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Boulder Laboratories

MEAN ELECTRON DENSITY VARIATIONS OF THE QUIET IONOSPHERE

2 - APRIL 1959

BY J. W. WRIGHT AND L. A. FINE

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS

Technical Note

40-2

February 1960

Mean Electron Density Variations

of the Quiet Ionosphere 2 - April 1959

by J. W. Wright and L. A. Fine

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2 - APRIL 1959

By J. W. Wright and L. A. Fine
Central Radio Propagation Laboratory

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 April are illustrated graphically. This report is the second of a series illustrating the electron density variations in the mean quiet ionosphere between latitudes 15°N and 50°N along the 75°W meridian.

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I Introduction

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

In fact, the vertical sounding is potentially capable of providing the complete electron density profile of the underside of the ionosphere (i.e., below hmaxF2), and of providing a basis for extrapolation to much greater altitudes. However, because a lengthy and difficult calculation is required, little of this work had been done until quite recently when techniques and computers have become available, and the exigencies of the IGY and satellite programs have made it imperative.

In the course of its development of facilities for electron density profile calculations, the CRPL has succeeded in devising means by which basic data for this purpose may be scaled by the individual field stations, thereby decentralizing and simplifying the most onerous part of the work. Through its own station network and in cooperation with the U. S. Army Signal Ionosphere Stations of the Signal Radio Propagation Agency, the CRPL has initiated an extensive systematic data reduction program, from which hourly electron density profiles are being computed for the following stations:

Puerto Rico (NBS, January 1959)
Grand Bahama Island (U. S. Army Signal Corps, February 1959)
Fort Monmouth, New Jersey (U. S. Army Signal Corps, Feb. 1959)
White Sands, New Mexico (U. S. Army Signal Corps, March 1959)
St. Johns, Newfoundland (U. S. Army Signal Corps, April 1959)
Adak, Alaska (U. S. Army Signal Corps, June 1959)
Okinawa, Ryukus (U. S. Army Signal Corps, June 1959)
Thule, Greenland (U. S. Army Signal Corps, July 1959)

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.

This report contains these data for the stations at Newfoundland, Fort Monmouth, Grand Bahama Island, White Sands, and Puerto Rico. Pertinent facts concerning these stations are given in the following table:

Table 1

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

II Description of Basic Data

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

Tabulations of the mean electron density data at 10 km intervals and certain related quantities are the bases for the graphs and charts. A sample for the Puerto Rico April 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)	$\times 10^3$ = electron/cm^3	Body of table; given at each 10 km of height from the lowest hmin to 950 km.
NMAX	$\times 10^3$ = electron/cm^3	The mean value of Nmax.
COUNT		Count of the number of profiles entering the the mean.
HMIN	Kilometers	The average height of zero or very low electron density, obtained by linear extrapolation of the electron density of the individual profiles.
HMAX	Kilometers	The average height of maximum electron density, determined by fitting a parabola to the upper portion of the individual profiles.
SHMAX	$\times 10^{10}$ = 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 extrapola- of observed profiles into the region above HMAX. (See text)

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

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

B. Determination of hmax. The nature of the "true height" process is such that no direct measure of hmaxF2 is obtained, the virtual height at Nmax being immeasurable. A useful procedure is to fit the portion near hmaxF2 with a suitable curve and to determine hmax from this curve. A parabola is quite satisfactory for this purpose; it is fitted to two of the highest true heights and the measured value of Nmax(foF2).

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

D. Integrated Electron Densities. The total number of electrons in a unit column of the ionosphere between the effective bottom (hmin) and hmax is called Shmax; it is obtained by numerical integration of the observed profiles between these limits. An estimate of the total electron content to infinity, based upon the Chapman model, is called Shinf. It is obtained by adding to Shmax the quantity $N_A = 2.82$ HNmax where H is an (assumed constant) scale height for the region above hmax. Current evidence

(Wright, 1960) indicates H = 100 km, is an acceptable choice.

III Description of Graphical Representation

The relative smoothness of mean quiet ionosphere data lends itself to various kinds of graphical presentation which offer convenient aids to the visualization of the height, geographic, and temporal variability of the ionosphere. Three such graphical forms are included here, prepared from the tabulations described in Section II.

A. Vertical cross sections of the ionosphere along the 75°W meridian. Pages 12 through 35 give for each hour, a vertical cross section of the mean quiet ionosphere along a meridian section, nominally the 75°W geographic meridian, for the month of March 1959. Contours are parametric in "plasma" frequency (f_N) related to electron density N by

$$12{,}400\ f_N^2(\text{Mc/s}) = N(\text{electrons/cm}^3).$$

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 (150,200,300,350, 400 km), contours of electron density are drawn in the latitude vs. local time plane. To the extent to which longitude variations 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; the total electron content to nmax, Shmax and the estimated total electron content, Shinf, are also shown.

C. Electron density vs. time curves (N(t) curves). The mean quiet diurnal variation of electron density between 150 and 400 km heights above the sounding stations is illustrated by these curves. Dashed lines are used wherever the electron density at any height falls below the peak density (i.e. when the height hmaxF2 falls below the height for the curve in question.) Such electron densities are the result of the extrapolations by the Chapman model discussed in Section II C.

IV Discussion and Applications of the Data

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

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

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

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

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

Acknowledgements

We are indebted to Mr. A. H. Shapley, Assistant Chief of the Radio Propagation Physics Division for guidance in the course of this program, and to Dr. H. H. Howe for the development of the computer programs upon which the whole system heavily depends. The cooperation of the U. S. Army Signal Radio Propagation Agency, in particular, the enthusiastic assistance of Mr. F. H. Dickson (Chief) and Mr. H. F. Busch (Chief, Field Operations), is essential to the success of the program and is gratefully acknowledged.

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AVERAGE ELECTRON DENSITY KP BELOW 4.5

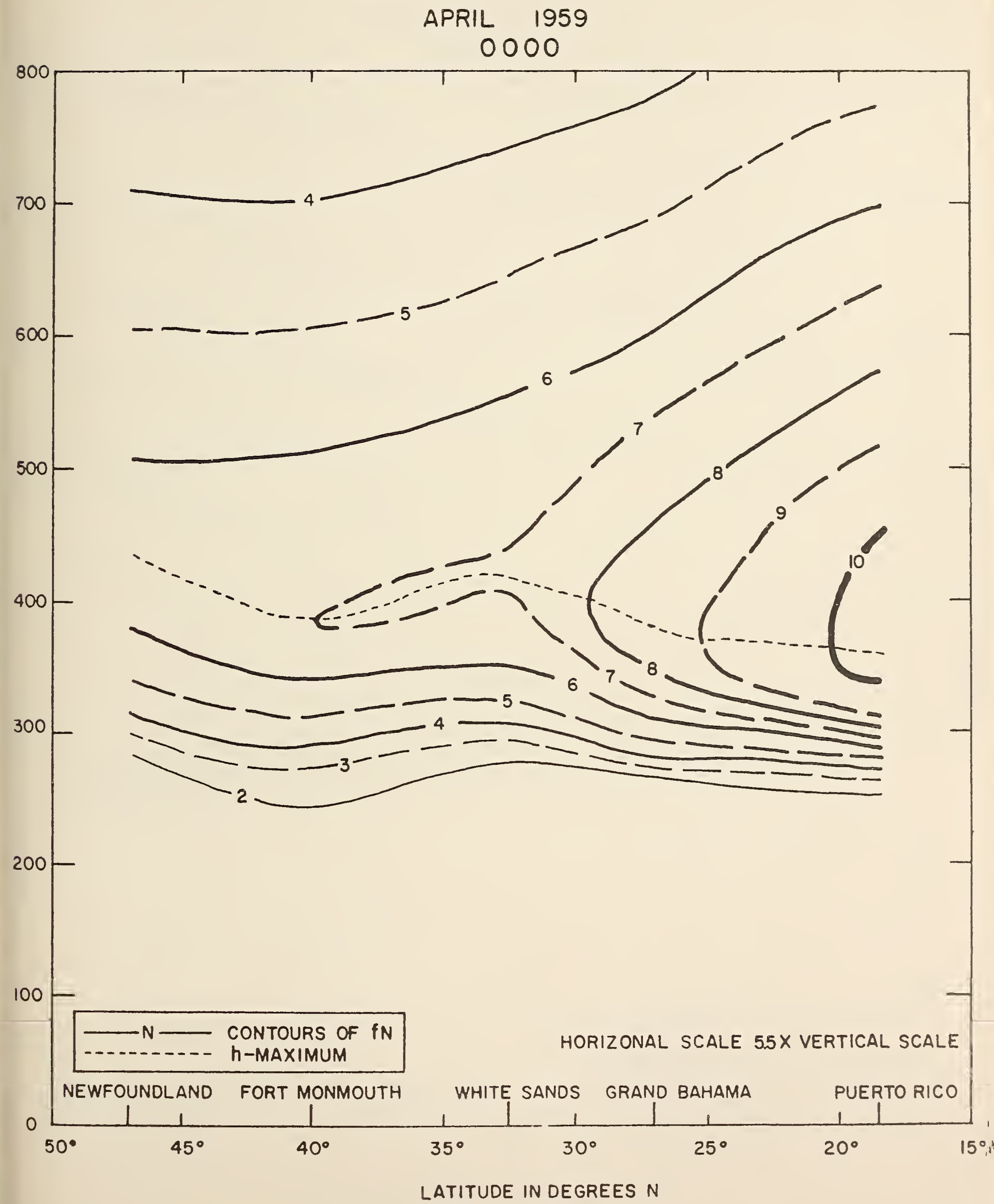
PUERTO RICO 60 W APR 1959

TIME	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100
COUNT	27	27	27	27	27	28	28	26	25	25	25	21
HMIN	263	246	228	228	239	243	266	114	110	110	110	109
RATIO	5.5	5.4	5.0	4.6	4.5	4.6	4.7	4.1	4.0	3.8	3.7	3.5
NMAX	1441	1310	1055	835	717	654	699	1180	1681	2049	2212	2418
HMAX	368	353	347	360	377	380	383	317	317	326	336	352
SHMAX	908	852	765	667	583	531	545	1092	1608	2039	2343	2722
SHINF	4974	4549	3740	3023	2605	2376	2515	4421	6349	7820	8584	9544
KM												
950	130	109	85.6	72.8	67.7	63.9	68.6	83.1	118	150	169	201
900	166	140	110	93.4	86.8	82.0	87.9	106	151	192	217	257
850	213	180	141	120	111	105	113	137	193	246	279	330
800	273	230	180	153	142	134	144	175	248	315	357	423
750	349	294	231	196	182	172	184	224	318	404	457	540
700	444	376	294	250	232	218	234	286	406	516	584	690
650	563	477	374	317	293	276	296	365	518	657	743	877
600	709	602	472	399	368	346	372	463	657	833	941	1107
550	881	752	590	497	456	426	458	583	827	1047	1180	1383
500	1071	921	725	606	551	511	551	725	1028	1299	1458	1698
490	1109	956	753	628	570	528	569	755	1072	1353	1517	1763
480	1148	991	781	650	589	544	587	786	1116	1407	1577	1829
470	1185	1026	809	672	607	559	604	818	1161	1463	1637	1895
460	1222	1061	837	693	624	574	621	849	1206	1518	1697	1960
450	1257	1095	864	714	641	587	636	881	1252	1574	1757	2023
440	1290	1127	891	733	656	600	649	913	1297	1629	1816	2085
430	1321	1158	916	752	670	610	661	945	1343	1684	1874	2145
420	1349	1188	940	769	682	619	671	976	1387	1737	1930	2200
410	1373	1215	963	784	692	624	679	1006	1431	1789	1983	2252
400	1392	1238	983	796	698	627	683	1036	1472	1838	2033	2298
390	1406	1259	1001	805	700	625	682	1063	1512	1884	2078	2338
380	1412	1274	1015	810	698	618	675	1089	1549	1926	2118	2371
370	1405	1283	1026	811	690	605	661	1112	1583	1963	2152	2395
360	1381	1285	1030	806	676	586	639	1132	1612	1994	2179	2408
350	1335	1274	1027	795	653	559	607	1149	1637	2018	2198	2409
340	1265	1251	1015	774	623	525	566	1162	1656	2035	2206	2390
330	1169	1207	992	745	583	485	515	1170	1668	2041	2198	2345
320	1038	1139	956	704	535	439	455	1171	1671	2033	2169	2274
310	877	1047	904	653	477	392	381	1164	1662	2005	2113	2174
300	690	923	836	591	412	341	307	1145	1636	1951	2029	2049
290	499	767	749	520	343	286	237	1113	1589	1870	1918	1900
280	318	590	646	442	273	229	176	1066	1521	1764	1785	1733
270	168	395	526	360	198	176	125	1001	1429	1629	1632	1556
260	66.0	219	401	277	130	127	81.6	919	1316	1473	1466	1376
250	17.7	79.8	276	192	76.6	82.2	45.5	821	1182	1300	1294	1196
240	1.0	18.6	159	120	36.2	46.7	20.1	711	1039	1120	1125	1029
230		2.1	71.9	62.4	15.3	23.7	5.1	591	884	939	959	884
220			19.9	25.6	5.0	8.8	.6	472	723	775	808	762
210			2.8	5.2	1.6	2.6		364	580	637	679	658
200				.5		.1		270	456	524	571	570
190								198	360	436	483	494
180								148	284	361	410	430
170								117	226	301	350	375
160								99.2	185	253	301	327
150								87.6	156	214	258	284
140								80.2	136	186	224	246
130								74.2	124	167	198	218
120								61.7	114	151	182	202
110								3.0	43.1	56.2	84.2	88.2

AVERAGE ELECTRON DENSITY KP BELOW 4.5

PUERTO RICO 60 W APR 1959

TIME	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
COUNT	25	25	24	26	25	21	14	24	27	27	27	27
HMIN	109	110	110	110	110	110	200	243	250	267	273	274
RATIO	3.5	3.5	3.4	3.3	3.3	3.3	4.1	4.3	4.2	4.5	4.8	4.9
NMAX	2537	2535	2433	2272	2110	1927	1909	1705	1573	1565	1522	1514
HMAX	358	364	369	375	374	378	376	383	406	406	399	395
SHMAX	2862	2921	2892	2778	2574	2312	1752	1480	1420	1258	1146	1088
SHINF	10018	10072	9755	9187	8526	7748	7136	6289	5858	5672	5441	5359
KM												
950	217	223	220	211	195	181	178	165	171	170	161	155
900	278	286	282	270	250	232	229	212	220	219	206	199
850	356	366	361	346	321	298	293	272	282	280	264	255
800	456	469	462	443	411	381	375	348	360	358	337	326
750	583	600	591	567	525	487	479	444	459	457	430	417
700	744	765	753	722	669	621	611	565	584	580	547	530
650	945	971	956	916	849	787	774	716	736	732	691	669
600	1192	1224	1203	1152	1067	988	973	898	918	913	863	837
550	1487	1524	1496	1429	1324	1224	1206	1111	1123	1117	1059	1029
540	1551	1589	1559	1488	1379	1275	1256	1156	1165	1160	1100	1069
530	1617	1656	1623	1549	1435	1326	1307	1202	1208	1202	1141	1109
520	1683	1723	1689	1610	1492	1378	1359	1248	1250	1244	1182	1150
510	1751	1791	1754	1672	1549	1430	1410	1294	1291	1285	1223	1190
500	1820	1860	1821	1734	1607	1482	1462	1340	1332	1326	1263	1229
490	1889	1929	1887	1795	1664	1534	1514	1386	1371	1364	1301	1268
480	1958	1998	1952	1856	1720	1585	1564	1430	1408	1401	1338	1305
470	2026	2066	2017	1916	1775	1634	1614	1473	1442	1436	1373	1340
460	2093	2132	2080	1973	1829	1682	1662	1514	1473	1467	1406	1374
450	2159	2197	2140	2028	1880	1728	1707	1553	1501	1495	1435	1404
440	2222	2258	2197	2080	1928	1770	1750	1589	1524	1518	1460	1429
430	2282	2316	2251	2127	1971	1808	1789	1620	1541	1536	1480	1450
420	2338	2369	2299	2169	2011	1842	1823	1648	1552	1547	1495	1465
410	2389	2416	2341	2205	2044	1870	1852	1669	1553	1548	1502	1473
400	2434	2457	2376	2234	2071	1892	1875	1684	1543	1535	1499	1471
390	2471	2490	2403	2254	2090	1907	1891	1691	1520	1505	1483	1457
380	2500	2513	2420	2264	2099	1912	1896	1686	1480	1453	1447	1428
370	2518	2524	2425	2262	2096	1907	1888	1668	1424	1380	1388	1380
360	2524	2521	2412	2241	2079	1888	1861	1631	1349	1285	1305	1312
350	2513	2497	2377	2200	2042	1851	1812	1573	1257	1171	1198	1220
340	2477	2443	2317	2134	1985	1794	1743	1492	1149	1033	1065	1100
330	2413	2359	2229	2043	1908	1718	1651	1391	1021	882	905	964
320	2317	2247	2117	1931	1810	1623	1539	1272	880	716	725	804
310	2193	2106	1980	1801	1694	1516	1405	1132	732	543	539	626
300	2042	1946	1823	1658	1565	1400	1250	976	581	380	360	438
290	1867	1770	1655	1503	1429	1273	1091	804	429	238	211	266
280	1679	1584	1483	1345	1287	1147	911	618	296	132	93.1	130
270	1489	1399	1311	1196	1140	1017	717	438	187	67.7	38.7	42.4
260	1303	1226	1145	1045	1002	889	521	268	103	31.7	18.2	11.3
250	1127	1067	996	915	875	771	333	139	45.3	15.4	8.4	2.7
240	972	928	870	800	763	663	182	46.7	16.6	8.5	4.0	
230	838	809	762	705	667	570	120	14.0	2.7	4.4	2.1	
220	728	711	676	626	586	488	83.7		.7	2.0	.2	
210	638	628	603	559	516	417	62.3					
200	564	557	539	500	453	352	47.9					
190	501	495	480	446	395	297	37.9					
180	444	439	425	394	341	249	31.0					
170	393	388	375	346	295	208	26.2					
160	347	344	330	303	254	176	23.2					
150	306	303	290	264	221	151	21.3					
140	267	265	254	232	193	134	20.0					
130	238	236	226	207	173	124	19.0					
120	219	216	208	192	161	117	13.5					
110	92.7	80.9	84.0	77.1	53.1	35.6	.9					


APRIL 1959
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HEIGHT IN KILOMETERS
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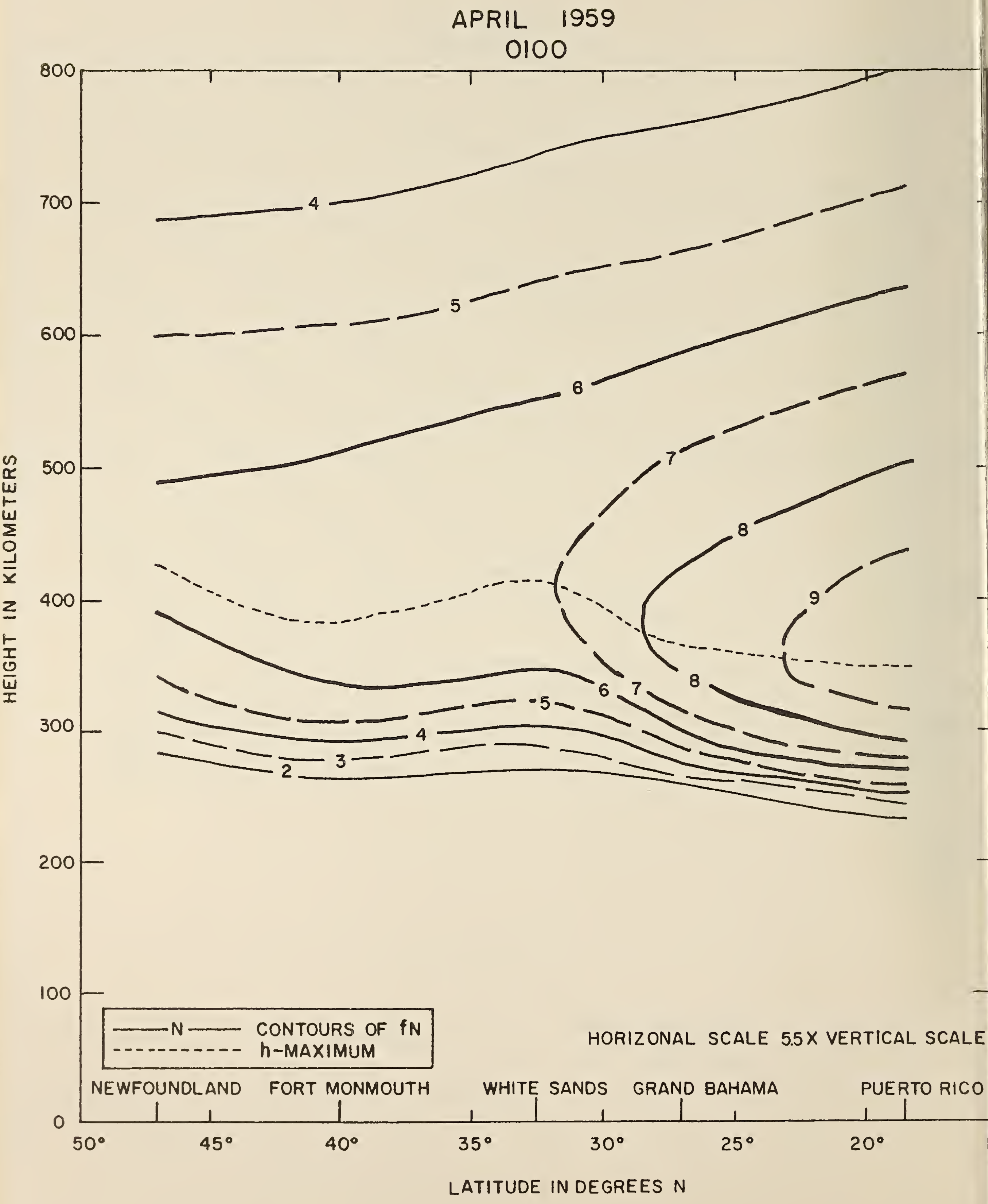
N CONTOURS OF fN
h-MAXIMUM
HORIZONAL SCALE 5.5 X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
45°
40°
35°
30°
25°
20°
15°
LATITUDE IN DEGREES N


