User's Manual for WHTGCTP1: A User-Friendly Map-Coordinate Projection Program

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Abstract

WHTGCTP1 is a Microsoft Windows program that allows the user to project coordinates between any coordinate systems supported by the General Cartographic Transformation Package, a total of twenty projections and geographic angular coordinates that includes most common coordinate systems. Although originally designed for use with the WHEAT software package, it can project coordinates entered interactively or any coordinates stored in a MS Access database.

When using WHTGCTP1 to project coordinates in a database, the coordinates can be for individual point locations, where X,Y pairs are stored in two separate fields, or coordinate chains of X,Y pairs stored in one Binary Large OBject field (XYBLOBs as used in the WHEAT package) for lines and polygons. WHTGCTP1 is based on NOAA's General Cartographic Transformation Package (GCTP), Version II.

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Introduction

This report describes the use of WHTGCTP1, the WHEAT implementation of the General Cartographic Transformation Package (see Related Publications for references). WHTGCTP1 is a user-friendly, MS Windows program that allows the user to transform geographic coordinates from one projection system to another, such as Universal Transverse Mercator (UTM) coordinates to longitude-latitude (Geographic Angular). GCTP supports twenty projection systems and geographic angular coordinates (longitude-latitude). WHTGCTP1 supports, directly or indirectly, all of twenty-one systems listed in Table 1.

WHTGCTP1 requires the user to supply projection parameter files, which are plain ascii text files explained in Projection File Format section. There is no Graphical User Interface support for creating these PRJ files, because this program should not be run very often: it is rarely worth the trouble of defining new projection parameters, and standard projections should be used whenever possible. In particular, projections that are available as tic marks on maps for the area covered should be given priority. This means that the Universal Transverse Mercator system and latitude-longitude should be the most commonly used systems. For geological work and other applications where angles are important, conformal projections should be used. See Appendix 1 for a copy of the USGS's projection properties table copied from Snyder (1982).

Most of the information in this manual is in the on-line help file provided with WHTGCTP1.

Related Publications and Software

WHTGCTP1 is based on the General Cartographic Transformation Package (GCTP), Version II from the National Oceanic and Atmospheric Administration (Elassal, 1987), a set of Fortran library routines.

WHEAT, the **W**indows-based **H**ydrogeologic **E**xploration and **A**ppraisal **T**oolkit, is a suite of user-friendly Microsoft Windows programs for natural resource exploration and management. WHEAT includes a computer-based mapping program that allows easy display and spatial querying of maps. The principle goals in development of WHEAT have been ease of use, hardware independence, low cost, and end-user extensibility. WHEAT's native data format is a Microsoft Access database. WHEAT stores an item's geographic coordinates as attributes so they can be easily accessed by the user. The WHEAT programs are designed to be used in conjunction with other Windows software to allow the natural resource scientist to perform work easily and effectively. WHEAT is available from the KGS World Wide Web server (http://www.kgs.ukans.edu) and as a series of Open File Reports from Kansas Geological Survey WHEAT (Pouch, 1994, 1995, 1996a, 1996b)

An excellent discussion of map projections is Snyder (1982), and other papers by the same author, especially Snyder (1987) and Snyder (1989).

In order to provide the flexibility of all possible GCTP projections, WHTGCTP1 is slightly harder to use than some closely-related programs: LLUTM14_ (KGS OFRs 95-10 and 95-11) and LLUTMN_ (KGS OFRs 95-12 and 95-13), which only work with Universal Transverse Mercator (UTM) and Longitude-Latitude. (LLUTM14_ is hard-wired for UTM Zone 14, as this is used for many databases distributed in WHEAT format by KGS Geohydrology.) If you are interested in only UTM-Angular conversions, use LLUTMN. If your interests are limited to UTM Zone 14, use LLUTM14_.

Limitations

Like other projection software, it cannot perform a datum shift. It can change ellipsoids at will, but not datums. That is to say, it cannot change coordinates from NAD27 to NAD83, although it can change projected coordinates from the Clarke 1866 ellipsoid to the WGS ellipsoid. If you do not know what these terms mean, do not try to perform a datum shift at all.

State Plane Coordinates are not directly supported in WHTGCTP1 for two reasons: it is quite possible to have a single feature that spans multiple SPCS Zones, and I could not get it to work. If you need to use State Plane Coordinates, you have two choices: use the State Plane Coordinate projection parameters to define a PRJ file and use that, keeping track of the SPCS Zone; or fix the Fortran source code (KGS OFR 95-15). Note that neither WHTGCTP1 nor GCTP keeps track of which SPCS zone you should be using.

Source Code

The Visual Basic source code, which can be used in Microsoft Visual Basic, Excel, or Access, is available as Kansas Geological Survey Open File Report 95-15. OFR 95-15 also includes a copy of the Fortran source code as used in this program, which differs slightly from the original GCTP source code, mainly in disabling the State Plane Coordinate read options. The original GCTP source code was obtained from the USGS by anonymous ftp from charon.er.usgs.gov.

Projection File Format

WHTGCTP1 uses projection parameter files to define the coordinate systems for input and output. The same file can be used for input and output coordinate systems. WHTGCTP1 requires projection parameters to be in a file organized as shown below. It does not allow interactive entry of projection parameters.

A PRJ file must always contain at least 18 lines, even when the projection system chosen does not require that many parameters. On all lines of PRJ file, except line 2, comments are allowed after the numbers.

