PROJECTIONS

Introduction to

Map Projections

with

TNTmips®

TNTedit™

TNTview®

Before Getting Started

Positional information in a georeferenced spatial object must refer to a particular geographic reference system. Most of the standard reference systems locate positions in a two-dimensional (planar) coordinate system. Such a system must use a map projection to translate positions from the Earth's nearly spherical surface to a hypothetical mapping plane. Although the projection procedure inevitably introduces systematic spatial distortions, particular types of distortion can be minimized to suit the geographic scope and intended use of the map data. This booklet provides an introduction to map projections and geographic reference systems and their use in the TNT products. Procedures for selecting projection and reference system parameters are presented in a series of simple exercises.

Prerequisite Skills This booklet assumes that you have completed the exercises in *Getting Started: Displaying Geospatial Data* and *Getting Started: Navigating*. Those exercises introduce essential skills and basic techniques that are not covered again here. Please consult those booklets and the TNTmips reference manual for any review you need.

Sample Data The exercises presented in this booklet use sample data that is distributed with the TNT products. If you do not have access to a TNT products CD, you can download the data from MicroImages' web site. In particular, this booklet uses sample files in the SF_DATA data collection.

More Documentation This booklet is intended only as an introduction to map projections and geographic reference systems. Consult the TNTmips reference manual, which contains more than 25 pages on geographic reference systems, for more information.

TNTmips® and TNTlite® TNTmips comes in two versions: the professional version and the free TNTlite version. This booklet refers to both versions as "TNTmips." If you did not purchase the professional version (which requires a hardware key), TNTmips operates in TNTlite mode, which limits object size and does not allow export. All of the exercises can be completed in TNTlite using the sample geodata provided.

Randall B. Smith, Ph.D., 12 September 2002

It may be difficult to identify the important points in some illustrations without a color copy of this booklet. You can print or read this booklet in color from MicroImages' web site. The web site is also your source for the newest Getting Started booklets on other topics. You can download an installation guide, sample data, and the latest version of TNTlite.

http://www.microimages.com

Introduction to Map Projections

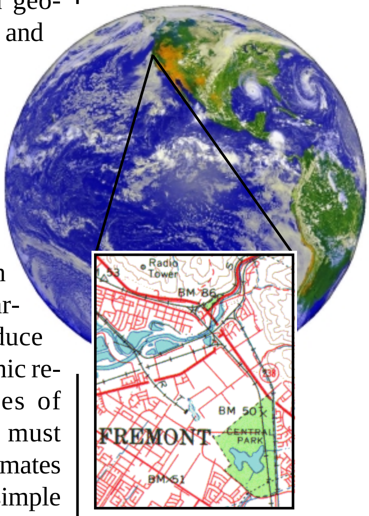
A core feature of the TNT products is the capability to relate information to specific geographic locations. Spatial data in any of the available forms (raster, vector, CAD, or TIN objects) can be *georeferenced*, or related to a standard geographic reference system. The locations of elements within a georeferenced object are then expressed in geographic coordinates, and meaningful distances and areas can be measured or calculated.

Although Earth images and map data that you use are typically rendered onto flat surfaces (such as a computer screen or a sheet of paper), the Earth's surface obviously is not flat. As a result of Earth's surface curvature, planar maps of all but the smallest areas contain significant geometric distortions of shapes, areas, distances, or angles. In order to produce two-dimensional maps that preserve geographic relationships and minimize particular types of distortion, several steps are required. We must choose a geometric model that closely approximates the shape of the Earth, yet can be described in simple mathematical terms. We must also adopt a coordinate system for referencing geographic locations in the mapping plane. Finally we must choose a method of transferring (or projecting) locations from the idealized Earth model to the chosen planar coordinate system.

You can choose coordinate system and map projection parameters in TNTmips when you establish georeference control for your project materials, when you import georeferenced data, or when you warp or resample georeferenced objects to a new projection. In addition, the Spatial Data Display process in all TNT products allows you to change the coordinate system and map projection for the layers in a group, either to control the display geometry or to provide coordinate readouts.

STEPS

☑ launch TNTmips
☑ select Display / Spatial Data from the main menu



Pages 4-8 introduce the interface used to select coordinate systems and map projections, and discuss the available predefined coordinate systems. Concepts concerning the shape of the Earth and geodetic datum and ellipsoid selection are covered on pages 9-11. Map projections are introduced on pages 12-14, and pages 15-21 discuss some widely used examples. Page 22 covers use of map projections in group display. Resources for further study are presented on page 23.

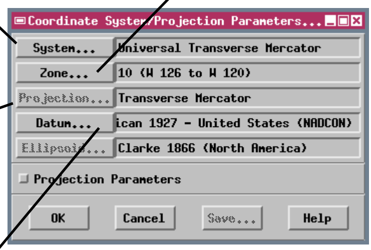
Parameters Window

STEPS
- ☑ click the Open icon button on the Display Spatial Data toolbar and choose Open Layout from the menu
- ☑ navigate to the LAYOUTS Project File in the SF_DATA data collection and select LAYOUT2
- ☑ from the Options menu on the View window choose Position Report / Projection

The Coordinate System / Projection Parameters window is the standard interface you use to set up geographic reference parameters in the relevant processes. You can use this window to choose a coordinate system and map projection, and to specify the geometric Earth model.

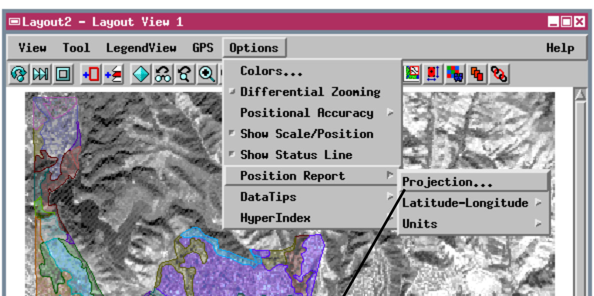
Click [System...] to select a coordinate system.

Some coordinate systems require you to select a geographic zone.



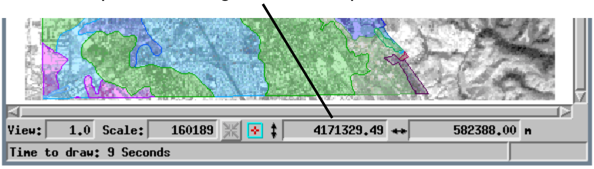
The Projection button is active when User-Defined is selected as the coordinate system, allowing you to choose a specific map projection. In this example the projection is already defined by the choice of coordinate system, so the button is dimmed and inactive.

The Datum and Ellipsoid parameters specify the geometric Earth model used to generate the map projection. The ellipsoid is usually determined by your choice of datum.



In most other relevant processes you can open the Coordinate System / Projection Parameters window by pressing a Projection... button on the appropriate control window.

Choose Projection under the Position Report option to set the geographic reference system for the Position Report fields at the bottom of the View window. We will use this example to introduce selection procedures and the important background concepts.



