G492 GIS for Earth Sciences
Map Projections and Coordinate Systems

I. Introduction
  A. Fundamental Concern with Map Work
    1. Maps / GIS
      a. 2-D representation of Earth surface
      b. locations of map features on cartesian coordinate system
        (1) Data Points
        (2) x,y coordinates in 2-D
    2. Earth Globe = 3-D
      a. spherical trigonometry / geometry
        (1) longitude / latitude system

    3. Map Projection - mathematical / geometric method for projecting spherical positions on a 2-D grid system
      a. transformation of geographic grid (lat / long) to 2-D cartesian coordinate system

  B. GIS and Map Layers
    1. Layer Concept = portion of Earth's surface divided into separate "coverages" or thematic layers
      a. Layer examples for a locality
        (1) geology, soils, topography, vegetation, roads, streams, buildings, etc.
          (a) each theme = layer
    2. Goal of Map Layers
      a. to overlay each layer on top of one another in proper geographic coordinate space
        (1) layers must precisely overlay on top of one another

    3. Problem with projections and layers: if separate layers are in different projections, maps will not properly align

NOTE: You must know the system of projection for each of the map layers in GIS, if they are not properly coordinated, layers will not properly align with one another, or with real world positions.

  C. Basic Terminology
    1. Georeference system - coordinate system used to plot position of points, lines, and polygons in map space
    2. Map Registration - proper alignment of map coordinates with real world coordinates of features on the Earth's surface
    3. Map Projection - converting digital maps from lat-long (geographic coordinates based on 3-D spherical geometry) to 2-D coordinates

II. Map Scale and Resolution
  A. Fractional Scaling
    1. 1:24,000 - common large scale used on topo sheets
      a. covers small area in great detail
    2. 1:1,000,000 - common small scale used on world maps
      a. covers large area in minimal detail

B. Map Resolution - ability to resolve surface features on a map, depends on scale

Example of Map Resolutions Based on Line Width of 0.5 mm

Line Width (0.5 mm)	Scale	Resolution	Smallest Detectable Object	Area (sq. m) (Minimum)
0.5	1:24,000	12 m	24 m	576
0.5	1:50,000	25 m	50 m	2500
0.5	1:250,000	125 m	250 m	62,500
0.5	1:5,000,000	2500m	5000 m	25,000,000

In-Class Exercise: Spatial Scales and Digital Image Resolution

In remote sensing, a given "scene" is a particular portion of the Earth's surface that is captured in and aerial photograph or satellite image. The digital resolution of the "scene" is the amount of land area that is covered in 1 pixel of the image. Each pixel is assigned a digital color code or shade. When all pixels are combined together a resultant digital image is produced. The resulting image is arranged in a series of columns and rows of pixel boxes.

Problems:

(1) Given a scale of 1:48,000 on a topographic map, a square plot of land covers 8 inches by 8 inches in map units.

Determine side distances of the plot in meters.

Determine the area of the plot is square kilometers.

(2) Determine the number of rows and columns in an image of the plot with the following spatial resolutions:
No. Rows No. Columns
1 - meter resolution

10-meter resolution

30-meter resolution

100-meter resolution

(3) If you had an image of the plot that was comprised of 2500 rows and columns, what is the resulting spatial resolution?

III. Geographic Grid

A. Spherical Coordinate System (lat / long)

1. meridians - N-S lines of longitude measured by angles in an E-W direction, relative to the prime meridian
   a. prime meridian = 0 long
      (1) 0-180 east long
      (2) 0-180 west long
2. parallels - E-W lines of latitude measured by angles in a N-S direction, relative to the equator.
   a. 0-90 north lat
   b. 0-90 south lat
3. Angular Measurement
   a. degrees-minutes-seconds (DMS)
      (1) 1 degree = 60 minutes
      (2) 1 minute = 60 seconds
      (3) 1 degree = 3600 seconds
   b. decimal degrees (DD)

      e.g. 44 degrees 30 min N lat = 44.5 degrees
      e.g. 45º52'30" = 45.875º
   c.
4. Origin of Geographic Grid = 0 deg Long, 0 Lat
   a. x coord = long
      (1) positive values: 0-180 east
      (2) negative values: 0-180 west
   b. y coord = lat
      (1) positive values: 0-90 north
      (2) negative values: 0-90 south

In-Class Exercise - Measuring Great Circle Distances on the Globe

Definition of Great Circle - a line passing between any two points on the globe, which can form an angle with the vertex at the center of the Earth (e.g. all meridians are great circles, the only parallel that is a great circle in the 0 degree lat parallel, or equator)
Equation for Great Circle Distance on a Sphere Between any Two Points, A and B on a sphere:

$$\cos(D) = (\sin(a)*\sin(b)) + (\cos(a)*\cos(b)*\cos|\gamma|)$$

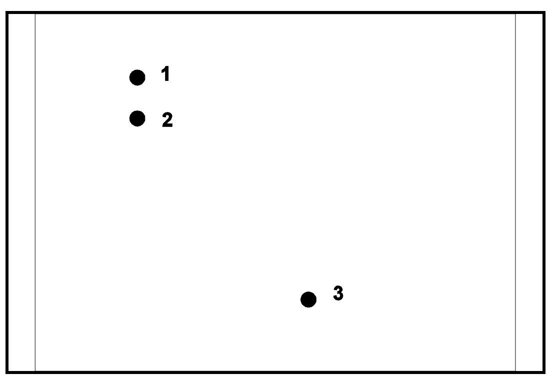
where D = angular distance in degrees between two points (1 degree on great circle = 69 miles), a and b are the geographic latitudes of points A and B, $|\gamma|$ = the absolute value of the difference in longitude between pts. A and B
Problem: determine the great circle distance in miles between Nome, AK and Miama, Fla. using the following positions.

