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Boulder Laboratories

MEAN ELECTRON DENSITY VARIATIONS OF THE QUIET IONOSPHERE

No. 5 - JULY 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 fourth of a series illustrating the electron density variations in the mean quiet ionosphere between latitudes 15°N and 50°N along the 75°W meridian.

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MEAN ELECTRON DENSITY VARIATIONS OF THE QUIET IONOSPHERE 5 - JULY 1959

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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. 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. 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 JULY 1959

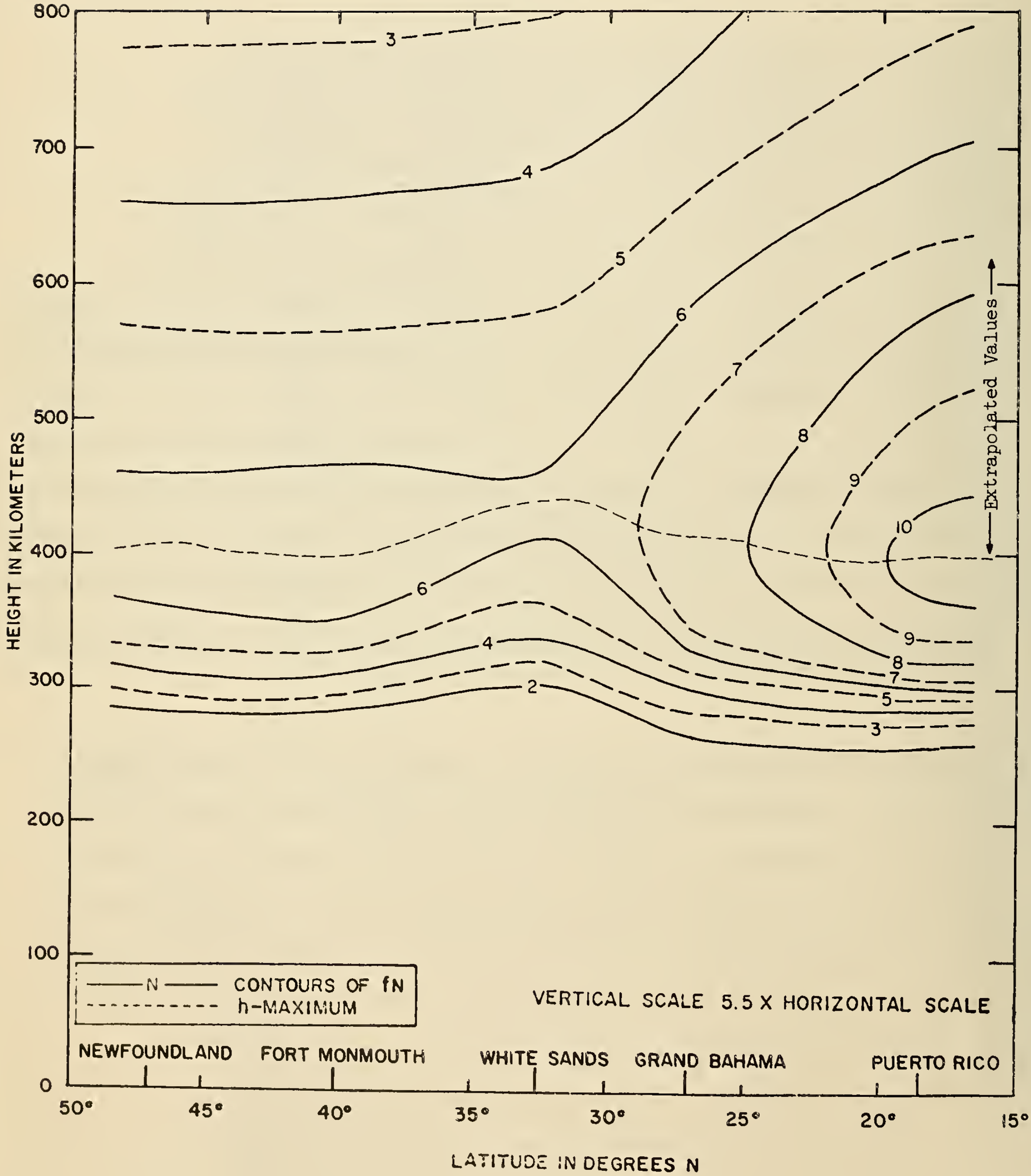
TIME	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100
COUNT	27	27	29	29	28	26	23	19	19	20	20	17
HMIN	269	253	255	262	261	254	242	134	110	108	109	109
NMAX	1303	1181	934	821	764	700	692	871	1063	1076	1256	1421
HMAX	385	362	377	385	381	376	362	341	343	345	364	370
SHMAX	892	782	686	616	543	510	507	902	1278	1377	1697	1892
SHINF	4567	4113	3321	2932	2699	2484	2460	3359	4216	4413	5239	5901
KM												
950	127	103	87.0	80.4	73.5	65.5	61.1	68.7	85.0	87.5	111	129
900	162	132	112	103	94.2	84.0	78.3	88.0	109	112	142	166
850	208	169	143	132	121	108	101	113	140	144	182	213
800	267	216	183	169	155	138	129	145	179	184	233	272
750	341	277	234	215	198	176	164	185	229	236	298	348
700	433	352	298	275	251	224	210	236	293	301	381	444
650	549	447	377	347	318	284	266	301	372	382	483	563
600	688	563	473	434	399	357	335	380	470	483	608	708
550	849	701	585	535	492	442	416	476	588	603	757	880
500	1023	854	707	640	592	534	506	586	723	741	923	1070
490	1057	885	731	661	611	552	525	609	751	769	957	1108
480	1090	916	755	681	630	570	543	632	780	798	991	1146
470	1123	947	779	700	649	588	561	655	808	827	1024	1184
460	1153	977	800	718	666	604	578	679	836	855	1057	1220
450	1182	1006	821	735	683	620	595	702	864	883	1089	1255
440	1208	1034	840	749	697	635	611	724	891	910	1119	1288
430	1231	1059	857	761	710	649	626	746	917	936	1147	1319
420	1251	1083	872	771	720	660	640	767	942	961	1173	1347
410	1265	1104	883	775	727	670	652	786	966	984	1196	1371
400	1273	1122	891	776	731	675	662	804	987	1005	1216	1390
390	1271	1135	893	771	729	677	668	820	1006	1023	1231	1405
380	1258	1143	890	759	722	674	672	834	1021	1038	1242	1414
370	1228	1141	879	741	708	665	672	845	1034	1049	1248	1415
360	1179	1129	860	716	685	650	666	853	1042	1055	1247	1407
350	1112	1102	830	682	651	625	654	856	1044	1056	1238	1387
340	1023	1060	789	638	606	591	634	853	1042	1051	1218	1354
330	909	998	737	586	552	545	603	842	1033	1038	1189	1307
320	766	916	673	527	487	490	561	826	1017	1019	1148	1250
310	616	817	598	463	416	427	507	803	993	990	1098	1181
300	459	690	516	395	340	359	435	772	959	955	1037	1104
290	302	551	423	321	269	284	352	732	916	911	971	1019
280	181	415	326	248	197	210	273	685	865	862	898	931
270	105	303	232	178	132	141	198	629	806	807	822	842
260	54.4	213	148	113	77.8	87.0	140	566	739	746	746	754
250	24.4	142	85.2	68.5	37.6	52.1	88.0	496	668	682	674	673
240	6.2	86.7	39.5	32.5	20.6	29.6	54.9	423	595	620	607	601
230	.4	45.3	14.8	14.3	11.2	13.3	28.4	348	523	560	546	541
220		14.4	4.5	5.5	4.0	3.2	16.0	281	459	504	496	493
210		3.4	.4	1.8	1.4		8.4	225	401	451	454	455
200		.4					3.8	184	350	404	418	424
190							3.4	151	304	361	386	397
180							3.1	124	263	323	355	370
170							2.8	103	226	287	325	342
160							2.6	88.3	193	251	291	312
150							2.5	77.6	165	219	253	276
140							2.3	71.2	144	189	219	240
130							2.2	66.6	131	169	193	213
120							2.1	55.5	117	156	179	194
110							.5	6.4	44.4	86.6	85.0	95.0

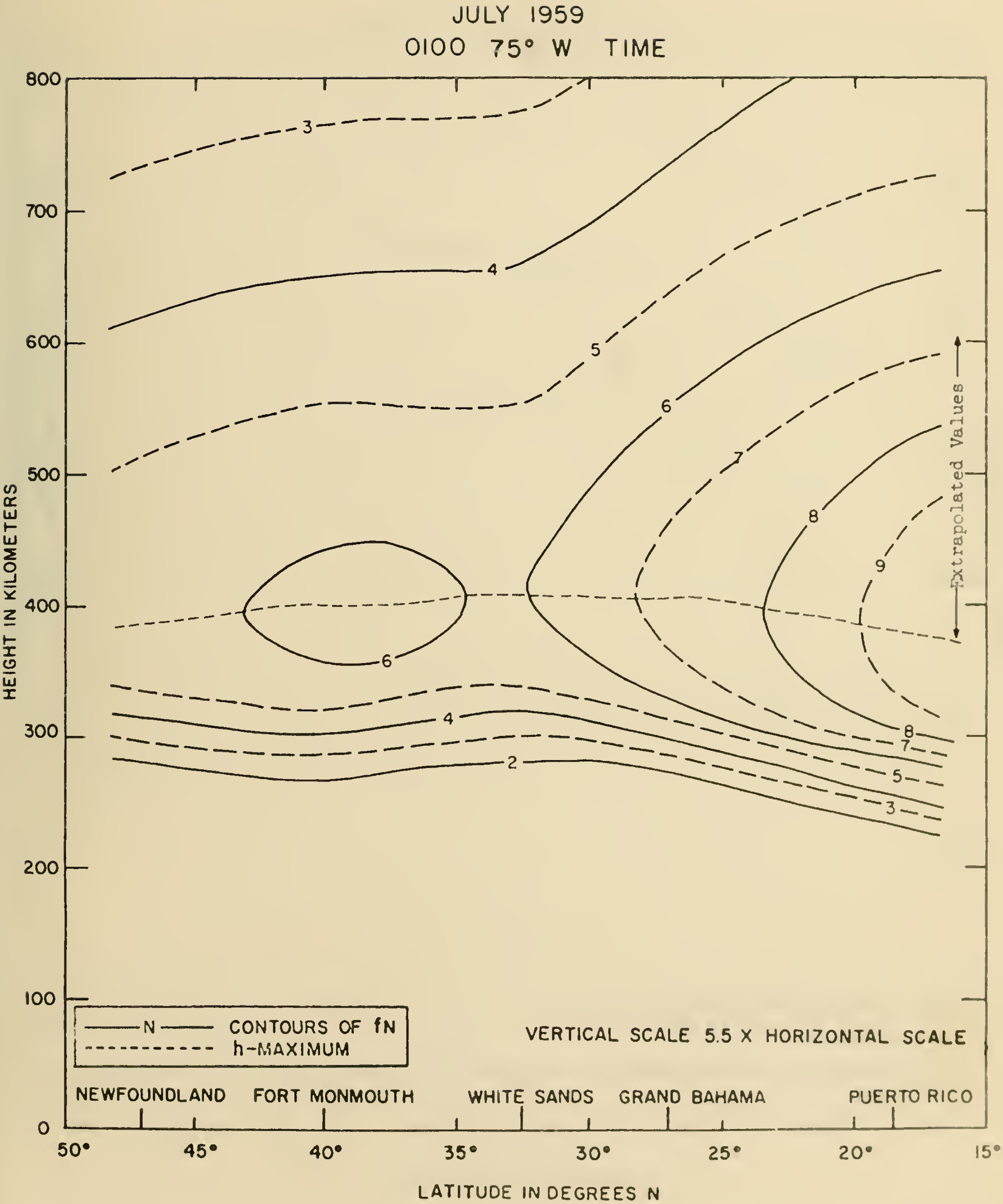
AVERAGE ELECTRON DENSITY KP BELOW 4.5

PUERTO RICO 60 W JULY 1959

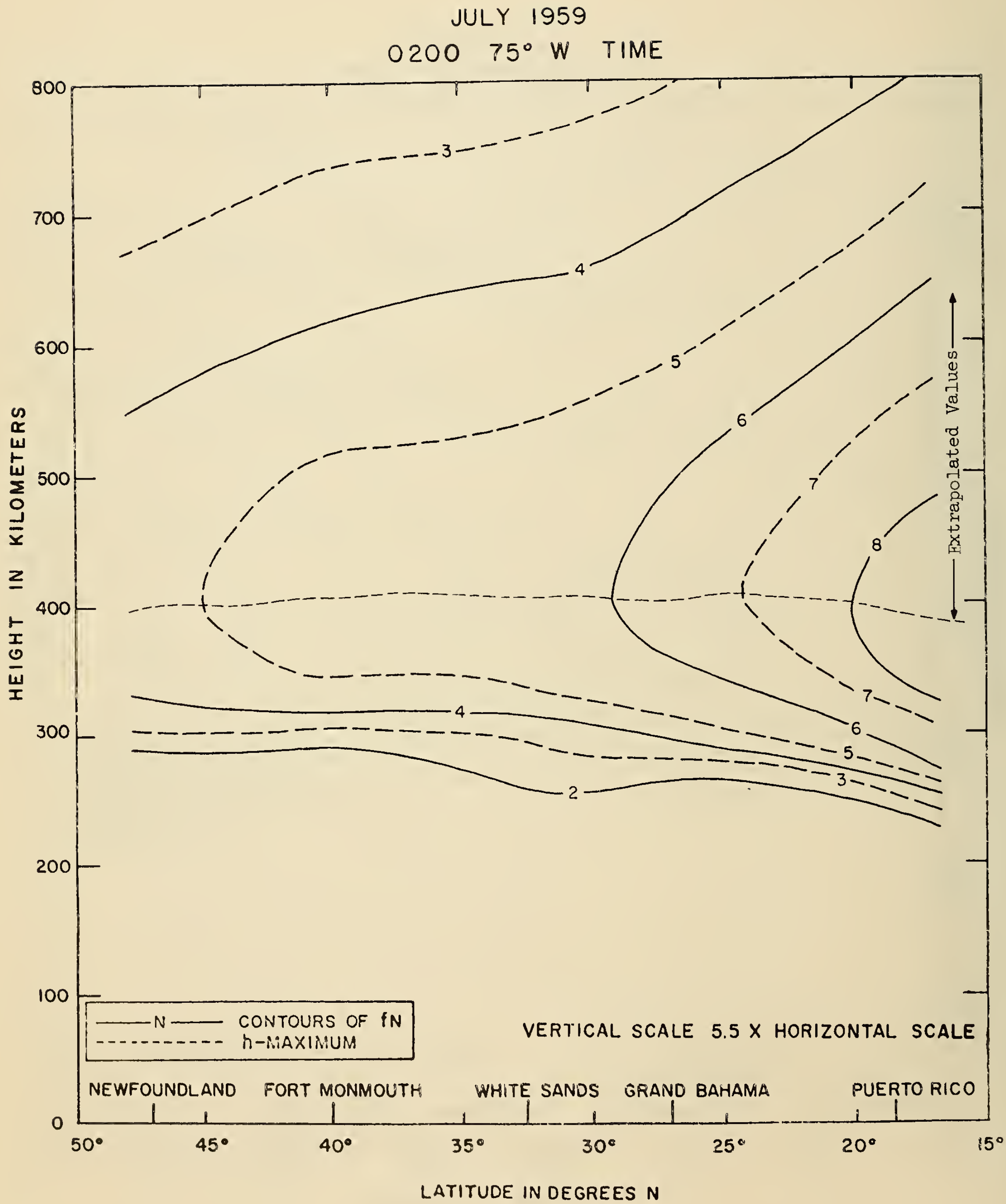
TIME	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
COUNT	15	19	16	20	20	14	9	22	25	26	25	27
HMIN	109	109	110	109	110	110	125	246	251	270	280	281
NMAX	1603	1672	1705	1645	1566	1523	1519	1376	1305	1265	1286	1319
HMAX	379	377	375	370	369	362	370	385	397	412	411	406
SHMAX	2111	2133	2145	2018	1881	1733	1641	1193	1123	1055	983	991
SHINF	6634	6851	6954	6657	6298	6030	5925	5075	4805	4623	4609	4712
KM												
950	152	157	159	150	141	135	139	134	135	141	144	142
900	195	202	203	192	181	173	179	172	174	181	185	183
850	251	258	261	246	233	222	229	221	222	231	236	234
800	321	331	334	315	298	285	293	282	284	296	302	299
750	410	423	426	403	380	364	375	361	363	377	385	382
700	522	539	543	514	485	464	478	459	462	479	489	485
650	662	683	689	651	615	589	606	581	583	603	616	612
600	831	858	866	820	774	742	762	728	729	751	766	763
550	1029	1063	1074	1018	962	922	945	899	896	917	935	934
540	1071	1107	1118	1061	1003	961	985	936	932	951	969	969
530	1115	1151	1164	1104	1044	1001	1025	972	967	985	1003	1004
520	1158	1196	1209	1148	1086	1041	1065	1009	1002	1019	1037	1040
510	1201	1242	1255	1193	1128	1082	1106	1047	1037	1052	1070	1074
500	1245	1287	1302	1237	1171	1123	1147	1083	1071	1084	1102	1108
490	1288	1332	1347	1282	1213	1164	1188	1119	1105	1115	1133	1141
480	1330	1376	1393	1326	1255	1205	1229	1155	1137	1143	1162	1172
470	1372	1419	1437	1369	1296	1245	1268	1189	1168	1170	1188	1201
460	1412	1461	1480	1411	1336	1285	1306	1221	1197	1194	1212	1228
450	1449	1500	1521	1452	1375	1322	1343	1252	1223	1215	1231	1251
440	1484	1537	1559	1490	1411	1359	1377	1280	1246	1231	1246	1271
430	1515	1570	1593	1525	1445	1392	1409	1304	1265	1243	1256	1286
420	1543	1600	1625	1557	1476	1423	1437	1325	1279	1248	1260	1294
410	1566	1624	1651	1584	1503	1450	1461	1341	1288	1245	1255	1295
400	1583	1643	1672	1607	1525	1473	1481	1351	1289	1230	1240	1284
390	1593	1655	1686	1624	1542	1490	1495	1354	1280	1203	1209	1259
380	1596	1659	1692	1634	1553	1502	1501	1348	1258	1160	1158	1218
370	1589	1653	1688	1635	1556	1506	1499	1331	1222	1101	1087	1158
360	1566	1633	1670	1624	1548	1502	1486	1302	1169	1025	995	1078
350	1530	1598	1639	1600	1527	1485	1460	1256	1101	932	883	976
340	1476	1548	1593	1559	1490	1453	1419	1194	1016	821	753	855
330	1410	1482	1530	1501	1436	1404	1363	1116	914	700	609	712
320	1327	1402	1449	1425	1364	1342	1289	1020	800	568	462	554
310	1235	1305	1354	1334	1278	1262	1202	910	675	434	313	395
300	1136	1200	1245	1230	1178	1165	1100	783	542	312	189	267
290	1027	1086	1126	1118	1070	1059	986	633	409	202	99.1	161
280	922	966	1001	994	949	943	864	487	289	115	50.3	90.7
270	822	850	980	867	829	824	744	348	191	54.1	22.6	41.7
260	731	742	769	751	719	707	631	209	108	23.3	11.6	14.2
250	651	650	671	648	622	606	526	109	56.8	9.1	4.9	4.0
240	584	576	592	565	541	520	431	56.9	30.0	1.9	2.0	
230	534	517	529	503	477	447	342	27.5	18.1		.6	
220	493	474	482	456	430	391	281	8.3	7.4			
210	460	442	447	421	394	347	235	1.1	2.4			
200	432	417	419	393	365	311	197		.1			
190	405	395	395	370	339	280	167					
180	380	373	372	347	314	251	142					
170	353	350	348	323	287	222	120					
160	323	322	320	296	257	193	104					
150	288	291	288	267	228	170	91.5					
140	252	255	252	237	202	151	82.8					
130	221	226	223	211	182	138	77.4					
120	204	208	202	192	168	128	72.2					
110	83.8	89.0	74.6	66.3	54.3	53.1	13.5					

