CR-102637

GE—9500—ECS—FR
20 FEBRUARY 1969

FINAL REPORT

DESIGN ENVIRONMENT CRITERIA

FACILITY FORM 602

N70-28420	
(ACCESSION NUMBER)	(THRU)
47	1
(PAGES)	(CODE)
CR-102637	29
(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

EDITED BY:

D. N. VACHON
SPACE PHYSICS LABORATORY

PREPARED FOR:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
G. C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA 35812
UNDER MSFC CONTRACT NUMBER NAS8—21420

GENERAL ELECTRIC
RE-ENTRY SYSTEMS
P. O. Box 8555 • Philadelphia, Penna. 19101

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LIST OF ILLUSTRATIONS

1.0 INTRODUCTION

In order to determine the need for updating, refining and/or amplifying the near-earth environment as defined in NASA-TM 53521, reviews of the present state of knowledge were conducted. These reviews were documented in seven scientific reports and provide the basis for the recommended changes to the criteria guidelines given in this final report.

The purpose of this final report is therefore restricted to the end results of the study, with the justification for the values recommended being available in the respective scientific reports listed below:

GE-9500-ECS-SR-1	"The Chemical Kinetics and the Composition of the Earth's Atmosphere", by M. Bortner and R. Kummler, July, 1968.
GE-9500-ECS-SR-2	"Near-Earth Meteoroid Environment", by R. Soberman and S. Neste, October, 1968.
GE-9500-ECS-SR-3	"Magnetosphere Environment" by T. Galbraith, November, 1968.
GE-9500-ECS-SR-4	"Near-Earth Electromagnetic Radiation Environment", by J. Kaplan, December, 1968.
GE-9500-ECS-SR-5	"A Model of the Geomagnetic Field", by T. Galbraith, December, 1968.

GE-9500-ECS-SR-6	"Solar Flare and Cosmic Ray Environment", by T. Galbraith, December 1968.
GE-9500-ECS-SR-7	"On the Variation of Density at High Altitudes", by D. Vachon, December, 1968.

2.0 METEOROID ENVIRONMENT

The recommended meteoroid flux as a function of mass is given in Figure 2-1 along with an estimate of the uncertainty extremes.

The recommended estimate of the penetration depth as a function of the penetrating particle flux is given in Figure 2-2. It is recommended that a listing of the characteristics of the major meteor streams be included in the design criteria handbook (NASA-TMX-53798). Such a listing is presented in Table 2-I and includes the meteor streams incorporated in the recent criteria handbook NASA-TMX-53798.

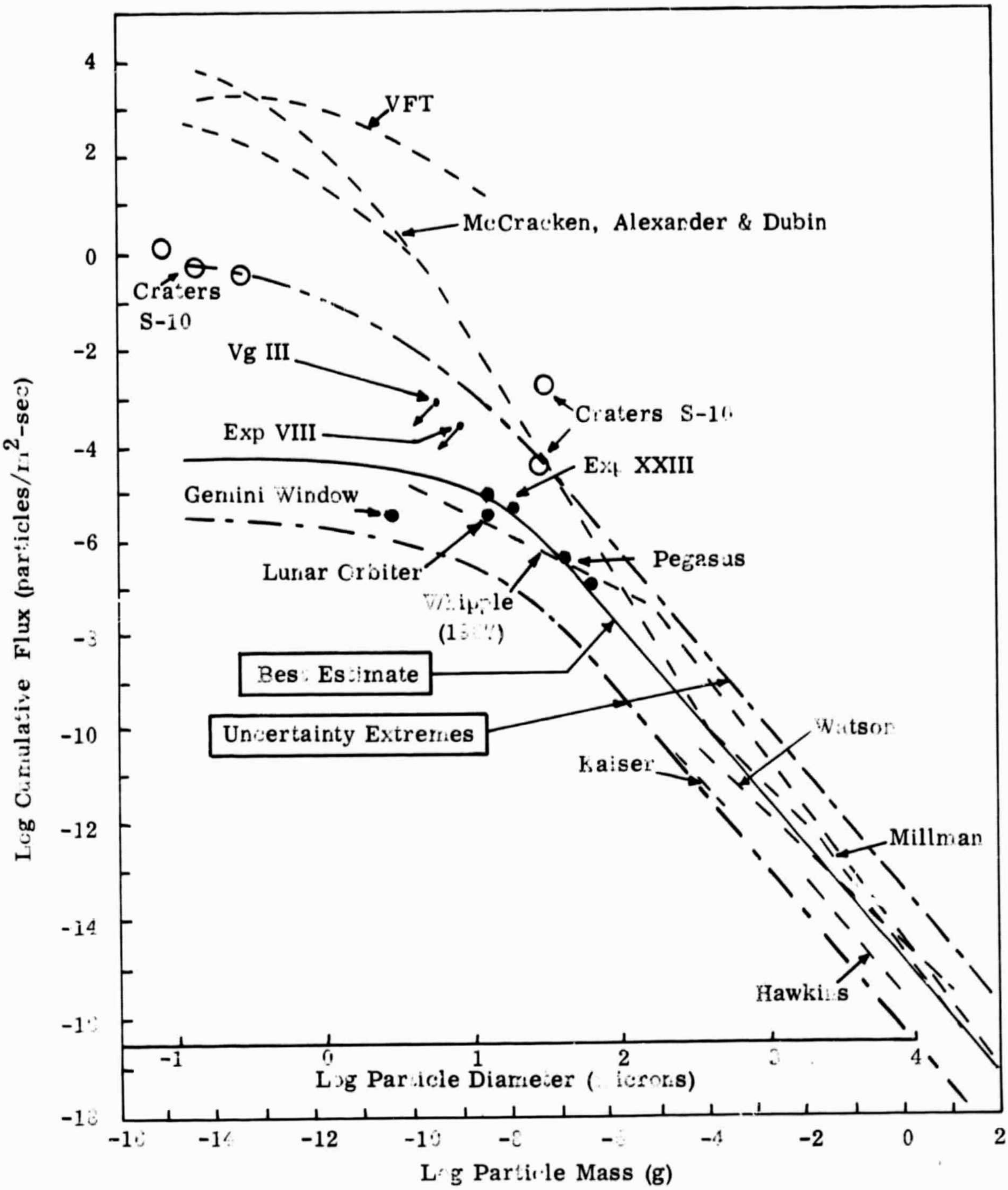


Figure 2-1. Log Cumulative Flux vs. Log Particle Mass and Size (Density 3)

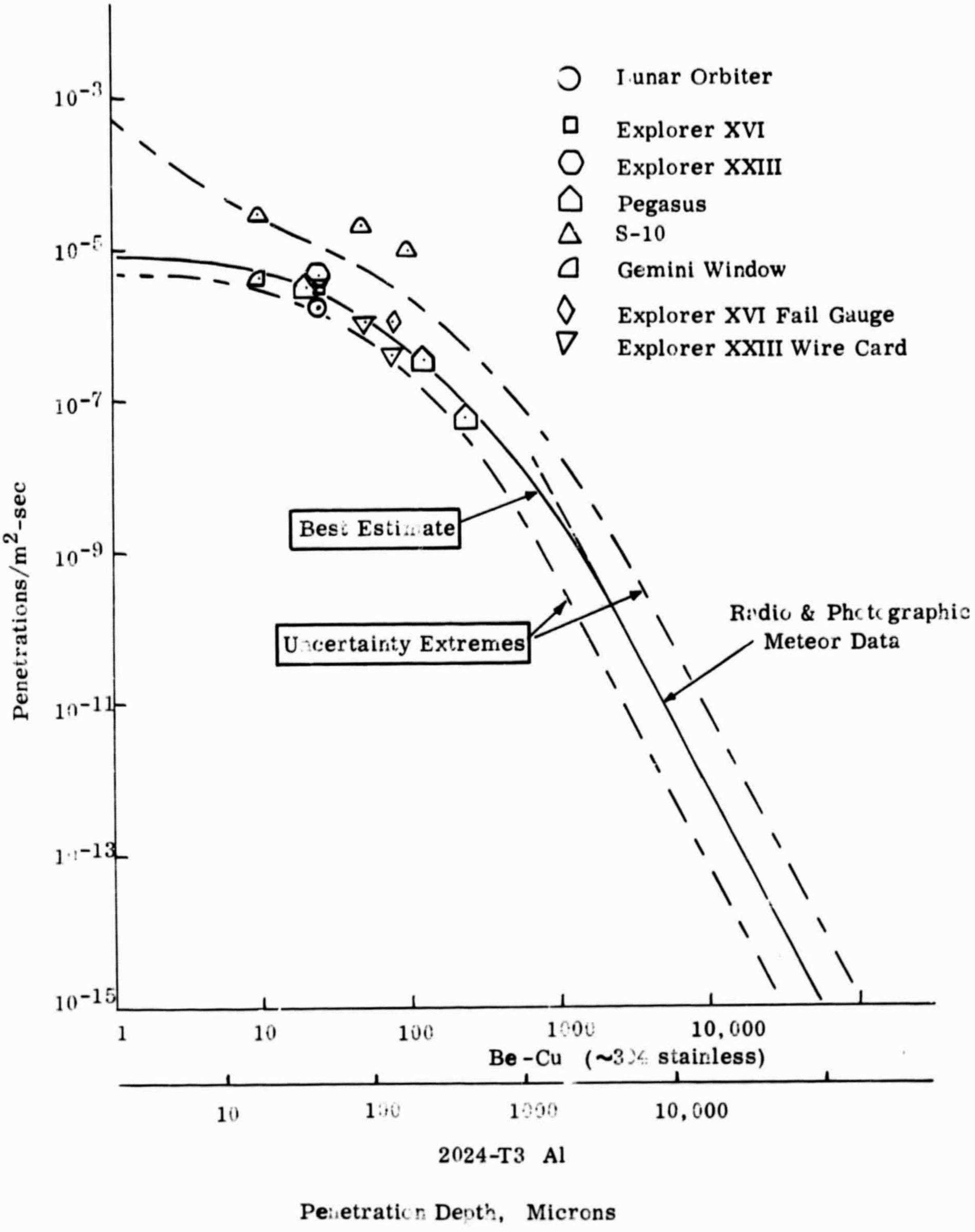


Figure 2-2. Log Cumulative Penetrations vs. Penetration Depth

Table 2-I. The Major Meteor Showers

(1) Shower	(2) Date of peak activity	(3) Radiant Coordinates		(4) Dates of detectable meteors	(5) Duration of peak, days	(6) Approx. local time of radiant transit	(7) Observed velocity V_0 km/sec	(8) Equivalent visual hourly rates
		R. A.	Dec.					
Quadrantids	Jan. 3	231°	+50°	1 - 4 Jan.	0.5	0835	41	50
Corona Australids	Mar. 16	245	-48	14 - 18 Mar.	(5)	0445	--	(5)
Virginids	Mar. 20	190	00	Mar. 5 - Apr. 2	(20)	0050	30	(< 5)
Lyrids	Apr. 21	272	+32	19 - 24 Apr.	2	0410	48	5
Eta Aquarids	May 4	336	00	Apr. 21 - May 12	10	0735	64	20
Arietids (D)	June 7	45	+23	May 29 - June 19	20	1000	39	60
Zeta Perseids (D)	June 9	62	+24	1 - 17 June	15	1100	29	40
Ophuichids	June 20	260	-20	17 - 26 June	(10)	2325	--	(20)
Beta Taurids (D)	June 29	87	+20	June 25 - July 5	10	1115	31	20
Capricornids	July 25	315	-15	July 10 - Aug. 5	(20)	0050	--	(20)
Southern Delta Aquarids	July 29	339	-17	July 21 - Aug. 15	15	0210	41	20
Northern Delta Aquarids	July 29	339	00	July 15 - Aug. 18	20	0210	41	10
Pisces Australids	July 30	340	-30	July 15 - Aug. 20	(20)	0210	--	(20)
Alpha Capricornids	Aug. 1	309	-10	July 15 - Aug. 20	(25)	0000	23	5
Southern Iota Aquarids	Aug. 5	338	-15	July 15 - Aug. 25	(25)	0410	35	(10)
Northern Iota Aqaurids	Aug. 5	331	-6	July 15 - Aug. 25	(25)	0110	30	(10)
Perseids	Aug. 12	46	+58	July 25 - Aug. 17	5	0540	60	50
Kappa Cygnids	Aug. 20	290	+55	18 - 22 Aug.	(3)	2125	26	(5)
Orionids	Oct. 21	95	+15	18 - 26 Oct.	5	0420	66	20
Southern Taurids	Nov. 1	52	+14	Sept. 15 - Dec. 15	(45)	0045	29	(5)
Northern Taurids	Nov. 1	54	+21	Oct. 15 - Dec. 1	(30)	0055	30	(< 5)
Leonids	Nov. 16	152	+22	14 - 20 Nov.	4	0026	72	(5)
Phoenicids	Dec. 5	15	-55	(Dec. 5)	(0.5)	2000	(13)	(50)
Geminids	Dec. 13	113	+32	7 - 15 Dec.	6	0205	35	50
Ursids	Dec. 22	217	+80	17 - 24 Dec.	2	0825	34	15

3.0 RADIATION ENVIRONMENT

3.1 Cosmic Radiation

It is recommended that the cosmic radiation section of the design criteria handbook (TMX-53521) be extended to include an estimate of the cosmic radiation differential energy spectrum given in Figure 3-1.

3.2 Solar Flares

It is recommended that the solar flare section of both the TMX-53521 and TMX-53798 handbooks be extended to provide a representation of the time variations of the integral spectra given in Figure 3-2.

3.3 Trapped Radiation

From the viewpoint of design criteria the radiation environment depiction of widest appeal appears to be the R-λ mapping. Since the radiation environment has a very pronounced time-space variation, it is difficult to provide a meaningful presentation for designers. For example, the radiation dose encountered by two satellites with the same perigee and apogee, but different inclinations, can differ by a substantial amount.

In general, the maximum particle flux is encountered over the geomagnetic equator and quite often the design is based on assuming the maximum flux throughout the orbit. For preliminary design evaluations this is perhaps a most acceptable procedure, and for such usage the values given in Table 3-I should suffice. It is noted that the values given for the electron flux are for a time period of December 1968, which is a period of high solar activity and thus reflect a high intensity of electrons in the outer zone. For more general design usage, the R-λ maps given as Figures 3-3 through 3-7 provide sufficient definition of the vertical variation of the flux to enable bracketing the optimum altitude region for flight. Once the satellite orbital characteristics are bracketed, the integrated particle flux can be defined using the computerized version of the information provided in the NASA-SP3024 reports.

