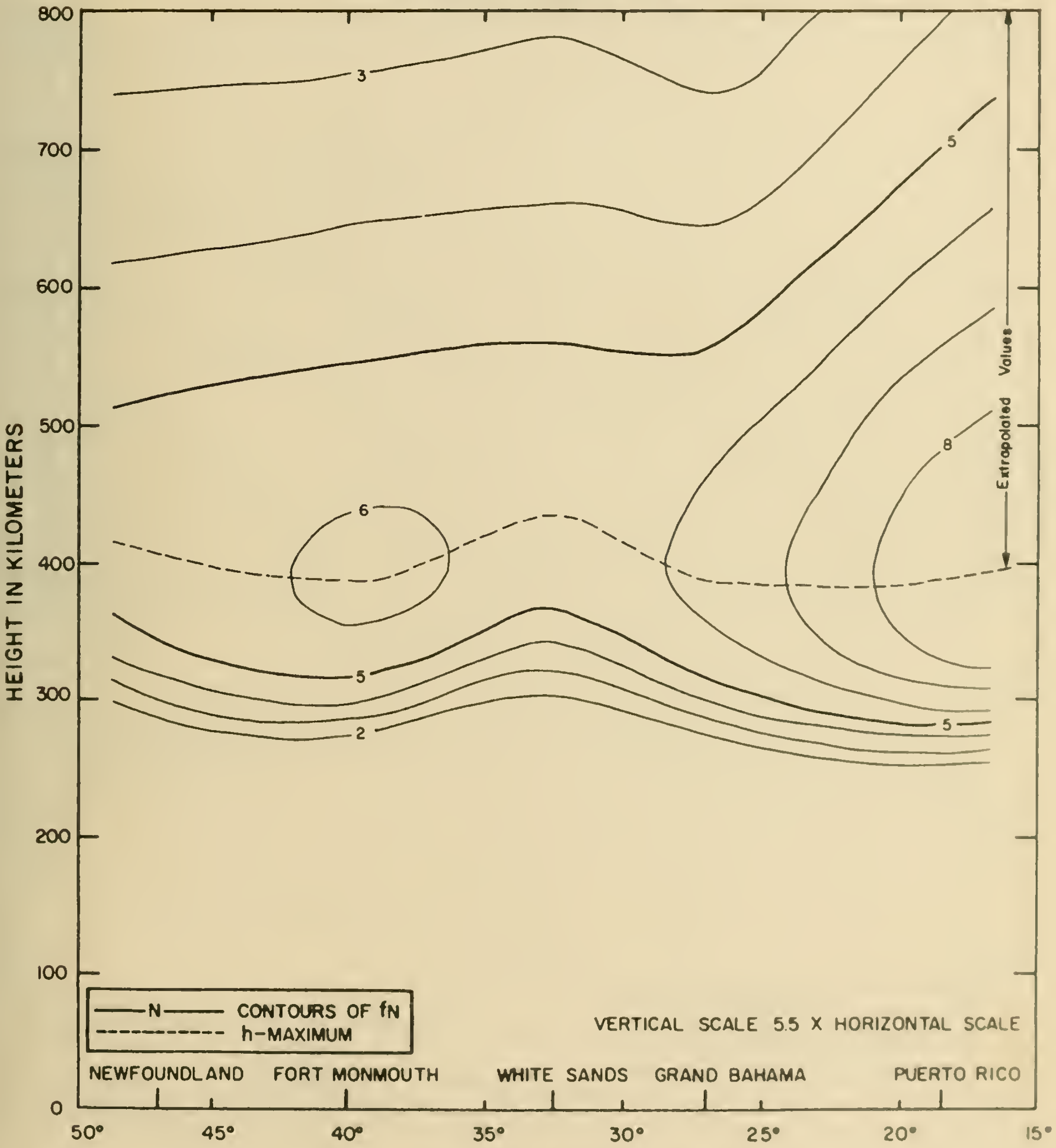
PUERTO RICO — 60 W — AUG 1959

TIME	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
COUNT	20	19	12	17	15	20	13	26	28	29	29	28
HMIN	110	110	109	110	110	111	113	243	251	272	293	290
NMAX	1778	1846	1769	1680	1577	1533	1381	1250	1110	1091	1088	1075
HMAX	373	379	388	381	383	367	366	384	409	421	424	417
SHMAX	2275	2393	2395	2194	2042	1740	1572	1157	1013	931	834	817
SHINF	7291	7599	7384	6933	6491	6063	5417	4684	4145	4009	3901	3851
KM												
950	165	177	177	163	154	138	124	124	123	128	129	123
900	212	227	227	209	198	177	159	159	158	164	165	158
850	272	291	290	268	254	227	204	203	202	210	212	202
800	348	372	372	343	325	290	262	260	258	268	271	259
750	445	476	474	438	415	371	334	332	329	342	345	330
700	567	605	604	557	528	473	426	423	418	433	437	419
650	719	767	764	705	668	600	541	535	527	545	549	527
600	904	963	957	885	838	756	681	670	656	677	681	655
550	1121	1191	1181	1094	1035	939	846	827	801	823	826	798
540	1167	1240	1228	1138	1077	979	882	860	831	852	855	827
530	1215	1290	1276	1183	1119	1019	918	893	861	881	884	855
520	1262	1339	1324	1228	1162	1060	955	927	890	910	912	884
510	1311	1389	1372	1274	1205	1101	992	960	919	938	940	912
500	1359	1439	1419	1319	1247	1143	1030	993	947	964	966	938
490	1407	1489	1465	1363	1289	1184	1067	1026	974	989	990	963
480	1454	1537	1511	1407	1330	1226	1104	1058	1000	1013	1012	987
470	1500	1584	1554	1449	1369	1266	1140	1088	1023	1033	1032	1008
460	1545	1630	1596	1489	1407	1305	1176	1118	1044	1051	1048	1027
450	1580	1672	1634	1527	1442	1343	1210	1144	1063	1066	1061	1043
440	1628	1712	1668	1561	1474	1379	1242	1169	1077	1077	1069	1055
430	1664	1747	1698	1592	1503	1413	1272	1190	1088	1082	1071	1061
420	1697	1778	1723	1618	1527	1443	1299	1208	1093	1079	1065	1061
410	1724	1803	1742	1639	1546	1469	1323	1222	1091	1066	1045	1051
400	1746	1821	1754	1654	1559	1491	1343	1230	1081	1041	1012	1027
390	1761	1832	1756	1660	1564	1508	1358	1233	1060	1002	961	990
380	1768	1833	1747	1657	1561	1518	1367	1228	1028	948	895	937
370	1764	1822	1727	1644	1546	1521	1369	1214	983	880	812	868
360	1747	1796	1691	1618	1519	1513	1363	1189	926	800	717	783
350	1711	1754	1642	1578	1478	1490	1346	1152	858	709	607	680
340	1659	1696	1576	1524	1424	1453	1315	1100	777	609	488	562
330	1588	1620	1497	1454	1349	1392	1271	1034	688	500	365	431
320	1501	1530	1403	1371	1268	1318	1212	958	592	387	255	306
310	1400	1427	1301	1275	1180	1232	1138	865	494	279	160	195
300	1289	1312	1195	1173	1079	1134	1054	760	393	192	89.5	108
290	1173	1186	1082	1063	973	1025	957	642	296	123	43.4	47.3
280	1052	1062	966	953	865	908	855	506	213	68.6	17.0	19.6
270	939	935	857	847	760	792	741	362	141	36.3	5.3	6.6
260	831	820	761	750	669	681	679	221	84.3	17.4		2.5
250	740	720	679	664	592	583	522	121	49.3	6.1		.6
240	663	637	612	594	529	500	431	47.5	24.0			
230	600	573	558	536	479	434	353	10.3	8.7			
220	550	522	515	491	440	381	289	2.6	1.8			
210	508	483	480	454	406	338	239	.4	.2			
200	472	451	449	422	375	302	200					
190	414	421	418	391	346	269	170					
180	382	393	387	357	314	236	145					
170	349	363	355	324	282	205	125					
160	314	330	321	290	250	180	109					
150	281	295	286	257	218	159	97.6					
140	249	263	254	227	194	143	90.8					
130	223	238	232	207	179	134	85.7					
120	206	214	211	185	165	125	72.1					
110	48.9	52.3	67.6	41.3	33.2	17.2	3.4					