Nome lat = 63° 30' N long = 165° 20' W
Miami lat = 25° 45' N long = 80° 11' W

hint: you must convert your lat and long to decimal degrees

Part 2 - Examine the map figure below with pt. locations 1, 2, and 3. The points are located at the following UTM coordinates

	Easting (m)	Northing (m)
pt. 1	481320	4966620
pt. 2	481320	4966580
pt. 3	481490	4966400



Use Pythagorean's theorem to determine the distances between the following point combinations (SHOW all of your math work!):

Distance 1-2 (meters) =__________
Distance 1-3 (meters)=__________
Distance 2-3 (meters)=__________
Distance 3-3 (meters)=__________

IV. Map Projection: transformation of spherical Earth surface position to plane surface, cartesian coordinate system

A. Utility of Map Projections

1. allow work in 2-D linear coordinates, rather than 3-D spherical coordinates
2. Problem: projecting a sphere onto a flat surface involves distortion
   a. distortion of map shapes
   b. distortion of map areas
   c. distortion of distance / scale

B. Projection Types

1. conformal projection - preserves shapes, but distorts areas
2. equivalent projection - preserves areas, but distorts shapes
   a. aka "equal area projections"
3. equidistant projection - maintains equivalency of scale and distance
4. azimuthal projection - maintains true directional / angular relationships

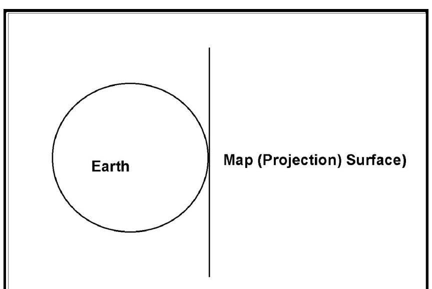
C. Projections Methods

1. Terminology
   a. reference globe - 3-D reference spheroid of the Earth that is being projected
   b. aspect: direction about which the Earth is projected to a surface
      (1) polar projection - projected from poles of earth
      (2) equatorial projection - projected from the equator of earth
   c. Projection suface = 2-D map surface upon which the globe is projected

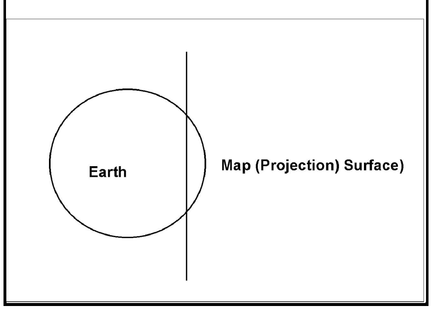
2. Cylindrical Projection: projecting the Earth's surface to a cylinder enveloping the reference globe
3. Conical Projection: projecting the Earth's surface to a cone enveloping a portions of the reference globe
4. Planar (azimuthal) Projection: projecting the earth's surface to a flat plane

D. Styles / Methods of Projections

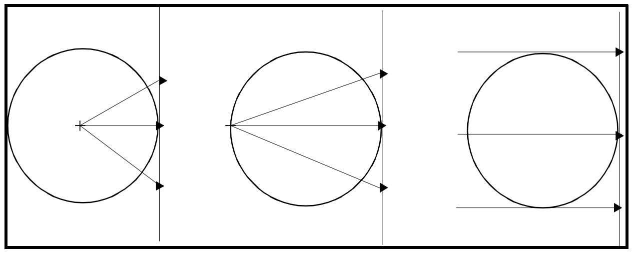
1. Tangent - projection surfaces tangent to the Earth's surface
2. Secant - projection surfaces that form line segments between arcs of the spherical surface



Tangent Projection: scaling factor at point of tangency = 1:1 (no distortion), distortion increases away from tangency point.



Secant Projection: scaling factors at two points of intersection = 1:1 (no distortion), distortion increases to center of map.



gnomonic stereographic orthographic

Styles of Geometric Projection to a Map Surface

3. Standard Line - line of tangency between the projection surface and the reference globe
4. Standard Parallel - standard line that follows a parallel (line of lat.)
5. Standard Meridian - standard line that follows a meridian (line of long)
6. Scale Factor = ratio local scale / scale of reference globe

   a. standard line scale factor = 1 (i.e. standard line has same scale as the reference globe)

7. Central Parallel = E-W line that forms the base for northings (0 base line)
8. Central Meridian = N-S line that forms the base for eastings (0 base line)
   a. quadrants defined by central parallel and central meridian
      (1) NE = + X and +Y
      (2) NW = -X and +Y
      (3) SE = +X and - Y
      (4) SW = -X and -Y

9. False Eastings / False Northings
   a. A false origination point set to the southwest of the map projection, results in placing all positions in the NE Quadrant with + X and + Y values for all positions

Special Term: "Metadata" = data / information about the spatial data. Text files that include the following information: source of data, year, projection used, measurement units, reference spheroid, etc.

V. Types of Map Projections
   A. Transverse Mercator
      1. basis = standard meridian (line of longitude)
         a. arranged in north-south elongated zones with origin at equator
            (1) Oregon = zone 10 N
      2. parameters for projection
         a. scale factor at central meridian
         b. longitude of central meridian
         c. latitude of origin (central parallel)
         d. false easting
         e. false northing

B. Lambert Conformal Conic
  1. Common Use
    a. mid-latitudes
    b. east-west dimension > north-south dimension
      (1) e.g. Oregon
  2. Parameters
    a. secant projection
    b. first and second standard parallels
    c. central meridian
    d. latitude of projections origin
    e. false easting / false northing

C. Considerations for Choosing a Projection
  1. Latitude
    a. low latitude = cylindrical projection is best
    b. mid-latitude = conical projection is best

VI. Spheroid and Datum
  A. Spheroid (or ellipsoid) - 3-D model that approximates the shape of the Earth
    1. shape of Earth = oblate spheroid
      a. D poles < D equator
  B. Datum = mathematical relationship between the approximation of the spheroid and the actual shape of the Earth
    1. Question: is the Earth really a smooth basketball?

  C. Example Spheroids / Datum
    1. Clarke 1866 - ground measured spheroid
      a. equatorial radius = 6378206.4 m
      b. polar radius = 6356583.8 m
      c. Distortion Effects of Speroid
        (1) of small consequence over small areas
        (2) of great consequence over global scales
      d. example
        (1) North American Datum 1927 (NAD 1927) = based on Clarke 1866 spheroid
          (a) center of datum = Meades Ranch, Kansas
    2. World Geodetic System 1984 (WGS1984)
      a. satellite-derived spheroid from orbital data
        (1) equatorial radius = 6378137.0 m
        (2) polar radius = 6356752.3 m
    3. GRS80 (Geodetic Reference System 1980)
      a. similar to WGS1984
    4. North American Datum 1983 (NAD1983)
      a. Based on WGS1984 or GRS80 spheroids

D. Discussion

1. Datum for many USGS topographic maps in Oregon - NAD27
    a. NAD83
        (1) more accurate
        (2) based on satellite positioning, compatible with GPS
        (3) Conversion from NAD27 to NAD83
            (a) errors = shifts in positions up to 100 m

IMPORTANT INFORMATION: In using GIS, the very first information about the data you must collect (or the metadata) is knowing what coordinate system, map units, projection, and datum the data are in!!! DANGER: if the projection and datum are off, map layers will not properly align and overlay!!!

