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MAP
PROJECTION
SOFTWARE

Frederick Pearson, II
Computer Sciences Corporation

Sigma Scientific, Inc.
Blacksburg, Virginia

1984

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110

P43

MAP PROJECTION SOFTWARE

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**MAP
PROJECTION
SOFTWARE**

THE SIGMA SERIES IN APPLIED MATHEMATICS FOR SCIENCE AND ENGINEERING

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SECTION 1

INTRODUCTION

Program MAPPROJ, written in BASICA for the International Business Machines (IBM) family of personal computers, provides a means for computing Cartesian map coordinates from given geographic latitude and longitude (in a direct transformation), or geographic latitude and longitude from given Cartesian map coordinates (in an inverse transformation). A dozen of the more common/useful projections are provided as standard options. This Users Guide provides a description of the software and specific instructions for the efficient use of this software. Examples are given wherein the various options of the software are demonstrated. Selected graphic output are also included.

For a detailed analytical background in map projections, the reader is referred to the companion text *Map Projection Methods* (1984) by Frederick Pearson, II; cross-referencing is provided to this text for the derivation of the equations used in each map projection implicit in MAPPROJ.

The software has been developed and executed on the IBM PC and IBM PCjr with DOS 2.1. The compatibility with other "IBM-PC-Compatible" computers is not guaranteed, but we anticipate little difficulty in portability of this software. A FORTRAN 77 version of this software can be made available, inquiries should be directed to the author.

SECTION 2

MAP PROJECTION TECHNIQUES

As indicated in the reference, a large number of map projection techniques are available to the user. It is the user's responsibility to choose a projection which will satisfy his/her needs, and permit a minimum of (shape, length, angle, or area) distortion in the areas of greatest interest. The projection technique incorporated in program MAPPROJ are one answer to providing an ensemble of projection techniques of universal utility.

Certain types of projections have a natural adaptability to certain areas of the earth. The azimuthal polar projections can easily, and with minimal distortion, handle areas immediately adjacent to the poles of the earth. Likewise, the cylindrical projections are natural for the regions immediately above or below the equator. The areas of mid-latitudes are conveniently spanned by conical projections of one or two standard parallels. Recall that, in these projections, distortion is not a function of longitude. (See Chapter 7 of the reference.) Thus, the entire earth can be conveniently portrayed on a series of five types of maps: a north and a south polar azimuthal, a north and a south conical, and an equatorial projection.

Also from the reference, there are two major categories of map projections defined by unique mathematical criteria: the equal area and the conformal projections. The equal area projections maintain the equal area quality faithfully on the map. However, this is purchased by the possibility of extreme distortion in shape. On the other hand, the conformal projections maintain shape relatively well, but at the expense of size.

Combining the requirements of maintaining either equal area or conformal properties with the natural plotting surfaces, one is led to a series of projections which will cover a limited area of the world. Such a choice is made in program MAPPROJ.

For limited equal area coverage, the azimuthal equal area, the equal area conical with two standard parallels, and the equal area cylindrical projections cover sections of the entire earth. Similarly, for limited conformal coverage, the polar stereographic, Lambert conformal with two standard parallels, and the equatorial Mercator accomplish the same result. For this reason, these six projections are in this mapping package.

Sometimes, it is desired to portray statistical data on a map. All three of the equal area projections mentioned above are suitable for limited areas of coverage. If it is desired to map statistical information over the entire earth, then other equal area projections are useful: the Sinusoidal, the Parabolic, and the Mollweide projections. That is why these projections have been included in this mapping software system.

Three conventional and commonly used projections (reference Chapter 6) are also a part of the software package: the azimuthal equidistant, the gnomonic, and the polyconic. Each has individual features which make it attractive for specific uses. The main feature of the azimuthal equidistant projection is that distances from the origin of the map to any other point on the map are true length. This can be useful in such applications as locating a central office in relation to satellite offices. On the gnomonic projection, every great circle is a straight line. This is a useful aid to navigation. The polyconic projection has

served as a useful and satisfying means of portraying geographic information, and has seen wide acceptance in road maps.

Thus, the projections selected for inclusion in program MAPPROJ give the user a useful means to map all or portions of the earth, and some versatility in unique applications.

Another feature of the projections included in this package is that they are applicable to both the northern and southern hemispheres. This is of particular importance for the conical and azimuthal projections which can be respectively, secant or tangent to the northern or southern hemispheres.

The model of the earth taken for these projections is the spherical earth. This is of sufficient accuracy for the vast number of practical mapping projects of small scale.

Before going to the description of the program, the macroscopic characteristics of the map projections included in this package are reviewed.

The equal area azimuthal projection, in its polar form, has intersecting straight lined meridians, and circular parallels. The spacing between the parallels increase as the poles are approached.

The equal area conical projection has straight lined inclined meridians, and parallels which are circular arcs. The two standard parallels are true scale.

The equal area cylindrical projection has straight lined meridians and parallels intersecting at 90° . The spacing between the parallels decreases as the poles are approached.

The Sinusoidal projection has straight lined parallels, and its meridians are sine curves. Only the central meridian is a straight line. The meridians intersect at a point.

The Mollweide projection has straight lined parallels, and its meridians are ellipses. The $\pm 90^\circ$ meridians are circular arcs, and the central meridian is a straight line.

The Parabolic projection also has straight lined parallels. However, the meridians are parabolic curves. The central meridian is a straight line. This also leads to the meridians intersecting at a point.

The Stereographic projection, in its polar form, like the equal area azimuthal, has intersecting straight lined meridians and circular parallels. However, the spacing between the parallels decreases as the poles are approached.

The Lambert conformal projection with two standard parallels also has inclined straight lined meridians, and parallels which are circular arcs. The two standard parallels are true length. The spacing of the parallels differentiates this projection from the equal area conical.

The equatorial Mercator projection has straight lined meridians and parallels, intersecting at 90° . However, with this projection, the spacing between the parallels increase as the poles are approached.

