Coordinate Systems and Map Projections

Outline

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

Georeferencing

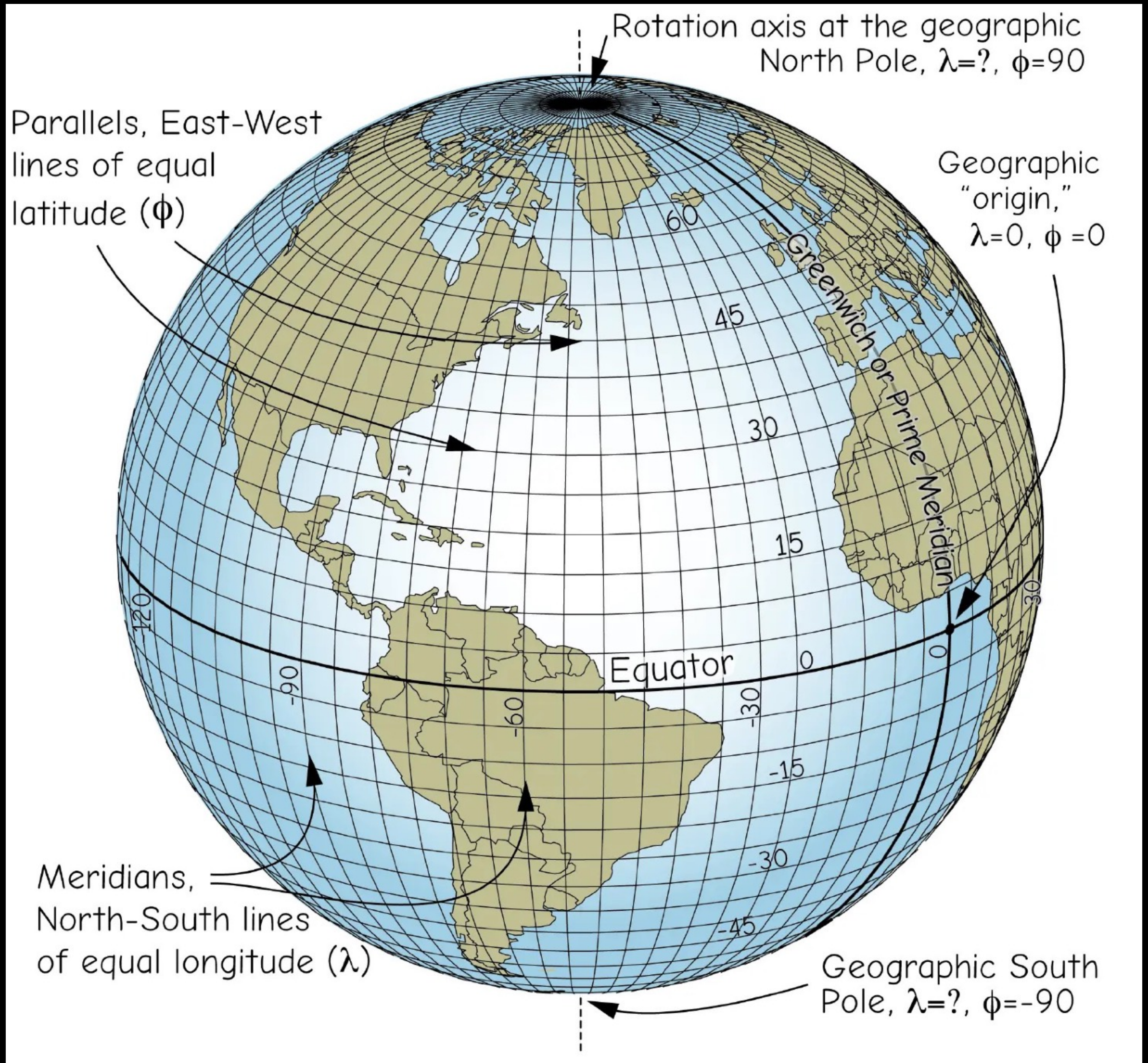
Linking information to specific locations

- Unique
  - location = f (georeference)
- Shared
  - means the same thing to everybody
- Persistent
  - means the same thing tomorrow

Types of Georeferences

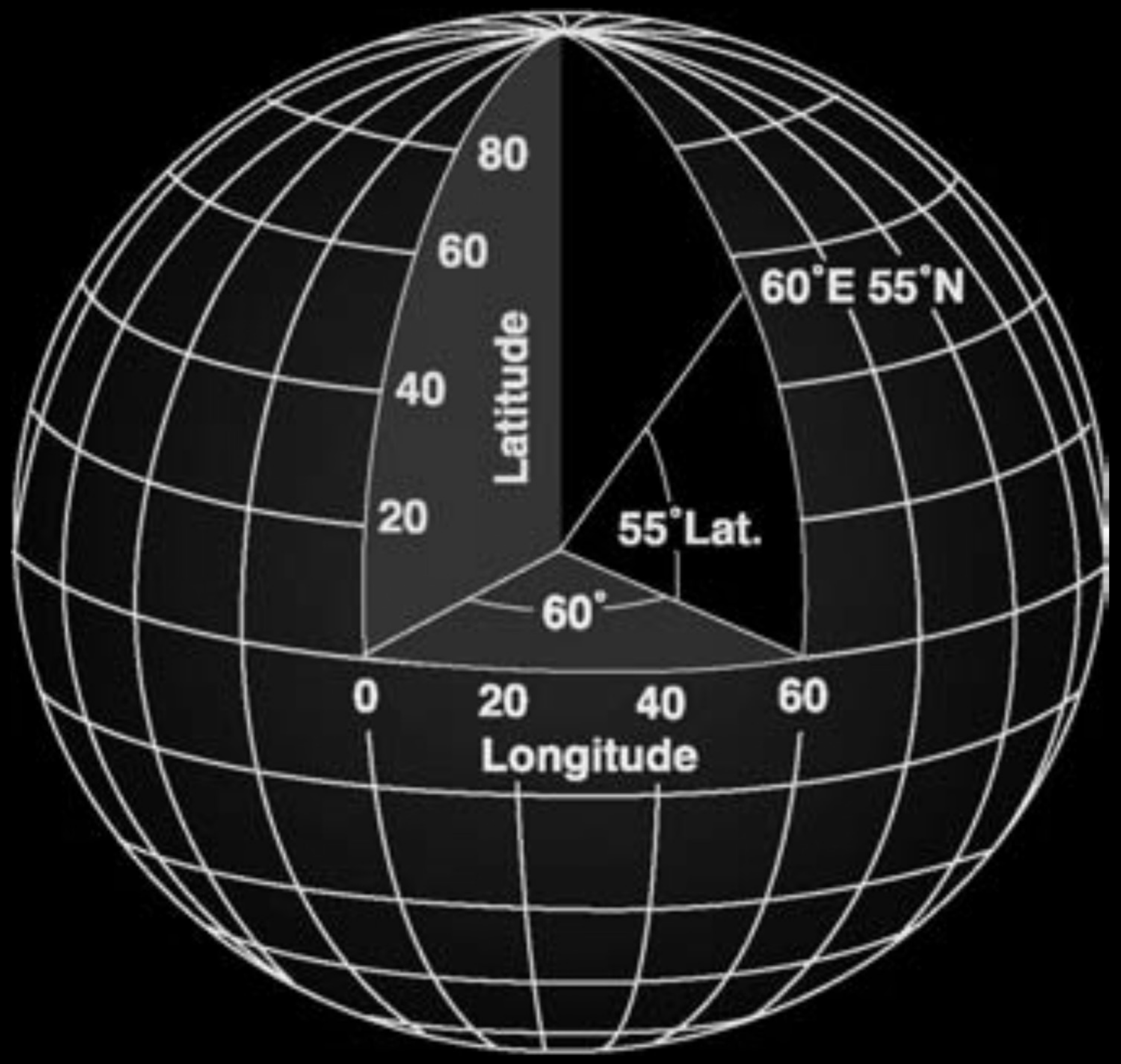
- Nominal
  - Placenames
- Ordinal
  - street addresses (in some of the world, anyway…)
- Interval or Cyclic
  - linear or angular distance from fixed places
    - e.g. from Equator or Greenwich Meridian

