Geographic Information Systems

ESM 263 - Winter 2023

Coordinate Systems and Map Projections

Outline

- Introduction
- Latitude and longitude
- Projections and coordinate systems
- Cadasters
- Postal addresses and postal codes
- Placenames
- Converting georeferences

Georeferencing

Linking information to specific locations

- Unique
  location = f (georeference)

- Shared
  means the same thing to everybody

- Persistent
  means the same thing tomorrow

Types of Georeferences

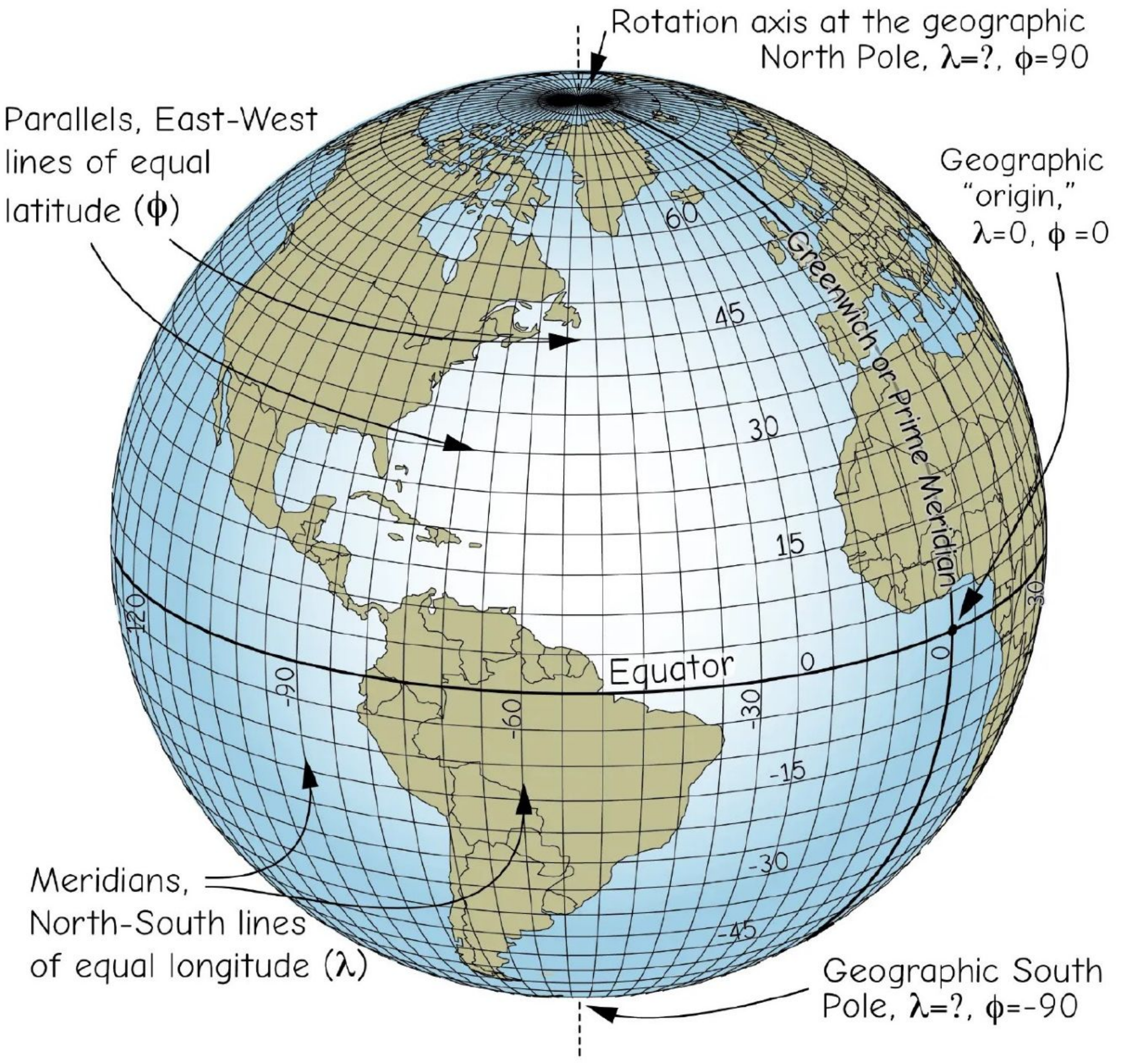
- Nominal
  Placenames

- Ordinal
  street addresses (in some of the world, anyway...)

- Interval or Cyclic
  linear or angular distance from fixed places
  e.g. from Equator or Greenwich Meridian

Geographic Coordinates

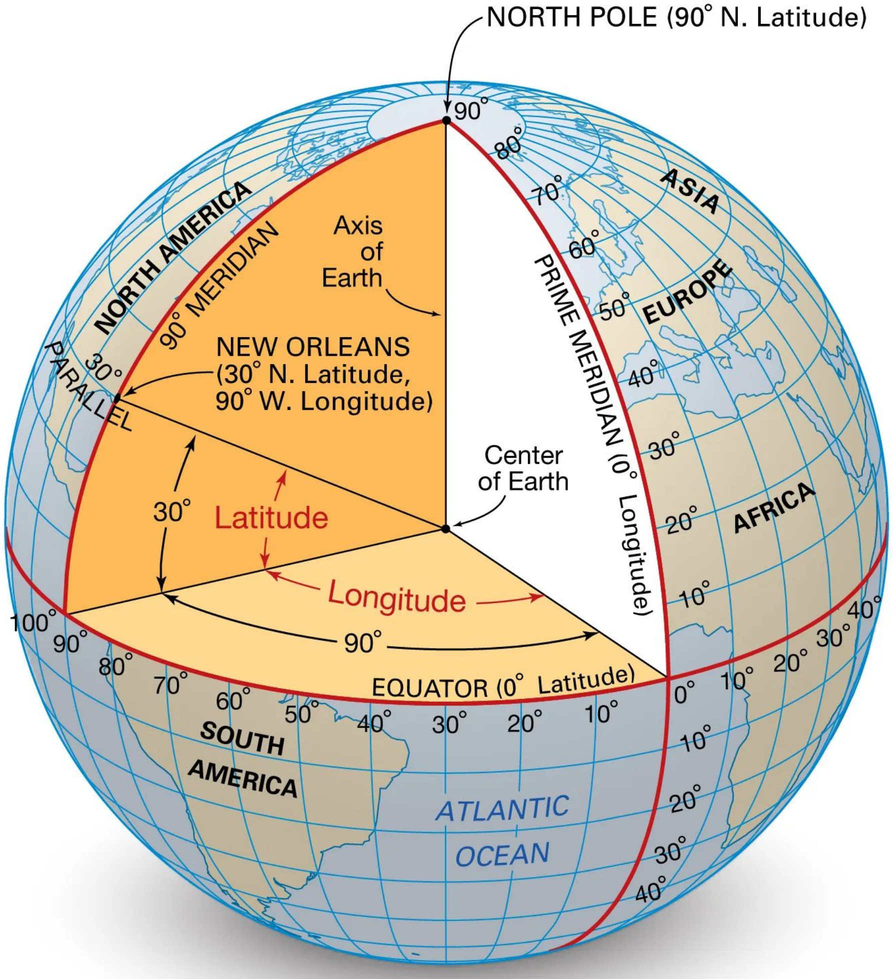
- Spherical coordinates
  - Latitude
  - Longitude
- Defined by
  - Center of mass
  - Equator = f(rotation)
  - Zero meridian = f(politics)
- Spherical Earth
  - R ≈ 6 371 km
  - A ≈ 510 000 000 km^2