APRIL 1959
0100
HEIGHT IN KILOMETERS
800
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N CONTOURS OF fN
h-MAXIMUM
HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
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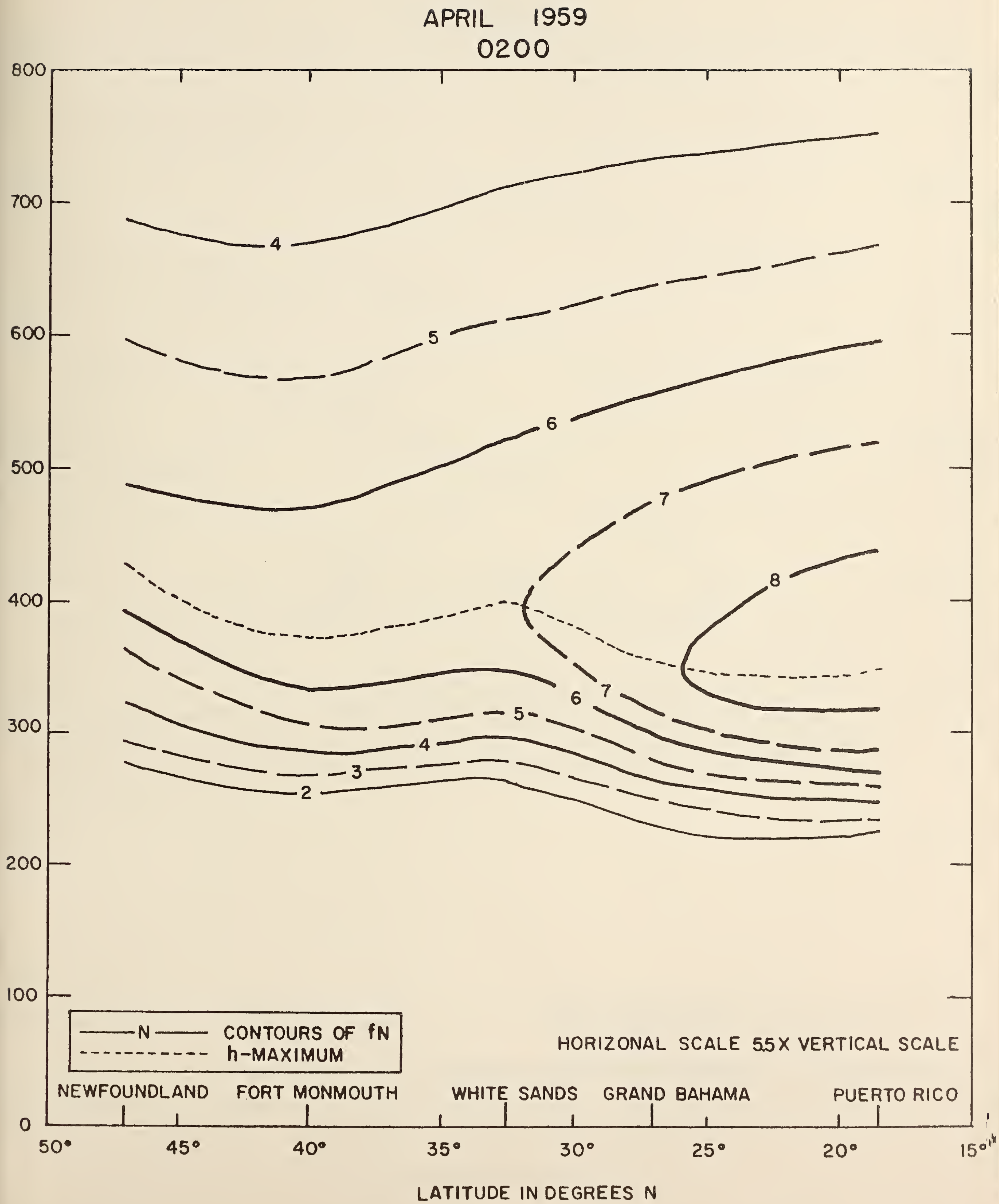
LATITUDE IN DEGREES N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CONTOURS OF fN
h-MAXIMUM
HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
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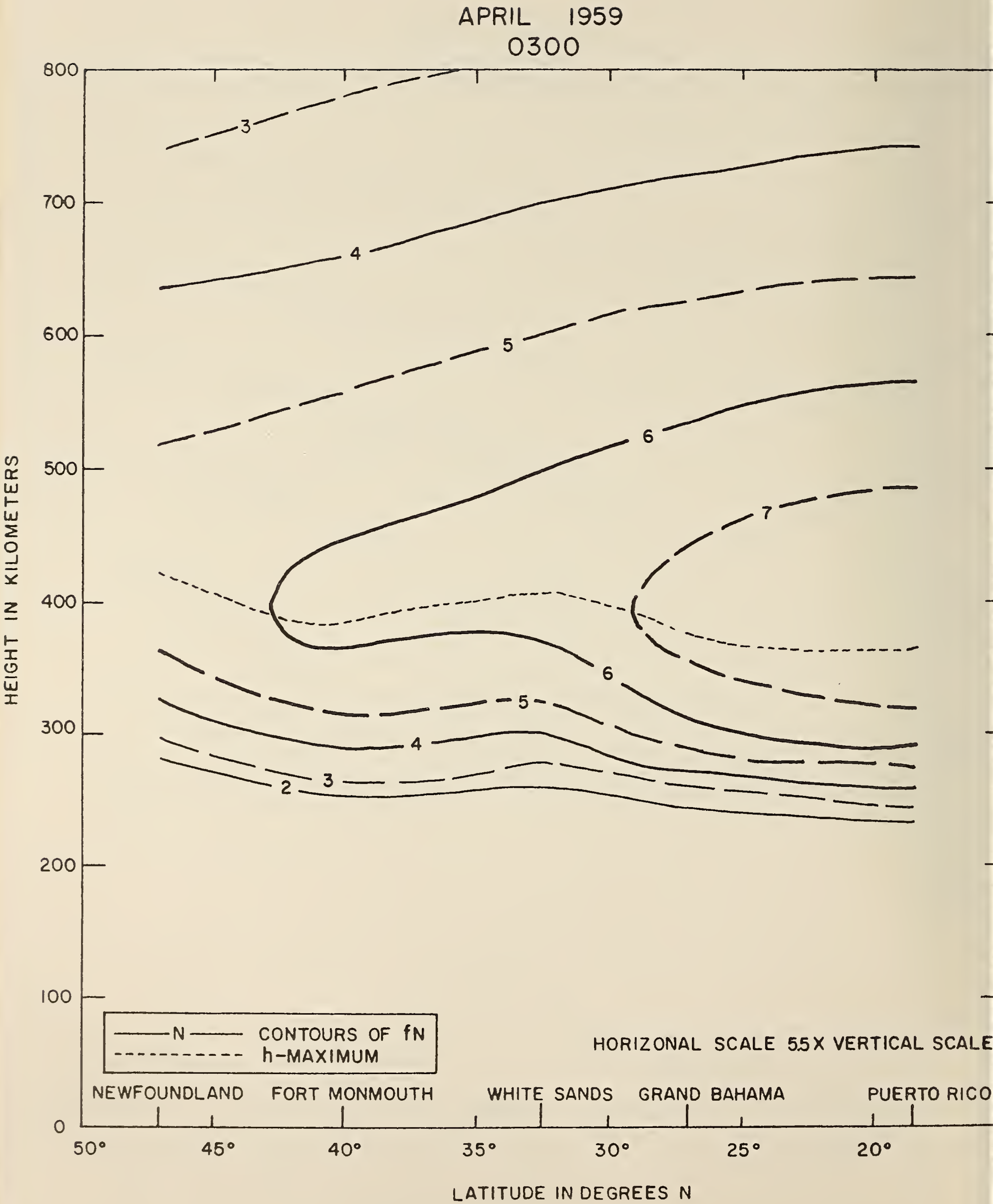
LATITUDE IN DEGREES N


APRIL 1959
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HEIGHT IN KILOMETERS
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N CONTOURS OF fN
h-MAXIMUM
HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
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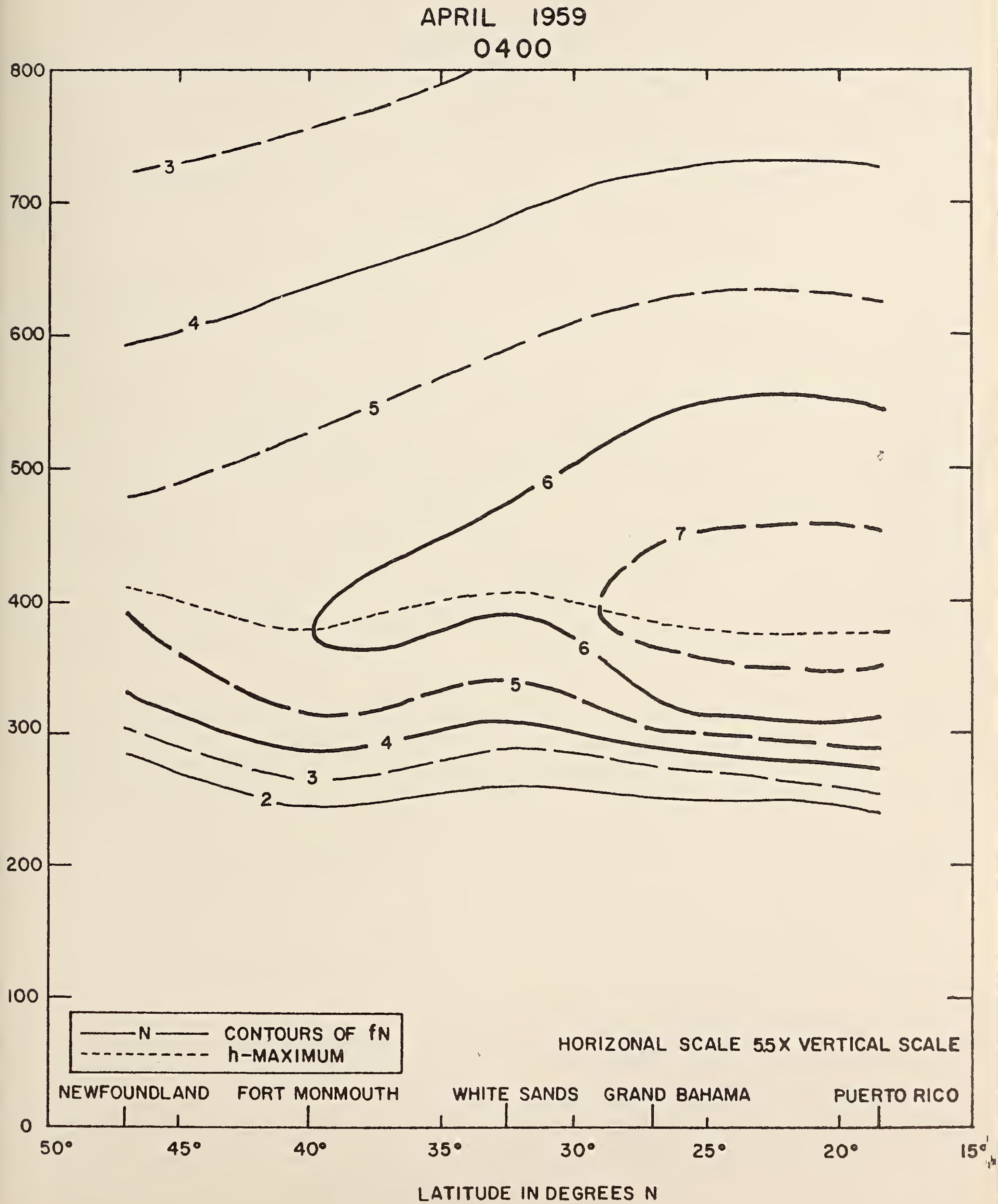
LATITUDE IN DEGREES N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CONTOURS OF fN
h-MAXIMUM
HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
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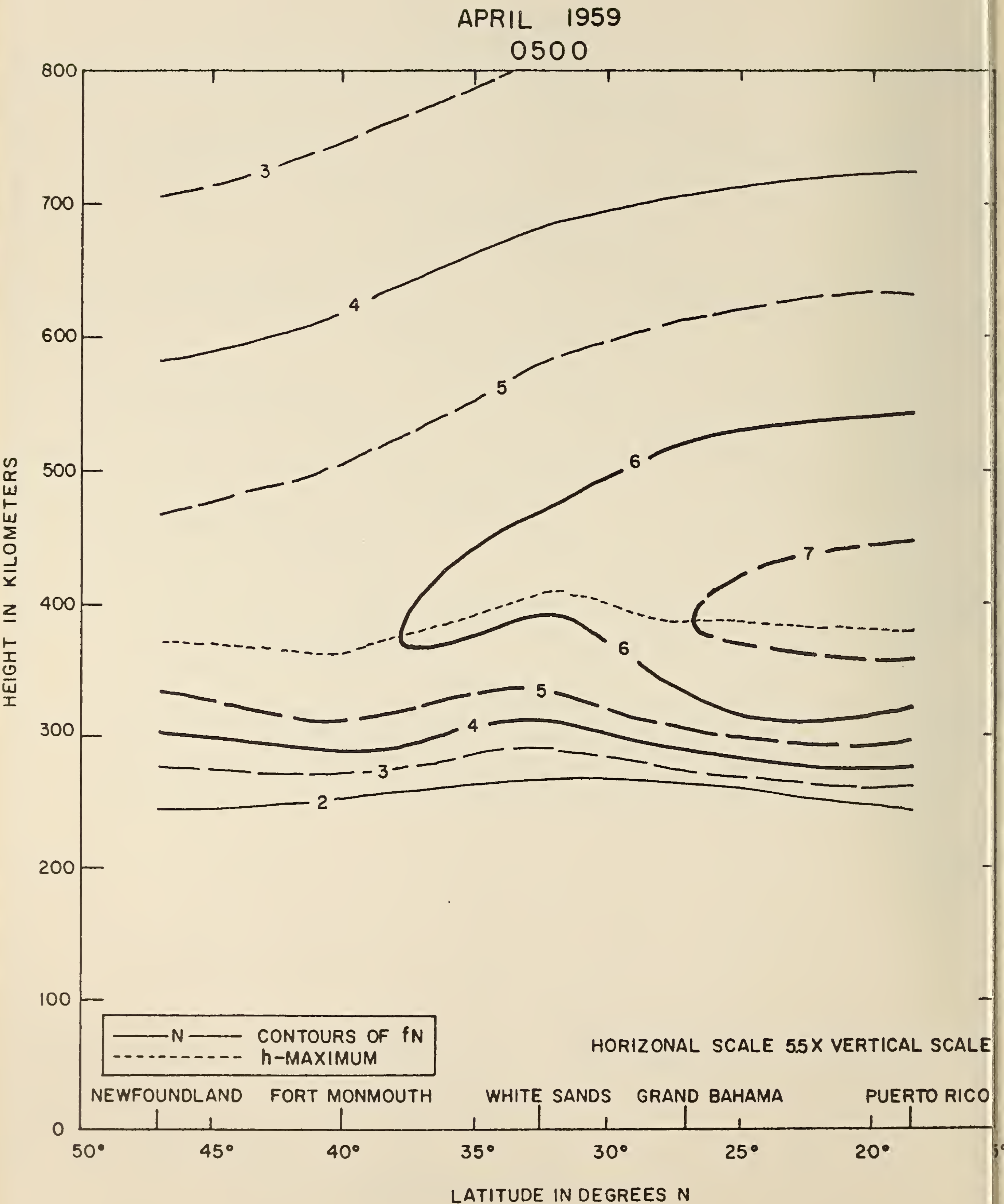
LATITUDE IN DEGREES N


APRIL 1959
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HEIGHT IN KILOMETERS
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N CONTOURS OF fN
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HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
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PUERTO RICO
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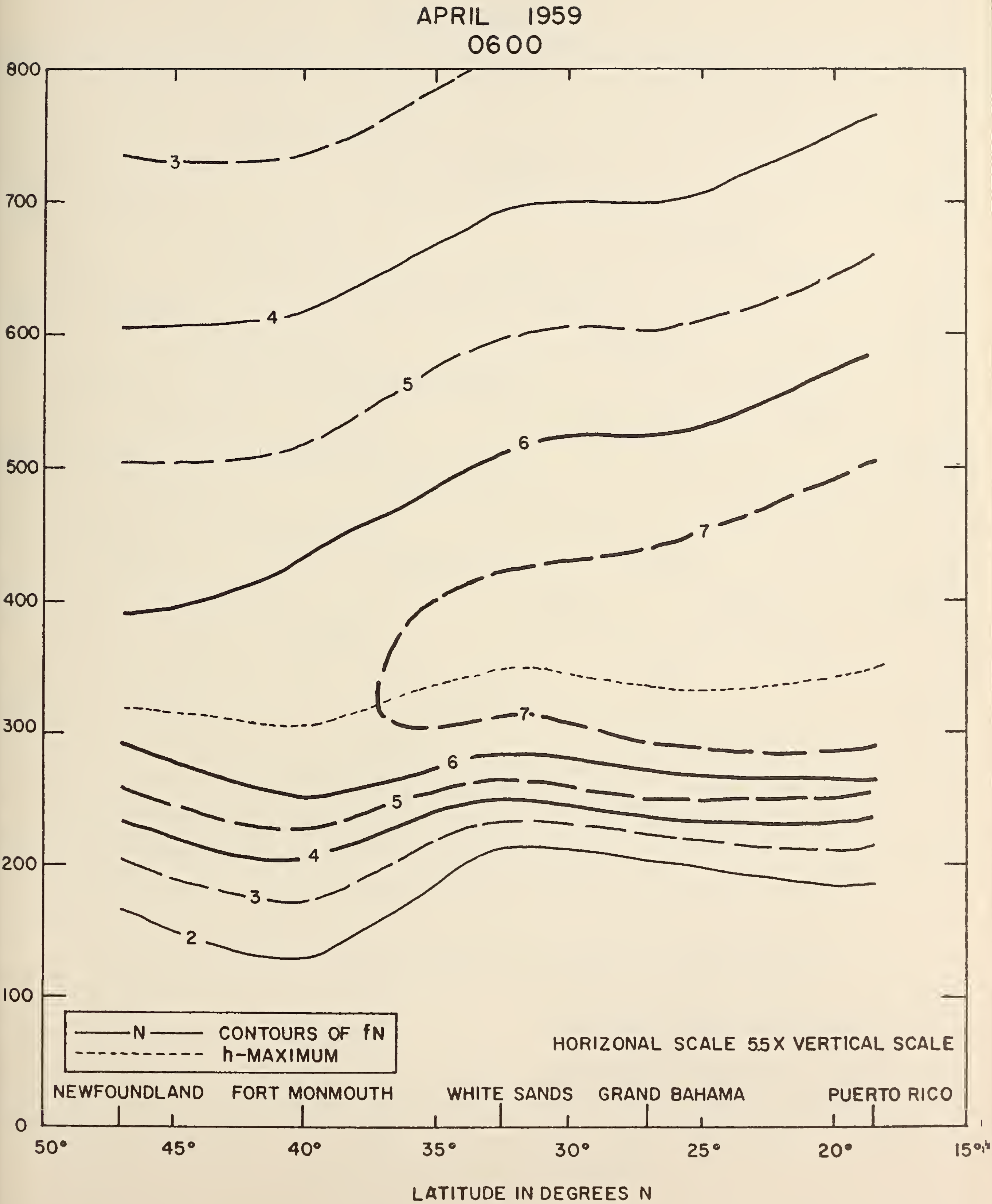
LATITUDE IN DEGREES N


