NBS

Technical Note 40-8

MEAN ELECTRON DENSITY VARIATIONS OF THE QUIET IONOSPHERE NO. 8 - OCTOBER 1959

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

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to government agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. Research projects are also performed for other government agencies when the work relates to and supplements the basic program of the Bureau or when the Bureau's unique competence is required. The scope of activities is suggested by the listing of divisions and sections on the inside of the back cover.

Publications

The results of the Bureau's research are published either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three periodicals available from the Government Printing Office: The Journal of Research, published in four separate sections, presents complete scientific and technical papers; the Technical News Bulletin presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: Monographs, Applied Mathematics Series, Handbooks, Miscellaneous Publications, and Technical Notes.

A complete listing of the Bureau's publications can be found in National Bureau of Standards Circular 460, Publications of the National Bureau of Standards, 1901 to June 1947 ($1.25), and the Supplement to National Bureau of Standards Circular 460, July 1947 to June 1957 ($1.50), and Miscellaneous Publication 240, July 1957 to June 1960 (Includes Titles of Papers Published in Outside Journals 1950 to 1959) ($2.25); available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

NATIONAL BUREAU OF STANDARDS

Technical Note

40-8

SEPTEMBER 1962

MEAN ELECTRON DENSITY VARIATIONS OF THE QUIET IONOSPHERE NO. 8 - OCTOBER 1959

J. W. Wright, L. R. Wescott and D. J. Brown

Central Radio Propagation Laboratory
NBS Boulder Laboratories
Boulder, Colorado

NBS Technical Notes are designed to supplement the Bureau's regular publications program. They provide a means for making available scientific data that are of transient or limited interest. Technical Notes may be listed or referred to in the open literature.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C. Price 35 cents

CONTENTS

ABSTRACT

The CRPL has initiated a program for large-scale computation of electron density profiles from ionospheric vertical soundings. Scaling is performed at field stations, permitting computation of hourly profiles at the Central Laboratory. These profiles are combined to form hourly mean quiet profiles for each station and month. The results of this program for the month of October are illustrated graphically. This report is the eighth of a series illustrating the electron density variations in the mean quiet ionosphere between latitudes 15°N and 50°N along the 75°W meridian.

MEAN ELECTRON DENSITY VARIATIONS OF THE QUIET IONOSPHERE No. 8 - October 1959

J. W. Wright, L. R. Wescott and D. J. Brown
Central Radio Propagation Laboratory

I. Introduction

Part of the basic responsibility of the Central Radio Propagation Laboratory is to gather ionospheric, solar, or other geophysical data necessary in the pursuit of research leading to improvements in radio communication and knowledge of the earth's upper atmosphere. The existing network of ionospheric vertical sounding stations is an important source of such data. Typically, the radio sounding data directly provide observations of peak electron densities (corresponding to "critical" frequencies foE, foF1, foF2), data on Sporadic E, and certain derived propagation data such as maximum usable frequencies or MUF factors (Smith, 1939).

In fact, the vertical sounding is potentially capable of providing the complete electron density profile of the underside of the ionosphere (i.e., below hmax F2) and of providing a basis for extrapolation to much greater altitudes. However, because a lengthy and difficult calculation is required, little of this work had been done until quite recently when techniques and computers have become available and the exigencies of the IGY and satellite programs have made it imperative.

In the course of its development of facilities for electron density profile calculations, the CRPL has succeeded in devising means by which basic data for this purpose may be scaled by the individual field stations, thereby decentralizing and simplifying the most onerous part of the work. Through its own station network and those of the U. S.

Army Signal Radio Propagation Agency, and through cooperation with closely associated stations in other countries, the CRPL has initiated an extensive systematic data reduction program, from which hourly electron density profiles are being computed for the following stations:

Puerto Rico (NBS, January 1959)
Grand Bahama Island (U. S. Army Signal Corps, February 1959)
Fort Monmouth, New Jersey (U.S. Army Signal Corps, Feb. 1959)
White Sands, New Mexico (U.S. Army Signal Corps, March 1959)
St. Johns, Newfoundland (Def. Res. Tel. Establ. Canada, June 1959)
Adak, Alaska (U.S. Army Signal Corps, June 1959)
Okinawa, Ryukus (U.S. Army Signal Corps, June 1959)
Thule, Greenland (U.S. Army Signal Corps, July 1959)
Huancayo, Peru (January 1960)
Talara, Peru (January 1960)
Baguio, Philippines (February 1960)

Affiliation and approximate date of initial participation in this program are given in parentheses.

The hourly electron density profiles are extensively used in the research programs of CRPL and are supplied directly to certain other agencies as part of various research and practical activities. However, in this comparatively early stage, broad dissemination of the computed data is a somewhat difficult problem.

In an attempt to make at least a summary of the results of the program widely and rapidly available, the CRPL has initiated the present series of reports. These provide graphical representations of the monthly mean quiet hourly electron densities from certain of the stations in the preceding list, from which a fairly clear picture of the local ionosphere morphology may be obtained.

These reports contain N(h) data for the stations at Newfoundland, Fort Monmouth, Grand Bahama Island, White Sands, and Puerto Rico. Pertinent facts concerning these stations are given in the following table:

Table 1

	Geomag. Coordinates			Geog. Coordinates	
	fH	Lat.	Dip		
St. Johns, Newf.	1.38 Mc/s	58.5°N	72°N	47°33'N	52°40'W
Ft. Monmouth, N. J.	1.46	51.7°N	71.5°N	40°15'N	74°01'W
White Sands, N. M.	1.30	41.2°N	60°N	32°24'N	106°52'W
Grand Bahama Island	1.30	37.9°N	59.5°N	26°40'N	78°22'W
Puerto Rico	1.15	30°N	51.5°N	18°30'N	67°12'W

II. Description of Basic Data

True heights of reflection of radio waves are calculated from the observed or "virtual" heights by the method of Budden (1954); this method need not be described her e, but it should be pointed out that full correction for geomagnetic field effects is made and that the usual restrictions to monotonic profiles apply.

Tabulations of the mean electron density data at 10 km intervals and certain related quantities are the bases for the graphs and charts. A sample for the Puerto Rico October data is given on Page 11. The table on the following page identifies the quantities appearing on the tabulation.

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

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

A. Averaging process. Each hour of each day is identified with its magnetic character figure, Kp. For each hour, those days for which Kp is less than 4+ are included in the "quiet" average. The other days are similarly combined to form a "disturbed" average; however, this rarely has physical significance because the number of disturbed periods is usually small and the behavior of the ionosphere during disturbed hours is not consistent. Thus, graphs for these latter averages are not presented here.

B. Determination of hmax. The nature of the "true height" process is such that no direct measure of hmax F2 is obtained, the virtual height at Nmax being immeasurable. A useful procedure is to fit the portion near hmax F2 with a suitable curve and to determine hmax from this curve. A parabola is quite satisfactory for this purpose; it is fitted to two of the highest true heights and the measured value of Nmax (foF2).

C. Extrapolation of profiles above hmax. Before averaging, the individual profiles are extrapolated above hmax by a Chapman distribution of 100 km scale height. This assumed model seems to agree well with the few published measurements dealing with the profile of the F region above hmax (Wright, 1960). Extrapolation is necessary in order to calculate homogeneous averages near hmax, and the average profiles are, in fact, given to 950 km.

D. Integrated electron densities. The total number of electrons in a unit column of the ionosphere between the effective bottom (hmin) and hmax is called Shmax; it is obtained by numerical integration of the observed profiles between these limits. An estimate of the total electron content to infinity, based upon the Chapman model, is called Shinf. It is obtained by adding to Shmax the quantity $N_A = 2.82\,HN_{max}$ 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 October 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 anomalies imposed by White Sands on these contours are the result of the well-known longitudinal asymmetry of the ionosphere.

B. Local time vs. Latitude Maps. Another form of presentation, useful for indicating the two-dimensional geographic variations of the ionosphere, is that illustrated by the maps of pages 36 through 45. Here, for fixed levels in the ionosphere (150, 200, 250, 300, 350, 400 km), contours of electron density are drawn in the latitude vs. local time plane. To the extent to which longitude anomalies are negligible, these maps give also the longitude vs. latitude distribution of electron densities at the indicated heights when it is noon over the 75°W meridian. Similar maps for the peak density, Nmax; its height, hmax; its characteristic thickness, Scat; the total electron content to Nmax, Shmax; and the estimated total electron content, Shinf, are also shown.

C. Electron density vs. time curves (N(t) curves). The mean quiet diurnal variation of electron density between 150 and 400 km heights above the sounding stations is illustrated by these curves. Dashed lines are used wherever the electron density at any height falls below the peak density (i.e. when the height hmax F2 falls below the height for the curve in question.) Such electron densities are the result of the extrapolations by the Chapman model discussed in Section II C.

IV. Discussion and Applications of the Data

Mean quiet electron density data over wide geographic areas are essential for application to numerous problems of both practical and scientific interest. For example, the assessment of the radio refraction errors and Faraday rotation effects in satellite tracking requires a knowledge of the electron density profile in the direction of the satellite or an estimate of the electron density at the satellite itself. Alternatively these properties of the ionosphere, or estimates of the total electron content in a column, may be measured by observations from rockets and satellites, or from radar moon-echoes, and compared with ground-based observations of the kind shown here.

Frequently it will be necessary to use instantaneous density data because of the considerable variability of the ionosphere about the quiet mean. In such cases, the mean data are of value as a "reference level" in the design of the experiment; for example, in the choice of radio frequencies, satellite heights, antennas, etc.

Since electron density data represent virtually our only source of continuous, widespread data on the earth's upper atmosphere, such data also are essential to geophysical problems involving the electrical, neutral, and magnetic properties of the atmosphere.

For example, data on the vertical cross sections may be compared with theoretical expectations for the meridional height dependence of the quiet ionosphere. Several workers (Hirono, 1955; Martyn 1956) have investigated the equilibrium height (of hmax) for an ionosphere controlled by diffusion, height-varying electron loss rate, and uniform (or zero) vertical electron drift. The results are qualitatively in agreement with these observations in predicting a rise of hmax towards the equator in daytime and a reversal of this tendency at night.

The N(t) curves are perhaps the most physically significant representation of electron density data. The strong solar control at all levels and the important perturbations of this solar control in the upper F region may be easily seen.

Acknowledgments

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

References

Budden, K. G., "A method for determining the variation of electron density with height (N(z) curves) from curves of equivalent height against frequency (h'(f) curves). Proc. Cambridge Conf. on the Physics of the Ionosphere, pp 332-339, September 1954, Pub. by the Physical Society (1955).

Martyn, D. F., "Processes controlling ionization distribution in the ionosphere," Aust. J. Phys. 9, pp 161-165, March 1956.

Hirono, M., "Effect of gravity and pressure gradient on vertical drift in the F2 region," Rpt. on Iono. Res. in Japan, 9, No. 2, pp 95-104, (1955).

Smith, N., "The relation of Radio Skywave Transmission to Ionosphere Measurements," Proc. IRE, 27, No. 5, pp 332-347, (1939).

Wright, J. W. "A model of the F region above hmax F2," Journal of Geophysical Research, 65, pp 185-191, January 1960.

AVERAGE ELECTRON DENSITY KP BELOW 4.5

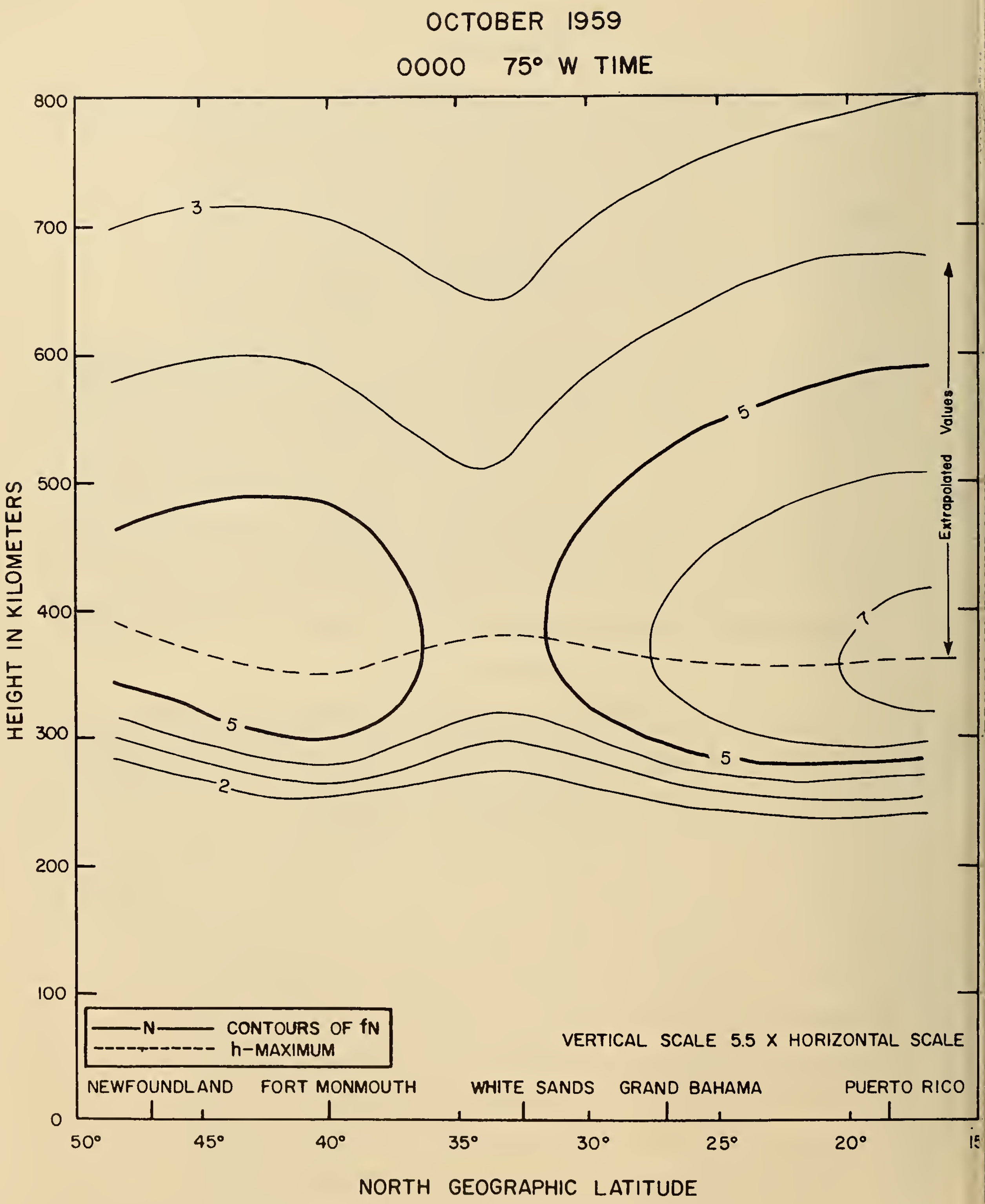
PUERTO RICO 60 W OCT 1959

TIME	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100
COUNT	26	26	26	26	26	26	26	17	26	22	22	24
HMIN	242	243	235	217	218	265	232	119	111	110	111	111
RATIO	6.1	6.1	6.6	6.6	4.7	4.5	4.8	5.5	4.8	4.6	4.4	4.2
NMAX	664	630	543	414	253	223	249	804	1334	1741	2035	2194
HMAX	338	338	320	298	344	395	353	275	289	295	309	315
SHMAX	373	344	284	216	202	189	186	511	1007	1360	1747	1941
SHINF	2247	2037	1815	1382	917	816	884	2779	4772	6271	7489	8131
KM												
950	51.7	47.1	39.0	26.5	20.2	23.2	20.5	45.3	81.2	109	137	152
900	66.3	60.5	50.0	33.9	25.8	29.7	26.3	58.2	104	139	176	194
850	85.0	77.5	64.1	43.5	33.1	38.1	33.8	74.6	133	178	225	249
800	109	99.3	82.2	55.8	42.4	48.7	43.2	95.6	171	229	289	319
750	139	127	105	71.5	54.2	62.2	55.3	123	219	293	370	409
700	178	162	134	91.5	69.2	79.0	70.6	157	281	375	473	523
650	226	206	171	117	87.0	99.6	89.7	201	358	479	603	667
600	286	261	217	148	111	124	113	256	456	609	765	846
550	358	326	27.	187	138	152	141	324	577	770	965	1066
500	441	400	337	234	170	181	173	407	723	964	1202	1327
490	459	416	351	244	176	186	180	426	755	1006	1253	1383
480	476	432	365	255	183	191	186	445	788	1050	1306	1441
470	494	448	379	265	189	196	193	465	822	1094	1360	1499
460	512	463	393	276	196	201	200	485	856	1140	1414	1558
450	529	479	403	287	20[illegible]	205	206	505	892	1186	1468	1617
440	546	494	422	298	209	208	212	527	927	1233	1523	1677
430	563	50[illegible]	436	309	214	211	218	548	963	1280	1578	1736
420	578	52[illegible]	449	320	220	213	224	570	999	1327	1632	1795
410	593	535	46.	331	225	214	229	591	1035	1374	1685	1852
400	607	547	475	34.	229	213	234	613	1071	1420	1737	1907
390	619	557	486	35[illegible]	233	211	237	635	1106	1465	1787	1960
380	630	565	496	363	236	208	241	657	1140	1509	1834	2009
370	637	571	[illegible]0[illegible]	372	238	20.	243	678	1173	1551	1877	2054
360	641	573	[illegible]13	381	[illegible]39	193	[illegible]44	698	1204	1590	1916	2094
350	640	571	[illegible]17	389	239	18.	242	717	1233	1626	1950	2128
340	53[illegible]	56.	519	396	[illegible]	168	[illegible]39	736	1259	1657	1977	2154
330	613	545	[illegible]15	401	235	151	231	752	1281	1684	1997	2171
320	58[illegible]	517	5[illegible]7	404	230	132	220	767	1300	1705	2006	2177
310	[illegible]	47[illegible]	4[illegible]	404	224	113	205	780	1313	1719	1999	2164
300	478	[illegible]	46[illegible]	401	214	91.6	187	790	1319	1721	1973	2123
290	4[illegible]	[illegible]	4[illegible]4	39[illegible]	20.	74.0	164	797	1315	1709	1921	2047
280	377	[illegible]	[illegible]	375	188	5[illegible].	14[illegible]	800	1295	1675	1841	1932
270	[illegible]	[illegible]31	[illegible]03	347	171	39.1	114	794	1253	1609	1725	1778
260	1[illegible]	[illegible]75	[illegible]7	303	143	[illegible].1	97.6	774	1191	1506	1570	1594
250	1[illegible]1	[illegible]14	14[illegible]	240	1.[illegible]	19.1	6[illegible].8	73[illegible]	1077	1362	1385	1387
240	[illegible]3.1	7[illegible].[illegible]	[illegible].1	170	93.1	14.[illegible]	4[illegible].8	663	969	1189	1191	1170
230	3[illegible].1	[illegible].1	[illegible]1.[illegible]	104	6[illegible].1	10.5	[illegible]7.7	56[illegible]	820	988	990	967
220	14.1	[illegible]	[illegible]	[illegible]1.[illegible]	34.9	[illegible].3	14.4	43[illegible]	662	796	802	793
210	[illegible]	[illegible]	[illegible]	1.[illegible]	15.7	[illegible].1	[illegible]	316	518	620	642	646
200		.[illegible]	.1	5.[illegible]	4.1	.5	1.9	2[illegible]	397	485	520	534
190				.5	.[illegible]			157	302	389	429	450
180								113	233	315	360	384
170								89.2	184	259	304	331
160								74.8	149	215	258	287
150								67.[illegible]	126	181	219	247
140								62.[illegible]	113	156	189	213
130								55.3	106	143	170	190
120								41.6	9[illegible].[illegible]	127	146	168
110								1.5	14.7	36.3	53.3	43.7

