Geography 360
Principles of Cartography

May 10, 2006

Outlines

1. Framework for position
   - Spatial reference systems: Relative vs. Absolute
   - Coordinate systems: Geographic vs. Cartesian

2. Grid coordinate system
   - Universal Transverse Mercator
   - State Plane Coordinate System

3. Spatial object types
   - SDTS definition of spatial objects

1. Framework for Position

- Spatial reference systems
  - Broadly defined term referring to any framework for position
  - Two types of spatial reference systems: relative vs. absolute
- Coordinate systems
  - One of absolute types of spatial reference systems
  - Two types of coordinate systems: geographic vs. Cartesian coordinates

- Think about different ways of referring to position
  - Place name
  - Street address
  - Turn left, turn right
  - South of Seattle
  - The grid of campus map
  - Latitude and longitude
  - etc.
- How are these different frameworks for position organized?

Spatial reference systems

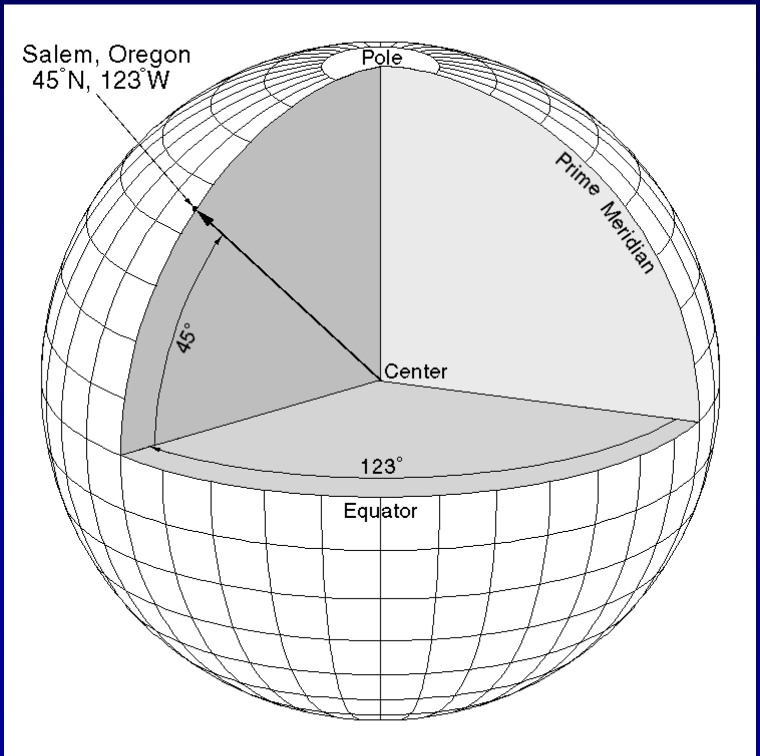
- Relative position referencing
  - Arbitrary grids and relative directions
  - Campus map grid cell reference: row numbers and column letters (works for single sheet)
  - Relative directions: here, there, near, far, to left, to right, relative words
- Absolute position referencing
  - Coordinate systems and cardinal directions
  - Spatial reference system as coordinate system
  - Cardinal directions: North, south, east, NW, SSW, etc

Coordinate systems

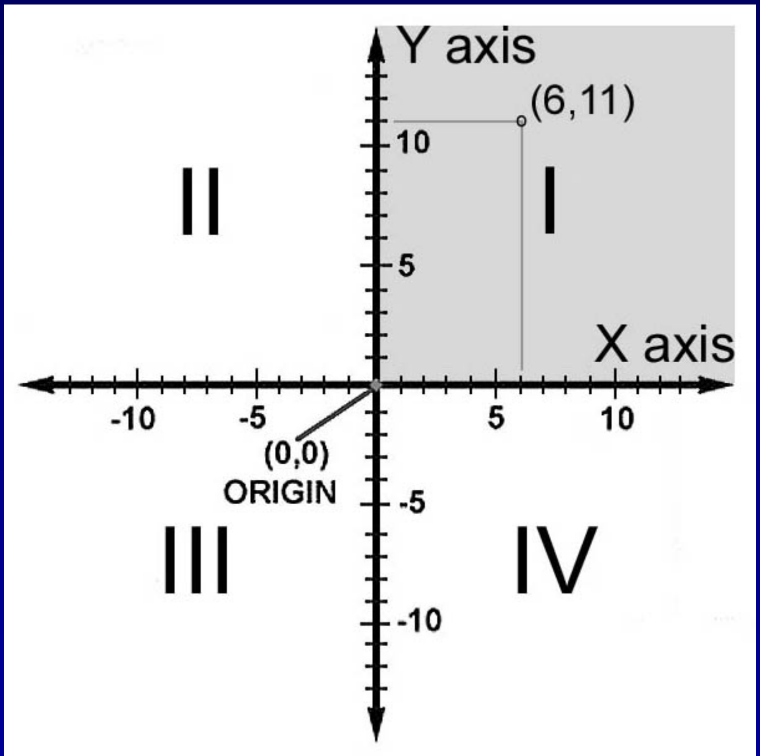
- Geographic coordinates (unprojected)
  - Position is described by longitude and latitude
  - The mathematics of geographic coordinates is trigonometry: Angle and distance measurements using functions like sine, cosine

