INSTRUCTIONS FOR THE PRODUCTION OF THE CANADIAN GEOMAGNETIC REFERENCE FIELD

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INTRODUCTION

The Canadian Geomagnetic Reference Field (CGRF) is a combination of the International Geomagnetic Reference Field (IGRF) and a spherical cap harmonic model (SCHM) of the residual field over Canada (i.e., the field after subtraction of the IGRF). The data used in the production of the SCHM are a combination of Canadian Phase 2 aeromagnetic data (Haines, 1983, Fig 3), MAGSAT data, Canadian and American repeat station data, and observatory data from Canada and adjacent regions.

The computer programs used to produce the SCHM which forms part of the CGRF are similar to those published by Haines (1988). However, many modifications have been made to the programs to tailor them to our particular data sets. The procedure also requires several programs which have not been published by Haines, and there are many other practical details which must be taken into account in the course of producing the CGRF.

In this report we will give a step-by-step description of how the CGRF 1990 was produced along with a complete listing of all necessary programs. It is hoped that the detail is sufficient to allow anyone with at least some knowledge of the subject to produce a future model.

Modifications and innovations will undoubtedly be incorporated into the production methodology in the future.

In fact, several possible enhancements, based on current perceived problems, are suggested in the last section of the report. As changes such as these are implemented they should be incorporated in future revisions of this manual.

THE DATA

All data used in the production of the CGRF are contained in one of three files:

[NEWITT.CGRF]MAGSAT.DAT

[NEWITT.CGRF]MAGAIR.DAT

[NEWITT]OBSREP1.DAT

The first file contains decimated MAGSAT data in the region north of 40° latitude. (See Haines, 1985 for a description of the decimation procedure.) A listing of the first few dozen records of the file is shown in Appendix 1.

The parameters listed in each field are as follows:

PASS NUMBER - I5

SEQUENTIAL DAY OF THE YEAR* - I5

HOUR - I5

MINUTE - I5

SECOND - I5

GEOCENTRIC LATITUDE - F10.3

LONGITUDE - F10.3

RADIAL DISTANCE - F10.3

F - F8.1

X - F8.1

Y - F8.1

Z - F8.1

F RESIDUAL RELATIVE TO MGST 4/81-2 MODEL - F8.1

X RESIDUAL RELATIVE TO MGST 4/81-2 MODEL - F8.1

Y RESIDUAL RELATIVE TO MGST 4/81-2 MODEL - F8.1

Z RESIDUAL RELATIVE TO MGST 4/81-2 MODEL - F8.1

F RESIDUAL RELATIVE TO QUADRATIC - F8.1

X RESIDUAL RELATIVE TO QUADRATIC - F8.1

Y RESIDUAL RELATIVE TO QUADRATIC - F8.1

Z RESIDUAL RELATIVE TO QUADRATIC - F8.1

* The year is not contained in the record; when the sequential day of the year is less than 162, the year is 1980; when it is greater than 302, the year is 1979.

The last eight fields contain information which is not used in the production of the CGRF.

The next file contains aeromagnetic data. A sample is shown in Appendix 2. These data are actually average values of all Phase II half-minute values in a cell 127 km by 127 km. (See Haines and Newitt, 1986). This corresponds to a half-inch square on a 1:10000000 scale equal area map sheet. The format for each record is:

I BIN NUMBER - I3

J BIN NUMBER - I3

YEAR - F10.3

MEAN LATITUDE - F10.3

MEAN LONGITUDE - F10.3

DUM (not relavent) - F10.3

DUM (not relavent) - F10.3

MEAN ALTITUDE (KM) - F8.1

STANDARD DEVIATION OF ALTITUDE - F8.1

X - F8.1

STANDARD DEVIATION OF X - F8.1

Y - F8.1

STANDARD DEVIATION OF Y - F8.1

Z - F8.1

STANDARD DEVIATION OF Z - F8.1

NUMBER OF VALUES IN BIN - I5

Neither of these files needs to be altered before producing a new model since the data sets are fixed. However, the third file contains a continually growing data set. This is the file of observatory and repeat station observations since 1960; it is used to update the aeromagnetic and MAGSAT data to the epoch of the model. A sample of the file, showing both observatory and repeat station records is given in Appendix 3. The format of each record is:

STATION NAME - A12

CODE (9 FOR REPEAT STATIONS) - A1, 7X

LATITUDE - F10.3

EAST LONGITUDE - F10.3

YEAR - F10.1

X - F10.1

Y - F10.1

Z - F10.1

New observations must be added to this file before it is used. Since observatories and repeat stations undergo site relocations, care must be taken that the values added to the file have the correct site differences added to them if required. There is no uniformity in how this is done. Sometimes the values have been reduced to the latest location; sometimes to the earliest location. To determine what corrections have actually been added for a particular station, compare the values in the file against the master listings of observatory and repeat station observations.

At the end of OBSREP1.DAT there are values for 16 simulated observatories located in oceanic areas and near the edge of the spherical cap where there are no real data. These values were generated from the DGRF/IGRF. As described in Newitt and Haines (1989), cubic polynomials were fitted to the spherical harmonic coefficients for each degree and order for the period 1960-1985. Values were computed from these smoothed IGRF coefficients. These simulated observatory values only go up to 1985 since, at the time of writing, the IGRF 85 was the latest model. When the IGRF 1990 becomes available, the process should be repeated, so that the simulated values can be generated for 1990. This will mean redoing the least squares fit to the coefficients. This program, called **FITCOEF.FOR** is shown in Appendix 4. The program used to calculate the X, Y and Z values at each location, **SVIGRF.FOR** is shown in Appendix 5. Both programs are found in subdirectory [NEWITT.CGRF]. Throughout this report it will be assumed that this is the default subdirectory for all programs unless otherwise stated.

SECULAR VARIATION MODEL

The first step in producing the CGRF is to produce a model of the secular variation from 1960 to the current epoch. To do this, it is first necessary to create a file of first differences for the data found in OBSREP1.DAT. A first difference is the difference between two consecutive observatory annual means; for repeat station values it is the difference between two values divided by the time interval between them.

A version of program **SVPLOT.FOR**, listed in Appendix 6, is used to compute the first differences. Make certain that the parameter IPLOT is set equal to 0, and that the first GO TO 219 statement has been commented out. The first differences are output onto unit 2 as a binary file with a name such as FIRSTDIFEXT.DAT.

Note that for the 1990 model, an addition was made to the program so that the 1988 first differences at each observatory were repeated up to 1992. This was done to constrain the polynomial fit in that time interval.

There are two more practical points to note about this program. First, it must be linked with Haines' library, **GVHLIB.OLB** found in the [NEWITT] directory (e.g. LINK SVPLOT+[NEWITT]GVHLIB/LIB). Secondly, the program asks for the first and last points to be plotted, input parameter which is important for the programs second function, but which is irrelevant here. Just enter: 1,9999.

Each record on the first difference output file contains the following variables:

STATION NAME

CODE (9 FOR REPEAT STATIONS)

YEAR

GEODETIC LATITUDE

GEODETIC LONGITUDE

ALTITUDE (KM ABOVE SEA LEVEL)

GEOCENTRIC LATITUDE

RADIAL DISTANCE

X DIFFERENCE

Y DIFFERENCE

Z DIFFERENCE

GEOCENTRIC X DIFFERENCE

GEOCENTRIC Z DIFFERENCE

SPHERICAL CAP LATITUDE

SPHERICAL CAP LONGITUDE

SPHERICAL CAP X DIFFERENCE

SPHERICAL CAP Y DIFFERENCE

TIME INTERVAL BETWEEN OBSERVATIONS

Note that the altitudes of the observatories and repeat stations are all assumed to be sea level at the present time. It is planned to revise OBSREP.DAT to include altitudes before the next model is produced. However, from a practical point of view, the error in assuming zero altitude is negligible.

After the file of first differences has been produced, a spherical cap harmonic analysis is performed on the first differences. Program **SCHFIT.FOR**, shown in Appendix 7, is used for this. Note that this program can be compiled, linked (with GVHLIB.OLB) and run using a COM file, **SCHFIT.COM**, also shown in Appendix 7.

It is important to check, and modify if necessary, the following parameters, variables and statements: KINT, the spatial index, was set equal to 7 for the 1990 model. LINT, the temporal index was set equal to 3. ICEN was set equal to 1, and the geodetic values were read off the input file. However, since the spherical cap values are also present on the input file, it is possible to set ICEN equal to 0 and to read the spherical cap first differences instead of the geodetic first differences. This change will probably be made before the next production. TZERO is the epoch of the model divided by the length of the data interval. For example, in 1990, TZERO = 1990/(1990-1960) = 66.3333. This must be modified for future epochs. The parameters FIN and FOUT, which control the level of significance of the coefficients produced by subroutine STEPREG, can also be changed if desired. We have found values of 3.0 to be acceptable. The OPEN and READ statements appropriate for SV data must be chosen and the ones used for main field data must be commented out. (It is planned to modify this, and many other pieces of inelegant programming before the next model is produced.) Likewise, the filename for the output file (unit 3) which contains the model coefficients should be changed to something meaningful. In 1990, the filename was SCHCOEFEXT.K7L3. A sample listing for the 1990 SV model is given in Appendix 8.

To plot the SV model produced by program **SCHFIT**, program **SVPLOT** is run again in its second form, shown in Appendix 9. In this version, IPLOT is set equal to 1, and the statement GO TO 219 has been activated. It is also necessary to change the OPEN statement in subroutine **SCHNEV** so that the filename agrees with the coefficient file previously created.

SVPLOT creates a BUPLOT file which is plotted on the Zeta plotter using the ZRPL command. However, the physical length of a plot of the entire file exceeds the maximum length permitted by the plotter. The file must therefore be plotted in sections. This is done by choosing appropriate point numbers when **SVPLOT** asks for the first and last points to be plotted.

In addition to the plots generated by **SVPLOT**, it is also useful to generate contour plots of XSV, YSV and ZSV at different epochs. To do this, it is first necessary to generate a file of values calculated at regular grid intervals. This is done using a program called **SCHE.FOR**, which is listed in Appendix 10, along with **SCHE.COM**, the COM file which is used to run it. Note that **SCHE.COM** has not been set up to compile and link the program. **SCHE** must be linked with **GVHLIB.OLB**. **SCHE** creates, in free format, an output file for each component for which there is an OPEN statement. For SV data, the parameter IREF should be set equal to 0. The plot boundaries, YN1, YN2 (south, north), XE1, XE2, (west, east) refer to inches on a full size map sheet, where the point 0,0 is referenced to the north pole. DELE and DELN are the increment values in inches. For reduced size maps, which are commonly produced for developing the SV model, an increment of 1.0 is adequate. ICEN should be set equal to 1 to produce a plot in geodetic co-ordinates. TM refers to the epoch of the plot you wish to produce. In the sample listing it is divided by 30, but this will have to be changed to correspond to the divisor used in **SCHFIT** when producing the model. Near the end of the program, the write statements for the components you do not wish plotted should be commented out. In subroutine **SCHNEV**, the filename in the OPEN statement should be changed as appropriate.

The actual contouring is performed by a program called **[NEWITT]CONTOUR.EXE** which was obtained from Alan Jones. (We do not have the FORTRAN code for this.) It is run by a COM file called **CONTOURSV.COM**, shown in Appendix 11. All plotting parameters are defined in this file. The second line contains the name of the output plotting file; the third line contains the name of the input file, created by **SCHE;** the fourth line gives the array size of the input file (width by height). This is calculated by taking the size of the full sized plot, in inches, divided by the increment in inches, plus 1 (e.g. 25/1+1). The fifth line gives the title of the plot; the eight line gives the actual coordinates, in inches, of the full sized plot boundaries. These values correspond to XE1, XE2, YE1, YE2 in **SCHE.FOR**. The ninth and tenth lines give the actual height and width of the plot. The values given in the example correspond to a reduction of 2.85 from a full size map and were chosen to fit a particular odd-ball base map in Newitt's possession. It probably makes sense to choose another more standard 8 by 10 base map, in which case these values will have to be changed. The next three lines give the desired contour values. The second to last line gives the plot height, 10.5" for the Zeta plotter.

UPDATING MAIN FIELD DATA

The file MAGSAT.DAT contains data from 1979 and 1980. MAGAIR.DAT contains data from 1965 to 1976. Before these observations can be used to produce a main field model, they must be updated to the desired epoch of the model. The SV model just produced is used to do this. First, however, the model coefficients must be integrated using program **MAINSV.FOR**, listed in Appendix 12. This program was originally written to merge coefficient files as well as to integrate the coefficients. Since we only use the program to integrate, much of the first half of the program, down to statement 275, is irrelevent and has been bypassed. Between statements 290 and 295, make certain that the divisor (30 for the 1990 model) is changed to the appropriate value. FORMAT 450 might also have to be changed if you increase the order of the model.

Check the header record of the output coefficient file (SVCOEFINT90.K7L3). Make certain that the temporal order (LINT) is one greater than for the original SV model coefficients.

The integrated coefficients are used by program **UPDATE.FOR** to update the data to epoch. There are two versions of the program. The version shown in Appendix 13 is used to update the MAGSAT data; the version shown in Appendix 14 is used to update the aeromagnetic data. In both cases, make certain that YEARUP is set equal to the desired year, and that YRUPDIV and YRDIV are divided by the appropriate time interval. Also check the OPEN statement in SCHNEV to verify that the appropriate coefficient file has been added.

UPDATE must be linked with **GVHLIB.OLB**.

MAIN FIELD MODEL

Although a SCH model can be created directly from the updated main field data, it is better from the numerical point of view first to subtract a reference field and model the residuals. For the 1990 model, the reference field was the IGRF 1985 evaluated at 1990. The subtraction of a reference field is performed using program **RESROT.FOR.** This program also converts geodetic to geocentric coordinates, if necessary, and rotates the geocentric coordinates, along with the magnetic field components, to the spherical cap coordinate system. This eliminates the necessity of doing this in program **SCHFIT**, thus saving time in that program.

RESROT comes in two versions. The version shown in Appendix 15 is used with MAGSAT data. Its input file (MAGSAT.UP7 in 1990) is an output file of **UPDATE.** The output file, MAGSATUP7.RESROT, contains the following parameters:

SPHERICAL CAP LATITUDE - F10.3

SPHERICAL CAP LONGITUDE - F10.3

RADIUS - F10.3

SPHERICAL CAP X RESIDUAL - F10.1

SHPERICAL CAP Y RESIDUAL - F10.1

SPHERICAL CAP Z RESIDUAL - F10.1

EPOCH OF MODEL - F10.1

GEOCENTRIC LATITUDE - F10.3

GEOCENTRIC LONGITUDE - F10.3

UPDATED X - F10.1

UPDATED Y - F10.1

UPDATED Z - F10.1

In subroutine field, you must open the correct coefficient file, IGRF85.GC. This file assumes a spherical earth, which is correct for MAGSAT data whose positions are given in geocentric coordinates.

The program must be linked with **GVHLIB.OLB**

The second version of the program, used for aeromagnetic data, is given in Appendix 16. The output file has the same structure as that for the MAGSAT data except that geodetic, as opposed to geocentric, latitude is given on each record. Note that in FIELD, IGRF85.GD is opened, since the aeromagnetic data are given with geodetic coordinates.

The two output files can now be combined using the VMS copy command to produce a single file:

COPY MAGAIRUP7.RESROT+MAGSATUP7.RESROT MAGDATA90.RESROT7

These data are now used to produce a spherical cap harmonic model of the residual field using the version of **SCHFIT.FOR** shown in Appendix 17. Note that in this version KINT=16 (for the 1990 model). ICEN=0 since the input data have already been converted to spherical cap coordinates, and IREF=0 since the reference field has already been subtracted. The input filename in the OPEN statement will have to be changed as appropriate. The READ statement at 100 differs from that of the SV data. Also, at statement 70, the call to SPHNEWF must be commented out since the data have been rotated, and four identities must be inserted. The filename in the OPEN statement after the call to STEPREG must, of course, be changed. It should be remarked that on the microVax it takes about 30 hours for this program to execute. It is therefore advisable to submit it on a Friday night so that it can run uninterrupted over the weekend.

To produce the final model, the main field SCH coefficients must be merged with the SV coefficients. This is done using program **MERGECO.FOR**, shown in Appendix 18. A partial listing of the final set of coefficients (for 1990) is given in Appendix 19. It may be necessary to manually adjust the temporal order (LINT) on the header record. It should be the same as that of the integrated SV coefficients. This set of coefficients, along with the IGRF coefficients, form the CGRF. The CGRF is used in the Magnetic Information Retrieval Program for answering routine requests. (See the manual by Newitt et al, 1990). The CGRF and appropriate software are also distributed directly to some users. (See the manual by Newitt and Haines, 1990.)

MAIN FIELD CHARTS

Normally, full sized plots of both the residual field components, as derived from the SCH coefficients, and the main field components (the residual field plus the IGRF) are desired. Grid values are derived using **SCHE.FOR** (Appendix 20). This example is for the production of a declination plot. Other components may be obtained by implementing the appropriate OPEN and WRITE statements. There are several differences between this version and the version given in Appendix 10.

First, for a main field chart, IREF is set equal to 1. If a chart of the residual field is wanted, set IREF to 0. A full sized chart cannot be plotted in its entirety on the ZETA plotter. It is necessary to plot it in three overlapping sections. Thus **SCHE** must be run three times with different values of YN1 and YN2. The example shows the set up for plotting the bottom section. The middle and top sections can be plotted by implementing the appropriate statements which have been commenced out. A value of 0.5 for DELE and DELN has been found adequate for most purposes. However, around the pole, were both D and DSV contours come very close together, it will be necessary to replot using a value of 0.25, and possibly 0.1. In this case, don't forget to use the correct values of IIIMAX and JJJMAX.

The program has been set up to plot the main field, but it can also be used to plot secular variation by changing ICHANGE and DELT to the values given in the commented-out statements.

North of the pole, the plotter will have trouble because of the coincidence of the -180° and 180° contour lines. Therefore it will be necessary to replot this region changing all D values to degrees east by instituting the statement:

```
if (d.lt.0.)d=d+360.
```

Don't forget to use the appropriate WRITE statements to go along with the OPEN statements. Also, check that the OPEN statement in subroutine **SCHNEV** attaches the correct file (SCHCOEF.90 for the 1990 model). Subroutine FIELD should be set up to add the same IGRF model that was subtracted by program RESROT. Note that this version of FIELD differs from the version used in RESROT. That version only attached the coefficients for a single IGRF model. This version attaches the entire suite of DGRF/IGRF models from 1945 to 1985 (in this example). If a new IGRF model is used (e.g. IGRF 1990), it will have to be added to the coefficient file in some manner, and various DIMENSION and READ statements will have to be modified in the subroutine.

Various versions of the **CONTOUR** plotting program are used to plot the various components after the grid files have been generated by **SCHE**. Appendix 21 shows **CONTOURB.COM**, which is set up to plot the bottom third of the D chart. By choosing the appropriate group of level values it can also be used to plot any other component, or the secular variation. **CONTOURM.COM** and **CONTOURT.COM** are used to plot the middle and top thirds of the chart respectively.

PROBLEMS AND POSSIBLE MODIFICATIONS

The experience gained through producing three CGRF models has led to the realization that there are problems with the present methodology which need to be resolved before the next model is produced. Two major problems concern the secular variation model. First, although the overall fit of the secular variation model to the first differences is reasonable, about 10 nT/yr, there are areas and time periods in which the error is considerably greater than this. When the model is integrated and used to update the data, unacceptably large updating errors can result. An example of this is evident at Godhavn and is shown in Figure 1. The major problem illustrated here is the inability of the model to fit properly the rapid change in the Z first differences. The effect of this is shown in Table 1; the accumulated SV as given by the CGRF model is compared to the observed SV at the observatory.

TABLE 1 ACCUMULATED SV AT GODHAVN

	OBSERVED			CGRF			ERROR		
	X	Y	Z	X	Y	Z	X	Y	Z
1990	5991	-6110	56169	5750	-5726	55513			
	143	126	-110	148	139	-111	5	13	-1
1985	5848	-6236	56279	5602	-5865	55624			
	295	249	-193	333	256	-194	38	7	-1
1980	5696	-6359	56362	5417	-5982	55707			
	531	332	-222	513	326	-130	-18	-6	92
1975	5460	-6442	56391	5237	-6052	55643			
	700	362	23	668	355	94	-32	-7	71
1970	5291	-6472	56146	5082	-6081	55419			
	785	368	313	786	369	397	1	1	84
1965	5206	-6478	55856	4964	-6095	55116			

Errors of up to 92 nT are present in the Z component. This is considerable given that features in the residual field we are trying to model seldom have amplitudes in excess of 300 nT. The problem is even more serious for satellite data where residual amplitudes are only a dozen or so nT in magnitude. Here the error due to updating is larger than the signal.

One might expect that this problem can be overcome by increasing both the spatial and temporal order (K and L).

Indeed this is the reason we went from KINT=5 to KINT=7 and from LINT=2 to LINT=3 for the 1990 model. However, to increase these parameters further creates extrapolation problems outside the data area and does not create much improvement inside the data area. Furthermore, increasing L creates terrible extrapolation problems near and after the epoch of the model. These problems are evident even at lower orders. To overcome them, we have inserted synthetic observatory values in the oceanic areas, and have repeated observatory data up to 1992. However, these are at best ad hoc remedies, and other solutions should be considered in the future. Haines is currently investigating a method of directly modelling differences between observations rather than modelling an estimate of the secular variation which subsequently has to be integrated. Another possible solution might be to fit Fourier series instead of a polynomial to the temporal variations.

Another problem is evident when we compare a model, derived from aeromagnetic data alone, with a model derived from MAGSAT data alone. The agreement between the two is not good. This is seen by comparing Figure 2 with Figure 3. The former is a plot of the Z residual field derived from a model of aeromagnetic data. The latter is a plot of the Z residual field derived from a model of MAGSAT data. In both cases, the field has been calculated at sea level. Also, in both cases the model was derived from a 10% sample of the data. In addition, there is often little agreement between the anomalies and many known geological features. The Alpha ridge, for example, one of the largest known magnetic features, does not show up distinctly on the aeromagnetic plot.

Some of these discrepancies might be due to the updating problems previously discussed. Others might be due to the fact that in some areas the aeromagnetic bin values are based on very few data; in other words, the weighting isn't equal. (This, however, is quite a complex problem; see Haines and Newitt, 1986). Likewise, there are areas over which the MAGSAT data coverage is quite sparse. In addition, there is the whole question of whether it is legitimate to combine surface and satellite data with equal weighting.

Another problem arises when we consider the fact that the anomalies shown in Figure 2 and 3 are only about 200 nT or 300 nT in magnitude. Are these sufficiently different from the IGRF to make the production of the CGRF worthwhile? Given that crustal anomalies of much greater magnitude exist at shorter wavelengths should we, and can we, show more detail?

To show more detail, we need to go to a higher spatial index. The current K maximum is presently 16. An attempt to go to K = 20, based on a 10% sample, appeared to be unstable, but this might have been due to the low data density. Given that it takes 30 hours to produce a K=16 model on the microVax, it is probably unrealistic to try higher order models on that computer. We should give thought to converting the programs to the Convex or some other more powerful machine so that we can at least try higher order models.

Hand in hand with a higher order is the necessity for denser data coverage. As already mentioned, the aeromagnetic data are averaged in cells of approximately 16000 sq km area. Even in the small sample of data given in Appendix 2 it can be seen that some cells contain as few as two data values. Obviously we can use more data. A large, untapped source is the low-level aeromagnetic data set which is housed within our division. Unfortunately, many of these are unsuitable for our use because of the great amount of undocumented levelling and other adjustments which have been made to them. However, some aeromagnetic data, along with the Hudsom Bay marine magnetic data, and possibly some other marine magnetic data may be suitable. These data could be used to increase the density of data within each cell. It might also be possible to average in smaller cells, thus allowing a higher spatial index. However, all these data are scalar data. The SCHA program at present can handle only vector data. It will have to be modified to handle scalar, and other single component data, as well.

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FIGURE CAPTIONS

1) Plot of first differences of the magnetic field components at Godhavn. X,Y and Z refer to the observed values of the first differences of the X, Y and Z components respectively. The solid lines depict the values computed by the spherical harmonic model of the secular variation field.

2) Z residual field based on a spherical cap harmonic model of a 10% sample of aeromagnetic data. The field is calculated for 1990 at sea level.

3) Z residual field based on a spherical cap harmonic model of a 10% sample of MAGSAT data. The field is calculated from 1990 at sea level.

Figure 1

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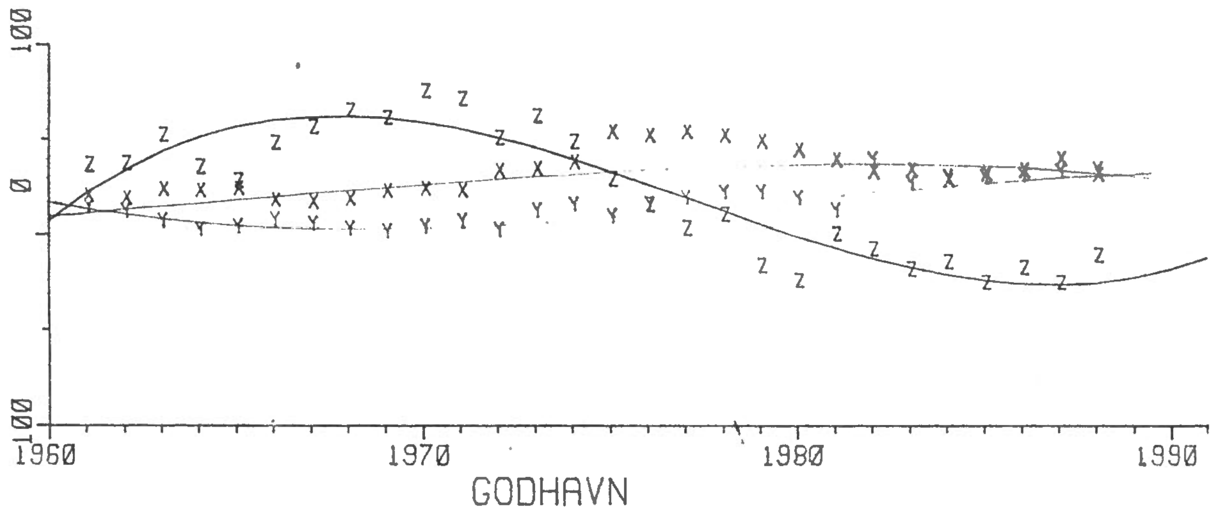

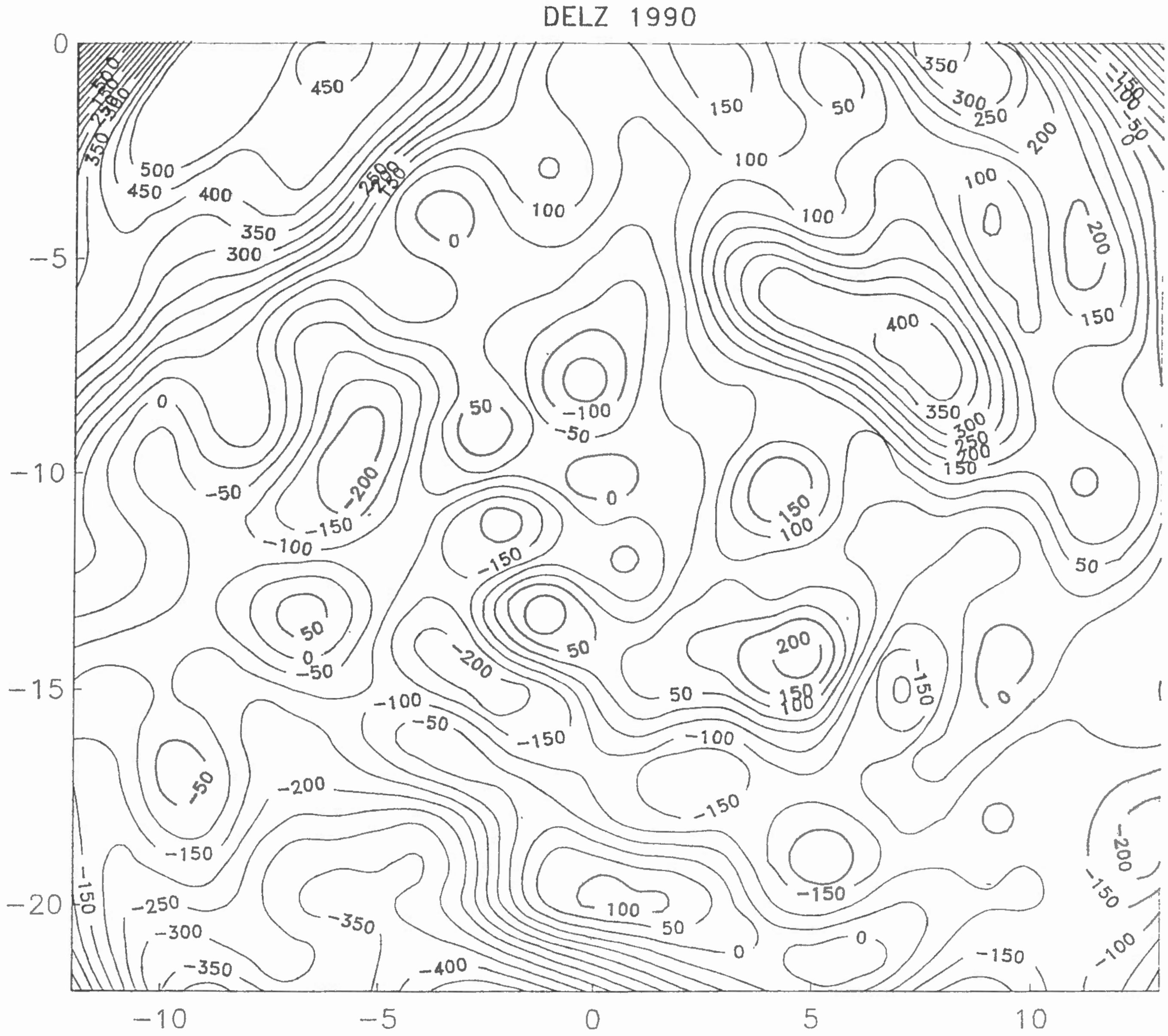

Figure 2

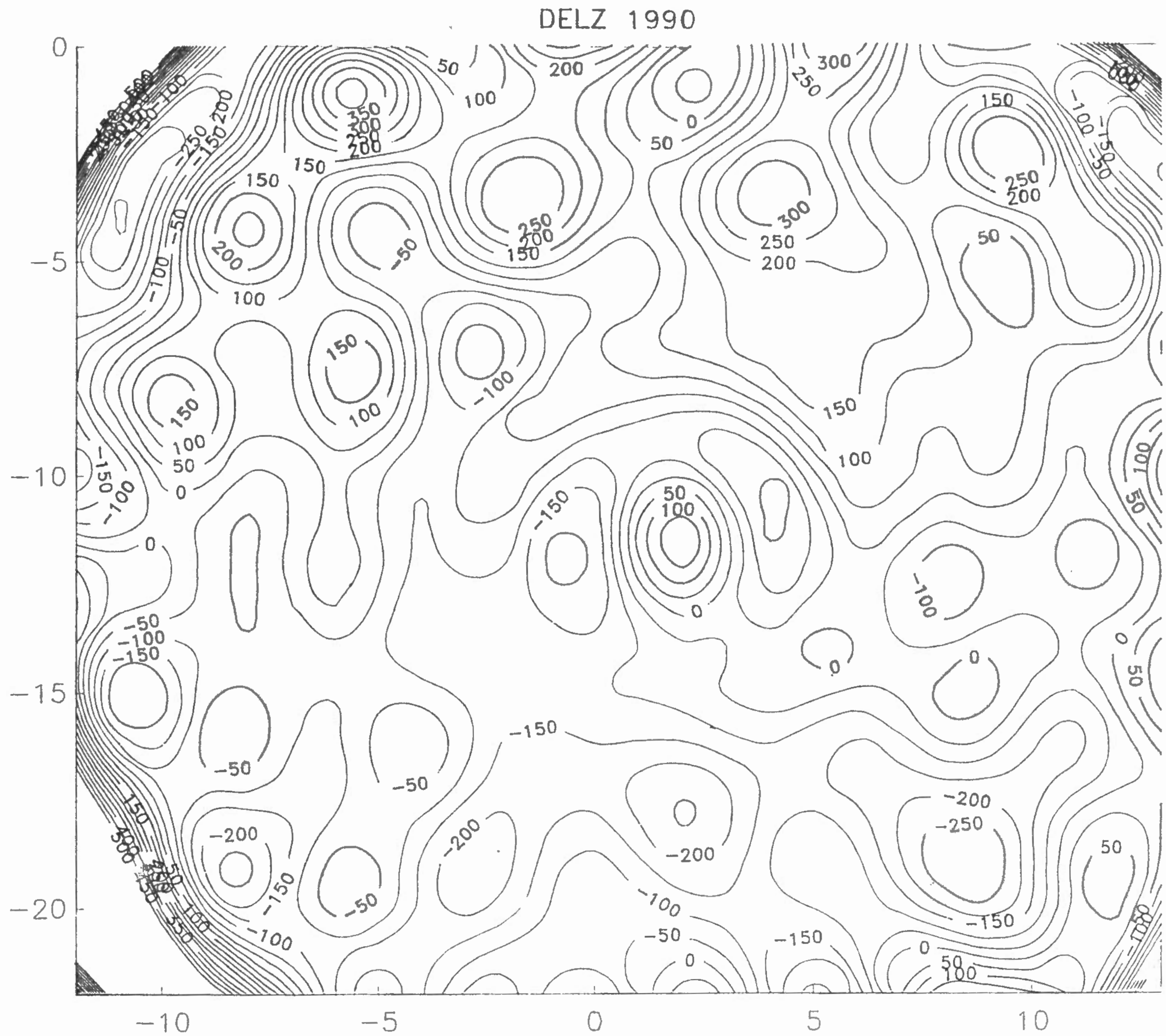

Figure 3

APPENDIX 1

MAGSAT.DAT

17	307	2	20	59	42.282	-132.107	6812.102	41801.4	17285.0	5736.0	37625.6	2.5	-25.8	-5.4
.5	.2	-1.9	3.1	.7										
17	307	2	22	28	47.911	-133.836	6801.254	43976.2	15305.5	5849.6	40809.7	6.0	-24.1	-8.3
16.7	-.4	-2.0	.4	.3										
17	307	2	23	46	52.912	-135.653	6791.902	45579.4	13382.6	5791.1	43183.9	8.9	-26.5	-9.5
18.9	-.7	-5.8	-.8	1.3										
17	307	2	25	20	58.836	-138.338	6781.273	46995.8	11024.1	5469.4	45355.8	15.3	-21.1	-14.0
22.6	2.4	-1.9	-5.5	3.7										
17	307	2	26	58	65.027	-142.210	6770.777	47917.3	8624.1	4814.0	46888.2	21.4	-20.9	-9.2
26.5	5.7	-2.8	-1.2	6.4										
17	307	2	29	1	72.593	-150.241	6758.875	48473.7	6015.8	3541.6	47968.3	14.7	-13.6	-5.0
16.9	-3.5	3.6	2.1	-4.2										
17	307	2	31	58	81.874	174.764	6744.586	49027.1	3108.6	1194.3	48913.9	36.6	-3.6	-3.6
37.0	16.4	13.2	1.4	14.9										
17	307	2	38	11	68.780	67.697	6727.809	48933.0	8043.1	2603.6	48197.1	18.1	-15.9	16.6
20.1	.8	3.8	14.4	-1.6										
17	307	2	40	39	59.418	60.840	6726.719	47260.6	12527.7	2640.0	45493.4	8.5	-16.1	11.1
12.6	-5.1	6.0	5.1	-8.0										
17	307	2	42	22	52.756	57.793	6727.859	45565.8	15728.8	2329.2	42701.5	9.5	-29.9	7.8
20.7	-.5	-5.5	-1.3	1.2										
17	307	2	43	46	47.334	55.855	6729.906	43930.4	18356.0	1986.3	39862.1	15.2	-30.6	13.7
30.1	8.5	-4.1	1.9	11.6										
17	307	2	45	9	41.896	54.214	6732.934	42053.2	20995.1	1607.4	36401.7	-1.5	-27.4	12.3
13.3	-4.4	1.4	-2.3	-4.0										
48	309	2	49	41	43.800	-139.749	6795.898	41383.5	17312.1	5927.9	37118.0	-.3	-17.6	-3.2
8.4	-2.5	-2.2	2.5	-2.1										
48	309	2	50	55	48.509	-141.238	6787.270	43208.0	15801.7	5973.4	39768.8	2.9	-10.3	-6.9
.3	-3.1	5.3	-2.4	-4.5										
48	309	2	52	14	53.527	-143.100	6778.445	44899.7	14028.1	5846.7	42249.3	6.6	-8.0	-8.4
10.8	-3.2	7.7	-5.2	-4.3										
48	309	2	53	57	60.093	-146.211	6767.574	46630.3	11529.5	5345.3	44865.2	19.5	-15.4	-10.3
25.4	5.6	.6	-8.8	7.8										
48	309	2	55	40	66.595	-150.667	6757.672	47771.1	9022.9	4443.0	46700.4	16.2	-15.7	-12.9
20.8	-.9	.5	-13.0	1.1										
48	309	2	57	53	74.690	-161.049	6746.598	48635.7	6004.4	2816.2	48181.3	19.3	-28.4	6.0
22.6	-.7	-11.7	3.8	.9										
48	309	3	1	19	83.199	135.348	6733.695	49390.1	2308.3	669.7	49331.6	12.9	-18.5	21.9
13.5	-8.8	-.9	16.6	-9.6										
48	309	3	8	47	59.932	53.927	6726.480	46505.3	12472.9	2520.8	44730.5	17.2	-23.8	11.3
23.9	3.6	-3.7	-.3	4.5										