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 (≈ actual)

Latitude and Longitude



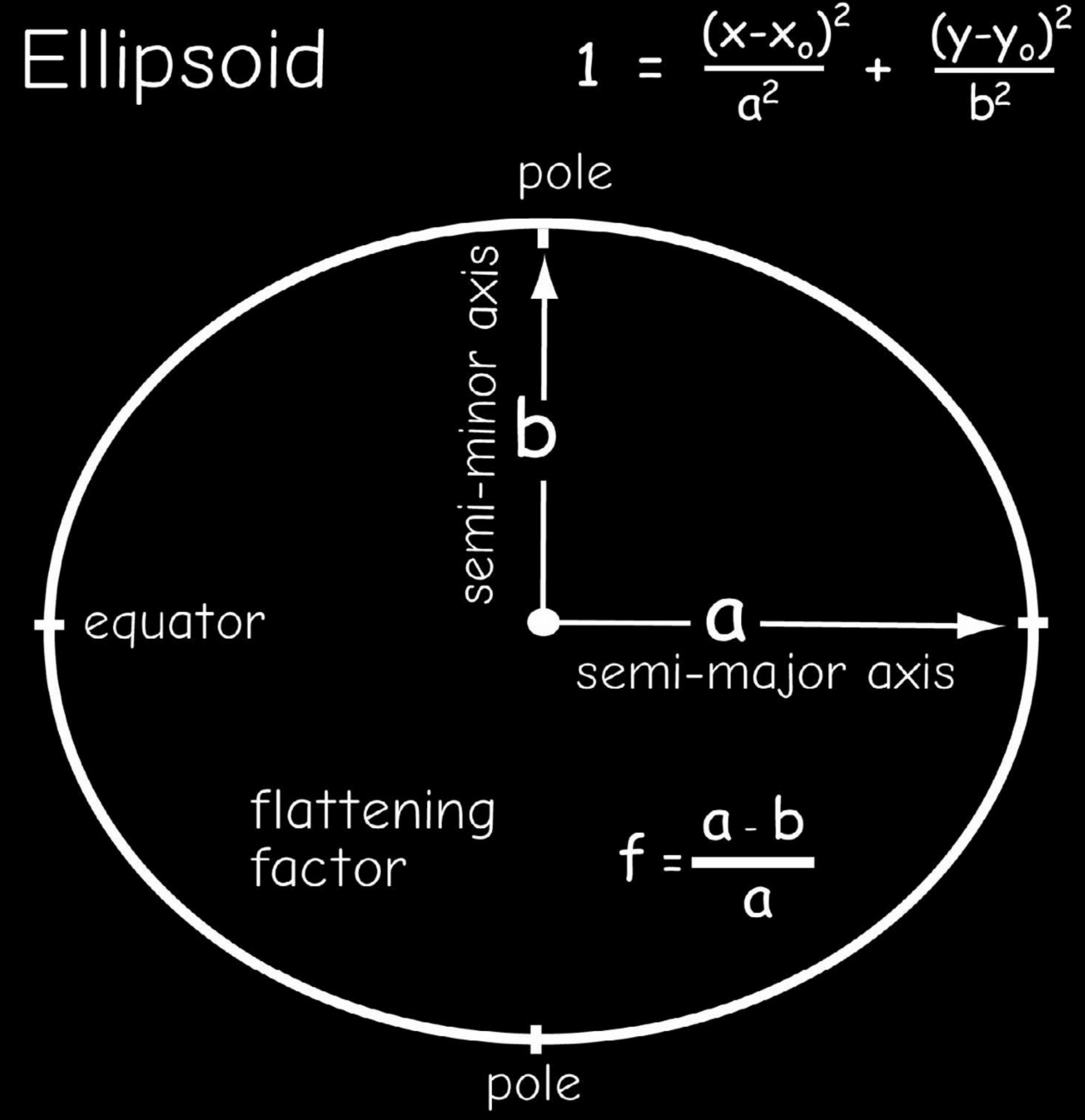
- Latitude
  - angle from equator (+ = N), on meridional plane
- Longitude
  - angle from prime meridian (+ = E), on equatorial plane

