CANADA

INSTITUT OCÉANOGRAPHIQUE DE BEDFORD INSTITUTE OF OCEANOGRAPHY

DARTMOUTH, N. S.

CALCULATION OF TOTAL MAGNETIC INTENSITY IN NORTH ATLANTIC

by

M. FRIEDLAENDER

BIO COMPUTER NOTE 66-4-C

November, 1966

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A. THEORY AND RESULTS

A.1 INTRODUCTION

A regional expression for total magnetic intensity in the North Atlantic was obtained by fitting a 3rd degree polynomial to 224 data points obtained by the Dutch research vessel SNELLIUS in 1965. The area delimited by 20°N, 50°N, 8°W, 68°W is covered with the exception of the region lying both south of 30° and west of 60°.

A.2 THEORY

Spherical harmonic analysis can be used to obtain an expression to fit magnetic intensity data over a part of the earth's surface. However, when the region considered is small, it is simpler and probably just as effective to fit a polynomial by least squares, ignoring sphericity of the earth (Bullard, 1963).

Accordingly, a polynomial p (x,y) in north latitude (x) and west longitude (y) was chosen. In most of this work p (x,y) was the general 3rd degree polynomial.

The problem of fitting a function of the given form p (x,y) $=\sum_{j=1}^{N} a_j \xi_j(x,y)$ in the least squares sence to a set of ν values $f(x_i,y_i)$ is solved by determining values for the N coefficients $a_1,\ldots,a_N$ so that $\sum_{i=1}^{\nu}[p(x_i,y_i)-f(x_i,y_i)]^2$ is minimized. This is done by solving the N equations

$$\frac{\partial}{\partial a_j}\sum_{i=1}^{\nu}[p(x_i,y_i)-f(x_i,y_i)]^2=0,$$

i.e. the linear equations

$$\sum_{k=1}^{N} a_k \sum_{i=1}^{\nu} \xi_j(x_i,y_i)\xi_k(x_i,y_i)-\sum_{i=1}^{\nu}\xi_j(x_i,y_i)f(x_i,y_i)=0 \qquad (1)$$

with $j = 1,\ldots,N$.

Goodness of fit is measured by the RMS error, or standard error, σ, given by

$$\sigma=\left[\frac{\sum_{i=1}^{\nu}[p(x_i,y_i)-f(x_i,y_i)]^2}{\nu}\right]^{1/2} \qquad (2)$$

Substituting (1) into (2) we get

$$\nu\sigma^2=-\sum_{k=1}^{N} a_k \sum_{i=1}^{\nu}\xi_k(x_i,y_i)f(x_i,y_i)+\sum_{i=1}^{\nu}[f(x_i,y_i)]^2 \qquad (3)$$

Equation (3) has the advantage over (2) that it can be computed in one pass without storing the original data points. The number of data points, ν, must also be taken into account when examining the quality of a fit, as one can bring σ to zero by reducing ν to N or less. The objective is to use as many points as possible while keeping the standard error as low as possible.

A.3 DATA

The data was obtained from magnetic profiles drawn on a scale of 1:1 million from the records of HMNS SNELLIUS Cruise NAVADO III, November 1964 to September 1965. This survey covered the Atlantic, from south to north, between 20°N and 50°N latitude and 8°W and 70°W longitude, approximately. All 224 points for which the records give latitude, longitude, and total magnetic intensity were used. These points do not represent single readings, but are in themselves mean values.

Secular variation during the survey was not taken into account.

Although there are many sets of two practically coincident points (start and end of a station), none of these points were rejected, as the pairs, being uniformly distributed, do not introduce appreciable distortion. Retention of these points results in better smoothing.

The data points are given in Table B.7 and a contour map drawn from these points is shown in Figure B.3.

A.4 PROCEDURE AND RESULTS

Normal Equations

To solve the system of N normal equations (1), the elements of the augmented matrix are accumulated during one pass of the data cards through the computer.

The rows of the matrix are then rearranged so as to maximize, loosely speaking, the absolute values of the diagonal elements. This is done by placing on the diagonal, whenever possible, the largest element of each row; processing starts with the row containing the absolutely smallest element of the matrix and continues according to the same criterion.

This method gives better results than standard pivotal condensation, although it, too, need not produce the best ordering. An example of such a situation is the matrix $\begin{Vmatrix} 1 & 10 \\ 2 & 1000 \end{Vmatrix}$ which is transformed to $\begin{Vmatrix} 2 & 1000 \\ 1 & 10 \end{Vmatrix}$. After row-ordering, the system is solved by Gauss-Jordan elimination (Hildebrand, 1956). The standard error is computed from equation (3); a numerically more accurate value can be obtained from an "EVALUATE"[1] pass using equation (2)[2].

Procedure

All data points outside the rectangle bounded by 20°N, 50°N, 8°W, 68°W, were discarded because their distribution outside that area was irregular and thin. An attempt to fit a 3rd degree polynomial to the remaining 175 data points produced a standard error of 167 gammas. Some of the anomalies with respect to this polynomial were larger than 500 gammas. Such local anomalies (or data errors) can seriously distort the map, especially if they are large. This is undesirable, as the computed regional trend map is to be a base against which local anomalies stand out, and should be influenced as little as possible by those local anomalies which happen to have been picked up in the sample of 175 data points.

Accordingly, all data points for which the difference between the observed value and the fitted value exceeded twice the standard error were discarded. A new set of coefficients and standard error were computed.

This process was repeated 8 times, at which time the polynomial fitted the 135 points still being used with a standard error of 72.5 gammas. The polynomial so obtained[3] was adopted to represent total magnetic intensity scalar field in the North Atlantic. With coefficients rounded to 7 significant places, this polynomial is given by

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1. See section C.1 on the computer program.
2. Cumulative rounding errors are smaller in this more direct computation.
3. This polynomial is referred to as the adopted polynomial throughout the present report.

$$p(x,y) = 28906.96 + 334.6679\,x + \\ - 327.6748\,y + 7.508479\,xy + \\ 3.196153\,x^2 + 8.239534\,y^2 + \\ - 0.06198770\,x^2y - 0.04094623\,xy^2 + \\ - 0.04505608\,x^3 - 0.03517914\,y^3,$$

where x is north latitude in degrees and y west longitude in degrees. A complete listing of the coefficients is in table B.1, while Table B.6, gives values of the adopted polynomial, and map B.4 shows the polynomial contoured at 1000 gamma intervals.

Table B.2 indicates the number of points used and the standard error at each of the 9 runs leading to the adopted run.

Goodness of Fit and Restrictions

In Figure B.5, contour maps drawn from the adopted polynomial and directly from the data are superimposed. The fit is poor in the corner south of 30° and west of 60°, and most data points in this area were in fact discarded. Clearly the isomagnetic lines bend so strongly here that a 3rd degree polynomial is not a good approximation if it is to fit in the remainder of the region. Accordingly the adopted polynomial should never be used in this southwestern corner.

As the fit is good elsewhere, the adopted polynomial should be a satisfactory expression for the regional field in the region 20° to 50°N, 8° to 68°W, except for the southwestern corner.

Distortion and Stability

Non-uniform distribution of data points introduces distortion. The set of SNELLIUS data points contains many pairs of closely spaced points. As an experiment, some runs were done with only one point from each pair. There were no significant differences in results.

Coefficients rounded to seven significant places produce polynomial values which, rounded to the nearest gamma, agree with those obtained from the full 11 digit coefficients. This shows that the adopted polynomial is "stable" as a function of its coefficients, and can be computed on machines not possessing the 11 digit precision in which it was originally defined. Coefficients rounded to five places produce agreement to within 1 gamma with the correct values.

A.5 DISCUSSION

North-South Lineation of Anomalies

Anomalies with respect to the adopted polynomial appear to be banded into vertical stripes of positive and negative regions, each band with a width in the order of 1000 miles (see map B.8)[1]. This means that if anomalies with respect to the regional field are to be randomly distributed, a more complex function than a 3rd degree polynomial is required to express the regional field.

To reduce the possibility of the phenomenon being the result of the choice of a particular polynomial and hence of no interest, a 4th degree polynomial was fitted. (See below). Map B.9[1] shows anomalies with respect to this polynomial. The appearance of similar principal features in maps based on an even and on an odd polynomial suggests that the phenomenon is inherent in the data, in the sense that no low order polynomial will produce a fit with randomly distributed deviations.

It is clear that increasing the degree of the polynomials used to the point where only noise remains would mean fitting the crustal anomalies rather than the regional field. It is unlikely that a slight increase in the degree used would drastically decrease the extent of the banding, as can be seen from the fit in Fig. B.5. On the other hand, the large width of the bands suggests that some less rational function than a low order polynomial may remove most of the banding without becoming a fit to the local crustal anomalies. It is, therefore, not clear what physical reality can be attributed to the banding phenomenon.

Other Polynomials

1) A 4th degree polynomial was fitted in the region 20° to 50°N, 8° to 72°W. The coefficients are listed in Table B.10, and Table B.11 shows the number of points used and the standard error for each run in

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1. The anomaly values do not permit greater detail than the zero contours.

this trial. In the 7th run, with 158 points being used, standard error was 72 gammas. This polynomial fits more points better than the adopted polynomial, and the problem in the southwestern corner has also vanished. On the other hand, the polynomial is so unstable (as function of coefficients) that rounding coefficients to 7 places can introduce errors of several thousand gammas, a property that makes it useless for routine computations.

2) A 3rd degree polynomial was fitted without area restrictions, giving a standard error of 468 gammas on 224 data points. After 10 runs, the polynomial fitted the 183 points being used with a standard error of 138 gammas, all 183 points lying within 276 gammas of the computed values. This method was not adopted because of the pronouncedly non-uniform distribution of data points.

Comparison with earlier work

Bullard, Hill and Mason (1962) published an expression for total magnetic intensity for the eastern part of the region considered here, reduced to 1958.0. Contours of the present adopted polynomial considered as an anomaly with respect to Bullard, Mason and Hill's function are plotted in map B.12. If secular variation is taken to be +25 gammas/year over the entire region, 175 gammas must be subtracted from all values shown on the map. The zero anomaly contour then falls into a region of dense ship tracks, whereas the southwestern part of Bullard, Mason, Hill's survey, where tracks are sparse, agrees poorly with present results.

Vestine et al (1947) tabulated total magnetic intensity for 1945 at 5 degrees intervals of latitude and longitude.

Map B.13 contours the present adopted polynomial as anomaly with respect to Vestine's values. As the secular variation changes sign in this area, it is not surprising that the picture is confusing.

Improvements

Results described in this report could be improved by using a better equation-solving technique (e.g. Crout's method), and especially by interpolating the observed field on to a uniform grid before attempting least squares fitting. (See IBM 1620 Numerical Surface Techniques and Contour Map Plotting). Compensation for secular variation during the survey would also be an improvement.

A.6 CONCLUSION

A 3rd degree polynomial in latitude and longitude was determined as an expression for the regional field of total magnetic intensity (1965) in the area 20° to 50°N, 8° to 68°W, with the exception of the corner south of 30° and west of 60°. The polynomial fits the 135 data points (out of 175 available in the area) which were used to determine it with a standard error of 73 gammas. The expression makes it possible, in actual survey work, to calculate magnetic anomalies using a regional field based entirely on shipboard observations.

North-south lineation of magnetic anomalies in the Atlantic was observed, a phenomenon which may be of significance.

COEFFICIENTS	
0.28906959477+005	1
0.33466785813+003	X
-0.32767477699+003	Y
0.75084788376+001	XY
0.31961525104+001	XX
0.82395343755+001	YY
-0.61987699061-001	XXY
-0.40946229636-001	XYY
-0.45056075835-001	XXX
-0.35179144049-001	YYY

TABLE B 1 ADOPTED POLYNOMIAL COEFFICIENTS

RUN	NO.OF POINTS	STANDARD ERROR
1	175	167
2	166	121
3	158	106
4	150	91
5	145	83
6	143	81
7	140	78
8	137	75
9	135	73

TABLE B 2 RUNS LEADING TO ADOPTED POLYNOMIAL

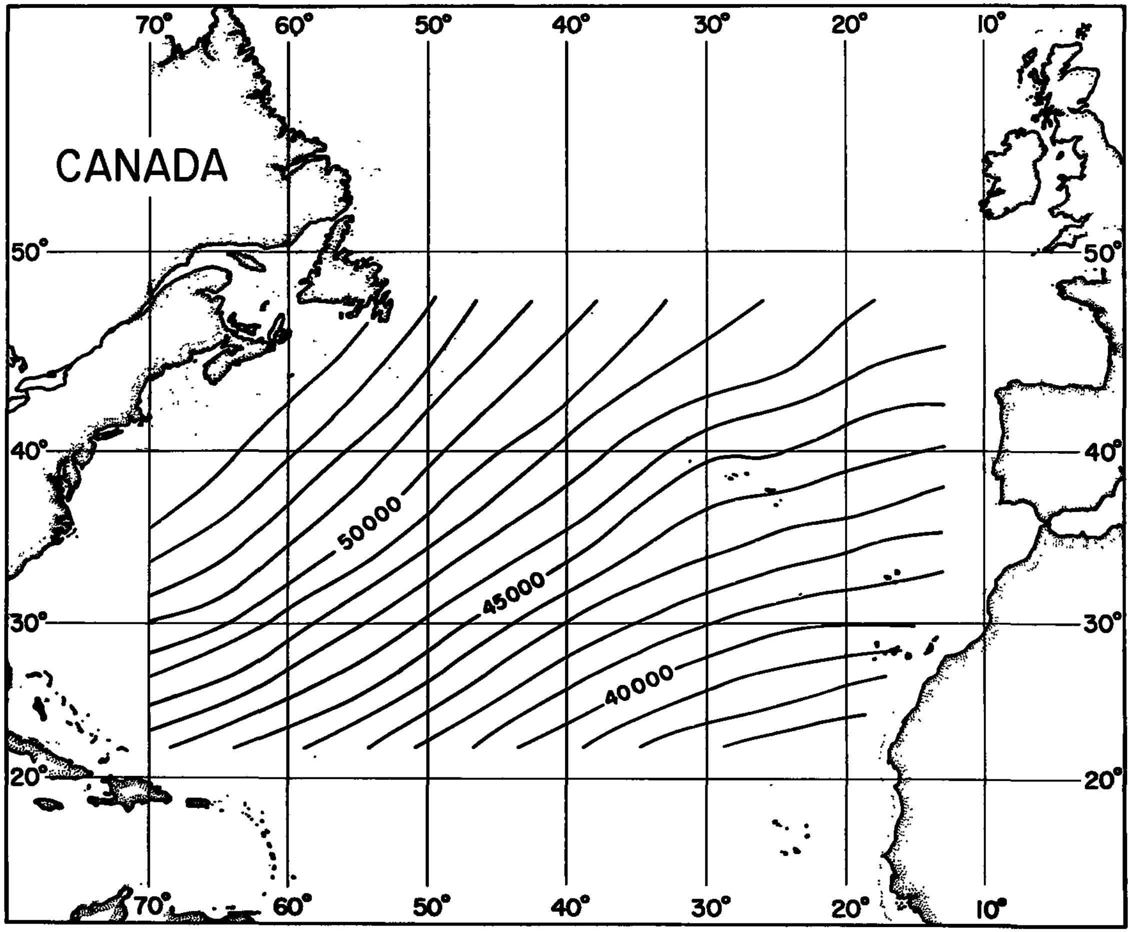

Fig. B.3 Total magnetic intensity in North Atlantic (1965). SNELLIUS data. Contour interval 1000 gammas.