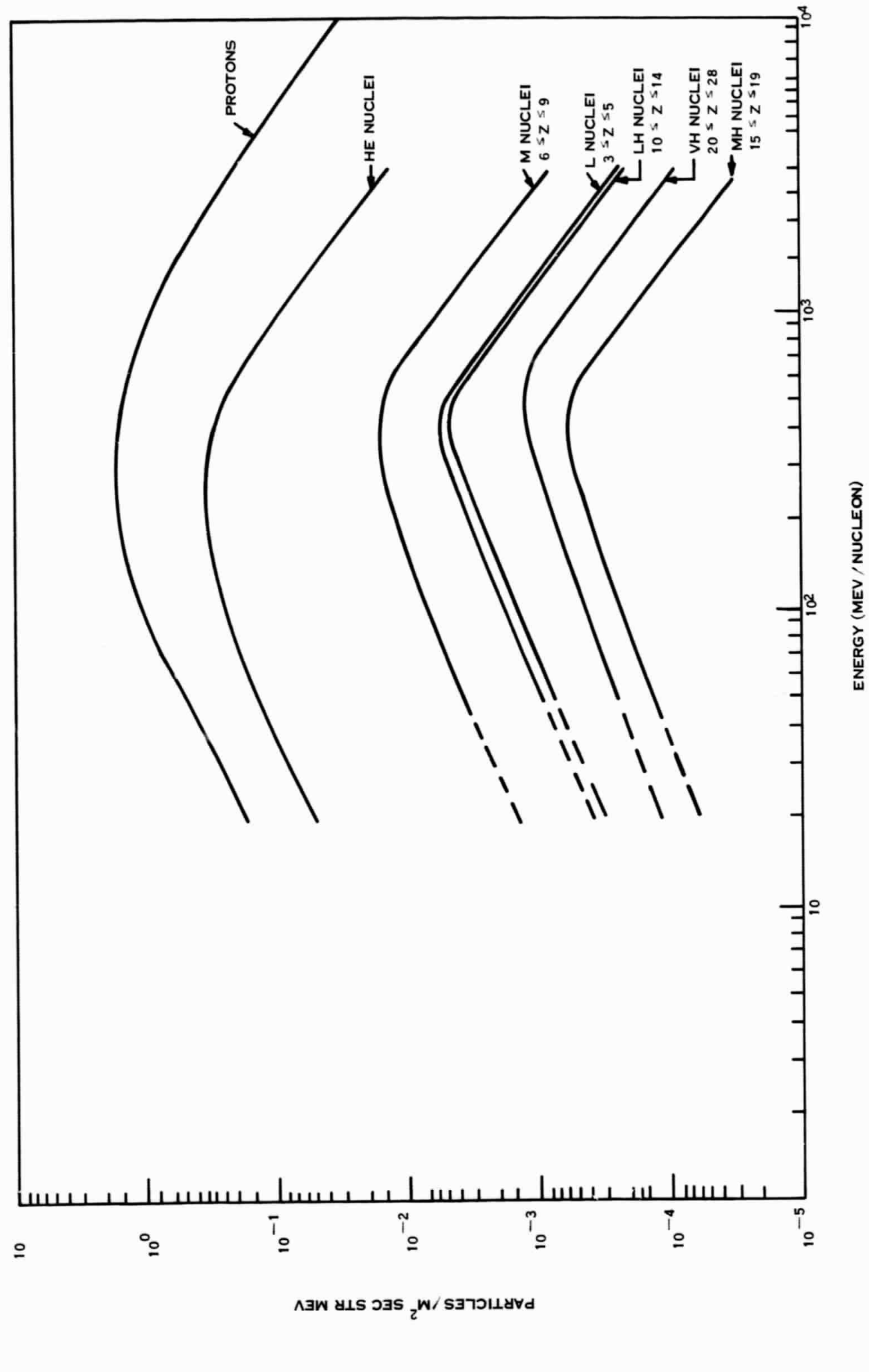
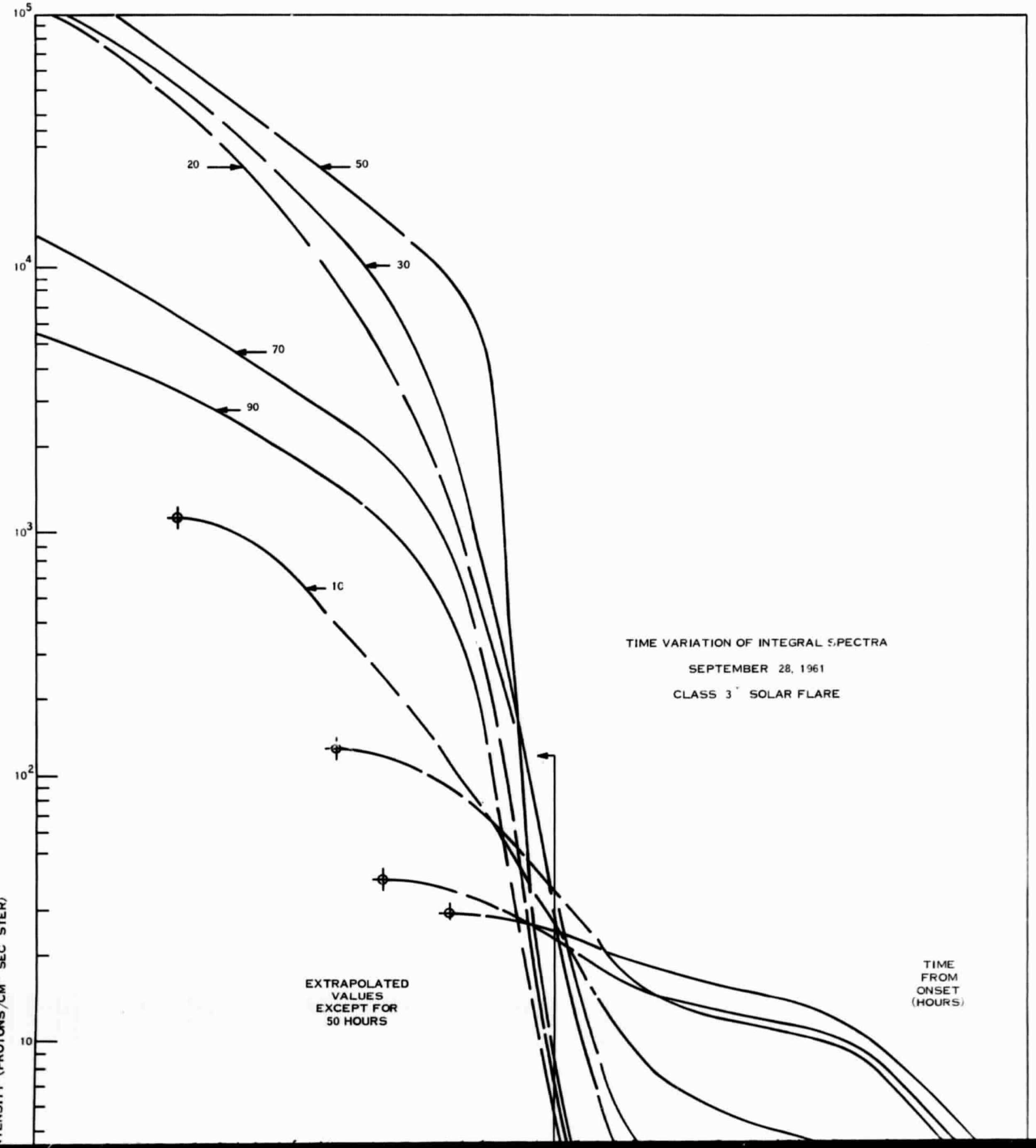


Figure 3-1. Cosmic Ray Differential Particle Energy Spectrum as a Function of Z Number Categories

FOLDOUT FRAME



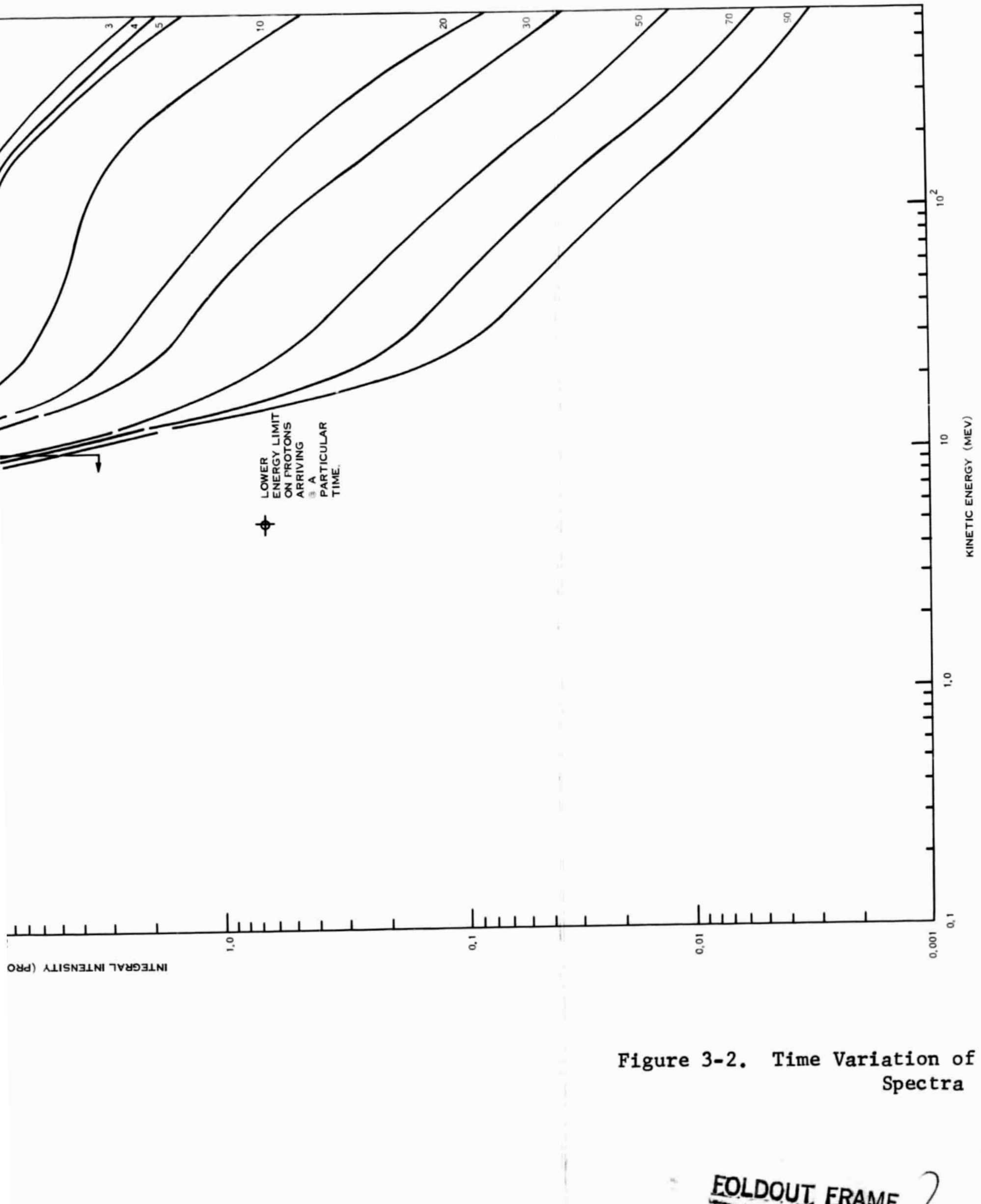


Figure 3-2. Time Variation of Integral Spectra

TABLE 3-I

PARTICLE INTENSITY FOR CIRCULAR ORBITAL ALTITUDE, INCLINATION = 0°

CIRCULAR ORBITAL ALTITUDE n.m.	PROTONS $E > 4$ MeV protons/cm^2 day	PROTONS $E > 30$ MeV protons/cm^2 day	ELECTRONS $E > 0.5$ MeV electrons/cm^2 day (1968)	ELECTRONS $E > 5$ MeV electrons/cm^2 day (1968)
150	$< 10^5$		$< 10^5$	< 1
300	4.57×10^4	2.88×10^4	2.67×10^5	8.4×10^0
450	2.49×10^7	1.01×10^7	4.91×10^8	1.19×10^5
600	2.43×10^8	6.85×10^7	2.51×10^{10}	1.73×10^7
800	1.73×10^9	3.16×10^8	2.17×10^{11}	3.03×10^8
1000	5.8×10^9	7.35×10^8	8.22×10^{11}	1.60×10^9
1250	1.61×10^{10}	1.22×10^9	1.49×10^{13}	6.65×10^9
1500	3.64×10^{10}	1.49×10^9	3.57×10^{12}	1.31×10^{10}
1750	7.65×10^{10}	1.65×10^9	3.03×10^{12}	1.41×10^{10}
2000	1.40×10^{11}	1.83×10^9	1.17×10^{12}	5.47×10^9
2500	2.5×10^{11}	1.49×10^9	1.79×10^{11}	8.80×10^8
3000	2.61×10^{11}	8.26×10^9	8.31×10^{10}	4.04×10^8
4000	1.03×10^{11}	6.08×10^9	1.07×10^{11}	4.34×10^8
5000	3.55×10^{10}	4.39×10^7	3.59×10^{11}	5.19×10^8

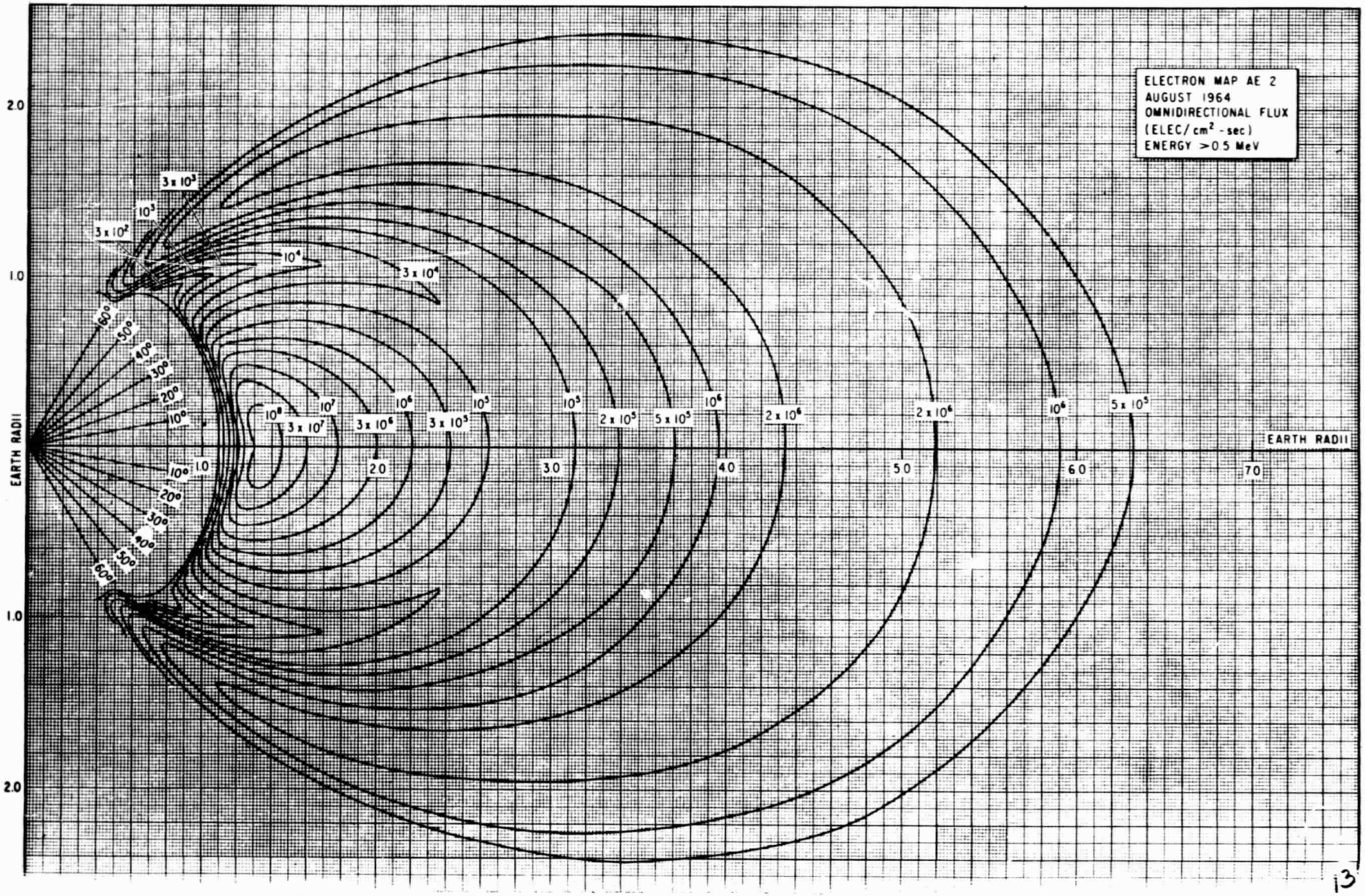


Figure 3-3. Electron Map AE2 August 1964 Omnidirectional Flux (Elec/cm^2-sec) Energy > 0.5 mev

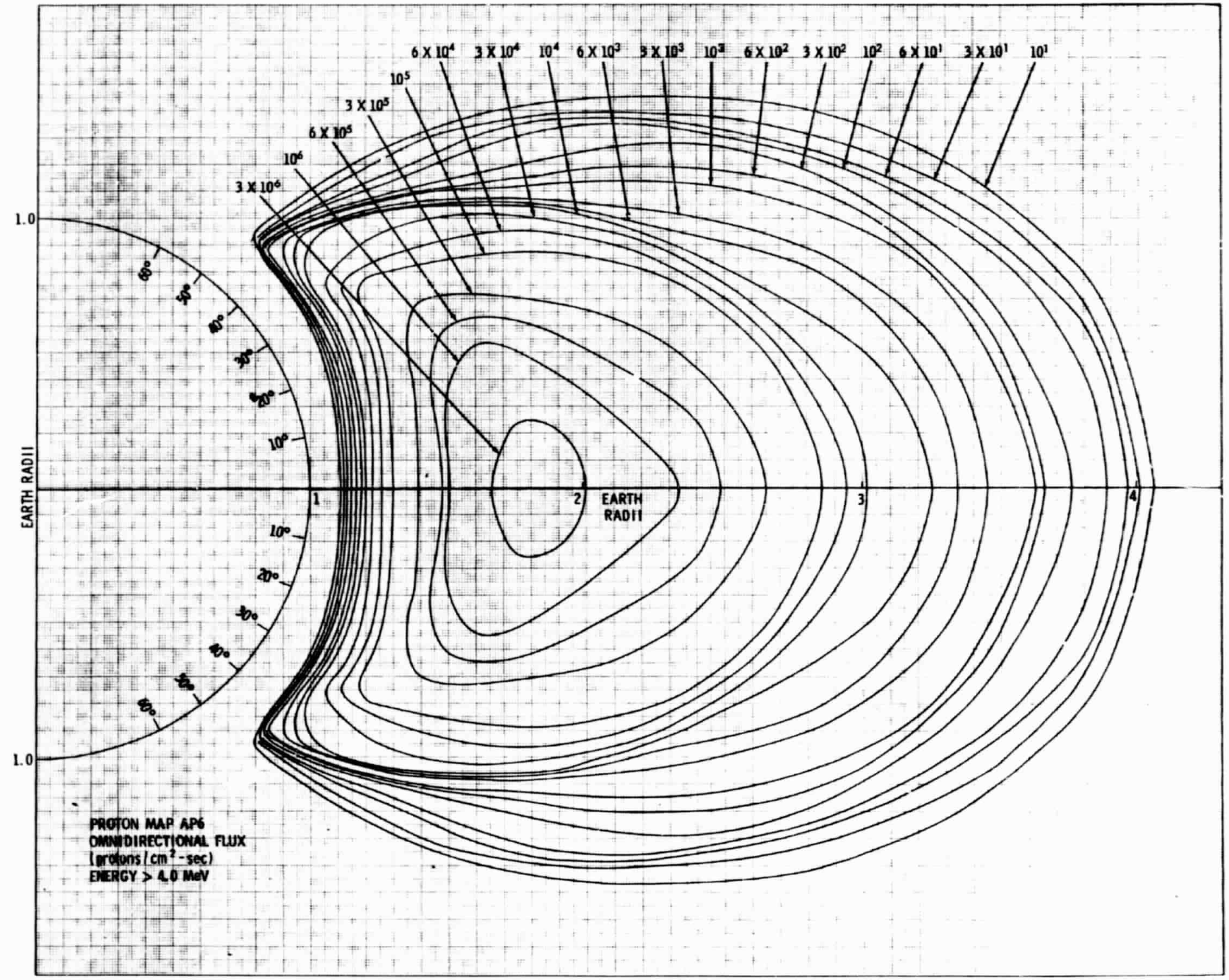


Figure 3-4. Proton Map AP6 Omnidirectional Flux (Protons/cm^2-sec) Energy > 4.0 mev