Prime Meridian at Greenwich, UK

Why the Greenwich meridian moved

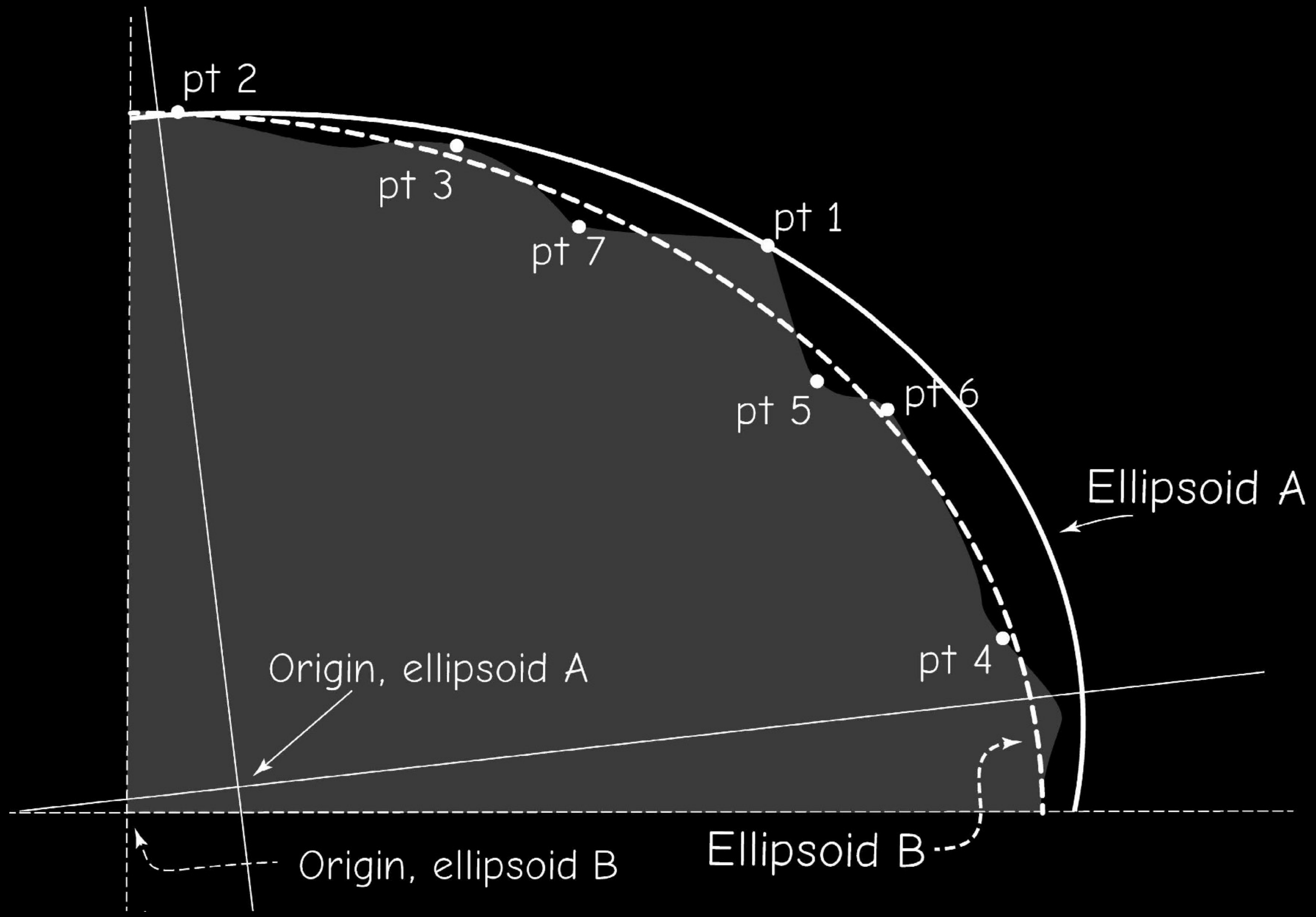
Earth Isn't Round 😕

- 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)

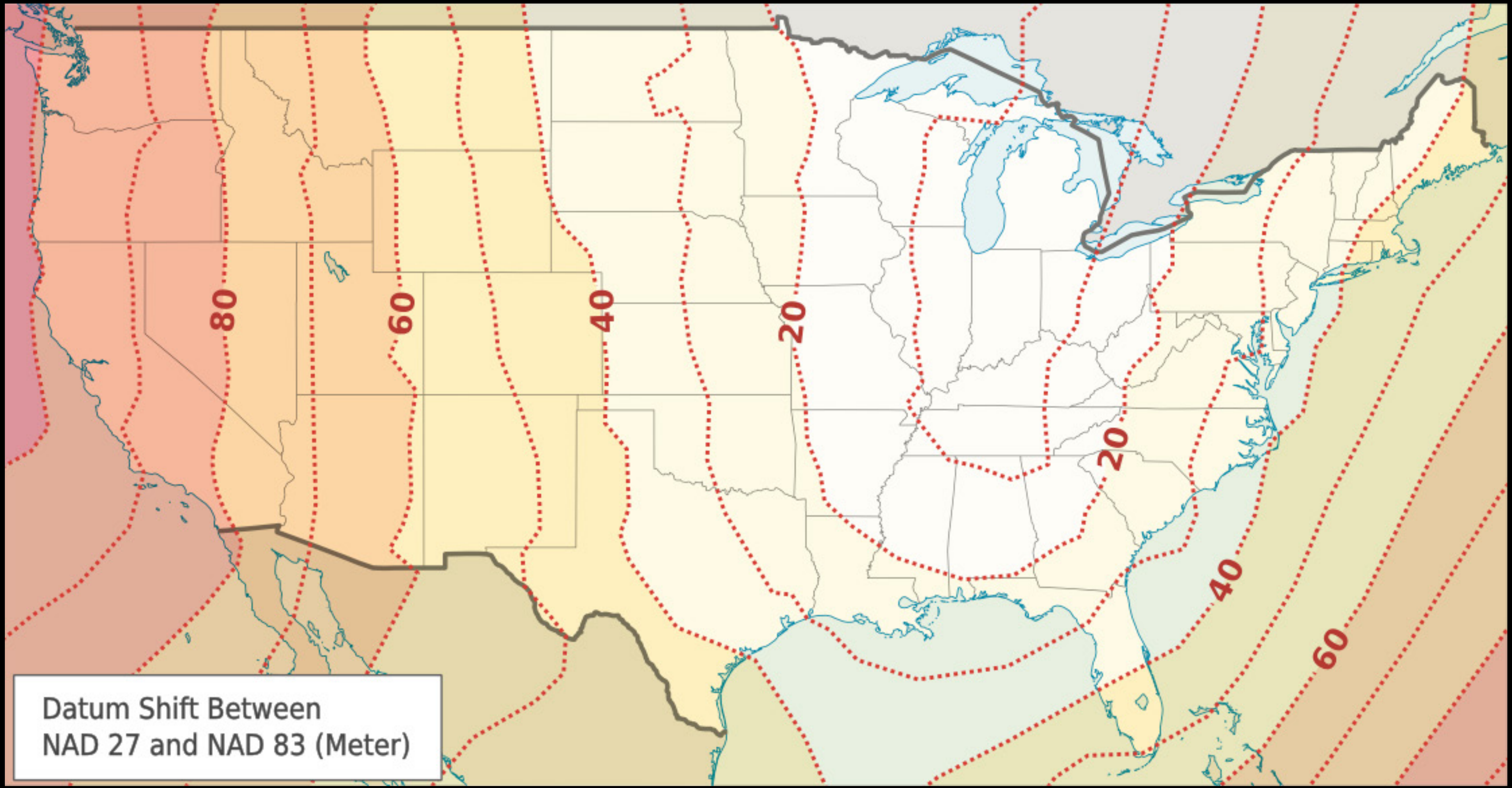


Why Different Datums?

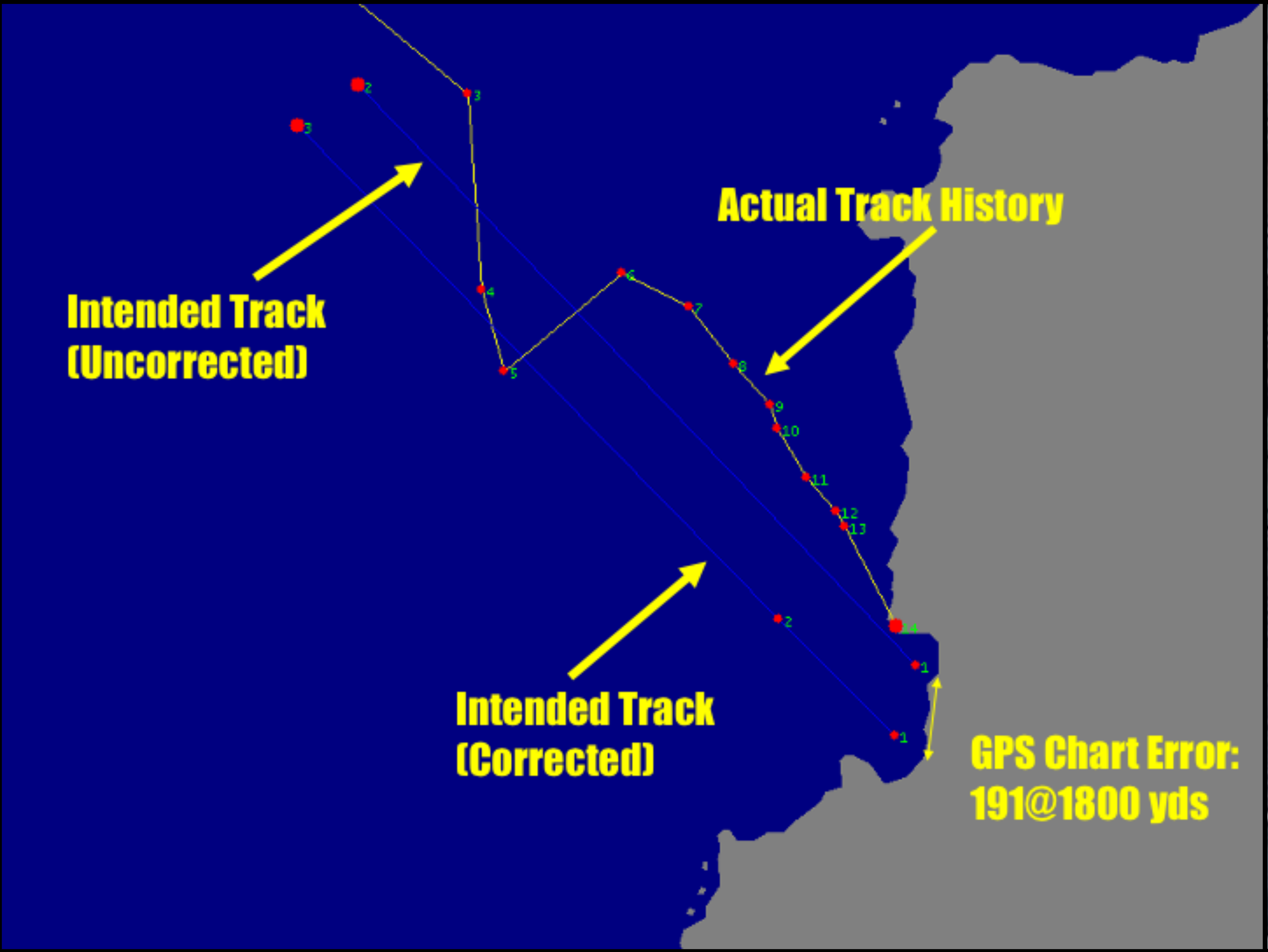
- Before satellites: many
  - Each country used “local best fit” ellipsoid
  - US: North American Datum of 1927 (**NAD27**)
    - Clarke 1866 ellipsoid
    - tangent to surface at Meades Ranch, KS
  - US: North American Datum of 1983 (**NAD83**)
    - GRS 1980 ellipsoid
      - Earth-centered
    - up 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



