# Coordinate Systems

# Review

- What is a Map Projection?
- Datums
- Geographic Coordinate System

# What is a Map Projection?

- Transformation of 3D surface to 2D flat sheet
- Causes distortion in the shape, area, distance or direction of data
- Uses mathematical formulas to relate spherical coordinates to planar coordinates
- Different projections cause different distortions
- Map projections designed for specific purpose – i.e. large-scale data in limited area

# Datums

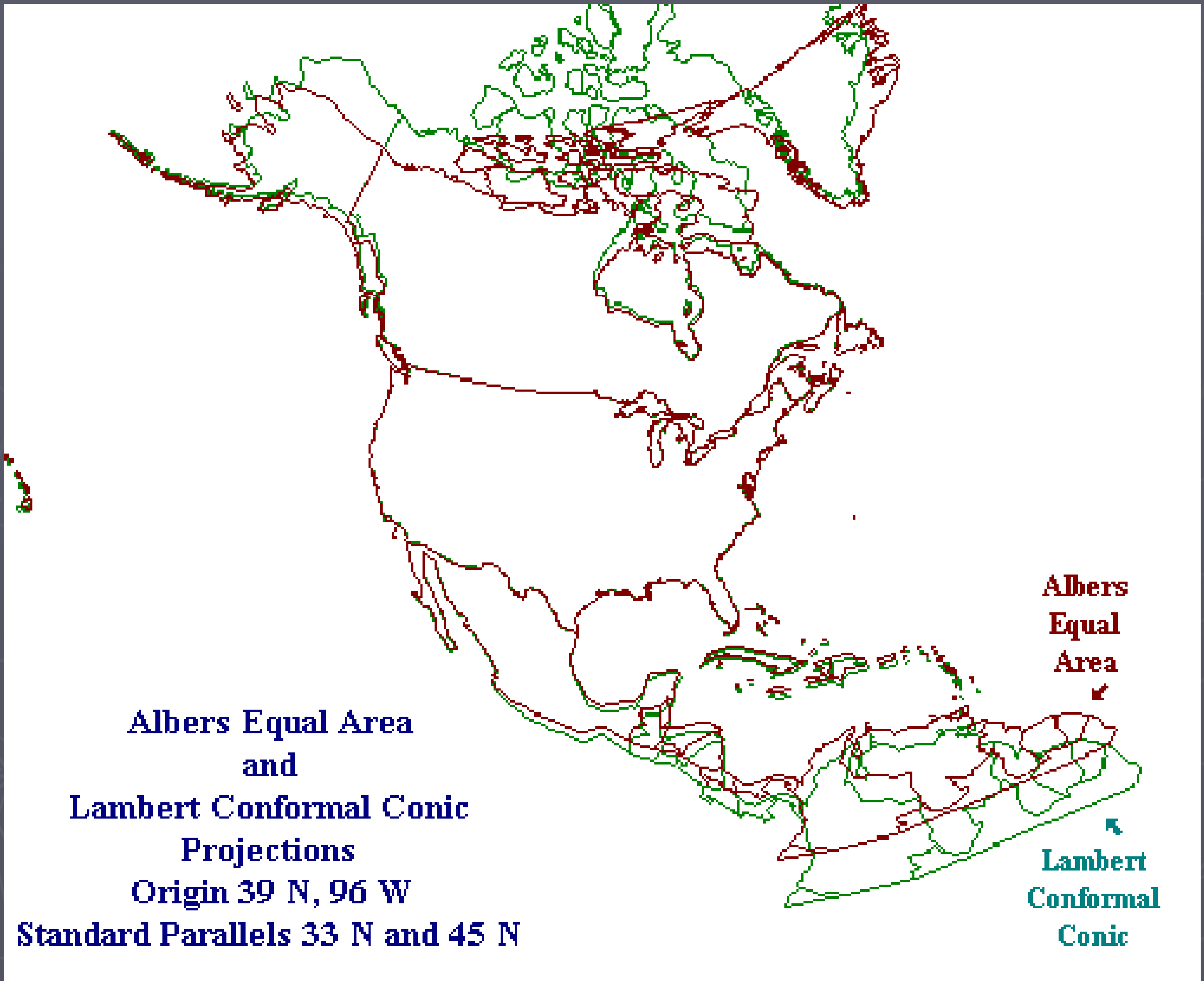
- Spheroids approximate earth's shape
- Datum defines position of spheroid relative to center of the earth
- Datum defines origin and orientation of lat/long lines
- Local datum aligns spheroid to fit surface in a particular area