A valid PRJ file is organized out as follows:

Line 1) Comment line or blank line at top (ignored by program)
Line 2) Suffix/name for coordinate system (added to field name; shows up on labels and buttons)
Line 3) GCTP Coordinate System Code Number
Line 4) Zone Number
Line 5) Unit Codes for Coordinates
Lines 6-18) Projection parameters, one on each line. There must be 13 parameters defining the projection. All 13 must always be present.

This is a valid PRJ file that describes the projection used in the USGS's 1:2,000,000 series Digital Line Graphs of the contiguous 48 states.

Used in 1:2M DLGs	1	Ignored by program
USAMap48	2	Used as suffix on output field names
3	3	GCTP Projection Code Number
9999	4	GCTP Zone Number
2	5	GCTP Units Code Number
6378206.400000000000000	6	GCTP Projection Parameter 1
6.768657997291090E-003	7	GCTP Projection Parameter 2
293000.0000	8	GCTP Projection Parameter 3
453000.0000	9	GCTP Projection Parameter 4
-960000.0000	10	GCTP Projection Parameter 5
230000.0000	11	GCTP Projection Parameter 6
0.000000000000000E+000	12	GCTP Projection Parameter 7
0.000000000000000E+000	13	GCTP Projection Parameter 8
0.000000000000000E+000	14	GCTP Projection Parameter 9
0.000000000000000E+000	15	GCTP Projection Parameter 10
0.000000000000000E+000	16	GCTP Projection Parameter 11
0.000000000000000E+000	17	GCTP Projection Parameter 12
0.000000000000000E+000	18	GCTP Projection Parameter 13

All lines after line 18 are ignored

Lines 6 through 18 contain GCTP projection parameters. These depend on the coordinate system chosen. Distances should be specified in meters and angles as packed DMS numbers. Most projections use parameters 1 and 2 to contain ellipsoid information: the semi-major axis and the squared eccentricity. Projections that use a sphere store the radius in the parameter 1 and don't use parameter 2.

GCTP Coordinate System Codes

The following coordinate systems are supported by GCTP. All except State Plane Coordinates are directly supported by WHTGCTP1; for SPCZ, the user would need to provide all the input projection parameters and treat it like any other coordinate system.

It is strongly recommended that you use as few coordinate systems as possible, and try to use only coordinate systems for which maps provide coordinate ticks. This generally means Geographic, UTM, and State Plane Coordinates. UTM is strongly recommended.

Table copied from Elassal (1987).

Table 1 GCTP Coordinate Systems and Code Numbers

Coordinate System Name	Coordinate System Code Number
Geographic Angular	0
Universal Transverse Mercator UTM	1
State Plane SPCZ (not supported)	2
Albers Conic Equal-Area	3
Lambert Conformal Conic	4
Mercator	5
Polar Stereographic	6
Polyconic	7
Equidistant Conic	8
Transverse Mercator	9
Stereographic	10
Lambert Azimuthal Equal-Area	11
Azimuthal Equidistant	12
Gnomonic	13
Orthographic	14
General Vertical near-side perspective	15
Sinusoidal	16
Equirectangular	17
Miller Cylindrical	18
Van der Grinten I	19
Oblique Mercator (Hotine)	20

Unit Codes

In WHTGCTP1, the unit of measurement must be specified by using a code number listed in Table 2.

Table copied from Elassal (1987).

Table 2 GCTP Unit Codes

Unit Of Measure	Unit Code Number	Remark
feet	1	
meters	2	
seconds of arc	3	
decimal degrees of arc	4	
packed DMS	5	looks like ±DDDMMSS.ssss

Packed DMS degrees are angles in **D**egree **M**inute **S**econd format written as a single decimal number in the form ±DDDMMSS.ssss, where DDD is the degrees portion, MM is the minutes, SS is the seconds, and .ssss is the fractional seconds.
Thus, 101° 32' 30" W would be written as -1053230.0000 and
101° 33' 30.5130" W would be written as -1053330.5130

Zone Numbers

For UTM coordinates, there are pre-defined zone numbers ranging from 1 to 60. Consult a map near the center of your area of interest to find the appropriate UTM zone. For other coordinate systems, there are no pre-defined zones. For these, choose a number greater than 60 for the projection.

EACH DIFFERENT PROJECTION YOU USE MUST HAVE A UNIQUE ZONE NUMBER. The reason is that when WHTGCTP1 projects coordinates, it checks whether the projection system has already been initialized, by looking at the zone number. If the same zone number is used for both input and output systems, the results will be unpredictable and probably wrong.

Ellipsoid Parameters

The following table was copied from Snyder (1982).

Table 3 Ellipsoids

Ellipsoid Name	**Date**	**Semi-major axis *a***	**Ellipticity Squared**	**Polar Radius b**	**1/f**	
Clarke1866	1866	6378206.4	0.006768628	6356583.8	294.98	**NAD27**
GRS80	1980	6378137	0.006694385	6356752.3	298.257	**NAD83**
WGS72	1972	6378135	0.006694318	6356750.5	298.26	
Australian	1965	6378160	0.006694542	6356774.7	298.25	
Krasovsky	1940	6378245	0.006693422	6356863	298.3	
International	1924	6378388	0.00672267	6356911.9	297	
Clarke1880	1880	6378249.1	0.006803627	6356514.9	293.46	
Airy	1849	6377563.4	0.00667065	6356256.9	299.32	
Bessel	1841	6377397.2	0.006674435	6356079	299.15	
Everest	1830	6377276.3	0.006637884	6356075.4	300.8	

Normal Use of WHTGCTP1

WHTGCTP1 is designed to be a rarely-run program that guides the user through the process. When you first start WHTGCTP1, it will prompt you to open input and output projection files. After opening an input and an output projection file, you can project interactively-entered points, which might provide a useful check on the projection files.