AVERAGE ELECTRON DENSITY KP BELOW 4.5

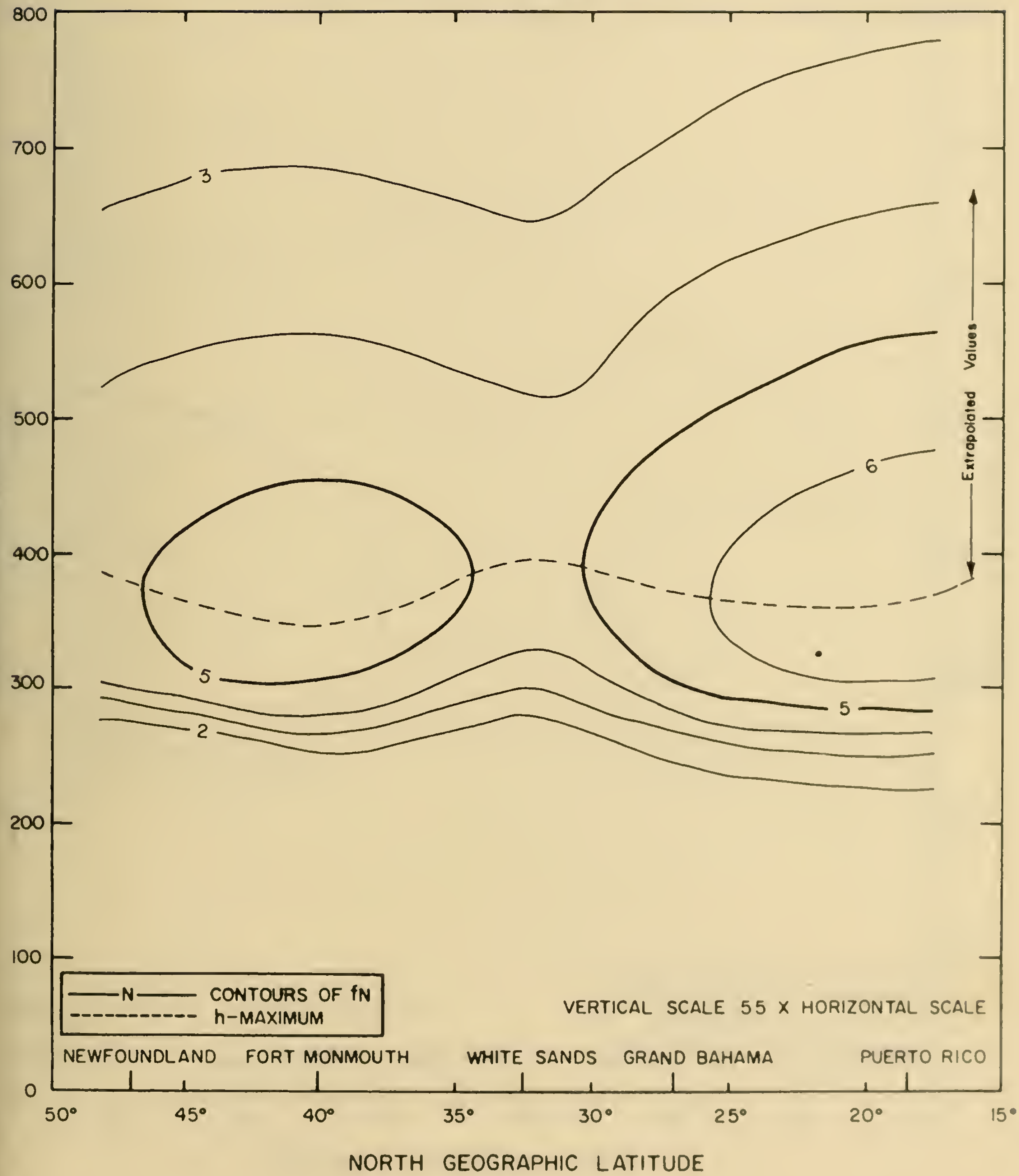
PUERTO RICO 60 W OCT 1959

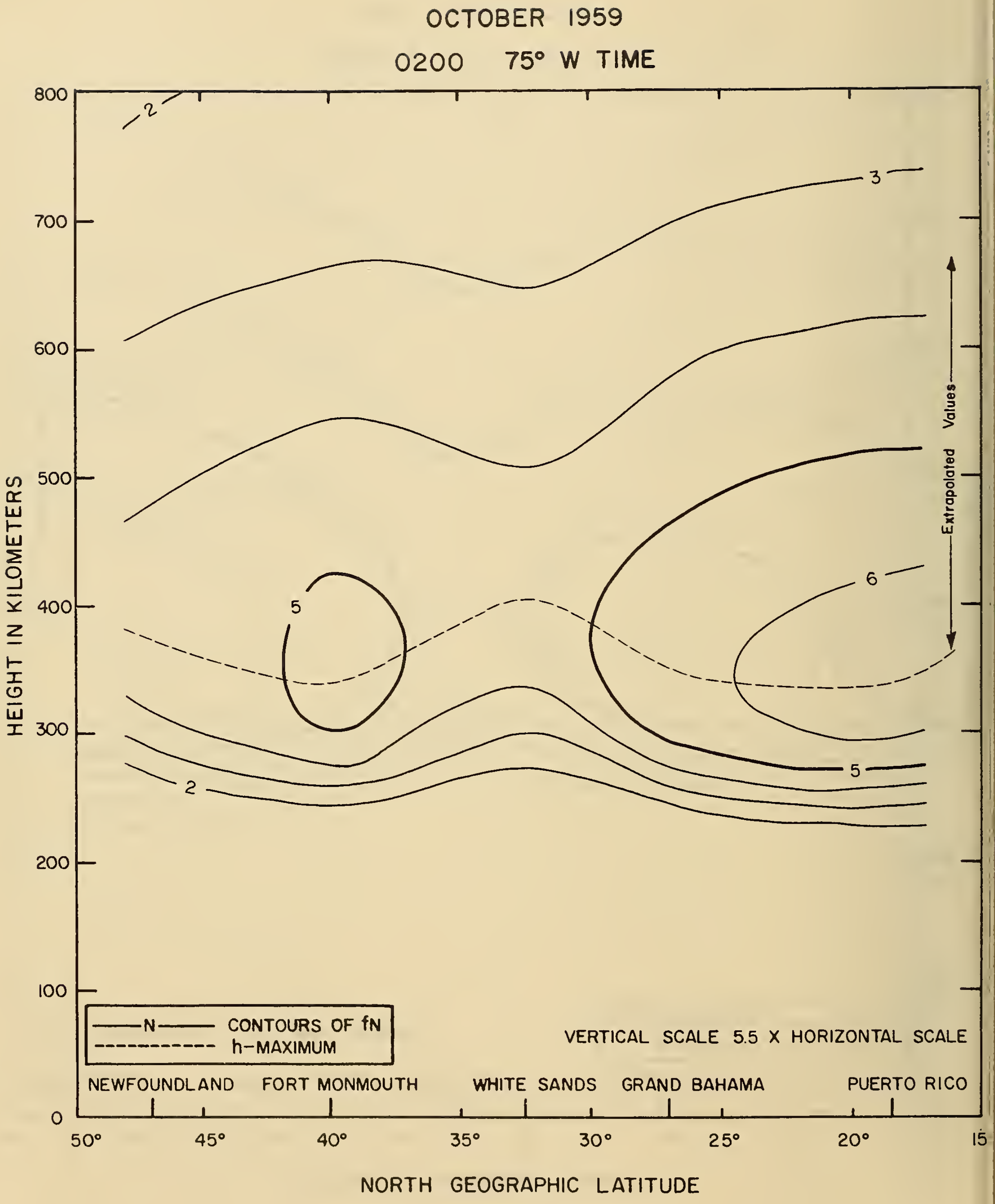
TIME	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
COUNT	25	21	22	20	22	12	19	26	26	25	26	26
HMIN	111	110	111	111	111	112	212	210	218	242	253	243
RATIO	4.0	3.8	4.0	3.8	3.9	4.1	4.6	4.7	4.7	4.9	5.6	5.7
NMAX	2167	2203	2244	2166	1997	1812	1602	1190	988	831	806	743
HMAX	325	337	332	338	335	333	340	346	352	368	359	344
SHMAX	2063	2226	2134	2179	1971	1694	1275	924	758	611	500	451
SHINF	8176	8441	8464	8289	7605	6806	5793	4281	3545	2955	2773	2548
KM												
950	158	171	170	168	152	137	126	96.3	81.9	74.3	69.4	60.0
900	202	219	217	215	195	176	161	123	105	95.3	89.0	76.9
850	259	281	279	276	251	225	207	158	135	122	114	98.6
800	332	360	357	354	321	289	265	203	173	156	146	126
750	425	461	457	453	411	370	339	259	221	200	187	162
700	543	588	584	578	525	473	433	331	282	255	238	206
650	692	749	744	736	669	602	551	421	358	324	302	262
600	878	947	942	931	847	762	697	532	452	407	381	331
550	1103	1137	1182	1167	1062	956	873	666	564	506	474	414
500	1368	1464	1461	1440	1313	1182	1076	818	692	616	579	509
490	1424	1523	1521	1498	1366	1231	1119	850	718	639	601	528
480	1482	1582	1581	1556	1420	1279	1162	883	745	661	622	548
470	1540	1641	1641	1615	1474	1329	1205	915	771	683	643	568
460	1599	1701	1702	1674	1529	1378	1248	947	797	704	664	588
450	1657	1760	1763	1732	1583	1427	1291	978	823	725	684	607
440	1716	1817	1823	1789	1636	1475	1333	1009	848	744	704	626
430	1773	1874	1881	1845	1688	1523	1374	1039	872	762	722	644
420	1829	1928	1938	1899	1739	1569	1413	1067	894	779	739	662
410	1883	1979	1992	1950	1787	1613	1450	1093	915	793	754	678
400	1935	2027	2043	1997	1832	1654	1484	1117	933	805	767	692
390	1983	2070	2090	2040	1873	1692	1514	1138	949	814	776	705
380	2027	2108	2132	2078	1910	1726	1541	1155	962	819	781	715
370	2066	2139	2168	2110	1941	1755	1562	1169	970	818	780	722
360	2099	2162	2197	2134	1966	1779	1577	1177	973	809	771	725
350	2125	2175	2217	2148	1983	1795	1586	1178	970	788	750	720
340	2140	2177	2225	2151	1991	1803	1584	1168	958	755	716	706
330	2144	2160	2216	2138	1985	1800	1568	1143	933	708	670	680
320	2132	2120	2181	2101	1957	1778	1536	1100	894	647	608	639
310	2098	2052	2113	2038	1905	1735	1484	1041	839	572	533	581
300	2034	1954	2014	1945	1827	1669	1410	965	768	486	451	505
290	1937	1829	1880	1825	1723	1577	1311	868	683	394	364	421
280	1809	1675	1720	1678	1594	1466	1186	757	582	303	275	335
270	1652	1503	1540	1510	1441	1331	1033	632	470	216	189	254
260	1473	1320	1344	1335	1281	1184	853	503	353	144	117	177
250	1282	1140	1151	1150	1107	1019	656	374	242	87.9	65.7	114
240	1094	973	968	975	941	852	435	250	152	47.0	33.8	66.2
230	915	821	808	813	773	682	255	150	81.4	23.6	14.7	32.9
220	757	692	674	670	627	5[illegible]	112	72.6	32.6	11.1	6.2	12.9
210	625	587	567	552	506	390	31.6	29.9	10.3	3.4	2.5	2.9
200	520	504	481	458	409	283	3.[illegible]	6.1	1.6	.8		.3
190	442	438	412	384	331	207		.1				
180	380	382	358	323	271	156						
170	331	334	310	276	223	123						
160	287	291	269	238	186	104						
150	248	251	232	205	158	92.3						
140	215	216	201	179	140	85.2						
130	194	194	182	163	129	80.5						
120	170	176	169	151	120	73.3						
110	22.6	48.6	39.6	34.1	22.3	6.2						

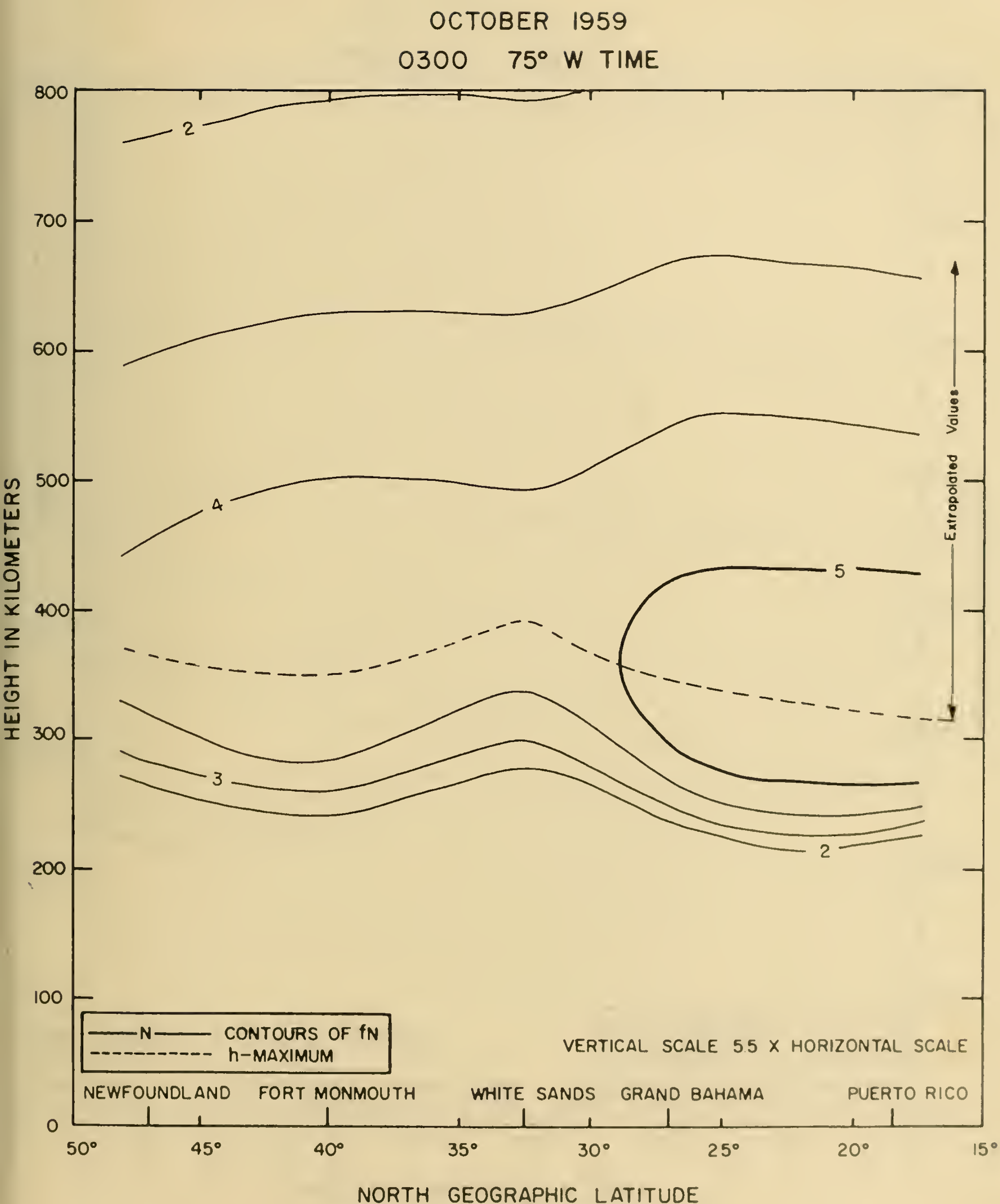

OCTOBER 1959
0000 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
5
5
5
7
2
Extrapolated Values
—N— CONTOURS OF fN
- - - - - h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
NORTH GEOGRAPHIC LATITUDE

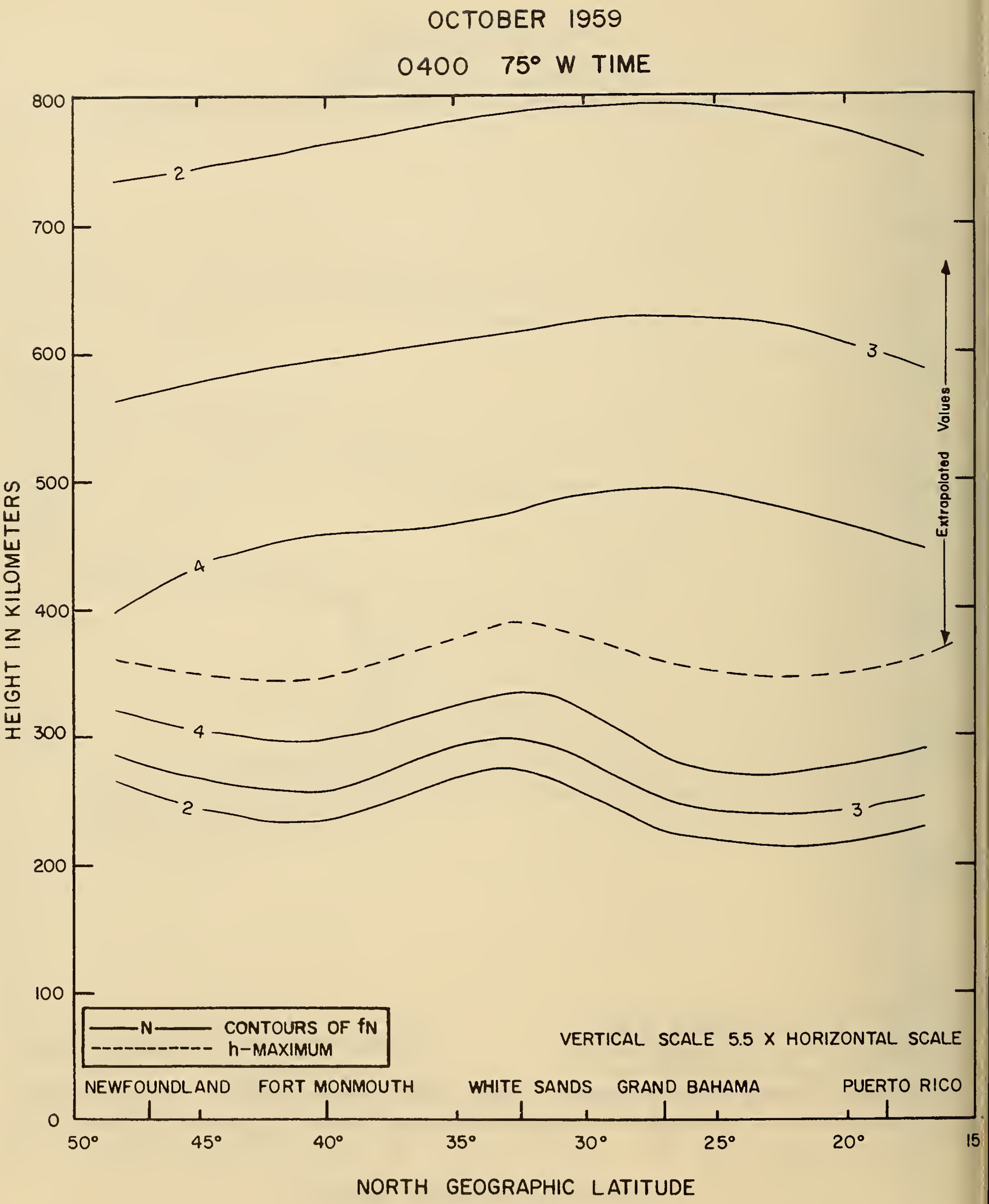
OCTOBER 1959

0100 75° W TIME



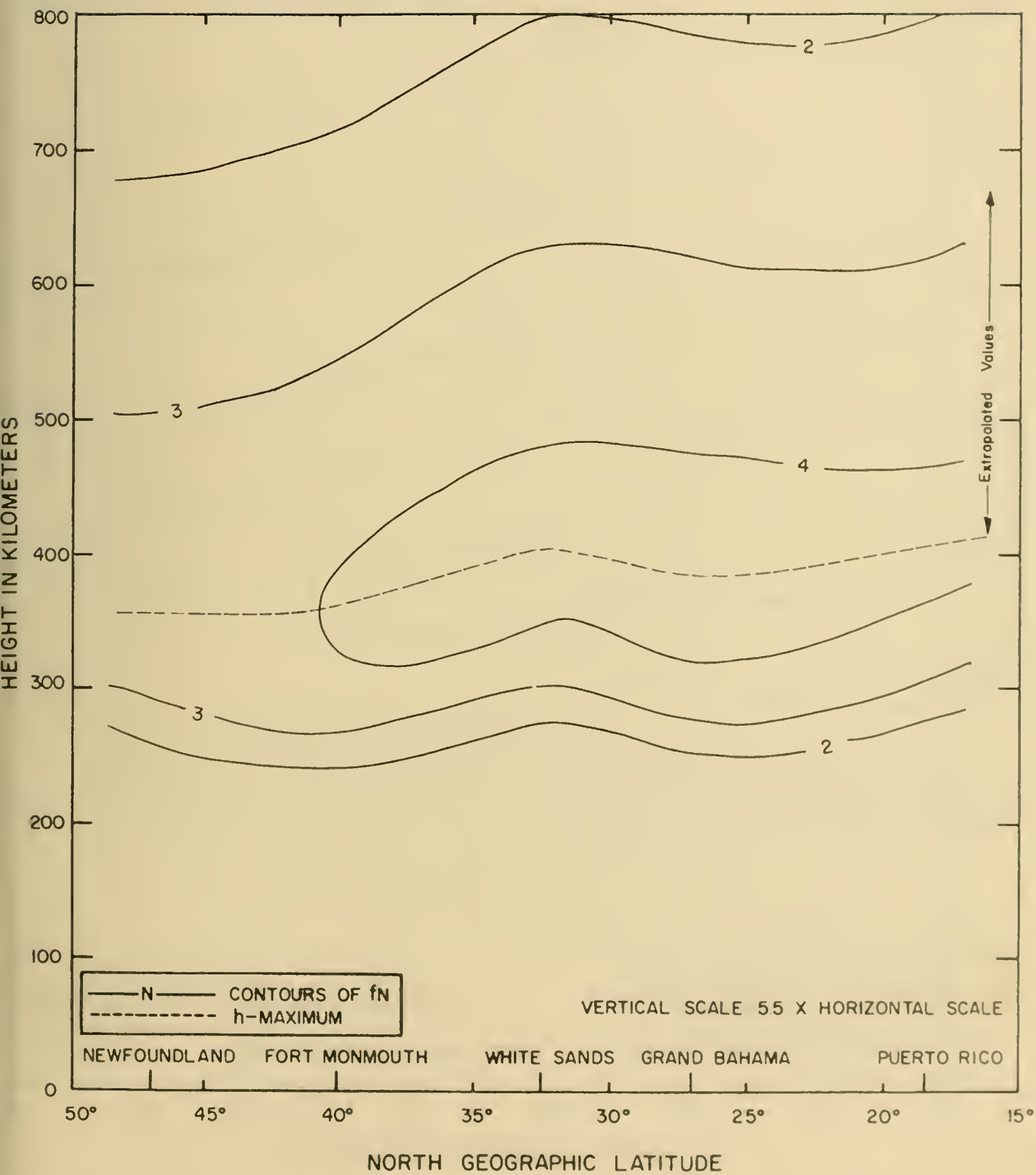

OCTOBER 1959
0200 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
2
3
5
6
5
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15
NORTH GEOGRAPHIC LATITUDE


OCTOBER 1959
0300 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
2
4
5
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°
NORTH GEOGRAPHIC LATITUDE


OCTOBER 1959
0400 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
2
3
4
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
NORTH GEOGRAPHIC LATITUDE