- Cartesian coordinates (projected, planar)
  - Position is described by X and Y
  - The mathematics of Cartesian coordinates is Euclidean geometry: basic algebra

Geographic coordinate system



Cartesian coordinate system



Source: Kimerling et al "Map Use"

- What is the relationship between coordinate system and map projection?
- Map projection is a mathematical equation that transforms angular location into (x, y) location
- In geographic (unprojected) coordinate system, location is described by angular offset from the center of the earth
- In Cartesian (projected) coordinate system, location is described by distance offset from the origin (0, 0)
- Let's look at <u>predefined planar coordinate systems</u> that are commonly used – State Plane and UTM.

2. Grid Coordinate Systems

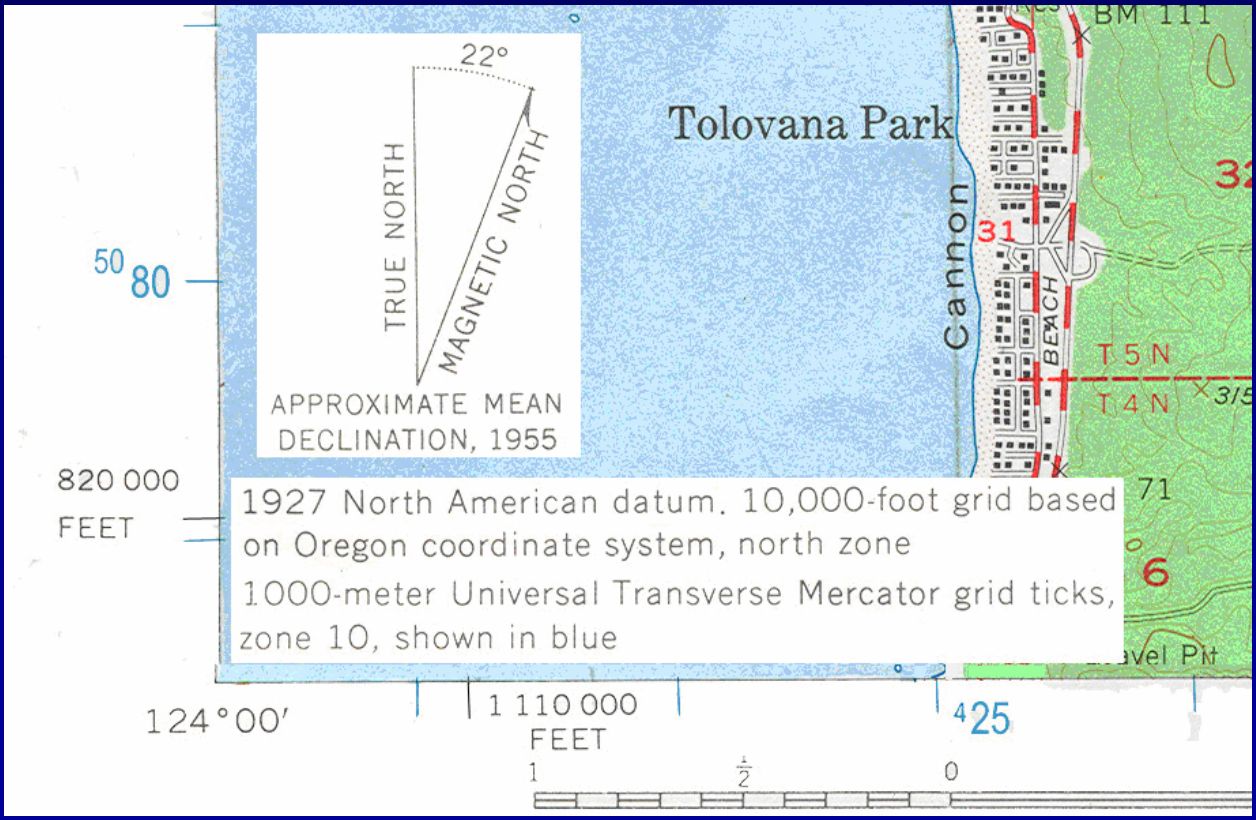
- Universal Transverse Mercator (UTM)
  - Developed as a global coordinate system

- State Plane Coordinate (SPC)
  - Developed in order to provide local reference systems that were tied to a national datum in the U.S.