VII. Coordinate Systems

A. General Rule on Distortion

1. The larger the scale (the less area covered and more detailed) the less the distortion from 3-D to 2-D
2. The smaller the scale (the more area covered and less detailed) the more the distortion from 3-D to 2-D

B. Coordinate Systems Commonly Encountered in the U.S.

1. Universal Transverse Mercator (UTM -meters)
    a. applied to latitudes ranging from 84N to 80 S
    b. 60 longitudinal zones, north and south of equator
        (1) 1 zone = 6 degrees of longitude (6 x 60 = 360)
        (2) zone 1 begins at 180W long.
        (3) western Oregon = zone 10 N
        (4) eastern Oregon = zone 11 N
2. State Plane Coordinates (SPC - feet)
    a. Developed in the 1930's to survey states
    b. accuracy requirments: 1 part per 10,000 or less
        (1) e.g. 1 ft error for every 10,000 ft distance on ground
    c. projections
        (1) Lambert Conformal
            (a) used for states elongated in E-W direction
        (2) transverse mercator
            (a) used for states elongated in N-S direction
3. Public Land Survey System (PLSS)
    a. Township-Range-Section Systems
        (1) 1 section = 1 mi x 1 mi
        (2) 1 township = 36 sections or 36 sq. miles
            (a) 6 ranges x 6 townships

C. Oregon Coordinate Systems in Use by GIS Coverages

1. UTM NAD1927 - meters - used by most federal agencies on Oregon Topo Quads
    a. Oregon divided by zone 10 N and zone 11 N boundary
    b. transverse mercator projections
    c. Vital information for projections in ArcView with Oregon Data

UTM Zone 10 N NAD1927
Units: meters
False Easting: 500000
False Northing 0
Prime Meridian: Greenwich
Transverse Mercator
Central Meridian: -123
Central Parallel: 0
Scale Factor: 0.9996
Ellipsoid (spheroid): Clarke 1866

UTM Zone 11 N NAD1927
Units: meters
False Easting: 500000
False Northing 0
Prime Meridian: Greenwich
Transverse Mercator
Central Meridian: -117
Central Parallel: 0
Scale Factor: 0.9996
Ellipsoid (spheroid): Clarke 1866

2. SPC NAD 1983 - used by Polk County and other local agencies
    a. state divided into SPC North and SPC South zones
    b. Lambert conformal projection
    c. Vital information for projections in ArcView with Oregon Data

Oregon State Plane North - NAD 1983
Units: feet
False Easting: 2500000
False Northing 0
Prime Meridian: Greenwich
Lambert Conformal Conic
Central Meridian: -120.5
Central Parallel: 43.6666
Standard Parallel 1: 44.333333
Standard Parallel 2: 46
Ellipsoid (spheroid): GRS 1980

Oregon State Plane South - NAD 1983
Units: feet
False Easting: 1500000
False Northing 0
Prime Meridian: Greenwich
Lambert Conformal Conic
Central Meridian: -120.5
Central Parallel: 41.6666
Standard Parallel 1: 42.333333
Standard Parallel 2: 44
Ellipsoid (spheroid): GRS 1980

3. Oregon Lambert Projection
    a. customized state projection used by state agencies
    b. Lamber conformal projection
    c. NAD1983 - feet
    d. advantage: state has 1 continuous projection ("1 zone", with no divisions)
    e. Vital information for projections in ArcView with Oregon Data

Oregon Lambert Projection

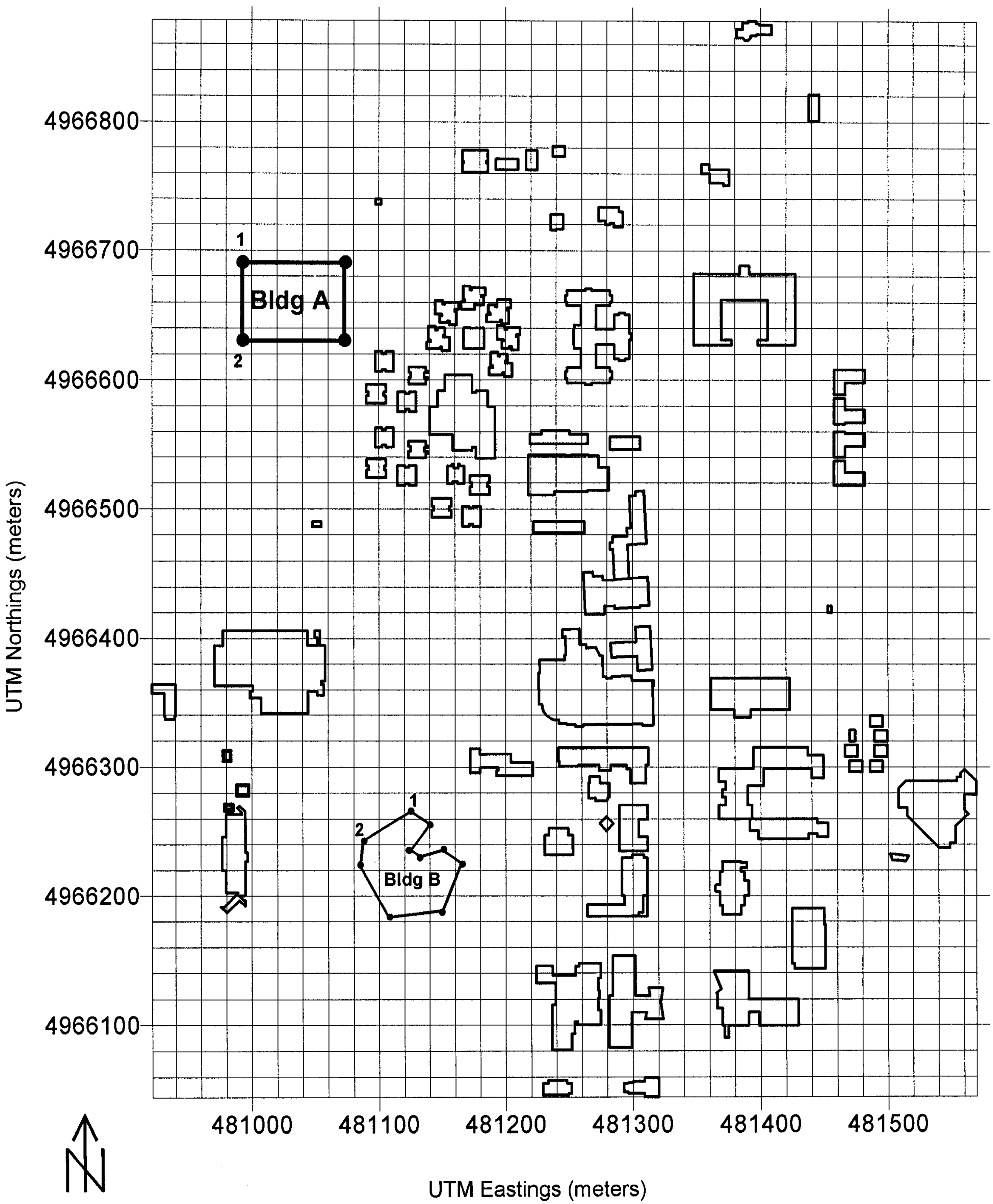
Geographic Datum: 1983_NAD
Units: Foot (international 1 ft - 0.3048 m)
Geographic Coordinate System: GCS_North_American_1983
False Easting: 1312335.958
False Northing: 0.0