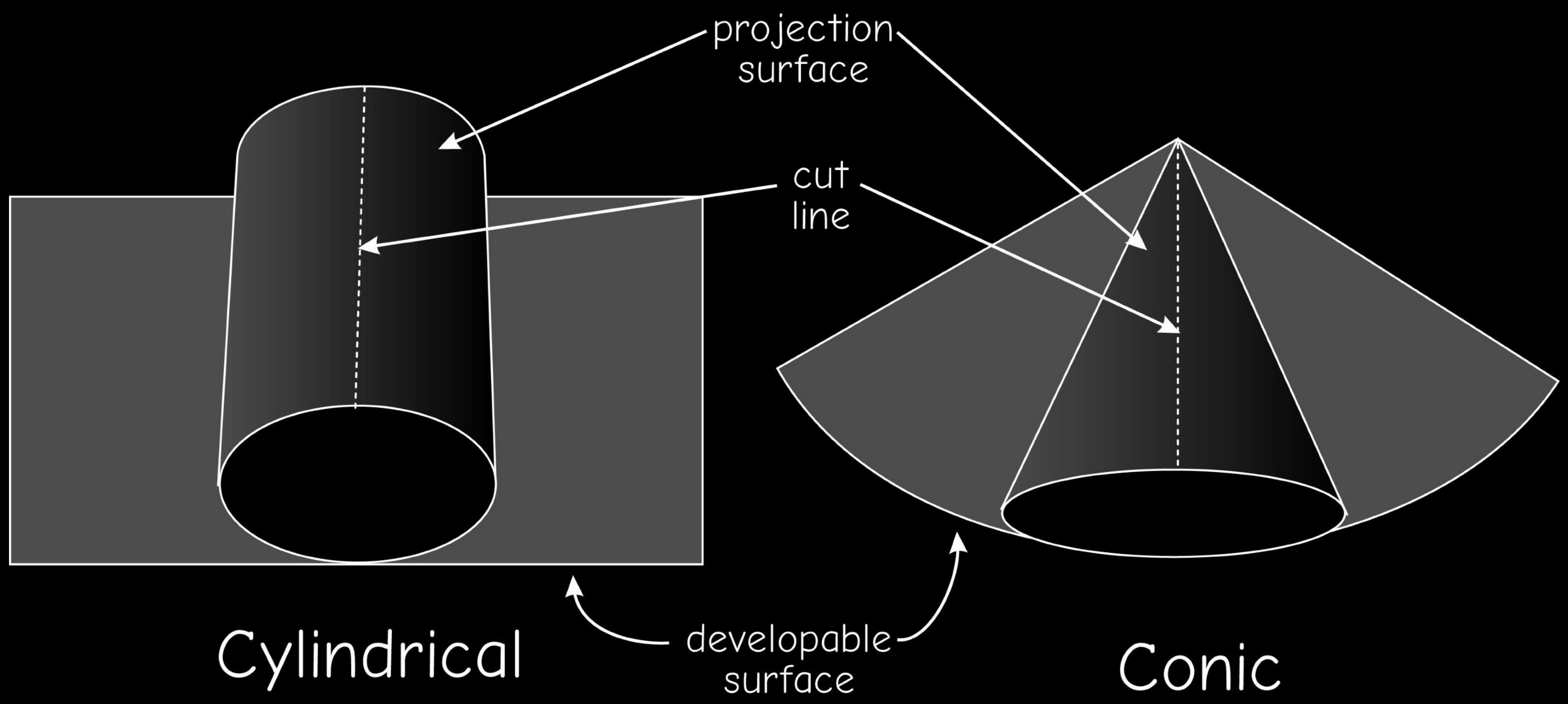
USS LA MOURE COUNTY ran aground in Caleta Cifuncho Bay, Chile
after navigating with GPS (WGS-84 datum) on a local chart with a local datum.