Keep the Coordinate System / Projection Parameters window open and continue to the next page.

Choosing a Coordinate System

The Coordinate System window allows you to choose from several predefined map coordinate systems that automatically specify an associated map projection. If necessary, you can use the User Defined option to choose a map projection and coordinate system that may be more appropriate for your data and project needs.

The United States State Plane and Universal Transverse Mercator coordinate systems are planar coordinate systems with associated map projections. These systems can be used to accurately represent positions, distances, and shapes of features in small geographic areas, such as a state or province. Both of these systems use a set of geographic zones, with each zone having its own coordinate grid. Grid coordinates are customarily referred to as *easting* (relative to a north-south axis) and *northing* (relative to an east-west axis). In order to minimize scale distortion effects related to the map projection, one of the coordinate axes may be located within the geographic zone. A large positive value, called a *false easting* or *false northing*, is usually assigned to this axis. This procedure moves the origin (0,0 point) of the coordinate system outside the zone, ensuring that all northing and easting values are positive.

The Latitude/Longitude and Geographic options both refer to the familiar global system of spherical coordinates. This system uses a grid of east-west latitude lines (parallels) and north-south longitude lines (meridians) to designate position.

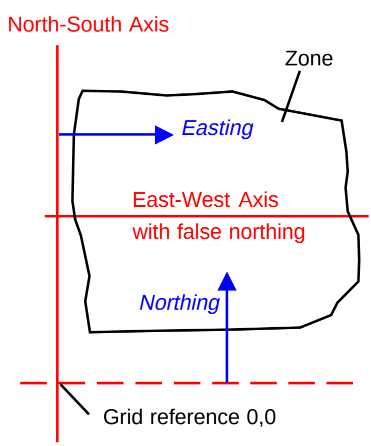
The predefined coordinate system choices are explored in more detail on the following pages.

STEPS

☑ click [System] on the Coordinate System / Projection Parameters window

☑ examine the choices in the Coordinate System window

Planar Coordinate Systems

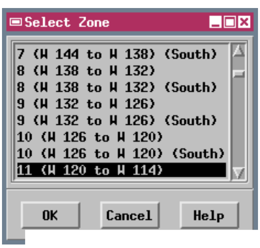


☑ click [OK] to close the Coordinate System window and continue to the next page

Universal Transverse Mercator System

STEPS

- ☑ click [Zone...] on the Coordinate System / Projection Parameters window
- ☑ examine the list of available UTM zones, then click [Cancel] on the Select Zone window
- ☑ click [Cancel] on the Coordinate System / Projection Parameters window
- ☑ move the screen cursor to the location of the intersection shown below and check the values in the Position Report fields at the bottom of the View window



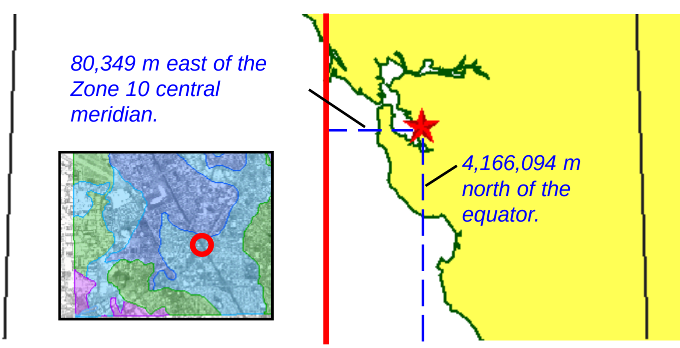
The group in the view window is referenced to the Universal Transverse Mercator (UTM) coordinate system. This global coordinate system is commonly used in the United States on topographic maps and for some digital cartographic data. The UTM system divides the world into uniform zones with a width of 6 degrees of longitude. The zones are numbered from 1 to 60 eastward, beginning at 180 degrees. Easting is measured from a zone's central meridian, which is assigned a false easting of 500,000 meters. Northing is measured relative to the equator, which has a value of 0 meters for coordinates in the northern hemisphere. Northing values in the southern hemisphere decrease southward from a false northing of 10,000,000 meters at the equator. (You must choose either northern or southern hemisphere coordinates when choosing a UTM zone.)

The UTM coordinate system uses the Transverse Mercator map projection, which minimizes shape distortions for small geographic features. The inherent accuracy of distance measurements (related to scale variations) is one part in 2500.

Hayward Quadrangle Highway Intersection UTM Coordinates

Easting 580,349 m, Northing 4,166,094 m

Zone 10 (120° W to 126° W), North American Datum 1927



126° W 123° W 120° W

Central Meridian (500,000 m False Easting)

State Plane Coordinate System

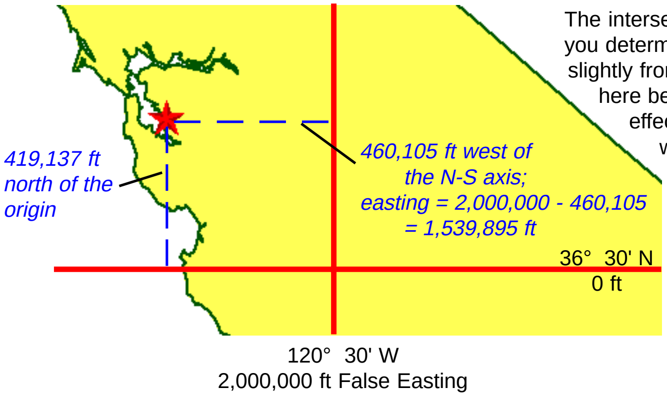
The United States State Plane Coordinate System has been widely used as a grid system for land surveys. It was devised to provide each state with rectangular coordinates that could be tied to locations in the national geodetic survey system. The original system, based on the North American Datum 1927, uses coordinates in feet. A more recent revision which measures distances in meters is based on the North American Datum 1983.

Most states are divided into two or more overlapping state plane zones, each with its own coordinate system and projection. A few smaller states use a single zone. The Lambert Conformal Conic projection is used for zones with a larger east-west than north-south extent. Zones that are more elongate in the north-south direction are mapped using the Transverse Mercator projection. Scale variations are minimized to provide an accuracy of one part in 10,000 for distance measurements. State Plane Coordinate tick marks and zone information can be found on U.S. Geological Survey topographic maps.

STEPS

- ☑ from the Options menu on the View window choose Position Report / Projection
- ☑ click [System...] on the Coordinate System / Projection Parameters window
- ☑ from the Coordinate System window select United States State Plane 1927 and click [OK]
- ☑ click [Zone...], then select California III and click [OK] in the Select Zone window
- ☑ click [OK] on the Coordinate System / Projection Parameters window
- ☑ from the Options menu on the View window choose Position Report / Units / Feet
- ☑ move the screen cursor to the location of the highway intersection and check the values in the Position Report fields
- ☑ set the Position Report / Units option back to Meters

Hayward Quadrangle Highway Intersection
State Plane Coordinates
Easting 1,539,895 ft, Northing 419,137 ft
California Zone III, North American Datum 1927



The intersection coordinates you determine may differ slightly from those shown here because of rounding effects related to your window size and zoom level.