Only in the polar case of the azimuthal equidistant projection are the meridians and parallels regular curves (intersecting straight lined meridians, and circular parallels equally spaced). For all other points of tangency, the meridians and parallels are irregular curves.

In the gnomonic projection, all great circles are straight lines. Thus the meridians are straight lines. All parallels are curves.

In the polyconic projection, the central meridian and the equator are straight lines. The parallels are circular arcs. The other meridians are irregular curves.

SECTION 3

DESCRIPTION OF THE SOFTWARE

The MAPPROJ software was developed using the top-down concept. The computational sequence flows from the main calling program down through several tiers of subroutines which evaluate options and read and initialize parameters. The lowest tier of subroutines contains the computational algorithms which carry out the desired transformations. Figure 1 shows the relation of the main program to the various tiers of subroutines.

The main program enters the decision variable IORD which directs the logic to the inverse or direct transformation. It also enters and prints the title of the case. The origin or poles of the projection, the standard parallels, and the scale factor are entered and printed. The main program also signals the end of a particular sequence of computations.

Below the main calling program are subroutines INVERSE and MAP. These are the two basic options of the program: inverse or direct transformation of the coordinates. Subroutine INVERSE reads the variable NPROJ which selects the inverse transformation desired, and the last case indicator NCASE. It prints "Inverse Transformation," and the name of the projection desired. It also prints the headers for the columns of data. Subroutine INVERSE accepts input of a data point, and checks whether this is the last one. It exercises the desired inverse transformation, and prints the input and transformed coordinates. Subroutine MAP reads the variable NPROJ which selects the direct transformation desired, the last case indicator NCASE, and the variable NPNT which directs the logic to another subroutine POINT or GRID. It prints

MAP PROJECTION SOFTWARE

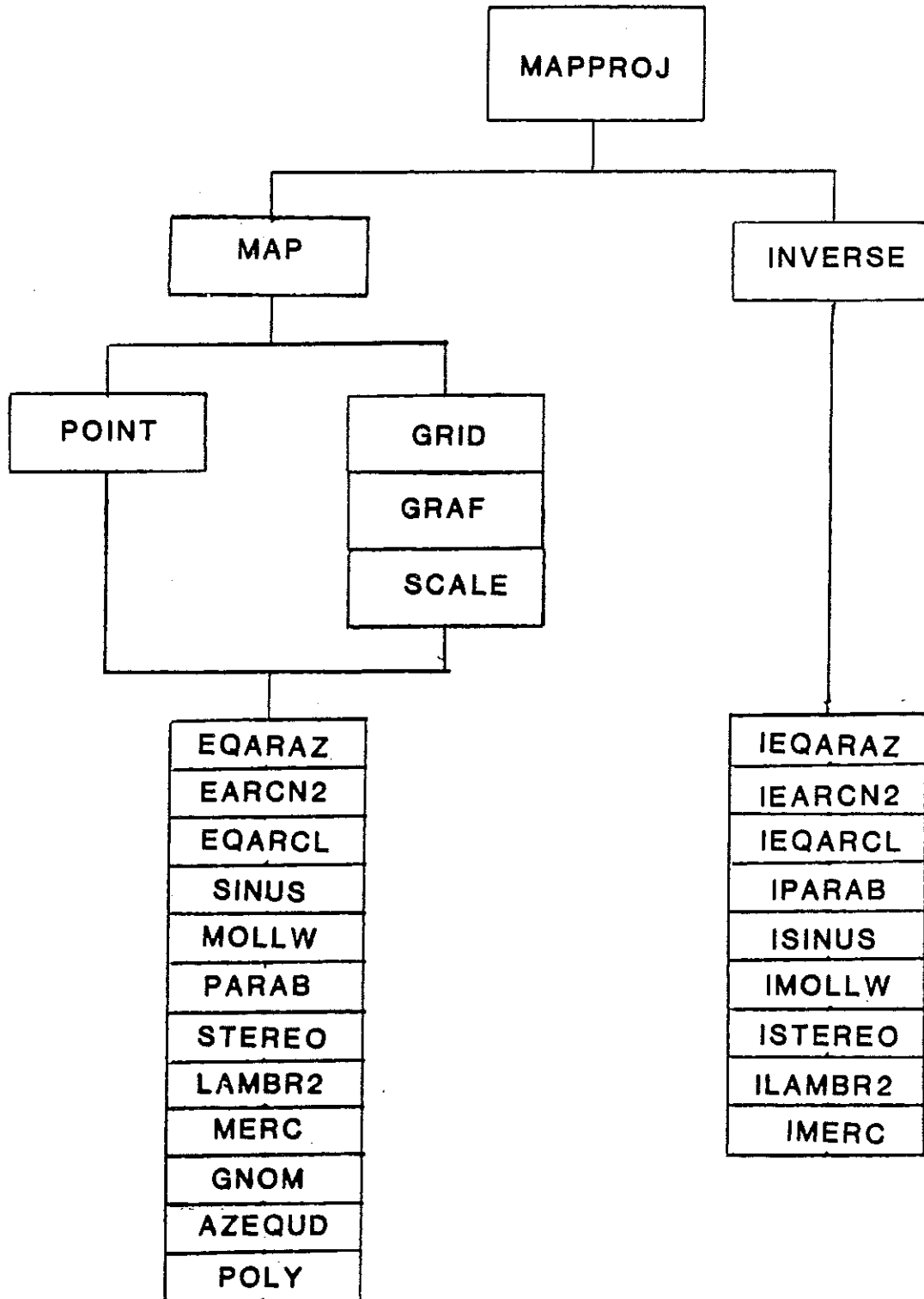


Figure 1 Program MAPPROJ Modules

"Direct Transformation," and the name of the projection desired. It also prints the headers for the columns of data. It then selects subroutine POINT or GRID to initiate the required transformations.

The next tier of subroutines below MAP are subroutines POINT and GRID. Subroutine POINT carries out the transformation of selected geographic latitudes and longitudes to mapping coordinates. A series of individual data points are read and transformed. If a complete grid is required, subroutine GRID is used. The beginning point of the grid is read, as are the plotting intervals, and the number of graticules desired. Both subroutines POINT and GRID print out the initial and transformed coordinates.

