X-612-67-373

NASA TM X-55876

MAGNETIC CHART OF THE BRAZILIAN ANOMALY – A VERIFICATION

JOSEPH C. CAIN
ROBERT A. LANGEL
SHIRLEY J. HENDRICKS

AUGUST 1967

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

MAGNETIC CHART OF THE BRAZILIAN ANOMALY - A VERIFICATION

by

Joseph C. Cain

Robert A. Langel

Shirley J. Hendricks

August 1967

Goddard Space Flight Center
Greenbelt, Maryland

MAGNETIC CHART OF THE BRAZILIAN ANOMALY - A VERIFICATION

by

Joseph C. Cain
Robert A. Langel
Shirley J. Hendricks

Introduction

In a recent paper Konovalova and Nalivayko (1967) have reported the results of the Cosmos-26 and 49 satellites (1964-13 and 69 respectively) in mapping the magnetic "low" in total field which centers on southern Brazil. We wish to take this opportunity to compare their results with an evaluation from a recently derived field model which is partly based on the magnetic field experiment from the OGO-2 satellite (Cain et al., 1967a). These magnetic survey satellites are contributers to the bilateral cooperation between the U.S. and the USSR for the IQSY World Magnetic Survey (Frutkin, 1965).

The periods for which the USSR satellite acquired data were March 18-24, 1964, for Cosmos-26, and October 24 to November 6, 1964, for Cosmos 49 (Dolginov et al., 1965). The altitude range for Cosmos 26 was 270-403 km and that for Cosmos 49 was 270-490 km. Although OGO-2 is still making measurements whenever its orbital plane is completely sunlit (Cain et al., 1967a), the period from which data were taken for the analysis reported here was October 29-November 19, 1965. This interval was chosen as being the first for which a good data distribution and orbits are available and which is magnetically very quiet. Our analysis differs from that of Konovalova and Nalivayko (1967) in that we employed a least squares technique to fit a potential expansion (Cain et al., 1965). The fit was made not only to a sample of OGO-2 data, but also to a selection of all available magnetic survey data since 1900. The resulting field model, labeled GSFC(12/66), is described by a series of 120 spherical harmonic coefficients and their first and second time derivatives (Cain et al., 1967b). It is thus possible to evaluate the field from these coefficients and to produce maps over the Brazilian area.

Maps of the field evaluated for 1965.0 are given in Figure 1 for 350 and 450 km altitude. These field contours were plotted using an automatic technique [similar to that reported by Cain and Neilon (1963)] which results in an accuracy relative to the original field model within the thickness of the lines.

We have also plotted on these figures the locations of the field observations taken since 1960 that were used in the analysis. There are about 20 north-south tracks of the OGO-2 observations plus numerous tracks from project MAGNET and a few shipboard observations. Of course earlier data from this area (including those from the Zarya) entered the computation to help adjust the field values and secular change terms.

A table of the position of the minimum of this low field area was computed from the coefficients for different epochs as follows:

Altitude	Epoch	Position		Field(γ)
350 km	1960	23.8 S	46.8 W	21140
	1965	23.9 S	48.0 W	20970
	(1970	23.9 S	49.1 W	20780)
450 km	1960	23.2 S	46.4 W	20350
	1965	23.3 S	47.6 W	20190
	(1970	23.3 S	48.7 W	20010)