APRIL 1959
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HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
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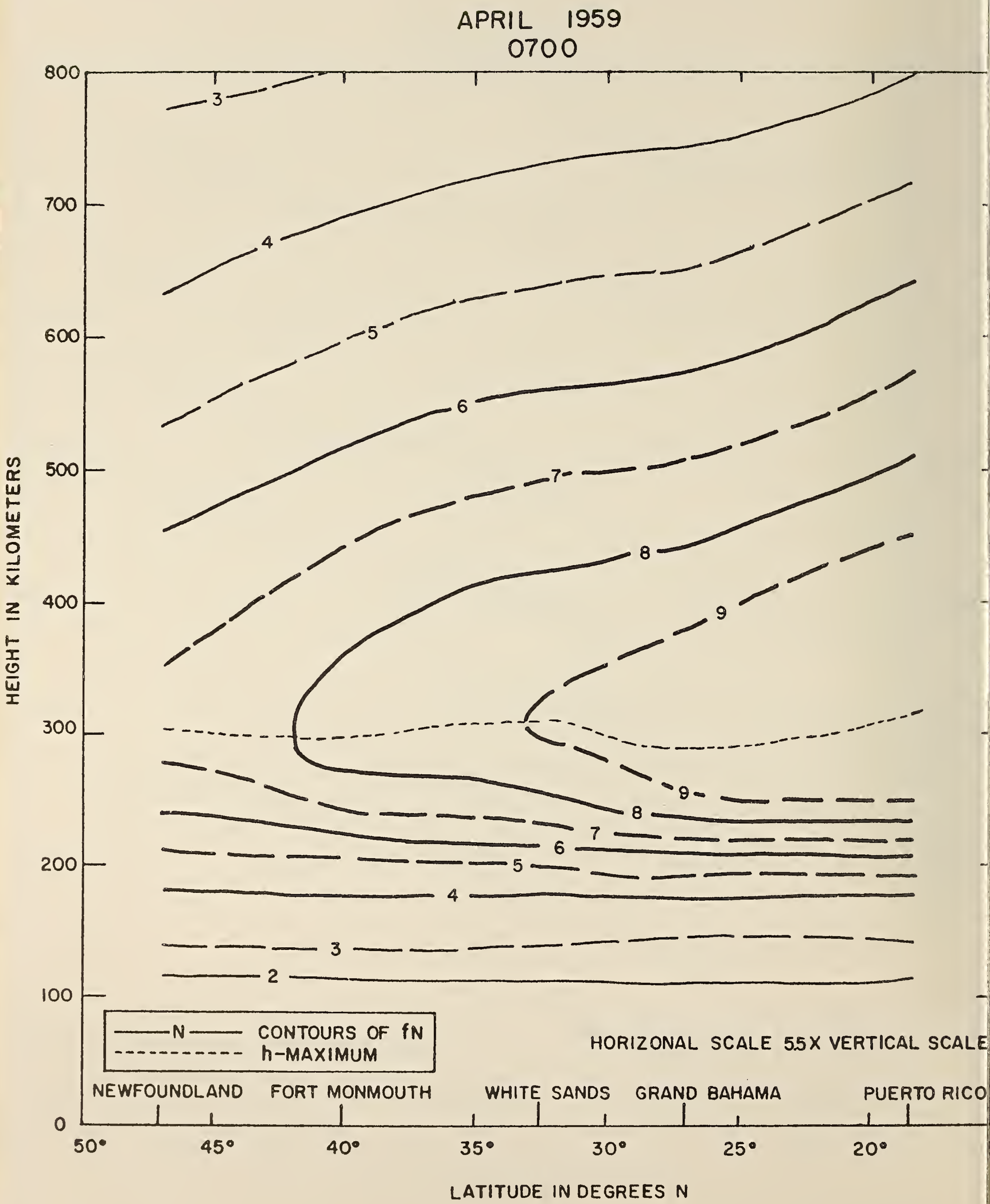
LATITUDE IN DEGREES N


APRIL 1959
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N CONTOURS OF fN
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HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
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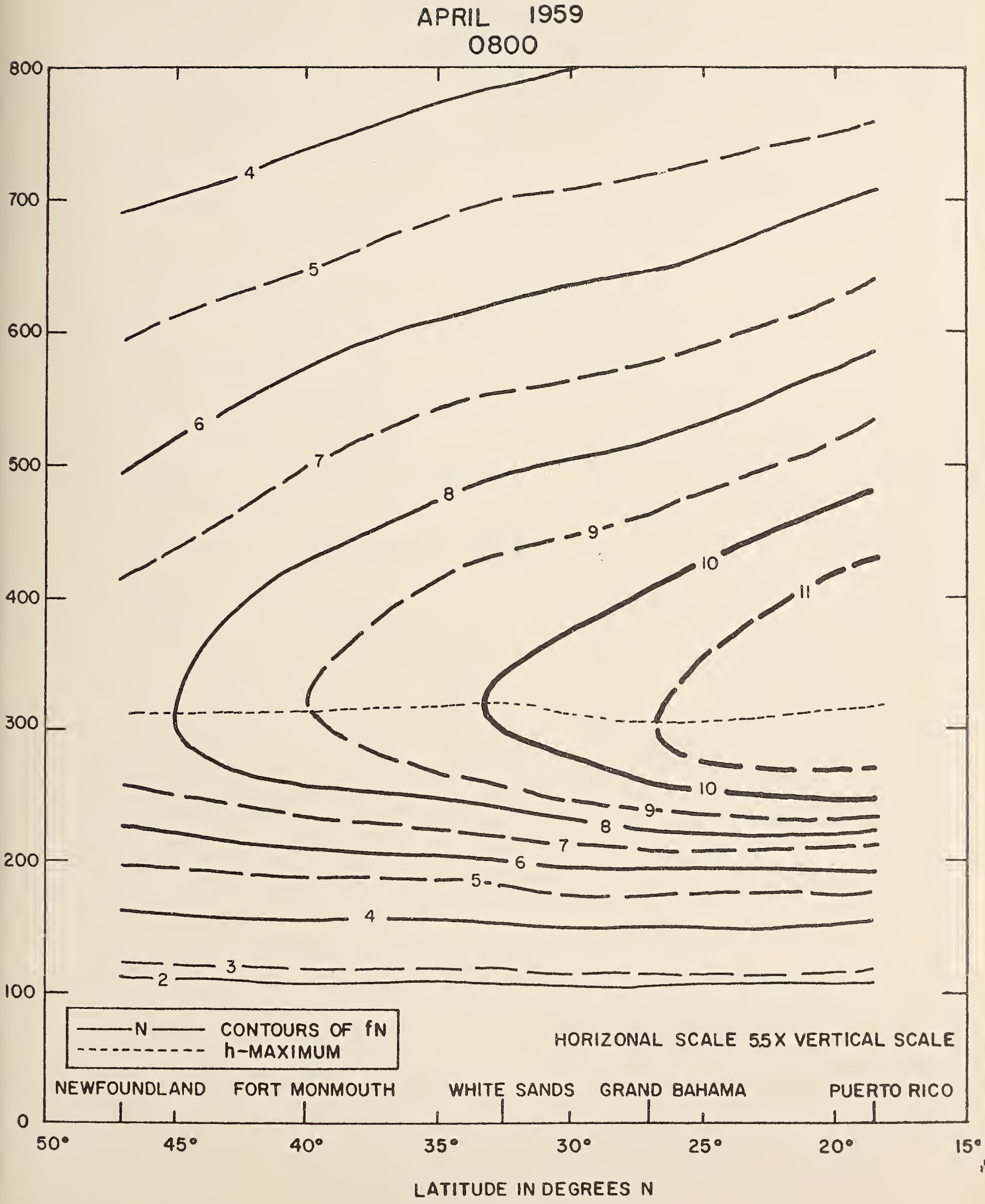
LATITUDE IN DEGREES N



APRIL 1959
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HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
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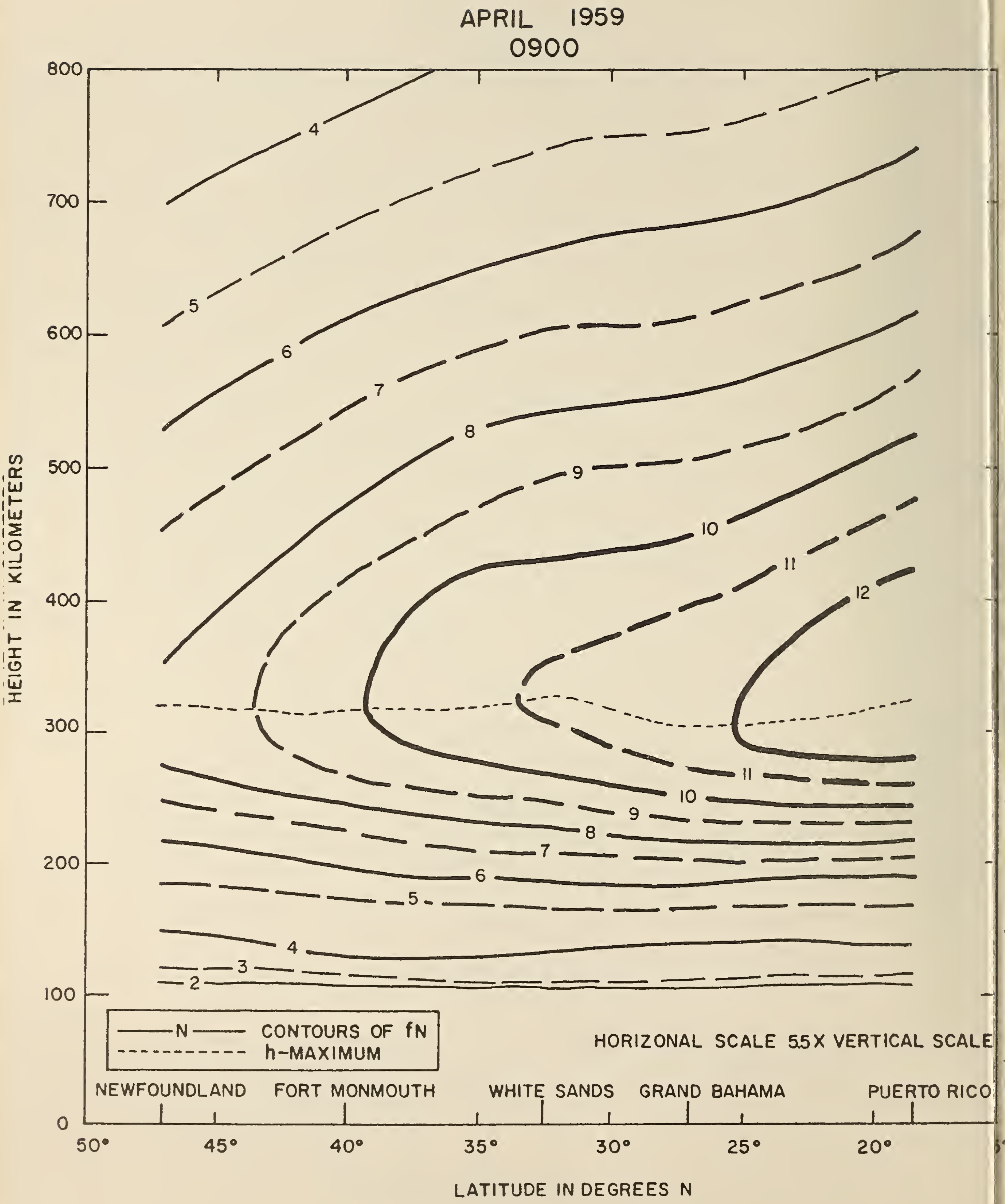
LATITUDE IN DEGREES N


APRIL 1959
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HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
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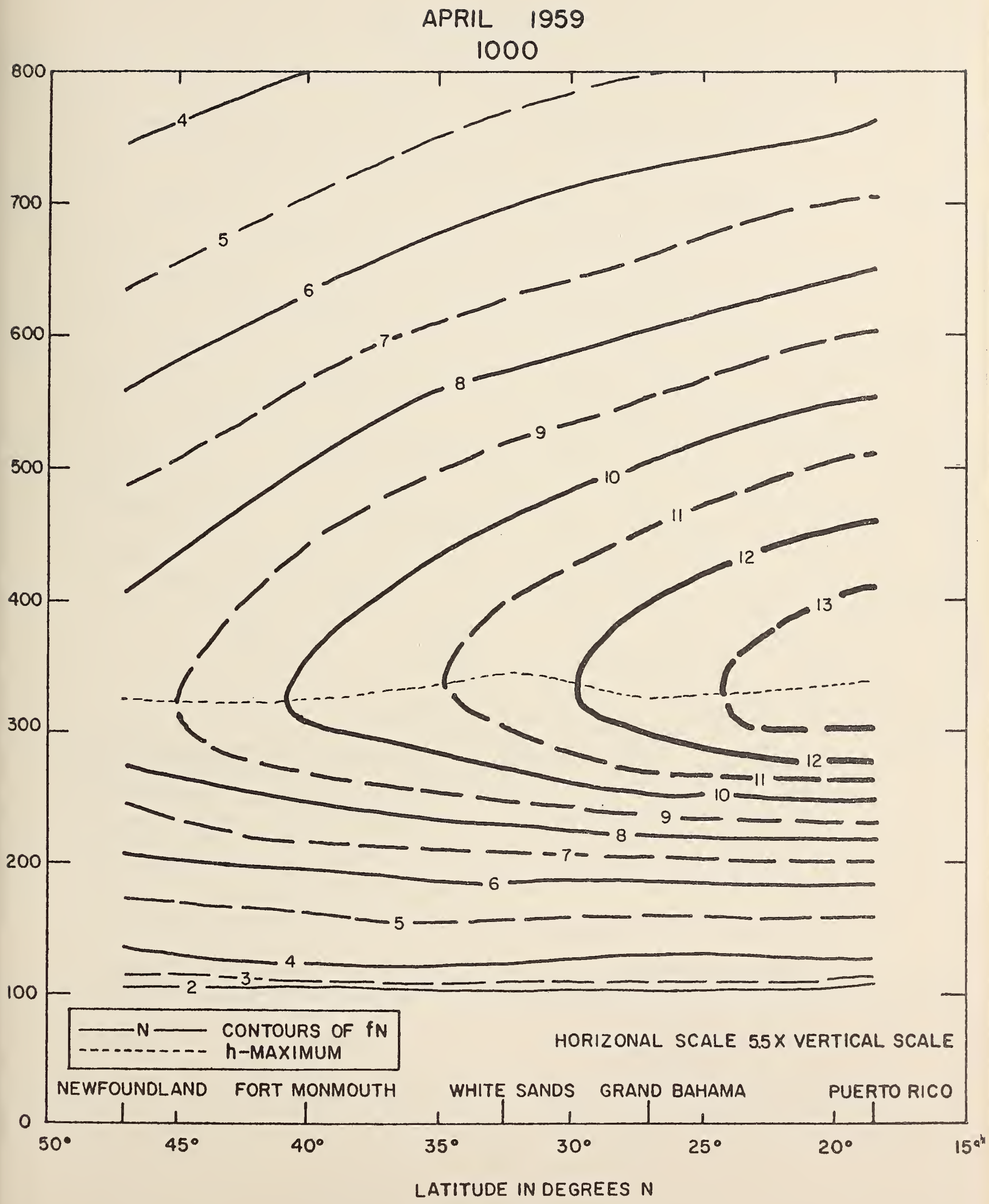
LATITUDE IN DEGREES N



APRIL 1959
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HORIZONAL SCALE 5.5 X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
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GRAND BAHAMA
PUERTO RICO
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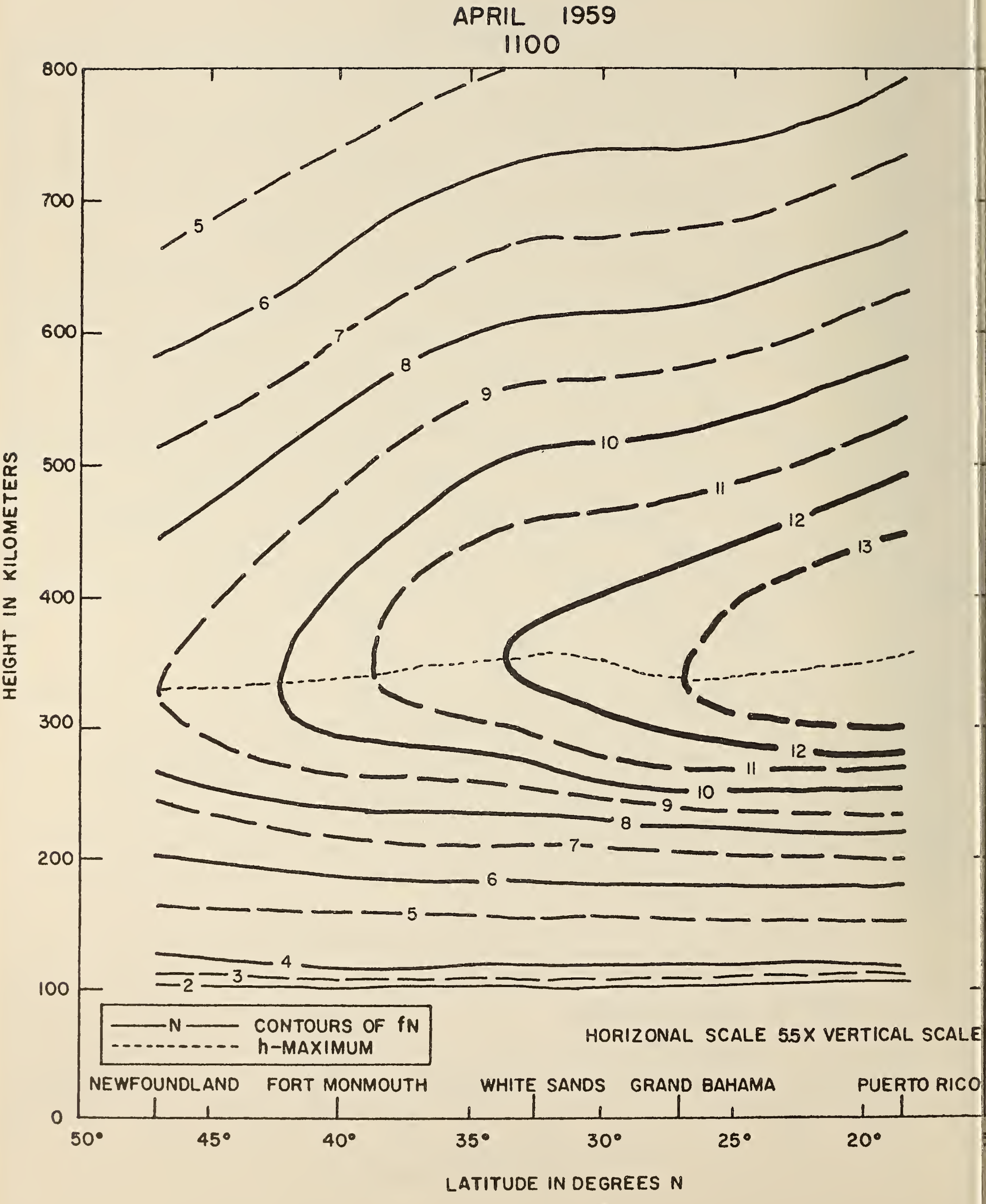
LATITUDE IN DEGREES N