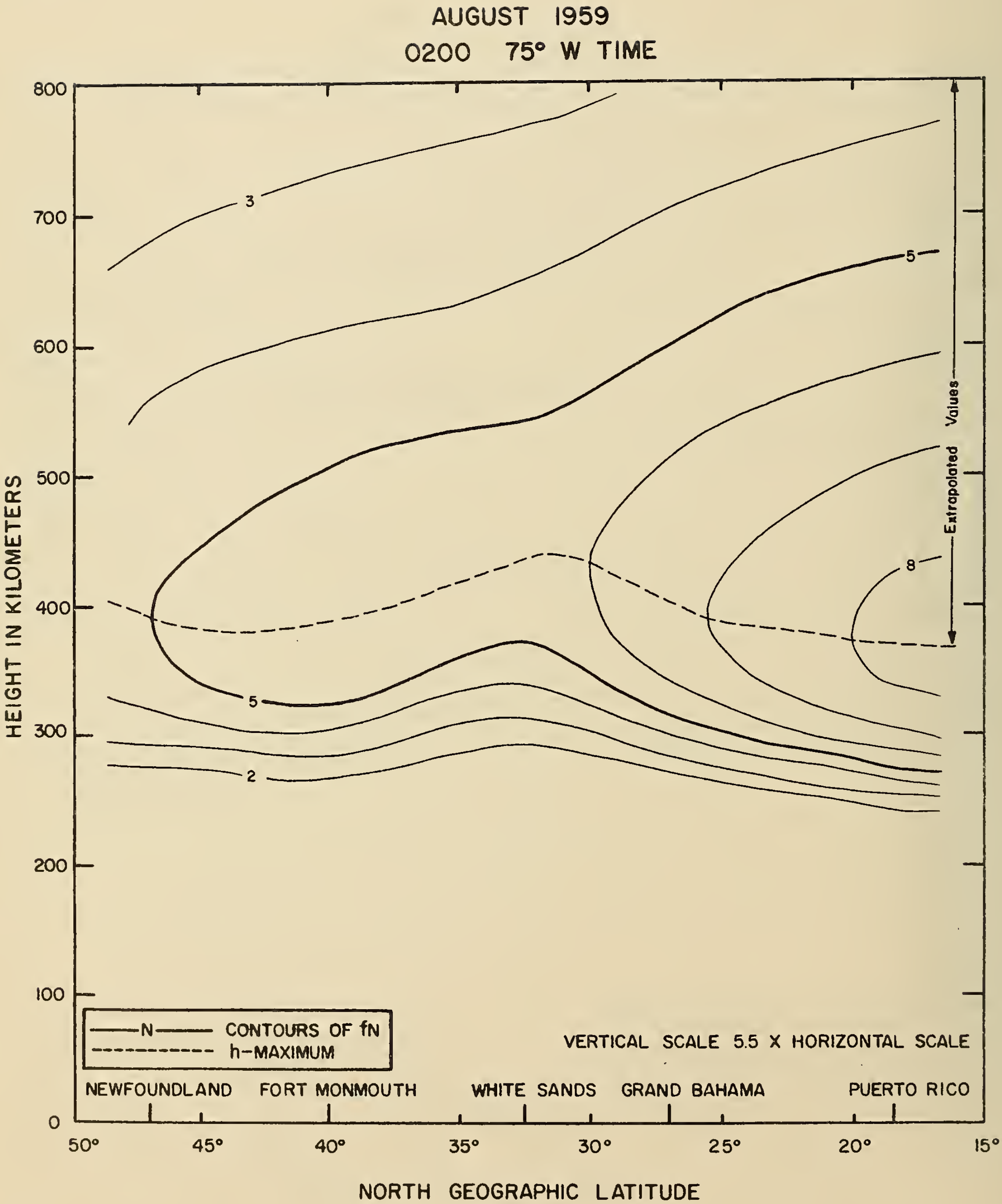
AUGUST 1959
0000 75° W TIME



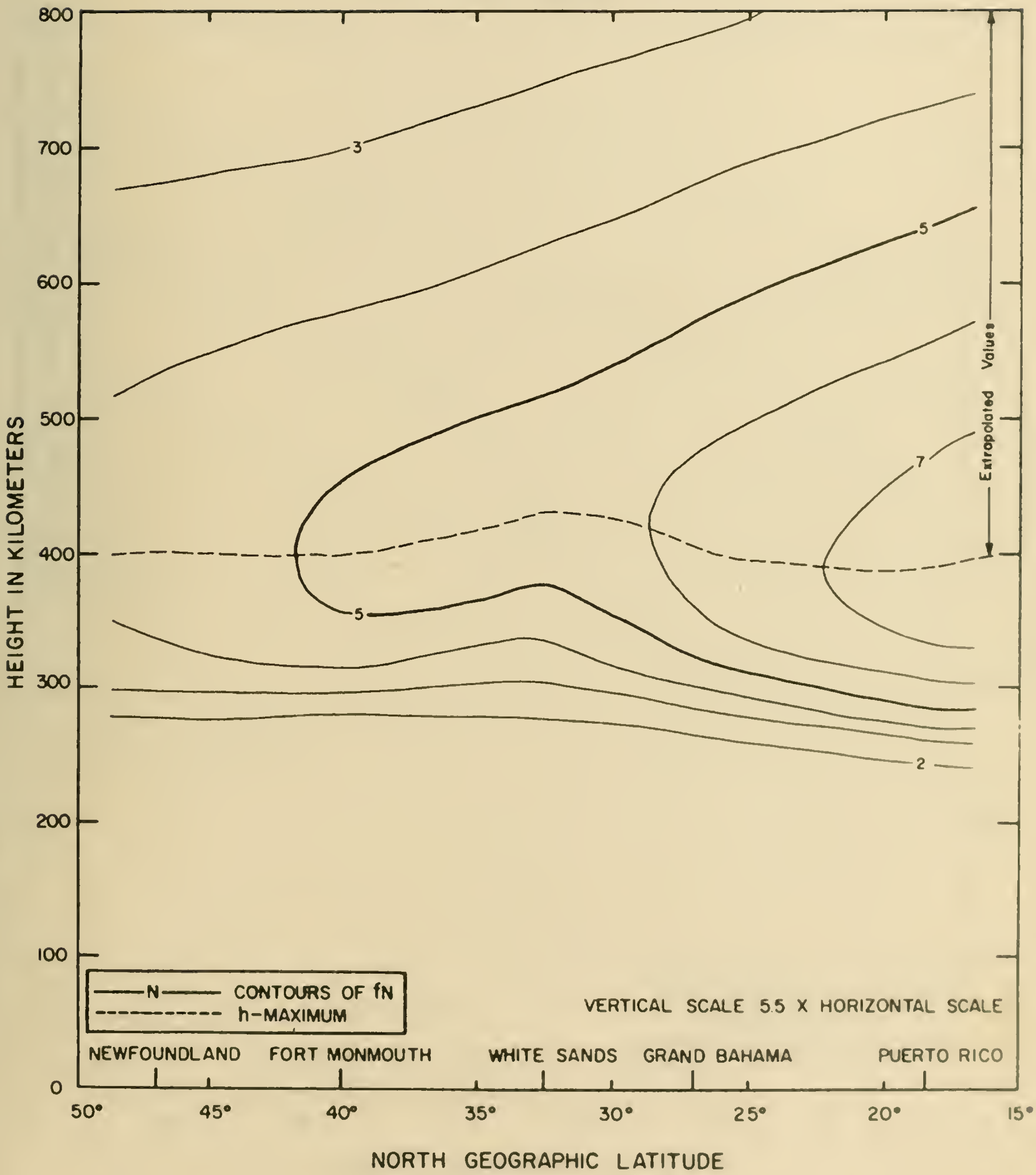
AUGUST 1959
0100 75° W TIME

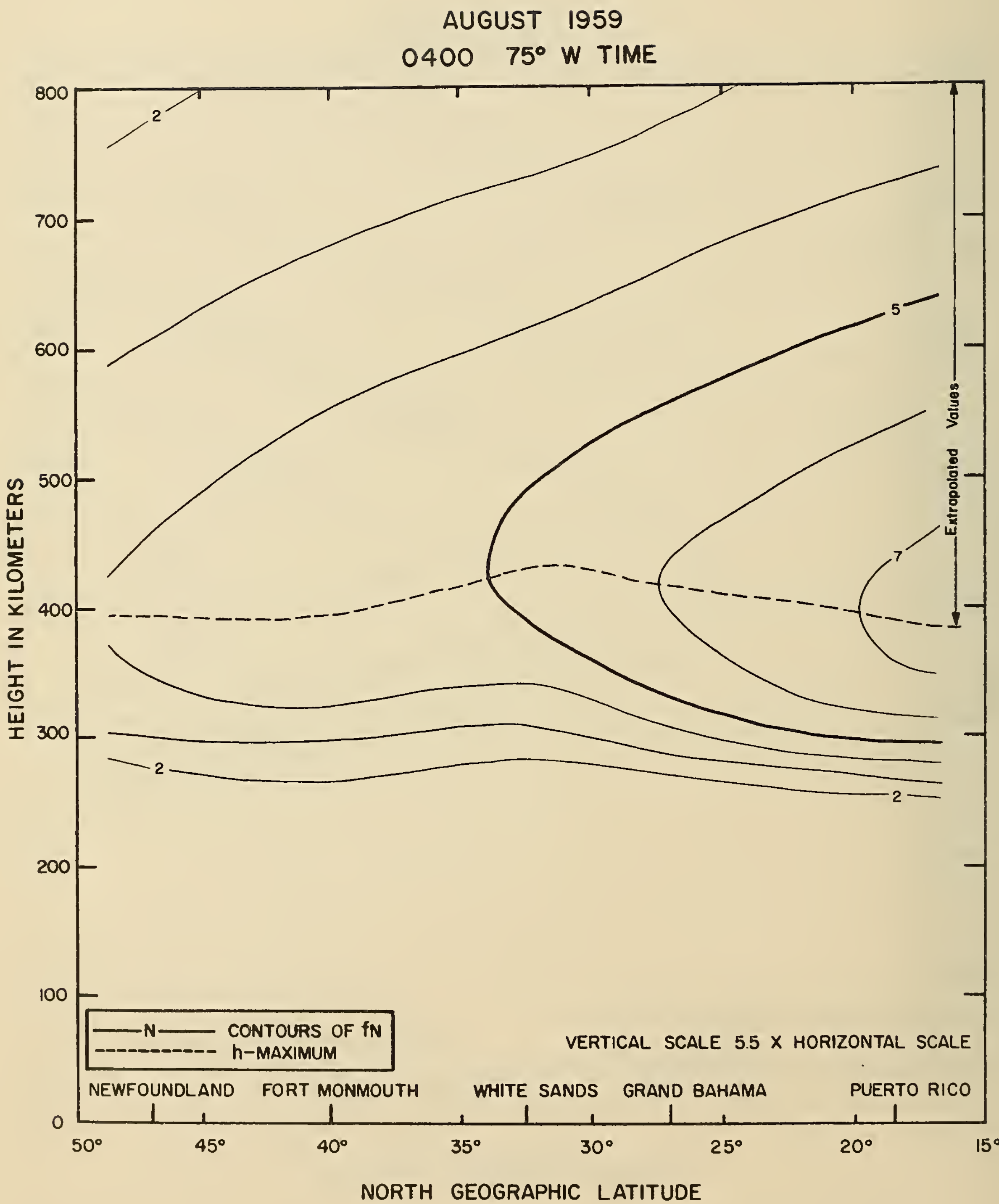


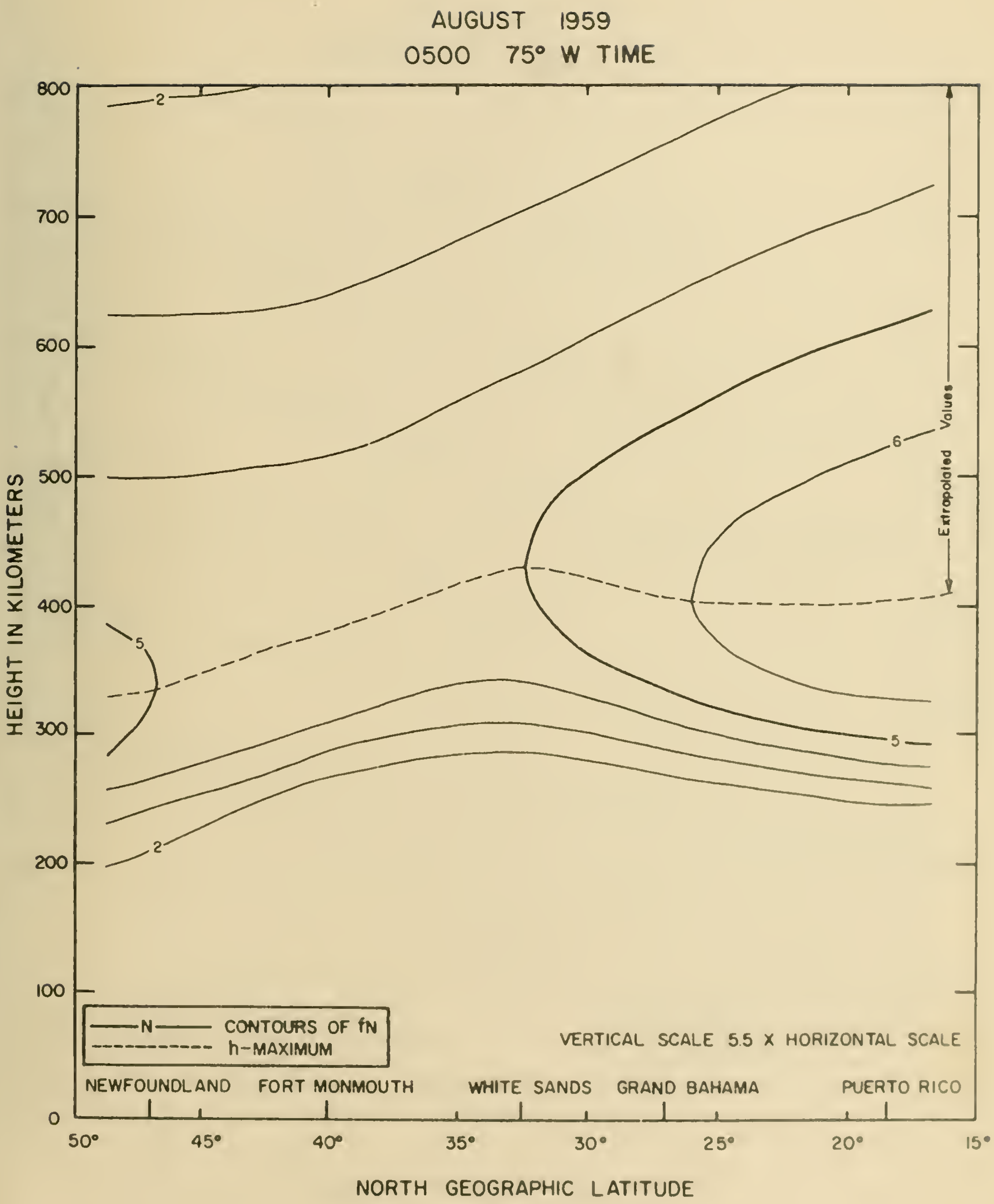
NORTH GEOGRAPHIC LATITUDE

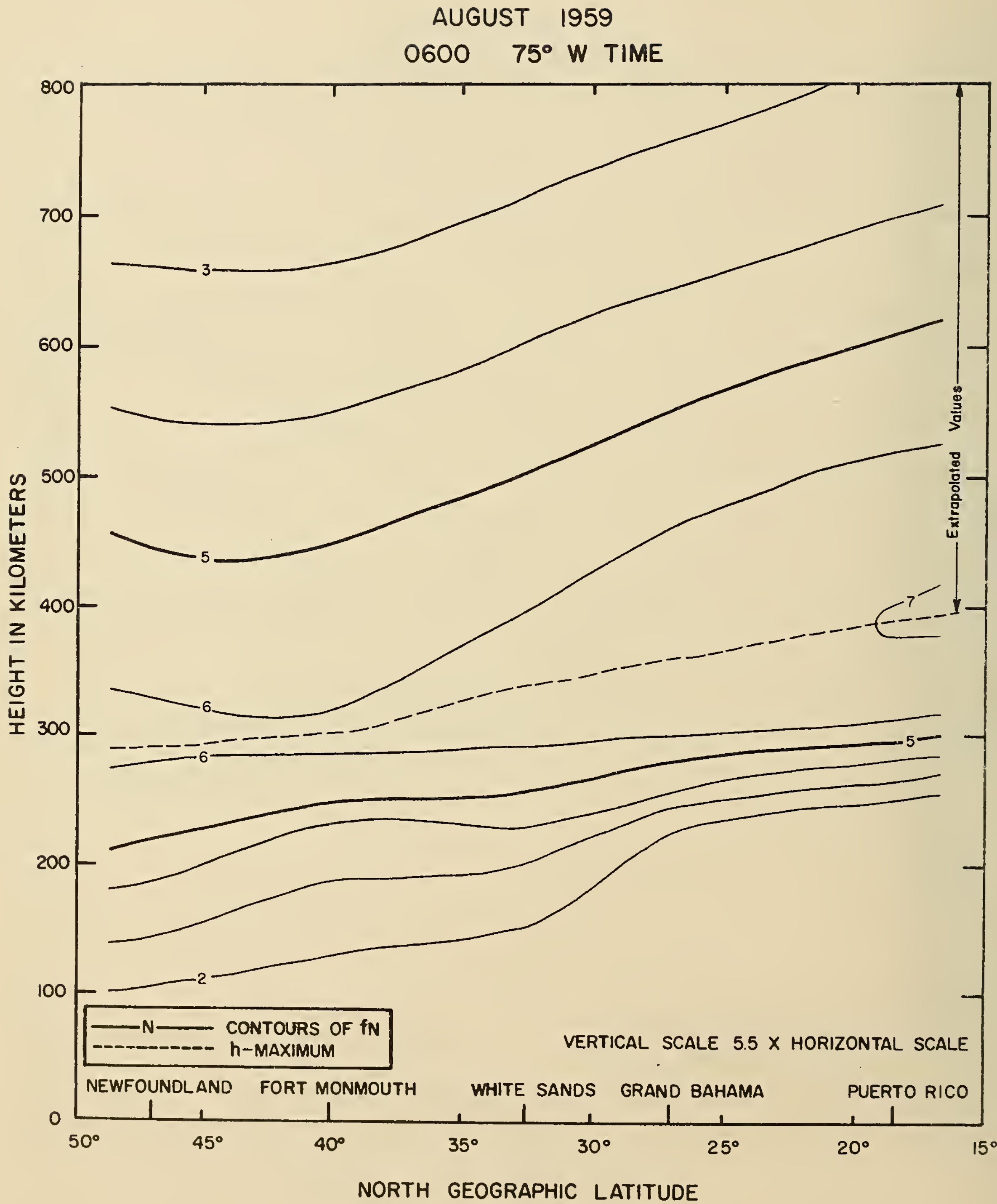

AUGUST 1959
0200 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
5
2
8
Extrapolated Values
CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

AUGUST 1959
0300 75° W TIME

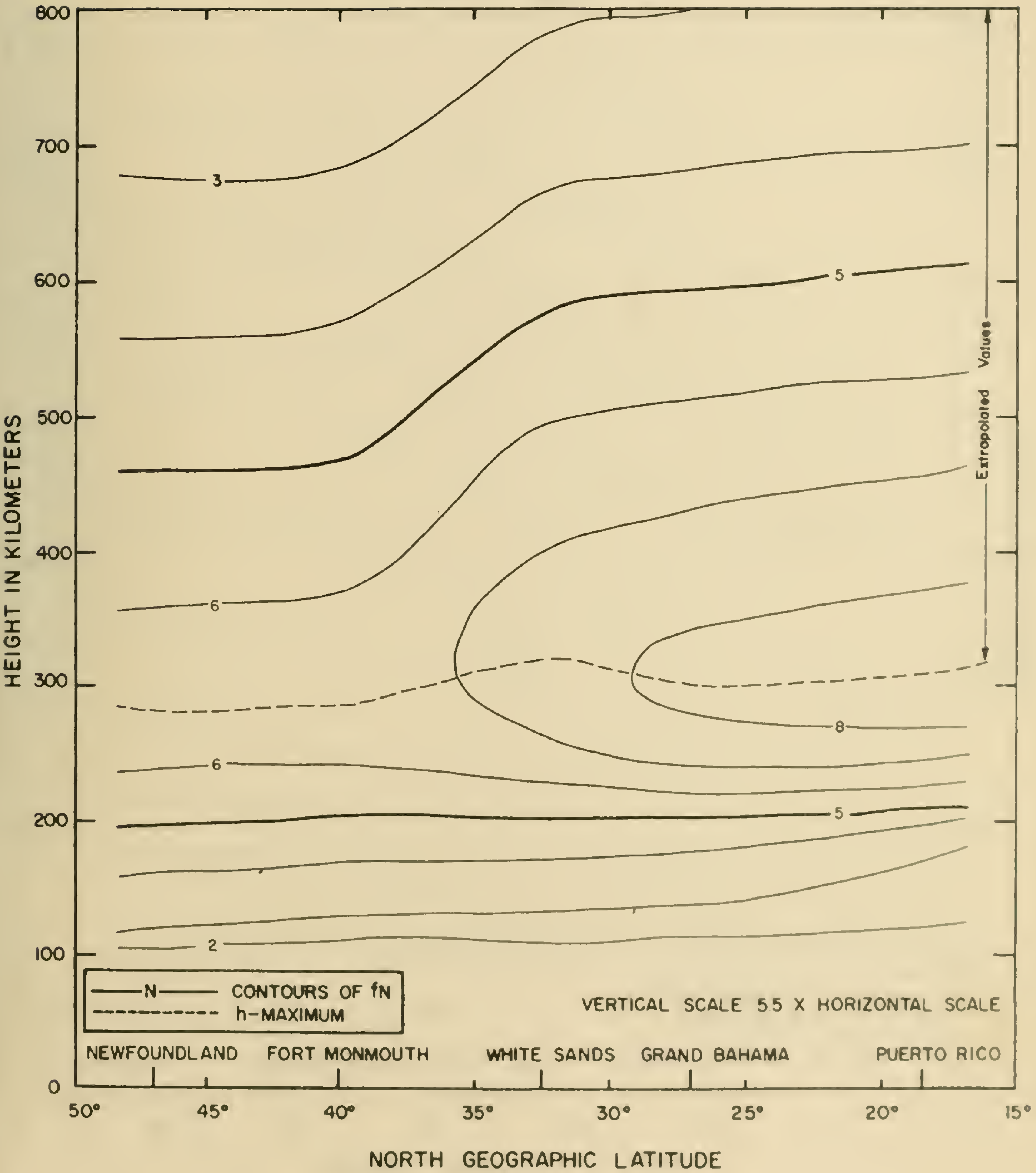



AUGUST 1959
0400 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
2
5
7
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

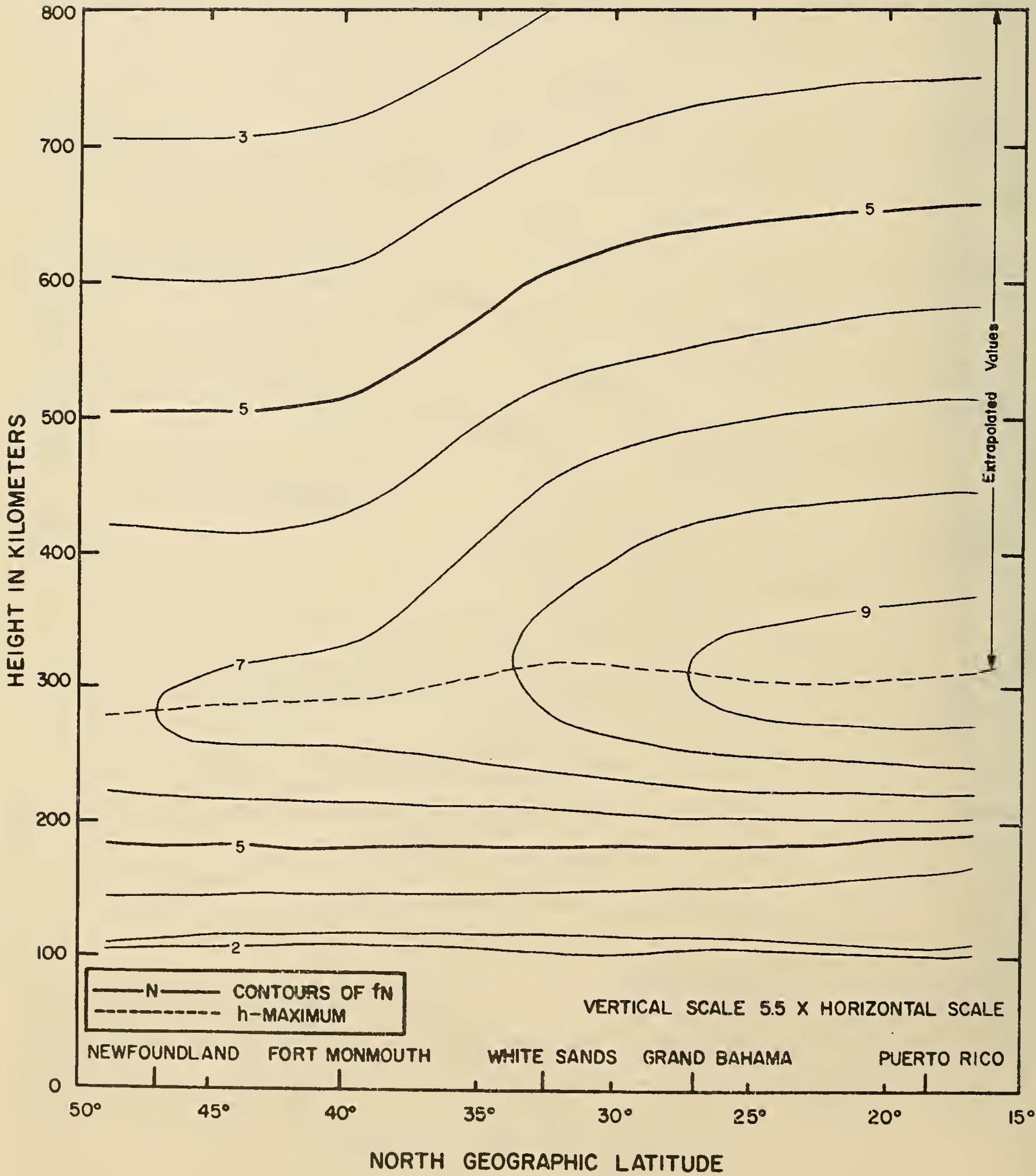

AUGUST 1959
0500 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
2
5
6
Extrapolated Values
CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE


AUGUST 1959
0600 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
5
6
6
7
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