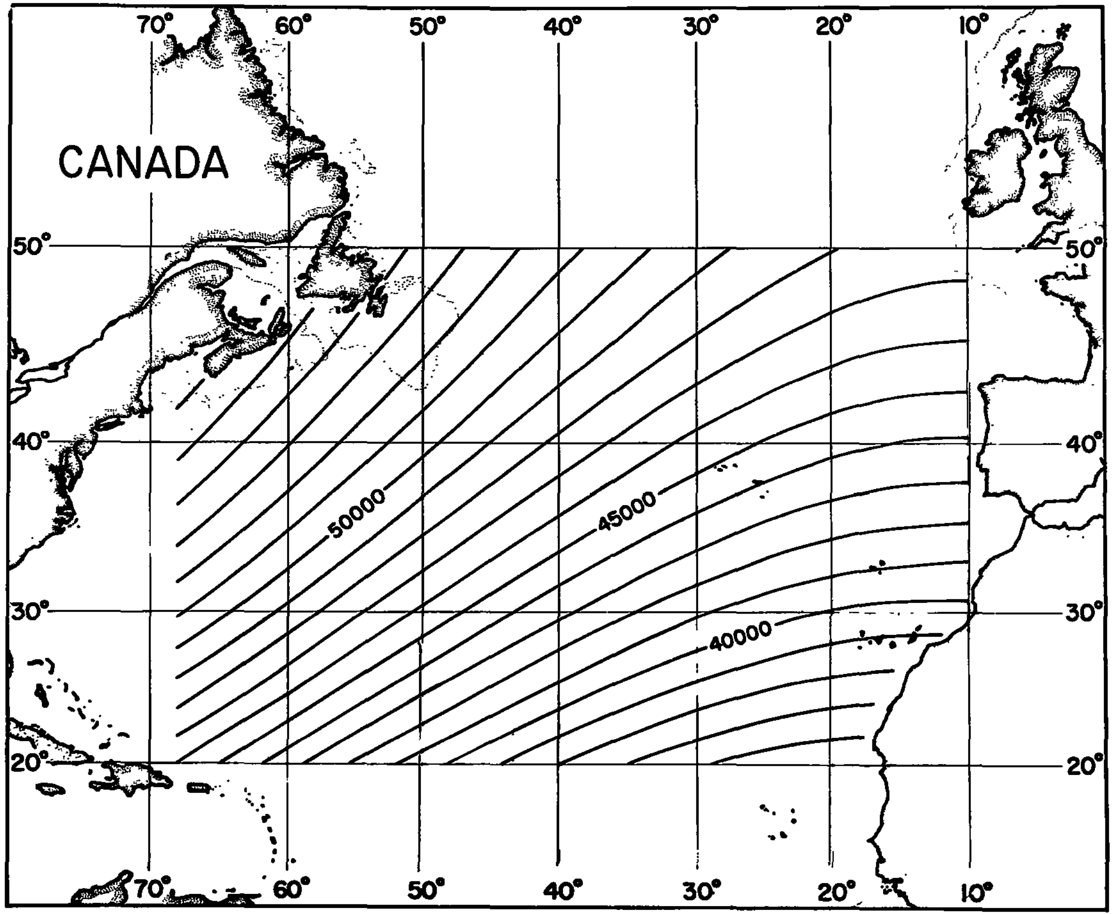

Fig. B.4 Total magnetic intensity in North Atlantic (1965). Adopted polynomial. Contour interval 1000 gammas.

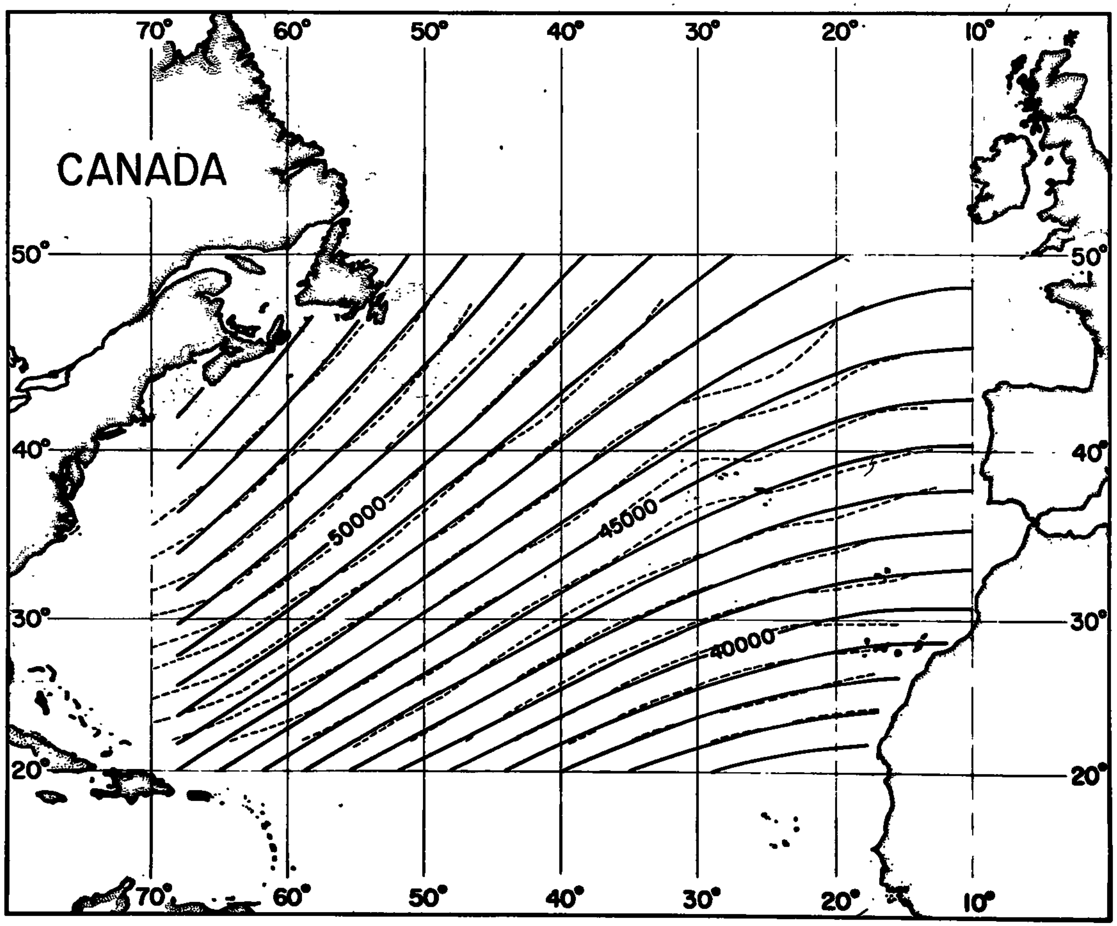

Fig. B.5 Total magnetic intensity in North Atlantic (1965). Solid
Solid lines: Fitted polynomial
Broken lines: SNELLIUS data.

TABLE B.6 Table of polynomial values (adopted polynomial)

20	0.0	10	0.0	35202.	35144.	35099.	35065.	35044.	35035.	35037.	35051.	35076.	35112.
20	0.0	20	0.0	35159.	35217.	35285.	35363.	35451.	35549.	35657.	35773.	35899.	36034.
20	0.0	30	0.0	36178.	36330.	36491.	36659.	36836.	37020.	37211.	37410.	37616.	37829.
20	0.0	40	0.0	38048.	38273.	38505.	38743.	38987.	39236.	39490.	39750.	40014.	40284.
20	0.0	50	0.0	40557.	40835.	41118.	41404.	41693.	41986.	42283.	42582.	42884.	43189.
20	0.0	60	0.0	43496.	43805.	44116.	44429.	44744.	45060.	45377.	45695.	46013.	
21	0.0	10	0.0	35657.	35603.	35561.	35532.	35514.	35509.	35515.	35532.	35561.	35601.
21	0.0	20	0.0	35651.	35712.	35783.	35864.	35956.	36057.	36167.	36287.	36415.	36553.
21	0.0	30	0.0	36699.	36854.	37017.	37187.	37366.	37552.	37746.	37947.	38154.	38369.
21	0.0	40	0.0	38590.	38817.	39051.	39290.	39535.	39785.	40041.	40302.	40567.	40838.
21	0.0	50	0.0	41112.	41391.	41674.	41961.	42251.	42544.	42841.	43141.	43443.	43748.
21	0.0	60	0.0	44055.	44365.	44676.	44989.	45303.	45619.	45935.	46253.	46571.	
22	0.0	10	0.0	36111.	36061.	36023.	35997.	35984.	35982.	35992.	36013.	36045.	36088.
22	0.0	20	0.0	36141.	36205.	36279.	36364.	36458.	36562.	36675.	36797.	36928.	37068.
22	0.0	30	0.0	37217.	37374.	37539.	37712.	37893.	38081.	38277.	38479.	38689.	38905.
22	0.0	40	0.0	39128.	39357.	39591.	39832.	40078.	40330.	40587.	40849.	41115.	41386.
22	0.0	50	0.0	41662.	41941.	42225.	42512.	42803.	43097.	43394.	43693.	43996.	44301.
22	0.0	60	0.0	44608.	44917.	45228.	45541.	45855.	46170.	46486.	46803.	47120.	
23	0.0	10	0.0	36564.	36518.	36484.	36462.	36452.	36454.	36467.	36491.	36526.	36572.
23	0.0	20	0.0	36629.	36696.	36773.	36861.	36958.	37064.	37180.	37305.	37438.	37581.
23	0.0	30	0.0	37732.	37891.	38058.	38233.	38416.	38606.	38804.	39008.	39219.	39437.
23	0.0	40	0.0	39661.	39891.	40127.	40369.	40617.	40869.	41127.	41390.	41657.	41929.
23	0.0	50	0.0	42205.	42486.	42769.	43057.	43348.	43642.	43939.	44239.	44542.	44847.
23	0.0	60	0.0	45154.	45463.	45774.	46086.	46399.	46714.	47029.	47345.	47662.	
24	0.0	10	0.0	37016.	36973.	36943.	36925.	36918.	36924.	36940.	36968.	37006.	37055.
24	0.0	20	0.0	37115.	37185.	37265.	37355.	37455.	37564.	37682.	37809.	37945.	38090.
24	0.0	30	0.0	38243.	38404.	38574.	38751.	38935.	39127.	39326.	39532.	39745.	39964.
24	0.0	40	0.0	40190.	40421.	40658.	40901.	41150.	41404.	41662.	41926.	42194.	42466.
24	0.0	50	0.0	42743.	43024.	43308.	43596.	43887.	44181.	44479.	44779.	45081.	45386.
24	0.0	60	0.0	45692.	46001.	46311.	46623.	46936.	47250.	47564.	47880.	48195.	
25	0.0	10	0.0	37467.	37428.	37401.	37386.	37383.	37392.	37411.	37442.	37483.	37535.
25	0.0	20	0.0	37598.	37671.	37754.	37846.	37948.	38060.	38181.	38310.	38449.	38595.
25	0.0	30	0.0	38751.	38914.	39085.	39264.	39450.	39644.	39844.	40052.	40266.	40486.
25	0.0	40	0.0	40713.	40946.	41184.	41428.	41677.	41932.	42191.	42456.	42724.	42997.
25	0.0	50	0.0	43274.	43555.	43840.	44128.	44419.	44714.	45011.	45311.	45613.	45917.
25	0.0	60	0.0	46223.	46532.	46841.	47152.	47464.	47777.	48091.	48406.	48720.	
26	0.0	10	0.0	37916.	37880.	37857.	37846.	37846.	37857.	37880.	37914.	37958.	38013.
26	0.0	20	0.0	38078.	38154.	38239.	38334.	38439.	38553.	38676.	38807.	38948.	39097.
26	0.0	30	0.0	39254.	39419.	39592.	39772.	39960.	40155.	40358.	40566.	40782.	41003.
26	0.0	40	0.0	41231.	41465.	41704.	41949.	42199.	42454.	42715.	42979.	43248.	43522.
26	0.0	50	0.0	43799.	44080.	44365.	44653.	44944.	45239.	45536.	45835.	46137.	46441.
26	0.0	60	0.0	46747.	47054.	47363.	47673.	47985.	48297.	48610.	48923.	49236.	
27	0.0	10	0.0	38363.	38331.	38311.	38303.	38306.	38321.	38346.	38383.	38430.	38488.
27	0.0	20	0.0	38556.	38634.	38721.	38819.	38926.	39042.	39167.	39301.	39443.	39594.
27	0.0	30	0.0	39753.	39920.	40094.	40276.	40466.	40662.	40866.	41076.	41292.	41515.
27	0.0	40	0.0	41744.	41978.	42218.	42464.	42715.	42971.	43231.	43496.	43766.	44039.
27	0.0	50	0.0	44317.	44598.	44883.	45171.	45462.	45756.	46053.	46352.	46653.	46957.

TABLE B.6 (Cont'd) Table of polynomial values (adopted polynomial)

27	0.0	60	0.0	47262.	47568.	47877.	48186.	48496.	48807.	49119.	49431.	49743.	
28	0.0	10	0.0	38808.	38779.	38763.	38757.	38764.	38781.	38810.	38849.	38899.	38959.
28	0.0	20	0.0	39029.	39110.	39200.	39300.	39409.	39527.	39654.	39790.	39934.	40087.
28	0.0	30	0.0	40247.	40416.	40592.	40775.	40966.	41164.	41368.	41579.	41797.	42021.
28	0.0	40	0.0	42250.	42486.	42727.	42973.	43224.	43480.	43741.	44007.	44278.	44550.
28	0.0	50	0.0	44828.	45109.	45394.	45681.	45972.	46266.	46562.	46861.	47161.	47464.
28	0.0	60	0.0	47768.	48074.	48382.	48690.	48999.	49309.	49619.	49930.	50241.	
29	0.0	10	0.0	39251.	39225.	39211.	39209.	39218.	39239.	39270.	39312.	39364.	39427.
29	0.0	20	0.0	39500.	39582.	39675.	39777.	39888.	40008.	40137.	40274.	40420.	40574.
29	0.0	30	0.0	40737.	40907.	41084.	41269.	41461.	41660.	41865.	42078.	42296.	42521.
29	0.0	40	0.0	42751.	42987.	43228.	43475.	43727.	43983.	44245.	44510.	44780.	45054.
29	0.0	50	0.0	45331.	45612.	45897.	46184.	46475.	46768.	47063.	47361.	47661.	47963.
29	0.0	60	0.0	48267.	48572.	48878.	49185.	49493.	49802.	50110.	50420.	50729.	
30	0.0	10	0.0	39691.	39668.	39657.	39658.	39670.	39693.	39726.	39771.	39826.	39891.
30	0.0	20	0.0	39966.	40051.	40145.	40249.	40362.	40484.	40615.	40754.	40902.	41057.
30	0.0	30	0.0	41221.	41392.	41571.	41757.	41950.	42150.	42357.	42570.	42789.	43014.
30	0.0	40	0.0	43245.	43482.	43724.	43971.	44223.	44479.	44741.	45006.	45276.	45550.
30	0.0	50	0.0	45827.	46108.	46392.	46679.	46969.	47261.	47556.	47853.	48153.	48453.
30	0.0	60	0.0	48756.	49060.	49365.	49671.	49977.	50284.	50592.	50899.	51207.	
31	0.0	10	0.0	40128.	40108.	40100.	40103.	40118.	40143.	40179.	40226.	40283.	40351.
31	0.0	20	0.0	40428.	40515.	40611.	40717.	40832.	40956.	41088.	41229.	41378.	41535.
31	0.0	30	0.0	41700.	41872.	42052.	42239.	42433.	42634.	42842.	43055.	43275.	43501.
31	0.0	40	0.0	43732.	43969.	44212.	44459.	44711.	44968.	45229.	45495.	45765.	46038.
31	0.0	50	0.0	46315.	46595.	46879.	47165.	47455.	47746.	48040.	48337.	48635.	48935.
31	0.0	60	0.0	49236.	49539.	49842.	50147.	50452.	50758.	51063.	51369.	51675.	
32	0.0	10	0.0	40562.	40545.	40539.	40545.	40562.	40590.	40629.	40678.	40737.	40806.
32	0.0	20	0.0	40885.	40974.	41073.	41180.	41297.	41422.	41556.	41698.	41848.	42007.
32	0.0	30	0.0	42173.	42347.	42527.	42716.	42910.	43112.	43320.	43534.	43755.	43981.
32	0.0	40	0.0	44213.	44450.	44693.	44940.	45192.	45449.	45710.	45976.	46245.	46518.
32	0.0	50	0.0	46795.	47074.	47357.	47643.	47932.	48223.	48516.	48811.	49108.	49407.
32	0.0	60	0.0	49707.	50008.	50310.	50613.	50917.	51221.	51525.	51829.	52132.	
33	0.0	10	0.0	40992.	40978.	40975.	40983.	41002.	41033.	41073.	41125.	41186.	41257.
33	0.0	20	0.0	41338.	41429.	41529.	41638.	41756.	41883.	42018.	42162.	42313.	42473.
33	0.0	30	0.0	42640.	42815.	42997.	43185.	43381.	43583.	43792.	44007.	44228.	44454.
33	0.0	40	0.0	44686.	44924.	45166.	45414.	45666.	45923.	46184.	46449.	46717.	46990.
33	0.0	50	0.0	47266.	47545.	47827.	48112.	48400.	48690.	48982.	49276.	49572.	49869.
33	0.0	60	0.0	50168.	50467.	50768.	51070.	51371.	51673.	51976.	52278.	52579.	
34	0.0	10	0.0	41419.	41407.	41406.	41417.	41438.	41471.	41514.	41567.	41630.	41703.
34	0.0	20	0.0	41786.	41878.	41980.	42091.	42210.	42338.	42475.	42620.	42772.	42933.
34	0.0	30	0.0	43101.	43276.	43459.	43649.	43845.	44048.	44257.	44472.	44693.	44920.
34	0.0	40	0.0	45152.	45390.	45632.	45879.	46131.	46388.	46648.	46913.	47181.	47453.
34	0.0	50	0.0	47728.	48007.	48288.	48572.	48859.	49147.	49438.	49731.	50026.	50322.
34	0.0	60	0.0	50619.	50917.	51216.	51515.	51815.	52116.	52416.	52716.	53015.	
35	0.0	10	0.0	41841.	41832.	41833.	41846.	41870.	41904.	41949.	42004.	42069.	42144.
35	0.0	20	0.0	42229.	42323.	42426.	42538.	42659.	42788.	42926.	43071.	43225.	43386.
35	0.0	30	0.0	43555.	43732.	43915.	44105.	44302.	44505.	44714.	44930.	45151.	45378.