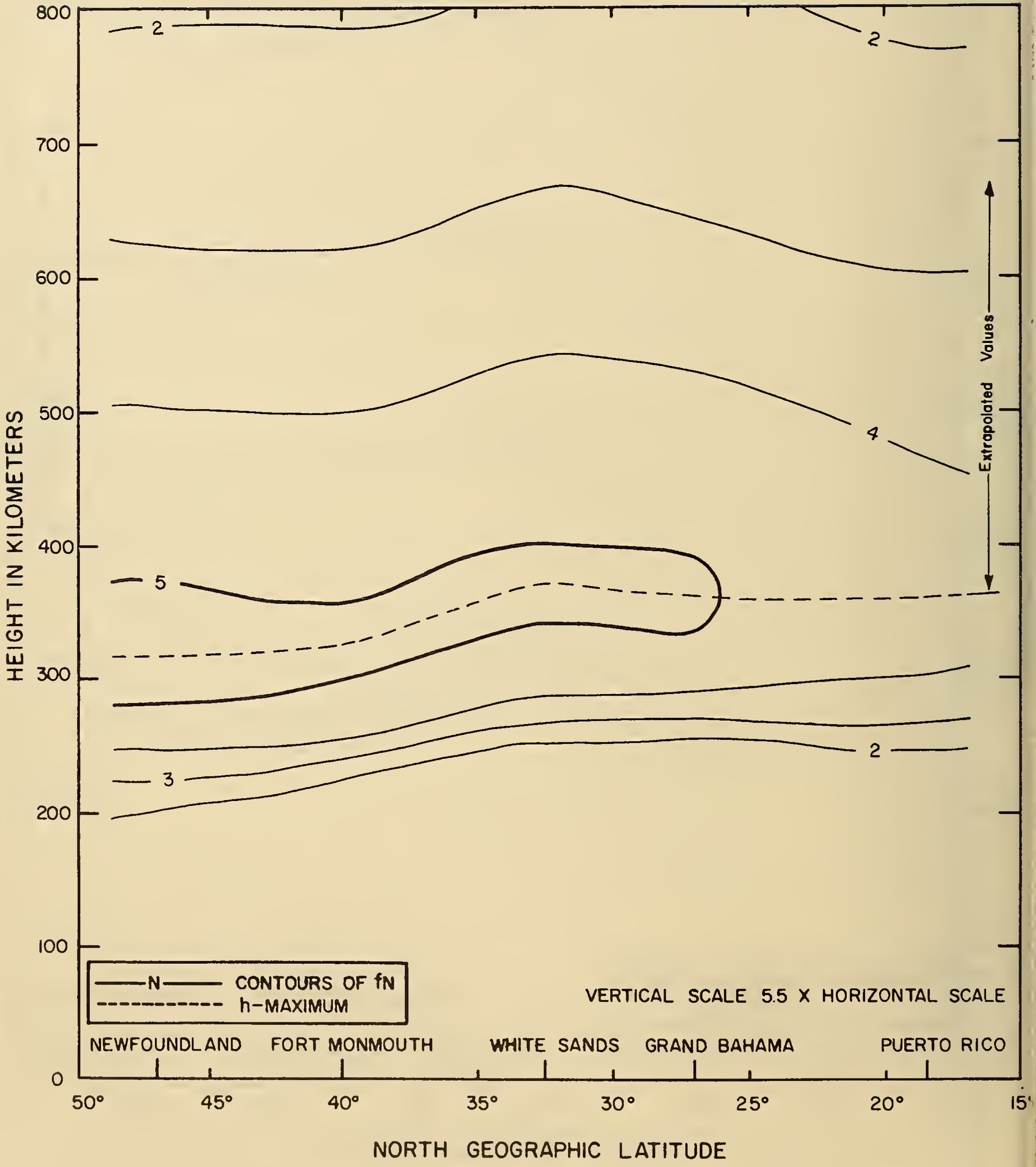
OCTOBER 1959

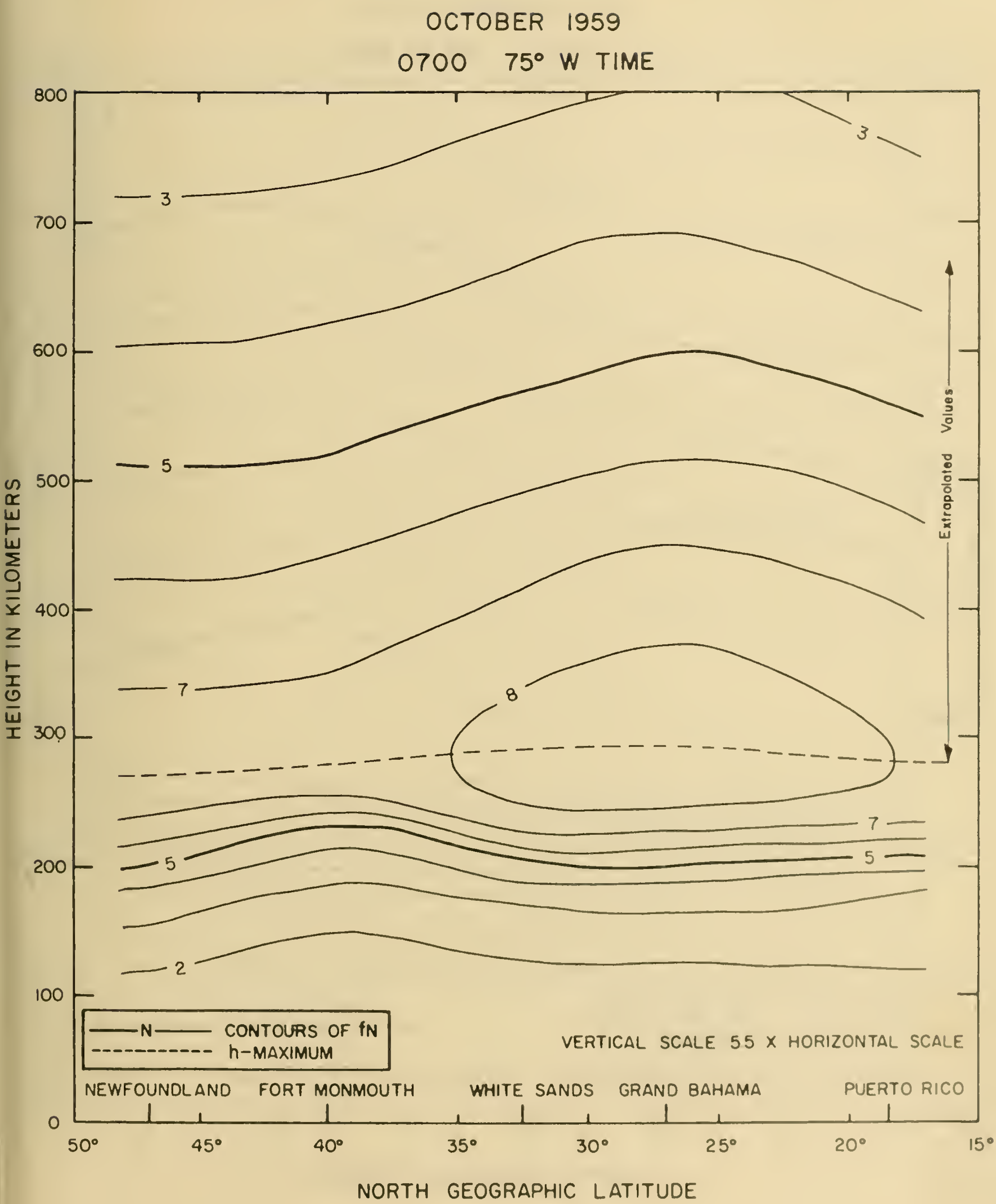
0500 75° W TIME



OCTOBER 1959

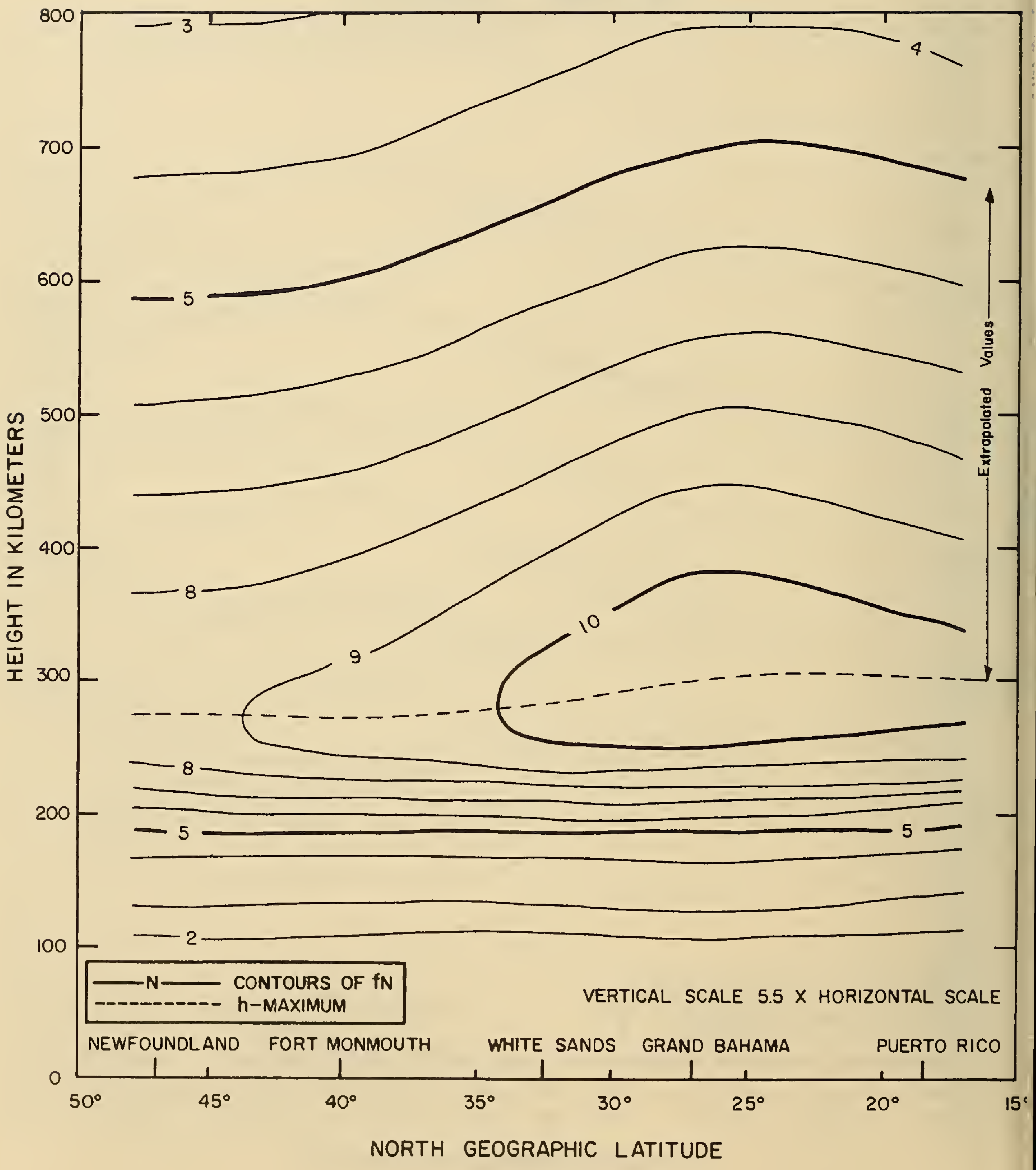
0600 75° W TIME




OCTOBER 1959
0700 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
5
7
8
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