APPENDIX 2

MAGAIR.DAT

36	33	1965.800	69.430	-52.557	.000	33.722	4.8	.0	4804.3	110.4	-6144.8	45.2
					54884.1	68.6	12					
37	33	1965.800	69.548	-51.876	.000	33.933	4.8	.0	5207.2	37.0	-6079.7	55.9
					54763.7	24.6	5					
37	34	1965.800	69.823	-49.919	.000	34.501	4.8	.0	5051.2	240.9	-6171.2	27.3
					54495.6	178.8	41					
34	35	1965.800	72.829	-54.772	.000	35.717	4.8	.0	3593.5	86.7	-5725.0	81.0
					55066.0	87.5	22					
36	35	1965.800	71.643	-50.299	.000	35.639	4.6	.0	4597.4	135.8	-6063.0	78.4
					54714.1	67.0	27					
37	35	1965.800	70.186	-46.992	.000	35.328	4.9	.0	5383.3	95.1	-6182.5	108.0
					54229.6	86.5	25					
38	35	1965.800	70.370	-45.168	.000	35.824	4.9	.0	5610.6	69.4	-6233.8	48.2
					54104.6	32.0	13					
34	36	1965.800	73.065	-53.050	.000	36.148	4.8	.0	3680.9	53.6	-5829.8	60.5
					54788.0	36.8	11					
35	36	1965.800	73.315	-50.996	.000	36.644	4.8	.0	3903.4	88.4	-5669.8	102.7
					54659.5	41.9	28					
36	36	1965.800	72.004	-47.067	.000	36.466	4.6	.0	4846.2	151.4	-5995.6	96.0
					54385.4	74.5	37					
37	36	1965.800	72.205	-45.040	.000	36.977	4.6	.0	5029.5	36.1	-6034.9	16.3
					54317.8	19.9	2					
38	36	1965.800	70.576	-42.601	.000	36.499	4.9	.0	5871.7	110.5	-6259.6	109.7
					53599.3	196.0	39					
46	36	1965.800	62.746	-28.680	.000	36.612	3.0	.0	11130.1	114.5	-6140.9	145.6
					50354.3	112.5	43					
47	36	1965.800	62.283	-27.935	.000	36.698	3.0	.0	11437.5	152.8	-6180.1	162.8
					50125.0	228.1	51					
30	37	1965.800	77.230	-66.159	.000	37.755	4.8	.1	1210.3	247.4	-4205.1	140.7
					55944.1	56.5	41					
32	37	1965.800	75.977	-58.499	.000	37.517	4.5	.0	2183.5	163.8	-5025.6	100.8
					55465.3	237.8	40					
33	37	1965.800	74.837	-53.510	.000	37.316	4.6	.0	3147.5	171.1	-5617.7	183.3
					55219.2	61.7	10					
34	37	1965.800	75.008	-51.481	.000	37.720	4.6	.0	3600.8	254.3	-5623.0	109.8
					54787.9	80.5	22					
35	37	1965.800	73.696	-47.306	.000	37.503	4.8	.0	4298.4	95.4	-5699.2	69.7
					54459.1	99.5	41					
37	37	1965.800	72.373	-42.901	.000	37.495	4.6	.0	5222.5	187.1	-5982.8	175.1
					54099.5	231.6	38					
38	37	1965.800	70.730	-40.036	.000	37.156	4.9	.0	6345.4	195.1	-6151.7	19.0
					53303.1	69.0	12					

APPENDIX 3

OBSREP1.DAT

UELEN	66.163	190.165	1970.5	13690.5	3604.4	53549.0
UELEN	66.163	190.165	1971.5	13712.7	3610.3	53530.0
UELEN	66.163	190.165	1972.5	13732.1	3615.3	53525.0
UELEN	66.163	190.165	1973.5	13750.3	3624.4	53530.0
UELEN	66.163	190.165	1974.5	13775.6	3626.8	53535.0
UELEN	66.163	190.165	1975.5	13759.2	3684.6	53512.0
UELEN	66.163	190.165	1976.5	13770.3	3646.8	53525.0
UELEN	66.163	190.165	1977.5	13770.7	3625.5	53530.0
UELEN	66.163	190.165	1978.5	13765.4	3645.6	53530.0
UELEN	66.163	190.165	1979.5	13726.8	3635.3	53540.0
UELEN	66.163	190.165	1980.5	13725.1	3622.1	53530.0
UELEN	66.163	190.165	1981.5	13711.0	3627.0	53522.0
UELEN	66.163	190.165	1982.5	13703.0	3629.0	53520.0
UELEN	66.163	190.165	1983.5	13674.0	3600.0	53530.0
UELEN	66.163	190.165	1984.5	13641.0	3570.0	53500.0
UELEN	66.163	190.165	1985.5	13621.0	3565.0	53480.0
UELEN	66.163	190.165	1986.5	13597.0	3538.0	53480.0
UELEN	66.163	190.165	1987.5	13583.0	3513.0	53480.0
ANCHORAGE NB9	61.235	210.130	1975.4	13937.0	6774.0	54002.0
ANCHORAGE NB9	61.235	210.130	1980.4	13968.0	6693.0	54082.0
ANCHORAGE NB9	61.235	210.130	1983.6	13975.0	6597.0	54035.0
BARTER I IGY9	70.132	216.017	1963.6	7283.7	5136.5	57110.7
BARTER I IGY9	70.132	216.017	1965.6	7347.7	5154.8	57164.6
BARTER I IGY9	70.132	216.017	1975.8	7510.3	5252.9	57240.0
BETHEL AIR2 9	60.783	198.168	1980.6	16074.0	5484.0	51462.0
BETHEL AIR2 9	60.783	198.168	1983.6	16056.0	5416.0	51486.0
CHITINA ALAS9	61.522	215.552	1965.5	12764.6	7020.3	54538.9
CHITINA ALAS9	61.522	215.552	1975.5	12925.8	7082.5	54538.0
CORDOVA 19289	60.547	214.228	1963.5	13677.0	6919.7	54119.3
CORDOVA 19289	60.547	214.228	1965.6	13709.3	6913.1	54102.6
EAGLE FT E A9	64.788	218.792	1963.6	10172.3	6721.0	56311.3
EAGLE FT E A9	64.788	218.792	1966.5	10233.8	6720.2	56324.8
EAGLE FT E A9	64.788	218.792	1971.6	10324.3	6759.0	56340.0
FT YUKON IGY9	66.563	214.740	1963.5	9724.4	5883.5	56165.5
FT YUKON IGY9	66.563	214.740	1965.7	9792.6	5880.9	56186.6
FT YUKON IGY9	66.563	214.740	1975.6	9949.2	5933.2	56270.0
FT YUKON IGY9	66.563	214.740	1980.6	9967.0	5844.0	56308.0
IGRF16	80.000	210.000	1971.0	2693.2	2560.6	57417.9
IGRF16	80.000	210.000	1972.0	2713.1	2566.3	57444.2
IGRF16	80.000	210.000	1973.0	2731.5	2571.1	57469.7
IGRF16	80.000	210.000	1974.0	2748.1	2575.1	57493.8
IGRF16	80.000	210.000	1975.0	2762.9	2577.8	57515.8
IGRF16	80.000	210.000	1976.0	2775.5	2579.3	57535.0
IGRF16	80.000	210.000	1977.0	2785.9	2579.4	57550.9
IGRF16	80.000	210.000	1978.0	2794.0	2577.8	57562.7
IGRF16	80.000	210.000	1979.0	2799.4	2574.4	57569.8
IGRF16	80.000	210.000	1980.0	2802.1	2569.1	57571.5
IGRF16	80.000	210.000	1981.0	2801.9	2561.6	57567.2
IGRF16	80.000	210.000	1982.0	2798.6	2551.9	57556.3
IGRF16	80.000	210.000	1983.0	2792.1	2539.7	57538.0
IGRF16	80.000	210.000	1984.0	2782.1	2524.8	57511.8
IGRF16	80.000	210.000	1985.0	2768.5	2507.1	57476.9

APPENDIX 4

FITCOEF.FOR

```
      PROGRAM FITCOEF
C
C  FITS CUBIC COEFFICIENTS TO IGRF AND DGRF COEFFICIENTS
C
C  PROGRAMMED BY L.R. NEWITT
C
      DIMENSION G(45:85), H(45:85)
      DIMENSION SUMG(4), SUMH(4), SG(4,4), SH(4,4), TG(4), TH(4)
      DIMENSION BOUTG(4), BOUTH(4), SIGG(4), SIGH(4)
      DIMENSION BG(4), BH(4), SBG(4), SBH(4)
      DIMENSION IVARG(4), IVARH(4), ICBLANK(4)
      CHARACTER*40 AID
      IBO=1
      NP1=4
      ITMAX=6
      FIN=3.
      FOUT=3.
      CMBLANK=0
      IPRTS=0
      IPRT1=3
      IPRT2=3
      OPEN(UNIT=1,FILE='IGRF4585.BYYEAR',STATUS='OLD')
      OPEN(UNIT=2,FILE='IGRF6085.CUBIC',STATUS='NEW')
      READ(1,100)J,K,TZ,RE,A,FLAT,AID
      TZERO=1987.5
      WRITE(2,120)J,K,TZERO,RE,A,FLAT
10    READ(1,110,END=900)N,M,G(45),H(45),G(50),H(50),G(55),H(55),
     +G(60),H(60),G(65),H(65),G(70),H(70),G(75),H(75),G(80),H(80),
     &G(85),H(85),GT85,HT85
      IENTER=0
      JENTER=0
      DO 200 I=60,85,5
      TG(1)=I-87.5
      TG(2)=TG(1)*TG(1)
      TG(3)=TG(1)*TG(2)
      TG(4)=G(I)
      CALL SUMPRD(IBO,NP1,NG,TG,SUMG,SG,IENTER)
      IF(M.EQ.0)GO TO 200
      TH(1)=TG(1)
      TH(2)=TG(2)
      TH(3)=TG(3)
      TH(4)=H(I)
      CALL SUMPRD(IBO,NP1,NH,TH,SUMH,SH,JENTER)
200   CONTINUE
      PRINT 140, N,M
      CALL STEPREG(IBO,0,1,NG,NP1,SUMG,SG,FIN,FOUT,ITMAX,
     +BOUTG,SIGG,IVARG,BG,SBG,ICBLANK,IPRTS,IPRT1,IPRT2)
      IF(M.EQ.0)THEN
      BOUTH(1)=0.
      BOUTH(2)=0.
      BOUTH(3)=0.
```

```
      BOUTH(4)=0.
      ELSE
      PRINT 150, N,M
      CALL STEPREG(IBO,0,1,NH,NP1,SUMH,SH,FIN,FOUT,ITMAX,
     +BOUTH,SIGH,IVARH,BH,SBH,ICBLANK,IPRTS,IPRT1,IPRT2)
      ENDIF
      WRITE(2,130)N,M,BOUTG(NP1),BOUTH(NP1),((BOUTG(I),BOUTH(I)),
     +I=1,NP1-1)
C
C  COMPARE INPUT AND MODEL VALUES
C
      PRINT 170
      DO 300 K=60,85,5
      T=K-87.5
      GM=BOUTG(1)*T+BOUTG(2)*T*T+BOUTG(3)*T*T*T+BOUTG(4)
      HM=BOUTH(1)*T+BOUTH(2)*T*T+BOUTH(3)*T*T*T+BOUTH(4)
      GDIF=G(K)-GM
      HDIF=H(K)-HM
300   PRINT 160, G(K),GM,GDIF, H(K),HM,HDIF
      GO TO 10
100   FORMAT(2I1,F8.2,3F10.3,A40)
110   FORMAT(2I5,20F10.1)
120   FORMAT(2I1,F8.2,3F10.3,'  IGRF1960-85, CUBIC FIT')
130   FORMAT(2I4,8F12.4)
140   FORMAT(1H0,'**** G',2I3,' ****')
150   FORMAT(1H0,'**** H',2I3,' ****')
160   FORMAT(1H ,3F12.4,5X,3F10.4)
170   FORMAT(1H0)
900   STOP
      END
      SUBROUTINE STEPREG (IBO,IBLNK,IORD,N,NP1,S,A,FIN,FOUT,ITMAX,BOUT,
     *                    SIG,IVAR,B,SB,ICBLNK,
     *                    IPRTS,IPRT1,IPRT2)

C     STEPWISE REGRESSION, GIVEN SUMS (IF NECESSARY) AND SUMS OF SQUARES
C     AND PRODUCTS.

C     REFERENCES - MATHEMATICAL METHODS FOR DIGITAL COMPUTERS, VOL. 1,
C                  EDITED BY A.RALSTON AND H.WILF.  CHAPTER 17 BY M.A. EFROYMSON
C                - APPLIED REGRESSION ANALYSIS BY N.R. DRAPER AND H. SMITH
C                  SECTIONS 6.4 AND 6.8.

C  INPUT PARAMETERS
C     IBO     = 0 FORCES REGRESSION THROUGH ORIGIN.
C     IBLNK   .LT. 0  ALLOWS PARAMETERS TO BE EXCLUDED FROM REGRESSION.
C     IORD    .NE. 0  PRE-ORDERS REGRESSION.
C     N       =  NUMBER OF OBSERVATIONS.
C     NP1     =  NUMBER OF INDEPENDENT VARIABLES (NP) + 1
C     S       =  MATRIX OF SUMS.  NOT NEEDED IF IBO=0.
C     A       =  MATRIX OF SUMS OF SQUARES AND PRODUCTS.
C                NOTE:  THIS MATRIX IS DESTROYED.
C     FIN     =  F LEVEL FOR ENTERING VARIABLE INTO REGRESSION.
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C      FOUT    =  F LEVEL FOR TAKING VARIABLE OUT OF REGRESSION.
C                 NOTE:  FIN MUST BE .GE. FOUT.
C      ITMAX   =  MAXIMUM NUMBER OF REGRESSION STEPS PERMITTED.
C      ICBLNK  =  BLANKING ARRAY,  INPUT IF IBLNK.LT.0.
C      IPRTS   =  0  TO PRINT NO MATRICES
C                 1  TO PRINT ALL MATRICES
C                -1  TO PRINT ALL MATRICES EXCEPT COVARIANCE MATRICES.
C      IPRT1   =  FIRST STEP NUMBER TO HAVE COEFFICIENTS PRINTED.
C      IPRT2   =  LAST STEP NUMBER TO HAVE COEFFICIENTS PRINTED.
C                 NOTE.  FINAL SET ARE PRINTED REGARDLESS OF IPRT1,IPRT2.
C   OUTPUT PARAMETERS
C      BOUT    =  OUTPUT MATRIX OF REGRESSION COEFFICIENTS.
C      SIG     =  MATRIX OF STANDARD DEVIATIONS.
C      IVAR    =  VARIABLE NUMBER FOR ELEMENTS OF B,SB.
C      B       =  MATRIX OF REGRESSION COEFFICIENTS, IN STEP-WISE ORDER.
C      SB      =  MATRIX OF STANDARD ERRORS OF COEFFICIENTS, IN STEP-WISE ORDER.

       REAL  MSE, MSR
       DIMENSION  S(NP1),BOUT(NP1)
       DIMENSION A(NP1,NP1),SIG(NP1),IVAR(NP1),B(NP1),SB(NP1),ICBLNK(NP1)

       NP = NP1 - 1
       ITN = 0
       IZERO = 0

C      PRINT PARAMETERS
       PRINT 100,  IBO,IBLNK,IORD,N,NP1,FIN,FOUT,ITMAX,IPRTS,IPRT1,IPRT2
  100  FORMAT (20H STEPWISE REGRESSION//
     *         8X,3HIBO, 5X,5HIBLNK, 6X,4HIORD, 9X,1HN, 7X,3HNP1,
     *         7X,3HFIN, 6X,4HFOUT, 5X,5HITMAX, 5X,5HIPRTS,
     *         5X,5HIPRT1, 5X,5HIPRT2/ 1X,5I10,2F10.3,4I10)
       IF (FIN .LT. FOUT)   STOP
       IF (IPRTS .EQ. 0)  GO TO 101
C      PRINT INPUT MATRIX A
       PRINT 115
  115  FORMAT  (//62H0MATRIX OF SUMS OF SQUARES AND PRODUCTS, UNCORRECTED
     *  FOR MEANS)
       DO 110 I=1,NP1
  110  PRINT 116,  (A(I,J),I,J, J=I,NP1)
  116  FORMAT (E17.8,3H A(,I2,1H,,I2,1H),E17.8,3H A(,I2,1H,,I2,1H),
     *         E17.8,3H A(,I2,1H,,I2,1H),E17.8,3H A(,I2,1H,,I2,1H),
     *         E17.8,3H A(,I2,1H,,I2,1H))
  101  CONTINUE
       PRINT 131,  A(NP1,NP1)
  131  FORMAT (43H0TOTAL SUM OF SQUARES, UNCORRECTED FOR MEAN, E29.12)
       PRINT 132,  SQRT(A(NP1,NP1)/N)
  132  FORMAT (41H0STANDARD DEVIATION, UNCORRECTED FOR MEAN, E31.12)

       IF (IBO .EQ. 0)  GO TO 117
       IF (IPRTS .EQ. 0)  GO TO 102
C      PRINT INPUT MATRIX S
       PRINT 112
```

```
  112 FORMAT (15H0MATRIX OF SUMS )
      PRINT 108,  (S(I),I, I=1,NP1)
  108 FORMAT (E17.8,3H S(,I2,1H),E20.8,3H S(,I2,1H),
     *   E20.8,3H S(,I2,1H),E20.8,3H S(,I2,1H),E20.8,3H S(,I2,1H))
  102 CONTINUE

C     COMPUTE MEAN OF EACH VARIABLE
      DO 114 J=1,NP1
  114 S(J) = S(J)/N
      CONST=S(NP1)

      IF (IPRTS .EQ. 0)  GO TO 124
C     PRINT MEANS
      PRINT 118
  118 FORMAT (6H0MEANS)
      PRINT 108,  (S(I),I, I=1,NP1)
  124 CONTINUE
      PRINT 133,  S(NP1)
  133 FORMAT (27H0MEAN OF DEPENDENT VARIABLE, E45.12)

C     COMPUTE  RESIDUAL SUMS OF SQUARES AND CROSS PRODUCTS
      DO 113 I=1,NP1
      DO 113 J=I,NP1
  113 A(I,J) = A(I,J) - N*S(I)*S(J)
      IF (IPRTS .EQ. 0)  GO TO 117
      PRINT 137
  137 FORMAT (  '0MATRIX OF SUMS OF SQUARES AND PRODUCTS, CORRECTED FOR
     *MEANS')
      DO 119 I=1,NP1
  119 PRINT 116,  (A(I,J),I,J, J=I,NP1)
  117 CONTINUE
      SST = A(NP1,NP1)
      IF (IBO .EQ. 0)  GO TO 139
      PRINT 134,  SST
  134 FORMAT (41H0TOTAL SUM OF SQUARES, CORRECTED FOR MEAN, E31.12)
      PRINT 135,  SQRT(SST/(N-1))
  135 FORMAT (39H0STANDARD DEVIATION, CORRECTED FOR MEAN, E33.12)
  139 CONTINUE

C     COMPUTE STANDARD DEVIATION.  SET DIAGONALS OF CORRELATION MTRX=1.
C     NORMALIZE, THEN EXPAND UPPER TRIANGULAR MATRIX TO FULL
      DO 120 I=1,NP1
      SIG(I)=SQRT(A(I,I))
  120 A(I,I)=1.0
      DO 121 I=1,NP
      II=I+1
      DO 121 J=II,NP1
      IF (J .NE. NP1)  GO TO 184
      IF (SIG(J) .NE. 0.)  GO TO 184
      A(I,J) = 0.
      GO TO 121
  184 A(I,J)=A(I,J)/(SIG(I)*SIG(J))
```

```
  121 A(J,I)=A(I,J)

      IF (IPRTS .EQ. 0)  GO TO 103
C     PRINT STANDARD DEVIATIONS AND CORRELATION MATRIX
      PRINT 126
  126 FORMAT (20H0STANDARD DEVIATIONS)
      IF (IBO .NE. 0)  DF = SQRT(FLOAT(N-1))
      IF (IBO .EQ. 0)  DF = SQRT (FLOAT(N))
      PRINT 108, (SIG(I)/DF,I, I=1,NP1)
      PRINT 122
  122 FORMAT (19H0CORRELATION MATRIX )
      DO 123 I=1,NP
      IP1 = I + 1
  123 PRINT 116, (A(I,J),I,J, J=IP1,NP1)
  103 CONTINUE

C     SET UP A BLANKING ARRAY IF IBLNK .LT. 0
C     OTHERWISE, INCLUDE ALL VARIABLES IN REGRESSION.
      IF (IBLNK .LT. 0)  GO TO 109
      DO 107 I=1,NP
  107 ICBLNK(I) = 1.
      GO TO 111
C     READ COEFFICIENT BLANKING ARRAY (ICBLNK).
C     IF ICBLNK(I) = 0,  DO NOT INCLUDE VARIABLE I IN THE REGRESSION.
  109 READ  104, (ICBLNK(I),I=1,NP)                                     INPUT
  104 FORMAT (80I1)
      NPL = NP
      IF (NP .GT. 50)  NPL = 50
      PRINT 105,  (I,I=1,NPL)
  105 FORMAT (27H0COEFFICIENT BLANKING ARRAY/ 1X,50I2)
      PRINT 106, (ICBLNK(I),I=1,NP)
  106 FORMAT (1X,50I2)
  111 CONTINUE

      PRINT 401
  401 FORMAT (///6H ANOVA,8X,2HDF,24X,2HSS,22X,2HMS,13X,1HF,8X,6HTOTVAR,
     *         12X,2HSY,6X,4HNVAR,9X,6HFLEVEL)

C     COMPUTE DEGREES OF FREEDOM
      PHI = N - 1
      IF (IBO .EQ. 0)  PHI = N
      DFT = PHI

C     VARIABLES ARE ORDERED (1,2,3,...) IF IORD .NE. 0
      INOR = 0
      NORD = NP
      IF (IORD .NE. 0)  NORD = 1
      GO TO 129
  130 NORD = NORD + 1
      IF (NORD .GT. NP)  GO TO 175
      INOR = 0
      NOR = NORD
```

```
      GO TO 128

C     INITIALIZATION PROCEDURE FOR DETERMINING MOST SIGNIFICANT VARIABLE
C     TO BE ADDED  TO REGRESSION
C     COMPUTE STANDARD ERROR OF DEPENDENT VARIABLE
  125 INOR = 1
  129 NOR = 1
      SSE = A(NP1,NP1)*SST
      MSE = SSE/PHI
      SY = SQRT(MSE)
      SSR = SST - SSE
      DFR = DFT - PHI
      IF (DFR .LE. 0.)  GO TO 127
      MSR = SSR/DFR
      F = MSR/MSE
  127 CONTINUE
      VMIN=-10.E37
      NMIN=0
      NOIN=0
  128 VMAX=0.0
      NMAX=0
      DO 150 I=NOR,NORD
      IF (A(I,I) .LE. .00001)  GO TO 150

C     COMPUTE VARIANCE
      V=A(I,NP1)*A(NP1,I)/A(I,I)
      IF (V) 142,150,143
  143 IF (V .LE. VMAX)  GO TO 150
      IF (ICBLNK(I) .EQ. 0)  GO TO 150
      VMAX=V
      NMAX=I
      GO TO 150

C     X(I) IS IN REGRESSION...COMPUTE COEFFICIENT B AND STAND. ERROR OF
C     COEFF.
  142 NOIN=NOIN+1
      IVAR(NOIN)=I
      B(NOIN)=A(I,NP1)*SIG(NP1)/SIG(I)
      SB(NOIN)=SY*SQRT(A(I,I))/SIG(I)
      IF (V .LE. VMIN)  GO TO 150
      VMIN=V
      NMIN=I
  150 CONTINUE

      IF (INOR .EQ. 0)  GO TO 153
      IF (IBO .EQ. 0)  GO TO 160
C     COMPUTE CONSTANT
      TEMP=0.0
      IF (NOIN .LE. 0)  GO TO 156
      DO 151 I=1,NOIN
      II=IVAR(I)
  151 TEMP=TEMP+B(I )*S(II)
```

```
  156 CONTINUE
      CONST = S(NP1) - TEMP
  160 CONTINUE

C     PRINT RESULTS FROM STEP NUMBER ITN.
      PRINT 405, ITN,NVAR,FLEVEL
  405 FORMAT (12H0STEP NUMBER,I4,92X,I10,F15.5)
      VTNTOT = (1.-A(NP1,NP1))*100.
      PRINT 416, DFR,SSR,MSR,F,VTNTOT,SY, PHI,SSE,MSE
  416 FORMAT (11H REGRESSION,F6.0,E25.12,E24.12,3F14.5/
     *        9H RESIDUAL,F8.0,E25.12,E24.12)
      IF (ITN .LT. IPRT1)  GO TO 420
      IF (ITN .GT. IPRT2)  GO TO 420
  407 PRINT 400
  400 FORMAT (9H VARIABLE,22X,11HCOEFFICIENT,10X,14HSTANDARD ERROR,
     *        7X,7HT VALUE,6X,7HF VALUE)
      IF (IBO .NE. 0)  PRINT 415, IZERO,CONST
  415 FORMAT (1H ,I8,E33.12,E24.12,2F14.5)
      DO 410 I=1,NOIN
      T = B(I)/SB(I)
      TSQ = T**2
  410 PRINT 415, IVAR(I),B(I),SB(I),T,TSQ
      IF (ITN .LT. 0)  RETURN
      IF (IPRTS .LE. 0)  GO TO 181
C     PRINT VARIANCE-COVARIANCE MATRIX
      PRINT 179
  179 FORMAT (18H COVARIANCE MATRIX)
      IF (IBO .NE. 0)  PRINT 178, MSE/N
  178 FORMAT (1H+,26X,E18.9,9H V(YMEAN))
      DO 180 II=1,NOIN
      I = IVAR(II)
  180 PRINT 116, (MSE*A(I,IVAR(JJ))/SIG(I)/SIG(IVAR(JJ)),I,IVAR(JJ),
     *           JJ=II,NOIN)
  181 CONTINUE
  420 CONTINUE

      IF (ITN .GE. ITMAX)  GO TO 170

C     COMPARE F LEVELS...
  417 FLEVEL=VMIN*PHI/A(NP1,NP1)
      IF (FOUT+FLEVEL) 153,153,152
  152 K=NMIN
      PHI=PHI+1.0
      NVAR=-K
      GO TO 200
  153 FLEVEL=VMAX*(PHI-1.)/(A(NP1,NP1)-VMAX)
      IF (FIN-FLEVEL) 154,130,130
  154 K=NMAX
      PHI=PHI-1.0
      NVAR=K

C     CALCULATE NEW MATRIX
```

```
  200 ITN = ITN + 1
      DO 210 I=1,NP1
      IF (I .EQ. K)  GO TO 210
      DO 240 J=1,NP1
      IF (J .EQ. K)  GO TO 240
      A(I,J)=A(I,J) - A(I,K)*A(K,J)/A(K,K)
  240 CONTINUE
  210 CONTINUE
      DO 280 I=1,NP1
      IF (I .EQ. K)  GO TO 280
      A(I,K)=-A(I,K)/A(K,K)
  280 CONTINUE
      DO 320 J=1,NP1
      IF (J .EQ. K)  GO TO 320
      A(K,J)=A(K,J)/A(K,K)
  320 CONTINUE
      A(K,K)=1.0/A(K,K)
      GO TO 125

  170 PRINT 172, ITN
  172 FORMAT (46H0MAXIMUM NUMBER OF ITERATIONS REACHED.   ITN =,I5)

  175 DO 176 I=1,NP
  176 BOUT(I) = 0.
      DO 177 I=1,NOIN
      II = IVAR(I)
  177 BOUT(II) = B(I)
       IF (IBO .NE. 0)  BOUT(NP1) = CONST

C     PRINT COEFFICIENTS FROM FINAL STEP IF NOT ALREADY PRINTED.
      IF (ITN .LT. IPRT1)  GO TO 350
      IF (ITN .GT. IPRT2)  GO TO 350
      RETURN
  350 ITN = -1
      GO TO 407
      END
```