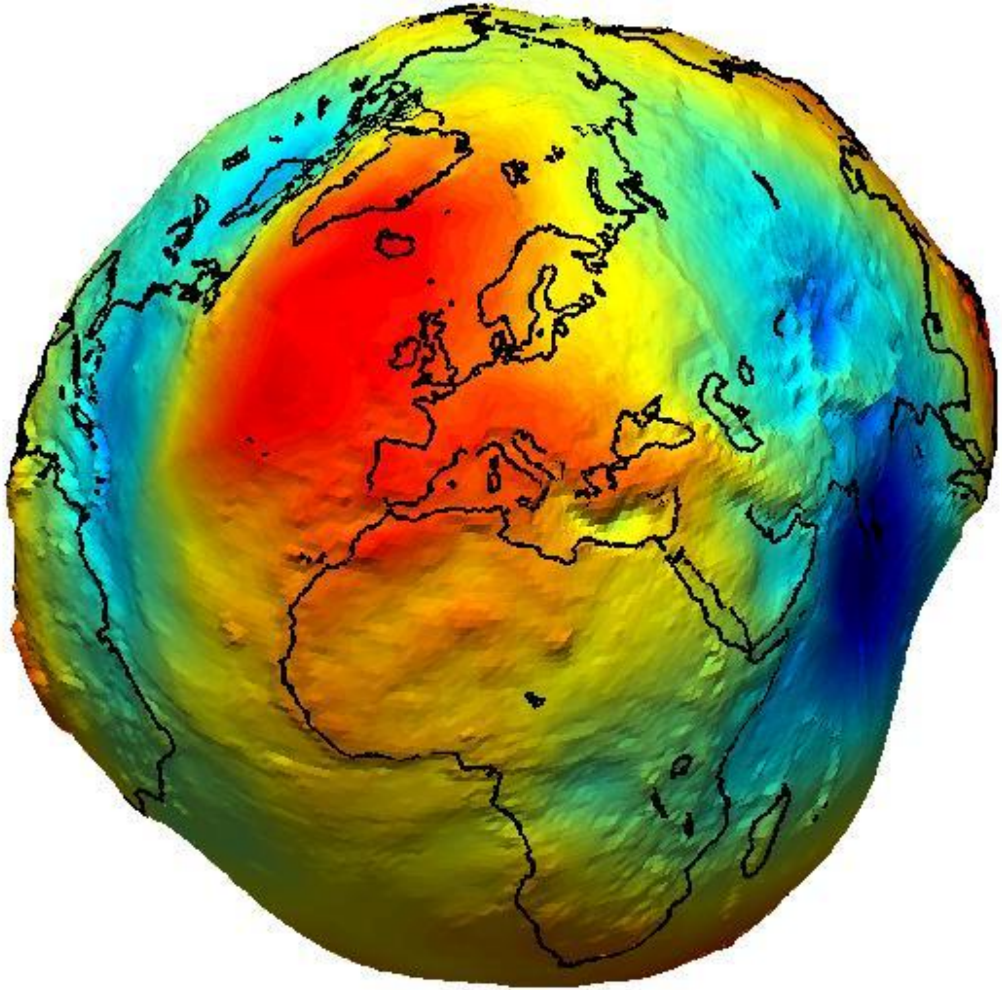
Latitude and Longitude

- Latitude
  angle from equator (+ = N)
  on meridional plane

- Longitude
  angle from prime meridian (+ = E)
  on equatorial plane



Prime Meridian at Greenwich, UK

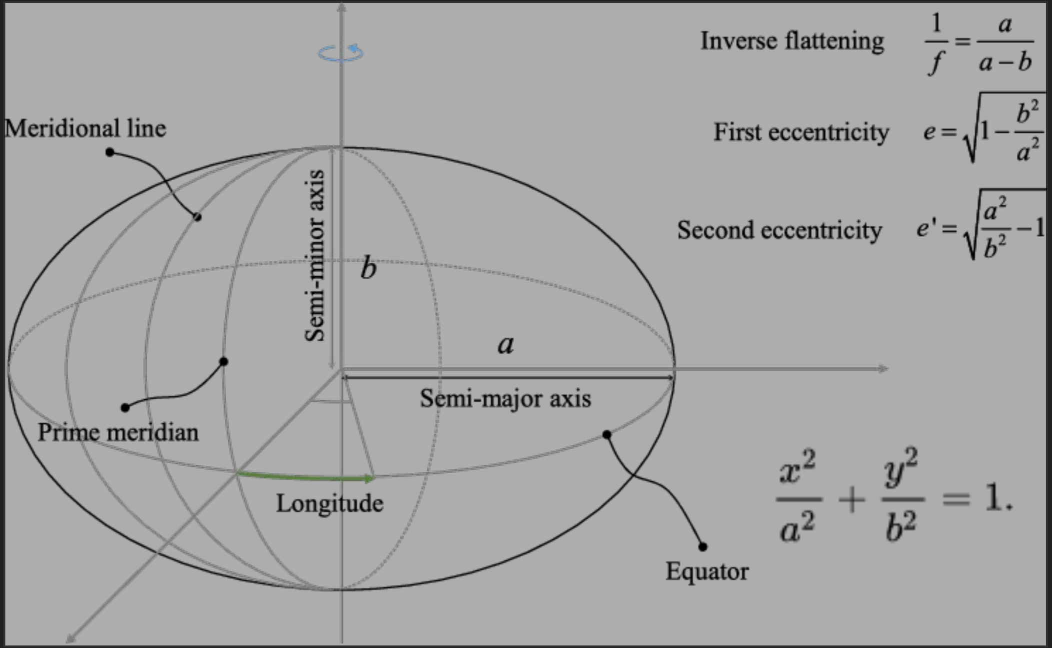


Earth Isn't Round (nor is it flat …)

- Closer to an ellipsoid than a sphere
  - an ellipse rotated about its minor axis
  - centrifugal "bulge" →
    N-S diameter ~ 1/300 less than E-W

- Example: WGS 84 ellipsoid
  - Radius at Equator: 6378.137 km
  - Flattening: 1/298.257

- Datum:
  model of the Earth as an ellipsoid
  - dimensions (radii, flattening)
  - location (center ↔ center of Earth)
  - orientation (semi-minor axis ↔ Earth axis)

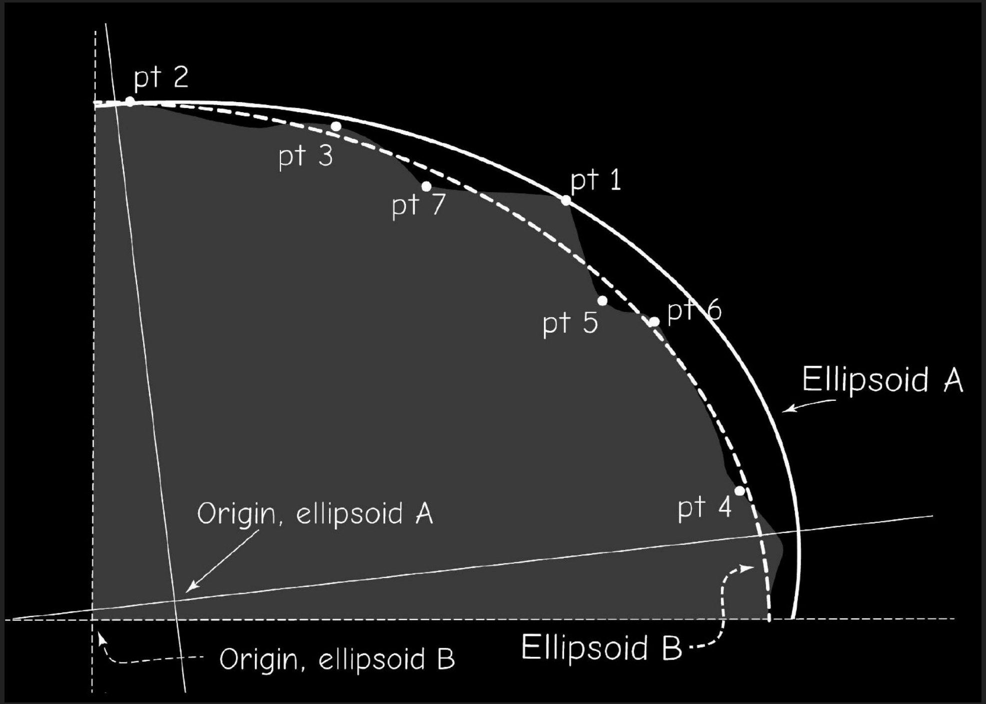


Why Different Datums?

