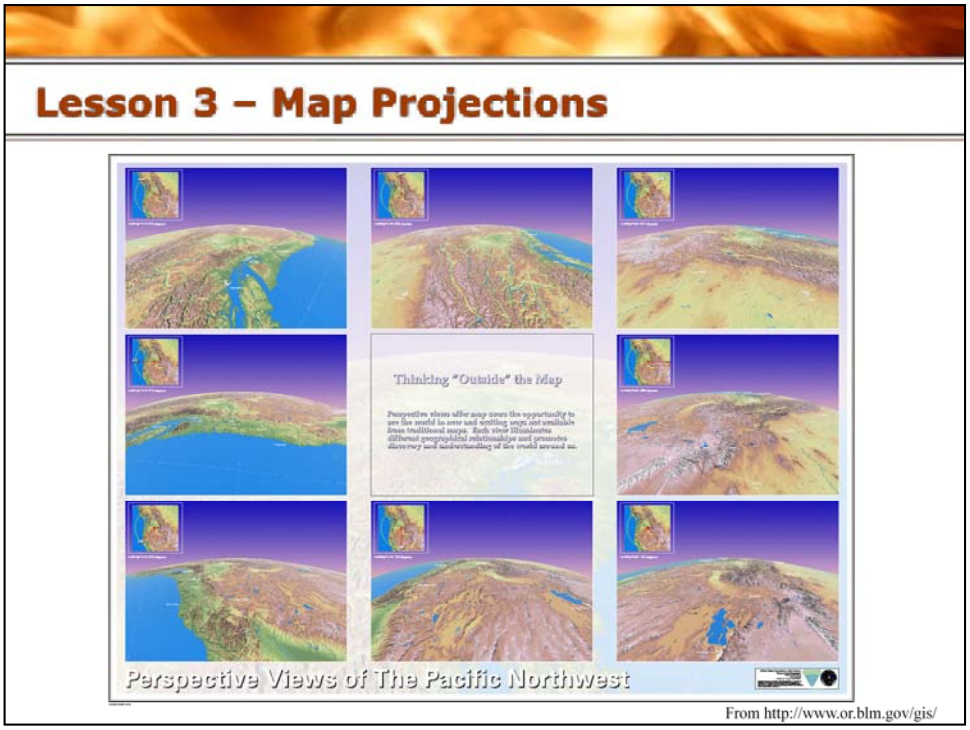
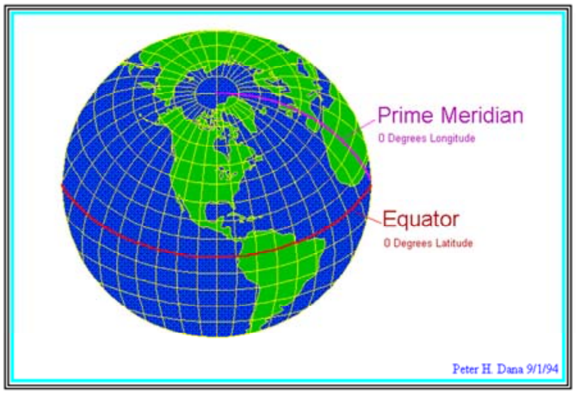


Welcome to Lesson 3. It is important for a GIS analyst to have a thorough understanding of map projections and coordinate systems. A GIS without coordinates would simply be a database like Microsoft Excel or Access. It is thanks to the coordinates that we can create overlays in a GIS and perform analyses that incorporate data from more than one layer. Without coordinates associated with the geographic data (points, lines, polygons or rasters) ArcMap would not know where to place the different layers in relation to each other.

Geographic coordinates

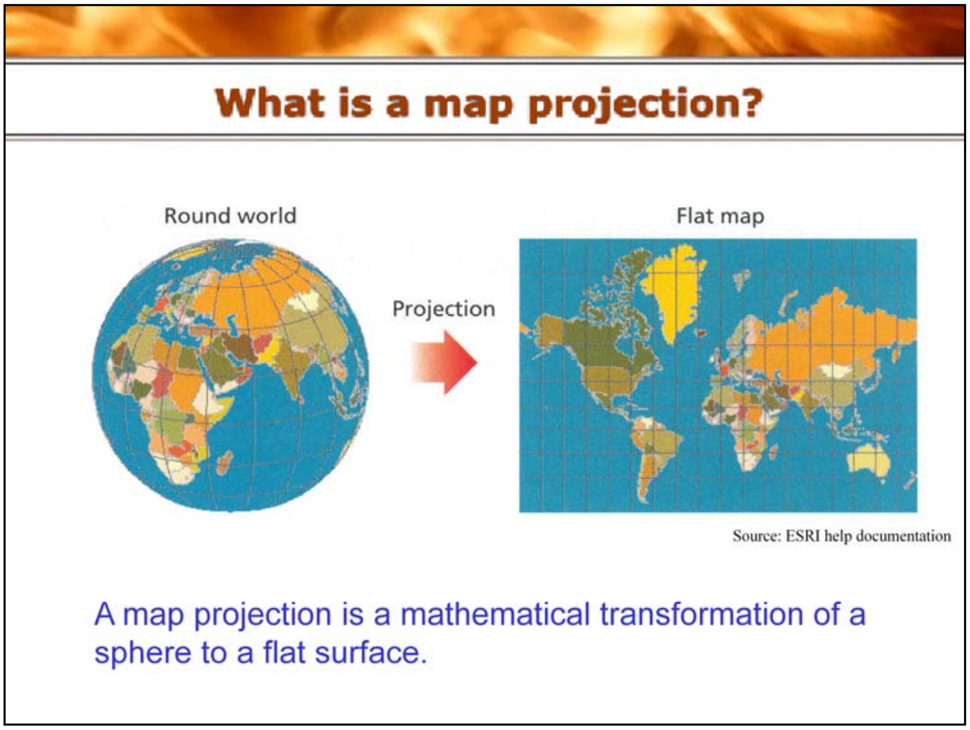


Coordinates are expressed as Latitude and Longitude in Degrees, Minutes, Seconds (DMS) or Decimal Degrees (DD).