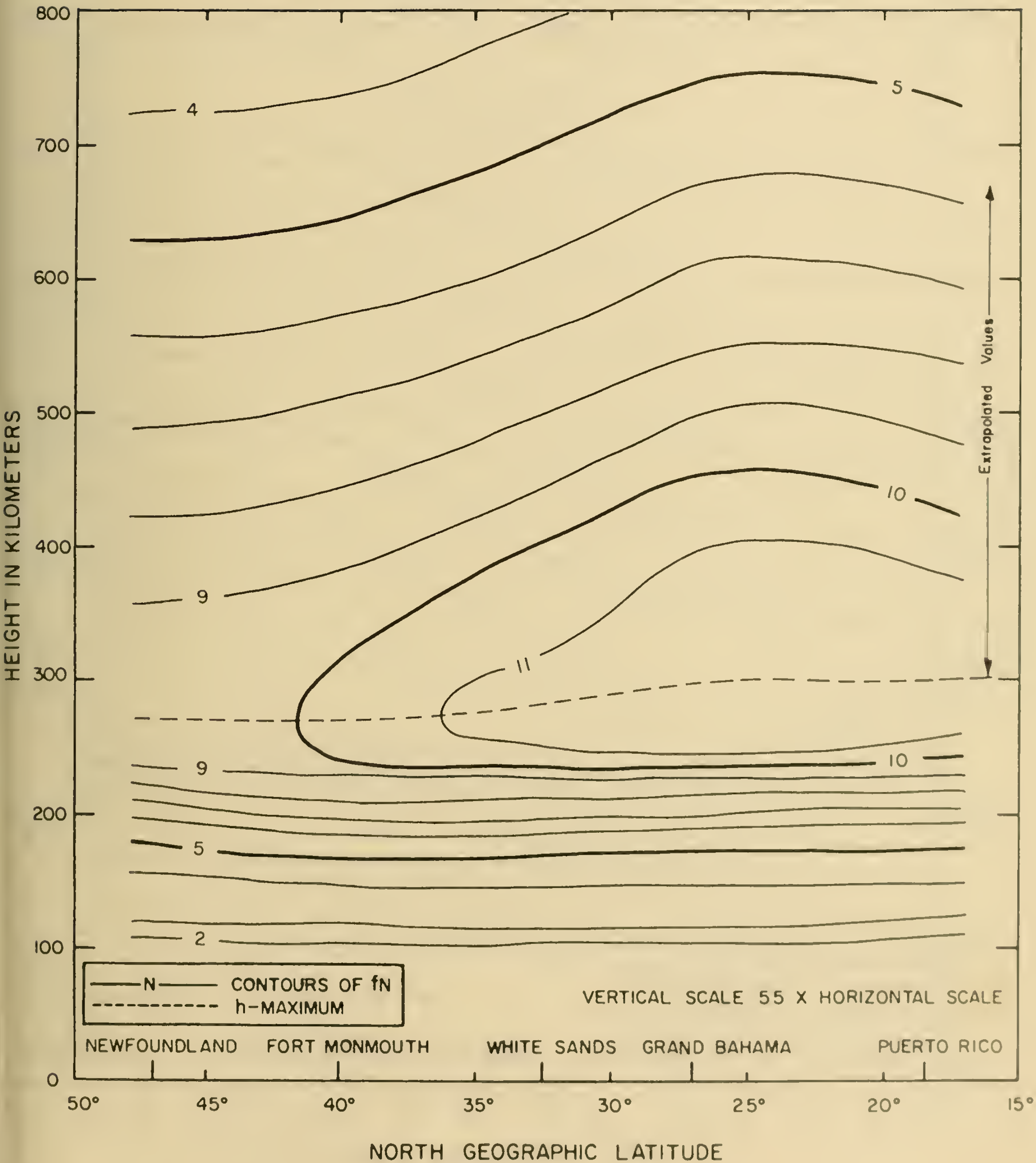
OCTOBER 1959

0800 75° W TIME



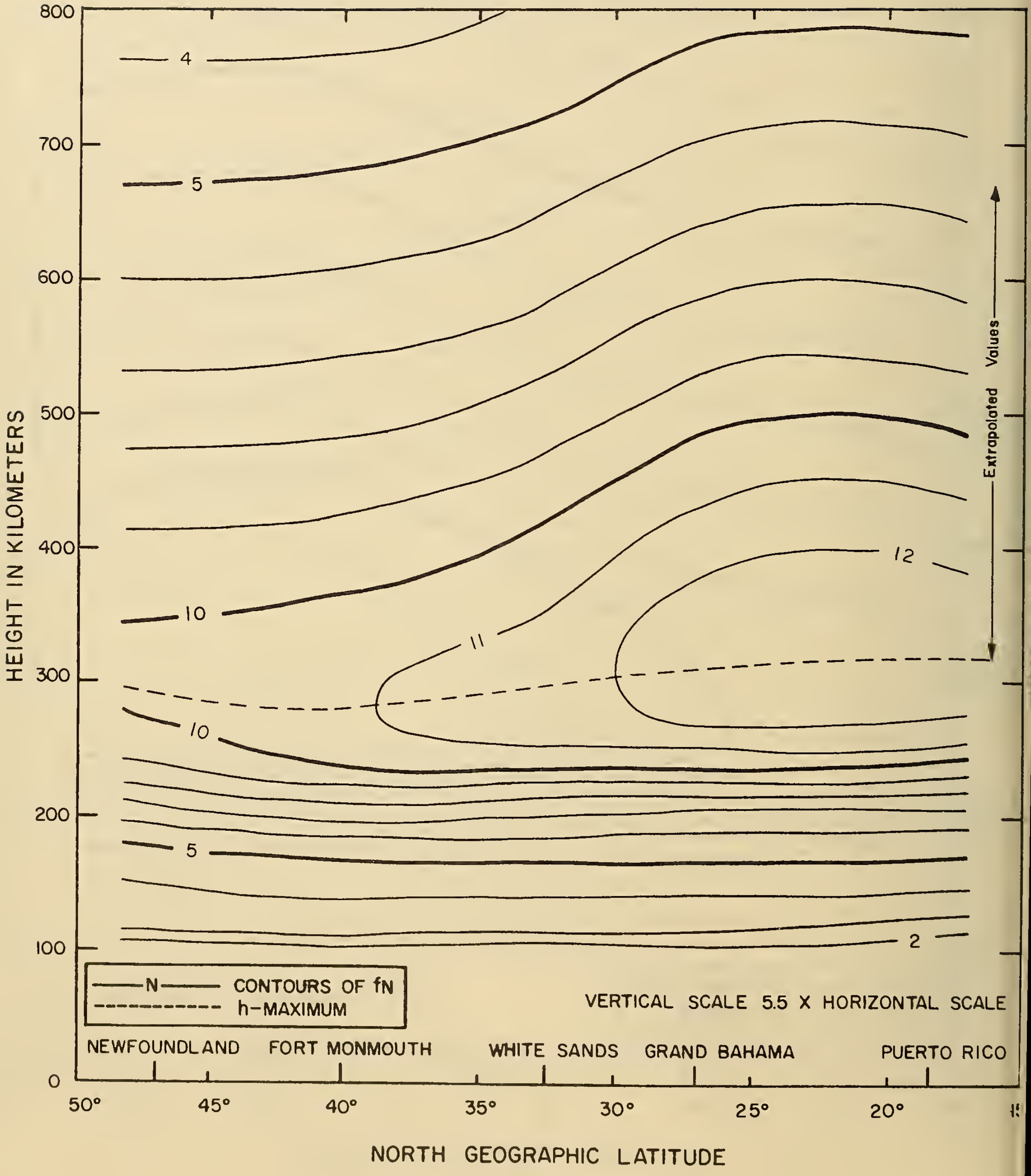
OCTOBER 1959

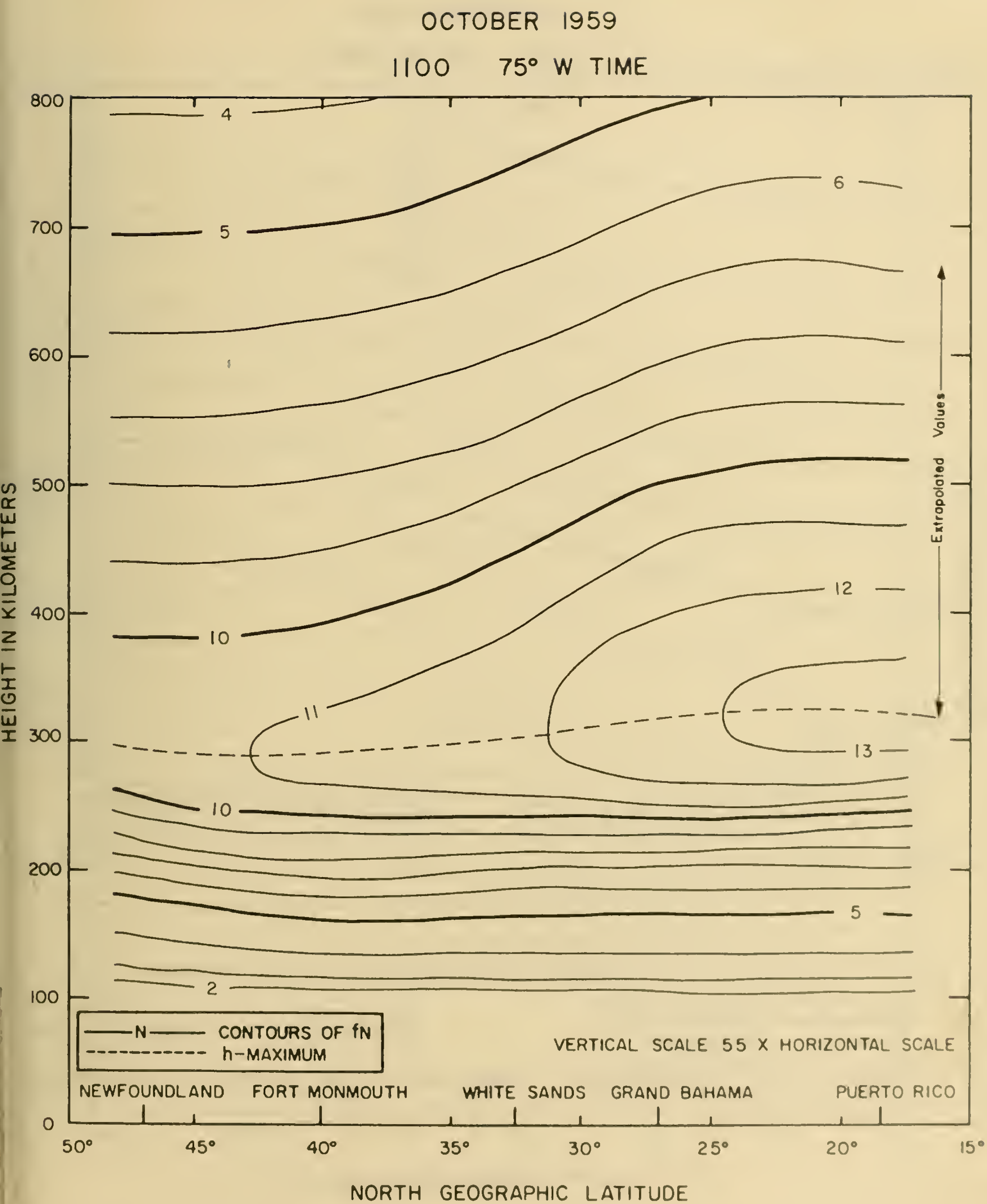
0900 75° W TIME



OCTOBER 1959

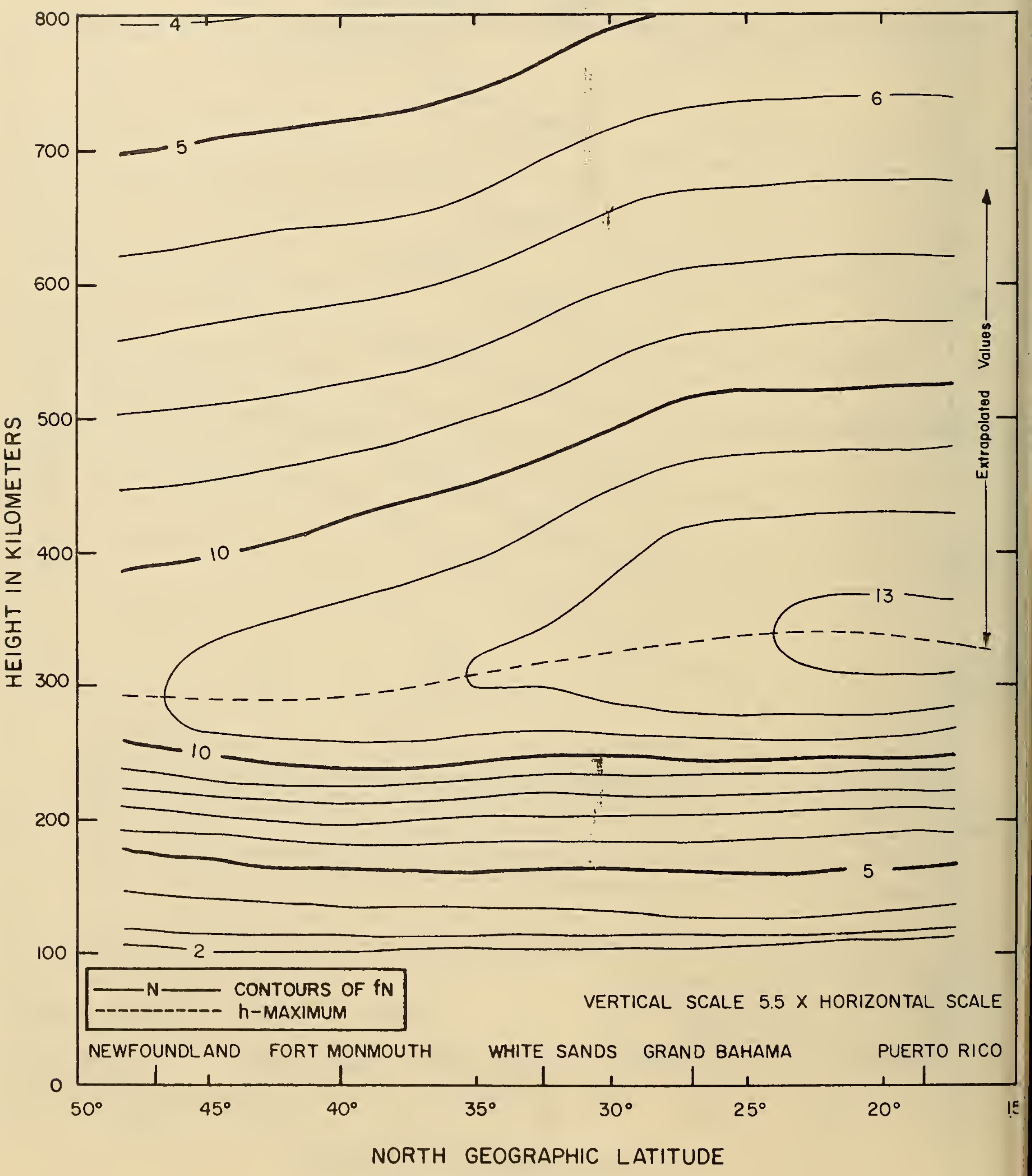
1000 75° W TIME

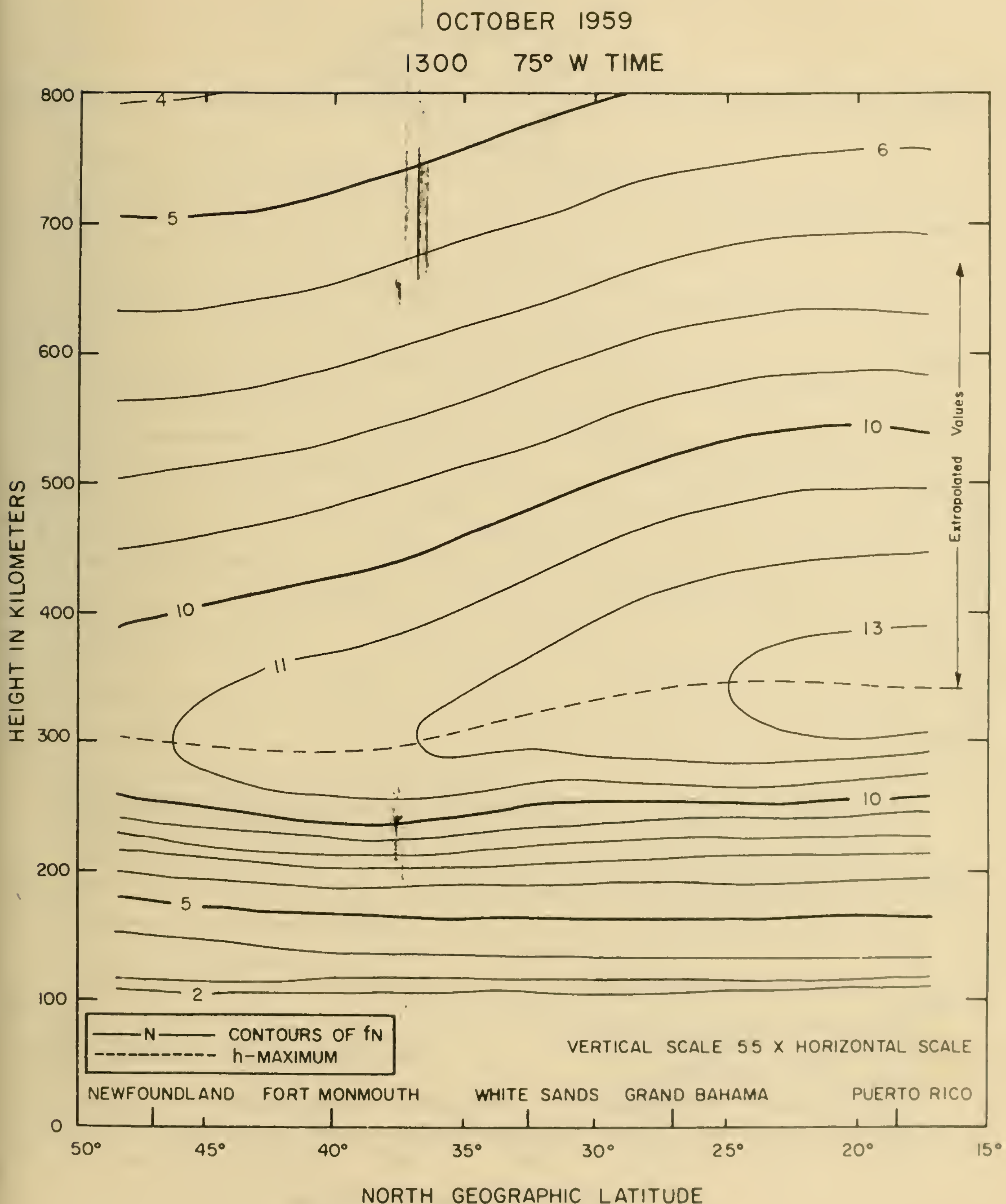



OCTOBER 1959
1100 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
4
5
6
10
11
12
13
10
5
2
Extrapolated Values
—N— CONTOURS OF fN
---------- h-MAXIMUM
VERTICAL SCALE 55 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

OCTOBER 1959

1200 75° W TIME

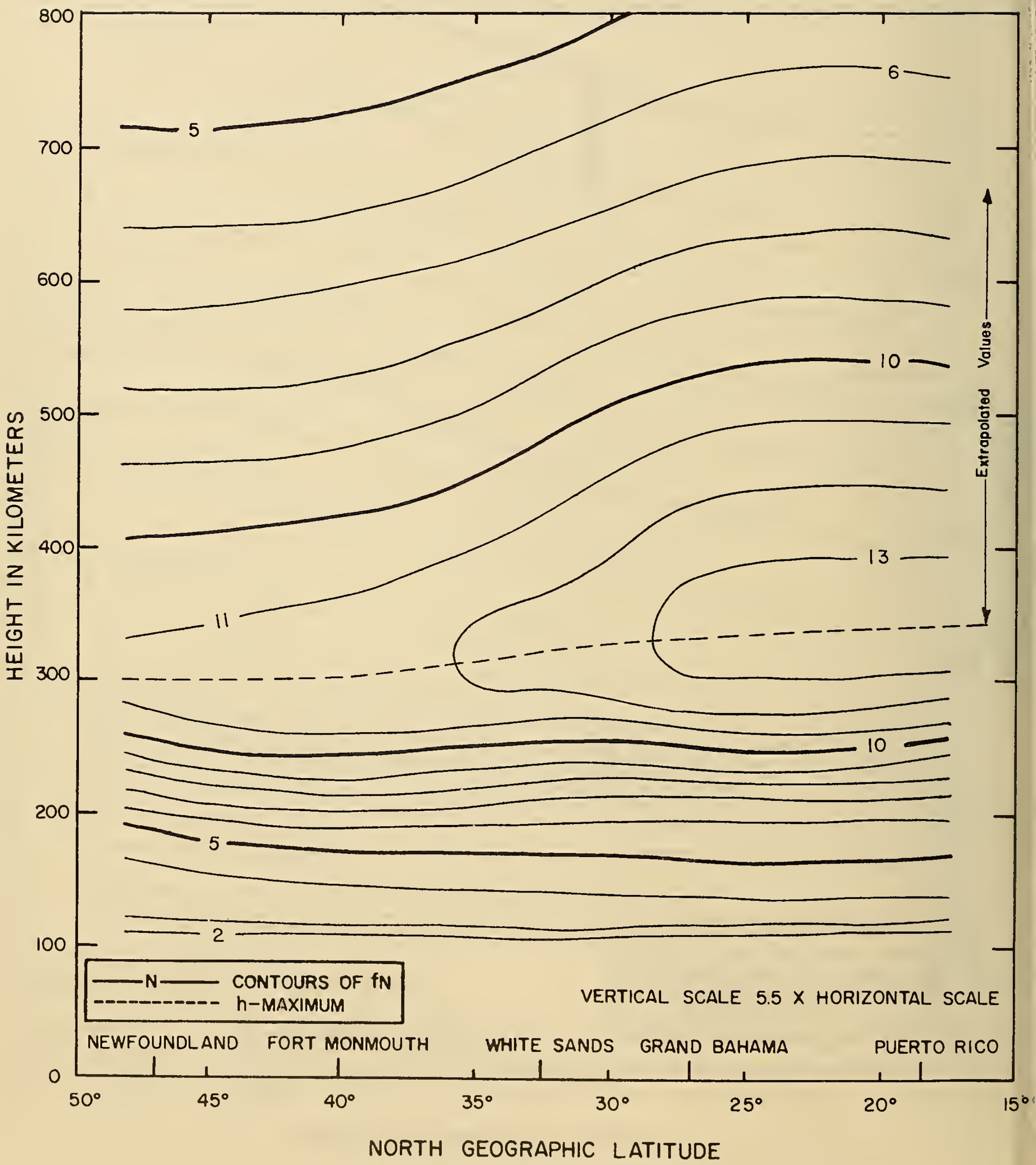




OCTOBER 1959
1300 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
4
5
6
10
11
13
10
5
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 55 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

