GEOG 204

LECTURE 3

Coordinate Systems

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Coordinate systems

- Context/Backdrop
  - There is a need to know positions on the Earth's surface
  - The Earth is round
    - The nature of geographic information
      - Paper is an important medium
      - Rasters are inherently flat
  - Graticule of meridians and parallels on a spheroid

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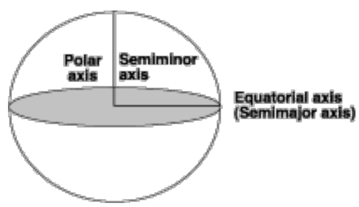
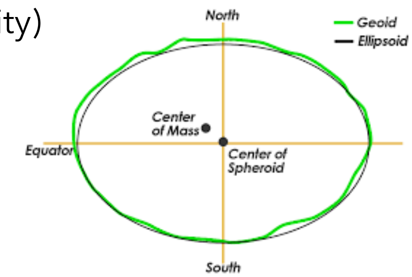
Surfaces to characterise the Earth's shape

- the Ellipsoid/Spheroid
- the Geoid (approximates earth's gravity)





- the Mean Sea Level
  - Over oceans MSL = geoid; differ on landmass
- the Terrain

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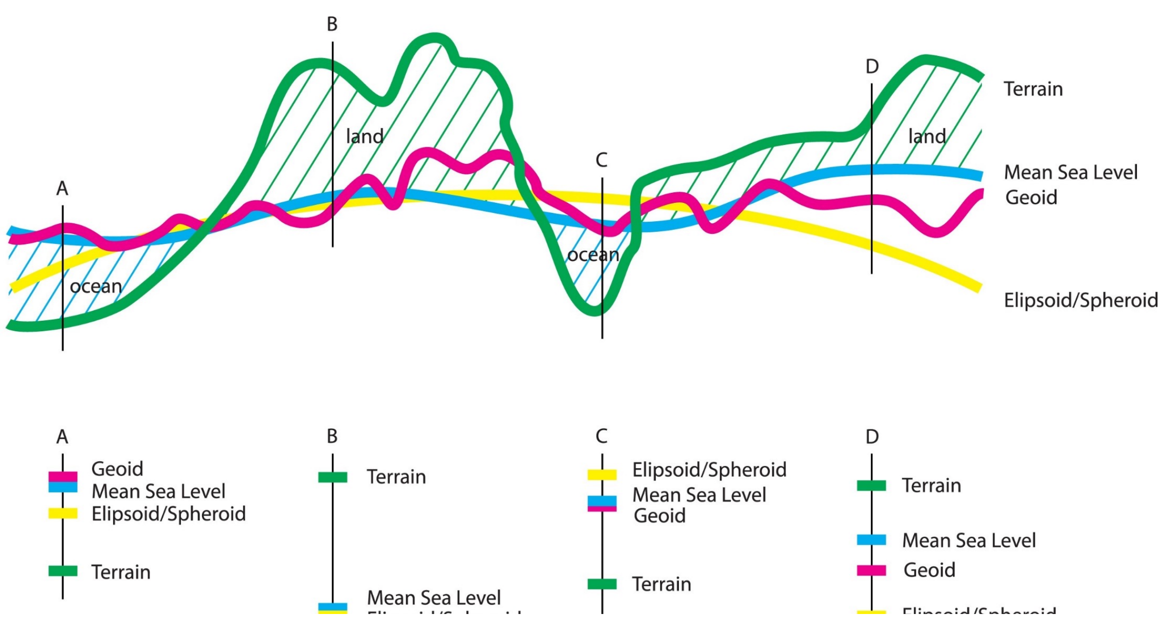

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Coordinate Systems

- A coordinate system: a reference system used to represent the locations of geographic features
  - Allows geographic datasets to use common locations for integration
- Types of coordinate systems
  - Geographic coordinate systems
  - Projected coordinate systems

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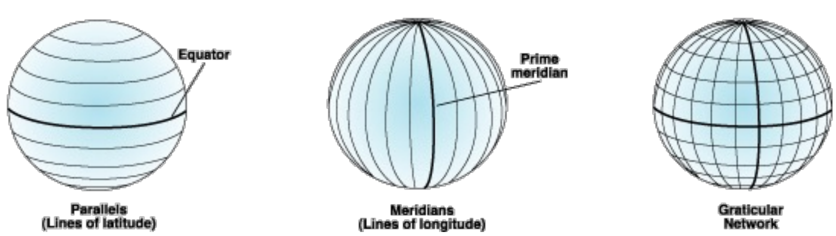
Coordinate Systems

- Assuming the Earth is spherical
  - Graticule of meridians and parallels on a spheroid



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Types of Coordinate Systems

- Geographic coordinate systems
  - Global or spherical coordinate systems such as latitude-longitude.
    - Prime meridian
    - Latitude, Longitude
    - Parallels, meridians
    - Units of measure
- Projected coordinate systems
  - Examples

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Geographic Coordinate Systems

- Global or spherical coordinate systems such as latitude-longitude.
  - Coordinates based upon "spherical" coordinates modified to account for the imperfect shape of the earth
  - The most commonly used coordinate system today is the **latitude**, **longitude**, and height system.
  - The **Prime Meridian** and the **Equator** are the reference planes used to define latitude and longitude.