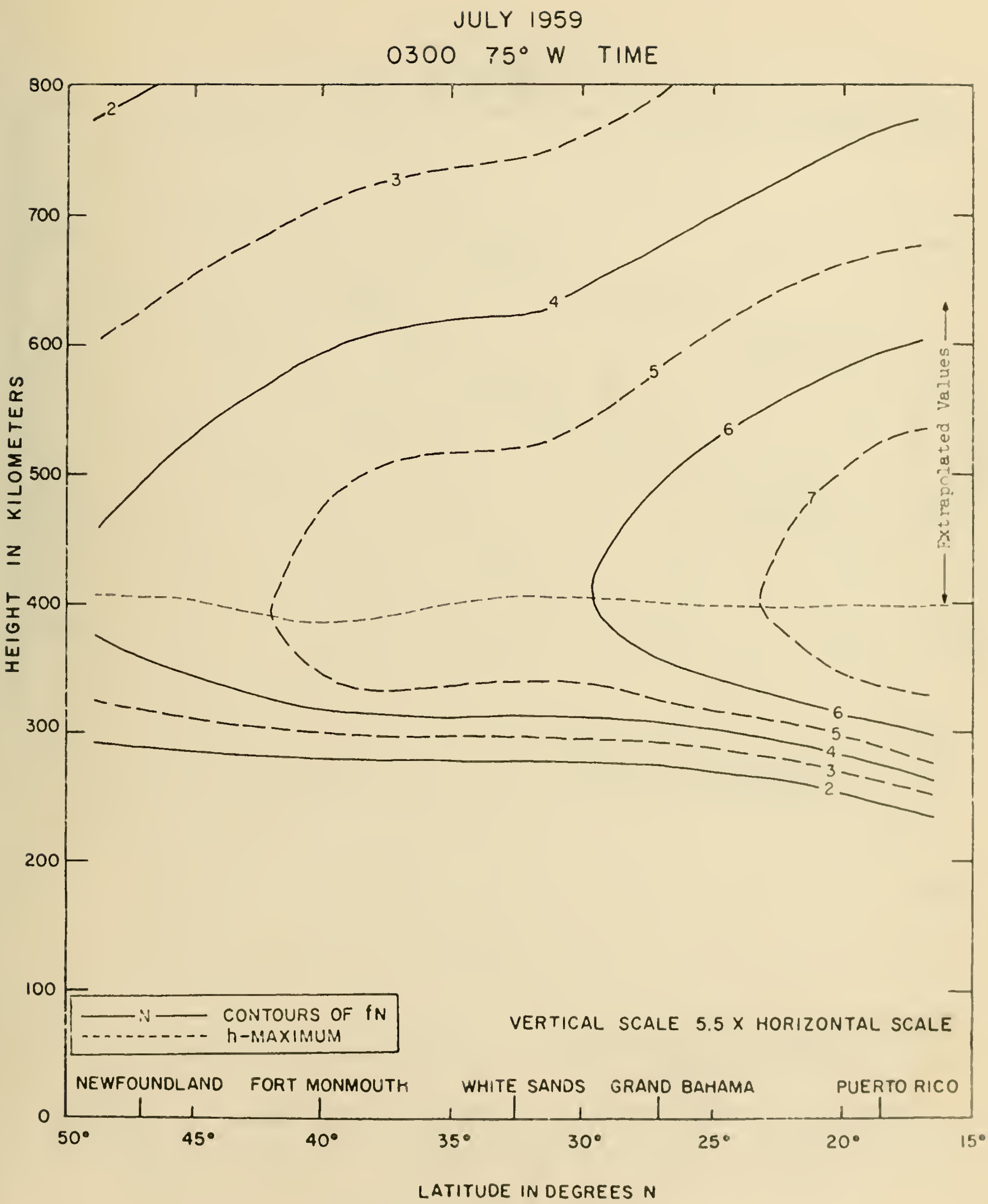
JULY 1959
0000 75° W TIME





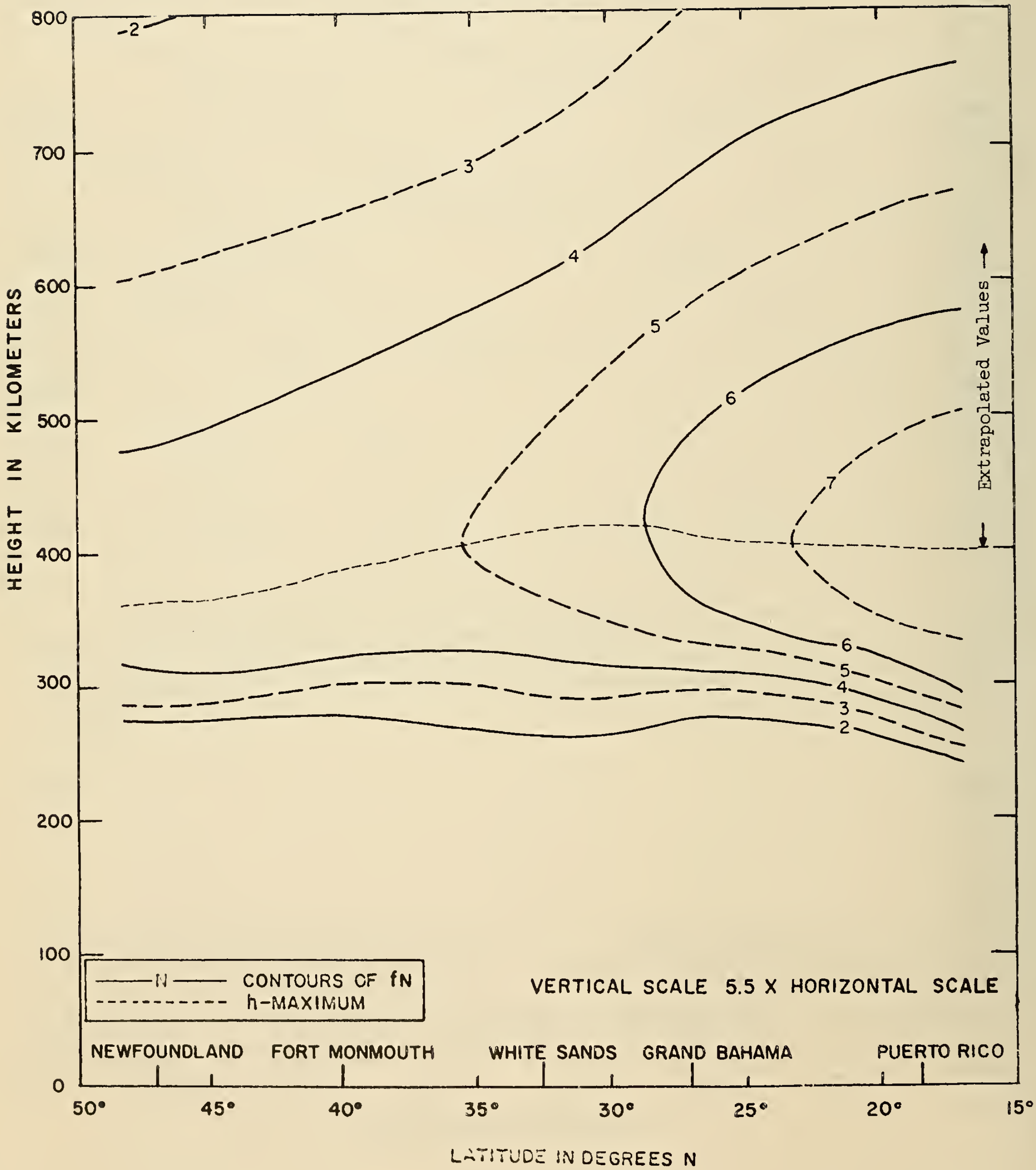
JULY 1959
0100 75° W TIME
800
700
600
500
400
300
200
100
0
HEIGHT IN KILOMETERS
3
4
5
6
7
8
9
2
Extrapolated Values
—N— CONTOURS OF fN
---------- h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
LATITUDE IN DEGREES N


JULY 1959
0200 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
4
5
6
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°
LATITUDE IN DEGREES N



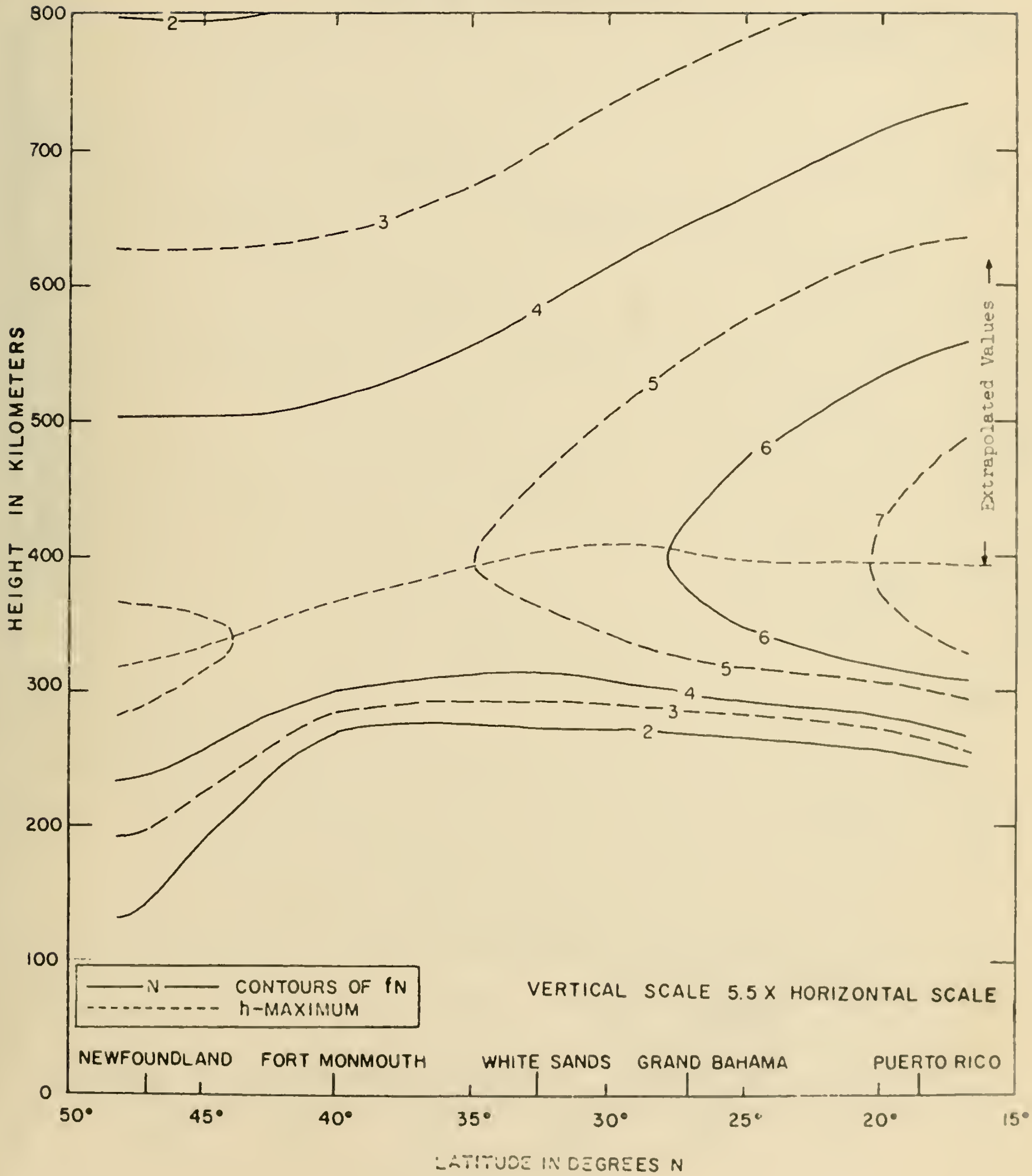
JULY 1959
0300 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
2
3
4
5
6
7
6
5
4
3
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
LATITUDE IN DEGREES N