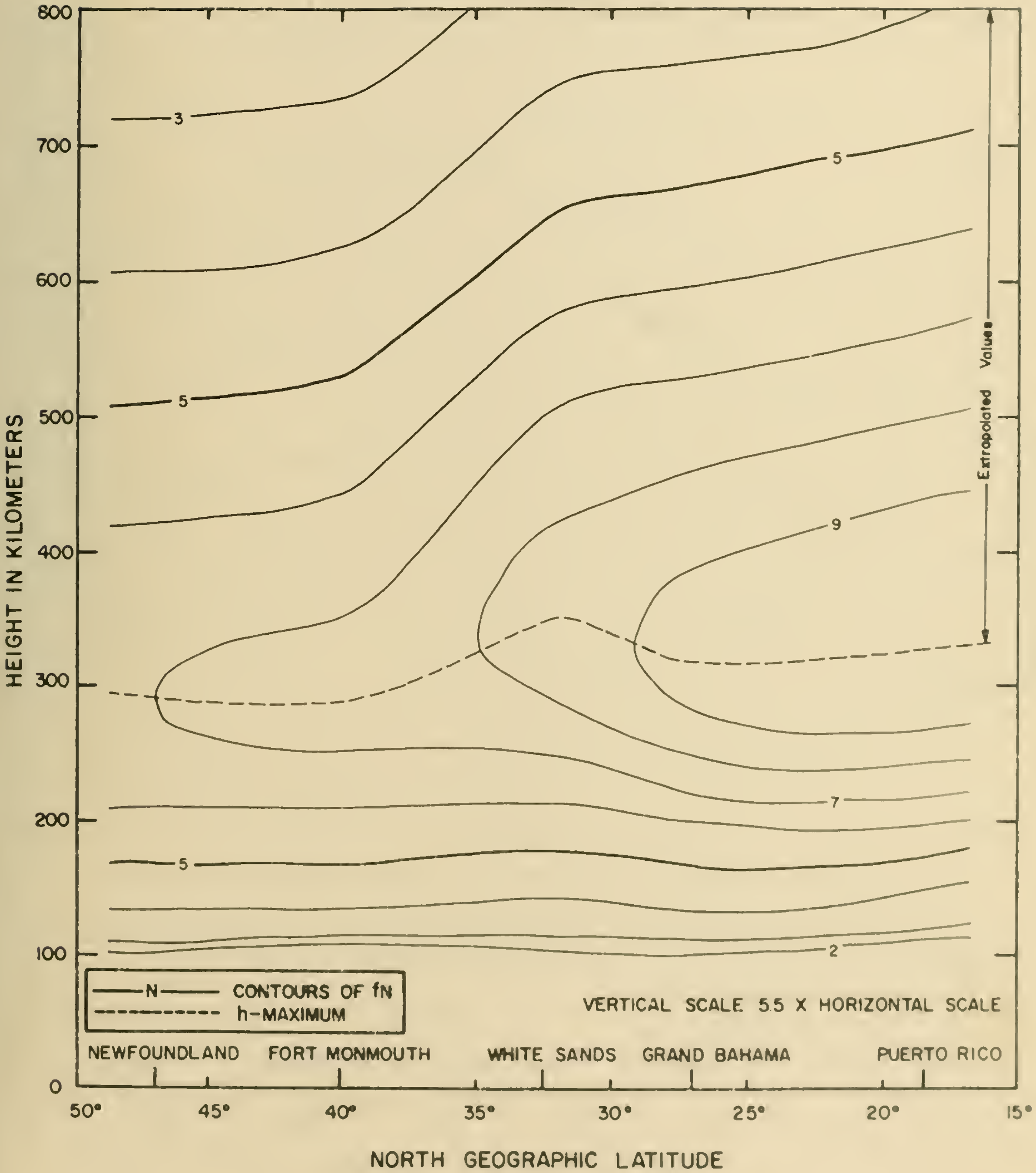
AUGUST 1959
0700 75° W TIME

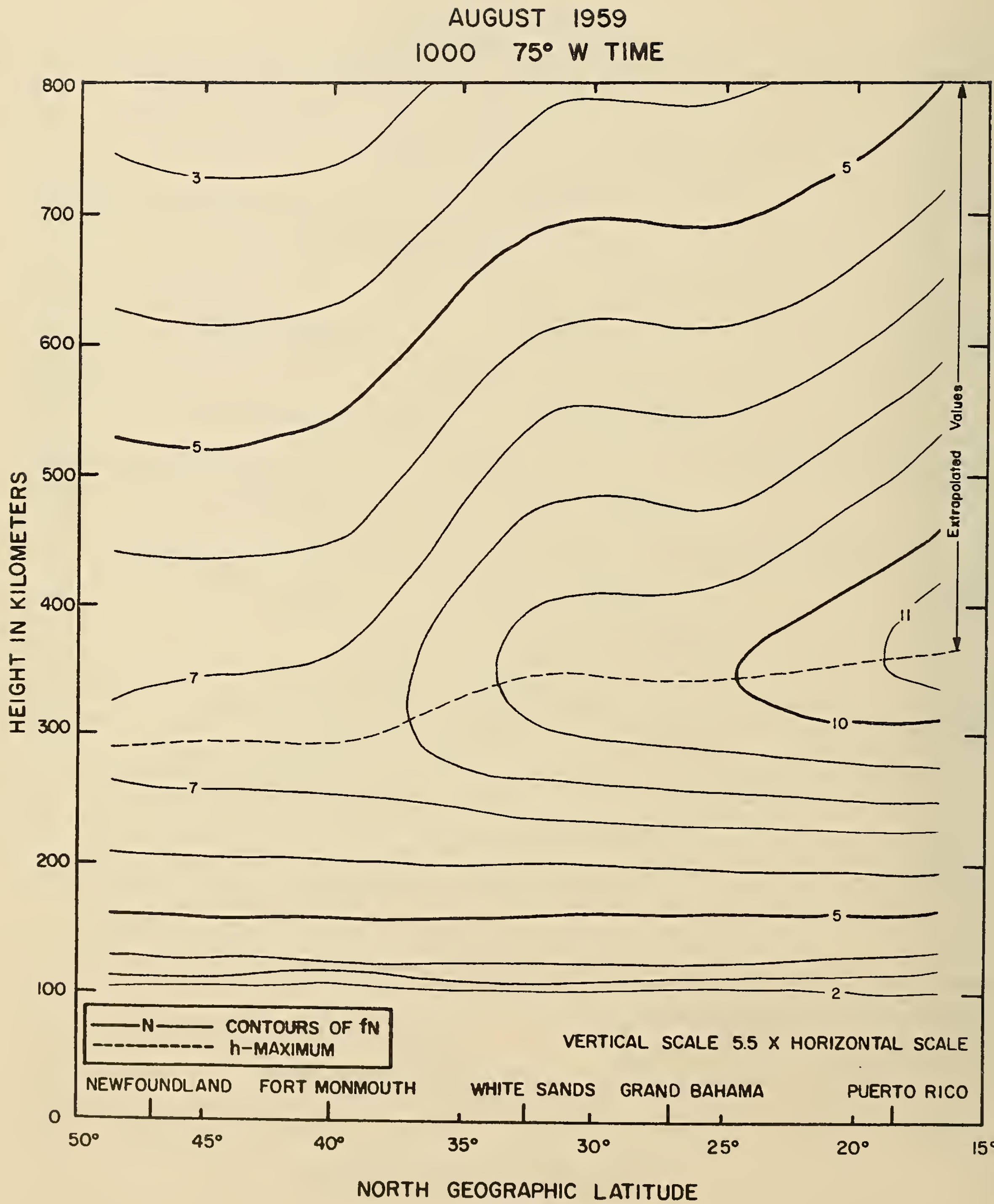


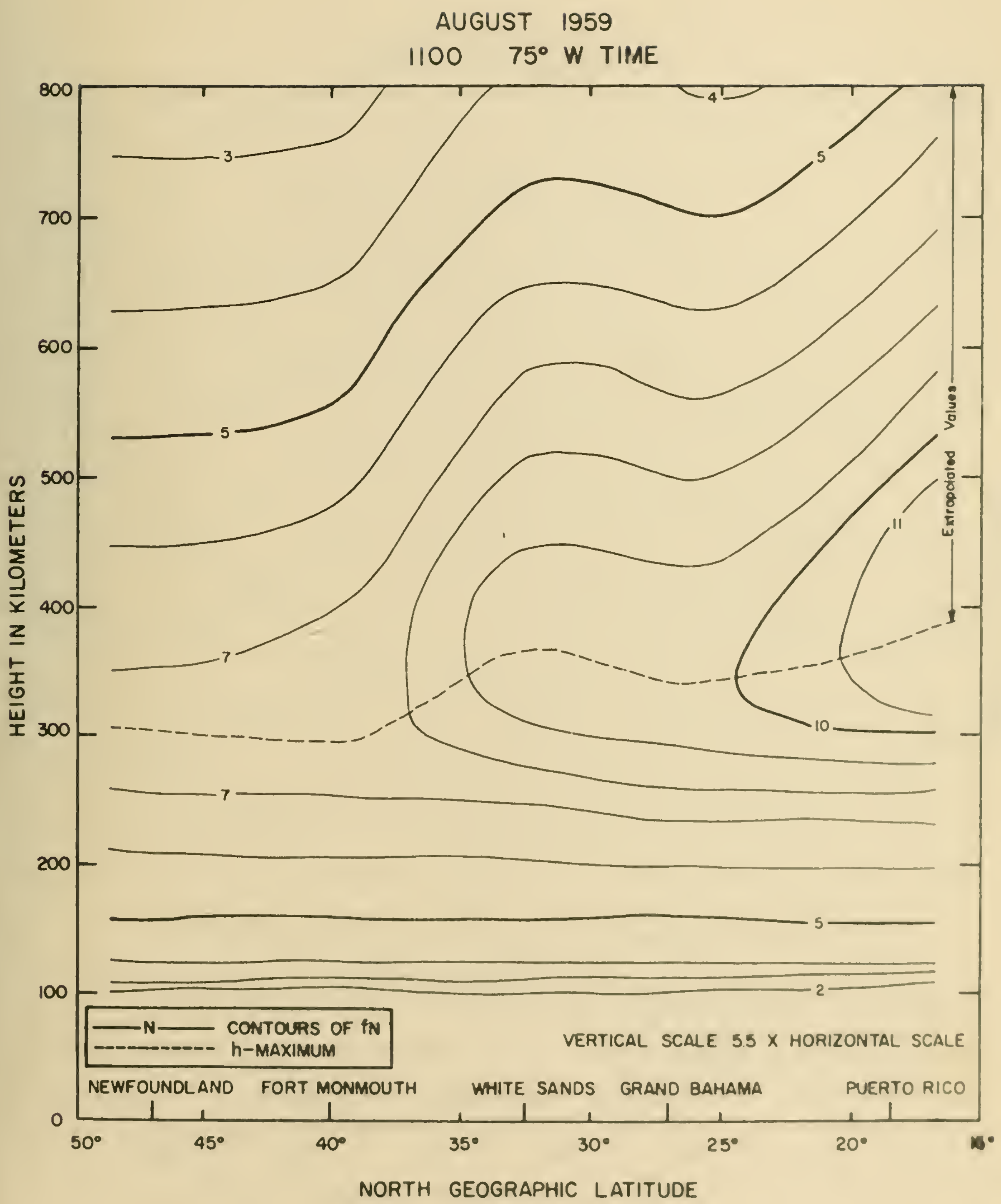
AUGUST 1959
0800 75° W TIME



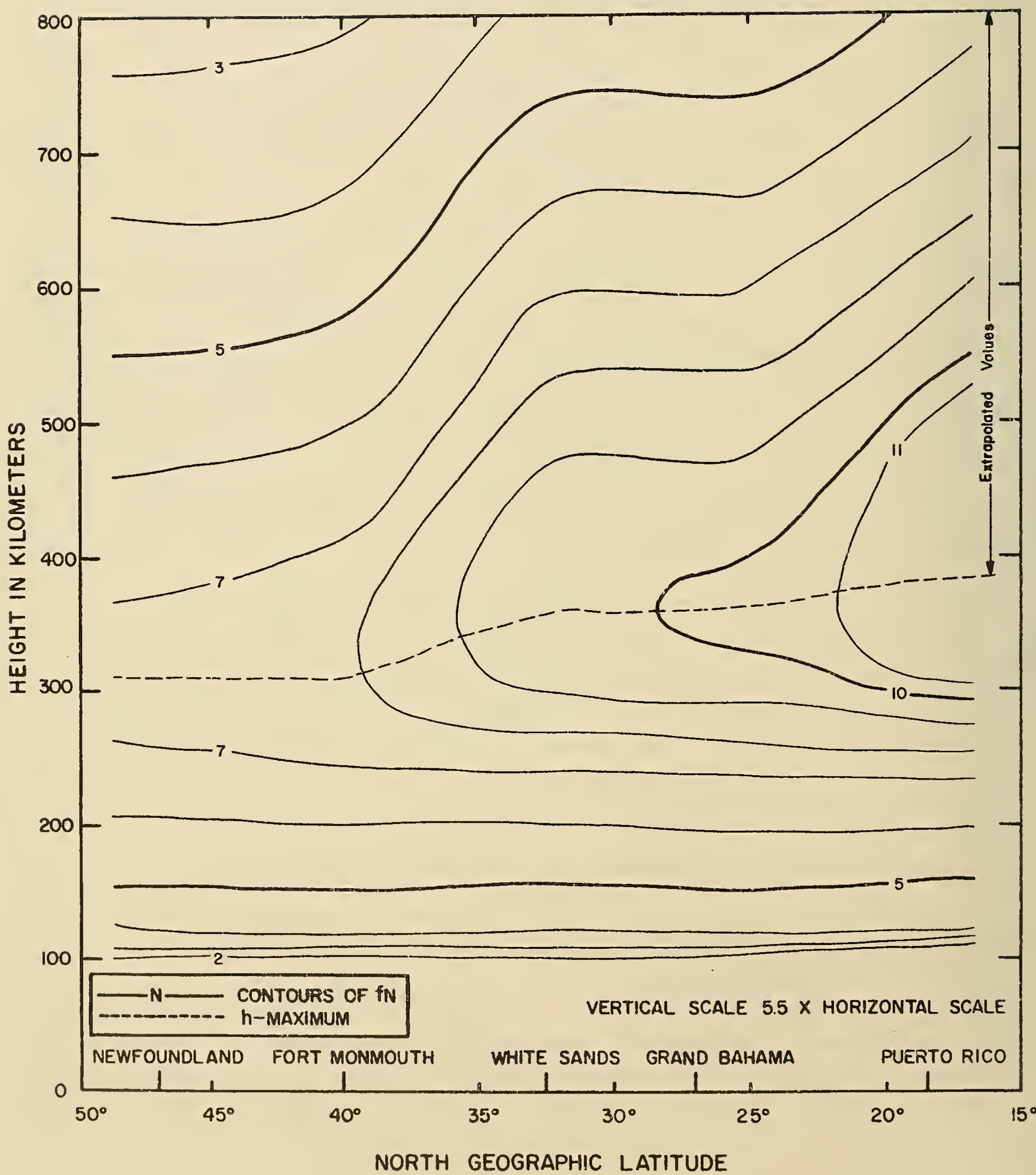
AUGUST 1959
0900 75° W TIME

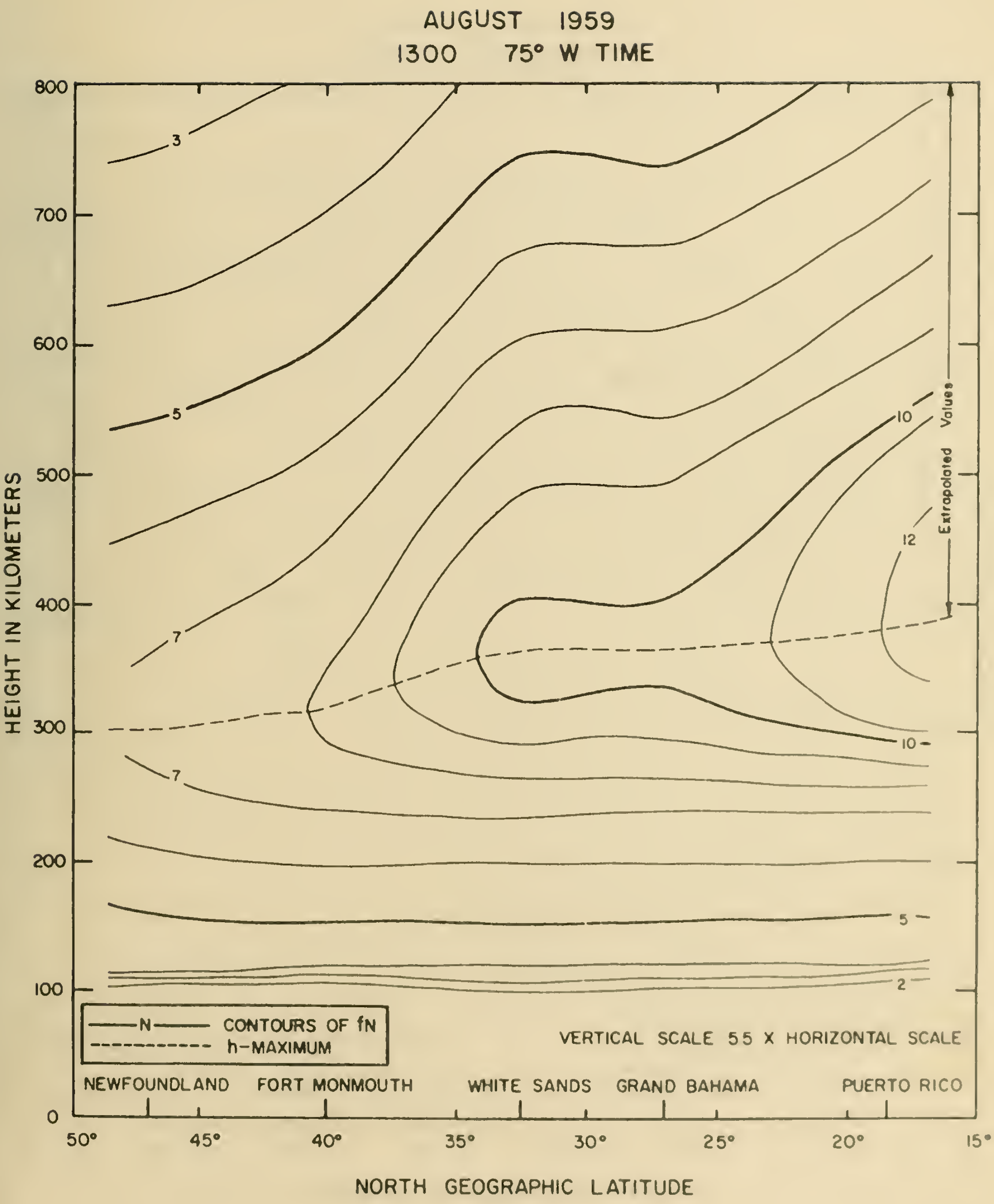


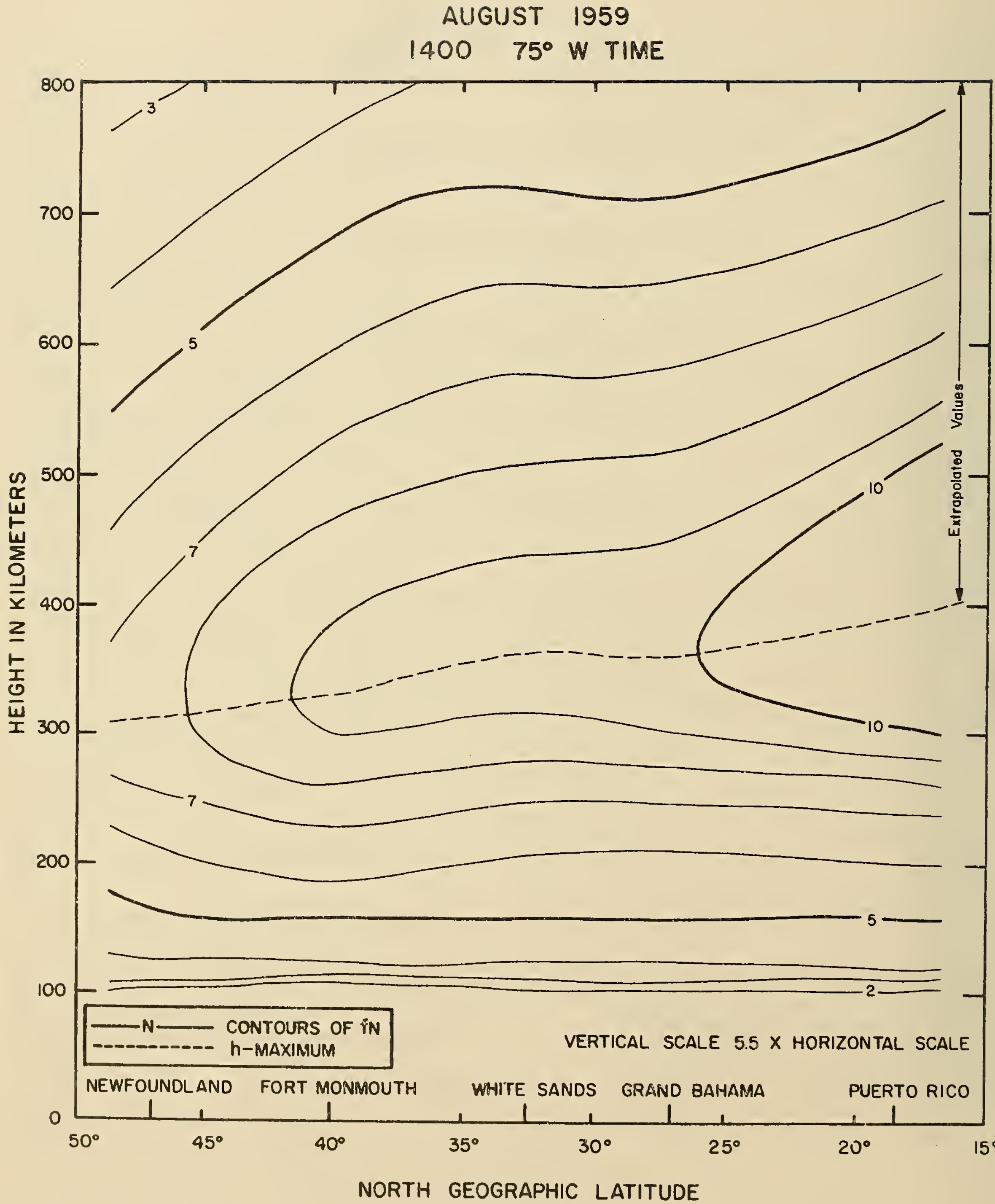

AUGUST 1959
1000 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
5
7
7
5
2
10
11
5
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE


AUGUST 1959
1100 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
4
5
7
10
11
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°
NORTH GEOGRAPHIC LATITUDE