Latitude / Longitude

STEPS

☑ from the Options menu on the View window choose Position Report / Projection

☑ click [System...] on the Coordinate System / Projection Parameters window

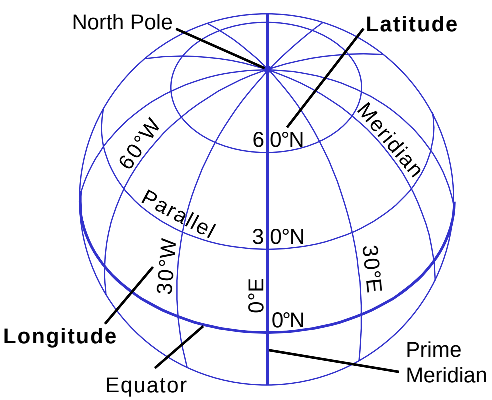
☑ from the Coordinate System window select Latitude/Longitude and click [OK]

☑ click [OK] to close the Coordinate System / Projection Parameters window

☑ move the screen cursor to the location of the highway intersection and check the values in the Position Report fields

The oldest global coordinate system is the Latitude/Longitude system (also referred to as Geographic coordinates). Because this is a spherical coordinate system, latitude and longitude values are expressed as angles relative to standard reference planes. Latitude is measured from 0 to 90 degrees north and south of the equator. Longitude values range from 0 to 180 degrees east or west of the Prime Meridian, which by international convention passes through the Royal Observatory at Greenwich, England. (South latitude and west longitude coordinates are treated as negative values in the TNT products, but you can use the standard directional notation and omit the minus sign when entering values in process dialogs.)

Because the Latitude/Longitude system references locations to a spheroid rather than to a plane, it is not associated with a map projection. Use of latitude/longitude coordinates can complicate data display and spatial analysis. One degree of latitude represents the same horizontal distance anywhere on the Earth's surface. However, because lines of longitude are farthest apart at the equator and converge to single points at the poles, the horizontal distance equivalent to one degree of longitude varies with latitude. Many TNTmips processes adjust distance and area calculations from objects with latitude/longitude coordinates to compensate for this effect, but these approximations are less accurate than calculations with data projected to a planar coordinate system. If you have data with Geographic coordinates, you will achieve the best results by warping or resampling the data to a planar coordinate system.



Latitude / Longitude is used as the native coordinate system for several widely available forms of spatial data (including the U.S. Census Bureau's TIGER / Line data, the Digital Chart of the World, and some types of USGS Digital Elevation Models and Digital Line Graphs).

The Shape of the Earth

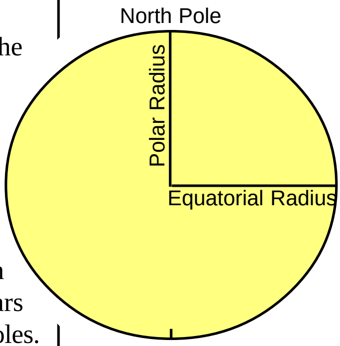
From our traditional human vantage point on the ground, the Earth's surface appears rough and irregular. But spacecraft images show that on a planetary scale, the Earth has a regular geometric shape with a very smooth surface. Knowledge of this shape is a prerequisite if we are to accurately transform geographic coordinates through a map projection to a planar coordinate system.

Sir Isaac Newton was the first to suggest that the Earth, because it rotates on its polar axis, is not quite spherical, but bulges outward slightly at the equator. As a result the polar radius is slightly shorter than the equatorial radius. If expressed as a fraction of the equatorial radius, the difference according to current measurements is about 1/298.257, a value known as the polar flattening. The earth thus appears slightly elliptical in a cross section through the poles. Rotating this ellipse about the polar axis results in a three-dimensional shape known as an **ellipsoid**. It is this geometric shape that cartographers use as the reference surface for creating large-scale maps (such as topographic maps).

While cartographers need a simple geometric representation of the Earth's shape, geodesists are interested in defining a level surface to provide a basis for land surveys. A level surface at any point is the plane perpendicular to the local direction of gravity (the direction in which the surveyor's plumb bob points). Because of local topography and the irregular distribution of mass within the Earth, the local direction of gravity may not be exactly perpendicular to the ideal ellipsoidal surface. Hence the **geoid** (the level surface on which gravity is everywhere equal to its strength at mean sea level) is not perfectly ellipsoidal in shape. Instead it has smooth, irregular undulations that depart from the ideal ellipsoid by as much as 100 meters.

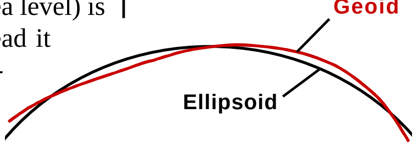
Geodesy is the branch of science concerned with measuring the size and shape of the Earth.

The Earth Ellipsoid
(flattening exaggerated)



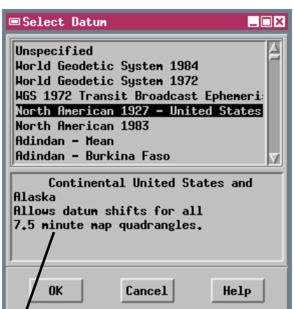
The spherical latitude/longitude coordinate system has been adapted mathematically to account for Earth's ellipsoidal shape, yielding **geodetic latitude and longitude** values.

Horizontal survey positions are adjusted to conform to an ideal ellipsoidal surface. The elevations shown on topographic maps, however, are expressed relative to the mean sea level geoid.



Geodetic Datums

STEPS
- ☑ from the Options menu on the View window choose Position Report / Projection
- ☑ reset the coordinate system to Universal Transverse Mercator
- ☑ click [Datum...] on the Coordinate System / Projection Parameters window
- ☑ examine the list of available geodetic datums, then click [Cancel] on the Select Datum window
- ☑ click [Cancel] on the Coordinate System / Projection Parameters window

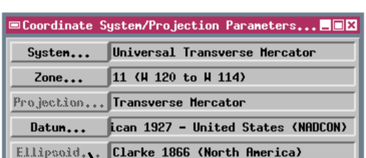


The lower part of the Select Datum window identifies the appropriate region for the selected datum.

Many different reference ellipsoids have been used by cartographers over the years. Estimates of the ellipsoid dimensions that best fit the overall shape of the Earth have changed as new technologies have permitted increasingly refined measurements of the planet. In addition, any global best-fit ellipsoid does not fit all parts of the surface equally well because of the irregular undulations of the geoid. For this reason many additional reference ellipsoids have been defined for surveying and mapping in different countries. Each regionally-defined ellipsoid has been chosen to conform as closely as possible to the geoid over that specific region. The resulting ellipsoids differ in their dimensions, the location of their centers, and the orientation of their polar axes.