TABLE B.6 Cont'd. Table of polynomial values (adopted polynomial)

35	0.0	40	0.0	45610.	45848.	46090.	46337.	46589.	46845.	47105.	47369.	47636.	47907.
35	0.0	50	0.0	48182.	48459.	48740.	49023.	49308.	49596.	49885.	50177.	50470.	50764.
35	0.0	60	0.0	51059.	51356.	51653.	51951.	52249.	52547.	52845.	53143.	53440.	
36	0.0	10	0.0	42259.	42252	42256.	42271.	42297.	42333.	42380.	42436.	42503.	42580.
36	0.0	20	0.0	42666.	42761.	42865.	42979.	43101.	43231.	43370.	43517.	43671.	43833.
36	0.0	30	0.0	44003.	44180.	44364.	44554.	44751.	44955.	45164.	45380.	45601.	45828.
36	0.0	40	0.0	46060.	46297.	46539.	46786.	47037.	47293.	47552.	47815.	48082.	48353.
36	0.0	50	0.0	48626.	48903.	49182.	49464.	49748.	50034.	50322.	50612.	50903.	51196.
36	0.0	60	0.0	51490.	51784.	52080.	52375.	52671.	52967.	53263.	53558.	53853.	
37	0.0	10	0.0	42673.	42668.	42674.	42691.	42718.	42756.	42805.	42863.	42932.	43010.
37	0.0	20	0.0	43097.	43194.	43299.	43414.	43537.	43668.	43808.	43955.	44111.	44273.
37	0.0	30	0.0	44444.	44621.	44805.	44996.	45193.	45397.	45607.	45822.	46043.	46270.
37	0.0	40	0.0	46502.	46739.	46980.	47227.	47477.	47732.	47991.	48253.	48519.	48788.
37	0.0	50	0.0	49061.	49336.	49614.	49895.	50177.	50462.	50749.	51037.	51327.	51617.
37	0.0	60	0.0	51909.	52202.	52495.	52789.	53082.	53376.	53669.	53962.	54255.	
38	0.0	10	0.0	43082.	43079.	43087.	43105.	43135.	43174.	43224.	43284.	43354.	43433.
38	0.0	20	0.0	43522.	43620.	43727.	43842.	43966.	44098.	44239.	44387.	44543.	44706.
38	0.0	30	0.0	44877.	45054.	45239.	45430.	45627.	45831.	46041.	46256.	46477.	46704.
38	0.0	40	0.0	46935.	47171.	47413.	47658.	47908.	48162.	48420.	48681.	48946.	49214.
38	0.0	50	0.0	49486.	49760.	50036.	50315.	50597.	50880.	51165.	51451.	51739.	52028.
38	0.0	60	0.0	52318.	52608.	52899.	53191.	53482.	53773.	54064.	54354.	54644.	
39	0.0	10	0.0	43485.	43484.	43494.	43514.	43545.	43587.	43638.	43699.	43770.	43851.
39	0.0	20	0.0	43941.	44040.	44147.	44264.	44388.	44521.	44662.	44811.	44968.	45131.
39	0.0	30	0.0	45302.	45480.	45665.	45856.	46054.	46257.	46467.	46682.	46902.	47128.
39	0.0	40	0.0	47359.	47595.	47836.	48080.	48330.	48583.	48839.	49100.	49364.	49631.
39	0.0	50	0.0	49900.	50173.	50448.	50726.	51005.	51287.	51570.	51854.	52140.	52427.
39	0.0	60	0.0	52715.	53003.	53292.	53581.	53870.	54158.	54447.	54734.	55021.	
40	0.0	10	0.0	43884.	43884.	43896.	43918.	43950.	43993.	44046.	44108.	44180.	44262.
40	0.0	20	0.0	44353.	44453.	44561.	44678.	44804.	44937.	45079.	45228.	45385.	45549.
40	0.0	30	0.0	45720.	45898.	46083.	46274.	46471.	46675.	46884.	47099.	47319.	47544.
40	0.0	40	0.0	47775.	48010.	48249.	48493.	48741.	48993.	49249.	49508.	49771.	50037.
40	0.0	50	0.0	50305.	50576.	50850.	51125.	51403.	51683.	51964.	52246.	52530.	52815.
40	0.0	60	0.0	53100.	53386.	53673.	53959.	54245.	54531.	54817.	55102.	55386.	
41	0.0	10	0.0	44276.	44278.	44291.	44315.	44349.	44393.	44447.	44510.	44584.	44666.
41	0.0	20	0.0	44758.	44859.	44968.	45086.	45212.	45346.	45488.	45637.	45794.	45959.
41	0.0	30	0.0	46130.	46308.	46492.	46683.	46880.	47083.	47292.	47506.	47726.	47951.
41	0.0	40	0.0	48180.	48415.	48653.	48896.	49143.	49394.	49649.	49907.	50168.	50432.
41	0.0	50	0.0	50699.	50968.	51240.	51514.	51790.	52068.	52347.	52627.	52909.	53191.
41	0.0	60	0.0	53474.	53758.	54041.	54325.	54609.	54892.	55175.	55456.	55737.	
42	0.0	10	0.0	44663.	44667.	44681.	44706.	44741.	44786.	44841.	44906.	44980.	45064.
42	0.0	20	0.0	45156.	45257.	45367.	45486.	45612.	45746.	45889.	46038.	46196.	46360.
42	0.0	30	0.0	46531.	46709.	46893.	47084.	47280.	47483.	47691.	47905.	48124.	48348.
42	0.0	40	0.0	48577.	48810.	49048.	49289.	49535.	49785.	50038.	50294.	50554.	50817.
42	0.0	50	0.0	51082.	51349.	51619.	51891.	52165.	52441.	52718.	52996.	53275.	53555.
42	0.0	60	0.0	53836.	54116.	54398.	54679.	54959.	55240.	55519.	55798.	56076.	
43	0.0	10	0.0	45044.	45049.	45064.	45090.	45126.	45173.	45229.	45294.	45369.	45454.

TABLE B.6 Cont'd. Table of polynomial values (adopted polynomial)

43	0.0	20	0.0	45547.	45649.	45759.	45878.	46004.	46139.	46281.	46431.	46588.	46752.
43	0.0	30	0.0	46923.	47101.	47285.	47475.	47671.	47873.	48081.	48294.	48512.	48735.
43	0.0	40	0.0	48963.	49195.	49432.	49672.	49917.	50165.	50417.	50671.	50929.	51190.
43	0.0	50	0.0	51454.	51719.	51987.	52257.	52529.	52802.	53077.	53353.	53629.	53907.
43	0.0	60	0.0	54185.	54463.	54741.	55019.	55297.	55574.	55851.	56127.	56401.	
44	0.0	10	0.0	45418.	45424.	45441.	45468.	45505.	45552.	45609.	45675.	45751.	45836.
44	0.0	20	0.0	45930.	46032.	46143.	46262.	46389.	46523.	46666.	46815.	46972.	47136.
44	0.0	30	0.0	47307.	47484.	47668.	47857.	48053.	48254.	48461.	48673.	48890.	49112.
44	0.0	40	0.0	49339.	49570.	49805.	50044.	50287.	50534.	50784.	51037.	51294.	51552.
44	0.0	50	0.0	51814.	52078.	52344.	52611.	52881.	53152.	53424.	53697.	53971.	54246.
44	0.0	60	0.0	54521.	54797.	55072.	55347.	55622.	55896.	56169.	56441.	56712.	
45	0.0	10	0.0	45785.	45792.	45810.	45838.	45876.	45924.	45982.	46049.	46125.	46210.
45	0.0	20	0.0	46304.	46407.	46518.	46637.	46764.	46899.	47041.	47191.	47348.	47511.
45	0.0	30	0.0	47681.	47858.	48041.	48230.	48425.	48625.	48831.	49042.	49258.	49479.
45	0.0	40	0.0	49704.	49934.	50168.	50406.	50647.	50892.	51141.	51392.	51646.	51903.
45	0.0	50	0.0	52163.	52424.	52688.	52953.	53220.	53489.	53758.	54029.	54301.	54572.
45	0.0	60	0.0	54845.	55117.	55389.	55662.	55933.	56204.	56474.	56743.	57010.	
46	0.0	10	0.0	46145.	46153.	46172.	46201.	46240.	46289.	46347.	46415.	46491.	46577.
46	0.0	20	0.0	46671.	46774.	46885.	47004.	47131.	47266.	47408.	47557.	47713.	47877.
46	0.0	30	0.0	48046.	48222.	48405.	48593.	48787.	48986.	49191.	49401.	49616.	49835.
46	0.0	40	0.0	50059.	50288.	50520.	50756.	50996.	51239.	51486.	51735.	51987.	52242.
46	0.0	50	0.0	52499.	52759.	53020.	53283.	53547.	53813.	54080.	54348.	54617.	54886.
46	0.0	60	0.0	55155.	55424.	55694.	55962.	56231.	56498.	56764.	57029.	57293.	
47	0.0	10	0.0	46498.	46507.	46527.	46557.	46596.	46645.	46704.	46772.	46849.	46935.
47	0.0	20	0.0	47029.	47132.	47243.	47362.	47489.	47623.	47765.	47914.	48070.	48232.
47	0.0	30	0.0	48401.	48577.	48758.	48945.	49138.	49337.	49540.	49749.	49963.	50181.
47	0.0	40	0.0	50403.	50630.	50861.	51095.	51333.	51574.	51819.	52066.	52316.	52569.
47	0.0	50	0.0	52824.	53081.	53339.	53600.	53862.	54125.	54389.	54654.	54920.	55186.
47	0.0	60	0.0	55452.	55718.	55984.	56249.	56514.	56778.	57041.	57302.	57562.	
48	0.0	10	0.0	46843.	46853.	46874.	46904.	46944.	46994.	47053.	47121.	47198.	47284.
48	0.0	20	0.0	47379.	47481.	47592.	47711.	47838.	47972.	48113.	48261.	48416.	48578.
48	0.0	30	0.0	48746.	48921.	49101.	49288.	49479.	49677.	49879.	50086.	50298.	50515.
48	0.0	40	0.0	50736.	50961.	51190.	51422.	51658.	51898.	52140.	52385.	52633.	52883.
48	0.0	50	0.0	53136.	53390.	53646.	53904.	54163.	54424.	54685.	54947.	55209.	55472.
48	0.0	60	0.0	55735.	55998.	56260.	56522.	56783.	57043.	57303.	57560.	57816.	
49	0.0	10	0.0	47181.	47192.	47213.	47243.	47284.	47334.	47393.	47461.	47539.	47624.
49	0.0	20	0.0	47719.	47821.	47932.	48051.	48177.	48310.	48451.	48598.	48753.	48914.
49	0.0	30	0.0	49081.	49255.	49434.	49619.	49810.	50005.	50206.	50412.	50623.	50838.
49	0.0	40	0.0	51057.	51280.	51507.	51738.	51972.	52209.	52449.	52692.	52937.	53185.
49	0.0	50	0.0	53435.	53687.	53940.	54195.	54451.	54709.	54967.	55226.	55485.	55745.
49	0.0	60	0.0	56004.	56263.	56522.	56781.	57038.	57294.	57550.	57803.	58055.	
50	0.0	10	0.0	47511.	47522.	47543.	47574.	47615.	47665.	47724.	47793.	47870.	47956.
50	0.0	20	0.0	48050.	48152.	48262.	48380.	48506.	48639.	48779.	48925.	49079.	49239.
50	0.0	30	0.0	49405.	49578.	49756.	49940.	50129.	50323.	50523.	50727.	50936.	51149.
50	0.0	40	0.0	51366.	51587.	51812.	52041.	52272.	52507.	52745.	52986.	53229.	53474.
50	0.0	50	0.0	53721.	53970.	54221.	54473.	54726.	54980.	55235.	55491.	55747.	56003.
50	0.0	60	0.0	56259.	56515.	56770.	57024.	57278.	57530.	57782.	58031.	58279.	

TABLE B.7 SNELLIUS data (serial number, latitude, longitude, total magnetic intensity).

1	43. 9.0	41. 58.7	49440.
2	43. 3.6	32. 36.2	47260.
3	43. 4.8	32. 32.4	47400.
4	43. 2.5	31. 20.1	47232.
5	43. 6.4	23. 9.9	46122.
6	43. 0.0	23. 21.7	46106.
7	43. 9.5	17. 12.2	45438.
8	42. 55.6	17. 14.4	45237.
9	42. 59.2	14. 49.2	45183.
10	43. 0.9	13. 29.1	45153.
11	43. 3.1	9. 26.6	45065.
12	34. 0.0	7. 23.7	41300.
13	33. 59.0	12. 52.0	41300.
14	33. 52.2	16. 49.9	41615.
15	33. 52.2	19. 7.1	41792.
16	33. 52.9	19. 33.3	41795.
17	33. 59.6	26. 11.6	42545.
18	34. 3.7	30. 5.7	43121.
19	34. 4.7	30. 10.1	43127.
20	34. 8.2	36. 31.2	44293.
21	34. 5.5	45. 0.2	46450.
22	34. 23.9	44. 58.0	46461.
23	34. 20.1	46. 14.8	46879.
24	34. 9.8	55. 24.7	49480.
25	34. 11.3	55. 18.2	49490.
26	34. 5.5	61. 13.7	51030.
27	34. 10.9	60. 57.2	51060.
28	34. 6.4	65. 2.6	52110.
29	33. 57.4	65. 2.5	52117.
30	33. 53.2	70. 58.0	53207.
31	33. 49.6	76. 42.4	54320.
32	36. 51.2	75. 30.0	55379.
33	36. 50.4	72. 17.9	54669.
34	36. 38.1	71. 53.0	54659.
35	36. 40.7	65. 18.4	53219.
36	36. 35.9	63. 9.5	52679.
37	36. 46.1	63. 11.3	52860.
38	36. 47.8	54. 59.5	50590.
39	36. 40.5	55. 0.5	50430.
40	37. 3.1	45. 58.9	48070.
41	37. 11.0	43. 49.0	47489.
42	37. 22.4	38. 47.3	46448.
43	37. 29.6	38. 45.5	46440.
44	37. 30.6	37. 15.4	46140.
45	37. 15.4	27. 37.4	44164.
46	37. 35.5	25. 19.6	43900.
47	37. 42.8	25. 37.8	43840.
48	37. 10.1	19. 30.1	43300.
49	37. 14.4	14. 20.9	42830.
50	37. 2.8	14. 25.6	42700.
51	37. 2.5	9. 3.8	42700.
52	37. 12.7	9. 6.2	42700.
53	38. 34.8	9. 26.4	42700.
54	39. 1.6	9. 32.2	43428.
55	39. 58.2	10. 33.6	43680.
56	39. 55.9	10. 32.5	43712.
57	39. 58.5	17. 8.0	44148.
58	40. 2.8	23. 0.3	44932.
59	39. 55.4	22. 45.8	44915.
60	39. 56.5	26. 54.7	45308.
61	39. 57.0	29. 52.4	45012.