Usually, you use WHTGCTP1 to project coordinates stored in a database (in Microsoft Access format) from one system to another. To project coordinates stored in a database,

1 Open the database using the menu-item File|Open Database...
2 Click on the XY Pairs (for symbols or text labels) or XY BLOBs (for lines or polygons) button
3 Choose a table or query from the list at the top of the tab.
4 Select the input field names from the lists. The "from" fields are on the left.
5 Select the names of the output fields on the right. You can save the output in a new field (good idea) or in an old field (bad idea).
6 Click the button, which will have a name and > > indicating the "from" and "to" projections
7 Go get some pop or coffee while this runs.

You can also specify the input and output projection systems and the database on the command-line using Program Manager. For example, the following line specifies all three.

WHTGCTP1.exe IN=e:\gis_lib\usamap48\USAMAP48.PRJ OUT=e:\gis_lib\usamap48\UTM14.PRJ db=e:\gis_lib\usamap48\junk1.mdb

Tips

It may be useful to create a dummy query that simply retrieves the fields of interest under new names that WHTGCTP1 will recognize, such as X_something, Y_something for X,Y pairs or XY_something for coordinate chains.

Installation

Run the SETUP.EXE program on the included diskette.

References

Elassal, Atef A., 1987, General Cartographic Transformation Package (GCTP), Version II, NOAA Technical Report NOS 124 CGS 9, 23 pp.

Pouch, G.W., 1994, User's Guide to WHEAT : the Windows-based Hydrogeologic Exploration and Analysis Toolkit, Open File Report 94-51, Kansas Geological Survey, 28 pages.

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Snyder, John P., 1982, *Map Projections Used by U.S. Geological Survey*, Bulletin 1532, United States Geological Survey, 313 pages.

Snyder, John P., 1987, *Map projections: a working manual*, Professional Paper 1395, United States Geological Survey, 383 pages.

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Appendix 1 Properties of Selected Map Projections

The Properties and Uses of Selected Map Projections, adapted from Snyder (1982)

Name of Projection	Lines of longitude (meridians)	Lines of latitude (parallels)	Graticule spacing	Linear scale	Notes	Uses
Mercator	Meridians are straight and parallel.	Latitude lines are straight an parallel.	Meridian spacing is equal, and the parallel spacing increases away from the equator. The graticule spacing retains the property of conformality. The graticule is symmetrical. Meridians and parallels intersect at right angles.	Linear scale is true along the equator only (line of tangency), or along two parallels equidistant from th equator (the secant form). Scale can be determined by measuring one degree of latitude, which equals 60 nautical miles, 69 statute miles or 111 kilometers.	Projection can be thought of as being mathematically based on a cylinder tangent at the equator. Any straight line is a constant-azimuth (rhumb) line. Areal enlargement is extreme away from the equator; poles cannot be represented. Shape is true only within any small area. Reasonably accurate projection within a 15° band along the line of tangency.	An excellent projection for equatorial regions. Otherwise the Mercator is a special-purpose map best suited for navigation. Secant constructions are used for large-scale coastal charts. The use of the Mercator map projection as the base for nautical charts is universal. Examples are the charts published by the National Ocean Survey, U.S. Dept. of Commerce.
Oblique Mercator	Meridians are complex curves concave toward the line of tangency, except each 180th meridian is straight.	Parallels are complex curves concave toward the nearest pole.	Graticule spacing increases away from the line of tangency and retains the property of conformality.	Linear scale is true along the line of tangency, or along two lines equidistant from and parallel to the line of tangency.	Projection is mathematically based on a cylinder tangent along any great circle other than the equator or a meridian. Shape is true only within any small area. Areal enlargement increases away from the line of tangency. Reasonably accurate projection within a 15° band along the line of tangency.	Useful for plotting linear configurations that are situated along a line oblique to the earth's equator. Examples are: NASA Surveyor Satellite tracking charts, ERTS flight indexes, strip charts for navigation, and the National Geographic Society's maps "West Indies", "Countries of the Caribbean", "Hawaii", and "New Zealand".
Transverse Mercator	Meridians are complex curves concave toward a straight central meridian that is tangent to the globe. The straight central meridian intersects the equator and one meridian at a 90° angle.	Parallels are complex curves concave toward the nearest pole; the equator is straight.	Parallels are spaced at their true distances on the straight central meridian. Graticule spacing increases away from the tangent meridian. The graticule retains the property of conformality.	Linear scale is true along the line of tangency, or along two lines equidistant from and parallel to the line of tangency.	Projection is mathematically based on a cylinder tangent to a meridian. Shape is true only within any small area. Areal enlargement increases away from the tangent meridian. Reasonably accurate projection within a 15° band along the line of tangency. Cannot be edge-joined in an east-west direction if each sheet has its own central meridian.	Used where the north-south dimension is greater than the east-west dimension. Used as the base for the U.S. Geological Survey's 1:250,000-scale series and for some of the 7½-minute and 15-minute quadrangles of the National Topographic Map Series.