A **geodetic datum** is an ellipsoidal surface used as a reference for mapping horizontal positions in a particular country or region. Each datum specifies the dimensions, location, and orientation of the reference ellipsoid. The TNT products include specifications for a great many geodetic datums. When you select a datum, the name of the associated ellipsoid is automatically shown in the Ellipsoid field of the Coordinate System / Projection Parameters window.

Planar coordinates used to express positions for georeferenced data always refer to a specific geodetic datum (usually that of the map from which the data were abstracted). When you import or georeference data, be sure to check the datum specification. (You may need to consult the documentation or metadata that accompanies the data). *Referencing map coordinates to the wrong datum can lead to positioning errors of tens to hundreds of meters!*



Because a geodetic datum specifies a particular ellipsoid, the Ellipsoid button is dimmed and inactive when you choose a predefined geodetic datum. (The button is only active when Unspecified is selected from the datum list.)

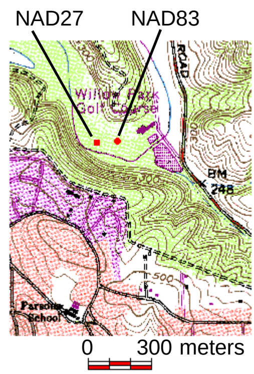
North American Datums

There are two geodetic datums in common use in North America. The North American Datum of 1927 (NAD27) is an example of a regional datum, in which the ellipsoid (Clarke 1866) is tied to an initial point of reference on the surface. NAD27 was developed in conjunction with the adjustment of a number of independent geodetic survey networks to form a single integrated network originating at Meades Ranch, Kansas. The ellipsoid's position and orientation are specified relative to the Meades Ranch survey station, with the result that the ellipsoid is not earth-centered.

The vast majority of U.S. Geological Survey topographic maps have been produced using NAD27. Over the years, however, it has become clear that the accuracy of the survey network associated with this datum is not sufficient for many modern needs. Surveying errors, destruction of survey monuments, and horizontal movements of the Earth's crust have led to horizontal errors in control point positions as large as 1 part in 15,000. The creation of satellite-based positioning systems also now requires the use of a global best-fit ellipsoid centered on the Earth's center of mass.

As a result of these problems, the U.S. National Geodetic Survey has introduced a new datum, the North American Datum of 1983 (NAD83). The reference ellipsoid used is that of the International Union of Geodesy and Geophysics Geographic Reference System 1980 (GRS 1980), which is geocentric, and thus has no single initial reference point on the surface. New latitude and longitude coordinates were computed for geodetic control points by least squares adjustment. The calculations included over 1.75 million positions obtained by traditional survey and satellite observations, using sites throughout North America, Greenland, and the Caribbean.

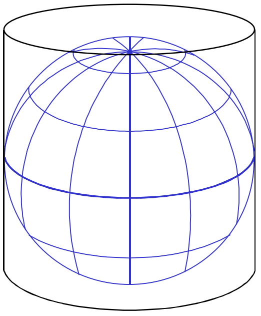
The position of a given set of geodetic latitude and longitude coordinates in North America can shift up to 300 meters with the change from NAD27 to NAD83. The amount of the shift varies from place to place. The illustration shows position N 37° 43' 31.84", W 122° 05' 01.03" in the Hayward, California quadrangle plotted with respect to both datums.



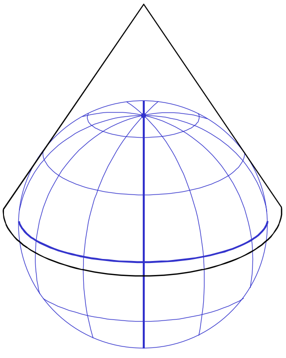
The U.S. Geological Survey has begun converting its primary series of topographic maps (1:24,000 scale 7.5-minute quadrangles) to NAD83 as part of the periodic revision process.

The World Geodetic System 1984 (WGS84) datum, developed by the U.S. Department of Defense, is almost identical to NAD83. Positions in the two systems agree to within about 0.1 millimeter. WGS84 is the reference used for positions determined from the Global Positioning System satellites.

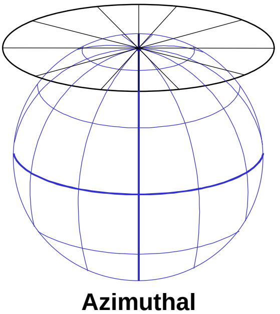
Map Projections



Cylindrical Projection



Conic Projection



Azimuthal Projection

A map projection can be thought of as a process or as the output of the process. For example, a map projection can be described as a systematic representation of all or part of the Earth's surface on a plane. But this representation is the result of a complex transformation process. The input for the map projection process is a set of horizontal positions on the surface of a reference ellipsoid. The output is a corresponding set of positions in a reference plane at a reduced scale. In this sense, a map projection is a complex mathematical formula that produces the desired coordinate transformations. However, a mathematical approach is not required for understanding the basic concepts surrounding the map projection process.

Transforming coordinates from the Earth ellipsoid to a map involves projection to a simple geometric surface that can be flattened to a plane without further distortion (such as stretching or shearing). Such a surface is called a **developable surface**. Three types of developable surfaces form the basis of most common map projections: a cylinder, a cone, or the plane itself.

Simple **cylindrical projections** are constructed using a cylinder that has its entire circumference tangent to the Earth's surface along a great circle, such as the equator. Simple **conic projections** use a cone that is tangent to the surface along a small circle, such as a parallel of latitude. Projecting positions directly to a plane tangent to the Earth's surface creates an **azimuthal projection**.

Regular cylindrical and conic projections orient the axis of the cylinder or cone parallel to the Earth's axis. If the axes are not parallel, the result is a transverse (perpendicular axes) or oblique projection. Additional variants involve the cylinder, cone, or plane cutting through the globe rather than being merely tangent to the surface.

Map Distortions

Projecting the Earth's curving surface to a mapping plane cannot be done without distorting the surface features in some way. Therefore all maps include some type of distortion. When selecting a map projection, cartographers must decide which characteristic (or combination thereof) should be shown accurately at the expense of the others. The map properties that enter into this choice are scale, area, shape, and direction.

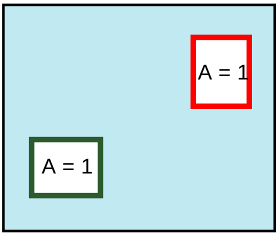
All maps are scaled representations of the Earth's surface. Exact distance measurements from map features would require constant scale throughout the map, but no map projection can achieve this. In most projections scale remains constant along one or more standard lines, and careful positioning of these lines can minimize scale variations elsewhere in the map. Specialized **equidistant** map projections maintain constant scale in all directions from one or two standard points.

In many types of spatial analysis it is important to compare the areas of different features. Such comparisons require that surface features with equal areas are represented by the same map area regardless of where they occur. A map projection with this property is an **equal-area** projection.