Projections

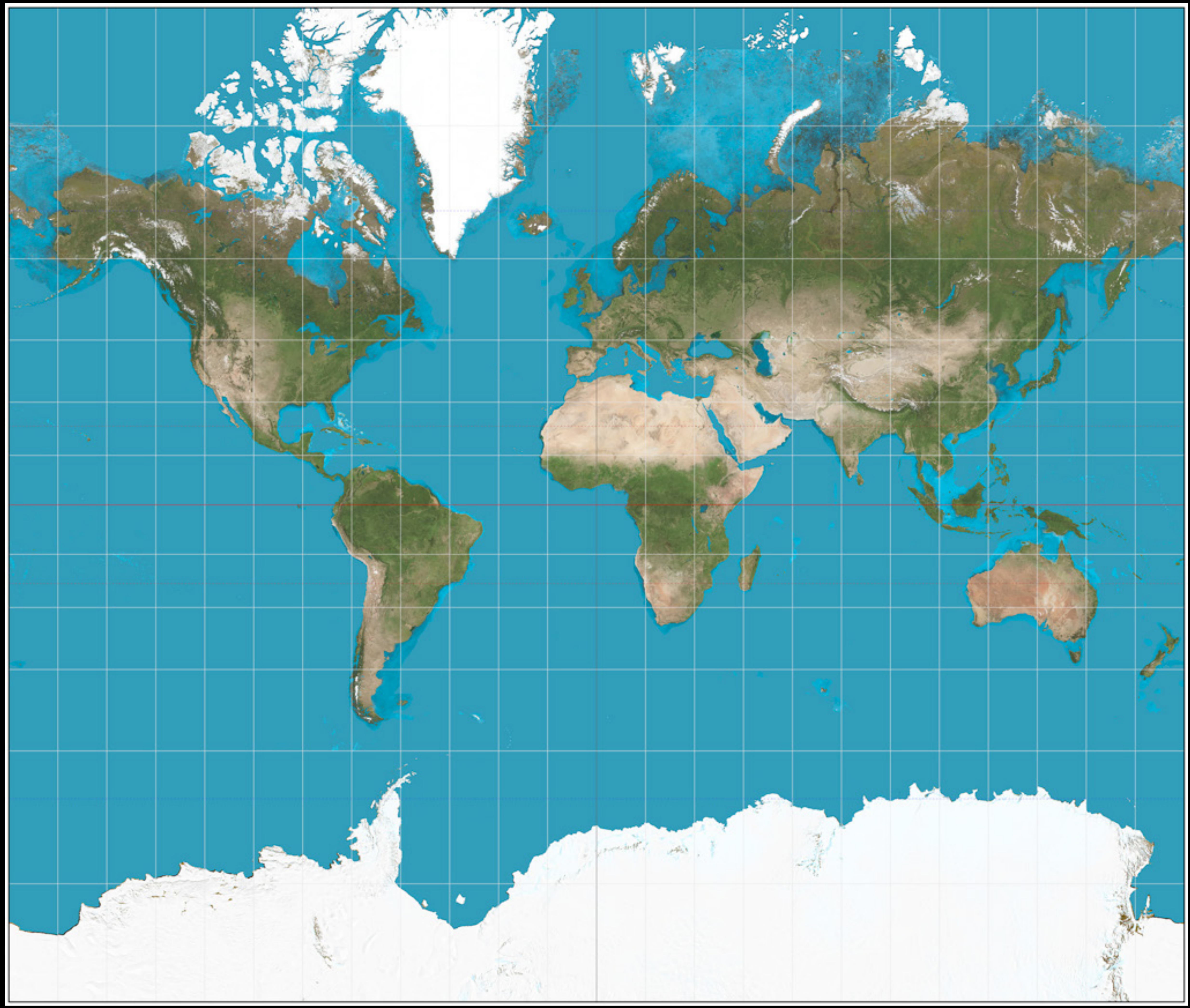
Why project Earth's surface onto plane?

- 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...