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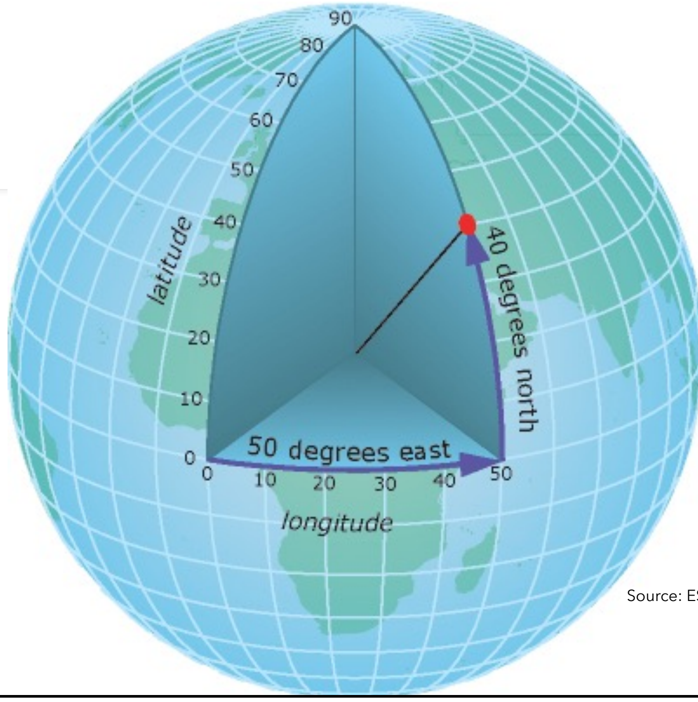

Source: ESRI

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Geographic Coordinate Systems

- Degree-Minute-Second
  - 1 deg = 60 min
  - 1 min = 60 sec
- Decimal Degrees
  - 62°52′30″= 62.875 °
- Range
  - Longitude: -180 to 180 (180W to 180E)
  - Latitude: -90 to 90 (90S to 90N)

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Geographic Coordinate Systems

- "Null Island"
  - GIS fails to associate coordinates to a position and instead assigns [0,0] or [Null, Null]
- A long a meridian
  - 1° =~ 111 km, 1" ~ 2 km, 1' =~ 30metres
  - It is more complicated along the parallels because they get smaller towards the pole

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Geographic Coordinate Systems

- A GCS includes
  - an angular unit of measure,
  - a prime meridian,
  - a datum
- The spheroid defines the size and shape of the earth model, while the datum connects the spheroid to the earth's surface.

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Projected coordinate systems

- Basic Concepts
  - "Project" features on the Earth's curved surface onto a flat surface (e.g. sheet of paper)
  - Therefore "map projection" is about preserving the properties of real-world features when they are depicted on a 2D map.
    - The properties are:
      - Area
      - Shape
      - Distance
      - Direction

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Map Projections Classes

- There are different ways to classify map projections
  - One is based on developable surface on which a network of meridians and parallels is projected
    - Cylindrical
    - Conical
    - Planar/Azimuthal

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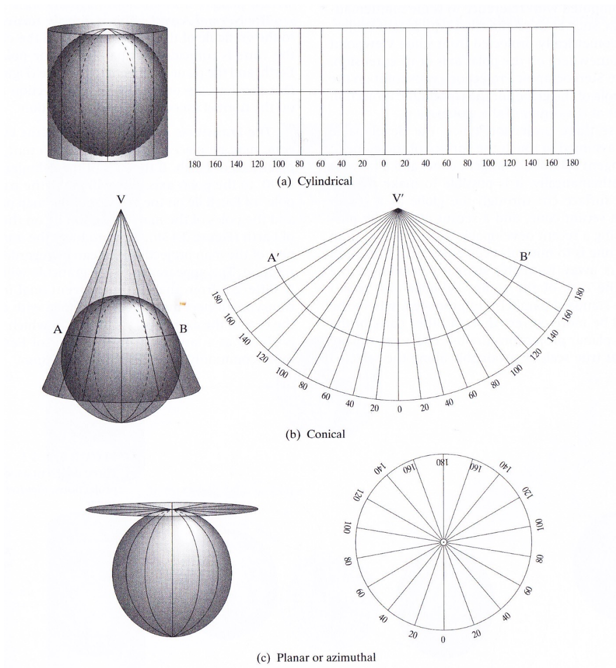