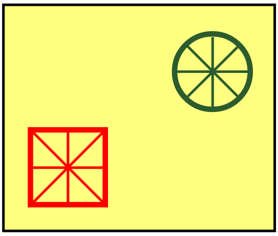
A map projection is **conformal** if the shapes of small surface features are shown without distortion. This property is the result of correctly representing local angles around each point, and maintaining constant local scale in all directions. Conformality is local property; while small features are shown correctly, large shapes must be distorted. A map projection cannot be both conformal and equal-area.

No map projection can represent all great circle directions as straight lines. **Azimuthal** projections show all great circles passing through the projection center as straight lines.

Map scale is the mathematical relationship between distances on the map and corresponding distances on the surface.



Equal-Area Projection
Shapes are distorted, but all map features are shown with the correct relative areas.



Conformal Projection
Small shapes maintain correct proportions, as local scale and angles are constant around each point. Relative area of features varies throughout the map.

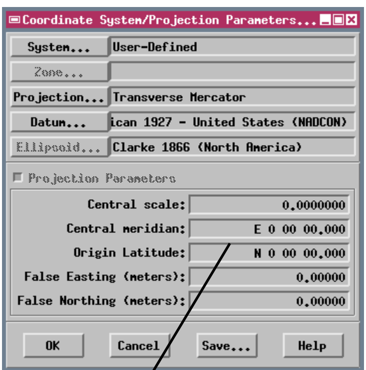
Choosing a Map Projection

STEPS

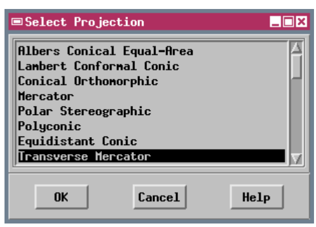
- ☑ from the Options menu on the View window choose Position Report / Projection
- ☑ click [System...] on the Coordinate System / Projection Parameters window
- ☑ choose User Defined from the Coordinate System window and click [OK]
- ☑ click [Projection...] on the Coordinate System / Projection Parameters window
- ☑ examine the list of available projections in the Select Projection window, then click [OK]
- ☑ click [Cancel] on the Coordinate System / Projection Parameters window

If data you are importing or georeferencing requires the use of a map projection other than those provided by the standard predefined coordinate system options, choose User-defined as the system option. The Projection option button on the Coordinate System / Projection Parameters window is then enabled. This button opens the Map Projection Selection window, which lists a number of commonly used projections. Some representative examples are discussed on the pages that follow, and illustrated using maps of North America with a superimposed latitude-longitude grid.

If necessary, georeferenced data can be transformed to a new map projection and coordinate system more appropriate to the location, size, and shape of the project area, and to the anticipated use of the data. A particular projection can be centered on the project area by choosing appropriate projection parameters. (The parameters vary depending on the projection type; the principal parameters for cylindrical, conic, and azimuthal projections are discussed with the examples that follow.) Because of varying patterns of distortion, some projections are better for areas elongate in an east-west direction, and others for areas elongate north-south. Large-scale maps used to determine or plot directions, such as navigational charts and topographic maps, should use a conformal map projection. Equal-area projections are appropriate for smaller-scale thematic or distribution maps.



When you select User-Defined for the coordinate system, the Projection Parameters panel opens automatically. The parameters vary depending on the projection you select. In general, they determine the geographic positioning of the projection. All projections allow you to specify a False Northing and a False Easting value for the origin. When you import data in a specific projection, be sure to consult the accompanying metadata for the relevant projection parameters.

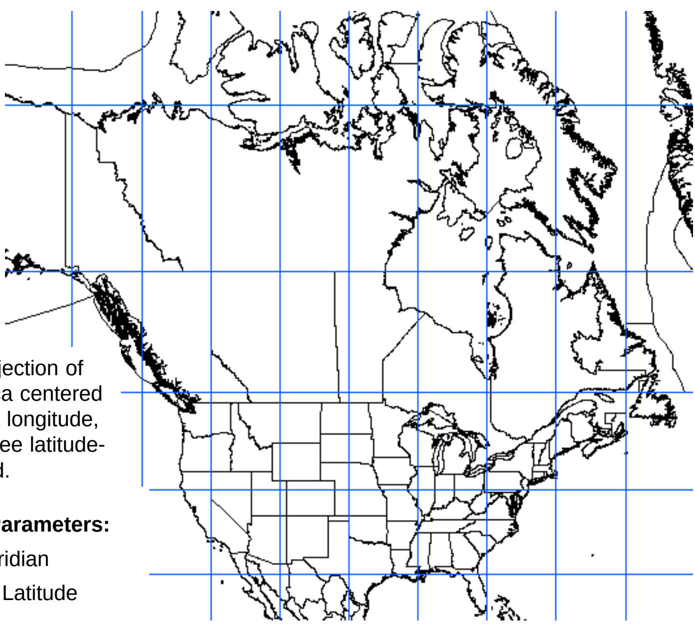


Mercator Projection

One of the best known map projections, the Mercator projection was devised specifically as an aid to navigation. A ship's course can be plotted easily with the Mercator projection because a course with constant azimuth (compass direction) is shown as a straight line.

The Mercator is a regular cylindrical projection (the cylinder axis passes through the north and south poles). Meridians of longitude are shown as equally spaced vertical lines, intersected at right angles by straight horizontal parallels. The spacing between parallels increases away from the Equator to produce a conformal projection. The scale is true along the equator for a tangent Mercator projection (specified by the default setting for the True Scale Latitude parameter). Assigning a different true scale latitude produces an intersecting cylindrical projection with two standard parallels (with true scale) equidistant from the equator.

The poleward increase in spacing of parallels produces great distortions of area in high-latitude regions. In fact, the *y* coordinate for the poles is infinity, so maps using the Mercator projection rarely extend poleward of 75 degrees latitude. The Mercator projection remains in common use on nautical charts. Because scale distorion is minor near the equator, it also is a suitable conformal projection for equatorial regions.



Mercator projection of North America centered on 100° west longitude, with ten-degree latitude-longitude grid.

Projection Parameters:

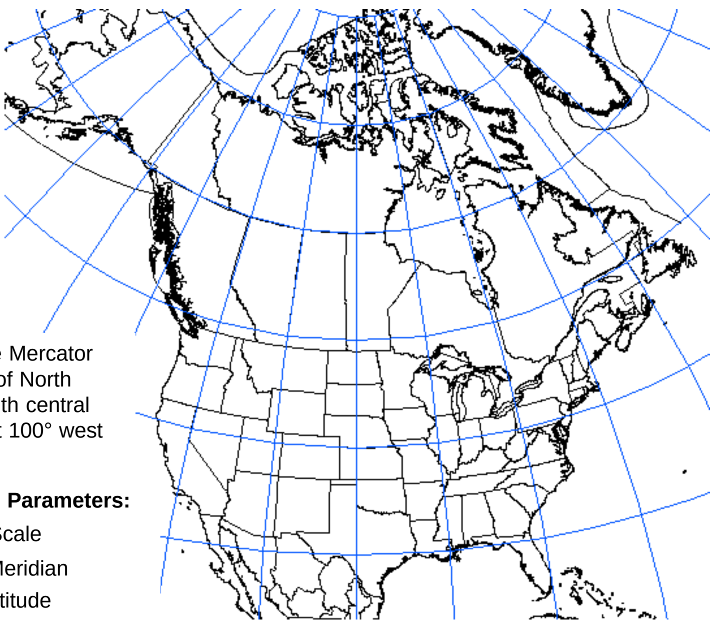
- Central Meridian
- True-Scale Latitude

Transverse Mercator Projection

The Transverse Mercator projection is a conformal cylindrical projection with the cylinder rotated 90 degrees with respect to the regular Mercator projection. The cylinder is tangent to a central meridian of longitude around its entire circumference. The central meridian and equator are straight lines, but all other meridians and parallels are complex curves.