Subroutine GRID also reads the variable NGRAF which selects the graphics option when so desired. Subroutine SCALE supports the graphics option by generating a scale factor which assures that the size of the figure will be within the bounds of the IBM-PC CRT screen. This scaling is done automatically and requires no action by the user.

The final tier of subroutines are the projection transformation subroutines themselves. These are summarized in Tables 1 and 2 for the direct and inverse transformations, respectively. The section number indicates the section in MAP PROJECTION METHODS where each of the plotting equations is derived.

TABLE 1
Direct Transformation Subroutines

| <u>Subroutine</u> | <u>Projection</u> | <u>Section</u> |
|-------------------|--|----------------|
| EQARAZ | Equal Area Azimuthal | 4.3 |
| EARCN2 | Equal Area Conical | 4.2 |
| EQARCL | Two Standard Parallels | 4.5 |
| PARAB | Equal Area Cylindrical | 4.8 |
| SINUS | Parabolic | 4.6 |
| MOLLW | Sinusoidal | 4.7 |
| STEREO | Mollweide | 5.4 |
| LAMBR2 | Stereographic | 5.3 |
| MERC | Lambert Conformal, Two Standard Parallels | 5.2 |
| GNOM | Mercator | 6.1 |
| AZEQUO | Gnomonic | 6.2 |
| POLY | Azimuthal Equidistant | 6.5 |
| | Polyconic | |

TABLE 2
Inverse Transformation Subroutines

| <u>Subroutine</u> | <u>Transformation</u> | <u>Section</u> |
|-------------------|---|----------------|
| IEQARAZ | Equal Area Azimuthal | 4.3 |
| IEARCN2 | Equal Area Conical | |
| IEQARCL | Two Standard PARAllels | 4.5 |
| IPARAB | Equal Area Cylindrical | 4.8 |
| ISINUS | Parabolic | 4.6 |
| IMOLLW | Sinusoidal | 4.7 |
| ISTEREO | Mollweide | 5.4 |
| ILAMBR2 | Stereographic | |
| IMERC | Lambert Conformal Two Standard Parallels | 5.2 |
| | Mercator | |

Figure 2 gives the flowchart of the program MAPPROJ software. As is obvious from the flowchart, if the inverse option is chosen, all points of a particular run will be inversely transformed. This applies also for the direct transformation. Likewise, if the point option is chosen, all the transformations will be for individual points. The same applies to the grid option. If the grid option is selected, the user will be given the option to display numerical x-y output or to plot on the CRT.

The bulk of the numerical computation is carried out in the direct and inverse transformation subroutines. The higher tiers of subroutines, with their decision points serve to direct the scheme of calculations.