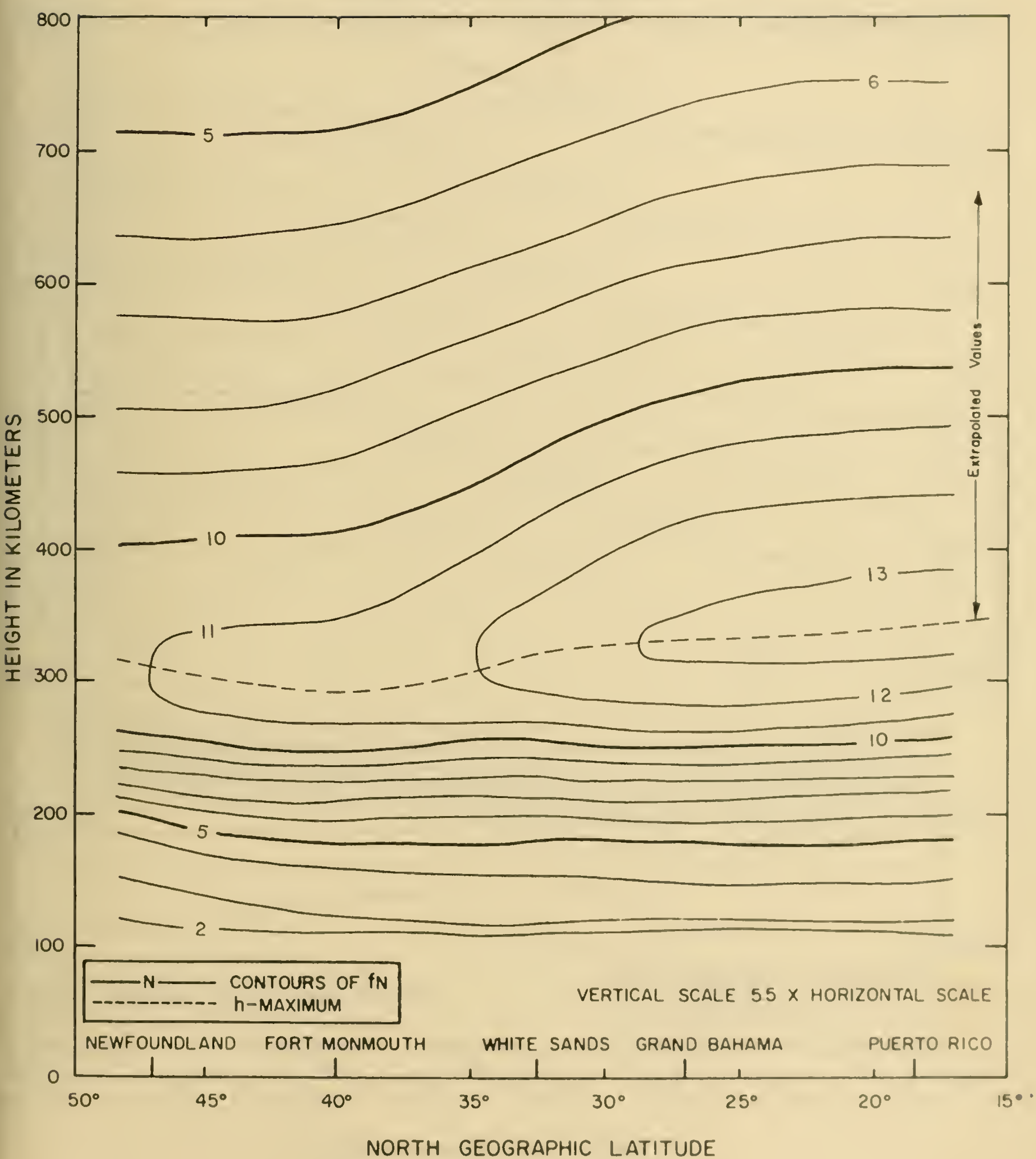
OCTOBER 1959

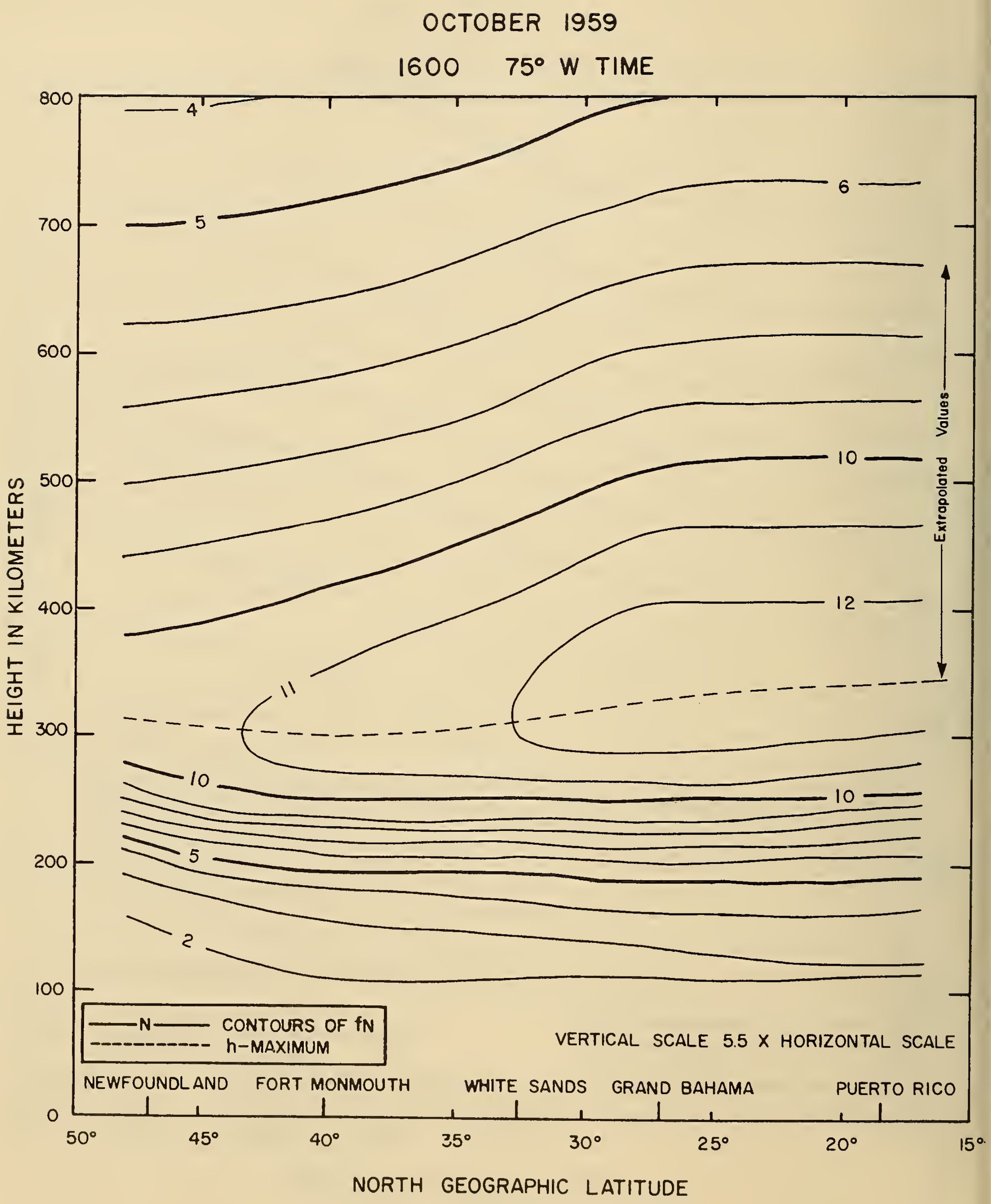
1400 75° W TIME



OCTOBER 1959

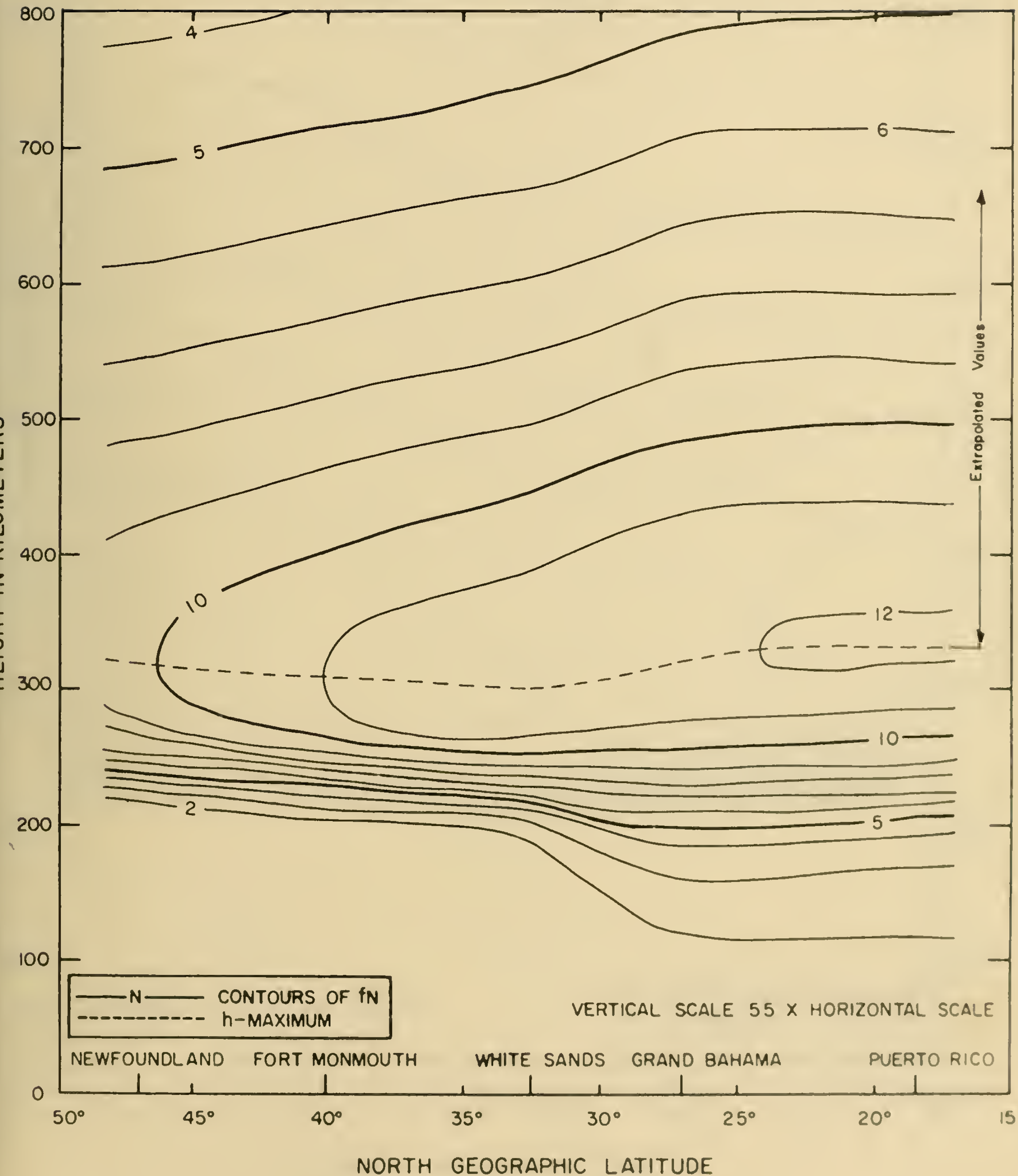
1500 75° W TIME

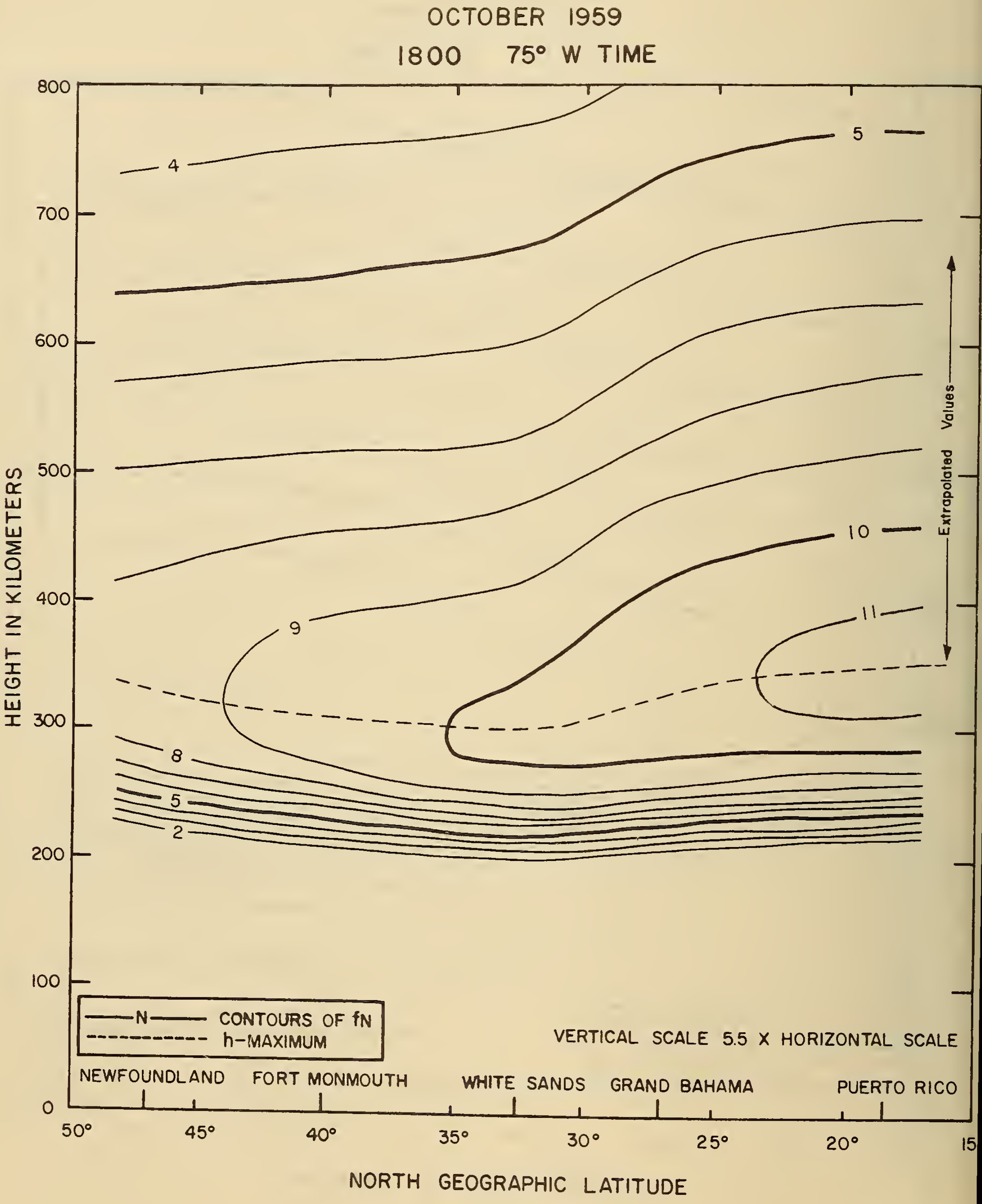



OCTOBER 1959
1600 75° W TIME
800
700
600
500
400
300
200
100
0
HEIGHT IN KILOMETERS
4
5
6
10
12
11
10
5
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

OCTOBER 1959

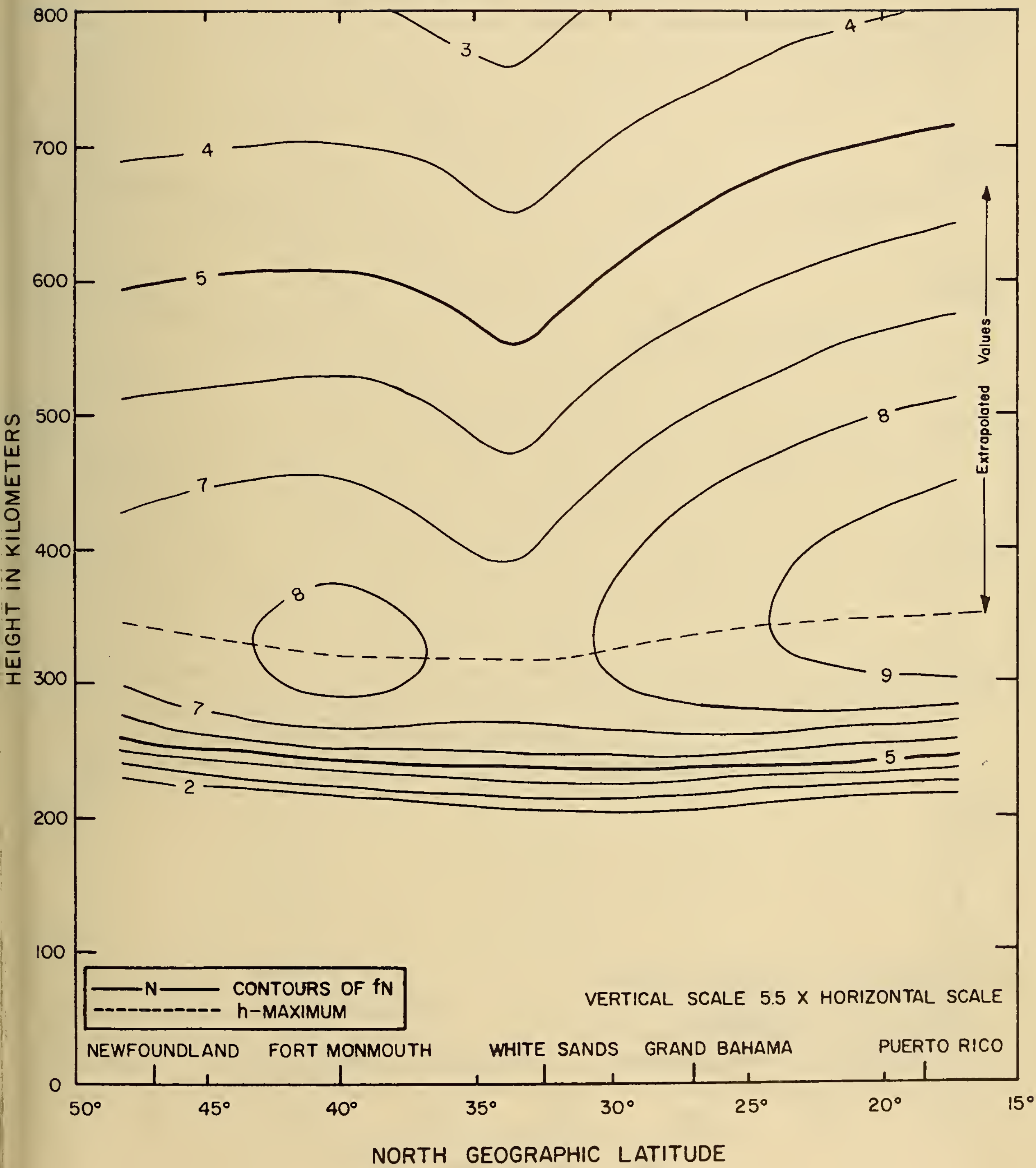
1700 75° W TIME

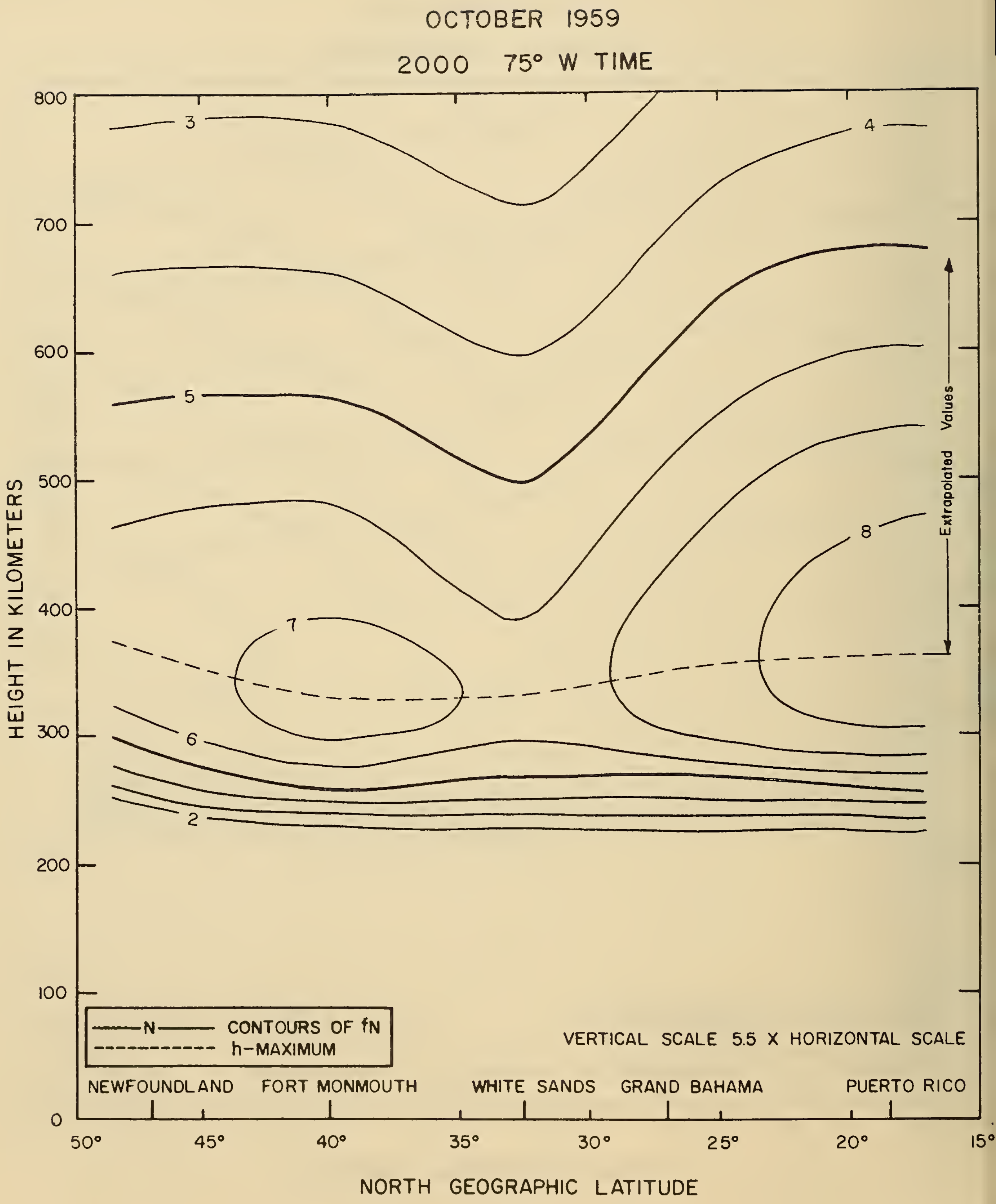



OCTOBER 1959
1800 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
4
5
9
10
11
8
5
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15
NORTH GEOGRAPHIC LATITUDE

OCTOBER 1959

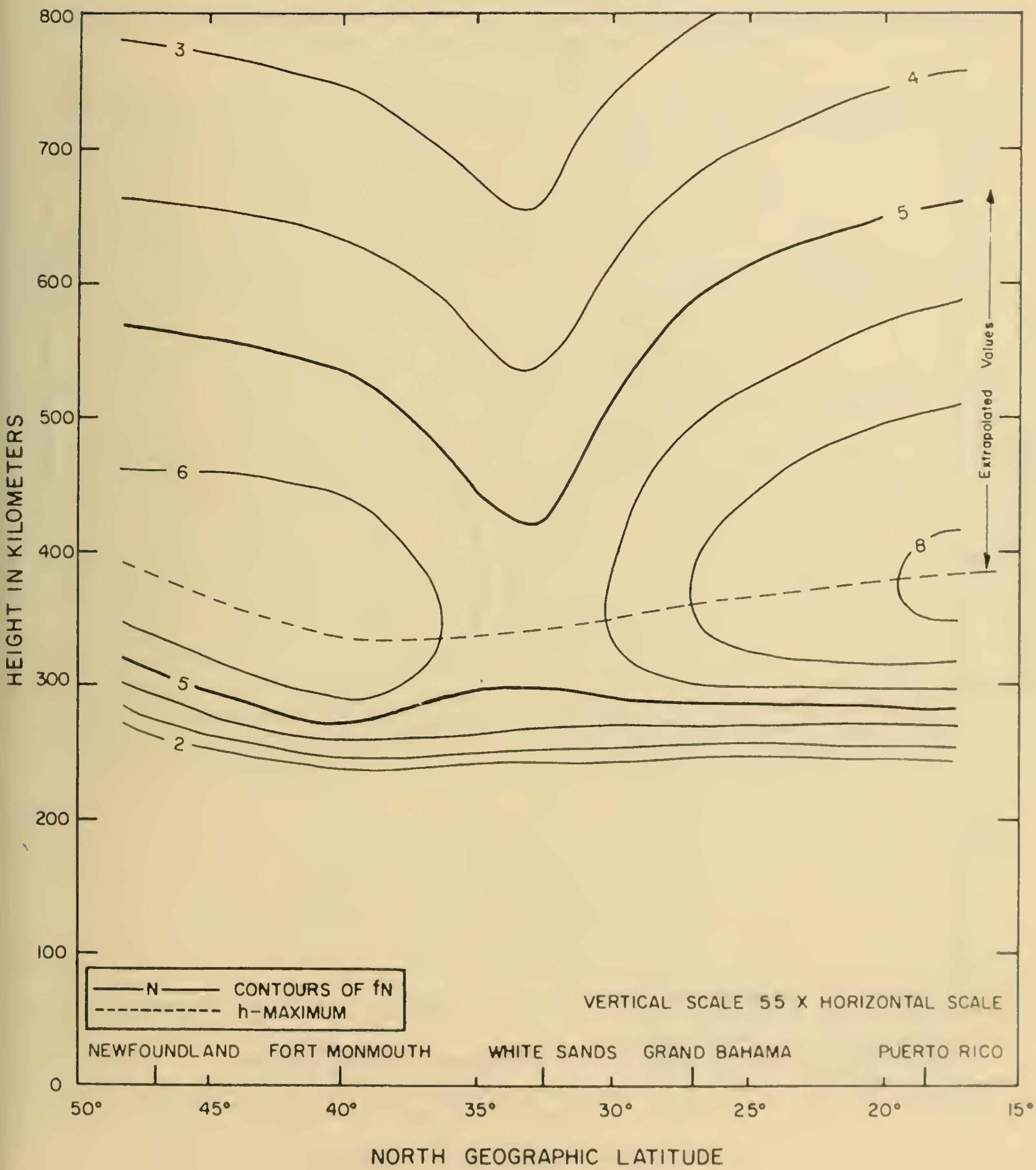
1900 75° W TIME

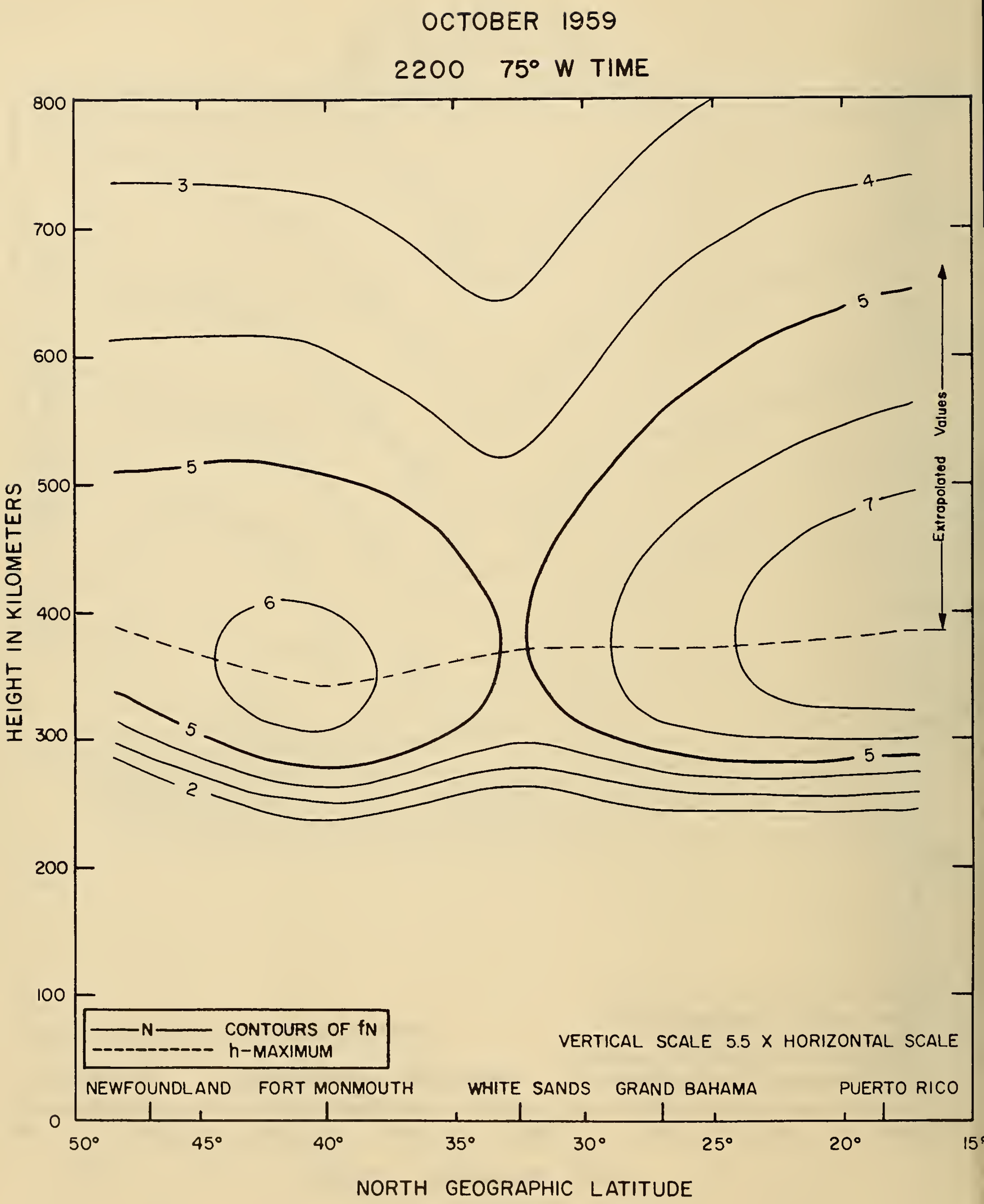


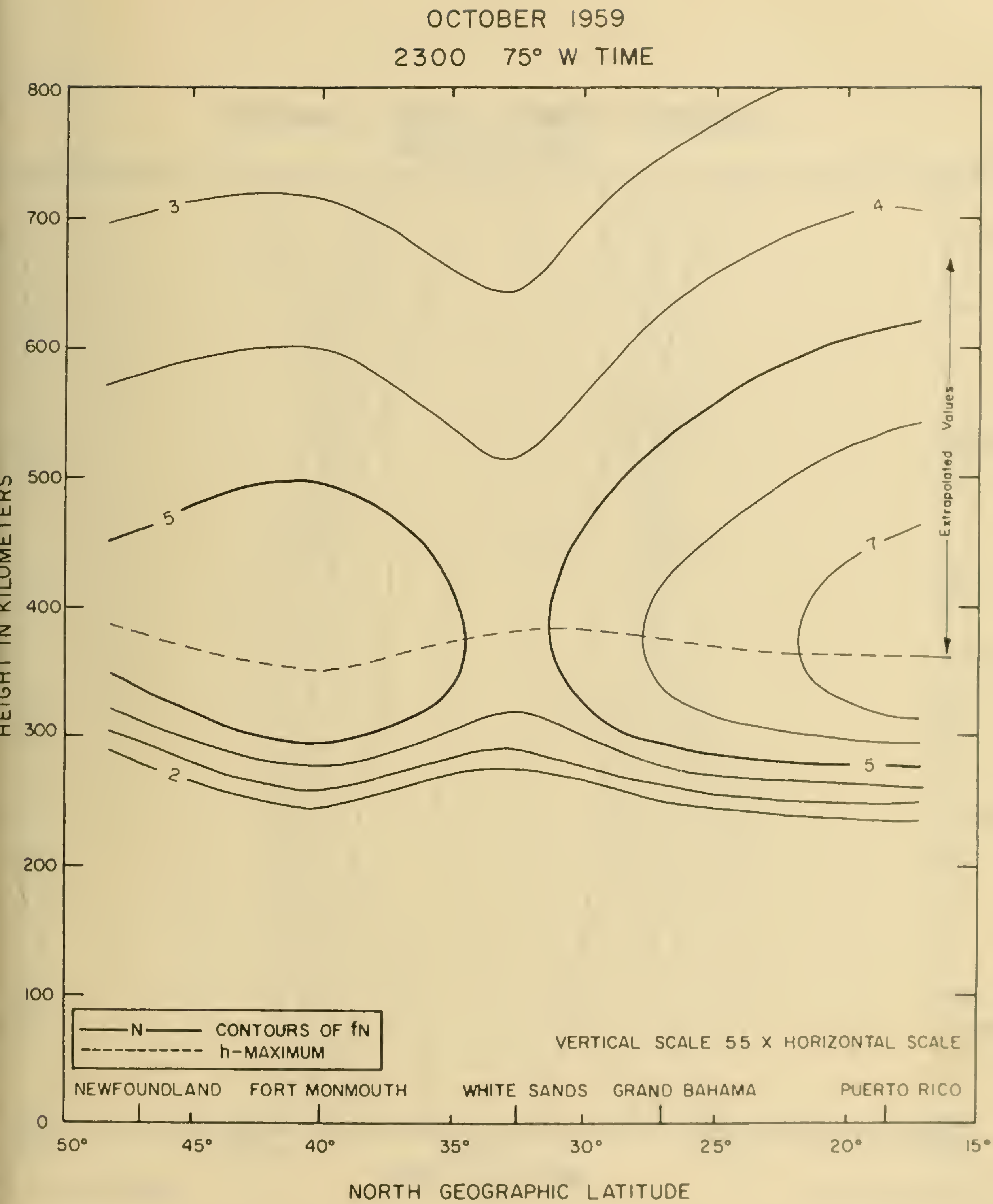

OCTOBER 1959
2000 75° W TIME
800
700
600
500
400
300
200
100
0
HEIGHT IN KILOMETERS
3
4
5
6
7
8
2
Extrapolated Values
N CONTOURS OF fN
h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