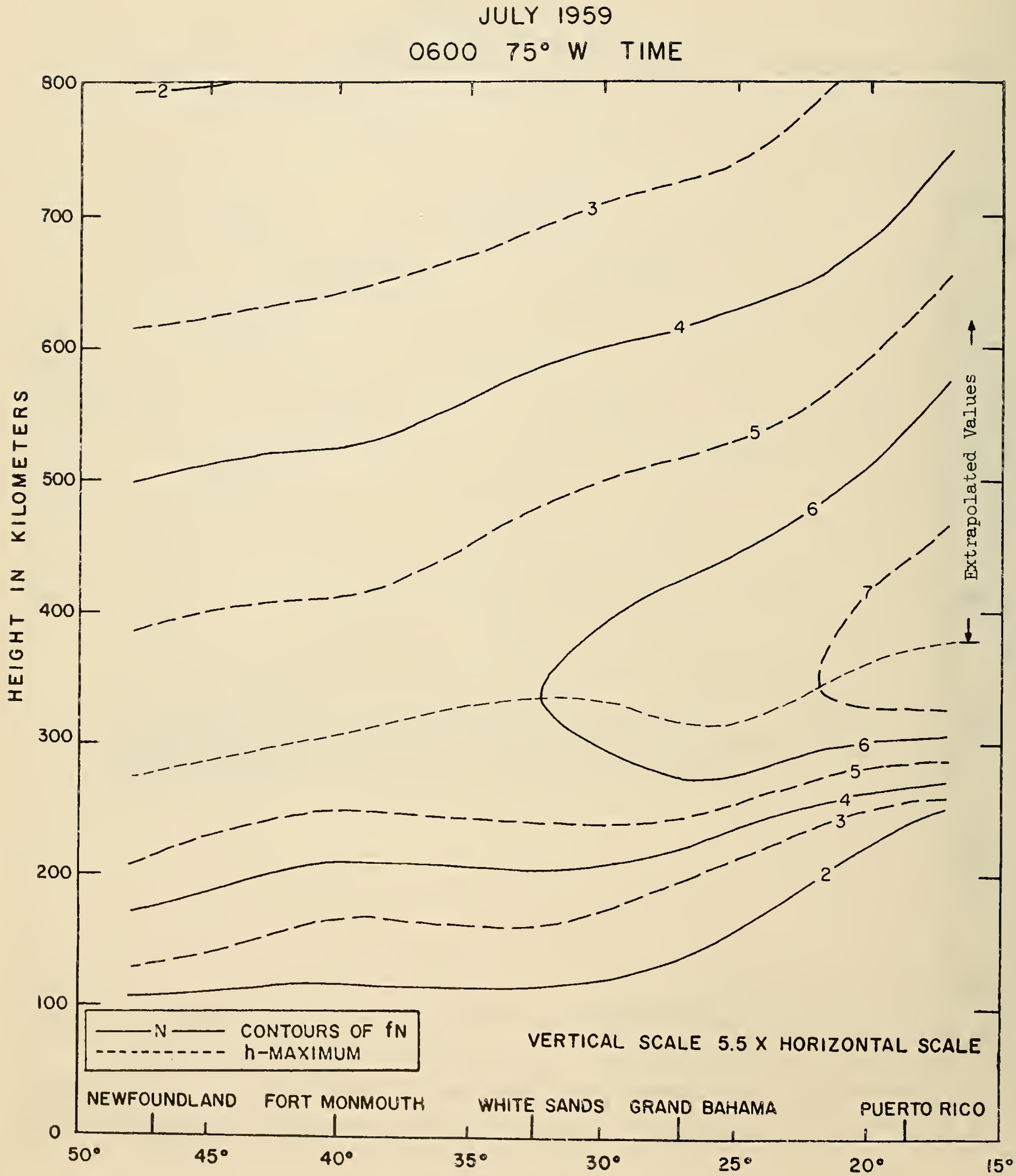
JULY 1959
0400 75° W TIME



JULY 1959

0500 75° W TIME

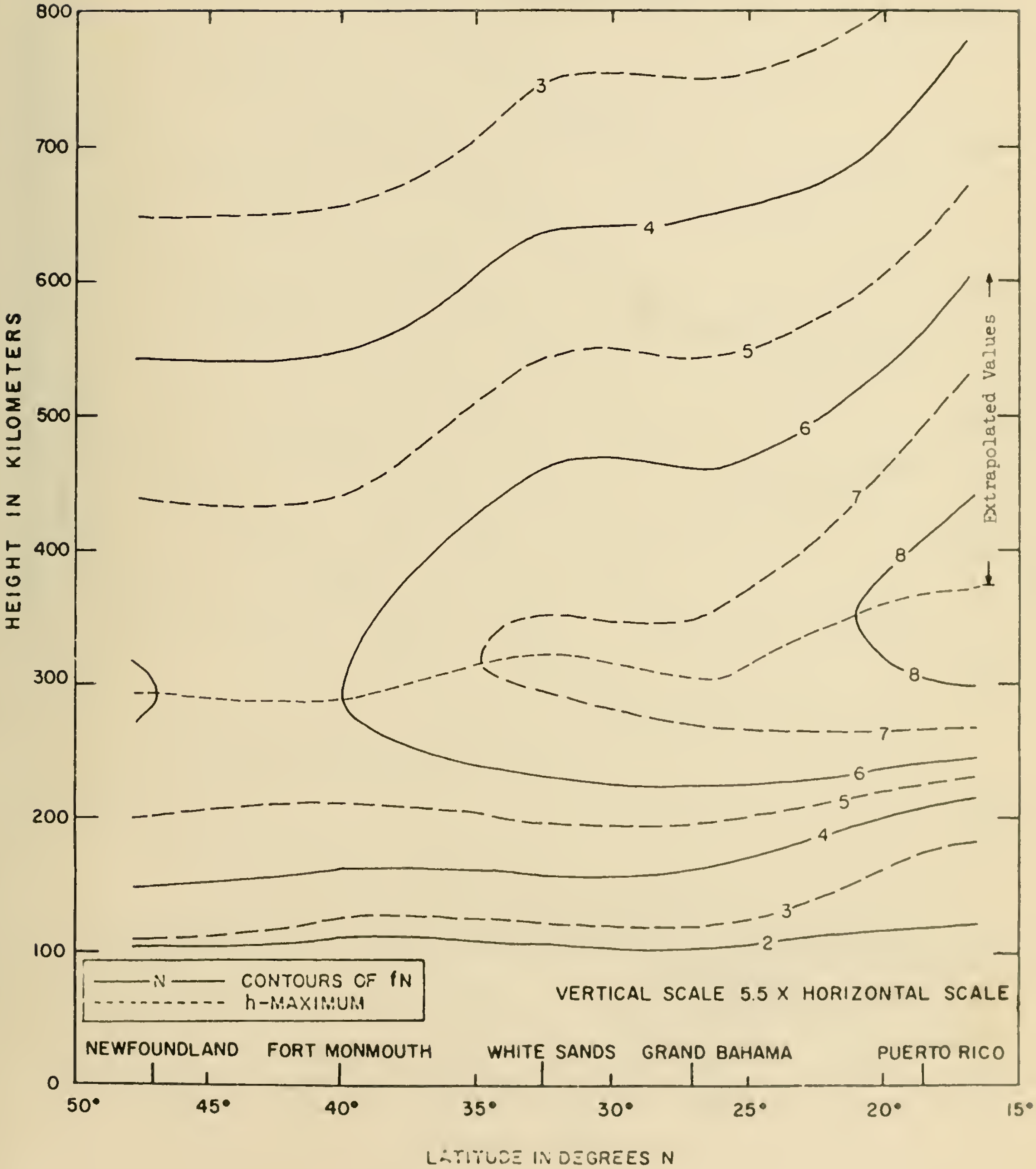


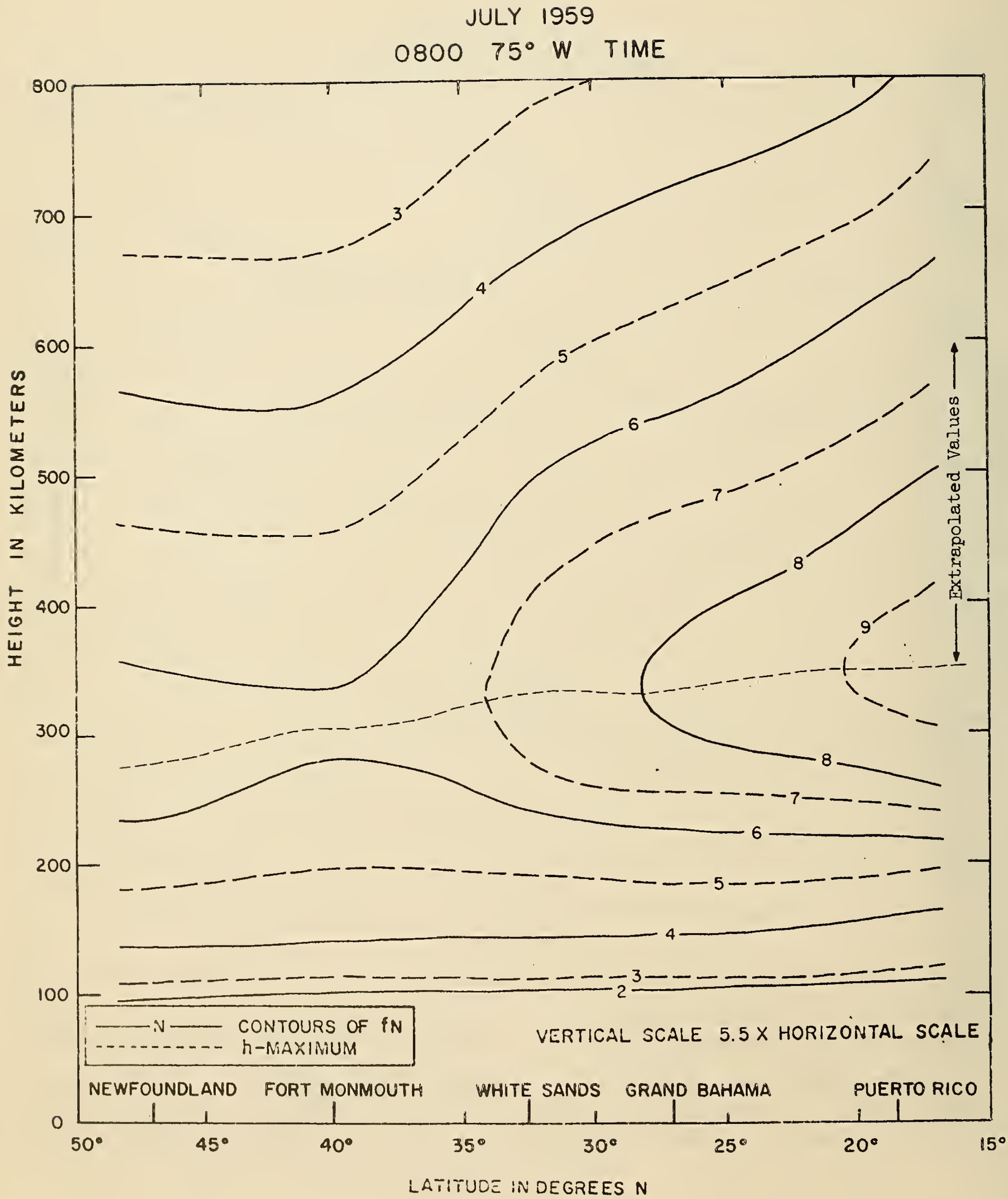


LATITUDE IN DEGREES N

JULY 1959

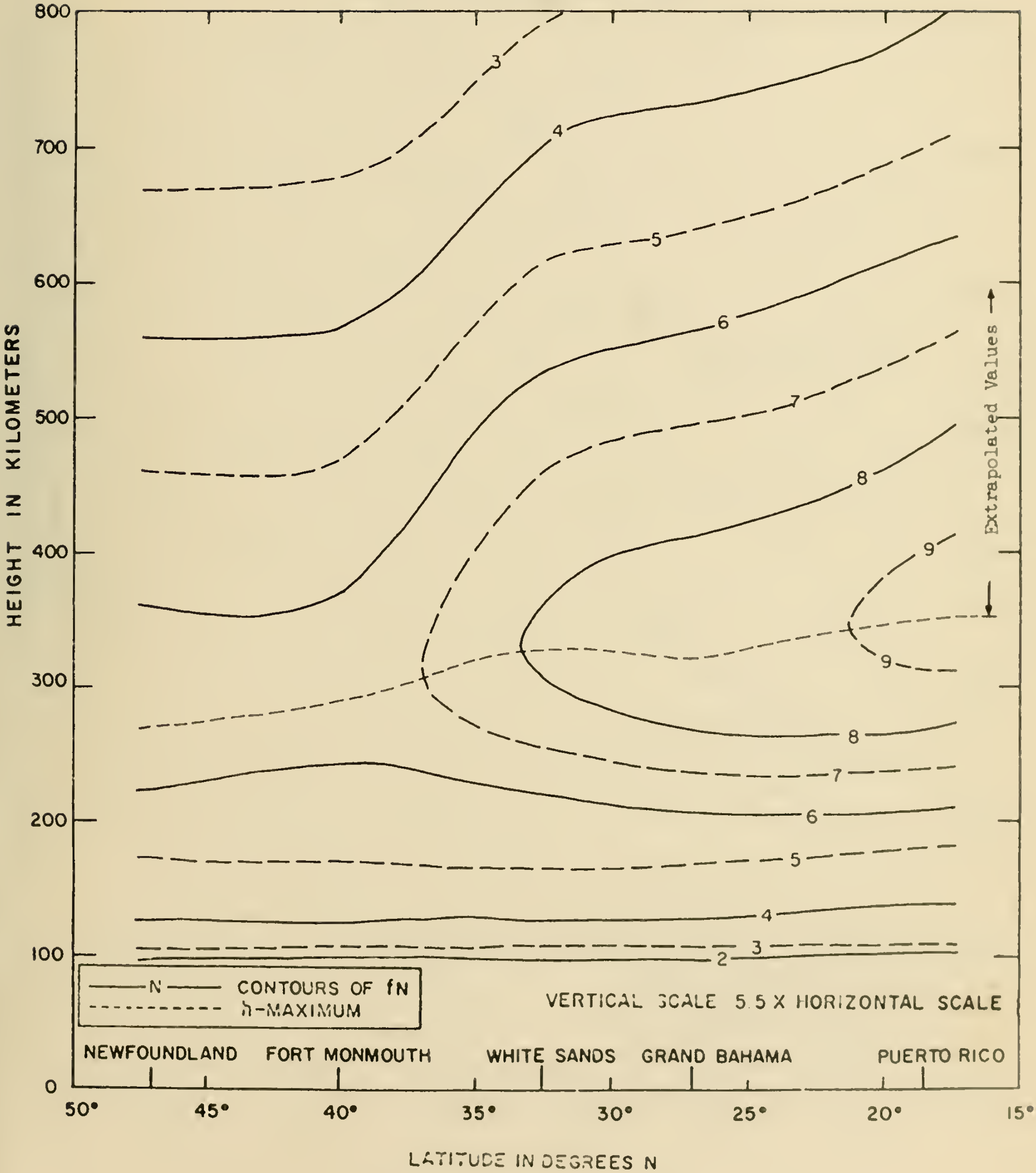
0700 75° W TIME

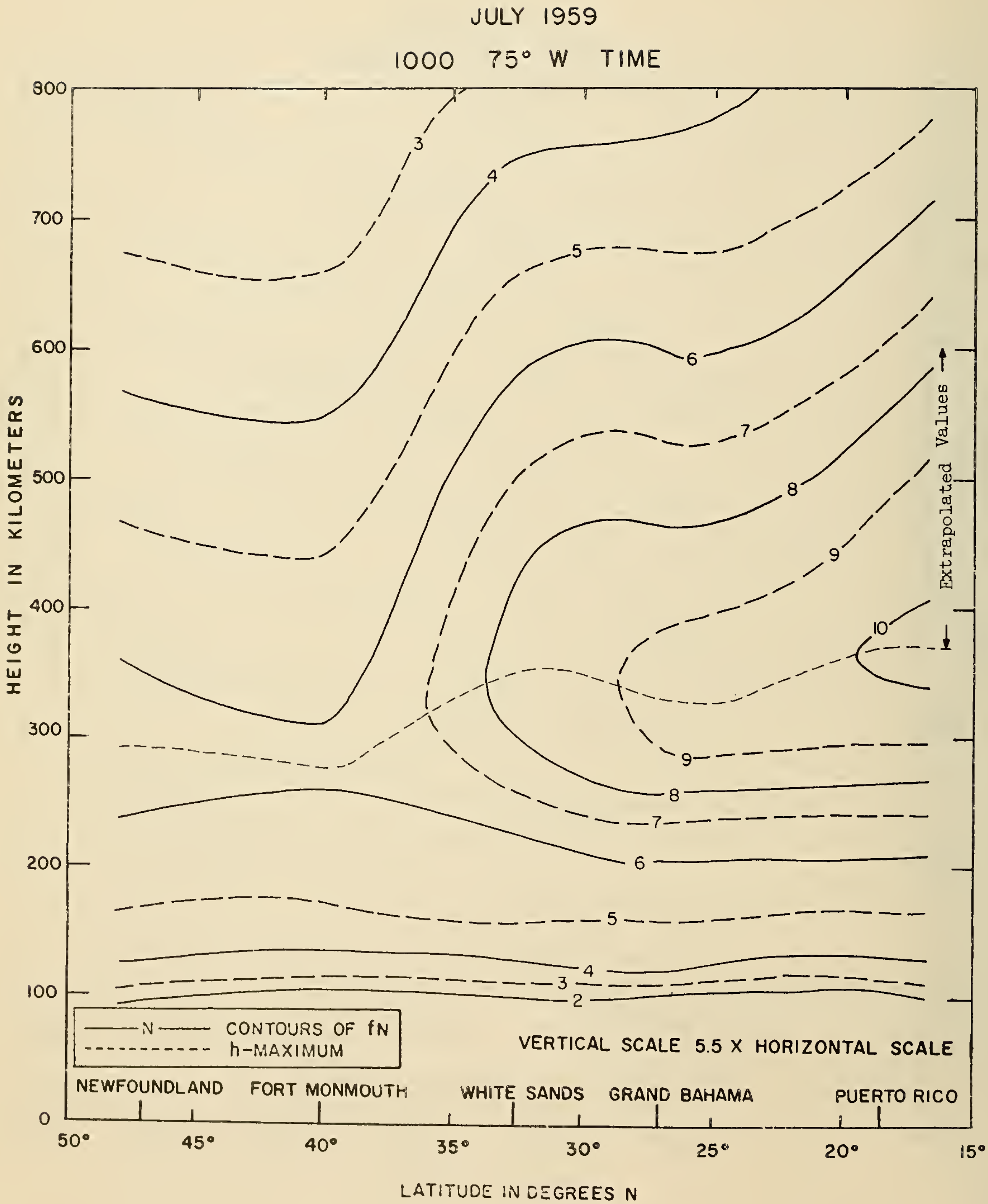




JULY 1959
0800 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
4
5
6
7
8
9
8
7
6
5
4
3
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
LATITUDE IN DEGREES N

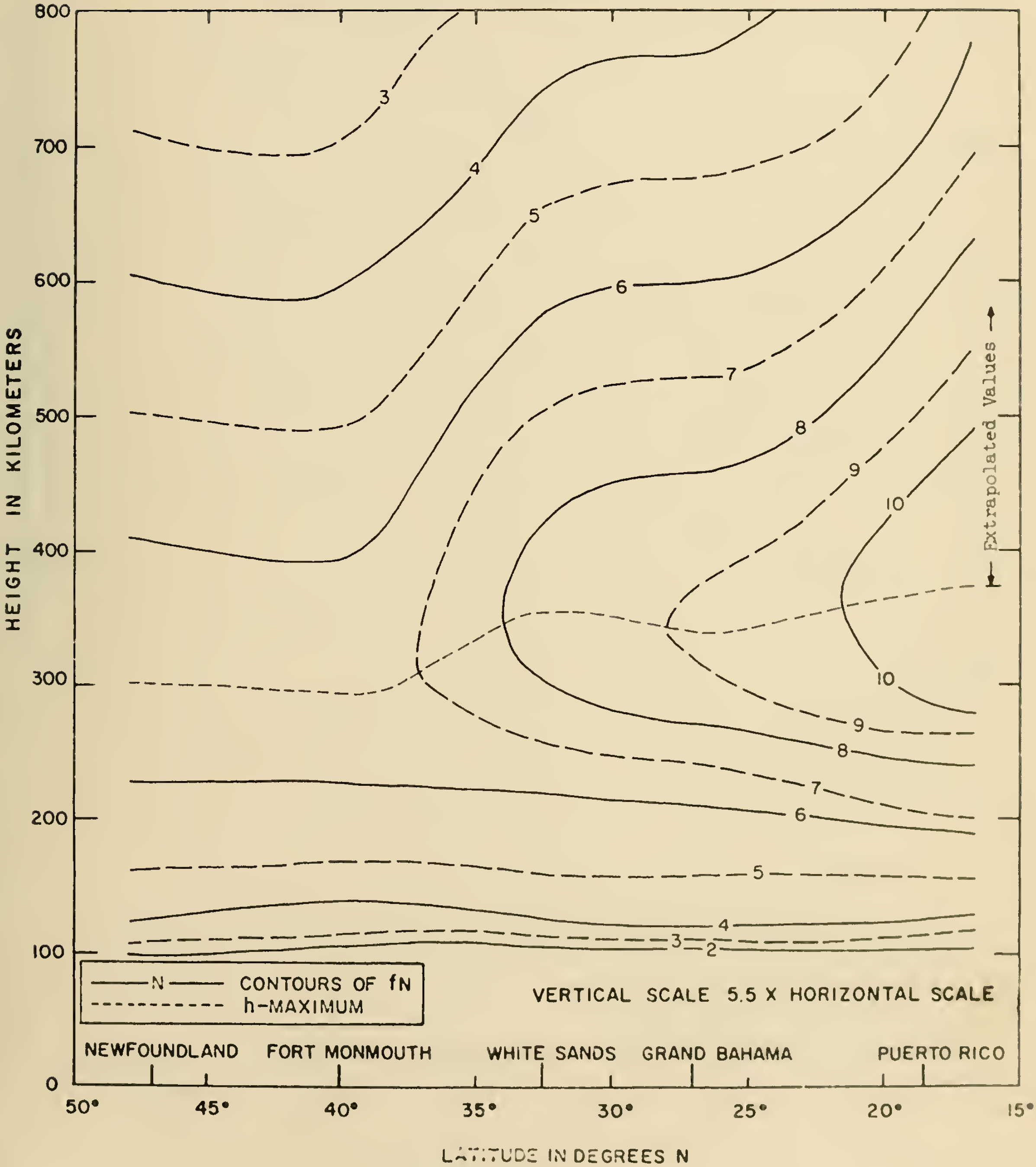
JULY 1959
0900 75° W TIME




JULY 1959
1000 75° W TIME
800
700
600
500
400
300
200
100
0
HEIGHT IN KILOMETERS
3
4
5
6
7
8
9
10
9
8
7
6
5
4
3
2
Extrapolated Values
CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
LATITUDE IN DEGREES N