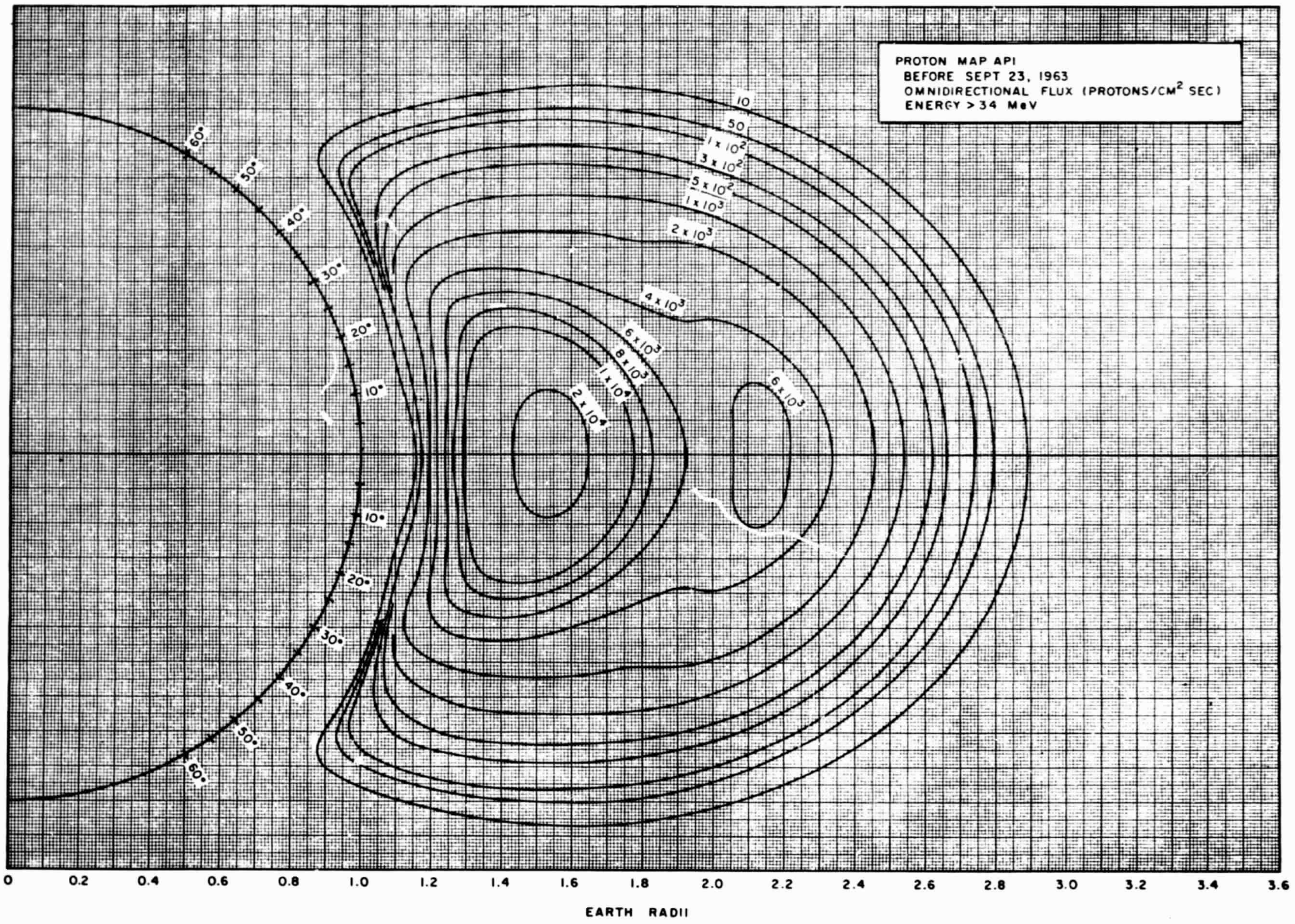


Figure 3-5. Proton Map API Before September 23, 1963 Omnidirectional Flux (Protons/cm^2-sec) Energy > 34 mev

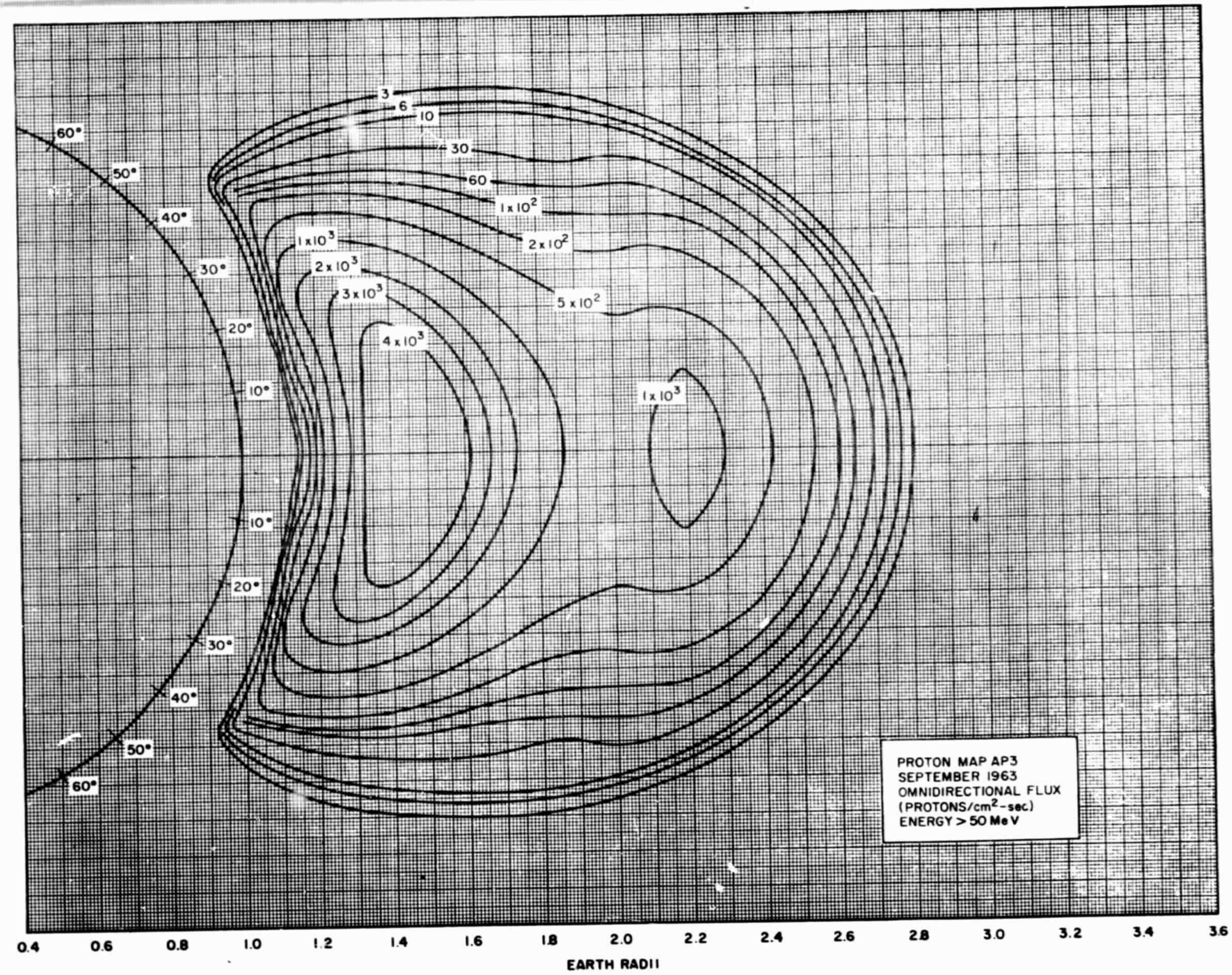


Figure 3-6. Proton Map AP3 September 1963 Omnidirectional Flux (Protons/cm^2-sec) Energy > 50 mev

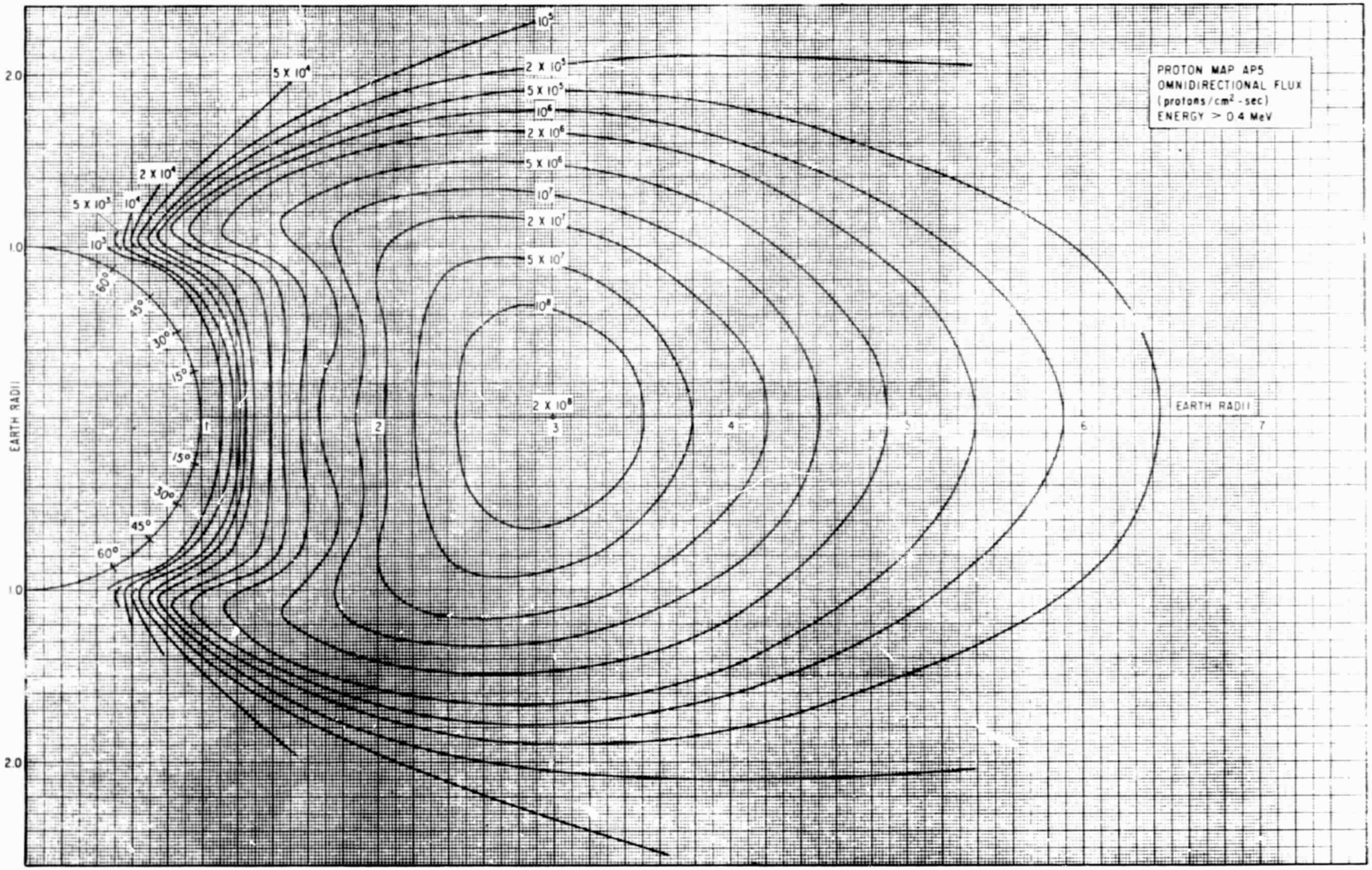


Figure 3-7. Proton Map AP5 Omnidirectional Flux (Protons/cm^2-sec) Energy > 0.4 mev

4.0 GAS PROPERTIES

The static diffusion model of the upper atmosphere contained in NASA-TMX-53798 is preferred to the model used in NASA-TMX-53521. Although the preferred model is seriously handicapped by the use of an invariant boundary at 120 kilometers, the model is generally quite acceptable above 250 kilometers and below 1,000 kilometers. It is recommended that the model presented in NASA-TMX-53798 be accepted for use as a design criteria pending future studies directed at extending the model to include self-consistent variable boundary conditions.

For preliminary design purposes, such as evaluating the influence of atmospheric density on particular systems, the range of variation of density likely to be experienced as a function of time is quite useful. The range of variation of density can be obtained through use of the conditions associated with the maximum and minimum of solar activity (Tables 4-I and 4-II).

Table 4-I. Atmospheric Properties Associated with High Solar Activity (from Jacchia, 1965)

Table 1.—Detailed atmospheric data as a function of height and exospheric temperature

EXOSPHERIC TEMPERATURE = 2100 DEGREES

HEIGHT KM	TEMP DEG K	LOG N(O2) /CM3	LOG N(O) /CM3	LOG N(N2) /CM3	LOG N(HE) /CM3	LOG N(H) /CM3	MEAN MOL WT	SCALE HT KM	DENSITY GM/CM3	LOG DEN GM/CM3
120.0	355.0	10.8751	10.8808	11.6021	7.5315		26.90	11.62	0.2461E-10	-10.609
130.0	573.0	10.3227	10.5007	11.0926	7.3555		26.33	19.21	0.7715E-11	-11.113
140.0	763.7	9.9618	10.2579	10.7611	7.2526		25.86	26.13	0.3651E-11	-11.438
150.0	930.6	9.6908	10.0794	10.5132	7.1762		25.49	32.43	0.2096E-11	-11.679
160.0	1076.7	9.4719	9.9383	10.3136	7.1174		25.14	38.16	0.1346E-11	-11.871
170.0	1204.5	9.2866	9.8213	10.1454	7.0702		24.81	43.39	0.9290E-12	-12.032
180.0	1316.4	9.1249	9.7212	9.9990	7.0308		24.51	48.16	0.6748E-12	-12.171
190.0	1414.3	8.9805	9.6334	9.8686	6.9973		24.22	52.52	0.5088E-12	-12.293
200.0	1499.9	8.8491	9.5549	9.7504	6.9683		23.94	56.53	0.3947E-12	-12.404
210.0	1574.9	8.7279	9.4837	9.6417	6.9426		23.66	60.21	0.3132E-12	-12.504
220.0	1640.5	8.6148	9.4183	9.5405	6.9197		23.40	63.62	0.2530E-12	-12.597
230.0	1697.9	8.5082	9.3576	9.4453	6.8990		23.15	65.77	0.2074E-12	-12.683
240.0	1748.1	8.4071	9.3007	9.3552	6.8801		22.90	69.71	0.1721E-12	-12.764
250.0	1792.1	8.3105	9.2470	9.2693	6.8626		22.65	72.45	0.1443E-12	-12.841
260.0	1830.5	8.2176	9.1959	9.1869	6.8465		22.41	75.03	0.1221E-12	-12.913
270.0	1864.2	8.1280	9.1471	9.1074	6.8313		22.18	77.45	0.1040E-12	-12.983
280.0	1893.6	8.0410	9.1003	9.0304	6.8171		21.95	79.73	0.8924E-13	-13.049
290.0	1919.4	7.9564	9.0550	8.9556	6.8036		21.72	81.90	0.7700E-13	-13.114
300.0	1942.0	7.8738	9.0112	8.8826	6.7907		21.50	83.97	0.6677E-13	-13.175
320.0	1979.0	7.7136	8.9270	8.7414	6.7666		21.08	87.83	0.5089E-13	-13.293
340.0	2007.3	7.5589	8.8465	8.6051	6.7442		20.67	91.39	0.3936E-13	-13.405
360.0	2029.0	7.4083	8.7689	8.4727	6.7231		20.28	94.72	0.3081E-13	-13.511
380.0	2045.7	7.2611	8.6935	8.3434	6.7029		19.91	97.86	0.2438E-13	-13.613
400.0	2058.4	7.1166	8.6199	8.2166	6.6835		19.55	100.84	0.1946E-13	-13.711
420.0	2068.1	6.9743	8.5478	8.0918	6.6647		19.22	103.68	0.1565E-13	-13.805
440.0	2075.6	6.8339	8.4768	7.9687	6.6463		18.91	106.41	0.1268E-13	-13.897
460.0	2081.3	6.6952	8.4068	7.8471	6.6284		18.61	109.05	0.1034E-13	-13.985
480.0	2085.7	6.5579	8.3377	7.7267	6.6107		18.33	111.59	0.8479E-14	-14.072
500.0	2089.0	6.4218	8.2693	7.6075	6.5934	2.9454	18.07	114.05	0.6989E-14	-14.156
520.0	2091.6	6.2868	8.2016	7.4893	6.5762	2.9406	17.82	116.45	0.5789E-14	-14.237
540.0	2093.6	6.1530	8.1344	7.3720	6.5593	2.9360	17.59	118.78	0.4816E-14	-14.317
560.0	2095.1	6.0201	8.0678	7.2556	6.5425	2.9315	17.37	121.06	0.4022E-14	-14.396
580.0	2096.2	5.8881	8.0017	7.1401	6.5258	2.9271	17.17	123.29	0.3373E-14	-14.472
600.0	2097.1	5.7570	7.9361	7.0252	6.5093	2.9228	16.97	125.49	0.2838E-14	-14.547
620.0	2097.8	5.6267	7.8709	6.9112	6.4930	2.9185	16.78	127.65	0.2396E-14	-14.621
640.0	2098.3	5.4972	7.8061	6.7978	6.4767	2.9144	16.60	129.80	0.2028E-14	-14.693
660.0	2098.7	5.3686	7.7417	6.6852	6.4606	2.9102	16.43	131.94	0.1723E-14	-14.764
680.0	2099.0	5.2407	7.6777	6.5732	6.4446	2.9061	16.26	134.08	0.1467E-14	-14.834
700.0	2099.2	5.1135	7.6141	6.4619	6.4286	2.9021	16.10	136.23	0.1252E-14	-14.902
750.0	2099.6	4.7989	7.4568	6.1864	6.3892	2.8921	15.70	141.75	0.8516E-15	-15.070
800.0	2099.8	4.4888	7.3017	5.9149	6.3504	2.8823	15.29	147.63	0.5869E-15	-15.231
850.0	2099.9	4.1830	7.1488	5.6472	6.3121	2.8726	14.85	154.07	0.4093E-15	-15.388
900.0	2099.9	3.8814	6.9980	5.3832	6.2744	2.8631	14.38	161.33	0.2886E-15	-15.540
950.0	2100.0	3.5839	6.8493	5.1228	6.2372	2.8538	13.87	169.66	0.2056E-15	-15.687
1000.0	2100.0	3.2906	6.7026	4.8659	6.2005	2.8445	13.30	179.35	0.1480E-15	-15.830