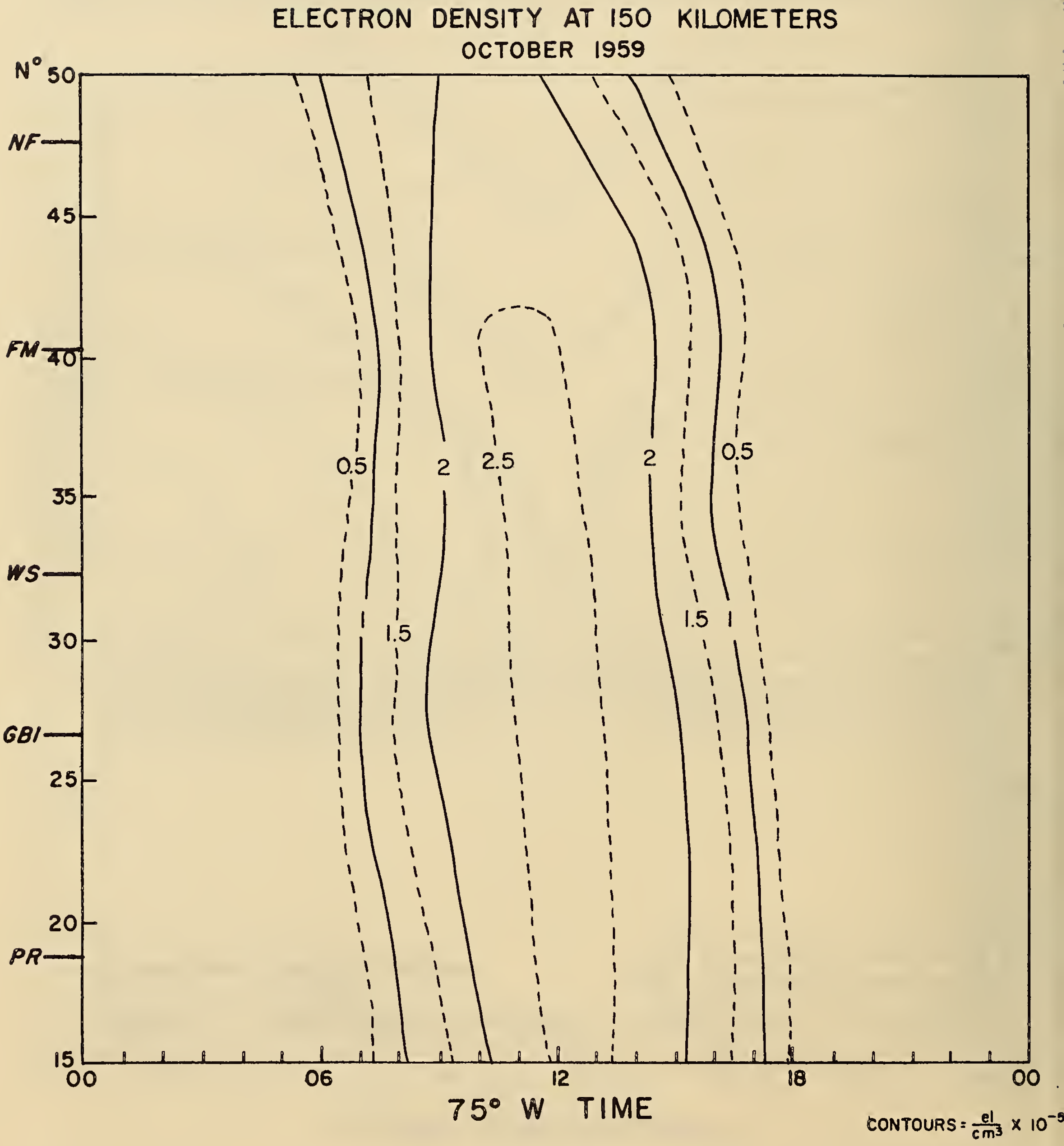
OCTOBER 1959

2100 75° W TIME

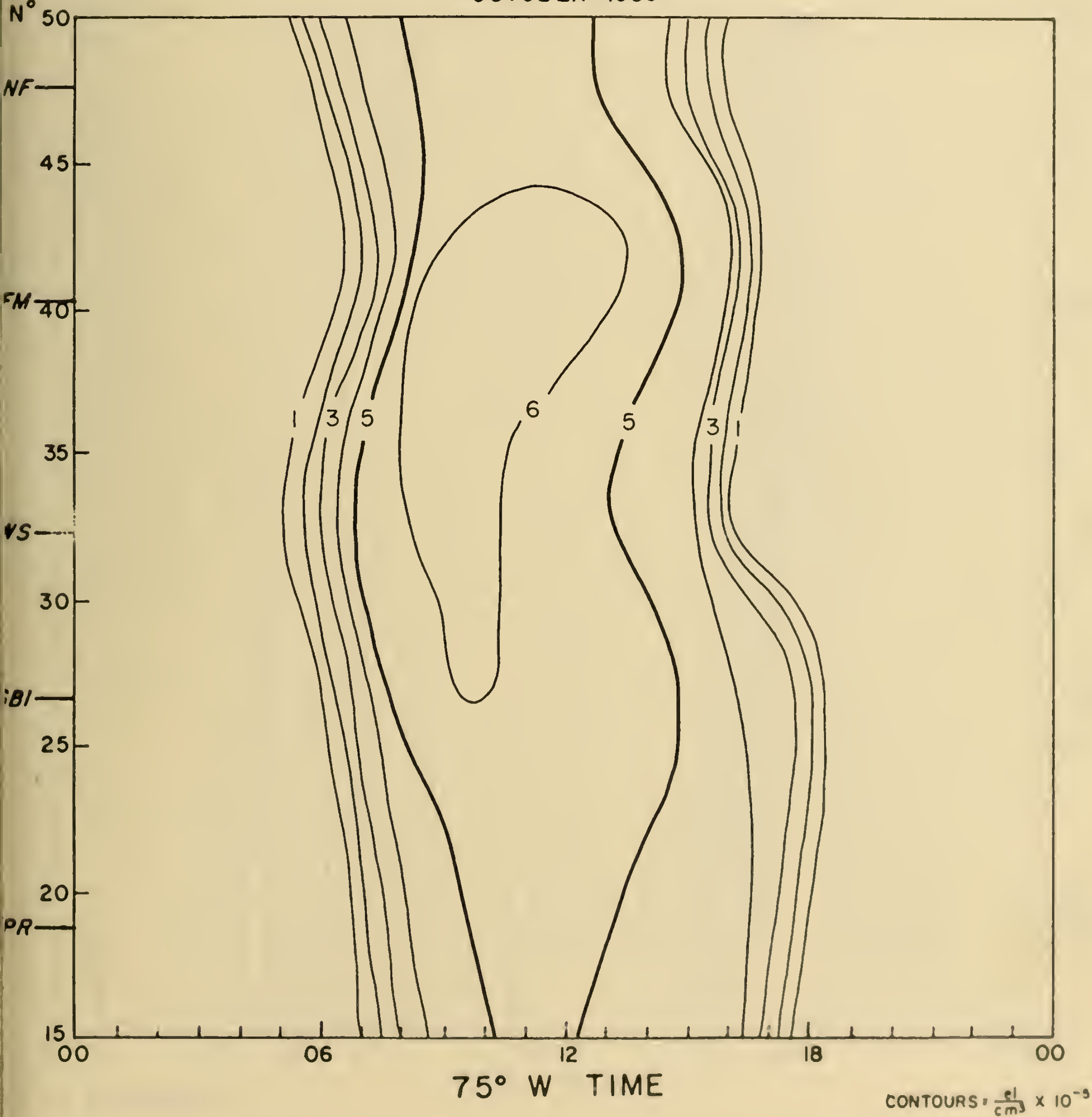


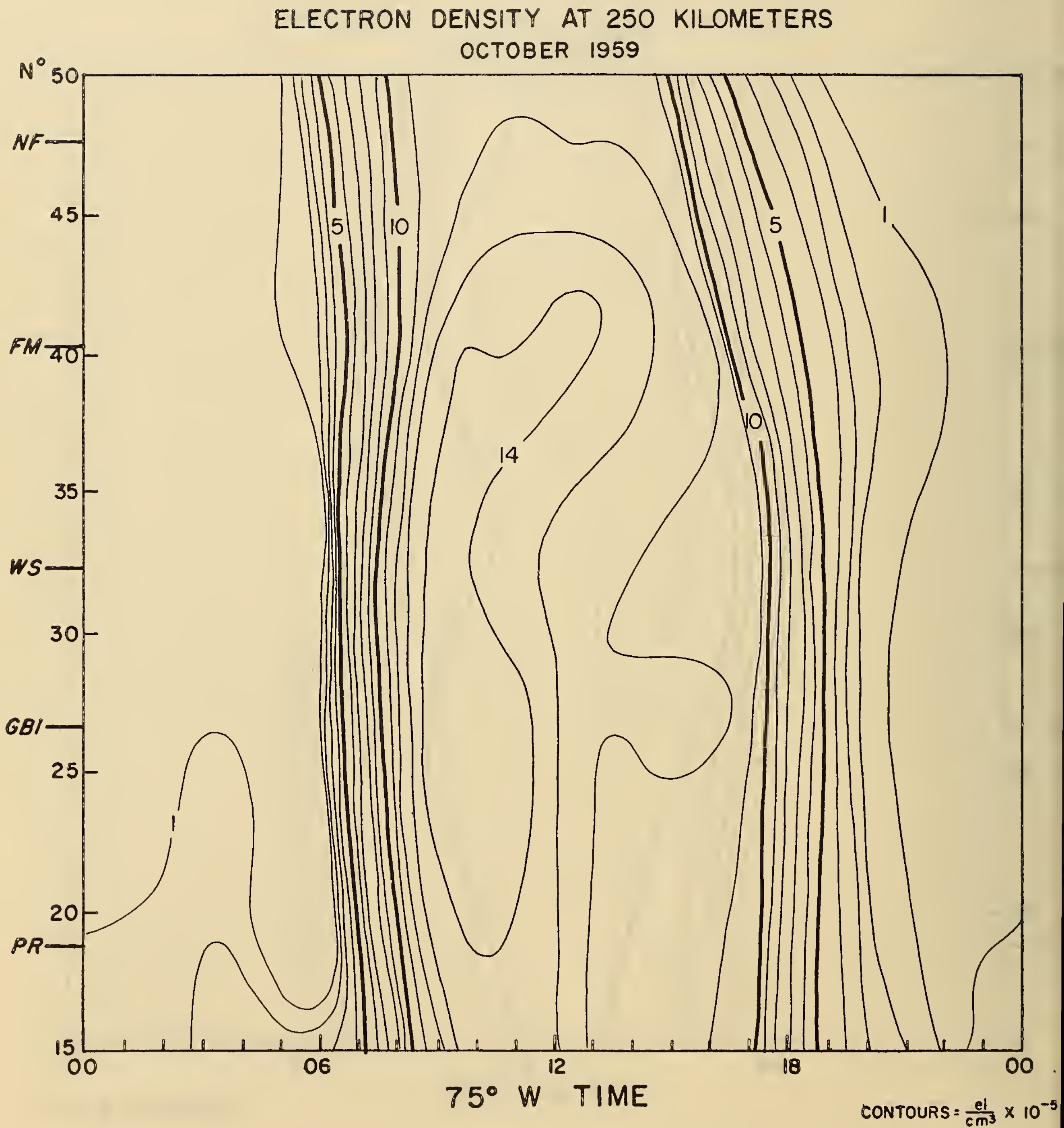

OCTOBER 1959
2200 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
4
5
5
6
7
5
5
2
Extrapolated Values
—N— CONTOURS OF fN
---------- h-MAXIMUM
VERTICAL SCALE 5.5 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH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


OCTOBER 1959
2300 75° W TIME
HEIGHT IN KILOMETERS
800
700
600
500
400
300
200
100
0
3
4
5
7
5
2
Extrapolated Values
—N— CONTOURS OF fN
---------- h-MAXIMUM
VERTICAL SCALE 55 X HORIZONTAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
NORTH GEOGRAPHIC LATITUDE

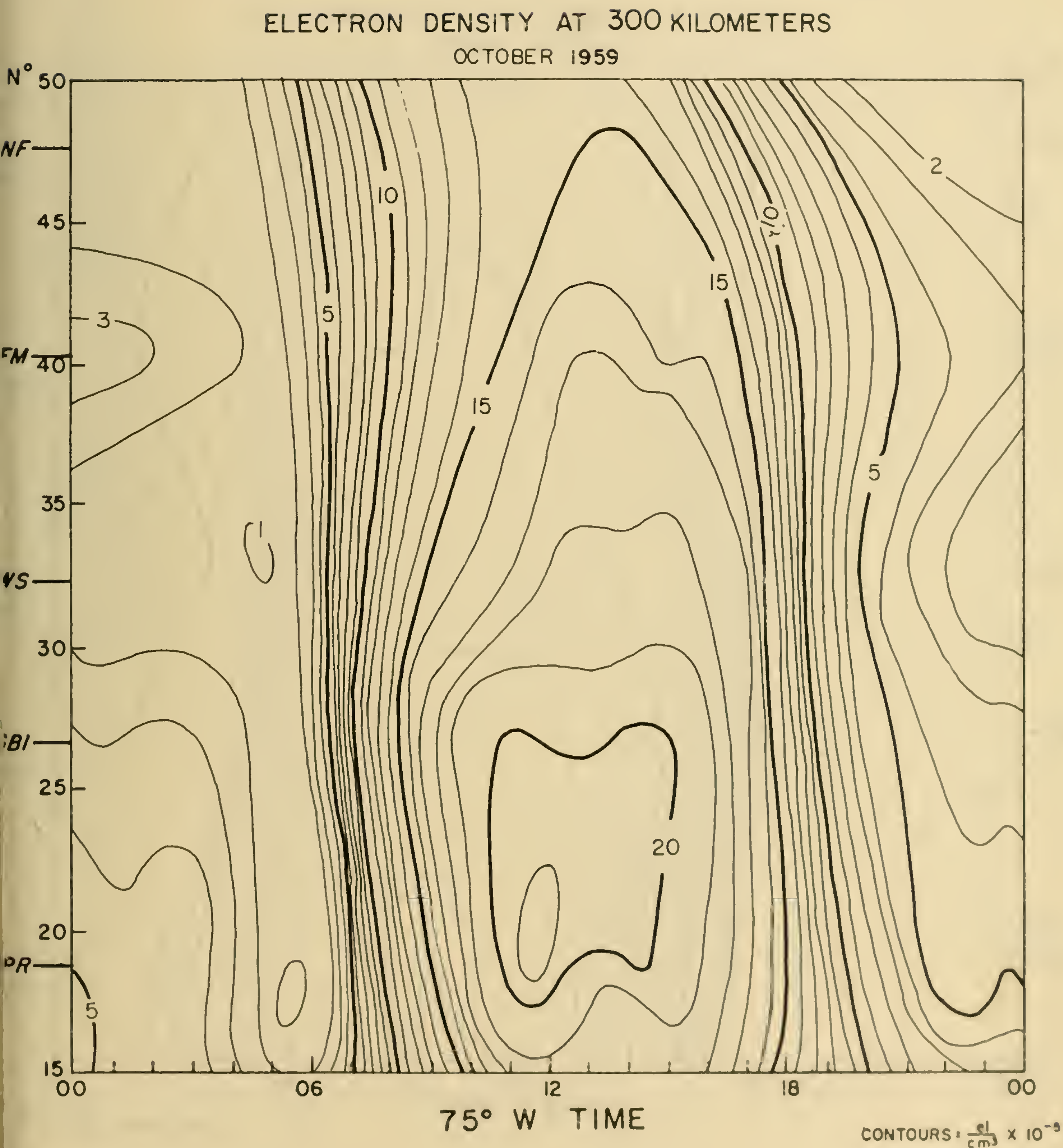

ELECTRON DENSITY AT 150 KILOMETERS
OCTOBER 1959
N°
50
NF
45
FM
40
35
WS
30
GBI
25
20
PR
15
0.5
1.5
2
2.5
2
1.5
1
0.5
00
06
12
18
00
75° W TIME
CONTOURS = el/cm³ x 10⁻⁵