APRIL 1959
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HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
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GRAND BAHAMA
PUERTO RICO
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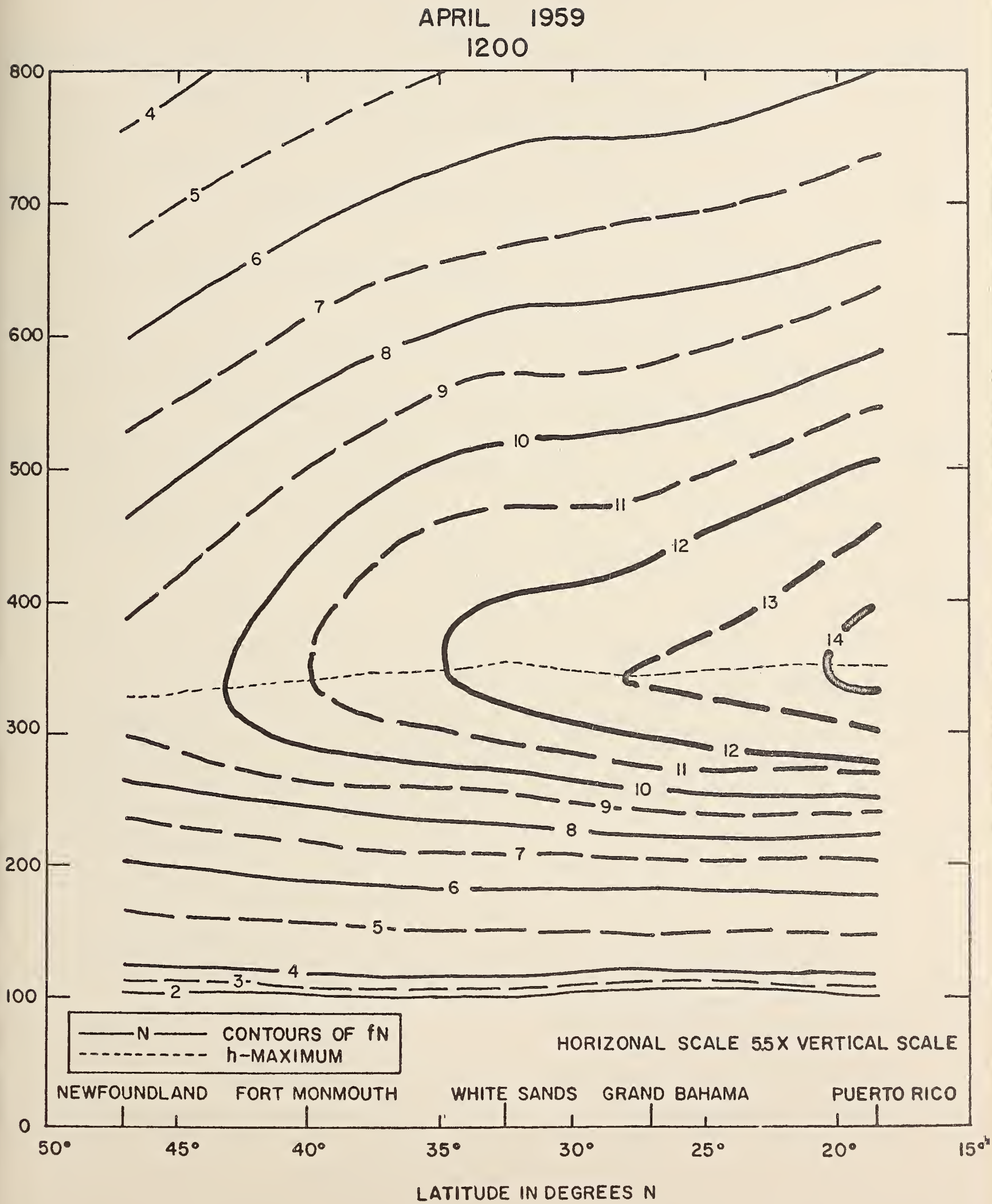
LATITUDE IN DEGREES N


APRIL 1959
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HORIZONAL SCALE 5.5 X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
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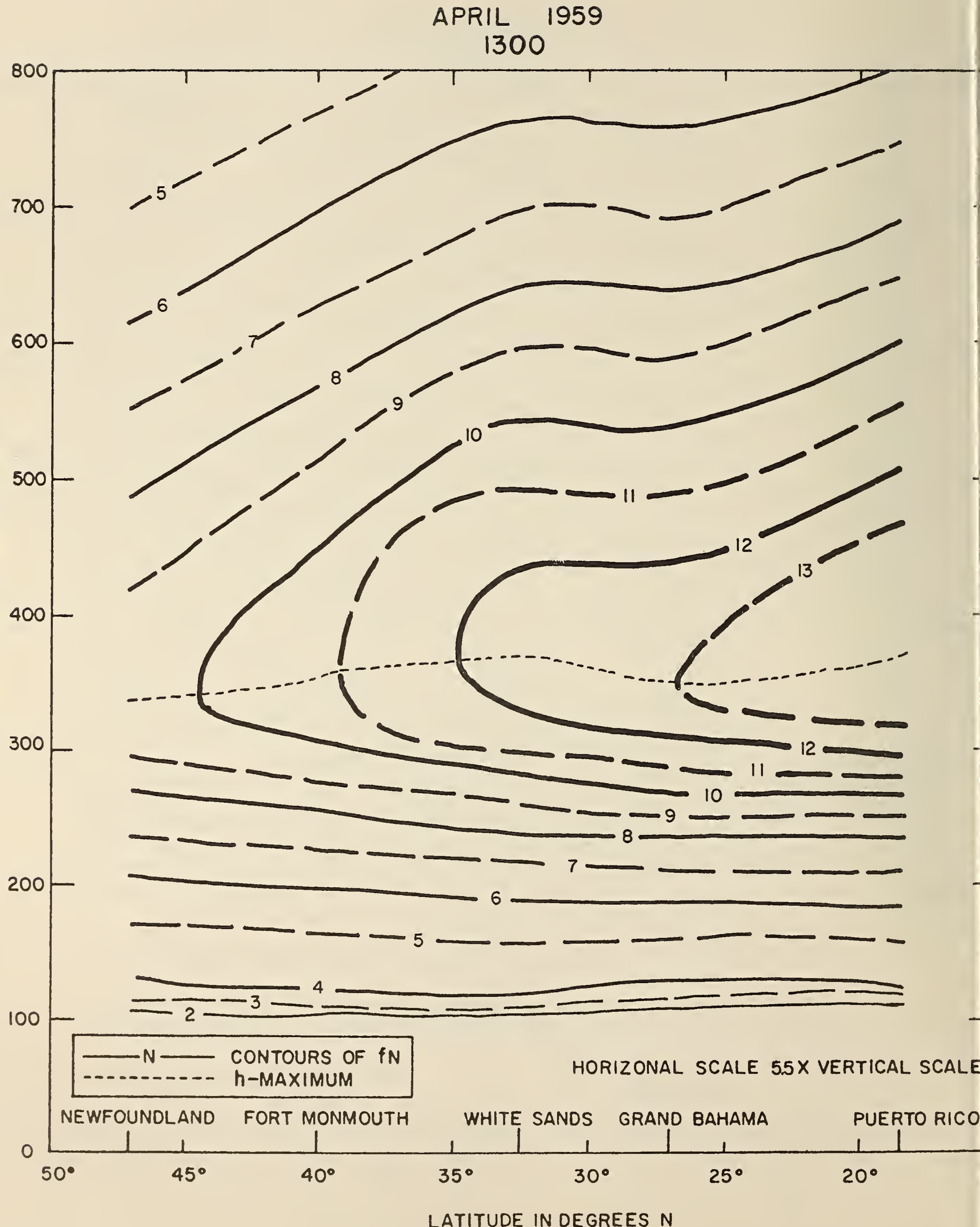
LATITUDE IN DEGREES N


APRIL 1959
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CONTOURS OF fN
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HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
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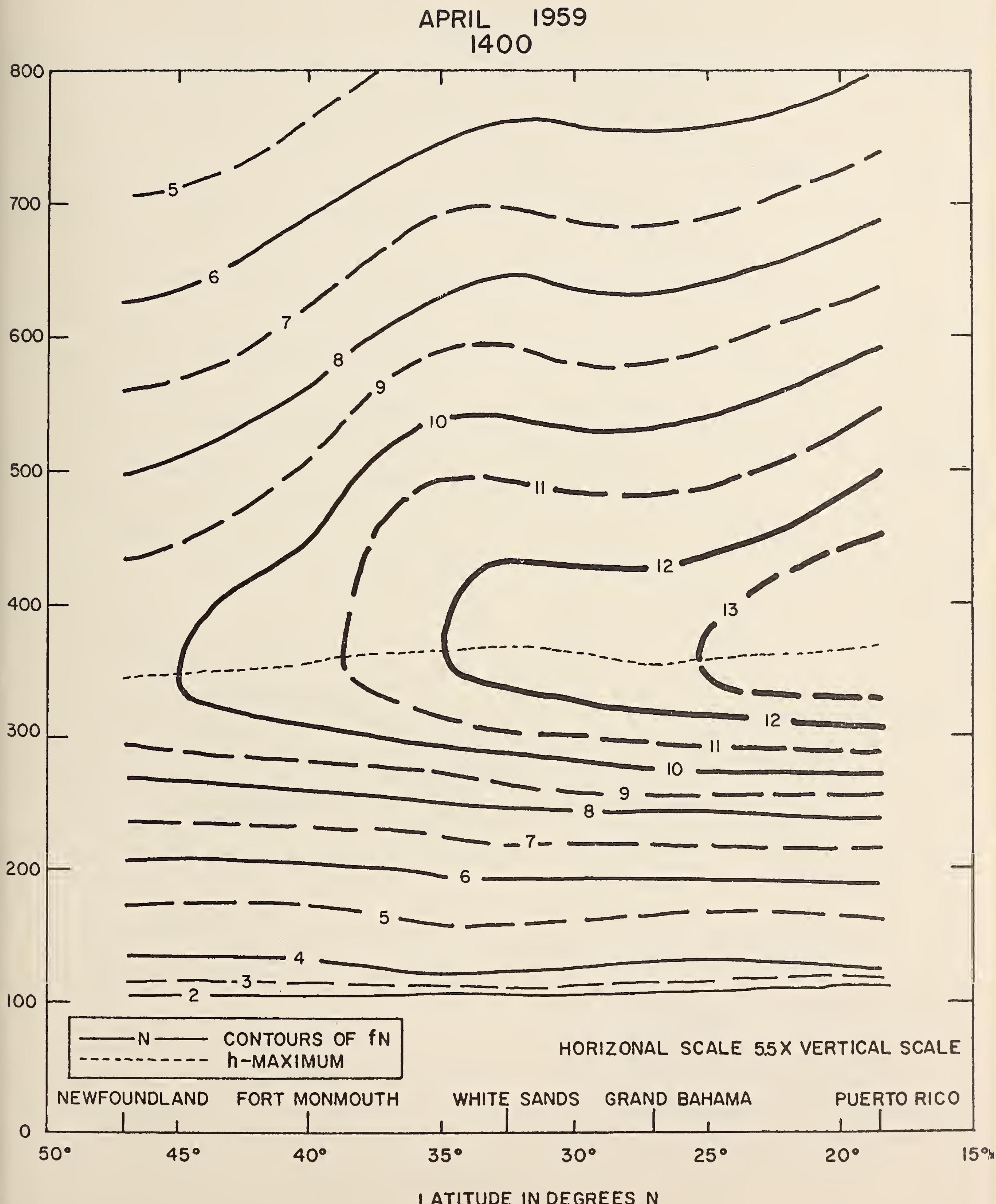
LATITUDE IN DEGREES N


APRIL 1959
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HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
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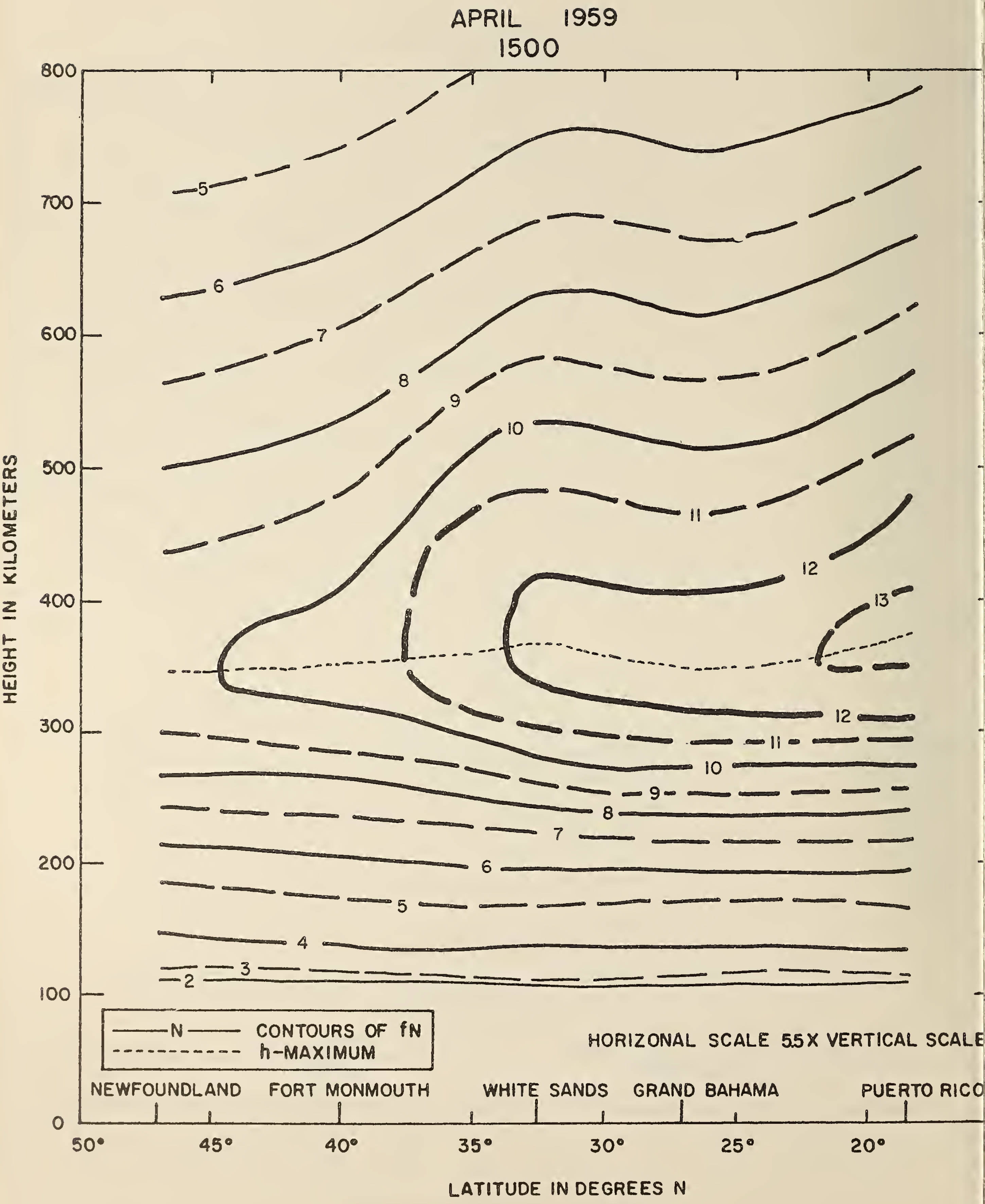
LATITUDE IN DEGREES N


APRIL 1959
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HEIGHT IN KILOMETERS
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h-MAXIMUM
HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
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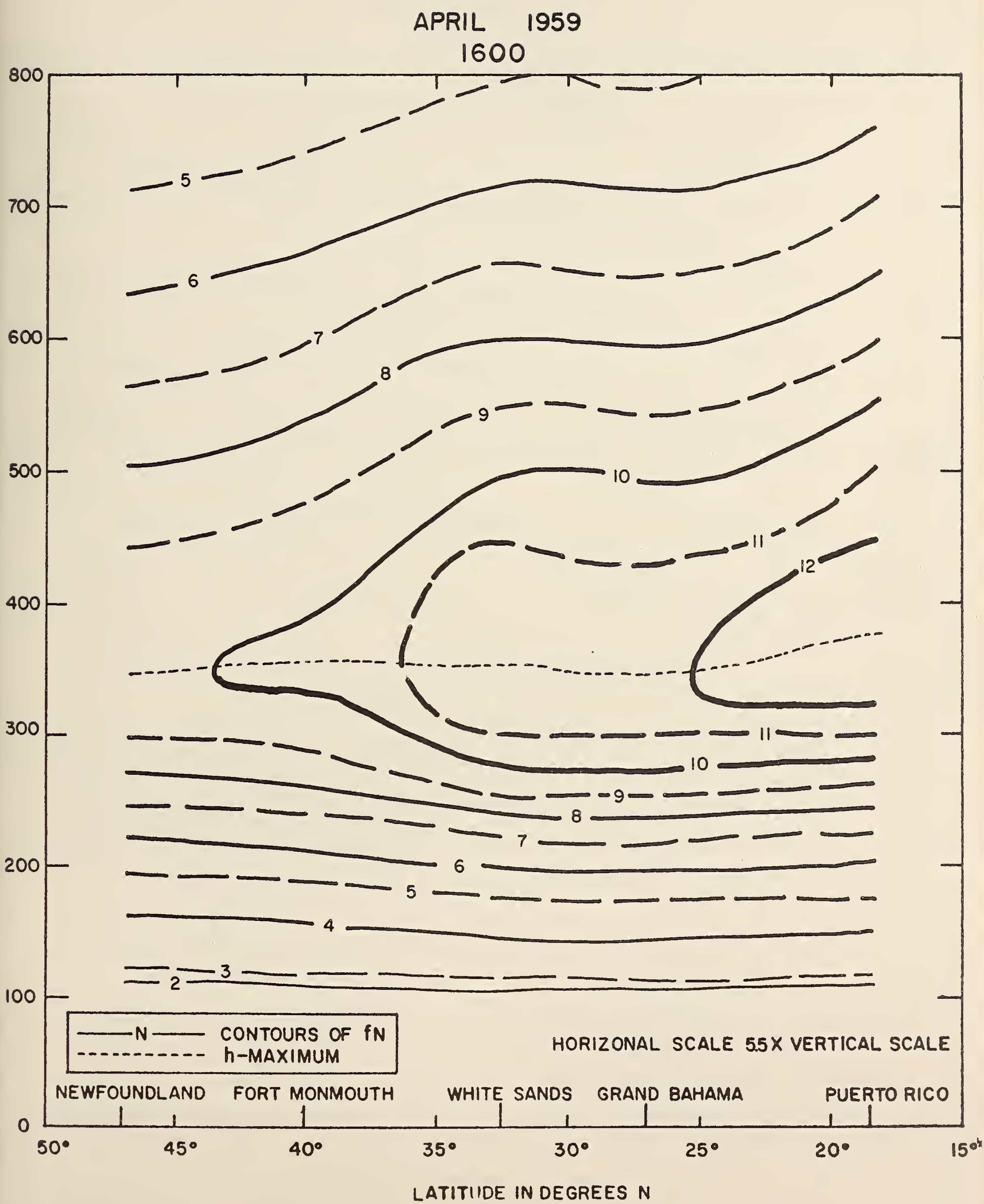
LATITUDE IN DEGREES N