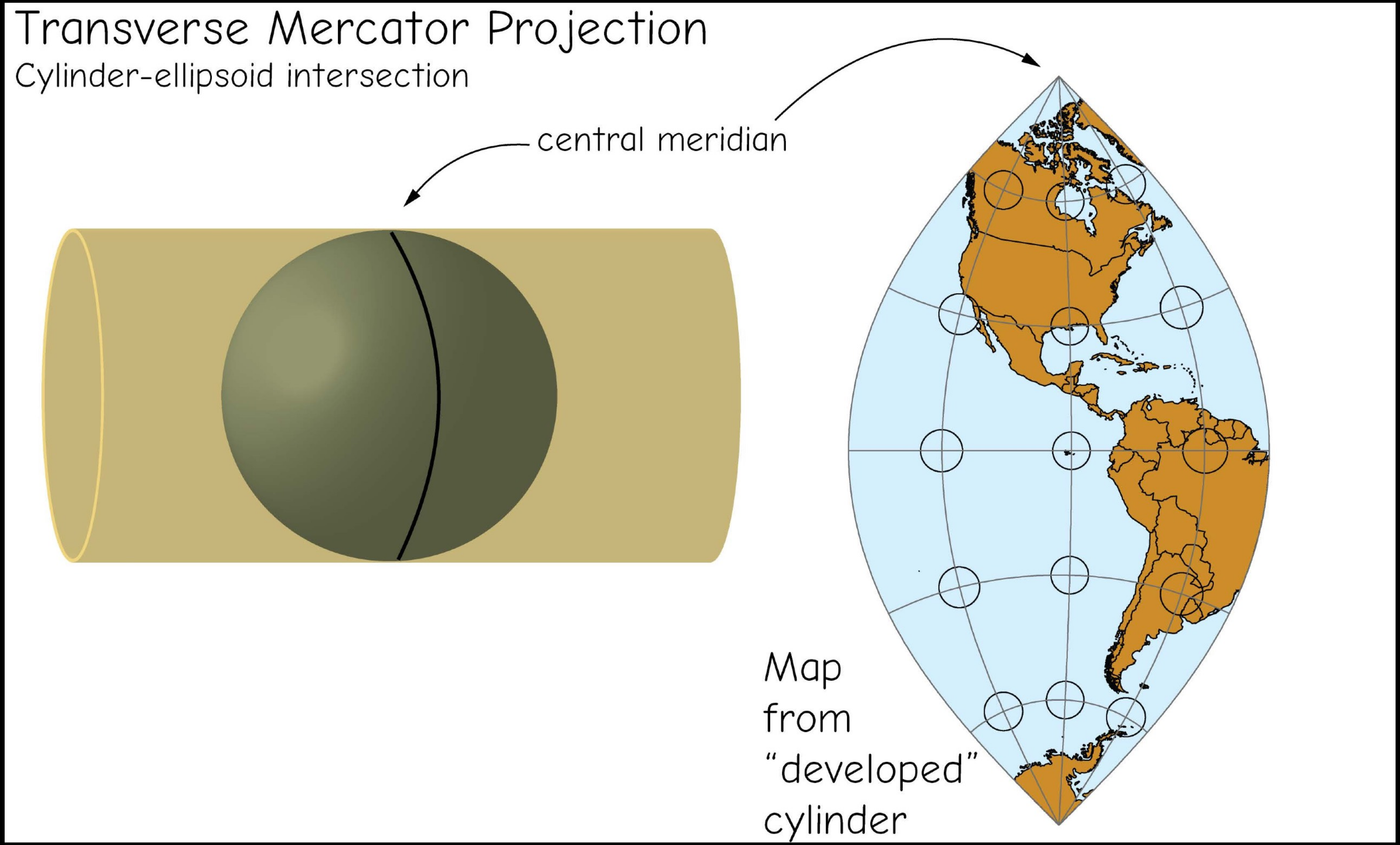
Projections



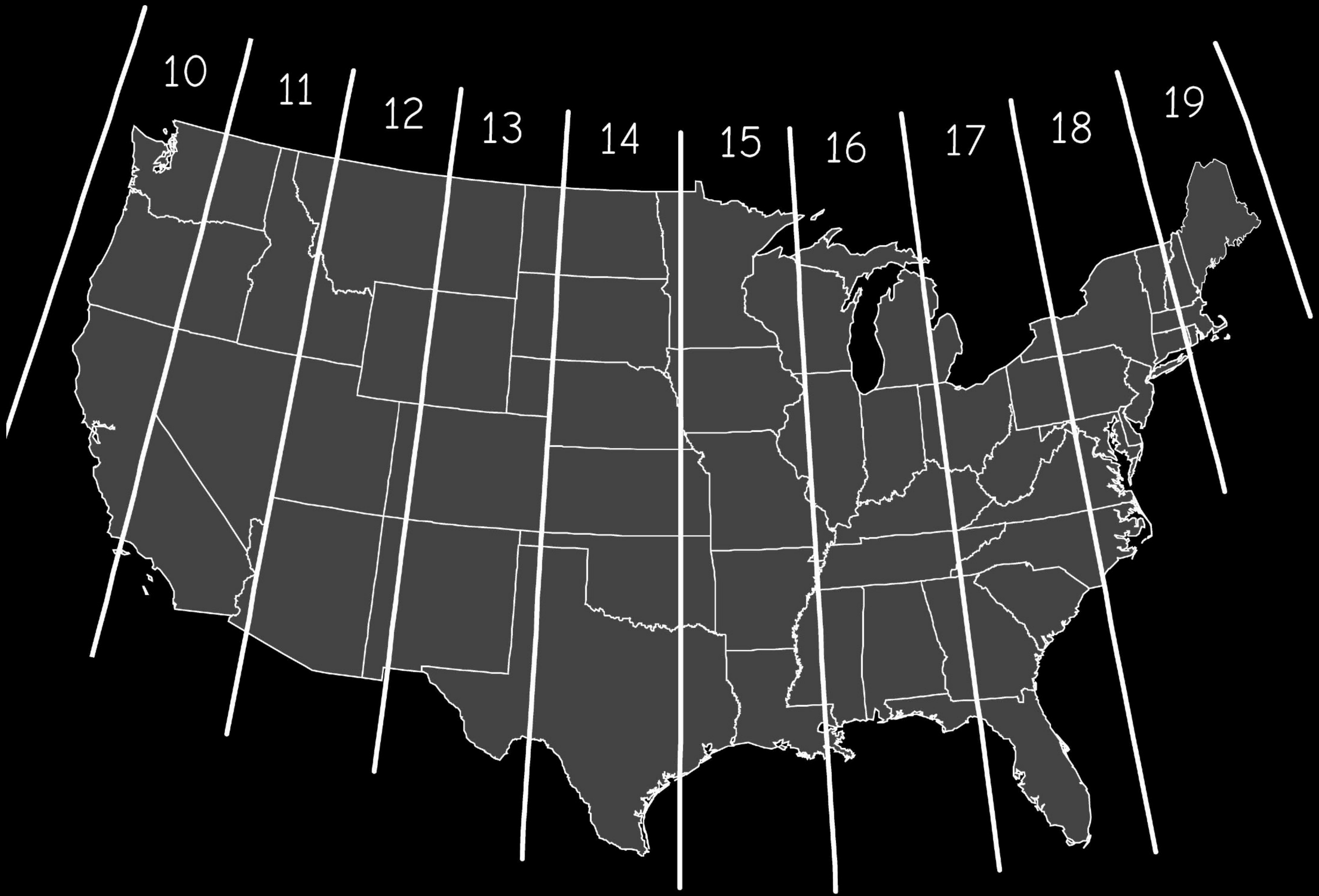
Cylindrical Projection Example: Mercator