Table 4-II. Atmospheric Properties Associated with Low Solar Activities (from Jacchia, 1965)

TABLE 1.—Detailed atmospheric data as a function of height and exospheric temperature—Continued

EXOSPHERIC TEMPERATURE = 650 DEGREES

HEIGHT KM	TEMP DEG K	LOG N(O2) /CM3	LOG N(O) /CM3	LOG N(N2) /CM3	LOG N(HE) /CM3	LOG N(H) /CM3	MEAN MOL WT	SCALE HT KM	DENSITY GM/CM3	LOG DEN GM/CM3
120.0	355.0	10.8751	10.8808	11.6021	7.5315		26.90	11.62	0.2461E-10	-10.609
130.0	428.2	10.3916	10.5984	11.1687	7.4307		26.23	14.42	0.9222E-11	-11.035
140.0	483.3	9.9948	10.3737	10.8147	7.3550		25.53	16.76	0.4189E-11	-11.378
150.0	524.7	9.6486	10.1828	10.5072	7.2941		24.82	18.78	0.2137E-11	-11.670
160.0	555.8	9.3348	10.0133	10.2293	7.2424		24.08	20.56	0.1178E-11	-11.929
170.0	579.2	9.0426	9.8583	9.9714	7.1970		23.34	22.18	0.6859E-12	-12.164
180.0	596.7	8.7658	9.7134	9.7273	7.1559		22.60	23.67	0.4167E-12	-12.380
190.0	610.0	8.4998	9.5757	9.4923	7.1180		21.87	25.08	0.2617E-12	-12.582
200.0	619.9	8.2420	9.4432	9.2667	7.0822		21.16	26.42	0.1690E-12	-12.772
210.0	627.4	7.9902	9.3147	9.0456	7.0481		20.49	27.70	0.1118E-12	-12.952
220.0	633.0	7.7430	9.1892	8.8287	7.0153		19.87	28.91	0.7543E-13	-13.122
230.0	637.2	7.4994	9.0659	8.6151	6.9834		19.29	30.07	0.5184E-13	-13.285
240.0	640.4	7.2586	8.9445	8.4040	6.9522		18.77	31.16	0.3620E-13	-13.441
250.0	642.8	7.0201	8.8244	8.1951	6.9215		18.29	32.19	0.2563E-13	-13.591
260.0	644.6	6.7835	8.7055	7.9878	6.8913		17.87	33.14	0.1838E-13	-13.736
270.0	645.9	6.5485	8.5876	7.7819	6.8615		17.49	34.04	0.1333E-13	-13.875
280.0	646.9	6.3149	8.4704	7.5773	6.8319		17.14	34.88	0.9761E-14	-14.011
290.0	647.7	6.0824	8.3539	7.3737	6.8026		16.83	35.68	0.7209E-14	-14.142
300.0	648.3	5.8510	8.2380	7.1711	6.7734		16.54	36.45	0.5364E-14	-14.271
320.0	649.0	5.3910	8.0078	6.7683	6.7156		15.99	37.97	0.3026E-14	-14.519
340.0	649.4	4.9344	7.7793	6.3685	6.6584		15.44	39.58	0.1743E-14	-14.759
360.0	649.7	4.4808	7.5524	5.9714	6.6015		14.83	41.47	0.1021E-14	-14.991
380.0	649.8	4.0301	7.3271	5.5768	6.5451		14.10	43.90	0.6069E-15	-15.217
400.0	649.9	3.5823	7.1031	5.1847	6.4890		13.20	47.15	0.3660E-15	-15.437
420.0	649.9	3.1371	6.8805	4.7950	6.4323		12.13	51.62	0.2240E-15	-15.650
440.0	650.0	2.6946	6.6592	4.4076	6.3779		10.91	57.75	0.1395E-15	-15.855
460.0	650.0	2.2547	6.4393	4.0224	6.3229		9.60	66.04	0.8870E-16	-16.052
480.0	650.0	1.8173	6.2206	3.6396	6.2682		8.29	76.92	0.5782E-16	-16.238
500.0	650.0	1.3826	6.0032	3.2589	6.2138	5.8199	7.07	90.63	0.3883E-16	-16.411
520.0	650.0	0.9503	5.7871	2.8805	6.1597	5.8063	6.02	107.07	0.2698E-16	-16.569
540.0	650.0	0.5206	5.5722	2.5043	6.1059	5.7927	5.16	125.67	0.1946E-16	-16.711
560.0	650.0	0.0934	5.3586	2.1303	6.0525	5.7793	4.48	145.50	0.1458E-16	-16.836
580.0	650.0	-0.3314	5.1462	1.7584	5.9993	5.7659	3.97	165.49	0.1134E-16	-16.946
600.0	650.0	-0.7537	4.9351	1.3867	5.9465	5.7526	3.57	184.70	0.9113E-17	-17.040
620.0	650.0	-1.1736	4.7251	1.0211	5.8939	5.7394	3.28	202.56	0.7537E-17	-17.123
640.0	650.0	-1.5911	4.5164	0.6556	5.8417	5.7262	3.05	218.85	0.6381E-17	-17.195
660.0	650.0	-2.0063	4.3088	0.2921	5.7897	5.7131	2.87	233.65	0.5502E-17	-17.259
680.0	650.0	-2.4190	4.1024	-0.0692	5.7381	5.7001	2.73	247.21	0.4813E-17	-17.318
700.0	650.0	-2.8295	3.8972	-0.4286	5.6867	5.6872	2.61	259.82	0.4256E-17	-17.371
750.0	650.0	-3.8454	3.3892	-1.3180	5.5596	5.6552	2.38	289.07	0.3233E-17	-17.490
800.0	650.0	-4.8472	2.8883	-2.1950	5.4343	5.6236	2.20	317.51	0.2531E-17	-17.597
850.0	650.0	-5.8351	2.3944	-3.0599	5.3107	5.5925	2.04	346.84	0.2021E-17	-17.694
900.0	650.0	-6.8093	1.9073	-3.9128	5.1888	5.5618	1.90	377.64	0.1639E-17	-17.785
950.0	650.0	-7.7702	1.4268	-4.7541	5.0686	5.5315	1.78	409.90	0.1348E-17	-17.870
1000.0	650.0	-8.7181	0.9529	-5.5839	4.9500	5.5017	1.67	443.29	0.1124E-17	-17.949

5.0 ELECTROMAGNETIC RADIATION

5.1 Solar Radiation Criteria

The solar electromagnetic radiation spectrum shown in Figure 5-1 should be used for the thermal design of space vehicles. Because of the importance of the optical region, the spectral irradiance for that region is tabulated in Table 5-I. The recommended solar constant for the various system conditions is shown in Table 5-II. The tolerance associated with the solar constant is primarily due to the uncertainty as to its absolute magnitude and is not a time variational effect. The time variation of the integrated solar irradiance is shown in Figure 5-2.

5.2 Albedo Radiation Criteria

Using the available data, a mean latitudinal distribution has been constructed and is shown in Figure 5-3. The recommended thermal design criteria is given in Table 5-III. In general, near-Earth orbiting vehicles experience albedo effects for periods of 0.6 to 3 hours (albedo flux considerations become much less significant with greater orbit periods). For systems with a thermal constant between .3 and 3 hours, the suggested tolerance includes the extreme "effective albedos" (as determined by system thermal response) the system may see during a particular orbit. Systems with small thermal time constants (<20 min.) will respond quickly to variations in the albedo radiation. For this case, the "effective albedo " approaches the measured albedo values, and the tolerance approaches the extreme values of Figure 5-3. For systems with thermal constants <3 hours, global and hemispherical values are of prime importance. The tolerance includes data inaccuracies and a small seasonal variation.

5.3 Earth Thermal Radiation

Assuming the earth-atmosphere system is in near radiative equilibrium and a global albedo of 30%, the equivalent blackbody temperature of the earth-atmosphere system is 254 °K, corresponding to an outward long-wave radiation flux of 0.34 cal $cm^{-2}min^{-1}$. A mean latitudinal distribution is given in Figure 5-4. There are no seasonal variations of the global or hemispheric averages of the outgoing long-wave earth radiation. No statistically significant seasonal variations at particular latitudes have been established either. The design values are given in Table 5-IV. The discussion of the tolerances for the albedo apply here as well. The small suggested tolerances (percentage-wise) reflect the relatively small impact of the thermal radiation upon the thermal state of orbiting systems.

TABLE 5-I

Solar Spectral Irradiance (Based on Measurements on Board NASA 711 "Galileo" at 38,000 feet) λ--wavelength in microns; P_λ -Solar Spectral Irradiance averaged over small bandwidth centered at λ, in watts cm^{-2}micron^{1}; D_λ -- percentage of the Solar Constant associated with wavelengths shorter than wavelength λ. Solar Constant 0.13510 watt cm^{-2} (From NASA GSFC 1968).

λ	P_λ	D_λ	λ	P_λ	D_λ	λ	P_λ	D_λ	λ	P_λ	D_λ
0.140	0.0000048	0.00050	0.395	0.1191	8.189	0.630	0.1542	39.26	3.8	0.00111	98.902
0.150	0.0000176	0.00059	0.400	0.1433	8.675	0.640	0.1517	40.39	3.9	0.00103	98.982
0.160	0.000059	0.00087	0.405	0.1651	9.245	0.650	0.1487	41.50	4.0	0.00095	99.055
0.170	0.00015	0.00164	0.410	0.1759	9.876	0.660	0.1468	42.00	4.1	0.00087	99.122
0.180	0.00035	0.00349	0.415	0.1783	10.53	0.670	0.1443	43.67	4.2	0.00078	99.182
0.190	0.00076	0.00760	0.420	0.1758	11.19	0.680	0.1418	44.73	4.3	0.00071	99.238
0.200	0.00130	0.0152	0.425	0.1705	11.83	0.690	0.1398	45.78	4.4	0.00065	99.289
0.205	0.00167	0.0207	0.430	0.1651	12.45	0.700	0.1369	46.80	4.5	0.00059	99.335
0.210	0.00269	0.0288	0.435	0.1675	13.06	0.710	0.1344	47.80	4.6	0.00053	99.376
0.215	0.00445	0.0420	0.440	0.1823	13.71	0.720	0.1314	48.79	4.7	0.00048	99.414
0.220	0.00575	0.0609	0.445	0.1936	14.41	0.730	0.1290	49.75	4.8	0.00045	99.448
0.225	0.00649	0.0835	0.450	0.2020	15.14	0.740	0.1260	50.69	4.9	0.00041	99.480
0.230	0.00667	0.1079	0.455	0.2070	15.90	0.750	0.1235	51.62	5.0	0.000383	99.509
0.235	0.00593	0.1312	0.460	0.2080	16.66	0.800	0.1107	55.95	6.0	0.000175	99.716
0.240	0.00630	0.1554	0.465	0.2060	17.43	0.850	0.0988	59.83	7.0	0.000099	99.817
0.245	0.00723	0.1788	0.470	0.2045	18.19	0.900	0.0889	63.30	8.0	0.000060	99.876
0.250	0.00704	0.2053	0.475	0.2055	18.95	0.950	0.0835	66.49	9.0	0.000038	99.912
0.255	0.0104	0.2375	0.480	0.2085	19.72	1.000	0.0746	69.42	10.0	0.000025	99.935
0.260	0.0130	0.2808	0.485	0.1936	20.47	1.1	0.0592	74.37	11.0	0.0000170	99.951
0.265	0.0185	0.3391	0.490	0.1959	21.20	1.2	0.0484	78.35	12.0	0.0000120	99.962
0.270	0.0232	0.4163	0.495	0.1966	21.92	1.3	0.0396	81.61	13.0	0.0000087	99.969
0.275	0.0204	0.4960	0.500	0.1946	22.65	1.4	0.0336	84.32	14.0	0.0000055	99.975
0.280	0.0222	0.5758	0.505	0.1922	23.36	1.5	0.0287	86.62	15.0	0.0000049	99.9785
0.285	0.0315	0.6752	0.510	0.1882	24.07	1.6	0.0244	88.59	16.0	0.0000038	99.9817
0.290	0.0482	0.8225	0.515	0.1833	24.76	1.7	0.0202	90.24	17.0	0.0000031	99.9843
0.295	0.0584	1.020	0.520	0.1833	25.43	1.8	0.0159	91.58	18.0	0.0000024	99.9863
0.300	0.0514	1.223	0.525	0.1852	26.12	1.9	0.0126	92.63	19.0	0.0000020	99.9879
0.305	0.0602	1.430	0.530	0.1842	26.80	2.0	0.0103	93.48	20.0	0.0000016	99.9893
0.310	0.0686	1.668	0.535	0.1818	27.48	2.1	0.0090	94.19	λ_∞		100.0
0.315	0.0757	1.935	0.540	0.1783	28.14	2.2	0.0079	94.82			
0.320	0.0819	2.227	0.545	0.1754	28.80	2.3	0.0068	95.36			
0.325	0.0958	2.555	0.550	0.1725	29.44	2.4	0.0064	95.85			
0.330	0.1037	2.925	0.555	0.1720	30.08	2.5	0.0054	96.287			
0.335	0.1057	3.312	0.560	0.1695	30.71	2.6	0.0048	96.664			
0.340	0.1050	3.702	0.565	0.1700	31.34	2.7	0.0043	97.001			
0.345	0.1047	4.090	0.570	0.1705	31.97	2.8	0.0039	97.305			
0.350	0.1074	4.483	0.575	0.1710	32.60	2.9	0.0035	97.579			
0.355	0.1067	4.879	0.580	0.1705	33.23	3.0	0.0031	97.823			
0.360	0.1055	5.271	0.585	0.1700	33.86	3.1	0.0026	98.034			
0.365	0.1122	5.674	0.590	0.1685	34.49	3.2	0.00226	98.214			
0.370	0.1173	6.099	0.595	0.1665	35.11	3.3	0.00192	98.368			
0.375	0.1152	6.529	0.600	0.1646	35.72	3.4	0.00166	98.501			
0.380	0.1117	6.949	0.605	0.1626	36.33	3.5	0.00146	98.616			
0.385	0.1097	7.359	0.610	0.1611	36.93	3.6	0.00135	98.720			
0.390	0.1099	7.765	0.620	0.1576	38.11	3.7	0.00123	98.816			

Table 5-II. Design Criteria For Solar Constant

System Conditions	Recommended Criteria		
	cal cm^{-2}min.$^{-1}$	watts m^{-2}	BTU ft^{-2}hr^{-1}
20 min < system thermal time constant > 3 hrs.	1.95 ± .03	1359 ± 21	431 ± 6.7
System thermal time constant < 20 min.	1.95 ± .03	1359 ± 21	431 ± 6.7
System thermal time constant > 3 hrs.	1.95 ± .03	1359 ± 21	431 ± 6.7

Table 5-III. Design Criteria For Albedo

Systems Conditions	Recommended Criteria (%)
20 min < system thermal time constant > 3 hrs.	30 ± 10
System thermal time constant < 20 min.	$30 \; {}^{+\,30}_{-\,15}$
System thermal time constant > 3 hrs.	30 ± 5

Table 5-IV. Design Criteria For Earth-Atmosphere Thermal Radiation

System Conditions	Recommended Criteria		
	cal cm^{-2} min^{-1}	watts m^{-2}	BTU ft^{-2} hr^{-1}
0 min < system thermal time constant > 3 hrs.	$.34^{+.02}_{-.07}$	235^{+14}_{-48}	$76^{+4.6}_{-16}$
system thermal time constant < 20 min.	$.34^{+.04}_{-.14}$	235^{+28}_{-97}	$76^{+9.2}_{-32}$
system thermal time constant > 3 hrs.	.34 ±.03	235 ±21	76 ±6.7