Name of Projection	Lines of longitude (meridians)	Lines of latitude (parallels)	Graticule spacing	Linear scale	Notes	Uses
Modified Transverse Mercator	On pre-1973 editions of the Alaska Map E, meridians are curved concave toward the center of the projection. On post-1973 editions the meridians are straight.	Parallels are arcs concave to the pole.	Meridian spacing is approximately equal and decreases toward the pole. Parallels are approximately equally spaced. The graticule is symmetrical on post-1973 editions of the Alaska Map E.	Linear scale is more nearly correct along the meridians than along the parallels.	The Alaska Map E was adapted from a set of transverse Mercator projections 8° wide and approximately 18° long, repeated east and west of an arbitrary point of origin until a projection 72° wide was obtained. The post-1973 editions of the Alaska Map E more nearly approximate an equidistant conic map projection.	The U.S. Geological Survey's Alaska Map E at the scale of 1:2,500,000. The figure below represents the 1954 edition. The 1973 edition is similar, but the meridians are straight. The Bathymetric Maps Eastern Continental Margin USA, published by the American Association of Petroleum Geologists, uses these straight meridians on its Modified Transverse Mercator and is more equivalent to the Equidistant Conic map projection.
Equidistant Conic Simple Conic	Meridians are straight lines converging on a polar axis but not at the pole.	Parallels are arcs of concentric circles concave toward a pole.	Meridian spacing is true on the standard parallels and decreases toward the pole. Parallels are spaced at true scale along the meridians. Meridians and parallels intersect each other at right angles. The graticule is symmetrical.	Linear scale is true along all meridians and along the standard parallel or parallels.	Projection is mathematically based on a cone that is tangent at one parallel or conceptually secant at two parallels. North or South Pole is represented by an arc.	The Equidistant Conic projection is used in atlases for portraying mid-latitude areas. It is good for representing regions with a few degrees of latitude lying on one side of the Equator. The Kavraisky No. 4 map projection is an Equidistant conic map projection, in which standard parallels are chosen to minimize overall error.
Lambert Conformal Conic	Meridians are straight lines converging at a pole.	Parallels are arcs of concentric circles concave toward a pole and centered at the pole.	Meridian spacing is true on the standard parallels and decreases toward the pole. Parallel spacing increases away from the standard parallels and decreases between them. Meridians and parallels intersect each other at right angles. The graticule spacing retains the property of conformality. The graticule is symmetrical.	Linear scale is true on standard parallels. Maximum scale error is 2½ percent on a map of the United States (48 states) with standard parallels at 33° N. and 45° N.	Projection is mathematically based on a core that is tangent at one parallel or (more often) that is conceptually secant on two parallels. Areal distortion is minimal but increases away from the standard parallels. North or South Pole is represented by a point; the other pole cannot be shown. Great circle lines are approximately straight. Retains its properties at various scales; sheets can be joined along their edges.	Used for large countries in the mid-latitudes having an east-west orientation. The United States (50 states) Base Map uses standard parallels at 37° N. and 65° N. Some of the National Topographic Map Series 7½-minute and 15-minute quadrangles and the State Base Map Series are constructed on the Lambert Conformal Conic map projection. The latter series uses standard parallels of 33° N. and 45° N. Aeronautical charts for Alaska use standard parallels at 55° N. and 65° N. The National Atlas of Canada uses standard parallels at 49° N. and 77° N. In the figure below, the outline represents the United States (50 states) Base Map.
Albers Conic Equal-Area	Meridians are straight lines converging on the polar axis, but not at the pole.	Parallels are arcs of concentric circles concave toward a pole.	Meridian spacing is equal on the standard parallels and decreases toward the poles. Parallel spacing decreases away from the	Linear scale is true on the standard parallels. Maximum scale error is 1¼ percent on a map of the United States (48 states)	Projection is mathematically based on a cone that is conceptually secant on two parallels. No areal deformation. North or South Pole is represented by an arc. Retains its properties at various scales; individual sheets	Used for thematic maps. Used for large countries with an east-west orientation. Maps based on he Albers equal-area conic for Alaska use standard parallels 55° N. and 65° N.; for Hawaii, the standard parallels are