APRIL 1959
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h-MAXIMUM
HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
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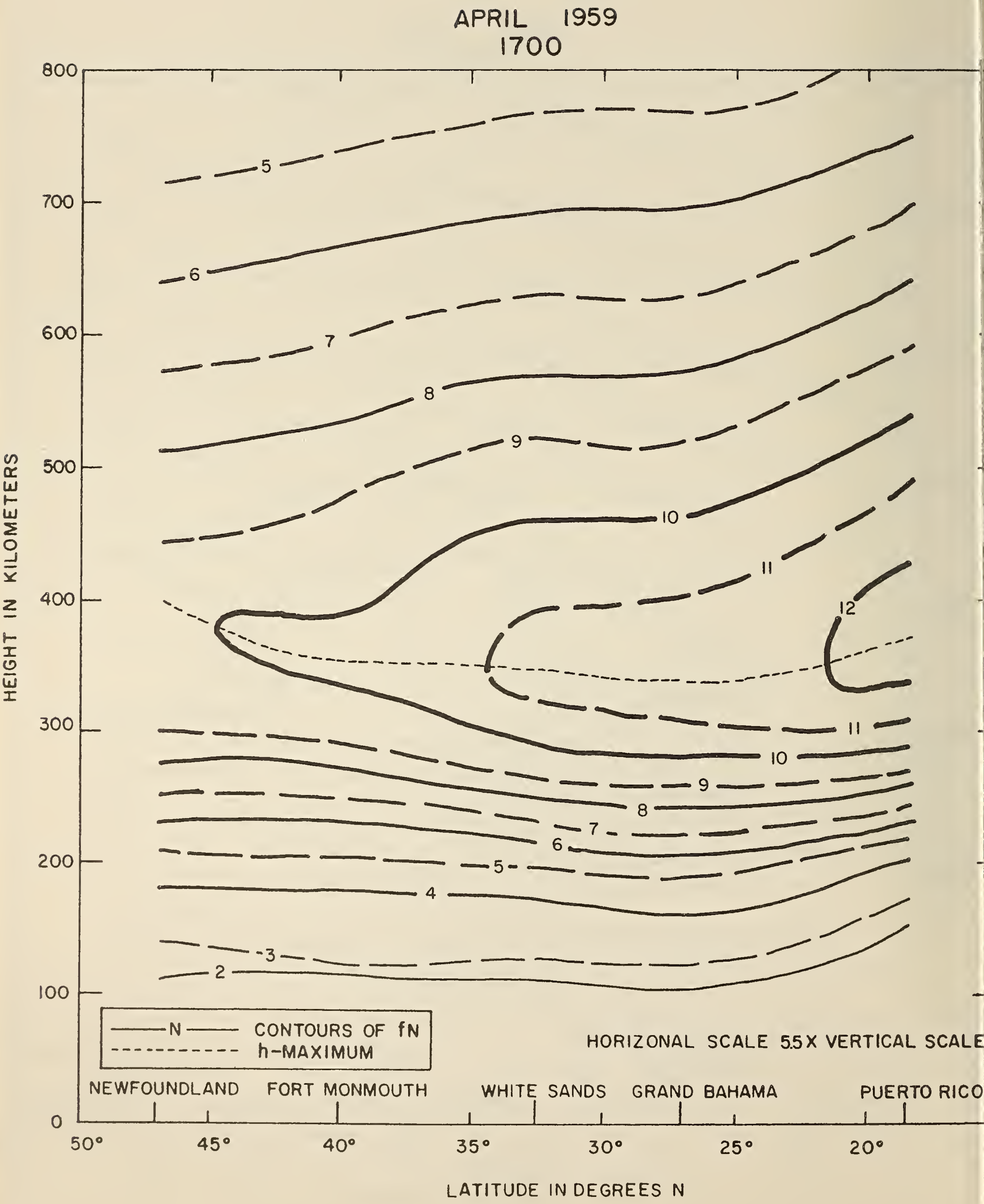
LATITUDE IN DEGREES N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N CONTOURS OF fN
h-MAXIMUM
HORIZONAL SCALE 5.5 X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
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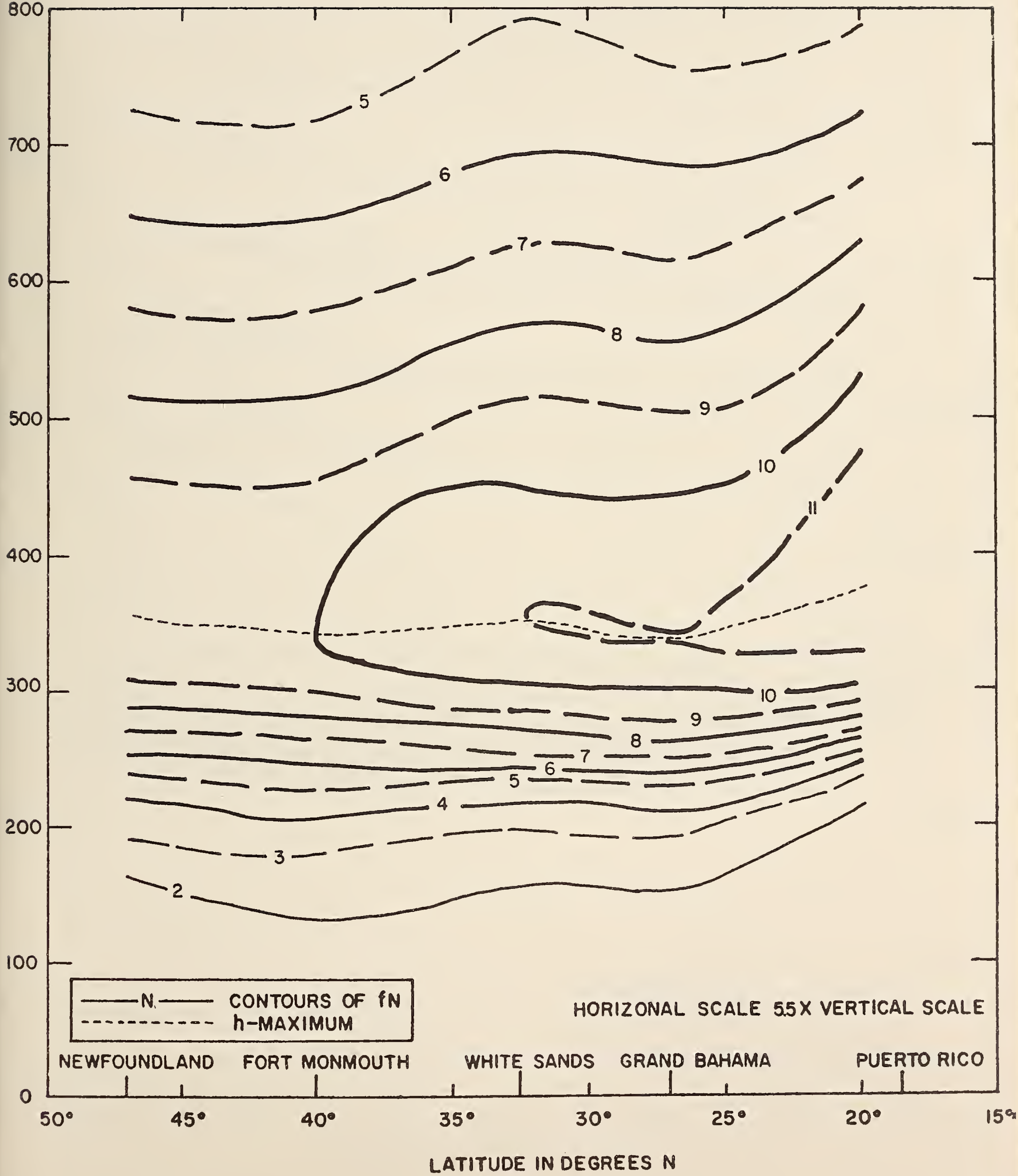
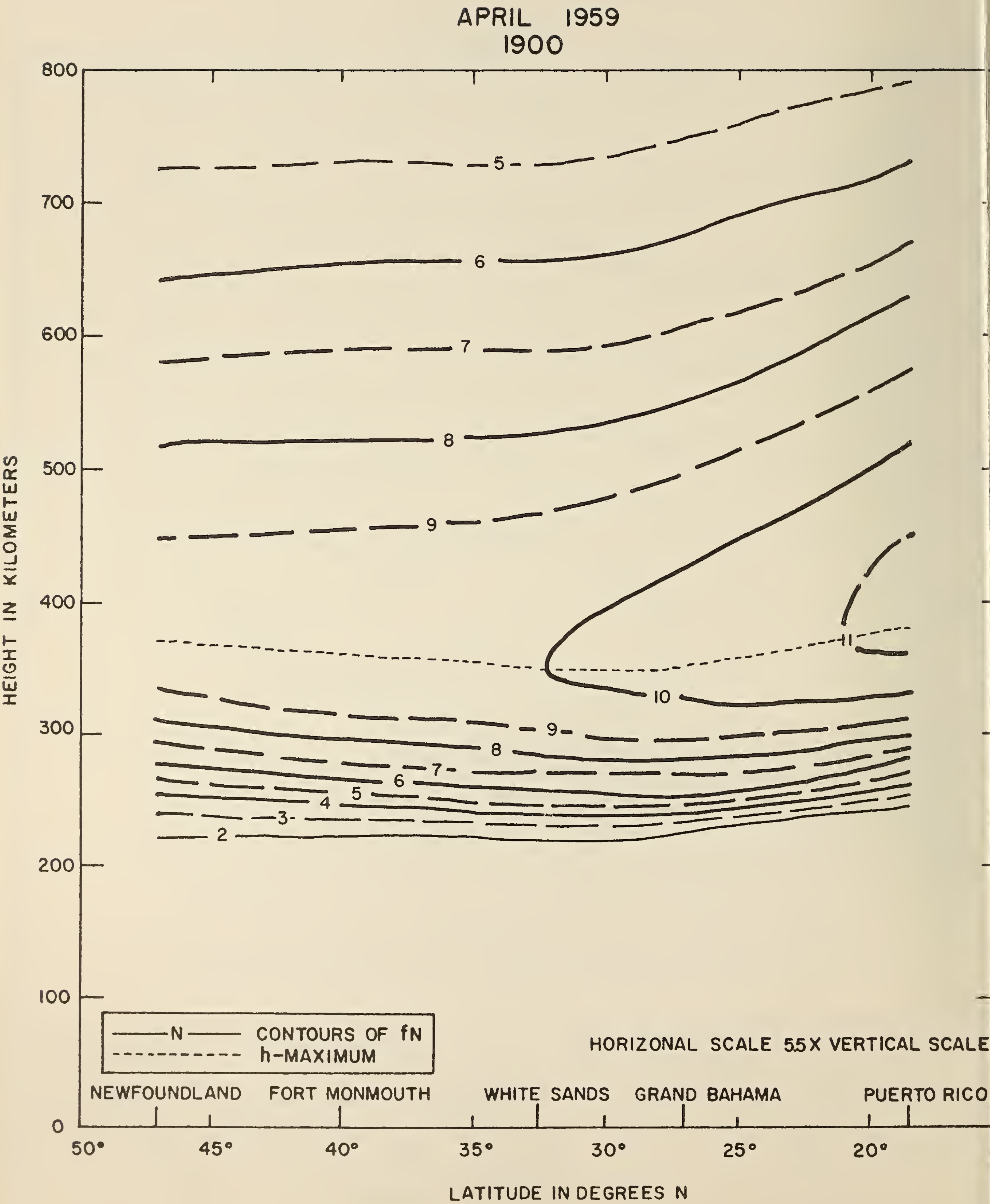
LATITUDE IN DEGREES N

APRIL 1959
1800




APRIL 1959
1900
HEIGHT IN KILOMETERS
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CONTOURS OF fN
h-MAXIMUM
HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
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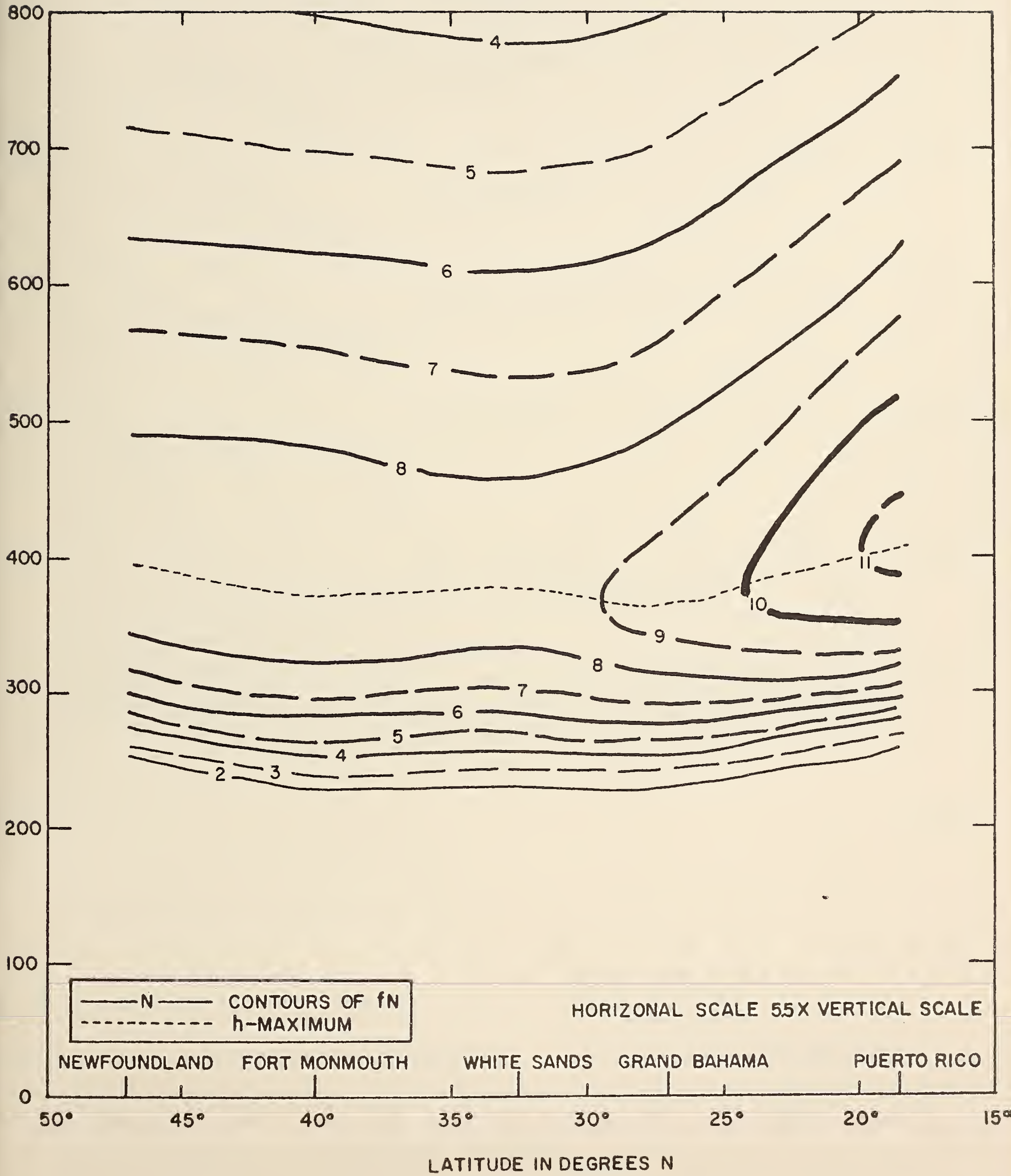
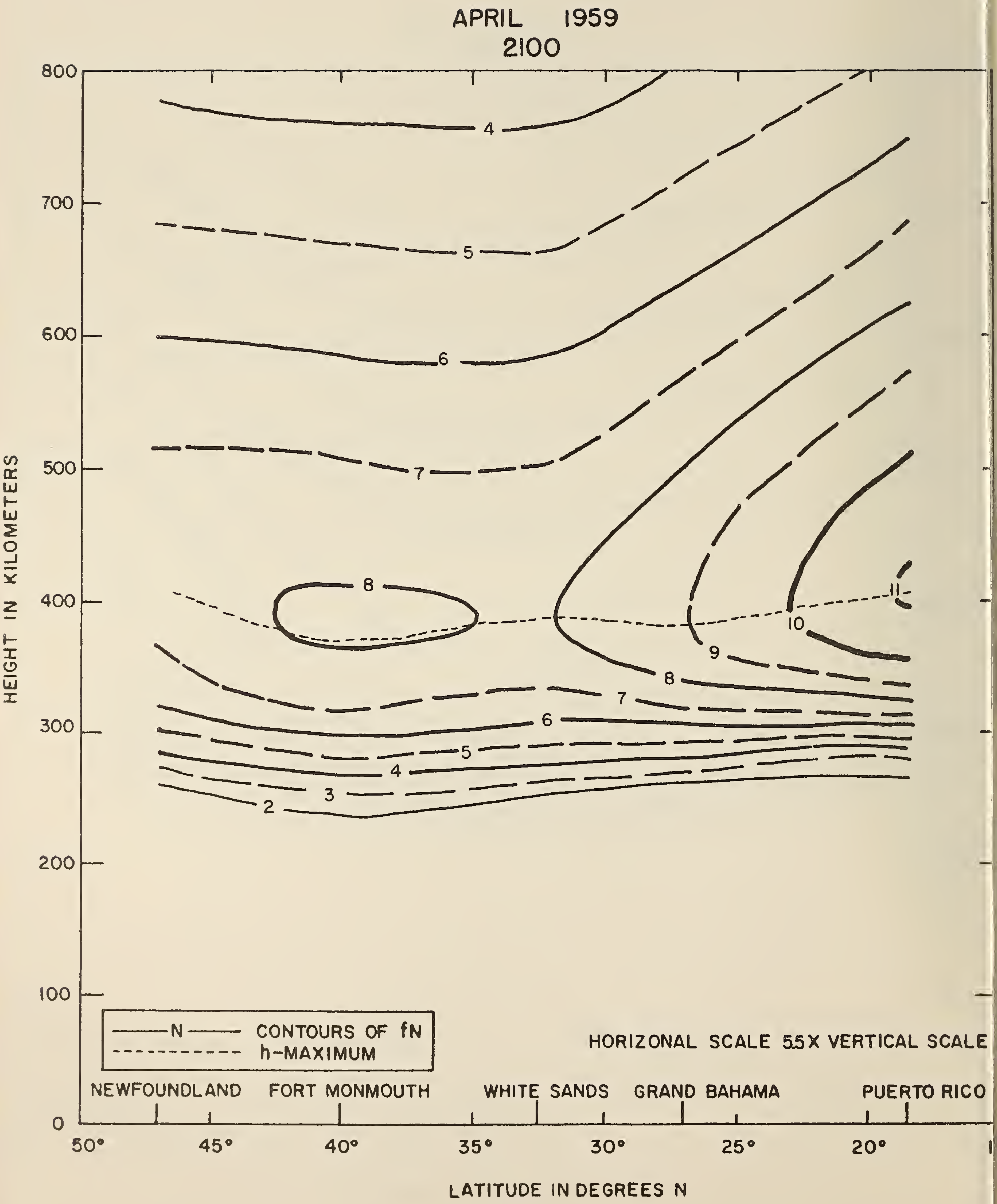
LATITUDE IN DEGREES N

APRIL 1959
2000




APRIL 1959
2100
HEIGHT IN KILOMETERS
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CONTOURS OF fN
h-MAXIMUM
HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
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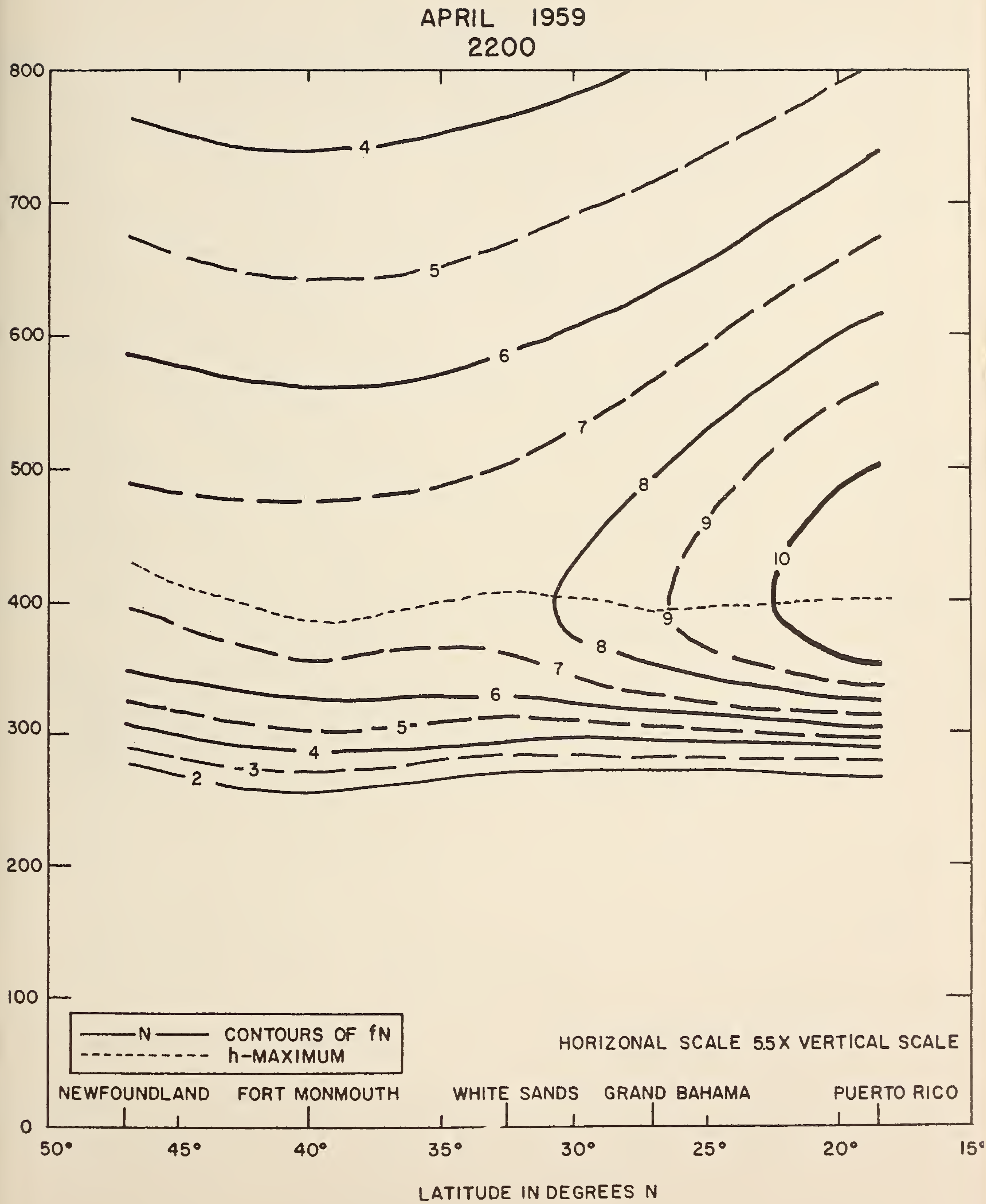
LATITUDE IN DEGREES N