62	39. 52.7	35. 58.2	46782.
63	40. 0.5	35. 47.3	46807.
64	40. 6.8	45. 47.6	48195.
65	40. 3.0	46. 54.0	49519.
66	39. 57.2	46. 56.2	49337.
67	40. 2.5	52. 4.0	50310.
68	39. 10.8	69. 22.5	50520.
69	39. 20.8	72. 26.6	51270.
70	40. 6.9	70. 49.5	55880.
71	40. 20.5	62. 36.0	53960.
72	40. 41.5	51. 49.4	51370.
73	45. 43.0	6. 40.8	45916.
74	45. 43.7	6. 40.0	45916.
75	46. 54.5	5. 56.0	46196.
76	46. 53.0	5. 54.1	46196.
77	43. 0.2	50. 3.5	51347.
78	43. 2.7	53. 10.9	52904.
79	43. 8.9	53. 8.0	52304.
80	43. 4.3	57. 55.0	53609.
81	43. 1.2	61. 49.3	54654.
82	50. 15.8	6. 28.2	47330.
83	51. 29.3	8. 48.6	47755.
84	55. 6.9	5. 45.5	48435.
85	55. 18.6	6. 32.6	48590.
86	48. 25.9	5. 12.2	46709.
87	47. 56.8	5. 4.5	46515.
88	45. 55.2	4. 42.5	45705.
89	45. 56.6	6. 5.0	45860.
90	46. 3.0	6. 5.5	45860.
91	46. 6.1	9. 43.8	46067.
92	46. 8.9	19. 10.0	46680.
93	46. 10.1	18. 57.8	46692.
94	45. 59.5	28. 23.5	47768.
95	45. 57.0	32. 18.5	48383.
96	46. 1.0	32. 4.0	48390.
97	46. 5.2	37. 34.7	493[illegible]6.
98	45. 45.2	43. 49.8	50516.
99	44. 37.6	62. 33.4	55360.
100	45. 50.0	56. 5.0	54100.
101	46. 20.6	52. 58.4	53500.
102	47. 24.5	52. 32.0	53654.
103	47. 39.9	52. 31.9	53654.
104	49. 0.0	50. 58.6	53680.
105	49. 0.5	47. 43.7	52896.
106	49. 7.6	41. 33.0	51492.
107	49. 12.0	41. 31.5	51531.
108	48. 51.0	34. 35.8	49815.
109	48. 50.1	34. 16.8	49727.
110	48. 51.4	34. 5.2	49750.
111	48. 45.4	24. 34.6	48188.
112	48. 37.7	24. 28.9	48188.
113	48. 41.5	22. 51.1	47972.
114	48. 55.0	17. 12.5	47194.
115	48. 51.0	17. 12.0	47200.
116	49. 16.8	10. 43.5	47200.
117	50. 3.8	4. 29.9	47200.
118	21. 42.2	58. 17.0	43840.
119	22. 3.4	66. 12.3	45660.
120	21. 55.7	49. 47.7	41750.
121	21. 51.0	56. 39.5	43450.
122	21. 42.0	56. 41.8	43480.
123	21. 42.2	58. 17.0	43804.

124	22. 4.6	42. 18.8	39810.
125	22. 4.5	42. 56.5	39970.
126	22. 7.6	43. 5.8	39970.
127	22. 5.3	50. 2.1	41760.
128	21. 55.1	33. 13.2	37730.
129	21. 59.8	35. 25.3	38100.
130	22. 4.4	35. 36.1	38110.
131	22. 4.6	42. 18.8	39810.
132	27. 53.7	15. 16.8	38566.
133	22. 0.2	17. 7.0	36000.
134	22. 1.4	24. 55.8	36650.
135	22. 3.8	28. 29.2	36970.
136	21. 56.1	28. 41.5	36970.
137	21. 55.1	33. 13.2	37730.
138	36. 13.7	12. 26.0	42490.
140	30. 19.8	14. 30.8	40180.
141	42. 7.2	9. 44.0	44800.
142	36. 13.7	12. 26.0	42490.
143	47. 59.5	5. 35.1	46500.
144	42. 15.2	9. 19.6	44860.
145	22. 3.4	66. 12.3	45660.
146	22. 5.0	68. 53.7	46275.
147	21. 58.8	69. 4.9	46280.
148	21. 25.8	71. 3.5	46280.
149	21. 25.0	71. 1.2	46200.
150	19. 53.4	67. 47.0	44600.
151	18. 32.7	66. 9.1	43675.
152	18. 32.3	66. 10.5	43800.
153	18. 1.6	67. 48.8	43800.
154	12. 11.6	69. 50.4	39750.
155	12. 15.4	69. 14.4	39700.
156	25. 8.2	77. 19.6	49100.
157	25. 14.3	76. 2.8	49100.
158	25. 1.4	70. 23.7	48345.
159	25. 22.3	70. 22.9	48195.
160	25. 18.6	69. 6.7	48030.
161	25. 9.3	65. 13.0	47495.
162	25. 23.7	65. 15.5	47525.
163	25. 16.2	60. 10.8	46190.
164	25. 11.4	57. 22.1	45450.
165	25. 13.5	57. 30.3	45530.
166	24. 59.5	51. 49.1	43850.
167	24. 55.5	49. 20.1	43130.
168	24. 54.0	49. 10.8	43130.
169	24. 55.8	42. 56.0	41255.
170	24. 56.0	39. 30.7	40525.
171	24. 45.5	39. 24.1	40200.
172	24. 57.6	34. 4.7	39435.
173	25. 9.5	27. 0.2	38370.
174	25. 9.4	26. 49.9	38350.
175	25. 10.6	25. 25.6	38225.
176	25. 8.8	19. 49.5	37730.
177	25. 13.8	19. 36.0	37730.
178	25. 9.3	17. 28.3	37540.
179	25. 3.0	15. 2.9	37300.
180	27. 44.6	15. 24.0	38760.
181	28. 28.5	16. 11.7	38860.
182	28. 6.3	15. 22.3	38860.
183	28. 7.2	15. 23.7	38500.
184	28. 0.7	13. 4.7	38860.
185	27. 59.6	13. 5.5	38725.
186	27. 59.7	17. 21.1	39040.

187	28. 9.5	24. 42.8	39585.
188	28. 12.5	24. 36.7	39500.
189	28. 12.5	25. 34.8	39640.
190	28. 8.4	32. 50.3	40753.
191	28. 7.6	37. 31.0	41480.
192	28. 5.0	37. 20.0	41400.
193	28. 2.5	41. 6.0	42465.
194	27. 54.5	49. 3.0	44690.
195	27. 34.4	49. 19.5	44510.
196	27. 56.6	58. 0.5	46900.
197	27. 53.0	65. 50.6	48987.
198	27. 39.4	65. 53.8	48987.
199	27. 58.1	72. 44.8	50204.
200	28. 4.1	72. 34.4	50252.
201	27. 52.3	77. 24.9	51080.
202	27. 52.2	77. 30.9	51010.
203	25. 24.5	76. 8.6	48850.
204	31. 0.2	71. 9.1	51855.
205	31. 1.0	70. 42.8	51900.
206	30. 56.5	62. 47.9	50076.
207	30. 53.3	62. 31.2	49800.
208	32. 23.4	64. 34.5	51280.
209	32. 20.9	64. 32.2	51300.
210	31. 3.3	62. 45.2	50240.
211	31. 4.0	62. 30.1	50000.
212	31. 4.5	55. 9.1	47910.
213	31. 10.8	54. 55.7	49860.
214	31. 2.8	45. 13.4	44979.
215	31. 8.2	45. 10.3	45000.
216	31. 11.4	35. 11.8	42494.
217	30. 44.7	24. 25.7	40700.
218	30. 40.9	23. 3.0	40478.
219	30. 26.7	24. 37.2	40478.
220	31. 0.5	23. 20.5	40718.
221	30. 51.9	23. 6.3	40700.
222	31. 13.0	12. 56.0	40122.
223	31. 13.5	10. 2.9	39944.
224	33. 25.4	8. 37.0	41145.
225	33. 39.8	7. 40.9	41233.

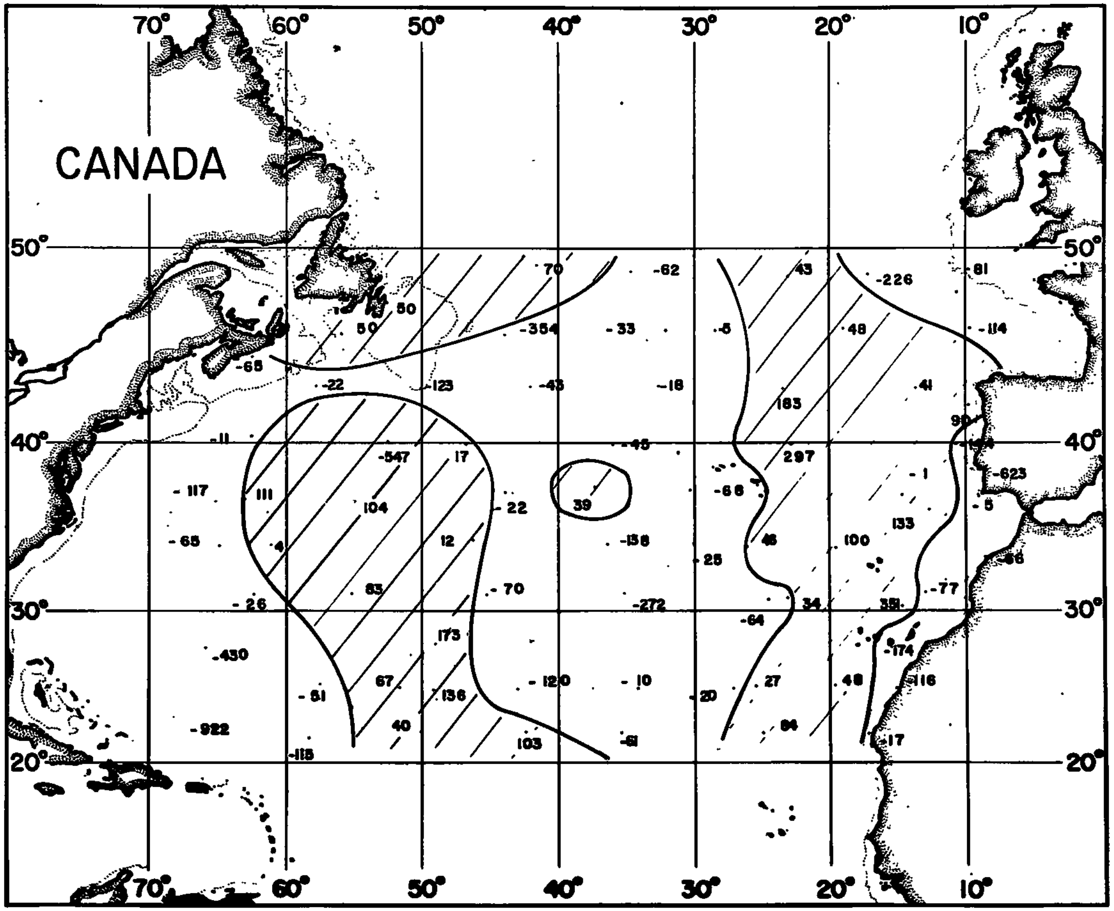

Fig. B.8 SNELLIUS data as anomaly with respect to adopted polynomial (gammas). Zero anomaly contours; selected individual anomalies.

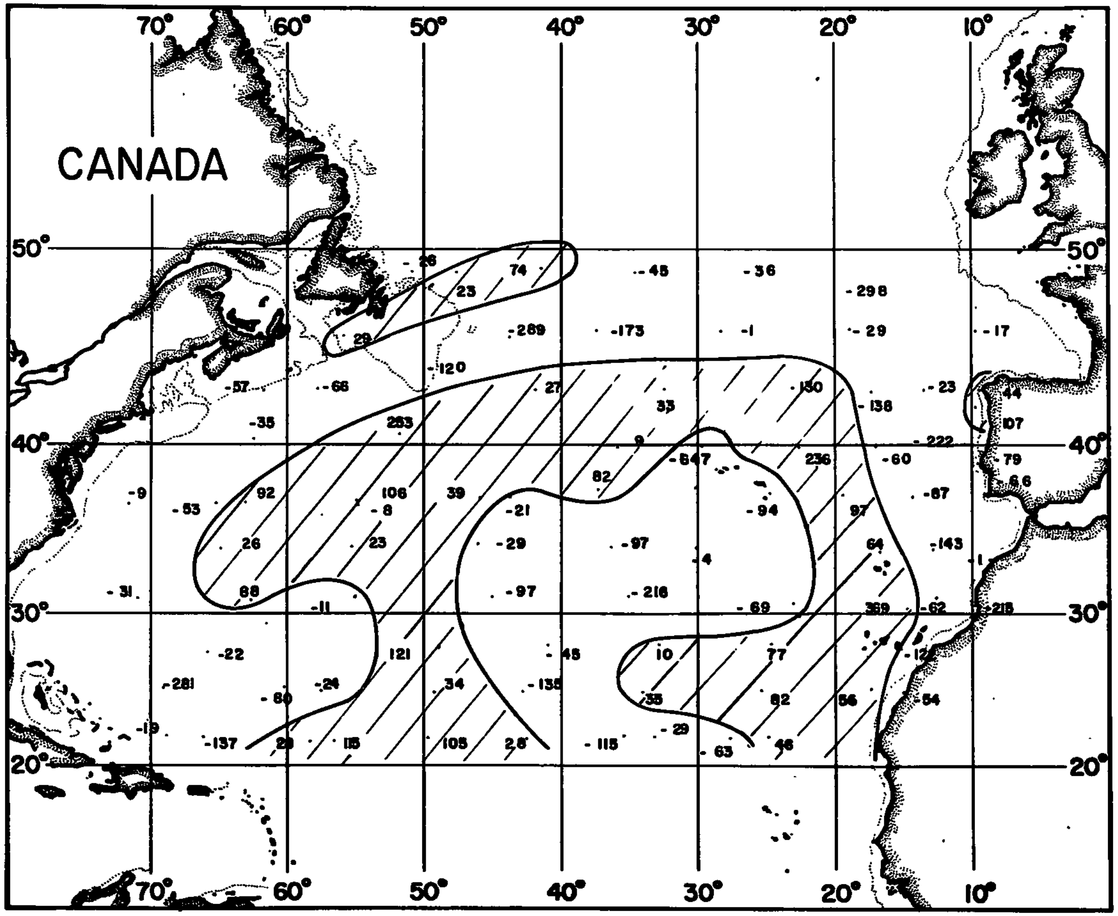

Fig. B.9 SNELLIUS data as anomaly with respect to 4th degree polynomial (gammas). Zero anomaly contours; selected individual anomalies.

COMPUTED COEFFICIENTS

1	0.38725000031+005	1
2	-0.91142003447+003	X
3	-0.23846326675+003	Y
4	0.94974456141+001	XY
5	0.56155674521+002	XX
6	0.31833315699+001	YY
7	-0.17813663653+000	XXY
8	-0.55429186395-002	XYY
9	-0.99520755891+000	XXX
10	0.56282944185-001	YYY
11	0.22215014334-002	XXXY
12	0.99273510867-003	XYYY
13	-0.18174070729-002	XXYY
14	0.60142837340-002	XXXX
15	-0.88692322686-003	YYYY

TABLE B 10. 4TH DEGREE POLYNOMIAL COEFFICIENTS

RUN	NO.OF POINTS	STANDARD ERROR
1	188	340
2	185	140
3	180	101
4	171	87
5	163	77
6	158	72
7	158	72

TABLE B 11. RUNS LEADING TO BEST 4TH DEGREE POLYNOMIAL

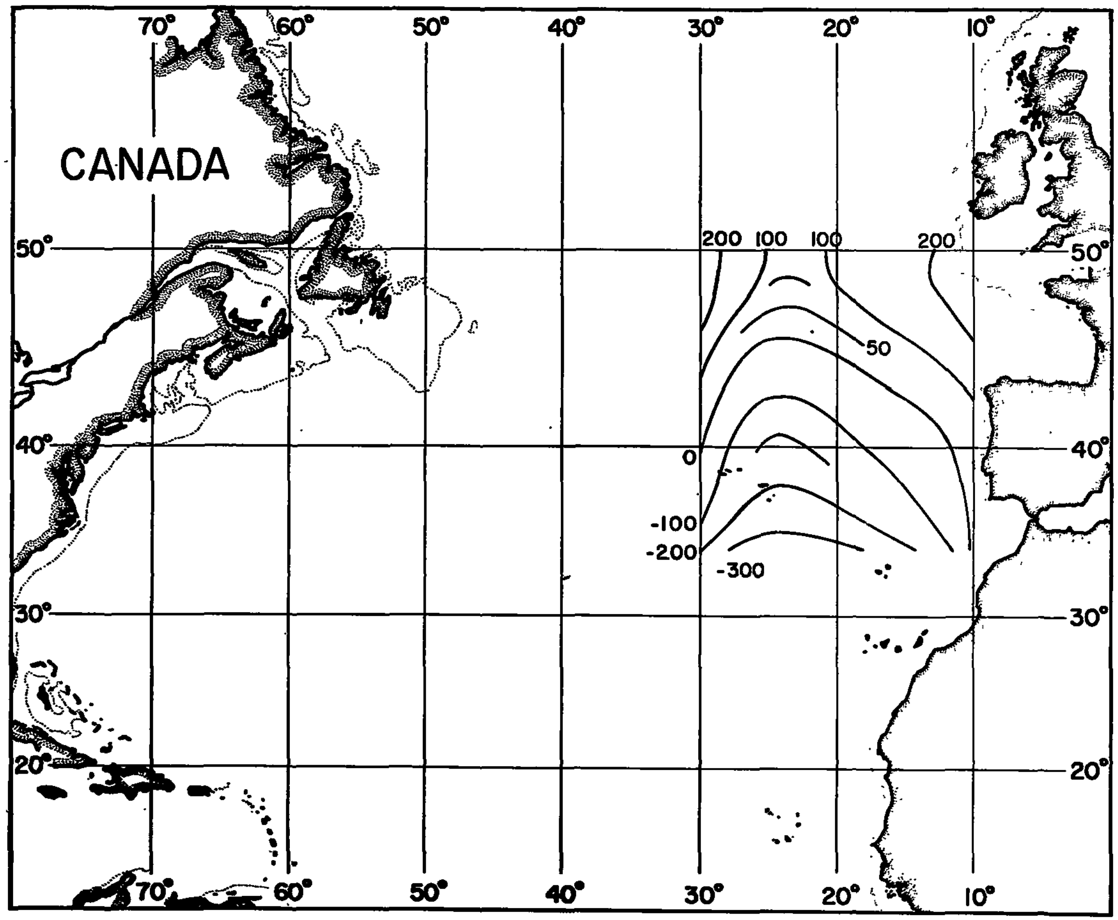

Fig. B.12 Adopted polynomial minus Bullard, Hill, Mason (1962) expression for total magnetic intensity