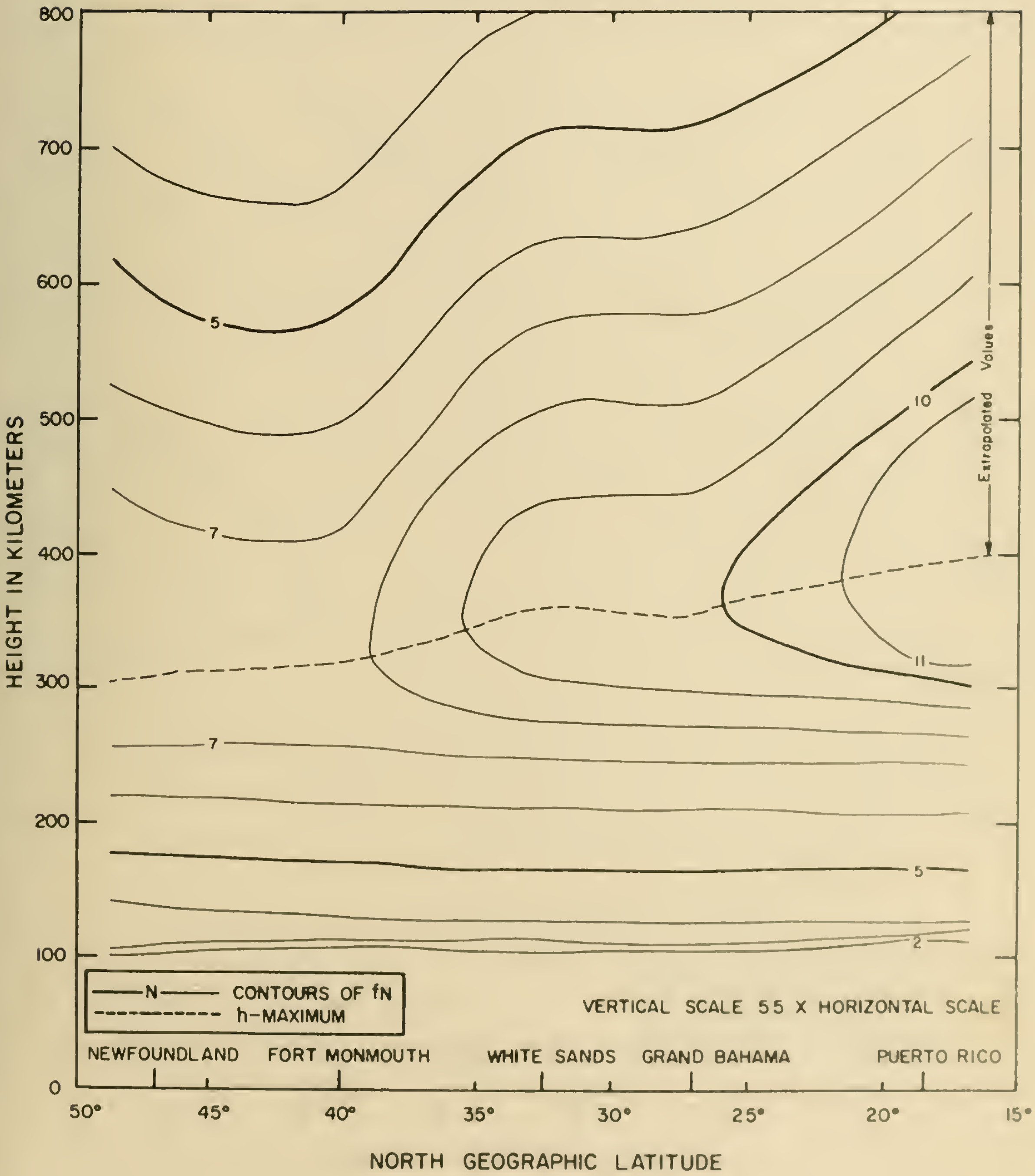
AUGUST 1959
1200 75° W TIME

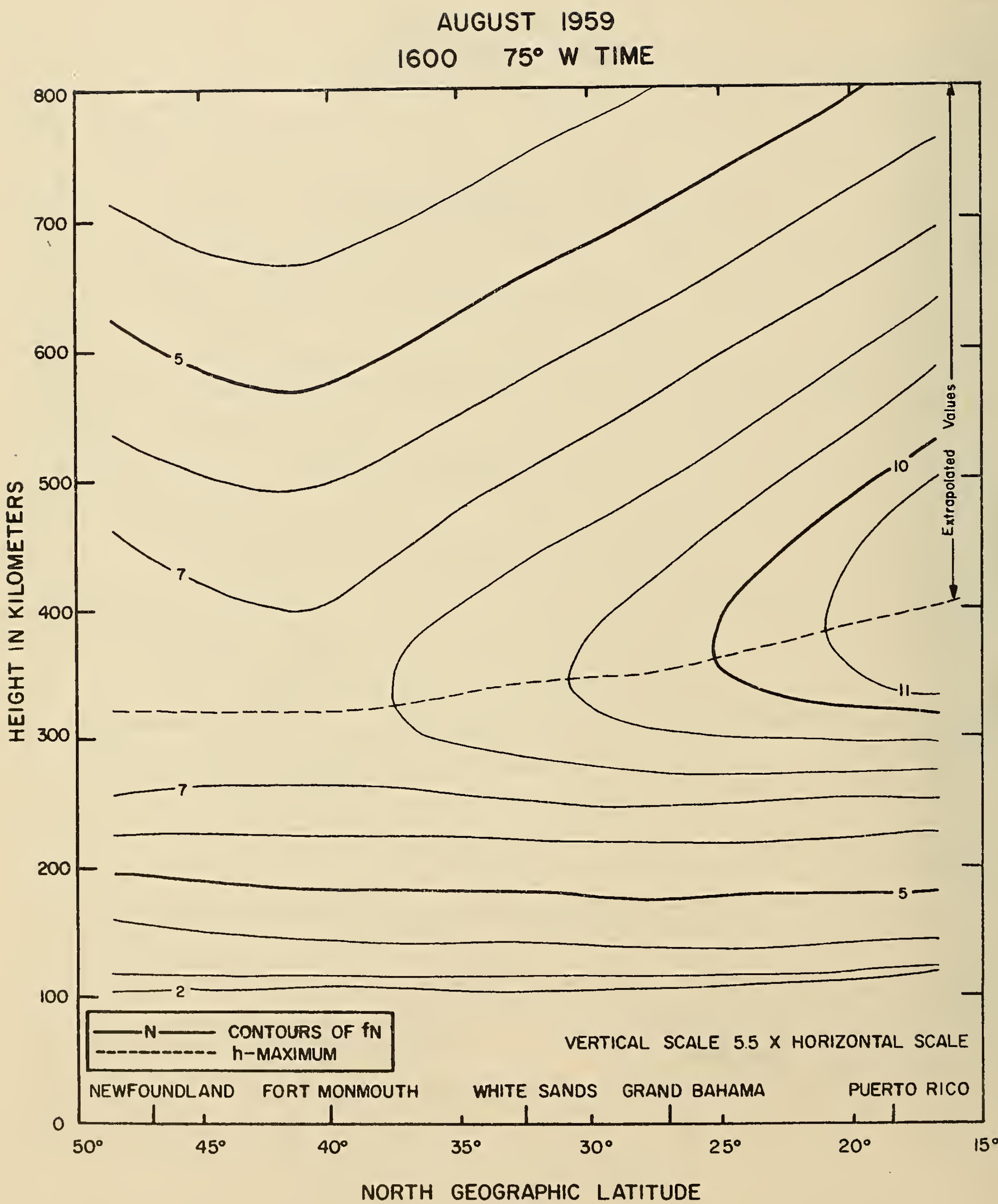



AUGUST 1959
1300 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
5
7
7
10
12
10
5
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

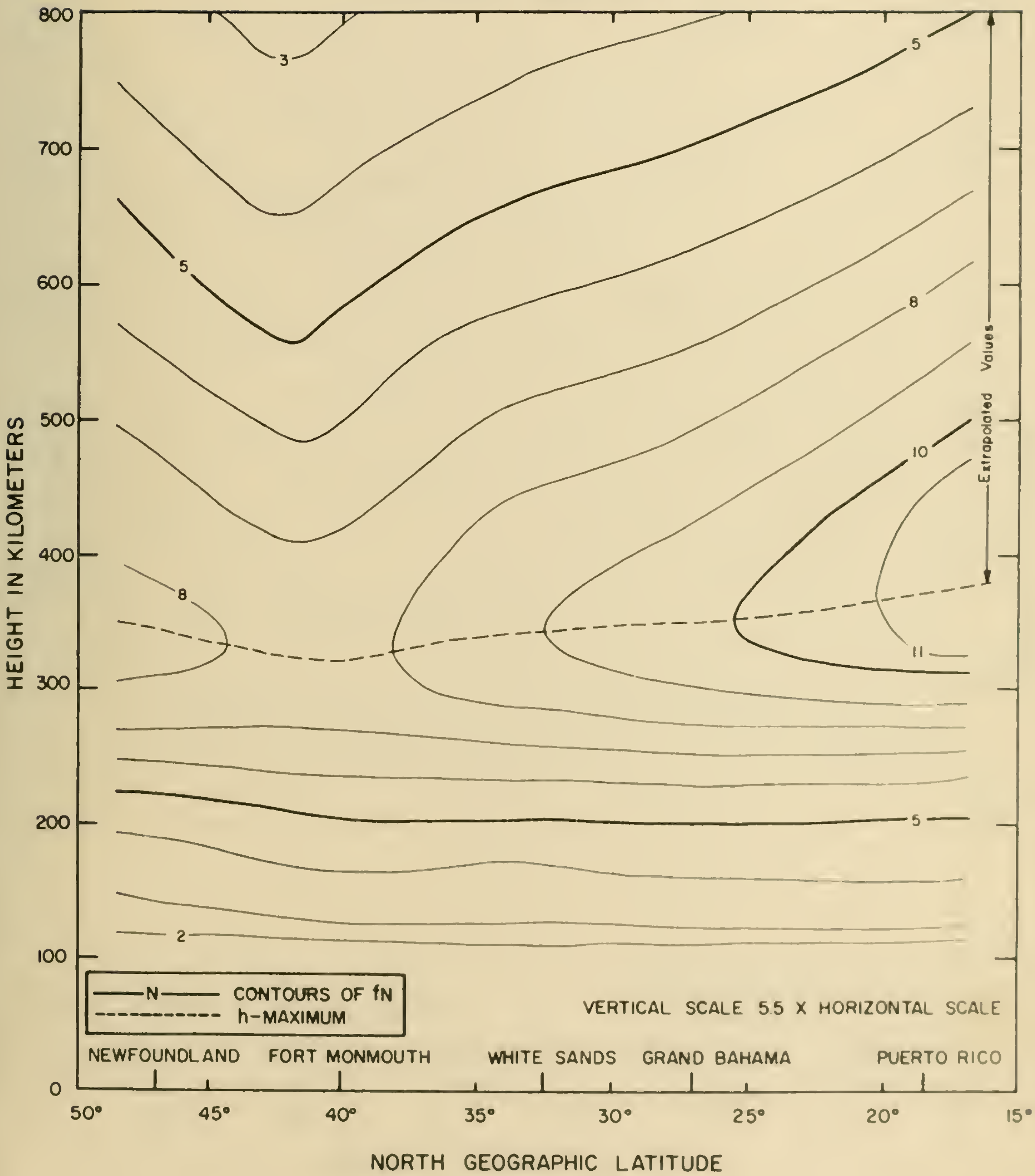

AUGUST 1959
1400 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
5
7
10
7
5
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

AUGUST 1959
1500 75° W TIME

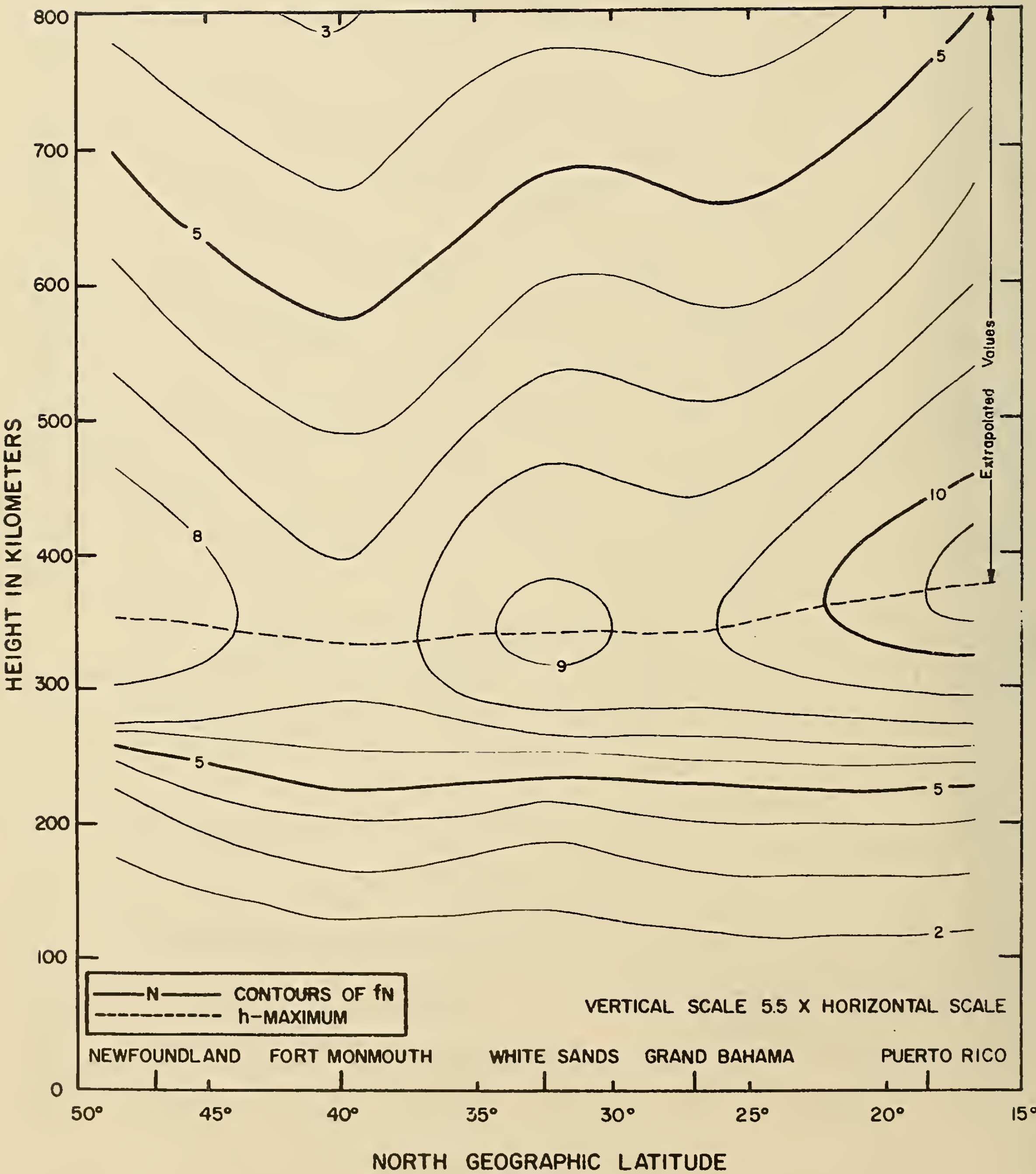



AUGUST 1959
1600 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
5
7
7
5
2
10
11
5
Extrapolated Values
—N— CONTOURS OF fN
----------- h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH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