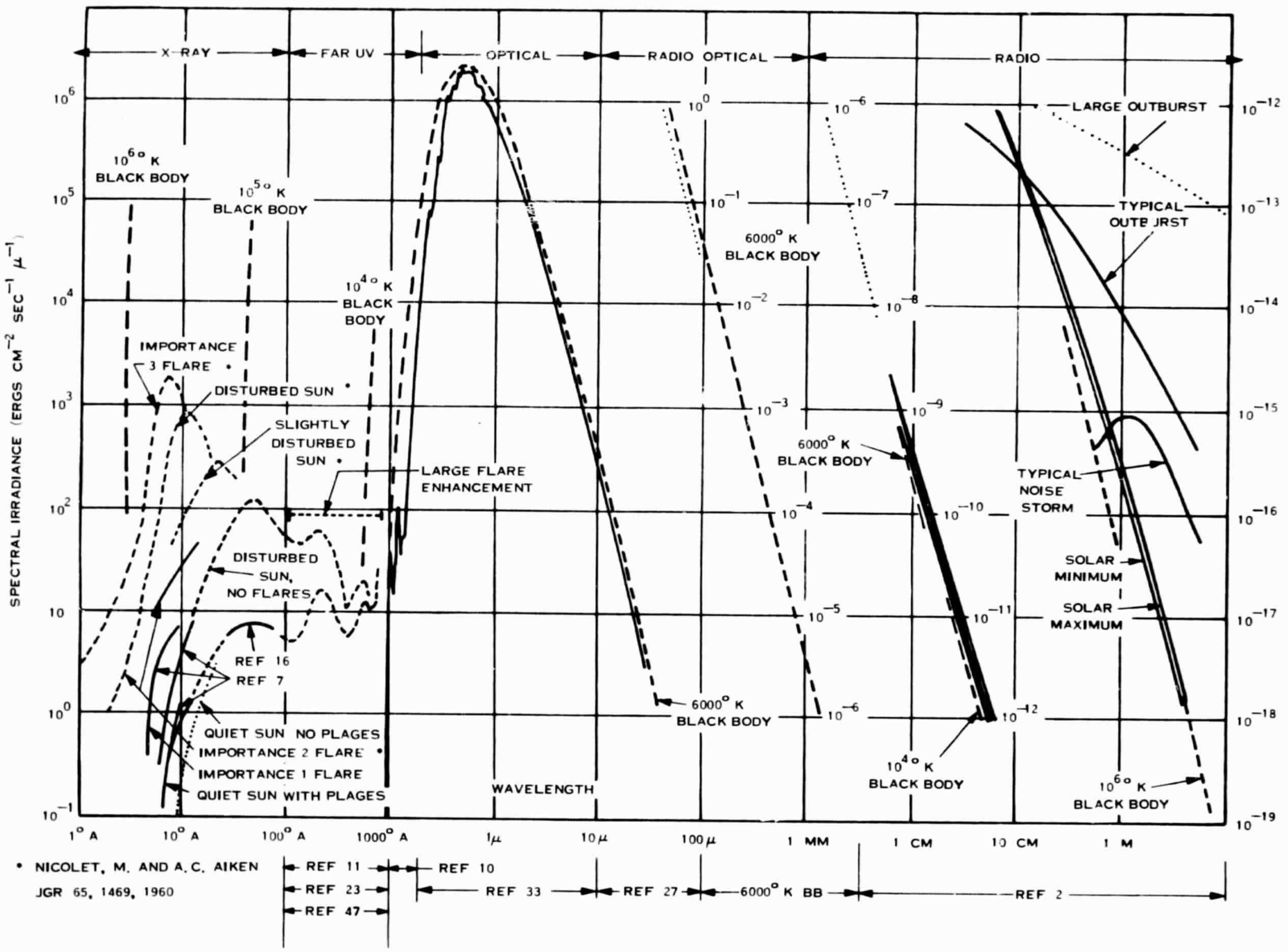


Figure 5-1. The Solar Electromagnetic Radiation Spectrum. Solid Lines Represent Measurements; Dotted Lines, Estimates. (From Malitson, 1965; Includes Data Update where Applicable)

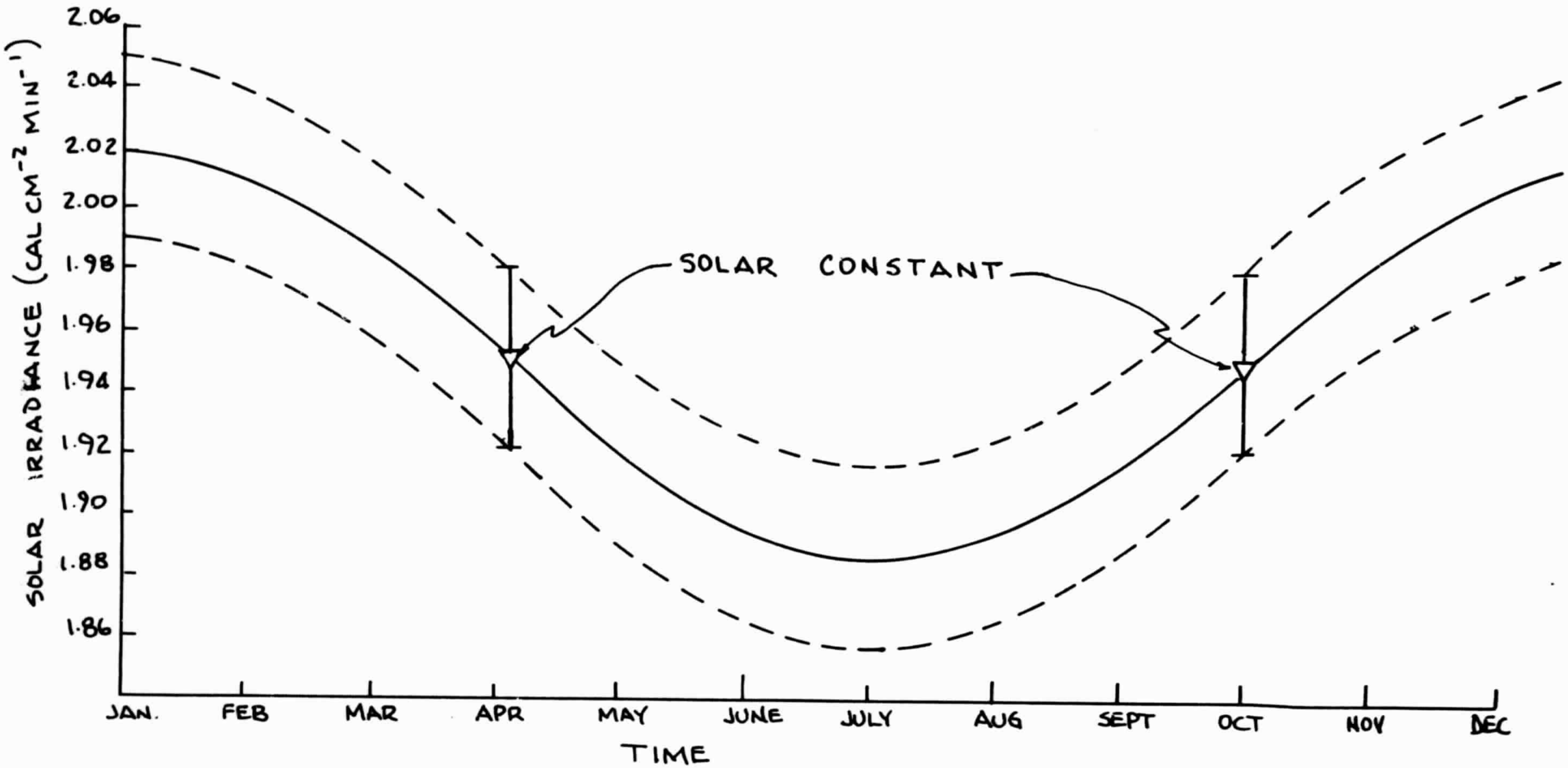


Figure 5-2. Variation of Integrated Solar Irradiance Above the Atmosphere with Time.

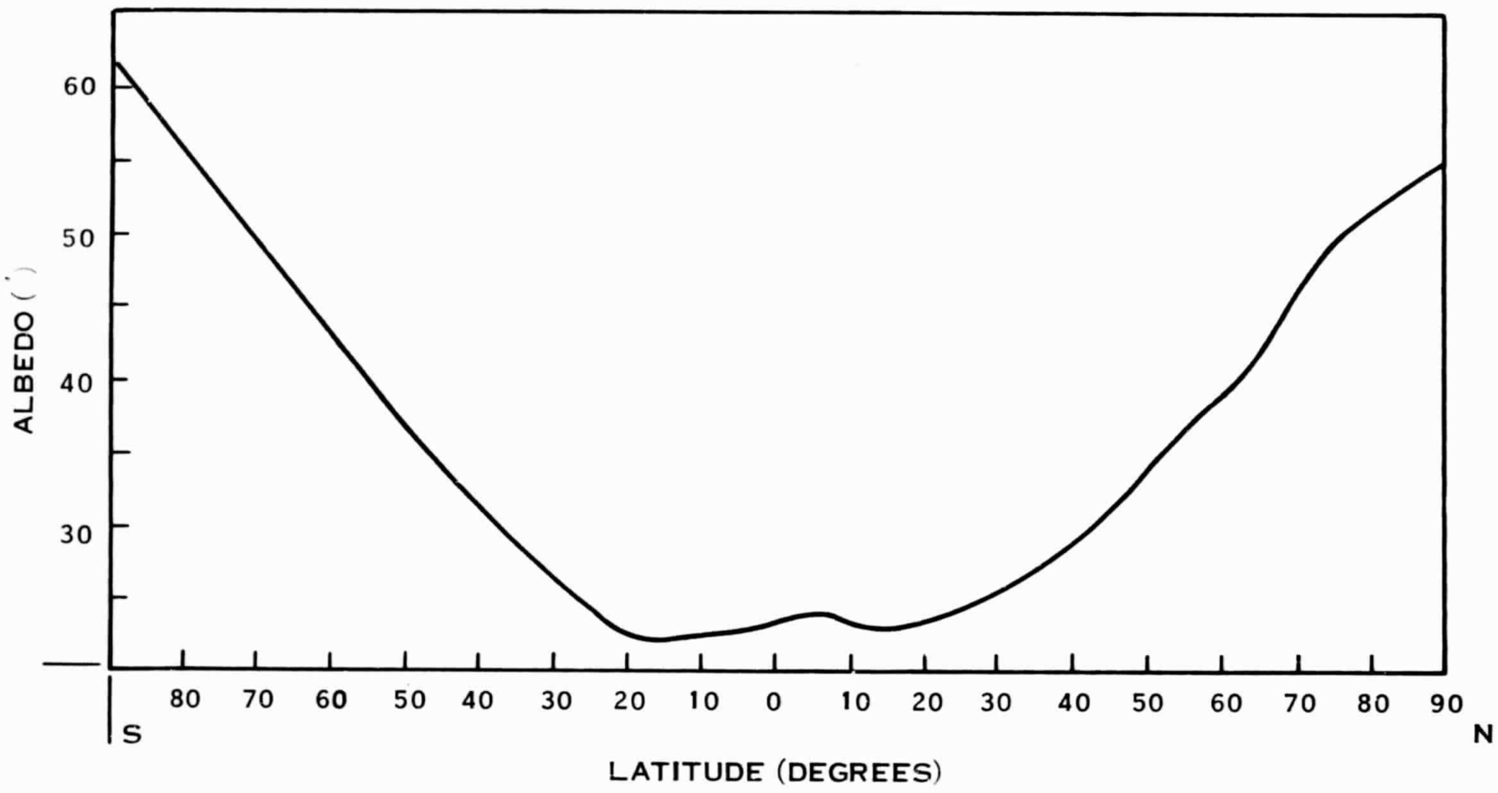


Figure 5-3. Mean Latitudinal Distribution of Albedo

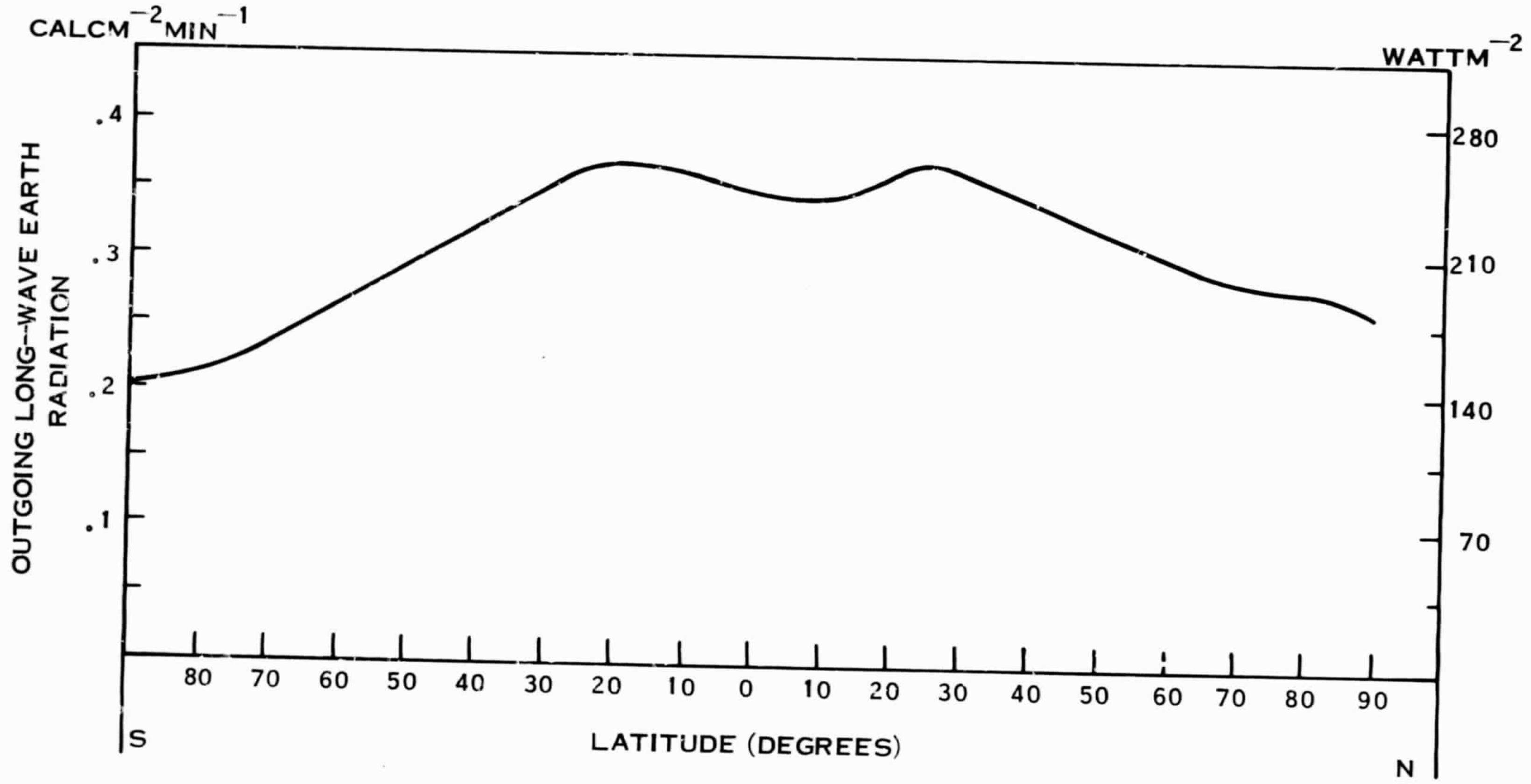
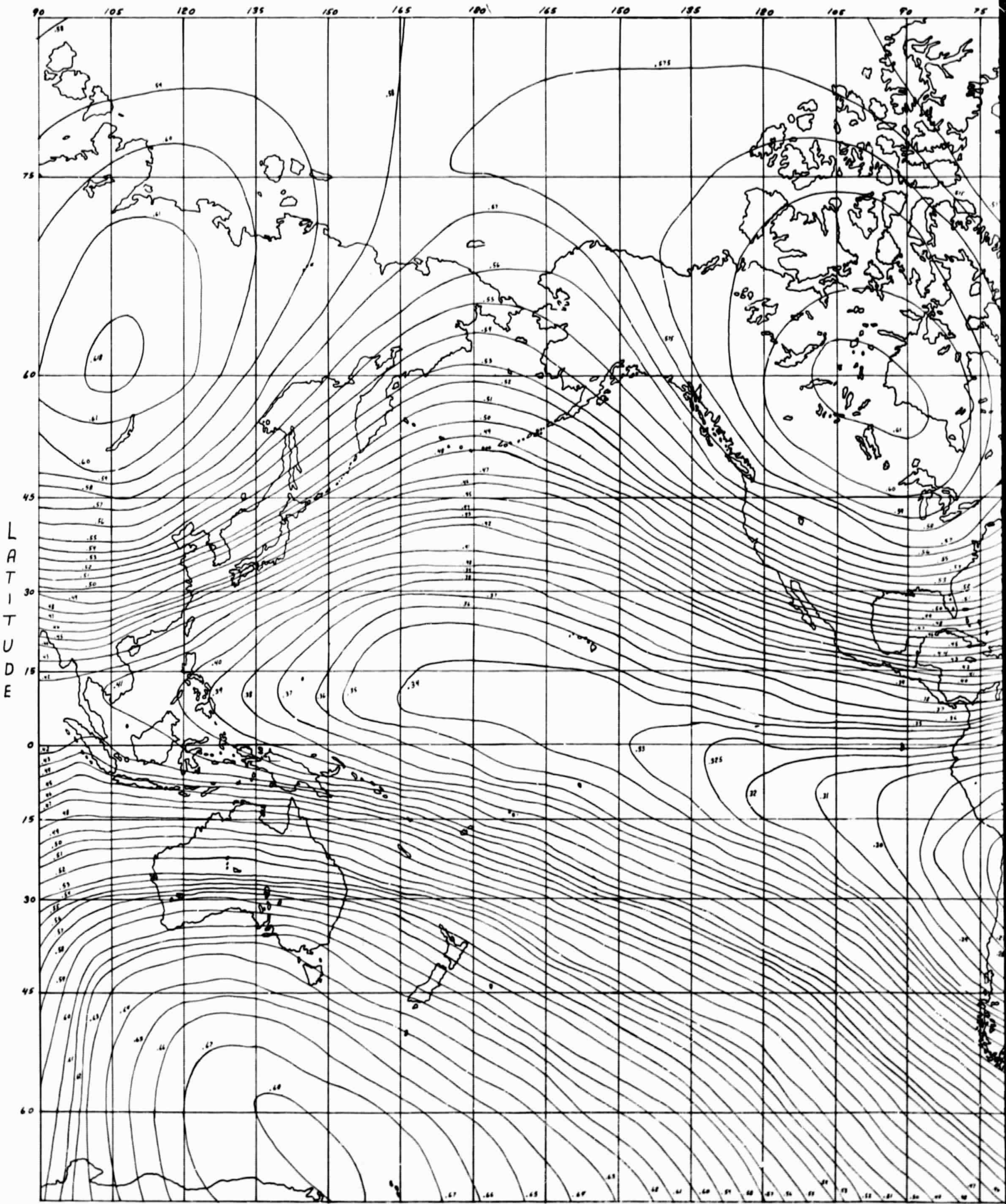


