P R O J C T

PROJECTION AND DEPROJECTION OF CARTOGRAPHIC DATA AT THE KGS

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The PROJCT System

The PROJCT system is a collection of FORTRAN77 subroutines adapted from GIMMAP. It is designed to perform map projection of points from the geographic (longitude-latitude) reference system to Cartesian reference systems in (x,y). It is also designed to 'deproject' points from (x,y) to longitude-latitude and to 'reproject' previously projected (x,y) points from one (known) projection to another.

The geographic reference system is used universally for locating points on the surface of the earth. It is thus the ideal intermediate reference system for translating between any two projected coordinate systems. However, it can not be used directly for cartographic display due to the great amount of distortion which results. Thus, both systems have wide usage, and conversion between the two is essential. This is the function of the PROJCT system.

Projection, Deprojection, and Reprojection

Map projection is a mathematical transferrence of points on the 3-dimensional surface of the earth to the 2-dimensional form of a paper map. It is the conversion from the geographic reference system of longitude and latitude to the common Cartesian coordinate system of (x,y). In the PROJCT system, only the single 'output' projection (defined by SETPRO) need be specified to perform projection.

Only two of many different map projections are supported in the PROJCT system. These are the Lambert Conformal Conic and the Modified Polyconic projections, both based on projection from the surface of the earth onto imaginary cones. Both projections require the specification of parameters such as the map scale (the ratio of the projected unit to the true unit on the surface of the earth), and the map area (area of interest) or the central lines of longitude and latitude.

Since the surface of the earth is 3-dimensional, and paper maps and graphics screens are 2-dimensional, no projection can simultaneously preserve the accuracy of scale, area and shape which would be ideal. Each unique projection will preserve parts of these, but all maps have distortions.

The conversion of projected (x,y) points to geographic (longitude- latitude) coordinates is called deprojection, and is essentially the inverse of the projection process. The same unique set of parameters used in the original projection must be provided to properly convert the points back into longitude and latitude. For deprojection, only the 'input' projection (defined by SETDPRO) need be defined for PROJCT.

In practice, deprojection is not the inverse of projection. Instead, knowledge of the projection provides an excellent first approximation of the latitude of the point being deprojected. Subsequent bracketing approximations are based on the errors of former ones until the point is located within acceptable tolerances. In USGS 7.5′ maps (Scale 1:24,000), the first approximation is often the only one needed.

Projected points may be converted to other scales and projections through the process of reprojection. In this process, both an input (deprojection) and an output projection (projection) must be specified. The input projection parameters, used for deprojection, are set by a call to SETDPRO. The output projection parameters, used for projection following the deprojection, are set by a call to the SETPRO routine. Each point is deprojected according to the specified (original) input projection, then projected in the new projection.

Map Projection in the PROJCT System

The two map projections used in PROJCT (and generally in the state of Kansas) are both conic. The Lambert Conformal Conic projection is used in mid-latitudes with areas of large east-west extent. It uses two standard parallels and is the principal projection for maps of the whole state of Kansas. The Modified Polyconic projection is ideal for small areas in Kansas, and is based on a collection of cones, each tangent to the earth's surface at the latitude of the point to be projected.

The Lambert Conformal Conic projection is the most commonly used projection for the state of Kansas as a whole, because at mid-latitudes the projection minimizes distortion for areas of great east-west extent. For this reason, the Automated Cartography section has adopted it with the usual scale of 1:500,000 as their standard for whole-state maps and the GIMMAP system has incorporated this standard as an option wherever projections are performed. The standard is described below. The Lambert Conformal Conic projection is a conic projection with two standard parallels, and has been used traditionally by the U.S. Geological Survey whenever they map the whole state.