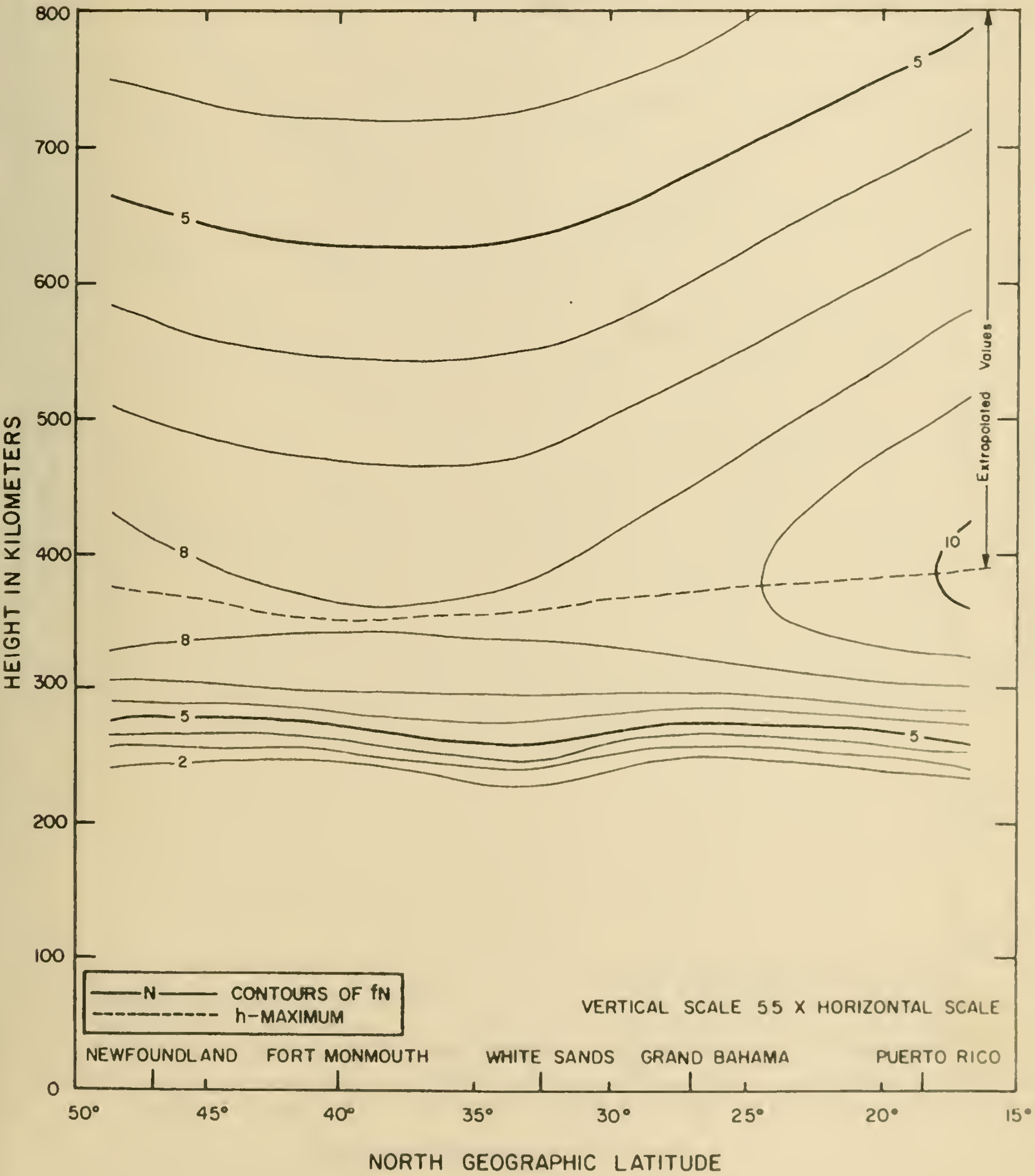
AUGUST 1959
1700 75° W TIME



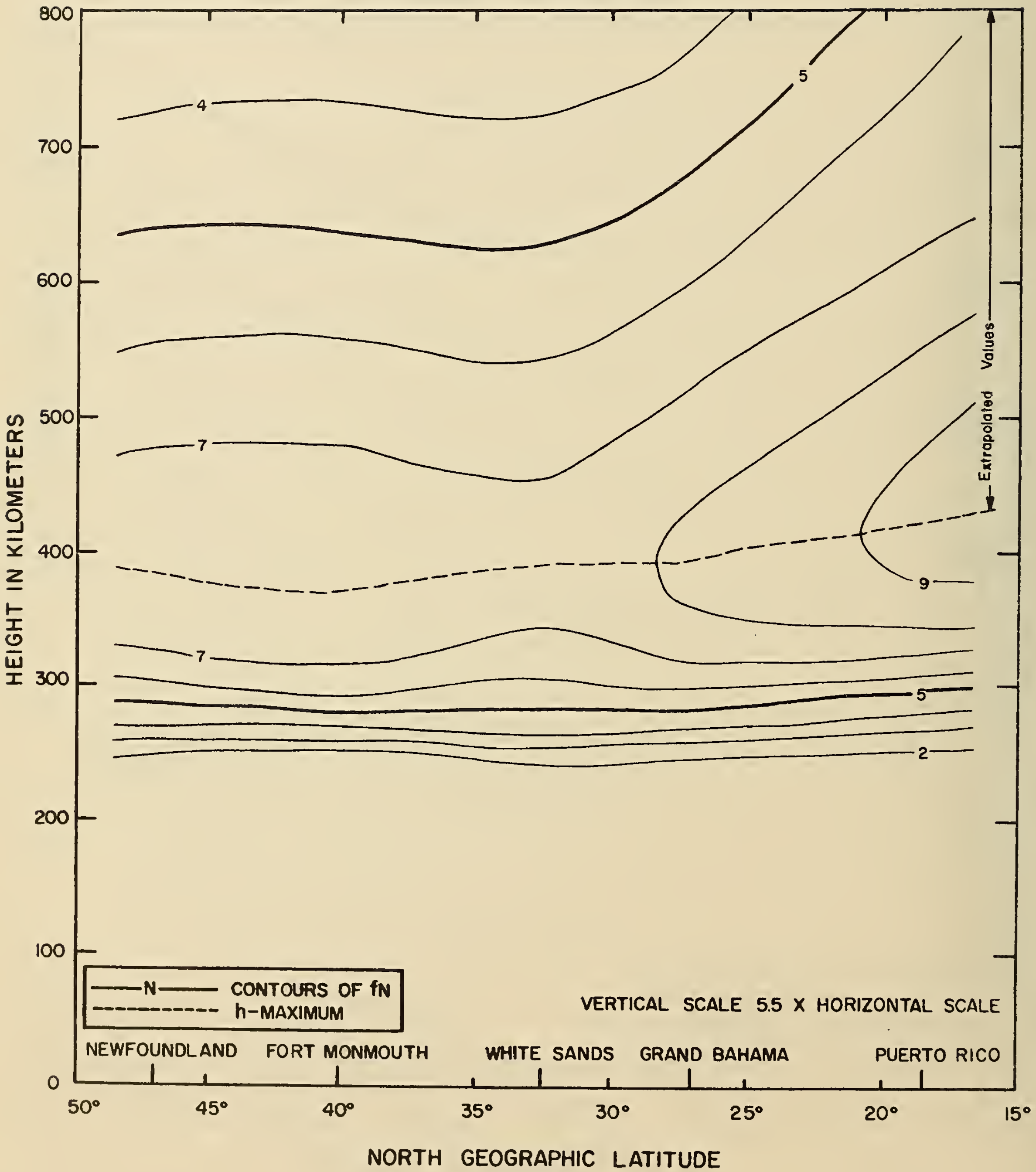
AUGUST 1959
1800 75° W TIME

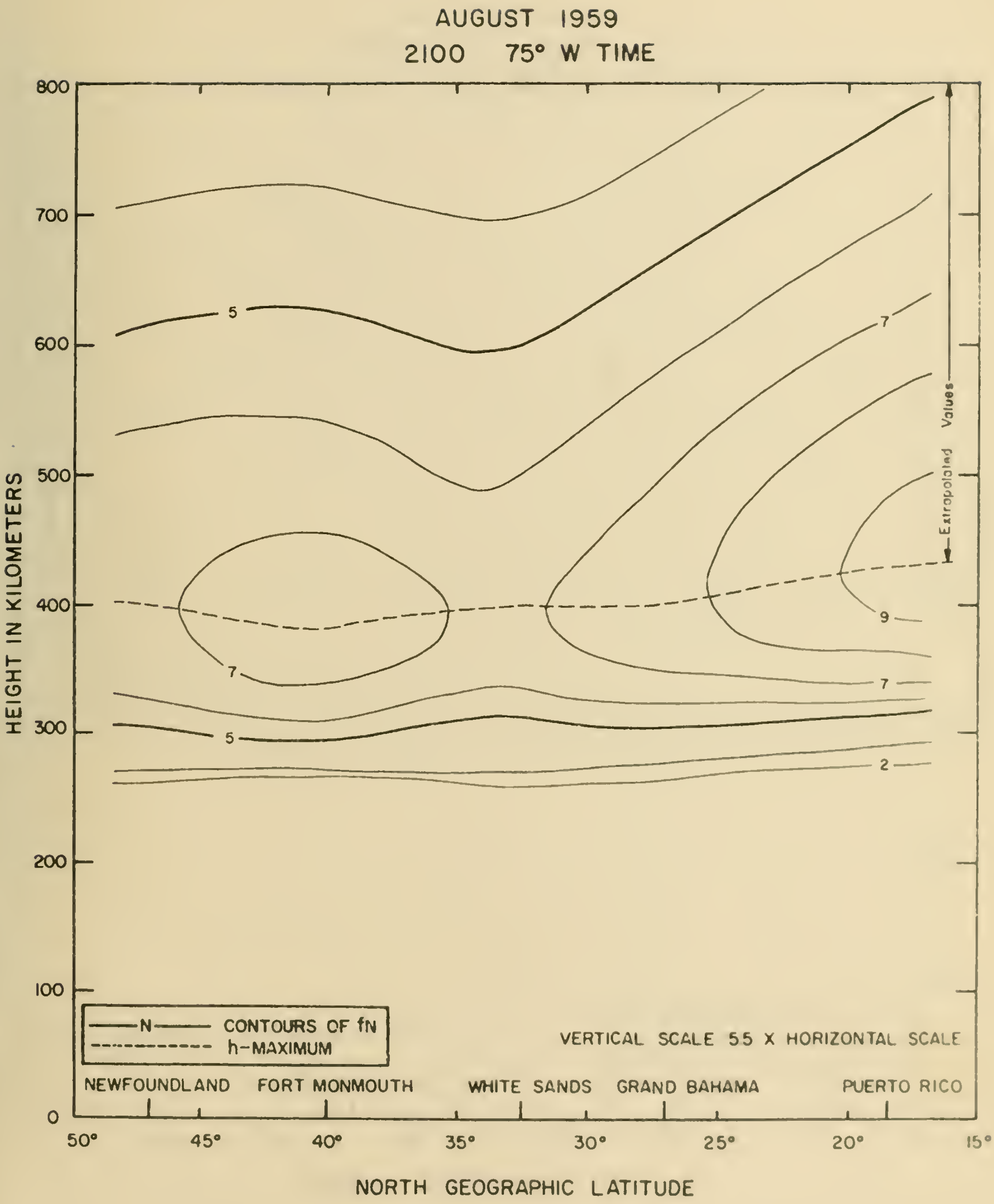


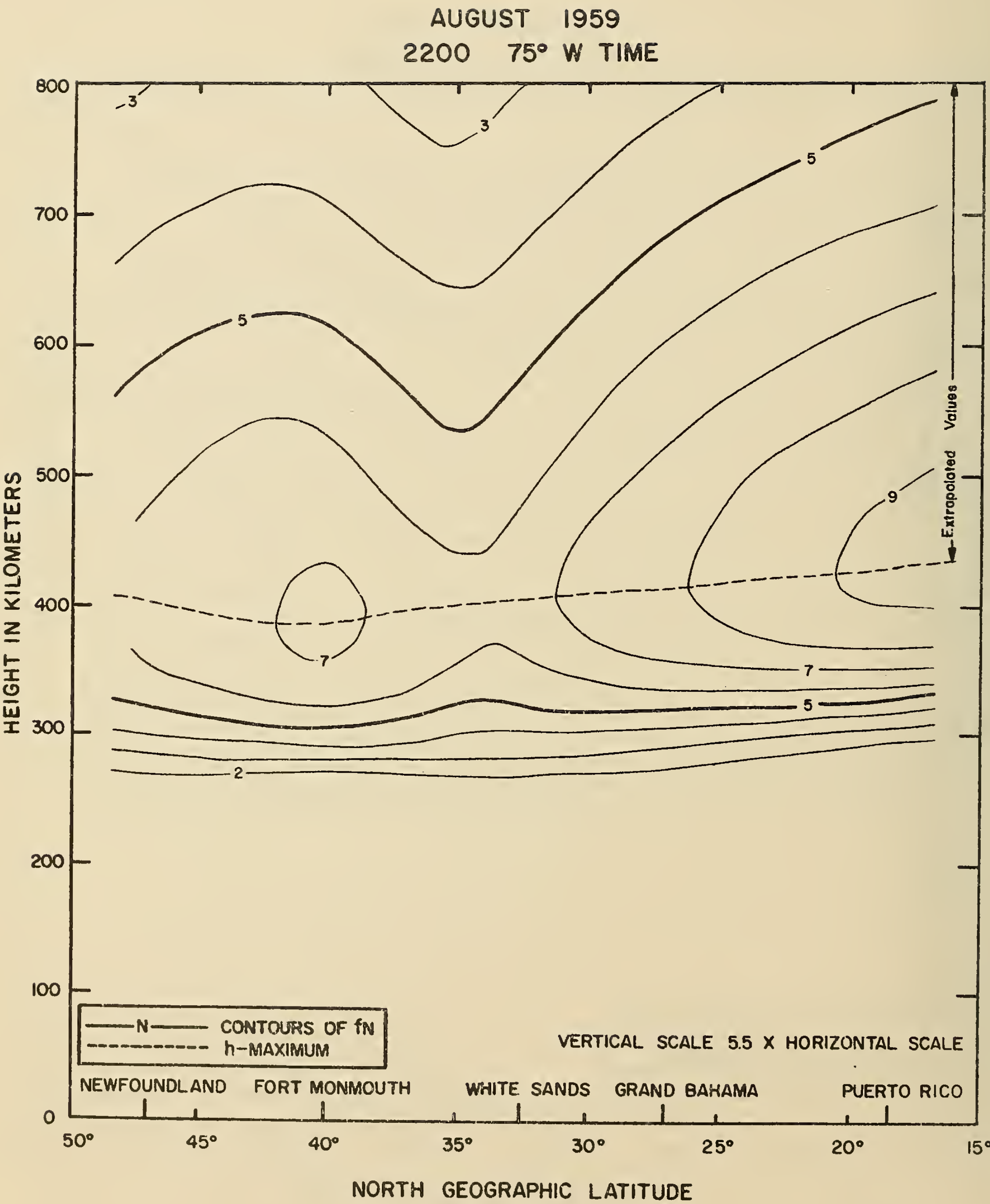
AUGUST 1959
1900 75° W TIME



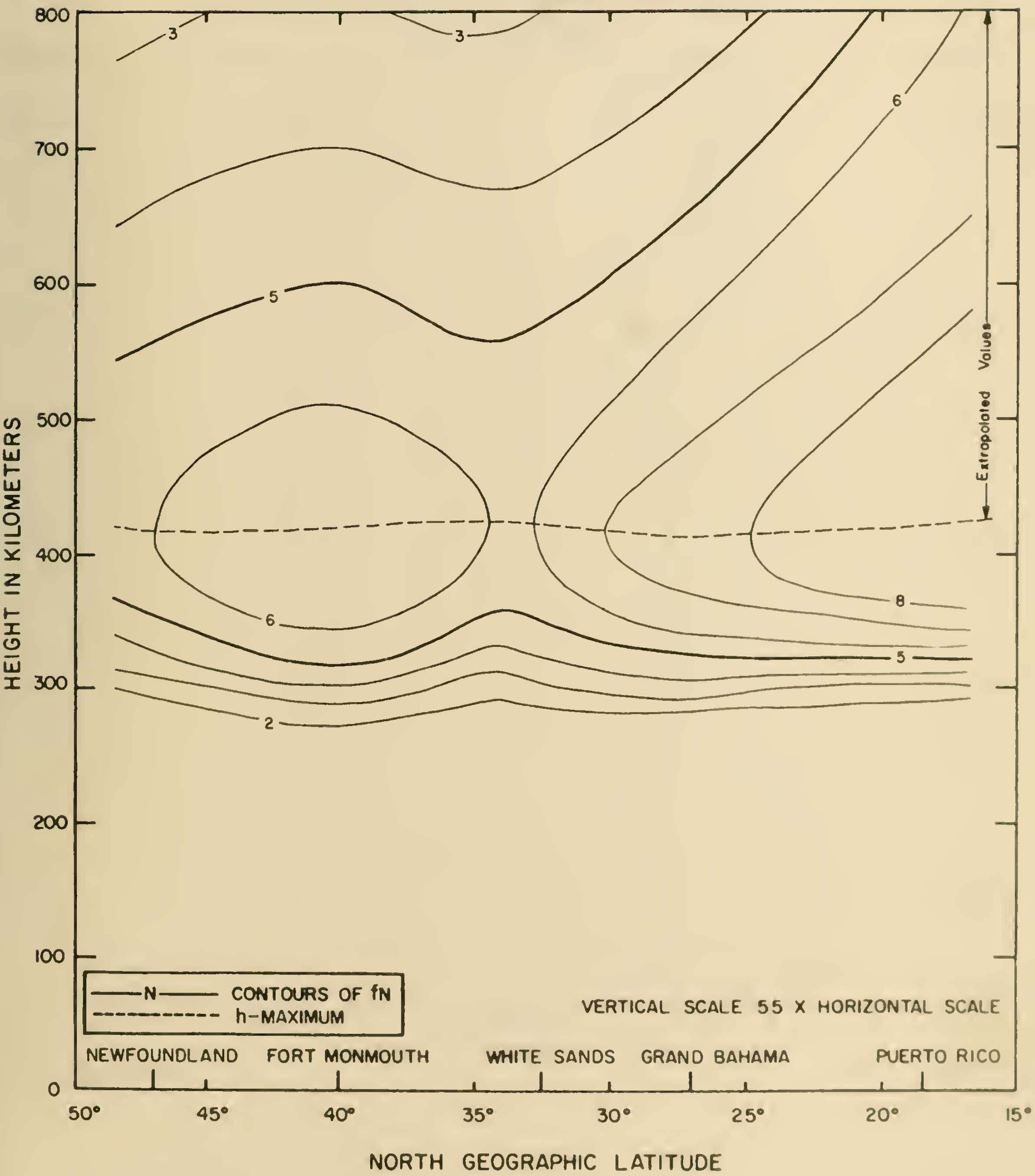
AUGUST 1959
2000 75° W TIME



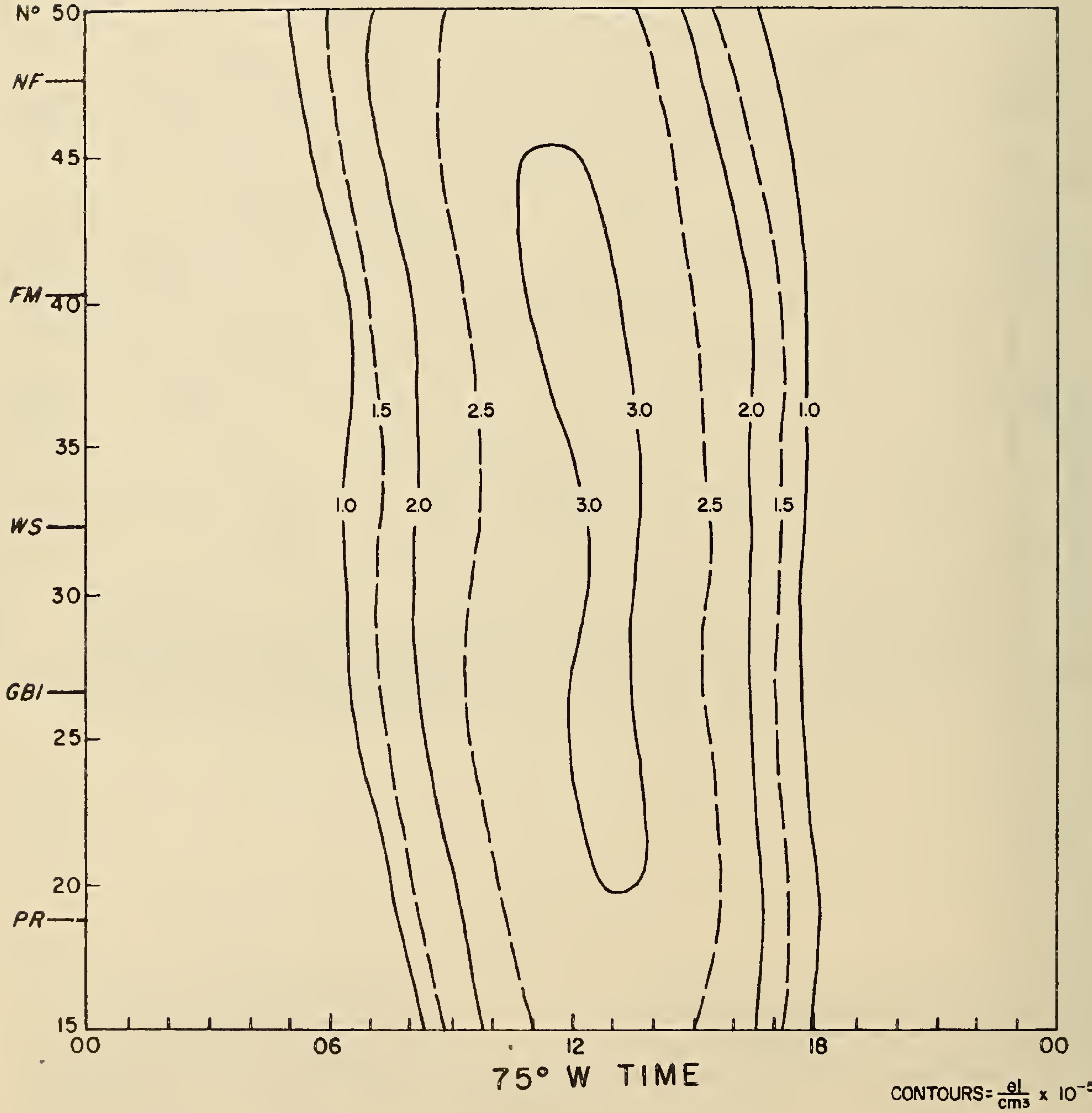

AUGUST 1959
2100 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
5
7
9
2
Extrapolated Values
—N— CONTOURS OF fN
------- h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE


AUGUST 1959
2200 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
5
7
9
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