Figure 5-4. Mean Latitudinal Distribution of Outgoing Long-Wave Radiation

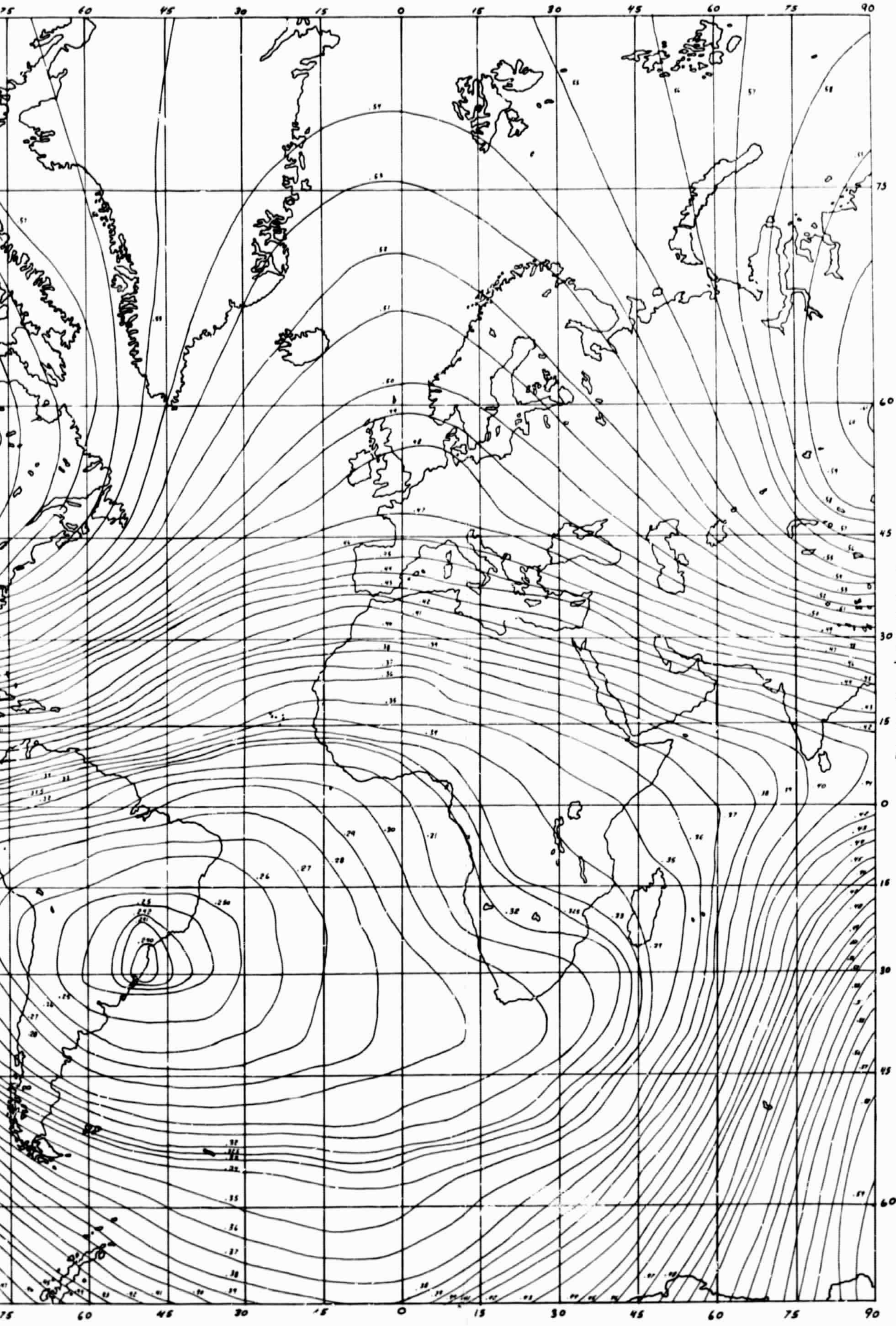
6.0 GEOMAGNETIC FIELD

The total field strength at selected altitudes is presented in Figure 6-1 through to 6-7 and was obtained using the NASA-GSFC coefficients published in May 1968. For those instances where additional information is required, such as the component variations, dip angles, etc., it is recommended that use be made of the computerized version of the geomagnetic field contained in: "NASA-GSFC - Data Users Note - NSSDC 68-11, May, 1968".



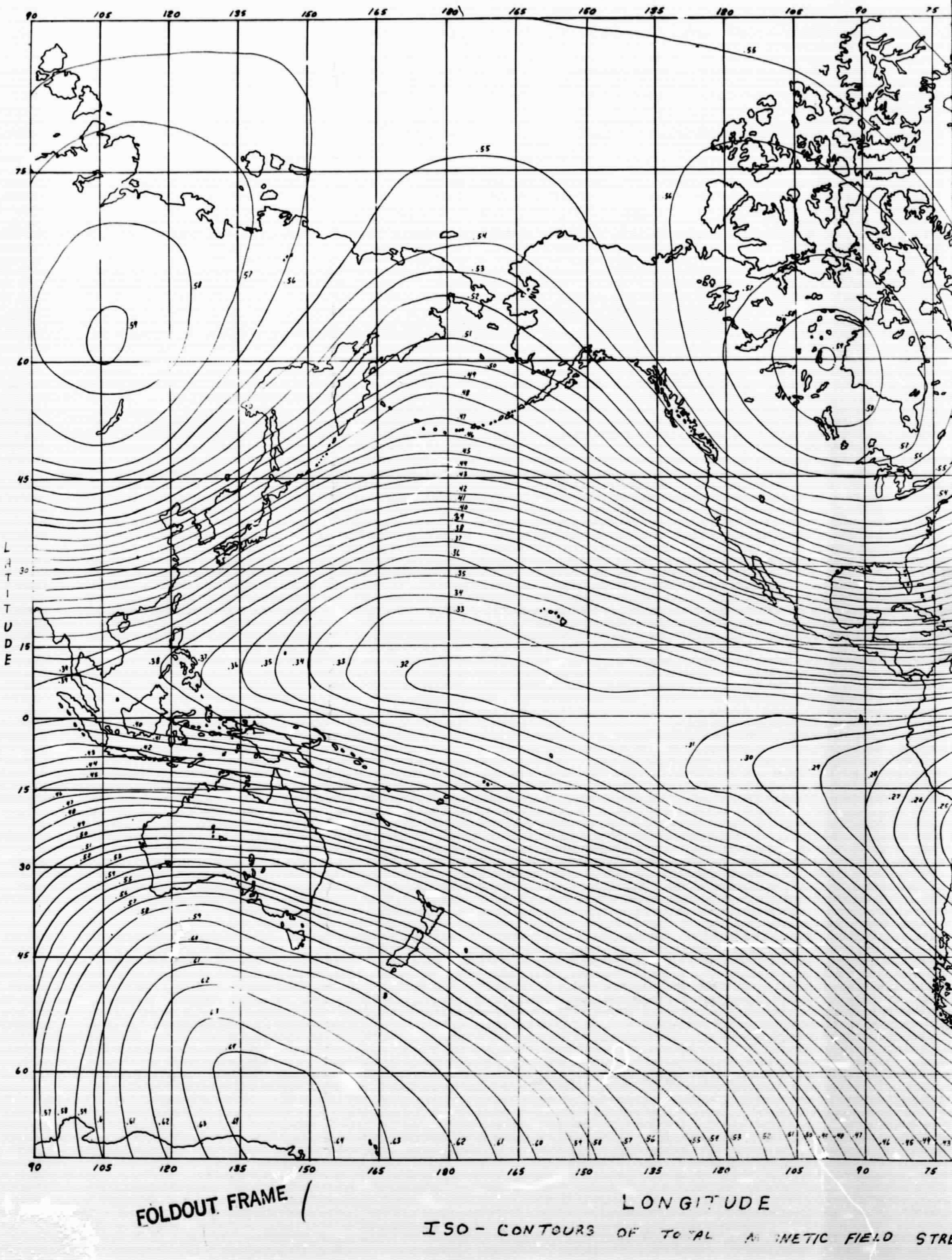
FOLDOUT FRAME

ISO-CONTOURS OF TOTAL MAGNETIC FIELD STRENGTH



TH (GAUSS) H = 0 KM

Figure 6-1. FOLDOUT FRAME 2



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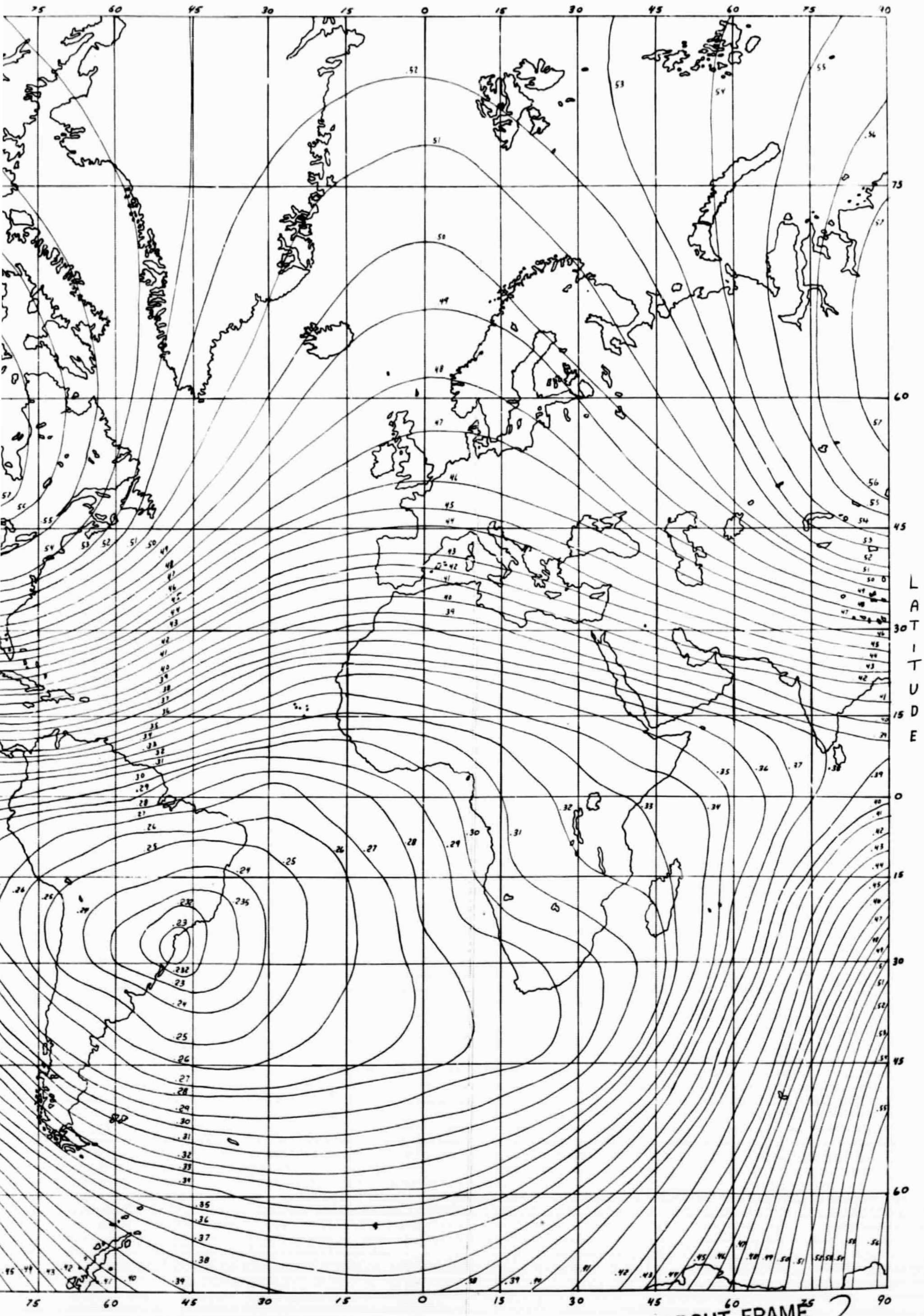
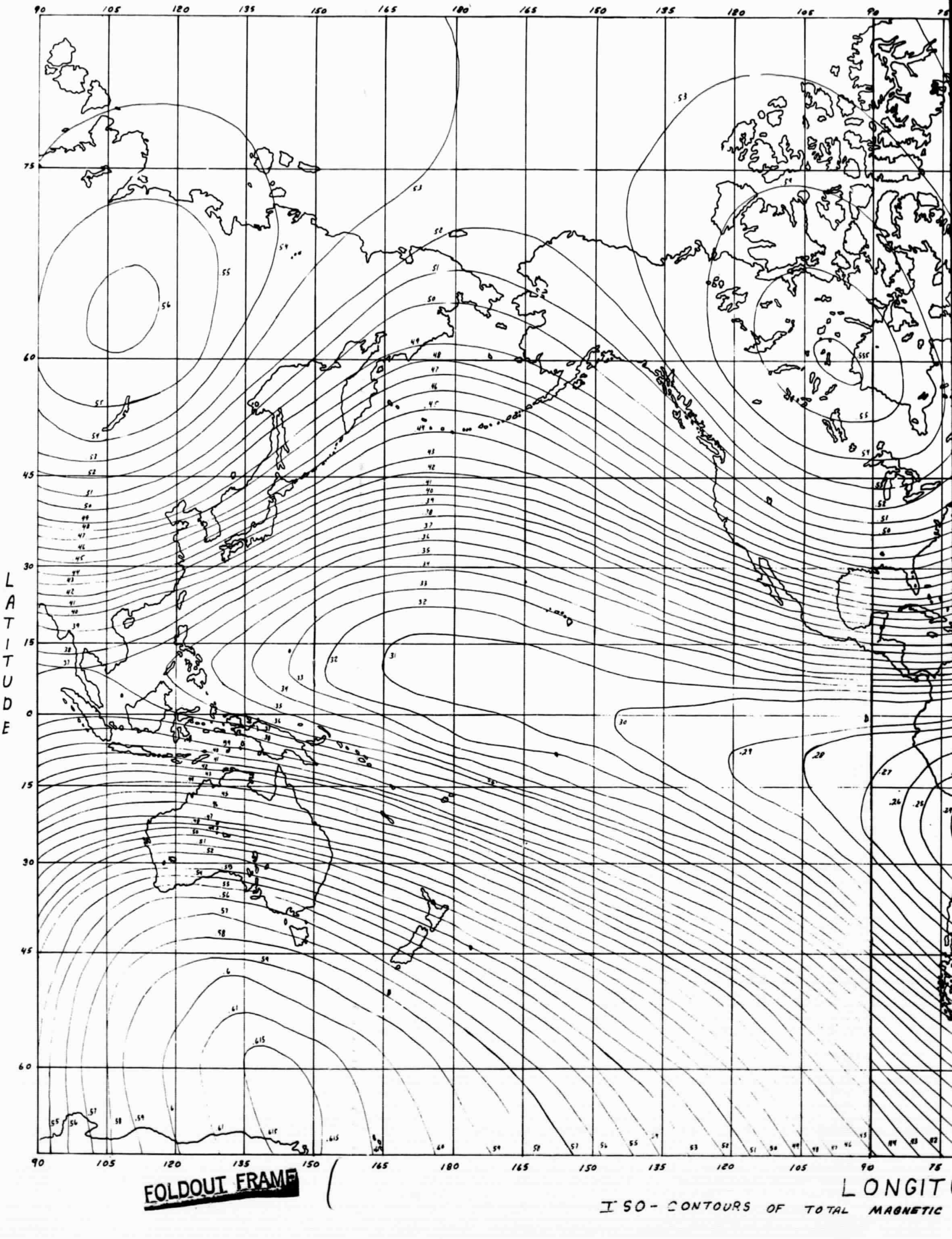
ISO - CONTOURS OF TOTAL MAGNETIC FIELD STRE



STRENGTH (GAUSS) h = 100 KM

Figure 6-2.