Scale is constant along any meridian. Scale change along parallels is insignificant near the central meridian, but increases rapidly away from it, so the Transverse Mercator projection is useful only for narrow bands along the central meridian. It forms the basis for the Universal Transverse Mercator Coordinate System, and is primarily used for large-scale (1:24,000 to 1:250,000) quadrangle maps. The central meridian can be mapped at true scale (Central Scale parameter = 1.0), or at a slightly reduced constant scale (for example, the value 0.9996 used in the UTM system). In the latter case a pair of meridians bracketing the central one maintain true scale, and the mean scale for the entire map is closer to the true scale.

In the United States the Transverse Mercator projection is also used in the State Plane Coordinate System for states (or individual state zones) which are more elongate in the north-south direction. In Europe it is sometimes called the Gauss Conformal or Gauss-Kruger projection.



Transverse Mercator projection of North America with central meridian at 100° west longitude.

Projection Parameters:

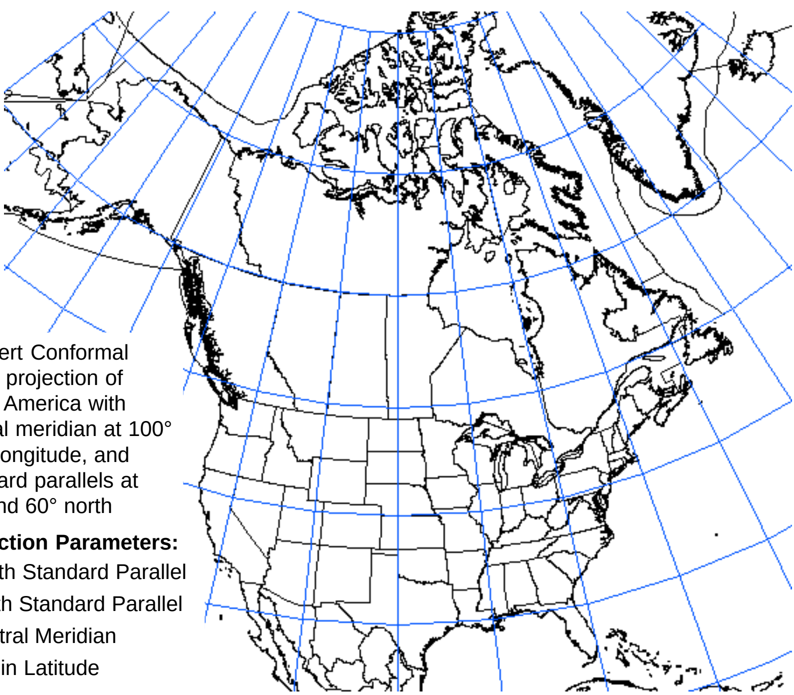
- Central Scale
- Central Meridian
- Origin Latitude

Lambert Conformal Conic Projection

The Lambert Conformal Conic projection is normally constructed with a developable surface that intersects the globe along two standard parallels. You must specify the latitude for each standard parallel when setting up the projection, as well as the latitude to use as the origin for northing coordinates. Scale is true along the standard parallels, smaller between them, and larger outside them. Area distortion is also relatively small between and near the standard parallels. This projection therefore is particularly useful for mid-latitude regions which are elongate in the east-west direction.

The parallels in the Lambert Conformal Conic projection are concentric circles, while the meridians are equally-spaced straight radii of these circles. The meridians intersect parallels at right angles (as expected in a conformal projection). Spacing of the parallels increases north and south from the band defined by the standard parallels.

In the United States the Lambert Conformal Conic projection (also known as Conical Orthomorphic) is used in the State Plane Coordinate System for state zones with greater east-west than north-south extent. It is also used for regional world aeronautical charts and for topographic maps in some countries.



Lambert Conformal Conic projection of North America with central meridian at 100° west longitude, and standard parallels at 20° and 60° north

Projection Parameters:

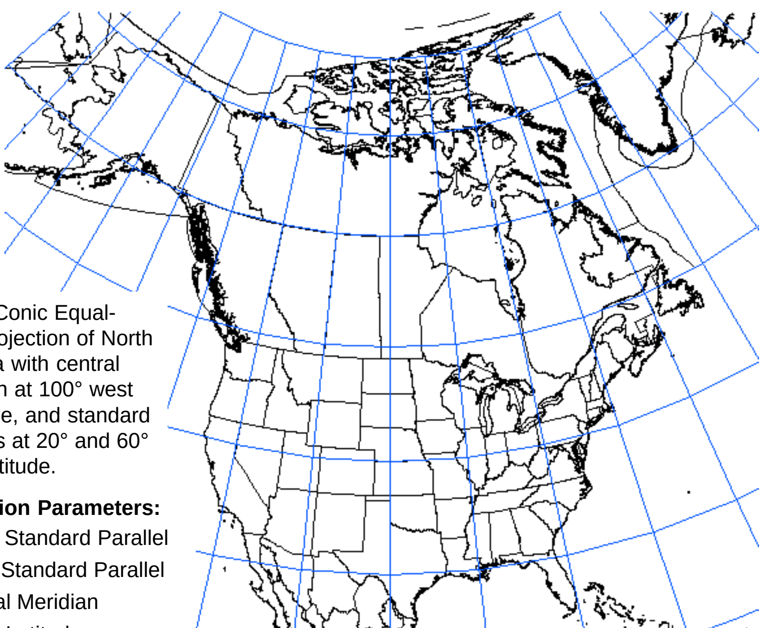
- South Standard Parallel
- North Standard Parallel
- Central Meridian
- Origin Latitude

Albers Conic Equal-Area Projection

The Albers Conic Equal-Area Projection is commonly used to map large areas in the mid-latitudes, such as the entire “lower 48” United States. In this normal application there are two standard parallels. Like other conic projections, the parallels are concentric circular arcs with equally-spaced meridians intersecting them at right angles. The change in spacing between parallels is opposite from the Lambert Conformal Conic projection; parallels are more widely spaced between the standard parallels, and more closely spaced outside them.