# Geographic Coordinate System

- Uses 3D spherical surface to define locations
- Often incorrectly called a datum
- Includes angular unit of measure, prime meridian and datum
- Point referenced by longitude/latitude
- Angles measured by degrees

# Possible Error Associated with Coordinate Systems

# Comparison of 2 Projections



# Errors from Projections

- because we are trying to represent a 3-D sphere on a 2-D plane, **distortion is inevitable**
- thus, **every** two dimensional map is **inaccurate** with respect to **at least** one of the following:
  - area
  - shape
  - distance
  - direction

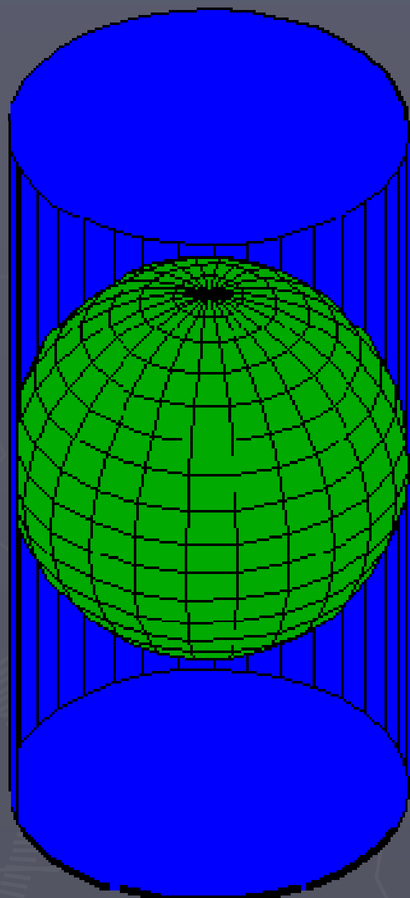
We are trying to represent **this** amount of the earth on

**this** amount of map space.

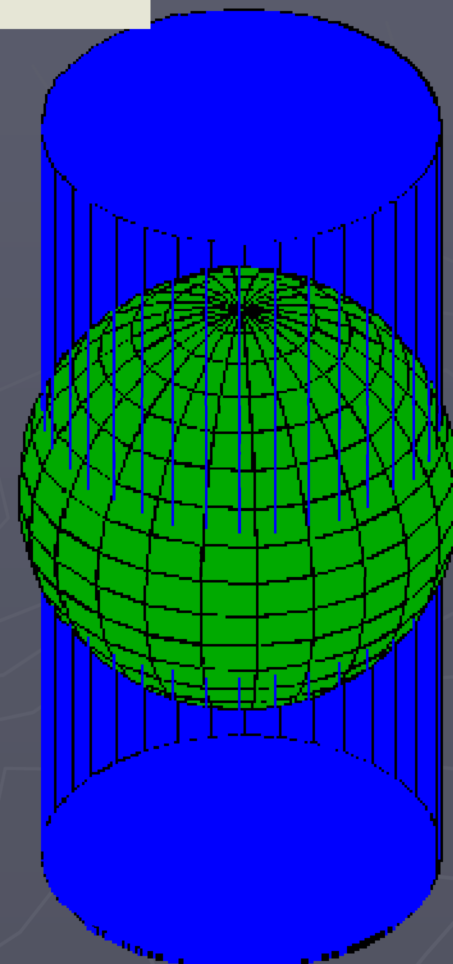
# General Classes of Projections

- Cylindrical
  - tangent case, secant case, transverse tangent case, oblique tangent case
- Conic
  - tangent case, secant case
- Azimuthal
  - tangent case, secant case
- Miscellaneous
  - unprojected