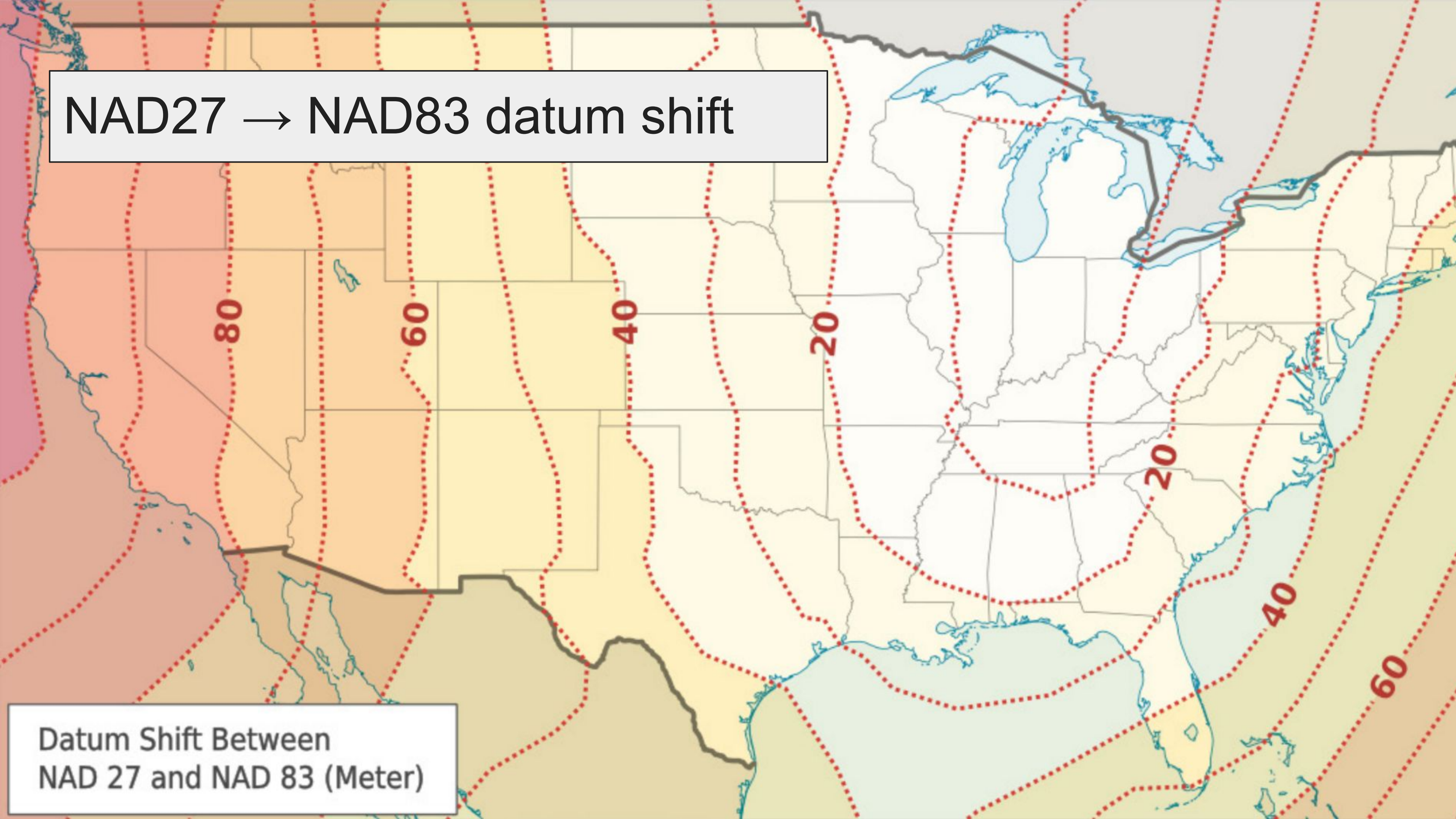
- Before GPS: many
  - Each country used “local best fit” ellipsoid
  - US: North American Datum of 1927 (NAD27)
    - Clarke 1866 ellipsoid
    - tangent to surface at [Meades Ranch, KS]()

  - US: North American Datum of 1983 (NAD83)
    - GRS 1980 ellipsoid (Earth-centered)
    - up to 200 m displacement from NAD27 (in US)

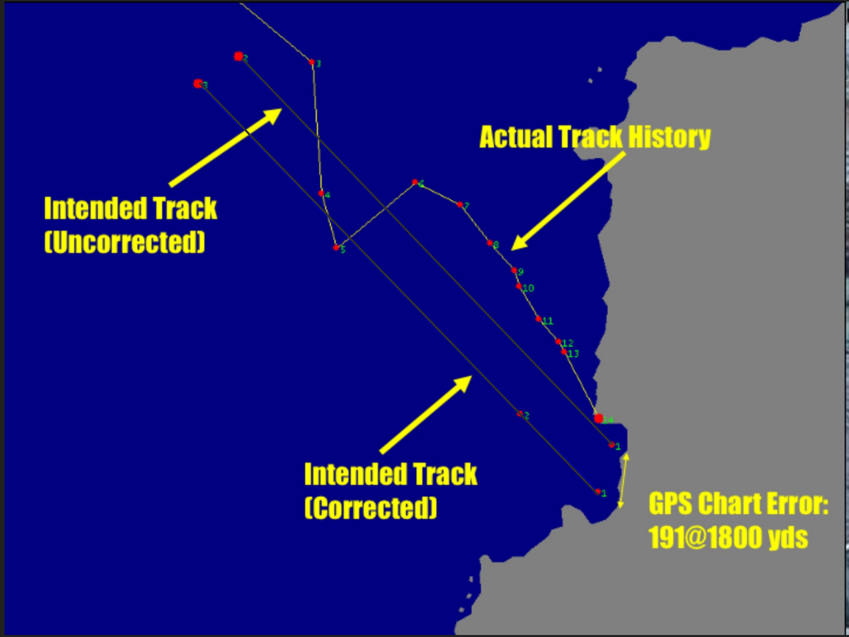
- Since GPS: WGS 84
  - Earth-centered ellipsoid
    <1 m offset from NAD 83 (in US)



NAD27 → NAD83 datum shift



What Can Happen If You Ignore Datums



USS LA MOURE COUNTY ran aground in Caleta Cifuncho Bay, Chile after navigating with GPS (WGS-84 datum) on a local chart with a local datum.

Projections

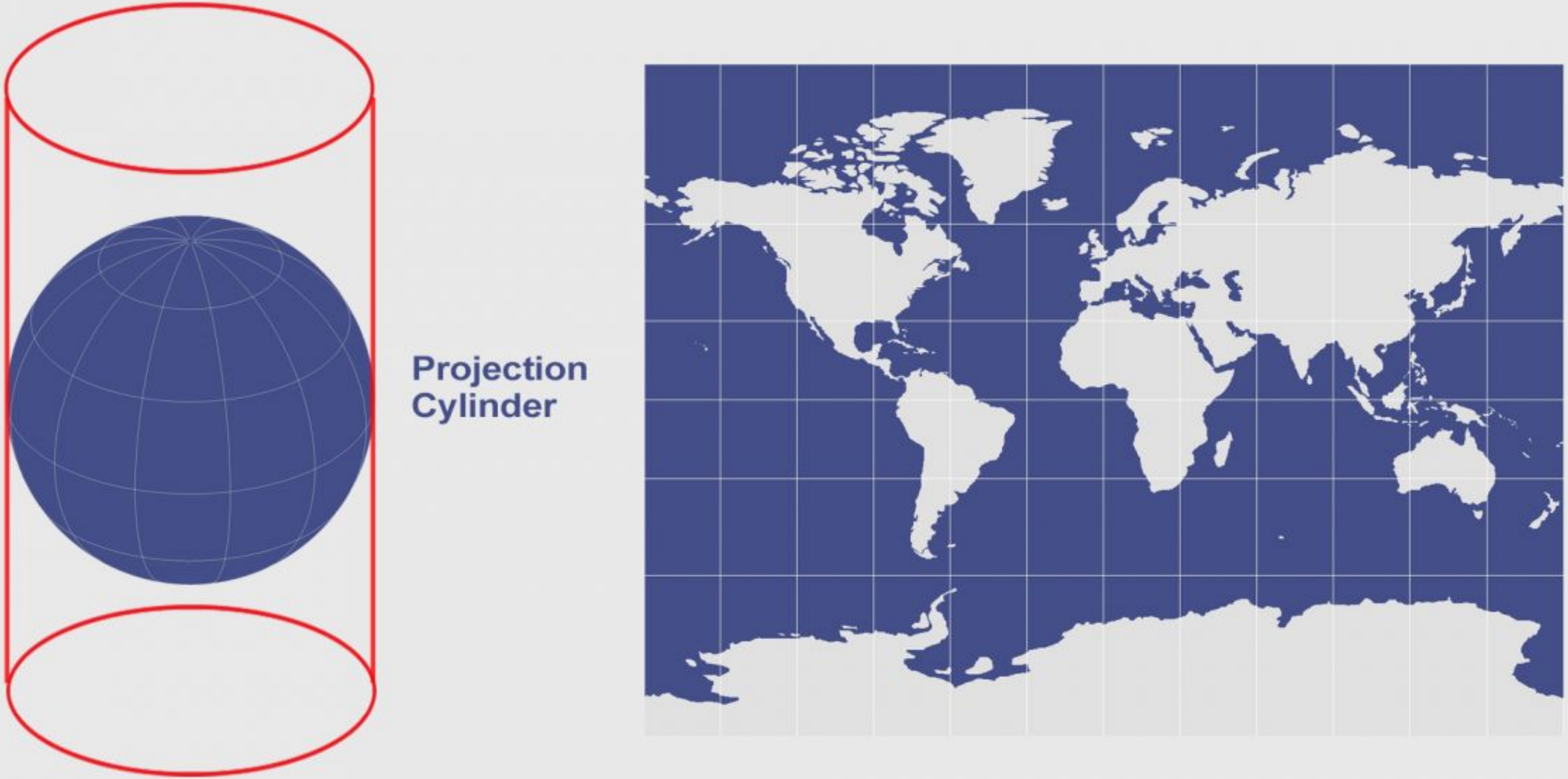
Why project Earth's surface onto plane?