The location on earth can be described by specifying the latitude and the longitude. The longitude is the horizontal direction that measures the angle east- or west-ward from the Prime meridian (longitude = 0) that passes through Greenwhich London. The maximum measure of longitude is 180 degrees located at the dateline on the opposite side of the earth from Greenwhich. Locations east of Greenwhich are located in the eastern hemisphere (positive) and locations west of Greenwhich are located in the western hemisphere (negative).

The latitude is the vertical direction that measures the angle from the equator (latitude = 0) north-or southward to the poles. The north pole is located at 90 degrees north (90°)and the south pole is located at 90 degrees south (-90°).

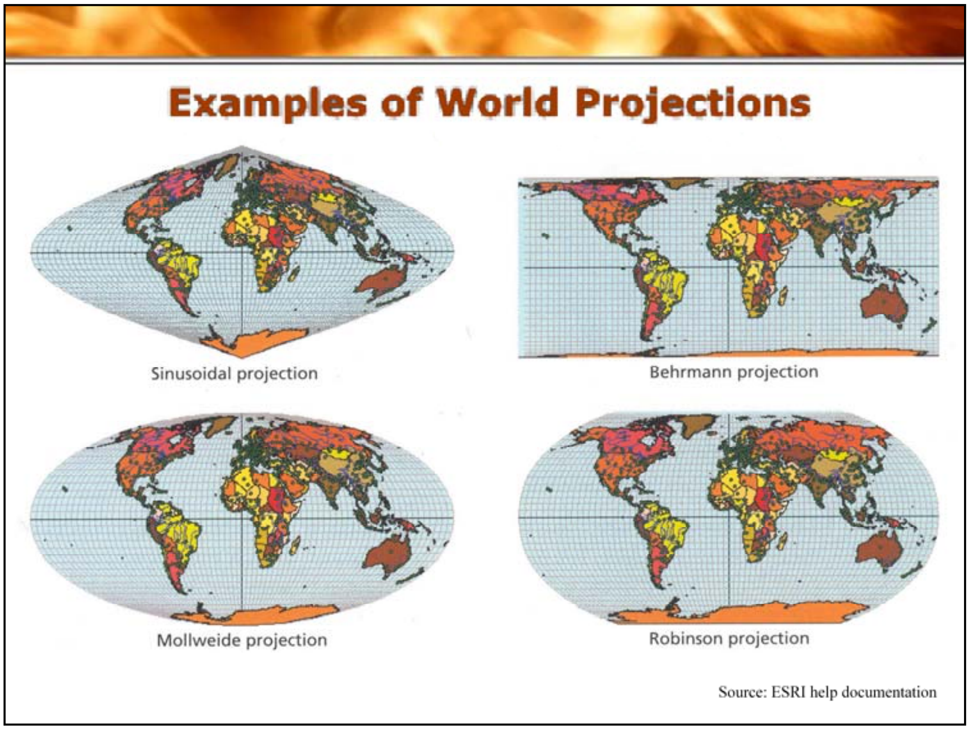
Longitude and latitude can be expressed in degrees, minutes and seconds (longitude: -117° 01’ 45’’, latitude: 46 45’ 30’’) or as decimal degrees (longitude: -117.029167, latitude: 46.758333). Notice that longitudes and latitudes in the western and southern hemisphere are expressed as negative numbers, while latitude and longitude measures in the eastern and northern hemisphere are positive.



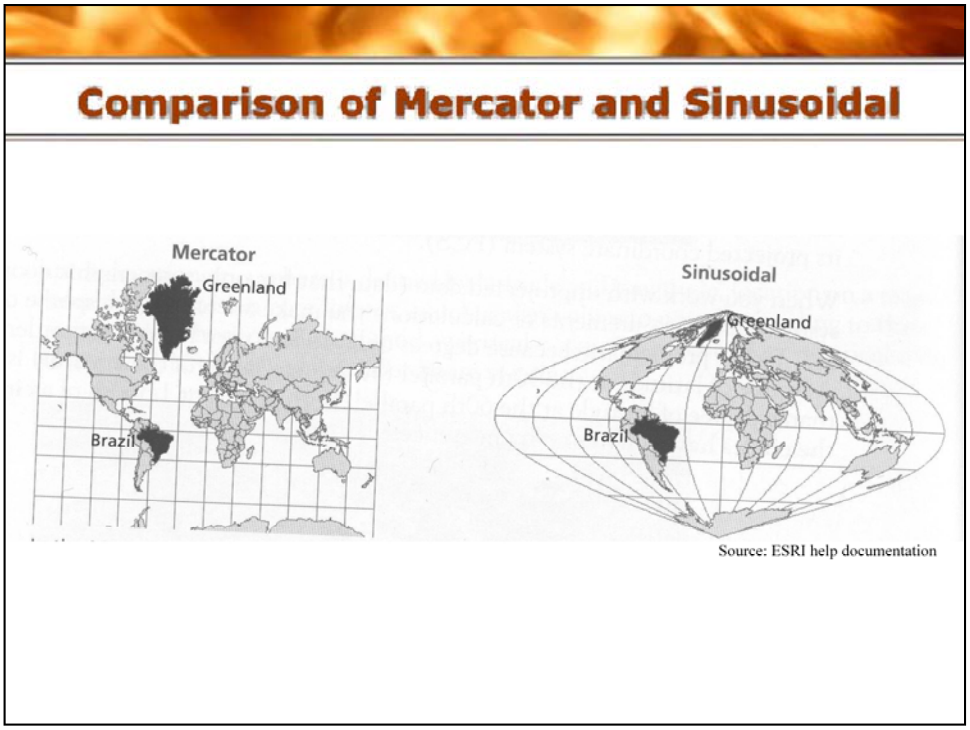
A map projection is a mathematical transformation of a sphere (earth) to a flat surface (map).