Reading: section 2.3.2 and 2.3.4 at
http://courses.washington.edu/geog360/private/GridCoordSys.pdf

Universal Transverse Mercator (UTM)

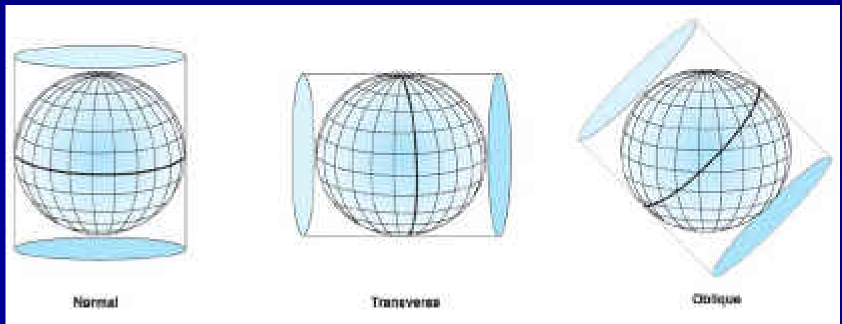
- UTM is widely used for large-scale mapping all around the world. A USGS topographic map is not an exception



UTM: how it works

- Divide the world into 6 degree longitudinal strip, and use the strip as a developable surface
- Each strip employs Transverse Mercator

Aspects of Cylindrical projection family

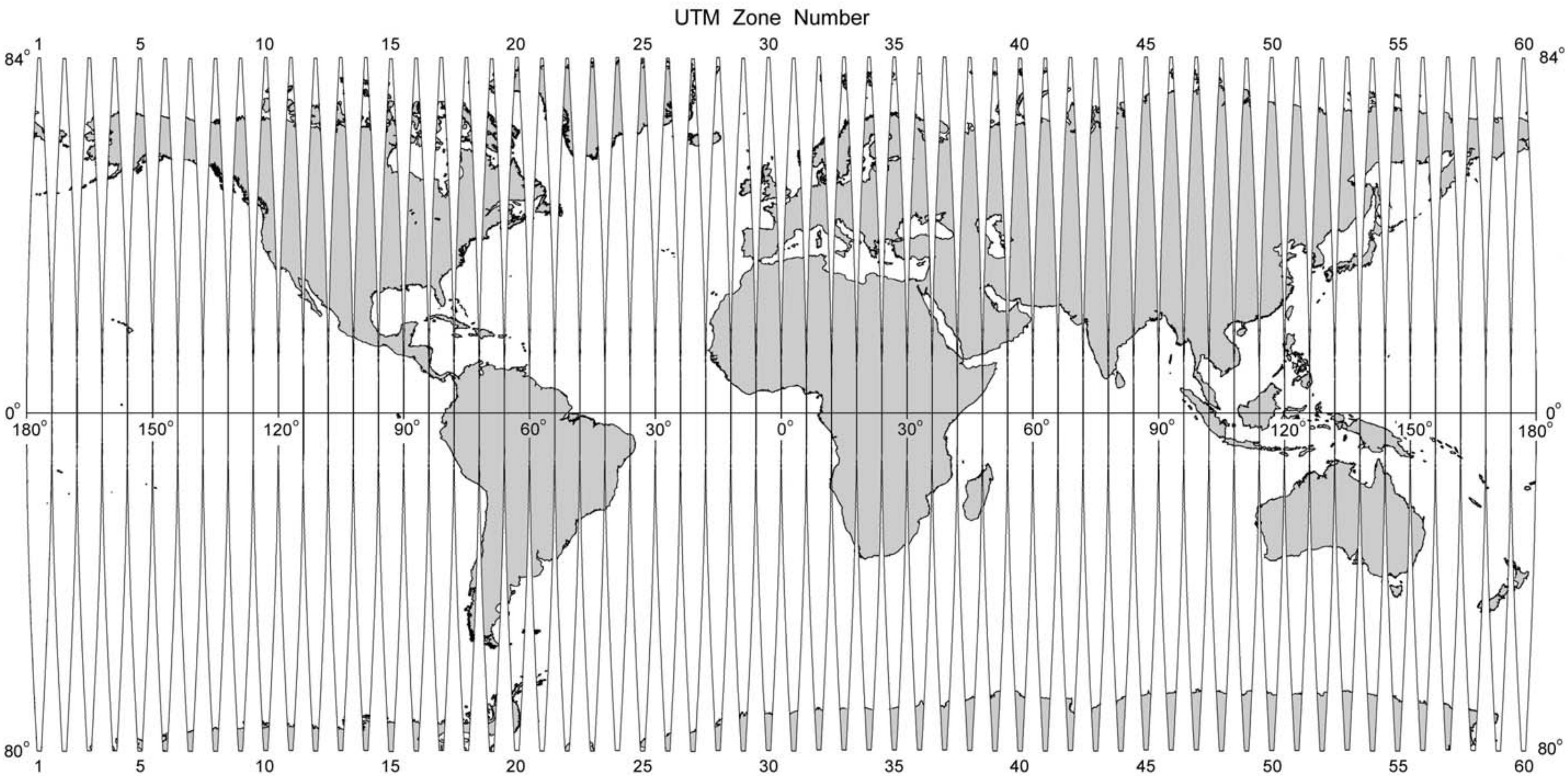


Normal Transverse Oblique

Source: ESRI, “Understanding Map Projections”

UTM: zone numbering

- Zones are numbered for every 6 degree longitude strip from 180 ° W to 180 ° E (international date lines)



UTM: zones in U.S.