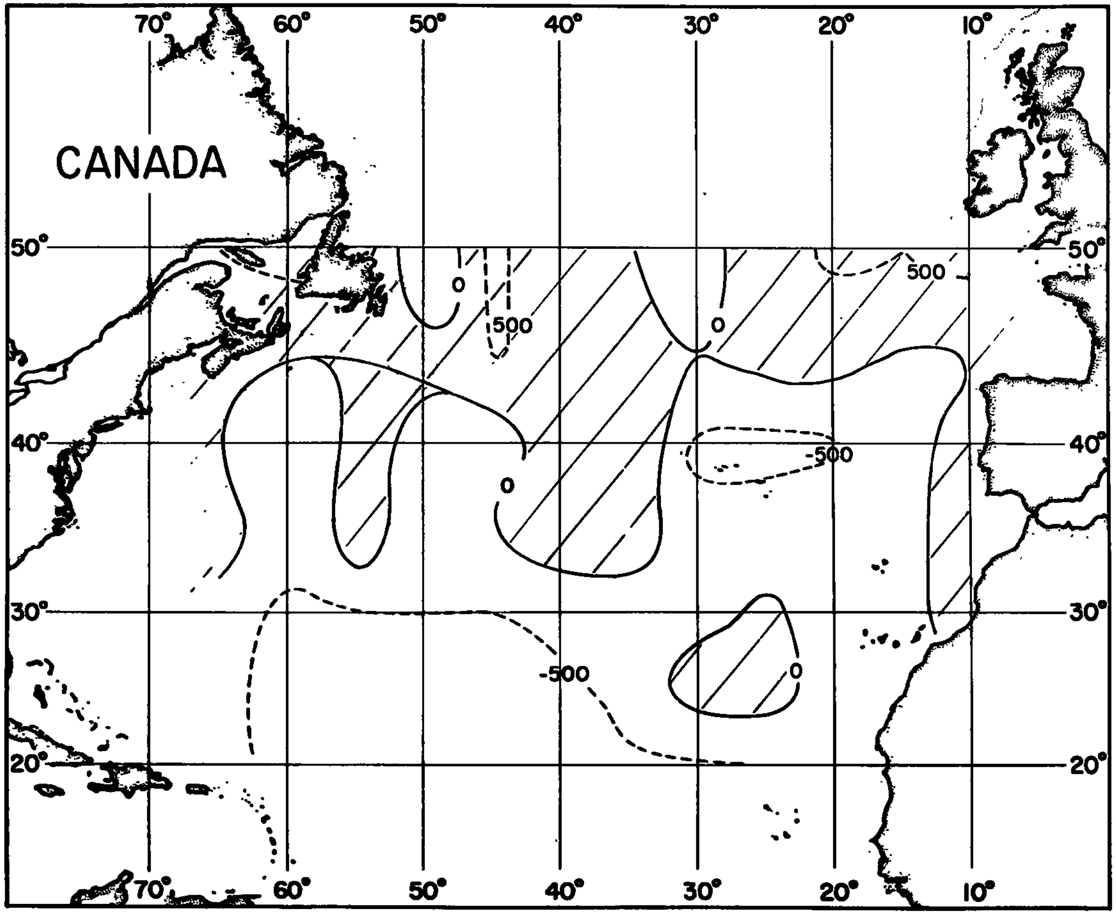

Fig. B.13 Adopted polynomial minus Vestine et al (1947) tabulated values for total magnetic intensity.

C. COMPUTER PROGRAM

C.1. INTRODUCTION

The purpose of program system MIG is to perform least squares fitting of a real function of form $p(x)=\sum_{j=1}^{N} a_j \xi_j(x)$ to a finite number of function values $f(x_i)$, where x, an element of an arbitrary space, is a "position", the ξ are given functions of x, and a_j are real coefficients to be determined. MIG basic system[1] assumes that position points are elements (x,y) of the Euclidean plane. In other words, the fitting function is

$$p(x,y) = \sum_{j=1}^{N} a_j \xi_j(x,y).$$

There are two distinct types of program executions. In "compute"[2] runs[3] the basic task is computation[4] of coefficients a_j and of standard error; in "evaluate" runs, the function $p(x,y)$ is evaluated at given points and the standard error is computed directly. External and internal sense switches are used for detailed flow control.

It is possible to use the results of one run to control rejection of data points in the next run (SW 1); other features are pre-rejection of up to 100 individually selected points (SW 7), and rejection of all points outside a designated rectangular region (SW 8).

The program is written in FORTRAN II for the CDC 3100.

C.2 SYSTEM DESCRIPTION

Central control unit for MIG system is the main program, labelled STARTOFF in program listings. Most distinct phases of problem solution are relegated to specific subroutines. This permits easy removal and replacement of defective subroutines.

---

1. MIG basic system is the version described in this report.
2. The terms "compute" and "evaluate" are descriptive terms referring to the two types of program executions.
3. A run is a segment of program execution consisting of one pass of the original data and all computations pertaining thereto.
4. For details of theory, see A.2.

System Flow chart D.1 gives an overall view of program organization; the name in the top left hand corner of each box is the subroutine name. Details of system structure are shown in section C.8, especially table D.4.

Function subprogram XA1 defines the N functions $\xi_j\ (x,y)$. The basic system contains a XA1 routine which defines as follows:

$$
\begin{aligned}
\xi_1\ (x,y) &= 1 \\
\xi_2\ (x,y) &= x \\
\xi_3\ (x,y) &= y \\
\xi_4\ (x,y) &= xy \\
\xi_5\ (x,y) &= x^2 \\
\xi_6\ (x,y) &= y^2 \\
\xi_7\ (x,y) &= x^2y \\
\xi_8\ (x,y) &= xy^2 \\
\xi_9\ (x,y) &= x^3 \\
\xi_{10}\ (x,y) &= y^3 \\
\xi_{11}\ (x,y) &= x^3y \\
\xi_{12}\ (x,y) &= xy^3 \\
\xi_{13}\ (x,y) &= x^2y^2 \\
\xi_{14}\ (x,y) &= x^4 \\
\xi_{15}\ (x,y) &= y^4
\end{aligned}
$$

That is, $p\ (x,y)$ is a general 1st, 2nd, 3rd or 4th order polynomial in x and y, depending on whether N is 3, 6, 10, or 15.

To use different functions ξ_j, it is sufficient to write a suitable XAI routine and compile it in place of the one in the basic system.

C.3 DATA INPUT

Table D.2 contains information on card input. Note the following:

1) Cards must be entered in the same order as given in table D.2. Some cards are required only with certain switch settings (switch column in table).
2) No cards will be read if switch 4 is on.

3) If T, discard factor, is entered as 0, the program sets it to 2.
4) The card value of N is ignored in "evaluate" runs, i.e. when switch 3 is on. The card must be present, however.
5) Latitude is positive north, longitude positive west. No sign is required for minutes. For example a Y value entered as -103505 is interpreted as 103°50' .5 East Longitude.
6) Tapes for paper tape and magnetic tape input must be in the same format as tapes produced by MIG system with switches 6 and 17 respectively. See section C.5.

C.4 OPERATION

Table D.3 lists program switches and their functions. Note the following:

1) Each run begins with a PAUSE statement located at the beginning of STARTOFF. If console switch 4 is on when this point is reached, the PAUSE is skipped.
2) At the beginning of each run, internal switches 1 to 6 as well as 14 and 17 are cleared (i.e. set to zero or turned off). The other switches are not changed unless a new switch card is input.
3) All switches are set and locked soon after the beginning of execution of a run, immediately prior to listing of the "ON" switches on the printer. Changing console switches after this has no effect, except for switches 2 and 4.
4) For internal switches 1 to 6, the value adopted is the logical OR of the card value and the console value.
5) Switch 2 may be turned on at console at any time during an "evaluate" run.
6) In the basic system, all switch combinations are legal except 4, 17 and 14, 17.

Typical switch sequences are as follows:

1) "compute" sequence. (2), 4, (6), (7),(8);
1, (2), 4, (6), (7), 8); .....; 1, (2), 4, (6), (7), (8);
1, (2), 3, 4, (7), (8).
At each run, all data points whose function values are further from the value of the fitting polynomial than T times the previously computed standard error are discarded. (SW 1).

This procedure is used to discard points clearly in error. The points discarded should be examined, however, since systematic discards might mean inability of the fitting function to follow the observed function over the entire area under consideration. In that case the area considered can be restricted by using switches 7 and 8. The last run in the sequence shown is an evaluate run, useful as a record of the goodness of fit, listing of points discarded, and direct computation of standard error.

2) Resume interrupted "compute" sequence.
1, (2), 4, 5, (6), (7),(8).
The first run in any one job will use switch 17 instead of switch 4, to create the magnetic data tape.

Also note the following points on program operations.

a) Any run inputing the original data from cards should be checked, either by comparison with a previous run or by examining a detailed "evaluate" listing. The card reader may occasionally interpret a data card as a blank card, and there is no other way of detecting this.
b) To reset the "run" counter to 1, STOP MC GO. The machine will stop at the PAUSE in STARTOFF, as it does after any run.
c) Paper tape is peripheral unit 8, magnetic tape unit 4.
d) The following are the main error stops of the system.

MESSAGE	REMEDY AND EFFECT
INTERNAL ERROR	START NEW RUN[1] OR RELOAD PROGRAM
ILLEGAL SWITCH	GO (SW 17 IGNORED) OR START NEW RUN
ZERO DIAG ELT	DO NOT CONTINUE[2]
CARD AFTER NO.__ IS NOT BLANK	GO (LAST CARD READ IGNORED) OR START NEW RUN
N TOO LARGE FOR XAI ROUTINE	GO (XAI = 0) OR MODIFY PROGRAM

1. To start new run, STOP MC GO GO.
2. The coefficient matrix, after row ordering, has a zero diagonal elt. Coefficient matrix singular.

C.5 OUTPUT

Output is on the line printer, the paper tape punch, and on magnetic tape.

1. "Compute" run, printer output: Augmented matrix, reordered matrix, sample roundoff check data (depending on the value of EPS, output cutoff, which is the last item on each such line), computed coefficients a_0 to a_{80} basic information regarding the run, solution check (i.e. substitution in the equations to be solved). Much of this information is omitted if switch 2 is not on.
2. "Compute" run, paper tape output: number of coefficients, number of data points, number of data points used, computed coefficients, standard error.
3. "Evaluate" run, printer output: Each line contains latitude (degrees, minutes and tenths of minutes), longitude, function value input, value of approximating function, anomaly with respect to value of approximating function. Points discarded on input are followed by "DISCARD", except for those lying outside the designated area or otherwise prerejected, which are not listed. Basic information, including the value of the standard error from direct computation, follows listing of the individual points.
4. Magnetic tape: Each record written on magnetic tape contains the same information as a corresponding data input card. Contents of the start deck are not written on magnetic tape.

C.6 RELIABILITY AND ERRORS

1. Gauss-Jordan elimination program. No mathematical error analysis was carried out for this program. Instead, the program was tested for N = 2 up to 10 on the systems of N equations

$$\sum_{j=1}^{N} \frac{a_j}{i+j-1} = \sum_{j=1}^{N} \frac{1}{i+j-1} \qquad (i = 1, \ldots, N)$$

The coefficient matrix for each of these systems is a truncated classical Hilbert matrix. (See Leeson, 1962). As these matrices are known to be ill-conditioned, performance on these systems may be considered a lower bound for the accuracy of results on any system.

N	Maximum Relative Error		Accuracy Signif. Places
2		$< 10^{-11}$	11
3	1.8	10^{-9}	8
4	5.7	10^{-8}	7
5	5.9	10^{-8}	7
6	1.4	10^{-5}	4
7	1.5	10^{-4}	3
8	6.7	10^{-4}	3
9	9.9	10^{-1}	0
10	2.2	10^{1}	0

Up to N = 8, at least 3 significant digit accuracy is maintained. By N = 9, all accuracy is lost.

In actual use of MIG system, the Gauss-Jordan elimination program performed well at N = 10. In the equation-solving process, the 9 most significant digits out of 11 were usually not affected by cumulative roundoff errors, as measured by a check sum column carried during the process. Also, substitution of the solution vector into the system produced agreement to 9 significant digits.

At N = 15 only 3 significant digits were unaffected by cumulative roundoff, whereas substitution still produced agreement to 9 significant digits.

2. Standard error: The standard error obtained in a "compute" run agrees with the directly computed value ("evaluate" run) to at least 3 significant digits even for N = 15.

C.7 MISCELLANEOUS

1. Standard subroutines used. ABSF, SQRTF, LEADER.
2. Storage (approximate Program: $(4670)_8$
   Common $(1260)_8$ (N = 10) or Common $(2330)_8$ (N - 15).
   Total storage for basic system is accordingly about $(7220)_8$ locations.
3. Timing. Program is input and output limited (on CDC 3100 configuration at B.I.O.). Computation times are not significant.

4. D.5 is a complete source deck listing.
   D.6 shows sample output.

C.8 DETAILED STRUCTURAL INFORMATION

Table D.4 shows the relation of the various subroutines to one another and to the main program. The following information should be useful to those wishing to modify the program:

1. The N x(N + 1) - matrix BB is used only for the feature "solution check". Eliminating this feature saves storage space.
2. A different data input format requires a change in the data card read statement in DATAREAD only.
3. A different position space requires a change in DATAREAD as well as, possibly, changes in the statements calling XAI and P, as well as in those two routines themselves.
4. Up to 18 switches are provided in the basic system. Those not used by the basic system may be used for other options.

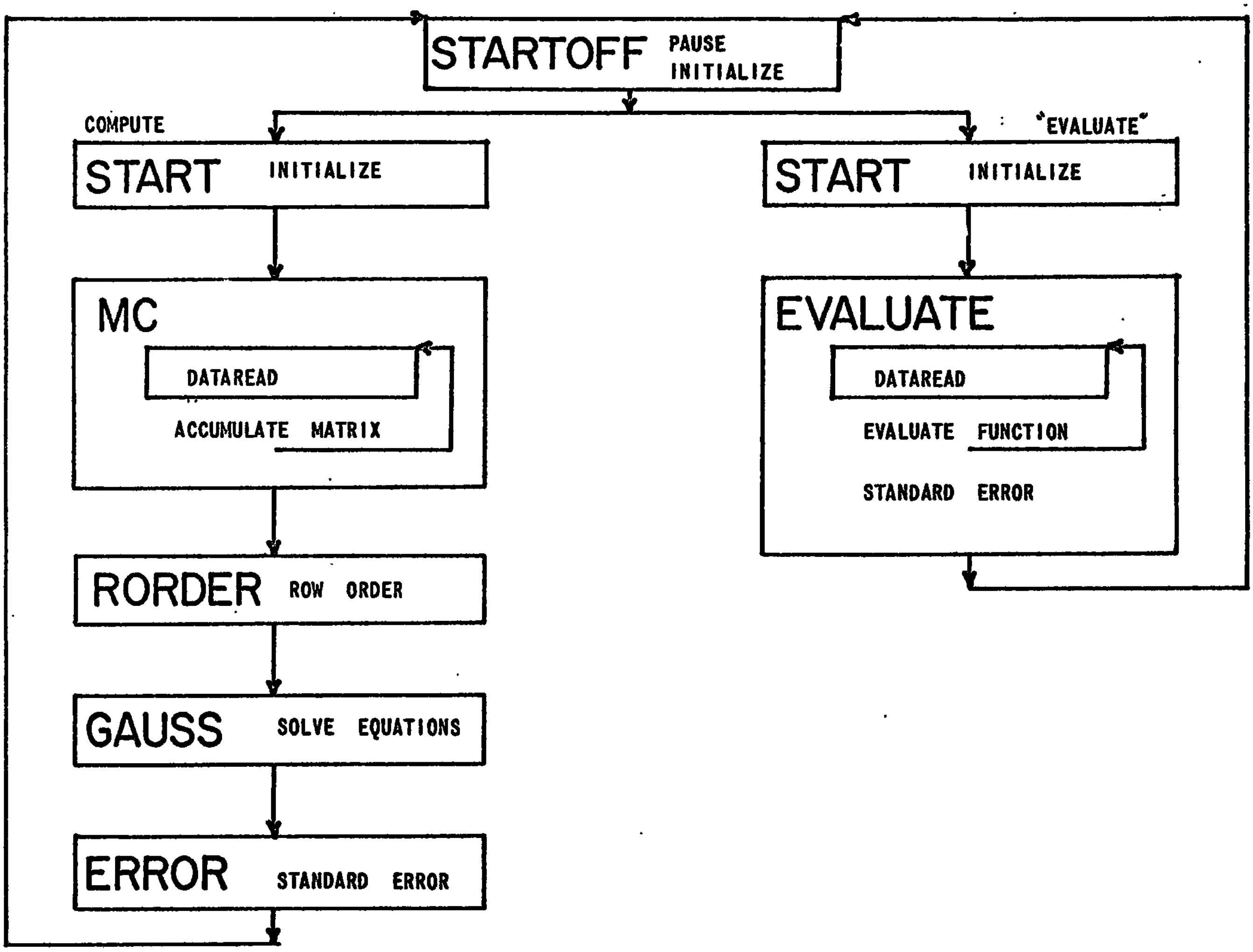

Fig. D.1 System Flow Chart (general).