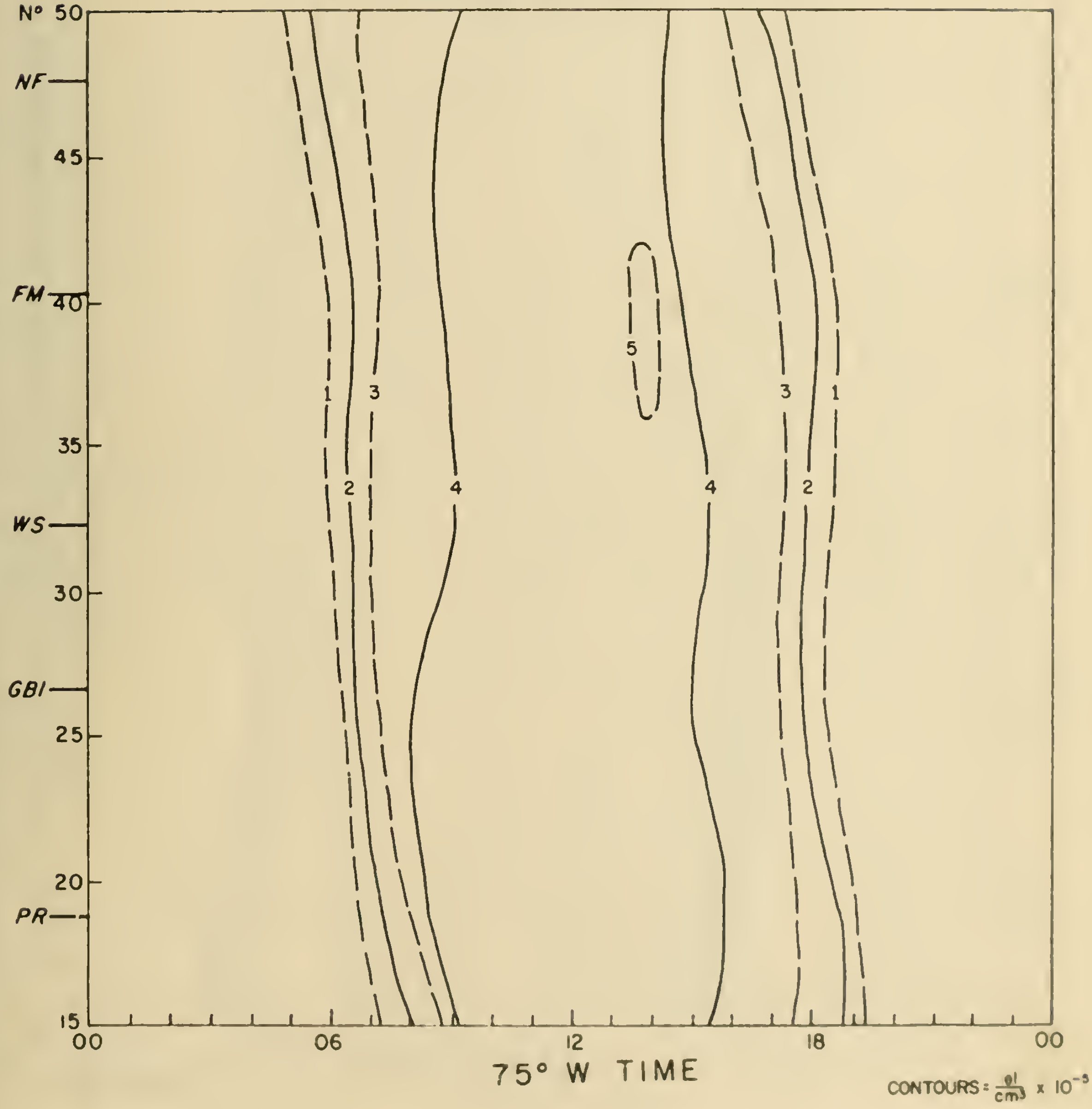
AUGUST 1959
2300 75° W TIME



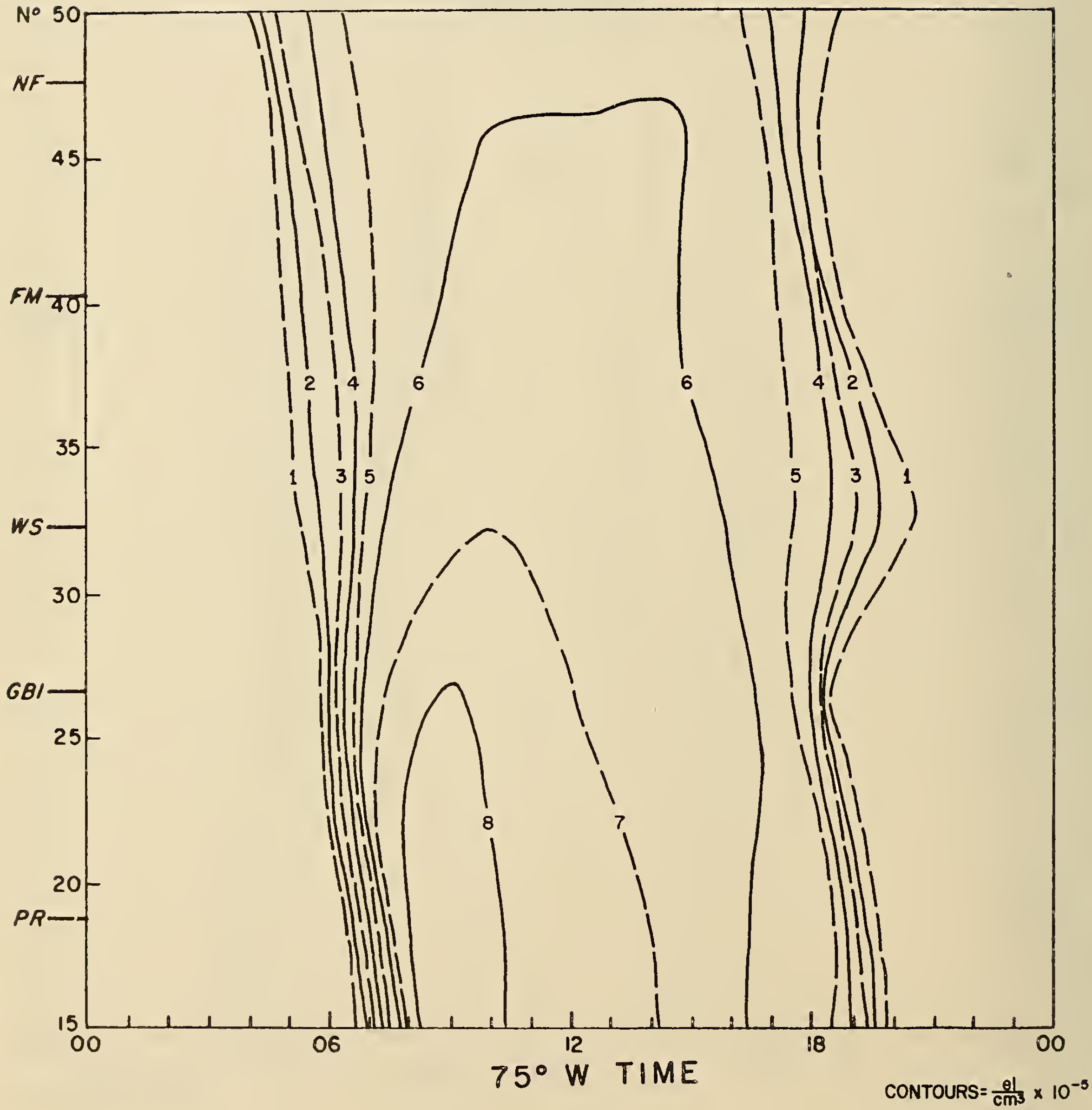
ELECTRON DENSITY AT 150 KILOMETERS
AUGUST 1959



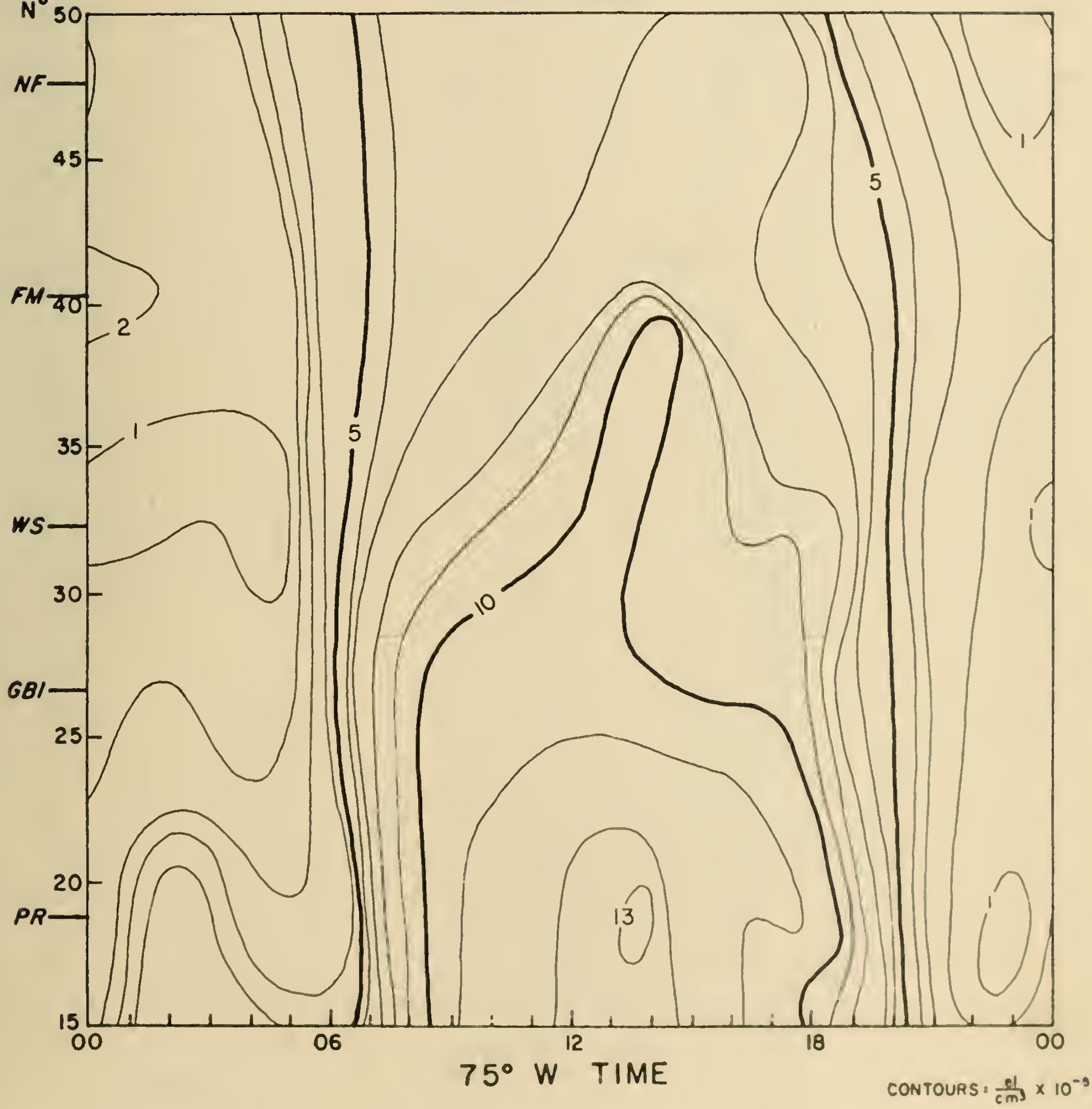
ELECTRON DENSITY AT 200 KILOMETERS
AUGUST 1959

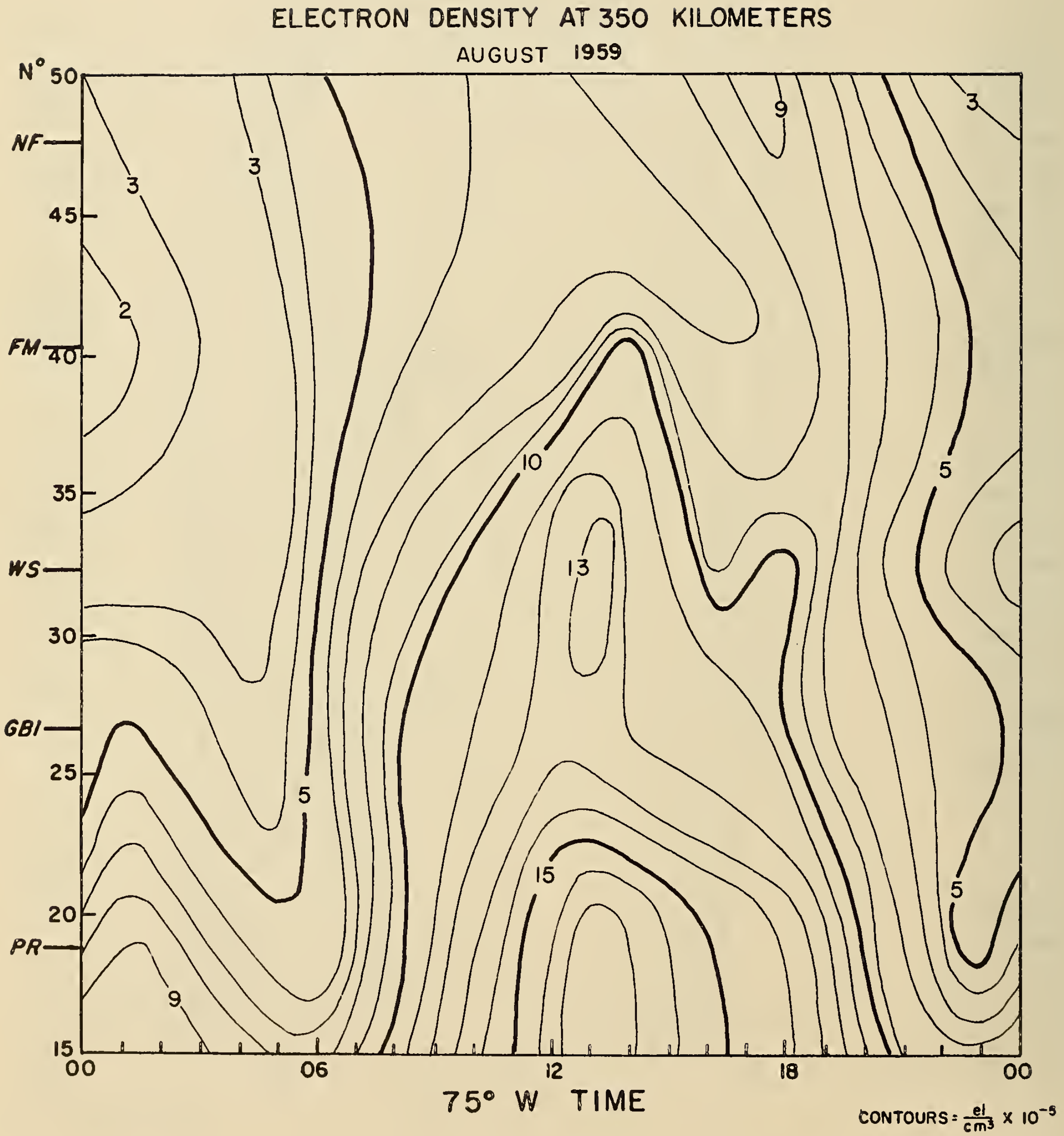


ELECTRON DENSITY AT 250 KILOMETERS
AUGUST 1959

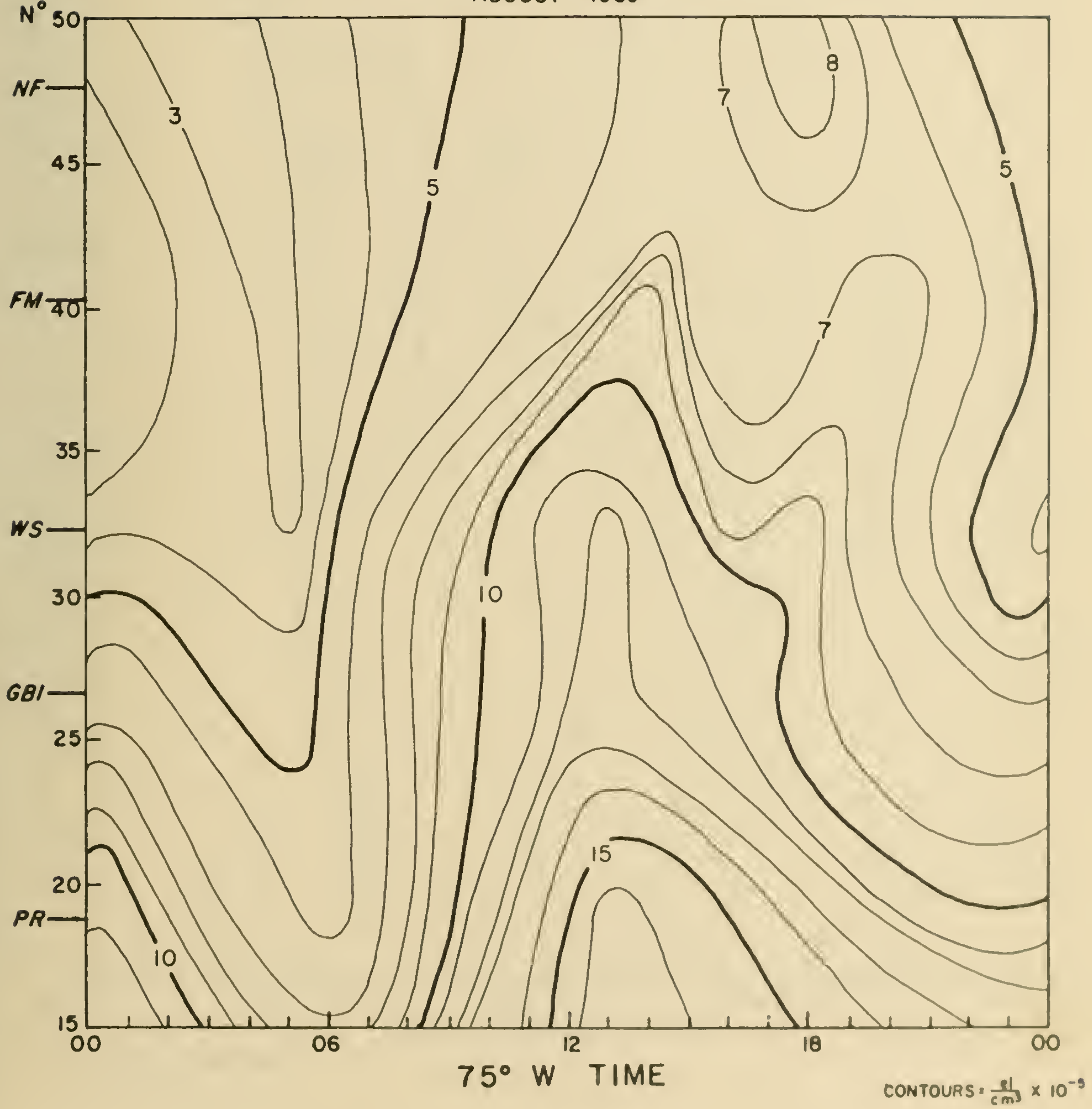


ELECTRON DENSITY AT 300 KILOMETERS
AUGUST 1959




ELECTRON DENSITY AT 350 KILOMETERS
AUGUST 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
2
3
3
5
9
10
13
15
9
3
5
5