- See whole Earth surface at once

- GIS ↔ maps/displays
  - scan, digitize
  - print, plot

- Much easier to measure distance

- Represent Earth surface as a rectangular grid
  (we'll talk more about this in the "raster" section…)

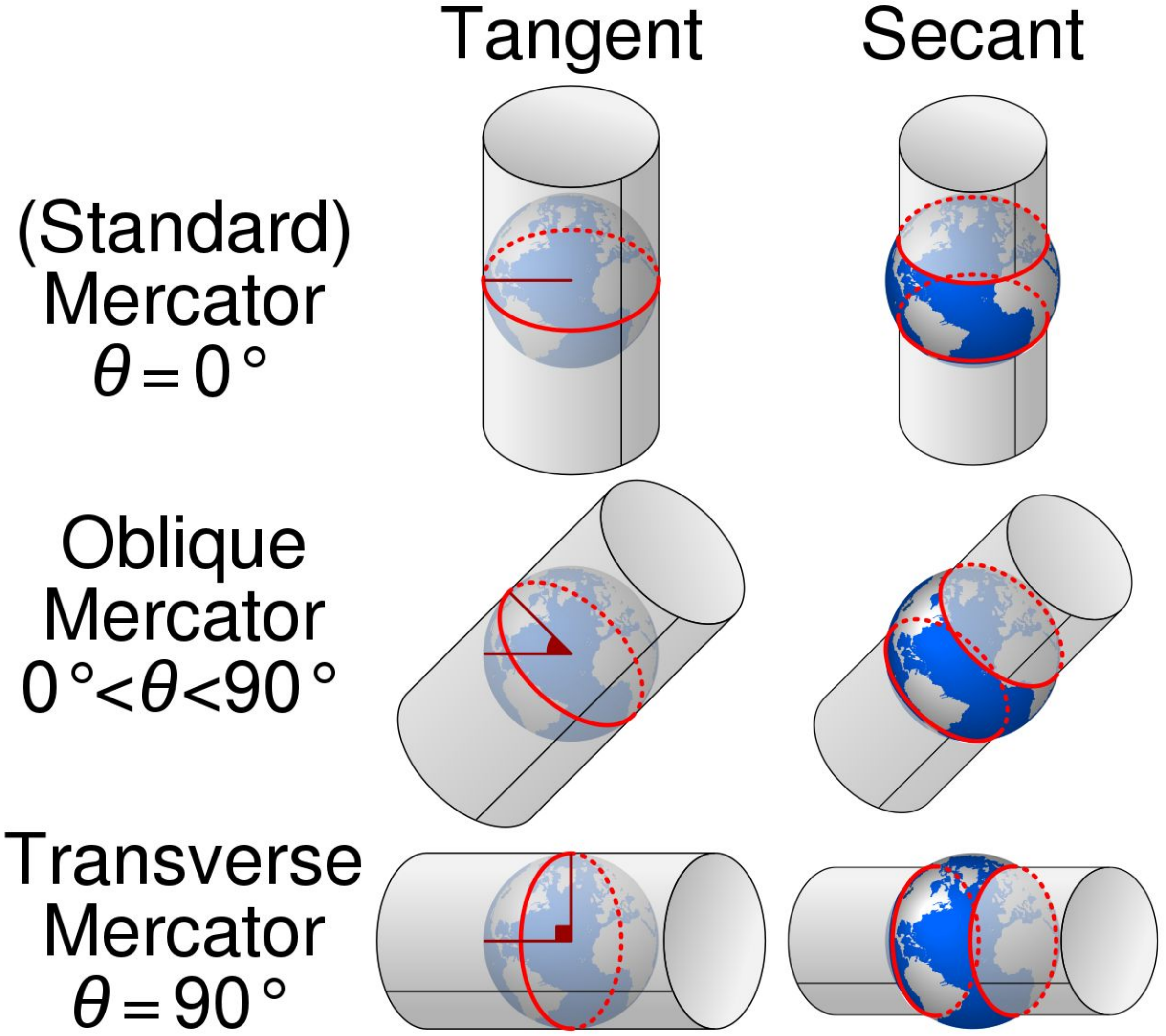

Projection
Cylinder


Projection
Cone

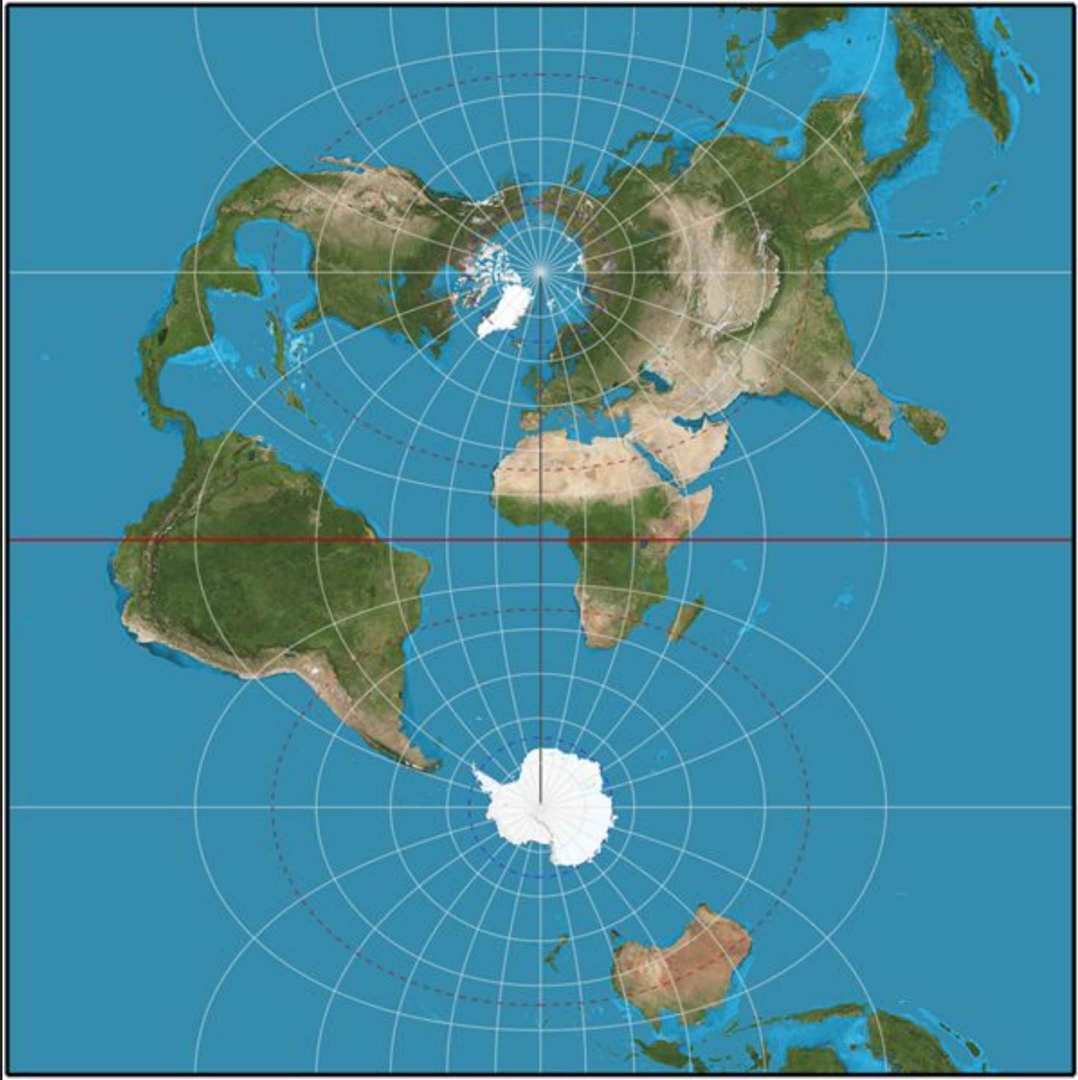
Cylindrical Projection Example: Mercator

Turning the cylinder:

- Standard
- Oblique
- Transverse

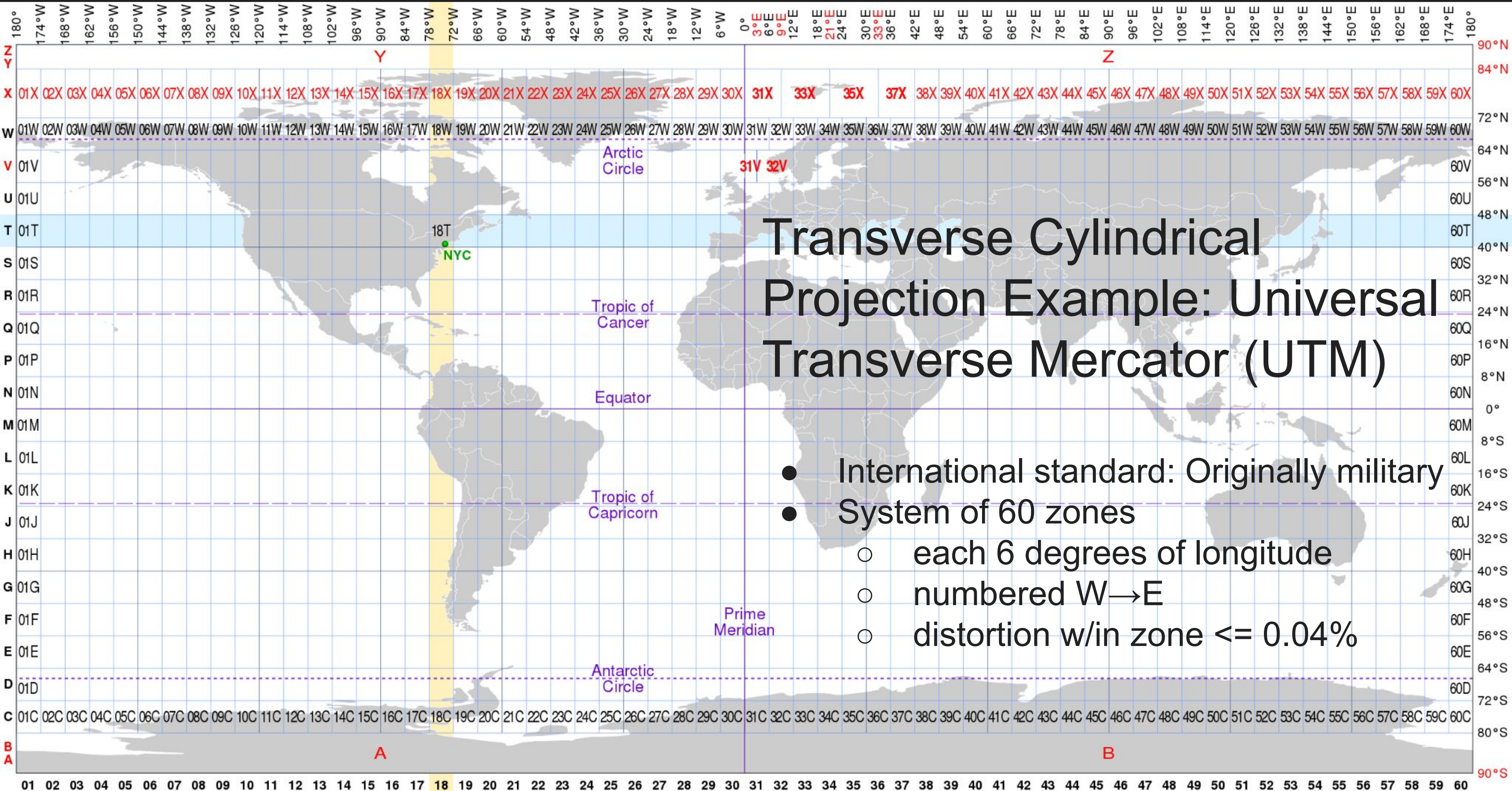


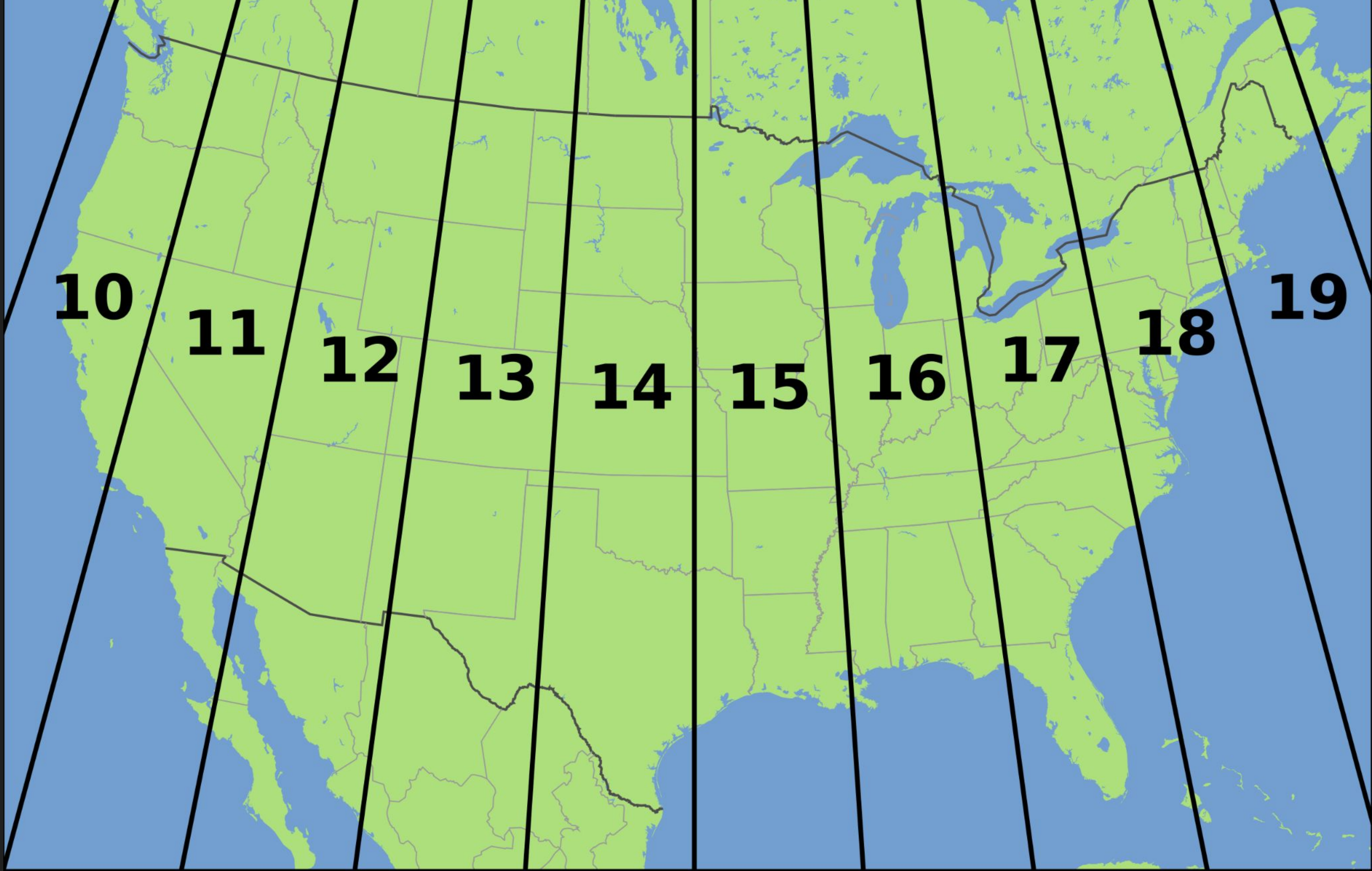
Cylindrical Projection Example: Transverse Mercator



Transverse Cylindrical Projection Example: Universal Transverse Mercator (UTM)

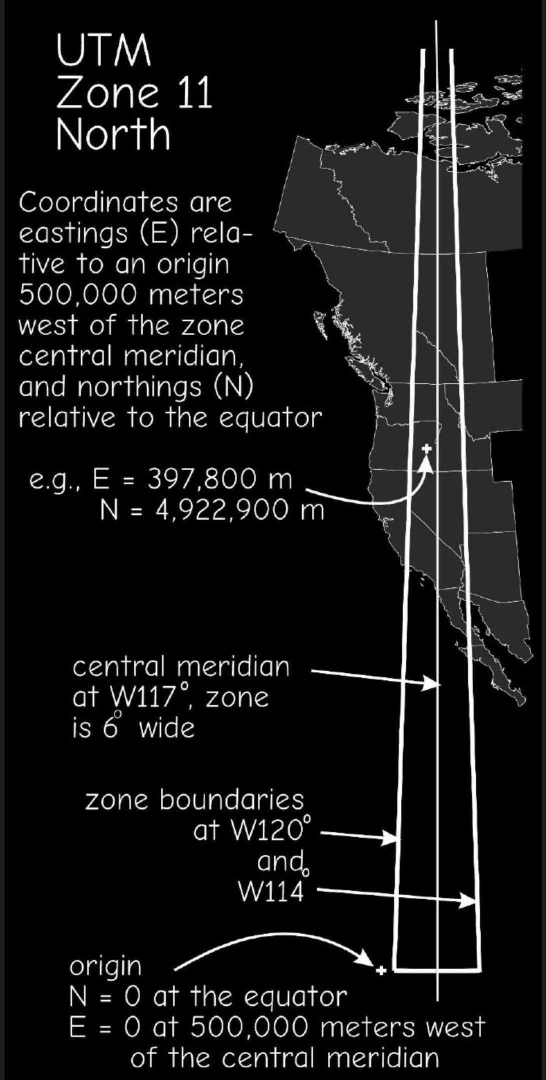
- International standard: Originally military
- System of 60 zones
  - each 6 degrees of longitude
  - numbered W→E
  - distortion w/in zone <= 0.04%