Measures of latitude and longitude expressed in degrees, minutes and seconds cannot be used as a distance measure. You could say that the distance from London to Moscow, Idaho is 117 degrees and 1 minute, however this would be meaningless information since the measure on the ground of one degree (or minute) varies by the latitude. A degree on the equator is much longer than a degree at 45 degrees latitude and at the poles all longitudes meet and there is no distance at all between 0 and 117 degrees longitude.

Conversion of the spherical coordinates to a Cartesian coordinate system is necessary if we want to measure distances in meaningful units such as meters, feet or miles or if we want to estimate the area of a land unit.

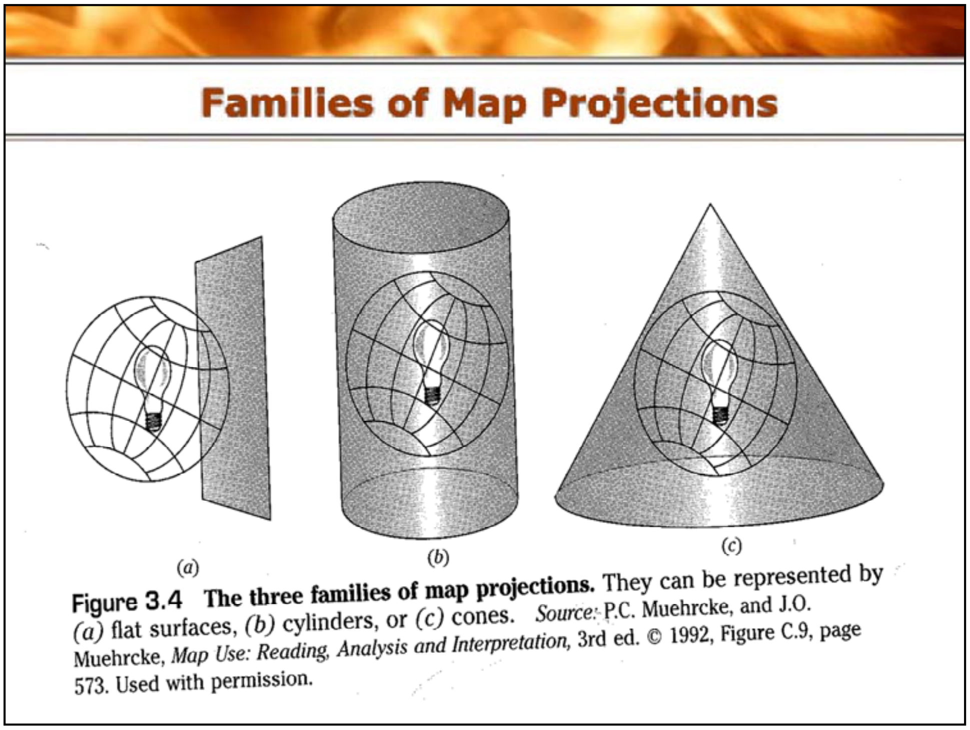


A projection is a mathematical model for converting locations on the earth’s surface from spherical to planar coordinates.
All projection methods involve ‘stretching’ or ’shrinking’ part of the globe. Different projections have their advantages and disadvantages; none is perfect



In the Mercator projection, Greenland looks larger than Brazil, although Brazil is four times its size. Direction is preserved and Brazil correctly appears due south of Greenland.

In the sinusoidal projection the proportional size of Greenland and Brazil are correct, however their shapes are distorted.



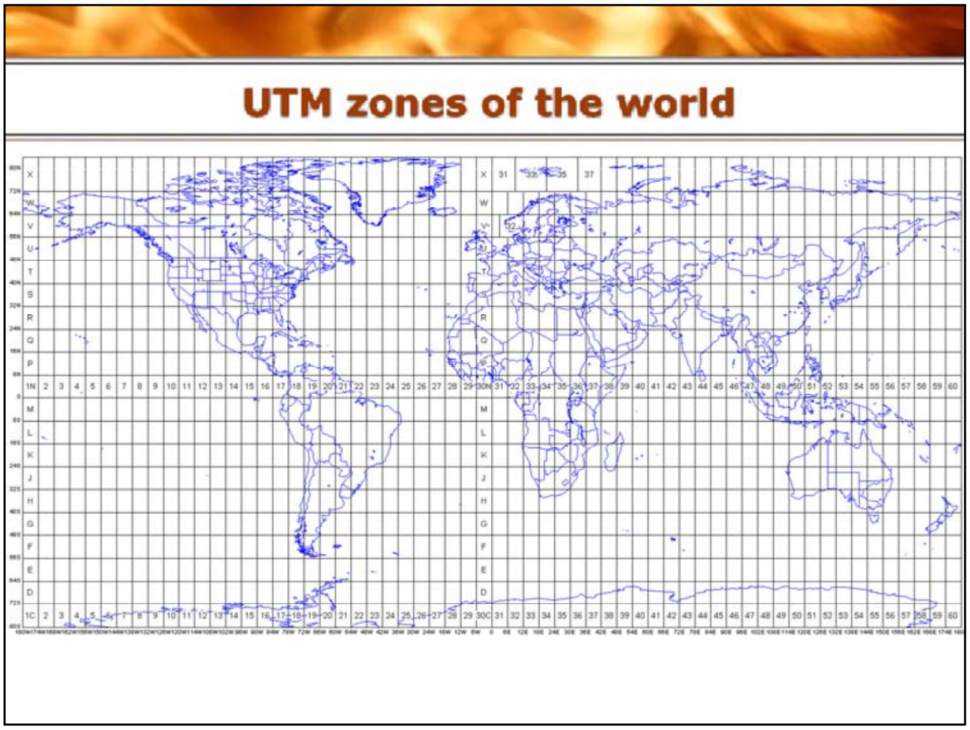
Azimuthal projection - One point on the globe (the center or the azimuth) is touching a flat plane. Distortion increases away from the center point.
Cylindrical projection - Is made as if a cylinder were wrapped around the globe and then laid flat. Longitude lines run straight at right angles to latitude lines Countries near the poles look too large. This is Mercator's method of globe projection. In a Transverse Mercator projection the cylinder is turned 90 degrees (a cylinder on its side).
Conical projection - Is made as if a cone were placed over the globe and then spread out in a flat fan shape. Latitude lines look curved
This projection shows areas and distances fairly accurately but distortions increase away from the line where the cone touched the globe.