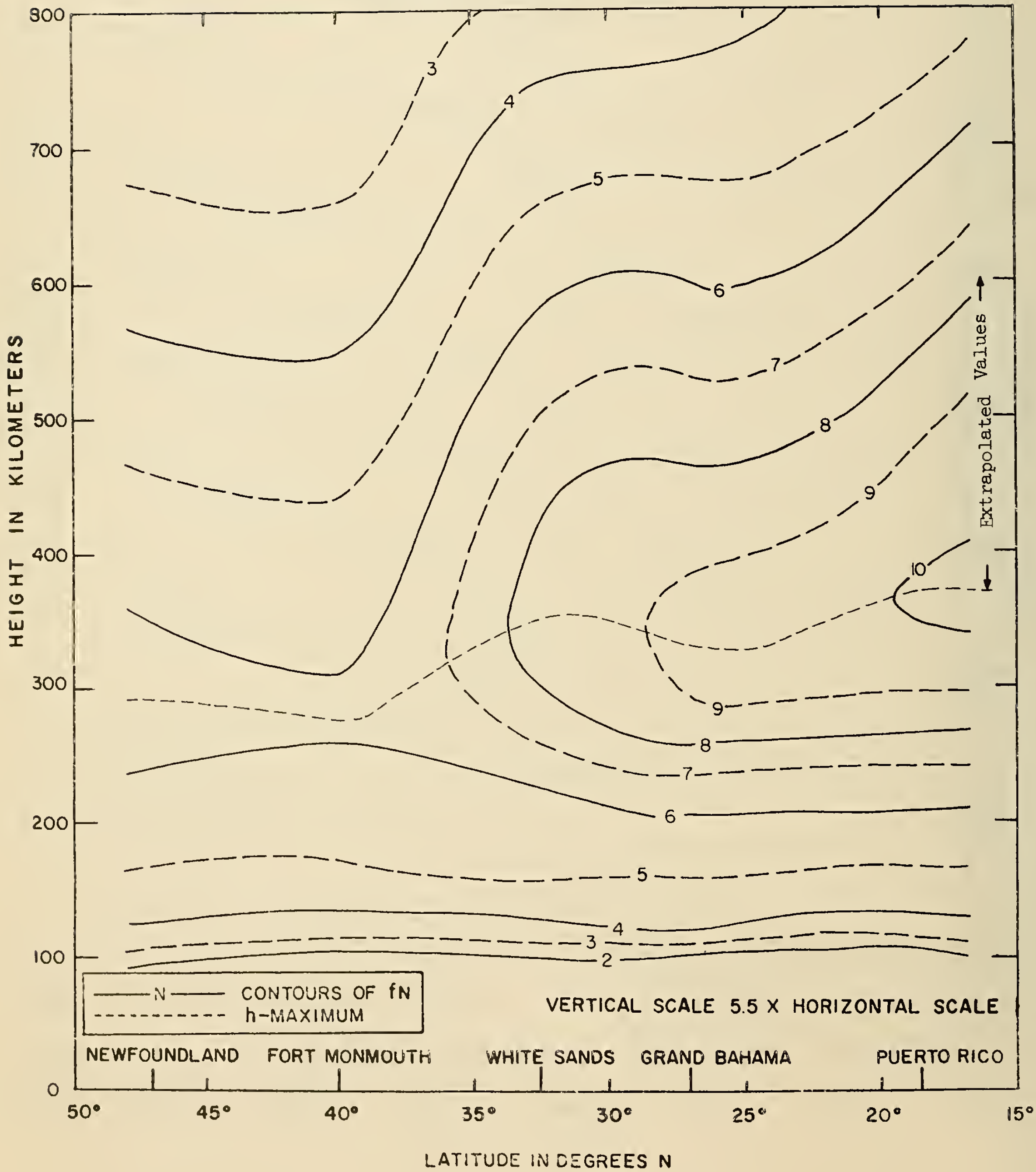
JULY 1959

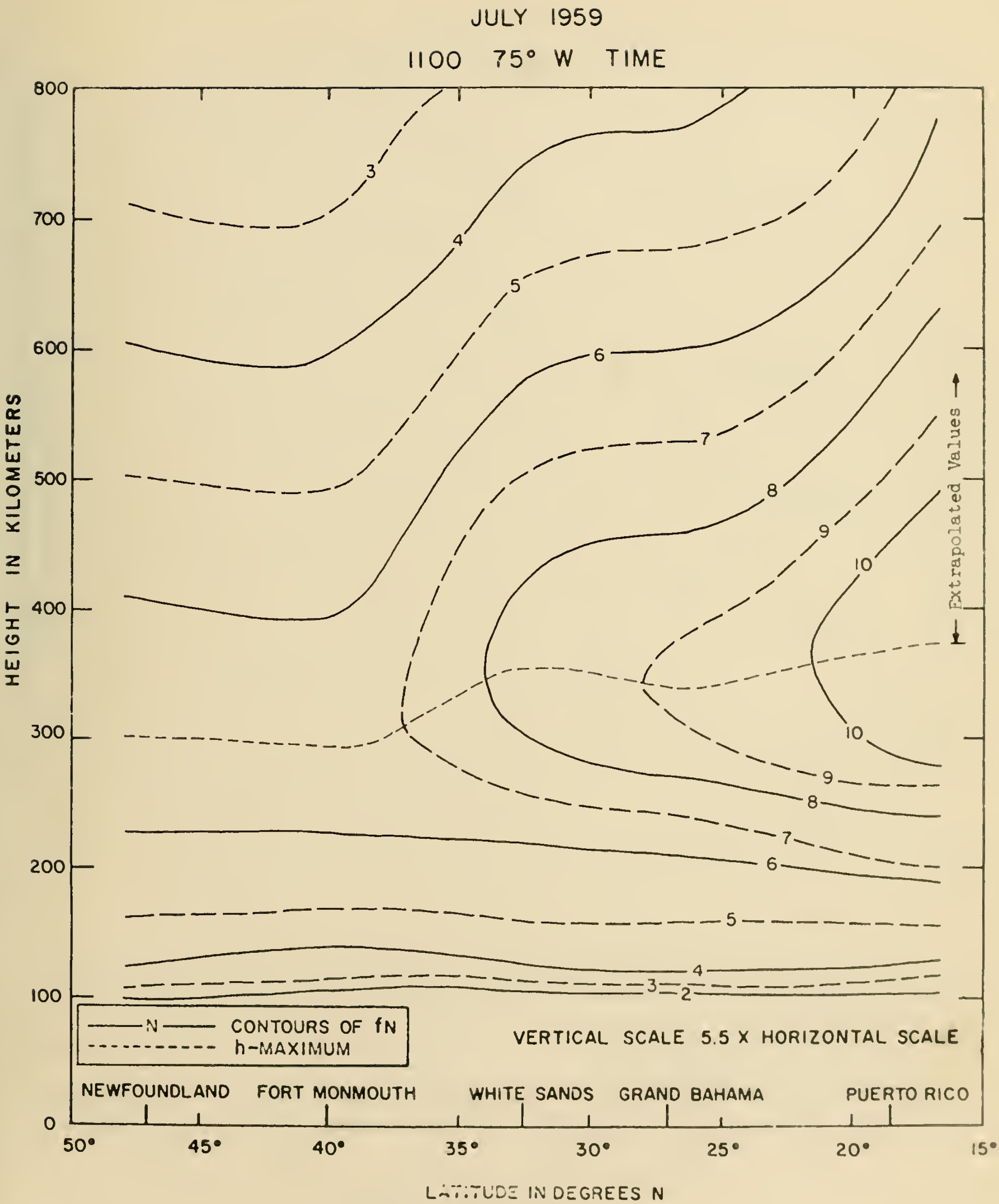
1100 75° W TIME



JULY 1959

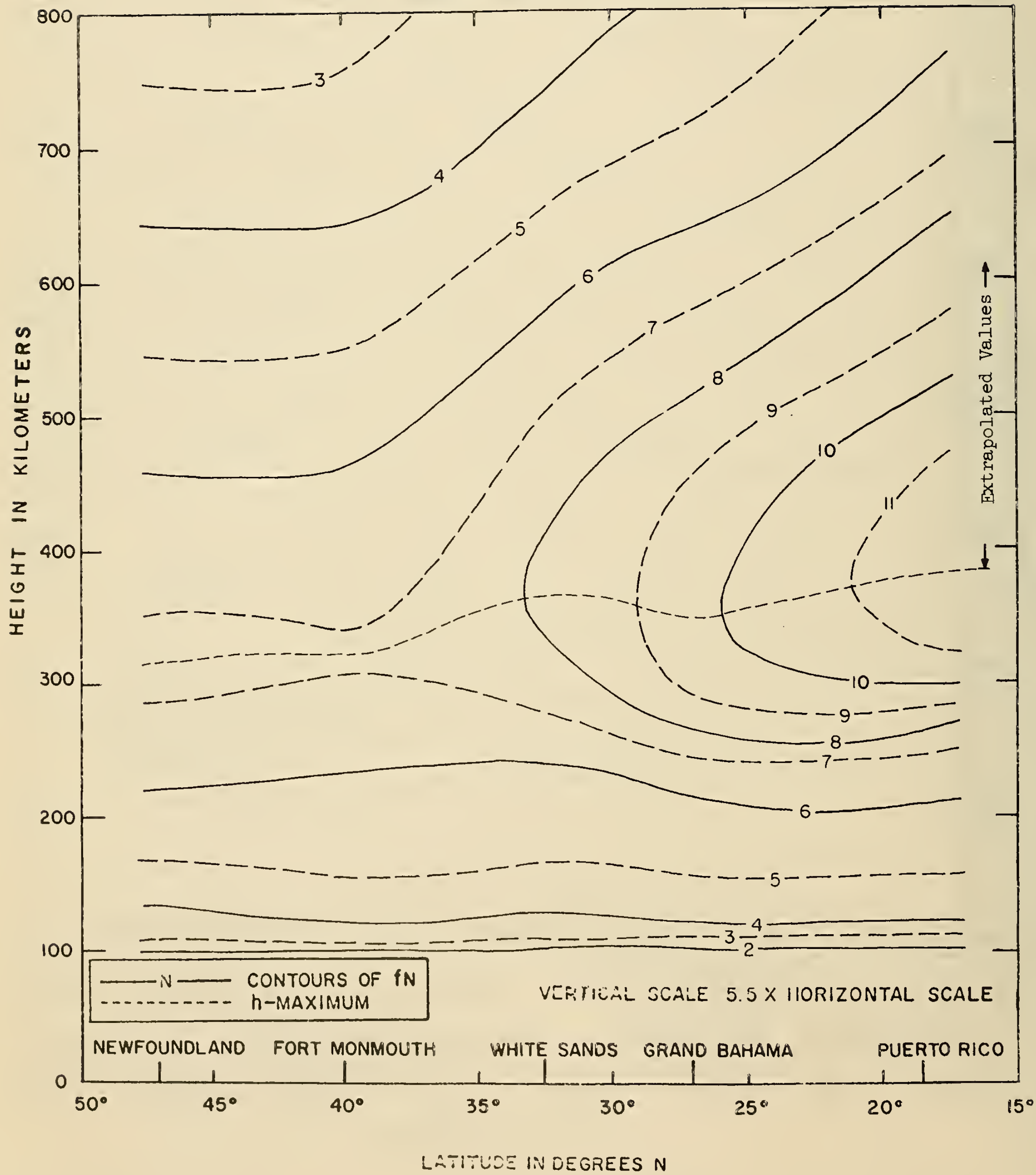
1000 75° W TIME

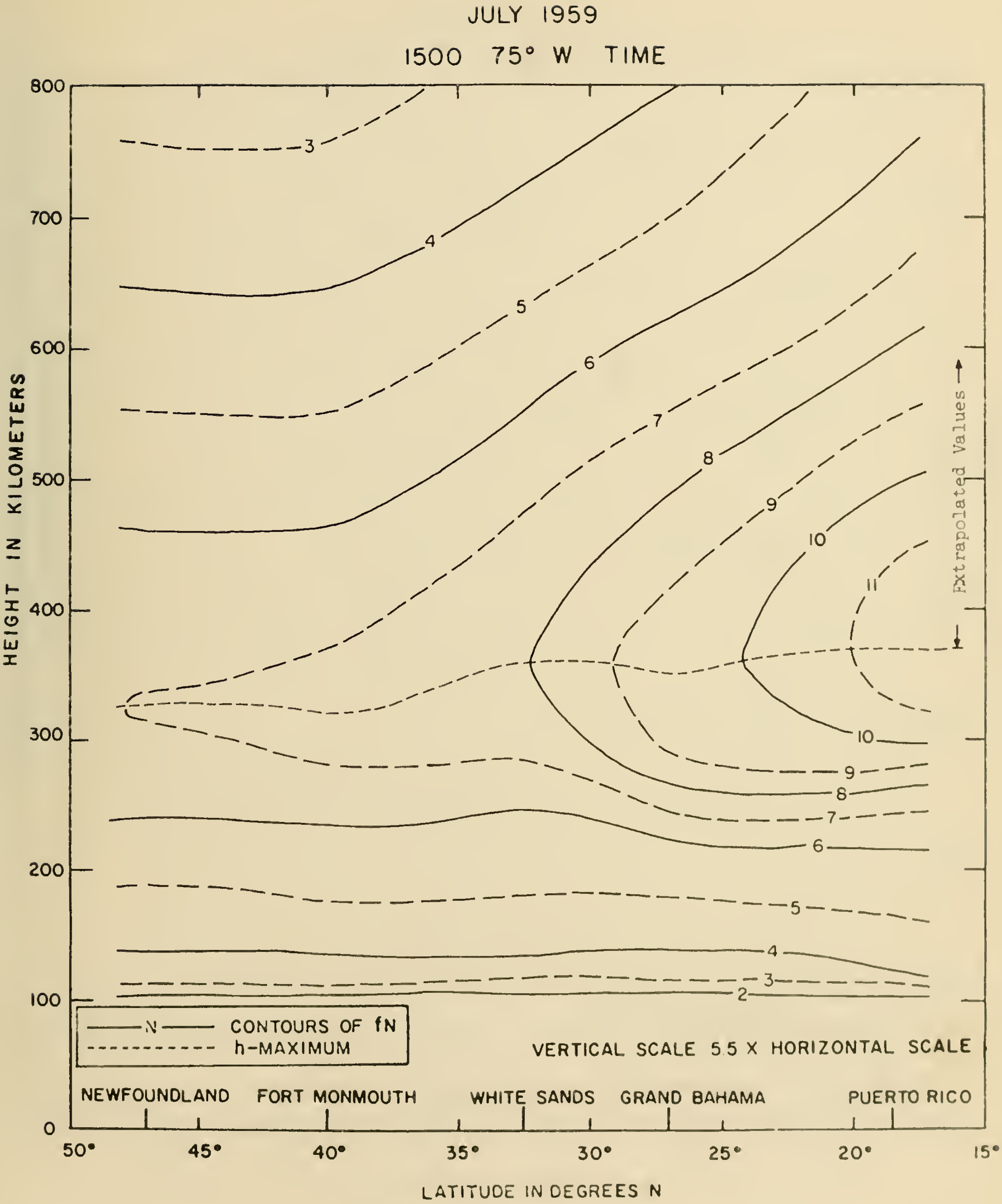


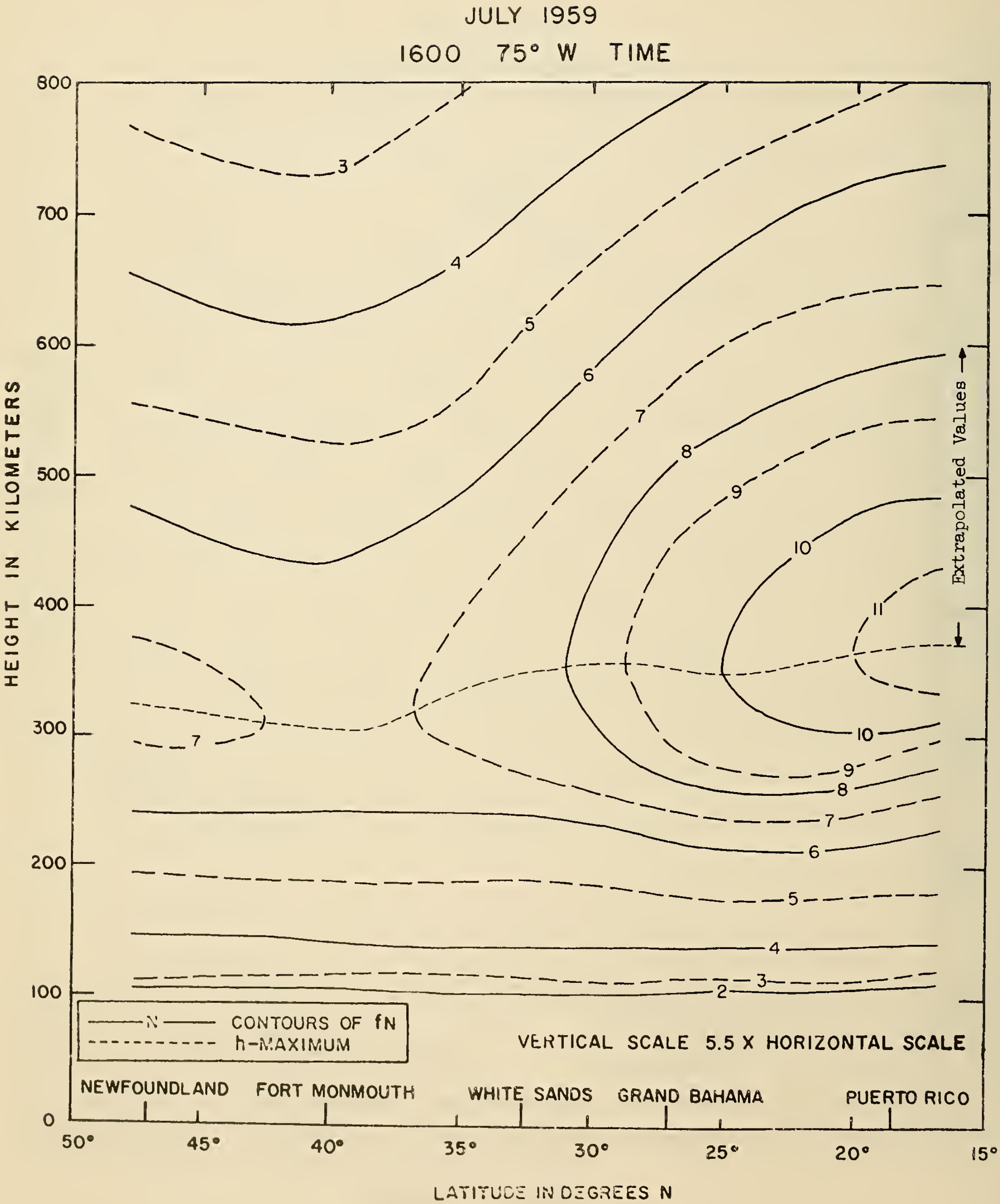

JULY 1959
1100 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
4
5
6
7
8
9
10
10
9
8
7
6
5
4
3
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
LATITUDE IN DEGREES N

JULY 1959

1400 75° W TIME

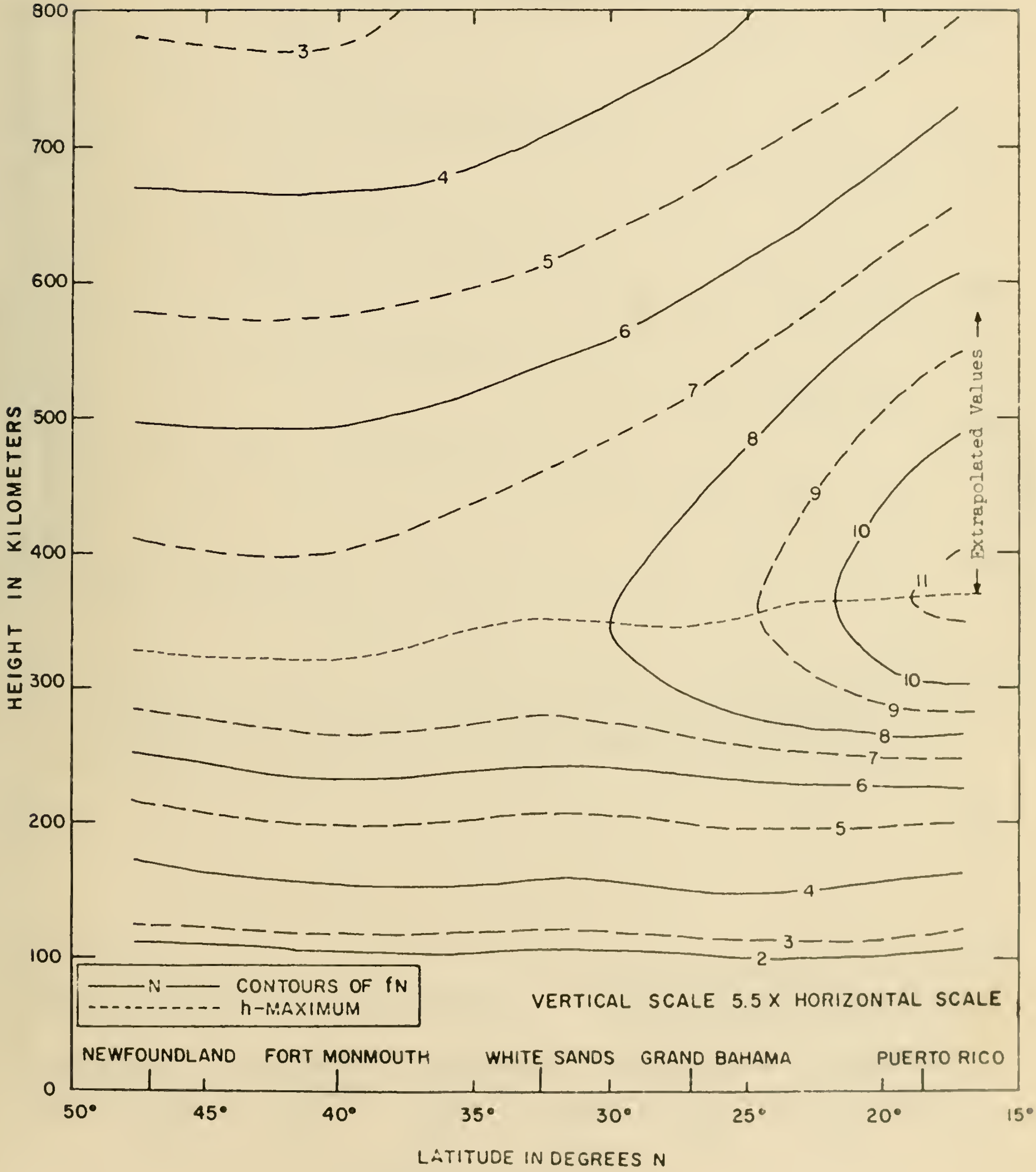



JULY 1959
1500 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
4
5
6
7
8
9
10
11
10
9
8
7
6
5
4
3
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
LATITUDE IN DEGREES N


JULY 1959
1600 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
4
5
6
7
8
9
10
11
7
6
5
4
3
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°
LATITUDE IN DEGREES N