10
11
12
13
14
15
16
17
18
19

UTM Coordinates

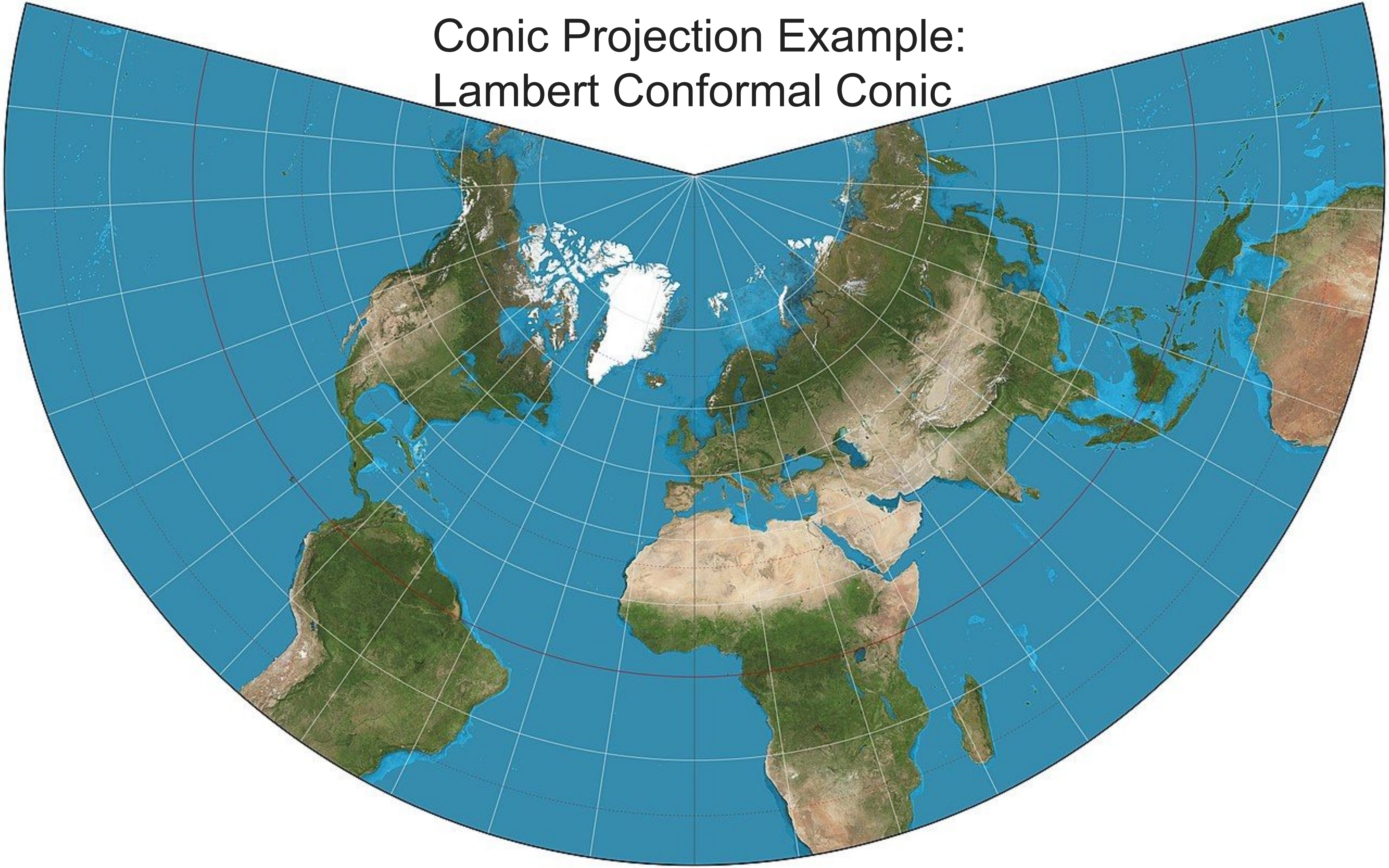
- X: easting (meters east)
  Y: northing (meters north)
- X = 500 km @ central meridian
  “false easting”: makes all X’s in the zone positive
  Y = 0 @ Equator
- Eastings and northings are both in meters allowing easy distance calculation
- UTM georeference
  - zone number
  - six-digit easting
  - seven-digit northing
  - e.g.: 11, 397900 E, 4922900 N