The Modified Polyconic projection is really a collection of many projections based on the cone. Points are projected on cones tangent to the earth at the latitude of each point. Unlike other projections, the points are not projected onto the same surface, but rather onto many surfaces. These surfaces are then (mathematically) positioned through simple scaling of the cones by the map scale. The result is a map which, at the scale of the USGS 7.5′ quadrangle sheets (1:24,000), has distortion so slight as to be almost negligible for small areas.

For both the Lambert Conformal Conic and the Modified Polyconic projections, the map scale and the area of the projection must be described to PROJCT by the south and north latitudes and the west and east longitudes of a rectangangle bounding the area of interest to be mapped. The Lambert projection also requires specification of two standard parallels. For the standard Lambert projection for the state of Kansas, these values are shown below. Additional values control translation and location of the origin in the projection system.

Using the PROJCT System

Coordinates in the geographic system will be expressed as decimal degrees, i.e. 38 degrees, 37 minutes and 30 seconds will be expressed as 38.625 degrees. Longitudes in Kansas may be expressed as positive or negative. Longitudes are interpreted as west of the prime meridian. Coordinates in projected space may actually represent inches, miles or centimeters.

In the PROJCT software, there are three functions available. One is to project, one is to deproject, and the third is to reproject. Projection may occur given points expressed in longitude and latitude, and specifications for the exact (output) projection to be used. These are described below. Deprojection requires points in (x,y) and specifications for an (input) projection equivalent to the projection which originally created. Finally, a projected point in (x,y) created by the PROJCT system may be converted to longitude-latitude and then back into a different projection (x,y).

The object file containing the PROJCT routines is:

:UTIL:GIMMAP.PROJCT.OB

which must be linked to in the usual manner. The five routines needed for set-up, projection, deprojection and reprojection are:

SETPRO - Call to initialize the output projection, (before calling PROJCT or REPROJCT). Usually called once.

SETDPRO - Call to initialize the input projection (before calling DEPROJCT or REPROJCT). Called once.

PROJCT - Call to project from longitude-latitude to the (x,y) system. Call once for each point.

DEPROJCT - Call to deproject a projected (x,y) point back to longitude-latitude. Call once for each point.

REPROJCT - Call to deproject to longitude-latitude and then project to (x,y). Call once for each point.

Initializing Input and Output Projections

To initialize the input and output projections, the following parameters must be declared and set as follows:

```
      INTEGER*4 NONEG, NPRO
      REAL EAST, NORTH, SCALE, SN, SOUTH, SS, WEST, XORG, XNE,
     +           XNW, XSE, XSW, YMIN, YORG, YNE, YNW, YSE, YSW
```

where,

NPRO = 1 for Modified Polyconic projection
= 2 for Lambert Conformal Conic projection
= 3 for the Standard Kansas Projection (see below)

SCALE = The Scale Factor (Scale is 1 : Scale Factor)

SOUTH = Degrees latitude of South Edge of Area
NORTH = Degrees latitude of North Edge of Area
WEST = Degrees longitude of West Edge of Area
EAST = Degrees longitude of East Edge of Area

SS = South Standard Parallel in Degrees
SN = North Standard Parallel in Degrees

Note: For Lambert projection. Minimum distortion at 1/6th of height from south and north edges.

XORG = X-coordinate of southwest corner of Area
YORG = Y-coordinate of southwest corner of Area

Note: The southwest corner is at (1,1). Use of the NONEG option (below) may overide these values.

NONEG = 0 for normal use (no special translation)
= 1 to translate if negative Y values are indicated (Consult with GIMMAP staff)

For the use of PROJCT or REPROJCT, the output projection must be set up. To do so, set the variables listed above and then execute:

```
      CALL SETPRO ( NPRO, SCALE, SOUTH, NORTH, WEST, EAST, SS, SN,
     +         XORG, YORG, NONEG, XSW, YSW, XSE, YSE, XNE, YNE, XNW,
     +         YNW, YMIN )
```