			standard parallels and increases between them. Meridians and parallels intersect each other at right angles. The graticule spacing preserves the property of equivalence of area. The graticule is symmetrical.	with standard parallels of 29½° N. and 45½° N.	can be joined along their edges.	8° N. and 18° N. The National Atlas of the United States, United States Base Map (48 states), and the Geologic map of the United States (outlined below) are based on the standard parallels of 29½° N. and 45½° N.
American Polyconic	Meridians are complex curves concave toward a straight central meridian.	Parallels are non-concentric circles except for a straight equator.	Meridian spacing is equal and decreases toward the poles. Parallels are spaced true to scale on the central meridian, and the spacing increases toward the east and west borders. The graticule spacing results in a compromise of all properties.	Linear scale is true along each parallel and along the central meridian. Maximum scale error is 7 percent on a map of the United States (48 states).	Projection is mathematically based on an infinite number of cones tangent to an infinite number of parallels. Distortion increases away from the central meridian. Has both areal and angular deformation.	Used for areas with a north-south orientation. Only along central meridian does it portray true shape, area, distance, and direction. Formerly used as the base of the 7½-minute and 15-minute quadrangles of the National Topographic Map Series. Individual sheets of this series can be edge-joined since they are drawn with straight meridians for convenience. They cannot be mosaicked beyond a few sheets.
Bipolar Oblique Conic	Meridians are complex curves concave toward the center of the projection.	Parallels are complex curves concave toward the nearest pole.	Graticule spacing increases away from the lines of true scale and retains the property of conformality.	Linear scale is true along two lines that do not lie along any meridian or parallel. Scale is compressed between these lines and expanded beyond them. Linear scale is generally good, but there is as much as a 10 percent error at the edge of the projection as used.	Projection is mathematically based on two cones whose apexes are 104° apart, and which conceptually are obliquely secant to the sphere along lines following the trend of North and South America.	Used to represent one or both of the American continents. Examples are the Basement map of North America and the Tectonic map of North America.
Sinusoidal	Meridians are sinusoidal curves, curved concave toward a straight central meridian.	All parallels are straight, parallel lines.	Meridian spacing is equal and decreases toward the poles. Parallel spacing is equal. The graticule spacing retains the property of equivalence of area.	Linear scale is true on the parallels and the central meridian.	Projection is mathematically based on a cylinder tangent on the equator. The sinusoidal projection may have several central meridians and may be interrupted on any meridian to help reduce distortion at high latitudes. There is no angular deformation along the central meridian and the equator.	Used as an equal-area projection to portray areas that have a maximum extent in a north-south direction. Used as a world equal-area projection in atlases to show distribution patterns. The figure below represents an interrupted version of the sinusoidal projection with three central meridians. Used by the U.S. Geological Survey as the base for maps showing prospective hydrocarbon provinces of the world and sedimentary basins of the world.
Eckert No. 6	Meridians are sinusoidal curves concave toward a straight central meridian.	All parallels are straight, parallel lines.	Meridian and parallel spacing decreases toward the poles. The graticule spacing retains the property of equivalence of area.	Linear scale is true along parallel 49° 16′ north and south of the equator.	Projection is mathematically based on a cylinder tangent at the equator. Poles are represented by straight lines half the length of the equator. Distortion of shape is extreme at high latitudes.	Used as an equal-area map projection of the world in atlases such as the Great Soviet World Atlas, 1937. Kavraisky No. 6 map projection closely resembles Eckert No. 6 and is used in the Ocean Atlas, 1953, Vol. 2.

Name of Projection	Lines of longitude (meridians)	Lines of latitude (parallels)	Graticule spacing	Linear scale	Notes	Uses
Van Der Grinten	Meridians are circular arcs concave toward a straight central meridian.	Parallels are circular arcs concave toward the poles except for a straight equator.	Meridian spacing is equal at the equator. The parallels are spaced farther apart toward the poles. Central meridian and equator are straight lines. The poles commonly are not represented. The graticule spacing results in a compromise of all properties.	Linear scale is true along the equator. Scale increases rapidly toward the poles.	The projection has both areal and angular deformation. It was conceived as a compromise between the Mercator and the Mollweide, which shows the world in an ellipse. The Van der Grinten shows the world in a circle.	The Van der Grinten projection is used by the National Geographic Society for world maps. Used by the U.S. Geological Survey to show distribution of mineral resources on the sea floor (McKelvey and Wang, 1970).
Azimuthal Equidistant	Polar aspect: the meridians are straight lines radiating from the point of tangency. Oblique aspect: the meridians are complex curves concave toward the point of tangency. Equatorial aspect: the meridians are complex curves concave toward a straight central meridian, except the outer meridian of a hemisphere, which is a circle.	Polar aspect: the parallels are concentric circles. Oblique aspect: the parallels are complex curves. Equatorial aspect: the parallels are complex curves concave toward the nearest pole; the equator is straight.	Polar aspect: the meridian spacing is equal and increases away from the point of tangency. Parallel spacing is equidistant. Angular and areal deformation increase away from the point of tangency.	Polar aspect: linear scale is true from the point of tangency along the meridians only. Oblique and equatorial aspects: linear scale is true from the point of tangency. In all aspects the Azimuthal Equidistant shows distances true to scale when measured between the point of tangency and any other point on the map.	Projection is mathematically based on a plane tangent to the earth. The entire earth can be represented. Generally the Azimuthal Equidistant map projection portrays less than one hemisphere, though the other hemisphere can be portrayed but is much distorted. Has true direction and true distance scaling from the point of tangency.	The Azimuthal Equidistant projection is used for radio and seismic work, as every place in the world will be shown at its true distance and direction from the point of tangency. The U.S. Geological Survey uses the oblique aspect of the Azimuthal Equidistant in the National Atlas and for large-scale mapping of Micronesia. The polar aspect is used as the emblem of the United Nations.
Lambert Azimuthal Equal-Area	Polar aspect: the meridians are straight lines radiating from the point of tangency. Oblique and equatorial aspects: meridians are complex curves concave toward a straight central meridian, except the outer meridian of a hemisphere, which is a circle.	Polar aspect: parallels are concentric circles. Oblique and equatorial aspects: the parallels are complex curves. The equator on the equatorial aspect is a straight line.	Polar aspect: the meridian spacing is equal and increases, and the parallel spacing is unequal and decreases toward the periphery of the projection. The graticule spacing in all aspects retains the property of equivalence of area.	Linear scale is better than most azimuthals but not as good as the equidistant. Angular deformation increases toward the periphery of the projection. Scale decreases radially toward the periphery of the map projection. Scale increases perpendicular to the radii toward the periphery.	The Lambert Azimuthal Equal-Area projection is mathematically based on a plane tangent to the earth. It is the only projection that can accurately represent both areas and true direction from the center of the projection. This projection generally represents only one hemisphere.	The polar aspect is used by the U.S. Geological Survey in the National Atlas. The polar, oblique, and equatorial aspects are used by the U.S. Geological Survey for the Circum-Pacific Map.