Three basic types of map projections

Source: C.P. Lo and A.K.W Yeung

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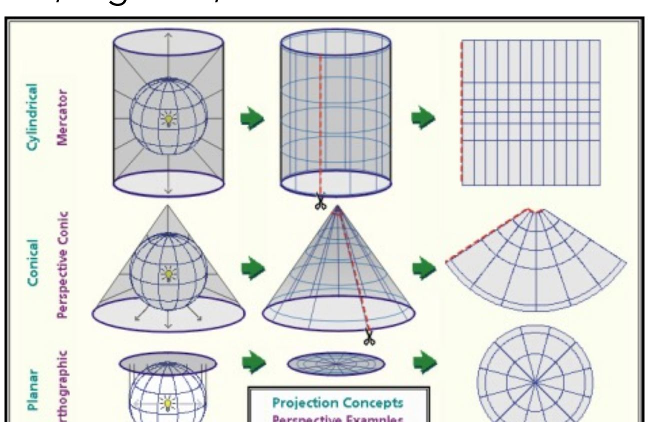
Major Projection Surfaces

- Cylindrical, Conical, Planar
- World, regional, local



http://www.gisdatatutorials.net/basics-of-coordinate-systems.html

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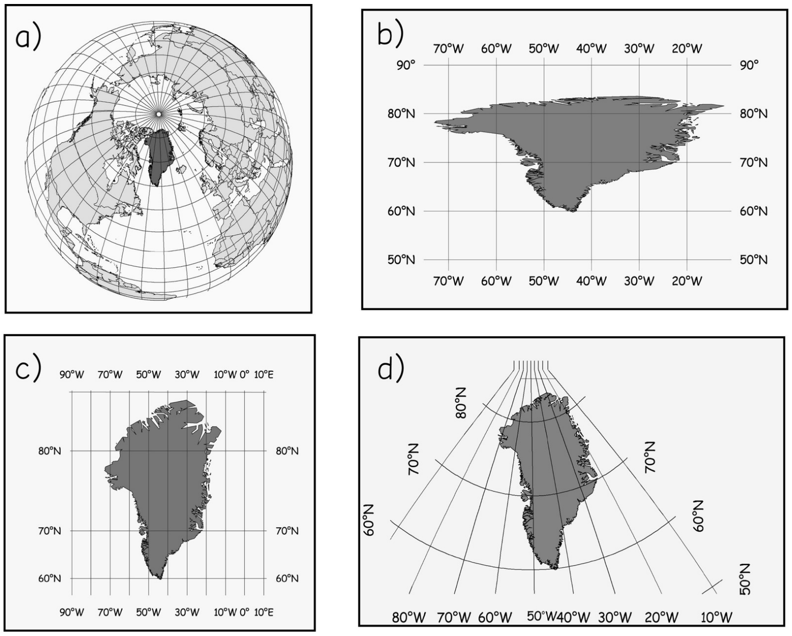

Bolstad, P. (2019). *GIS fundamentals : a first text on geographic information systems* (6th edition). XanEdu.

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Major Projection Classes

- The other is based on the projection properties
  - Conformal
    - Local shapes/angles are correct, areas allowed to vary
  - Equal-area
    - Areas are correct, shapes allowed to vary
  - Equidistant
    - Distance to certain point correct
    - Areas and shapes allowed to vary
  - Azimuthal
    - Directions are accurate

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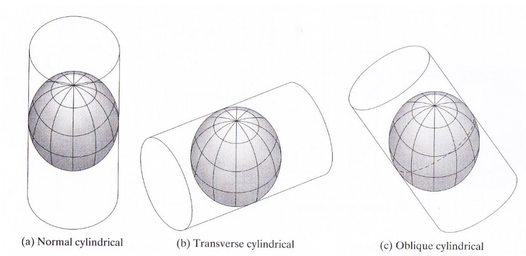
Aspects of Map Projections

- The Normal Aspect
  - Axis of cylinder or cone is coincident to the polar axis
- The Transverse Aspect
- The Oblique Aspect



Different aspects of map projections

Source: C.P. Lo and A.K.W Yeung

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Map Projections

- Coordinate Systems and Map Projections are distinct concepts
  - Coordinate Systems are constructed based on map projections
- The spherical system for geographic coordinates is non-Cartesian
  - formulae for area, distance, angles, and other geometric properties used in a Cartesian coordinate system should not be used with geographic coordinates.
  - Areas are usually calculated after converting to a projected system

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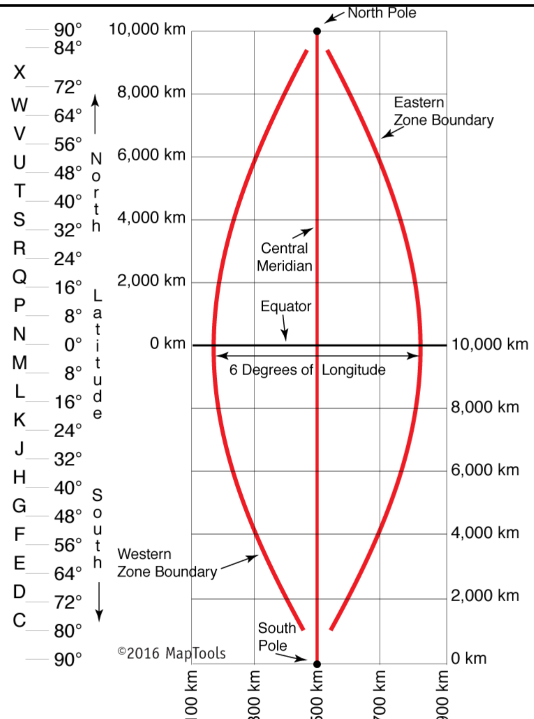