REPEAT	NAME	MEANING	ON CARD	FRMT	COLS	REQD BY	SW
	-	JOB IDENTIFICATION	JOB.ID.	80H	1-80	STARTOFF	
I 1,18	ISL I	INTERNAL SWITCH NO. I	ISL	I1	I	STARTOFF	
	N	NO. OF COEFFICIENTS	N	I7	1- 7	START	
	NU	NO. OF DATA POINTS	NU	I7	1- 7	START	
	EPS	OUTPUT TOL. FOR ROUNDOFF CHECK	EPS	E11.0	1-11	START	
	T	DISCARD FACTOR	EPS	E11.0	12-22	START	
	NDISC	NO. OF POINTS PREREJECTED	NDISC	I7	1- 7	START	7
I 1,NDISC	IDISC I	DATA PT. NO. IDISC I PREREJECTED	IDISC I	I7	1- 7	START	7
	Z 1,1	LATITUDE LOW LIMIT , DEGREES	Z	F4.0	1- 4	START	8
	Z 1,2	LATITUDE LOW LIMIT , MINUTES	Z	F3.1	5- 7	START	8
	Z 2,1	LATITUDE HIGH LIMIT , DEGREES	Z	F4.0	8-11	START	8
	Z 2,2	LATITUDE HIGH LIMIT , MINUTES	Z	F3.1	12-14	START	8
	Z 3,1	LONGITUDE LOW LIMIT , DEGREES	Z	F4.0	15-18	START	8
	Z 3,2	LONGITUDE LOW LIMIT , MINUTES	Z	F3.1	19-21	START	8
	Z 4,1	LONGITUDE HIGH LIMIT , DEGREES	Z	F4.0	22-25	START	8
	Z 4,2	LONGITUDE HIGH LIMIT , MINUTES	Z	F3.1	26-28	START	8
	-	BLANK CARD TO TERMINATE START DECK	-	-	1-80	ENDTEST	
K 1,NU	XDEG	LATITUDE DEGREES	DATA K	F4.0	1- 4	DATAREAD	
K 1,NU	XMIN	LATITUDE MINUTES	DATA K	F3.1	5- 7	DATAREAD	
K 1,NU	YDEG	LONGITUDE DEGREES	DATA K	F4.0	8-11	DATAREAD	
K 1,NU	YMIN	LONGITUDE MINUTES	DATA K	F3.1	12-14	DATAREAD	
K 1,NU	F	TOTAL MAGNETIC INTENSITY	DATA K	F5.0	15-19	DATAREAD	
	-	BLANK CARD TO TERMINATE DATA DECK	-	-	1-80	ENDTEST	

TABLE D.2 CARD INPUT

TYPE OF RUN	COMPUTE	EVALUATE
TYPE CONTROL	SWITCH 3 OFF	SWITCH 3 ON
SW 1 ON	DISCARD DATA POINTS FOR WHICH $\lvert p(x,y) - f(x,y) \rvert > T \cdot SE$ T PARAMETER INPUT,P LAST DEFINED FITTING FUNCTION,SE LAST COMPUTED VALUE OF STANDARD ERROR. P AND SE AS INPUT IF SW 5 ON	SAME
SW 2 ON	DETAILED OUTPUT	INDIVIDUAL DATA POINTS LISTED
SW 3	TYPE CONTROL /OFF/	TYPE CONTROL /ON/
SW 4 ON	MAG TAPE INPUT ON UNIT 4.NO CARD INPUT SKIP PAUSE AT BEGINNING OF RUN	SAME
SW 5 ON	PAPER TAPE INPUT	SAME
SW 6 ON	PAPER TAPE OUTPUT	NO EFFECT
SW 7 ON	DISCARD PREREJECTED POINTS	SAME
SW 8 ON	DISCARD POINTS OUTSIDE DESIGNATED AREA	SAME
SW 14 ON	READ START CARDS ONLY, THEN TURN SW 4 ON AND PROCEED USING MAG TAPE	SAME
SW 17 ON	WRITE DATA POINTS ONTO MAG TAPE UNIT 4 AS READ IN FROM CARDS	SAME

TABLE D.3 PROGRAM SWITCHES

ROUTINE	DESCRIPTION	CALLS	IS CALLED BY	COMMON USED
STARTOFF	SYSTEM CONTROL	START,MC,RORDER, GAUSS,ERROR, EVALUATE,INTER	-	ISL,N,NN,NNN
START	INITIALIZE DATA INPUT	ENDTEST,INTER	STARTOFF	ISL,N,S,NU,NUU,SE, EPS,T,Z,NDISC,IDISC
MC	MATRIX CONSTRUCT	DATAREAD,ENDTEST INTER,MATPRT,XAI	STARTOFF	ISL,N,NN,B,L,NU,BB,C SFSQ
DATAREAD	READ ONE DATA RECORD	P,INTER	MC,EVALUATE	ISL,N,S,NUU,T,Z,NDIS IDISC
RORDER	ROW ORDER MODIFIED	MATPRT,INTER	STARTOFF	ISL,N,NN,B,L
GAUSS	GAUSS-JORDAN ELIMINATION	-	STARTOFF	ISL,N,NN,NNN,B,L,S, EPS
ERROR	SOLN OUT, ST.ERROR, ETC	BOUT,INTER	STARTOFF	ISL,N,L,S,NU,NUU,BB, C,SFSQ,RESQ,SE
EVALUATE	EVALUATE AT GIVEN PTS	DATAREAD,P,INTER ENDTEST,BOUT	STARTOFF	ISL,N,S,NU,NUU,RESQ, SE
BOUT	BASIC INFORMATION OUTPUT	INTER	ERROR,EVALUATE	ISL,N,NU,NUU,RESQ,SE T,Z,NDISC
ENDTEST	TEST FOR BLANK CARD	INTER	START,EVALUATE	ISL
MATPRT	MATRIX PRINT	-	MC,RORDER	-
P	FUNCTION EVALUATION	XAI	DATAREAD,EVALUATE	-
XAI	FORM OF APPROXIM.FUNCTION	-	MC,P	-
INTER	INTERNAL ERROR	-	ALL EXC.LAST 3	-