Name of Projection	Lines of longitude (meridians)	Lines of latitude (parallels)	Graticule spacing	Linear scale	Notes	Uses
Orthographic	Polar aspect: the meridians are straight lines radiating from the point of tangency. Oblique aspect: the meridians are ellipses, concave toward the center of the projection. Equatorial aspect: the meridians are ellipses concave toward the straight central meridian.	Polar aspect: the parallels are concentric circles. Oblique aspect: the parallels are ellipses concave toward the poles. Equatorial aspect: the parallels are straight and parallel.	Polar aspect: meridian spacing is equal and increases, and the parallel spacing decreases from the point of tangency. Oblique and equatorial aspects: the graticule spacing decreases away from the center of the projection.	Scale is true on the parallels in the polar aspect and on all circles centered at the pole of the projection in all aspects. Scale decreases along lines radiating from the center of the projection.	The Orthographic projection is geometrically based on a plane tangent to the earth, and the point of projection is at infinity. The earth appears as it would from outer space. This projection is a truly graphic representation of the earth and is a projection in which distortion becomes a visual aid. It is the most familiar of the azimuthal map projections. Directions from the center of the Orthographic map projection are true.	The U.S. Geological Survey uses the Orthographic map projection in the National Atlas.
Stereographic	Polar aspect: the meridians are straight lines radiating from the point of tangency. Oblique and equatorial aspects: the meridians are arcs of circles concave toward a straight central meridian. In the equatorial aspect the outer meridian of the hemisphere is a circle centered at the projection center.	Polar aspect: the parallels are concentric circles. Oblique aspect: the parallels are non-concentric arcs of circles concave toward one of the poles with one parallel being a straight line. Equatorial aspect: parallels are non-concentric arcs of circles concave toward the poles; the equator is straight.	The graticule spacing increases away from the center of the projection in all aspects, and it retains the property of conformality.	Scale increases toward the periphery of the projection.	The Stereographic projection is geometrically projected onto a plane, and the point of the projection is on the surface of the sphere opposite the point of tangency. Circles on the earth appear as straight lines, parts of circles, or circles on the projection. Directions from the center of the stereographic projection is the most widely used azimuthal projection, mainly used for portraying large, continent-size areas of similar extent in all directions. It is used in geophysics for solving problems in spherical geometry.	The polar aspect is used for topographic maps and navigational charts. The American Geographical Society uses the stereographic map projection as the basis for its "Map of the Arctic". The U.S. Geological Survey uses the stereographic map projection as the basis for maps of Antarctica.
Gnomonic	Polar aspect: the meridians are straight lines radiating from the point of tangency. Oblique and equatorial aspects: the meridians are straight lines.	Polar aspect: the parallels are concentric circles. Oblique and equatorial aspects: parallels are ellipses, parabolas, or hyperbolas concave toward the poles (except for the equator, which is straight).	Polar aspect: the meridian spacing is equal and increases away from the pole. The parallel spacing increases very rapidly from the pole. Oblique and equatorial aspects: the graticule spacing increases very rapidly away from the center of the projection.	Linear scale and angular and areal deformation are extreme, rapidly increasing away from the center of the projection.	The Gnomonic projection is geometrically projected onto a plane, and the point of projection is at the center of the earth. It is impossible to show a full hemisphere with one Gnomonic map. It is the only projection in which any straight line is a great circle, and it is the only projection that shows the shortest distance between any two points as a straight line. Consequently, it is used in seismic work because seismic waves travel in approximately great circles.	The Gnomonic projection is used with the Mercator projection for navigation.

Appendix 2 Map Projection Parameters

The following definitions of projections parameters were copied from Elassal (1987). Only the Geographic Angular, UTM, and Alber's Conformal Conic systems have been tested.

Albers Conical Equal Area

This map projection is equal area and is used in the USGS 1:2,000,000 series Digital Line Graphs. It is useful for continental-size areas that span several UTM zone. The following is a valid PRJ file for use with the Alber's Conic Equal-Area projection. These parameters are used in the 1:2,000,000 DLGs of the contiguous 48 states by the USGS

Map projection used by USGS for 1:2M DLGs
USAMap48
3 Alber's Conic Equal-Area
9999 USGS traditional designation for this projection
2 units of meters

6378206.400000000000000	1	Semi-major axis of ellipsoid. Clarke 1866
6.768657997291090E-003	2	Eccentricity of ellipsoid squared Clarke 1866
293000.0000	3	Latitude of first standard parallel 29° 30' 00.00" N
453000.0000	4	Latitude of second standard parallel 45° 30' 00.00" N
-960000.0000	5	Longitude of central meridian 96° 00' 00.00" W
230000.0000	6	Latitude of projection's origin 23° 00' 00.00" N
0.000000000000000E+000	7	False easting =0
0.000000000000000E+000	8	False northing =0
0	9	NOT USED
0	10	NOT USED
0	11	NOT USED
0	12	NOT USED
0	13	NOT USED

Geographic Angular

The Geographic "projection" is not really a projection at all. It is the angular longitude-latitude system. Geographic is good for data inter-change, but not useful for map production and situations where metrics (distances, angles, areas) are calculated routinely.