# Cylindrical Projections

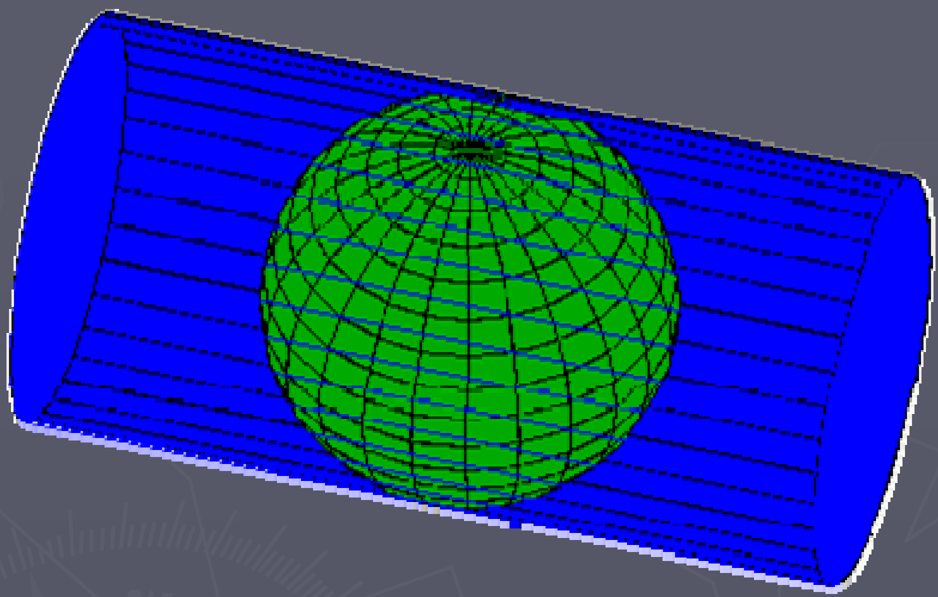


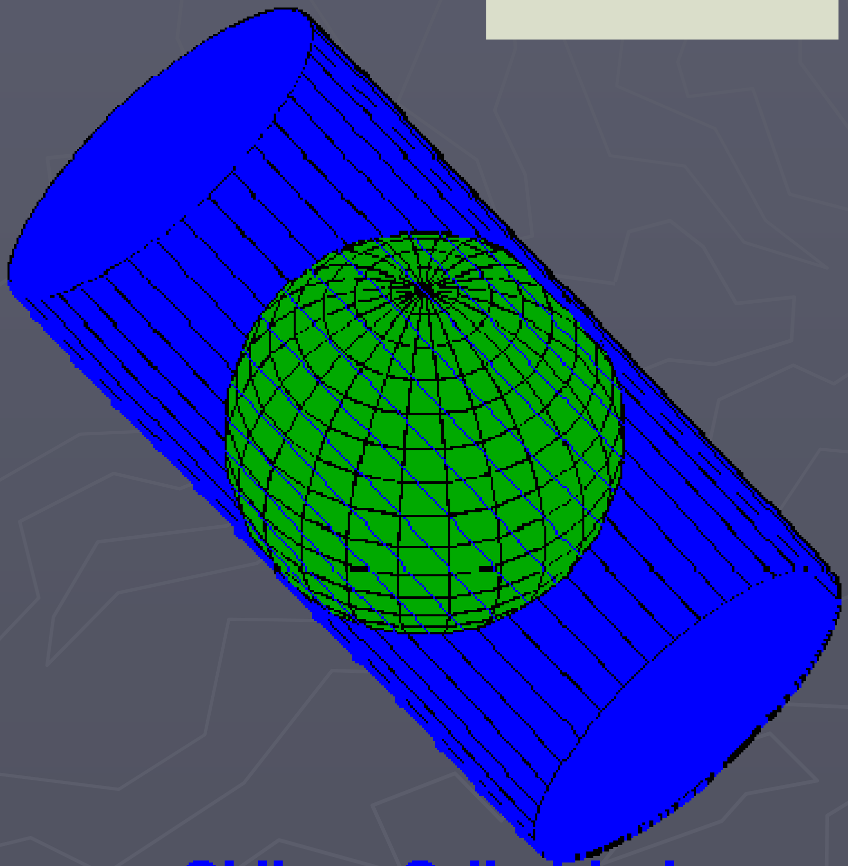
**Cylindrical Projection Surface**



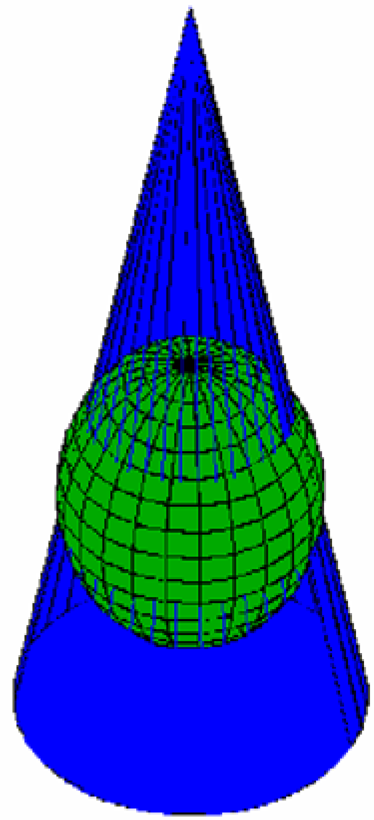
**Secant Cylindrical Projection**

# Cylindrical Projections

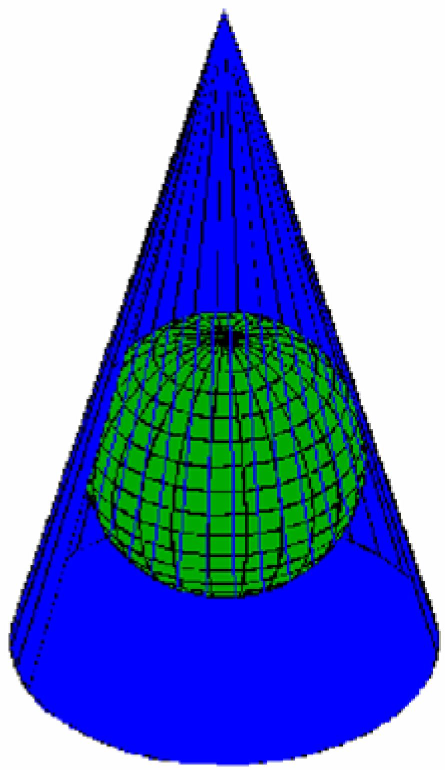


# Conic Projections

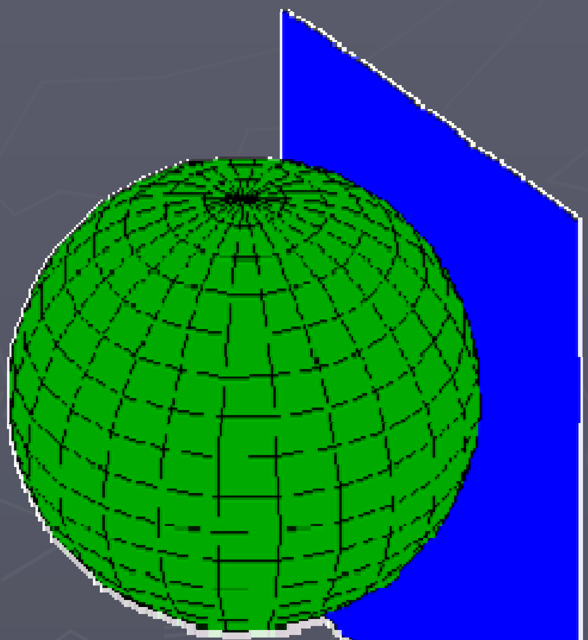


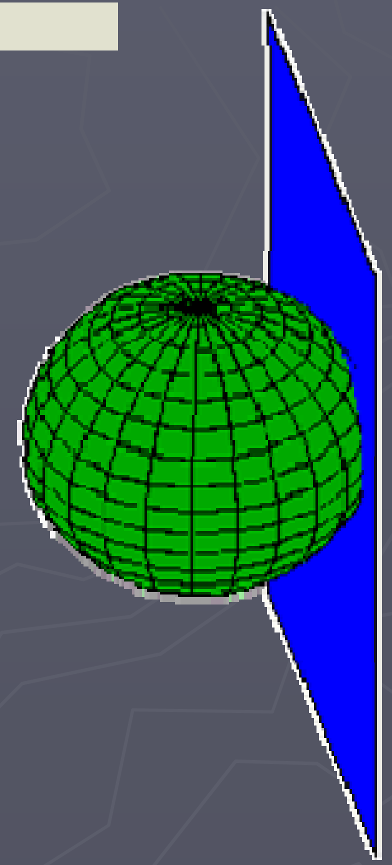
Secant Conic Projection



Conical Projection Surface

# Planar Projections



# Map Projection Parameters

- Map projection alone not enough to define projected coordinate system.
- Must know values for parameters in order to re-project dataset
- Parameters specify origin and customize a projection for specific area of interest

# Linear Parameters

- False Easting and False Northing - ensure *x,y* values are positive
- Scale Factor – Unitless value reduces overall distortion

# Angular Parameters

- Azimuth – defines center of projection
- Central Meridian – Defines origin of the x-coordinates
- Longitude of Origin – synonymous with Central Meridian
- Latitude of Origin – defines origin of the y-coordinates
- Standard Parallel 1 and Standard Parallel 2 – used with conic projections to define latitude lines where scale is 1.

# Projections by Property Preserved: *Shape and Area*

- **Conformal (orthomorphic)**