For DEPROJCT and REPROJCT, set the input projection variables to appropriate values (equal to those used to originally project the points) and call SETDPRO:

```
      CALL SETDPRO ( NPRO, SCALE, SOUTH, NORTH, WEST, EAST, SS,
     +         SN, XORG, YORG, NONEG, XSW, YSW, XSE, YSE, XNE, YNE,
     +         XNW, YNW, YMIN )
```

The following values are returned by SETPRO and SETDPRO:

XSW,YSW	=	Projected Southwest Corner of Area
XSE,YSE	=	Projected Southeast Corner of Area
XNE,YNE	=	Projected Northeast Corner of Area
XNW,YNW	=	Projected Northwest Corner of Area
YMIN	=	Minimum projected Y value in the Area

Note: Minimum Y occurs at SOUTH latitude and center longitude at (WEST+EAST)/2.

Standard Projection for the State of Kansas

When NPRO = 3 in the call to SETPRO or SETDPRO, the standard (GIMMAP) projection for the state of Kansas is assumed, with the parameters automatically set as follows by the GIMMAP software:

NPRO	=	2 (Lambert Conformal Conic)
SCALE	=	500000. (Scale is 1 : 500,000)
SOUTH	=	36.875 (Bounding Rectangle, Base Latitude)
NORTH	=	40.125
WEST	=	102.125
EAST	=	94.5
SS	=	33.
SN	=	45.
XORG	=	1.0 (Southwest Corner)
YORG	=	1.0
NONEG	=	0 (No Translation to Prevent Negative Y)

Projection of Points After SETPRO Is Called

Each longitude-latitude point is projected with a single call to the PROJCT routine, passing longitude-latitude in decimal degrees and receiving (x,y) coordinates to be used in inches:

```
REAL PLAT, PLON, X, Y

   :   :

CALL SETPRO ( ... )

   :   :

CALL PROJCT ( PLON, PLAT, X, Y )
```

where,

PLON,PLAT = Longitude, latitude of the point

X,Y = the projected point coordinates

Deprojection of Points After SETDPRO is Called

Deprojection of points which have been projected according to known parameters (especially if projected via GIMMAP) may be accomplished via the use of the SETDPRO and the DEPROJCT routines. To deproject points in (x,y) first set the parameters for deprojection, and call the SETDPRO routine one time. Then, to deproject each point, call the DEPROJCT routine:

```
INTEGER*4 SUCCESS
REAL PLAT, PLON, X, Y

   :   :

CALL SETDPRO ( ... )

   :   :

CALL DEPROJCT ( X, Y, PLON, PLAT, SUCCESS )
```

where,

X,Y = the projected coordinates of the point

PLON,PLAT = longitude/latitude of deprojected point

SUCCESS = 1 if deprojection was successful
= 0 if deprojection failed (the calling program should always check this)

Deprojection may fail, so the value of SUCCESS should be checked by the calling program after each call. All failures, indicated by the value of SUCCESS, should be reported to the GIMMAP staff along with the values of all parameters used in the call to DEPROJCT.

Reprojection After SETPRO and SETDPRO are Called

To convert points from one projection to another, both SETPRO and SETDPRO must be called to define the parameters for both the "input" and the "output" projections. Set-up of these two routines is described above. Once both projections have been set up, points in the input projection may be converted to the output projection by a single call to REPROJCT for each point. The REPROJCT routine essentially calls the DEPROJCT routine and then gives the results to the PROJCT routine:

```
INTEGER*4 SUCCESS
REAL PLAT, PLON, XP, XR, YP, YR

   :   :

CALL SETPRO ( ... )

   :   :

CALL SETDPRO ( ... )

   :   :

CALL REPROJCT ( XP, YP, XR, YR, SUCCESS )
```

where,

XP,YP = Coordinates in old (input) projection space

XR,YR = Coordinates in new (output) projection space
= -9999. , -9999. if deprojection failed

SUCCESS = See above under DEPROJCT

Because it uses the DEPROJCT routine, REPROJCT may fail. All such failures should be reported with parameter values.