The following is a valid PRJ file for Geographic coordinates for decimal degree coordinates.

```
Geographic Longitude Latitude
LongLat
0
99
4 decimal degrees    or 3 for seconds or 5 for packed DMS
 0.              1 . USED
 0.              2 . USED
 0.              3 . USED
 0.              4 . USED
 0.              5 . USED
 0.              6 . USED
 0.              7 . USED
 0.              8 . USED
 0.              9 . USED
 0.             10 . USED
 0.             11 . USED
 0.             12 . USED
 0.             13 . USED
```

Universal Transverse Mercator (UTM)

The UTM system is a transverse Mercator projection with regularly defined, internationally recognized zones. UTM is a conformal projection system. UTM coordinates appear as tic marks or grid lines on most maps, and is often used as the base projection of paper maps. UTM is available on most GPSs. Much publicly available map data, particularly from the US government, is distributed in UTM coordinates. For maps of areas 600 km across (400 miles) or less, especially where angles are significant, UTM is a good choice of coordinate system.

The UTM coordinates system is strongly recommended due to its wide use and universally defined projection parameters.

The following two sections show valid PRJ files for Universal Transverse Mercator coordinates. The first one explicitly chooses UTM Zone 14 by specifying Zone 14. The second one implicitly chooses UTM Zone 14 by specifying zone 0, and supplying a longitude-latitude pair in UTM Zone 14.

Universal Transverse Mercator Zone 14 EXPLICITLY CHOSEN
UTM14
1
14
2

6378206	1	Semi-major axis of ellipsoid. Clarke1866
6.768657997291090E-003	2	Eccentricity of ellipsoid squared Clarke1866
0	3	Longitude of a point within the zone NOT USED HERE
0	4	Latitude of any point within the zone NOT USED HERE
0	5	NOT USED
0	6	NOT USED
0	7	NOT USED
0	8	NOT USED
0	9	NOT USED
0	10	NOT USED
0	11	NOT USED
0	12	NOT USED
0	13	NOT USED

Universal Transverse Mercator Zone =14 IMPLICITLY CHOSEN
UTM
1
0
2

6378206	1	Semi-major axis of ellipsoid. Clarke1866
6.768657997291090E-003	2	Eccentricity of ellipsoid squared Clarke1866
-981845.0000	3	Longitude of a point within the zone Used to choose Zone
380000.0000	4	Latitude of any point within the zone Used to choose Zone
0	5	NOT USED
0	6	NOT USED
0	7	NOT USED
0	8	NOT USED
0	9	NOT USED
0	10	NOT USED
0	11	NOT USED
0	12	NOT USED
0	13	NOT USED

Lambert Conformal Conic

Warning: There are two Lambert projections available in GCTP: Conformal Conic and Azimuthal Equal-Area. Make sure this is the right one.

The following is a valid PRJ file for use with the Lambert Conformal Conic projection. These parameters are used by KGS in its Geologic Map of Kansas.

Map projection used by KGS in the Geologic Map of Kansas
KGSGeol
4 Lambert Conformal Conic
9998 an arbitrary serial number
1 units of feet

6378206.4	1 Semi-major axis of ellipsoid. Clarke1866
0.006768658	2 Eccentricity of ellipsoid squared Clarke1866
330000.0000	3 Latitude of first standard parallel 33° 00' 00.00" N
450000.0000	4 Latitude of second standard parallel 45° 00' 00.00" N
-981845.0000	5 Longitude of central meridian 98° 18' 45.00" N
365230.0000	6 Latitude of projection's origin 36° 52' 30.00" N
0	7 False easting
0	8 False northing
0	9 NOT USED
0	10 NOT USED
0	11 NOT USED
0	12 NOT USED
0	13 NOT USED

Mercator

Projection parameter definitions

1 Semi-major axis of ellipsoid.
2 Eccentricity of ellipsoid squared
3 NOT USED
4 NOT USED
5 Longitude of central meridian
6 Latitude of true scale, usually the equator (0.0)
7 False easting
8 False northing
9 NOT USED
10 NOT USED
11 NOT USED
12 NOT USED
13 NOT USED

Polar Stereographic

Projection parameter definitions

1 Semi-major axis of ellipsoid.
2 Eccentricity of ellipsoid squared
3 NOT USED
4 NOT USED
5 Longitude projected straight down below pole of map
6 Latitude of true scale
7 False easting
8 False northing
9 NOT USED
10 NOT USED
11 NOT USED
12 NOT USED
13 NOT USED

Polyconic

Projection parameter definitions

1 Semi-major axis of ellipsoid.
2 Eccentricity of ellipsoid squared
3 NOT USED
4 NOT USED
5 Longitude of central meridian
6 Latitude of projection's origin
7 False easting
8 False northing
9 NOT USED
10 NOT USED
11 NOT USED
12 NOT USED
13 NOT USED