  - preserves **local** *shape* by using correct *angles;* **local** direction also correct
  - lat/long lines intersect at 90 degrees
  - area (and distance) is usually grossly distorted on at least part of the map
  - no projection can preserve shape of larger areas everywhere
  - use for 'presentations'; most large scale maps by USGS are conformal
  - examples: mercator, stereographic
- **Equal-Area (Equivalent or homolographic))**
  - *area* of all displayed features is correct
  - shape, angle, scale or all three distorted to achieve equal area
  - commonly used in GIS because of importance of area measurements
  - use for thematic or distribution maps;
  - examples: Alber's conic, Lambert's azimuthal

# Projections by Property Preserved: *Distance and Direction*

- **Equidistant**
  - preserves distance (scale) between *some* points or along some line(s)
  - **no** map is equidistant (i.e. has correct scale) **everywhere** on map (i.e. between **all** points)
  - distances *true* along one or more lines (e.g. all parallels) or everywhere from one point
  - great circles (shortest distance between two points) appear as straight lines
  - important for long distance navigation
  - examples: sinusoidal, azimuthal
- **True-direction**
  - provides correct direction (bearing or azimuth) either locally or relative to center
  - rhumb lines (lines of constant direction) appear as straight lines
  - important for navigation
  - some may also be conformal, equal area, or equidistant
  - examples; mercator (for **local** direction), azimuthal (relative to a center point)

# Projections by Geometry:

## *Planar/Azimuthal/Zenithal*

- map plane is tangent to (touches) globe at *single point*
- accuracy (shape, area) declines away from this point
- projection point ('light source') may be
  - earth center (gnomic): all straight lines are great circles
  - opposite side of globe (stereographic): conformal
  - infinitely distant (orthographic): 'looks like a globe'
- good for polar mappings: parallels appear as circles
- also for navigation (laying out course): straight lines from tangency point are all great circles (shortest distance on globe).

# Projections by Geometry: *Conical*

- map plane is tangent along a **line,** most commonly a parallel of latitude which is then the map's *standard parallel*
- cone is cut along a meridian, and the meridian opposite the cut is the map's *central meridian*
- alternatively, cone may intersect (*secant to*) globe, thus there will be *two standard parallels*
- distortion increases as move away from the standard parallels (towards poles)
- good for mid latitude zones with east-west extent (e.g. the US), with polar area left off
- examples: Alber's Equal Area Conic, Lambert's Conic Conformal