APPENDIX 5

SVIGRF.FOR

```
      PROGRAM SVIGRF
C
C  PROGRAMMED BY L.R. NEWITT
C
      DIMENSION FLAT(16),FLON(16)
      OPEN(UNIT=2,FILE='IGRFSV.DAT',STATUS='NEW')
      DATA FLAT/64.,48.,36.,68.,55.,48.,39.,40.,48.,56.,56.,70.,76.,
     *88.,80.,80./
      DATA FLON/0.,-32.,-56.,176.,-144.,-136.,-65.,-56.,-44.,-40.,
     *-32.,-15.,0.,90.,-170.,-150./
      ALT=0.
      NMAX=10.
      L=1
      CALL FIELD(45.4,-75.4,ALT,1980.,NMAX,L,XT,YT,ZT)
C
      DO 100 K=1,16
      DO 100 J=1960,1985
      T=J
      CALL FIELD(FLAT(K),FLON(K),ALT,T,NMAX,L,X1,Y1,Z1)
      XD=X1
      YD=Y1
      ZD=Z1
      IF(FLON(K).LT.0.)FLON(K)=360.+FLON(K)
      WRITE(2,1)FLAT(K),FLON(K),T,XD,YD,ZD
      PRINT 2, FLAT(K),FLON(K),T,XD,YD,ZD
100   CONTINUE
      STOP
1     FORMAT('IGRF          ',7X,2F10.3,4F10.1)
2     FORMAT(1H ,2F10.3,4F10.1)
      END

      SUBROUTINE FIELD (DLAT,DLONG,ALT,TM,NMAX,L,BN,BE,BV)

C     GEOMAGNETIC FIELD COMPONENTS X,Y,Z, IN GAMMAS.
C     USES ANY SET OF COEFFICIENTS.
C     L POSITIVE READS A NEW SET OF COEFFICIENTS.

      PARAMETER  (ND=11)                                          DEGREE10
      DIMENSION P(ND,ND),G(ND,ND),H(ND,ND),DP(ND,ND),CONST(ND,ND),
     *   SP(ND),CP(ND),SHMIT(ND,ND),GT(ND,ND),HT(ND,ND),
     *   GTT(ND,ND),HTT(ND,ND),TG(ND,ND),TH(ND,ND),FM(ND),FN(ND)
      DIMENSION  AID(4)
      DIMENSION GTTT(ND,ND), HTTT(ND,ND)
      DATA  P(1,1)/0./
```

```
      IF (P(1,1) .EQ. 1.)  GO TO 9
      P(1,1)=1.
      IT = 75                                                          TAPE 75
      NDIM = ND
      DP(1,1)=0.
      SP(1)=0.
      CP(1)=1.
      RAD=57.295779513
      SHMIT(1,1)=-1.
      FM(1) = 0.
      DO 20 N=2,NDIM
      SHMIT(N,1)=SHMIT(N-1,1)*FLOAT (2*N-3)/FLOAT (N-1)
      FN(N)=N
      FM(N) = N - 1
      J=2
      DO 20 M=2,N
      SHMIT(N,M)=SHMIT(N,M-1)*SQRT (FLOAT ((N-M+1)*J)/FLOAT (N+M-2))
   20 J=1
      DO 4 N=3,NDIM
      NM2 = N-2
      DO 4 M=1,NM2
    4 CONST(N,M)=FLOAT ((N-2)**2-(M-1)**2)/FLOAT ((2*N-3)*(2*N-5))

    9 IF (L .EQ. 0)  GO TO 15
      IF (L .LT. 0)  GO TO 33
      OPEN(UNIT=IT,FILE='IGRF6085.CUBIC',STATUS='OLD')
      READ (IT,27) J,K,TZERO,RE,A,FLAT,(AID(I),I=1,4)                  TAPE 75
   27 FORMAT (2I1,F8.2,3F10.3,4A10)

C        J        - ZERO IF COEFFICIENTS ARE FOR OBLATE EARTH
C                 - NON-ZERO IF COEFFICIENTS ARE FOR SPHERICAL EARTH.
C        K        - ZERO IF COEFFICIENTS ARE SCHMIDT NORMALIZED
C                 - NON-ZERO IF GAUSS NORMALIZED.
C        TZERO    - EPOCH YEAR OF COEFFICIENTS.
C        RE       - RADIUS OF EQUIVALENT SPHERICAL EARTH USED IN DERIVING
C                   THE COEFFICIENTS.
C        A        - SEMI-MAJOR AXIS OF GEODETIC ELLIPSOID.
C        FLAT     - FLATTENING OF ELLIPSOID.
C        AID      - IDENTIFICATION (MAXIMUM 40 CHARACTERS)

      PRINT 28, (AID(I),I=1,4),J,K,TZERO,RE,A,FLAT
   28 FORMAT (32H0SPHERICAL HARMONIC COEFFICIENTS,9X,4A10/
     *   4X,1HJ,3X,1HK,7X,5HTZERO,10X,2HRE,11X,1HA,8X,4HFLAT/
     *   1X,2I4,F12.2,3F12.3/4X,1HN,3X,1HM,9X,3HGNM,9X,3HHNM,
     *   8X,4HGTNM,8X,4HHHTNM,7X,5HGTTNM,7X,5HHTTNM)
      MAXN=0
      TEMP=0.
      IF (J .NE. 0)  GO TO 25
      FLAT= 1.-1./FLAT
      A2=A**2
      A4=A**4
      B2=(A*FLAT)**2
```

```
      A2B2=A2*(1.-FLAT**2)
      A4B4=A4*(1.-FLAT**4)
   25 READ (IT,2)  N,M,GNM,HNM,GTNM,HTNM,GTTNM,HTTNM,GTTTNM,HTTTNM       TAPE 75
    2 FORMAT (2I4,8F12.4)
      IF (N .LE. 0)     GO TO 3
      IF (N .LT. NDIM)  GO TO 7
      PRINT 6,      N,M,GNM,HNM,GTNM,HTNM,GTTNM,HTTNM,GTTTNM,HTTTNM
    6 FORMAT (1H ,2I4,8F12.4,10X, 8HNOT USED)
      GO TO 25
    7 N=N+1
      M=M+1
      MAXN=  MAX0 (N,MAXN)
      G(N,M)=GNM
      H(N,M)=HNM
      GT(N,M)=GTNM
      HT(N,M)=HTNM
      GTT(N,M)=GTTNM
      HTT(N,M)=HTTNM
      GTTT(N,M)=GTTTNM
      HTTT(N,M)=HTTTNM
      TEMP=AMAX1(TEMP,ABS (GTNM))
      GO TO 25
    3 CONTINUE
      PRINT 24,    ((FM(N),FM(M),G(N,M),H(N,M),GT(N,M),HT(N,M),
     *     GTT(N,M),HTT(N,M),GTTT(N,M),HTTT(N,M),  M=1,N),N=2,MAXN)
   24 FORMAT (1H ,2F4.0,8F12.4)
      IF (NMAX .LT. MAXN)  GO TO 17
      MAXNM1 = MAXN-1
      PRINT 35,     NMAX,MAXNM1
   35 FORMAT(6H NMAX=, I2,6H MAXN=, I2,8H ERROR**   )
      STOP
   17 IF (TEMP .NE. 0)  GO TO 29
      L = -L
      GO TO 30
   29 L=0
   30 IF (K .NE. 0)  GO TO 16
      DO 32 N=2,MAXN
      DO 32 M=1,N
      GTTT(N,M)=GTTT(N,M)*SHMIT(N,M)
      HTTT(N,M)=HTTT(N,M)*SHMIT(N,M)
      G(N,M)=G(N,M)*SHMIT(N,M)
      H(N,M)=H(N,M) *SHMIT(N,M)
      GT(N,M)=GT(N,M)*SHMIT(N,M)
      HT(N,M)=HT(N,M)*SHMIT(N,M)
      GTT(N,M)=GTT(N,M)*SHMIT(N,M)
   32 HTT(N,M)=HTT(N,M)*SHMIT(N,M)
      BN = RE
      BE = TZERO
      RETURN
   15 IF (TM .EQ. TLAST)  GO TO 33
   16 T=TM-TZERO
      DO 22 N=2,MAXN
```

```
      DO 22 M=1,N
      TG(N,M)=G(N,M)+T *(GT(N,M)+GTT(N,M)*T+GTTT(N,M)*T*T  )
   22 TH(N,M)=H(N,M)+T *(HT(N,M)+HTT(N,M)*T+HTTT(N,M)*T*T )
      TLAST=TM

   33 RLAT=DLAT/RAD
      SINLA=SIN (RLAT)
      RLONG=DLONG/RAD
      CP(2)=COS (RLONG)
      SP(2)=SIN (RLONG)
      NMAXP1=NMAX+1
      DO 10 M=3,NMAXP1
      SP(M)=SP(2)*CP(M-1)+CP(2)*SP(M-1)
   10 CP(M)=CP(2)*CP(M-1)-SP(2)*SP(M-1)
      IF (J .EQ. 0)  GO TO 59
      R = RE + ALT
      R = ALT
      CT=SINLA
      GO TO 21
   59 SINLA2=SINLA*SINLA
      DEN2=A2-A2B2*SINLA2
      DEN=SQRT (DEN2)
      COSLA = SQRT(1.-SINLA2)
      IF (COSLA .NE. 0.)  GO TO 18
      THETA = 90./RAD
      IF (SINLA .LT. 0.)  THETA = -THETA
      GO TO 19
   18 ALTDEN = ALT*DEN
      THETA = ATAN((ALTDEN+B2)/(ALTDEN+A2)*SINLA/COSLA)
   19 R=SQRT (ALT*(ALT+2.*DEN)+(A4-A4B4*SINLA2)/DEN2)
      CT=SIN (THETA)
   21 STST = 1. - CT**2
      ST = SQRT(STST)
      CTST = CT*ST
      AOR = RE/R
      AR=AOR*AOR
      BN=0.
      BE=0.
      BV=0.
      DO 54 N=2,NMAXP1
      SUMN=0.
      SUME=0.
      SUMV=0.
      AR=AOR*AR
      IF (N .GE. 3)  GO TO 60
      P(2,2) = 1.
      DP(2,2) = CT
      GO TO 61
   60  P(N,N) = ST* P(N-1,N-1)
      DP(N,N) = ST*DP(N-1,N-1) +  CTST*P(N-1,N-1)
   61 FACT = ST
      DO 45 M=1,N
```

```
      TEMP = TG(N,M)*CP(M) + TH(N,M)*SP(M)
      IF (M .EQ. 2)  FACT = STST
      IF (M .LE. N-2)  GO TO 12
      IF (N .EQ. M)  GO TO 13
       P(N,M) = CT* P(N-1,M)
      DP(N,M) = CT*DP(N-1,M) - FACT*P(N-1,M)
      GO TO 13
   12  P(N,M) = CT* P(N-1,M) - CONST(N,M)* P(N-2,M)
      DP(N,M) = CT*DP(N-1,M) - CONST(N,M)*DP(N-2,M) - FACT*P(N-1,M)
   13 SUMN = SUMN - DP(N,M)*TEMP
      IF (M .EQ. 1)  GO TO 45
      SUME = SUME + P(N,M)*FM(M)*(-TG(N,M)*SP(M)+TH(N,M)*CP(M))
      TEMP = TEMP*ST
   45 SUMV = SUMV + P(N,M)*TEMP
      BN = BN + SUMN*AR
      BE = BE + SUME*AR
   54 BV = BV + SUMV*AR*FN(N)
      IF (J .NE. 0)  GO TO 23
C      TRANSFORMS FIELD TO GEODETIC DIRECTIONS
      SIND=SIN (RLAT-THETA  )
      COSD=SQRT (1.0-SIND*SIND)
      TN=BN
      BN=BN*COSD+BV*SIND
      BV=BV*COSD-TN*SIND
   23 RETURN
      END
```

APPENDIX 6

SVPLOT.FOR

```
      PROGRAM SVPLOT
C     PROGRAM FOR COMPUTING ANNUAL DIFFERENCES FOR SECULAR CHANGE
C     FROM OBSERVATORY MEAN ANNUAL VALUES, AND PLOTTING.
C
C  ORIGINAL PROGRAM BY G.V. HAINES
C  VERSION USED BY L. NEWITT IN PRODUCTION OF CGRF 1987.5
C
C  PROGRAM PRODUCES FIRST DIFFERENCES OF OBSERVATORY ANNUAL MEAN
C  VALUES AND REPEAT STATION DATA;  THESE VALUES GO INTO SCHFIT
C  TO PRODUCE A SCH MODEL OF THE SV OVER CANADA
C
C     PFN=SECVAR    CY=3    ID=GVH    SN=GMSM
      PARAMETER  (NDIM=40)
      DIMENSION  XP(NDIM), YP(NDIM), ZP(NDIM), TP(NDIM)
      DIMENSION  XF(NDIM), YF(NDIM), ZF(NDIM), TF(NDIM)
      CHARACTER*12 ID1, IDL1
      CHARACTER*1 ID2, IDL2
      CHARACTER*10 YTITLE
      CHARACTER*1 INTEQX,INTEQY,INTEQZ
C
      OPEN(UNIT=1,FILE='[NEWITT]OBSREP1.DAT',STATUS='OLD')
      OPEN(UNIT=2,FILE='FIRSTDIFEXT.DAT',FORM='UNFORMATTED',
     *STATUS='NEW')
      OPEN(UNIT=6,FILE='OUTPUT.DAT',STATUS='NEW')
C

      CAPLAT = 60.
      TMIN = 1960.
      TMAX = 1991.
C     PUT IPLOT =  0 IF NO PLOT WANTED
C                  1 IF A PLOT IS WANTED
      IPLOT = 0
C     PUT ICODE =  -1 FOR XSIZE=57,YSIZE=33   (CAL 960)
C                  -2 TO -24 FOR XSIZE=ABS(ICODE)*50,YSIZE=34
C                 -26 TO -50 FOR XSIZE=ABS(ICODE+25)*50,YSIZE=11
      ICODE = -30
      IT1 = 1
      IT2 = 2
      FLATL = 99.
      EOF=0
      PRINT 301
301   FORMAT(1H0,'ENTER NUMBERS OF FIRST AND LAST PONTS TO BE PLOTTED--
     *->')
      READ(*,*)NSTART,NFINISH
      NREC = 0
      PRINT 1
      WRITE(6,1)
```

```
    1 FORMAT (1H1)
      L=0
C      CALL SCHNEV(DUM,DUM,DUM,DUM,L,FLATO,FLONO,DUM)
      L=1
      FLATO=65.
      FLONO=-85.
      CALL SPHITF(FLATO,FLONO,DUM,DUM,DUM,DUM,DUM,DUM)                INPUT
      ALT=0.
      LL=1
      NMAX=10
C      CALL FIELD(FLATO,FLONO,ALT,0.,NMAX,LL,XT,YT,ZT)
      PRINT 210
      WRITE(6,210)
      ALT = 0.
      N = 0
      IF (IPLOT .EQ. 0)  GO TO 200
      TSCALE =  1.27*4.
      YSCALE =  25.4*4.
      TDIV = 10.
      ITDIV = 10
      NCHART = 12
      YDIV = 100.
      IYDIV = 2
      YTITLE = ' '
      NCHARY = 1
      NINC = 1
      ISLC = -1
      INTEQX = 'X'
      INTEQY = 'Y'
      INTEQZ = 'Z'
      SIZE = .07
      TBREAK = 1.
CT    JTDIV = IFIX(TDIV)
      JYDIV = IFIX(YDIV)
      I = 0
      DO 20 T=TMIN,TMAX
      I = I + 1
   20 TF(I) = T
      CALL OPNPLT(2,10.56,0)
  200 READ (IT1,205,END=216) ID1,ID2,FLAT,FLON,YR,X,Y,Z
  205 FORMAT (A12,A1,7X,2F10.3,4F10.1)
      NREC=NREC+1
C     REPEAT STATION DATA HAVE  9  AS 3RD CHARACTER OF ID2
      IF(NREC.GT.NFINISH)GO TO 216
      IF(NREC.LT.NSTART)GO TO 200
      GO TO 220
  216 EOF=1
  217 IF (N .EQ. 0)GO TO 222
      IF (N .LT. 0)  GO TO 900
C     IF (FLATR .LT. CAPLAT)  GO TO 221
CT    TMIN = (IFIX(TMIN)/JTDIV)*TDIV
CT    TMAX = TMAX + TDIV
```

```
CT    TMAX = (IFIX(TMAX)/JTDIV)*TDIV
      I = 0
      DO 250 T=TMIN,TMAX
      I = I+1
      TM=T/30.
      CALL SCHNEV (FLATR,FLONR,R,TM,L,BN,BE,ZF(I))
      PRINT 444, FLAT,FLON,FLATR,FLONR,R,T,L,BN,BE,ZF(I)
444   FORMAT(6F9.3,I5,3F8.1)
      CALL SPHOLDF(DUM,DUM,XF(I),YF(I),DUM,DUM,BN,BE)
      YMIN = MIN(XF(I),YF(I),ZF(I),YMIN)
  250 YMAX = MAX(XF(I),YF(I),ZF(I),YMAX)
      IF (YMIN .LT. 0.)  YMIN = YMIN - YDIV
      YMIN = (IFIX(YMIN)/JYDIV)*YDIV
      IF (YMAX .GT. 0.)  YMAX = YMAX + YDIV
      YMAX = (IFIX(YMAX)/JYDIV)*YDIV
      ICOL = 2
      CALL STPLOTS (TP,XP,N,TMIN,TMAX,TSCALE,YMIN,YMAX,YSCALE,
     *     TDIV,ITDIV,IDL1,NCHART,YDIV,IYDIV,YTITLE,NCHARY,
     *     NINC,ISLC,INTEQX,SIZE,ICOL,TBREAK,ICODE)
      ICODE = 0
      CALL STPLOTS (TF,XF,I,TMIN,TMAX,TSCALE,YMIN,YMAX,YSCALE,
     *     TDIV,ITDIV,IDL1,NCHART,YDIV,IYDIV,YTITLE,NCHARY,
     *     NINC,0,INTEQX,SIZE,ICOL,TBREAK,ICODE)
      ICODE = 0
      ICOL = 4
      CALL STPLOTS (TP,YP,N,TMIN,TMAX,TSCALE,YMIN,YMAX,YSCALE,
     *     TDIV,ITDIV,IDL1,NCHART,YDIV,IYDIV,YTITLE,NCHARY,
     *     NINC,ISLC,INTEQY,SIZE,ICOL,TBREAK,ICODE)
      ICODE = 0
      CALL STPLOTS (TF,YF,I,TMIN,TMAX,TSCALE,YMIN,YMAX,YSCALE,
     *     TDIV,ITDIV,IDL1,NCHART,YDIV,IYDIV,YTITLE,NCHARY,
     *     NINC,0,INTEQX,SIZE,ICOL,TBREAK,ICODE)
      ICODE = 0
      ICOL = 3
      CALL STPLOTS (TP,ZP,N,TMIN,TMAX,TSCALE,YMIN,YMAX,YSCALE,
     *     TDIV,ITDIV,IDL1,NCHART,YDIV,IYDIV,YTITLE,NCHARY,
     *     NINC,ISLC,INTEQZ,SIZE,ICOL,TBREAK,ICODE)
      ICODE = 0
      CALL STPLOTS (TF,ZF,I,TMIN,TMAX,TSCALE,YMIN,YMAX,YSCALE,
     *     TDIV,ITDIV,IDL1,NCHART,YDIV,IYDIV,YTITLE,NCHARY,
     *     NINC,0,INTEQX,SIZE,ICOL,TBREAK,ICODE)
  221 N = 0
  222 IF (EOF .NE. 0.)  GO TO 900
      IDL1 = ID1
      IDL2 = ID2
      FLATL = FLAT
      FLONL = FLON
C     CONVERT GEODETIC LATITUDE,ALTITUDE TO GEOCENTRIC LATITUDE,RADIUS
      CALL GEOCENF (FLAT,ALT,DUM,DUM,GCLAT,R,DUM,DUM)
      PRINT 210, ID1,FLAT,FLON,ALT,GCLAT,R
      WRITE(6,210)ID1,FLAT,FLON,ALT,GCLAT,R
  210 FORMAT (1H0,A12,F8.3,F9.3,F8.1,F8.3,F8.1)
```

```
      DT = 0.
      IF (IPLOT .EQ. 0)  GO TO 218
CT    TMIN =  9999.
CT    TMAX =     0.
      YMIN =  9999.
      YMAX = -9999.
  218 PRINT 225, YR,X,Y,Z,DT
      WRITE(6,225)YR,X,Y,Z,DT
  219 YRL = YR
      XL = X
      YL = Y
      ZL = Z
      GO TO 200
  220 IF (FLAT .NE. FLATL)  GO TO 217
      IF (FLON .NE. FLONL)  GO TO 217
      DT = YR-YRL
C     IF (DT .NE. 1.)  GO TO 218
C     IF (YR-IFIX(YR) .NE. .5)  GO TO 218
      T = (YR+YRL)/2.
      DX = (X-XL)/DT
      DY = (Y-YL)/DT
      DZ = (Z-ZL)/DT
      CALL GEOCENF (FLAT,ALT,DX,DZ,GCLAT,R,DN,DV)
C     ROTATE SPHERICAL COORDINATE SYSTEM:
      CALL SPHNEWF (GCLAT,FLON,DN,DY,FLATR,FLONR,DNR,DYR)
      IF (IPLOT .EQ. 0)  GO TO 224
      IF (N .GE. NDIM)  GO TO 224
      N = N + 1
      XP(N) = DN
      YP(N) = DY
      ZP(N) = DV
      TP(N) = T
CT    TMIN = MIN(T,TMIN)
CT    TMAX = MAX(T,TMAX)
      YMIN = MIN(XP(N),YP(N),ZP(N),YMIN)
      YMAX = MAX(XP(N),YP(N),ZP(N),YMAX)
224   CONTINUE
C
C DELETE THE FOLLOWING GO TO STATEMENT IF  OUTPUT FILE DESIRED
C
C      GO TO 219
c
      PRINT 225, YR,X,Y,Z,DT,T,DX,DY,DZ,DN,DV,FLATR,FLONR,DNR,DYR
      WRITE(6,225)YR,X,Y,Z,DT,T,DX,DY,DZ,DN,DV,FLATR,FLONR,DNR,DYR
  225 FORMAT (1X,4F8.1,F5.1,4F8.1,4X,2F8.1,4X,F8.3,F9.3,2F8.1)
      IF (FLATR .GE. CAPLAT)  GO TO 230
      PRINT 227
      WRITE(6,227)
  227 FORMAT (1H+,126X,5H  OUT)
  230 CONTINUE
      WRITE (IT2)  ID1,ID2,T,FLAT,FLON,ALT,GCLAT,R,DX,DY,DZ
     *            ,DN,DV,FLATR,FLONR,DNR,DYR,DT
```

```
c
c  the following code was inserted to copy the 1988 obseratory first
c  difference values through to 1992
c
      if(id2.ne.'9'.and.t.ge.1988..and.t.le.1992.)then
      t=t+1
      go to 224
      endif
      GO TO 219

  900 PRINT 905, NREC
      WRITE(6,905)NREC
  905 FORMAT (//7H NREC =, I5)
      IF (IPLOT .EQ. 0)  GO TO 999
      ICODE = 999
      CALL STPLOTS (TP,ZP,N,TMIN,TMAX,TSCALE,YMIN,YMAX,YSCALE,
     *     TDIV,ITDIV,IDL1,NCHART,YDIV,IYDIV,YTITLE,NCHARY,
     *     NINC,ISLC,INTEQZ,SIZE,ICOL,TBREAK,ICODE)
      CALL ENDPLT
  999 STOP
      END
      SUBROUTINE STPLOTS (X,Y,NPTS,XMIN,XMAX,XSCALE,YMIN,YMAX,YSCALE,
     *           XDIV,IXDIV,XTITLE,NCHARXT, YDIV,IYDIV,YTITLE,NCHARYT,
     *               NINC,ISLC,INTEQ,SIZE,ICOL,XBREAK,ICODE)

C     SUBROUTINE TO STACK PLOTS.
C     PROGRAMMED BY G V HAINES, EARTH PHYSICS BRANCH, PHONE 995-0754.

C        XSCALE  - X-UNITS PER INCH
C        YSCALE  - Y-UNITS PER INCH
C        XDIV    - X-UNITS BETWEEN ANNOTATED TICK-MARKS.
C        IXDIV   - FURTHER SUBDIVISION OF XDIV, FOR UNANNOTATED TICK-MARKS.
C                  EG,  IXDIV=5 SUBDIVIDES XDIV INTO 5 INTERVALS
C                       ( 4 TICK-MARKS, NOT ANNOTATED )
C        NINC    - EVERY NINC TH POINT WILL BE PLOTTED.  FOR EXAMPLE,
C                  NINC = 1  PLOTS EVERY POINT,
C                  NINC = 2  PLOTS 1ST, 3RD, 5TH, ETC.
C        ISLC    - SYMBOL-LINE COMBINATION
C                   -1  FOR SYMBOLS BUT NO LINE
C                    0 FOR LINE BUT NO SYMBOLS
C                    1 FOR BOTH LINE AND SYMBOLS
C        INTEQ   - INTEGER EQUIVALENT OF DATA SYMBOL TO BE PLOTTED.
C        SIZE    - SIZE, IN INCHES, OF DATA SYMBOL TO BE PLOTTED.
C        ICOL    - COLOR OF DATA SYMBOLS AND CONNECTING LINES.
C                  AXES ARE ALWAYS DRAWN IN BLACK.
C                    1 FOR BLACK
C                    2 FOR RED
C                    3 FOR BLUE
C                    4 FOR GREEN
C        XBREAK  - INTERVAL, IN X-UNITS, GREATER THAN WHICH POINTS WILL
C                  NOT BE JOINED.
C        ICODE   -  ON FIRST CALL TO STPLOTS:
```

```
C                        -2 TO -24  SPECIFIES XSIZE=ABS(ICODE)*50, YSIZE=34
C                       -26 TO -50  SPECIFIES XSIZE=ABS(ICODE+25)*50, YSIZE=11
C                        OTHERWISE  SPECIFIES XSIZE=57, YSIZE=33  (CAL 960)
C                    -  ON FURTHER CALLS TO STPLOTS:
C                      NEGATIVE  FOR STARTING NEW STACK OF PLOTS
C                        0  FOR OVERPLOTTING PREVIOUS AREA
C                      999  FOR ENDING PLOT
C   NOTES
C        (1)           ICODE MUST BE INPUT AS A VARIABLE, NOT A CONSTANT,
C                      SINCE IT IS CHANGED IN SUBROUTINE.
C        (2)           PROGRAM SETS ICODE = -1 FIRST TIME IN, THEN SETS TO 1
C                      AND STACKS AUTOMATICALLY.
C        (3)           IF NCHARXT = +999 OR -999,  X-AXIS WILL NOT BE DRAWN.
C                      IF NCHARYT = +999 OR -999,  Y-AXIS WILL NOT BE DRAWN.
C        (4)           IF X TITLE IS NOT WANTED, PUT NCHARXT=1, XTITLE=1H .
C                      SIMILARLY FOR NO Y TITLE.

      DIMENSION  X(1), Y(1)
      CHARACTER*12 XTITLE
      CHARACTER*12 YTITLE
      CHARACTER*1 INTEQ
      DATA        IPLOT/0/
      IF (ICODE .EQ. 999)  GO TO 99
      IF (IPLOT .NE. 0)  GO TO 10
      NPLOT = 0
      IF (ICODE .GE.  -1)  GO TO 1
      IF (ICODE .LT. -50)  GO TO 1
      IF (ICODE .LT. -25)  GO TO 3
      GO TO 2
C     CALCOMP  960
    1 XPMAX = 57.
      YPMAX = 33.
      GO TO 8
    2 YPMAX = 34.
      GO TO 4
    3 YPMAX = 11.
      ICODE = ICODE + 25
    4 XPMAX = IABS(ICODE)*50.
C     SET ICODE TO -1 IN CASE ICODE.GE.0 ON ENTRY.
    8 ICODE =  -1
      XLT   = 0.8
      XBINC = 2.5
      YMARG = 0.5
      YBINC = 1.
C        XBINC   - DISTANCE, IN INCHES, BETWEEN SUCCESSIVE PLOTS
C                  ALONG THE X-AXIS.
C        YBINC   - DISTANCE, IN INCHES, BETWEEN SUCCESSIVE STACKED PLOTS
C                  ALONG THE Y-AXIS.
      PRINT  9
    9 FORMAT (6H0IPLOT,7X,4HXMIN,7X,4HXMAX,5X,6HXSCALE,7X,4HYMIN,
     *   7X,4HYMAX,5X,6HYSCALE,3X,4HNPTS,6H  NINC,6H  ISLC,6H INTEQ,
     *   6H  SIZE,6H  ICOL,6X,6HXBREAK,2X,6HNPTSPL/)
```

```
   10 IPLOT = IPLOT + 1
C       IF (INTEQ .EQ. 72)  ISLC = 0
      PRINT 15, IPLOT,XMIN,XMAX,XSCALE,YMIN,YMAX,YSCALE,
     *          NPTS,NINC,ISLC,INTEQ,SIZE,ICOL,XBREAK
   15 FORMAT (1X,I5,6E12.5,I7,2I6,5X,A1,F6.2,I6,E12.5)
      IF (ICODE .LT. 0)  IC=-1
      IF (NPTS .LE. 0)  GO TO 90
      XL = (XMAX-XMIN)/XSCALE
      YL = (YMAX-YMIN)/YSCALE
      IF (XL .LE. 0.)  GO TO 90
      IF (YL .LE. 0.)  GO TO 90
      IF (XLT+XL .GT. XPMAX)  GO TO 90
      IF (YL .GT. YPMAX-YMARG)  GO TO 90
      IPLST = 0
      IPLAST = -1
      NPTSPL = 0
      IPENDN = 2
       IPENUP = IPENDN + 1
      IF (ISLC .LT. 0)  IPENDN = IPENUP
      IF (ICODE .EQ. 0)  CALL PCOLOR (ICOL)

      DO 60 I=1,NPTS,NINC
      YP = Y(I)
      IF (YP .GT. YMAX)  GO TO 55
      IF (YP .LT. YMIN)  GO TO 55
      XP = X(I)
      IF (XP .LT. XMIN)  GO TO 55
      IF (XP .GT. XMAX)  GO TO 55
      IF (IPLST .NE. 0)  GO TO 50
      IPLST = 1
      IPEN = IPENUP
      NPLOT = NPLOT + 1
      XPL = XP
      IF (NPLOT .NE. 1)  GO TO 30
      XPB = XLT
      GO TO 40
   30 IF (IC .LT. 0)  GO TO 35
      IF (ICODE .NE. 0)  GO TO 32
      ICODE = 1
      GO TO 48
   32 YM = YM + YBINC + YL
      IF(YM.GT.YPMAX)GO TO 35
      YPB= YLL + YBINC
      YORG =YORG+YPB
      GO TO 45
   35 XPB = XLMAX + XBINC
      XLT = XLT + XPB
      IF (XLT+XL .GT. XPMAX)  GO TO 100
   40 IF(NPLOT.EQ.1)THEN
      CALL PLOT(XPB,0.5,-3)
      YORG=0.
```

```
      ELSE
      CALL PLOT (XPB,-YORG,-3)
      YORG=0.
      ENDIF
      IC = 1
      ICODE = 1
      YPB = YMARG
      YM  = YMARG + YL
      XLMAX = XL
      GO TO 46
   45 CALL PLOT (0.,YPB,-3)
   46 CALL PCOLOR (1)
      IF (IABS(NCHARXT) .NE. 999)
     *  CALL AXIS2 (0.,0.,XTITLE,-NCHARXT,XL, 0.,XMIN,XSCALE,XDIV,IXDIV)
      CALL NUMBER (-.6,0.,.2,FLOAT(IPLOT),90.,'F4.0')
      IF (IABS(NCHARYT) .NE. 999)
     *  CALL AXIS2 (0.,0.,YTITLE, NCHARYT,YL,90.,YMIN,YSCALE,YDIV,IYDIV)
      CALL PCOLOR(ICOL)
      YLL = YL
   48 IF (XL .GT. XLMAX)  XLMAX = XL
   50 IF (ABS(XP-XPL) .GT. XBREAK)  IPEN=IPENUP
      XPL = XP
      XP = (XP-XMIN)/XSCALE
      YP = (YP-YMIN)/YSCALE
      IF (ISLC .EQ. 0)  GO TO 52
      CALL SYMBOL (XP,YP,SIZE,INTEQ,0.,1)
      GO TO 53
   55 IPEN = IPENUP
      IF (I .NE. IPLAST+1)  GO TO 60
      CALL SYMBOL (XPLAST,YPLAST,SIZE,INTEQ,0.,1)
      GO TO 54
   52 CALL PLOT (XP,YP,IPEN)
      IF (IPEN .EQ. IPENDN)  GO TO 54
      XPLAST = XP
      YPLAST = YP
      IPLAST = I
   53 IPEN = IPENDN
   54 NPTSPL = NPTSPL + 1
   60 CONTINUE

      PRINT 65, NPTSPL
   65 FORMAT (1H+,121X,I8)
      GO TO 100

   90 ICODE = 1
      GO TO 100

   99 PRINT 98, ICODE,NPLOT
   98 FORMAT (27H0END OF PLOTTING.   ICODE =,I4, 6X, 7HNPLOT =,I4)
      IF (NPLOT .EQ. 0)  GO TO 100

  100 RETURN
```

```
      END
      SUBROUTINE SCHNEV (FLAT,FLON,R,T,L,BN,BE,BV)
C
C  PROGRAMMED BY G.V. HAINES PHONE 995-0754
C
C     WHEN L IS POSITIVE:
C     COMPUTES SPHERICAL CAP HARMONIC (GEOCENTRIC) FIELD COMPONENTS
C     HORIZONTAL NORTH BN,HORIZONTAL EAST BE,AND VERTICAL DOWNWARD BV.
C     WHEN L IS NEGATIVE:
C     COMPUTES GENERAL FUNCTION BV, ITS HORIZONTAL NORTH DERIVATIVE BN,
C     AND ITS HORIZONTAL EAST DERIVATIVE BE, ON SPHERICAL CAP SURFACE.
C     NOTE THAT THESE ARE METRICAL DERIVATIVES, AND BE IS THE
C     LONGITUDINAL DERIVATIVE DIVIDED BY SIN(COLATITUDE).

C     FLAT,FLON,R ARE GEOCENTRIC SPHERICAL CAP LATITUDE,LONGITUDE,RADIAL
C     DISTANCE; T IS TIME.

C     L =  0  ON FIRST CALL:  RETURNS SPHERICAL CAP POLE POSITION FLATO,FLONO
C             AND HALF-ANGLE THETA AS BN,BE, AND BV AFTER INITIALIZATION.
C             ON SUBSEQUENT CALLS:  ACTS AS L=1.
C          1  COMPUTES POTENTIAL FIELD COMPONENTS FROM INTERNAL COEFFICIENTS.
C          2  COMPUTES POTENTIAL FIELD COMPONENTS FROM EXTERNAL COEFFICIENTS.
C          3  COMPUTES FIELD FROM BOTH INTERNAL AND EXTERNAL COEFFICIENTS.
C         -1  COMPUTES GENERAL FUNCTION BV AND DERIVATIVES BN WITH RESPECT TO
C             LATITUDE AND BE WITH RESPECT TO LONGITUDE DIVIDED BY COS(LAT)
C             (R IS DUMMY VARIABLE IN THIS CASE).
C     NOTE:   SUBROUTINE IS INITIALIZED DURING FIRST CALL REGARDLESS OF L.

C     SUBPROGRAM USED:  LEGFUN

      PARAMETER   (KDIM=16,LDIM=16)                                    SET UP
      DIMENSION   FN(0:KDIM,0:KDIM), CONST(0:KDIM,0:KDIM)
      DIMENSION   CML(KDIM), SML(KDIM)
      DIMENSION   GNM(0:LDIM), HNM(0:LDIM)
      DIMENSION   DELT(0:LDIM)
      DIMENSION   BINT(0:KDIM,0:KDIM,0:LDIM), BEXT(0:KDIM,0:KDIM,0:LDIM)
      CHARACTER*1 IE
      DATA        IENTER /0/

      IF (IENTER .NE. 0)  GO TO 100

      IENTER = 1
C     READ COEFFICIENT FILE
      IT1 = 85
      OPEN (UNIT=IT1,FILE='SCHCOEFEXTF0.K7L3',STATUS='OLD')
      READ (IT1,240,END=999)  FLATO,FLONO,THETA,RE,TZERO
      READ(IT1,241,END=999)IFIT,ICEN,IREF,IB,KINT,LINT,KEXT,LEXT
  240 FORMAT (F8.2,F9.2,F7.2,F8.1,F10.4)
  241 FORMAT(8I5)
      PRINT 236,  FLATO,FLONO,THETA,RE,TZERO
  236 FORMAT (//7X,5HFLATO,5X,5HFLONO,5X,5HTHETA,8X,2HRE,5X,5HTZERO/
     *        2X,3F10.2,2F10.1)
```

```
      PRINT 238,  IFIT,ICEN,IREF,IB,KINT,LINT,KEXT,LEXT
  238 FORMAT (/4X,48H  IFIT  ICEN  IREF    IB  KINT  LINT  KEXT  LEXT/
     *         4X,8I6)
      KMAX = MAX(KINT,KEXT)
      IF (KMAX .GT. KDIM)  GO TO 999
      KT = MAX(LINT,LEXT)
      IF (KT .GT. LDIM)  GO TO 999
      PRINT 242
  242 FORMAT (/4X,1HK,3H  M,6X,3HFNN,10X,5HCONST,
     *        <MIN(KT+1,5)>(7X,3HGNM,7X,3HHNM))
  247 READ (IT1,250,END=280) IE,N,M,FNN,CON,(GNM(J),HNM(J),J=0,KT)
  250 FORMAT (1X,A1,2I3,F9.4,E15.6,<KT+1>(E15.6,E15.6))
      IF (N .LT. 0)  GO TO 280
      IF (M .LT. 0)  GO TO 280
      IF (N .GT. KMAX)  GO TO 247
      IF (M .GT. KMAX)  GO TO 247
      IF (IE .EQ. 'I')  THEN
         IF (N .GT. KINT)  GO TO 247
         LJ = LINT
      ELSE
         IF (N .GT. KEXT)  GO TO 247
         LJ = LEXT
         END IF
      FN(N,M) = FNN
      CONST(N,M) = CON
      IF (M .GT. 0)  GO TO 300
      PRINT 255, IE,N,M, FNN,CON,(GNM(J),J=0,LJ)
  255 FORMAT (1X,A1,2I3,F9.4,E15.6,F10.3,4F20.3:/(22X,5F20.3))
      DO 301 J=0,LJ
      IF (IE .EQ. 'I')  THEN
         BINT(N,M,J)    = GNM(J)
      ELSE
         BEXT(N,M,J)    = GNM(J)
         END IF
  301 CONTINUE
      GO TO 247
  300 CONTINUE
      PRINT 260, IE,N,M,FNN,CON,(GNM(J),HNM(J),J=0,LJ)
  260 FORMAT (1X,A1,2I3,F9.4,E15.6,10F10.3:/(32X,10F10.3))
      DO 302 J=0,LJ
      IF (IE .EQ. 'I')  THEN
         BINT(N,M,J)    = GNM(J)
         BINT(M-1,N,J) = HNM(J)
      ELSE
         BEXT(N,M,J)    = GNM(J)
         BEXT(M-1,N,J) = HNM(J)
         END IF
  302 CONTINUE
      GO TO 247
  280 CLOSE (UNIT=IT1,STATUS='KEEP')

      IF (L .NE. 0)  GO TO 100
```

```
      BN = FLATO
      BE = FLONO
      BV = THETA
      T = TZERO
      RETURN

  100 IF (L .GE. 0)  THEN
         IF (IFIT .LT. 0)  GO TO 999
         AOR = RE/R
         AR = AOR**2
         IF (L .GT. 1)  GO TO 107
      ELSE
         IF (IFIT .GE. 0)  GO TO 999
         AR = -1.
         END IF
      KT = LINT
      GO TO 109
  107 IF (KEXT .GT. 0)  AOR3 = AOR*AR
      IF (L .GT. 2)  GO TO 108
      KT = LEXT
      GO TO 109
  108 KT = MAX (LINT,LEXT)
  109 DELT(0) = 1.
      IF (KT .LE. 0)  GO TO 103
      DEL = T - TZERO
      DO 102 I=1,KT
  102 DELT(I) = DELT(I-1)*DEL
  103 X = 0.
      Y = 0.
      Z = 0.
      IF (L .EQ. 2)  GO TO 106
      IF (KINT .LT. 0)  GO TO 106
      GTI = 0.
      DO 105 I=0,LINT
  105 GTI = GTI + BINT(0,0,I)*DELT(I)
      Z = -AR*GTI
  106 COLAT = 90. - FLAT
      DO 150 N=1,KMAX
      IF (N .GT. 1)  GO TO 115
      CL = COSD(FLON)
      SL = SIND(FLON)
      CML(1) = CL
      SML(1) = SL
      GO TO 120
  115 SML(N) = SL*CML(N-1) + CL*SML(N-1)
      CML(N) = CL*CML(N-1) - SL*SML(N-1)
  120 CONTINUE
      DO 150 M=0,N
      IF (IB .EQ. 2)  GO TO 121
      NMM = N - M
      IF ((NMM/2)*2 .NE. NMM)  GO TO 150
  121 FFN = FN(N,M)
```

```
      CALL LEGFUN (M,FFN,CONST(N,M),COLAT,P,DP,PMS,0)
      IF (L .GE. 0)  THEN
         AR = AOR**(FFN+2.)
      ELSE
         AR = 1.
         FFN = -2.
         DP = -DP
         PMS = -PMS
         END IF
      IF (M .NE. 0)  GO TO 130
      BT1 = 0.
      BT3 = 0.
      BT  = 0.
      IF (L .EQ. 2)  GO TO 123
      IF (N .GT. KINT)  GO TO 123
      GTI = 0.
      DO 122 I=0,LINT
  122 GTI  = GTI  + BINT(N,M,I)*DELT(I)
      BT1  = AR*GTI
      BT3  = BT1
  123 IF (L .LE. 1)  GO TO 125
      IF (N .GT. KEXT)  GO TO 125
      GTE = 0.
      DO 124 I=0,LEXT
  124 GTE = GTE + BEXT(N,M,I)*DELT(I)
      BT  = AOR3/AR*GTE
      BT1 = BT1 + BT
  125 X = X + BT1*DP
      Z = Z - (FFN*(BT3-BT)+BT3)*P
      GO TO 150
  130 BT1 = 0.
      BT2 = 0.
      BT3 = 0.
      BT  = 0.
      IF (L .EQ. 2)  GO TO 133
      IF (N .GT. KINT)  GO TO 133
      GTI = 0.
      HTI = 0.
      DO 132 I=0,LINT
      GTI = GTI + BINT(N,M,I)*DELT(I)
  132 HTI = HTI + BINT(M-1,N,I)*DELT(I)
      BT1 = AR*(GTI*CML(M) + HTI*SML(M))
      BT2 = AR*(GTI*SML(M) - HTI*CML(M))
      BT3 = BT1
  133 IF (L .LE.  1)  GO TO 135
      IF (N .GT. KEXT)  GO TO 135
      GTE = 0.
      HTE = 0.
      DO 134 I=0,LEXT
      GTE = GTE + BEXT(N,M,I)*DELT(I)
  134 HTE = HTE + BEXT(M-1,N,I)*DELT(I)
      RA = AOR3/AR
```

```
      BT = RA*(GTE*CML(M) + HTE*SML(M))
      BT1 = BT1 + BT
      BT2 = BT2 + RA*(GTE*SML(M) - HTE*CML(M))
  135 X = X + BT1*DP
      Y = Y + BT2*PMS
      Z = Z - (FFN*(BT3-BT)+BT3)*P
  150 CONTINUE
      BN = X
      BE = Y
      BV = Z
      RETURN

  999 STOP
      END
```