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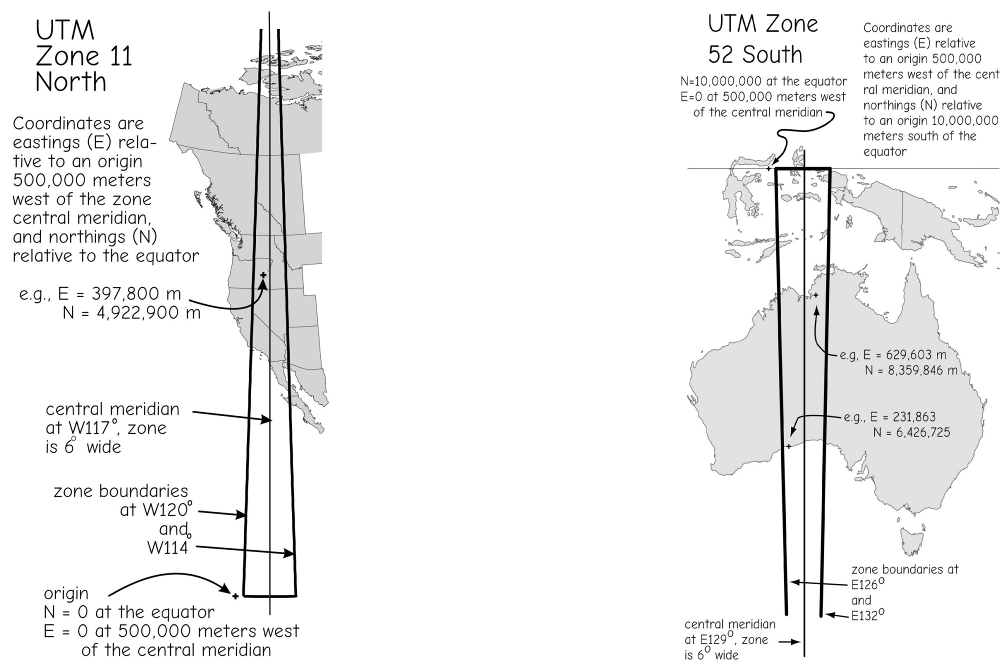

Bolstad, P. (2019). *GIS fundamentals : a first text on geographic information systems* (6th edition). XanEdu.

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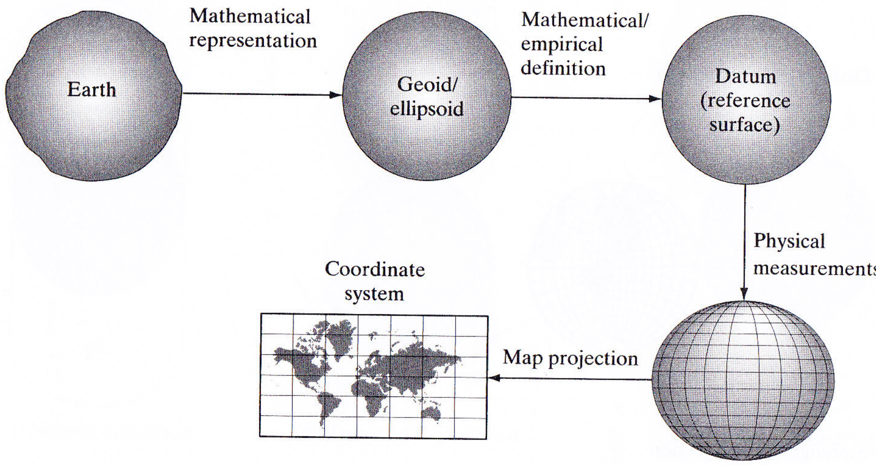
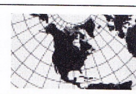
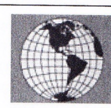
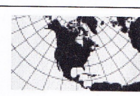
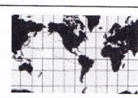


Georeferencing

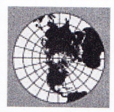
Source: C.P. Lo and A.K.W Yeung

Common Map Projections, Their Properties and Major Uses

Projection/Construction	*Appearance*	*Properties*	*Major Uses*
Albers equal-area/conical	 (a)	Equal area; conformal along standard parallels	Small regional and national maps
Azimuth equidistant/planar	 (b)	Equidistant; true directions from map center	Air and sea navigation charts; equatorial and polar area large-scale maps
Equidistant conic/conical	 (c)	Equidistant along standard parallel and central meridian	Region mapping of midlatitude areas with east–west extent; atlas maps for small countries
Lambert conformal conic/conical	 (d)	Conformal; true local directions	Navigation charts; U.S. State Plan Coordinate System (SPCS) for all east–west State Plane Zones; continental U.S. maps; Canadian maps
Mercator/cylindrical	 (e)	Conformal; true direction	Navigation charts; conformal world maps