APRIL 1959
2200
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N CONTOURS OF fN
h-MAXIMUM
HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
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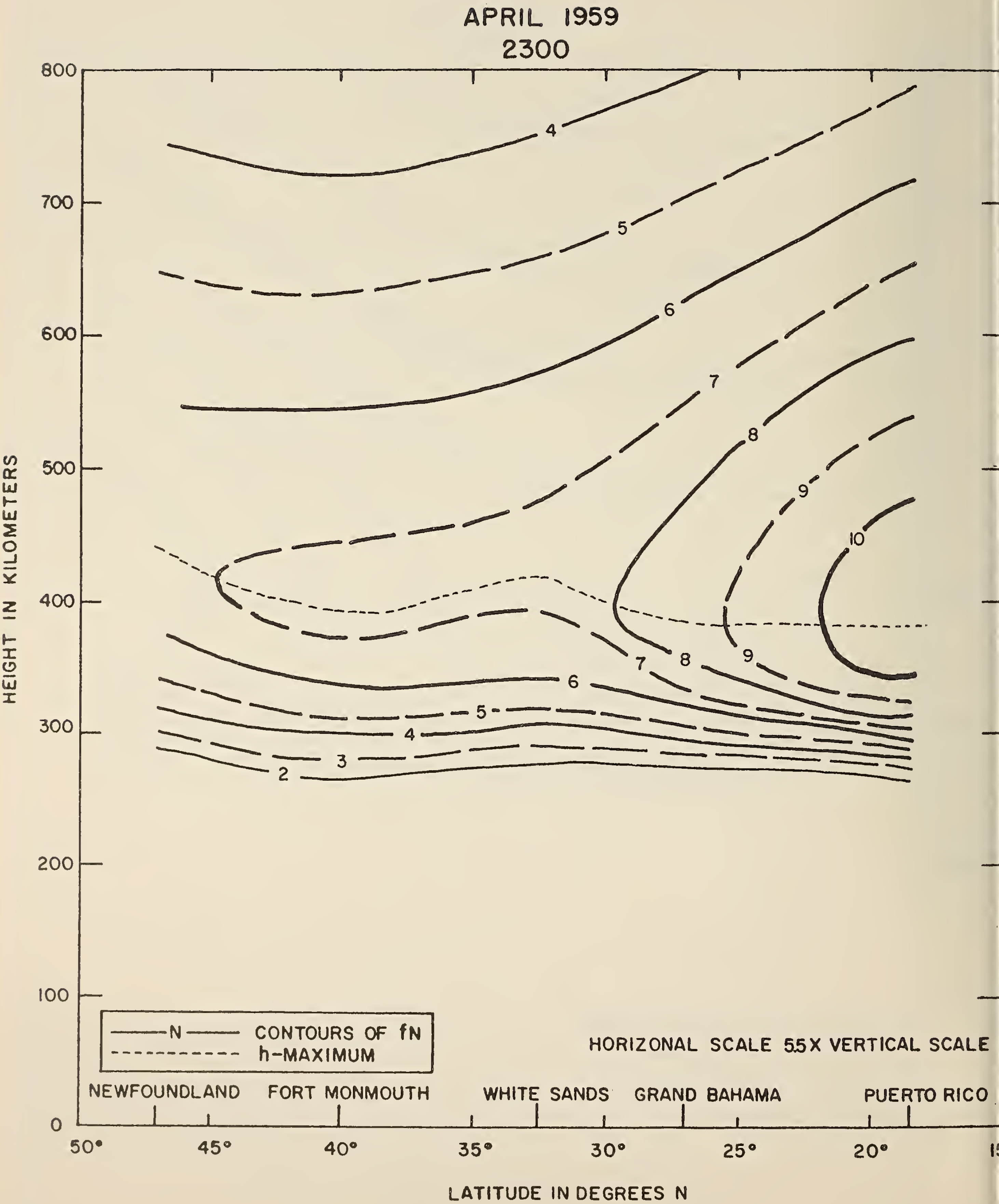
LATITUDE IN DEGREES N


APRIL 1959
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HEIGHT IN KILOMETERS
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HORIZONAL SCALE 5.5X VERTICAL SCALE
NEWFOUNDLAND
FORT MONMOUTH
WHITE SANDS
GRAND BAHAMA
PUERTO RICO
50°
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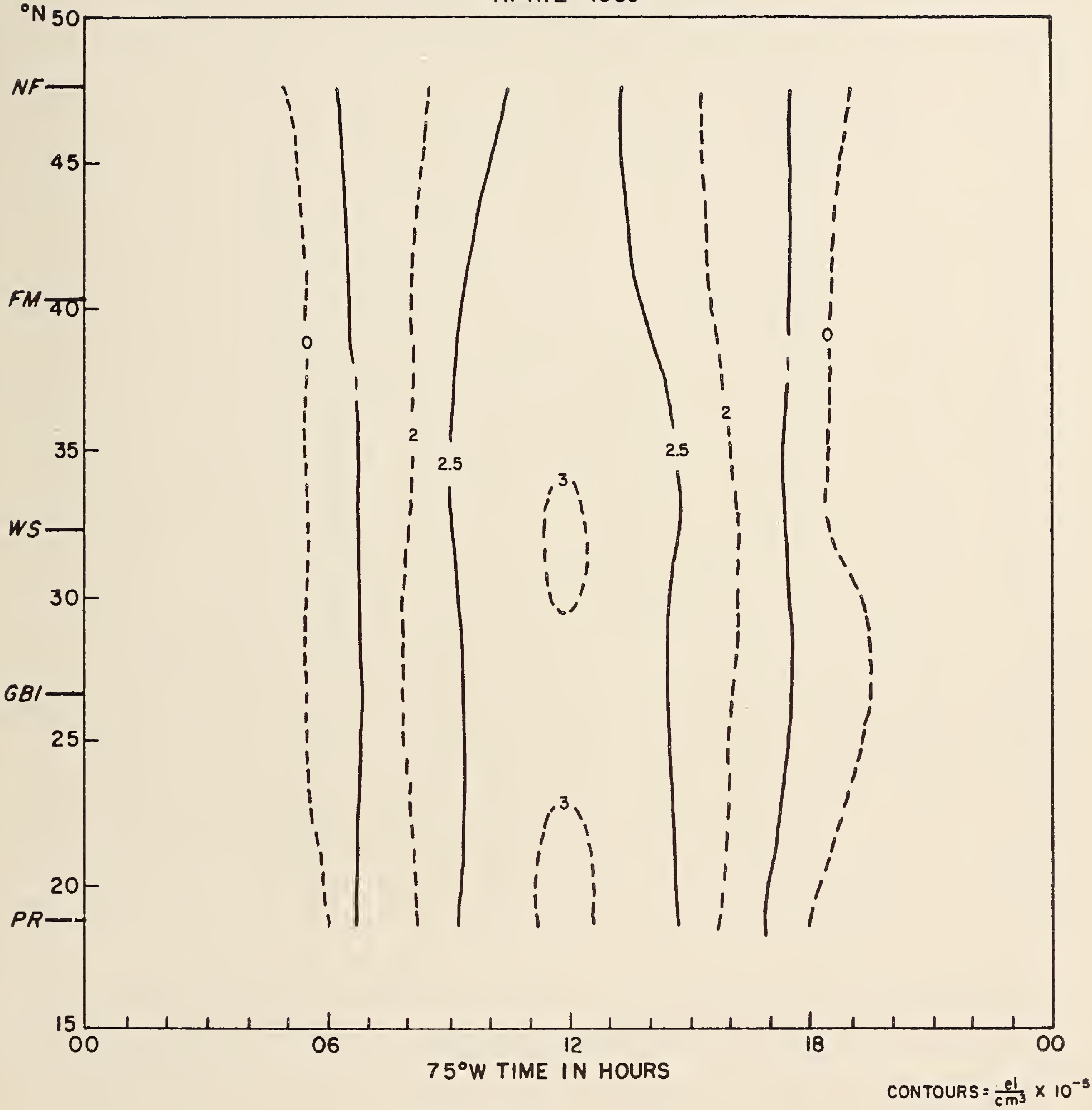
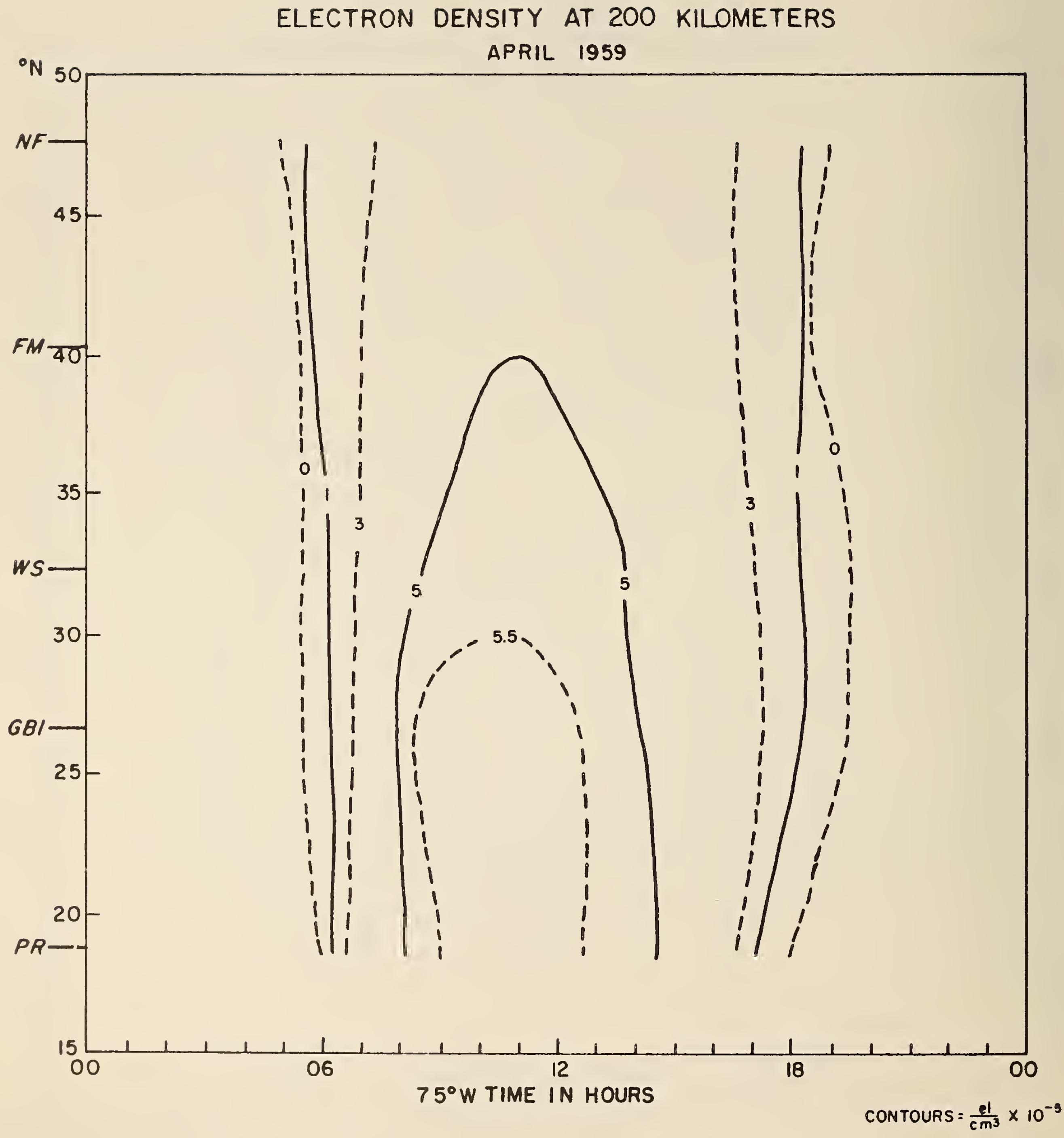
LATITUDE IN DEGREES N

ELECTRON DENSITY AT 150 KILOMETERS
APRIL 1959




ELECTRON DENSITY AT 200 KILOMETERS
APRIL 1959
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PR
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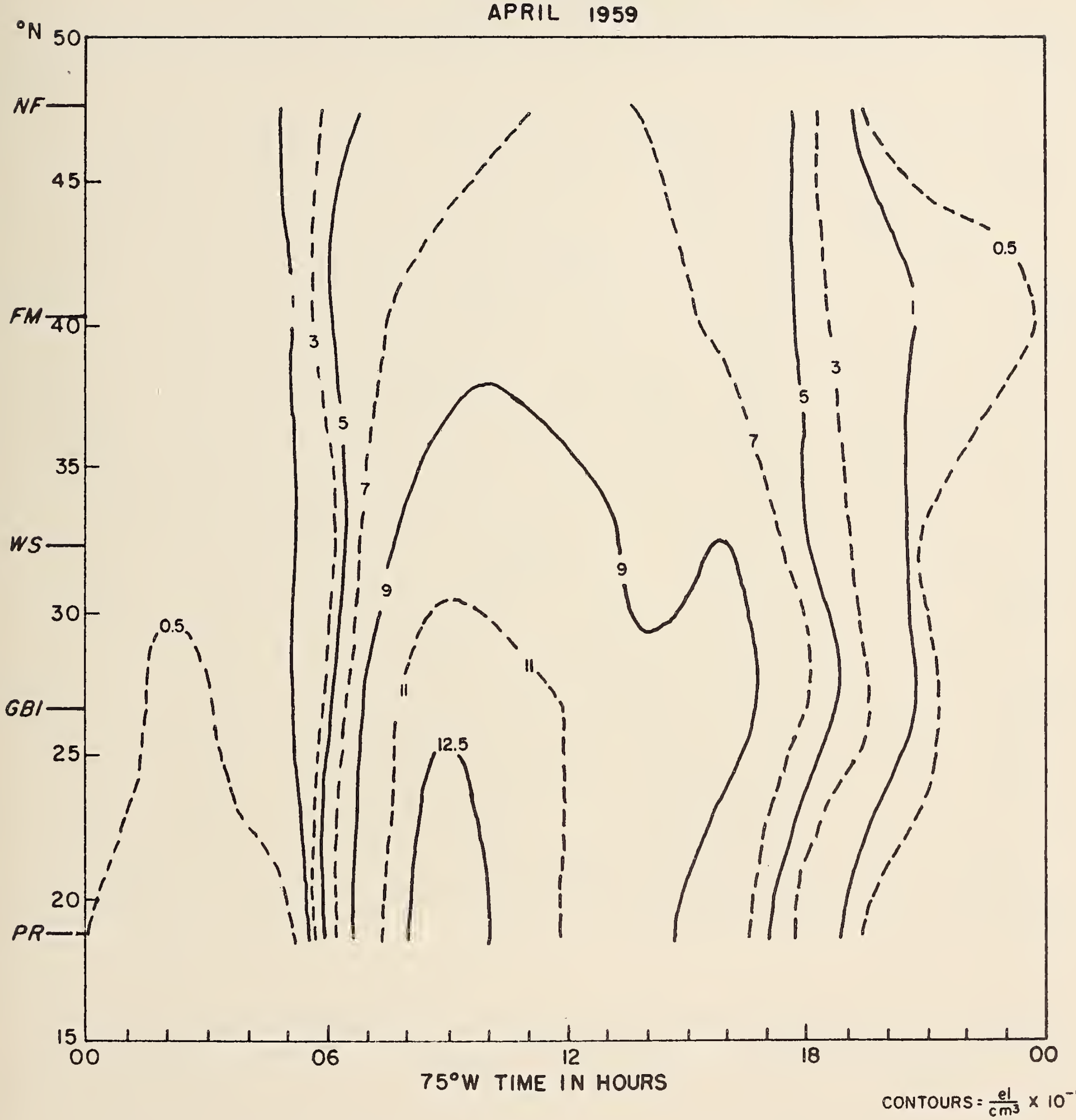
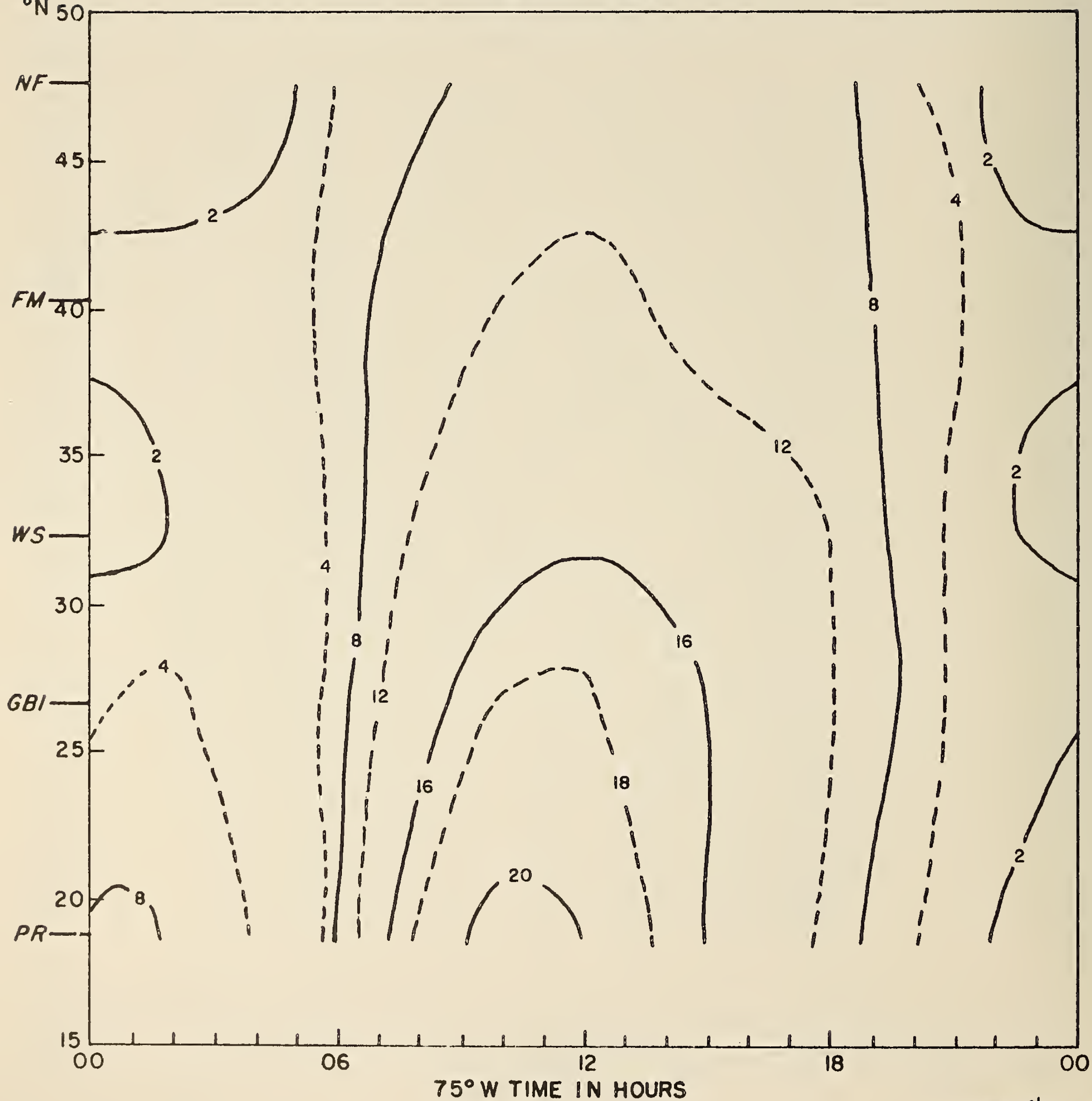
18
00
75°W TIME IN HOURS
CONTOURS: el/cm3 X 10^-5