PLUS SUBROUTINE FIELD (SEE LISTING, APPENDIX 5)

AND

SUBROUTINE AXIS2 (NOT LISTED)

APPENDIX 7

SCHFIT.FOR
SCHFIT.COM
SCH.COM

```
      PROGRAM SCHFIT

C     SPHERICAL CAP HARMONIC LEAST SQUARES FIT TO EITHER:
C     (1) POTENTIAL FIELD COMPONENTS NORTH X, EAST Y, VERTICAL DOWN Z; OR
C     (2) A GENERAL FUNCTION Z ON A SPHERICAL CAP SURFACE.
C     IN BOTH CASES, THE COEFFICIENTS ARE POLYNOMIALS IN TIME.
C
C  ORIGINAL PROGRAM BY G.V. HAINES
C  THIS VERSION USED BY L. NEWITT FOR PRODUCTION OF CGRF 1987.5
C
C     SUBPROGRAMS REQUIRED -  FNM, LEGFUN, SUMPRD, STEPREG, SPHNEWF
C             AND POSSIBLY -  GEOCENF, FIELD, PRTRES

C      PARAMETER   (IBASIS=2,KINT=16,LINT=0,KEXT=0,LEXT=-1)            SET UP
      PARAMETER (IBASIS=2,KINT=7,LINT=3,KEXT=0,LEXT=-1)

C     IBASIS = 1  TO USE 1 SET OF BASIS FUNCTIONS (K-M=EVEN)
C                 (FOR FITTING VERTICAL FIELD DATA, OR GENERAL FUNCTION
C                  NOT DIFFERENTIABLE IN LATITUDE)
C              2  TO USE 2 SETS OF BASIS FUNCTIONS
C                 (FOR FITTING THREE-COMPONENT DATA, OR GENERAL FUNCTION
C                  DIFFERENTIABLE IN LATITUDE)
C     KINT  =  MAXIMUM SPATIAL INDEX FOR INTERNAL SOURCES
C     LINT  =  TEMPORAL DEGREE FOR INTERNAL SOURCES
C     KEXT  =  MAXIMUM SPATIAL INDEX FOR EXTERNAL SOURCES
C     LEXT  =  TEMPORAL DEGREE FOR EXTERNAL SOURCES

C     NOTE:    FOR NO INTERNAL SOURCES, PUT KINT=-1,LINT=-1.
C              FOR NO EXTERNAL SOURCES, PUT KEXT= 0,LEXT=-1.

C     EXAMPLE:  FOR MAIN FIELD, INTERNAL SOURCES, PUT LINT=KEXT=0,LEXT=-1.
C     FOR LINEAR TIME TERMS, INTERNAL SOURCES,  PUT LINT=1,KEXT=0,LEXT=-1.
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      REAL*4 A1,A2,A3,A4,A5,A6,A7,A8,A9
      PARAMETER   (KB=2-IBASIS/2)
      PARAMETER   (NDIM=(((KINT+1)*(KINT+KB))/KB)*(LINT+1)
     *             +((KEXT*(KEXT+KB+1))/KB)*(LEXT+1)+1)
      PARAMETER   (KMAX=MAX(KINT,KEXT),KT=MAX(LINT,LEXT))
      DIMENSION   S(NDIM),SS(NDIM,NDIM)
      DIMENSION   XX(NDIM),XY(NDIM),XZ(NDIM)
      DIMENSION   FN(0:KMAX,0:KMAX), CONST(0:KMAX,0:KMAX)
      DIMENSION   CML(KMAX), SML(KMAX)
      DIMENSION   DELT(0:KT)
      DIMENSION   B(NDIM)
      DIMENSION   SIG(NDIM),IVAR(NDIM),BW(NDIM),SB(NDIM),ICBLNK(NDIM)
      CHARACTER*12 ID1
      CHARACTER*1 ID2
      CHARACTER*4 IE
C     EQUIVALENCE ARRAYS TO CONSERVE MEMORY:
      EQUIVALENCE (XX,SIG), (XY,IVAR), (XZ,SB)

      PRINT  1
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```
    1 FORMAT (1H1)

      IFIT =  1                                                       SET UP
C     PUT IFIT = -1 TO FIT A GENERAL FUNCTION OF LATITUDE AND LONGITUDE.
C                 0 TO FIT GEOCENTRIC VERTICAL POTENTIAL FIELD DATA.
C                 1 TO FIT THREE-COMPONENT POTENTIAL FIELD DATA.
      IF (IFIT .LT. 0)  THEN
         IF (KEXT .NE. 0)  GO TO 999
         IF (LEXT .NE. -1)  GO TO 999
         END IF

      ICEN = 1                                                        SET UP
C     PUT ICEN = 1 TO CONVERT INPUT DATA FROM GEODETIC TO GEOCENTRIC
C                  (INPUT DATA ARE GEODETIC LATITUDE, LONGITUDE, ALTITUDE)
C                0 FOR NO GEODETIC TO GEOCENTRIC CONVERSION
C                  (INPUT DATA ARE GEOCENTRIC LAT, LONG, RADIAL DISTANCE)
      IF (IFIT .LE. 0)  ICEN = 0                                      NOTE

      IREF = 0                                                        SET UP
C     PUT IREF = 1 TO SUBTRACT REFERENCE FIELD FROM INPUT DATA
C                0 FOR NO SUBTRACTION.

      RE = 6371.2
C     PUT RE = REFERENCE RADIUS OF THE SPHERICAL CAP.

C     INPUT SPHERICAL CAP POLE (SUBROUTINE SPHNEWF)
      FLATO=65.
      FLONO=-85.
      CALL SPHITF (FLATO,FLONO,DUM,DUM,DUM,DUM,DUM,DUM)               INPUT
C     TZERO IS 1990.
      TZERO = 66.333333                                          SET UP
C     TIME T, FOR SECULAR VARIATION POLYNOMIAL, WILL BE RELATIVE TO TZERO.
C     TIMES ARE DIVIDED BY 30.0 TO PREVENT NUMERICAL PROBLEMS

      ISUMS = 0                                                       SET UP
C     PUT ISUMS =  0  TO NEITHER PRINT NOR STORE SUMS OF SQUARES AND PRODUCTS
C                  1  TO STORE THEM
C                  2  TO STORE AND PRINT THEM
C                  3  TO PRINT THEM

      IRESID = 0                                                      SET UP
C     PUT IRESID = 1 FOR RESIDUALS TO BE CALCULATED AND PRINTED
C                  0 FOR NO RESIDUALS

      IFILES = 1                                                      SET UP
C     PUT IFILES = NUMBER OF END-OF-FILE RECORDS ON DATA FILE

      IPR = 50                                                        SET UP
C     SET IPR TO NUMBER OF INPUT RECORDS TO BE PRINTED.

C     READ IN PARAMETER FILE (REAL DEGREES, CONSTANTS)
C     (INPUT TO SUBROUTINE FNM MUST HAVE FN'S UP TO KMAX OR HIGHER)
```

```
      CALL FNM (KMAX,IBASIS,FN,CONST,THETA)                               PARAMS
      CAPLAT = 90. - THETA
C     CHANGE CAPLAT IF DATA BEYOND THETA IS TO BE INCLUDED

      IF (IREF .EQ. 0)  GO TO 20
      READ (*,15,END=999)  TF,NF
   15 FORMAT (F10.2,I5)
      PRINT 16,  TF,NF
   16 FORMAT (/9X,2HTF,8X,2HNF/1X,F10.2,I10)
C     INITIALIZE SUBROUTINE FIELD
      LF = 0
      CALL FIELD (DUM,DUM,DUM,TF,NF,LF,DUM,DUM,DUM)
      LF = 1

   20 NP1 = NDIM
      NP  = NDIM-1
      IBO = 0
      IENTER = 0
      NOB = 0
      IT1 = 1
C  SV DATA
      OPEN (IT1,FILE='FIRSTDIFEXT.DAT',STATUS='OLD',FORM='UNFORMATTED') DATAFILE
C  MAIN FIELD DATA
C      OPEN(IT1,FILE='MAGDATA90.RESROT7',STATUS='OLD')
      IF (IRESID .EQ. 0)  GO TO 90
      IT91 = 91
      OPEN (IT91,FILE='SCRES.BIN',STATUS='SCRATCH',FORM='UNFORMATTED')

   90 IFILE  =  1
C     SET DEFAULT FOR ALT AND T, IF NOT IN READ LIST
      IF (ICEN .NE. 0)  ALT = 0.
      IF (ICEN .EQ. 0)  ALT = RE
      T = TZERO
C     READ DATA FILE
C  MAIN FIELD DATA
C  100 CONTINUE
101   READ (IT1,111,END=200),FLAT,FLON,ALT,X,Y,Z,DUM,DUM,DUM,DUM,DUM,DUM
111   FORMAT(3F10.3,4F10.1,2F10.3,3F10.1)
C  SV DATA
  100 READ(IT1,END=200)ID1,ID2,A1,A2,A3,A4,A5,A6,A7,A8,A9
      T=A1
      FLAT=A2
      FLON=A3
      ALT=A4
      X=A7
      Y=A8
      Z=A9
      T=T/30.
      IF (ICEN .EQ. 0)  GO TO 60
C     CONVERT FROM GEODETIC TO GEOCENTRIC
      CALL GEOCENF (FLAT,ALT,X,Z,GCLAT,R,BN,BV)
      GO TO 65
```

```
   60 GCLAT = FLAT
      R = ALT
      BN = X
      BV = Z
   65 IF (IREF .EQ. 0)  GO TO 70
C     REMOVE GLOBAL REFERENCE FIELD
      CALL FIELD (GCLAT,FLON,R,TF,NF,LF,BNREF,YREF,BVREF)
      BN = BN - BNREF
      Y = Y - YREF
      BV = BV - BVREF
C     ROTATE SPHERICAL COORDINATE SYSTEM

70    CONTINUE
C
C  MAIN FIELD DATA ARE IN ROTATED GEOCENTRIC COORDINATES
C  COMMENT OUT THE FOLLOWING CALL AND  USE THE FOLLOWING 4 IDENTITIES
C
C      CALL SPHNEWF (GCLAT,FLON,BN,Y,SCLAT,SCLON,SCX,SCY)
C
C  USE THESE FOR MAIN FIELD DATA ONLY
C
C      SCLAT=GCLAT
C      SCLON=FLON
C      SCX=BN
C      SCY=Y
C
      IF (IPR .EQ. 0)  GO TO 80
      IF (IPR .LT. 0)  GO TO 75
      IPR = -IPR
      PRINT 103
  103 FORMAT (15H1IDENTIFICATION,5X,4HFLAT,4X,4HFLON,5X,3HALT,
     *        7X,1HX,7X,1HY,7X,1HZ,3X,5HSCLAT,3X,5HSCLON,7X,1HR,
     *        5X,3HSCX,5X,3HSCY,6X,2HBV/)
   75 PRINT 104, T,ID1,
     *           FLAT,FLON,ALT,X,Y,Z,SCLAT,SCLON,R,SCX,SCY,BV
  104 FORMAT (1X,F6.1,1X,A8,1X,3F8.3,3F8.0,2F8.3,F8.1,3F8.1)
      IPR = IPR + 1
   80 CONTINUE
C      IF (SCLAT .LT. CAPLAT)  GO TO 100
      DELT(0) = 1.
      DEL = T - TZERO
      DO 102 I=1,KT
  102 DELT(I) = DELT(I-1)*DEL
      IF (IFIT .GE. 0)  THEN
         AOR = RE/R
         AR = AOR**2
         IF (KEXT .GT. 0)  AOR3 = AOR*AR
      ELSE
         AR = -1.
         END IF
      K = 0
      IF (KINT .LT. 0)  GO TO 106
```

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      DO 105 I=0,LINT
      ART = AR*DELT(I)
      K = K + 1
      IF (IFIT .LE. 0)  GO TO 105
      XX(K) =  0.
      XY(K) =  0.
  105 XZ(K) =  -ART
  106 COLAT = 90. - SCLAT
      DO 150 N=1,KMAX
      IF (N .GT. 1)  GO TO 115
      CL = COSD(SCLON)
      SL = SIND(SCLON)
      CML(1) = CL
      SML(1) = SL
      GO TO 120
  115 SML(N) = SL*CML(N-1) + CL*SML(N-1)
      CML(N) = CL*CML(N-1) - SL*SML(N-1)
  120 DO 150 M=0,N
      IF (IBASIS .EQ. 2)  GO TO 121
      NMM = N-M
      IF ((NMM/2)*2 .NE. NMM)  GO TO 150
  121 FFN = FN(N,M)
      CALL LEGFUN (M,FFN,CONST(N,M),COLAT,P,DP,PMS,0)
      IF (IFIT .GE. 0)  THEN
         AR = AOR**(FFN+2.)
      ELSE
         AR = 1.
         FFN = -2.
         END IF
      IF (N .GT. KINT)  GO TO 135
      DO 130 I=0,LINT
      IF (M .NE. 0)  GO TO 125
      K = K + 1
      ART = AR*DELT(I)
      XZ(K) = -(FFN+1.)*ART*P
      IF (IFIT .LE. 0)  GO TO 130
      XX(K) =  ART*DP
      XY(K) =  0.
      GO TO 130
  125 K = K + 2
      ART = AR*DELT(I)
      ZT = -(FFN+1.)*ART*P
      XZ(K-1) =  ZT*CML(M)
      XZ(K) =  ZT*SML(M)
      IF (IFIT .LE. 0)  GO TO 130
      XT =  ART*DP
      XX(K-1) =  XT*CML(M)
      XX(K) =  XT*SML(M)
      YT =  ART*PMS
      XY(K-1) =  YT*SML(M)
      XY(K) = -YT*CML(M)
  130 CONTINUE
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  135 IF (N .GT. KEXT)  GO TO 150
      RA = AOR3/AR
      DO 145 I=0,LEXT
      IF (M .NE. 0)  GO TO 140
      K = K + 1
      RAT = RA*DELT(I)
      XZ(K) =  FFN*RAT*P
      IF (IFIT .EQ. 0)  GO TO 145
      XX(K) =  RAT*DP
      XY(K) =  0.
      GO TO 145
  140 K = K + 2
      RAT = RA*DELT(I)
      ZT =  FFN*RAT*P
      XZ(K-1) =  ZT*CML(M)
      XZ(K) =  ZT*SML(M)
      IF (IFIT .EQ. 0)  GO TO 145
      XT =  RAT*DP
      XX(K-1) =  XT*CML(M)
      XX(K) =  XT*SML(M)
      YT =  RAT*PMS
      XY(K-1) =  YT*SML(M)
      XY(K) = -YT*CML(M)
  145 CONTINUE
  150 CONTINUE
      IF (K .NE. NP)  THEN
          PRINT 151,  K,NP
  151     FORMAT (7H0***K =,I5,10X,4HNP =,I5)
          GO TO 999
          END IF
      IF (IFIT .LE. 0)  GO TO 155
      XX(NP1) =  SCX
      CALL SUMPRD (IBO,NP1,NOBS,XX,S,SS,IENTER)
      XY(NP1) =  SCY
      CALL SUMPRD (IBO,NP1,NOBS,XY,S,SS,IENTER)
  155 XZ(NP1) =  BV
      CALL SUMPRD (IBO,NP1,NOBS,XZ,S,SS,IENTER)
      IF (IRESID .EQ. 0)  GO TO 100
C     SAVE VARIABLES TO COMPUTE RESIDUALS IN SUBROUTINE PRTRES.
      ID = T
      IF (IFIT .LE. 0)  GO TO 160
      WRITE (IT91)  ID,ID1,(XX(K),K=1,NP1)
      WRITE (IT91)  ID,ID1,(XY(K),K=1,NP1)
  160 WRITE (IT91)  ID,ID1,(XZ(K),K=1,NP1)
      GO TO 100

C     END OF PROCESSING FILE=IFILE ON TAPE=IT1.
  200 NOB = NOBS - NOB
      PRINT 55
   55 FORMAT (/6X,5HIFILE, 7X,3HNOB, 6X,4HNOBS)
      PRINT 205, IFILE,NOB,NOBS
  205 FORMAT (1X,3I10)
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```
      NOB = NOBS
      IF (IFILE .GE. IFILES)  GO TO 300
      IFILE = IFILE + 1
C     DUM = EOF(IT1)
      GO TO 100

C     END OF PROCESSING TAPE=IT1.
  300 CLOSE (IT1,STATUS='KEEP')
      IF (NOBS .LE. 0)  GO TO 999
      IF (IRESID .EQ. 0)  GO TO 310
      ENDFILE IT91

C     STORE/PRINT SUMS OF SQUARES AND PRODUCTS MATRIX
  310 IF (ISUMS .LE. 0)  GO TO 320
      IF (ISUMS .GE. 3)  GO TO 315
      IT2 = 2
      OPEN (IT2,FILE='SUMSQUARES.DAT',STATUS='NEW',FORM='UNFORMATTED')
      WRITE (IT2)  NOBS,NP1
      WRITE (IT2)  ((SS(I,J),J=I,NP1),I=1,NP1)
      CLOSE (IT2,STATUS='KEEP')
      IF (ISUMS .EQ. 1)  GO TO 320
  315 PRINT 202
      DO 201 I=1,NP1
  201 PRINT 202,  (SS(I,J),J=I,NP1)
  202 FORMAT (1X,10E13.6)

C     PERFORM STEPWISE REGRESSION.
  320 IBLNK =   1                                                       SET UP
      IORD  =   0                                                       SET UP
      FIN   = 3.0                                                       SET UP
      FOUT  = 3.0                                                       SET UP
      IPRT1 =   0                                                       SET UP
      IPRT2 =  30                                                       SET UP
      IPRTS =   0                                                       SET UP
      ITMAX = 2*NP
      PRINT 1
      CALL STEPREG (IBO,IBLNK,IORD,NOBS,NP1,S,SS,FIN,FOUT,ITMAX,B,
     *              SIG,IVAR,BW,SB,ICBLNK,IPRTS,IPRT1,IPRT2)

C     STORE SPHERICAL CAP HARMONIC COEFFICIENTS
      IT3 = 3
      OPEN (IT3,FILE='SCHCOEFEXT.K7L3',STATUS='NEW',
     *      RECL=32+(MAX(LINT,LEXT)+1)*30)
      WRITE (IT3,245)  FLATO,FLONO,THETA,RE,TZERO
  245 FORMAT (F8.2,F9.2,F7.2,F8.1,F10.4)
      WRITE (IT3,246)  IFIT,ICEN,IREF,IBASIS,KINT,LINT,KEXT,LEXT
  246 FORMAT (8I5)
      PRINT 236,  FLATO,FLONO,THETA,RE,TZERO
  236 FORMAT (1H1,6X,5HFLATO,5X,5HFLONO,5X,5HTHETA,8X,2HRE,5X,5HTZERO/
     *       2X,3F10.2,F10.1,F10.4)
      PRINT 238,  IFIT,ICEN,IREF,IBASIS,KINT,LINT,KEXT,LEXT
  238 FORMAT (/4X,48H  IFIT  ICEN  IREF    IB  KINT  LINT  KEXT  LEXT/
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     *        4X,8I6)
      PRINT 242
  242 FORMAT (/4X,1HK,3H  M,6X,3HFNN,10X,5HCONST,
     *        <MIN(KT+1,5)>(7X,3HGNM,7X,3HHNM))
      K = 0
      LI = LINT + 1
      LE = LEXT + 1
      DO 270 N=0,KMAX
      IF (IBASIS .EQ. 2)  GO TO 230
      IF ((N/2)*2 .NE. N)  GO TO 260
  230 IF (N .GT. KINT)  GO TO 259
      IE = 'I'
      KO = K + 1
      K  = K + LI
      KF = LI
  276 DO 247 J=KO,K
  247 IF (B(J) .NE. 0.)  GO TO 248
      GO TO 258
  248 M = 0
      WRITE (IT3,250) IE,N,M,FN(N,M),CONST(N,M),(B(J),J=KO,K)
  250 FORMAT (1X,A1,2I3,F9.4,E15.6,<KF>(E15.6,15X))
      PRINT 255,       IE,N,M,FN(N,M),CONST(N,M),(B(J),J=KO,K)
  255 FORMAT (1X,A1,2I3,F9.4,E15.6,F10.3,4F20.3:/(22X,5F20.3))
  258 IF (IE .EQ. 'E')  GO TO 260
  259 IF (N .GT. KEXT)  GO TO 260
      IF (N .EQ. 0)  GO TO 260
      IE = 'E'
      KO = K + 1
      K  = K + LE
      KF = LE
      GO TO 276
  260 DO 270 M=1,N
      IF (IBASIS .EQ. 2)  GO TO 240
      NMM = N - M
      IF ((NMM/2)*2 .NE. NMM)  GO TO 270
  240 IF (N .GT. KINT)  GO TO 269
      IE = 'I'
      KO = K + 1
      K  = K + LI + LI
      KF = LI
  261 DO 262 J=KO,K
  262 IF (B(J) .NE. 0.)  GO TO 265
      GO TO 268
  265 WRITE (IT3,280)  IE,N,M,FN(N,M),CONST(N,M),(B(J),J=KO,K)
  280 FORMAT (1X,A1,2I3,F9.4,E15.6,<KF>(E15.6,E15.6))
      PRINT 285,        IE,N,M,FN(N,M),CONST(N,M),(B(J),J=KO,K)
  285 FORMAT (1X,A1,2I3,F9.4,E15.6,10F10.3:/(32X,10F10.3))
  268 IF (IE .EQ. 'E')  GO TO 270
  269 IF (N .GT. KEXT)  GO TO 270
      IE = 'E'
      KO = K + 1
      K  = K + LE + LE
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```
      KF = LE
      GO TO 261
  270 CONTINUE
      WRITE (IT3,255) ' ',-1,-1
      CLOSE (IT3,STATUS='KEEP')

      IF (IRESID .EQ. 0)  GO TO 999
C     COMPUTE AND PRINT SPHERICAL CAP HARMONIC RESIDUALS
      CALL PRTRES (IT91,IBO,NOBS,NP1,XX,B)
      CLOSE (IT91,STATUS='DELETE')

  999 STOP
      END

      SUBROUTINE LEGFUN (M,FN,CONST,COLAT,P,DP,PMS,IPRT)
C
C  PROGRAMMED BY G.V. HAINES
C
C     SERIES FORM FOR ASSOCIATED LEGENDRE FUNCTION P, ITS DERIVATIVE DP,
C     AND THE FUNCTION PMS=P*M/SIN(COLAT), IN POWERS OF (1-COS(COLAT))/2.
C     INTEGRAL ORDER M, REAL DEGREE FN, NORMALIZING CONSTANT CONST.
C     COLATITUDE COLAT IN DEGREES.
C     IPRT = 0      NO PRINT-OUT
C            1      PRINT PARAMETERS AND P SERIES
C            2      PRINT PARAMETERS AND DP SERIES
C            3      PRINT PARAMETERS AND BOTH P AND DP SERIES
C           -1      PRINT PARAMETERS ONLY
C     INPUT M,FN,CONST,COLAT,IPRT.   OUTPUT P,DP,PMS.
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      REAL*16  FNN,AL,DX,A,B,PNM,DPNM

      PARAMETER (JMAX=60)
      DIMENSION  AM(JMAX), BM(JMAX)