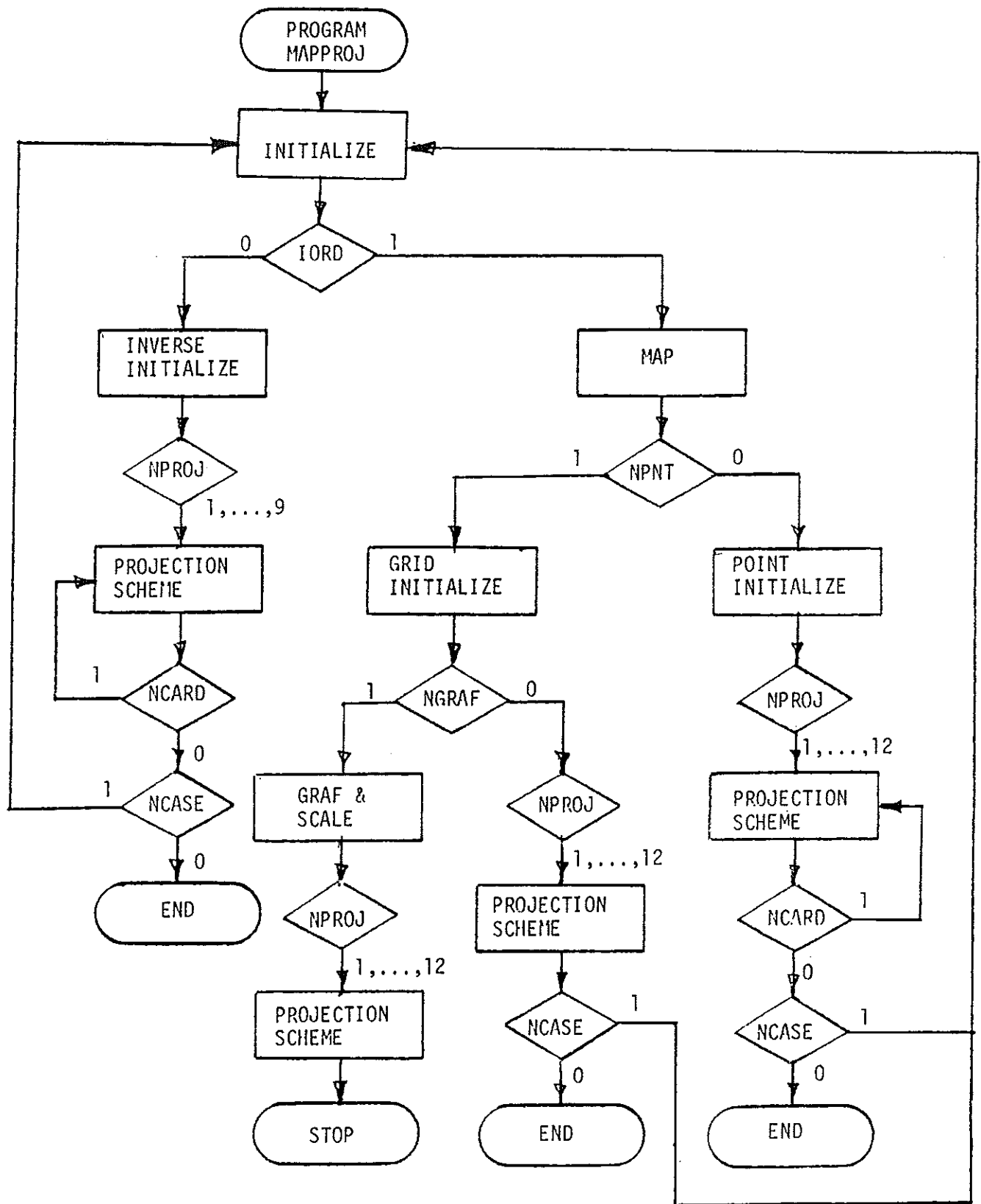


Figure 2 Map Projection Software Logic Flow Diagram

SECTION 4

INPUT GUIDE

The section contains a guide to the variables which must be entered at each stage of the program. The prompts which appear on the screen are given, and the input variables are defined. Units required for the input variable are indicated.

(1) Program MAPPROJ

Prompt: Enter 1 for Direct Transformation
Enter 0 for Inverse Transformation

Variable: IORD = 1 Direct Transformation
= 0 Inverse Transformation

Prompt: Enter PHIO, LAMO, PH1, PH2, S

Variable: PHIO = Latitude of the origin, the pole of the
auxiliary system, or the parallel of
tangency (degrees)

LAMO = Longitude of the origin, or the pole of the
auxiliary system (degrees)

PH1 = Lower standard parallel (degrees)

PH2 = Higher standard parallel (degrees)

S = Scale factor (decimal form)

The values for PHIO, LAMO, PH1, and PH2 required for each option of the program are given in Table 3.

(2) Subroutine INVERSE

Prompt: Enter NCASE, NPROJ

Variable: NCASE = 0 cases to follow
= 1 last case

NPROJ = Projection selector (See Table 4)

TABLE 3
INPUT VARIABLES FOR MAPPROJ

| Projection | PHI0 | LAM0 | PH1 | PH2 |
|------------------------|------|------|-----|-----|
| Equal Area Azimuthal | 0 | X | 0 | 0 |
| Equal Area Conical | 0 | X | X | X |
| Equal Area Cylindrical | 0 | x | 0 | 0 |
| Sinusoidal | 0 | X | 0 | 0 |
| Mollweide | 0 | X | 0 | 0 |
| Parabolic | 0 | X | 0 | 0 |
| Stereographic | 0 | X | 0 | 0 |
| Lambert Conformal | 0 | X | X | X |
| Equatorial Mercator | 0 | X | 0 | 0 |
| Azimuthal Equidistant | X | X | 0 | 0 |
| Gnomonic | X | X | 0 | 0 |
| Polyconic | 0 | X | 0 | 0 |

X denotes data specified by the user

TABLE 4
VALUES OF NPROJ

| Projection | NPROJ |
|------------------------|-------|
| Equal Area Azimuthal | 1 |
| Equal Area Conical | 2 |
| Equal Area Cylindrical | 3 |
| Sinusoidal | 4 |
| Mollweide | 5 |
| Parabolic | 6 |
| Stereographic | 7 |
| Lambert Conformal | 8 |
| Equatorial Mercator | 9 |
| Azimuthal Equidistant | 10 |
| Gnomonic | 11 |
| Polyconic | 12 |

Prompt: Enter X, Y, NCARD

Variables: X = Cartesian x-coordinate (units consistent
with scale factor)

Y = Cartesian y-coordinate (units consistent
with scale factor)

NCARD = 0 Points to follow
= 1 Last point

(3) Subroutine MAP

Prompt: Enter NCASE, NPROJ, NPNT

Variables: NCASE = 0 Cases to follow
= 1 Last case

NPROJ = Projection selector (see Table 4)

NPNT = 0 Generates a single point transformation
= 1 Generates grid of points of GRAPHICAL
OUTPUT

(4) Subroutine GRID

Prompt: Enter PHI1, LAM1, DPHI, DLAM, NPHI, NLAM

Variables: PHI1 = First latitude for grid (degrees)

LAM1 = First longitude for grid (degrees)

DPHI = Increment of latitude of grid (degrees)

DLAM = Increment of longitude of grid (degrees)

NPHI = Number of latitude points

NLAM = Number of longitude points

Prompt: Enter 1 for GRAPHICS output or 0 for NUMERICAL
VALUES output

Variables: NGRAPH = 1 Graphics on the CRT

= 0 Numerical values

(5) Subroutine POINT

Prompt: Enter PHI, LAM, NCARD

Variables: PHI = Latitude of point (degrees)

LAM = Longitude of point (degrees)

NCARD = 0 Points to follow

= 1 Last Point

SECTION 5

PROGRAM OUTPUT

The numerical output of the program is the same when using the options INVERSE, POINT, or GRID. Each of these subroutines prints on the printer the title of the case, the option, direct or inverse, selected, and the name of the map projection method used in the transformation. The scale factor, and the origin of the map, and standard parallels, where applicable, are also printed. This is followed by the headers for the columns of latitude, longitude, and Cartesian coordinates. Then, for each mapping or inverse point generated, the latitude and longitude, in degrees, and the Cartesian coordinates, in units consistent with the scale factor, are printed. Table 5 summarizes the output variables for each point transformed.

The graphical output requires the same input data as the GRID option.

TABLE 5
OUTPUT VARIABLES

| <u>Variable</u> | <u>Description</u> | <u>Units</u> |
|-----------------|-----------------------|--------------------------------|
| PHI | Latitude of point | (degrees) |
| LAM | Longitude of point | (degrees) |
| X | X-plotting coordinate | (consistent with scale factor) |
| Y | Y-plotting coordinate | (consistent with scale factor) |

A typical graphic output is demonstrated in Section 7.

SECTION 6

EXAMPLE EXECUTIONS

This section gives an example of the use of each of the direct and inverse transformations for the case of individual point transformations, and three examples of grid generation. It is intended to aid the user in becoming familiar with the operation of the program, and to establish his confidence in its use.