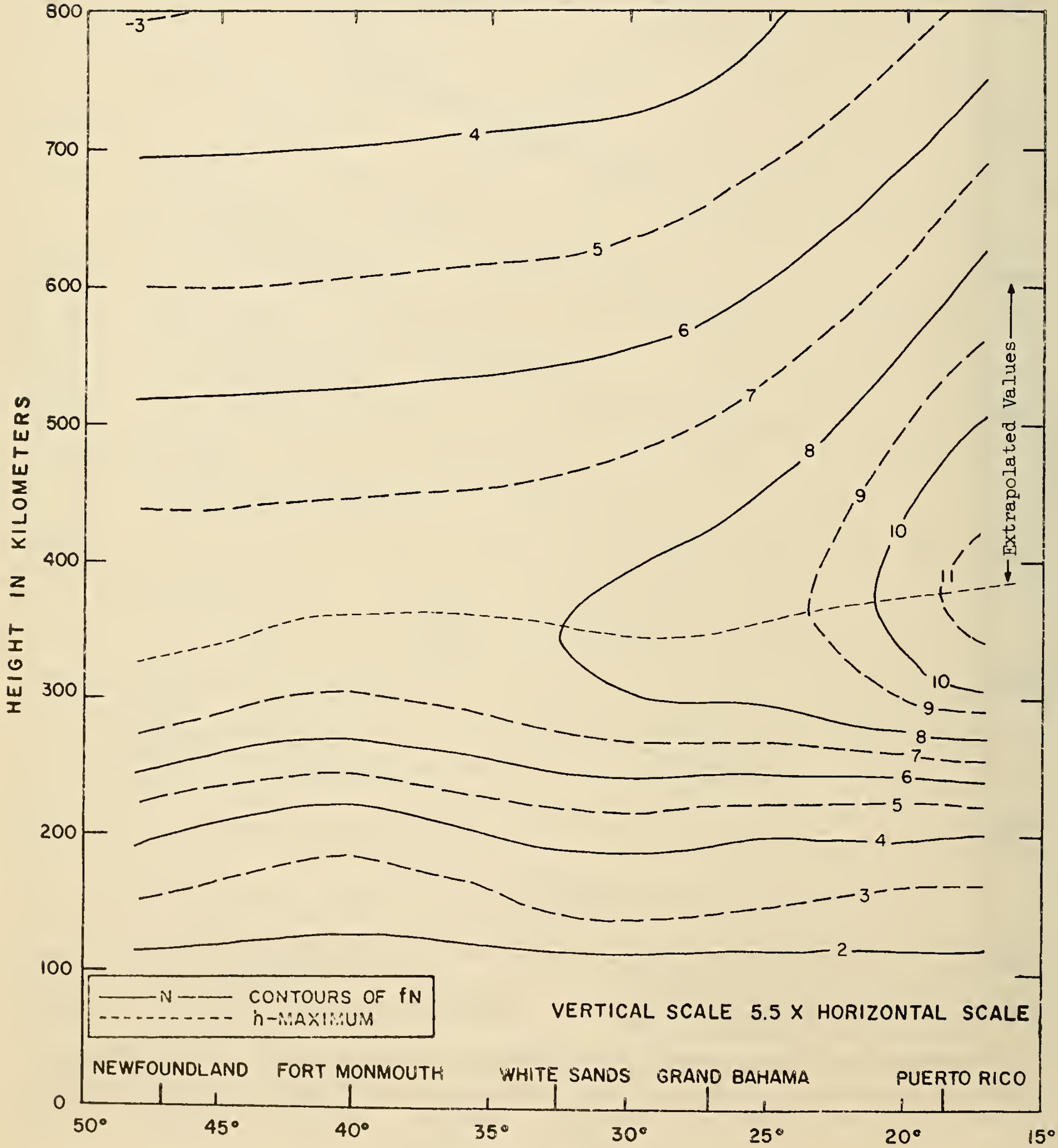
JULY 1959

1700 75° W TIME

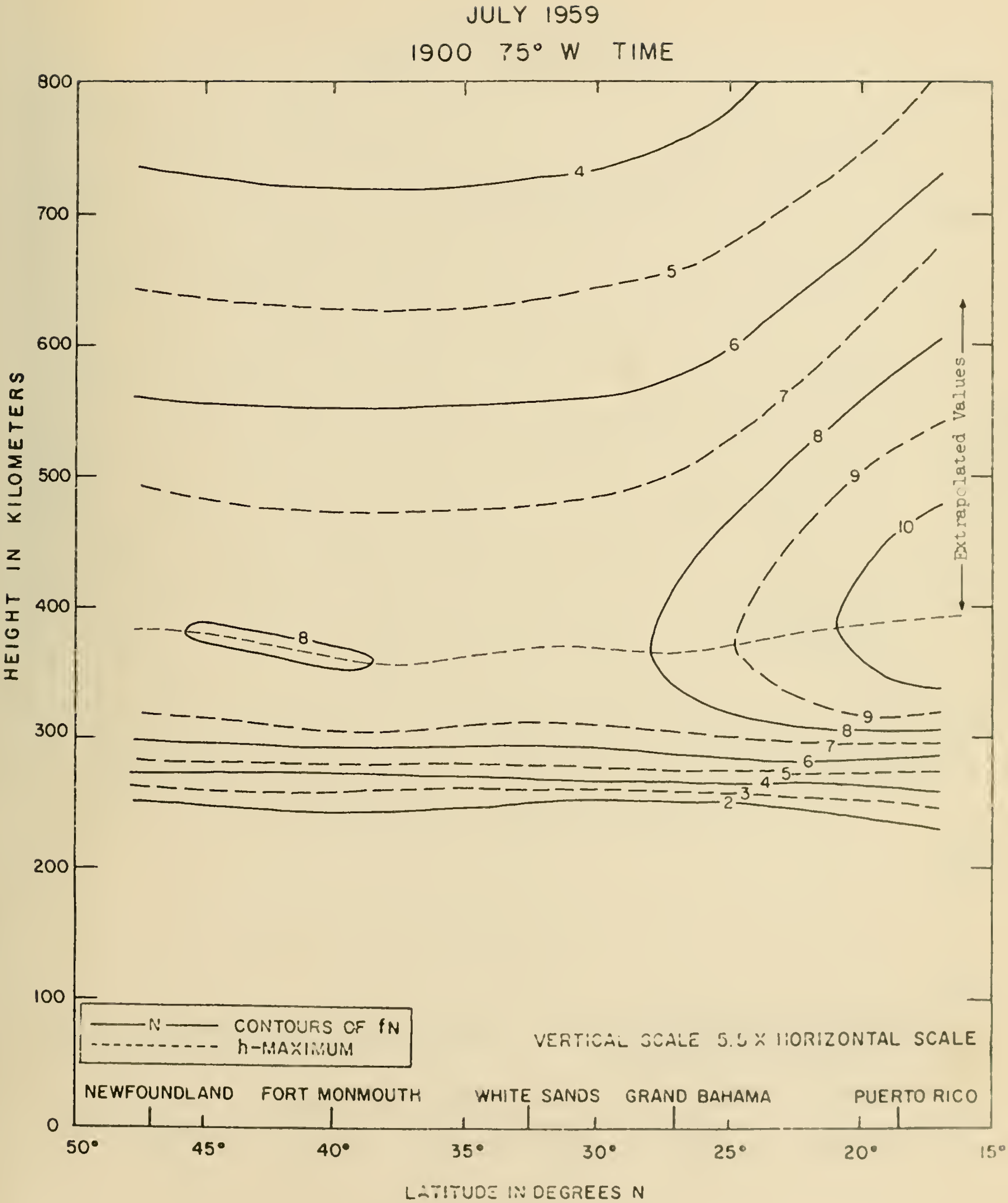


JULY 1959

1800 75° W TIME



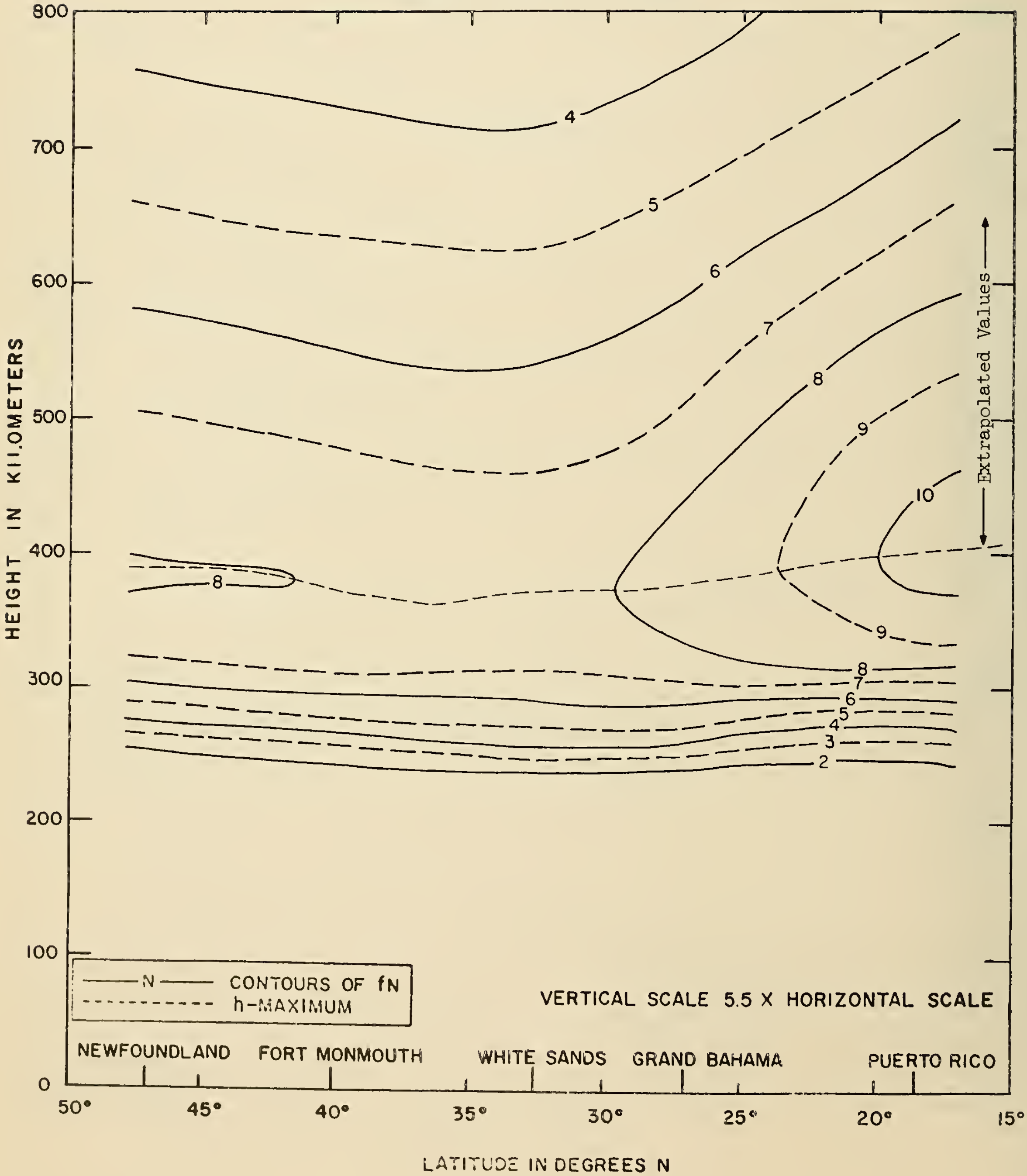
LATITUDE IN DEGREES N

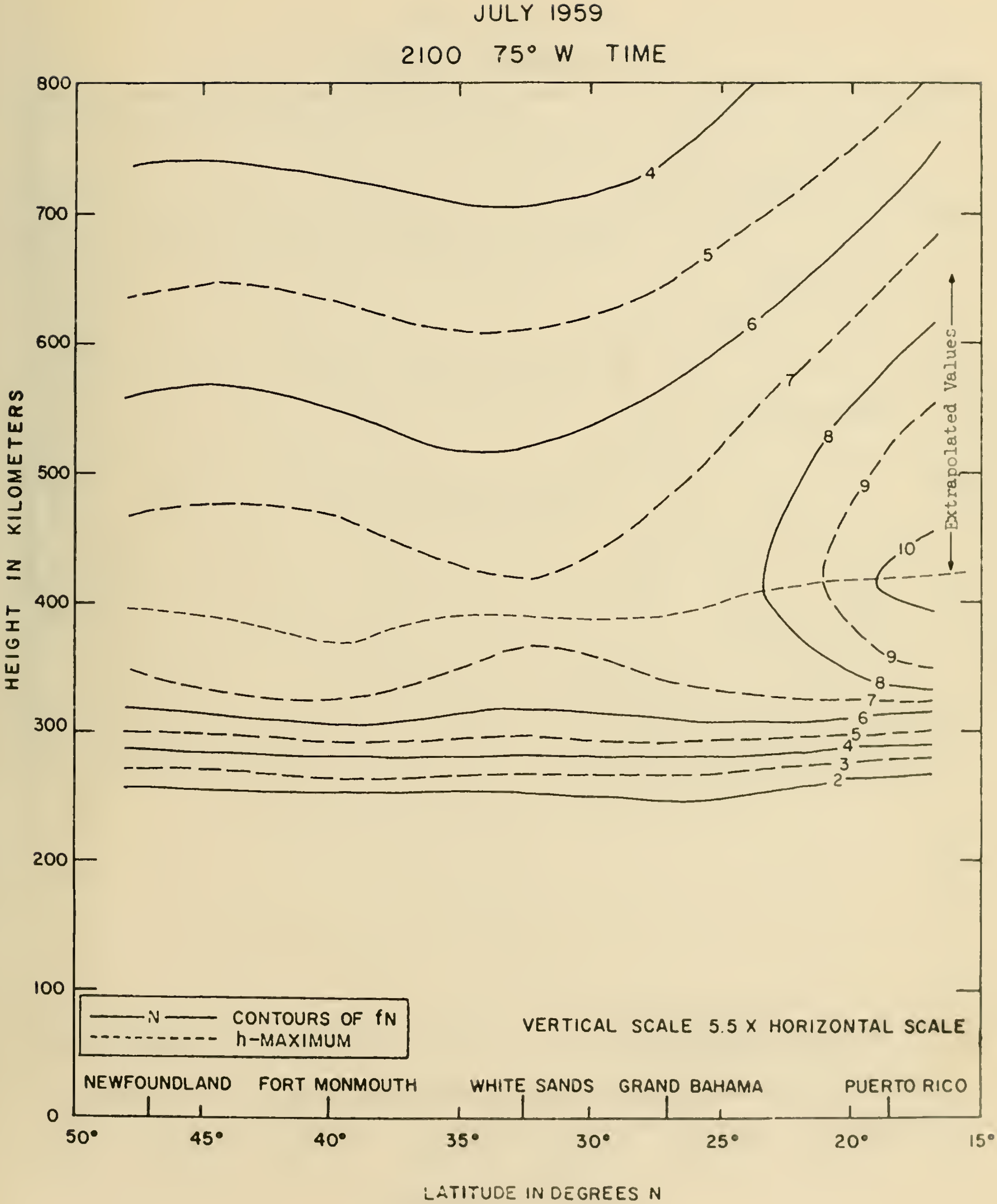


JULY 1959
1900 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
4
5
6
7
8
9
10
8
7
6
5
4
3
2
8
9
Extrapolated Values
N
CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
LATITUDE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

JULY 1959

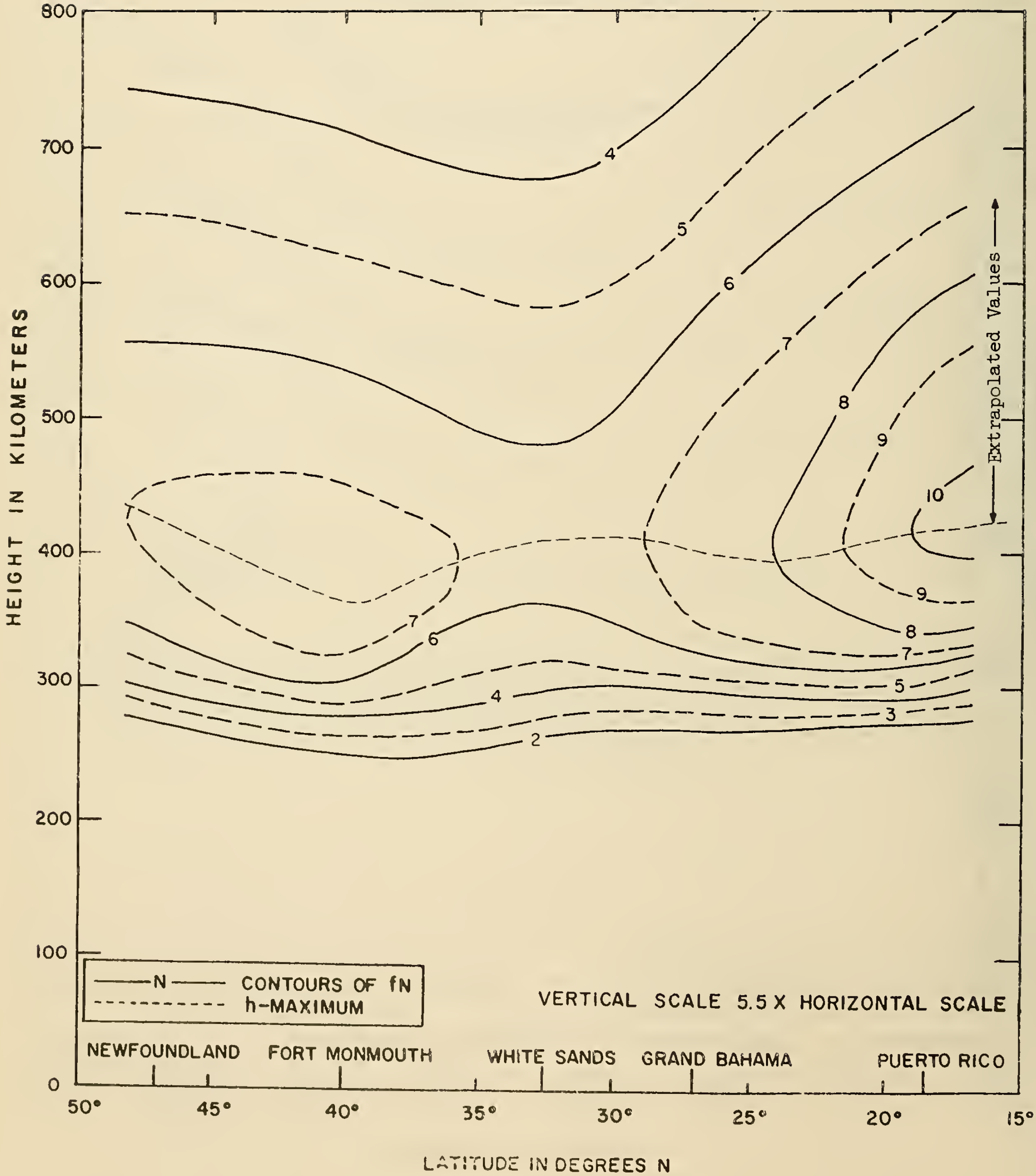
2000 75° W TIME




JULY 1959
2100 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
4
5
6
7
8
9
10
9
8
7
6
5
4
3
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°
LATITUDE IN DEGREES N