Each parallel has a constant scale, with true scale along the standard parallels, smaller scale between them, and larger scale outside them. To maintain equal area, scale variations along the meridians show a reciprocal pattern; the increase in east-west scale outside the standard parallels is balanced by a decrease in north-south scale.

The Albers Conic Equal-Area projection has been used by the U.S. Geological Survey for a number of small-scale maps of the United States, using latitude 29.5º and 45.5º north as standard parallels. Mid-latitude distortion is minor for most normal conic projections, so that differences between them become obvious only when the region mapped extends to higher or lower latitudes.



Albers Conic Equal-Area projection of North America with central meridian at 100° west longitude, and standard parallels at 20° and 60° north latitude.

Projection Parameters:

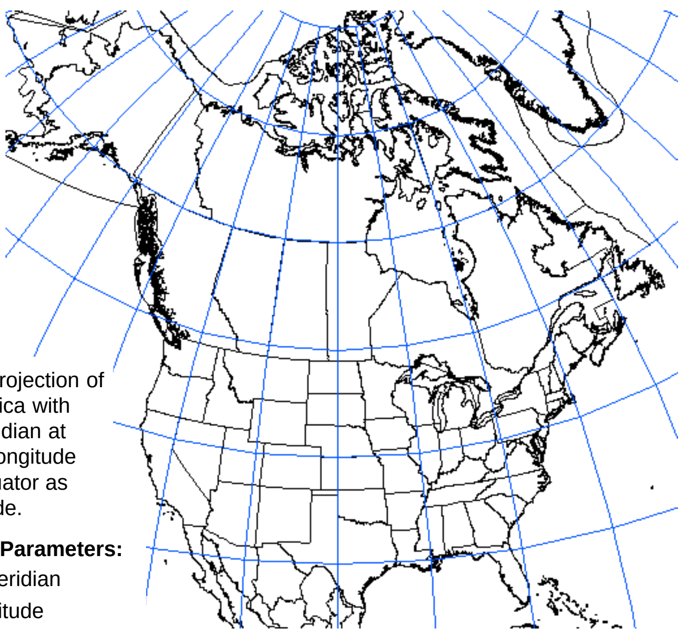
- South Standard Parallel
- North Standard Parallel
- Central Meridian
- Origin Latitude

Polyconic Projection

The Polyconic projection was devised in the early days of U.S. government surveying, and was used until the 1950's for all large-scale U.S. Geological Survey quadrangle maps (now superceded for most revised maps by Universal Transverse Mercator). The Polyconic projection produces extremely small distortion over small areas near the central meridian, despite being neither conformal nor equal-area.

Parallels in the Polyconic projection are circular arcs, but are not concentric. Each parallel is the trace of a unique cone tangent to the globe at that latitude. The name thus refers to the fact that there are many cones involved in creating the projection, rather than a single conic developable surface. When chosen as the origin latitude, the equator is a straight line. The central meridian is also a straight line, but all other meridians are complex curves that are not exactly perpendicular to the parallels.

Scale is true along each parallel and along the central meridian. When the central meridian is chosen to lie within a large-scale map quadrangle, scale distortion is almost neglible for the map. Because polyconic quadrangle maps are not precisely rectangular, they cannot be mosaicked in both north-south and east-west directions without gaps or overlaps.



Polyconic projection of North America with central meridian at 100° west longitude and the equator as origin latitude.

Projection Parameters:

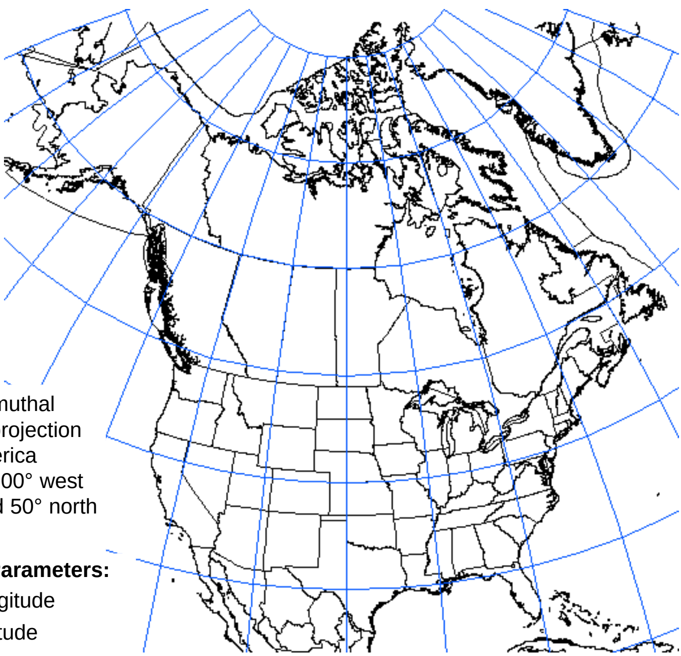
- Central Meridian
- Origin Latitude

Lambert Azimuthal Equal-Area Projection

The Lambert Azimuthal Equal-Area projection transforms surface coordinates directly to a plane tangent to the surface. The point of tangency forms the center of the projection, and is specified by the Center Longitude and Center Latitude parameters. In general, the projection center should coincide with the center of the area to be mapped. Scale is true only at the center point, but deviation from true scale for other points on the map is less than for other forms of azimuthal projection.

Scale in the radial direction decreases away from the center. Scale perpendicular to a radius increases with distance from the center, as required to produce the equal-area property. Distortion is symmetric about the central point, so this projection is appropriate for areas that have nearly equal north-south and east-west extents.

The pattern of meridians and parallels depends on the choice of central point. If the projection is centered at a pole, meridians are straight radii and parallels are concentric circles. In an oblique projection, such as the example illustrated below, only the central meridian is straight, and other meridians and parallels are complex curves. The Lambert Azimuthal Equal-Area projection has been used commonly for small-scale maps of the polar regions, ocean basins, and continents.



Lambert Azimuthal Equal-Area projection of North America centered at 100° west longitude and 50° north latitude.