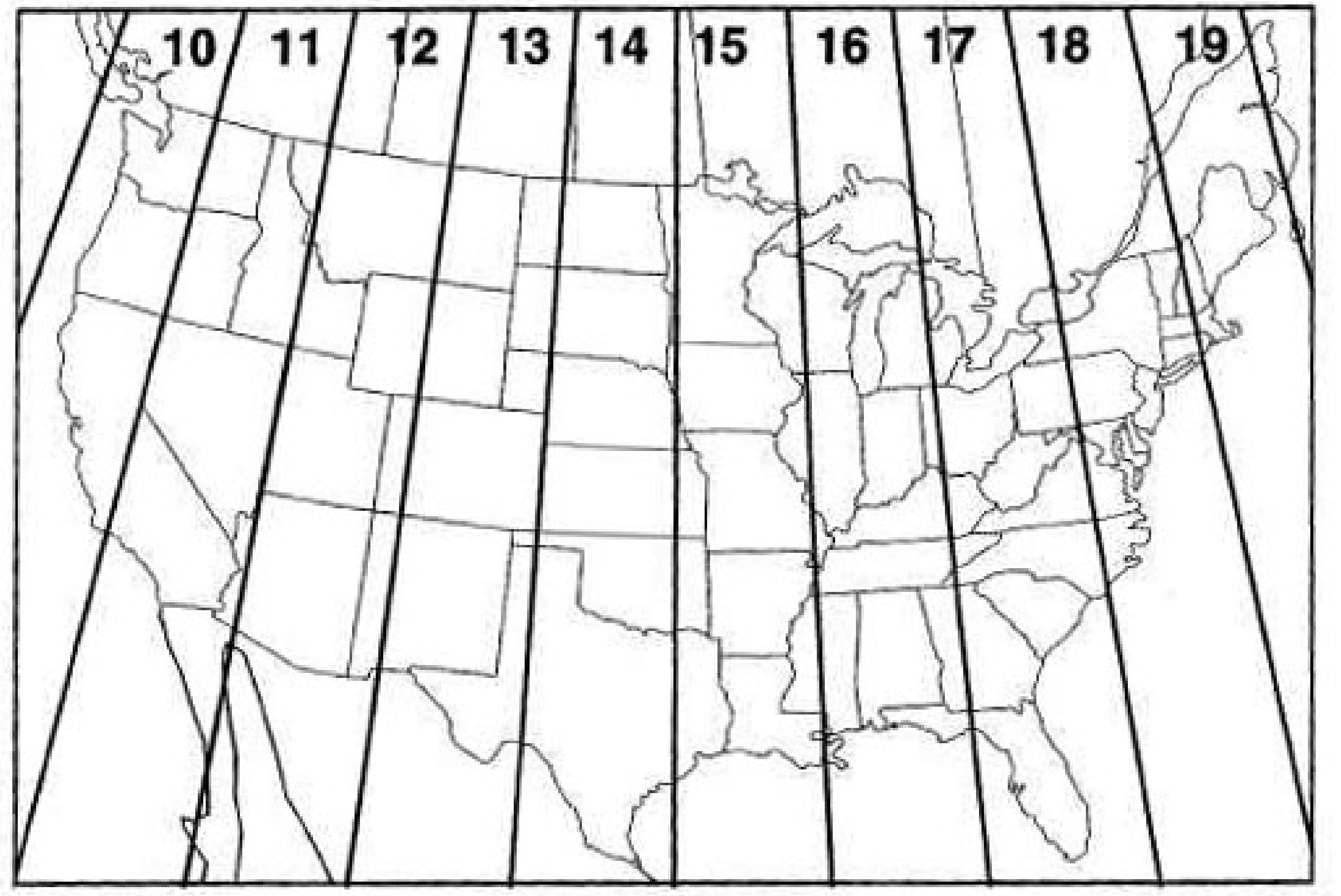


Figure 2.11 Universal transverse Mercator zones in the 48 contiguous states.

Source: Clarke 1999 “Getting Started with GIS”