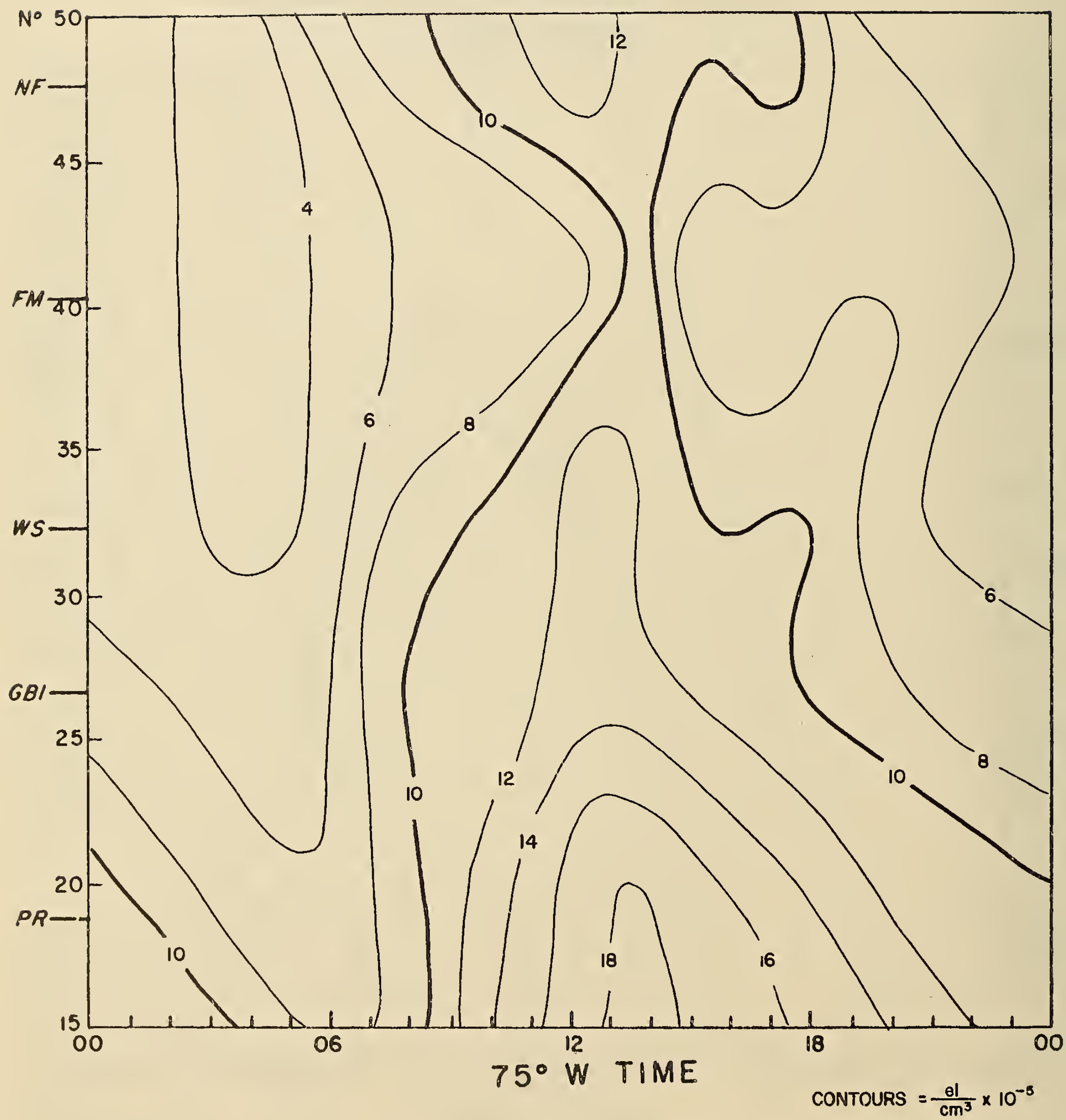
ELECTRON DENSITY AT 400 KILOMETERS
AUGUST 1959



MAXIMUM ELECTRON DENSITY

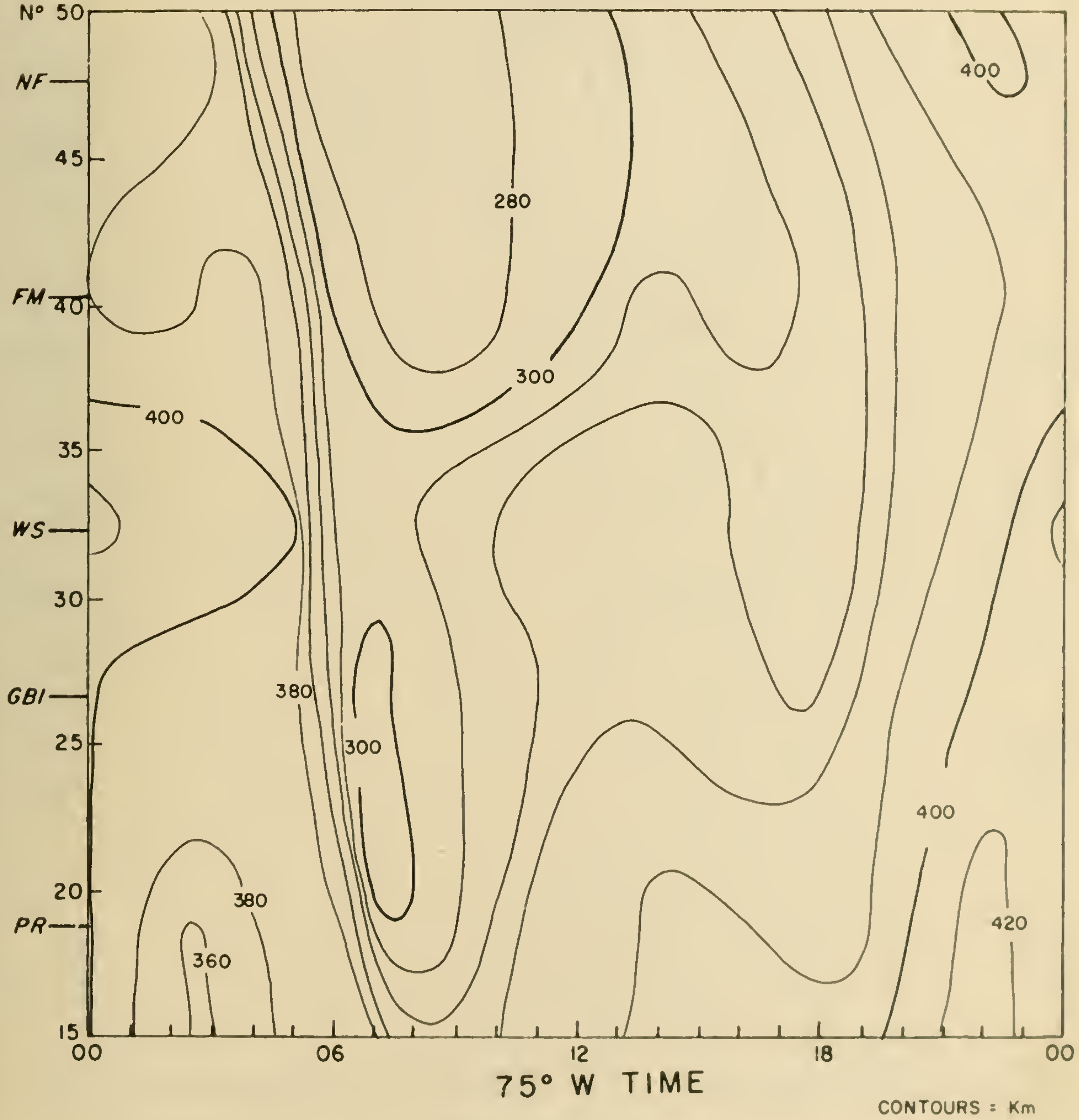
NMAX

AUG. 1959

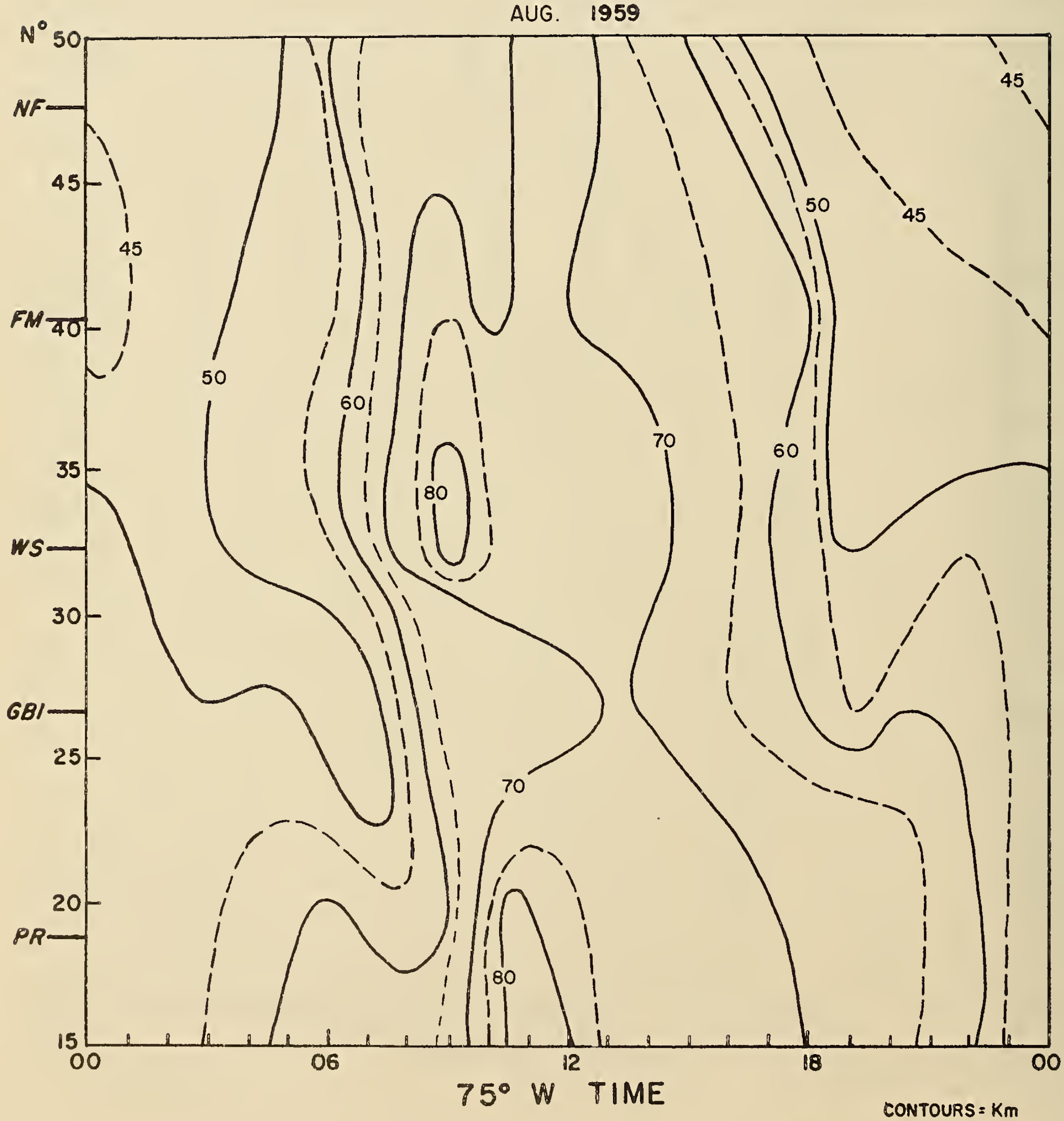


HEIGHT OF MAXIMUM ELECTRON DENSITY
HMAX

AUG. 1959

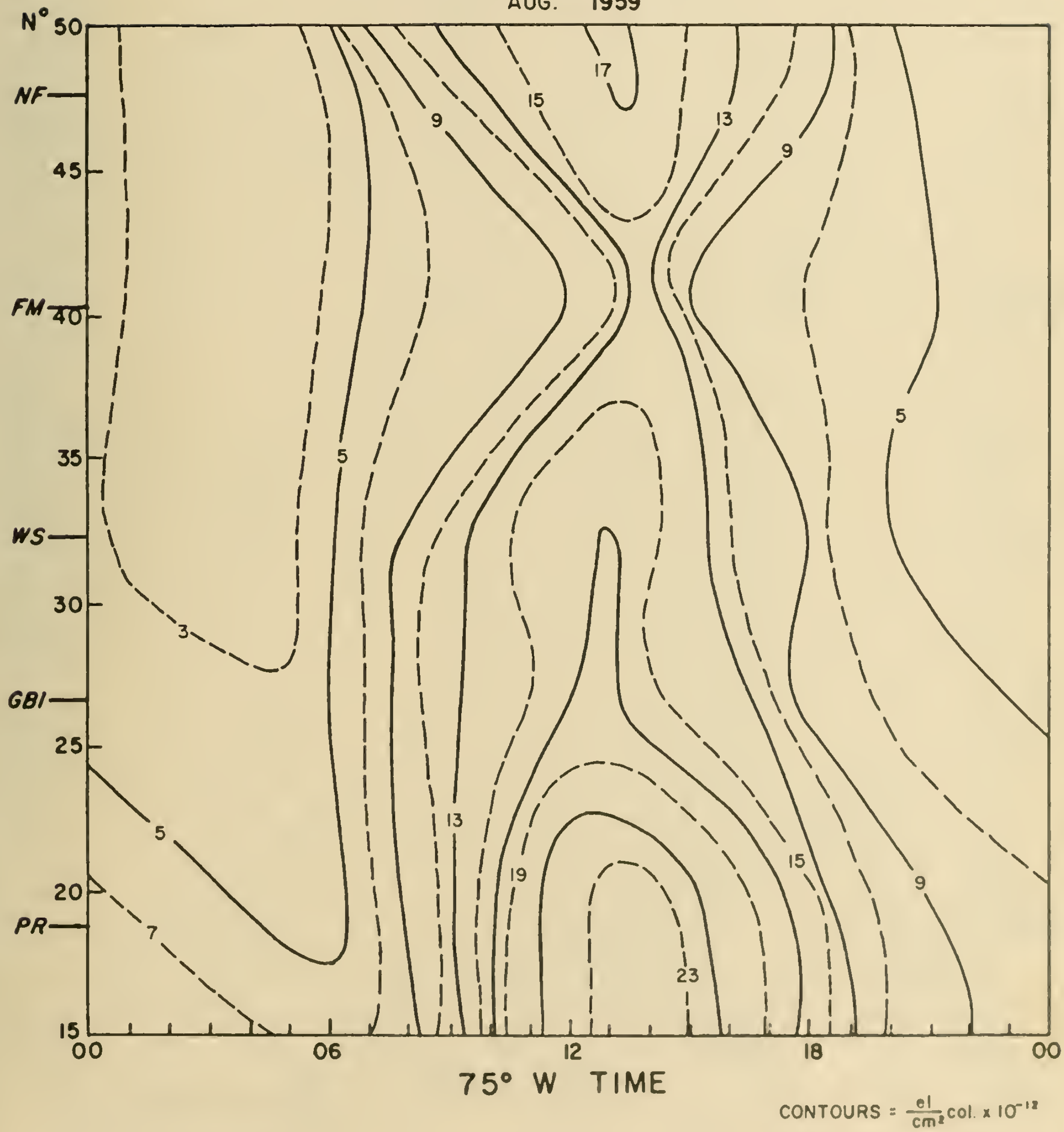


QUARTER THICKNESS OF F-REGION PEAK
SCAT
AUG. 1959

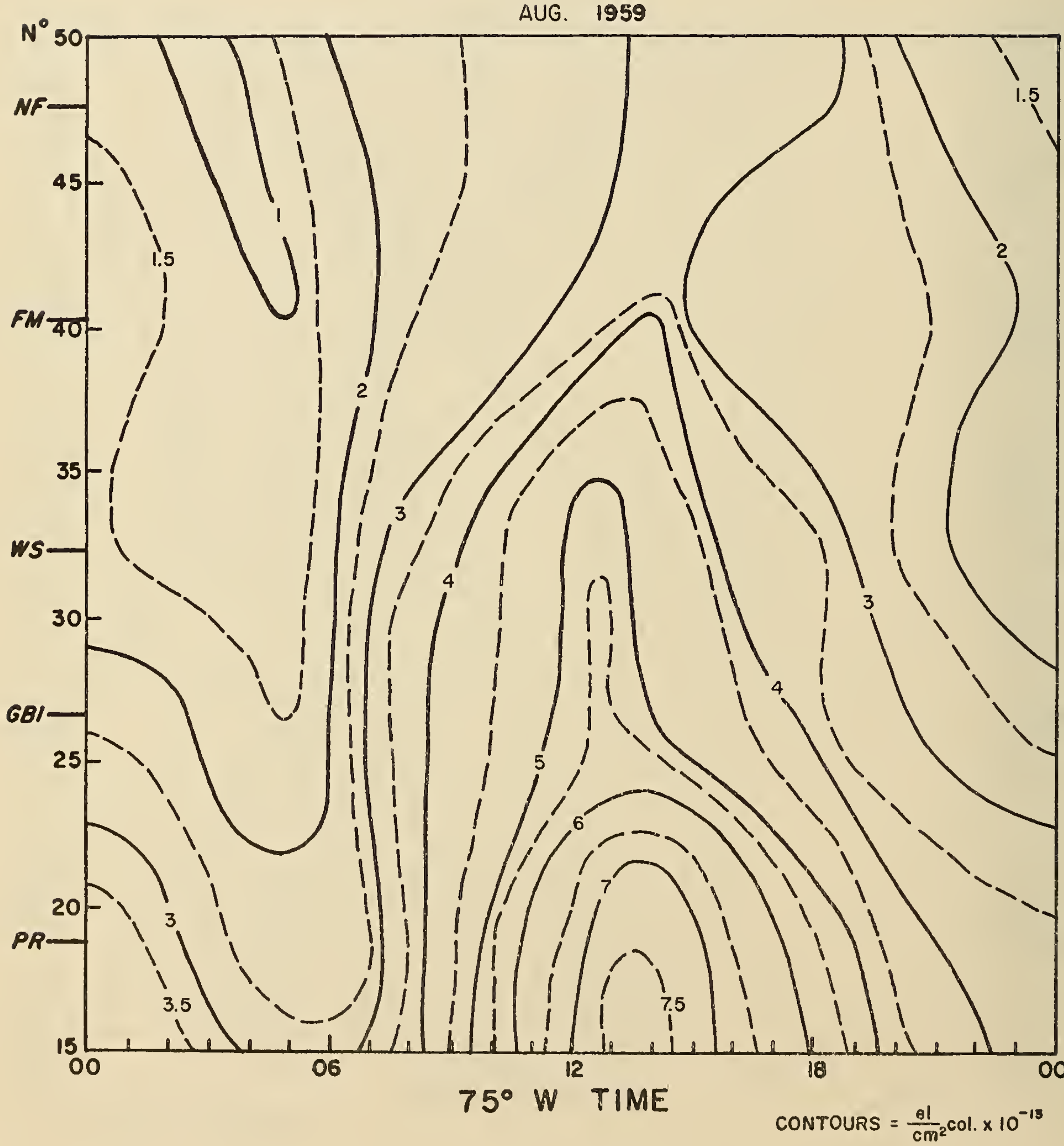


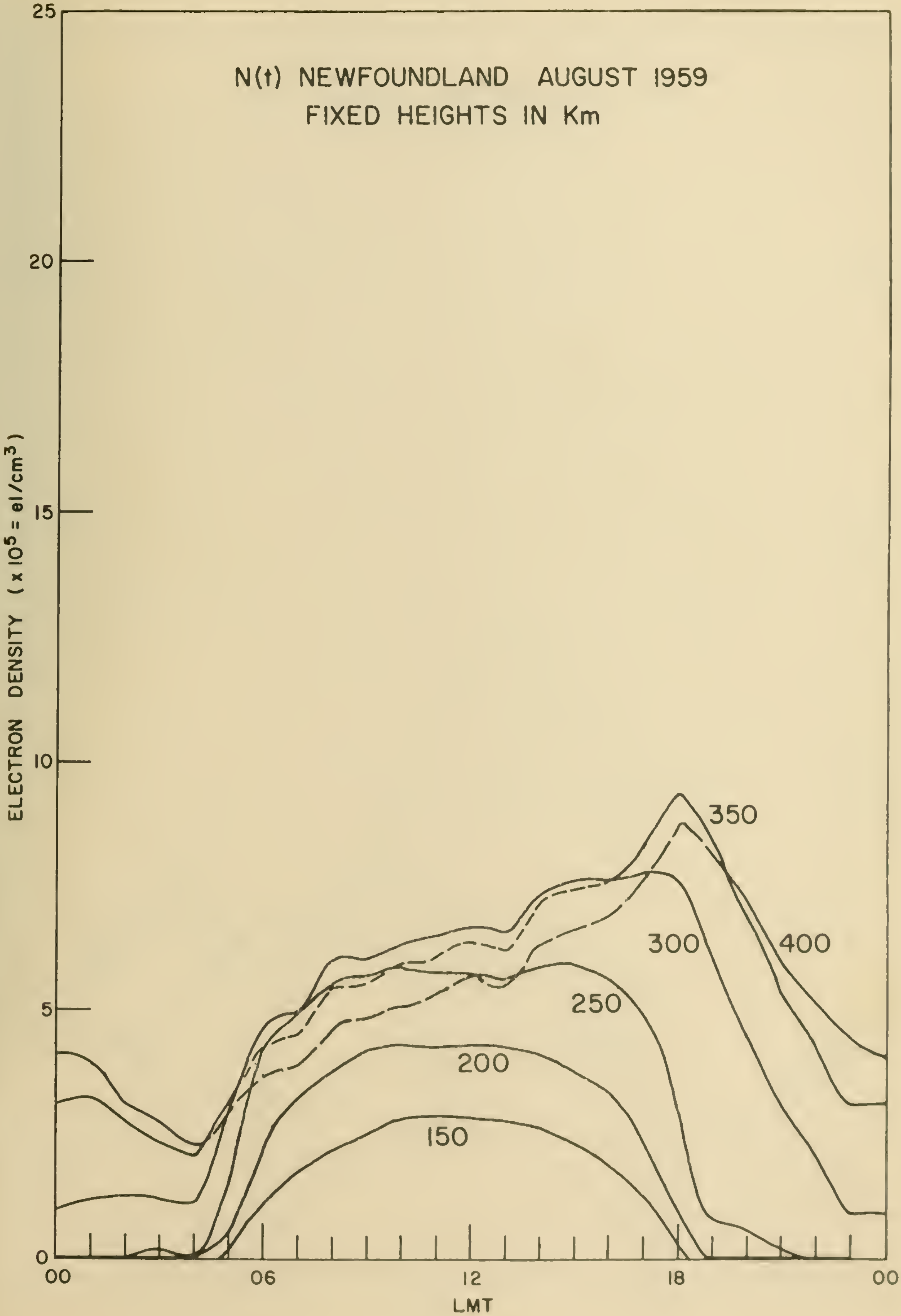
ELECTRON DENSITY INTEGRATED TO HEIGHT
OF MAXIMUM ELECTRON DENSITY
SHMAX

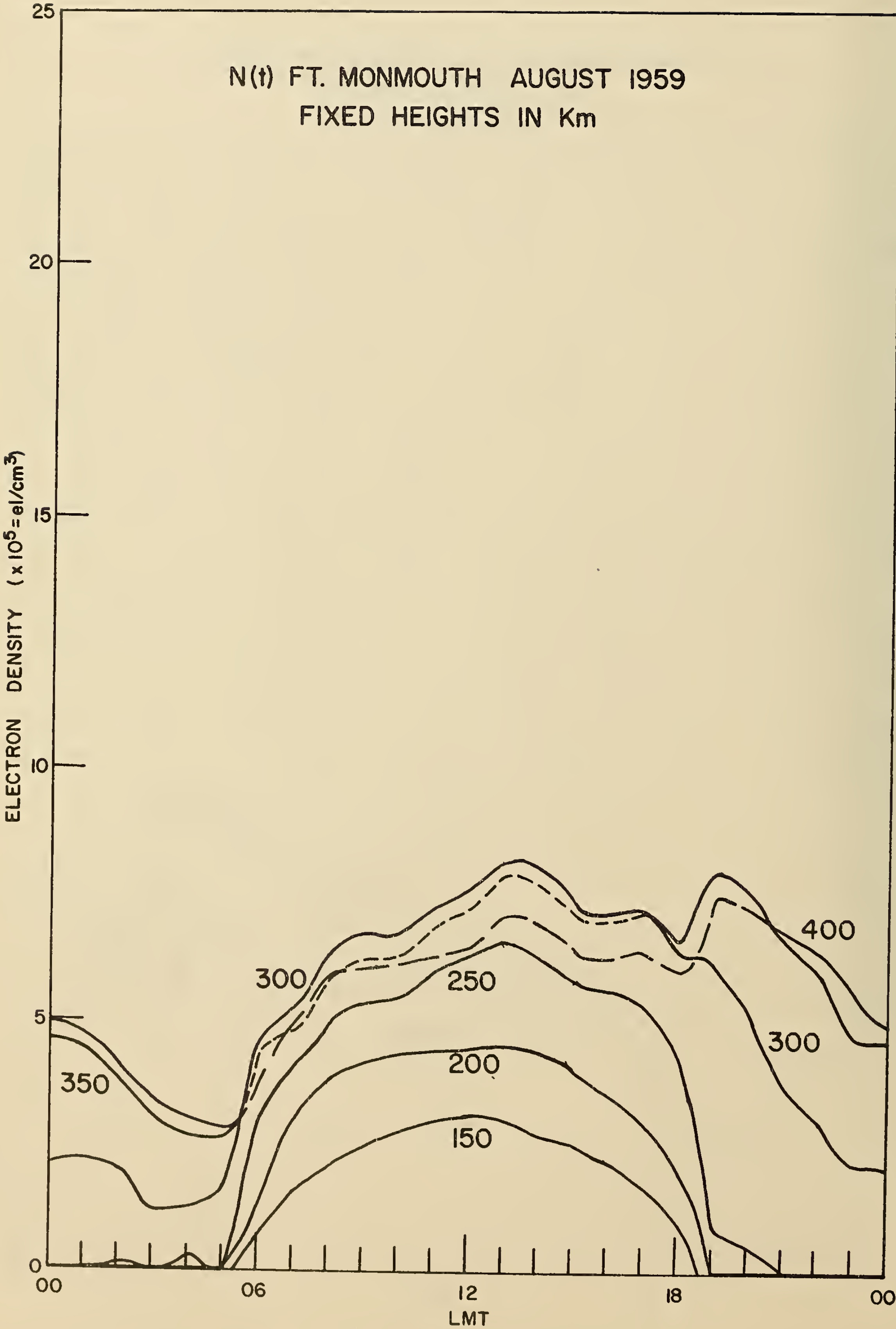
AUG. 1959

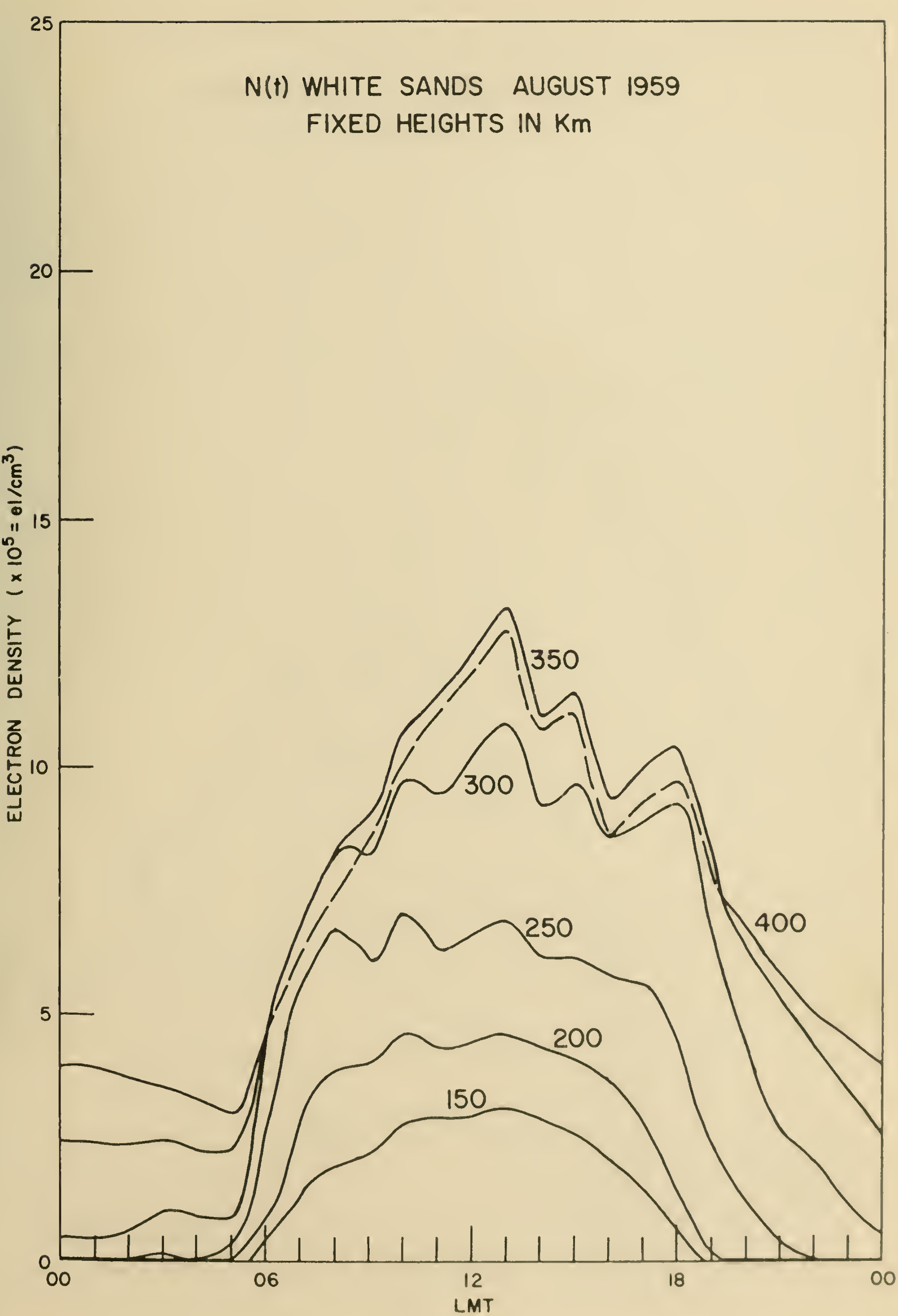


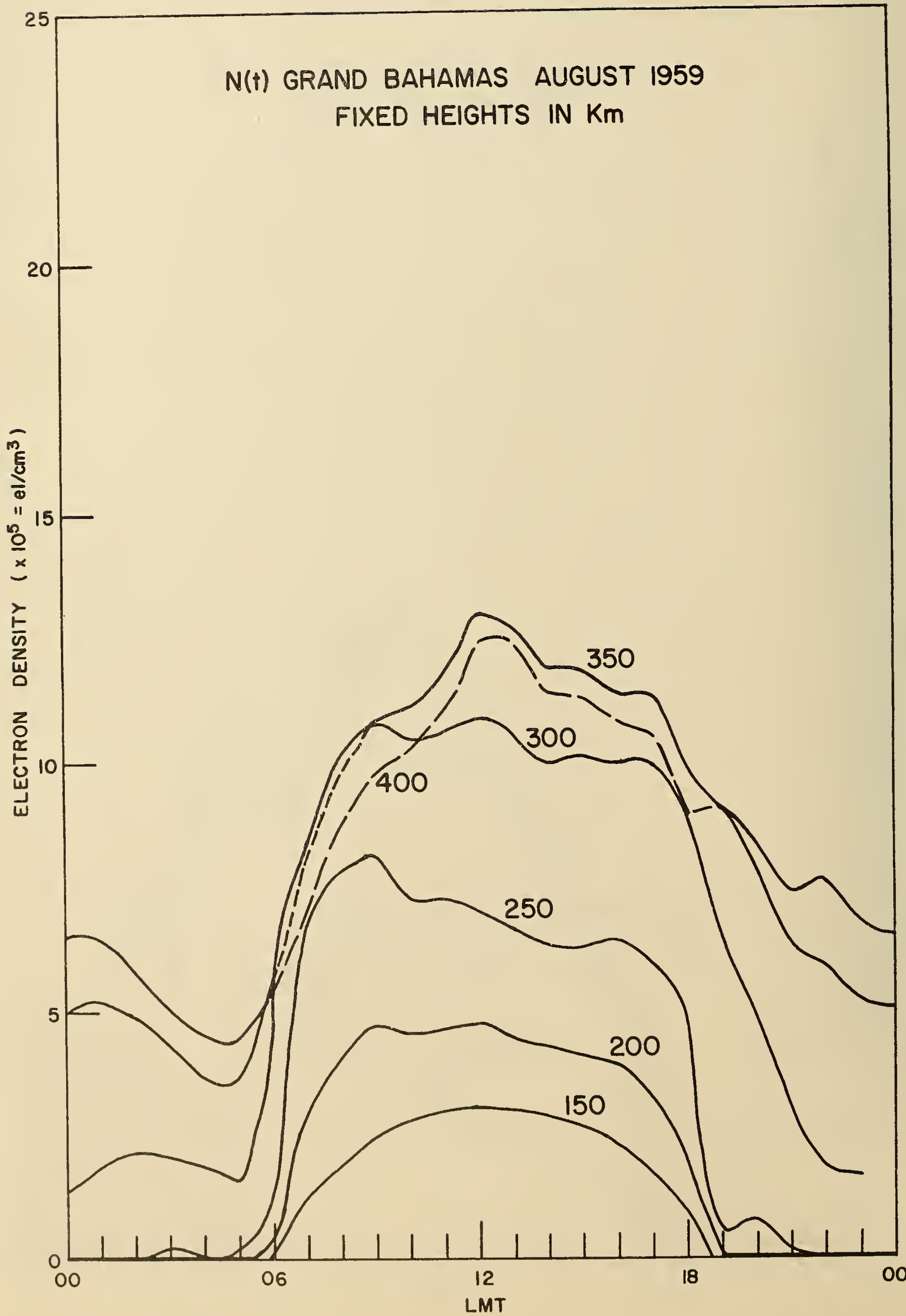
ELECTRON DENSITY INTEGRATED TO INFINITY
SHINF
AUG. 1959

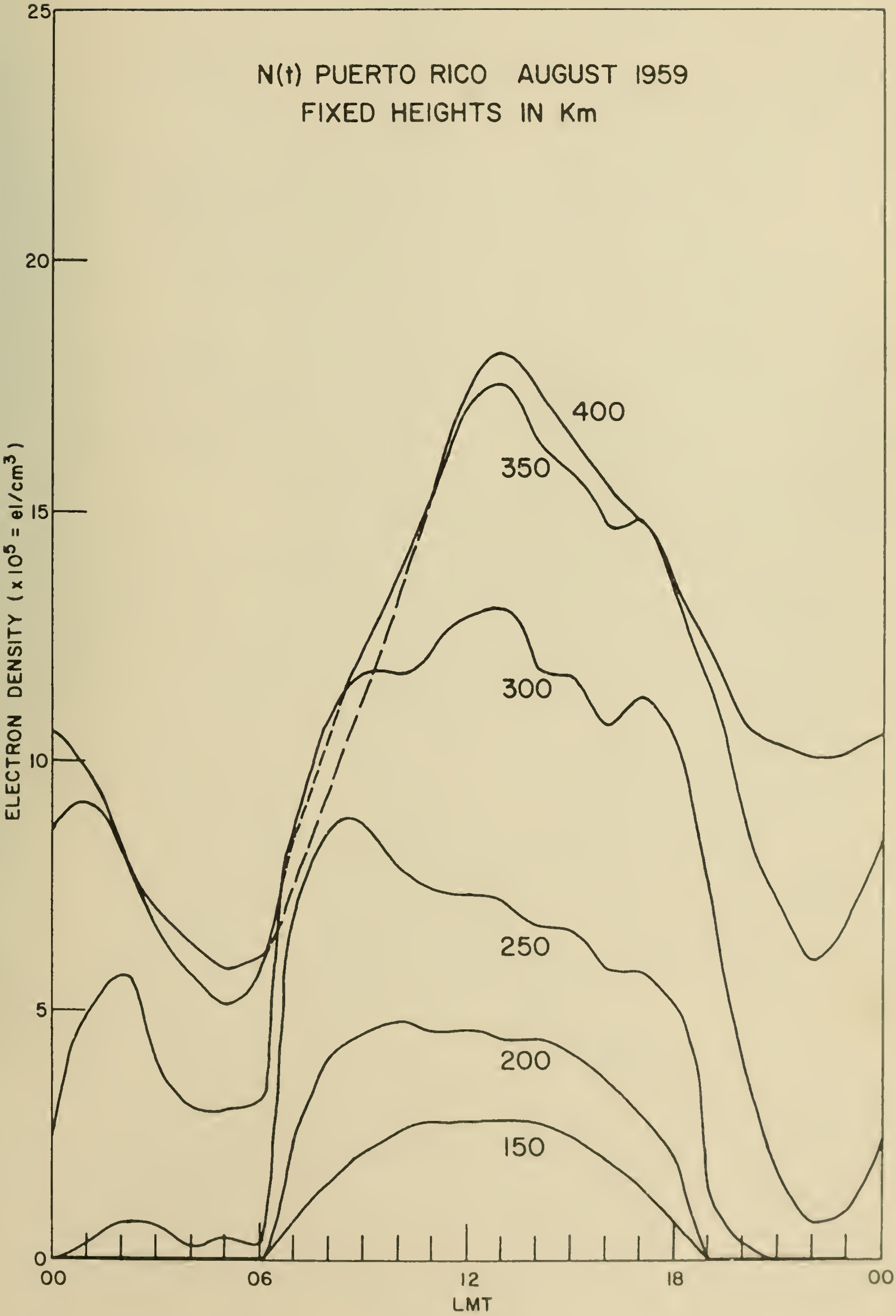



N(t) NEWFOUNDLAND AUGUST 1959
FIXED HEIGHTS IN Km
ELECTRON DENSITY (x 10^5 = el/cm^3)
25
20
15
10
5
0
350
300
400
250
200
150
00
06
12
18
00
LMT


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


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


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


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

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

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

THE NATIONAL BUREAU OF STANDARDS

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

WASHINGTON, D.C.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Office of Weights and Measures.

BOULDER, COLO.

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

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

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

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

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

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

NBS