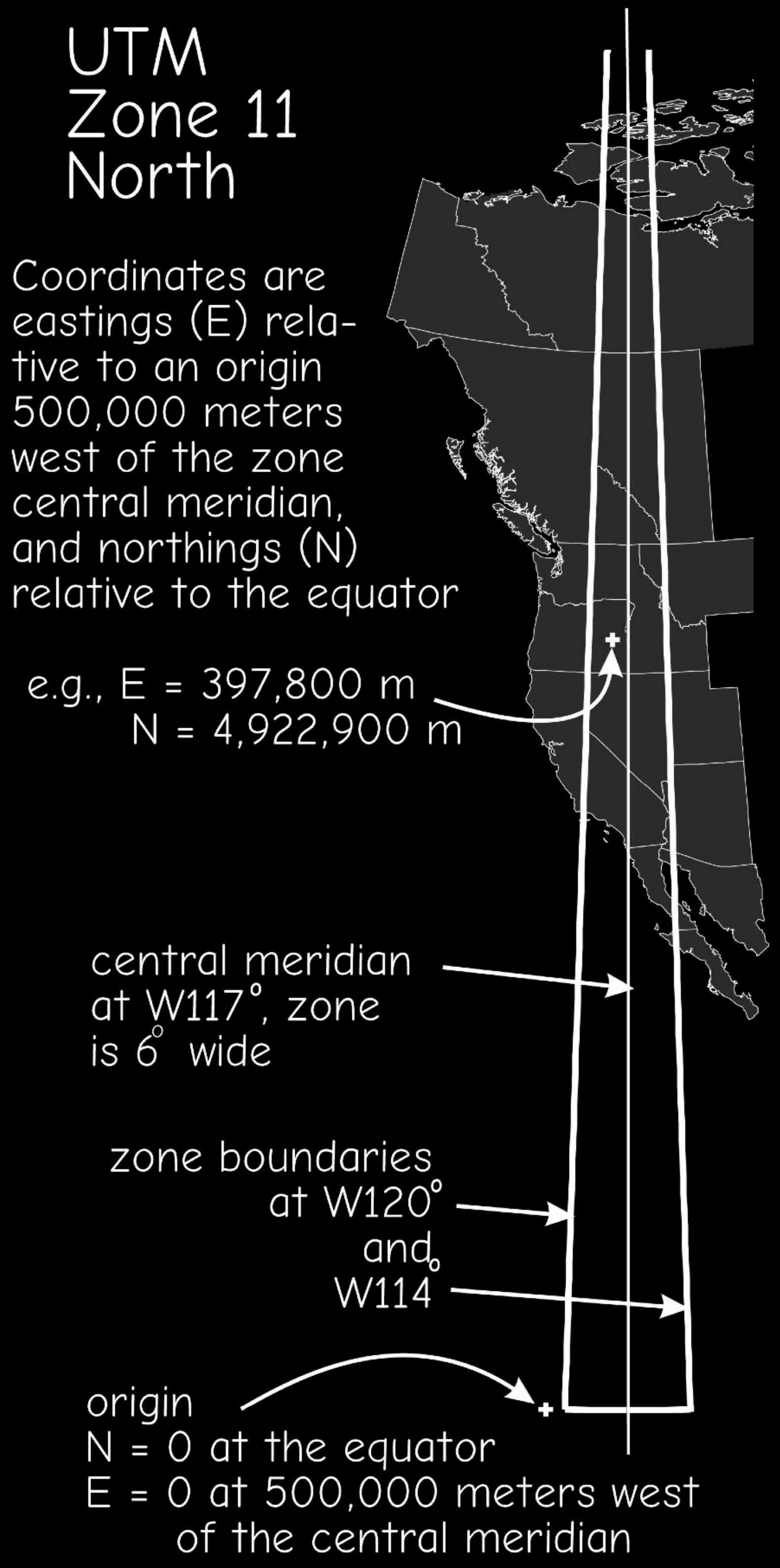
Transverse Cylindrical Projection



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%



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

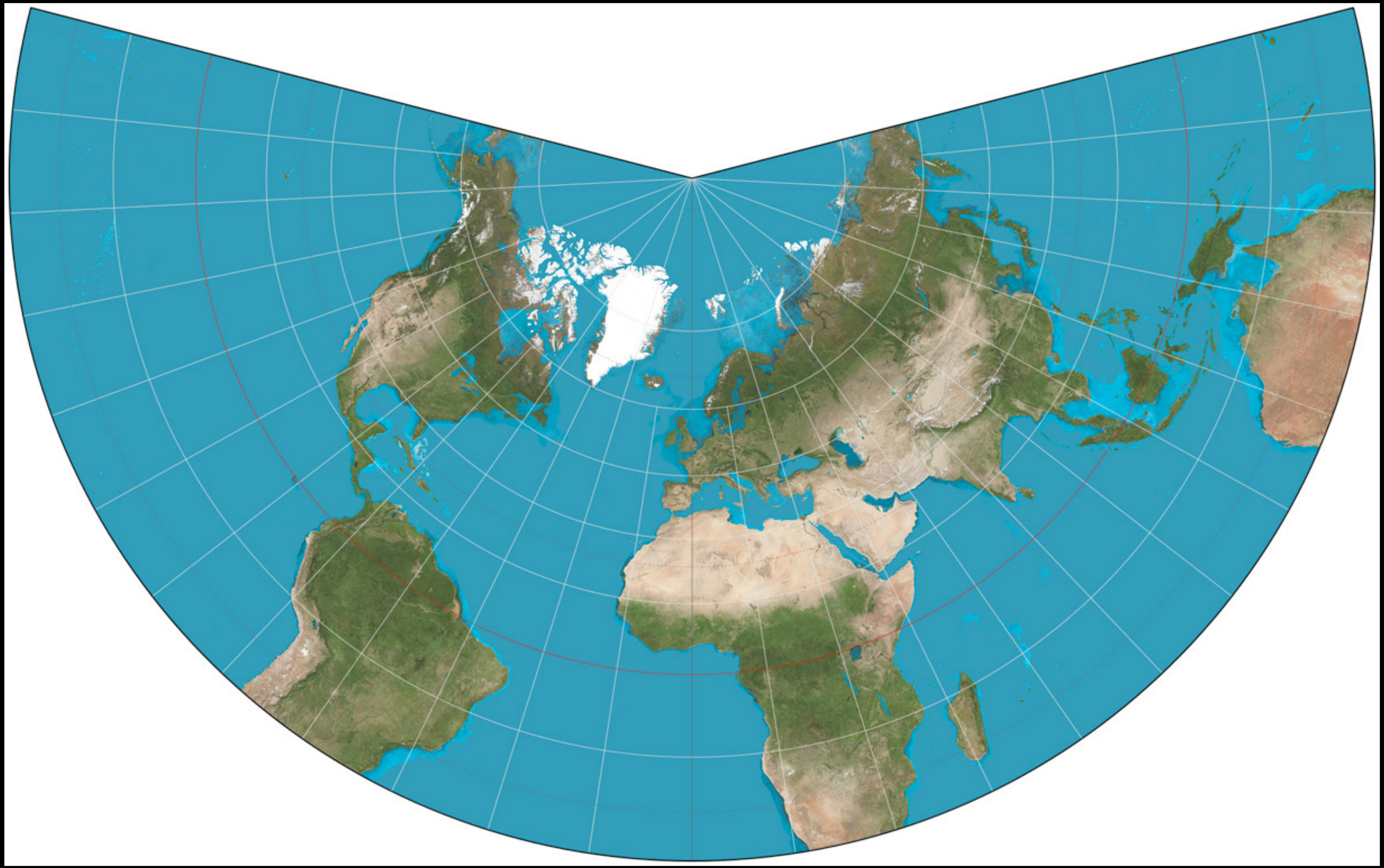
- Each zone is a different projection

- Adjacent zones won’t fit along border

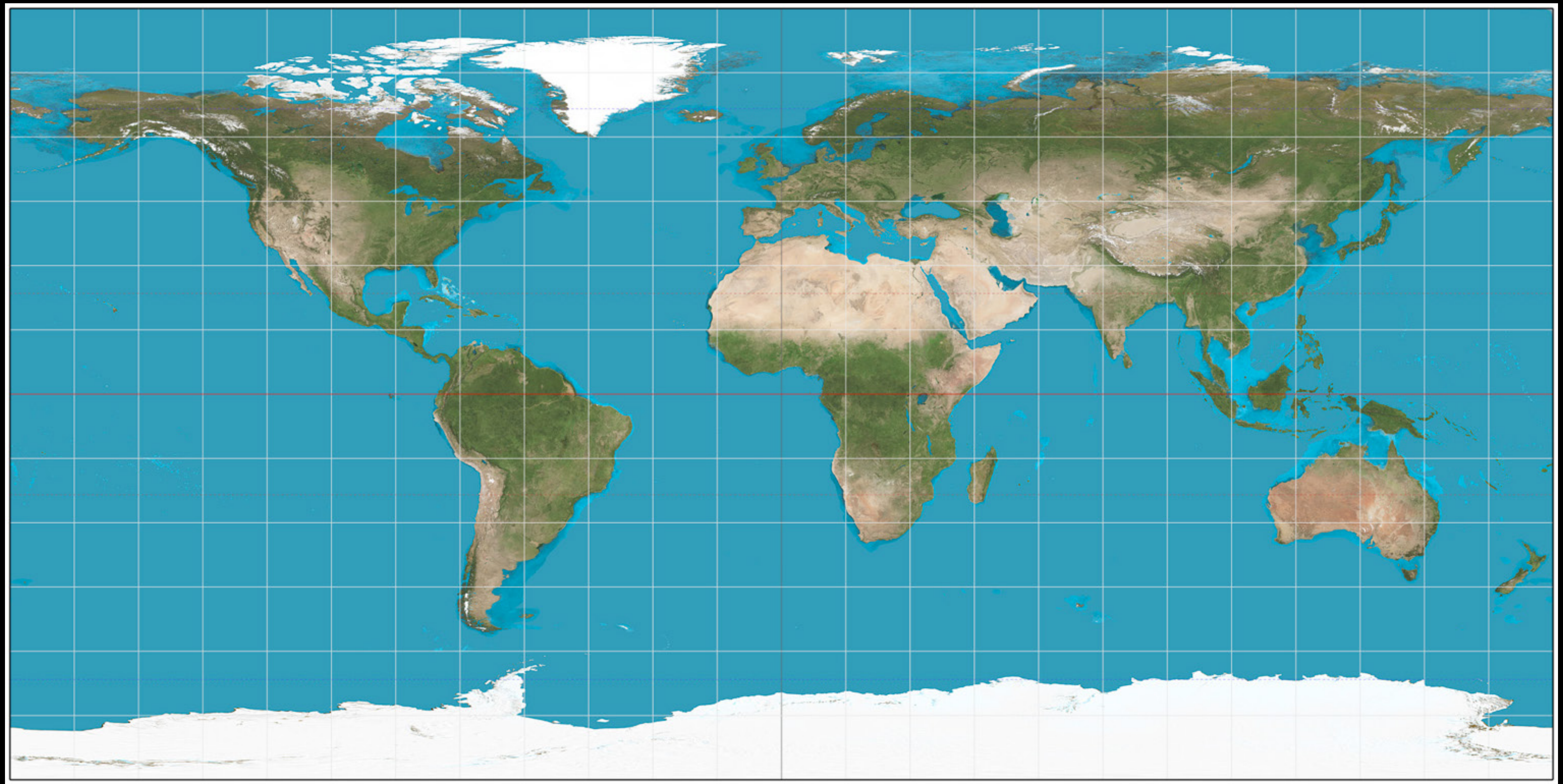
- What about areas that span zones?
  - Either: pick 1 zone
    - accept >normal distortions in other zone

  - Or: use other projection that spans area
    - E.g. CA (zones 10 & 11)
      - UTM zone “10½”
      - “California Albers” (equal area conic)