How to read UTM coordinates

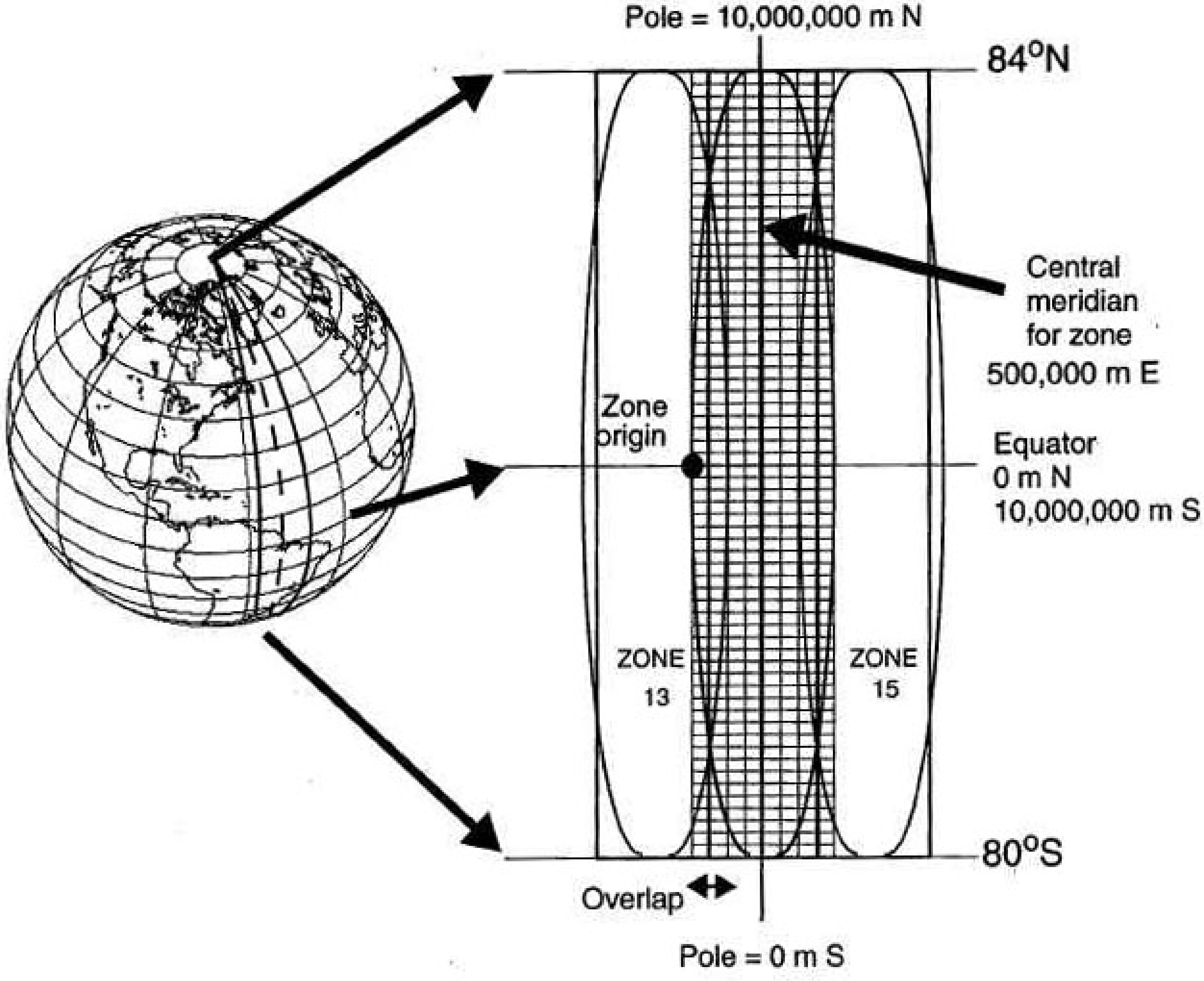
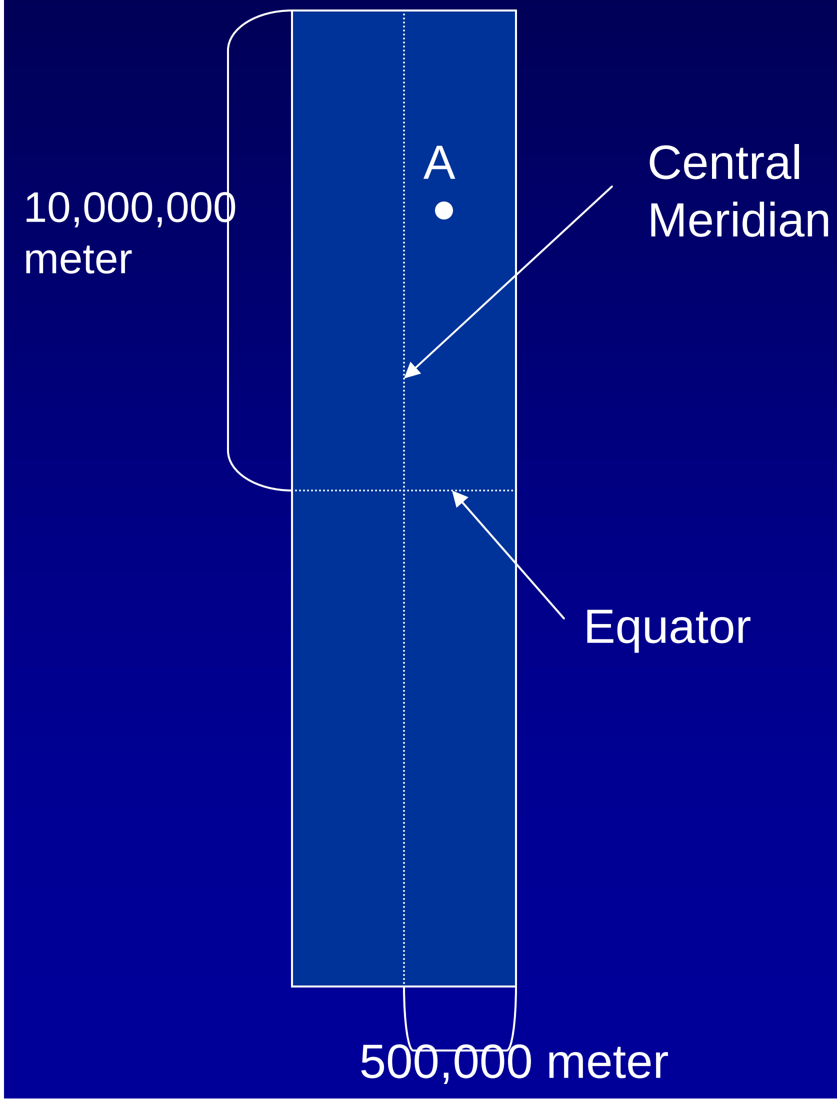