Prime Meridian: Greenwich
Base Projection: Lambert_Conformal_Conic
Central Meridian: -120.5
Central Parallel: 41.75
Standard Parallel 1: 43
Standard Parallel 2: 45.5

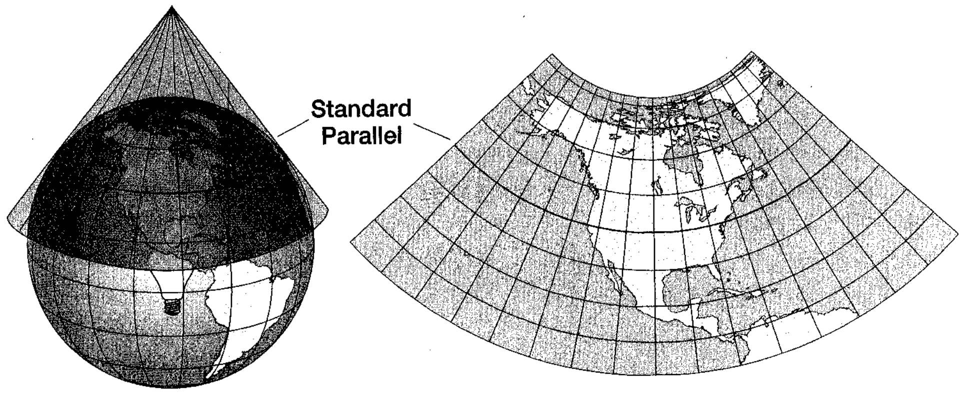
THE MAJOR RULE FOR DOWNLOADING GIS DATA FROM THE INTERNET:

You must download the data and metadata. The metadata file will give information on the datum, map units, projection, and coordinate system. You must know this before compiling GIS layers, otherwise the data will not properly align or overlay!!!

WOU Campus Building Basemap



c:wou:gis_492:woubase.srf



(a) (b)

Figure 2–6 (a) The origin of a conic projection, as illustrated by a globe with a light in its center, projecting images onto a cone. (b) The resulting map is called a conic projection.

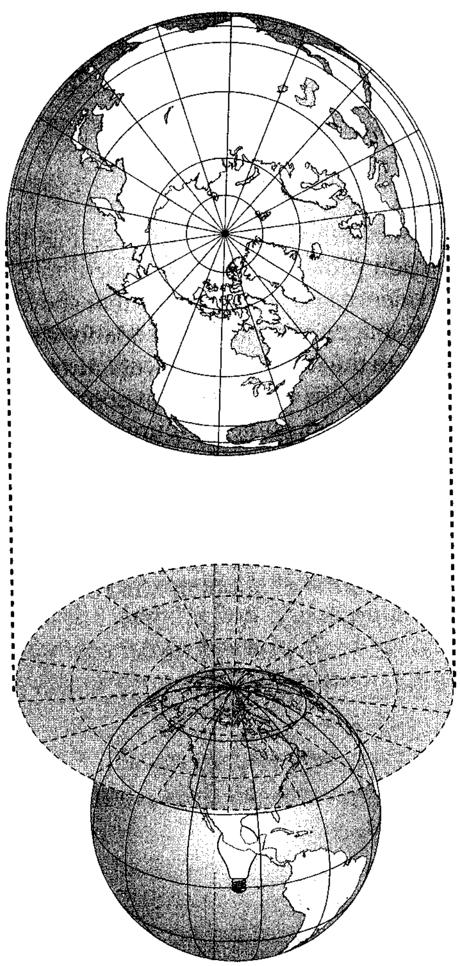


Figure 2–7 The origin of a plane projection as illustrated by a globe with a light in its center, projecting images onto an adjacent plane. The resulting map goes by various names: azimuthal projection, plane projection, or zenithal projection.

shape or size? This is the central problem both in constructing and in choosing a map projection. The projection properties involved are called *equivalence* and *conformality*.

Equivalence In an **equivalent projection**, the size ratio of any area on the map to the corresponding area on the ground is the same all over the map. To illustrate, suppose you have a world map before you and you place four dimes at different places (perhaps one on Brazil, one on Australia, one on Siberia, and one on South Africa). Calculate the area covered by each coin. If it is the same in all four cases, there is a good chance that the map is an equivalent projection—in other words, that there are equal areal relationships all over it.