The first order of business in preparing to execute this software package is to boot up the Disk Operating System (DOS) diskette as usual (see your IBM DOS manual). As soon as DOS is booted, you will see a prompt

A >

You must respond to two of these DOS prompts as follows

A > GRAPHICS <ENTER>

A > BASICA <ENTER>

You may now remove the DOS disk and store it, it will not be needed again. In the following discussion, we delete the <ENTER> statements, it is understood that you will press enter after each input line. Now insert the Map Projection Software Disk and type

RUN "MAP1"

You will then be asked whether or not you intend to use a printer. Then the first input prompt will appear (see next page).

We summarize the software prompts and user input for twenty five cases on the following pages. The first twelve cases are single or multiple point executions of all twelve *direct* transformations (see Table 4), whereas the second twelve cases (Examples 13-24) are twelve *inverse* transformation examples. Finally, Example 25 is a typical

generation of graphical output for the case of the sinusoidal projection.

(1) Direct Equal Area Azimuthal-Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 1

Prompt: Enter Title of Case

Input: Example 1

Prompt: Enter PHIO, LAMO, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ, NPNT

Input: 0, 1, 0

Prompt: Enter PHI, LAM, NCARD

Input: 70, 20, 0

Output: Example 1

PHIO = 0 LAMO = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Direct Transformation

Equal Area Azimuthal Projection

| Latitude | Longitude | X | Y |
|----------|-----------|----------|-----------|
| 70 | 20 | 2.081514 | 0.7576091 |

(2) Direct Equal Area Conical Two Standard Parallels-Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 1

Prompt: Enter Title of Case

Input: Example 2

Prompt: Enter PH10, LAM0, PH1, PH2, S

Input: 0, 0, 30, 60, .000001

Prompt: Enter NCASE, NPROJ, NPNT

Input: 0, 2, 0

Prompt: Enter PHI, LAM, NCARD

Input: 45, 20, 0

Output: Example 2

PH10 = 0 LAM0 = 0

PH1 = 30 PH2 = 60

Scale Factor = .000001

Direct Transformation

Equal Area Conical Two Standard Parallels

| Latitude | Longitude | X | Y |
|----------|-----------|----------|-----------|
| 45 | 20 | 1.507224 | 0.1765620 |

(3) Direct Equal Area Cylindrical-Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 1

Prompt: Enter Title of Case

Input: Example 3

Prompt: Enter PHIO, LAM0, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ, NPNT

Input: 0, 3, 0

Prompt: Enter PHI, LAM, NCARD

Input: 20, 20, 0

Output: Example 3

PHIO = 0 LAM0 = 0

PHI = 0 PH2 = 0

Scale Factor = .000001

Direct Transformation

Equal Area Cylindrical Projection

| Latitude | Longitude | X | Y |
|----------|-----------|----------|----------|
| 20 | 20 | 2.226389 | 2.181451 |

(4) Direct Sinusoidal Projection-Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 1

Prompt: Enter Title of Case

Input: Example 4

Prompt: Enter PHIO, LAM0, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ, NPNT

Input: 0, 4, 0

Prompt: Enter PHI, LAM, NCARD

Input: 20, 20, 0

Output: Example 4

PHIO = 0 LAM0 = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Direct Transformation

Sinusoidal Projection

| Latitude | Longitude | X | Y |
|----------|-----------|----------|----------|
| 20 | 20 | 2.092122 | 2.226389 |

(5) Direct Mollweide Projection-Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 1

Prompt: Enter Title of Case

Input: Example 5

Prompt: Enter PHIO, LAM0, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ, NPNT

Input: 0, 5, 0

Prompt: Enter PHI, LAM, NCARD

Input: 20, 20, 0

Output: Example 5

PHIO = 0 LAM0 = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Direct Transformation

Mollweide Projection

| Latitude | Longitude | X | Y |
|----------|-----------|----------|----------|
| 20 | 20 | 1.928874 | 2.453579 |

(6) Direct Parabolic Projection-Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 1

Prompt: Enter Title of Case

Input: Example 6

Prompt: Enter PHIO, LAMO, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ, NPNT

Input: 0, 6, 0

Prompt: Enter PHI, LAM, NCARD

Input: 20, 20, 0

Output: Example 6

PHIO = 0 LAMO = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Direct Transformation

Parabolic Projection

| Latitude | Longitude | X | Y |
|----------|-----------|----------|----------|
| 20 | 20 | 2.058363 | 2.273186 |

(7) Direct Stereographic Projection-Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 1

Prompt: Enter Title of Case

Input: Example 7

Prompt: Enter PHIO, LAM0, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ, NPNT

Input: 0, 7, 0

Prompt: Enter PHI, LAM, NCARD

Input: 70, 20, 0

Output: Example 7

PHIO = 0 LAM0 = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Direct Transformation

Stereographic Projection

| Latitude | Longitude | X | Y |
|----------|-----------|----------|-----------|
| 70 | 20 | 2.113628 | 0.7692974 |

(8) Direct Lambert Conformal Two Standard Parallels

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 1

Prompt: Enter Title of Case

Input: Example 8

Prompt: Enter PHIO, LAM0, PH1, PH2, S

Input: 0, 0, 30, 60, .000001

Prompt: Enter NCASE, NPROJ, NPNT

Input: 0, 8, 0

Prompt: Enter PHI, LAM, NCARD

Input: 45, 20, 0

Output: Example 8

PHIO = 0 LAM0 = 0

PH1 = 30 PH2 = 60

Scale Factor = .000001

Direct Transformation

Lambert Conformal Two Standard Parallels

| Latitude | Longitude | X | Y |
|----------|-----------|----------|----------|
| 45 | 20 | 1.368962 | 2.353018 |

(9) Direct Equatorial Mercator Projection-Two Points

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 1

Prompt: Enter Title of Case

Input: Example 9

Prompt: Enter PH10, LAM0, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ, NPNT