Figure 2.12 The universal transverse Mercator coordinate system.

How to read UTM coordinates



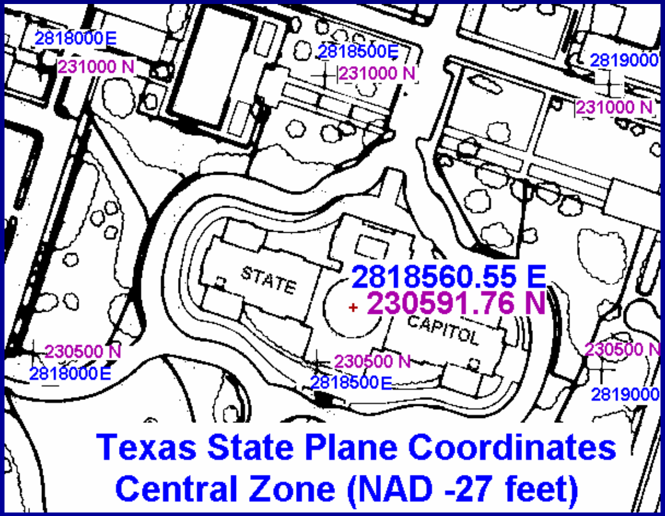
- The grid refers to one zone
- Where will be the true origin (0,0)?
- False northing to ensure positive y value in southern hemisphere
- False easting to ensure positive x value in the area west of central meridian
- Where will be the zone origin after false easting/northing?
- Given the zone origin, x coordinate of A will be larger than 500,000, and y coordinate of A will be larger than 5,000,000

UTM

- ArcGIS demo
  - Check projection parameters for zone number 10 (Seattle area)
  - WGS_1984_UTM_Zone_10N
  - Projection: Transverse_Mercator
  - False_Easting: 500000.000000
  - False_Northing: 0.000000
  - Central_Meridian: -123.000000
  - Scale_Factor: 0.999600
  - Latitude_Of_Origin: 0.000000

State Plane Coordinates (SPC)

- SPC has been used to write legal descriptions of properties and in engineering projects in many states (e.g. land record, utilities)
- When you obtain spatial data of Seattle area for your final project, it is quite likely that your data is stored in SPC (e.g. orthophoto from City of Seattle)



SPC: how it works

- Divide the country into zones, where zone boundaries follow state and county boundaries