TABLE D.4 SYSTEM STRUCTURE

Fig. D.5 Program System Listing

```
C     STARTOFF
      COMMON ISL,N,NN,NNN,B,L,S,NU,NUU,BB,C,SFSQ,RESQ,SE,EPS,
     1T,Z,NDISC,IDISC
      DIMENSION ISL(18),B(15,17),L(15),S(15),BB(15,17),C(15),Z(4,2),
     1IDISC(100)
      NRRR=0
      GO TO 917
901   IF(SENSE SWITCH 4)918,917
917   PAUSE
918   CONTINUE
      DO 929 I=1,6
929   ISL(I)=0
      ISL(14)=0
      ISL(17)=0
      NRRR=NRRR+1
      IF(SENSE SWITCH 4)930,909
909   READ 912
912   FORMAT(80H
     1
      READ 902,(ISL(I),I=1,18)
902   FORMAT(18I1)
930   DO 904 I=1,6
      IF(SENSE SWITCH I)903,904
903   ISL(I)=1
904   CONTINUE
      PRINT 912
      PRINT 913,NRRR
913   FORMAT(4H RUNI7//)
      DO 908 I=1,18
      IF(ISL(I))999,908,906
906   PRINT 907,I
907   FORMAT(7H SWITCHI3)
908   CONTINUE
      IF(ISL(3))999,910,950
C     COMPUTE CONTROL
910   CALL START(N)
      NN=N+1
      NNN=NN+1
      CALL MC
      CALL RORDER
      CALL GAUSS
      CALL ERROR
      GO TO 901
C     EVALUATE CONTROL
950   CALL START(NI)
      NN=N+1
      NNN=NN+1
      CALL EVALUATE
      GO TO 901
999   CALL INTER
      END


C     INITIALIZE DATA INPUT
      SUBROUTINE START(NI)
      COMMON ISL,N,NN,NNN,B,L,S,NU,NUU,BB,C,SFSQ,RESQ,SE,EPS,
```

```
      1T,Z,NDISC,IDISC
       DIMENSION ISL(18),B(15,17),L(15),S(15),BB(15,17),C(15),Z(4,2),
      1IDISC(100)
 86    IF(ISL(4))99,1,60
 1     READ 2,NI,NU
 2     FORMAT(I7)
       NUU=NU
       READ 3,EPS,T
 3     FORMAT(2E11.0)
       IF(T)20,4,20
 4     T=2.
 20    IF(ISL(7))99,30,21
 21    READ 22,NDISC
 22    FORMAT(I7)
       DO 23 I=1,NDISC
 23    READ 22,IDISC(I)
 30    IF(ISL(8))99,40,31
 31    READ 32,((Z(I,J),J=1,2),I=1,4)
 32    FORMAT(4(F4.0,F3.1))
       DO 34 I=1,4
       IF(Z(I,1))33,34,34
 33    Z(I,2)=0.-Z(I,2)
 34    Z(I,1)=Z(I,1)+Z(I,2)/60.
 40    GO TO 50
 50    GO TO 60
 60    IF(ISL(5))99,90,61
 61    READ INPUT TAPE 8,62,N
 62    FORMAT(I7)
       READ INPUT TAPE 8,63,(S(I),I=1,N)
 63    FORMAT(E20.11)
       READ INPUT TAPE 8,63,SE
       PRINT 66,(S(I),I=1,N)
 66    FORMAT(/19H COEFFICIENTS INPUT/1(E20.11))
       PRINT 67,SE
 67    FORMAT(21H STANDARD ERROR INPUTE20.11)
 90    CALL ENDTEST(0)
       PRINT 92
 92    FORMAT(11H DATA START)
       IF(ISL(14))99,94,93
 93    ISL(4)=1
 94    IF(ISL(4))99,89,95
 95    IF(ISL(17))99,96,88
 96    REWIND 4
       GO TO 98
 89    IF(ISL(17))99,98,96
 98    NUU=NU
       RETURN
 88    PRINT 87
 87    FORMAT(15H ILLEGAL SWITCH/1H1)
       PAUSE
       GO TO 98
 99    CALL INTER
       END



C      MATRIX CONSTRUCT
       SUBROUTINE MC
       COMMON ISL,N,NN,NNN,B,L,S,NU,NUU,BB,C,SFSQ
```

```
      DIMENSION ISL(18),B(15,17),L(15),S(15),BB(15,17),C(15)
      DO 107 I=1,N
      DO 107 J=1,NN
107   B(I,J)=0.
      SFSQ=0.
      DO 140 K=1,NU
      CALL DATAREAD(K,X,Y,F,XDEG,XMIN,YDEG,YMIN,ID,IE)
      IF(ID)140,140,141
141   CONTINUE
120   DO 111 I=1,N
      DO 110 J=I,N
110   B(I,J)=B(I,J)+XAI(I,X,Y)*XAI(J,X,Y)
111   B(I,NN)=B(I,NN)+F*XAI(I,X,Y)
112   SFSQ=SFSQ+F*F
140   CONTINUE
      DO 113 I=2,N
      II=I-1
      DO 113 J=1,II
113   B(I,J)=B(J,I)
      CALL ENDTEST(NU)
123   PRINT 117
117   FORMAT(12H DATA LOADED)
      DO 125 I=1,N
125   C(I)=B(I,NN)
130   DO 132 I=1,N
      DO 132 J=1,NN
132   BB(I,J)=B(I,J)
150   IF(ISL(2))199,151,118
199   CALL INTER
118   DO 119 I=1,N
119   L(I)=I
      CALL MATPRT(B,L,N,NN)
151   CONTINUE
      RETURN
      END
```

```
C     READ ONE DATA RECORD
      SUBROUTINE DATAREAD(K,X,Y,F,XDEG,XMIN,YDEG,YMIN,ID,IE)
      COMMON ISL,N,NN,NNN,B,L,S,NU,NUU,BB,C,SFSQ,RESQ,SE,EPS,
     1T,Z,NDISC,IDISC
      DIMENSION ISL(18),B(15,17),L(15),S(15),BB(15,17),C(15),Z(4,2),
     1IDISC(100)
      IE=1
      IF(ISL(4))99,1,400
1     READ 2,XDEG,XMIN,YDEG,YMIN,F
2     FORMAT(F4.0,F3.1,F4.0,F3.1,F5.0)
      IF(ISL(17))99,402,403
402   IF(XDEG)3,4,4
3     XMIN=0.-XMIN
4     IF(YDEG)5,6,6
5     YMIN=0.-YMIN
6     X=XDEG+XMIN/60.
      Y=YDEG+YMIN/60.
20    IF(ISL(7))99,30,21
21    DO 22 I=1,NDISC
      IF(K-IDISC(I))22,90,22
22    CONTINUE
```

```
30     IF(ISL(8))99,10,31
31     IF(X-Z(1,1))90,32,32
32     IF(Z(2,1)-X)90,33,33
33     IF(Y-Z(3,1))90,34,34
34     IF(Z(4,1)-Y)90,10,10
10     IF(ISL(1))99,40,11
11     IF(ABSF(F-P(X,Y,N,S))-T*SE)40,40,93
40     GO TO 50
50     GO TO 92
92     ID=1
       GO TO 91
90     IE=0
93     ID=0
       NUU=NUU-1
91     RETURN
99     CALL INTER
400    READ INPUT TAPE 4,404,XDEG,XMIN,YDEG,YMIN,F
       GO TO 402
403    WRITE OUTPUT TAPE 4,404,XDEG,XMIN,YDEG,YMIN,F
       GO TO 402
404    FORMAT(5E20.11)
       END
```

```
C      ROW ORDER MODIFIED
       SUBROUTINE RORDER
       COMMON ISL,N,NN,NNN,B,L
       DIMENSION ISL(18),B(15,17),L(15),IROUS(15),ICOUS(15)
       DO 11 J=1,N
       IROUS(J)=0
11     ICOUS(J)=0
15     IM=0
       JM=0
       BM=.1E307
       DO 50 I=1,N
       IF(IROUS(I)-1)21,50,99
21     DO 60 J=1,N
       IF(ABSF(BM)-ABSF(B(I,J)))60,60,31
31     IM=I
       JM=J
       BM=B(IM,JM)
60     CONTINUE
50     CONTINUE
       BRM=0.
       JRM=0
       DO 90 JJ=1,N
       IF(ICOUS(JJ)-1)70,90,99
70     IF(ABSF(B(IM,JJ))-ABSF(BRM))90,90,80
80     BRM=B(IM,JJ)
       JRM=JJ
90     CONTINUE
       IF(JRM)99,93,91
91     L(JRM)=IM
       ICOUS(JRM)=1
       IROUS(IM)=1
       DO 92 I=1,N
       IF(IROUS(I))99,15,92
92     CONTINUE
```

```
      IF(ISL(2))99,98,97
97    CALL MATPRT(B,L,N,NN)
98    RETURN
93    PRINT 94
94    FORMAT(14H ZERO DIAG ELT)
      DO 95 I=1,N
95    L(I)=I
      CALL MATPRT(B,L,N,NN)
      STOP
99    CALL INTER
      END
```

```
C     GAUSS JORDAN
      SUBROUTINE GAUSS
      COMMON ISL,N,NN,NNN,B,L,S,NU,NUU,BB,C,SFSQ,RESQ,SE,EPS
      DIMENSION ISL(18),B(15,17),L(15),S(15),BB(15,17),C(15)
200   NN=N+1
      DO 260 I=1,N
      B(I,NNN)=0.
      DO 260 J=1,NN
260   B(I,NNN)=B(I,NNN)+B(I,J)
      DO 230 K=1,N
      KK=L(K)
      BKK=B(KK,K)
      DO 201 J=K,NNN
201   B(KK,J)=B(KK,J)/BKK
      DO 204 I=1,N
      II=L(I)
      IF(I-K)202,204,202
202   BIK=B(II,K)
      IA=II
      DO 203 J=K,NNN
203   B(II,J)=B(II,J)-BIK*B(KK,J)
204   CONTINUE
      SUM=0.
      DO 231 J=1,NN
231   SUM=SUM+B(IA,J)
      BIANNN=B(IA,NNN)
      DEL=SUM-BIANNN
      IF(ABSF(DEL)-EPS)230,230,238
238   IF(ISL(2))299,230,233
299   CALL INTER
233   PRINT 234,K,IA,SUM,B(IA,NNN),DEL,EPS
234   FORMAT(1X,2I7,5H SUM=E20.11,10H CHECKSUM=3E20.11)
230   CONTINUE
      DO 280 I=1,N
      II=L(I)
280   S(I)=B(II,NN)
      RETURN
      END
```

```
C     SOLUTION OUTPUT AND VALIDITY
      SUBROUTINE ERROR
      COMMON ISL,N,NN,NNN,B,L,S,NU,NUU,BB,C,SFSQ,RESQ,SE,EPS,
     1T,Z,NDISC,IDISC
      DIMENSION ISL(18),B(15,17),L(15),S(15),BB(15,17),C(15),Z(4,2),
     1IDISC(100)
      PRINT 209
 209  FORMAT(//22H COMPUTED COEFFICIENTS)
      DO 911 I=1,N
 911  PRINT 208,I,S(I)
 208  FORMAT(1X,I7,E20.11)
      RESQ=0.
      DO 205 K=1,N
 205  RESQ=RESQ-S(K)*C(K)
      RESQ=RESQ+SFSQ
      IF(RESQ)220,206,206
 206  SE=SQRTF(RESQ/NUU)
 207  CALL BOUT
 213  IF(ISL(6))299,218,214
 299  CALL INTER
 214  CALL LEADER
      WRITE OUTPUT TAPE 8,215,N,NU,NUU
 215  FORMAT(3I7)
      WRITE OUTPUT TAPE 8,217,(S(I),I=1,N)
      WRITE OUTPUT TAPE 8,217,SE
 217  FORMAT(E20.11)
 218  IF(ISL(2))299,306,300
 220  PRINT 221
 221  FORMAT(30H RESID SUM OF SQUARES NEGATIVE)
      SE=0.
      GO TO 207
 300  PRINT 303
 303  FORMAT(//15H SOLUTION CHECK)
      DO 304 I=1,N
      SUBST=0.
      II=L(I)
      DO 301 J=1,N
 301  SUBST=SUBST+S(J)*BB(II,J)
      DEL=BB(II,NN)-SUBST
 304  PRINT 302,II,BB(II,NN),SUBST,DEL
 302  FORMAT(I7,3E20.11)
 306  PRINT 305
 305  FORMAT(1H1)
      RETURN
      END
```

```
C     EVALUATE AT GIVEN POINTS
      SUBROUTINE EVALUATE
      COMMON ISL,N,NN,NNN,B,L,S,NU,NUU,BB,C,SFSQ,RESQ,SE,EPS
      DIMENSION ISL(18)
      DIMENSION B(15,17),L(15),S(15),BB(15,17),C(15)
      RESQ=0.
      DO 550 K=1,NU
      CALL DATAREAD(K,X,Y,F,XDEG,XMIN,YDEG,YMIN,ID,IE)
 508  PL=P(X,Y,N,S)
      FP=F-PL
```

```
      IF(IE)536,536,534
534   IF(ISL(2))599,535,509
535   IF(SENSE SWITCH 2)509,536
536   IF(ID)599,537,511
599   CALL INTER
509   IF(ID)530,530,540
530   PRINT 531,K,XDEG,XMIN,YDEG,YMIN,F,PL,FP
531   FORMAT(I8,F13.0,F5.1,F10.0,F5.1,2F13.0,F15.0,8H DISCARD)
537   GO TO 550
540   PRINT 541,K,XDEG,XMIN,YDEG,YMIN,F,PL,FP
541   FORMAT(I8,F13.0,F5.1,F10.0,F5.1,2F13.0,F15.0)
511   RESQ=RESQ+(PL-F)*(PL-F)
550   CONTINUE
      CALL ENDTEST(NU)
512   IF(RESQ)517,513,513
513   SE=SQRTF(RESQ/NUU)
514   CALL BOUT
      PRINT 515
515   FORMAT(1H1)
      RETURN
517   PRINT 518
518   FORMAT(30H RESID SUM OF SQUARES NEGATIVE)
      SE=0.
      GO TO 514
      END



C     BASIC INFORMATION OUTPUT
      SUBROUTINE BOUT
      COMMON ISL,N,NN,NNN,B,L,S,NU,NUU,BB,C,SFSQ,RESQ,SE,EPS,
     1T,Z,NDISC,IDISC
      DIMENSION ISL(18),B(15,17),L(15),S(15),BB(15,17),C(15),Z(4,2),
     1IDISC(100)
      PRINT 2,NU,NUU,N,RESQ,SE
2     FORMAT(18H NO.OF DATA POINTSI7/23H NO.OF DATA POINTS USEDI7/19H NO
     1.OF COEFFICIENTSI7/24H RESIDUAL SUM OF SQUARESE20.11/15H STANDARD
     2ERRORE20.11/)
230   IF(ISL(7))299,213,231
299   CALL INTER
231   PRINT 232,NDISC
232   FORMAT(25H NO.OF POINTS PREREJECTEDI7)
213   IF(ISL(8))299,220,215
215   PRINT 216,(Z(I,1),I=1,4)
216   FORMAT(16H LATITUDE LIMITS2F10.2/17H LONGITUDE LIMITS2F10.2)
220   IF(ISL(1))299,240,221
221   PRINT 222,T
222   FORMAT(22H DEVIATION FACTOR USEDE20.11)
240   RETURN
      END



C     TEST FOR BLANK CARD
      SUBROUTINE ENDTEST(NU)
      COMMON ISL
```

```
      DIMENSION ISL(18)
      DIMENSION IK(16)
      IF(ISL(4))199,119,129
 129  REWIND 4
      GO TO 123
 119  READ 114,(IK(I),I=1,16)
 114  FORMAT(16I5)
      DO 116 I=1,16
      IF(IK(I))115,116,115
 116  CONTINUE
 123  RETURN
 115  PRINT 122,NU
 122  FORMAT(15H CARD AFTER NO.I7,13H IS NOT BLANK/16H TO CONTINUE GO
      PAUSE
      GO TO 123
 199  CALL INTER
      END
```

```
C     MATRIX PRINT
      SUBROUTINE MATPRT(B,L,N,NN)
      DIMENSION B(15,17),L(15)
      PRINT 48
 48   FORMAT(//)
      DO 47 I=1,N
      LL=L(I)
 47   PRINT 44,(B(LL,J),J=1,NN)
 44   FORMAT(6E20.11)
      PRINT 48
      RETURN
      END
```

```
C     FUNCTION EVALUATION SUBROUTINE
      FUNCTION P(X,Y,N,A)
      DIMENSION A(15)
      P=0.
      DO 10 I=1,N
 10   P=P+A(I)*XAI(I,X,Y)
      RETURN
      END
```

```
C     XAI DEFINES FORM OF APPROXIMATING FUNCTION - POLYN 4TH DEG
      FUNCTION XAI(K,X,Y)
      IF(15-K)598,599,599
 599  GO TO(601,602,603,604,605,606,607,608,609,610,611,612,613,
     1614,615),K
 600  RETURN
 601  XAI=1.
```

```
      GO TO 600
602   XAI=X
      GO TO 600
603   XAI=Y
      GO TO 600
604   XAI=X*Y
      GO TO 600
605   XAI=X*X
      GO TO 600
606   XAI=Y*Y
      GO TO 600
607   XAI=X*X*Y
      GO TO 600
608   XAI=X*Y*Y
      GO TO 600
609   XAI=X*X*X
      GO TO 600
610   XAI=Y*Y*Y
      GO TO 600
611   XAI=X*X*X*Y
      GO TO 600
612   XAI=X*Y*Y*Y
      GO TO 600
613   XAI=X*X*Y*Y
      GO TO 600
614   XAI=X*X*X*X
      GO TO 600
615   XAI=Y*Y*Y*Y
      GO TO 600
598   PRINT 597
597   FORMAT(28H N TOO LARGE FOR XAI ROUTINE)
      PAUSE
      XAI=0.
      GO TO 600
      END
```

```
C     INTER
      SUBROUTINE INTER
      PRINT 1
1     FORMAT(/32H INTERNAL ERROR.DO NOT CONTINUE./1H1)
      STOP
      RETURN
      END
```

```
C     TABULATE CONTROL
      DIMENSION S(15)
      DIMENSION ISL(18)
701   PAUSE
      READ 702
702   FORMAT(2H  )
      READ 703,(ISL(I),I=1,18)
703   FORMAT(18I1)
      DO 705 I=1,6
      IF(SENSE SWITCH I)704,705
704   ISL(I)=1
705   CONTINUE
      DO 708 I=1,18
      IF(ISL(I))799,708,706
799   CALL INTER
706   PRINT 707,I
707   FORMAT(7H SWITCHI3)
708   CONTINUE
      CALL TABULATE(ISL,N,S)
      GO TO 701
      END



      SUBROUTINE TABULATE(ISL,N,S)
      DIMENSION S(15)
      DIMENSION ISL(18),PL(10)
101   IF(ISL(5))99,200,300
99    CALL INTER
200   IF(N)201,201,400
201   PRINT 202
202   FORMAT(40H SURE YOU DIDNT WANT TO READ PAPER TAPE./23H SET SENSE S
     1W 5 AND GO.)
      PRINT 203
203   FORMAT(1H1)
      PAUSE
      IF(SENSE SWITCH 5)204,101
204   ISL(5)=1
      GO TO 101
300   READ INPUT TAPE 8,301, N,NU,NUU
301   FORMAT(3I7)
      PRINT 302,N,NU,NUU
302   FORMAT(19H NO.OF COEFFICIENTSI7/26H NO.OF POINTS IN DATA DECKI7/
     146H NO.OF POINTS USED WHEN COMPUTING COEFFICIENTSI7)
      READ INPUT TAPE 8,303,(S(I),I=1,N)
303   FORMAT(E20.11)
      READ INPUT TAPE 8,303,SE
      PRINT 304,SE
304   FORMAT(21H STANDARD ERROR INPUTE20.11/)
400   READ 401,XLD,XLM,XHD,XHM,YLD,YLM,YHD,YHM,DXD,DXM,DYD,DYM
401   FORMAT(6(F4.0,F3.1))
      XL=DEC(XLD,XLM)
      XH=DEC(XHD,XHM)
      YL=DEC(YLD,YLM)
      YH=DEC(YHD,YHM)
      DX=DEC(DXD,DXM)
      DY=DEC(DYD,DYM)
      PRINT 402,(S(I),I=1,N)
```

```
402   FORMAT(13H COEFFICIENTS/1(E20.11))
      PRINT 403,XLD,XLM,XHD,XHM,YLD,YLM,YHD,YHM,DXD,DXM,DYD,DYM
403   FORMAT(17H LATITUDE LIMITS 2(F10.0,F5.1)/17H LONGITUDE LIMITS 2(F
     10.0,F5.1)/9H LAT INCRF10.0,F5.1/9H LON INCRF10.0,F5.1/1H1)
      IF(DX)450,404,404
404   IF(DY)450,500,500
500   X=XL
501   Y=YL
508   DO 503 J=1,10
      IF(J-1)513,513,502
513   CALL SEX(X,KXD1,XM1)
      CALL SEX(Y,KYD1,YM1)
502   PL(J)=P(X,Y,N,S)
      Y=Y+DY
      IF(YH-Y)504,503,503
503   CONTINUE
      PRINT 511,KXD1,XM1,KYD1,YM1,(PL(I),I=1,10)
      GO TO 508
504   PRINT 511,KXD1,XM1,KYD1,YM1,(PL(I),I=1,J)
511   FORMAT(2(I6,F5.1),10F9.0)
      PRINT 512
512   FORMAT(/)
      X=X+DX
      IF(XH-X)506,501,501
506   RETURN
450   PRINT 451
451   FORMAT(19H INCREMENT NEGATIVE/1H1)
      GO TO 506
      END
```

```
      FUNCTION DEC(D,RM)
      IF(RM)2,3,3
2     RM=0.-RM
3     DEC=D+RM/60.
      RETURN
      END
```

```
      SUBROUTINE SEX(X,KD,RM)
      KD=X
      RM=ABSF(X-KD)*60.
      IF(RM)2,2,3
2     RM=0.
3     RETURN
      END
```

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RUN 1

Figure D.6 Sample Output

SWITCH 1
SWITCH 2
SWITCH 5
SWITCH 7
SWITCH 8
SWITCH 17

COEFFICIENTS INPUT
0.28951039957+005
0.32223954899+003
-0.32189544542+003
0.73790970468+001
0.36481974612+001
0.31676813753+001
-0.61855694909-001
-0.39629536359-001
-0.49414882278-001
-0.35631342519-001
STANDARD ERROR INPUT 0.74701986996+002
DATA START
DATA LOADED

0.13500000000+003	0.46805283308+004	0.48243649974+004	0.16563897546+006	0.17203609320+006	0.21256729048+006
0.60379958335+007	0.72767696332+007	0.66480372921+007	0.10549966979+008	0.60901340000+007	
0.46805283308+004	0.17203609320+006	0.16563897546+006	0.60379958335+007	0.66480372921+007	0.72767696332+007
0.23178787452+009	0.26387044415+009	0.26770529244+009	0.36084819769+009	0.21521200046+002	
0.48243649974+004	0.16563897546+006	0.21256729048+006	0.72767696332+007	0.60379958335+007	0.10549966979+008
0.26387044415+009	0.36084819770+009	0.23178787452+009	0.56108124178+009	0.22478756243+009	
0.16563897546+006	0.60379958335+007	0.72767696332+007	0.26387044415+009	0.23178787452+009	0.36084819770+009
0.10059593730+011	0.13027203088+011	0.92872660190+010	0.19185092858+011	0.78693957685+010	
0.17203609320+006	0.66480372921+007	0.60379958335+007	0.23178787452+009	0.26770529243+009	0.26387044415+009
0.92872660190+010	0.10059593730+011	0.11142555514+011	0.13027203088+011	0.80416723644+010	
0.21256729048+006	0.72767696332+007	0.10549966979+008	0.36084819770+009	0.26387044415+009	0.56108124178+009
0.13027203088+011	0.19185092857+011	0.10059593730+011	0.31160500787+011	0.10156327179+011	
0.60379958335+007	0.23178787452+009	0.26387044415+009	0.10059593730+011	0.92872660190+010	0.13027203088+011
0.39992924465+012	0.49305987950+012	0.38520516795+012	0.68980541968+012	0.29159998230+012	
0.72767696332+007	0.26387044415+009	0.36084819770+009	0.13027203088+011	0.10059593730+011	0.19185092857+011
0.49305987950+012	0.68980541968+012	0.39992924466+012	0.10653690374+013	0.35415350353+012	
0.66480372921+007	0.26770529244+009	0.23178787452+009	0.92872660190+010	0.11142555514+011	0.10059593730+011
0.38520516795+012	0.39992924466+012	0.47614077986+012	0.49305987950+012	0.31499674066+012	
0.10549966979+008	0.36084819769+009	0.56108124178+009	0.19185092858+011	0.13027203088+011	0.31160500787+011
0.68980541968+012	0.10653690374+013	0.49305987950+012	0.17817598823+013	0.51303697291+012	

0.10549966979+008	0.36084819769+009	0.56108124178+009	0.19185092858+011	0.13027203088+011	0.31160500787+011
0.68980541968+012	0.10653690374+013	0.49305987950+012	0.17817598823+013	0.51303697291+012	
0.66480372921+007	0.26770529244+009	0.23178787452+009	0.92872660190+010	0.11142555514+011	0.10059593730+011
0.38520516795+012	0.39992924466+012	0.47614077986+012	0.49305987950+012	0.31499674066+012	
0.72767696332+007	0.26387044415+009	0.36084819770+009	0.13027203088+011	0.10059593730+011	0.19185092857+011
0.49305987950+012	0.68980541968+012	0.39992924466+012	0.10653690374+013	0.35415350353+012	
0.60379958335+007	0.23178787452+009	0.26387044415+009	0.10059593730+011	0.92872660190+010	0.13027203088+011
0.39992924465+012	0.49305987950+012	0.38520516795+012	0.68980541968+012	0.29159998230+012	