Equivalent projections are very desirable because, with them, misleading impressions of size are avoided. (The world maps in this book are mostly equivalent projections because they are so useful in portraying distributions of the various geographic features we shall be studying.) They are by no means perfect, however. Equivalence is difficult to achieve on small-scale maps because shapes must be sacrificed to maintain proper areal relationships. Most equivalent world maps, which are small-scale maps, therefore display disfigured shapes. For example, as Figure 2-10b shows, Greenland and Alaska are usually shown as more squatty than they actually are.

Conformality A **conformal projection** is one in which proper angular relationships are maintained so that the shape of something on the map is the same as its shape on Earth. It is impossible to depict true shapes for large areas such as a continent, but they can be approximated, and for small areas the true shape can be shown on a conformal map. All conformal projections have meridians and parallels crossing each other at right angles, just as they do on a globe.

onto the cylinder. The cylinder in this case is the projection surface, and the globe is called the **reference globe**. Other common projection surfaces include a cone and a plane. A map projection is called a **cylindrical** projection if it can be constructed using a cylinder, a **conic** projection using a cone, and an **azimuthal** using a plane.

The use of a geometric object can also help explain two other concepts in map projection: case and aspect. Take the example of a conic projection: the cone can be placed so that it is tangent to the globe, or it can intersect the globe (Figure 2.3). The first is the simple case, which results in one line of tangency, and the second is the secant case, which results in two lines of tangency. A cylindrical projection behaves the same way as a conic projection in terms of case. An azimuthal projection, in contrast, has a point of tangency in the simple case and a line of tangency in the secant case. Aspect describes the placement of a geometric object relative to a globe. A plane, for example, may be tangent at any point on a globe (Figure 2.4). A polar aspect refers to tangency at the pole, an equatorial aspect at the equator, and an oblique aspect anywhere between the equator and the pole.

The concept of case relates directly to the **standard line** in map projection, which refers to the line of tangency between the projection surface and the reference globe. For cylindrical and conic projections the simple case has one standard line whereas the secant case has two standard lines. The standard line is called the **standard parallel** if it follows a parallel, and the **standard meridian** if it follows a meridian. There is no projection distortion along the standard line because it has the same scale as that of the reference globe. Another way to describe the standard line is that it has the scale factor of 1. The **scale factor** is defined as the ratio of the local scale to the scale of the reference globe or the **principal scale**. Because a scale factor of 1 means that the standard line has the same scale as the scale of the reference globe, the standard parallel is sometimes called the latitude of true scale. The degree of projection distortion increases away from the standard line.

The standard line should not be confused with the **central line**. Whereas the standard line dictates the distribution pattern of projection distortion, the central lines (the central parallel and meridian) define the center or the origin of a map projection. The central parallel, sometimes called the latitude of origin, often differs from the standard parallel. Likewise, the central meridian often differs from the standard meridian. A good example showing the difference between the central meridian and the standard line is the transverse Mercator projection.

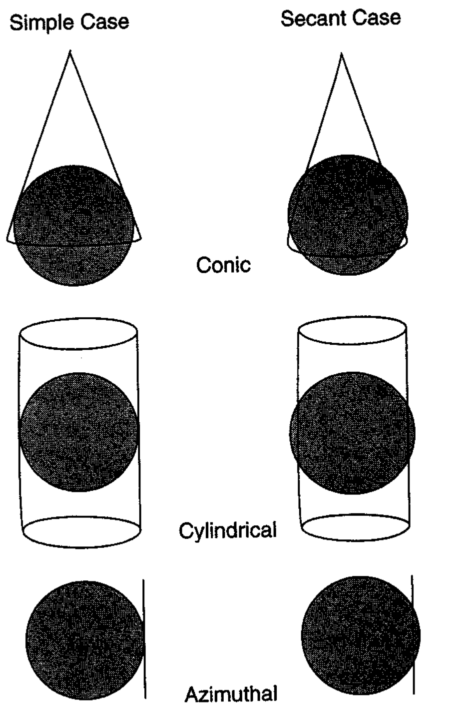


Figure 2.3
Use of a geometric object to construct a map projection.

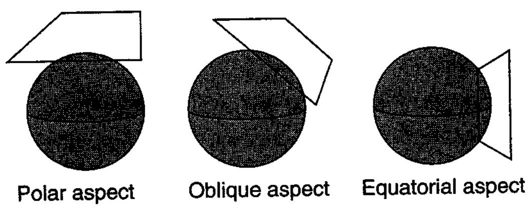


Figure 2.4
Aspect and map projection.

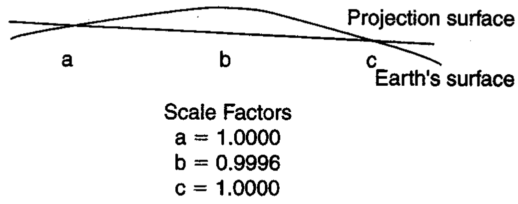


Figure 2.5
The central meridian in this secant case transverse Mercator projection has a scale factor of 0.9996. The two standard lines on either side of the central meridian have a scale factor of 1.

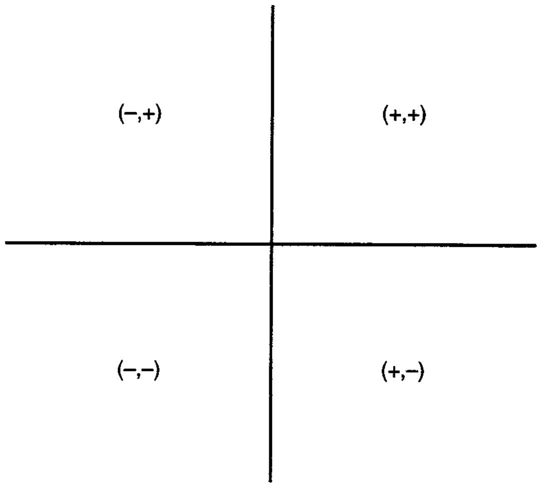


Figure 2.6
The central parallel and the central meridian divides a map projection into four quadrants. Points within the NE quadrant have positive *x*- and *y*-coordinates, points within the NW quadrant have negative *x*-coordinates and positive *y*-coordinates, points within the SE quadrant have positive *x*-coordinates and negative *y*-coordinates, and points within the SW quadrant have negative *x*- and *y*-coordinates.