      IF (COLAT .LT. 60.)  THEN
          X = SIND(COLAT/2.)**2
          C = 1. - 2.*X
      ELSE
          C = COSD(COLAT)
          X = (1. - C)/2.
          END IF
      S = SIND(COLAT)
      FNN = FN*(FN+1.)
      IF (M .GT.1)  GO TO 20
      IF (M .LT. 0)  STOP
      AL = CONST
      GO TO 50
   20 AL = CONST*S**(M-1)

   50 PNM = AL
      DPNM = 0.
      DX = X
```

```
      J = 0

  100 J = J + 1
      JPM = J + M
      B = AL*((JPM-1)-FNN/JPM)
      DPNM = DPNM + B
      A = (B*DX)/J
      PNM = PNM + A
      AL = A

C     STORE P OR DP SERIES FOR PRINTOUT.
      IF (IPRT .LE. 0)  GO TO 150
      IF (IPRT .EQ. 2)  GO TO 145
      AM(J) = A
      IF (IPRT .EQ. 1)  GO TO 150
  145 BM(J) = B

C     CHECK FOR TERMINATION OF SERIES.
  150 ABSA = ABS(A)
      ABSB = ABS(B)
      IF (ABSB .GE. 1.E-7)  GO TO 160
      IF (ABSA .LT. 1.E-7)  GO TO 110
  160 IF (ABSB .GE. 1.E+26)  GO TO 105
      IF (ABSA .GE. 1.E+26)  GO TO 105
C     CHANGE CHECK LIMITS ACCORDING TO ACCURACY DESIRED AND ACCORDING
C     TO WORD SIZE OF COMPUTER.
C     FOR 32-BIT WORD, DOUBLE PRECISION, E-7 AND E+9 GIVE 7 DIGITS ACCURACY.
C     FOR 60-BIT WORD, DOUBLE PRECISION, E-7 AND E+22 GIVE 7 DIGITS ACCURACY.
C     FOR 60-BIT WORD, SINGLE PRECISION, E-7 AND E+7 GIVE 7 DIGITS ACCURACY.
C     (DOUBLE OR SINGLE PRECISION REFER TO FNN,AL,A,B,PNM,DPNM)
      IF (J .LT. JMAX)  GO TO 100
C     CONVERGENCE SLOW OR JMAX TOO SMALL
  105 CONTINUE
C     NUMERICAL ERROR UNACCEPTABLY LARGE DUE TO ADDING OF
C     LARGE AND SMALL NUMBERS.
      PRINT 108, M,FN,CONST,J,A,B
  108 FORMAT (//12H ** ERROR **/1X,I5,F10.5,E15.7,I5,2D15.7)
      STOP

C     SERIES TRUNCATED SUCCESSFULLY.
  110 PS = PNM
      DPS = DPNM
      IF (M .NE. 0)  GO TO 115
      PMS = 0.
      P = PS
      DP = DPS*S/2.
      GO TO 120
  115 PMS = PS*M
      P = PS*S
      DP = DPS*S*S/2. + C*PMS
  120 CONTINUE
```

```
C     PRINT TERMS OF SERIES
      IF (IPRT .EQ. 0)  RETURN
      PRINT 125,  M,FN,CONST,COLAT,P,DP,PMS,J
  125 FORMAT (/1X,I5,F10.5,E20.12,F10.2,3F25.14,I5)
      IF (IPRT .LT. 0)  RETURN
      IF (IPRT .EQ. 2)  GO TO 135
      PRINT 130, (AM(I),I=1,J)
  130 FORMAT (1X,16E8.1)
      IF (IPRT .EQ. 1)  RETURN
  135 PRINT 130, (BM(I),I=1,J)

      RETURN
      END
      SUBROUTINE FNM (KMAX,IBASIS,FN,CONST,COLAT)
C
C  PROGRAMMED BY G.V. HAINES
C
C     READ PARAMETER FILE AND PUT DEGREE AND NORMALIZING CONSTANT
C     INTO ARRAYS FN AND CONST.
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION    FN(0:KMAX,0:KMAX), CONST(0:KMAX,0:KMAX)
      CHARACTER*4  IZERO

      IT = 80
      OPEN (UNIT=IT,FILE='SCPARMS.DAT',STATUS='OLD')

      READ (IT,40,END=190)  KM,MM,THETA,IB
   40 FORMAT (2I3,F9.4,I5)
      PRINT 50,  KM,MM,IB,THETA,KMAX,IBASIS
   50 FORMAT (/26H     KM    MM    IB     THETA,6X,4HKMAX,4X,6HIBASIS/
     *         1X,3I5,F10.2,2I10)
      IF (IBASIS .GT. IB)  GO TO 195
      IF (KMAX .GT. KM)  GO TO 195
      IF (MM .NE. KM)  GO TO 195
      COLAT = THETA

  100 READ  (IT,110,END=200)  K,M,FFN,CON
  110 FORMAT (2I3,F9.4,E15.6)
      IF (K .LT. 0)  GO TO 200
      IF (M .LT. 0)  GO TO 200
      IF (K .GT. KMAX)  GO TO 100
      IF (M .GT. K)  GO TO 100
      FN(K,M) = FFN
      CONST(K,M) = CON
      GO TO 100

  190 PRINT 191,  IT
  191 FORMAT (27H0*ERROR* NO FN DATA ON TAPE,I3)
  195 IFLAG = 1
      GO TO 350

  200 IFLAG = 0
```

```
      IVAR = 0
      PRINT 205
  205 FORMAT (6H0    K, 4X,1HM, 8X,7HFN(K,M), 10X,10HCONST(K,M))
      DO 220 K=0,KMAX
      DO 220 M=0,K
      IF (IBASIS .EQ. 2)  GO TO 210
      KMM = K-M
      IF ((KMM/2)*2 .NE. KMM)  GO TO 220
  210 IZERO = ' '
      IF (K .NE. 0)  GO TO 212
      IF (M .NE. 0)  GO TO 212
      IF (FN(K,M) .EQ. 0.)  GO TO 214
      GO TO 213
  212 IF (FN(K,M) .NE. 0.)  GO TO 214
  213 IZERO = ' ***'
      IFLAG = 1
  214 PRINT 215,  K,M,FN(K,M),CONST(K,M),IZERO
  215 FORMAT (1X,2I5,F15.5,E20.7,1X,A4)
  220 CONTINUE

  350 CLOSE (UNIT=IT,STATUS='KEEP')
      IF (IFLAG .EQ. 1)  STOP
      RETURN

      END
      SUBROUTINE GEOCENF (GDLAT,GDALT,X,Z,GCLAT,R,BN,BV)
C
C  PROGRAMMED BY G.V. HAINES
C
C     CONVERT FROM GEODETIC LATITUDE GDLAT, GEODETIC ALTITUDE GDALT
C             TO GEOCENTRIC LATITUDE GCLAT, GEOCENTRIC RADIAL DISTANCE R;
C     AND FROM GEODETIC NORTH AND VERTICAL DOWNWARD COMPONENTS X,Z
C         TO GEOCENTRIC NORTH AND VERTICAL DOWNWARD COMPONENTS BN,BV.
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C     CLARKE 1866 ELLIPSOID
      DATA  A/6378.2064/, ESQ/.00676872049824/

      SLAT = SIND(GDLAT)
      CLAT = COSD(GDLAT)
      FN = A/SQRT(1.-ESQ*SLAT**2)
      FNPH = FN + GDALT
      WC = FNPH*CLAT
      ZC = (FNPH-ESQ*FN)*SLAT
      R = SQRT(WC**2+ZC**2)
      IF (WC .LT. ABS(ZC)) THEN
          GCLAT = ACOSD(WC/R)
          IF (ZC .LT .0.) GCLAT=-GCLAT
      ELSE
          GCLAT = ASIND(ZC/R)
          END IF
      D = GDLAT - GCLAT
      SD = SIND(D)
```

```
      CD = COSD(D)
      BN = X*CD - Z*SD
      BV = X*SD + Z*CD
      RETURN

C     CONVERT BACK FROM GEOCENTRIC BN,BV TO GEODETIC X,Z.
C     THIS CALL MUST FOLLOW A CALL TO GEOCENF.

      ENTRY GEOCINV
      X = BN*CD + BV*SD
      Z = BV*CD - BN*SD
      RETURN

      END
      SUBROUTINE SPHNEWF (FLAT1,FLON1,X1,Y1,FLAT2,FLON2,X2,Y2)
C
CPROGRAMMED BY G.V. HAINES
C
C     SUBROUTINE FOR TRANSFORMING GEOGRAPHIC COORDINATES (FLAT1,FLON1)
C     TO SPHERICAL COORDINATES (FLAT2,FLON2) ABOUT A NEW POLE (FLAT0,FLON0).
C     FIELD COMPONENTS GEOGRAPHIC NORTH X1 AND EAST Y1 ARE ROTATED TO
C     NORTH X2 AND EAST Y2 IN THE NEW COORDINATE SYSTEM.
C     FLON2 = 0  IS THE MERIDIAN THROUGH THE SOUTH GEOGRAPHIC POLE.
C     ENTER NEW POLE BY CALLING EITHER SPHINF OR SPHITF.
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DATA   FLAT0/90./

      REAL*8 DFLAT0,DFLAT1,DFLAT2,FLOND1,
     *       SIN0,COS0,SIN1,COS1,SIND1,COSD1,SIN2,COS2,SLON2,PROD

      IF (FLAT0 .LT. 90.)  GO TO 100
      FLAT2 = FLAT1
      FLON2 = FLON1
      GO TO 105
  100 IF (FLAT0 .GT. -90.)  GO TO 101
      FLAT2 = -FLAT1
      FLON2 = -FLON1
      GO TO 107

  101 IF (FLAT1 .LT. 90.)  GO TO 102
  131 FLAT2 = FLAT0
      FLON2 = 180.
      ANG = FLON0-FLON1+180.
      GO TO 103
  102 IF (FLAT1 .GT. -90.)  GO TO 104
  132 FLAT2 = -FLAT0
      FLON2 = 0.
      ANG = FLON1-FLON0
  103 COSROT = COSD(ANG)
      SINROT = SIND(ANG)
      GO TO 225
  104 DFLAT1 = FLAT1
```

```
    SIN1 = SIND(DFLAT1)
    COS1 = COSD(DFLAT1)
    IF (COS1 .NE. 0.)  GO TO 133
    IF (SIN1 .GT. 0.)  GO TO 131
    GO TO 132
133 FLOND1 = FLON1 - FLONO
    COSD1 = COSD(FLOND1)
    SIN2 = SIN0*SIN1 + COS0*COS1*COSD1
    IF (SIN2 .LT. 1.)  GO TO 106
108 FLAT2 = 90.
    FLON2 = 0.
105 X2 = X1
    Y2 = Y1
    COSROT = 1.
    SINROT = 0.
    RETURN
106 IF (SIN2 .GT. -1.)  GO TO 110
109 FLAT2 = -90.
    FLON2 = 0.
107 X2 = -X1
    Y2 = -Y1
    COSROT = -1.
    SINROT =  0.
    RETURN
110 DFLAT2 = ASIND(SIN2)
    FLAT2 = DFLAT2
    COS2 = COSD(DFLAT2)
    IF (COS2 .NE. 0.)  GO TO 111
    IF (SIN2 .GT. 0.)  GO TO 108
    GO TO 109

111 PROD = SIN0*SIN2
    SIND1 = SIND(FLOND1)
    IF (SIN1 .NE. PROD)  GO TO 120
    IF (SIND1 .GT. 0.)  GO TO 115
112 FLON2 = -90.
    SLON2 = -1.
    GO TO 200
115 FLON2 =  90.
    SLON2 = 1.
    GO TO 200
120 SLON2 = (SIND1*COS1)/COS2
    IF (SLON2 .LE. -1.)  GO TO 112
    IF (SLON2 .GE.  1.)  GO TO 115
    IF (SIN1 .LT. PROD)  GO TO 125
    FLON2 = 180. - ASIND(SLON2)
    IF (FLON2 .GT. 180.)  FLON2 = FLON2 - 360.
    GO TO 200
125 FLON2 = ASIND(SLON2)

200 COSROT = (SIN0-SIN1*SIN2)/COS1/COS2
    SINROT = COS0*SLON2/COS1
```

```
  225 X2 = X1*COSROT - Y1*SINROT
      Y2 = X1*SINROT + Y1*COSROT
      RETURN

C     TRANSFORM BACK FROM ROTATED COMPONENTS X2,Y2
C                    TO GEOGRAPHIC COMPONENTS X1,Y1.

      ENTRY SPHOLDF
      X1 = X2*COSROT + Y2*SINROT
      Y1 = Y2*COSROT - X2*SINROT
      RETURN

C     INPUT NEW POLE POSITION FLATO,FLONO IN GEOGRAPHIC COORDINATES.
C     RETURN FLATO,FLONO AS FLAT1,FLON1.

      ENTRY SPHINF
      READ 10,  FLATO,FLONO                                          INPUT
   10 FORMAT (2F10.0)
      FLAT1 = FLATO
      FLON1 = FLONO
      GO TO 20

C     DEFINE NEW POLE POSITION THROUGH CALL PARAMETERS FLAT1,FLON1.

      ENTRY SPHITF
      FLATO = FLAT1
      FLONO = FLON1
   20 PRINT 30, FLATO,FLONO
   30 FORMAT (1HO, 5X,5HFLATO, 5X,5HFLONO / 1X,2F10.3)
      DFLATO = FLATO
      SINO = SIND(DFLATO)
      COSO = COSD(DFLATO)
      RETURN

      END
      SUBROUTINE SUMPRD (IBO,NP1,N,X,SUM,S,IENTER)
C
C  PROGRAMMED BY G.V. HAINES
C
C     CALCULATE SUMS (IF NECESSARY) AND SUMS OF SQUARES AND PRODUCTS.
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      DIMENSION  X(NP1), SUM(NP1), S(NP1,NP1)

      IF (IENTER .GT. 0)  GO TO 20
      IENTER=3
      N=0
      DO 11 I=1,NP1
      IF (IBO .NE. 0)  SUM(I) = 0.
      DO 11 J=I,NP1
   11 S(I,J)=0.

   20 N=N+1
```

```
      DO 21 I=1,NP1
      IF (IBO .NE. 0)  SUM(I) = SUM(I) + X(I)
      DO 21 J=I,NP1
   21 S(I,J)=S(I,J)+X(I)*X(J)

      RETURN
      END
```

PLUS SUBROUTINE FIELD (SEE LISTING, APPENDIX 5)
PLUS SUBROUTINE STEPPREG (SEE LISTING, APPENDIX 4)

SCHFIT.COM

```
$ SET DEFAULT [NEWITT.CGRF]
$ SUBMIT/NOPRINT/QUE=SYS$BATCH SCH
$ EXIT
```

SCH.COM

```
$ SET DEFAULT [NEWITT.CGRF]
$ FOR SCHFIT
$ LINK SCHFIT+[NEWITT]GVHLIB/LIB
$ DEL SCHFIT.OBJ;*
$ PURGE SCHFIT.*
$ DEL SCHFIT.LIS;*
$ DEL SCHFIT.MAP;*
$ RUN SCHFIT
$ EXIT
```

APPENDIX 8

SCHCOEFEXT.K7L3

```
  65.00   -85.00  30.00  6371.2   66.3333
   1    1    0    2    7    3    0   -1
 _ 0  0   0.0000   0.100000E+01   0.268404E+02                  -0.142244E+03                 -0.442117E+03
-0.308998E+03
I  1  0   4.0837   0.100000E+01   0.960523E+01                   0.184598E+02                 -0.643388E+02
-0.641302E+02
I  1  1   3.1196   0.253621E+01   0.219587E+02   0.111030E+02  -0.112914E+02  -0.203122E+02   0.000000E+00  -
0.493076E+02   0.181875E+02  -0.212082E+02
I  2  0   6.8354   0.100000E+01  -0.414485E+01                  -0.148746E+02                 -0.208055E+02
-0.162946E+02
I  2  1   6.8354   0.517746E+01  -0.971624E+01  -0.127619E+02   0.000000E+00  -0.324656E+01   0.000000E+00  -
0.133601E+02   0.165207E+01  -0.989256E+01
I  2  2   5.4928   0.612537E+01   0.473610E+01   0.942993E+01   0.000000E+00  -0.117191E+02  -0.590835E+01
0.000000E+00   0.000000E+00   0.127498E+02
I  3  0  10.0385   0.100000E+01   0.978475E+00                   0.313967E+01                  0.000000E+00
0.000000E+00
I  3  1   9.7121   0.721601E+01   0.855792E+01   0.122161E+02   0.000000E+00   0.000000E+00  -0.106881E+02
0.000000E+00  -0.104511E+02   0.000000E+00
I  3  2   9.3733   0.170110E+02   0.000000E+00  -0.813834E+01   0.000000E+00   0.483311E+01   0.000000E+00  -
0.661285E+01  -0.453442E+00  -0.927481E+01
I  3  3   7.7524   0.154891E+02  -0.625423E+01   0.249914E+01  -0.591778E+01   0.486209E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00
I  4  0  12.9083   0.100000E+01   0.000000E+00                   0.000000E+00                  0.144852E+01
0.000000E+00
I  4  1  12.9083   0.947928E+01  -0.516444E+01  -0.971079E+01   0.000000E+00   0.000000E+00   0.963486E+00
0.000000E+00   0.000000E+00   0.000000E+00
I  4  2  12.3720   0.290691E+02   0.000000E+00   0.828054E+01   0.000000E+00  -0.252301E+01   0.000000E+00
  000000E+00   0.000000E+00   0.163629E+01
I  4  3  11.8074   0.533354E+02   0.406698E+01  -0.126872E+01   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.431256E+01   0.000000E+00
I  4  4   9.9589   0.398615E+02  -0.455324E+00   0.922098E+00   0.118901E+01   0.000000E+00   0.000000E+00  -
0.671208E+00   0.000000E+00   0.000000E+00
I  5  1  15.8215   0.115415E+02   0.250077E+01   0.637557E+01   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00
I  5  2  15.6154   0.456895E+02   0.000000E+00  -0.623934E+01   0.000000E+00   0.000000E+00   0.115898E+01
0.000000E+00   0.183531E+01   0.000000E+00
I  5  3  14.9180   0.105995E+03  -0.349516E+01   0.783622E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00  -0.347940E+01   0.000000E+00
I  5  4  14.1778   0.162625E+03   0.823525E+00  -0.152547E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00
I  6  1  18.9364   0.137460E+02  -0.748042E+00  -0.285713E+01   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00
I  6  2  18.5830   0.641554E+02   0.000000E+00   0.331527E+01   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00
I  6  3  18.2219   0.190927E+03   0.214317E+01  -0.314845E+00   0.000000E+00   0.000000E+00  -0.182973E+01
0.000000E+00   0.000000E+00   0.000000E+00
I  6  4  17.3910   0.364976E+03  -0.628234E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00
I  6  5  16.5041   0.486587E+03   0.000000E+00   0.890605E-01   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00
I  6  6  14.2861   0.270001E+03   0.000000E+00  -0.136600E+00   0.260827E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00  -0.702578E+00
```

```
I  7  1  21.8702   0.158221E+02   0.000000E+00   0.862735E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00
I  7  2  21.7210   0.870680E+02   0.000000E+00  -0.101984E+01   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00
I  7  3  21.2461   0.300181E+03  -0.825800E+00   0.000000E+00  -0.488031E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00
I  7  4  20.7588   0.734755E+03   0.327272E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00
  -1 -1
```

APPENDIX 9

SVPLOT.FOR

```
      PROGRAM SVPLOT
C     PROGRAM FOR COMPUTING ANNUAL DIFFERENCES FOR SECULAR CHANGE
C     FROM OBSERVATORY MEAN ANNUAL VALUES, AND PLOTTING.
C
C  ORIGINAL PROGRAM BY G.V. HAINES
C  VERSION USED BY L. NEWITT IN PRODUCTION OF CGRF 1987.5
C
C  PROGRAM PRODUCES FIRST DIFFERENCES OF OBSERVATORY ANNUAL MEAN
C  VALUES AND REPEAT STATION DATA;  THESE VALUES GO INOT SCHFIT
C  TO PRODUCE A SCH MODEL OF THE SV OVER CANADA
C
C*************************************************************************
C
C  THIS VERSION OF THE PROGRAM IS RUN TO PRODUCE SECULAR VARIATION
C  PLOTS FROM A GIVEN SCHA MODEL
C
C*************************************************************************
C
C     PFN=SECVAR    CY=3    ID=GVH    SN=GMSM
      PARAMETER  (NDIM=40)
      DIMENSION  XP(NDIM), YP(NDIM), ZP(NDIM), TP(NDIM)
      DIMENSION  XF(NDIM), YF(NDIM), ZF(NDIM), TF(NDIM)
      CHARACTER*12 ID1, IDL1
      CHARACTER*1 ID2, IDL2
      CHARACTER*10 YTITLE
      CHARACTER*1 INTEQX,INTEQY,INTEQZ
C
      OPEN(UNIT=1,FILE='[NEWITT]OBSREP1.DAT',STATUS='OLD')
C      OPEN(UNIT=2,FILE='FIRSTDIFEXT.DAT',FORM='UNFORMATTED',
C     *STATUS='NEW')
C      OPEN(UNIT=6,FILE='OUTPUT.DAT',STATUS='NEW')
C

      CAPLAT = 60.
      TMIN = 1960.
      TMAX = 1991.
C     PUT IPLOT =  0 IF NO PLOT WANTED
C                  1 IF A PLOT IS WANTED
      IPLOT = 1
C     PUT ICODE =  -1 FOR XSIZE=57,YSIZE=33   (CAL 960)
C                  -2 TO -24 FOR XSIZE=ABS(ICODE)*50,YSIZE=34
C                 -26 TO -50 FOR XSIZE=ABS(ICODE+25)*50,YSIZE=11
      ICODE = -30
      IT1 = 1
      IT2 = 2
      FLATL = 99.
      EOF=0
      PRINT 301
301   FORMAT(1H0,'ENTER NUMBERS OF FIRST AND LAST PONTS TO BE PLOTTED--
     *->')
      READ(*,*)NSTART,NFINISH
```

```
      NREC = 0
      PRINT 1
      WRITE(6,1)
    1 FORMAT (1H1)
      L=0
C      CALL SCHNEV(DUM,DUM,DUM,DUM,L,FLATO,FLONO,DUM)
      L=1
      FLATO=65.
      FLONO=-85.
      CALL SPHITF(FLATO,FLONO,DUM,DUM,DUM,DUM,DUM,DUM)                INPUT
      ALT=0.
      LL=1
      NMAX=10
C      CALL FIELD(FLATO,FLONO,ALT,0.,NMAX,LL,XT,YT,ZT)
      PRINT 210
      WRITE(6,210)
      ALT = 0.
      N = 0
      IF (IPLOT .EQ. 0)  GO TO 200
      TSCALE =  1.27*4.
      YSCALE =  25.4*4.
      TDIV = 10.
      ITDIV = 10
      NCHART = 12
      YDIV = 100.
      IYDIV = 2
      YTITLE = ' '
      NCHARY = 1
      NINC = 1
      ISLC = -1
      INTEQX = 'X'
      INTEQY = 'Y'
      INTEQZ = 'Z'
      SIZE = .07
      TBREAK = 1.
CT    JTDIV = IFIX(TDIV)
      JYDIV = IFIX(YDIV)
      I = 0
      DO 20 T=TMIN,TMAX
      I = I + 1
   20 TF(I) = T
      CALL OPNPLT(2,10.56,0)
  200 READ (IT1,205,END=216) ID1,ID2,FLAT,FLON,YR,X,Y,Z
  205 FORMAT (A12,A1,7X,2F10.3,4F10.1)
      NREC=NREC+1
C     REPEAT STATION DATA HAVE  9  AS 3RD CHARACTER OF ID2
      IF(NREC.GT.NFINISH)GO TO 216
      IF(NREC.LT.NSTART)GO TO 200
      GO TO 220
  216 EOF=1
  217 IF (N .EQ. 0)GO TO 222
      IF (N .LT. 0)  GO TO 900
```

```
C     IF (FLATR .LT. CAPLAT)  GO TO 221
CT    TMIN = (IFIX(TMIN)/JTDIV)*TDIV
CT    TMAX = TMAX + TDIV
CT    TMAX = (IFIX(TMAX)/JTDIV)*TDIV
      I = 0
      DO 250 T=TMIN,TMAX
      I = I+1
      TM=T/30.
      CALL SCHNEV (FLATR,FLONR,R,TM,L,BN,BE,ZF(I))
      PRINT 444, FLAT,FLON,FLATR,FLONR,R,T,L,BN,BE,ZF(I)
444   FORMAT(6F9.3,I5,3F8.1)
      CALL SPHOLDF(DUM,DUM,XF(I),YF(I),DUM,DUM,BN,BE)
      YMIN = MIN(XF(I),YF(I),ZF(I),YMIN)
  250 YMAX = MAX(XF(I),YF(I),ZF(I),YMAX)
      IF (YMIN .LT. 0.)  YMIN = YMIN - YDIV
      YMIN = (IFIX(YMIN)/JYDIV)*YDIV
      IF (YMAX .GT. 0.)  YMAX = YMAX + YDIV
      YMAX = (IFIX(YMAX)/JYDIV)*YDIV
      ICOL = 2
      CALL STPLOTS (TP,XP,N,TMIN,TMAX,TSCALE,YMIN,YMAX,YSCALE,
     *     TDIV,ITDIV,IDL1,NCHART,YDIV,IYDIV,YTITLE,NCHARY,
     *     NINC,ISLC,INTEQX,SIZE,ICOL,TBREAK,ICODE)
      ICODE = 0
      CALL STPLOTS (TF,XF,I,TMIN,TMAX,TSCALE,YMIN,YMAX,YSCALE,
     *     TDIV,ITDIV,IDL1,NCHART,YDIV,IYDIV,YTITLE,NCHARY,
     *     NINC,0,INTEQX,SIZE,ICOL,TBREAK,ICODE)
      ICODE = 0
      ICOL = 4
      CALL STPLOTS (TP,YP,N,TMIN,TMAX,TSCALE,YMIN,YMAX,YSCALE,
     *     TDIV,ITDIV,IDL1,NCHART,YDIV,IYDIV,YTITLE,NCHARY,
     *     NINC,ISLC,INTEQY,SIZE,ICOL,TBREAK,ICODE)
      ICODE = 0
      CALL STPLOTS (TF,YF,I,TMIN,TMAX,TSCALE,YMIN,YMAX,YSCALE,
     *     TDIV,ITDIV,IDL1,NCHART,YDIV,IYDIV,YTITLE,NCHARY,
     *     NINC,0,INTEQX,SIZE,ICOL,TBREAK,ICODE)
      ICODE = 0
      ICOL = 3
      CALL STPLOTS (TP,ZP,N,TMIN,TMAX,TSCALE,YMIN,YMAX,YSCALE,
     *     TDIV,ITDIV,IDL1,NCHART,YDIV,IYDIV,YTITLE,NCHARY,
     *     NINC,ISLC,INTEQZ,SIZE,ICOL,TBREAK,ICODE)
      ICODE = 0
      CALL STPLOTS (TF,ZF,I,TMIN,TMAX,TSCALE,YMIN,YMAX,YSCALE,
     *     TDIV,ITDIV,IDL1,NCHART,YDIV,IYDIV,YTITLE,NCHARY,
     *     NINC,0,INTEQX,SIZE,ICOL,TBREAK,ICODE)
  221 N = 0
  222 IF (EOF .NE. 0.)  GO TO 900
      IDL1 = ID1
      IDL2 = ID2
      FLATL = FLAT
      FLONL = FLON
C     CONVERT GEODETIC LATITUDE,ALTITUDE TO GEOCENTRIC LATITUDE,RADIUS
      CALL GEOCENF (FLAT,ALT,DUM,DUM,GCLAT,R,DUM,DUM)
```

```
      PRINT 210, ID1,FLAT,FLON,ALT,GCLAT,R
      WRITE(6,210)ID1,FLAT,FLON,ALT,GCLAT,R
  210 FORMAT (1H0,A12,F8.3,F9.3,F8.1,F8.3,F8.1)
      DT = 0.
      IF (IPLOT .EQ. 0)  GO TO 218
CT    TMIN =  9999.
CT    TMAX =     0.
      YMIN =  9999.
      YMAX = -9999.
  218 PRINT 225, YR,X,Y,Z,DT
      WRITE(6,225)YR,X,Y,Z,DT
  219 YRL = YR
      XL = X
      YL = Y
      ZL = Z
      GO TO 200
  220 IF (FLAT .NE. FLATL)  GO TO 217
      IF (FLON .NE. FLONL)  GO TO 217
      DT = YR-YRL
C     IF (DT .NE. 1.)  GO TO 218
C     IF (YR-IFIX(YR) .NE. .5)  GO TO 218
      T = (YR+YRL)/2.
      DX = (X-XL)/DT
      DY = (Y-YL)/DT
      DZ = (Z-ZL)/DT
      CALL GEOCENF (FLAT,ALT,DX,DZ,GCLAT,R,DN,DV)
C     ROTATE SPHERICAL COORDINATE SYSTEM:
      CALL SPHNEWF (GCLAT,FLON,DN,DY,FLATR,FLONR,DNR,DYR)
      IF (IPLOT .EQ. 0)  GO TO 224
      IF (N .GE. NDIM)  GO TO 224
      N = N + 1
      XP(N) = DN
      YP(N) = DY
      ZP(N) = DV
      TP(N) = T
CT    TMIN = MIN(T,TMIN)
CT    TMAX = MAX(T,TMAX)
      YMIN = MIN(XP(N),YP(N),ZP(N),YMIN)
      YMAX = MAX(XP(N),YP(N),ZP(N),YMAX)
224   CONTINUE
C
C DELETE THE FOLLOWING GO TO STATEMENT IF  OUTPUT FILE DESIRED
C
      GO TO 219
c
      PRINT 225, YR,X,Y,Z,DT,T,DX,DY,DZ,DN,DV,FLATR,FLONR,DNR,DYR
      WRITE(6,225)YR,X,Y,Z,DT,T,DX,DY,DZ,DN,DV,FLATR,FLONR,DNR,DYR
  225 FORMAT (1X,4F8.1,F5.1,4F8.1,4X,2F8.1,4X,F8.3,F9.3,2F8.1)
      IF (FLATR .GE. CAPLAT)  GO TO 230
      PRINT 227
      WRITE(6,227)
  227 FORMAT (1H+,126X,5H  OUT)
```

```
  230 CONTINUE
      WRITE (IT2)  ID1,ID2,T,FLAT,FLON,ALT,GCLAT,R,DX,DY,DZ
     *            ,DN,DV,FLATR,FLONR,DNR,DYR,DT
c
c  the following code was inserted to copy the 1988 obseratory first
c  difference values through to 1992
c
      if(id2.ne.'9'.and.t.ge.1988..and.t.le.1992.)then
      t=t+1
      go to 224
      endif
      GO TO 219

  900 PRINT 905, NREC
      WRITE(6,905)NREC
  905 FORMAT (//7H NREC =, I5)
      IF (IPLOT .EQ. 0)  GO TO 999
      ICODE = 999
      CALL STPLOTS (TP,ZP,N,TMIN,TMAX,TSCALE,YMIN,YMAX,YSCALE,
     *     TDIV,ITDIV,IDL1,NCHART,YDIV,IYDIV,YTITLE,NCHARY,
     *     NINC,ISLC,INTEQZ,SIZE,ICOL,TBREAK,ICODE)
      CALL ENDPLT
  999 STOP
      END


     PLUS SUBROUTINE AXIS2 (SEE LISTING, APPENDIX 6)
     PLUS SUBROUTINE STPLOTS (SEE LISTING, APPENDIX 6)
     PLUS SUBROUTINE SCHNEV (SEE LISTING, APPENDIX 6)
     PLUS SUBROUTINE FIELD (SEE LISTING, APPENDIX 5)
```

APPENDIX 10

SCHE.FOR
SCHE.COM
SCHE2.COM

```
      PROGRAM SCHE

C     SPHERICAL CAP HARMONIC EXPANSION AT INTERVALS OF LAT, LONG, ALT.
C     ALSO GRID INTERVALS IN INCHES USING INVERSE LAMBERT ROUTINE
C     USED TO GRID VALUES BEFORE PLOTTING MAPS FROM CGRF
C  ORINGINAL PROGRAM BY G.V. HAINES
C  THIS VERSION USED BY L. NEWITT FOR CGRF1987.5
C

C     SUBPROGRAMS USED:  GEOCENF, SPHNEWF, SCHNEV, FIELD.
      DIMENSION AX(60,60), AY(60,60), AZ(60,60)
      DIMENSION AD(60,60), AI(60,60), AH(60,60), AF(60,60)
      PRINT 1
    1 FORMAT (14H1PROGRAM  SCHE)
      OPEN(UNIT=2,FILE='GRIDVAL.X',STATUS='NEW')
      OPEN(UNIT=3,FILE='GRIDVAL.Y',STATUS='NEW')
      OPEN(UNIT=4,FILE='GRIDVAL.Z',STATUS='NEW')
      OPEN(UNIT=6,FILE='OUTPUT.DAT',STATUS='NEW')
c      OPEN(UNIT=7,FILE='GRIDVAL.D',STATUS='NEW')
c      OPEN(UNIT=8,FILE='GRIDVAL.I',STATUS='NEW')
C      OPEN(UNIT=9,FILE='GRIDVAL.H',STATUS='NEW')
C      OPEN(UNIT=10,FILE='GRIDVAL.F',STATUS='NEW')
c      OPEN(UNIT=10,FILE='GRIDVALIA.DAT',STATUS='NEW')
      FMAX=-999999.
      FMIN=999999.
C     INPUT PARAMETER AND COEFFICIENT FILE
      CALL SCHNEV (DUM,DUM,DUM,DUM,0,FLATO,FLONO,THETA)                 COEFFS

C     DEFINE SPHERICAL CAP POLE
      CALL SPHITF (FLATO,FLONO,DUM,DUM,DUM,DUM,DUM,DUM)

      IREF=0
C     PUT IREF .EQ. 0 IF NO REFERENCE FIELD IS TO BE ADDED.
C     PUT IREF .NE. 0 IF ONE IS TO BE ADDED.
      PRINT 4,  IREF
    4 FORMAT (/7X,4HIREF/1X,I10)

      IF (IREF .EQ. 0)  GO TO 7
c      READ (*,5,END=99)  TF,NMAX                                        INPUT
    5 FORMAT (F10.2,I5)
      NMAX=10
      TF=1990.
      PRINT 6,  TF,NMAX
    6 FORMAT (/9X,2HTF,6X,4HNMAX/1X,F10.2,I10)
C     INPUT COEFFICIENTS OF GLOBAL REFERENCE FIELD
      LF = 1
      RE = 6371.2
      CALL FIELD (DUM,DUM,DUM,TF,NMAX,LF,DUM,DUM,DUM)
    7 CONTINUE
C   7 READ (*,10,END=99) FLAT1,FLAT2,DLAT,FLON1,FLON2,DLON,
C     *          ALT1,ALT2,DALT,IGRAT                                   INPUT
```

```
C   10 FORMAT(9F6.0,I5)
C
C  FOR BOTTOM THIRD OF CHART
C
C      YN1=-22.
C      YN2=-13.
C
C  FOR MIDDLE THIRD OF CHART
C
C      YN1=-16.
C      YN2=-7.
c      yn1=-12.
c      yn2=-5.
C
C  FOR TOP THIRD OF CHART
C
c     YN1=-9.
C      YN2=0.
c      yn1=-8.
c      yn2=-3.
C
C  FOR WHOLE MAP SHEET
C
      YN1=-22.
      YN2=0.
      DELE=1.
c      DELE=0.5
c      DELN=0.5
      DELN=1.
c      DELE=0.25
c      DELN=0.25
c      dele=0.1
c      deln=0.1
      XE1=-12.
      XE2=13.
c      IIIMAX=(XE2-XE1)*2.+1
c      JJJMAX=(YN2-YN1)*2.+1
c      IIIMAX=(XE2-XE1)*4.+1
c      JJJMAX=(YN2-YN1)*4.+1
c      iiimax=(xe2-xe1)*10.+1
c      jjjmax=(yn2-yn1)*10.+1
      IIIMAX=XE2-XE1+1
      JJJMAX=YN2-YN1+1
      III=1
      JJJ=1
      ALT1=0.
      ALT2=0.
      DALT=0.
      IGRAT=0
      CM=-92.
      SCAL=10000000.
      PARL1=49.
```

```
      PARL2=77.
      SEMMAJ=251110488.
      SEMMIN=250259197.
      CALL LAMBIT(CM,SCAL,SEMMAJ,SEMMIN,PARL1,PARL2,CUT)

C     PUT IGRAT .EQ. 0 FOR COMPUTATIONS AT LAT=FLAT1,FLAT2,DLAT
C                      AND LONG=FLON1,FLON2,DLON.
C               .NE. 0 FOR COMPUTATIONS AT LAT=FLAT1,FLAT2,DLAT
C                      AND LONG=FLON1,FLON2,DLAT/COS(LAT).