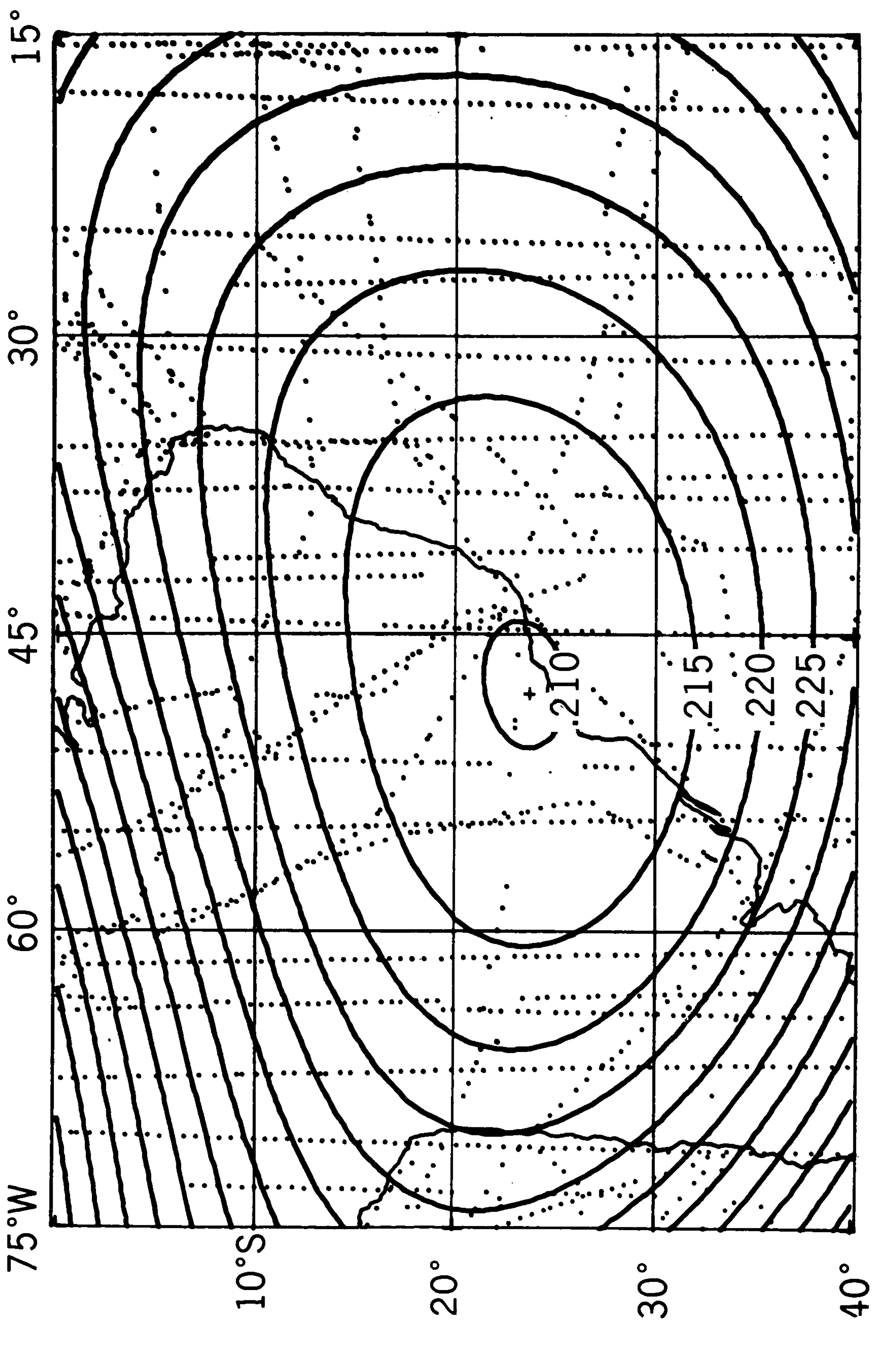

Figure 1a

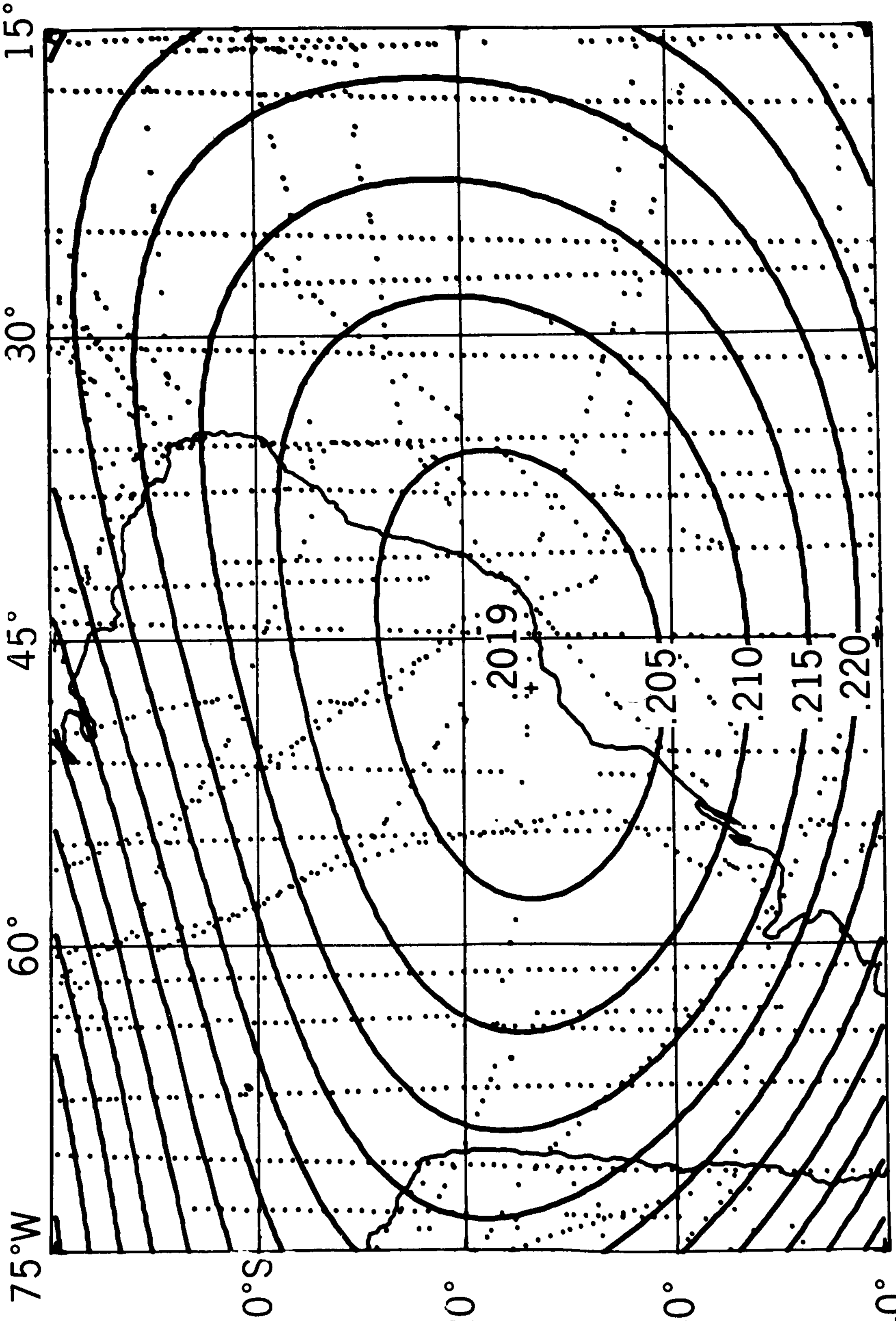

Figure 1b

The values for 1970 are enclosed in parentheses since they are extrapolations from the present data set. The approximate 0.2°/year westward drift of this feature which can be inferred from this table is in good agreement with the rate noted by Bullard (1950).

Although the positions given in the text by Konovalova and Nalivayko (1967) for the minimum at 350 km altitude is 23°S and 47°W, the center of their 21100 γ inner map contour appears to lie closer to 24°S and 48°W. For the broader feature at 450 km they give the minimum position at $\approx 23^{\circ}$S and $\approx 47^{\circ}$W. A scaling of the center of their 20300γ contour gives about 23°S and 47.5°W. For the minimum values they give the fields to be 20900 to 21100γ at 350 km and 20100 to 20300γ at 450 km. Although it is not explicitly stated in their paper that the 450 km map results from Cosmos 49 and the 350 km map from Cosmos 26, the lower altitude range of this earlier spacecraft makes this a logical assumption. We summarize below a comparison of results assuming the 350 km map to be epoch 1964.2, the 450 km map epoch 1964.8, and the center positions taken from the maps:

350 km	N & K	24°S 48°W	20900γ to 21100
1964.2	GSFC(12/66)	23.9°S 47.8°W	21000γ
450 km	N & K	23°S 47.5°W	20100γ to 20300
1964.8	GSFC(12/66)	23.3°S 47.5°W	20190

Considering the fact that these results were derived from entirely different data and techniques of analysis the agreement is remarkable! As we have indicated (Cain et al., 1967b) the error estimates on the GSFC(12/66) model are of the order of a few tens of gammas at epoch 1965.0. Although no explicit mention is made by Konovalova and Nalivayko

(1967) of the accuracy of their results, the close agreement in field between our results and a field value in the middle of their estimated field range indicates that their errors must be somewhat less than the 200γ tolerance they allow.