Source: C.P. Lo and A.K.W Yeung

Common Map Projections, Their Properties and Major Uses

Projection/Construction	Appearance	Properties	Major Uses
Polyconic/conical	 (f)	Equidistant along each standard parallel and central meridian	Topographic maps; USGS 7.5- and 15-min quadrangles
Robinson/ pseudocylindrical	 (g)	Compromise between properties	Thematic world maps
Sinusoidal/ pseudocylindrical	 (h)	Equal area; local directions correct along central meridian and equator	World maps and continental maps
Stereographic/planar	 (i)	Conformal; true directions from map center	Navigation charts; polar region maps
Transverse Mercator/cylindrical	 (j)	Conformal; true local directions	Topographic mapping for areas with north–south extent; U.S. State Plan Coordinate System (SPCS) for all north–south State Plane Zones

Source: C.P. Lo and A.K.W Yeung

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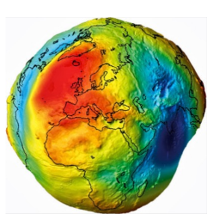
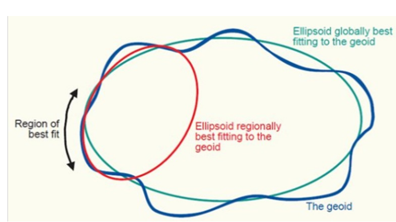
Datums

- A **datum**
  - Reference system which allows the location of latitudes and longitudes (and heights) to be identified onto the surface of the Earth
    - i.e. determine the position of the spheroid relative to the center of the earth.
      - GCS based on a spheroid
      - The Earth is not perfectly spherical





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Datum

- To project Earth to a flat plane we must choose an ellipsoid or spheroid to represent the Earth's surface.
- Choosing an ellipsoid implies selecting a horizontal datum for the projected map.
- Hundreds of datums have been created
- Reference ellipsoids are usually defined by semi-major (equatorial radius) and flattening (the relationship between equatorial and polar radii).

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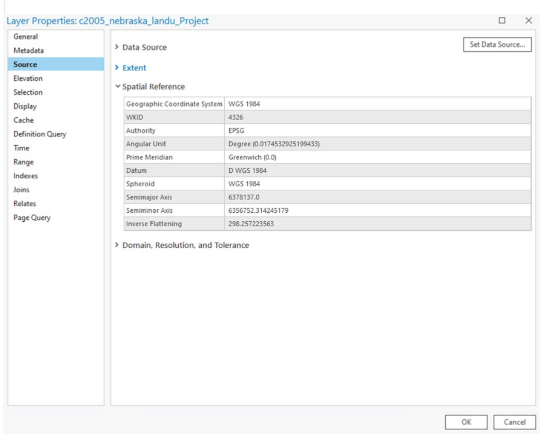
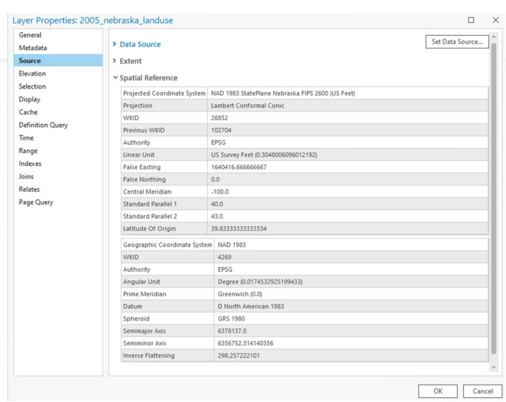
Datum





A Projected Coordinate System,
North American Datum, State Plane Projection

A Geographic Coordinate System
WGS1984

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Selected Reference Ellipsoids

Clarke 1866 Datum (NAD27)

World Geodetic System 1984 (North American Datum 1983 (NAD83))

Ellipse	Semi-Major Axis (meters)	1/Flattening
Airy 1830	6377563.396	299.3249646
Bessel 1841	6377397.155	299.1528128
Clarke 1866	6378206.4	294.9786982
Clarke 1880	6378249.145	293.465
Everest 1830	6377276.345	300.8017
Fischer 1960 (Mercury)	6378166.0	298.3
Fischer 1968	6378150.0	298.3
G R S 1967	6378160.0	298.247167427
G R S 1975	6378140.0	298.257
G R S 1980	6378137.0	298.257222101
Hough 1956	6378270.0	297.0
International	6378388.0	297.0
Krassovsky 1940	6378245.0	298.3
South American 1969	6378160.0	298.25
WGS 60	6378165.0	298.3
WGS 66	6378145.0	298.25
WGS 72	6378135.0	298.26
WGS 84	6378137.0	298.257223563