      IF (DELN .LE. 0.)  THEN
          YN2 = YN1
          DELN = 0.5
          IF (IGRAT .NE. 0)  XE2 = XE1
          END IF
      IF (DELE.LE.0. .AND. IGRAT.EQ.0)  THEN
          XE2 = XE1
          DELE = 1.
          END IF
      IF (DALT .LE. 0.)  THEN
          ALT2 = ALT1
          DALT = 1.
          END IF
      PRINT 15, YN1,YN2,DELN,XE1,XE2,DELE,ALT1,ALT2,DALT,IGRAT
   15 FORMAT (1H1,5X,5HFLAT1,5X,5HFLAT2,6X,4HDLAT,5X,5HFLON1,
     *        5X,5HFLON2,6X,4HDLON,6X,4HALT1,6X,4HALT2,6X,4HDALT,
     *        5X,5HIGRAT/1X,9F10.2,I10)
      L=1
      ICEN=1
      IDHF=1
C
      ICHANGE=0
      DELT=0.
      TM=1990.
      T=TM/30.
C     PUT L .EQ.  1 FOR INTERNAL POTENTIAL FIELD,
C           .EQ.  2 FOR EXTERNAL POTENTIAL FIELD,
C           .GE.  3 FOR BOTH INTERNAL AND EXTERNAL POTENTIAL FIELDS.
C           .EQ.  0 FOR GEOCENTRIC INTERNAL POTENTIAL FIELD.
C           .LE. -1 FOR GENERAL FUNCTION AND TWO SURFACE DERIVATIVES.
C     PUT ICEN .NE. 0  FOR GEODETIC COMPONENTS ON GEODETIC LAT-LONG-ALT GRID.
C              .EQ. 0  FOR GEOCENTRIC COMPONENTS ON GEOCENTRIC LAT-LONG-R GRID.
C     PUT IDHF .NE. 0  TO COMPUTE I,D,H,F
C              .EQ. 0  FOR NO I,D,H,F
C     PUT ICHANGE .EQ. 0 FOR FIELD VALUES AT TIME T.
C                 .NE. 0 FOR AVERAGE SECULAR CHANGE PER UNIT TIME
C                        FROM TIME T TO TIME T+DELT.

      IF (L .LE. 0)  ICEN = 0                                         NOTE
      IF (L .LT. 0)  IDHF = 0                                         NOTE
      IF (DELT .EQ. 0.)  ICHANGE = 0
      PRINT 14,  L,ICEN,IDHF,ICHANGE,T,DELT
```

```
   14 FORMAT (/10X,1HL,6X,4HICEN,6X,4HIDHF,3X,7HICHANGE,
     *         9X,1HT,6X,4HDELT/ 1X,4I10,2F10.2)
      LINE = 1
      NREC = 0

      ALT = ALT1
      GO TO 18
   17 ALT = ALT + DALT
      IF (ALT .GT. ALT2)  GO TO 7
      PRINT 81
      LINE = LINE + 1

   18 YN = YN1
      JJJ=1
      GO TO 25
   20 YN = YN + DELN
C      IF (YN .GT. YN2)  GO TO 17
      JJJ=JJJ+1
      IF(YN.GT.YN2)GO TO 99
      PRINT 81
      LINE = LINE + 1

   25 XE = XE1
      III=1
      IF (IGRAT .EQ. 0)  GO TO 35
C      CFLAT = COSD(FLAT)
C      IF (CFLAT .NE. 0.)  GO TO 58
C      DLON = 720.
C      GO TO 35
C   58 DLON = DLAT/CFLAT
C      GO TO 35
   30 XE = XE + DELE
      IF (XE .GT. XE2)  GO TO 20
      III=III+1

   35 IF (ICEN .EQ. 0)  GO TO 36
      CALL LAMBINV(XE,YN,FLAT,FLON,DUM,DUM,DUM)
C     CONVERT FROM GEODETIC TO GEOCENTRIC COORDINATES
      CALL GEOCENF (FLAT,ALT,DUM,DUM,GCFLAT,R,DUM,DUM)
      GO TO 37
   36 GCFLAT = FLAT
      R = ALT

C     CONVERT SPHERICAL TO SPHERICAL CAP COORDINATE SYSTEM
   37 CALL SPHNEWF (GCFLAT,FLON,DUM,DUM,SCFLAT,SCFLON,DUM,DUM)

C     COMPUTE SPHERICAL CAP HARMONIC FIELD
      CALL SCHNEV (SCFLAT,SCFLON,R,T,L,BNSC,BESC,BV)
c      PRINT 444, SCFLAT,SCFLON,R,T,L,BNSC,BESC,Bv
444   FORMAT(1H ,2F10.3,2F10.1,I3,3F12.1)

C     ROTATE S.C. COORDINATES BACK TO SPHERICAL COORDINATES
```

```
      CALL SPHOLDF (DUM,DUM,BN,Y,DUM,DUM,BNSC,BESC)

      IF (IREF .EQ. 0)  GO TO 40
C     ADD GLOBAL REFERENCE FIELD TO S.C. RESIDUAL FIELD.
      CALL FIELD (GCFLAT,FLON,R-RE,TF,NMAX,LF,XREF,YREF,ZREF)
      BN = BN + XREF
      Y = Y + YREF
      BV = BV + ZREF
   40 IF (ICEN .EQ. 0) GO TO 42
C     CONVERT CEOCENTRIC COORDINATES BACK TO GEODETIC
      CALL GEOCINV (DUM,DUM,X,Z,DUM,DUM,BN,BV)
      GO TO 44
   42 X = BN
      Z = BV
   44 CONTINUE

      IF (IDHF .EQ. 0) GO TO 50
      HSQ = X**2 + Y**2
      H = SQRT(HSQ)
      D = 0.
      IF (H .NE. 0.)  D=ATAN2D(Y,X)
c  convert to D east for plotting north of pole
C      if(d.lt.0.)d=d+360.
      F  = SQRT(HSQ +Z**2)
      FI = 90.
      IF (H .NE. 0.)  FI = ATAND(Z/H)

   50 IF (ICHANGE .EQ. 0)  GO TO 78
      CALL SCHNEV (SCFLAT,SCFLON,R,T+DELT/30.,L,BNSC2,BESC2,BV2)
      CALL SPHOLDF (DUM,DUM,BN2,Y2,DUM,DUM,BNSC2,BESC2)
      IF (IREF .EQ.0)  GO TO 77
      BN2 = BN2 + XREF
      Y2 = Y2 + YREF
      BV2 = BV2 + ZREF
   77 IF (ICEN .EQ. 0)  GO TO 52
      CALL GEOCINV (DUM,DUM,X2,Z2,DUM,DUM,BN2,BV2)
      GO TO 54
   52 X2 = BN2
      Z2 = BV2
   54 X = (X2-X)/DELT
      Y = (Y2-Y)/DELT
      Z = (Z2-Z)/DELT

      IF (IDHF .EQ. 0)  GO TO 78
      H2SQ = X2**2 + Y2**2
      H2 = SQRT(H2SQ)
      H = (H2-H)/DELT
      D2 = 0.
      IF (H2 .NE. 0.)  D2=ATAN2D(Y2,X2)
      D = D2 - D
      IF (D .GT. 180.)  D=D-360.
      IF (D .LT. -180.)  D = D+360.
```

```
      D = D*60./DELT
      FI2 = 90.
      IF (H2 .NE. 0.)  FI2 = ATAND(Z2/H2)
      FI = (FI2-FI)*60./DELT
C     D AND I SECULAR CHANGE ARE IN MINUTES OF ARC PER UNIT TIME.
      F2 = SQRT(H2SQ+Z2**2)
      F = (F2 - F)/DELT

   78 IF (LINE .LT. 0)  GO TO 60
      PRINT 80
   80 FORMAT (1H1,4X,3HALT,4X,3HLAT,4X,4HLONG,7X,1HX,7X,1HY,7X,1HZ)
      LINE = -57
      IF (IDHF .EQ. 0)  GO TO 83
      PRINT 82
   82 FORMAT (1H+,53X,1HD,7X,1HI,7X,1HH,7X,1HF)
   83 PRINT 81
      GO TO 90
   60 LINE = LINE + 1

   90 WRITE(6,81)  XE,YN,ALT,FLAT,FLON,X,Y,Z,D,FI,H,Z,F
   81 FORMAT (1X,2F8.3,F7.1,F7.2,F8.2,3F8.0,2F10.2,3F8.0)
c      WRITE(10,*)XE,YN,FI
      AX(III,JJJ)=X
      AY(III,JJJ)=Y
      AZ(III,JJJ)=Z
      AD(III,JJJ)=D
      AI(III,JJJ)=FI
      AH(III,JJJ)=H
      AF(III,JJJ)=F
      NREC = NREC + 1
      IF (IDHF .EQ. 0)  GO TO 30
c      PRINT 84, D,FI,H,F
   84 FORMAT (1H+,46X,2F8.2,2F8.0)
      GO TO 30
 99   CONTINUE
c      WRITE(10,443)
443   FORMAT('DSAA',/,'51 45',/,'-12 13',/,'-22 0')
c      WRITE(10,445)FMIN,FMAX
445   FORMAT(2F13.6)
      WRITE(2,*)((AX(III,JJJ),JJJ=1,JJJMAX),III=1,IIIMAX)
      WRITE(3,*)((AY(III,JJJ),JJJ=1,JJJMAX),III=1,IIIMAX)
      WRITE(4,*)((AZ(III,JJJ),JJJ=1,JJJMAX),III=1,IIIMAX)
c      WRITE(7,*)((AD(III,JJJ),JJJ=1,JJJMAX),III=1,IIIMAX)
c      WRITE(8,*)((AI(III,JJJ),JJJ=1,JJJMAX),III=1,IIIMAX)
C      WRITE(9,*)((AH(III,JJJ),JJJ=1,JJJMAX),III=1,IIIMAX)
C      WRITE(10,*)((AF(III,JJJ),JJJ=1,JJJMAX),III=1,IIIMAX)
C      WRITE(10,446)((AF(III,JJJ),III=1,IIIMAX),JJJ=1,JJJMAX)
446   FORMAT(5(10F12.5,/),F12.5,/,' ')
      STOP
      END
      SUBROUTINE FIELD (DLAT,DLONG,ALT,TM,NMAX,L,BN,BE,BV)
```

```
C     GEOMAGNETIC FIELD COMPONENTS X,Y,Z, IN GAMMAS.
C     USES ANY SET OF COEFFICIENTS.
C     L POSITIVE READS A NEW SET OF COEFFICIENTS.
C
C***************************************************************************
C  MODIFIED TO CALCULATE VALUES INTERPOLATING BETWEEN DGRF MODELS
C  FROM 1945 TO 1985
C  VALUES FROM 1985 TO 1990 ARE CALCULATED USING IGRF TIME TERMS
C***************************************************************************

      PARAMETER  (ND=11)                                                DEGREE10
      DIMENSION P(ND,ND),G(ND,ND,9),H(ND,ND,9),DP(ND,ND),CONST(ND,ND),
     *   SP(ND),CP(ND),SHMIT(ND,ND),GT(ND,ND),HT(ND,ND),
     *   GTT(ND,ND),HTT(ND,ND),TG(ND,ND),TH(ND,ND),FM(ND),FN(ND)
      DIMENSION  AID(4), GGNM(9), HHNM(9)
      DATA  P(1,1)/0./

      IF (P(1,1) .EQ. 1.)  GO TO 9
      P(1,1)=1.
      IT = 75                                                           TAPE 75
      NDIM = ND
      DP(1,1)=0.
      SP(1)=0.
      CP(1)=1.
      RAD=57.295779513
      SHMIT(1,1)=-1.
      FM(1) = 0.
      DO 20 N=2,NDIM
      SHMIT(N,1)=SHMIT(N-1,1)*FLOAT (2*N-3)/FLOAT (N-1)
      FN(N)=N
      FM(N) = N - 1
      J=2
      DO 20 M=2,N
      SHMIT(N,M)=SHMIT(N,M-1)*SQRT (FLOAT ((N-M+1)*J)/FLOAT (N+M-2))
   20 J=1
      DO 4 N=3,NDIM
      NM2 = N-2
      DO 4 M=1,NM2
    4 CONST(N,M)=FLOAT ((N-2)**2-(M-1)**2)/FLOAT ((2*N-3)*(2*N-5))

    9 IF (L .EQ. 0)  GO TO 15
      IF (L .LT. 0)  GO TO 33
C  FOR GEODETIC COORDINATES
C       OPEN(UNIT=IT,FILE='[NEWITT.MIRP]IGRF85.GD',STATUS='OLD')
C  FOR GEOCENTRIC COORDINATES
      OPEN(UNIT=IT,FILE='IGRF4585.BYYEAR',STATUS='OLD')
      READ (IT,27) J,K,TZERO,RE,A,FLAT,(AID(I),I=1,4)                   TAPE 75
   27 FORMAT (2I1,F8.2,3F10.3,4A10)

C        J       - ZERO IF COEFFICIENTS ARE FOR OBLATE EARTH
C                - NON-ZERO IF COEFFICIENTS ARE FOR SPHERICAL EARTH.
C        K       - ZERO IF COEFFICIENTS ARE SCHMIDT NORMALIZED
```

```
C                 - NON-ZERO IF GAUSS NORMALIZED.
C        TZERO    - EPOCH YEAR OF COEFFICIENTS.
C        RE       - RADIUS OF EQUIVALENT SPHERICAL EARTH USED IN DERIVING
C                   THE COEFFICIENTS.
C        A        - SEMI-MAJOR AXIS OF GEODETIC ELLIPSOID.
C        FLAT     - FLATTENING OF ELLIPSOID.
C        AID      - IDENTIFICATION (MAXIMUM 40 CHARACTERS)

C       PRINT 28, (AID(I),I=1,4),J,K,TZERO,RE,A,FLAT
   28 FORMAT (32HOSPHERICAL HARMONIC COEFFICIENTS,9X,4A10/
     *   4X,1HJ,3X,1HK,7X,5HTZERO,10X,2HRE,11X,1HA,8X,4HFLAT/
     *   1X,2I4,F12.2,3F12.3/4X,1HN,3X,1HM,9X,3HGNM,9X,3HHNM,
     *   8X,4HGTNM,8X,4HHTNM,7X,5HGTTNM,7X,5HHTTNM)
      MAXN=0
      TEMP=0.
      IF (J .NE. 0)  GO TO 25
      FLAT= 1.-1./FLAT
      A2=A**2
      A4=A**4
      B2=(A*FLAT)**2
      A2B2=A2*(1.-FLAT**2)
      A4B4=A4*(1.-FLAT**4)
   25 READ (IT,2)  N,M,((GGNM(I),HHNM(I)),I=1,9),GTNM,HTNM              TAPE 75
    2 FORMAT (2I5,20F10.1)
      IF (N .LE. 0)     GO TO 3
      IF (N .LT. NDIM)  GO TO 7
C      PRINT 6,     N,M,GNM,HNM,GTNM,HTNM,GTTNM,HTTNM
    6 FORMAT (1H ,2I4,6F12.4,10X, 8HNOT USED)
      GO TO 25
    7 N=N+1
      M=M+1
      MAXN=  MAX0 (N,MAXN)
      DO 47 JK=1,9
      G(N,M,JK)=GGNM(JK)
47    H(N,M,JK)=HHNM(JK)
      GT(N,M)=GTNM
      HT(N,M)=HTNM
      TEMP=AMAX1(TEMP,ABS (GTNM))
      GO TO 25
    3 CONTINUE
C      PRINT 24,    ((FM(N),FM(M),((G(N,M,I),H(N,M,I)),I=1,9),
C     +GT(N,M),HT(N,M),  M=1,N),N=2,MAXN)
   24 FORMAT (1H ,2F3.0,10F9.1,/,1H ,6X,10F9.1)
      IF (NMAX .LT. MAXN)  GO TO 17
      MAXNM1 = MAXN-1
C      PRINT 35,     NMAX,MAXNM1
   35 FORMAT(6H NMAX=, I2,6H MAXN=, I2,8H ERROR**   )
      STOP
   17 IF (TEMP .NE. 0)  GO TO 29
      L = -L
      GO TO 30
   29 L=0
```

```
   30 IF (K .NE. 0)  GO TO 16
      DO 32 N=2,MAXN
      DO 32 M=1,N
      DO 232 KK=1,9
      G(N,M,KK)=G(N,M,KK)*SHMIT(N,M)
      H(N,M,KK)=H(N,M,KK) *SHMIT(N,M)
232   CONTINUE
      GT(N,M)=GT(N,M)*SHMIT(N,M)
  32  HT(N,M)=HT(N,M)*SHMIT(N,M)
   15 IF (TM .EQ. TLAST)  GO TO 33
   16 T=TM-TZERO
      IF(TM.GE.TZERO)THEN
      DO 22 N=2,MAXN
      DO 22 M=1,N
      TG(N,M)=G(N,M,9)+T *GT(N,M)
      TH(N,M)=H(N,M,9)+T *HT(N,M)
22    CONTINUE
      ELSE
      KT=T/5
      DELT=(T-KT*5.)/5.
      KKT=KT+9
      DO 222 N=2,MAXN
      DO 222 M=1,N
      TG(N,M)=G(N,M,KKT)+DELT*(G(N,M,KKT)-G(N,M,KKT-1))
222   TH(N,M)=H(N,M,KKT)+DELT*(H(N,M,KKT)-H(N,M,KKT-1))
      ENDIF
      TLAST=TM

   33 RLAT=DLAT/RAD
      SINLA=SIN (RLAT)
      RLONG=DLONG/RAD
      CP(2)=COS (RLONG)
      SP(2)=SIN (RLONG)
      NMAXP1=NMAX+1
      DO 10 M=3,NMAXP1
      SP(M)=SP(2)*CP(M-1)+CP(2)*SP(M-1)
   10 CP(M)=CP(2)*CP(M-1)-SP(2)*SP(M-1)
      IF (J .EQ. 0)  GO TO 59
      R = RE + ALT
C      R = ALT
      CT=SINLA
      GO TO 21
   59 SINLA2=SINLA*SINLA
      DEN2=A2-A2B2*SINLA2
      DEN=SQRT (DEN2)
      COSLA = SQRT(1.-SINLA2)
      IF (COSLA .NE. 0.)  GO TO 18
      THETA = 90./RAD
      IF (SINLA .LT. 0.)  THETA = -THETA
      GO TO 19
   18 ALTDEN = ALT*DEN
      THETA = ATAN((ALTDEN+B2)/(ALTDEN+A2)*SINLA/COSLA)
```

```
   19 R=SQRT (ALT*(ALT+2.*DEN)+(A4-A4B4*SINLA2)/DEN2)
      CT=SIN (THETA)
   21 STST = 1. - CT**2
      ST = SQRT(STST)
      CTST = CT*ST
      AOR = RE/R
      AR=AOR*AOR
      BN=0.
      BE=0.
      BV=0.
      DO 54 N=2,NMAXP1
      SUMN=0.
      SUME=0.
      SUMV=0.
      AR=AOR*AR
      IF (N .GE. 3)  GO TO 60
      P(2,2) = 1.
      DP(2,2) = CT
      GO TO 61
   60  P(N,N) = ST* P(N-1,N-1)
      DP(N,N) = ST*DP(N-1,N-1) +  CTST*P(N-1,N-1)
   61 FACT = ST
      DO 45 M=1,N
      TEMP = TG(N,M)*CP(M) + TH(N,M)*SP(M)
      IF (M .EQ. 2)  FACT = STST
      IF (M .LE. N-2)  GO TO 12
      IF (N .EQ. M)  GO TO 13
       P(N,M) = CT* P(N-1,M)
      DP(N,M) = CT*DP(N-1,M) - FACT*P(N-1,M)
      GO TO 13
   12  P(N,M) = CT* P(N-1,M) - CONST(N,M)* P(N-2,M)
      DP(N,M) = CT*DP(N-1,M) - CONST(N,M)*DP(N-2,M) - FACT*P(N-1,M)
   13 SUMN = SUMN - DP(N,M)*TEMP
      IF (M .EQ. 1)  GO TO 45
      SUME = SUME + P(N,M)*FM(M)*(-TG(N,M)*SP(M)+TH(N,M)*CP(M))
      TEMP = TEMP*ST
   45 SUMV = SUMV + P(N,M)*TEMP
      BN = BN + SUMN*AR
      BE = BE + SUME*AR
   54 BV = BV + SUMV*AR*FN(N)
      IF (J .NE. 0)  GO TO 23
C      TRANSFORMS FIELD TO GEODETIC DIRECTIONS
      SIND=SIN (RLAT-THETA  )
      COSD=SQRT (1.0-SIND*SIND)
      TN=BN
      BN=BN*COSD+BV*SIND
      BV=BV*COSD-TN*SIND
   23 RETURN
      END
```

PLUS SUBROUTINE SCHNEV (LISTED IN APPENDIX 6)

PLUS SUBROUTINE LEGFUN (LISTED IN APPENDIX 7)

SCHE.COM

```
$ SET DEFAULT [NEWITT.CGRF]
$ SUBMIT/NOPRINT/QUE=SYS$BATCH/RESTART SCHE2
$ EXIT
```

SCHE2.COM

```
$ SET DEF [NEWITT.CGRF]
$ RUN SCHE
$ EXIT
```

APPENDIX 11

CONTOURSV.COM

```
$run contour
outp CONTOUR.pf
file [NEWITT.CGRF]GRIDVAL.Z
read 26 23 0
titl \dup\ ZSV 1990
ytit \ita\ Longitude
xtit \ita\ Latitude
axes -12 +13 -22 0
height 7.72
width 8.78
level -200 -190 -180 -170 -160 -150 -140 -130 -120 -110 -100 -90 -80 -70 -60
-50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
170 180 190 200
plot
d
10.5
stop
```

APPENDIX 12

MAINSV.FOR

```
      PROGRAM MAINSV

C     PFN=SCFIT   CY=3   ID=GVH   SN=GMSM

C     MERGE MAIN FIELD AND SECULAR VARIATION COEFFICIENTS.
C
C  PROGRAMMED BY G.V. HAINES
C  USED BY L. NEWITT IN PRODUCTION OF CGRF1987.5
C
C     IN THIS INSTANCE THE PROGRAM WAS ONLY USED TO INTEGRATE THE SV
C     COEFFICIENTS; MERGECO WAS USED TO ACTUALLY MERGE THE FILES
C

      PARAMETER  (KMAX=16,KT1=4)
      DIMENSION  GKM(0:KT1), HKM(0:KT1)
      DIMENSION  G(0:KMAX,0:KMAX,0:KT1), H(0:KMAX,0:KMAX,0:KT1)
      DIMENSION  FN(0:KMAX,0:KMAX), CONST(0:KMAX,0:KMAX)
      CHARACTER*1, A
      EQUIVALENCE  (THETA,THETA1),(IB,IB1),(RE,RE1),(TZERO,TZERO1)

      IT1 = 1
      IT2 = 2
      IT3 = 3
C     OPEN(UNIT=1,FILE='',STATUS='OLD')
      OPEN(UNIT=2,FILE='SCHCOEFEXT.K7L3',STATUS='OLD')
      OPEN(UNIT=3,FILE='SVCOEFINT90.K7L3',STATUS='NEW',RECL=182)
      DO 333 K=1,KMAX
      DO 333 M=1,KMAX
      G(K,M,0)=0.
333   H(K,M,0)=0.
      GO TO 275
      PRINT 1
    1 FORMAT (1H1)
      READ  (IT1,240) FLATO1,FLONO1,THETA1,RE1,TZERO1
      READ (IT1,241)IFIT1,ICEN1,IRE1,IB1,KINT1,LINT1,KEXT1,LEXT1
  240 FORMAT (F8.2,F9.2,F7.2,F8.1,F10.4)
  241 FORMAT(8I5)
      PRINT 245,     FLATO1,FLATO2,THETA1,RE1,TZERO1
  245 FORMAT (1X,F8.2,F9.2,F7.2,F8.1,F10.4)
  246 FORMAT(1H ,8I5)

  247 READ  (IT1,250) A,K,M,FNN,CON,GKM(0),HKM(0)
  250 FORMAT (1X,A1,2I3,F9.4,E15.6,8E15.6)
      IF (K .LT. 0)  GO TO 275
      PRINT 255, K,M,FNN,CON,GKM(0),HKM(0)
  255 FORMAT (1X,A1,2I3,F9.4,E15.6,10F12.4)
      IF (K .GT. MAXK1)  GO TO 247
      FN(K,M) = FNN
      CONST(K,M) = CON
      G(K,M,0) = GKM(0)
      H(K,M,0) = HKM(0)
      KMAXM = MAX(K,KMAXM)
      GO TO 247
```

```
  275 PRINT 1
      READ  (IT2,240) FLATO2,FLONO2,THETA2,RE2,TZERO2
      READ (IT2,241)IFIT2,ICEN2,IRE2,IB2,KINT2,LINT2,KEXT2,LEXT2
      PRINT 245,       FLATO2,FLONO2,THETA2,RE2,TZERO2
      PRINT 246, IFIT2,ICEN2,IRE2,IB2,KINT2,LINT2,KEXT2,LEXT2
C      IF (THETA1 .NE. THETA2)  STOP
C      IF (RE1 .NE. RE2)  STOP
C      IF (TZERO1 .NE. TZERO2)  STOP
  400 KINT=MAX(KINT1,KINT2)
      KEXT=MAX(KEXT1,KEXT2)
      LINT=LINT2+1
      LEXT=LEXT2+1
      PRINT 1
      IF (IB .EQ. 1)  NP = ((MAXK+1)*(MAXK+2))/2
      IF (IB .EQ. 2)  NP = (MAXK+1)**2
      ND = NP*(KT1+1) + 1
      PRINT 245
      WRITE (IT3,240) FLATO2,FLONO2,THETA2,RE2,TZERO2
      WRITE(IT3,241)IFIT2,ICEN2,IREF2,IB2,KINT,LINT,KEXT,LEXT
      PRINT 245,      FLATO2,FLONO2,THETA2,RE2,TZERO2
      PRINT 246,IFIT2,ICEN2,IREF2,IB2,KINT,LINT,KEXT,LEXT

  280 READ  (IT2,250) A, K,M,FNN,CON,(GKM(J),HKM(J),J=1,KT1)
      IF (K .LT. 0)  GO TO 410
      PRINT 255, A,K,M,FNN,CON,(GKM(J),HKM(J),J=1,KT1)
      IF (K .GT. KINT2)  GO TO 280
      FN(K,M) = FNN
      CONST(K,M) = CON
  290 DO 295 J=1,KT1
      G(K,M,J) = GKM(J)/J*30.
  295 H(K,M,J) = HKM(J)/J*30.
      KMAXSV = MAX(K,KMAXSV)
  407 WRITE (IT3,450)A,K,M,FN(K,M),CONST(K,M),(G(K,M,J),H(K,M,J),
     +J=0,KT1)
  450 FORMAT (1X,A1,2I3,F9.4,E15.6,10E15.6)
c      PRINT 255,    A,K,M,FN(K,M),CONST(K,M),(G(K,M,J),H(K,M,J),J=0,KT1)
      GO TO 280
  410 CONTINUE

      K = -1
      M = -1
      WRITE (IT3,260)  K,M
260   FORMAT(2X,2I3)

      STOP
      END
```

APPENDIX 13

UPDATE.FOR

```
      PROGRAM UPDATE
C
C     PROGRAM UPDATES AIRBORNE OR SATELITE DATA TO EPOCH
C     IN PREPARATION FOR SCH MODELLING
C
C  USED BY L. NEWITT IN PRODUCTION OF CGRF 1987.5
C
C      OPEN(UNIT=1,FILE='MAGAIR.DAT',STATUS='OLD')
C      open(unit=2,file='magairup7',status='new')
      OPEN(UNIT=1,FILE='MAGSAT.DAT',STATUS='OLD')
      open(unit=2,file='magsat.up7',status='new')
      YEARUP=1990.
      YRUPDIV=YEARUP/30.
      L=0
      CALL SCHNEV(DUM,DUM,DUM,DUM,L,FLATO,FLONO,THETA)
      CALL SPHITF(FLATO,FLONO,DUM,DUM,DUM,DUM,DUM,DUM)
      L=1
10    CONTINUE
C  READ FOR AEROMAG DATA
C      READ(1,101,END=999)I,J,YR,FLAT,FLON,DUM,DUM,ALT,DUM,
C     +X,DUM,Y,DUM,Z,DUM,K
C  READ FOR MAGSAT DATA
      READ(1,111,END=999)IPASS,IDAY,IHR,IMIN,ISEC,GCLAT,FLON,R,
     &F,X,Y,Z,FRES,XRES,YRES,ZRES,FRESQ,XRESQ,YRESQ,ZRESQ
101   FORMAT(2I3,5F10.3,8F8.1,I5,3X)
111   FORMAT(5I5,3F10.3,12F8.1,9X)
C  THE FOLLOWING STATEMENTS ARE FOR MAGSAT DATA ONLY
      IF(IDAY.GT.200)THEN
      YR=1979.+(IDAY/365.)
      ELSE
      YR=1980.+(IDAY/366.)
      ENDIF
      YRDIV=YR/30.
C COMMENT OUT THE FOLLOWING STATEMENT FOR MAGSAT DATA
C      CALL GEOCENF(FLAT,ALT,DUM,DUM,GCLAT,R,DUM,DUM)
      CALL SPHNEWF(GCLAT,FLON,DUM,DUM,SCFLAT,SCFLON,DUM,DUM)
      IF(SCFLAT.LT.60.)GO TO 10
      CALL SCHNEV(SCFLAT,SCFLON,R,YRUPDIV,L,FX,FY,FZ)
      CALL SCHNEV(SCFLAT,SCFLON,R,YRDIV,L,BN,BE,BV)
      PRINT 122,GCLAT,R,SCFLAT,SCFLON,FX,FY,FZ,BN,BE,BV
122   FORMAT(4F10.3,6F8.1)
      BN=FX-BN
      BE=FY-BE
      BV=FZ-BV
C  USE THE FOLLOWING TWO STATEMENTS FOR AEROMAG DATA
C      CALL SPHOLDF(DUM,DUM,BX,FY,DUM,DUM,BN,BE)
C      CALL GEOCINV(DUM,DUM,FX,FZ,DUM,DUM,BX,BV)
C  USE THE FOLLOWING TWO STATEMENTS FOR MAGSAT DATA
      CALL SPHOLDF(DUM,DUM,FX,FY,DUM,DUM,BN,BE)
      FZ=BV
      XUP=X+FX
      YUP=Y+FY
```