# Projections by Geometry: *Cylindrical*

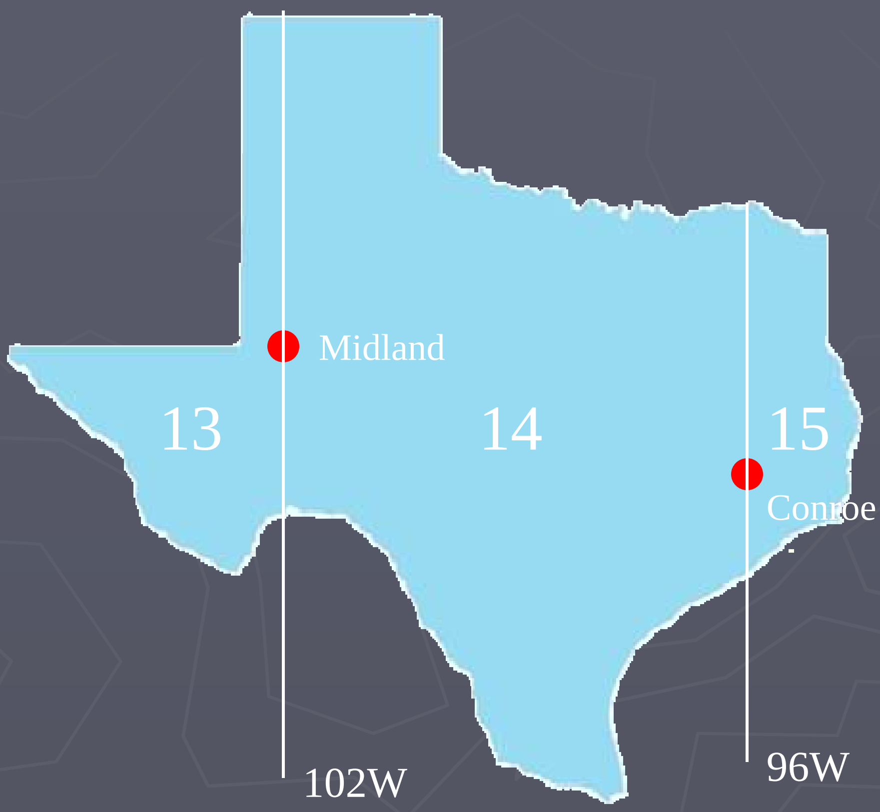
- as with conic projection, map plane is either *tangent* along a *single* line, or passes through the globe and is thus *secant* along *two* lines
- **mercator** is most famous cylindrical projection; equator is its line of tangency
- **transverse mercator** uses a meridian as its line of tangency
- oblique cylinders use any great circle
- lines of tangency or secancy are lines of equidistance (true scale), but other properties vary depending on projection

# Commonly Encountered Map Projections in Texas

- Universal Transverse Mecator
- State Plane
- Texas Statewide Mapping System

# Universal Transverse Mercator (UTM)

UTM in Texas:
3 zones



# State Plane Coordinate System (SPCS)

- began in 1930s for public works projects
- states divided into 1 or more zones (~130 total for US)
- Five zones for Texas
- Different projections used:
  - transverse mercator (conformal) for States with large N/S extent
  - Lambert conformal conic for rest (incl. Texas)
  - some states use both projections (NY, FL, AK)
  - oblique mercator used for Alaska panhandle

# Parameters for SPCS in Texas

| State & Zone Name | Abbrev. | Datum ZONE | FIPSZONE |
|---|---|---|---|
| Texas, North | TX_N | 5326 | 4201 |
| Texas, North Central | TX_NC | 5351 | 4202 |
| Texas, Central | TX_C | 5376 | 4203 |
| Texas, South Central | TX_SC | 5401 | 4204 |
| Texas, South | TX_S | 5426 | 4205 |

State Plane Zones - Lambert Conformal Conic Projection (parameters in degrees, minutes, seconds)