If you are interested in details of map projections go to:
http://en.wikipedia.org/wiki/Map_projection

Universal Transverse Mercator (UTM)

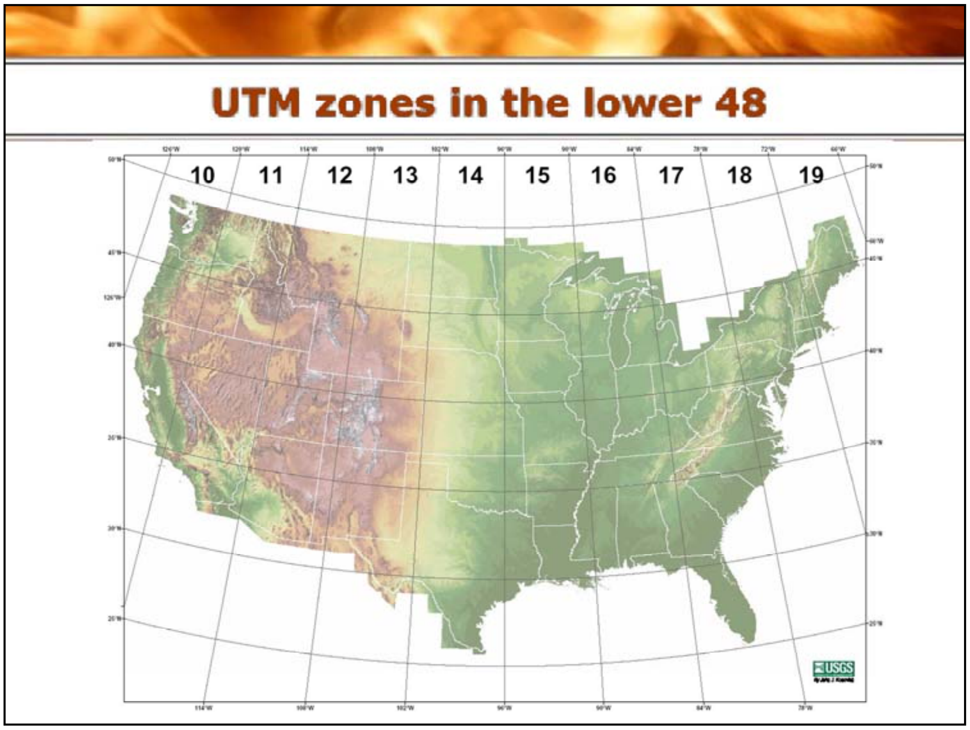
- The most prevalent grid system used in GIS operations. It has been adopted for most remote sensing applications, topographic map preparation, and natural resource database development
- It allows precise measurement using a **metric** system of measure, which is accepted by most countries and the scientific community.
- UTM is commonly used at the state-wide scale, however never used where the map extent is much larger than one UTM zone (6 degrees wide).

UTM (Universal Transverse Mercator is the most commonly used coordinate system in the lower 48 states. The measurement units for UTM is meters.



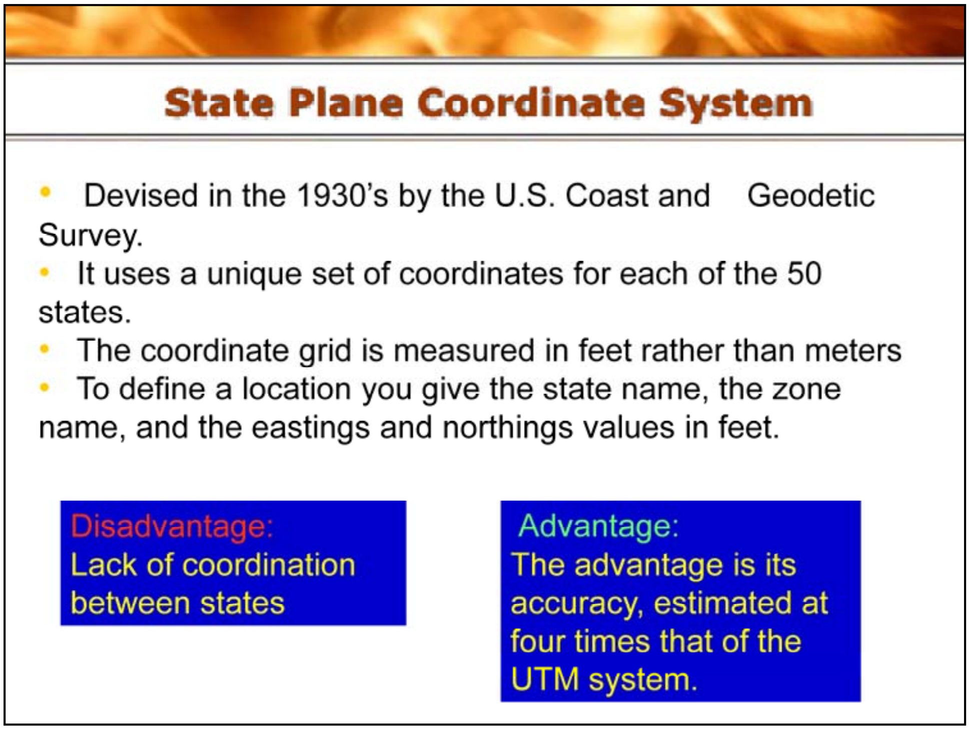
The UTM coordinate system is divided into 60 zones, beginning with zone 1 at the data line. Zone 1 covers 180-174 W, zone 2 covers 174-168 W, zone 3 covers 168-162 w etc. The UTM coordinates are expressed as easting (x-coordinate) and northing (y-coordinate). The northing originates at the equator (northing 0). In the northern hemisphere the northing is a direct measure of the distance to the equator (in meters) and increase as you go north towards the north pole. A value of 10,000,000 has been added to the northing value in the southern hemisphere in order to avoid negative numbers.