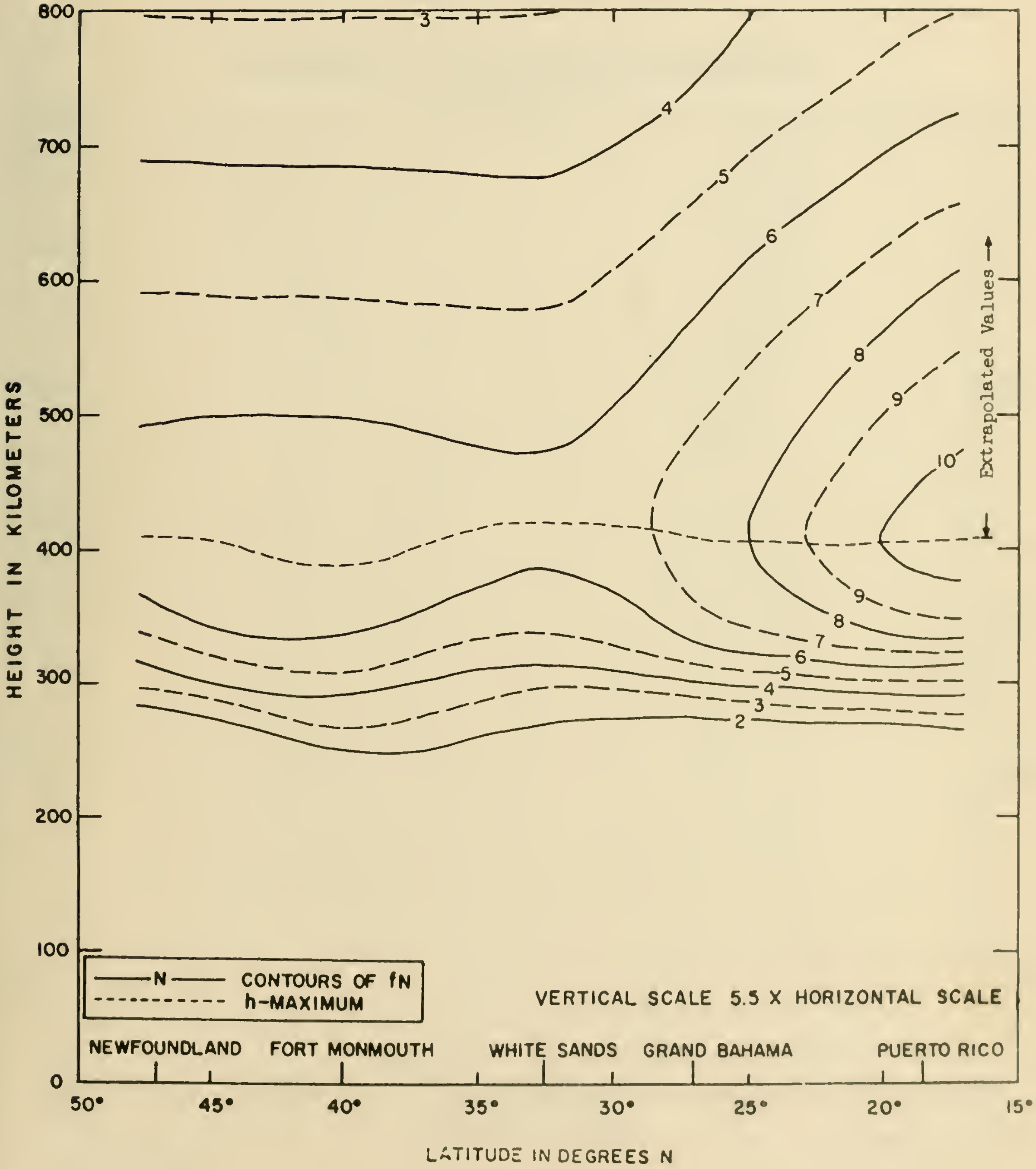
JULY 1959

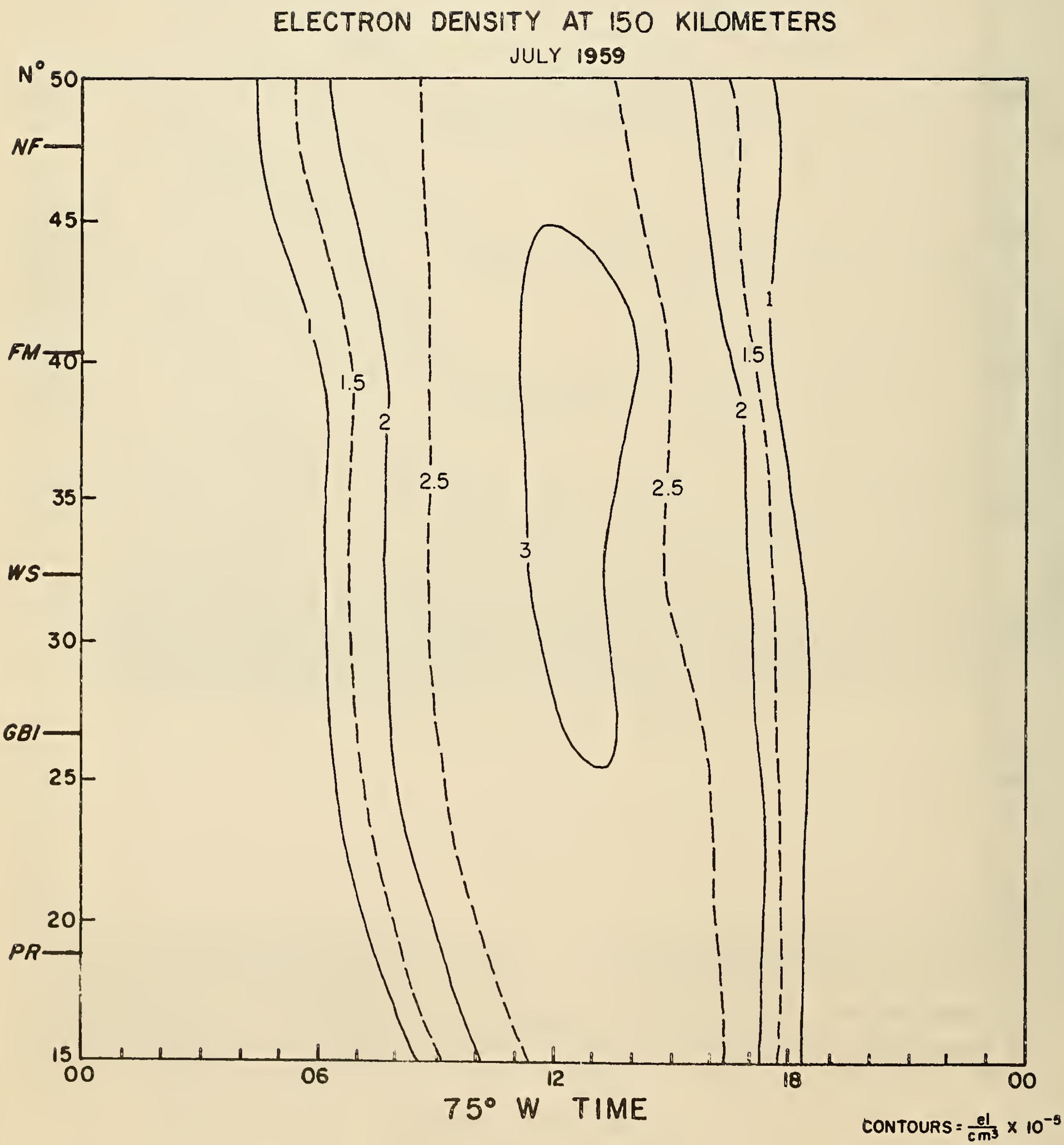
2200 75° W TIME



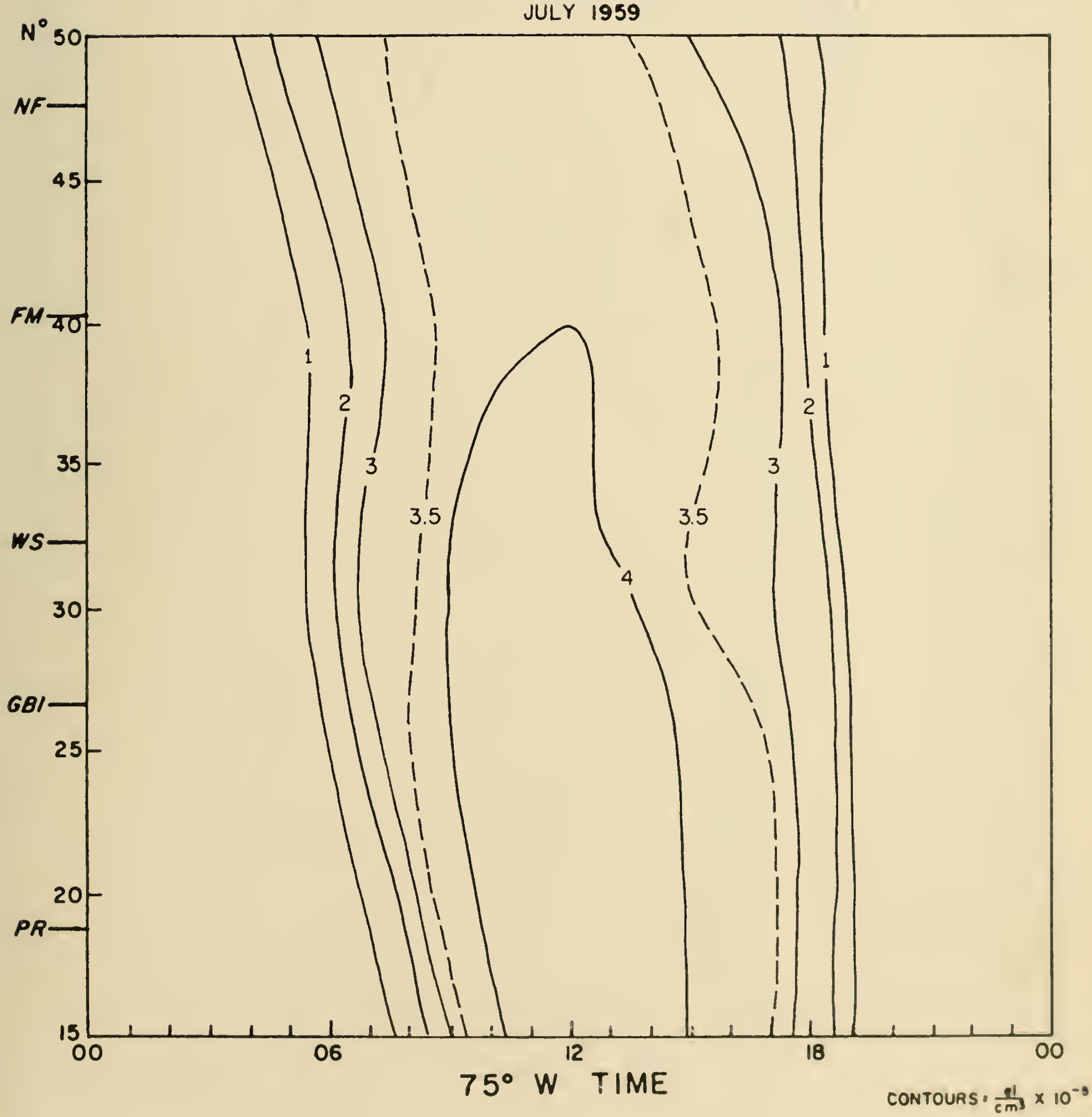
JULY 1959

2300 75° W TIME



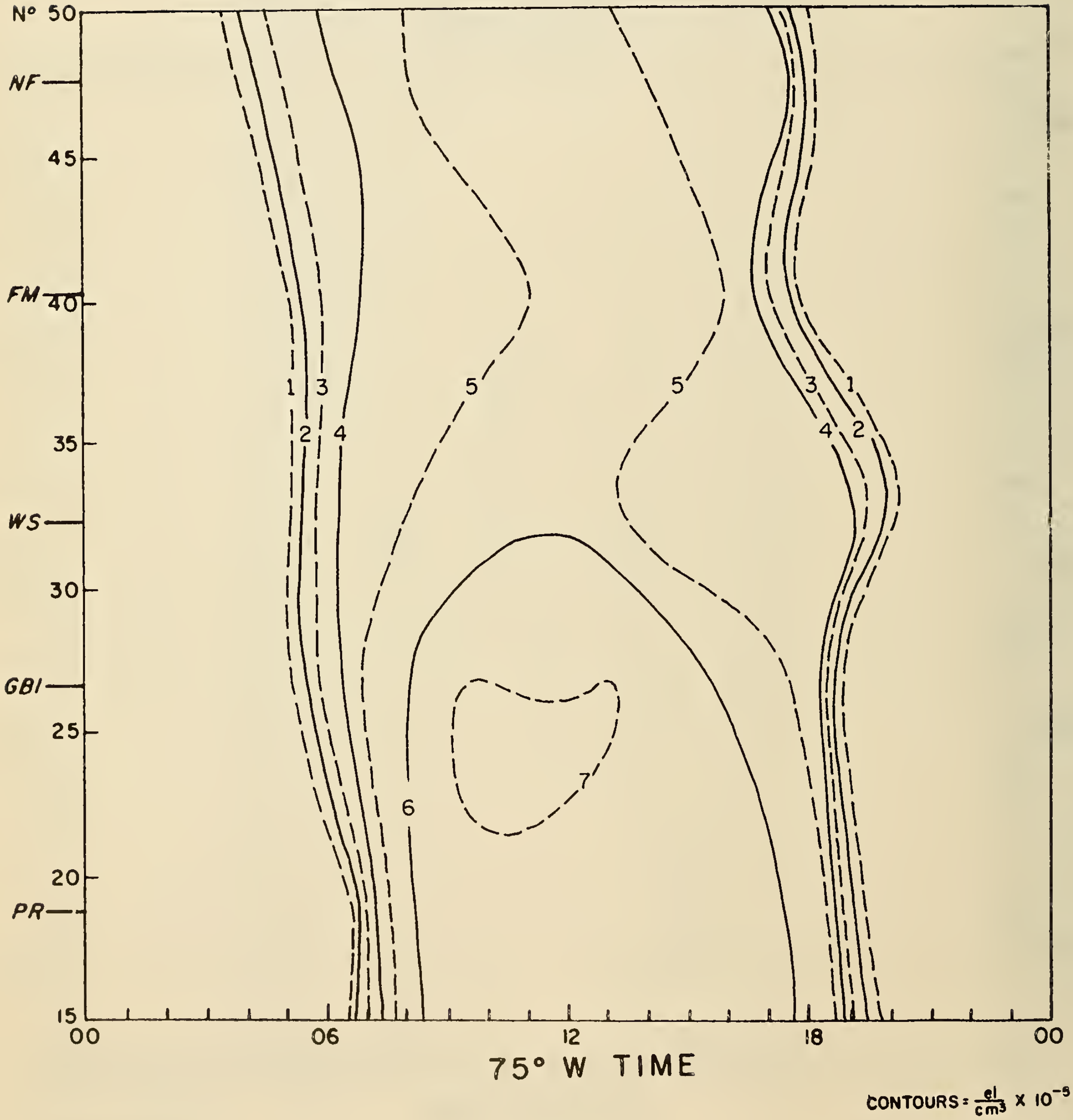

ELECTRON DENSITY AT 150 KILOMETERS
JULY 1959
N°
50
NF
45
FM
40
35
WS
30
GBI
25
20
PR
15
00
06
12
18
00
75° W TIME
1.5
2
2.5
3
2.5
2
1.5
1
CONTOURS = el/cm³ x 10⁻⁵