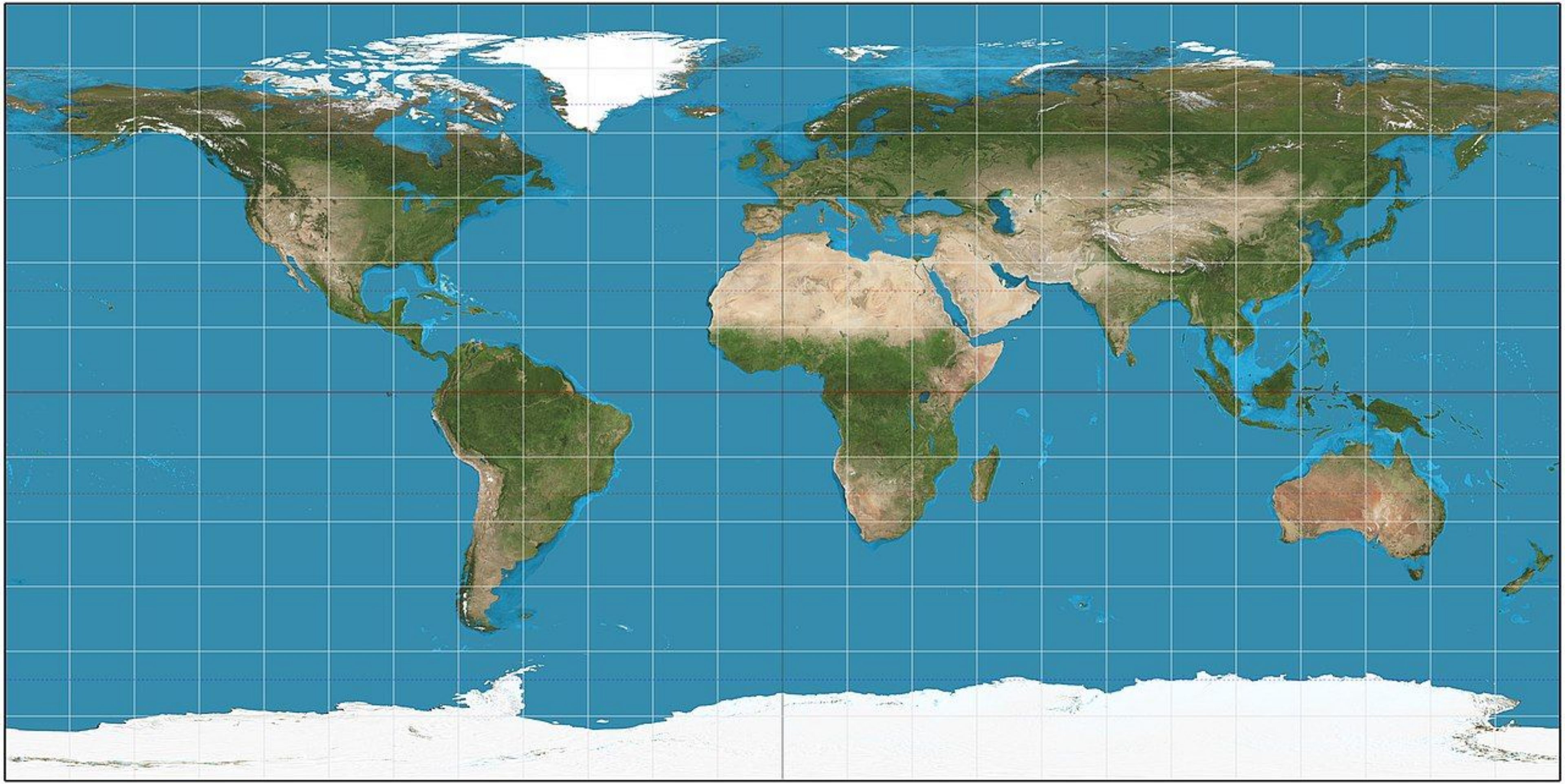


UTM Zones: Implications

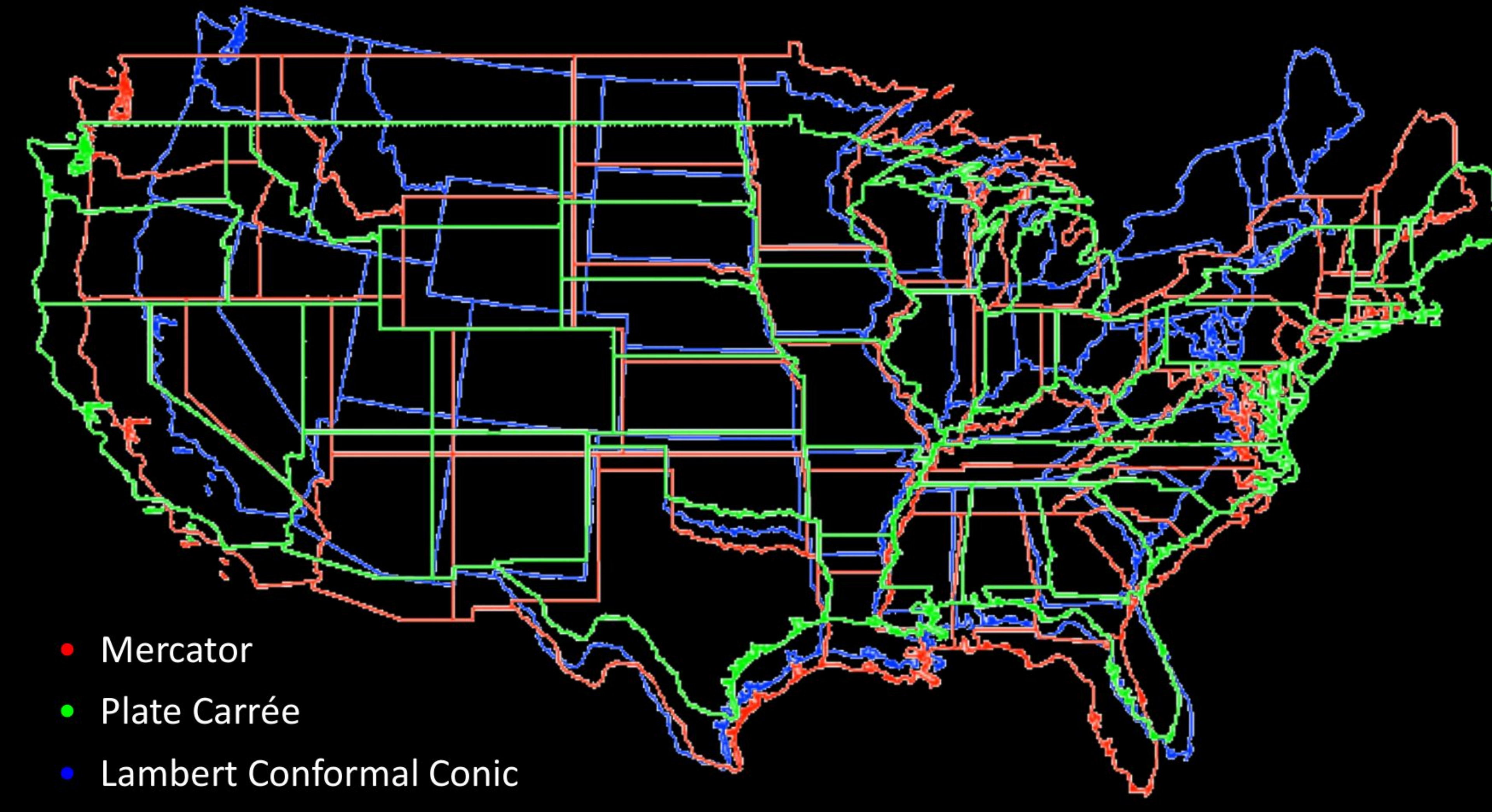
- Each zone is a different projection
- Adjacent zones won't fit along border
- What about areas that span zones?
  - Either: pick 1 zone; accept >normal distortions in other zone
  - Or: use other projection that spans area
    - E.g. CA (zones 10 & 11) UTM zone "10.5"
    - "California Albers" (equal area conic)

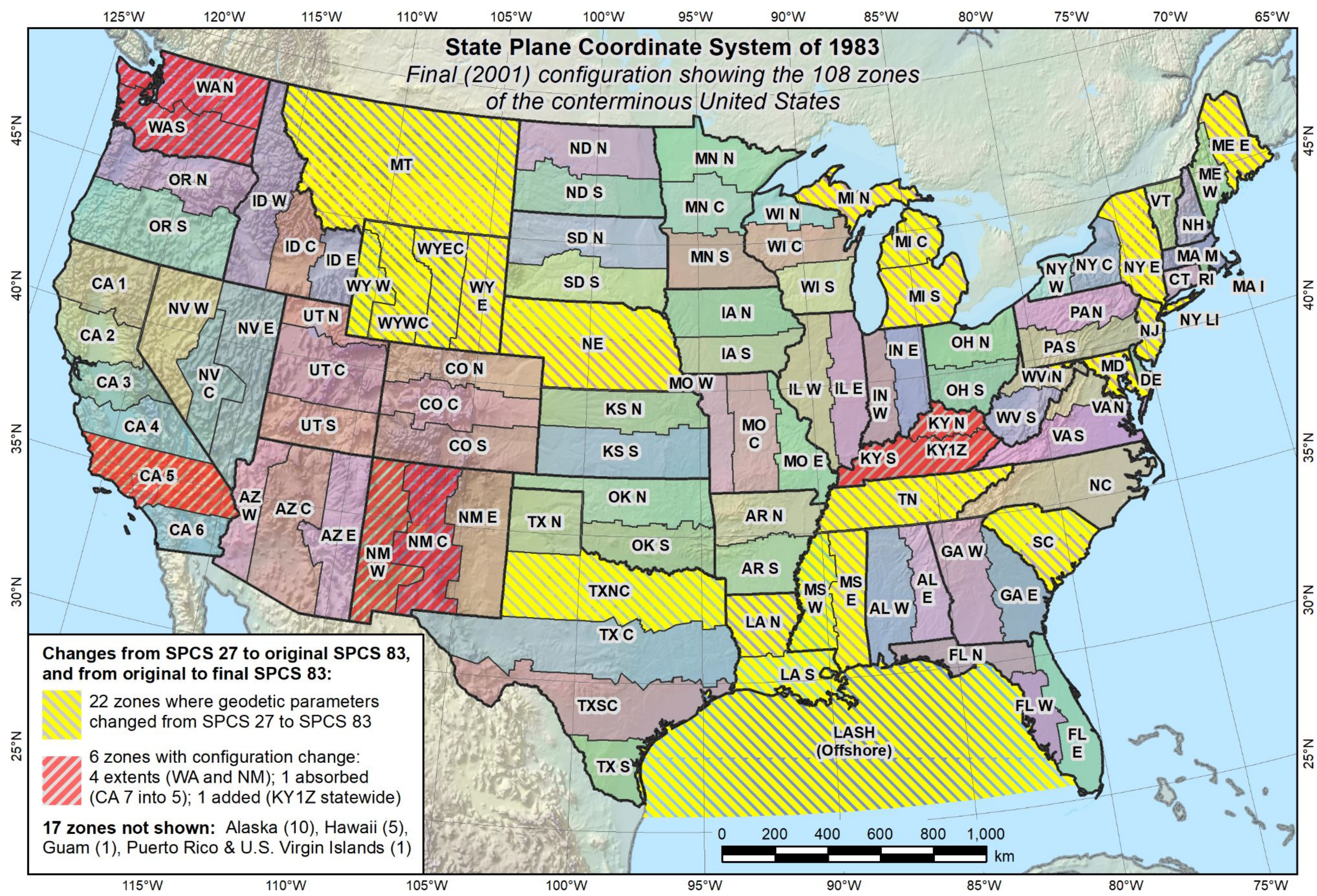
Conic Projection Example: Lambert Conformal Conic





“Unprojected” Projection: Plate Carrée / Equirectangular projection


Mercator
Plate Carrée
Lambert Conformal Conic


State Plane Coordinate System of 1983
Final (2001) configuration showing the 108 zones
of the conterminous United States
Changes from SPCS 27 to original SPCS 83, and from original to final SPCS 83:
22 zones where geodetic parameters changed from SPCS 27 to SPCS 83
6 zones with configuration change: 4 extents (WA and NM); 1 absorbed (CA 7 into 5); 1 added (KY1Z statewide)
17 zones not shown: Alaska (10), Hawaii (5), Guam (1), Puerto Rico & U.S. Virgin Islands (1)
0 200 400 600 800 1,000 km
WA N
WA S
OR N
OR S
ID W
ID C
ID E
MT
WYEC
WY W
WY E
WYWC
CA 1
CA 2
CA 3
CA 4
CA 5
CA 6
NV W
NV E
NV C
UT N
UT C
UT S
AZ W
AZ C
AZ E
CO N
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KY1Z
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MS W
MS E
AL W
AL E
GA W
GA E
FL N
FL W
FL E
SC
NC
VA N
VA S
WV N
WV S
MD
DE
NJ
PA N
PA S
NY W
NY C
NY E
NY LI
VT
NH
ME E
ME W
MA M
MA I
CT
RI
125°W 120°W 115°W 110°W 105°W 100°W 95°W 90°W 85°W 80°W 75°W 70°W 65°W
45°N 40°N 35°N 30°N 25°N

Distortion

- All projections distort the Earth in some way
- Which is most important? (Pick one)
    - Shape? Use conformal projection
      →Distortion same in all directions
    - Area? Use equal area projection
      →Distorts shapes to preserve area

      (No projection has both of these properties.)