Within each UTM zone the central meridian (center longitude of the zone) is set to 500,000 in order to avoid negative numbers in the UTM easting value.



UTM zones in the lower 48 – what UTM zone do you live in?

The distortion of the map increases as you move away from the center of the UTM zone.



Another commonly used coordinate system is 'State Plane'. This coordinate system is particularly used by the US Corps of Engineers and in surveying. This coordinate system is appropriate to used for smaller geographic areas (counties).

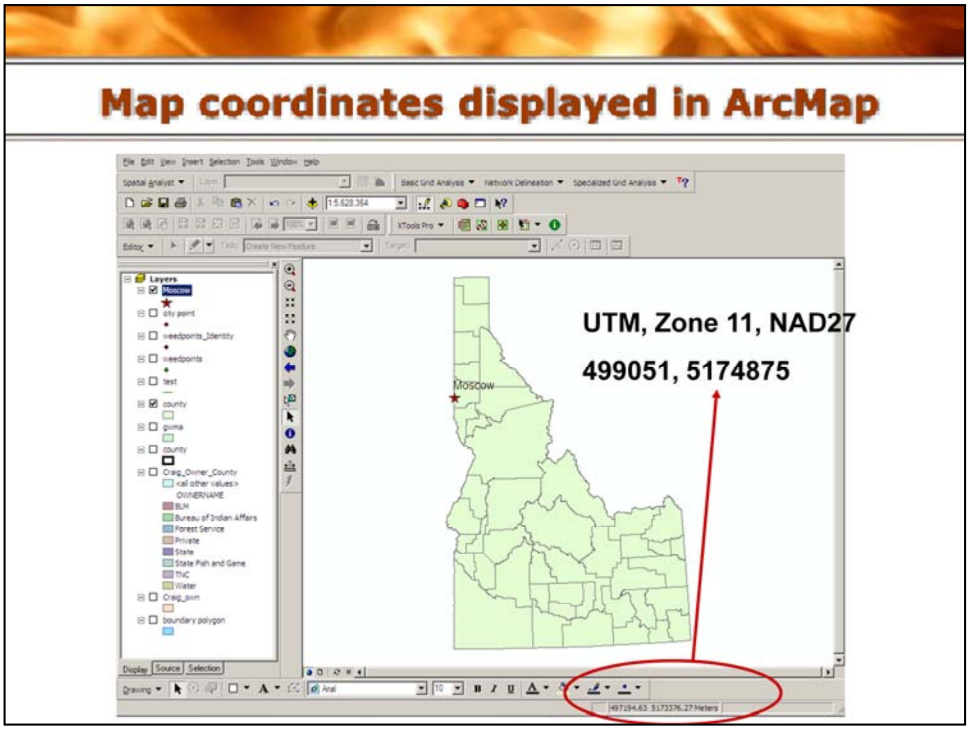
Coordinates of Moscow, Idaho

…in different geographic and map projections

Projection	Longitude (x)	Latitude (y)
UTM zone 11	499051	5174875
State Plane Idaho West	183419	1848034
Geographic (DD)	-117.0124	46.7294
Idaho Transverse	269825	629720
Albers Equal Area (ICRB)	699055	637173

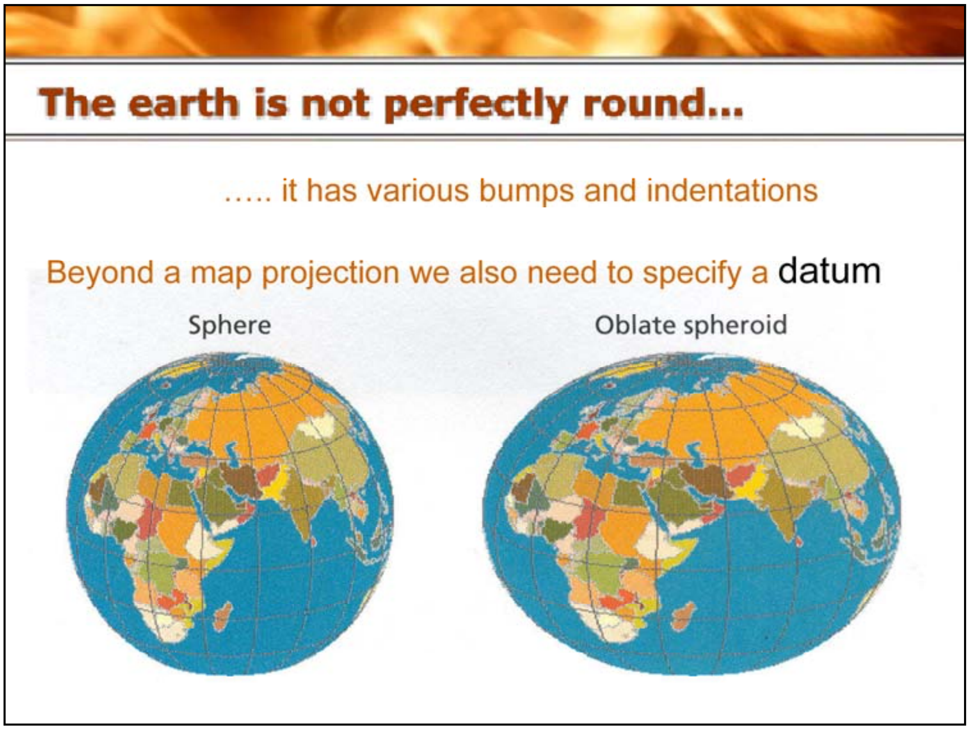
The map coordinates for a specific location depends on the coordinate system used. In the table above you can see the coordinate pairs for Moscow, Idaho reported in different coordinate systems.

In a GIS these numbers are simply treated as x and y coordinates and you can imagine that data expressed in different coordinate systems will not overlay properly in the map. In ArcMap there are however tools that will enable you to overlay data layers expressed in different coordinate systems. The trick is to always be aware of and correctly define the coordinate system for your GIS data layers.