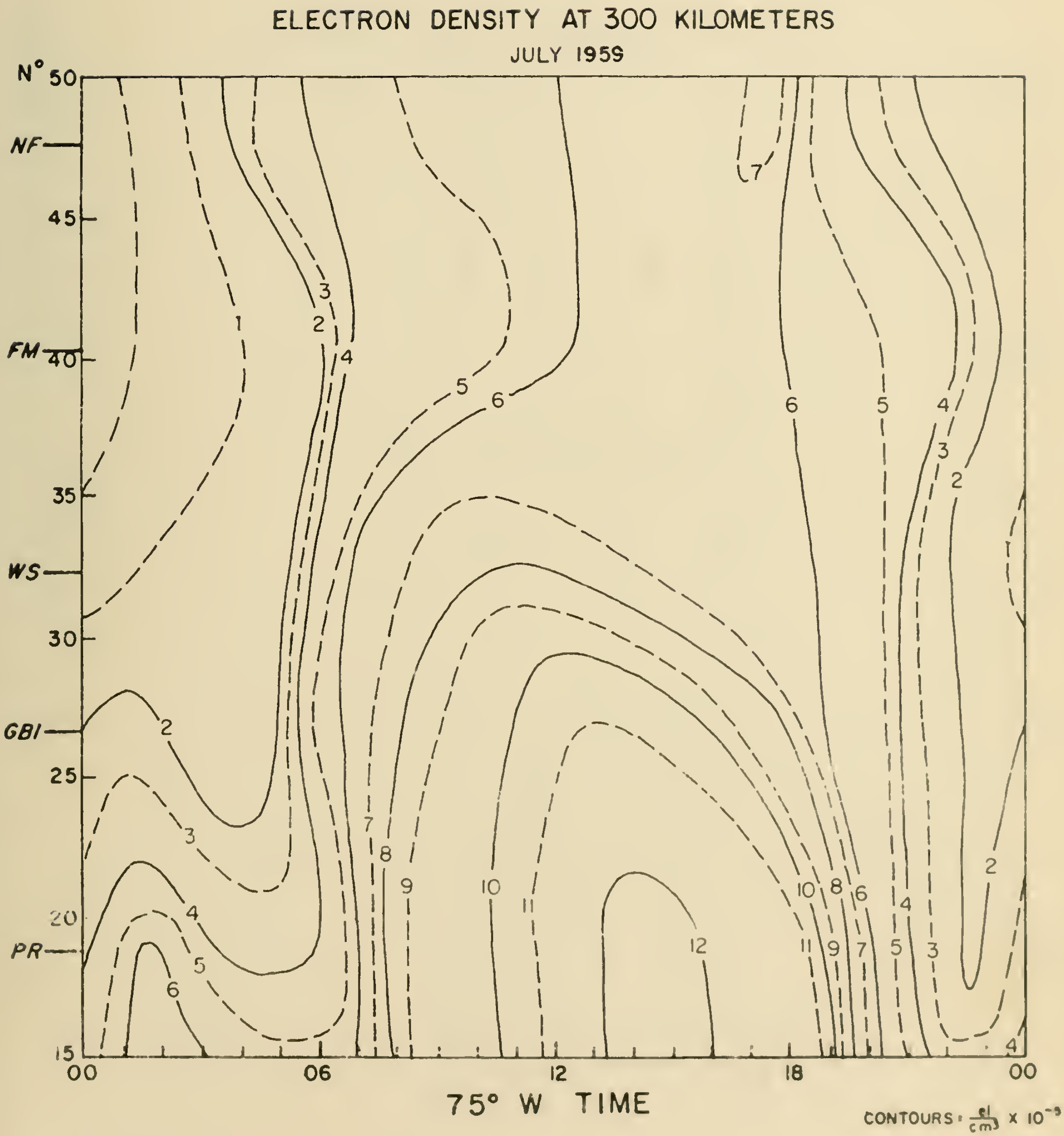
ELECTRON DENSITY AT 200 KILOMETERS
JULY 1959



ELECTRON DENSITY AT 250 KILOMETERS

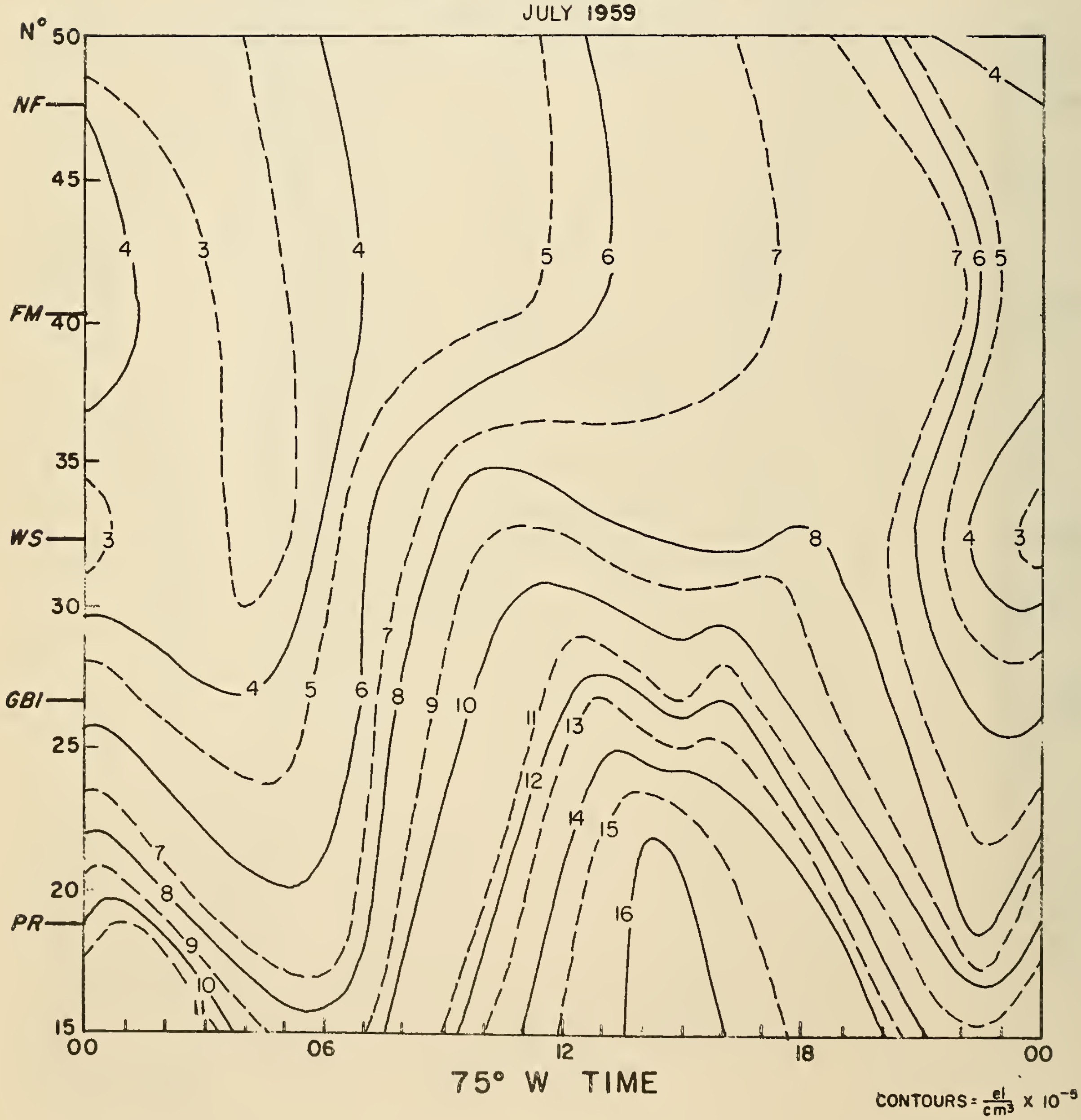
JULY 1959

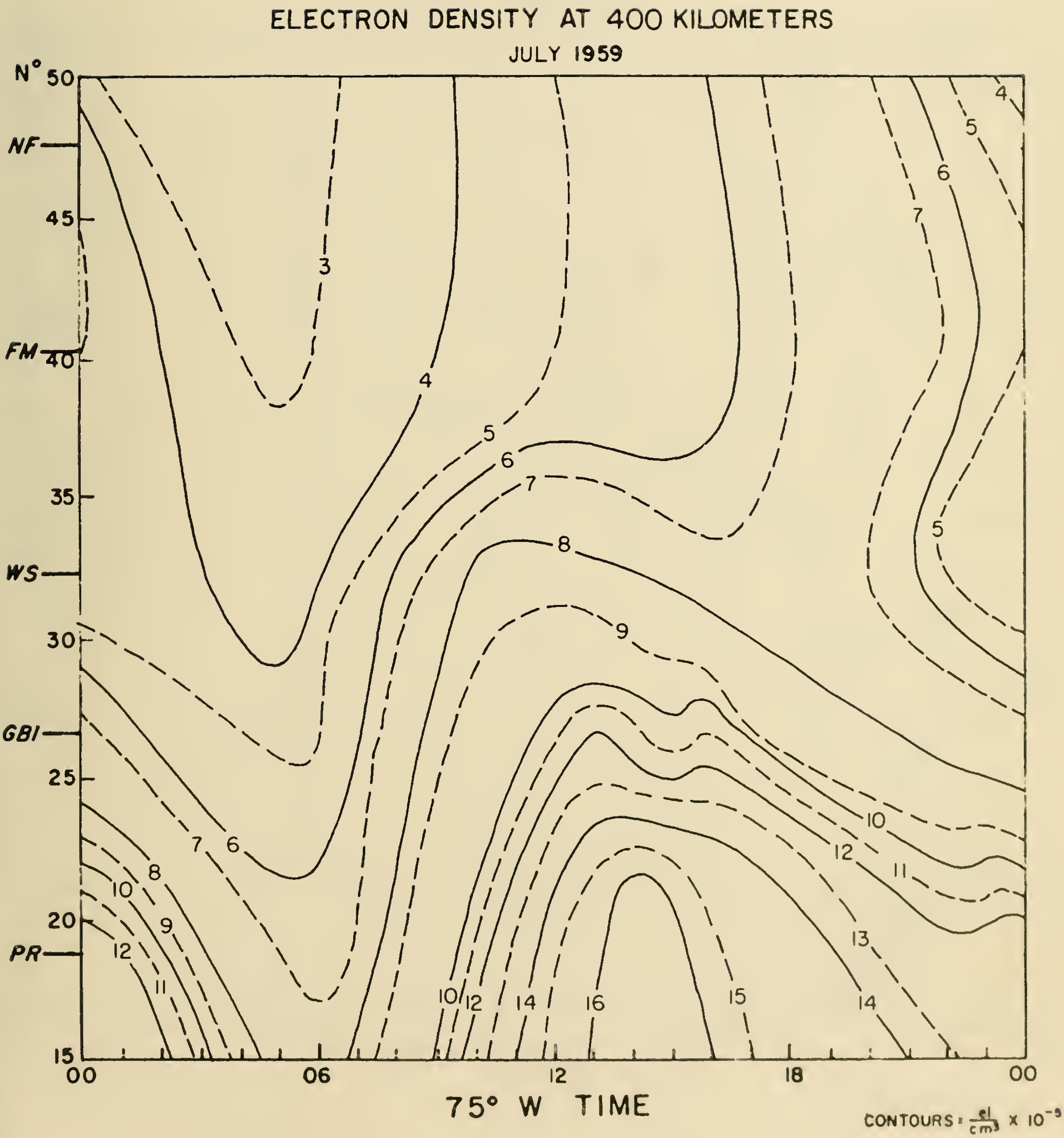


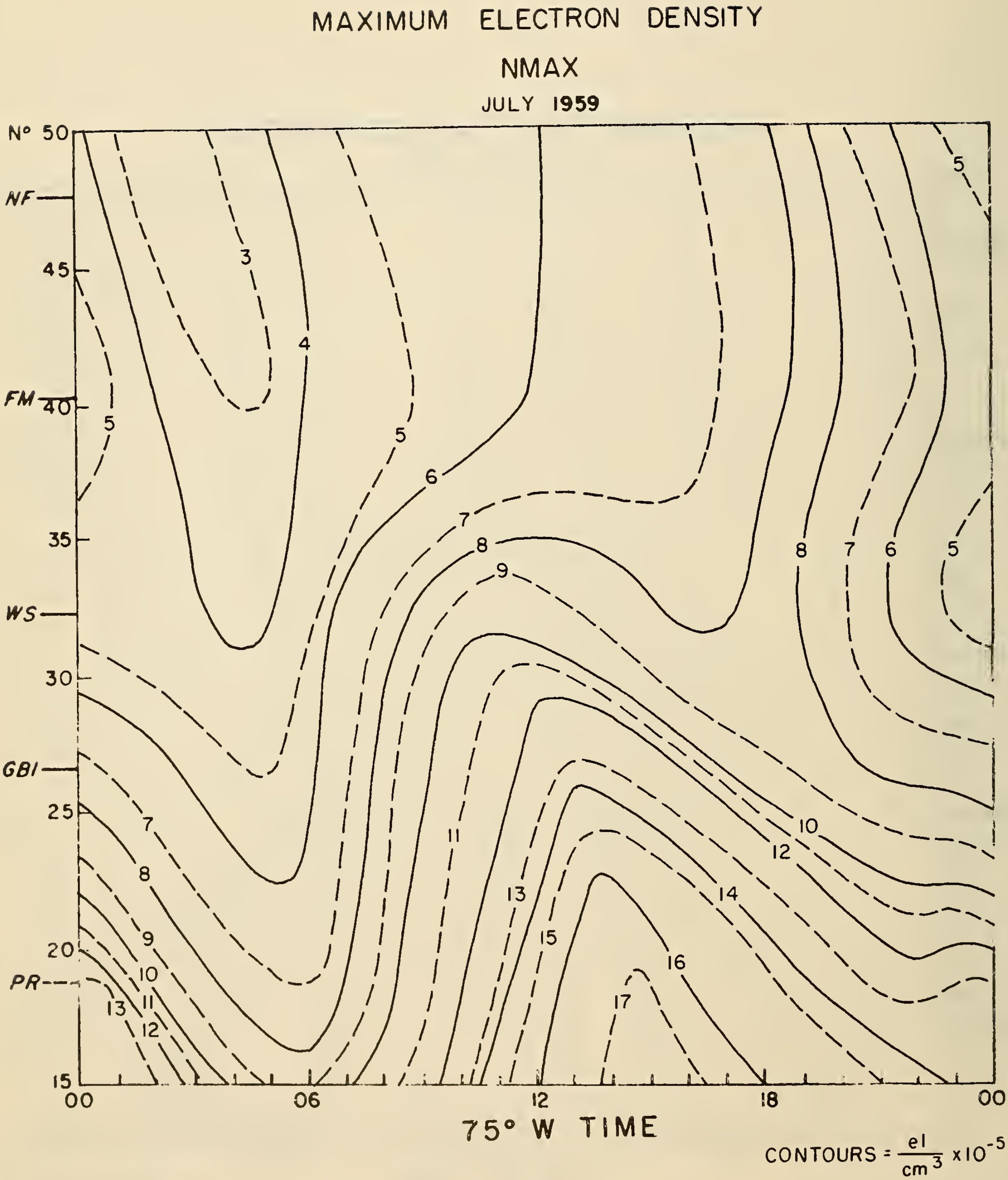

ELECTRON DENSITY AT 300 KILOMETERS
JULY 1959
N°
50
45
40
35
30
25
20
15
NF
FM
WS
GBI
PR
00
06
12
18
00
75° W TIME
CONTOURS: el/cm³ x 10⁻⁵

ELECTRON DENSITY AT 350 KILOMETERS

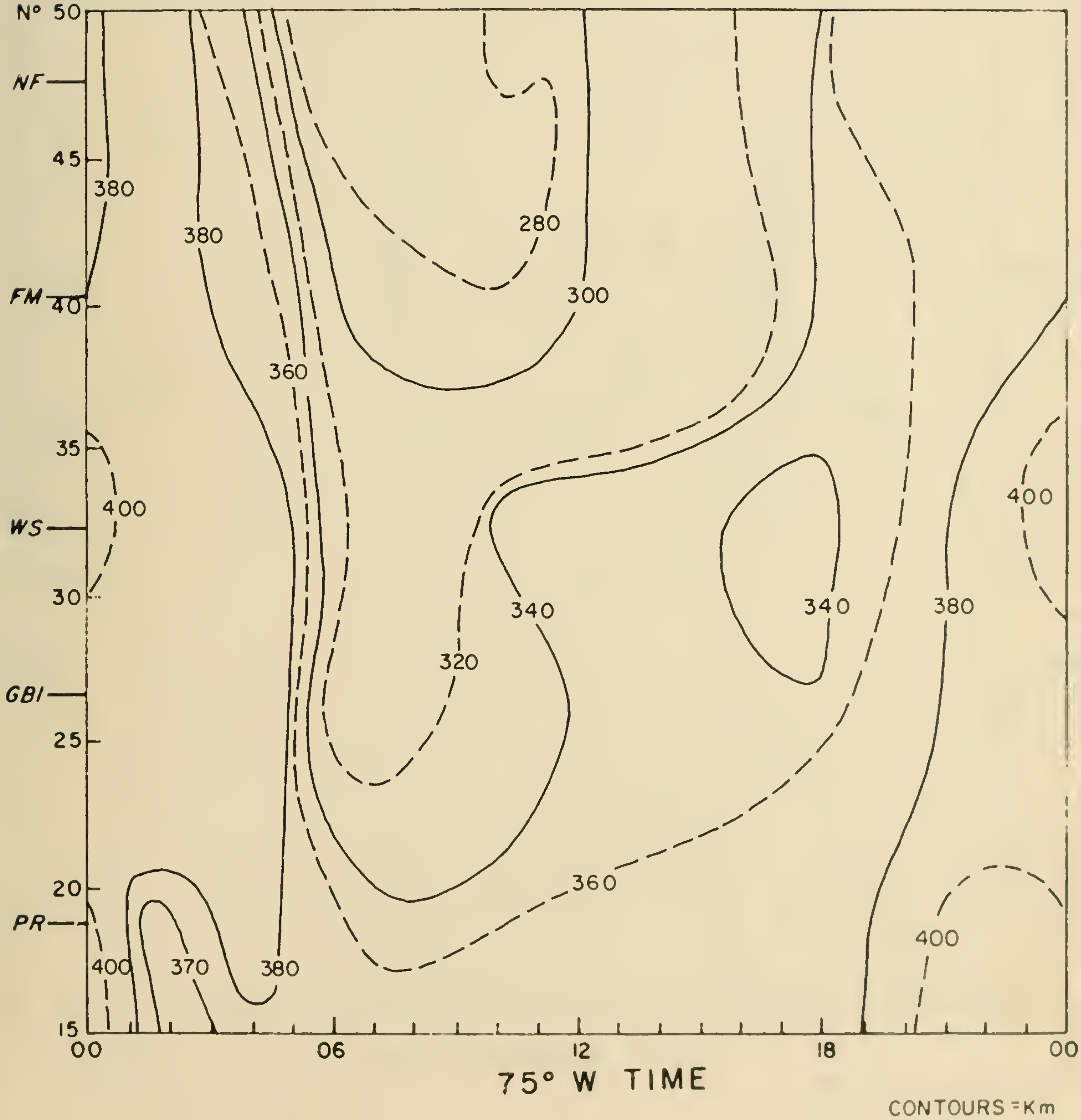
JULY 1959



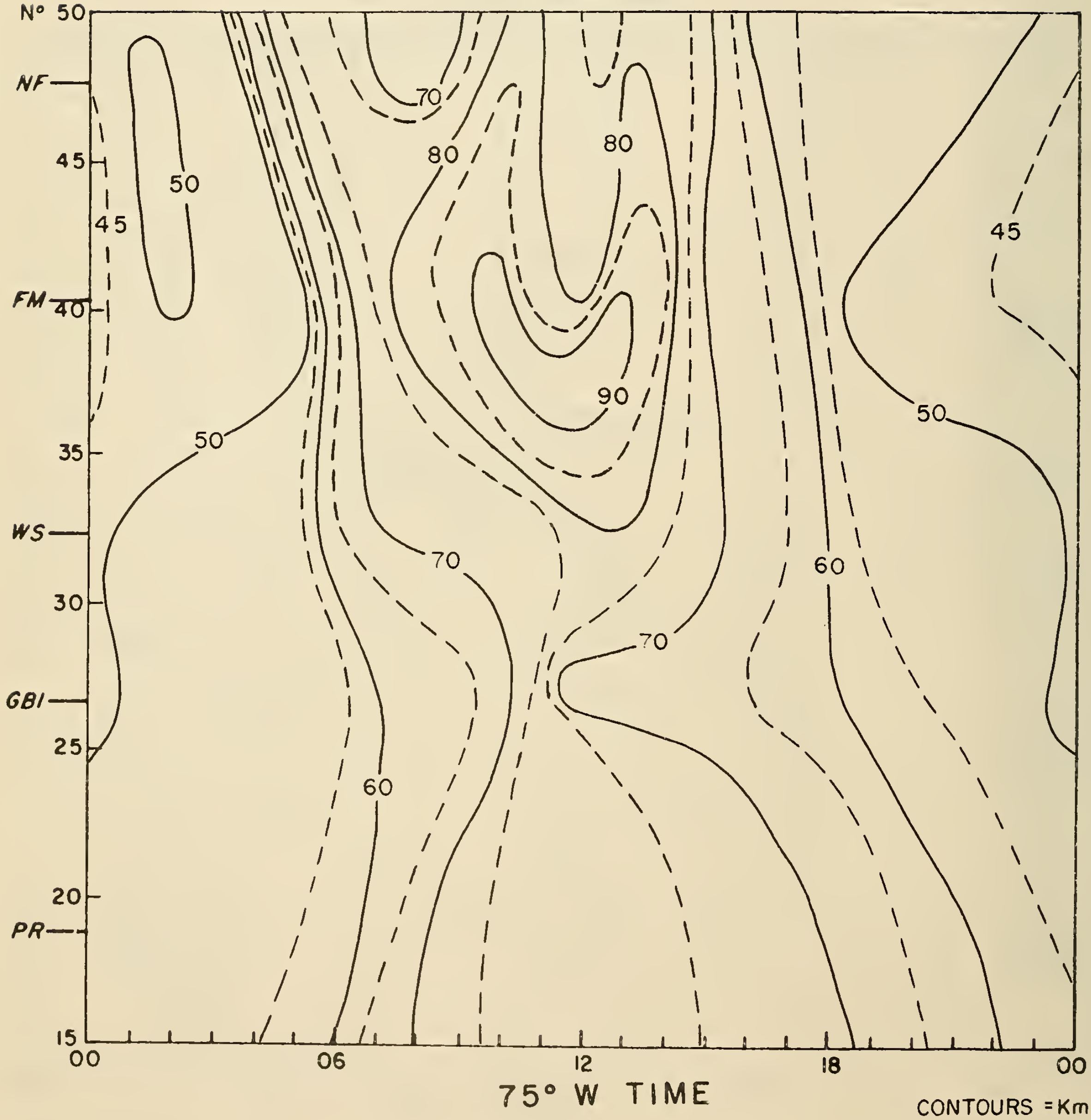

ELECTRON DENSITY AT 400 KILOMETERS
JULY 1959
N°
50
45
40
35
30
25
20
15
NF
FM
WS
GBI
PR
00
06
12
18
00
75° W TIME
CONTOURS: el/cm³ x 10⁻⁵
3
4
5
6
7
8
9
10
11
12
13
14
15
16


MAXIMUM ELECTRON DENSITY
NMAX
JULY 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 x10⁻⁵
3
4
5
5
5
6
7
8
9
10
11
12
13
14
15
16
17
8
7
6
5
5

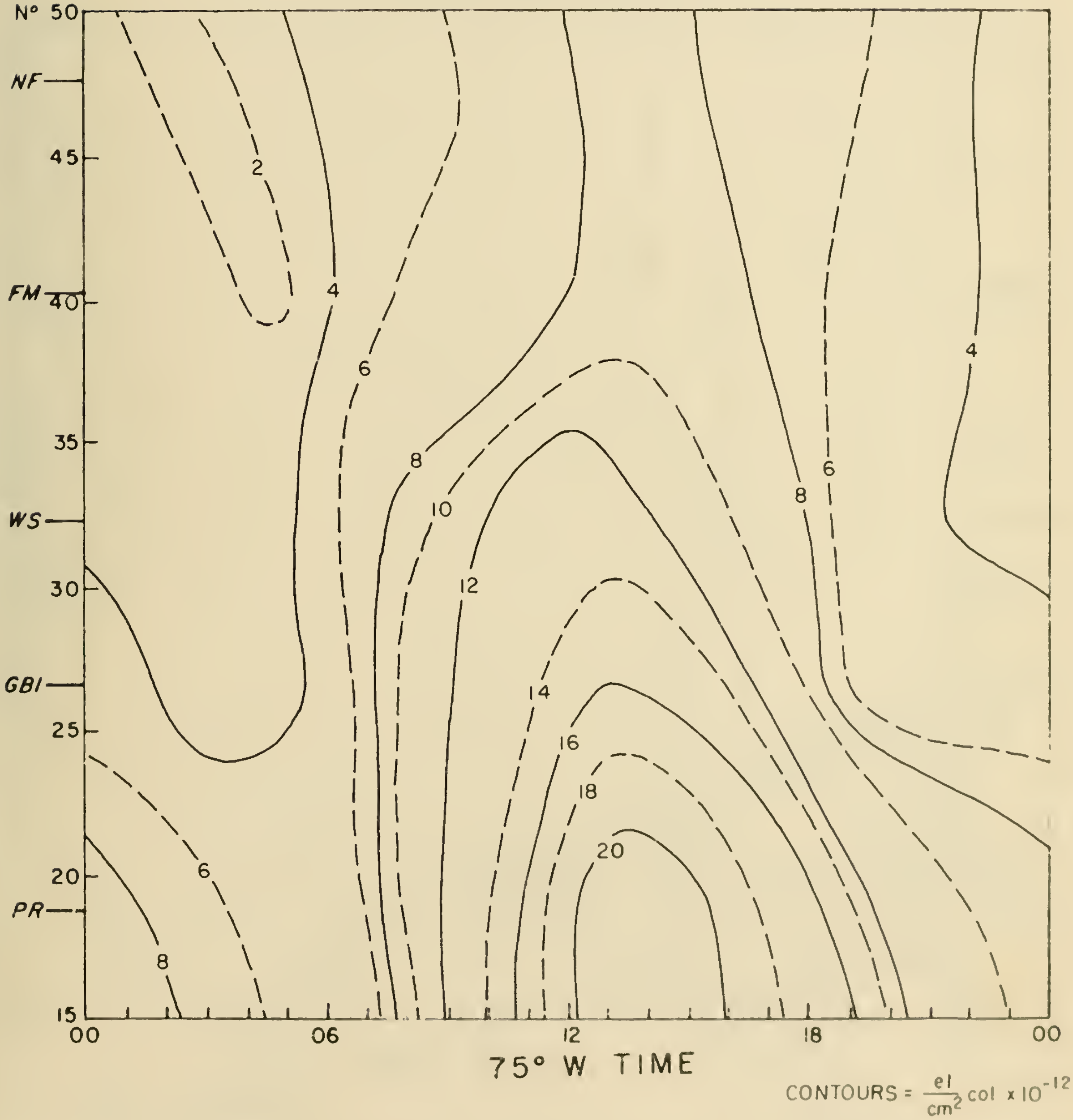
HEIGHT OF MAXIMUM ELECTRON DENSITY
HMAX
JULY 1959



QUARTER THICKNESS OF F-REGION PEAK
SCAT
JULY 1959



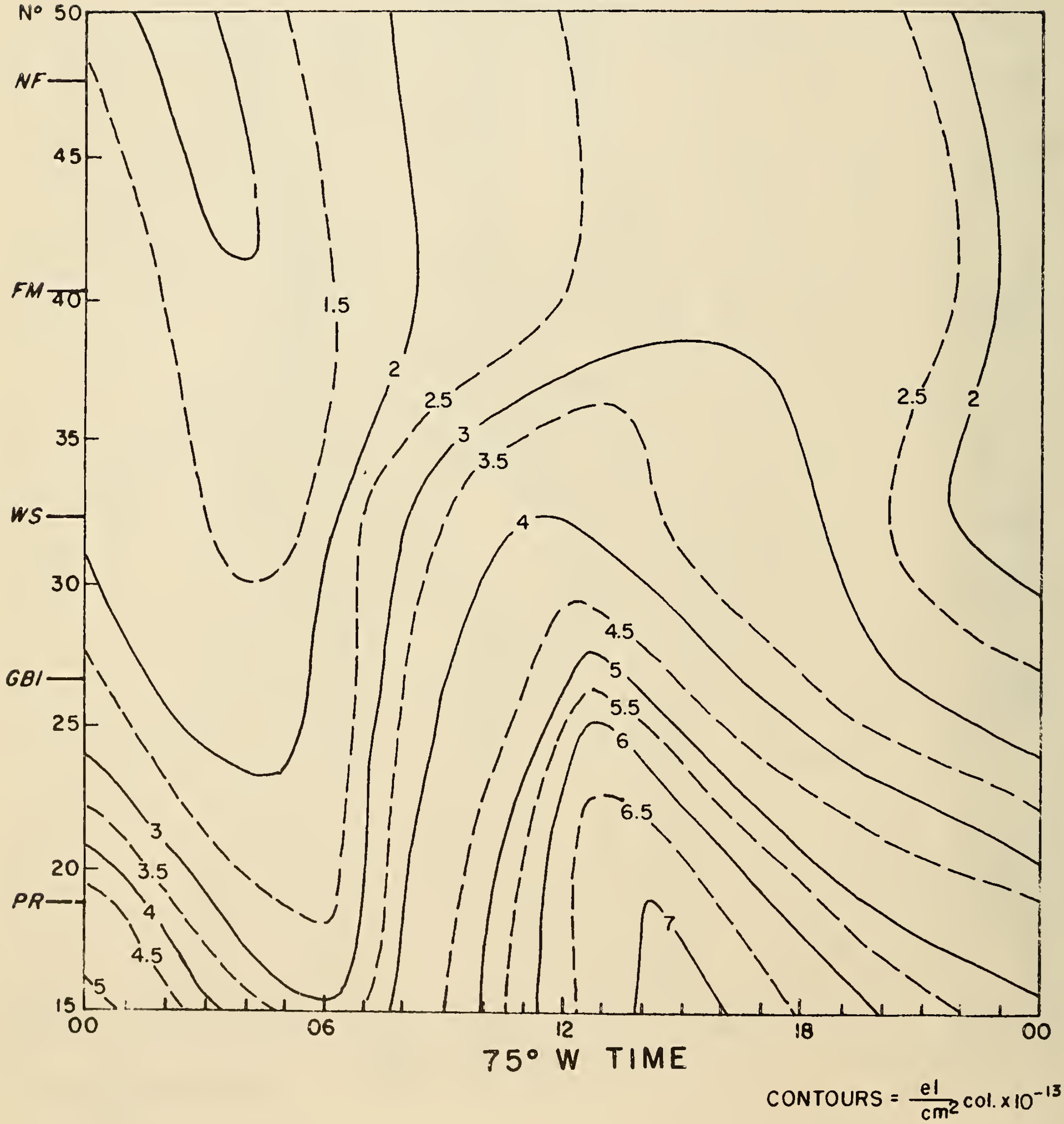
ELECTRON DENSITY INTEGRATED TO HEIGHT OF MAXIMUM ELECTRON DENSITY
SHMAX
JULY 1959