Normally a secant projection, a transverse Mercator projection is defined by its central meridian and two standard lines on either side. The standard line has a scale factor of 1, and the central meridian has a scale factor of less than 1 (Figure 2.5).

A map projection can be used directly as a coordinate system in a GIS project. The center of the map projection, as defined by the central parallel and the central meridian, becomes the origin of the coordinate system and divides the coordinate system into four quadrants. The *x*-, *y*-coordinates of a point are either positive or negative, depending on where the point is located (Figure 2.6). To avoid having negative coordinates, GIS users can apply a **false easting** for *x* and a **false northing** for *y* to the origin of the map projection. Essentially, the false easting and false northing move the origin of the coordinate system to its SW corner so that all points will fall within the NE quadrant and have positive coordinates. False easting and false northing are optional parameters in map projection.

x-, *y*-coordinates based on a false origin often have very large numbers. For example, the NW corner of the Moscow East, Idaho quadrangle map (quad) has the UTM coordinates of 500,000 and 5,177,164 meters. To preserve data precision for computations with coordinates, ***x*-shift** and ***y*-shift** values can be applied to all coordinate readings to reduce the number of digits. Therefore, if the *x*-shift value is set as −500,000 meters and the *y*-shift value as −5,170,000 meters for the quad, the coordinates for its NW corner will be changed to 0 and 7164 meters. Because *x*-shift and *y*-shift, or false easting and false northing, change the values of *x*-, *y*-coordinates in a digital map, these changes should be documented in the metadata (information about data), especially if the map is to be shared with other users.

Finally, to help users choose from among hundreds of map projections, cartographers sometimes group map projections by how well they can be used to map the world, a hemisphere, a continent, a country, or a region. ArcView, for example, uses this approach with the predefined map projections.

2.3.1 Commonly Used Map Projections

2.3.1.1 Transverse Mercator

The **transverse Mercator** projection is a variation of the Mercator projection, probably the best-known projection of the world. Instead of using the standard parallel as in the case of the Mercator

PROJECTIONS

Figure 3.2 - Some commonly-used projections.

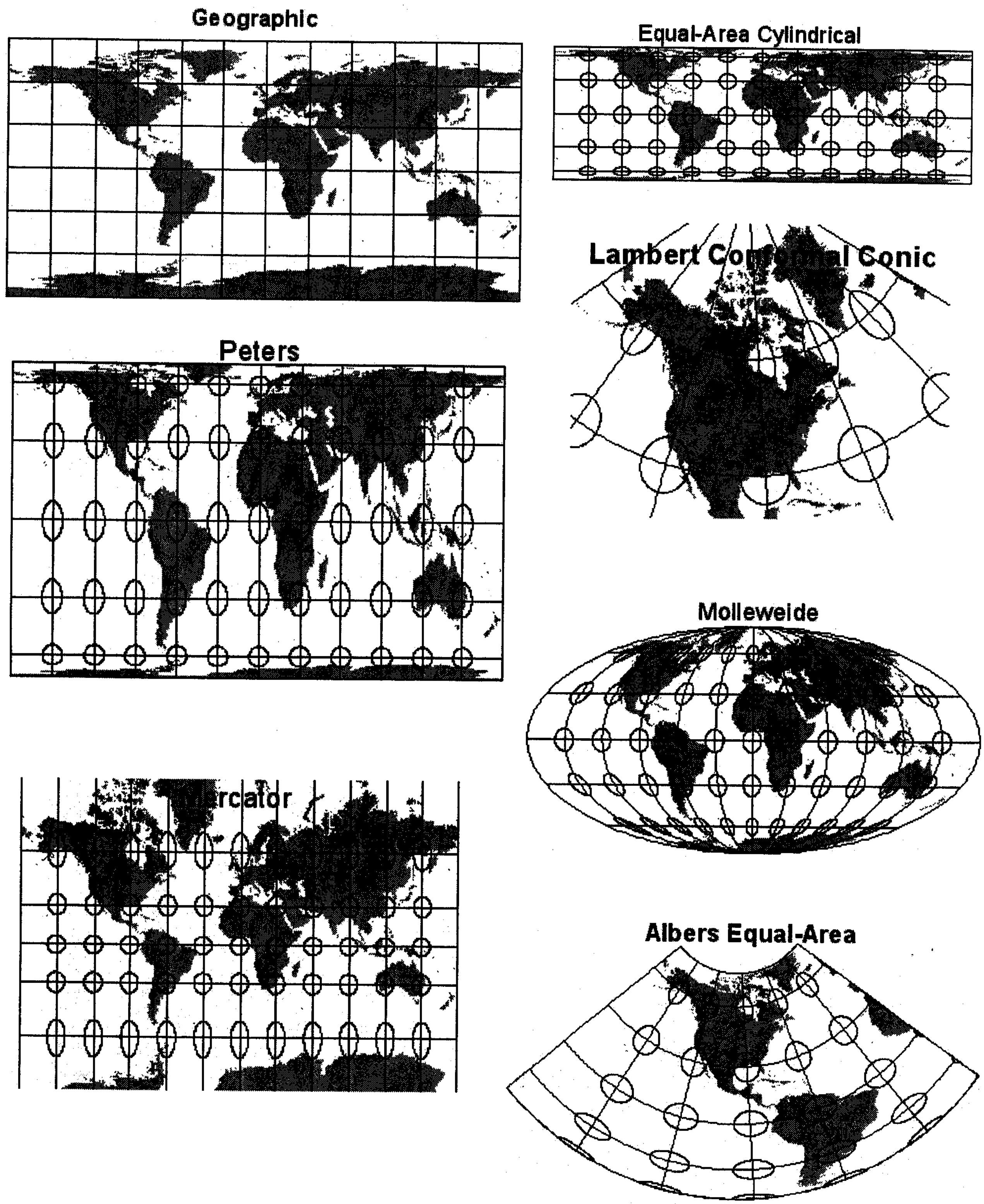


Figure 3.3 UTM zones for the world.