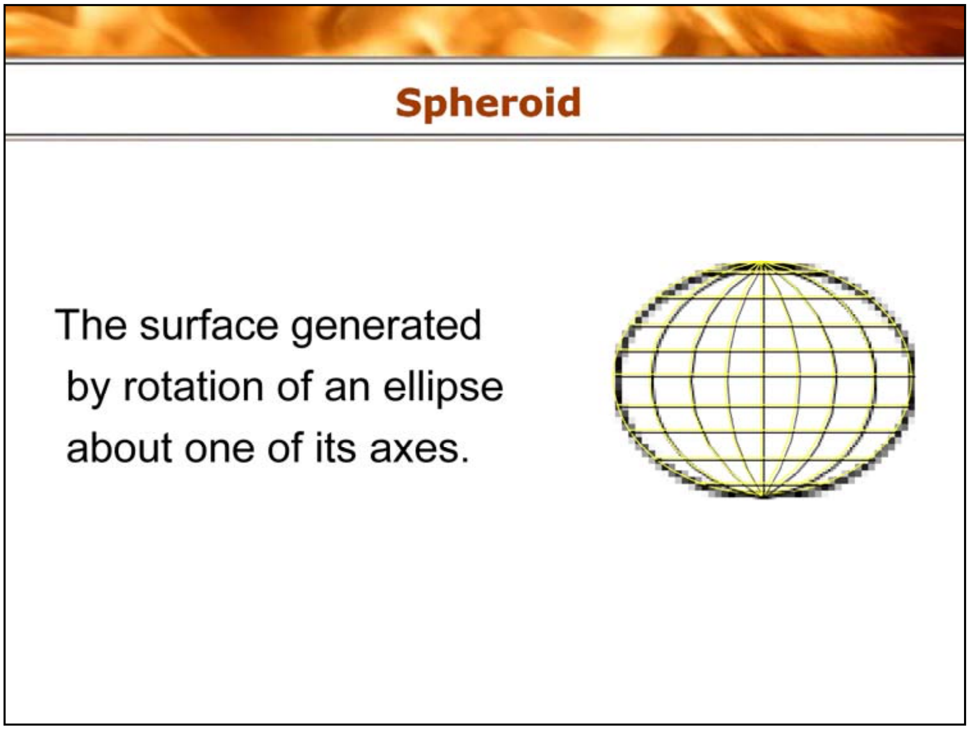


In ArcMap the coordinates of the location of the cursor on the map is displayed on the lower bar.

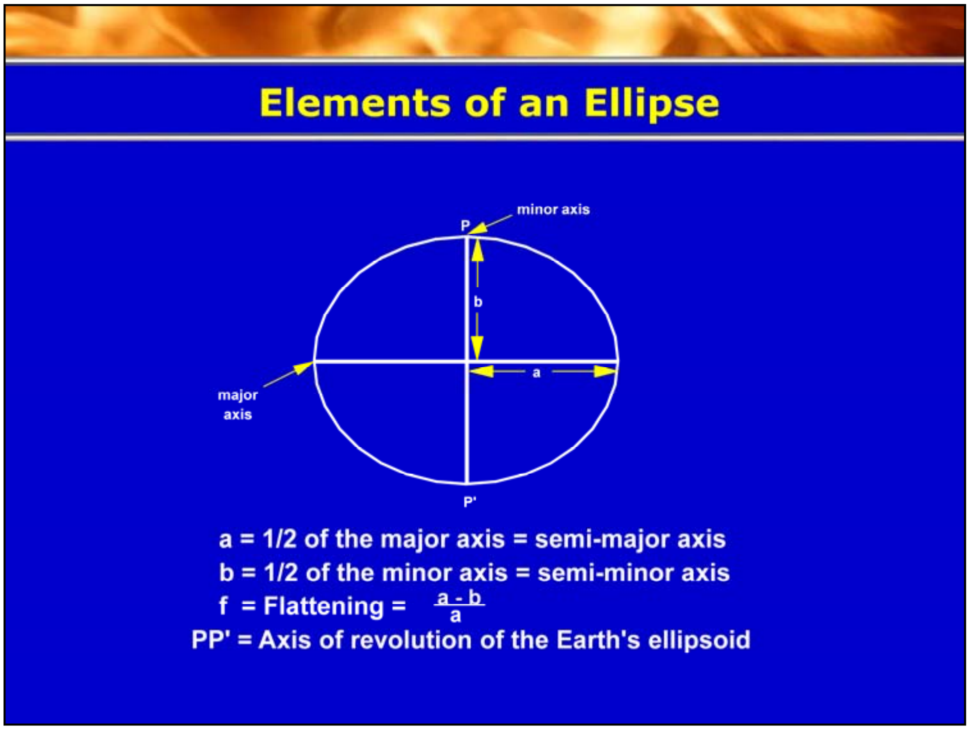
Remember from Exercise 1 that the coordinate system of the first data layer added to an ArcMap project determines the coordinate system for the data frame. If layers of a different map projection are added later they will be projected ‘on the fly’ to match the data in the data frame (contingent upon the fact that the map orjection for the dataset is defined).