| **Zone** | **1st Parallel** | **2nd Parallel** | **C. Meridian** | **Origin(Latitude)** | **False Easting (m)** | **False Northing(m)** |
|---|---|---|---|---|---|---|
| NAD83 | | | | | | |
| TX_N | 34 39 00 | 36 11 00 | -101 30 00 | 34 00 00 | 200000 | 1000000 |
| TX_NC | 32 08 00 | 33 58 00 | -98 30 00 | 31 40 00 | 600000 | 2000000 |
| TX_C | 30 07 00 | 31 53 00 | -100 20 00 | 29 40 00 | 700000 | 3000000 |
| TX_SC | 28 23 00 | 30 17 00 | -99 00 00 | 27 50 00 | 600000 | 4000000 |
| TX_S | 26 10 00 | 27 50 00 | -98 30 00 | 25 40 00 | 300000 | 5000000 |
| NAD27 | | | | | | |
| TX_N | 34 39 00 | 36 11 00 | -101 30 00 | 34 00 00 | 609601.21920 | 0 |
| TX_NC | 32 08 00 | 33 58 00 | -97 30 00 | 31 40 00 | 609601.21920 | 0 |
| TX_C | 30 07 00 | 31 53 00 | -100 20 00 | 29 40 00 | 609601.21920 | 0 |
| TX_SC | 28 23 00 | 30 17 00 | -99 00 00 | 27 50 00 | 609601.21920 | 0 |
| TX_S | 26 10 00 | 27 50 00 | -98 30 00 | 25 40 00 | 609601.21920 | 0 |

# Texas Statewide Mapping System

## NAD-27

Projection: Lambert Conformal Conic
Ellipsoid: Clarke 1866
Datum: North American 1927
Longitude of Origin: W 100º (-100)
Latitude of Origin: N 31º 10’
Standard Parallel # 1: N 27º 25’
Standard Parallel # 2: N 34º 55’
False Easting: 3,000,000 feet
False Northing: 3,000,000 feet
Unit of Measure: feet (international)

## NAD-83

Projection: Lambert Conformal Conic
Ellipsoid: GRS-80
Datum: North American 1983
Longitude of Origin: W 100º (-100)
Latitude of Origin: N 31º 10’
Standard Parallel # 1: N 27º 25’
Standard Parallel # 2: N 34º 55’
False Easting: 1,000,000 feet
False Northing: 1,000,000 feet
Unit of Measure: meters

# Brazos County Projections

- City of Bryan, Brazos County
  - State Plane, TxCentral, NAD-27, feet
- City of College Station, BCSMPO
  - State Plane, TxCentral, NAD-83, feet
- TAMU
  - State Plane, TxCentral, NAD-83, meters
- Texas Department of Transportation
  - Lambert Conformal (Shackelford), NAD-27/NAD-83, feet/meters
- Texas Digital Orthometric Quadrangles
  - UTM, Zone 14, NAD-83, meters

# Choosing an Appropriate Projection

- **You must consider the map's**
  - subject
  - purpose
- **The subjects area's**
  - size
  - shape
  - location
- **also, the audience and general attractiveness, size and shape of page, appearance of the graticule**

# Choosing an Appropriate Projection

<u>subject and map purpose</u>

- for distribution maps, use equal-area
- for navigation, use projections that show azimuths or angles properly

<u>size and shape of area</u>

- Some projections are better suited to east-west extent, others to north-south
- for small areas (large-scale), projection is relatively unimportant, but for large areas it is VERY IMPORTANT
- interrupted or uninterrupted? Water, land, or both?