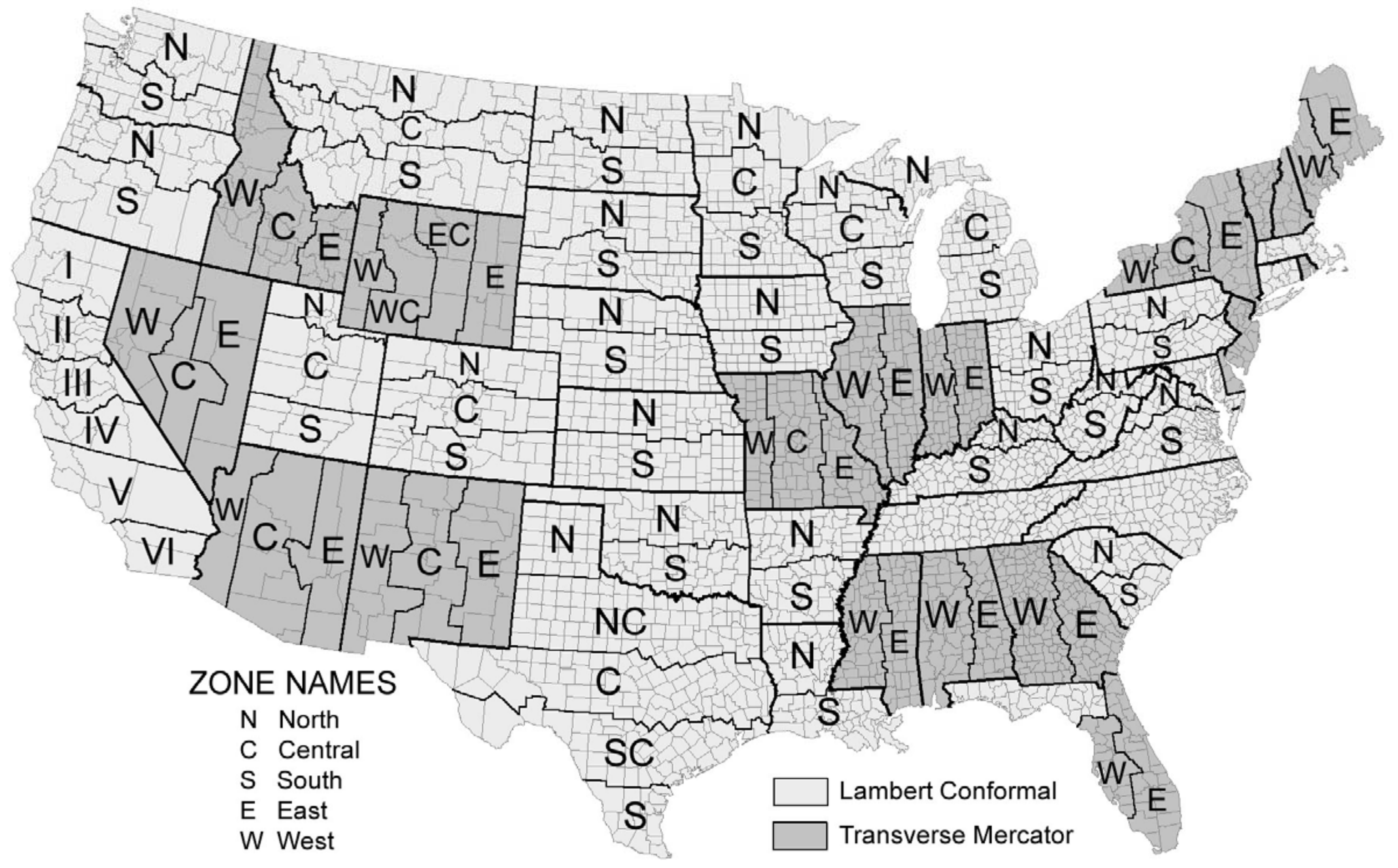
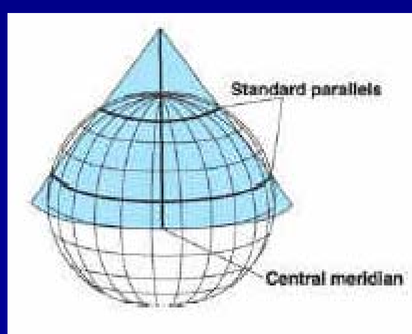
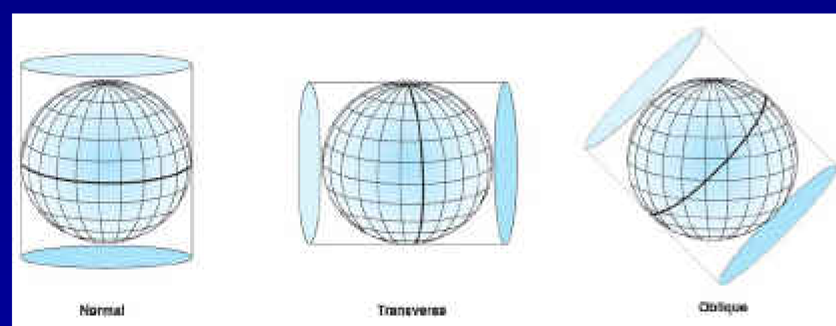


Image source: Kimerling 2005

SPC: how it works

- Each zone has its own projection surface
  - Lambert conformal conic for areas with greater east-west extent
  - Transverse Mercator for areas with greater north-south extent
  - Oblique Mercator for areas with greater oblique extent





Normal Transverse Oblique

SPC: two national datum

- SPC 27 is based on NAD27
  - Reference ellipsoid: Clarke 1866
  - Measurement unit: feet
- SPC83 is based on NAD83
  - Reference ellipsoid: GRS 80
  - Measurement unit: meter

SPC

- ArcGIS demo
  - Check parameters of projections when different SPC zones are chosen
    - Washington North Zone
    - Georgia West Zone
    - Alaska Zone 1

3. Spatial Objects

- Defined as the building block of "digital representation of spatial phenomena"
- Typology
  - Dimension: zero, one, two, and three-dimensional object
  - Intended use: geometry vs. topology (display only or operation?)
  - Aggregation: simple vs. composite object

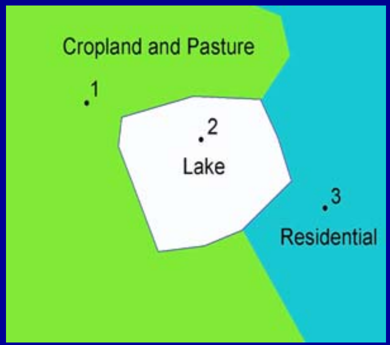
Reading: Section 2 from Electronic reserve SDTS