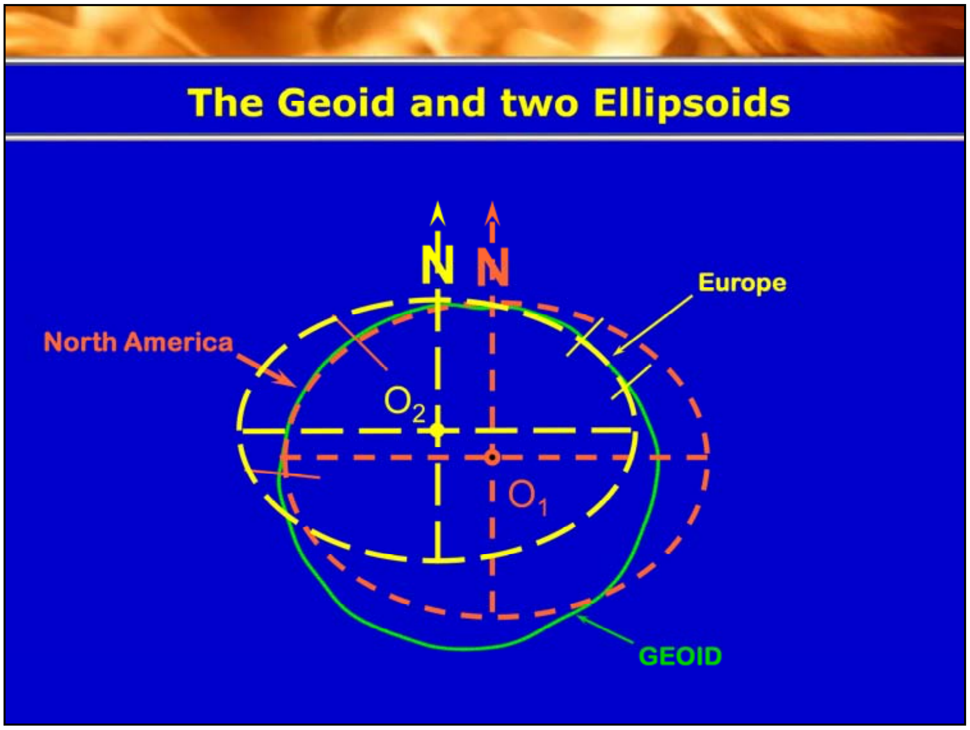
The earth is not perfectly round and is mathematically better approximated by a spheroid (elliptic) than a sphere. In simplified term the DATUM is a correction for the fact that the earth is not completely spherical.



A spheroid (or ellipsoid) is the surface generated by rotation of an ellipse.



The DATUM is calculated based on the flattening of the ellipse – see diagram above.



Different values for the ‘flattening’ are used to approximate the earth at different locations. The red ellipsoid approximates the earth’s surface well in North America while the yellow ellipsoid approximates the earths surface well in Europe.

Reference ellipsoid.....

.....an ellipsoid of specified dimensions which is associated with a geodetic reference system (mathematically defined model of the earth's surface).

Different reference ellipsoids (different flattening) are associated with different DATUMS.

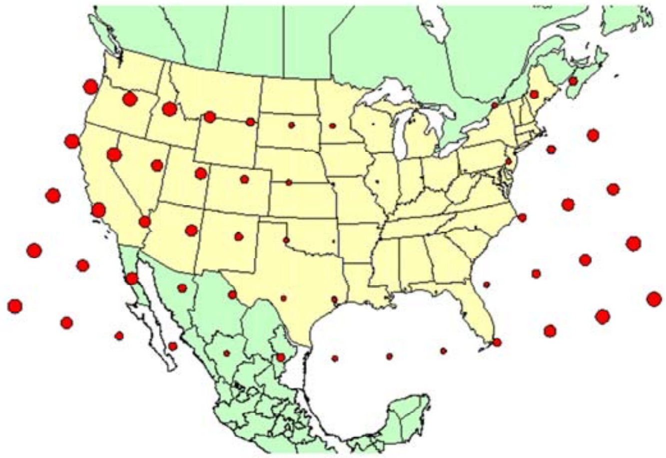
Reference Ellipsoid Constants

REFERENCE ELLIPSOID	A (meters)	f
Clark 1866 (NAD1927)	6378206.4	1/294.978692
Geodetic Reference System 1980 (NAD1983)	6378137	1/298.257222101
WGS84	6378137	1/298.257223563

If you work in North America the most commonly used datums are North American Datum 1927 (NAD27) and North American Datum 1983 (NAD83). WGS84 is a spherical datum. NAD27 is based on the spheroid Clark 1866 and NAD 83 is based on the spheroid GRS80. In some cases the spheroid is reported rather than the datum.

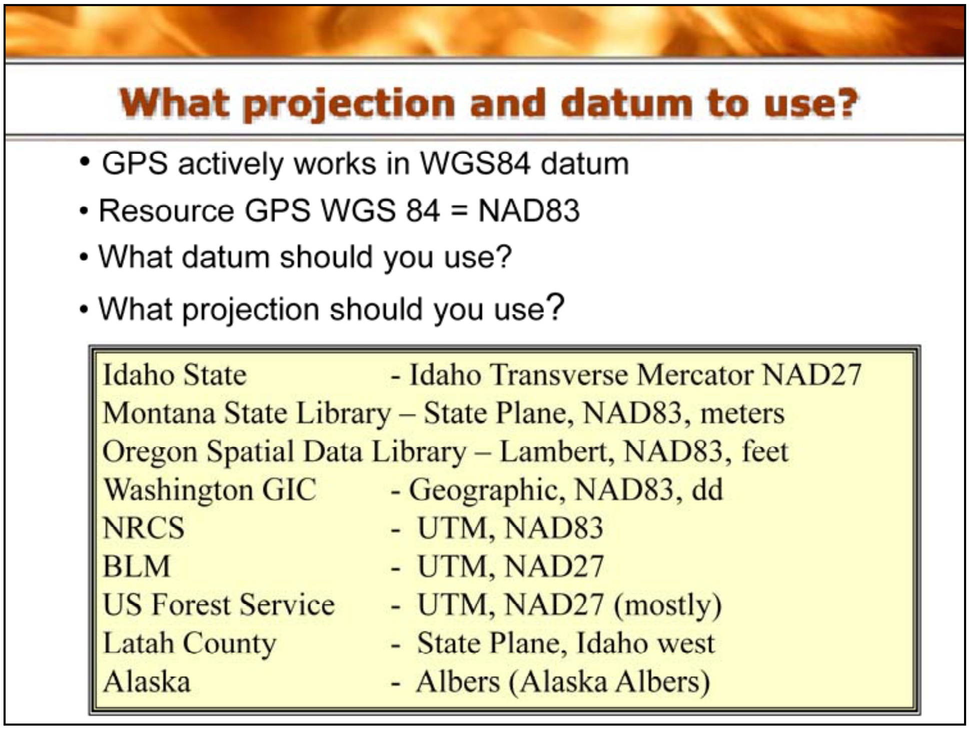
The distance on the ground between coordinates measured in NAD 83 and WGS84 is very small and can be ignored for resource GPS and mapping.