Peter H. Dana 9/1/94

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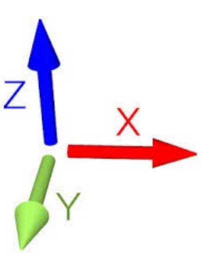
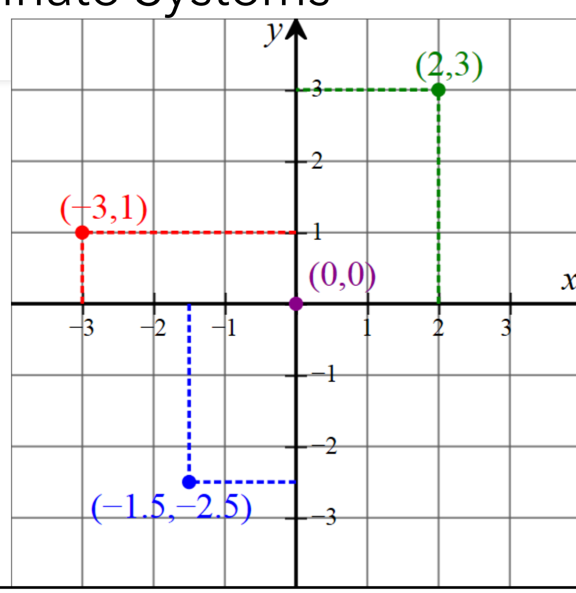
Projected Coordinate Systems

- Ordered Pairs
- Units
- X: East/West
- Y: North/South
- Z: Elevation





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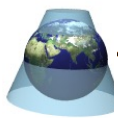
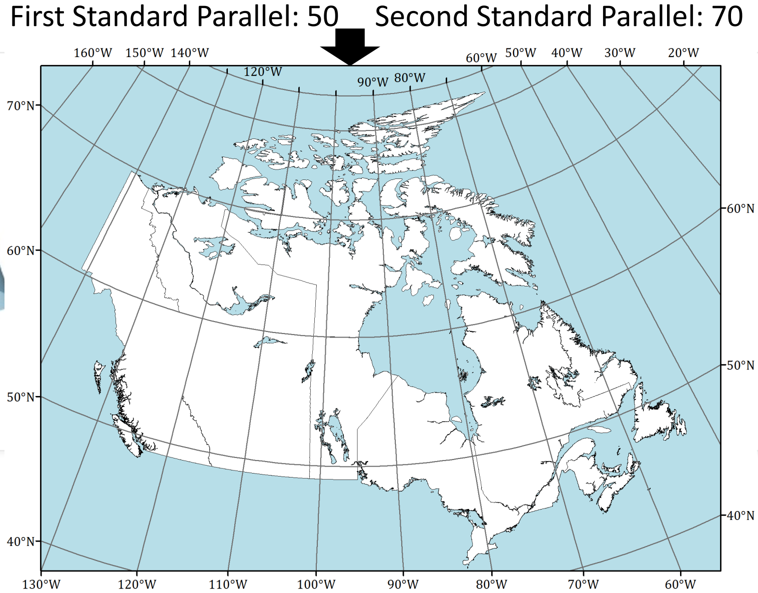
Canada Albers Equal Area Conic:

Central Meridian: -96 Latitude Of Origin: 40

First Standard Parallel: 50 Second Standard Parallel: 70





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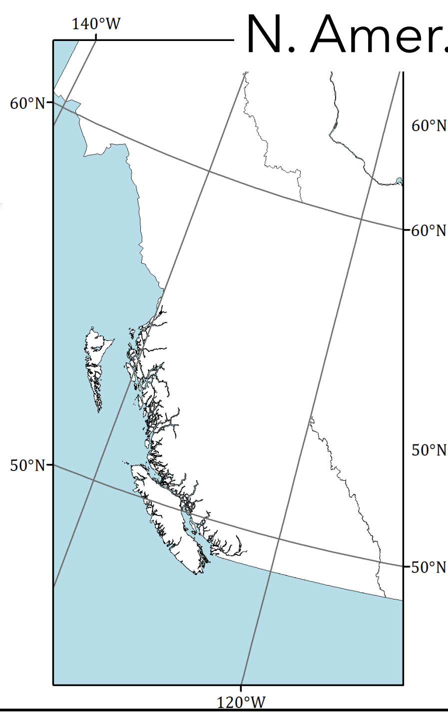
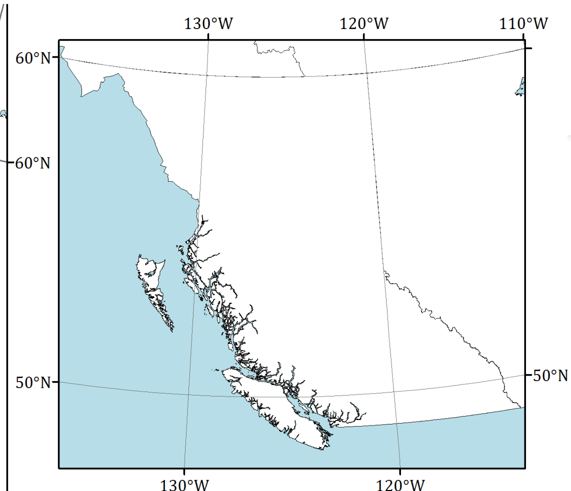
N. Amer. vs BC Albers