```
      ZUP=Z+FZ
C  WRITE STATEMENT FOR AEROMAG DATA
C       WRITE(2,102)FLAT,FLON,YR,ALT,X,Y,Z,YEARUP,XUP,YUP,ZUP,
C      +FX,FY,FZ
C  WRITE STATEMENT FOR MAGSAT DATA
      WRITE(2,102)GCLAT,FLON,YR,R,X,Y,Z,YEARUP,XUP,YUP,ZUP,
     &FX,FY,FZ
102   FORMAT(2F10.3,F8.1,F8.3,10F8.1)
      PRINT 103,FLAT,FLON,YR,ALT,X,Y,Z
      PRINT 103,YEARUP,FX,FY,FZ,XUP,YUP,ZUP
103   FORMAT(1H ,7F10.1)
      GO TO 10
999   STOP
      END
```

PLUS SUBROUTINE SCHNEV (SEE LISTING APPENDIX 6)

APPENDIX 14

UPDATE.FOR

```
      PROGRAM UPDATE
C
C     PROGRAM UPDATES AIRBORNE OR SATELITE DATA TO EPOCH
C     IN PREPARATION FOR SCH MODELLING
C
C  USED BY L. NEWITT IN PRODUCTION OF CGRF 1987.5
C
      OPEN(UNIT=1,FILE='MAGAIR.DAT',STATUS='OLD')
      open(unit=2,file='magairup7',status='new')
c      OPEN(UNIT=1,FILE='MAGSAT.DAT',STATUS='OLD')
c      open(unit=2,file='magsat.up7',status='new')
      YEARUP=1990.
      YRUPDIV=YEARUP/30.
      L=0
      CALL SCHNEV(DUM,DUM,DUM,DUM,L,FLATO,FLONO,THETA)
      CALL SPHITF(FLATO,FLONO,DUM,DUM,DUM,DUM,DUM,DUM)
      L=1
10    CONTINUE
C  READ FOR AEROMAG DATA
      READ(1,101,END=999)I,J,YR,FLAT,FLON,DUM,DUM,ALT,DUM,
     +X,DUM,Y,DUM,Z,DUM,K
c  READ FOR MAGSAT DATA
c      READ(1,111,END=999)IPASS,IDAY,IHR,IMIN,ISEC,GCLAT,FLON,R,
c     &F,X,Y,Z,FRES,XRES,YRES,ZRES,FRESQ,XRESQ,YRESQ,ZRESQ
101   FORMAT(2I3,5F10.3,8F8.1,I5,3X)
111   FORMAT(5I5,3F10.3,12F8.1,9X)
C  THE FOLLOWING STATEMENTS ARE FOR MAGSAT DATA ONLY
c      IF(IDAY.GT.200)THEN
c      YR=1979.+(IDAY/365.)
c      ELSE
c      YR=1980.+(IDAY/366.)
c      ENDIF
      YRDIV=YR/30.
C COMMENT OUT THE FOLLOWING STATEMENT FOR MAGSAT DATA
      CALL GEOCENF(FLAT,ALT,DUM,DUM,GCLAT,R,DUM,DUM)
      CALL SPHNEWF(GCLAT,FLON,DUM,DUM,SCFLAT,SCFLON,DUM,DUM)
      IF(SCFLAT.LT.60.)GO TO 10
      CALL SCHNEV(SCFLAT,SCFLON,R,YRUPDIV,L,FX,FY,FZ)
      CALL SCHNEV(SCFLAT,SCFLON,R,YRDIV,L,BN,BE,BV)
      PRINT 122,GCLAT,R,SCFLAT,SCFLON,FX,FY,FZ,BN,BE,BV
122   FORMAT(4F10.3,6F8.1)
      BN=FX-BN
      BE=FY-BE
      BV=FZ-BV
C  USE THE FOLLOWING TWO STATEMENTS FOR AEROMAG DATA
      CALL SPHOLDF(DUM,DUM,BX,FY,DUM,DUM,BN,BE)
      CALL GEOCINV(DUM,DUM,FX,FZ,DUM,DUM,BX,BV)
C  USE THE FOLLOWING TWO STATEMENTS FOR MAGSAT DATA
c      CALL SPHOLDF(DUM,DUM,FX,FY,DUM,DUM,BN,BE)
c      FZ=BV
      XUP=X+FX
```

```
      YUP=Y+FY
      ZUP=Z+FZ
C  WRITE STATEMENT FOR AEROMAG DATA
      WRITE(2,102)FLAT,FLON,YR,ALT,X,Y,Z,YEARUP,XUP,YUP,ZUP,
     +FX,FY,FZ
C  WRITE STATEMENT FOR MAGSAT DATA
c      WRITE(2,102)GCLAT,FLON,YR,R,X,Y,Z,YEARUP,XUP,YUP,ZUP,
c     &FX,FY,FZ
102   FORMAT(2F10.3,F8.1,F8.3,10F8.1)
      PRINT 103,FLAT,FLON,YR,ALT,X,Y,Z
      PRINT 103,YEARUP,FX,FY,FZ,XUP,YUP,ZUP
103   FORMAT(1H ,7F10.1)
      GO TO 10
999   STOP
      END
```

PLUS SUBROUTINE SCHNEV (SEE LISTING APPENDIX 6)

APPENDIX 15

RESROT.FOR

```
      PROGRAM RESROT
C
C  REMOVES IGRF FROM UPDATED DATA AND TRANSFORMS TO ROTATED
C  GEOCENTRIC COORDINATES
C
C  USED BY L. NEWITT IN PRODUCTION OF CGRF 1987.5
C
c      open(unit=1,file='magair.up7',status='old')
c      open(unit=2,file='magairup7.resrot',status='new')
      open(unit=1,file='magsat.up7',status='old')
      open(unit=2,file='magsatup7.resrot',status='new')
      L=1
      NMAX=10
      T=1985.
      CALL FIELD(45.4,-75.4,0.,T,NMAX,L,XT,YT,ZT)
      FLATO=65.
      FLONO=-85.
      CALL SPHITF(FLATO,FLONO,DUM,DUM,DUM,DUM,DUM,DUM)
10    CONTINUE
C  READ AEROMAG DATA
c      READ(1,100,END=900)FLAT,FLON,YR,ALT,X,Y,Z,YEARUP,
c     +                   XUP,YUP,ZUP,DELX,DELY,DELZ
C  READ MAGSAT DATA
      READ(1,100,END=900)GCLAT,FLON,YR,R,X,Y,Z,YEARUP,
     +                   XUP,YUP,ZUP,DELX,DELY,DELZ
100   FORMAT(2F10.3,F8.1,F8.3,10F8.1)
C  USE THIS CALL FOR AEROMAG DATA
c      CALL FIELD(FLAT,FLON,ALT,YEARUP,NMAX,L,XIGRF,YIGRF,ZIGRF)
C  USE THIS CALL FOR MAGSAT DATA - MUST CHANGE HEADER ON COEFFICIENTS
      CALL FIELD(GCLAT,FLON,R,YEARUP,NMAX,L,XIGRF,YIGRF,ZIGRF)
      PRINT 555, XIGRF,YIGRF,ZIGRF
555   FORMAT(1H ,3F12.1)
      XRES=XUP-XIGRF
      YRES=YUP-YIGRF
      ZRES=ZUP-ZIGRF
C  COMMENT OUT THIS STATEMENT FOR MAGSAT DATA
c      CALL GEOCENF(FLAT,ALT,XRES,ZRES,GCLAT,R,XRESGC,ZRESGC)
C  INSERT THESE TWO STATEMENTS FOR MAGSAT DATA
      XRESGC=XRES
      ZRESGC=ZRES
      CALL SPHNEWF(GCLAT,FLON,XRESGC,YRES,SCFLAT,SCFLON,
     +             XRESROT,YRESROT)
      WRITE(2,200)SCFLAT,SCFLON,R,XRESROT,YRESROT,ZRESGC,YEARUP,
c     +FLAT,FLON,XUP,YUP,ZUP
     +GCLAT,FLON,XUP,YUP,ZUP
200   FORMAT(3F10.3,4F10.1,2F10.3,3F10.1)
      PRINT 300, FLAT,FLON,ALT,YEARUP,X,Y,Z,SCFLAT,SCFLON,R,
     +           XRESROT,YRESROT,ZRESGC
300   FORMAT(1H ,2F10.3,5F10.1,/,1H ,3F10.3,10X,3F10.1)
      GO TO 10
900   STOP
      END
```

PLUS SUBROUTINE FIELD (SEE LISTING, APPENDIX 5)

APPENDIX 16

RESROT.FOR

```
      PROGRAM RESROT
C
C  REMOVES IGRF FROM UPDATED DATA AND TRANSFORMS TO ROTATED
C  GEOCENTRIC COORDINATES
C
C  USED BY L. NEWITT IN PRODUCTION OF CGRF 1987.5
C
      open(unit=1,file='magair.up7',status='old')
      open(unit=2,file='magairup7.resrot',status='new')
C      open(unit=1,file='magsat.up7',status='old')
C      open(unit=2,file='magsatup7.resrot',status='new')
      L=1
      NMAX=10
      T=1985.
      CALL FIELD(45.4,-75.4,0.,T,NMAX,L,XT,YT,ZT)
      FLAT0=65.
      FLON0=-85.
      CALL SPHITF(FLAT0,FLON0,DUM,DUM,DUM,DUM,DUM,DUM)
10    CONTINUE
C  READ AEROMAG DATA
      READ(1,100,END=900)FLAT,FLON,YR,ALT,X,Y,Z,YEARUP,
     +                    XUP,YUP,ZUP,DELX,DELY,DELZ
C  READ MAGSAT DATA
C      READ(1,100,END=900)GCLAT,FLON,YR,R,X,Y,Z,YEARUP,
C     +                    XUP,YUP,ZUP,DELX,DELY,DELZ
100   FORMAT(2F10.3,F8.1,F8.3,10F8.1)
C  USE THIS CALL FOR AEROMAG DATA
      CALL FIELD(FLAT,FLON,ALT,YEARUP,NMAX,L,XIGRF,YIGRF,ZIGRF)
C  USE THIS CALL FOR MAGSAT DATA - MUST CHANGE HEADER ON COEFFICIENTS
C      CALL FIELD(GCLAT,FLON,R,YEARUP,NMAX,L,XIGRF,YIGRF,ZIGRF)
      PRINT 555, XIGRF,YIGRF,ZIGRF
555   FORMAT(1H ,3F12.1)
      XRES=XUP-XIGRF
      YRES=YUP-YIGRF
      ZRES=ZUP-ZIGRF
C  COMMENT OUT THIS STATEMENT FOR MAGSAT DATA
      CALL GEOCENF(FLAT,ALT,XRES,ZRES,GCLAT,R,XRESGC,ZRESGC)
C  INSERT THESE TWO STATEMENTS FOR MAGSAT DATA
C      XRESGC=XRES
C      ZRESGC=ZRES
      CALL SPHNEWF(GCLAT,FLON,XRESGC,YRES,SCFLAT,SCFLON,
     +             XRESROT,YRESROT)
      WRITE(2,200)SCFLAT,SCFLON,R,XRESROT,YRESROT,ZRESGC,YEARUP,
     +FLAT,FLON,XUP,YUP,ZUP
C     +GCLAT,FLON,XUP,YUP,ZUP
200   FORMAT(3F10.3,4F10.1,2F10.3,3F10.1)
      PRINT 300, FLAT,FLON,ALT,YEARUP,X,Y,Z,SCFLAT,SCFLON,R,
     +           XRESROT,YRESROT,ZRESGC
300   FORMAT(1H ,2F10.3,5F10.1,/,1H ,3F10.3,10X,3F10.1)
      GO TO 10
900   STOP
      END
```

PLUS SUBROUTINE FIELD (SEE LISTING, APPENDIX 5)

APPENDIX 17

SCHFIT.FOR

```
      PROGRAM SCHFIT

C     SPHERICAL CAP HARMONIC LEAST SQUARES FIT TO EITHER:
C     (1) POTENTIAL FIELD COMPONENTS NORTH X, EAST Y, VERTICAL DOWN Z; OR
C     (2) A GENERAL FUNCTION Z ON A SPHERICAL CAP SURFACE.
C     IN BOTH CASES, THE COEFFICIENTS ARE POLYNOMIALS IN TIME.
C
C  ORIGINAL PROGRAM BY G.V. HAINES
C  THIS VERSION USED BY L. NEWITT FOR PRODUCTION OF CGRF 1987.5
C
C     SUBPROGRAMS REQUIRED -  FNM, LEGFUN, SUMPRD, STEPREG, SPHNEWF
C             AND POSSIBLY -  GEOCENF, FIELD, PRTRES

      PARAMETER   (IBASIS=2,KINT=16,LINT=0,KEXT=0,LEXT=-1)               SET UP
C      PARAMETER (IBASIS=2,KINT=7,LINT=3,KEXT=0,LEXT=-1)

C     IBASIS = 1  TO USE 1 SET OF BASIS FUNCTIONS (K-M=EVEN)
C                 (FOR FITTING VERTICAL FIELD DATA, OR GENERAL FUNCTION
C                  NOT DIFFERENTIABLE IN LATITUDE)
C              2  TO USE 2 SETS OF BASIS FUNCTIONS
C                 (FOR FITTING THREE-COMPONENT DATA, OR GENERAL FUNCTION
C                  DIFFERENTIABLE IN LATITUDE)
C     KINT  =  MAXIMUM SPATIAL INDEX FOR INTERNAL SOURCES
C     LINT  =  TEMPORAL DEGREE FOR INTERNAL SOURCES
C     KEXT  =  MAXIMUM SPATIAL INDEX FOR EXTERNAL SOURCES
C     LEXT  =  TEMPORAL DEGREE FOR EXTERNAL SOURCES

C     NOTE:    FOR NO INTERNAL SOURCES, PUT KINT=-1,LINT=-1.
C              FOR NO EXTERNAL SOURCES, PUT KEXT= 0,LEXT=-1.

C     EXAMPLE:  FOR MAIN FIELD, INTERNAL SOURCES, PUT LINT=KEXT=0,LEXT=-1.
C     FOR LINEAR TIME TERMS, INTERNAL SOURCES,  PUT LINT=1,KEXT=0,LEXT=-1.
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      REAL*4 A1,A2,A3,A4,A5,A6,A7,A8,A9
      PARAMETER   (KB=2-IBASIS/2)
      PARAMETER   (NDIM=(((KINT+1)*(KINT+KB))/KB)*(LINT+1)
     *            +((KEXT*(KEXT+KB+1))/KB)*(LEXT+1)+1)
      PARAMETER   (KMAX=MAX(KINT,KEXT),KT=MAX(LINT,LEXT))
      DIMENSION   S(NDIM),SS(NDIM,NDIM)
      DIMENSION   XX(NDIM),XY(NDIM),XZ(NDIM)
      DIMENSION   FN(0:KMAX,0:KMAX), CONST(0:KMAX,0:KMAX)
      DIMENSION   CML(KMAX), SML(KMAX)
      DIMENSION   DELT(0:KT)
      DIMENSION   B(NDIM)
      DIMENSION   SIG(NDIM),IVAR(NDIM),BW(NDIM),SB(NDIM),ICBLNK(NDIM)
      CHARACTER*12 ID1
      CHARACTER*1 ID2
      CHARACTER*4 IE
C     EQUIVALENCE ARRAYS TO CONSERVE MEMORY:
      EQUIVALENCE (XX,SIG), (XY,IVAR), (XZ,SB)
```

```
      PRINT  1
    1 FORMAT (1H1)

      IFIT =  1                                                        SET UP
C     PUT IFIT = -1 TO FIT A GENERAL FUNCTION OF LATITUDE AND LONGITUDE.
C                 0 TO FIT GEOCENTRIC VERTICAL POTENTIAL FIELD DATA.
C                 1 TO FIT THREE-COMPONENT POTENTIAL FIELD DATA.
      IF (IFIT .LT. 0)  THEN
         IF (KEXT .NE. 0)  GO TO 999
         IF (LEXT .NE. -1)  GO TO 999
         END IF

      ICEN = 0                                                         SET UP
C     PUT ICEN = 1 TO CONVERT INPUT DATA FROM GEODETIC TO GEOCENTRIC
C                  (INPUT DATA ARE GEODETIC LATITUDE, LONGITUDE, ALTITUDE)
C                0 FOR NO GEODETIC TO GEOCENTRIC CONVERSION
C                  (INPUT DATA ARE GEOCENTRIC LAT, LONG, RADIAL DISTANCE)
      IF (IFIT .LE. 0)  ICEN = 0                                       NOTE

      IREF = 0                                                         SET UP
C     PUT IREF = 1 TO SUBTRACT REFERENCE FIELD FROM INPUT DATA
C                0 FOR NO SUBTRACTION.

      RE = 6371.2
C     PUT RE = REFERENCE RADIUS OF THE SPHERICAL CAP.

C     INPUT SPHERICAL CAP POLE (SUBROUTINE SPHNEWF)
      FLATO=65.
      FLONO=-85.
      CALL SPHITF (FLATO,FLONO,DUM,DUM,DUM,DUM,DUM,DUM)                INPUT
C     TZERO IS 1990.
      TZERO = 66.333333                                                SET UP
C     TIME T, FOR SECULAR VARIATION POLYNOMIAL, WILL BE RELATIVE TO TZERO.
C     TIMES ARE DIVIDED BY 30.0 TO PREVENT NUMERICAL PROBLEMS

      ISUMS = 0                                                        SET UP
C     PUT ISUMS =  0  TO NEITHER PRINT NOR STORE SUMS OF SQUARES AND PRODUCTS
C                  1  TO STORE THEM
C                  2  TO STORE AND PRINT THEM
C                  3  TO PRINT THEM

      IRESID = 0                                                       SET UP
C     PUT IRESID = 1 FOR RESIDUALS TO BE CALCULATED AND PRINTED
C                  0 FOR NO RESIDUALS

      IFILES = 1                                                       SET UP
C     PUT IFILES = NUMBER OF END-OF-FILE RECORDS ON DATA FILE

      IPR = 50                                                         SET UP
C     SET IPR TO NUMBER OF INPUT RECORDS TO BE PRINTED.

C     READ IN PARAMETER FILE (REAL DEGREES, CONSTANTS)
```

```
C     (INPUT TO SUBROUTINE FNM MUST HAVE FN'S UP TO KMAX OR HIGHER)
      CALL FNM (KMAX,IBASIS,FN,CONST,THETA)                              PARAMS
      CAPLAT = 90. - THETA
C     CHANGE CAPLAT IF DATA BEYOND THETA IS TO BE INCLUDED

      IF (IREF .EQ. 0)  GO TO 20
      READ (*,15,END=999)  TF,NF
   15 FORMAT (F10.2,I5)
      PRINT 16,  TF,NF
   16 FORMAT (/9X,2HTF,8X,2HNF/1X,F10.2,I10)
C     INITIALIZE SUBROUTINE FIELD
      LF = 0
      CALL FIELD (DUM,DUM,DUM,TF,NF,LF,DUM,DUM,DUM)
      LF = 1

   20 NP1 = NDIM
      NP  = NDIM-1
      IBO = 0
      IENTER = 0
      NOB = 0
      IT1 = 1
C  SV DATA
C      OPEN (IT1,FILE='FIRSTDIFEXT.DAT',STATUS='OLD',FORM='UNFORMATTED')DATAFILE
C  MAIN FIELD DATA
      OPEN(IT1,FILE='MAGDATA90.RESROT7',STATUS='OLD')
      IF (IRESID .EQ. 0)  GO TO 90
      IT91 = 91
      OPEN (IT91,FILE='SCRES.BIN',STATUS='SCRATCH',FORM='UNFORMATTED')

   90 IFILE  =  1
C     SET DEFAULT FOR ALT AND T, IF NOT IN READ LIST
      IF (ICEN .NE. 0)  ALT = 0.
      IF (ICEN .EQ. 0)  ALT = RE
      T = TZERO
C     READ DATA FILE
C  MAIN FIELD DATA
  100 CONTINUE
101   READ (IT1,111,END=200),FLAT,FLON,ALT,X,Y,Z,DUM,DUM,DUM,DUM,DUM,DUM
111   FORMAT(3F10.3,4F10.1,2F10.3,3F10.1)
C  SV DATA
C  100 READ(IT1,END=200)ID1,ID2,A1,A2,A3,A4,A5,A6,A7,A8,A9
C      T=A1
C      FLAT=A2
C      FLON=A3
C      ALT=A4
C      X=A7
C      Y=A8
C      Z=A9
C      T=T/30.
      IF (ICEN .EQ. 0)  GO TO 60
C     CONVERT FROM GEODETIC TO GEOCENTRIC
      CALL GEOCENF (FLAT,ALT,X,Z,GCLAT,R,BN,BV)
```

```
      GO TO 65
   60 GCLAT = FLAT
      R = ALT
      BN = X
      BV = Z
   65 IF (IREF .EQ. 0)  GO TO 70
C     REMOVE GLOBAL REFERENCE FIELD
      CALL FIELD (GCLAT,FLON,R,TF,NF,LF,BNREF,YREF,BVREF)
      BN = BN - BNREF
      Y = Y - YREF
      BV = BV - BVREF
C     ROTATE SPHERICAL COORDINATE SYSTEM

70    CONTINUE
C
C  MAIN FIELD DATA ARE IN ROTATED GEOCENTRIC COORDINATES
C  COMMENT OUT THE FOLLOWING CALL AND  USE THE FOLLOWING 4 IDENTITIES
C
C      CALL SPHNEWF (GCLAT,FLON,BN,Y,SCLAT,SCLON,SCX,SCY)
C
C  USE THESE FOR MAIN FIELD DATA ONLY
C
      SCLAT=GCLAT
      SCLON=FLON
      SCX=BN
      SCY=Y
C
      IF (IPR .EQ. 0)  GO TO 80
      IF (IPR .LT. 0)  GO TO 75
      IPR = -IPR
      PRINT 103
  103 FORMAT (15H1IDENTIFICATION,5X,4HFLAT,4X,4HFLON,5X,3HALT,
     *        7X,1HX,7X,1HY,7X,1HZ,3X,5HSCLAT,3X,5HSCLON,7X,1HR,
     *        5X,3HSCX,5X,3HSCY,6X,2HBV/)
   75 PRINT 104, T,ID1,
     *           FLAT,FLON,ALT,X,Y,Z,SCLAT,SCLON,R,SCX,SCY,BV
  104 FORMAT (1X,F6.1,1X,A8,1X,3F8.3,3F8.0,2F8.3,F8.1,3F8.1)
      IPR = IPR + 1
   80 CONTINUE
C      IF (SCLAT .LT. CAPLAT)  GO TO 100
      DELT(0) = 1.
      DEL = T - TZERO
      DO 102 I=1,KT
  102 DELT(I) = DELT(I-1)*DEL
      IF (IFIT .GE. 0)  THEN
         AOR = RE/R
         AR = AOR**2
         IF (KEXT .GT. 0)  AOR3 = AOR*AR
      ELSE
         AR = -1.
         END IF
      K = 0
```

```
      IF (KINT .LT. 0)  GO TO 106
      DO 105 I=0,LINT
      ART = AR*DELT(I)
      K = K + 1
      IF (IFIT .LE. 0)  GO TO 105
      XX(K) =  0.
      XY(K) =  0.
  105 XZ(K) =  -ART
  106 COLAT = 90. - SCLAT
      DO 150 N=1,KMAX
      IF (N .GT. 1)  GO TO 115
      CL = COSD(SCLON)
      SL = SIND(SCLON)
      CML(1) = CL
      SML(1) = SL
      GO TO 120
  115 SML(N) = SL*CML(N-1) + CL*SML(N-1)
      CML(N) = CL*CML(N-1) - SL*SML(N-1)
  120 DO 150 M=0,N
      IF (IBASIS .EQ. 2)  GO TO 121
      NMM = N-M
      IF ((NMM/2)*2 .NE. NMM)  GO TO 150
  121 FFN = FN(N,M)
      CALL LEGFUN (M,FFN,CONST(N,M),COLAT,P,DP,PMS,0)
      IF (IFIT .GE. 0)  THEN
         AR = AOR**(FFN+2.)
      ELSE
         AR = 1.
         FFN = -2.
         END IF
      IF (N .GT. KINT)  GO TO 135
      DO 130 I=0,LINT
      IF (M .NE. 0)  GO TO 125
      K = K + 1
      ART = AR*DELT(I)
      XZ(K) = -(FFN+1.)*ART*P
      IF (IFIT .LE. 0)  GO TO 130
      XX(K) =  ART*DP
      XY(K) =  0.
      GO TO 130
  125 K = K + 2
      ART = AR*DELT(I)
      ZT = -(FFN+1.)*ART*P
      XZ(K-1) =  ZT*CML(M)
      XZ(K) =  ZT*SML(M)
      IF (IFIT .LE. 0)  GO TO 130
      XT =  ART*DP
      XX(K-1) =  XT*CML(M)
      XX(K) =  XT*SML(M)
      YT =  ART*PMS
      XY(K-1) =  YT*SML(M)
      XY(K) = -YT*CML(M)
```

```
  130 CONTINUE
  135 IF (N .GT. KEXT)  GO TO 150
      RA = AOR3/AR
      DO 145 I=0,LEXT
      IF (M .NE. 0)  GO TO 140
      K = K + 1
      RAT = RA*DELT(I)
      XZ(K) =  FFN*RAT*P
      IF (IFIT .EQ. 0)  GO TO 145
      XX(K) =  RAT*DP
      XY(K) =  0.
      GO TO 145
  140 K = K + 2
      RAT = RA*DELT(I)
      ZT =  FFN*RAT*P
      XZ(K-1) =  ZT*CML(M)
      XZ(K) =  ZT*SML(M)
      IF (IFIT .EQ. 0)  GO TO 145
      XT =  RAT*DP
      XX(K-1) =  XT*CML(M)
      XX(K) =  XT*SML(M)
      YT =  RAT*PMS
      XY(K-1) =  YT*SML(M)
      XY(K) = -YT*CML(M)
  145 CONTINUE
  150 CONTINUE
      IF (K .NE. NP)  THEN
          PRINT 151,  K,NP
  151     FORMAT (7H0***K =,I5,10X,4HNP =,I5)
          GO TO 999
          END IF
      IF (IFIT .LE. 0)  GO TO 155
      XX(NP1) =  SCX
      CALL SUMPRD (IBO,NP1,NOBS,XX,S,SS,IENTER)
      XY(NP1) =  SCY
      CALL SUMPRD (IBO,NP1,NOBS,XY,S,SS,IENTER)
  155 XZ(NP1) =  BV
      CALL SUMPRD (IBO,NP1,NOBS,XZ,S,SS,IENTER)
      IF (IRESID .EQ. 0)  GO TO 100
C     SAVE VARIABLES TO COMPUTE RESIDUALS IN SUBROUTINE PRTRES.
      ID = T
      IF (IFIT .LE. 0)  GO TO 160
      WRITE (IT91)  ID,ID1,(XX(K),K=1,NP1)
      WRITE (IT91)  ID,ID1,(XY(K),K=1,NP1)
  160 WRITE (IT91)  ID,ID1,(XZ(K),K=1,NP1)
      GO TO 100

C     END OF PROCESSING FILE=IFILE ON TAPE=IT1.
  200 NOB = NOBS - NOB
      PRINT 55
   55 FORMAT (/6X,5HIFILE, 7X,3HNOB, 6X,4HNOBS)
      PRINT 205, IFILE,NOB,NOBS
```

```
  205 FORMAT (1X,3I10)
      NOB = NOBS
      IF (IFILE .GE. IFILES)  GO TO 300
      IFILE = IFILE + 1
C     DUM = EOF(IT1)
      GO TO 100

C     END OF PROCESSING TAPE=IT1.
  300 CLOSE (IT1,STATUS='KEEP')
      IF (NOBS .LE. 0)  GO TO 999
      IF (IRESID .EQ. 0)  GO TO 310
      ENDFILE IT91

C     STORE/PRINT SUMS OF SQUARES AND PRODUCTS MATRIX
  310 IF (ISUMS .LE. 0)  GO TO 320
      IF (ISUMS .GE. 3)  GO TO 315
      IT2 = 2
      OPEN (IT2,FILE='SUMSQUARES.DAT',STATUS='NEW',FORM='UNFORMATTED')
      WRITE (IT2)  NOBS,NP1
      WRITE (IT2)  ((SS(I,J),J=I,NP1),I=1,NP1)
      CLOSE (IT2,STATUS='KEEP')
      IF (ISUMS .EQ. 1)  GO TO 320
  315 PRINT 202
      DO 201 I=1,NP1
  201 PRINT 202,  (SS(I,J),J=I,NP1)
  202 FORMAT (1X,10E13.6)

C     PERFORM STEPWISE REGRESSION.
  320 IBLNK =   1                                                       SET UP
      IORD  =   0                                                       SET UP
      FIN   = 3.0                                                       SET UP
      FOUT  = 3.0                                                       SET UP
      IPRT1 =   0                                                       SET UP
      IPRT2 =  30                                                       SET UP
      IPRTS =   0                                                       SET UP
      ITMAX = 2*NP
      PRINT 1
      CALL STEPREG (IBO,IBLNK,IORD,NOBS,NP1,S,SS,FIN,FOUT,ITMAX,B,
     *              SIG,IVAR,BW,SB,ICBLNK,IPRTS,IPRT1,IPRT2)

C     STORE SPHERICAL CAP HARMONIC COEFFICIENTS
      IT3 = 3
      OPEN (IT3,FILE='SCHCOEFMAIN7.K16',STATUS='NEW',
     *      RECL=32+(MAX(LINT,LEXT)+1)*30)
      WRITE (IT3,245)  FLATO,FLONO,THETA,RE,TZERO
  245 FORMAT (F8.2,F9.2,F7.2,F8.1,F10.4)
      WRITE (IT3,246)  IFIT,ICEN,IREF,IBASIS,KINT,LINT,KEXT,LEXT
  246 FORMAT (8I5)
      PRINT 236,  FLATO,FLONO,THETA,RE,TZERO
  236 FORMAT (1H1,6X,5HFLATO,5X,5HFLONO,5X,5HTHETA,8X,2HRE,5X,5HTZERO/
     *        2X,3F10.2,F10.1,F10.4)
      PRINT 238,  IFIT,ICEN,IREF,IBASIS,KINT,LINT,KEXT,LEXT
```

```
238 FORMAT (/4X,48H  IFIT  ICEN  IREF    IB  KINT  LINT  KEXT  LEXT/
   *        4X,8I6)
    PRINT 242
242 FORMAT (/4X,1HK,3H  M,6X,3HFNN,10X,5HCONST,
   *        <MIN(KT+1,5)>(7X,3HGNM,7X,3HHNM))
    K = 0
    LI = LINT + 1
    LE = LEXT + 1
    DO 270 N=0,KMAX
    IF (IBASIS .EQ. 2)  GO TO 230
    IF ((N/2)*2 .NE. N)  GO TO 260
230 IF (N .GT. KINT)  GO TO 259
    IE = 'I'
    KO = K + 1
    K  = K + LI
    KF = LI
276 DO 247 J=KO,K
247 IF (B(J) .NE. 0.)  GO TO 248
    GO TO 258
248 M = 0
    WRITE (IT3,250) IE,N,M,FN(N,M),CONST(N,M),(B(J),J=KO,K)
250 FORMAT (1X,A1,2I3,F9.4,E15.6,<KF>(E15.6,15X))
    PRINT 255,      IE,N,M,FN(N,M),CONST(N,M),(B(J),J=KO,K)
255 FORMAT (1X,A1,2I3,F9.4,E15.6,F10.3,4F20.3:/(22X,5F20.3))
258 IF (IE .EQ. 'E')  GO TO 260
259 IF (N .GT. KEXT)  GO TO 260
    IF (N .EQ. 0)  GO TO 260
    IE = 'E'
    KO = K + 1
    K  = K + LE
    KF = LE
    GO TO 276
260 DO 270 M=1,N
    IF (IBASIS .EQ. 2)  GO TO 240
    NMM = N - M
    IF ((NMM/2)*2 .NE. NMM)  GO TO 270
240 IF (N .GT. KINT)  GO TO 269
    IE = 'I'
    KO = K + 1
    K  = K + LI + LI
    KF = LI
261 DO 262 J=KO,K
262 IF (B(J) .NE. 0.)  GO TO 265
    GO TO 268
265 WRITE (IT3,280)  IE,N,M,FN(N,M),CONST(N,M),(B(J),J=KO,K)
280 FORMAT (1X,A1,2I3,F9.4,E15.6,<KF>(E15.6,E15.6))
    PRINT 285,       IE,N,M,FN(N,M),CONST(N,M),(B(J),J=KO,K)
285 FORMAT (1X,A1,2I3,F9.4,E15.6,10F10.3:/(32X,10F10.3))
268 IF (IE .EQ. 'E')  GO TO 270
269 IF (N .GT. KEXT)  GO TO 270
    IE = 'E'
    KO = K + 1
```