Input: 0, 9, 0

Prompt: Enter PHI, LAM, NCARD

Input: 20, 20, 1

Output: Example 9

PH10 = 0 LAM0 = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Direct Transformation

Equatorial Mercator Projection

| Latitude | Longitude | X | Y |
|----------|-----------|----------|----------|
| 20 | 20 | 2.226389 | 2.273032 |

Prompt: Enter PH1, LAM, NCARD

Input: 20, 40, 0

| Latitude | Longitude | X | Y |
|----------|-----------|----------|----------|
| 20 | 40 | 4.452779 | 2.273032 |

(10) Direct Azimuthal Equidistant Projection-Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 1

Prompt: Enter Title of Case

Input: Example 10

Prompt: Enter PHIO, LAM0, PH1, PH2, S

Input: 30, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ, NPNT

Input: 0, 10, 0

Prompt: Enter PHI, LAM, NCARD

Input: 45, 45, 0

Output: Example 10

PHIO = 30 LAM0 = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Direct Transformation

Azimuthal Equidistant Projection

| Latitude | Longitude | X | Y |
|----------|-----------|----------|----------|
| 45 | 45 | 3.437281 | 2.491151 |

(11) Direct Gnomonic Projection-Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 1

Prompt: Enter Title of Case

Input: Example 11

Prompt: Enter PHIO, LAMO, PH1, PH2, S

Input: 30, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ, NPNT

Input: 0, 11, 0

Prompt: Enter PHI, LAM, NCARD

Input: 45, 45, 0

Output: Example 11

PHIO = 30 LAMO = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Direct Transformation

Gnomonic Projection

| Latitude | Longitude | X | Y |
|----------|-----------|----------|----------|
| 45 | 45 | 4.054418 | 2.938418 |

(12) Direct Polyconic Projection-Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 1

Prompt: Enter Title of Case

Input: Example 12

Prompt: Enter PHIO, LAMO, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ, NPNT

Input: 0, 12, 0

Prompt: Enter PHI, LAM, NCARD

Input: 20, 20, 0

Output: Example 12

PHIO = 0 LAMO = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Direct Transformation

Polyconic Projection

| Latitude | Longitude | X | Y |
|----------|-----------|----------|----------|
| 20 | 20 | 2.087155 | 2.351126 |

(13) Inverse Equal Area Azimuthal Projection-Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 0

Prompt: Enter Title of Case

Input: Example 13

Prompt: Enter PH10, LAM0, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ

Input: 0, 1

Prompt: Enter X, Y, NCARD

Input: 2.081414, .7575839, 0

Output: Example 13

PH10 = 0 LAM0 = 0

PH1 = 30 PH2 = 60

SCALE FACTOR = .000001

Inverse Transformation

Equal Area Azimuthal Projection

| Latitude | Longitude | X | Y |
|----------|-----------|----------|----------|
| 20 | 20 | 2.081414 | 0.757584 |

(14) Inverse Equal Area Conical Two Standard Parallels-Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 0

Prompt: Enter Title of Case

Input: example 14

Prompt: Enter PHIO, LAM0, PH1, PH2, S

Input: 0, 0, 30, 60, .000001

Prompt: Enter NCASE, NPROJ

Input: 0, 2

Prompt: Enter X, Y, NCARD

Input: 1.507226, 0.1766566, 0

Output: Example 14

PHIO = 0 LAM0 = 0

PH1 = 30 PH2 = 60

Scale Factor = .000001

Inverse Transformation

Equal Area Conical Two Standard Parallels

| Latitude | Longitude | X | Y |
|----------|-----------|----------|-----------|
| 45.00080 | 20.00032 | 1.507226 | 0.1766566 |

(15) Inverse Equal Area Cylindrical-Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 0

Prompt: Enter Title of Case

Input: Example 15

Prompt: Enter PHIO, LAM0, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ

Input: 0, 3

Prompt: Enter X, Y, NCARD

Input: 2.22642, 2.181479, 0

Output: Example 15

PHIO = 0 LAM0 = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Inverse Transformation

Equal Area Cylindrical Projection

| Latitude | Longitude | X | Y |
|----------|-----------|---------|----------|
| 20.00027 | 20.00028 | 2.22642 | 2.181479 |

(16) Inverse Sinusoidal Projection-Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 0

Prompt: Enter Title of Case

Input: Example 16

Prompt: Enter PH10, LAM0, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ

Input: 0, 4

Prompt: Enter X, Y, NCARD

Input: 2.092146, 2.22642, 0

Output: Example 16

PH10 = 0 LAM0 = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Inverse Transformation

Sinusoidal Projection

| Latitude | Longitude | X | Y |
|----------|-----------|----------|---------|
| 20.00028 | 20.00027 | 2.092146 | 2.22642 |

(17) Inverse Mollweide Projection-Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 0

Prompt: Enter Title of Case

Input: Example 17

Prompt: Enter PHIO, LAMO, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ

Input: 0, 5

Prompt: Enter X, Y, NCARD

Input: 1.928898, 2.45361, 0

Output: Example 17

PHIO = 0 LAMO = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Inverse Transformation

Mollweide Projection

| Latitude | Longitude | X | Y |
|----------|-----------|----------|---------|
| 20.00026 | 20.00027 | 1.928898 | 2.45361 |

(18) Inverse Parabolic Projection

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 0

Prompt: Enter Title of Case

Input: Example 18

Prompt: Enter PH10, LAM0, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ

Input: 0, 6

Prompt: Enter X, Y, NCARD

Input: 2.058388, 2.273217, 0

Output: Example 18

PH10 = 0 LAM0 = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Inverse Transformation

| Latitude | Longitude | X | Y |
|----------|-----------|----------|----------|
| 20.00027 | 20.00028 | 2.058388 | 2.273217 |

(19) Inverse Stereographic Projection-Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 0

Prompt: Enter Title of Case

Input: Example 19

Prompt: Enter PHIO, LAM0, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ

Input: 0, 7

Prompt: Enter X, Y, NCARD

Input: 2.113512, 0.7692669, 0

Output: Example 19

PHIO = 0 LAM0 = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Inverse Transformation