We also find that we are in good, though not perfect, agreement with their experimental field gradients as illustrated by the following table:

			$\Delta F / \Delta h$ (γ/km)		
Position	Lat.	Long.	GSFC*		N & K
			(350 km)	(450 km)	
1	-6	-37	10.2	9.6	10.9
2	-9	-35	9.9	9.3	10.4
3	-16	-53	8.9	8.4	9.9
4	-18	-50	8.6	8.1	9.3
5	-27	-42	7.9	7.5	8.7
6	-37	-29	8.1	7.7	7.7
7	-32	-43	7.6	7.3	8.4
8	-6	-51	10.5	9.9	10.3

Thus the closeness of agreement of the field value at the minimum may not reflect such good comparisons at other locations. Over an altitude range of several hundred kilometers it would appear that differences of the order of a few hundred gammas could be anticipated.

*Evaluated at 1965.0. The gradients change less than 0.1γ/km per year.

The possibility of the Brazilian anomaly's having a double minimum near 42°W and 55°W was noted by Muzzio, et al., (1965) as a preliminary result from the Alouette ionospheric satellite. Since the highest harmonic in the GSFC(12/66) field is of order and degree 10, the resolvable wavelength near the minimum is of the order of $(360/10)\cos 23^\circ = 33^\circ$ in longitude, a figure much larger than the 13° difference between centers suggested by Muzzio, et al. (1965). The field model would thus not follow such a rapid variation and if this feature existed it would be clearly evident in the residuals of the data. An inspection of sample data in this area shows no evidence of deviations larger than a few tens of gammas. We are thus in substantial agreement with Konovalova and Nalivayko that the field minimum is a single low without appreciable structure.

Appendix

Listed on the next page are the GSFC(12/66)-1 coefficients (Schmidt normalized) used in this comparison. The value of a = 6371.2 km. is used in the (a/r) terms. The epoch is 1960.0 and the fit is to survey data taken over the period 1900-1965.

n	m	g	h	$\dot{g}$	$\dot{h}$	$\ddot{g}$	$\ddot{h}$
1	0	-30401.2		14.03		-0.062	
1	1	-2163.8	5778.2	8.76	-3.71	0.114	-0.043
2	0	-1540.1		-23.29		-0.154	
2	1	2997.9	-1932.0	-0.09	-14.31	-0.018	0.054
2	2	1590.3	202.9	-4.56	-16.62	-0.253	-0.016
3	0	1307.1		-0.93		-0.123	
3	1	-1988.9	-425.4	-10.62	5.20	-0.027	0.095
3	2	1276.8	227.8	2.31	2.53	0.028	-0.007
3	3	881.2	-133.8	-5.89	-6.98	-0.183	0.079
4	0	949.3		1.45		0.001	
4	1	803.5	160.3	0.90	-2.19	-0.044	0.004
4	2	502.9	-274.3	-1.75	-0.14	0.017	0.056
4	3	-397.7	2.3	0.66	1.88	0.007	-0.035
4	4	266.5	-246.6	-3.01	-6.52	-0.097	-0.047
5	0	-233.5		1.61		0.045	
5	1	355.7	5.1	0.60	2.24	0.001	-0.046
5	2	228.4	117.8	3.34	1.59	0.075	0.007
5	3	-28.8	-114.8	-0.04	-2.61	0.008	-0.007
5	4	-157.9	-108.9	-0.60	0.50	0.015	0.001
5	5	-62.2	82.4	1.76	-0.12	0.056	-0.024
6	0	49.2		-0.42		-0.006	
6	1	57.5	-12.1	0.82	0.05	0.015	0.020
6	2	-0.8	104.4	0.82	0.09	0.010	-0.011
6	3	-238.3	56.6	2.35	2.55	0.050	0.015
6	4	-1.5	-23.4	0.83	-1.19	-0.011	-0.029
6	5	-2.0	-14.8	0.01	0.33	0.026	0.029
6	6	-108.9	-13.3	0.23	0.84	0.023	-0.010
7	0	72.2		-0.57		-0.014	
7	1	-53.7	-53.7	-0.34	-0.96	-0.006	-0.014
7	2	7.9	-27.4	-1.44	0.01	-0.034	0.016
7	3	15.6	-8.1	-0.90	0.43	-0.004	0.014
7	4	-24.3	7.0	0.03	0.75	-0.006	0.005
7	5	-3.6	24.3	-0.60	-0.33	-0.027	-0.008
7	6	15.5	-22.5	-0.17	0.49	-0.001	0.016
7	7	3.6	-21.4	-0.64	0.90	-0.004	0.011
8	0	8.5		0.35		0.006	
8	1	6.5	5.4	0.50	-0.50	0.008	-0.015
8	2	-9.3	-11.7	1.70	-0.21	0.039	-0.012
8	3	-9.6	4.2	-0.11	0.03	-0.008	0.005
8	4	-6.1	-15.3	0.34	-0.79	0.015	-0.011
8	5	5.5	4.6	-0.07	0.05	-0.002	-0.000
8	6	-8.1	21.9	0.43	0.10	0.005	-0.003
8	7	13.0	-0.7	-0.15	-0.36	-0.008	-0.009
8	8	7.4	-17.1	-0.42	-0.43	-0.007	-0.003
9	0	10.4		-0.10		-0.005	
9	1	5.8	-22.4	-0.13	0.66	-0.001	0.022
9	2	7.5	13.8	-1.20	0.54	-0.027	0.007
9	3	-15.1	6.3	0.08	0.03	0.005	-0.002
9	4	12.1	-3.0	-0.08	0.35	-0.007	0.009
9	5	4.7	-1.9	-0.39	-0.03	-0.006	0.006
9	6	0.2	9.0	-0.36	-0.01	-0.009	-0.001
9	7	1.6	11.5	0.47	0.45	0.006	0.009
9	8	0.9	0.1	0.37	-0.05	0.005	-0.004
9	9	0.2	-1.5	-0.46	0.75	-0.009	0.019
10	0	-2.9		-0.01		-0.003	
10	1	-0.9	-0.1	-0.13	-0.61	-0.003	-0.012
10	2	-2.2	4.5	0.88	-0.64	0.020	-0.014
10	3	0.8	-1.0	-0.18	0.02	-0.008	0.001
10	4	-2.8	2.6	0.17	0.05	0.007	0.001
10	5	6.4	-4.4	-0.02	-0.63	0.001	-0.011
10	6	4.7	-1.3	0.05	-0.07	0.001	-0.001
10	7	-0.2	-3.6	0.17	0.07	0.001	0.001
10	8	1.8	4.0	0.16	-0.03	0.005	-0.001
10	9	2.0	1.0	0.31	-0.02	0.004	0.001
10	10	1.1	-2.0	-0.23	-0.45	-0.002	-0.006