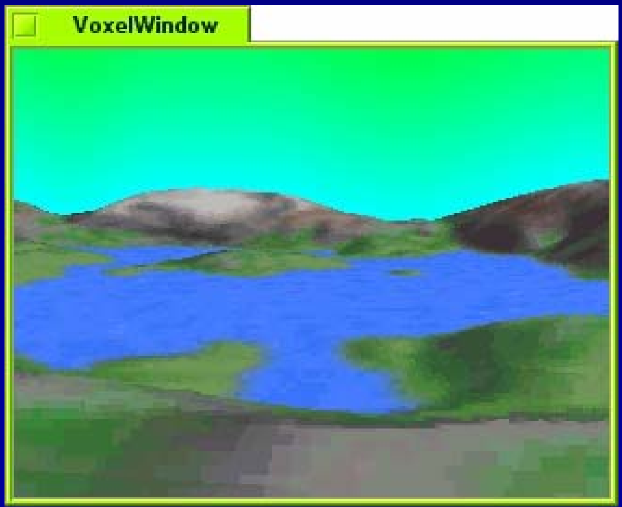
Motivations

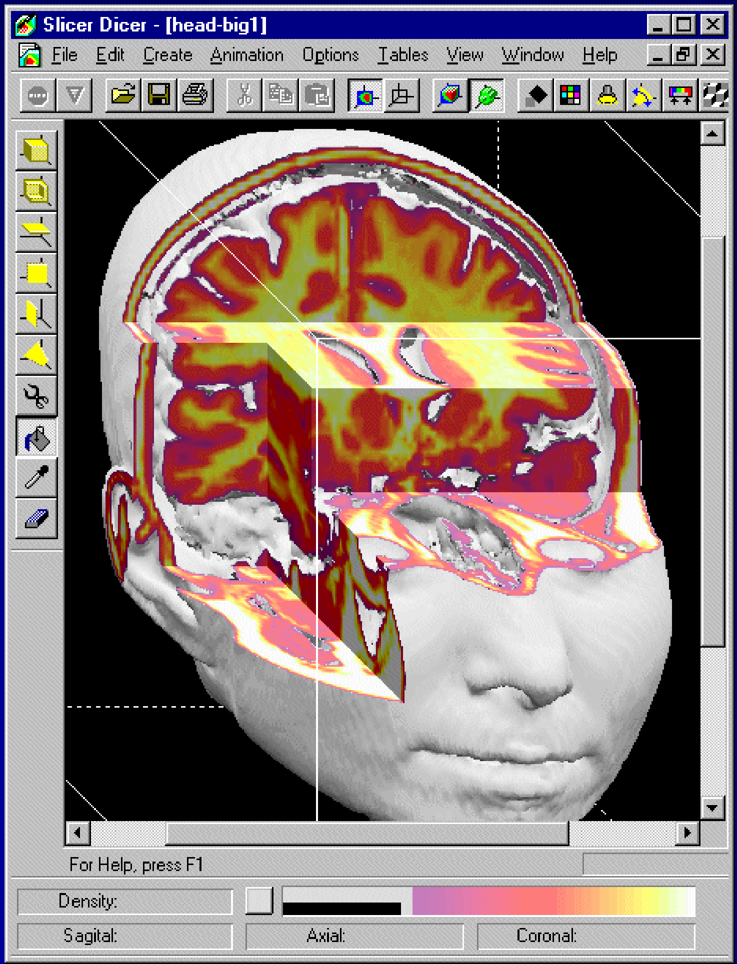
- The same phenomenon is represented differently in the computer. For example,
  - Pixel constitutes aerial photo showing Green Lake
  - Point for labeling the location of Green Lake
  - Line for displaying the trail surrounding Green Lake
  - Polygon for displaying the extent of Green Lake
  - Network for navigating directions to Green Lake
- Spatial object has wide applicability. For example,
  - Representing the terrain of Mars, and human brain, as well as geographic phenomenon (such as traffic volume, traffic accident, road condition, gas emission) – anything that is spatial and anything that can use spatial metaphor (e.g. social network)

Dimensions

- Zero-dimensional spatial objects have
  - Location
- One-dimensional spatial objects have
  - + Length, direction
- Two-dimensional spatial objects have
  - + Extent
- Three-dimensional spatial objects have
  - + Altitude or any other z-value







Intended uses of spatial object

- Most of spatial objects have geometry
  - Spatial position based on coordinates; create shape of spatial data object
  - Used for display only (e.g. visualization)
  - Heavily draw upon Euclidean geometry
- Some spatial objects have topology
  - Spatial relationships between data objects based on connectedness, adjacency, and containment
  - Used for analytical operations (e.g. routing)
  - Heavily draw upon graph theory

From the 2.3 in SDTS, which spatial object has topology?

Aggregation

- Simple spatial object
  - Point, line, polygon
  - Pixel
- Composite objects are constructed from the simple objects by aggregation
  - Layer: an areally distributed set of spatial data representing entity instances within one theme
  - Graph: a set of topologically interrelated objects that conform to a set of defined constraint rules