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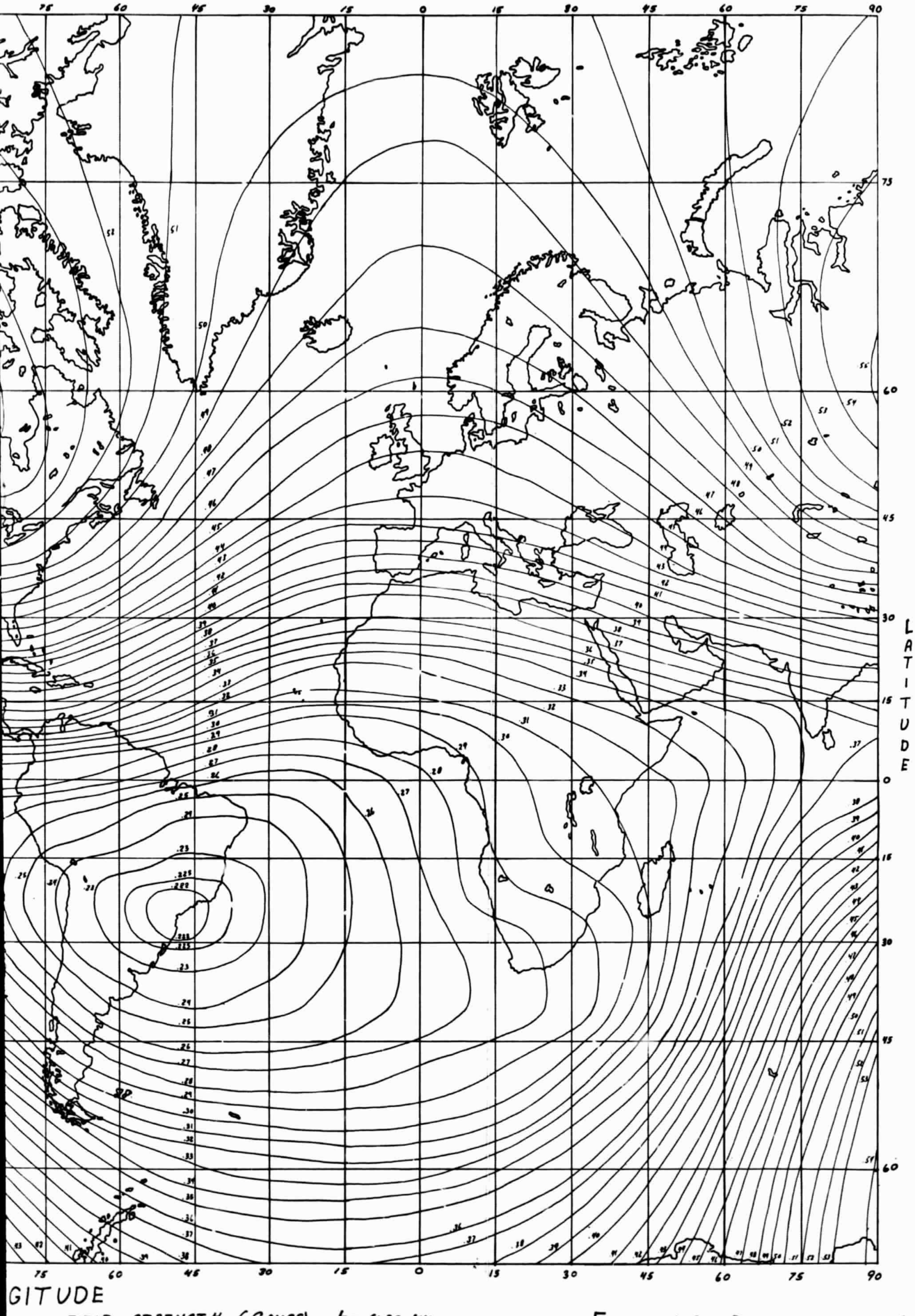
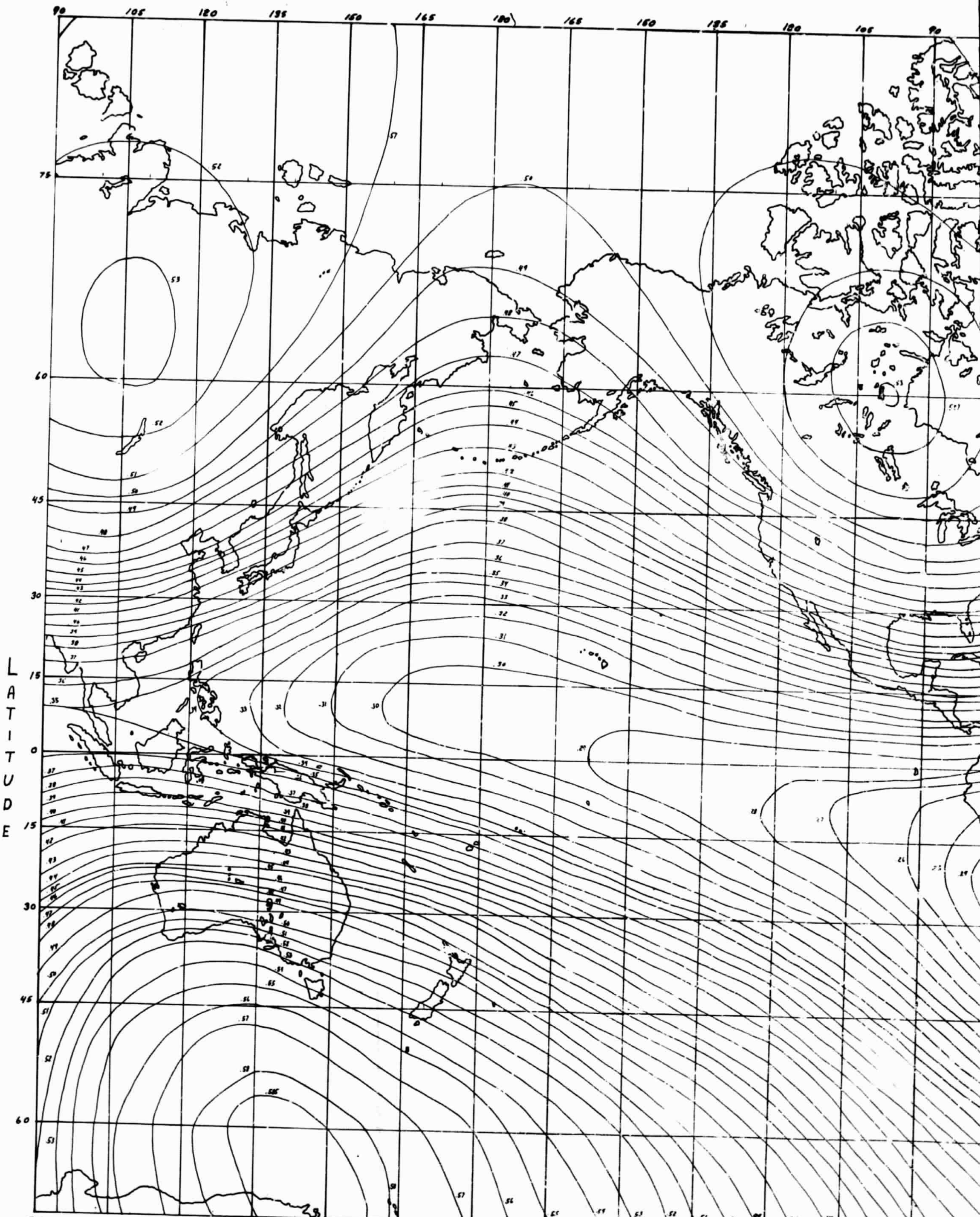
ISO-CONTOURS OF TOTAL MAGNETIC



NETIC FIELD STRENGTH (GAUSS) h= 200 KM

Figure 6-3. FOLDOUT FRAME 2



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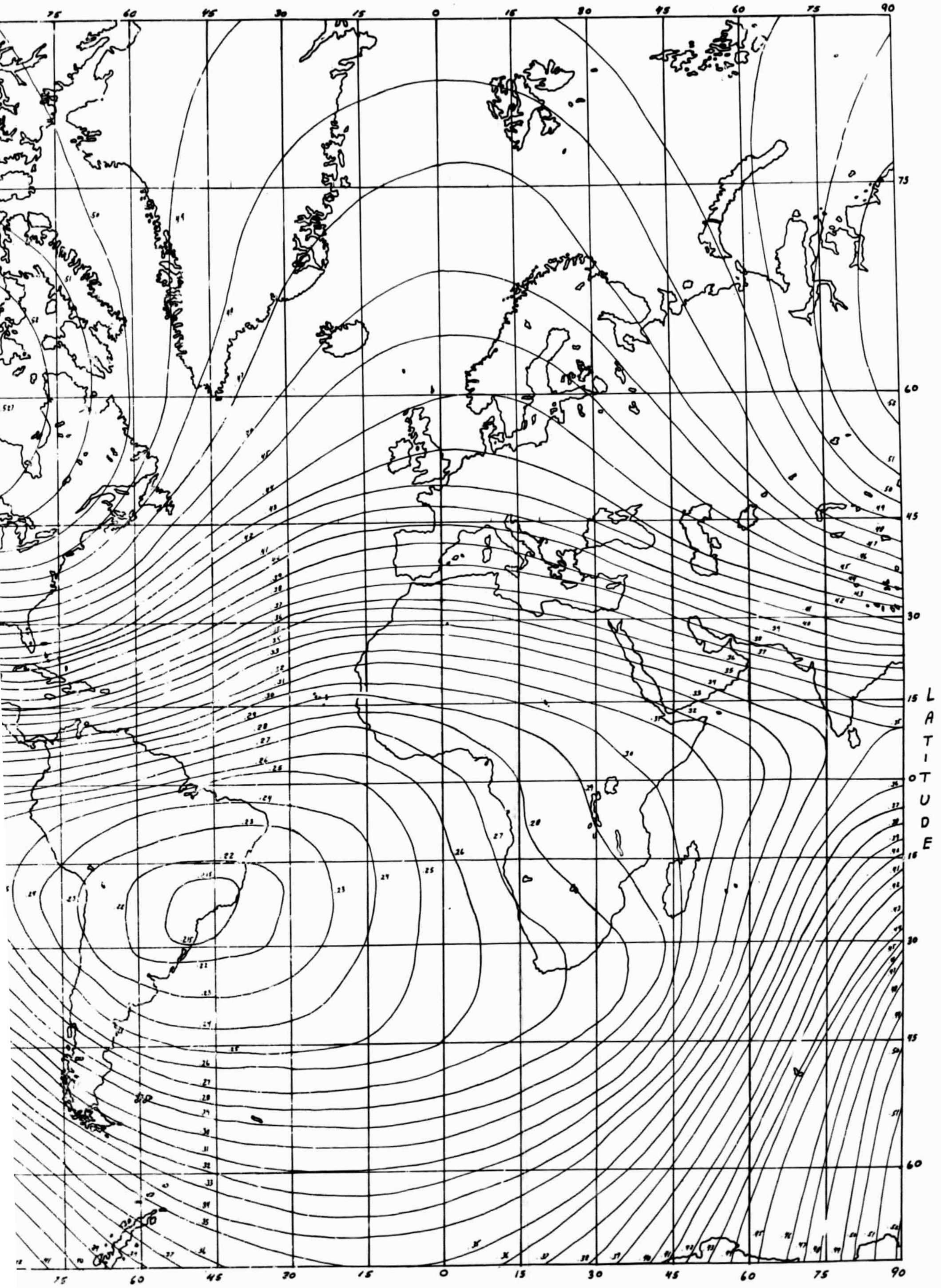
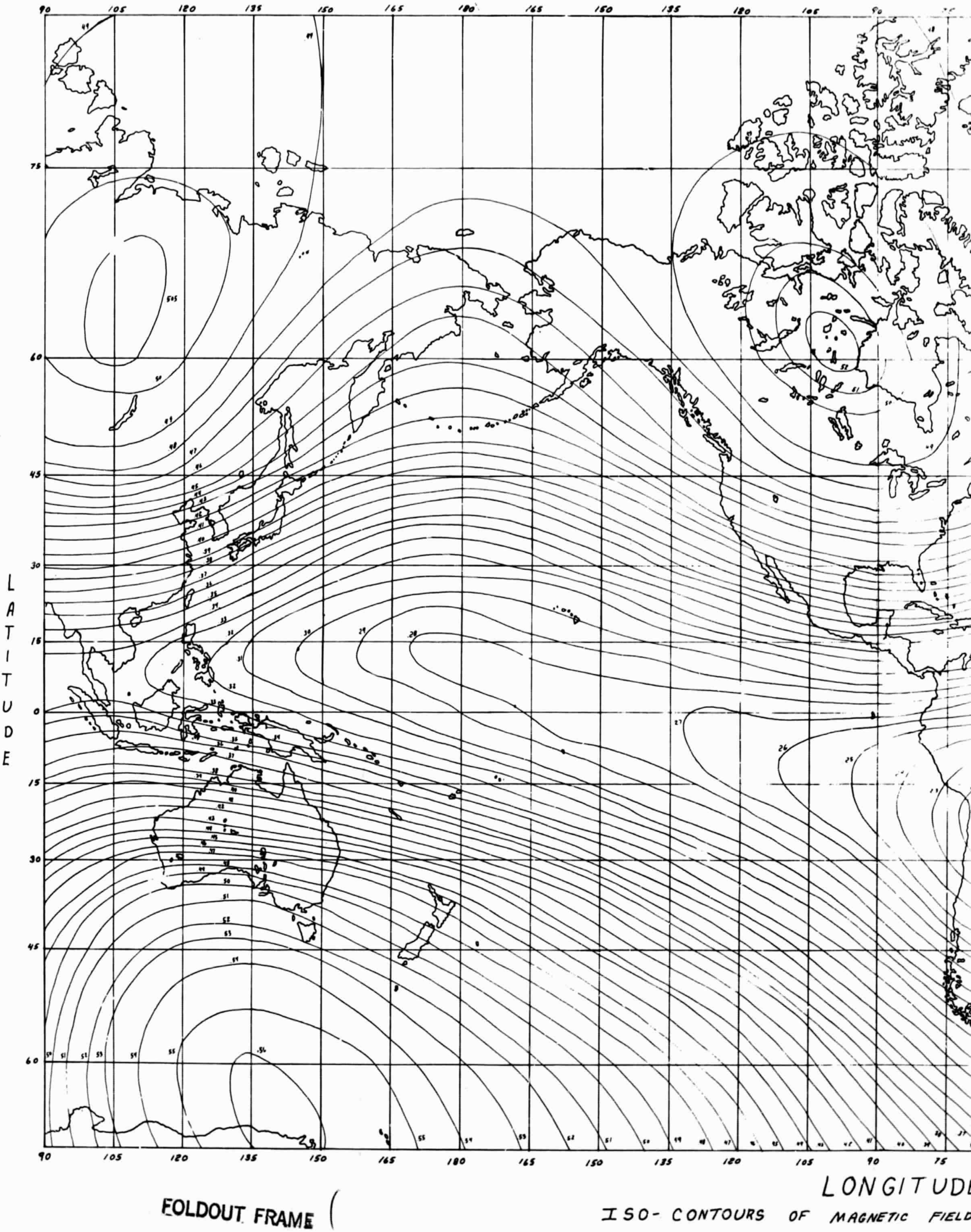
ISO CONTOURS OF TOTAL MAGNETIC FIELD STRENGTH