REFERENCES

Bullard, E. C., C. Freedman, H. Gellman, and J. Nixon, The westward drift of the earth's magnetic field, Phil Trans. Roy. Soc., 243A, 67-92, 1950.

Cain, Joseph C., and James R. Neilon, Automatic mapping of the geomagnetic field, J. Geophys. Res., 68, 4689-4698, 1963.

Cain, Joseph C., W. E. Daniels, Shirley J. Hendricks, and Duane C. Jensen, An evaluation of the main geomagnetic field, 1940-1962, J. Geophys. Res., 70, 3647, 1965.

Cain, J. C., R. A. Langel, and S. J. Hendricks, First magnetic field results from the OGO-2 satellite, Space Research VII, 1466-1476, North-Holland, Amsterdam, 1967a.

Cain, J. C., S. J. Hendricks, R. A. Langel, and W. V. Hudson, A proposed model for the international geomagnetic reference field, NASA X-612-67-173, Greenbelt, Maryland, 1967b.

Dolginov, Sh. Sh., V. I. Nalivayko, A. V. Tyurmin, and M. N. Chinchevoy, Experiments under the program of the World Magnetic Survey, Sp. Issl. Kosm. Prostr., 606-614, 1965; also NASA TT-F-389, pp. 806-816.

Frutkin, A. W., International Cooperation in Space, p. 121, Prentice-Hall, Engelwood, N. J., 1965.

Konovalova, L. V., and V. I. Nalivayko, Magnetic chart of the Brazilian anomaly, Geomagnetizm i Aeronomiya, (in English), 7,__________ (Original Russian pp. 394-395), 1967.

Muzzio, J. L. R., R. Ramirez Pardo, and F. de Mendonca, Measurements of the earth's total magnetic field at heights of 1000 km in the Brazilian anomaly, COSPAR 60th International Space Science Symposium, Buenos Aires, 1965.

FIGURE CAPTIONS

Figure 1 Contours of total field F over the Brazilian anomaly computed from GSFC(12/66) coefficients. Positions of data after 1960.0 used in determination of coefficients are plotted as dots. (a) 350 km altitude (b) 450 km altitude.