ELECTRON DENSITY AT 200 KILOMETERS
OCTOBER 1959

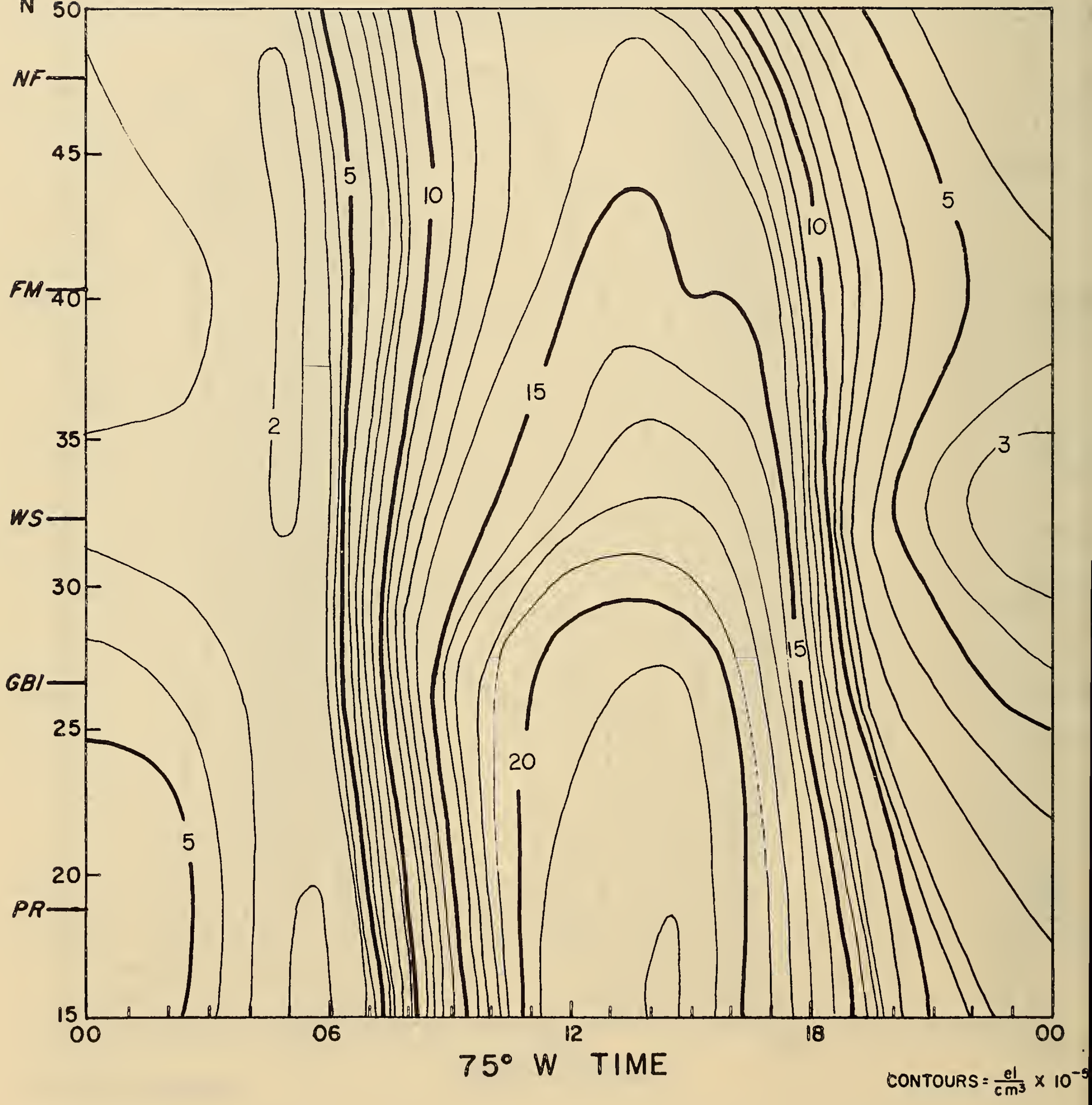


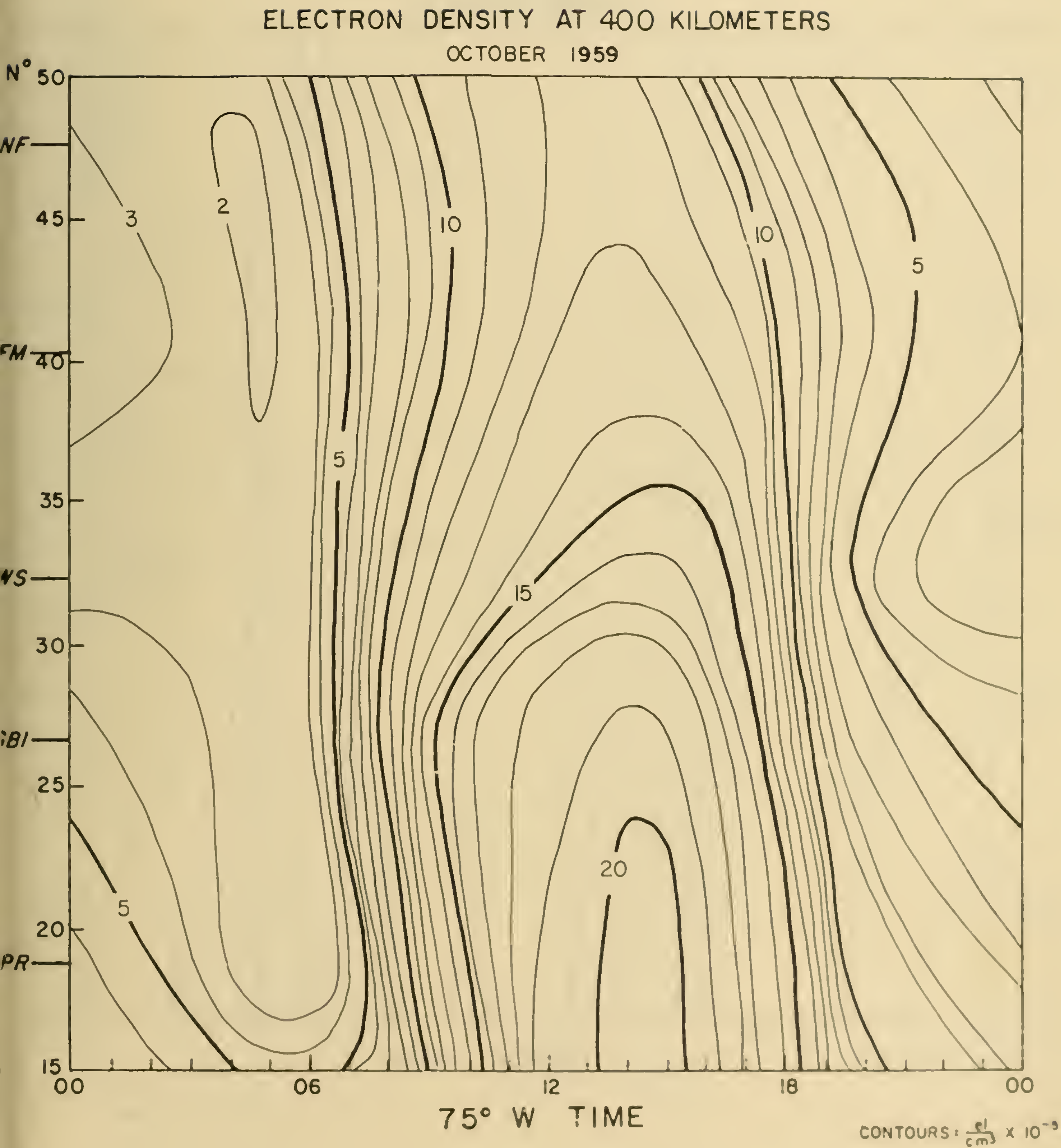


ELECTRON DENSITY AT 250 KILOMETERS
OCTOBER 1959
N°
50
45
40
35
30
25
20
15
NF
FM
WS
GBI
PR
5
10
14
1
00
06
12
18
00
75° W TIME
CONTOURS = el/cm³ x 10⁻⁵


ELECTRON DENSITY AT 300 KILOMETERS
OCTOBER 1959
N°
50
45
40
35
30
25
20
15
NF
FM
VS
BI
PR
3
1
5
10
15
20
2
00
06
12
18
00
75° W TIME
CONTOURS: el/cm³ x 10⁻⁵

ELECTRON DENSITY AT 350 KILOMETERS
OCTOBER 1959

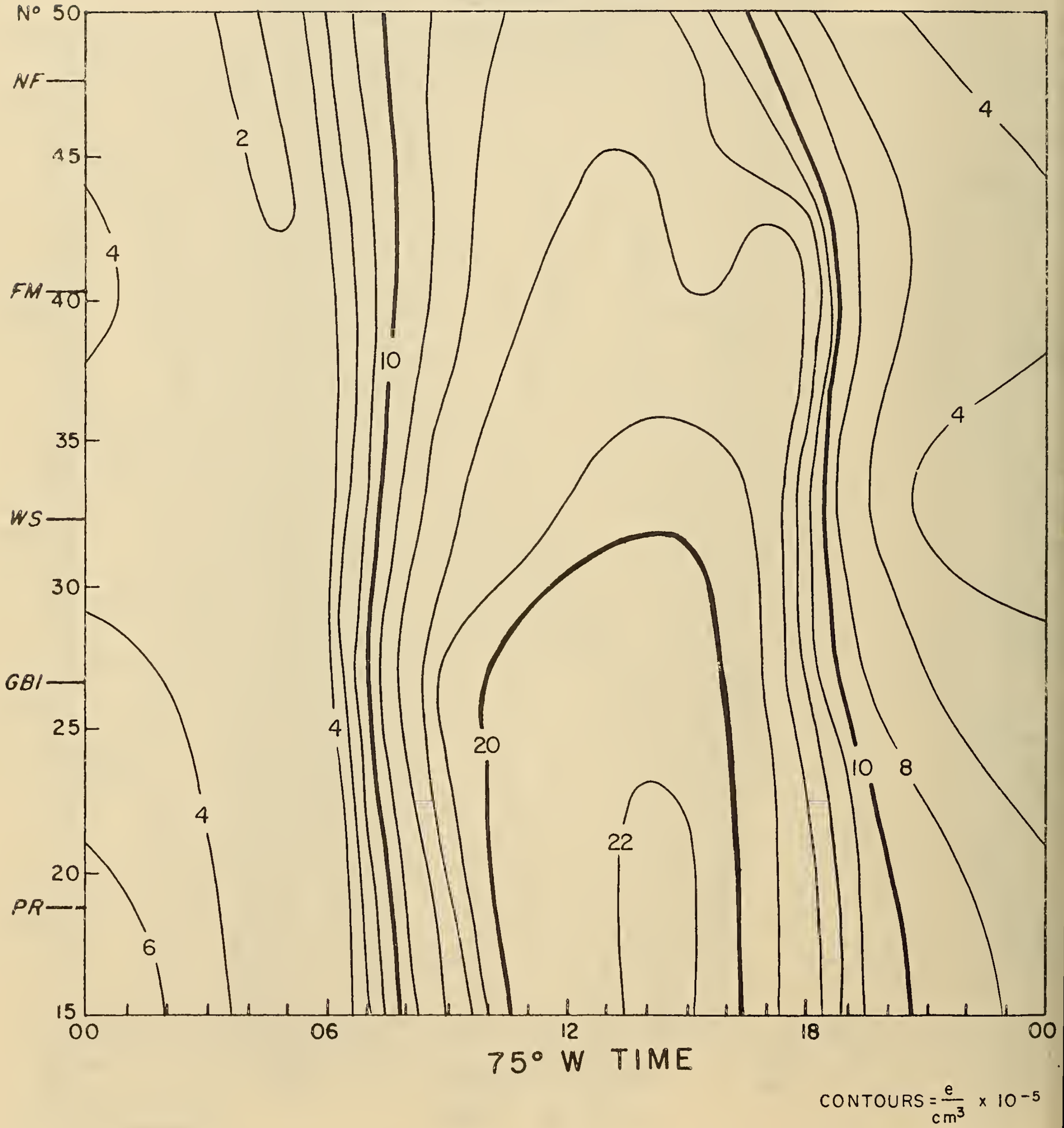



ELECTRON DENSITY AT 400 KILOMETERS
OCTOBER 1959
N° 50
NF
45
FM 40
35
NS
30
GBI
25
20
PR
15
00
06
12
18
00
75° W TIME
CONTOURS: el/cm³ x 10⁻⁵
2
3
5
10
15
20