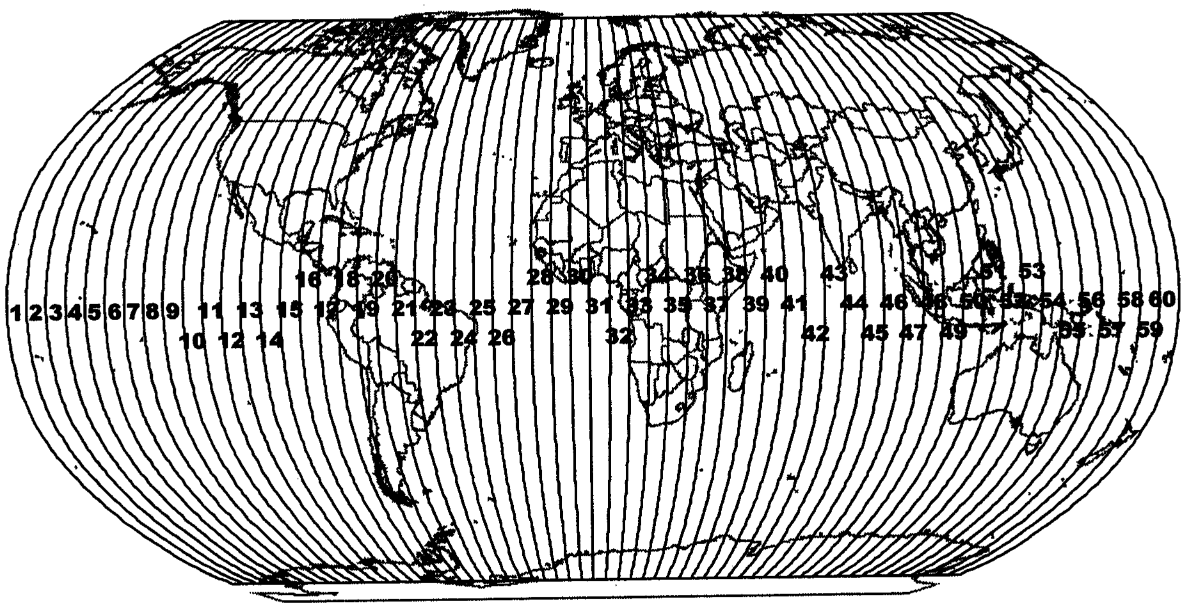


Figure 3.4 UTM zones for the United States

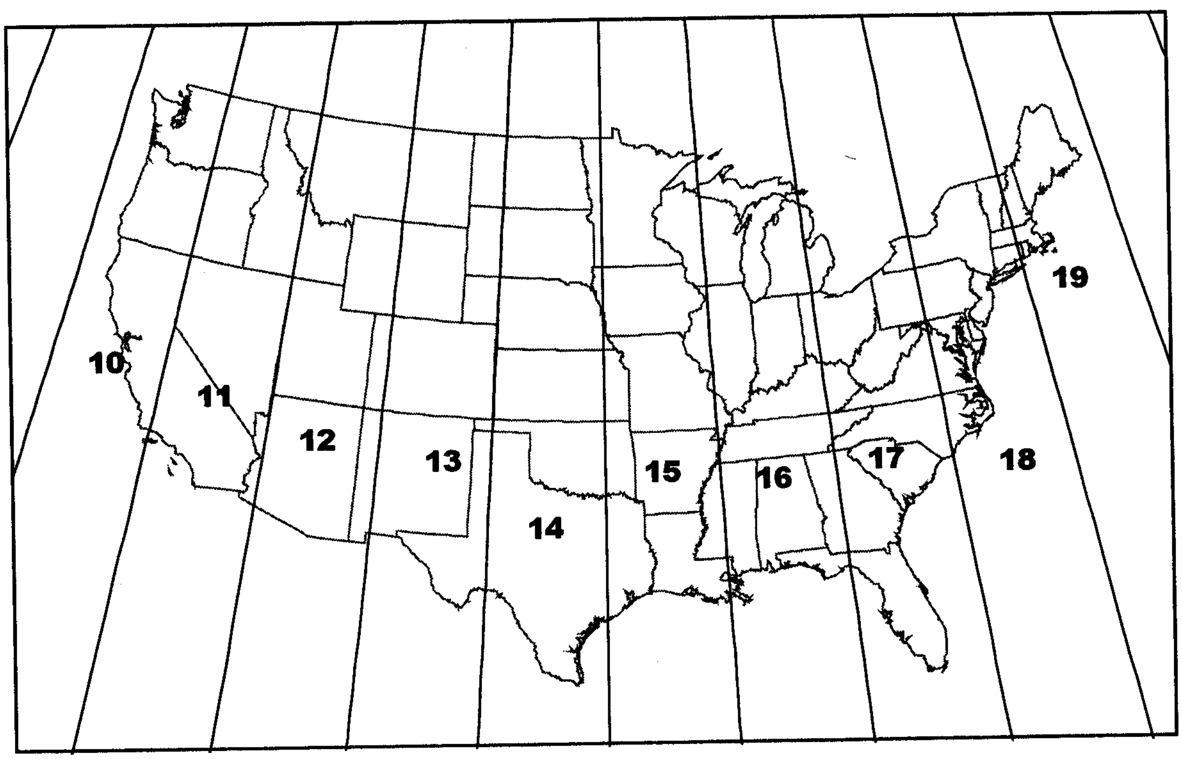


Figure 3.6 1983 State Plane Coordinate System Zones for the Western US with counties.

Table 3.2 - The type, properties, and common uses of available projections.