0.17203609320+006	0.66480372921+007	0.60379958335+007	0.23178787452+009	0.26770529243+009	0.26387044415+009
0.92872660190+010	0.10059593730+011	0.11142555514+011	0.13027203083+011	0.80416723644+010	
0.21256729048+006	0.72767696332+007	0.10549966979+008	0.36084819770+009	0.26387044415+009	0.56108124178+009
0.13027203088+011	0.19185092857+011	0.10059593730+011	0.31160500787+011	0.10156327179+011	
0.16563897546+006	0.60379958335+007	0.72767696332+007	0.26387044415+009	0.23178787452+009	0.36084819770+009
0.10059593730+011	0.13027203088+011	0.92872660190+010	0.19185092858+011	0.78693957685+010	
0.48243649974+004	0.16563897546+006	0.21256729048+006	0.72767696332+007	0.60379958335+007	0.10549966979+008
0.26387044415+009	0.36084819770+009	0.23178787452+009	0.56108124178+009	0.22478756243+009	
0.46805283308+004	0.17203609320+006	0.16563897546+006	0.60379958335+007	0.66480372921+007	0.72767696332+007
0.23178787452+009	0.26387044415+009	0.26770529244+009	0.36084819769+009	0.21521200046+009	
0.13500000000+003	0.46805283308+004	0.48243649974+004	0.16563897546+006	0.17203609320+006	0.21256729048+006
0.60379958335+007	0.72767696332+007	0.66480372921+007	0.10549966979+008	0.60901340000+007	

1	1 SUM=	-0.21793836754+008	CHECKSUM=	-0.21793836755+008	0.10375976562-002	0.10000000000-004
2	1 SUM=	-0.20538614896+008	CHECKSUM=	-0.20538614897+008	0.10375976562-002	0.10000000000-004
3	1 SUM=	-0.17484564882+007	CHECKSUM=	-0.17484564893+007	0.11024475098-002	0.10000000000-004
4	1 SUM=	0.11707907175+009	CHECKSUM=	0.11707907205+009	-0.30102539062+000	0.10000000000-004
5	1 SUM=	0.98513477004+006	CHECKSUM=	0.98513476782+006	0.22144317627-002	0.10000000000-004
6	1 SUM=	0.18658712753+007	CHECKSUM=	0.18658712092+007	0.66074371338-001	0.10000000000-004
7	1 SUM=	0.22833753289+006	CHECKSUM=	0.22833753855+006	-0.56533581848-002	0.10000000000-004
8	1 SUM=	-0.18151500310+005	CHECKSUM=	-0.18151503083+005	0.27723903424-002	0.10000000000-004
9	1 SUM=	-0.90110406935+004	CHECKSUM=	-0.90110419724+004	0.12789071606-002	0.10000000000-004

COMPUTED COEFFICIENTS

1	0.28906959477+005
2	0.33466785813+003
3	-0.32767477699+003
4	0.75084788376+001
5	0.31961525104+001
6	0.82395343755+001
7	-0.61987699061-001
8	-0.40946229636-001
9	-0.45056075835-001
10	-0.35179144049-001

NO.OF DATA POINTS 225
NO.OF DATA POINTS USED 135
NO.OF COEFFICIENTS 10
RESIDUAL SUM OF SQUARES 0.70969700000+006
STANDARD ERROR 0.72505274391+002

NO.OF POINTS PREREJECTED 3
LATITUDE LIMITS 20.00 50.00
LONGITUDE LIMITS 8.00 68.00
DEVIATION FACTOR USED 0.20000000000+001

SOLUTION CHECK

10	0.51303697291+012	0.51303697263+012	0.28100000000+003
9	0.31499674066+012	0.31499674046+012	0.20100000000+003
8	0.35415350353+012	0.35415350334+012	0.19300000000+003
7	0.29159998230+012	0.29159998212+012	0.17700000000+003
5	0.80416723644+010	0.80416723593+010	0.51406250000+001
6	0.10156327179+011	0.10156327173+011	0.55312500000+001
4	0.78693957685+010	0.78693957639+010	0.46406250000+001
3	0.22478756243+009	0.22478756229+009	0.13330078125+000
2	0.21521200046+009	0.21521200033+009	0.12939453125+000
1	0.60901340000+007	0.60901339962+007	0.37994384766-002

7 JULY 1966 0900
RUN 2

SWITCH 1
SWITCH 2
SWITCH 3
SWITCH 4
SWITCH 7
SWITCH 8
DATA START

1	43. 9.0	41. 58.7	49440.	49483.	-43.
2	43. 3.6	32. 36.2	47260.	47422.	-162. DISCARD
3	43. 4.8	32. 32.4	47400.	47418.	-18.
4	43. 2.5	31. 20.1	47232.	47178.	54.
5	43. 6.4	23. 9.9	46122.	45939.	183. DISCARD
6	43. 0.0	23. 21.7	46106.	45923.	183. DISCARD
7	43. 9.5	17. 12.2	45438.	45370.	68.
8	42. 55.6	17. 14.4	45237.	45283.	-46.
9	42. 59.2	14. 49.2	45183.	45159.	24.
10	43. 0.9	13. 29.1	45153.	45112.	41.
11	43. 3.1	9. 26.6	45065.	45065.	0.
13	33. 59.0	12. 52.0	41300.	41408.	-108.
14	33. 52.2	16. 49.9	41615.	41500.	115.
15	33. 52.2	19. 7.1	41792.	41655.	137.
16	33. 52.9	19. 33.3	41795.	41695.	100.
17	33. 59.6	26. 11.6	42545.	42499.	46.
18	34. 3.7	30. 5.7	43121.	43146.	-25.
19	34. 4.7	30. 10.1	43127.	43166.	-39.
20	34. 8.2	36. 31.2	44293.	44431.	-138.
21	34. 5.5	45. 0.2	46450.	46431.	19.
22	34. 23.9	44. 58.0	46461.	46562.	-101.
23	34. 20.1	46. 14.8	46879.	46867.	12.
24	34. 9.8	55. 24.7	49480.	49341.	139.
25	34. 11.3	55. 18.2	49490.	49321.	169. DISCARD
26	34. 5.5	61. 13.7	51030.	51026.	4.
27	34. 10.9	60. 57.2	51060.	50983.	77.
28	34. 6.4	65. 2.6	52110.	52175.	-65.
29	33. 57.4	65. 2.5	52117.	52109.	8.
35	36. 40.7	65. 18.4	53219.	53336.	-117.
36	36. 35.9	63. 9.5	52679.	52671.	8.
37	36. 46.1	63. 11.3	52860.	52749.	111.
38	36. 47.8	54. 59.5	50590.	50373.	217. DISCARD
39	36. 40.5	55. 0.5	50430.	50326.	104.
40	37. 3.1	45. 58.9	48070.	48008.	62.
41	37. 11.0	43. 49.0	47489.	47511.	-22.
42	37. 22.4	38. 47.3	46448.	46384.	64.
43	37. 29.6	38. 45.5	46440.	46430.	10.
44	37. 30.6	37. 15.4	46140.	46101.	39.
45	37. 15.4	27. 37.4	44164.	44163.	1.
46	37. 35.5	25. 19.6	43900.	43968.	-68.
47	37. 42.8	25. 37.8	43840.	44063.	-223. DISCARD
48	37. 10.1	19. 30.1	43300.	43124.	176. DISCARD
49	37. 14.4	14. 20.9	42830.	42831.	-1.
50	37. 2.8	14. 25.6	42700.	42753.	-53.
51	37. 2.5	9. 3.8	42700.	42705.	-5.
52	37. 12.7	9. 6.2	42700.	42774.	-74.
53	38. 34.8	9. 26.4	42700.	43323.	-623. DISCARD
54	39. 1.6	9. 32.2	43428.	43501.	-73.
55	39. 58.2	10. 33.6	43680.	43871.	-191. DISCARD

56	39. 55.9	10. 32.5	43712.	43856.	-144.	
57	39. 58.5	17. 8.0	44148.	44107.	41.	
58	40. 2.8	23. 0.3	44932.	44698.	234.	DISCARD
59	39. 55.4	22. 45.8	44915.	44618.	297.	DISCARD
60	39. 56.5	26. 54.7	45308.	45191.	117.	
61	39. 57.0	29. 52.4	45012.	45677.	-665.	DISCARD
62	39. 52.7	35. 58.2	46782.	46827.	-45.	
63	40. 0.5	35. 47.3	46807.	46843.	-36.	
65	40. 3.0	46. 54.0	49519.	49502.	17.	
66	39. 57.2	46. 56.2	49337.	49473.	-136.	
67	40. 2.5	52. 4.0	50310.	50884.	-574.	DISCARD
71	40. 20.5	62. 36.0	53960.	53971.	-11.	
72	40. 41.5	51. 49.4	51370.	51073.	297.	DISCARD
77	43. 0.2	50. 3.5	51347.	51470.	-123.	
78	43. 2.7	53. 10.9	52904.	52323.	581.	DISCARD
79	43. 8.9	53. 8.0	52304.	52347.	-43.	
80	43. 4.3	57. 55.0	53609.	53631.	-22.	
81	43. 1.2	61. 49.3	54654.	54698.	-44.	
91	46. 6.1	9. 43.8	46067.	46181.	-114.	
92	46. 8.9	19. 10.0	46680.	46646.	34.	
93	46. 10.1	18. 57.8	46682.	46634.	48.	
94	45. 59.5	28. 23.5	47768.	47773.	-5.	
95	45. 57.0	32. 18.5	48383.	48444.	-61.	
96	46. 1.0	32. 4.0	48390.	48423.	-33.	
97	46. 5.2	37. 34.7	49306.	49555.	-249.	DISCARD
98	45. 45.2	43. 49.8	50516.	50870.	-354.	DISCARD
99	44. 37.6	62. 33.4	55360.	55425.	-65.	
100	45. 50.0	56. 5.0	54100.	54050.	50.	
101	46. 20.6	52. 58.4	53500.	53386.	114.	
102	47. 24.5	52. 32.0	53654.	53604.	50.	
103	47. 39.9	52. 31.9	53654.	53682.	-28.	
104	49. 0.0	50. 58.6	53680.	53681.	-1.	
105	49. 0.5	47. 43.7	52896.	52873.	23.	
106	49. 7.6	41. 33.0	51492.	51444.	48.	
107	49. 12.0	41. 31.5	51531.	51461.	70.	
108	48. 51.0	34. 35.8	49815.	49877.	-62.	
109	48. 50.1	34. 16.8	49727.	49810.	-83.	
110	48. 51.4	34. 5.2	49750.	49780.	-30.	
111	48. 45.4	24. 34.6	48188.	48171.	17.	
112	48. 37.7	24. 28.9	48188.	48115.	73.	
113	48. 41.5	22. 51.1	47972.	47929.	43.	
114	48. 55.0	17. 12.5	47194.	47449.	-255.	DISCARD
115	48. 51.0	17. 12.0	47200.	47426.	-226.	DISCARD
116	49. 16.8	10. 43.5	47200.	47281.	-81.	
118	21. 42.2	58. 17.0	43840.	43919.	-79.	
119	22. 3.4	66. 12.3	45660.	46582.	-922.	DISCARD
120	21. 55.7	49. 47.7	41750.	41566.	184.	DISCARD
121	21. 51.0	56. 39.5	43450.	43508.	-58.	
122	21. 42.0	56. 41.8	43480.	43437.	43.	
123	21. 42.2	58. 17.0	43804.	43919.	-115.	
124	22. 4.6	42. 18.8	39810.	39707.	103.	
125	22. 4.5	42. 56.5	39970.	39858.	112.	
126	22. 7.6	43. 5.8	39970.	39924.	46.	
127	22. 5.3	50. 2.1	41760.	41720.	-40.	
128	21. 55.1	33. 13.2	37730.	37709.	21.	
129	21. 59.8	35. 25.3	38100.	38161.	-61.	
130	22. 4.4	35. 36.1	38110.	38237.	-127.	
131	22. 4.6	42. 18.8	39810.	39707.	103.	
132	27. 53.7	15. 16.8	38566.	38740.	-174.	DISCARD
133	22. 0.2	17. 7.0	36000.	36017.	-17.	
134	22. 1.4	24. 55.8	36650.	36566.	84.	
135	22. 3.8	28. 29.2	36970.	37028.	-58.	

136	21. 56.1	28. 41.5	36970.	36991.	-21.	
137	21. 55.1	33. 13.2	37730.	37709.	21.	
138	36. 13.7	12. 26.0	42490.	42357.	133.	
140	30. 19.8	14. 30.8	40190.	39829.	351.	DISCARD
141	42. 7.2	9. 44.0	44800.	44710.	90.	
142	36. 13.7	12. 26.0	42490.	42357.	133.	
144	42. 15.2	9. 19.6	44860.	44764.	96.	
145	22. 3.4	66. 12.3	45660.	46582.	-922.	DISCARD
161	25. 9.3	65. 13.0	47495.	47926.	-431.	DISCARD
162	25. 23.7	65. 15.5	47525.	48064.	-539.	DISCARD
163	25. 16.2	60. 10.8	46190.	46421.	-231.	DISCARD
164	25. 11.4	57. 22.1	45450.	45522.	-72.	
165	25. 13.5	57. 30.3	45530.	45581.	-51.	
166	24. 59.5	51. 49.1	43850.	43783.	67.	
167	24. 55.5	49. 20.1	43130.	43050.	80.	
168	24. 54.0	49. 10.8	43130.	42994.	136.	
169	24. 55.8	42. 56.0	41255.	41375.	-120.	
170	24. 56.0	39. 30.7	40525.	40567.	-42.	
171	24. 45.5	39. 24.1	40200.	40451.	-251.	DISCARD
172	24. 57.6	34. 4.7	39435.	39445.	-10.	
173	25. 9.5	27. 0.2	38370.	38390.	-20.	
174	25. 9.4	26. 49.9	38350.	38366.	-16.	
175	25. 10.6	25. 25.6	38225.	38198.	27.	
176	25. 8.8	19. 49.5	37730.	37657.	73.	
177	25. 13.8	19. 36.0	37730.	37682.	48.	
178	25. 9.3	17. 28.3	37540.	37534.	6.	
179	25. 3.0	15. 2.9	37300.	37416.	-116.	
180	27. 44.6	15. 24.0	38760.	38673.	87.	
181	28. 28.5	16. 11.7	38860.	39036.	-176.	DISCARD
182	28. 6.3	15. 22.3	38860.	38839.	21.	
183	28. 7.2	15. 23.7	38500.	38846.	-346.	DISCARD
184	28. 0.7	13. 4.7	38860.	38763.	97.	
185	27. 59.6	13. 5.5	38725.	38754.	-29.	
186	27. 59.7	17. 21.1	39040.	38863.	177.	DISCARD
187	28. 9.5	24. 42.8	39585.	39568.	17.	
188	28. 12.5	24. 36.7	39500.	39580.	-80.	
189	28. 12.5	25. 34.8	39640.	39700.	-60.	
190	28. 8.4	32. 50.3	40753.	40815.	-62.	
191	28. 7.6	37. 31.0	41480.	41755.	-275.	DISCARD
192	28. 5.0	37. 20.0	41400.	41693.	-293.	DISCARD
193	28. 2.5	41. 6.0	42465.	42531.	-66.	
194	27. 54.5	49. 3.0	44690.	44517.	173.	DISCARD
195	27. 34.4	49. 19.5	44510.	44423.	87.	
196	27. 56.6	58. 0.5	46900.	47135.	-235.	DISCARD
197	27. 53.0	65. 50.6	48987.	49513.	-526.	DISCARD
198	27. 39.4	65. 53.8	48987.	49417.	-430.	DISCARD
206	30. 56.5	62. 47.9	50076.	50058.	18.	
207	30. 53.3	62. 31.2	49800.	49948.	-148.	DISCARD
208	32. 23.4	64. 34.5	51280.	51270.	10.	
209	32. 20.9	64. 32.2	51300.	51239.	61.	
210	31. 3.3	62. 45.2	50240.	50098.	142.	
211	31. 4.0	62. 30.1	50000.	50026.	-26.	
212	31. 4.5	55. 9.1	47910.	47827.	83.	
214	31. 2.8	45. 13.4	44979.	45049.	-70.	
215	31. 8.2	45. 10.3	45000.	45079.	-79.	
216	31. 11.4	35. 11.8	42494.	42766.	-272.	DISCARD
217	30. 44.7	24. 25.7	40700.	40764.	-64.	
218	30. 40.9	23. 3.0	40478.	40574.	-96.	
219	30. 26.7	24. 37.2	40478.	40647.	-169.	DISCARD
220	31. 0.5	23. 20.5	40718.	40759.	-41.	
221	30. 51.9	23. 6.3	40700.	40666.	34.	
222	31. 13.0	12. 56.0	40122.	40199.	-77.	

223	31. 13.5	10. 2.9	39944.	40225.	-281. DISCARD
224	33. 25.4	8. 37.0	41145.	41211.	-66.

NO.OF DATA POINTS 225
NO.OF DATA POINTS USED 134
NO.OF COEFFICIENTS 10
RESIDUAL SUM OF SQUARES 0.68767930513+006
STANDARD ERROR 0.71637525870+002

NO.OF POINTS PREREJECTED 3
LATITUDE LIMITS 20.00 50.00
LONGITUDE LIMITS 8.00 68.00
DEVIATION FACTOR USED 0.20000000000+001

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