ELECTRON DENSITY AT 250 KILOMETERS
APRIL 1959

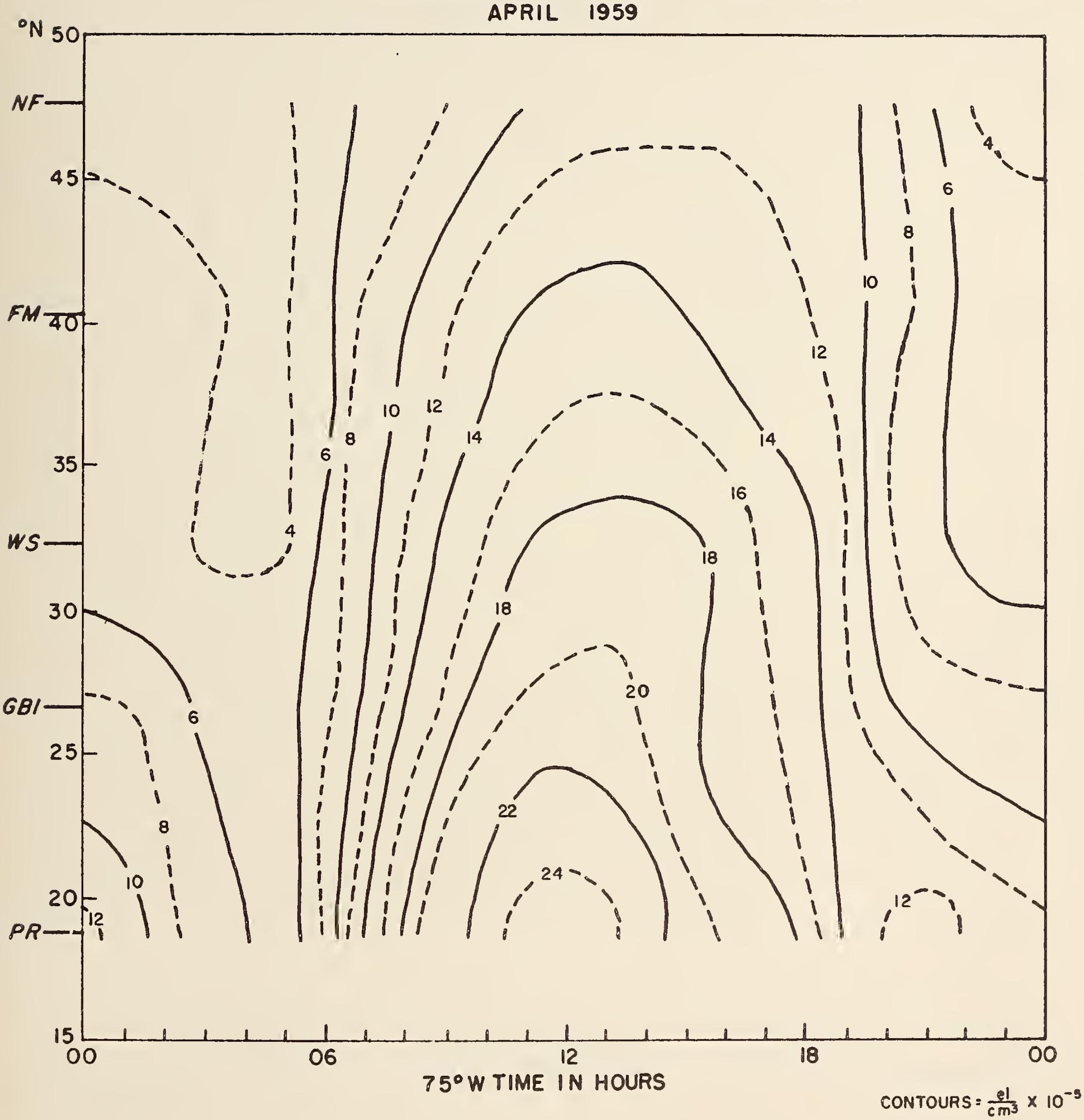


ELECTRON DENSITY AT 300 KILOMETERS
APRIL 1959

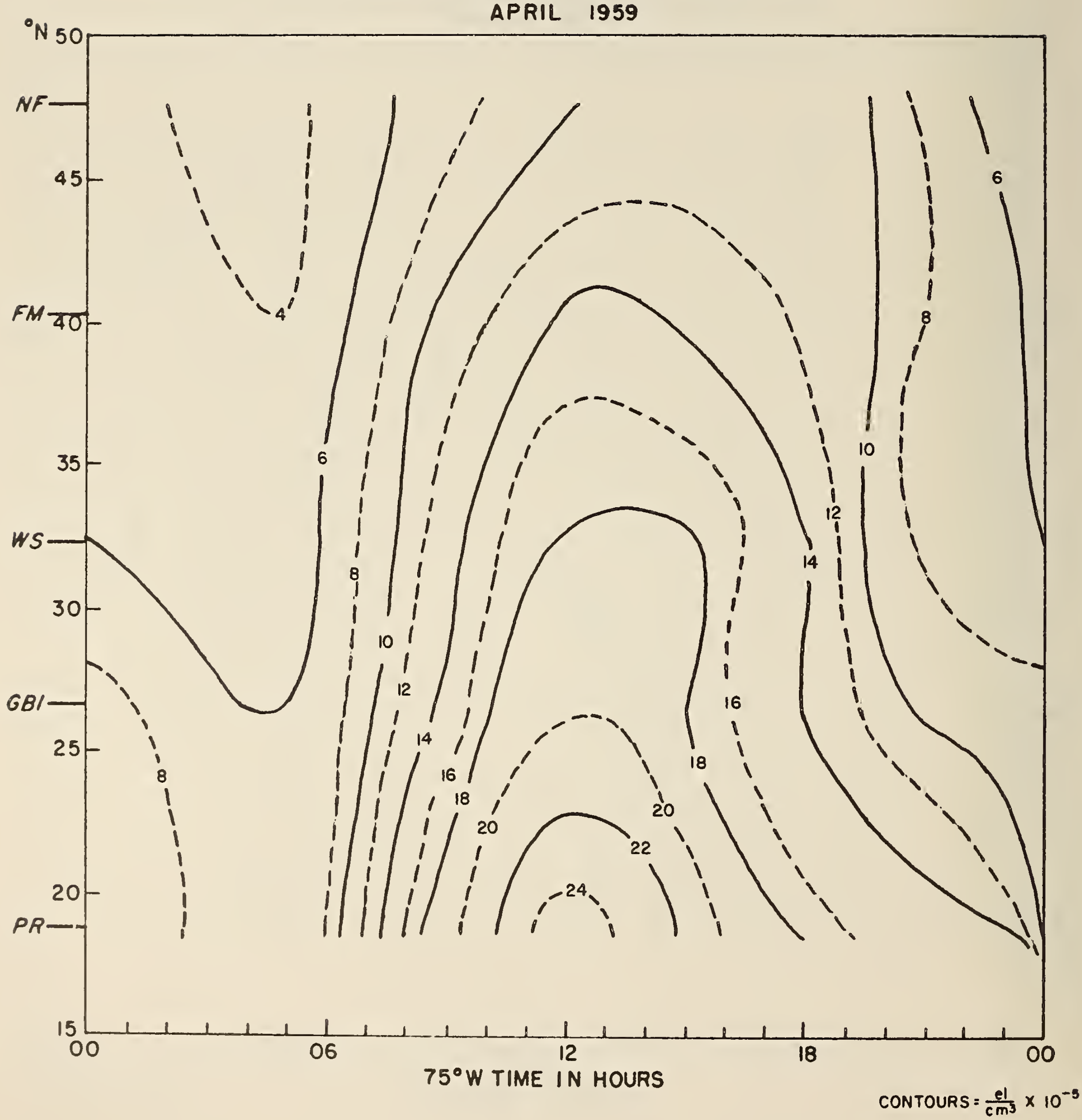


CONTOURS = $\frac{el}{cm^3} \times 10^{-5}$

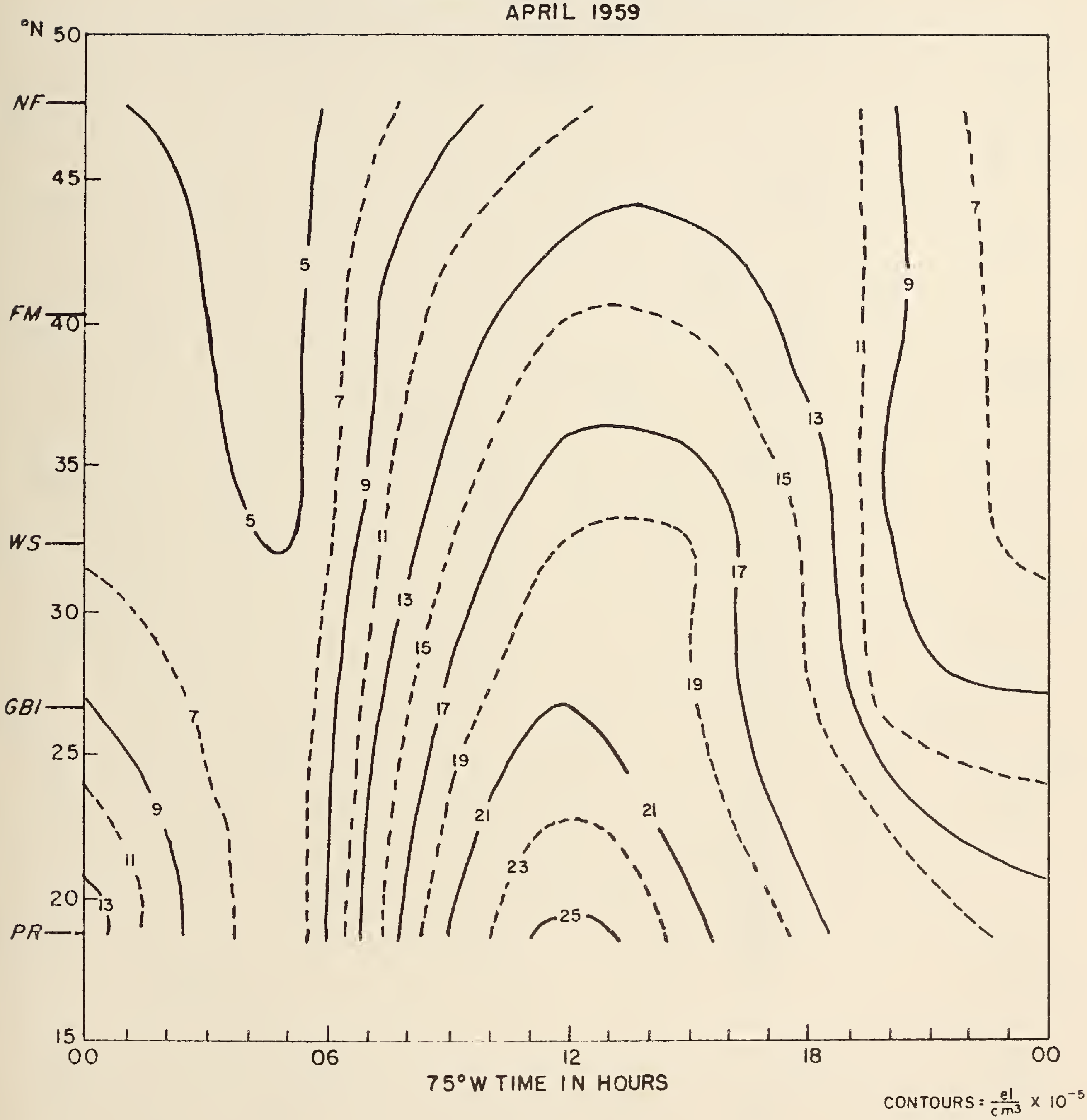
ELECTRON DENSITY AT 350 KILOMETERS
APRIL 1959



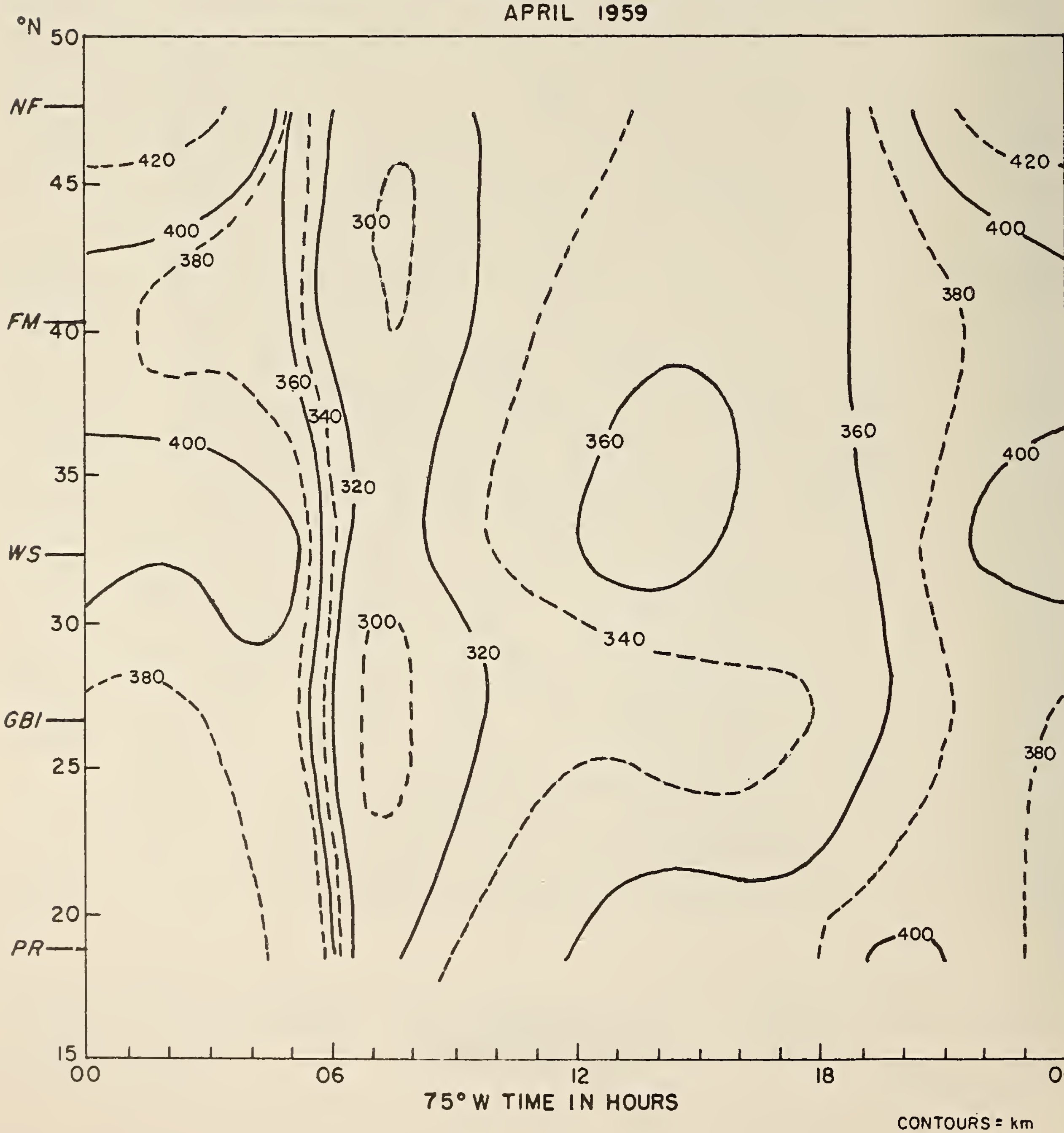
ELECTRON DENSITY AT 400 KILOMETERS
APRIL 1959



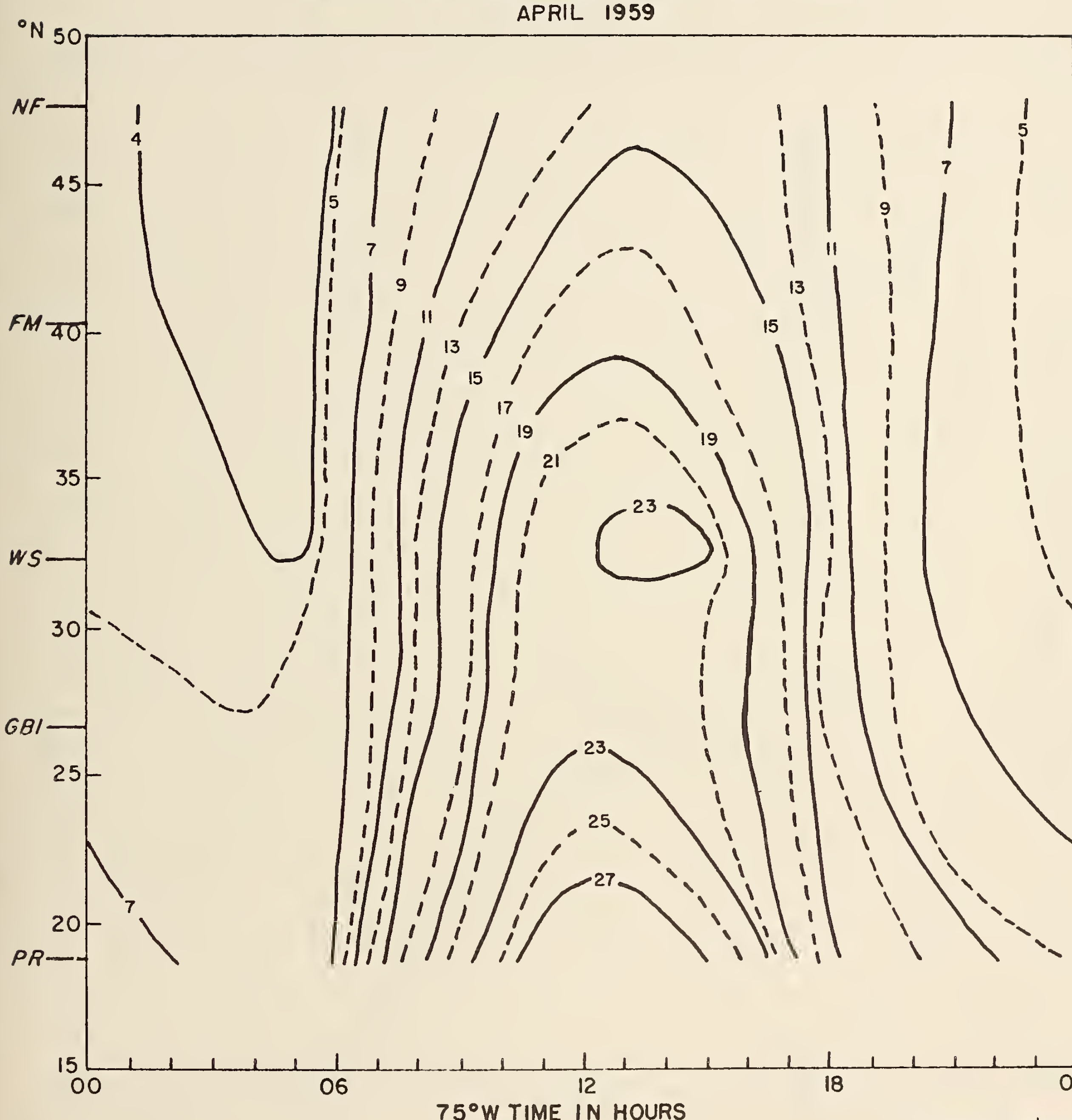
MAXIMUM ELECTRON DENSITY
APRIL 1959



HEIGHT OF MAXIMUM ELECTRON DENSITY
APRIL 1959



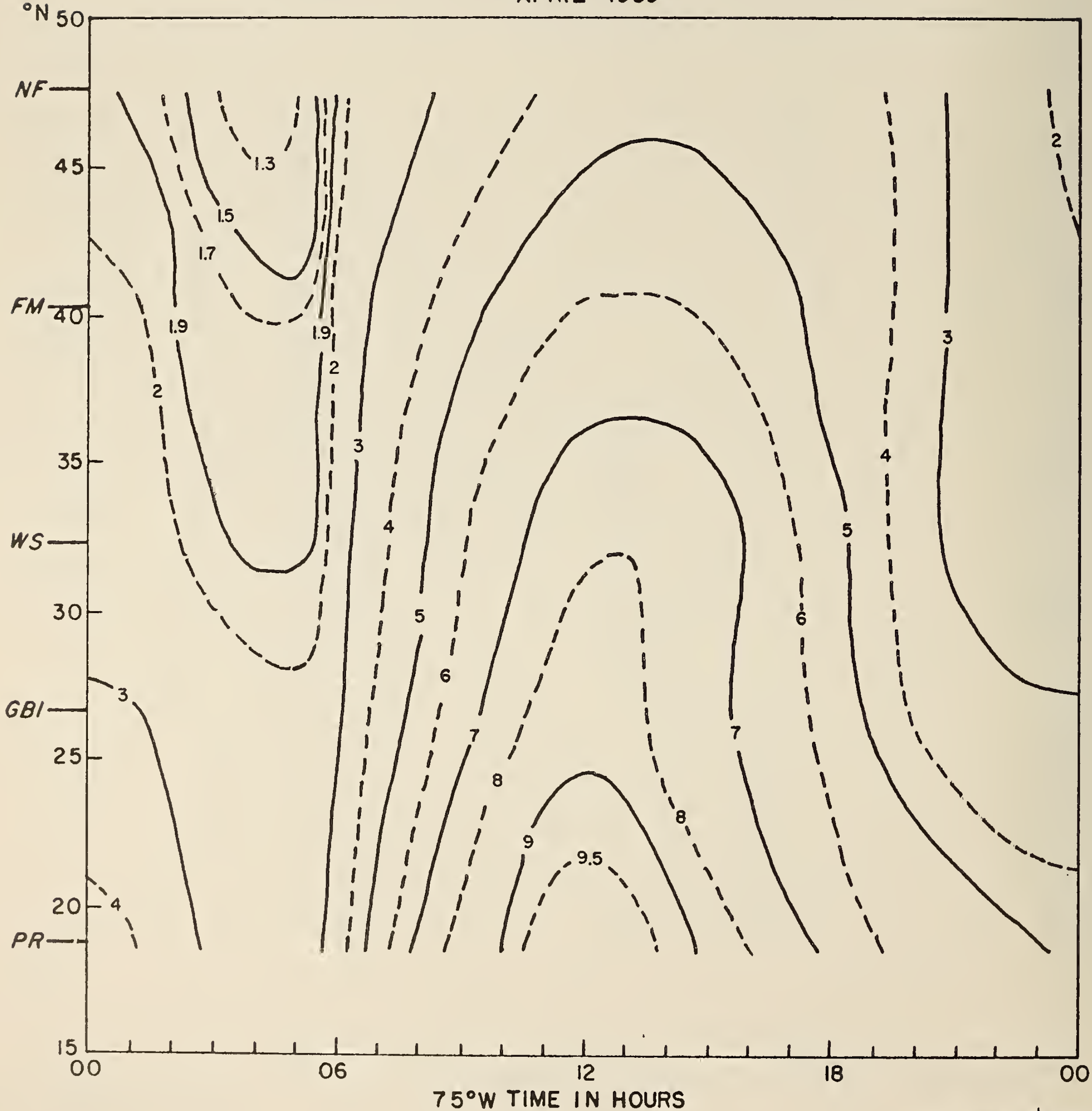
ELECTRON DENSITY INTEGRATED TO HEIGHT OF MAXIMUM ELECTRON DENSITY
APRIL 1959



CONTOURS = $\frac{el}{cm^2}$ col. X 10^{-12}

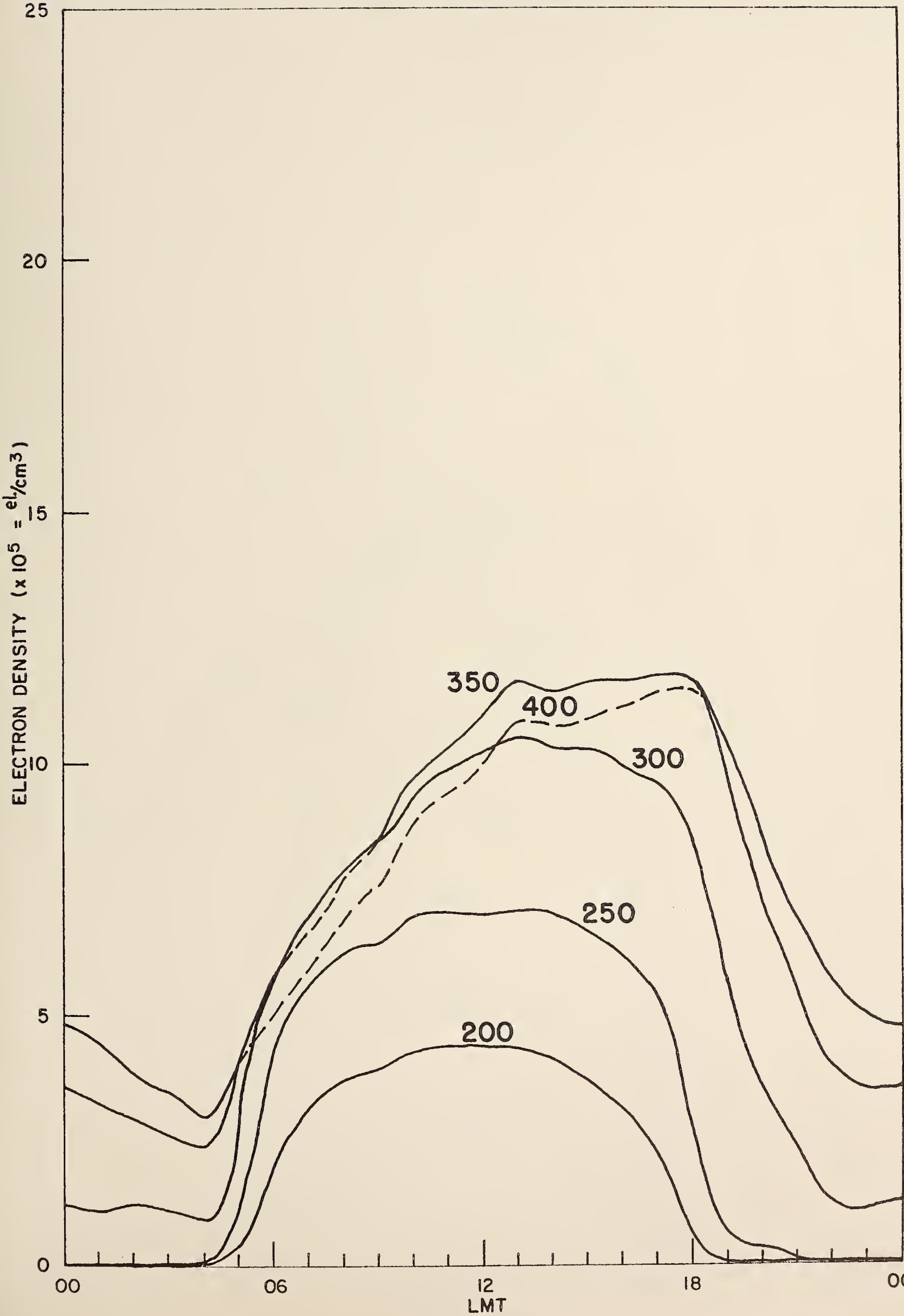
ELECTRON DENSITY INTEGRATED TO INFINITY

APRIL 1959

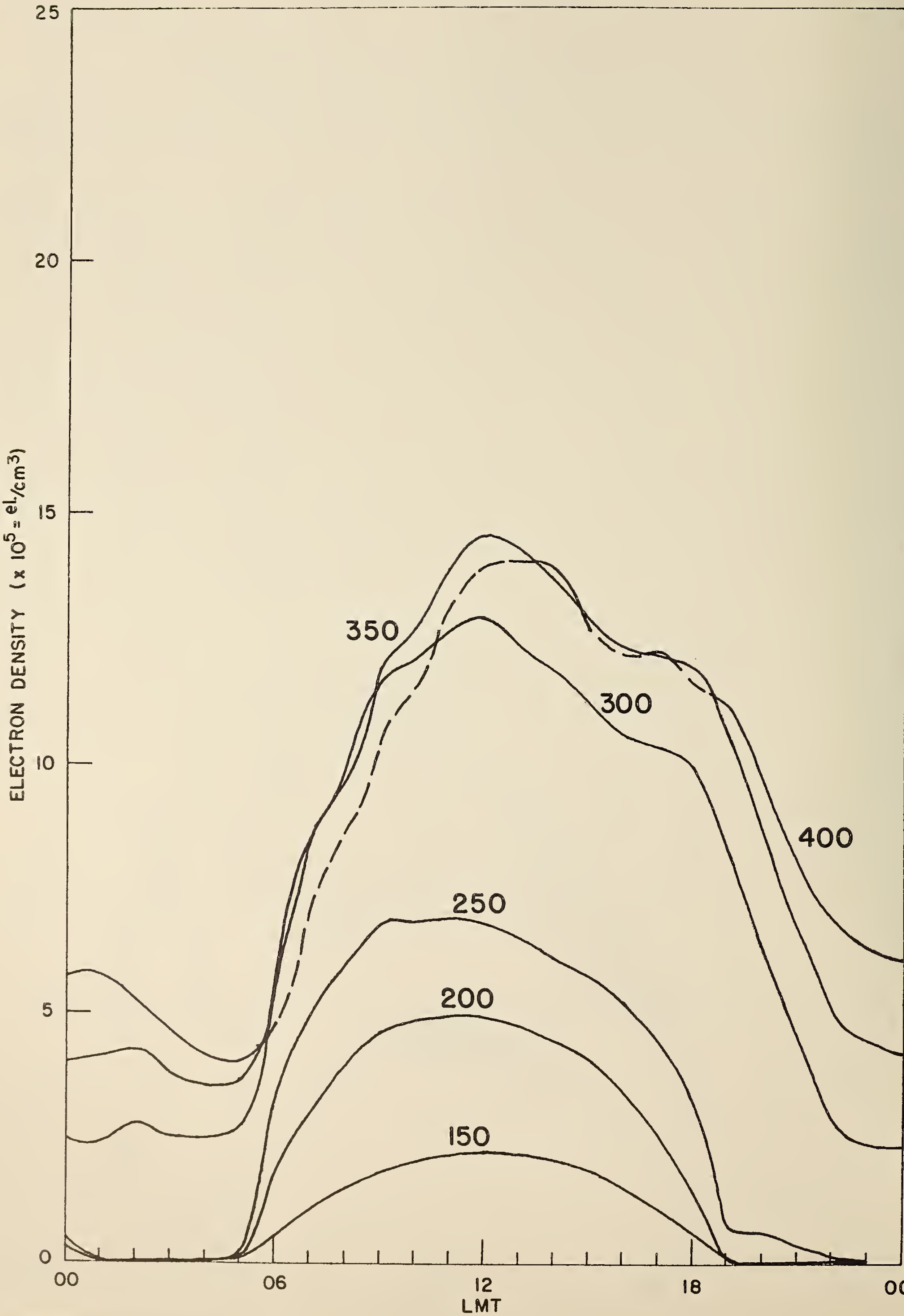


CONTOURS = $\frac{el}{cm^2}$col. X 10^{-12}

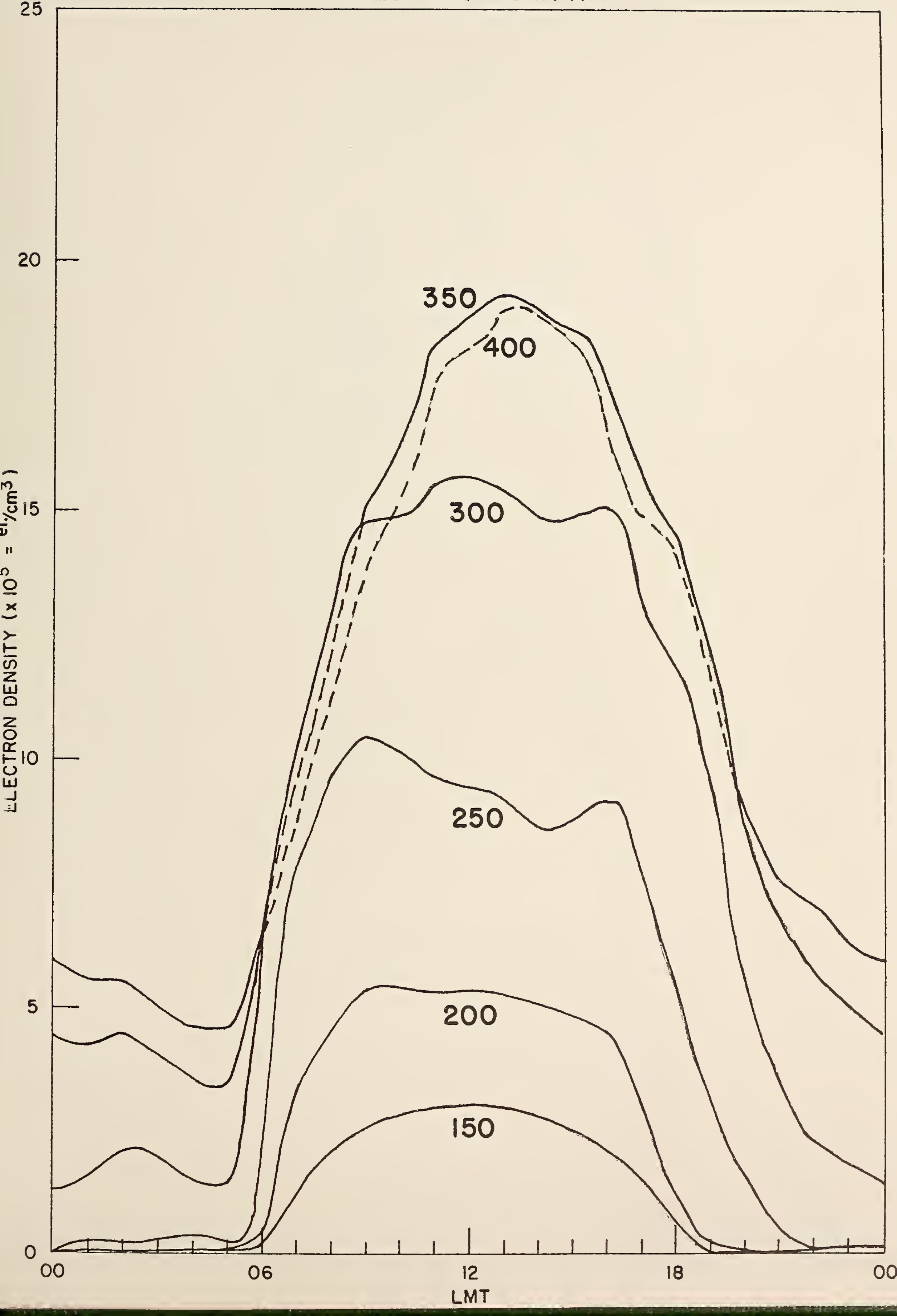
N(t) ST. JOHNS, NEW FOUNDLAND APRIL 1959
FIXED HEIGHTS IN Km



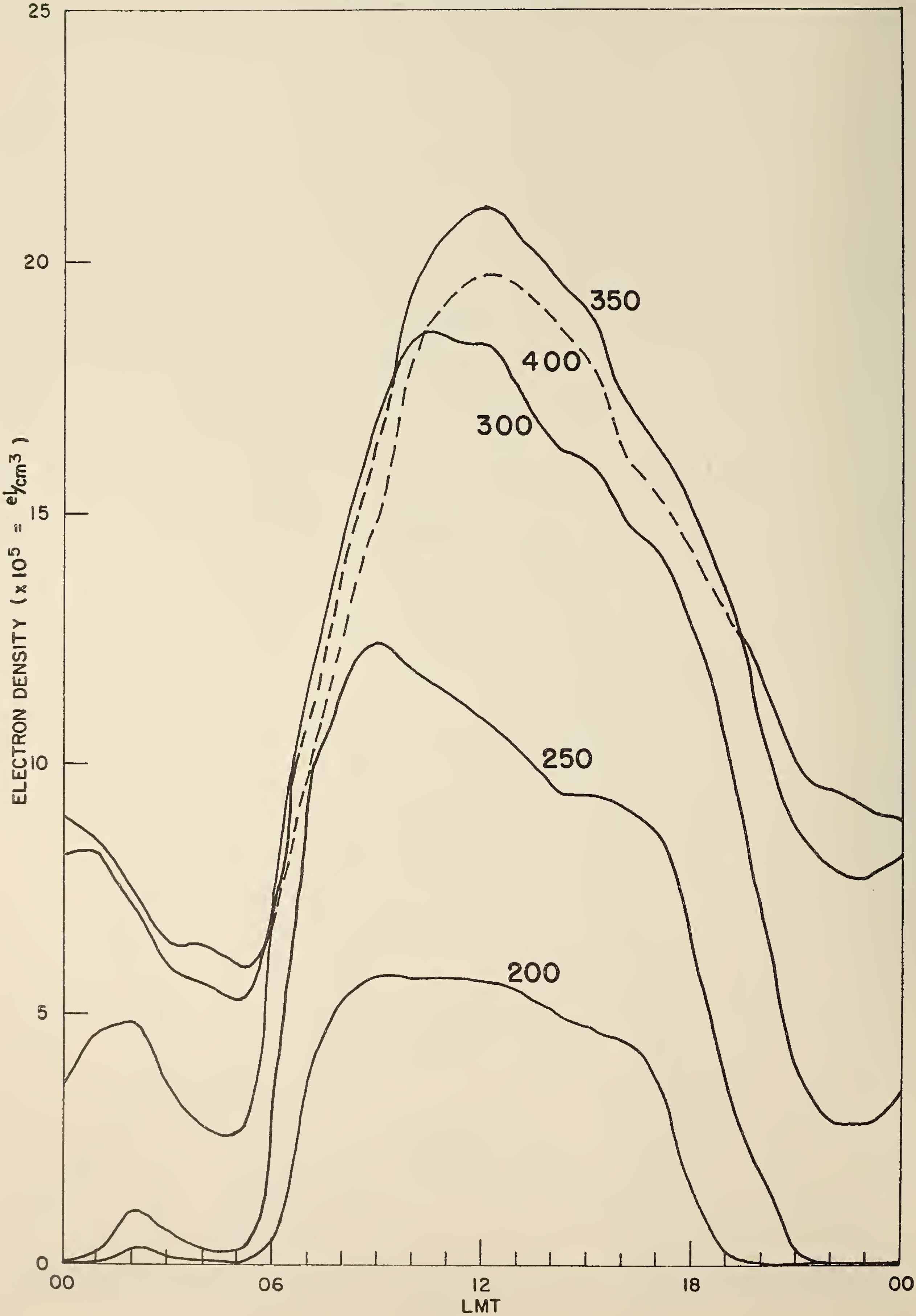
N(t) FORT MONMOUTH APRIL 1959
FIXED HEIGHTS IN Km

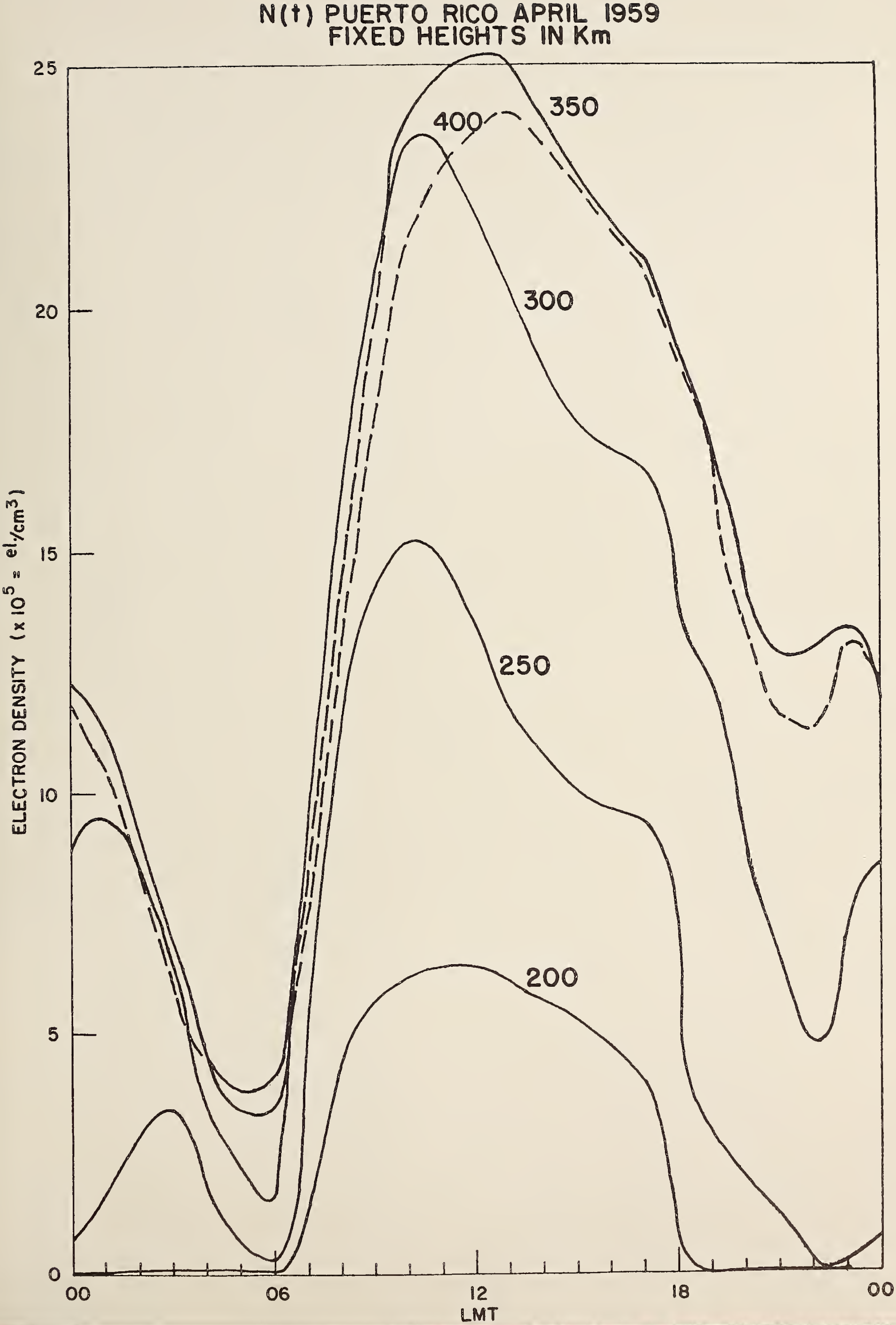


N(t) WHITE SANDS APRIL 1959
FIXED HEIGHTS IN Km



N(t) GRAND BAHAMA ISLAND APRIL 1959
FIXED HEIGHTS IN Km




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

U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, *Secretary*

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

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, 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 and Electronics. Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Photographic Technology. Length. Engineering Metrology.

Heat. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Molecular Kinetics. Free Radicals Research.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Radiation Theory. Radioactivity. X-rays. High Energy Radiation. Nucleonic Instrumentation. Radiological Equipment.

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

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

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

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer. Concreting Materials.

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

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.

- Office of Basic Instrumentation.
- Office of Weights and Measures.

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research. Radio Warning Services. Airglow and Aurora. Radio Astronomy and Arctic Propagation.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Research. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation Obstacles Engineering. Radio-Meteorology. Lower Atmosphere Physics.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Electronic Calibration Center. Microwave Physics. Microwave Circuit Standards.

Radio Communication and Systems. Low Frequency and Very Low Frequency Research. High Frequency and Very High Frequency Research. Ultra High Frequency and Super High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Systems Analysis. Field Operations.

COMM-NBS-B.

NBS