VGTH (GAUSS)   h = 300 km   Figure 6-4



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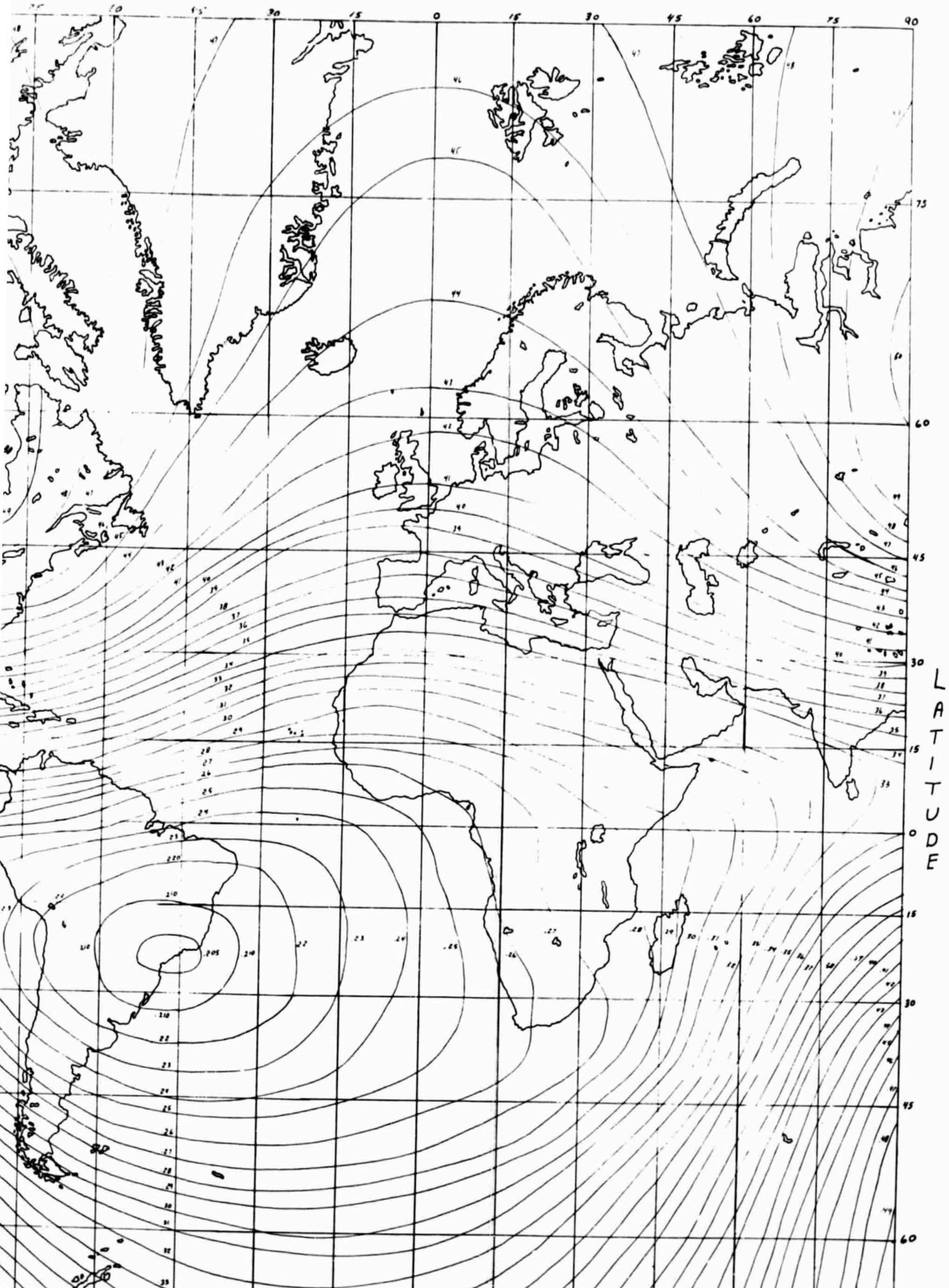

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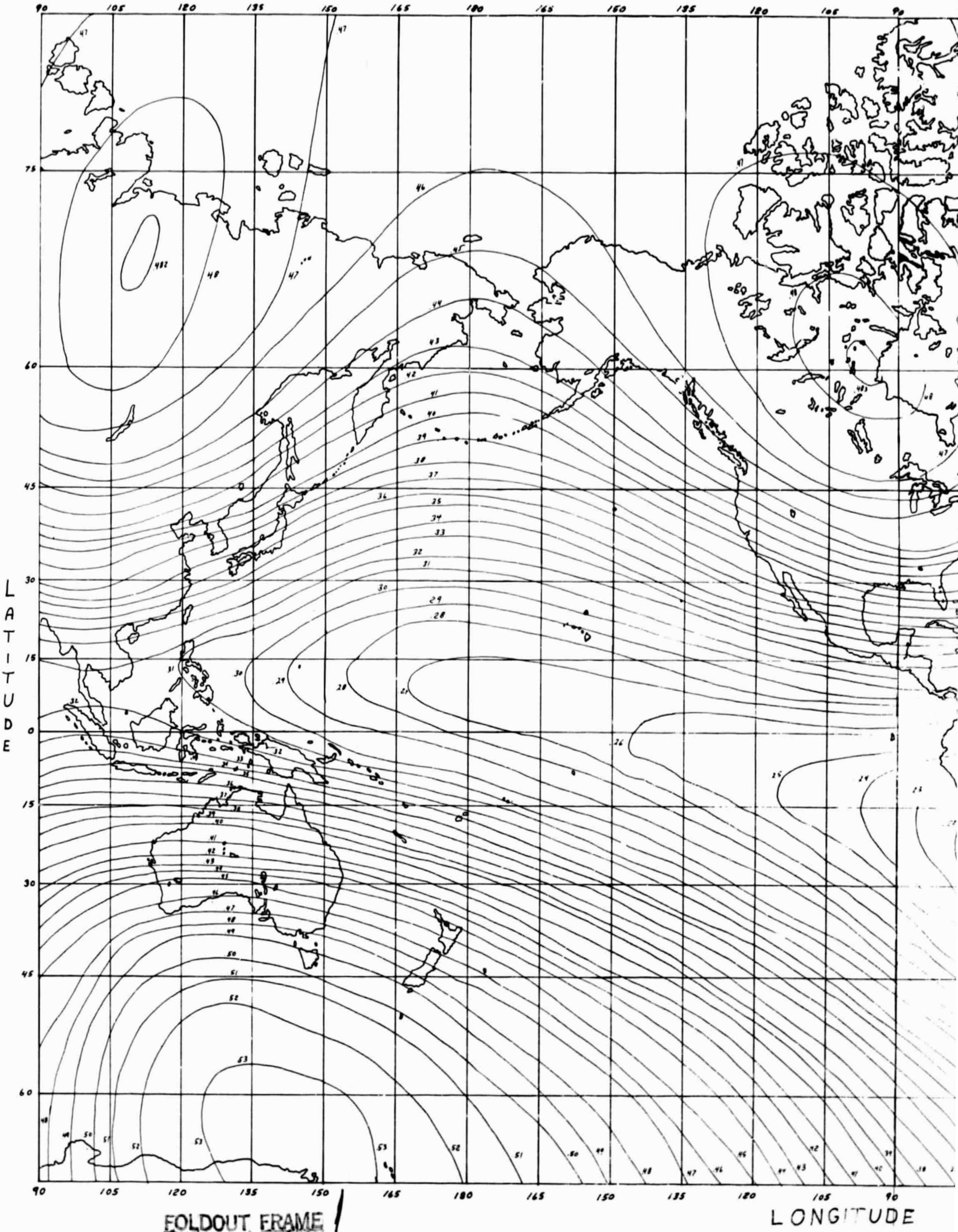
FIELD STRENGTH (GAUSS) h= 400 km

Figure 6-5



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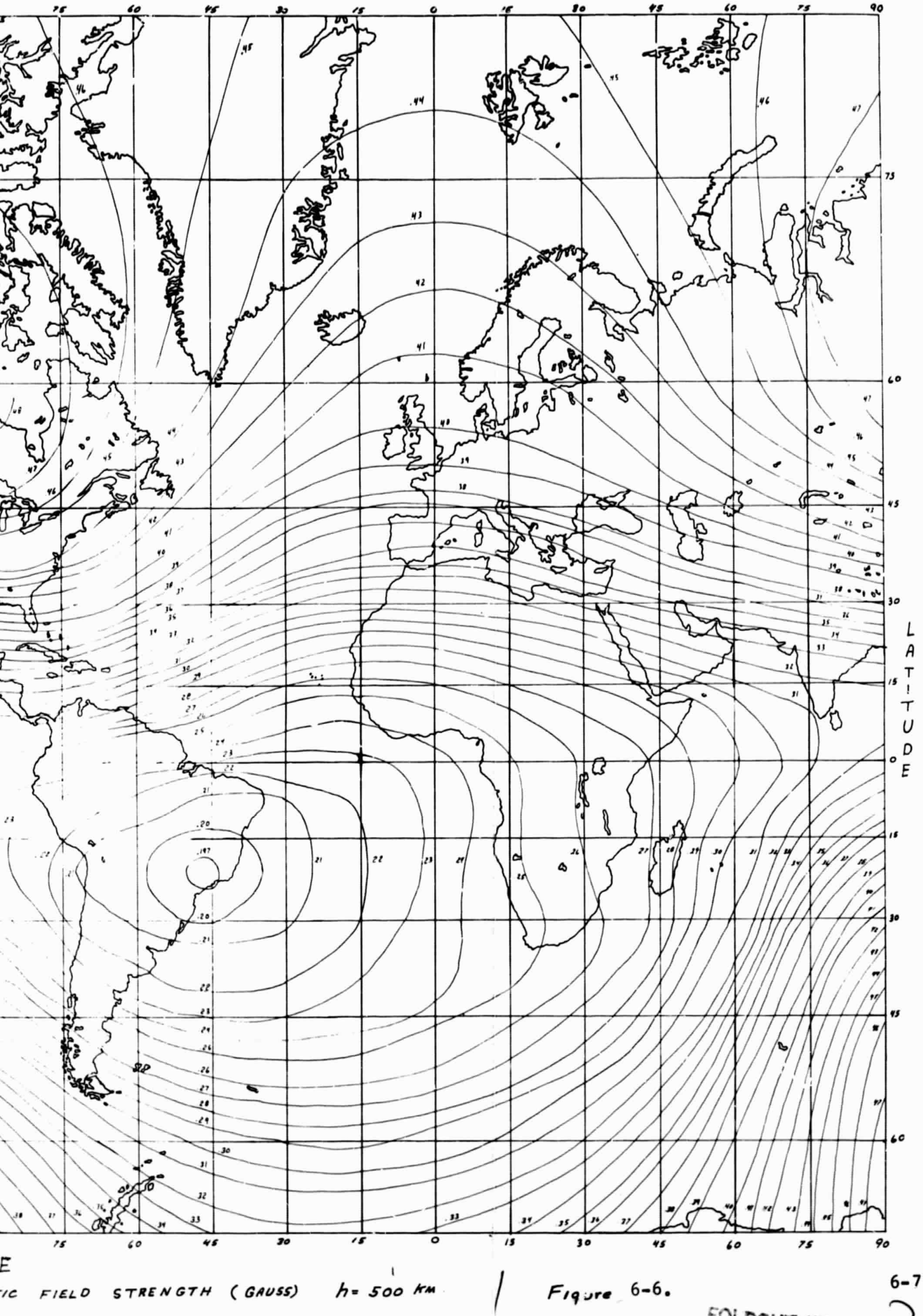
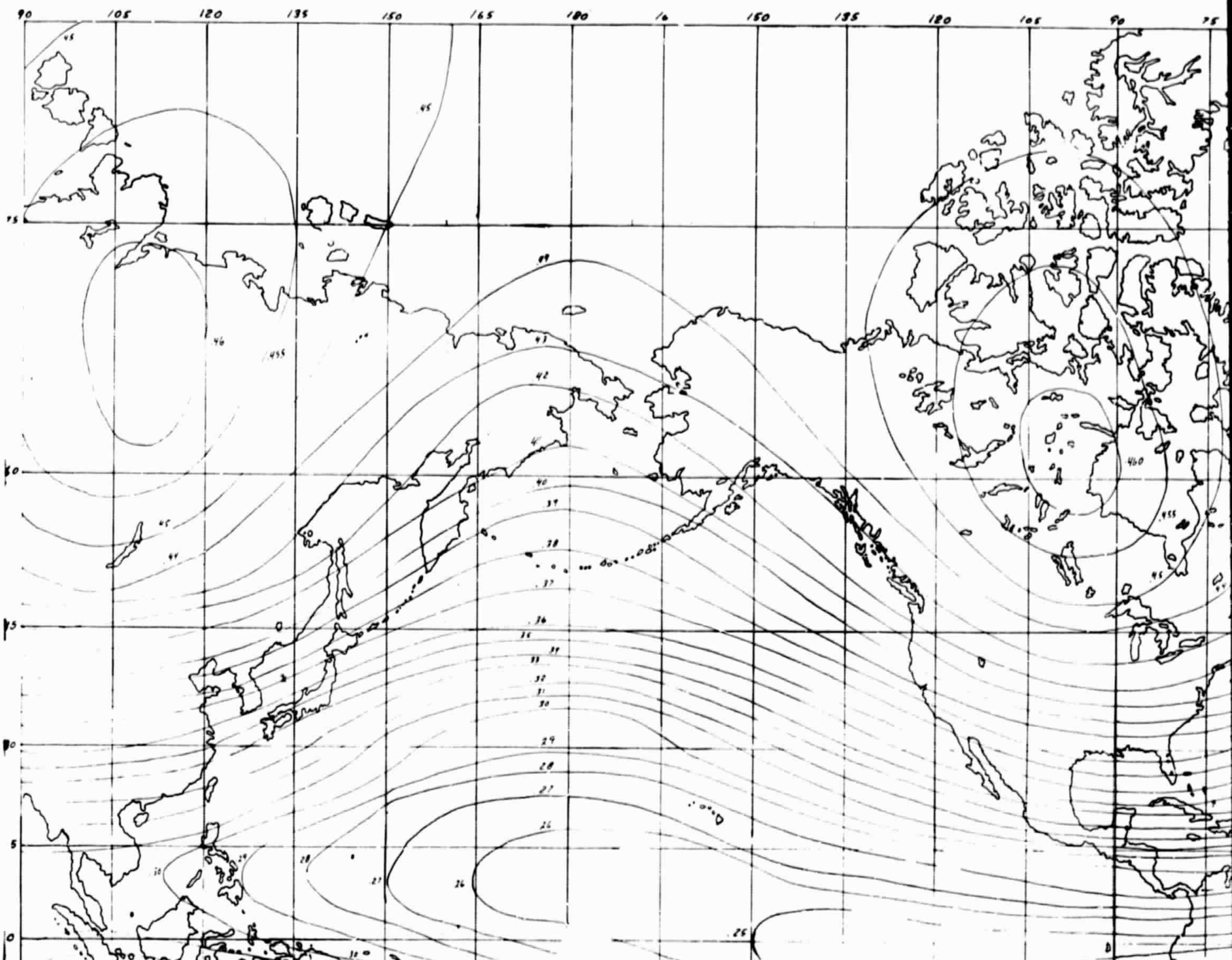


IC FIELD STRENGTH (GAUSS) h= 500 KM Figure 6-6.



LONGITUDE

ISO - CONTOURS OF MAGNETIC FIE

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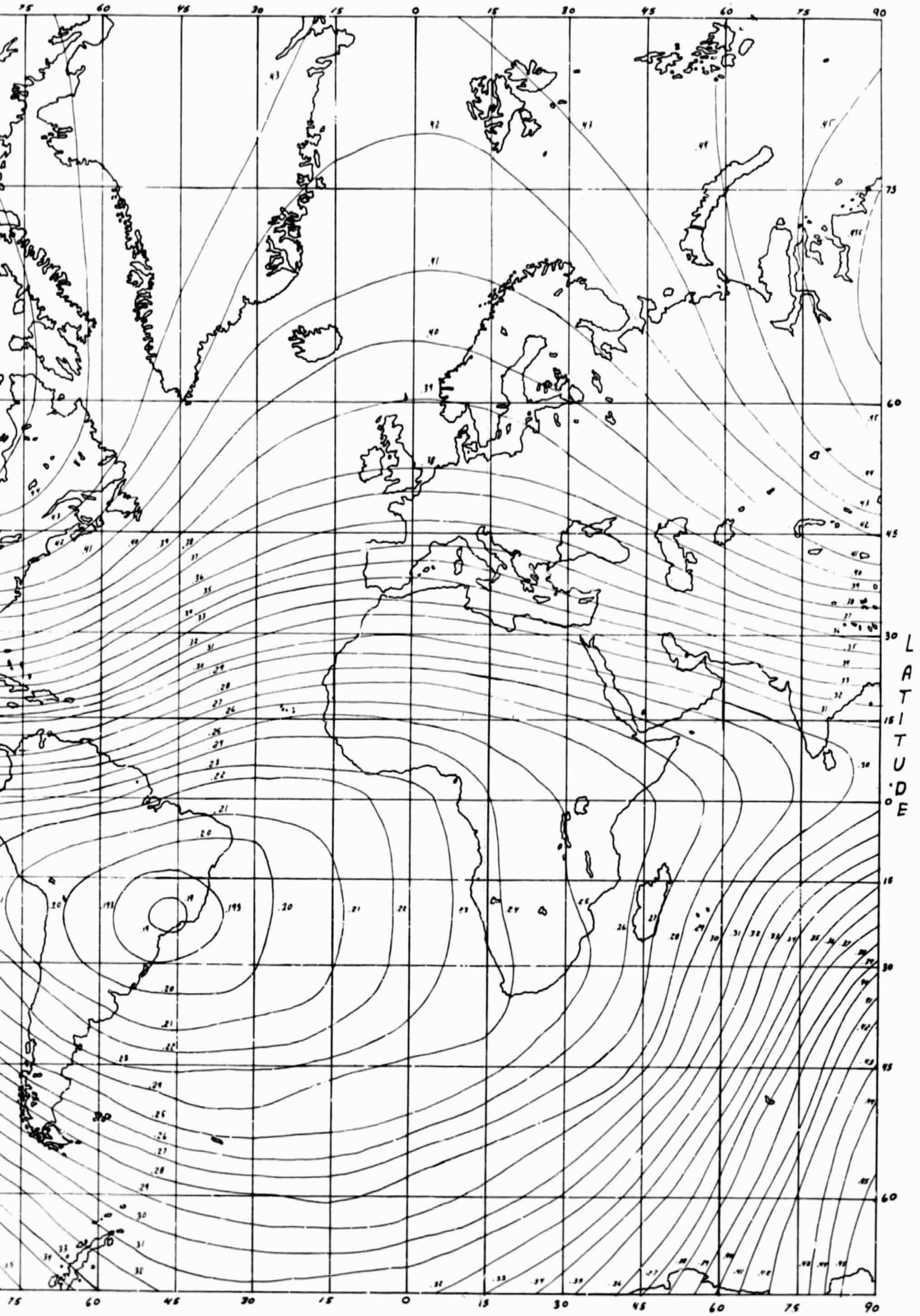

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FIELD STRENGTH (GAUSS)   h= 600 km

Figure 6-7.

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