- (And maybe add)
    - Distance? Use equidistant projection
    - Only from 1 or 2 points, or along 1 line.

Which projection should I use?

- For data
  - generally: equal-area so calculations and comparisons make sense
  - specifically: whatever your project/client already uses so you don’t waste time/effort converting stuff
- For maps
  - generally: whatever’s most familiar to the map’s users
  - Specifically:
    - conformal: if it’s most important to recognize shapes
    - equal-area: if it’s most important to compare sizes
      (The smaller the area, the less important this distinction is.)

Cadasters

- Land ownership (property boundary) maps

- US Public Land Survey System (PLSS)
  - Georeferences local cadasters
  - esp. in western US: Natural resources
  - Similar systems in other countries

Placenames

- Earliest form of georeferencing
  most commonly used in everyday activities

- Work at many different scales
  continents → villages → neighborhoods

- Evolve
  - Peking → Peip'ing → Beijing
  - Taprobane → Ceylon → Sri Lanka
  - Poland …

Uniqueness: Which One?

- Domain-specific
  - many instances of “Springfield” in the U.S.
  - but only one per state

- Context-specific
  - Paris, France vs Paris, Texas

Postal Address as Georeference

- Works if mail destination (dwelling, office, ...)
  - is unique along: Street name
  - is unique within: Local area (city, county, ...)
  - is unique within: Region (state, province, ...)
- but not for…
  - Rural areas:
    e.g.: Star Route 1 Box 198
    (now: 1016 Mt. Morrison Rd.)
  - Natural features (lakes, mountains, rivers, ...)
  - Non-sequential street addresses
    - e.g. Japan

Postcodes as Georeferences

- Defined in many countries
  - US ZIP codes
  - UK postcodes
- Hierarchically structured
  - Leading characters → large areas
  - Trailing characters → smaller areas
- vs. postal address?
  - Ubiquitous
  - Less precise

Converting Georeferences

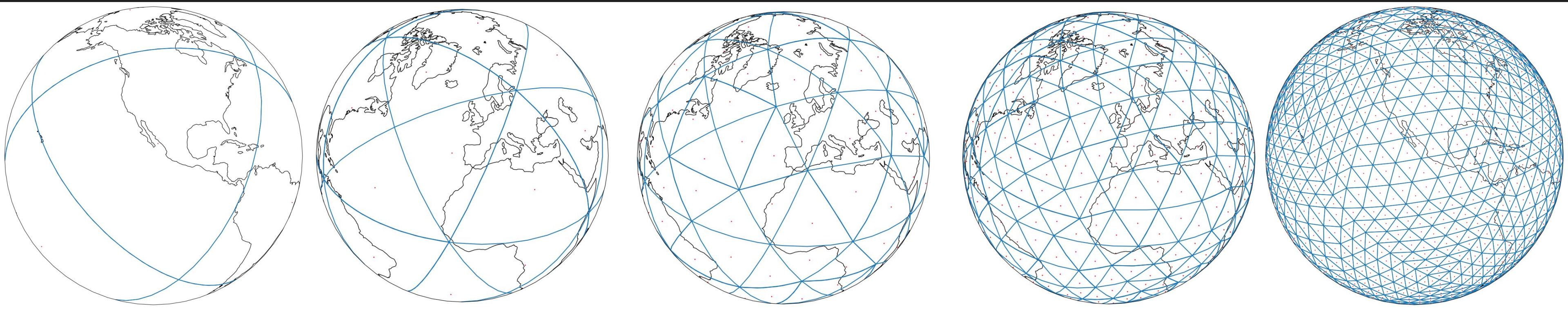
- Projection: Transform coordinates to new projection
  QGIS:
  - Working with Projections
  - Reproject layer

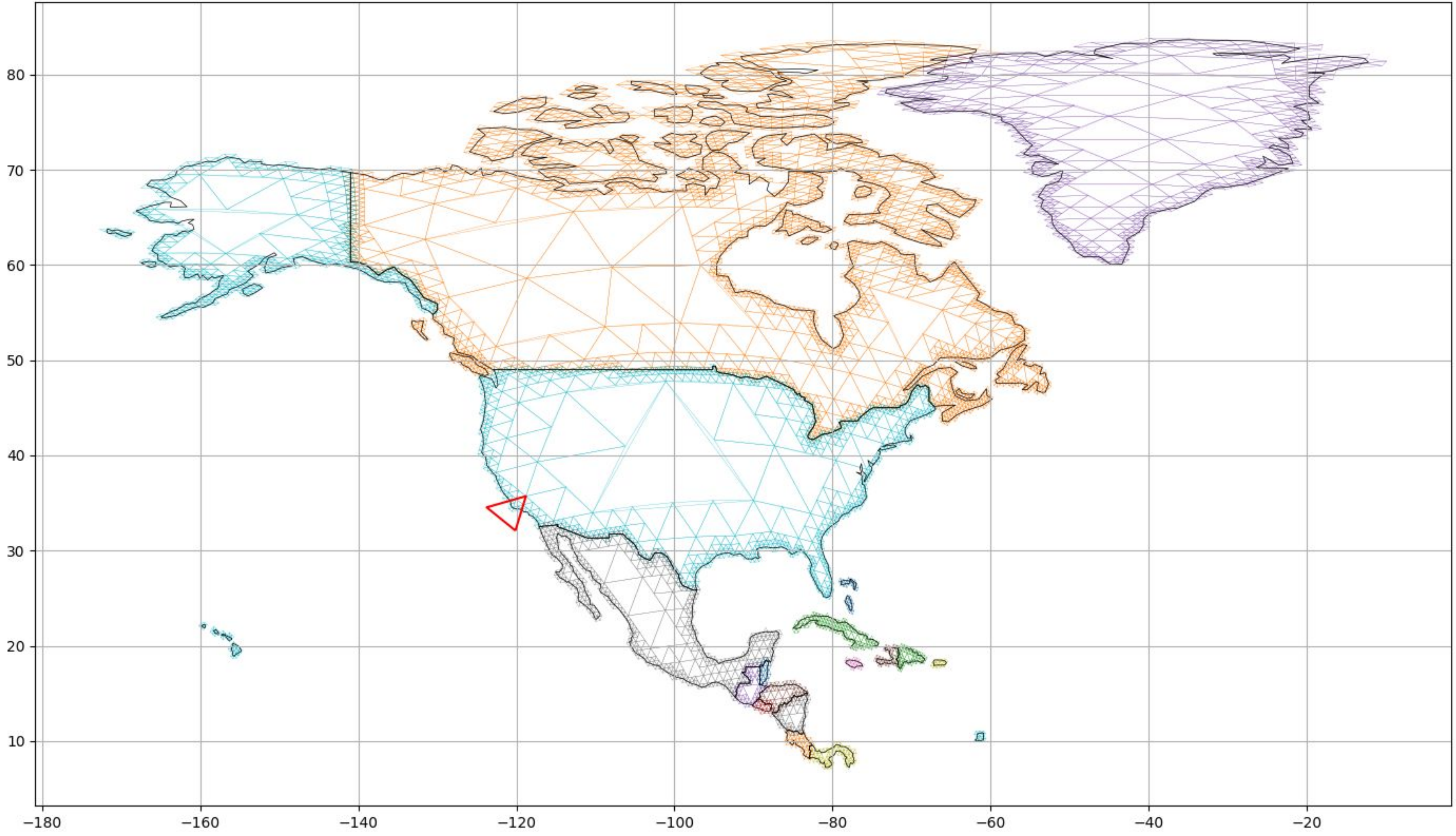
- Geocoding– Convert street addresses to coordinates (US Census)

- Gazetteer: database of place = (name, location, type)
  - U.S. Board on Geographic Names
  - GeoNames

Alternative Georeferencing

- What3Words
- STARE





80
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−80
−60
−40
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