Stereographic Projection

| Latitude | Longitude | X | Y |
|----------|-----------|----------|-----------|
| 70.00103 | 20.00027 | 2.113512 | 0.7692669 |

(20) Inverse Lambert Conformal Two Standard Parallels--Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 0

Prompt: Enter Title of Case

Input: Example 20

Prompt: Enter PHIO, LAM0, PH1, PH2, S

Input: 0, 0, 30, 60, .000001

Prompt: Enter NCASE, NPROJ

Input: 0, 8

Prompt: Enter X, Y, NCARD

Input: 1.368964, 2.353033, 0

Output: Example 20

PHIO = 0 LAM0 = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Inverse Transformation

| Latitude | Longitude | X | Y |
|----------|-----------|----------|----------|
| 45.00010 | 20.00009 | 1.368964 | 2.353033 |

(21) Inverse Equatorial Mercator Projection-Single Point

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 0

Prompt: Enter Title of Case

Input: Example 21

Prompt: Enter PHIO, LAMO, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NRPOJ

Input: 0, 9

Prompt: Enter X, Y, NCARD

Input: 2.22642, 2.273053, 0

Output: Example 21

PHIO = 0 LAMO = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Inverse Transformation

| Latitude | Longitude | X | Y |
|----------|-----------|---------|----------|
| 20.00019 | 20.00028 | 2.22642 | 2.273053 |

(22) Direct Equal Area Cylindrical Projection-Grid

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 1

Prompt: Enter Title of Case

Input: Example 22

Prompt: Enter PHIO, LAMO, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ, NPNT

Input: 0, 3, 1

Prompt: Enter 1 for Graphics Output or
0 for Numerical Output

Input: 0

Prompt: Enter PHI1, LAM1, DPHI, DLAM, NPHI, NLAM

Input: -20, -20, 20, 20, 3, 3

Output: Example 22

PHIO = 0 LAMO = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Direct Transformation

| Latitude | Longitude | X | Y |
|----------|-----------|-----------|-----------|
| -20 | -20 | -2.226389 | -2.181451 |
| -20 | 0 | 0 | -2.181451 |
| -20 | 20 | 2.226389 | -2.181451 |
| 0 | -20 | -2.226389 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 20 | 2.226389 | 0 |
| 20 | -20 | -2.226389 | 2.181451 |
| 20 | 0 | 0 | 2.181451 |
| 20 | 20 | 2.226389 | 2.181451 |

(23) Direct Sinusoidal Projection-Grid

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 1

Prompt: Enter Title of Case

Input: Example 23

Prompt: Enter PHIO, LAM0, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ, NPNT

Input: 0, 4, 1

Prompt: Enter 1 for Graphics Output or
0 for Numerical Output

Input: 0

Prompt: Enter PHI1, LAM1, DPHI, DLAM, NPHI, NLAM

Input: -20, -20, 20, 20, 3, 3

Output: Example 23

PHIO = 0 LAM0 = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Direct Transformation

| Latitude | Longitude | X | Y |
|----------|-----------|-----------|-----------|
| -20 | -20 | -2.092122 | -2.226389 |
| -20 | 0 | 0 | -2.226389 |
| -20 | 20 | 2.092122 | -2.226389 |
| 0 | -20 | -2.226389 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 20 | 2.226389 | 0 |
| 20 | -20 | -2.092122 | 2.226389 |
| 20 | 0 | 0 | 2.226389 |
| 20 | 20 | 2.226389 | 2.226389 |

(24) Direct Equatorial Mercator Projection-Grid

Prompt: Enter 1 For Direct Transformation
Enter 0 For Inverse Transformation

Input: 1

Prompt: Enter Title of Case

Input: Example 24

Prompt: Enter PHIO, LAM0, PH1, PH2, S

Input: 0, 0, 0, 0, .000001

Prompt: Enter NCASE, NPROJ, NPNT

Input: 0, 9, 1

Prompt: Enter 1 for Graphics Output or
0 for Numerical Output

Input: 0

Prompt: Enter PHI1, LAM1, DPHI, DLAM, NPHI, NLAM

Input: -20, -20, 20, 20, 3, 3

Output: Example 24

PHIO = 0 LAM0 = 0

PH1 = 0 PH2 = 0

Scale Factor = .000001

Direct Transformation

| Latitude | Longitude | X | Y |
|----------|-----------|-----------|-----------|
| -20 | -20 | -2.226389 | -2.273032 |
| -20 | 0 | 0 | -2.273032 |
| -20 | 20 | 2.226389 | -2.273032 |
| 0 | -20 | -2.226389 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 20 | 2.226389 | 0 |
| 20 | -20 | -2.226389 | 2.273032 |
| 20 | 0 | 0 | 2.273032 |
| 20 | 20 | 2.226389 | 2.273032 |

SECTION 7

GRAPHICAL OUTPUT

Here we illustrate the use of Map Projection Software to generate a global display of (ϕ, λ) grids in the (x, y) plane for the case of sinusoidal projection. We decide arbitrarily to plot parallels (lines of constant ϕ) with a $\Delta\phi = 10^\circ$ increment (this gives 19 parallels counting the equator and the poles) and to plot meridians (lines of constant λ) with a $\Delta\lambda = 15^\circ$ increment (this gives 25 meridians). The resulting figure is plotted on the CRT and can be "dumped" to a graphics dot matrix printer by pressing the "PRTSC" key upon completion. This figure is identical to one in Map Projection Methods, page 126.

Of course the following is only one of an infinity of options. Any one of the twelve direct projections can be used, and any (ϕ, λ) region can be selected and any $(\Delta\phi, \Delta\lambda)$ line increments can be used.