Central meridian: 126° W

First Standard Parallel: 50°N

2nd Standard Parallel: 58:30

Latitude of origin: 45N

False northing: 0

False easting: 1,000,000

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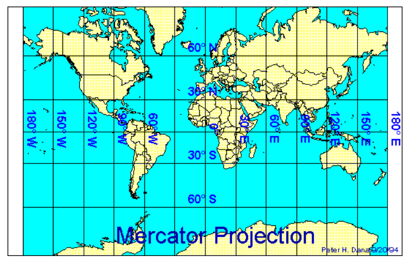
Transverse Mercator Projection

- Straight meridians and parallels intersect at right angles. Scale is true at the equator or at two standard parallels equidistant from the equator.
- Requires:
  - Standard Parallels
  - Central Meridian
  - Latitude of Origin
  - False Easting and Northing



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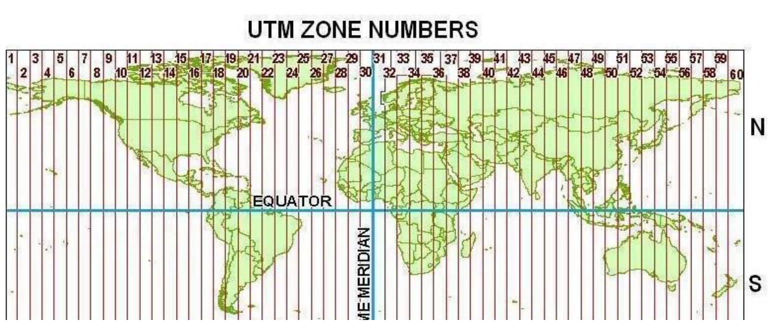
Universal Transverse Mercator

- 60 slices, 60 meridians (we are in 10N, **126°W**)
- Units: Meters
- Standard for field navigation (no world maps)
- <u>Conformal</u>
- Key purpose: horizontal position (no Z value)



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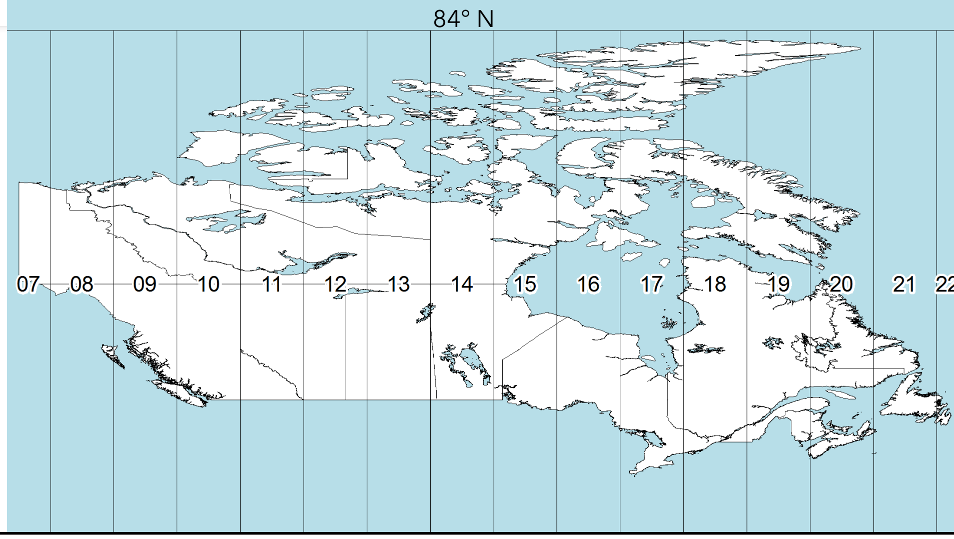
UTM Zones in Geographic Projection



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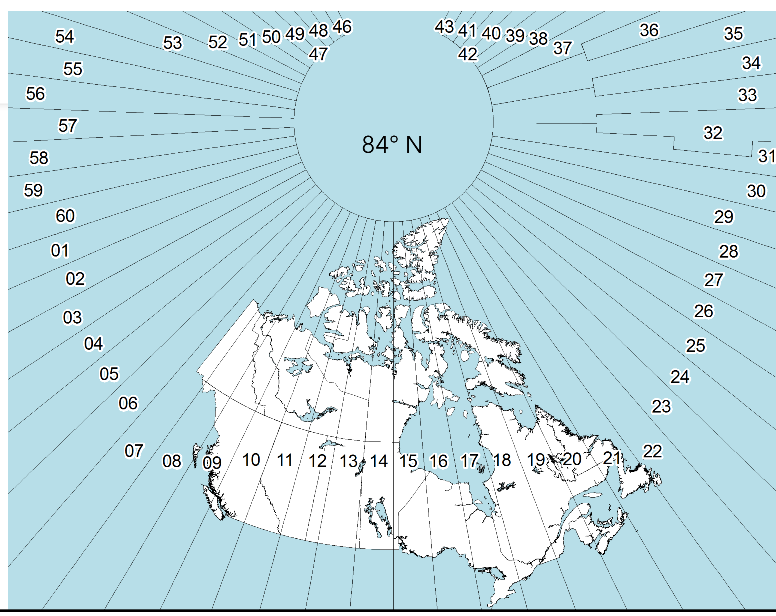
UTM Zones in Canada Albers