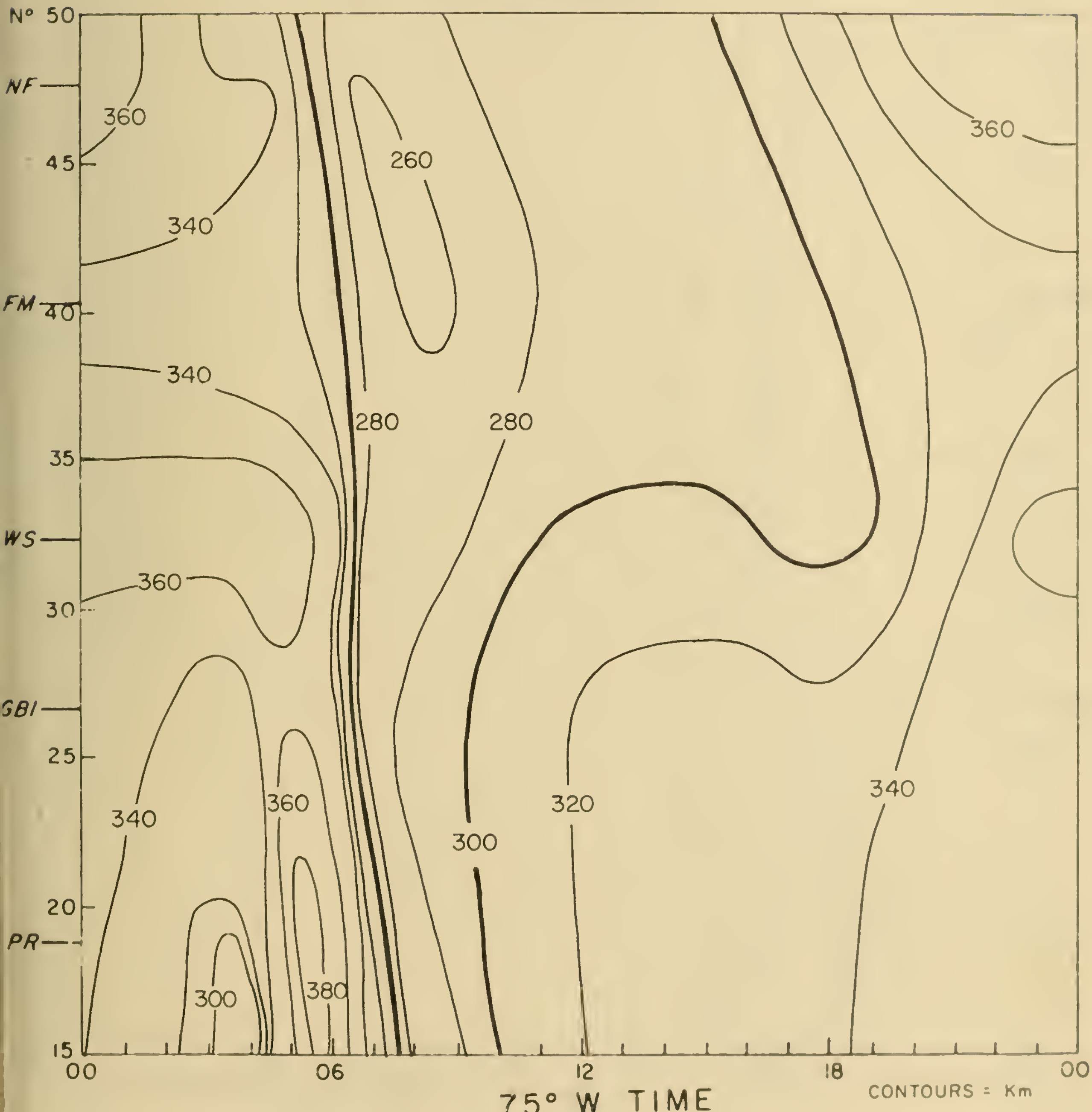
MAXIMUM ELECTRON DENSITY

NMAX

OCTOBER 1959



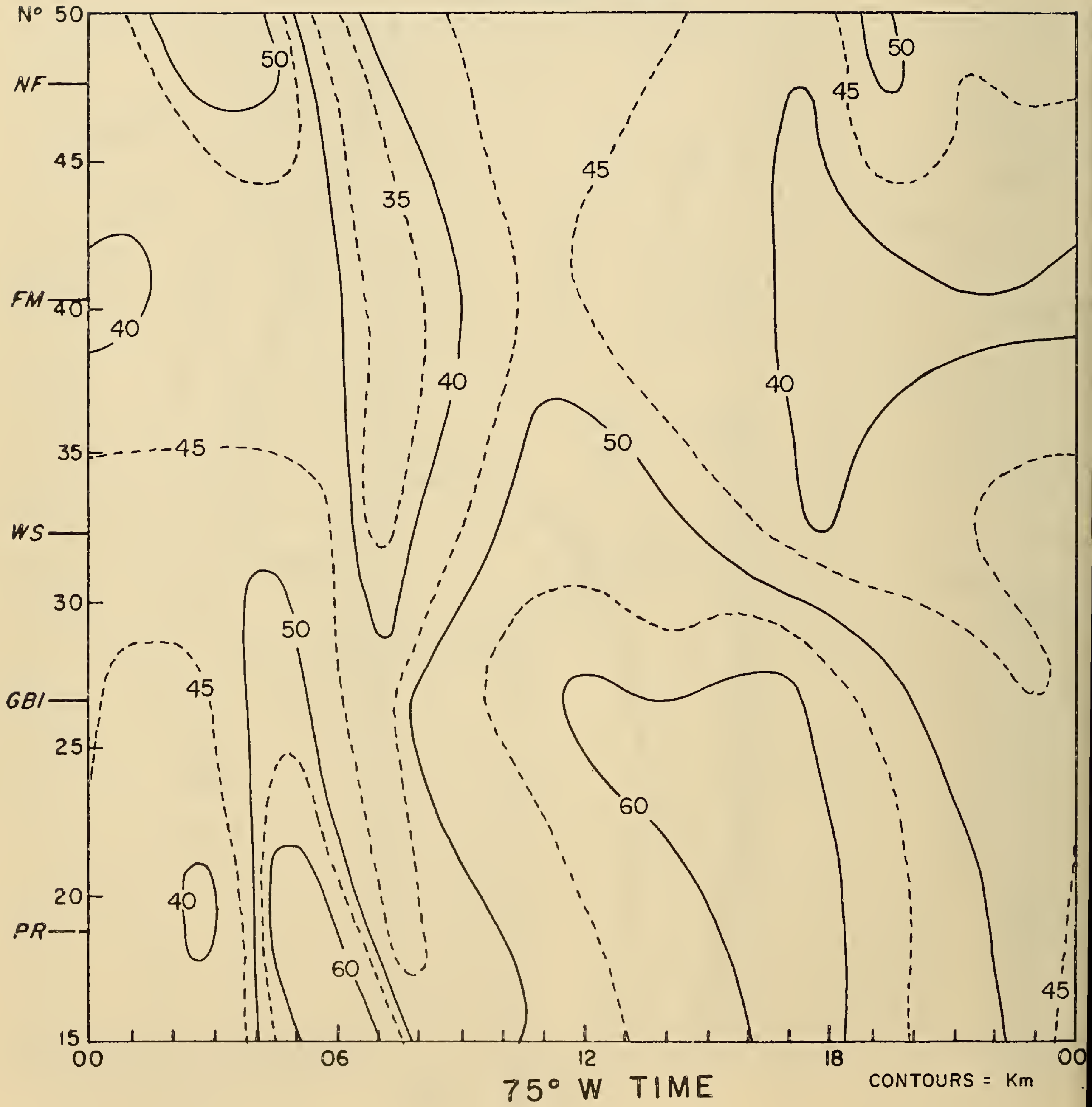
HEIGHT OF MAXIMUM ELECTRON DENSITY
HMAX
OCTOBER 1959



QUARTER THICKNESS OF F-REGION PEAK

SCAT

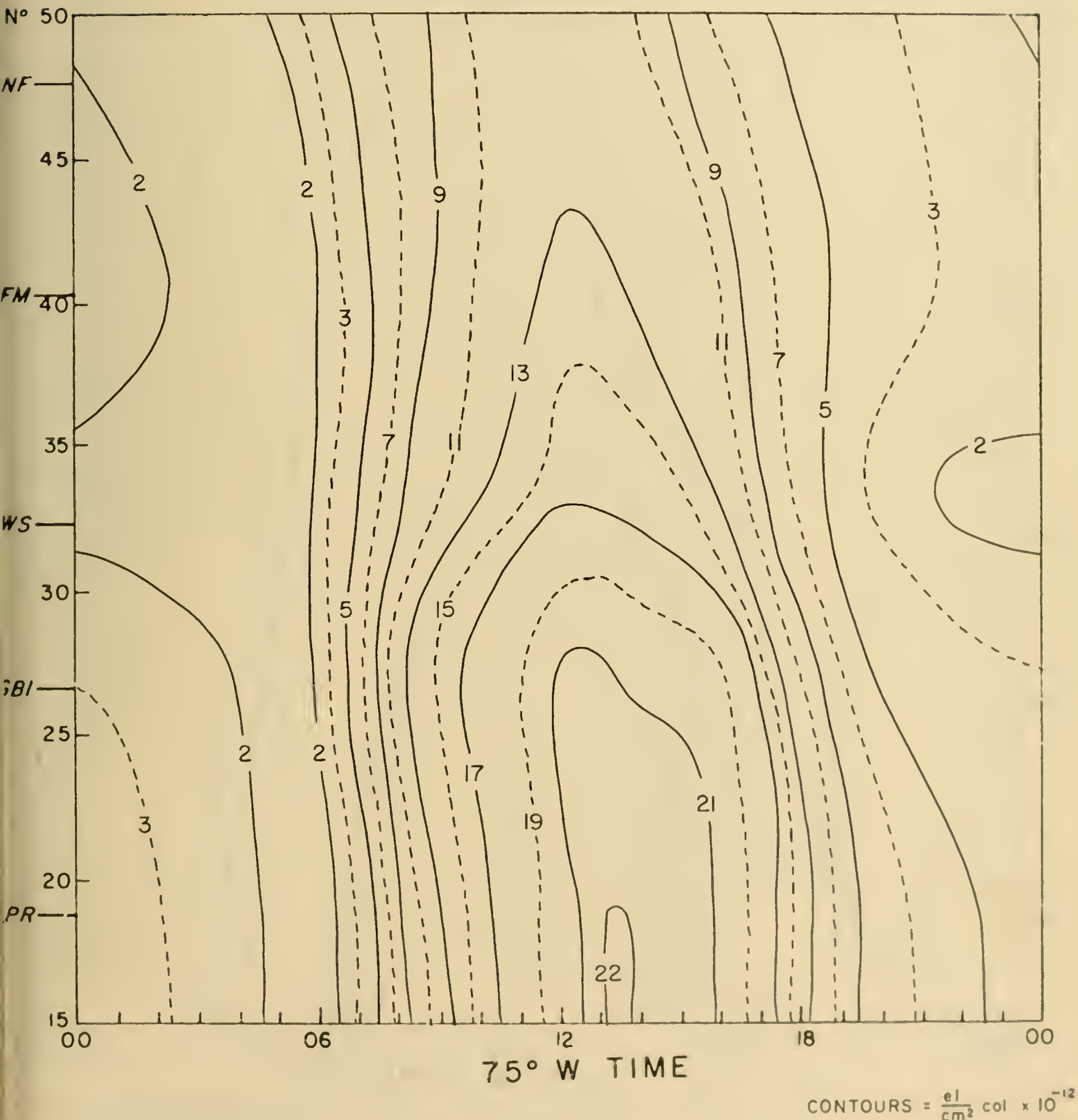
OCTOBER 1959



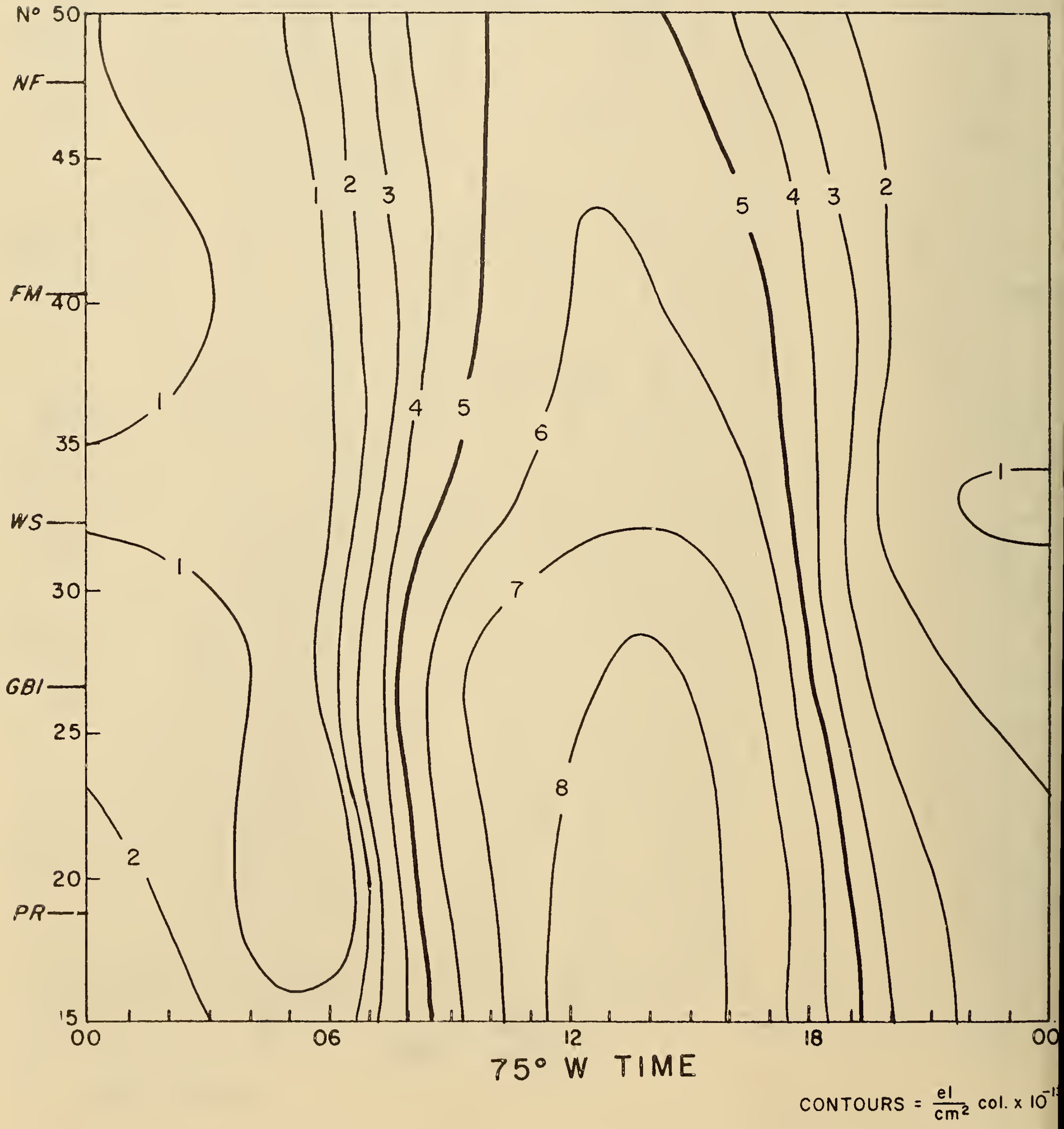
ELECTRON DENSITY INTEGRATED TO HEIGHT OF MAXIMUM ELECTRON DENSITY

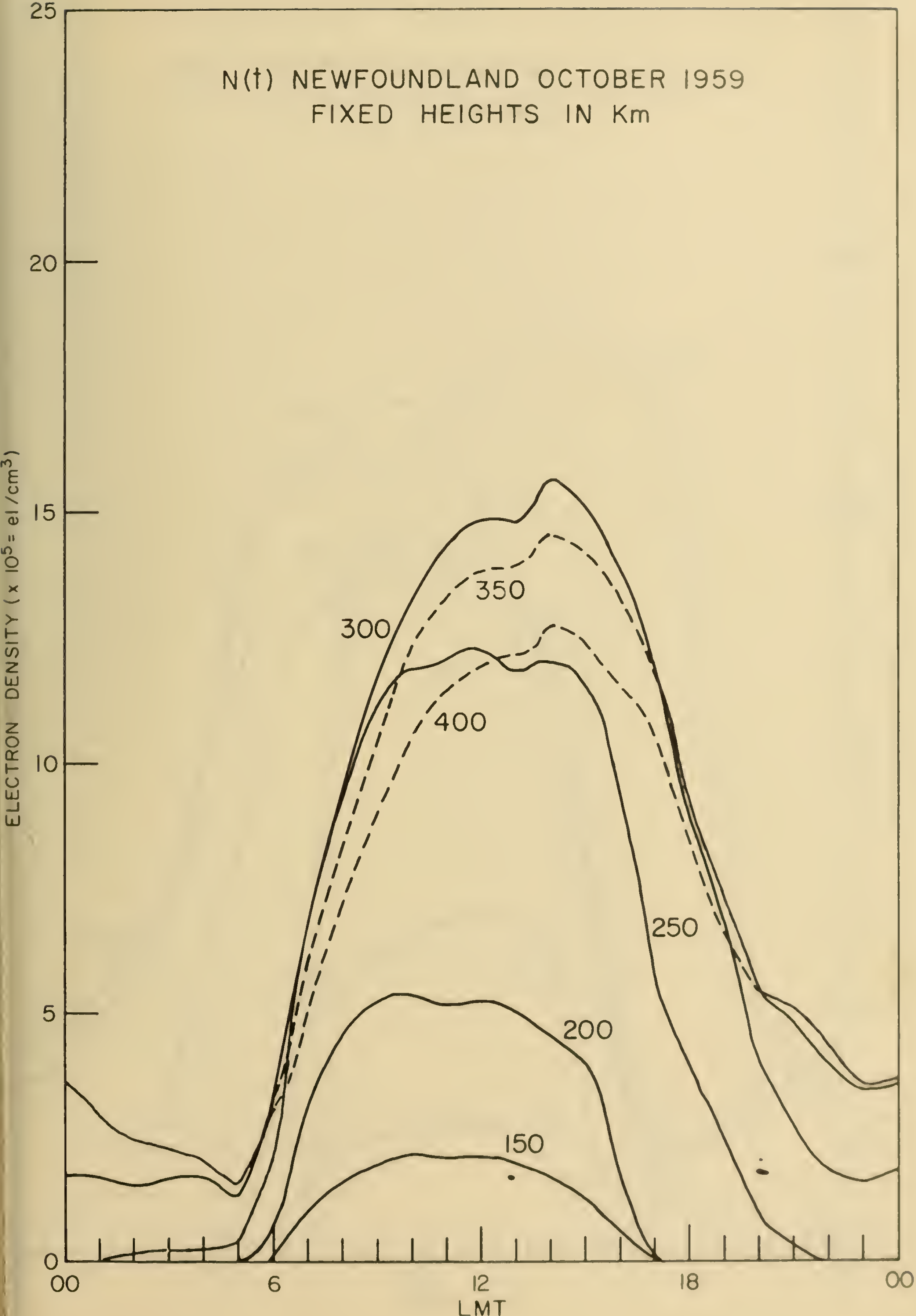
SHMAX

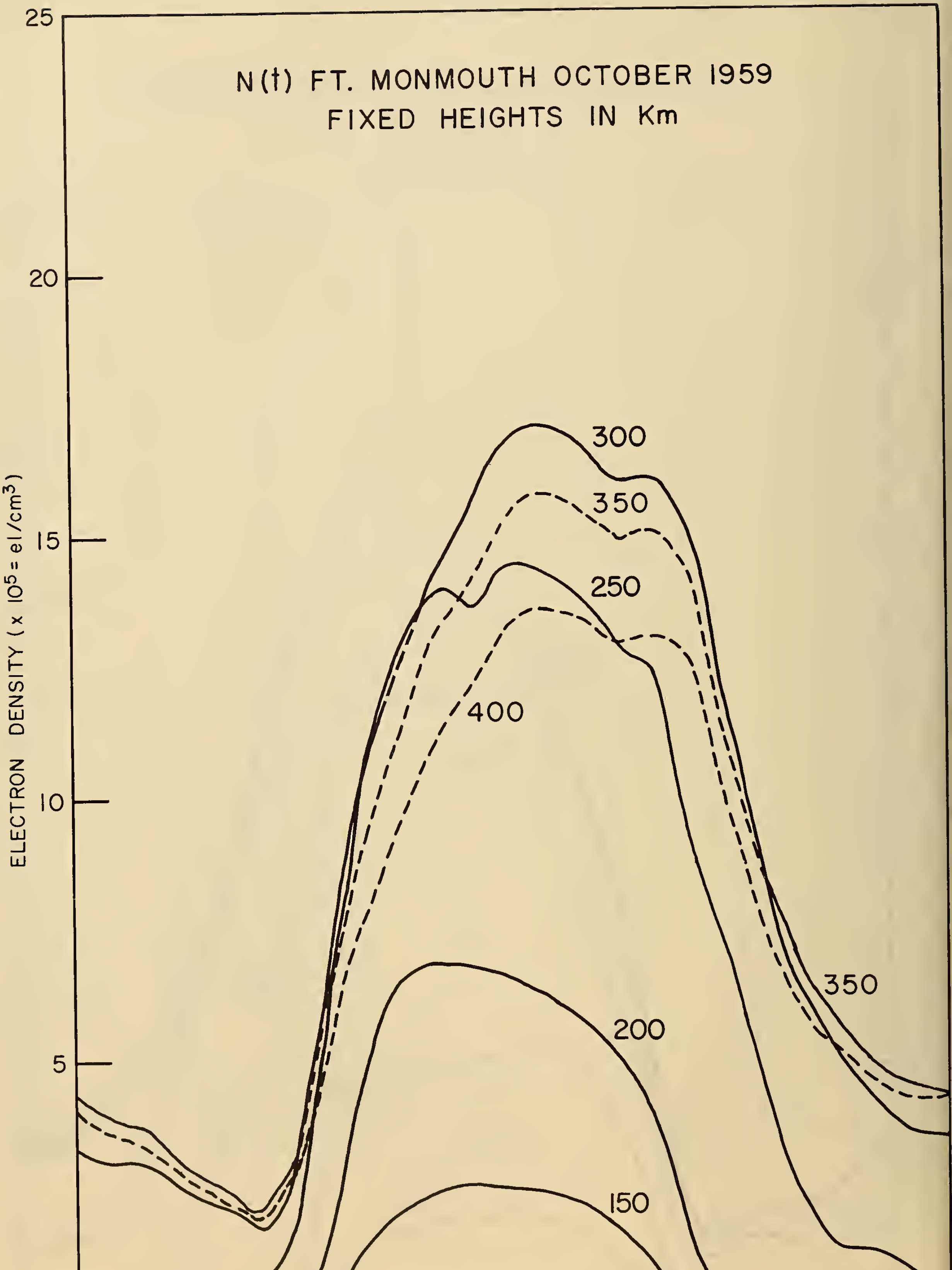
OCTOBER 1959

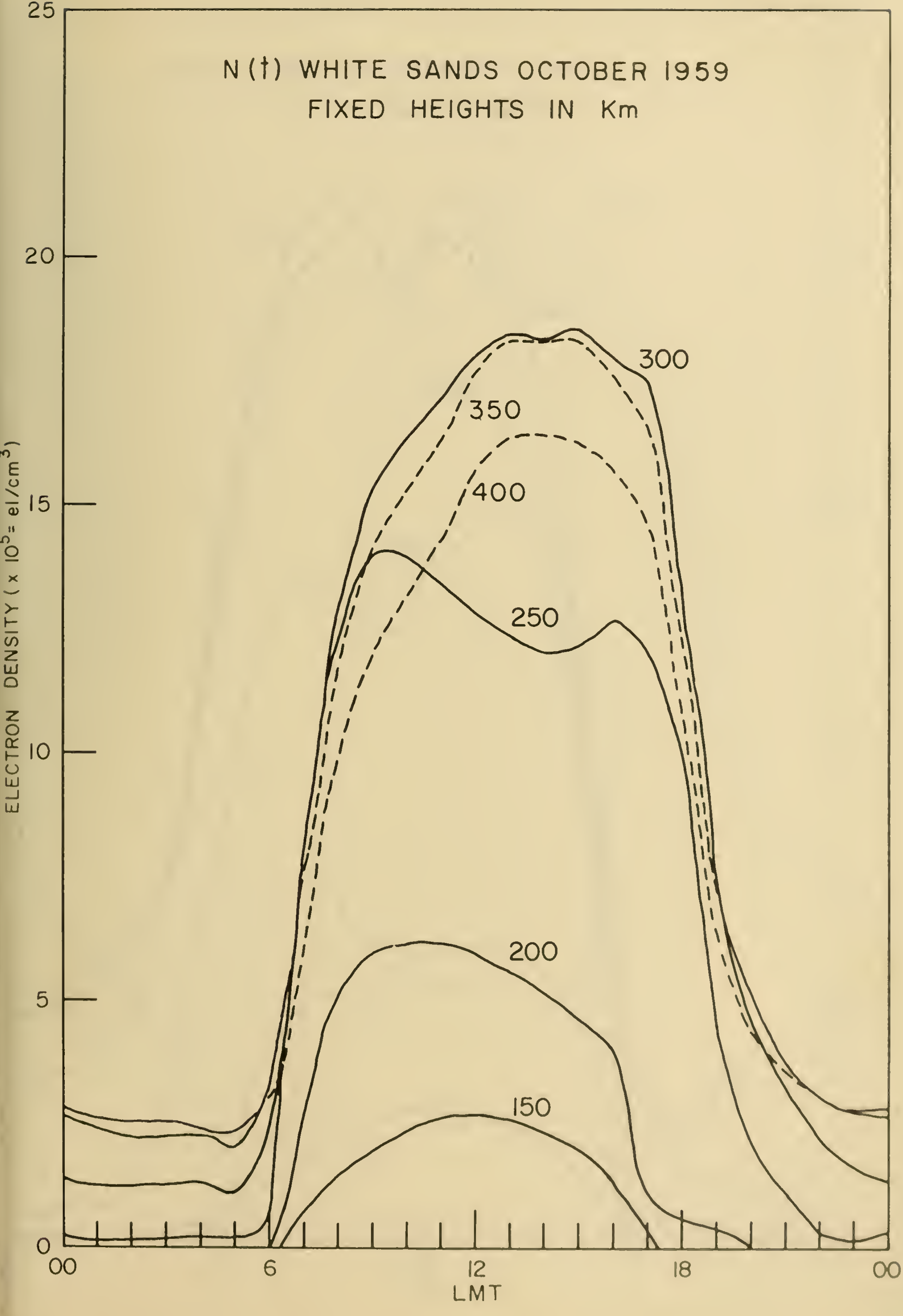


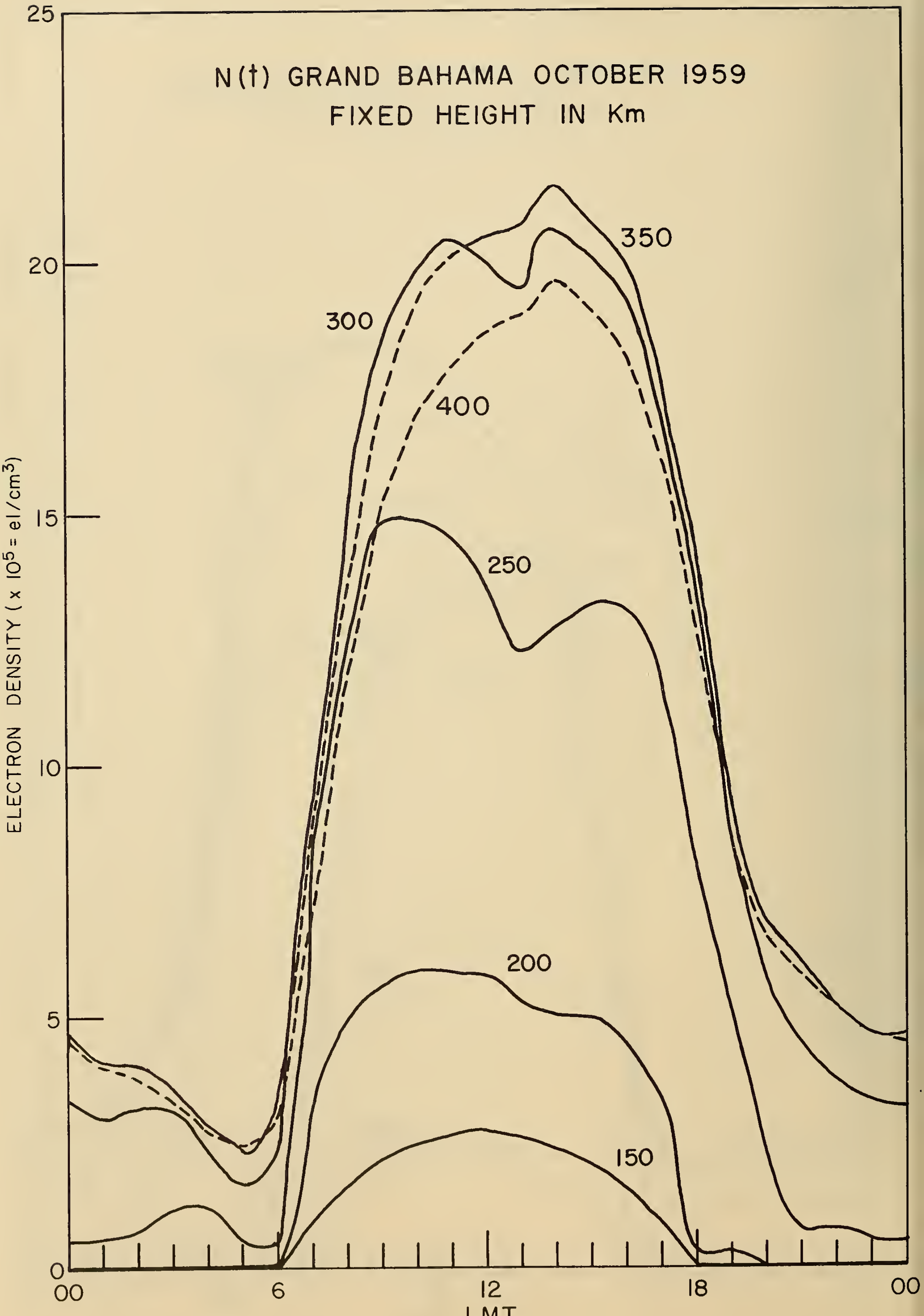
ELECTRON DENSITY INTEGRATED TO INFINITY
SHINF
OCTOBER 1959

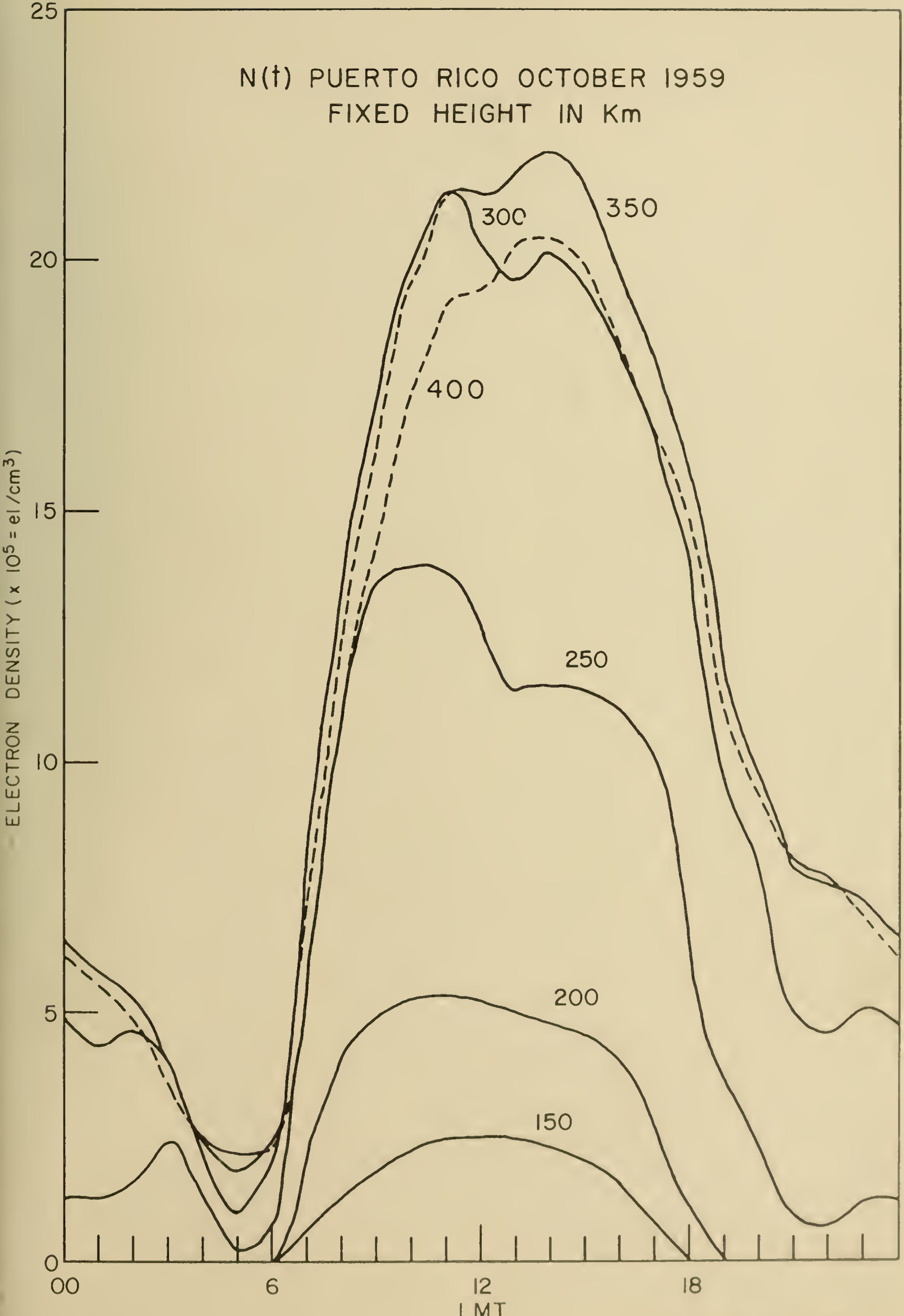



N(t) NEWFOUNDLAND OCTOBER 1959
FIXED HEIGHTS IN Km
ELECTRON DENSITY (x 10^5 = el/cm^3)
25
20
15
10
5
0
300
350
400
250
200
150
00
6
12
18
00
LMT


N(t) FT. MONMOUTH OCTOBER 1959
FIXED HEIGHTS IN Km
ELECTRON DENSITY (x 10^5 = el/cm^3)
25
20
15
10
5
0
300
350
250
400
350
200
150
00
6
12
18
LMT


N(t) WHITE SANDS OCTOBER 1959
FIXED HEIGHTS IN Km
300
350
400
250
200
150
ELECTRON DENSITY (x 10^5 = el/cm^3)
25
20
15
10
5
0
00
6
12
18
00
LMT


N(t) GRAND BAHAMA OCTOBER 1959
FIXED HEIGHT IN Km
ELECTRON DENSITY (x 10⁵ = el/cm³)
25
20
15
10
5
0
00
6
12
18
00
LMT
350
300
400
250
200
150



U.S. GOVERNMENT PRINTING OFFICE : 1962

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

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

THE NATIONAL BUREAU OF STANDARDS

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

WASHINGTON, D. C.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Office of Weights and Measures.

BOULDER, COLO.

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

CENTRAL RADIO PROPAGATION LABORATORY

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

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

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

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

RADIO STANDARDS LABORATORY

Radio Physics. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time-Interval Standards. Radio Plasma. Millimeter-Wave Research.

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

NBS