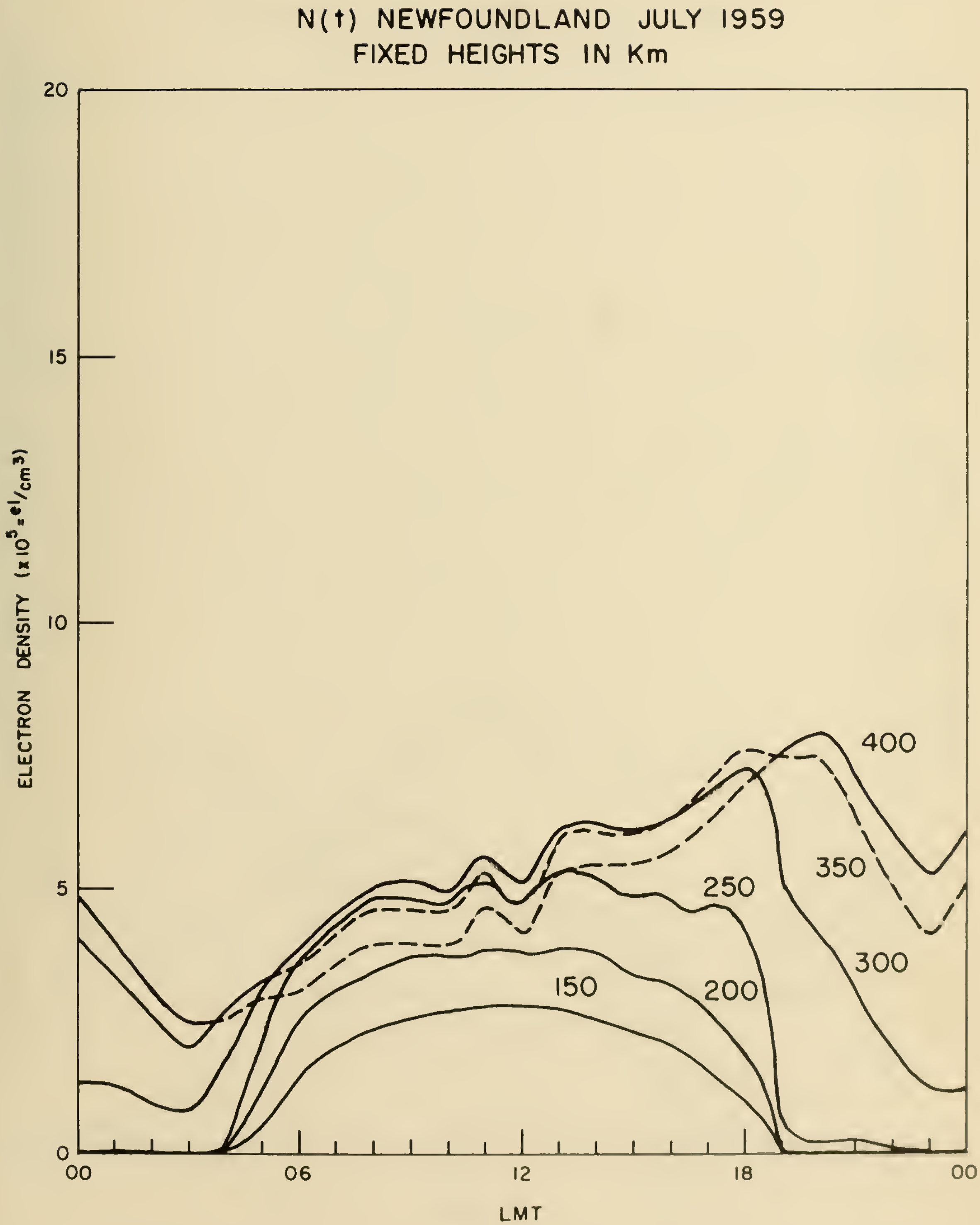


ELECTRON DENSITY INTEGRATED TO INFINITY

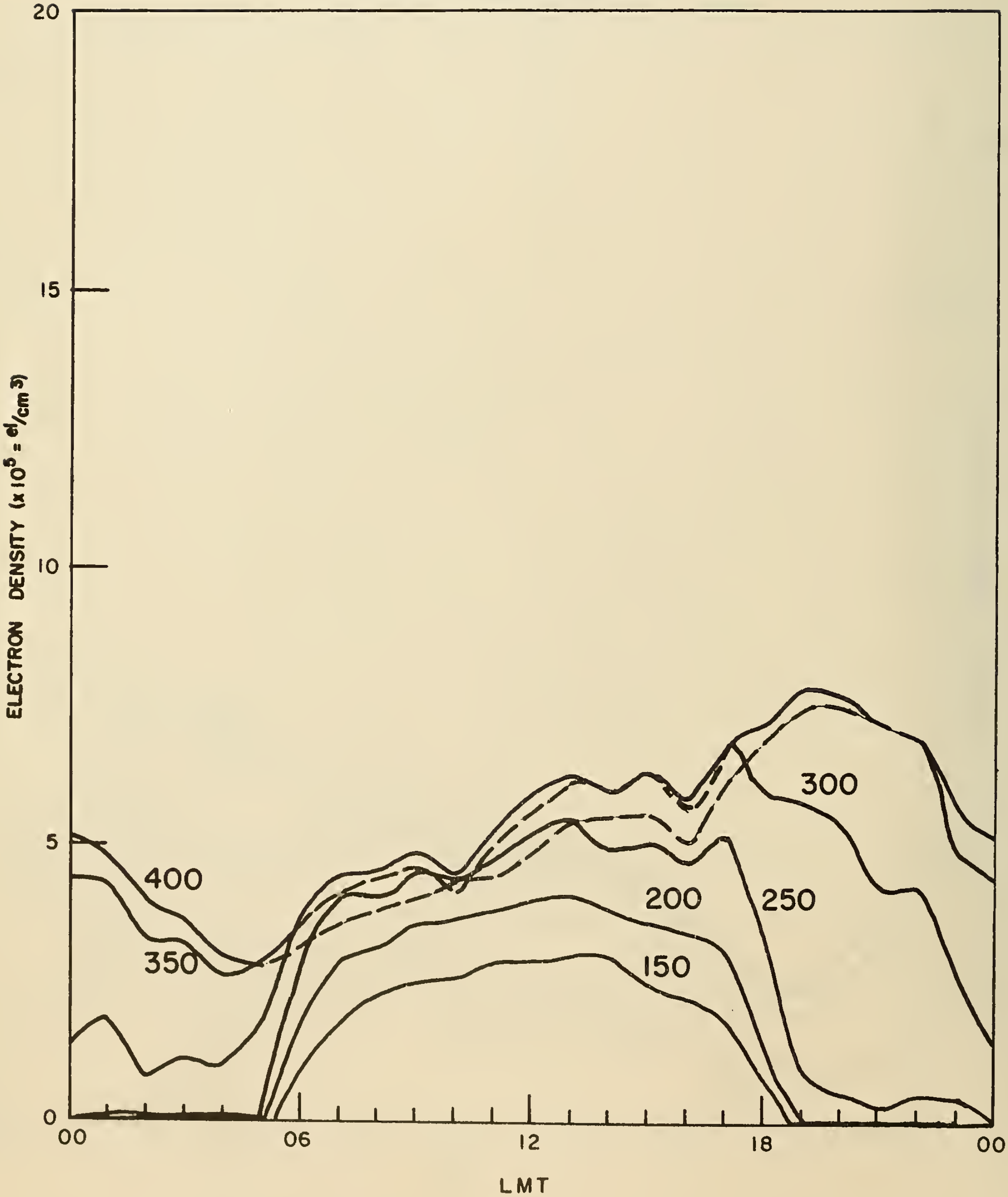
SHINF

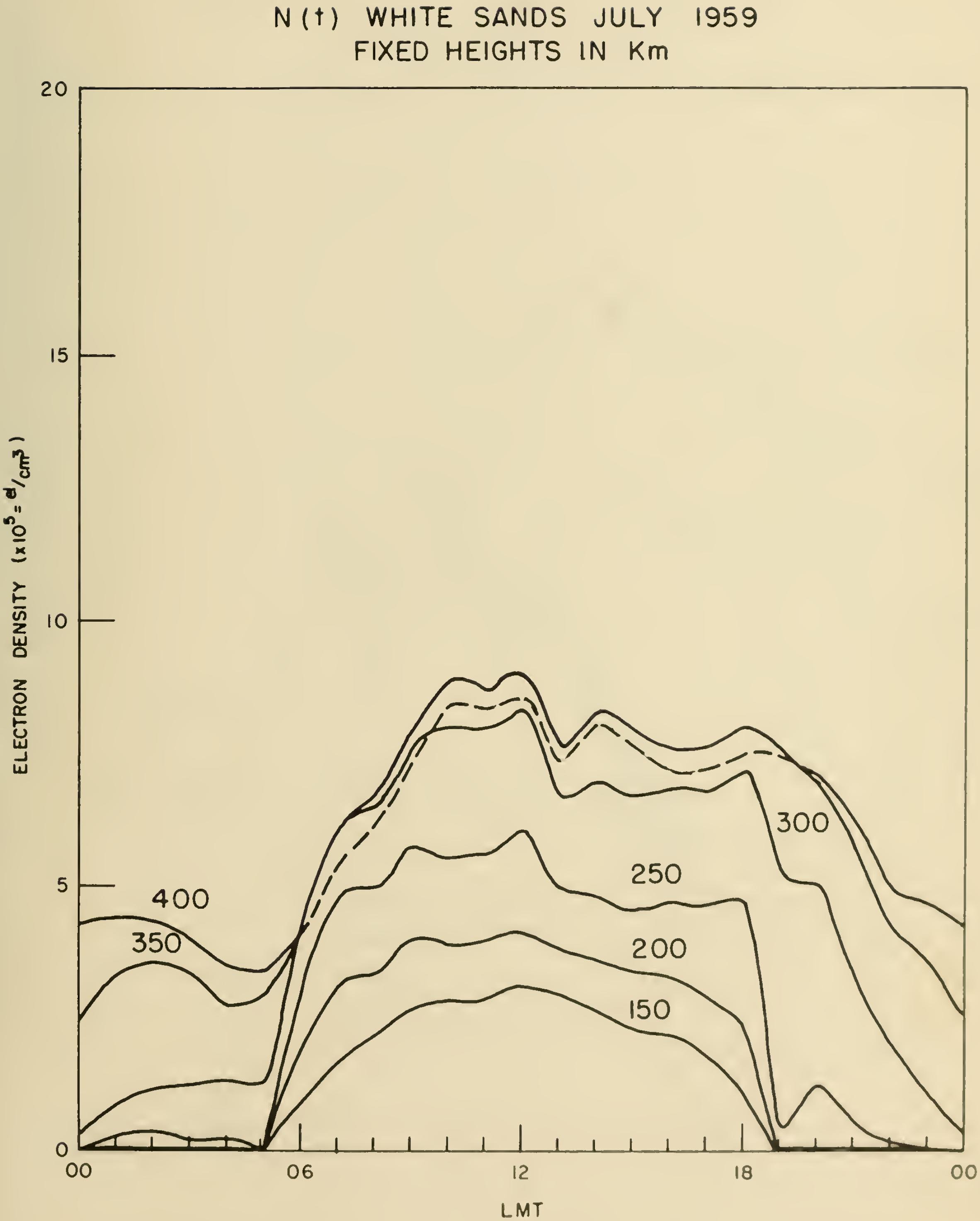
JULY 1959

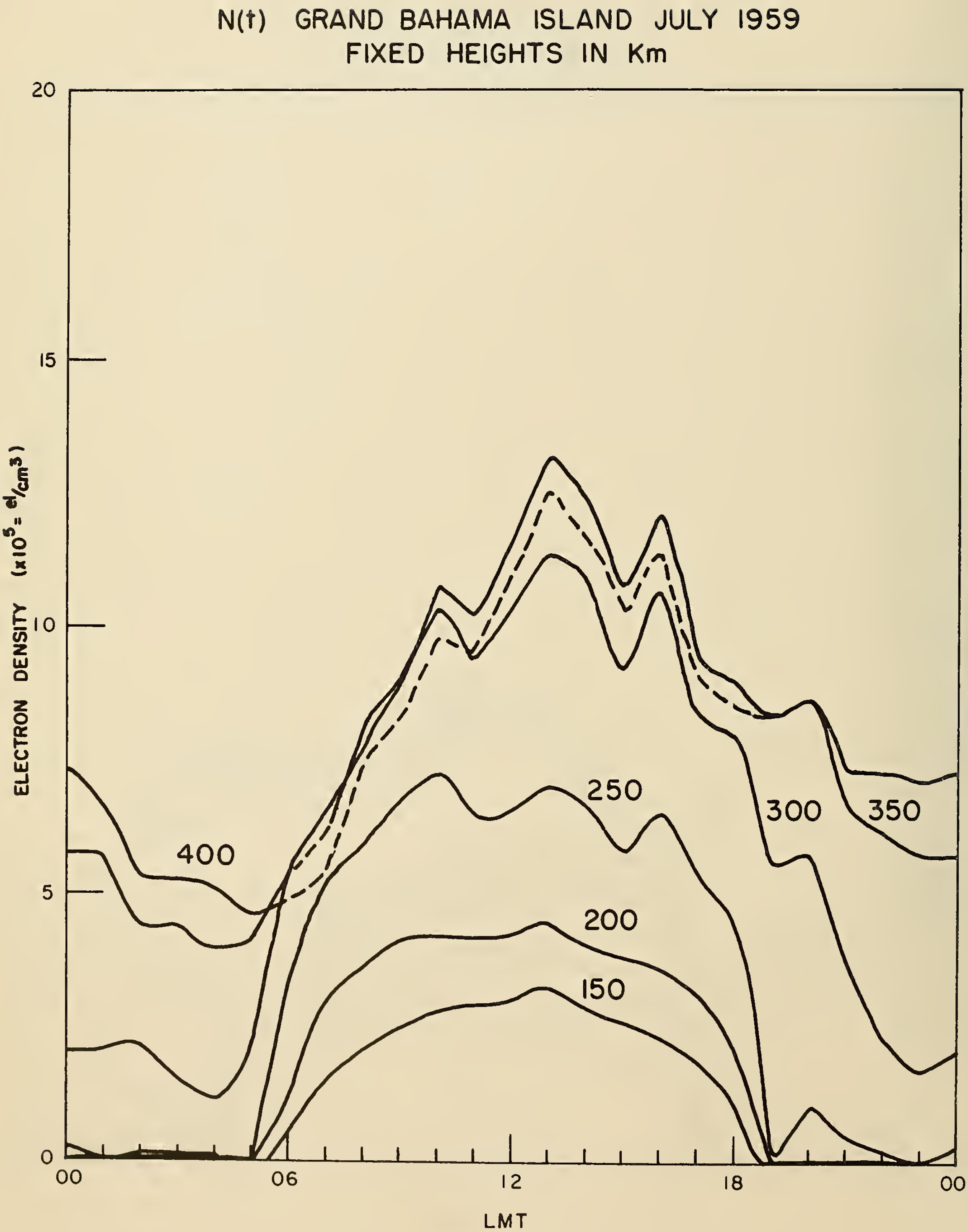


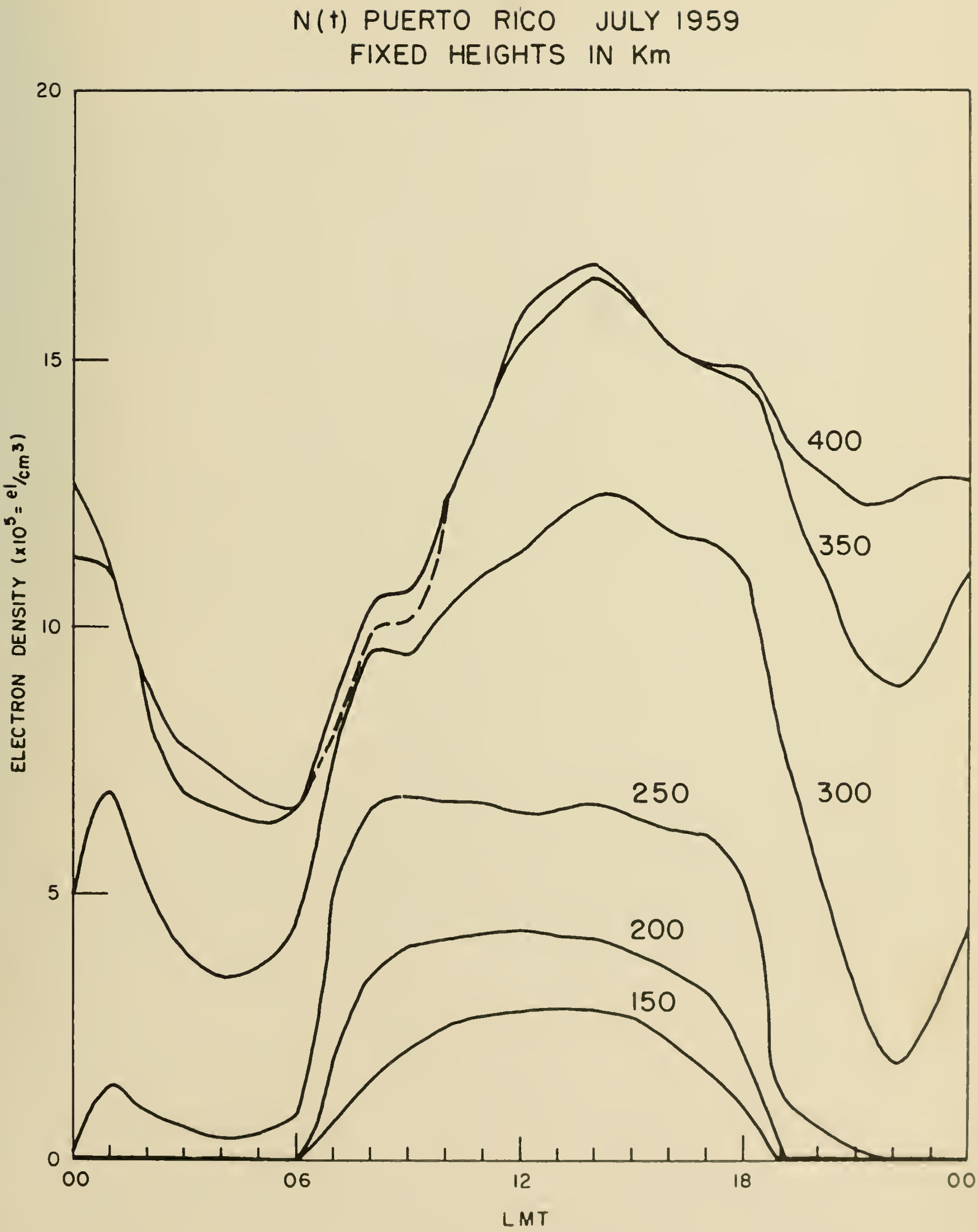

N(t) NEWFOUNDLAND JULY 1959
FIXED HEIGHTS IN Km
20
15
10
5
0
ELECTRON DENSITY (x10⁵ = el/cm³)
400
350
300
250
200
150
00
06
12
18
00
LMT

N(t) FORT MONMOUTH JULY 1959
FIXED HEIGHTS IN Km




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


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


N(t) PUERTO RICO JULY 1959
FIXED HEIGHTS IN Km
ELECTRON DENSITY (x10⁵ = el/cm³)
20
15
10
5
0
400
350
300
250
200
150
00
06
12
18
00
LMT

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