# Choosing an Appropriate Projection

location

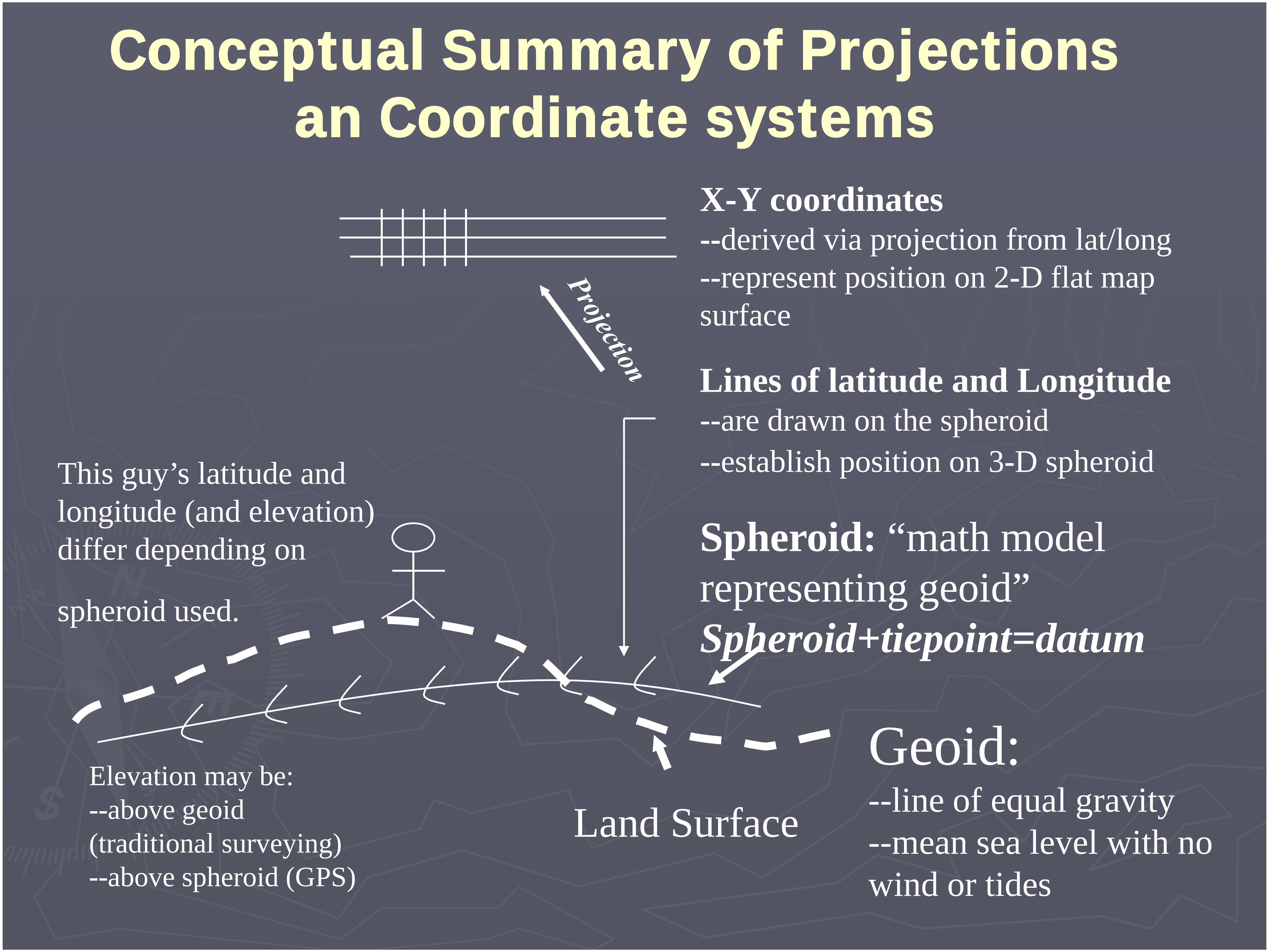
- Conic projections for mid-latitudes, especially areas with greater east-west extent than north-south
- An oblique conic or polyconic is suitable for mid-latitude north-south areas
- Cylindrical for equatorial regions
- azimuthal (planar) for poles

Because…

- Cylindricals are true at the equator and distortion increases toward the poles
- conics are true along some parallel between the poles and equator
- Azimuthals are true only at their center point, but distortion is generally worst at the edges

# Summary on Projections an Coordinate systems

- GCS uses 3D spherical surface to define locations
- Points referenced by latitude and longitude
  - Latitude: Parallels; equator is origin
  - Longitude: Meridians; Prime Meridian is origin
- Spheroids more accurately depict earth than sphere
- Datum defines position of spheroid relative to center of the earth
- Datum defines origin and orientation of lat/long lines
- Map projection transforms 3D surface to 2D
- Map projections distort shape, area, distance or direction of data


Conceptual Summary of Projections an Coordinate systems
X-Y coordinates
--derived via projection from lat/long
--represent position on 2-D flat map surface
Projection
Lines of latitude and Longitude
--are drawn on the spheroid
--establish position on 3-D spheroid
This guy’s latitude and longitude (and elevation) differ depending on spheroid used.
Spheroid: “math model representing geoid”
Spheroid+tiepoint=datum
Geoid:
--line of equal gravity
--mean sea level with no wind or tides
Land Surface
Elevation may be:
--above geoid (traditional surveying)
--above spheroid (GPS)

# References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