Equidistant Conic

Two cases: A) one standard parallel and B) two standard parallels

Projection parameter definitions

Case A: One standard parallel

1 Semi-major axis of ellipsoid.
2 Eccentricity of ellipsoid squared
3 Latitude of standard parallel
4 NOT USED
5 Longitude of central meridian
6 Latitude of projection's origin
7 False easting
8 False northing
9 0 for Single-parallel case
10 NOT USED
11 NOT USED
12 NOT USED
13 NOT USED

Case B: Two Standard Parallels

1 Semi-major axis of ellipsoid.
2 Eccentricity of ellipsoid squared
3 Latitude of standard parallel
4 Latitude of second standard parallel
5 Longitude of central meridian
6 Latitude of projection's origin
7 False easting
8 False northing
9 Any non-zero number for two-parallel case
10 NOT USED
11 NOT USED
12 NOT USED
13 NOT USED

Transverse Mercator

Projection parameter definitions

1 Semi-major axis of ellipsoid.
2 Eccentricity of ellipsoid squared
3 Scale factor at central meridian
4 NOT USED
5 Longitude of central meridian
6 Latitude of origin
7 False easting
8 False northing
9 NOT USED
10 NOT USED
11 NOT USED
12 NOT USED
13 NOT USED

Stereographic

Projection parameter definitions

1 Radius for reference sphere.
2 NOT USED
3 NOT USED
4 NOT USED
5 Longitude of center of projection
6 Latitude of center of projection
7 False easting
8 False northing
9 NOT USED
10 NOT USED
11 NOT USED
12 NOT USED
13 NOT USED

Lambert Azimuthal Equal-area

Projection parameter definitions

1 Radius for reference sphere.
2 NOT USED
3 NOT USED
4 NOT USED
5 Longitude of center of projection
6 Latitude of center of projection
7 False easting
8 False northing
9 NOT USED
10 NOT USED
11 NOT USED
12 NOT USED
13 NOT USED

Azimuthal Equidistant

Projection parameter definitions

1 Radius for reference sphere.
2 NOT USED
3 NOT USED
4 NOT USED
5 Longitude of center of projection
6 Latitude of center of projection
7 False easting
8 False northing
9 NOT USED
10 NOT USED
11 NOT USED
12 NOT USED
13 NOT USED

Gnomonic

Projection parameter definitions

1 Radius for reference sphere.
2 NOT USED
3 NOT USED
4 NOT USED
5 Longitude of center of projection
6 Latitude of center of projection
7 False easting
8 False northing
9 NOT USED
10 NOT USED
11 NOT USED
12 NOT USED
13 NOT USED

Orthographic

Projection parameter definitions

1 Radius for reference sphere.
2 NOT USED
3 NOT USED
4 NOT USED
5 Longitude of center of projection
6 Latitude of center of projection
7 False easting
8 False northing
9 NOT USED
10 NOT USED
11 NOT USED
12 NOT USED
13 NOT USED

General Vertical near-side perspective

Projection parameter definitions

1 Radius for reference sphere.
2 NOT USED
3 NOT USED
4 NOT USED
5 Longitude of center of projection
6 Latitude of center of projection
7 False easting
8 False northing
9 NOT USED
10 NOT USED
11 NOT USED
12 NOT USED
13 NOT USED

Sinusoidal

Projection parameter definitions

1 Radius for reference sphere.
2 NOT USED
3 NOT USED
4 NOT USED
5 Longitude of central meridian
6 NOT USED
7 False easting
8 False northing
9 NOT USED
10 NOT USED
11 NOT USED
12 NOT USED
13 NOT USED

Equirectangular

Projection parameter definitions

1 Radius for reference sphere.
2 NOT USED
3 NOT USED
4 NOT USED
5 Longitude of central meridian
6 Latitude of true scale, usually the equator (0.0)
7 False easting
8 False northing
9 NOT USED
10 NOT USED
11 NOT USED
12 NOT USED
13 NOT USED

Miller Cylindrical

Projection parameter definitions

1 Radius for reference sphere.
2 NOT USED
3 NOT USED
4 NOT USED
5 Longitude of central meridian
6 NOT USED
7 False easting
8 False northing
9 NOT USED
10 NOT USED
11 NOT USED
12 NOT USED
13 NOT USED

Van der Grinten

Projection parameter definitions

1 Radius for reference sphere.
2 NOT USED
3 NOT USED
4 NOT USED
5 Longitude of central meridian
6 NOT USED
7 False easting
8 False northing
9 NOT USED
10 NOT USED
11 NOT USED
12 NOT USED
13 NOT USED

Oblique Mercator

Projection parameter definitions

1 Semi-major axis of ellipsoid.
2 Eccentricity of ellipsoid squared
3 Scale factor at center of projection
4 NOT USED for format A, angle of azimuth east of north for central line of projection for format B
5 NOT USED for format A, longitude of point along central line of projection at which angle of azimuth is measured
6 Latitude of origin of projection
7 False easting
8 False northing
9 Longitude of first point defining central geodetic line of projection, NOT USED for format B
10 Latitude of first point defining central geodetic line of projection, NOT USED for format B
11 Longitude of second point defining central geodetic line of projection, NOT USED for format B
12 Latitude of second point defining central geodetic line of projection, NOT USED for format B
13 0 for format A, non-zero for format B

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