Difference between NAD27 and NAD83



Coordinates measured in NAD83 vs. NAD27 however translates to distances of over 100-200 meters on the ground in the western US and tens of meters in the central and eastern US. By not knowing what DATUM your GPS coordinates were collected in you may accidentally add an error of over 200 meters to you data locations.

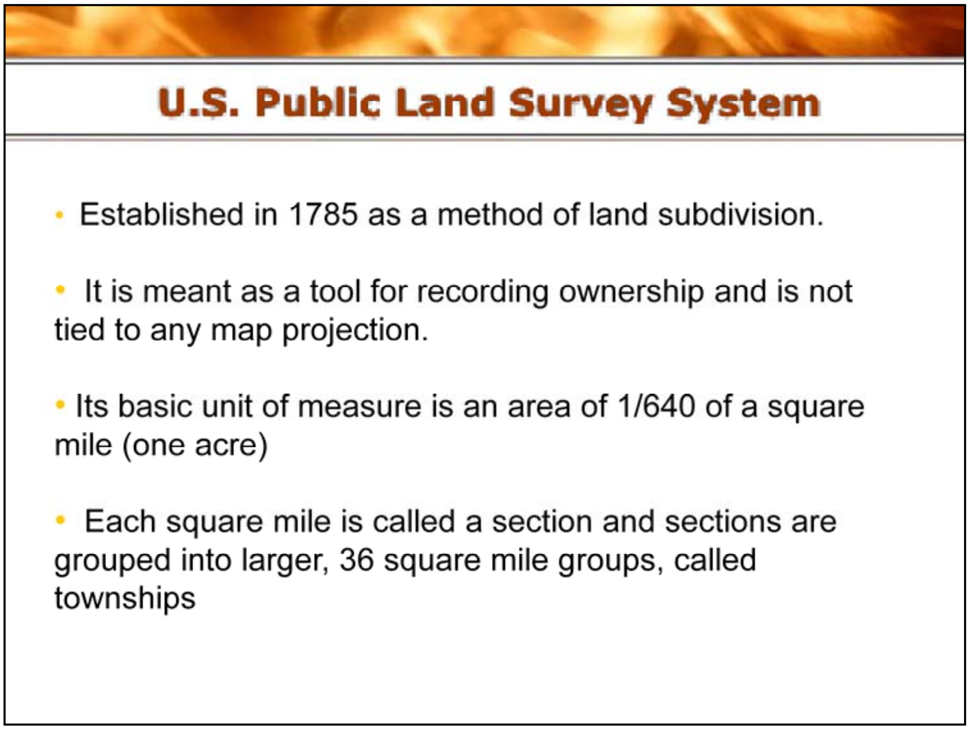
Large dots in the map indicate that the difference in coordinates between NAD27 and NAD83 is large. Small dots indicate that there is only a minor difference in coordinates (x and y direction) when NAD27 is compared to NAD83.



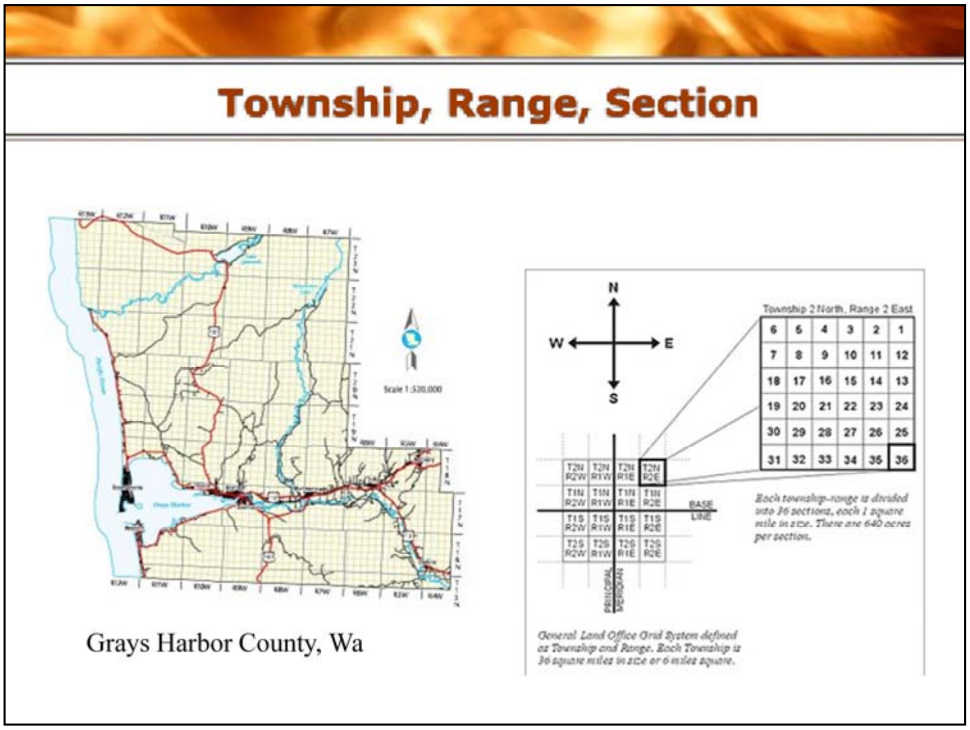
What projection and datum should you use? The easy answer to this question is that you should use the projection and datum that your maps or other GIS data is in. If you work for a federal or state agency or a private company it is probably best if you comply to the standards of your organization.

Do not use the UTM projection if your study area extends much beyond one UTM zone (6 degrees). In these cases an Albers or Lambert projection may work better.

The standard map projection for the Forest Service and Bureau of Land Management is UTM with a NAD27 datum.



The Public Land Survey System (PLSS) is not a map projection but a method applied for subdivision of lands.



Much of the land in the west is divided into Township-Range squares (36 square miles), containing 36 Sections (1 square mile each). Before the days of Global Positioning Systems (GPS) locations were often reported as Township, Range and Section, also known as ‘legal coordinates’.