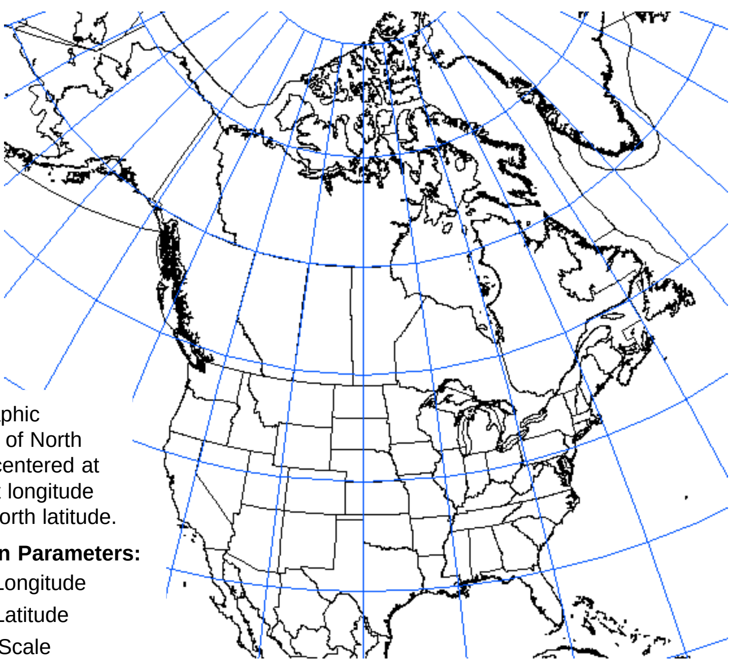
Projection Parameters:

- Center Longitude
- Center Latitude

Stereographic Projection

The Stereographic projection is a conformal azimuthal projection. When used for large areas, so that the spherical Earth model can be used, it is also a true perspective projection, unlike most map projections. Surface locations are projected to a tangent plane using a single projection point on the surface of the sphere exactly opposite the center of the projection. When used to map smaller areas, so that the ellipsoidal Earth model is used, the projection is not perspective, and, in order to maintain conformality, is not truly azimuthal.

The Stereographic projection is most commonly used to map polar regions, in which case the pole is chosen as the center point. (This Polar Sterographic form is provided as a separate selection in the Map Projection Selection window). In this form, the map shows meridians as straight radii of concentric circles representing parallels. In an oblique Stereographic projection, such as the illustration below, only the central meridian is straight. All other meridians and parallels are circular arcs intersecting at right angles. Scale increases away from the central point, which normally has true scale (Central Scale parameter = 1.0). Reducing the Central Scale value produces an intersecting rather than tangential plane. Scale is then true along an ellipse centered on the projection center, and the mean scale for the entire map is closer to the true scale.



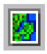
Stereographic projection of North America centered at 100° west longitude and 50° north latitude.

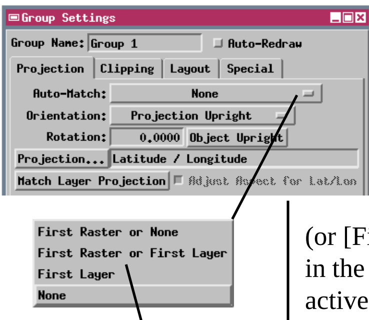
Projection Parameters:

- Center Longitude
- Center Latitude
- Central Scale

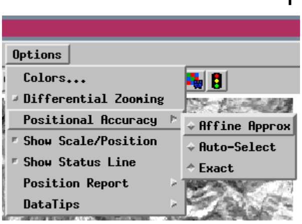
Using Map Projections in Group Display

In 2D Group or 3D Group Display, open the Group Settings window by choosing Projection / Clipping from the Group menu. If you are viewing a Layout, click the Group Settings icon button for the group.





The [First Raster or First Layer] and [First Layer] options always use the object coordinates of the indicated layer to control the group orientation and projection. "First" refers to the lowest layer in the layer list.



If a geospatial object has been created in or reprojected to a specific map projection, the object's coordinate system coincides with the map coordinate system. For many georeferenced objects, however, this is not the case. The Orientation / Projection Options controls in the Group Settings window determine whether a display group is oriented relative to object coordinates or to a specific map coordinate system.

The Auto-Match option determines whether object coordinates are used or not, and, for multiple layers, which object provides the basis for the group projection. To orient the group to a map projection, choose [None] (or [First Raster or None] if there is no raster layer in the group). The Projection button then becomes active, allowin you to open the Coordinate System / Projection Parameters window described earlier.

A vector, CAD, or TIN object in the display group is projected precisely to the selected map coordinates, subject to the inherent accuracy of the element coordinates. Reorientation of a raster object is governed by the Positional Accuracy option in the View window's Option menu. The Exact option provides an exact resampling to the projection, but can be slow. The quicker Affine Approximate option changes the orientation and scale in a uniform manner to approximately match the output projection. The Auto-Select option automatically chooses the appropriate method for the current zoom level.

As you gather spatial data from different sources for a project, you will probably end up with data in a number of different coordinate systems and projections. Although the Display process can overlay layers with different map projections and coordinate systems with reasonable registration, redisplay times can be long. For maximum efficiency, materials that will be used together routinely should be reprojected to a common map projection and coordinate system. For raster images, choose Process / Raster / Resample / Automatic from the TNTmips main menu. For vector objects, choose Process / Vector / Warp.

Looking Further

References

Langley, Richard B. (February, 1992). Basic geodesy for GPS. *GPS World*, *3*, 44-49.

A valuable introduction to geodetic concepts, including the geoid, the ellipsoid, and geodetic datums.

Maling, D. H., (1992). *Coordinate Systems and Map Projections*. Oxford: Pergamon Press. 255 pp.

Robinson, A. H., Morrison, J. L., Muehrcke, P. C., Kimerling, A. J., and Guptill, S. C. (1995). *Elements of Cartography* (6th ed.). New York: John Wiley & Sons, Inc. 674 pp.

Contains excellent chapters on Geodesy, Map Projections, and Reference and Coordinate Systems.

Snyder, John P. (1987). *Map Projections -- A Working Manual*. U.S. Geological Survey Professional Paper 1395. Washington, D.C.: U.S. Government Printing Office. 383 pp.

An exhaustive description and history of map projections and related concepts, including the mathematical details.

Snyder, John P., and Voxland, Philip M. (1989). *An Album of Map Projections*. U.S. Geological Survey Professional Paper 1453. Washington, D.C.: U.S. Government Printing Office. 249 pp.

Internet Resources

Map Projection Overview, *Coordinate Systems Overview*, and *Geodetic Datum Overview*:

http://www.colorado.edu/geography/gcraft/notes/mapproj/mapproj.html

These web pages by Peter H. Dana (part of The Geographer's Craft Project) provide an illustrated discussion of each topic.

NIMA Geospatial Sciences Publications:

http://www.nima.mil/GandG/pubs.html

This page at the U.S. National Imagery and Mapping Agency website provides links to a number of online documents on geodesy and mapping science (in PDF or HTML format), including *Geodesy for the Layman* and *All You Ever Wanted to Know and Couldn't Find Out About Precise Positioning...(In Plain English)*.

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TNTedit TNTedit provides interactive tools to create, georeference, and edit vector, image, CAD, TIN, and relational database project materials in a wide variety of formats.

TNTview TNTview has the same powerful display features as TNTmips and is perfect for those who do not need the technical processing and preparation features of TNTmips.

TNTatlas TNTatlas lets you publish and distribute your spatial project materials on CD-ROM at low cost. TNTatlas CDs can be used on any popular computing platform.

TNTserver TNTserver lets you publish TNTatlases on the Internet or on your intranet. Navigate through geodata atlases with your web browser and the TNTclient Java applet.

TNTlite TNTlite is a free version of TNTmips for students and professionals with small projects. You can download TNTlite from MicroImages' web site, or you can order TNTlite on CD-ROM.

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