Region	Name	Type (case, aspect, surface)	Properties	Comments
World	Behrmann	Normal. Tangent, cylindrical	Equal-area	Special case of Equal-Area cylindrical where standard parallel is set to 30 degrees.
	Cassini Soldner	Transverse, tangent, cylindrical	Compromise	Maintains scale along the central meridian and lines parallel to it. Usually used for detailed mapping with north-south extent. Distortion increases with distance from central meridian. It was formerly used by the Ordnance Survey in Great Britain, and is still used in Cyprus, Denmark, Germany, Malaysia, and former Czechoslovakia.
	Equal-Area Cylindrical (aka Lambert Cylindrical Equal-Area)	Normal, tangent, cylindrical	Equal-area	This projection is suitable for equatorial regions. Meridians are spaced 0.32 times the length of the Equator. Shape and distance distortion increases away from the standard parallel (equator). Behrmann, Gall orthographic, Trystan Edwards, and Peters are similar projections.
	Hammer-Aitoff	Tangent, transverse, planar	Equal area	This is a modification of the Lambert Azimuthal Equal-Area projection – its point of tangency is at the central meridian and the equator. It is typically used as a simple map of the world. Shape and distance distorts with increasing distance from the point of tangency.
	Mercator	Tangent, normal, cylindrical	Conformal	This projection was originally created to display accurate compass bearings for maritime navigation. Area is increasingly distorted towards the poles, e.g., Greenland appears larger than South America, but it is only one-eighth its size. Because of the large area distortion, it is unsuitable for general world maps, although it is still used as the backdrop for many a TV news program.
	Miller Cylindrical	Tangent, normal, cylindrical	Compromise	This projection is typically used as a general world map, but polar regions are not so distorted. Distortion is minimal between the 45° parallels and increases towards the poles.
	Mollweide	Pseudo-cylindrical	Equal area	This projection is typically used for general world maps. It is also known as: Babinet, Elliptical, Homolographic, and Homolographic. Distortion is minimal at the intersection of the central meridian and 40° 44' parallels, and increases outward from these points. This projection is combined with the Sinusoidal to create Goode's Homolosine and Boggs.
	Peters	Normal, tangent, cylindrical	Equal-area	This projection is a special case of the Equal-Area Cylindrical projection with standard parallels at 45°.
	Plate Carree	Tangent or secant, normal, cylindrical	Compromise	This projection is easy to construct because it forms a grid of equal rectangles, and it is the projection used when data are in geographic coordinates and no projection is specified. It is typically used for simple maps of the world. Shape and area distortion increases with increasing distance from standard parallels. The polar regions are less distorted in scale and area than they are with the Mercator projection.

PROJECTIONS

	Robinson	Secant, pseudo-cylindrical	Compromise	The central meridian is a straight line 0.51 times the length of the Equator, while parallels are equally-spaced straight lines between 38° N and S. Distortion is low within 45° of the equator and meridian. This is typically used for general and thematic world maps. It was developed by A.H. Robinson for Rand-McNally in 1963 and has been used by the National Geographic Society since 1988.
	Sinusoidal	Tangent, pseudocylindrical	Equal area	This is typically used as a general world map or for continents with large N-S extents such as South America and Africa. Alternative formats such as Goode's Homolosine use it to reduce the distortion along outer meridians by interrupting the continuity of the projection over the oceans and by re-centering the continents around their own central meridians. Distortion is minimal along the central meridian and the equator.
Hemisphere	Equidistant Azimuthal	Tangent, planar	Distance and direction from central point	This is most commonly used to map polar areas, or is centered on a city. Distortion increases with increasing distance from the center (30° from center has 4.7% distortion).
	Gnomonic	Tangent, planar		This projection uses the center of the Earth as its perspective point. All great circles are straight lines, which is useful for navigation because great circles are routes with the shortest distance. Shape and area distortion increases from the center, with minimal distortion at 15° (7.2%).
	Lambert Equal-Area Azimuthal	Tangent, planar	Equal area, direction from center	The distortion pattern is radial, increasing with increasing distance from the center of the projection: e.g., shape is distorted less than 2 percent within 15 degrees from the focal point. It is best used when the area of interest has an equal extent in both E-W, N-S.
	Orthographic	Tangent, oblique, planar		This projection views the globe from an infinite distance and gives the illusion of a three-dimensional globe. Area and shape distortion increase from the center outward.
	Vertical Near-side Perspective	Tangent, oblique, planar.		This projection views the globe from a specified distance rather than an infinite distance as in the Orthographic projection. This perspective provides the overall effect of a photograph of the earth taken from an orbiting satellite.
	Stereographic	Tangent, planar	Conformal	This is also known as the planar perspective projection and is viewed from the point on the globe opposite the point of tangency. All meridians and parallels are shown as circular arcs or straight lines. Scale and area distortion increases from the center.
International Grids	Great Britain			See UTM.
	New Zealand	Tangent, cylindrical	Conformal	This is the standard projection for large-scale maps of New Zealand. It is a sixth-order conformal modification of a Mercator using the International spheroid. Areal and scale distortion is minimal at 41° S and 173° E, but is less than 0.04% for New Zealand. It is not useful for areas outside New Zealand.
	Malaysia, Singapore, and Brunei	Tangent, oblique, cylindrical	Conformal	This projection is called the Rectified Skew Orthomorphic projection and is similar to the Oblique Mercator. It should not be used for outside of Malaysia, Singapore, and Brunei.

	UTM	Tangent and secant, transverse , cylindrical	Conformal	This is typically used for land masses that are predominately N-S in extent. Also, the State Plane Coordinate System uses this projection for all state zones oriented north to south. In North America, the central meridian scale factor (secant case) is 0.926. It is also used for topographic maps made by the Ordnance Survey of Great Britain after 1920.
United States	Albers Equal-Area	Normal, secant, conic	Equal area	This projection uses two standard parallels, typically at 29° 30' and 45° 30' for the coterminous US (maximum scale distortion is 1.25%). The latitude range should not exceed 30-35 degrees. This projection is typically used for east-west extent in mid-latitudes.
	Equidistant Conic	Sectant or tangent, conic	Equidistant	Shape and area distortion is constant along parallels, but increases with distance from the standard parallels. This projection is typically used in regional mapping of mid-latitude areas with predominant east-west extent (e.g., US and former USSR).
	Lambert Conformal Conic	Secant, normal, conic	Conformal	This projection is typically used for middle-latitude, east-west extent areas. For the coterminous US, standard parallels are 33° and 45°. For the entire US, standard parallels are 37° and 65°. It is similar to the Albers Conic Equal-Area projection but it portrays shape more accurately than area. It is used by the State Plane Coordinate System for all state zones that spread east to west and replaces the Polyconic projection which was used prior to 1957 for USGS 7.5' quads.
	State Plane (1927, 1983)			See UTM and Lambert Conformal Conic.
National grids	Oblique Mercator	Tangent, oblique, cylindrical	Conformal	This is an oblique rotation of the Mercator projection and was developed for conformal mapping of areas are obliquely oriented. It is typically used for detailed mapping in Switzerland, Borneo, and Madagascar, and the Alaskan panhandle.