```
      K  = K + LE + LE
      KF = LE
      GO TO 261
  270 CONTINUE
      WRITE (IT3,255) ' ',-1,-1
      CLOSE (IT3,STATUS='KEEP')

      IF (IRESID .EQ. 0)  GO TO 999
C     COMPUTE AND PRINT SPHERICAL CAP HARMONIC RESIDUALS
      CALL PRTRES (IT91,IBO,NOBS,NP1,XX,B)
      CLOSE (IT91,STATUS='DELETE')

  999 STOP
      END
```

PLUS SUBROUTINE FIELD (SEE LISTING, APPENDIX 5)
PLUS SUBROUTINE LEGFUN (SEE LISTING, APPENDIX 7)
PLUS SUBROUTINE FNM (SEE LISITING, APPENDIX 7)
PLUS SUBROUTINE SPHNEWF (SEE LISTING, APPENDIX 7)
PLUS SUBROUTINE SUMPRD (SEE LISTING, APPENDIX 7)
PLUS SUBROUTINE STEPREG (SEE LISINT, APPENDIX 4)

APPENDIX 18

MERGECO.FOR

```
      PROGRAM MERGECO
C
C  MERGES MAIN FIELD WITH INTEGRATED SV COEFFICIENTS
C  USED BY L. NEWITT IN PRODUCTION OF CGRF 1987.5
C
      DIMENSION FNM(0:16,0:16), CONST(0:16,0:16), G(0:16,0:16)
      DIMENSION GT(0:16,0:16), HT(0:16,0:16), GTT(0:16,0:16)
      DIMENSION H(0:16,0:16), HTT(0:16,0:16), GTTT(0:16,0:16)
      DIMENSION HTTT(0:16,0:16),GTTTT(0:16,0:16),HTTTT(0:16,0:16)
      CHARACTER*80 TITLE1,TITLE2
      CHARACTER*1 CH
      DO 110 I=0,16
      DO 110 J=0,16
      FNM(I,J)=0.
      CONST(I,J)=0.
      GTTTT(I,J)=0.
      HTTTT(I,J)=0.
      G(I,J)=0.
      H(I,J)=0.
      GT(I,J)=0.
      HT(I,J)=0.
      GTT(I,J)=0.
      HTT(I,J)=0.
      GTTT(I,J)=0.
110   HTTT(I,J)=0.
      OPEN(UNIT=1,FILE='SCHCOEFMAIN7.K16',STATUS='OLD')
      OPEN(UNIT=2,FILE='SVCOEFINT90.K7L3',STATUS='OLD')
      OPEN(UNIT=3,FILE='SCHCOEF.90',STATUS='NEW',RECL=182)
101   FORMAT(1X,A1,2I3,F9.4,E15.6,10E15.6)
100   FORMAT(A)
      READ(2,100) TITLE1
      READ(1,100) TITLE1
      WRITE(3,100) TITLE1
      READ(2,100)TITLE2
      READ(1,100)TITLE2
      WRITE(3,100)TITLE2
10    READ(1,111,END=20)CH,N,M,VAR1,VAR2,VAR3,VAR4
111   FORMAT(1X,A1,2I3,F9.4,3E15.6)
      IF(N.EQ.-1)GO TO 20
      FNM(N,M)=VAR1
      CONST(N,M)=VAR2
      G(N,M)=VAR3
      H(N,M)=VAR4
      GO TO 10
20    CONTINUE
      READ(2,101,END=30)CH,I,J,VVAR1,VVAR2,DUM,DUM,VAR5,VAR6,VAR7,VAR8,
     +VAR9,VAR10,VAR11,VAR12
      IF(I.EQ.-1)GO TO 30
      FNM(I,J)=VVAR1
      CONST(I,J)=VVAR2
      GT(I,J)=VAR5
```

```
      HT(I,J)=VAR6
      GTT(I,J)=VAR7
      HTT(I,J)=VAR8
      GTTT(I,J)=VAR9
      HTTT(I,J)=VAR10
      GTTTT(I,J)=VAR11
      HTTTT(I,J)=VAR12
      GO TO 20
30    CONTINUE
      CH='I'
      DO 40 N=0,16
      DO 40 M=0,16
      IF(CONST(N,M).EQ.0.)GO TO 40
      WRITE(3,101)CH,N,M,FNM(N,M),CONST(N,M),G(N,M),H(N,M),GT(N,M),
     +HT(N,M),GTT(N,M),HTT(N,M),GTTT(N,M),HTTT(N,M),GTTTT(N,M),
     +HTTTT(N,M)
40    CONTINUE
      STOP
      END
```

APPENDIX 19

SCHCOEF.90

```
  65.00   -85.00  30.00  6371.2   66.3333
    1     0     0     2    16     4     0    -1
 I  0  0   0.0000   0.100000E+01   0.000000E+00   0.000000E+00   0.805212E+03   0.000000E+00  -0.213366E+04
  000000E+00  -0.442117E+04   0.000000E+00  -0.231748E+04   0.000000E+00
 I  1  0   4.0837   0.100000E+01   0.393952E+01   0.000000E+00   0.288157E+03   0.000000E+00   0.276897E+03
0.000000E+00  -0.643388E+03   0.000000E+00  -0.480977E+03   0.000000E+00
 I  1  1   3.1196   0.253621E+01  -0.152553E+03  -0.350967E+02   0.658761E+03   0.333090E+03  -0.169371E+03  -
0.304683E+03   0.000000E+00  -0.493076E+03   0.136406E+03  -0.159062E+03
 I  2  0   6.8354   0.100000E+01   0.000000E+00   0.000000E+00  -0.124345E+03   0.000000E+00  -0.223119E+03
0.000000E+00  -0.208055E+03   0.000000E+00  -0.122209E+03   0.000000E+00
 I  2  1   6.8354   0.517746E+01   0.452437E+03   0.507498E+02  -0.291487E+03  -0.382857E+03   0.000000E+00  -
0.486984E+02   0.000000E+00  -0.133601E+03   0.123905E+02  -0.741942E+02
 I  2  2   5.4928   0.612537E+01   0.132779E+02  -0.188386E+03   0.142083E+03   0.282898E+03   0.000000E+00  -
0.175786E+03  -0.590835E+02   0.000000E+00   0.000000E+00   0.956235E+02
 I  3  0  10.0385   0.100000E+01   0.000000E+00   0.000000E+00   0.293542E+02   0.000000E+00   0.470950E+02
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  3  1   9.7121   0.721601E+01  -0.768652E+03  -0.774457E+02   0.256738E+03   0.366483E+03   0.000000E+00
0.000000E+00  -0.106881E+03   0.000000E+00  -0.783833E+02   0.000000E+00
 I  3  2   9.3733   0.170110E+02  -0.171574E+02   0.569208E+03   0.000000E+00  -0.244150E+03   0.000000E+00
0.724967E+02   0.000000E+00  -0.661285E+02  -0.340082E+01  -0.695611E+02
 I  3  3   7.7524   0.154891E+02   0.170846E+02  -0.333048E+01  -0.187627E+03   0.749742E+02  -0.887667E+02
0.729314E+01   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  4  0  12.9083   0.100000E+01   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.144852E+02   0.000000E+00   0.000000E+00   0.000000E+00
 I  4  1  12.9083   0.947928E+01   0.995386E+03   0.636325E+02  -0.154933E+03  -0.291324E+03   0.000000E+00
0.000000E+00   0.963486E+01   0.000000E+00   0.000000E+00   0.000000E+00
 I  4  2  12.3720   0.290691E+02   0.830277E+01  -0.113427E+04   0.000000E+00   0.248416E+03   0.000000E+00  -
0.378451E+02   0.000000E+00   0.000000E+00   0.000000E+00   0.122722E+02
 I  4  3  11.8074   0.533354E+02  -0.234119E+02   0.000000E+00   0.122009E+03  -0.380616E+02   0.000000E+00
 .000000E+00   0.000000E+00   0.000000E+00   0.323442E+02   0.000000E+00
 I  4  4   9.9589   0.398615E+02   0.000000E+00  -0.558992E+01  -0.136597E+02   0.276629E+02   0.178351E+02
0.000000E+00   0.000000E+00  -0.671208E+01   0.000000E+00   0.000000E+00
  65.00   -85.00  30.00  6371.2   66.3333
 I  5  0  16.0248   0.100000E+01   0.102724E+01   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  5  1  15.8215   0.115415E+02  -0.101329E+04  -0.382369E+02   0.750231E+02   0.191267E+03   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  5  2  15.6154   0.456895E+02   0.000000E+00   0.177861E+04   0.000000E+00  -0.187180E+03   0.000000E+00
0.000000E+00   0.115898E+02   0.000000E+00   0.137648E+02   0.000000E+00
 I  5  3  14.9180   0.105995E+03   0.135495E+02  -0.000000E+00  -0.104855E+03   0.235087E+02   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00  -0.260955E+02   0.000000E+00
 I  5  4  14.1778   0.162625E+03   0.000000E+00   0.000000E+00   0.247057E+02  -0.457641E+01   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  5  5  12.1334   0.103486E+03  -0.200459E+01   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  6  1  18.9364   0.137460E+02   0.779207E+03   0.123826E+02  -0.224413E+02  -0.857139E+02   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  6  2  18.5830   0.641554E+02   0.000000E+00  -0.217468E+04   0.000000E+00   0.994581E+02   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  6  3  18.2219   0.190927E+03  -0.410011E+01  -0.371005E+01   0.642951E+02  -0.944535E+01   0.000000E+00
0.000000E+00  -0.182973E+02   0.000000E+00   0.000000E+00   0.000000E+00
```

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 I  6  4  17.3910   0.364976E+03   0.253005E+01   0.000000E+00  -0.188470E+02   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  6  5  16.5041   0.486587E+03   0.000000E+00   0.000000E+00   0.000000E+00   0.267181E+01   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  6  6  14.2861   0.270001E+03   0.000000E+00  -0.466811E+01   0.000000E+00  -0.409800E+01   0.391241E+01
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00  -0.526934E+01
 I  7  1  21.8702   0.158221E+02  -0.464803E+03   0.000000E+00   0.000000E+00   0.258820E+02   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  7  2  21.7210   0.870680E+02   0.000000E+00   0.211087E+04   0.000000E+00  -0.305952E+02   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  7  3  21.2461   0.300181E+03   0.000000E+00   0.000000E+00  -0.247740E+02   0.000000E+00  -0.732047E+01
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  7  4  20.7588   0.734755E+03   0.000000E+00   0.000000E+00   0.981816E+01   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  7  5  19.8121   0.121018E+04   0.000000E+00   0.281860E+01   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  7  6  18.7979   0.143591E+04  -0.456082E+01   0.236503E+01   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  8  1  24.9514   0.180025E+02   0.182408E+03   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  8  2  24.6858   0.111915E+03   0.000000E+00  -0.165732E+04   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  8  4  23.8390   0.126951E+04   0.000000E+00   0.663180E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  8  7  21.0663   0.419235E+04  -0.134438E+01   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  8  8  18.5472   0.185281E+04   0.000000E+00  -0.207342E+01   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  9  1  27.8979   0.200874E+02  -0.408884E+02   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  9  2  27.7807   0.141168E+03   0.000000E+00   0.988606E+03   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  9  4  27.0470   0.209140E+04   0.401427E+01   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I  9  5  26.3784   0.501966E+04   0.000000E+00  -0.143431E+01   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I 10  2  30.7474   0.172387E+03   0.000000E+00  -0.455496E+03   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I 10  3  30.5325   0.876491E+03   0.000000E+00  -0.757373E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I 10  4  30.0829   0.318566E+04  -0.259024E+01   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I 10  8  26.8711   0.384162E+05   0.155144E+01   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I 10 10  22.7683   0.127842E+05   0.000000E+00  -0.229285E+01   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I 11  0  34.0120   0.100000E+01   0.123425E+01   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I 11  2  33.8193   0.207993E+03   0.564711E+00   0.137241E+03   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
 I 11  4  33.2235   0.471946E+04   0.000000E+00  -0.416833E+00   0.000000E+00   0.000000E+00   0.000000E+00
0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00   0.000000E+00
```

I 11 9 29.1761 0.117952E+06 0.000000E+00 0.158920E+01 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 11 10 27.7627 0.996787E+05 0.134952E+01 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
J.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 12 1 36.9669 0.265041E+02 0.276942E+01 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 12 2 36.7886 0.245582E+03 0.000000E+00 -0.218306E+02 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 12 6 35.2710 0.625103E+05 0.171012E+01 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 12 8 33.7718 0.242271E+06 0.000000E+00 0.795277E+00 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 12 12 26.9619 0.884337E+05 0.000000E+00 -0.310819E+01 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 13 0 40.0102 0.100000E+01 -0.531003E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 13 4 39.3438 0.922032E+04 0.428681E+01 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 13 6 38.4664 0.104918E+06 -0.684041E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 13 9 36.1810 0.834895E+06 -0.587816E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 13 12 32.1619 0.802105E+06 0.444168E+01 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 14 1 42.9715 0.307525E+02 -0.102928E+01 -0.400819E+00 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 14 3 42.6643 0.236389E+04 0.000000E+00 -0.779218E+00 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 14 4 42.3494 0.123446E+05 -0.972213E+01 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 14 5 42.0320 0.506746E+05 -0.409944E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 14 6 41.5359 0.165915E+06 0.000000E+00 0.102912E+01 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 14 8 40.3169 0.100244E+07 0.000000E+00 -0.202692E+01 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 14 9 39.5844 0.188373E+07 0.000000E+00 0.177718E+01 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 14 12 35.9940 0.321758E+07 -0.888707E+01 -0.172721E+01 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 14 13 34.3470 0.226154E+07 -0.104301E+01 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 15 2 45.8662 0.379827E+03 -0.606618E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 15 4 45.4313 0.163099E+05 0.992168E+01 -0.729867E+00 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 15 7 44.1294 0.751154E+06 0.527667E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 15 8 43.5694 0.186492E+07 0.000000E+00 0.161684E+01 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
I 15 9 42.7989 0.381372E+07 0.000000E+00 -0.384056E+01 0.000000E+00 0.000000E+00 0.000000E+00
0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00

I	15	10	42.0100	0.667923E+07	0.000000E+00	0.395886E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	15	11	40.9382	0.938057E+07	0.198927E+01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	15	12	39.8232	0.111063E+08	0.941816E+01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	15	13	38.2408	0.953823E+07	0.000000E+00	-0.178600E+01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	15	14	36.5239	0.635452E+07	0.000000E+00	-0.582115E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	15	15	33.2160	0.161204E+07	0.000000E+00	-0.919449E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	16	0	48.9749	0.100000E+01	0.307120E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	16	1	48.9749	0.350000E+02	0.000000E+00	0.598322E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	16	3	48.7056	0.350375E+04	0.000000E+00	-0.391360E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	16	4	48.4311	0.210193E+05	-0.452871E+01	0.121919E+01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	16	5	48.1549	0.995458E+05	0.000000E+00	0.279807E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	16	6	47.7278	0.380260E+06	0.000000E+00	0.281341E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	16	7	47.2962	0.121828E+07	0.000000E+00	0.964958E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	16	9	46.0801	0.742617E+07	0.000000E+00	0.269312E+01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	16	11	44.4162	0.232234E+08	-0.149749E+01	0.798591E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	16	12	43.2911	0.307483E+08	-0.529923E+01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	16	13	42.1198	0.345010E+08	0.000000E+00	0.185191E+01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	16	14	40.4771	0.281031E+08	0.924275E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00
I	16	15	38.6935	0.178002E+08	-0.107275E+01	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00	0.000000E+00

APPENDIX 20

SCHE.FOR

```
       PROGRAM SCHE

C     SPHERICAL CAP HARMONIC EXPANSION AT INTERVALS OF LAT, LONG, ALT.
C     ALSO GRID INTERVALS IN INCHES USING INVERSE LAMBERT ROUTINE
C     USED TO GRID VALUES BEFORE PLOTTING MAPS FROM CGRF
C  ORINGINAL PROGRAM BY G.V. HAINES
C  THIS VERSION USED BY L. NEWITT FOR CGRF1987.5
C

C     SUBPROGRAMS USED:  GEOCENF, SPHNEWF, SCHNEV, FIELD.
      DIMENSION AX(60,60), AY(60,60), AZ(60,60)
      DIMENSION AD(60,60), AI(60,60), AH(60,60), AF(60,60)
      PRINT 1
    1 FORMAT (14H1PROGRAM  SCHE)
c      OPEN(UNIT=2,FILE='GRIDVAL.X',STATUS='NEW')
c      OPEN(UNIT=3,FILE='GRIDVAL.Y',STATUS='NEW')
c      OPEN(UNIT=4,FILE='GRIDVAL.Z',STATUS='NEW')
c      OPEN(UNIT=6,FILE='OUTPUT.DAT',STATUS='NEW')
      OPEN(UNIT=7,FILE='GRIDVAL.D',STATUS='NEW')
c      OPEN(UNIT=8,FILE='GRIDVAL.I',STATUS='NEW')
C      OPEN(UNIT=9,FILE='GRIDVAL.H',STATUS='NEW')
C      OPEN(UNIT=10,FILE='GRIDVAL.F',STATUS='NEW')
c      OPEN(UNIT=10,FILE='GRIDVALIA.DAT',STATUS='NEW')
      FMAX=-999999.
      FMIN=999999.
C     INPUT PARAMETER AND COEFFICIENT FILE
      CALL SCHNEV (DUM,DUM,DUM,DUM,0,FLATO,FLONO,THETA)                 COEFFS

C     DEFINE SPHERICAL CAP POLE
      CALL SPHITF (FLATO,FLONO,DUM,DUM,DUM,DUM,DUM,DUM)

      IREF=1
C     PUT IREF .EQ. 0 IF NO REFERENCE FIELD IS TO BE ADDED.
C     PUT IREF .NE. 0 IF ONE IS TO BE ADDED.
      PRINT 4,  IREF
    4 FORMAT (/7X,4HIREF/1X,I10)

      IF (IREF .EQ. 0)  GO TO 7
c      READ (*,5,END=99)  TF,NMAX                                        INPUT
    5 FORMAT (F10.2,I5)
      NMAX=10
      TF=1990.
      PRINT 6,  TF,NMAX
    6 FORMAT (/9X,2HTF,6X,4HNMAX/1X,F10.2,I10)
C     INPUT COEFFICIENTS OF GLOBAL REFERENCE FIELD
      LF = 1
      RE = 6371.2
      CALL FIELD (DUM,DUM,DUM,TF,NMAX,LF,DUM,DUM,DUM)
    7 CONTINUE
C    7 READ (*,10,END=99) FLAT1,FLAT2,DLAT,FLON1,FLON2,DLON,
C     *          ALT1,ALT2,DALT,IGRAT                                    INPUT
C   10 FORMAT(9F6.0,I5)
```

```
C
C  FOR BOTTOM THIRD OF CHART
C
      YN1=-22.
      YN2=-13.
C
C  FOR MIDDLE THIRD OF CHART
C
C       YN1=-16.
C       YN2=-7.
c       yn1=-12.
c       yn2=-5.
C
C  FOR TOP THIRD OF CHART
C
C       YN1=-9.
C       YN2=0.
c FOR SMALL AREA AROUND POLE
C       yn1=-8.
C       yn2=-3.
C
C  FOR WHOLE MAP SHEET
C
c       YN1=-22.
c       YN2=0.
C       DELE=1.
      DELE=0.5
      DELN=0.5
C       DELN=1.
c       DELE=0.25
c       DELN=0.25
C       dele=0.1
C       deln=0.1
      XE1=-12.
      XE2=13.
C       xe1=-3.
C       xe2=1.
      IIIMAX=(XE2-XE1)*2.+1
      JJJMAX=(YN2-YN1)*2.+1
c       IIIMAX=(XE2-XE1)*4.+1
c       JJJMAX=(YN2-YN1)*4.+1
C       iiimax=(xe2-xe1)*10.+1
C       jjjmax=(yn2-yn1)*10.+1
      IIIMAX=XE2-XE1+1
      JJJMAX=YN2-YN1+1
      III=1
      JJJ=1
      ALT1=0.
      ALT2=0.
      DALT=0.
      IGRAT=0
      CM=-92.
```

```
      SCAL=10000000.
      PARL1=49.
      PARL2=77.
      SEMMAJ=251110488.
      SEMMIN=250259197.
      CALL LAMBIT(CM,SCAL,SEMMAJ,SEMMIN,PARL1,PARL2,CUT)

C     PUT IGRAT .EQ. 0 FOR COMPUTATIONS AT LAT=FLAT1,FLAT2,DLAT
C                      AND LONG=FLON1,FLON2,DLON.
C               .NE. 0 FOR COMPUTATIONS AT LAT=FLAT1,FLAT2,DLAT
C                      AND LONG=FLON1,FLON2,DLAT/COS(LAT).

      IF (DELN .LE. 0.)  THEN
          YN2 = YN1
          DELN = 0.5
          IF (IGRAT .NE. 0)  XE2 = XE1
          END IF
      IF (DELE.LE.0. .AND. IGRAT.EQ.0)  THEN
          XE2 = XE1
          DELE = 1.
          END IF
      IF (DALT .LE. 0.)  THEN
          ALT2 = ALT1
          DALT = 1.
          END IF
      PRINT 15, YN1,YN2,DELN,XE1,XE2,DELE,ALT1,ALT2,DALT,IGRAT
   15 FORMAT (1H1,5X,5HFLAT1,5X,5HFLAT2,6X,4HDLAT,5X,5HFLON1,
     *        5X,5HFLON2,6X,4HDLON,6X,4HALT1,6X,4HALT2,6X,4HDALT,
     *        5X,5HIGRAT/1X,9F10.2,I10)
      L=1
      ICEN=1
      IDHF=1
C
      ICHANGE=0
      DELT=0.
      TM=1990.
C
C  CALCULATE THE ANNUAL CHANGE FOR 1990 USING THE INTERVAL 1989.5 - 1990.5
C
C      ICHANGE = 1
C      DELT =1.
C      TM = 1989.5
C
      T=TM/30.
C     PUT L .EQ.  1 FOR INTERNAL POTENTIAL FIELD,
C           .EQ.  2 FOR EXTERNAL POTENTIAL FIELD,
C           .GE.  3 FOR BOTH INTERNAL AND EXTERNAL POTENTIAL FIELDS.
C           .EQ.  0 FOR GEOCENTRIC INTERNAL POTENTIAL FIELD.
C           .LE. -1 FOR GENERAL FUNCTION AND TWO SURFACE DERIVATIVES.
C     PUT ICEN .NE. 0  FOR GEODETIC COMPONENTS ON GEODETIC LAT-LONG-ALT GRID.
C              .EQ. 0  FOR GEOCENTRIC COMPONENTS ON GEOCENTRIC LAT-LONG-R GRID.
C     PUT IDHF .NE. 0  TO COMPUTE I,D,H,F
```

```
C               .EQ. 0  FOR NO I,D,H,F
C     PUT ICHANGE .EQ. 0 FOR FIELD VALUES AT TIME T.
C                  .NE. 0 FOR AVERAGE SECULAR CHANGE PER UNIT TIME
C                         FROM TIME T TO TIME T+DELT.

      IF (L .LE. 0)  ICEN = 0                                         NOTE
      IF (L .LT. 0)  IDHF = 0                                         NOTE
      IF (DELT .EQ. 0.)  ICHANGE = 0
      PRINT 14,  L,ICEN,IDHF,ICHANGE,T,DELT
   14 FORMAT (/10X,1HL,6X,4HICEN,6X,4HIDHF,3X,7HICHANGE,
     *         9X,1HT,6X,4HDELT/ 1X,4I10,2F10.2)
      LINE = 1
      NREC = 0

      ALT = ALT1
      GO TO 18
   17 ALT = ALT + DALT
      IF (ALT .GT. ALT2)  GO TO 7
      PRINT 81
      LINE = LINE + 1

   18 YN = YN1
      JJJ=1
      GO TO 25
   20 YN = YN + DELN
C      IF (YN .GT. YN2)  GO TO 17
      JJJ=JJJ+1
      IF(YN.GT.YN2)GO TO 99
      PRINT 81
      LINE = LINE + 1

   25 XE = XE1
      III=1
      IF (IGRAT .EQ. 0)  GO TO 35
C      CFLAT = COSD(FLAT)
C      IF (CFLAT .NE. 0.)  GO TO 58
C      DLON = 720.
C      GO TO 35
C   58 DLON = DLAT/CFLAT
C      GO TO 35
   30 XE = XE + DELE
      IF (XE .GT. XE2)  GO TO 20
      III=III+1

   35 IF (ICEN .EQ. 0)  GO TO 36
      CALL LAMBINV(XE,YN,FLAT,FLON,DUM,DUM,DUM)
C     CONVERT FROM GEODETIC TO GEOCENTRIC COORDINATES
      CALL GEOCENF (FLAT,ALT,DUM,DUM,GCFLAT,R,DUM,DUM)
      GO TO 37
   36 GCFLAT = FLAT
      R = ALT
```

```
C      CONVERT SPHERICAL TO SPHERICAL CAP COORDINATE SYSTEM
   37 CALL SPHNEWF (GCFLAT,FLON,DUM,DUM,SCFLAT,SCFLON,DUM,DUM)

C      COMPUTE SPHERICAL CAP HARMONIC FIELD
      CALL SCHNEV (SCFLAT,SCFLON,R,T,L,BNSC,BESC,BV)
c      PRINT 444, SCFLAT,SCFLON,R,T,L,BNSC,BESC,Bv
444   FORMAT(1H ,2F10.3,2F10.1,I3,3F12.1)

C      ROTATE S.C. COORDINATES BACK TO SPHERICAL COORDINATES
      CALL SPHOLDF (DUM,DUM,BN,Y,DUM,DUM,BNSC,BESC)

      IF (IREF .EQ. 0)  GO TO 40
C      ADD GLOBAL REFERENCE FIELD TO S.C. RESIDUAL FIELD.
      CALL FIELD (GCFLAT,FLON,R-RE,TF,NMAX,LF,XREF,YREF,ZREF)
      BN = BN + XREF
      Y = Y + YREF
      BV = BV + ZREF
   40 IF (ICEN .EQ. 0) GO TO 42
C      CONVERT CEOCENTRIC COORDINATES BACK TO GEODETIC
      CALL GEOCINV (DUM,DUM,X,Z,DUM,DUM,BN,BV)
      GO TO 44
   42 X = BN
      Z = BV
   44 CONTINUE

      IF (IDHF .EQ. 0) GO TO 50
      HSQ = X**2 + Y**2
      H = SQRT(HSQ)
      D = 0.
      IF (H .NE. 0.)  D=ATAN2D(Y,X)
c  convert to D east for plotting north of pole
C      if(d.lt.0.)d=d+360.
      F  = SQRT(HSQ +Z**2)
      FI = 90.
      IF (H .NE. 0.)  FI = ATAND(Z/H)

   50 IF (ICHANGE .EQ. 0)  GO TO 78
      CALL SCHNEV (SCFLAT,SCFLON,R,T+DELT/30.,L,BNSC2,BESC2,BV2)
      CALL SPHOLDF (DUM,DUM,BN2,Y2,DUM,DUM,BNSC2,BESC2)
      IF (IREF .EQ.0)  GO TO 77
      BN2 = BN2 + XREF
      Y2 = Y2 + YREF
      BV2 = BV2 + ZREF
   77 IF (ICEN .EQ. 0)  GO TO 52
      CALL GEOCINV (DUM,DUM,X2,Z2,DUM,DUM,BN2,BV2)
      GO TO 54
   52 X2 = BN2
      Z2 = BV2
   54 X = (X2-X)/DELT
      Y = (Y2-Y)/DELT
      Z = (Z2-Z)/DELT
```

```
      IF (IDHF .EQ. 0)  GO TO 78
      H2SQ = X2**2 + Y2**2
      H2 = SQRT(H2SQ)
      H = (H2-H)/DELT
      D2 = 0.
      IF (H2 .NE. 0.)  D2=ATAN2D(Y2,X2)
      D = D2 - D
      IF (D .GT. 180.)  D=D-360.
      IF (D .LT. -180.)  D = D+360.
      D = D*60./DELT
      FI2 = 90.
      IF (H2 .NE. 0.)  FI2 = ATAND(Z2/H2)
      FI = (FI2-FI)*60./DELT
C     D AND I SECULAR CHANGE ARE IN MINUTES OF ARC PER UNIT TIME.
      F2 = SQRT(H2SQ+Z2**2)
      F = (F2 - F)/DELT

   78 IF (LINE .LT. 0)  GO TO 60
      PRINT 80
   80 FORMAT (1H1,4X,3HALT,4X,3HLAT,4X,4HLONG,7X,1HX,7X,1HY,7X,1HZ)
      LINE = -57
      IF (IDHF .EQ. 0)  GO TO 83
      PRINT 82
   82 FORMAT (1H+,53X,1HD,7X,1HI,7X,1HH,7X,1HF)
   83 PRINT 81
      GO TO 90
   60 LINE = LINE + 1

   90 WRITE(6,81)  XE,YN,ALT,FLAT,FLON,X,Y,Z,D,FI,H,Z,F
   81 FORMAT (1X,2F8.3,F7.1,F7.2,F8.2,3F8.0,2F10.2,3F8.0)
c      WRITE(10,*)XE,YN,FI
      AX(III,JJJ)=X
      AY(III,JJJ)=Y
      AZ(III,JJJ)=Z
      AD(III,JJJ)=D
      AI(III,JJJ)=FI
      AH(III,JJJ)=H
      AF(III,JJJ)=F
      NREC = NREC + 1
      IF (IDHF .EQ. 0)  GO TO 30
c      PRINT 84, D,FI,H,F
   84 FORMAT (1H+,46X,2F8.2,2F8.0)
      GO TO 30
 99   CONTINUE
c      WRITE(10,443)
443   FORMAT('DSAA',/,'51 45',/,'-12 13',/,'-22 0')
c      WRITE(10,445)FMIN,FMAX
445   FORMAT(2F13.6)
c      WRITE(2,*)((AX(III,JJJ),JJJ=1,JJJMAX),III=1,IIIMAX)
c      WRITE(3,*)((AY(III,JJJ),JJJ=1,JJJMAX),III=1,IIIMAX)
c      WRITE(4,*)((AZ(III,JJJ),JJJ=1,JJJMAX),III=1,IIIMAX)
      WRITE(7,*)((AD(III,JJJ),JJJ=1,JJJMAX),III=1,IIIMAX)
```

```
c       WRITE(8,*)((AI(III,JJJ),JJJ=1,JJJMAX),III=1,IIIMAX)
C       WRITE(9,*)((AH(III,JJJ),JJJ=1,JJJMAX),III=1,IIIMAX)
C       WRITE(10,*)((AF(III,JJJ),JJJ=1,JJJMAX),III=1,IIIMAX)
C       WRITE(10,446)((AF(III,JJJ),III=1,IIIMAX),JJJ=1,JJJMAX)
446    FORMAT(5(10F12.5,/),F12.5,/,' ')
       STOP
       END
```

PLUS SUBROUTINE SCHNEV (SEE LISTING APPENDIX 6)
PLUS SUBROUTINE LEGFUN (SEE LISTING APPENDIX 7)
PLUS SUBROUTINE FIELD (SEE LISTING APPENDIX 10)

APPENDIX 21

CONTOURB.COM

```
$run contour
outp CONTOUR.pf
file [NEWITT.CGRF]GRIDVAL.D;1
read 51 19 0
  titl \dup\ DSV 1990
ytit \ita\ Longitude
xtit \ita\ Latitude
axes -12 +13 -22 -13
height 9.0
width 25.0
  level -10000 -9000 -8000 -7000 -6000 -5000 -4000 -3000 -2000 -1000 0 1000 2000
 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000 15000 16000
 17000 18000 19000 20000 21000 22000 23000 24000 25000 26000 27000 28000 29000
 30000 31000 32000 33000 34000 35000 36000 37000 38000 39000 40000 41000 42000
 43000 44000 45000 46000 47000 48000 49000 50000 51000 52000 53000 54000 55000
 56000 57000 58000 59000 60000 61000 62000 63000 64000 65000
level -90 -89 -88 -87 -86 -85 -84 -83 -82 -81 -80 -79 -78 -77 -76 -75 -74 -73
-72 -71 -70 -69 -68 -67 -66 -65 -64 -63 -62 -61 -60 -59 -58 -57 -56 -55 -54
-53 -52 -51 -50 -49 -48 -47 -46 -45 -44 -43 -42 -41 -40 -39 -38 -37 -36 -35
-34 -33 -32 -31 -30 -29 -28 -27 -26 -25 -24 -23 -22 -21 -20 -19 -18 -17 -16
-15 -14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11
12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37
38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63
64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90
 level -200 -190 -180 -170 -160 -150 -140 -130 -120 -110 -100 -90 -80 -70 -60
 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100 110 120 120 140 150 160
 170 180 190 200
plot
d
11.0
stop
```