(25) Global Graphical Display of the Sinusoidal Projection

Graticule

Prompt: Enter 1 for Direct Transformation
Enter 0 for Inverse Transformation

Input: 1

Prompt: Enter Title of Case

Input: Example 25

Prompt: Enter PHIO, LAMO, PH1, PH2, S

Input: 0, 0, 0, 0, 0.000001

Prompt: Enter NCASE, NPROJ, NPNT

Input: 0, 4, 1

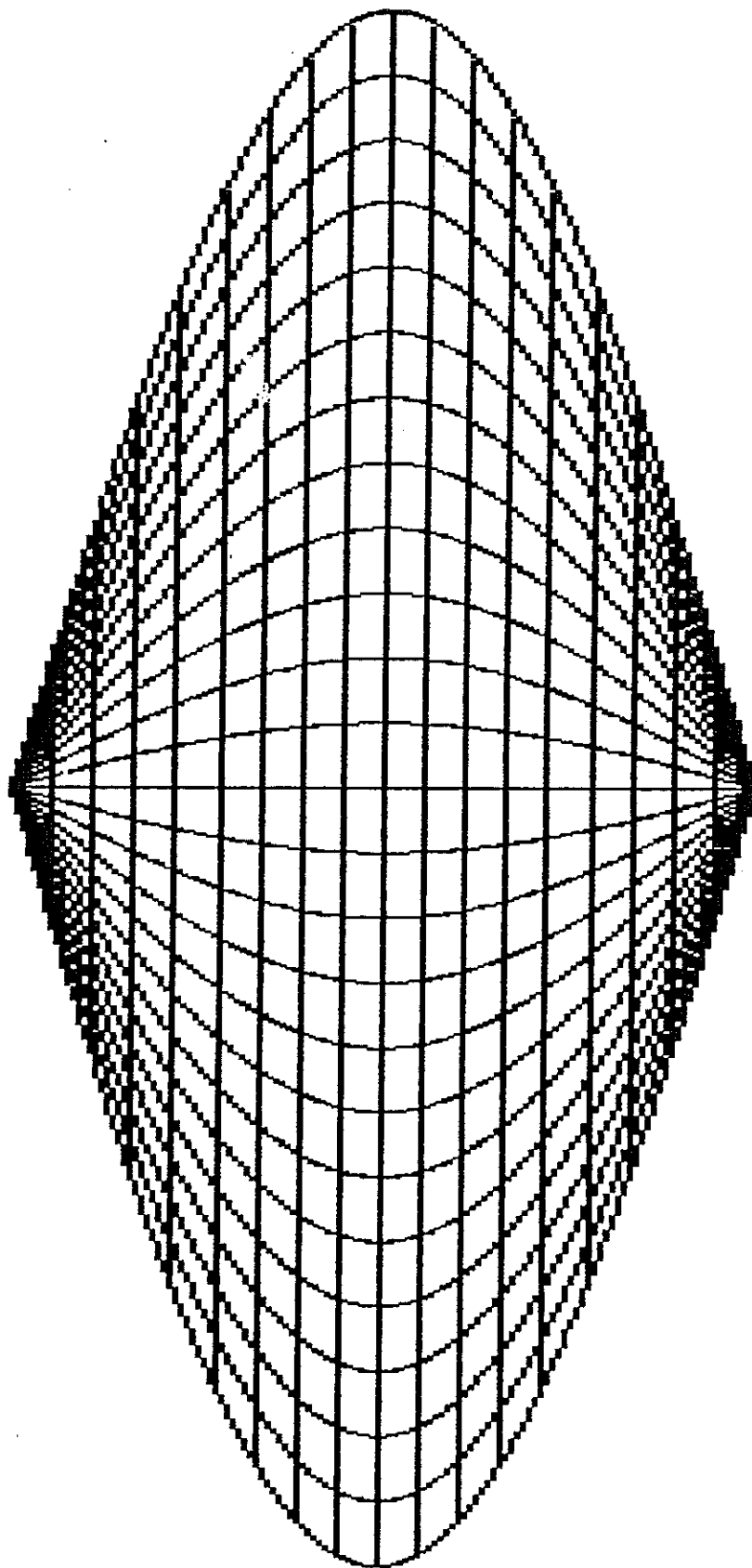
Prompt: Enter 1 for Graphics Output or
0 for Numerical Output

Input: 1

Prompt: Enter PHI1, LAM1, DPHI, DLAM, NPHI, NLAM

Input: -90, -180, 10, 15, 19, 25

Output: A nice figure (see next page). There are 300 points per each line of constant PHI, LAMDA, and since we have $19 + 25 = 44$ lines, the map transformation is calculated $300 \times 44 = 13,200$ times! Since the transformation computations require a fraction of a second per point (depending upon which transformation you select) the time to generate the graph can vary from a few minutes to half an hour.



SINUSOIDAL PROJECTION

Figure 4.6.1 on p.126 of MAP PROJECTION METHODS

For programmers and users with access to a plotter: much higher line quality can be achieved, of course, by driving a plotter directly (in lieu of plotting on the CRT and using the "PRTSC" option). The plots would be generated by replacing subroutine SCALE1 to determine an appropriate plotting output scale factor

$$GSL = \max \left[\text{ABS} \left(\frac{X_{\max} - X_{\min}}{XSCALE} \right), \text{ABS} \left(\frac{Y_{\max} - Y_{\min}}{YSCALE} \right) \right]$$

Subroutine GRAF must be modified at lines 3920, 3940, 3950, 4040, 4070, 4170, 4180, 4200 to generate output lines to your particular plotting device. In particular, lines 4040, 4050, 4170, 4180 would normally be written as

4040 XG(J) = X1 + X/GSL

4050 YG(J) = Y1 + Y/GSL

(The apparent sign switch (in subroutine GRAF) on Y and .4 scale factor account for the peculiar coordinates and rectangular pixels of the IBM CRT!) The coordinates along the line(s) to be plotted are contained in arrays XG, YG.

SECTION 8

REFERENCES

1. Pearson, Frederick, II., MAP PROJECTION METHODS, Sigma Scientific Series on Appl. Math., Sigma Scientific, Inc., Blacksburg, Va, 1984.
2. IBM Disk Operating System (DOS) 2.1, International Business Machines, 1984.