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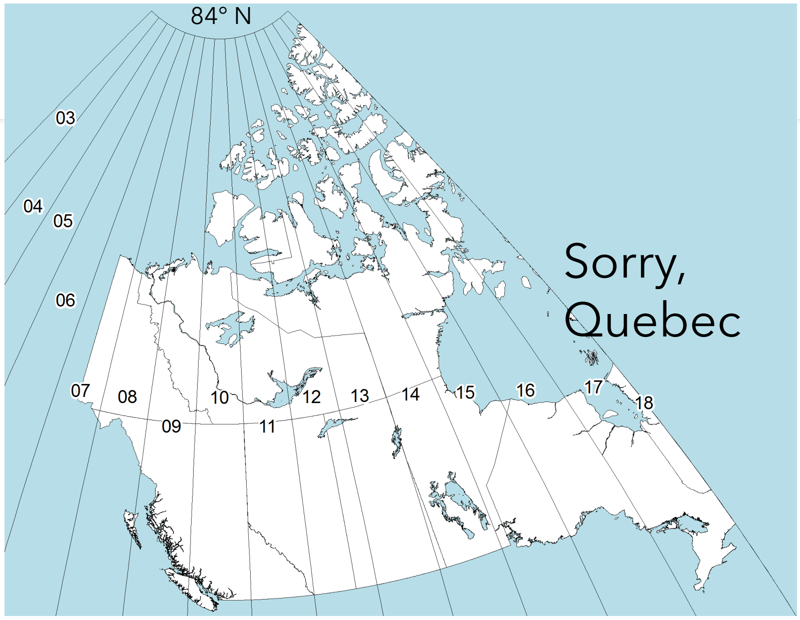
Canada According to UTM 10N



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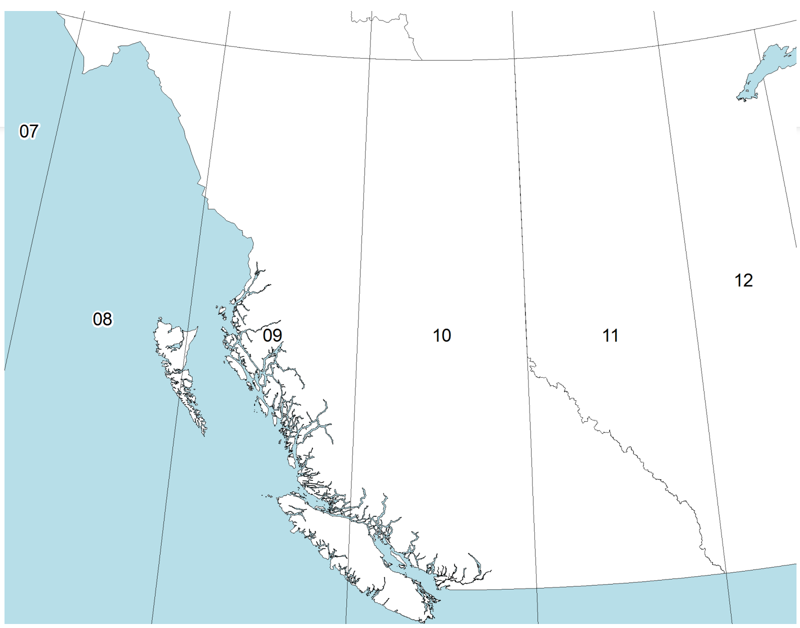
BC According to UTM 10N



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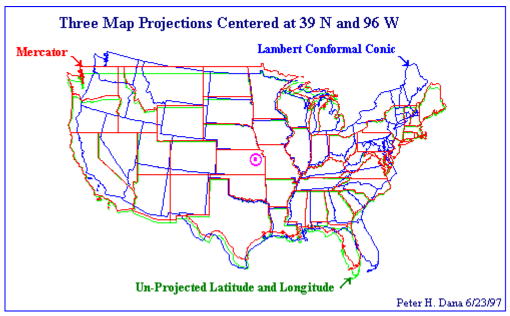
Projection on the Fly

- First layer defines coordinate system
  - May be changed manually (lab)
- All subsequent layers "projected on the fly"
- Same in ArcGIS, QGIS, Manifold, etc.
- Imagine displaying in 3 projections…



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Summary

- Never display in unprojected coordinates
- Local projections often the best
  - Most issues/debates surround world maps
- Know the major projection shapes/classes
- UTM for horizontal position

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