Conic Projection Example: Lambert Conformal Conic

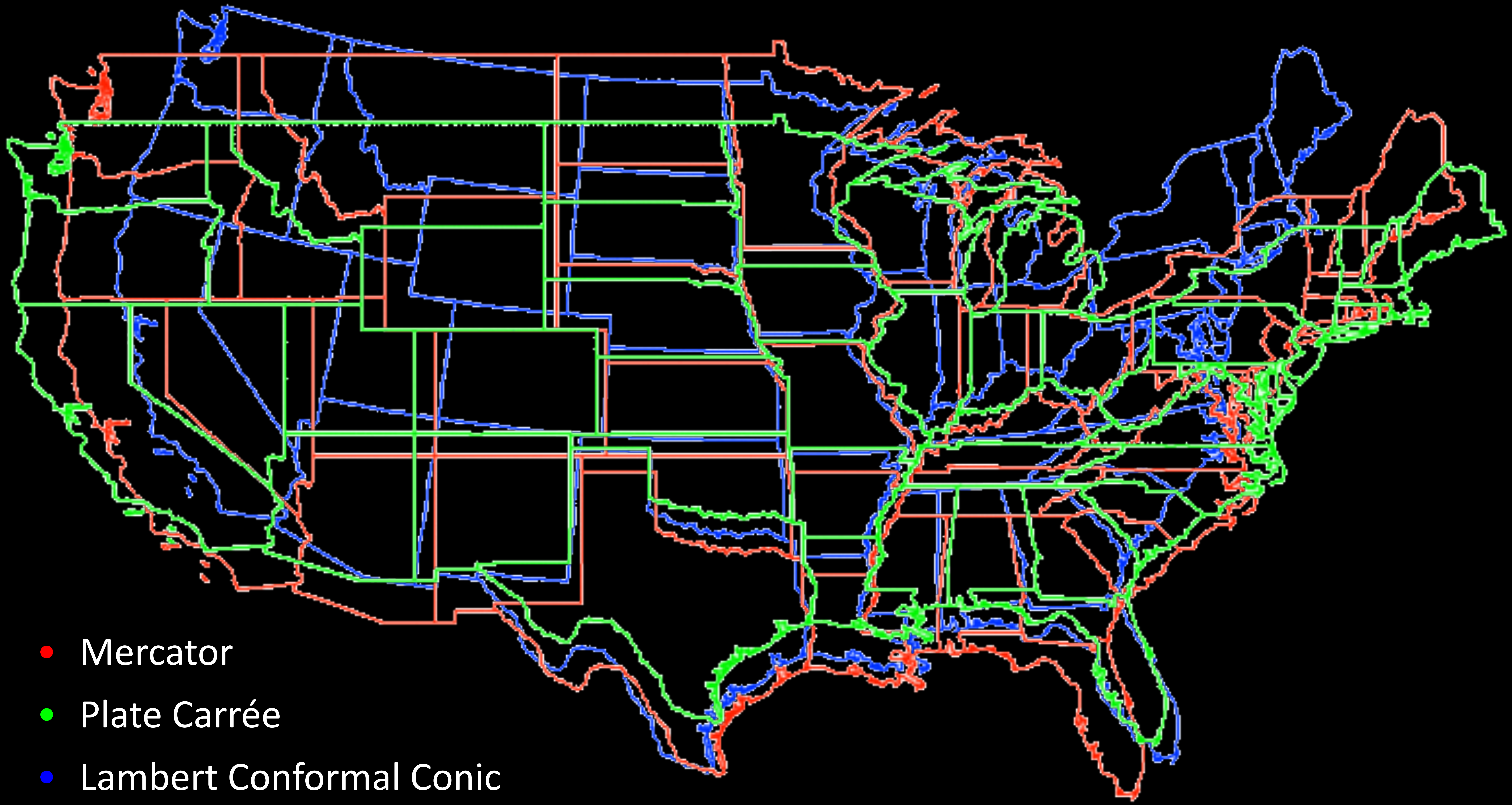


The “Unprojected” Projection (aka Plate Carrée)



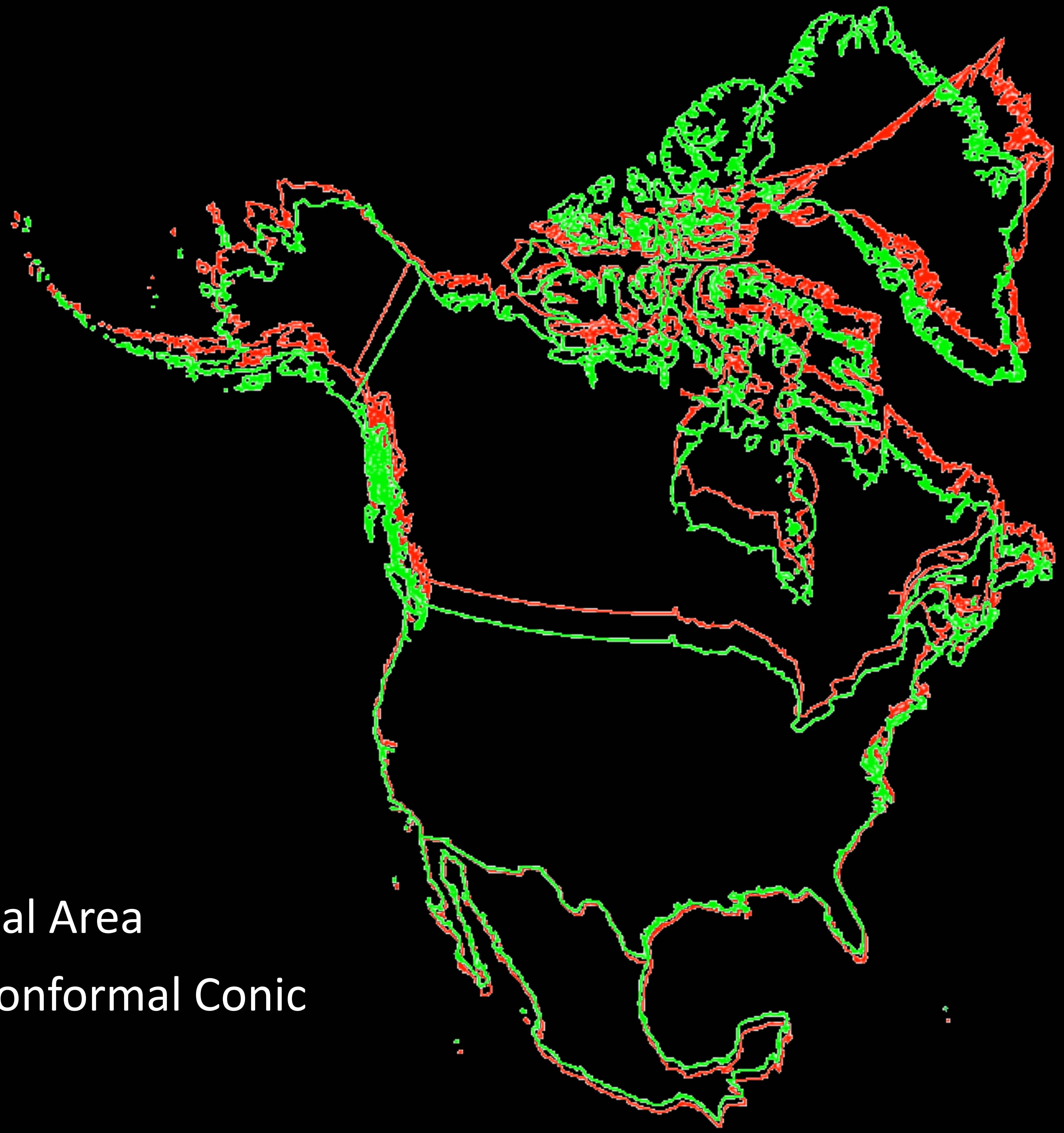
- X = longitude, Y = latitude
- Cylindrical projection
  - Neither conformal nor equal area

Comparing Projections: U.S.



- Mercator
- Plate Carrée
- Lambert Conformal Conic

Comparing Projections: North America



- Albers Equal Area
- Lambert Conformal Conic

State Plane Coordinates

- Defined in US by each state
  - Many different projections
  - Some states use multiple zones

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**

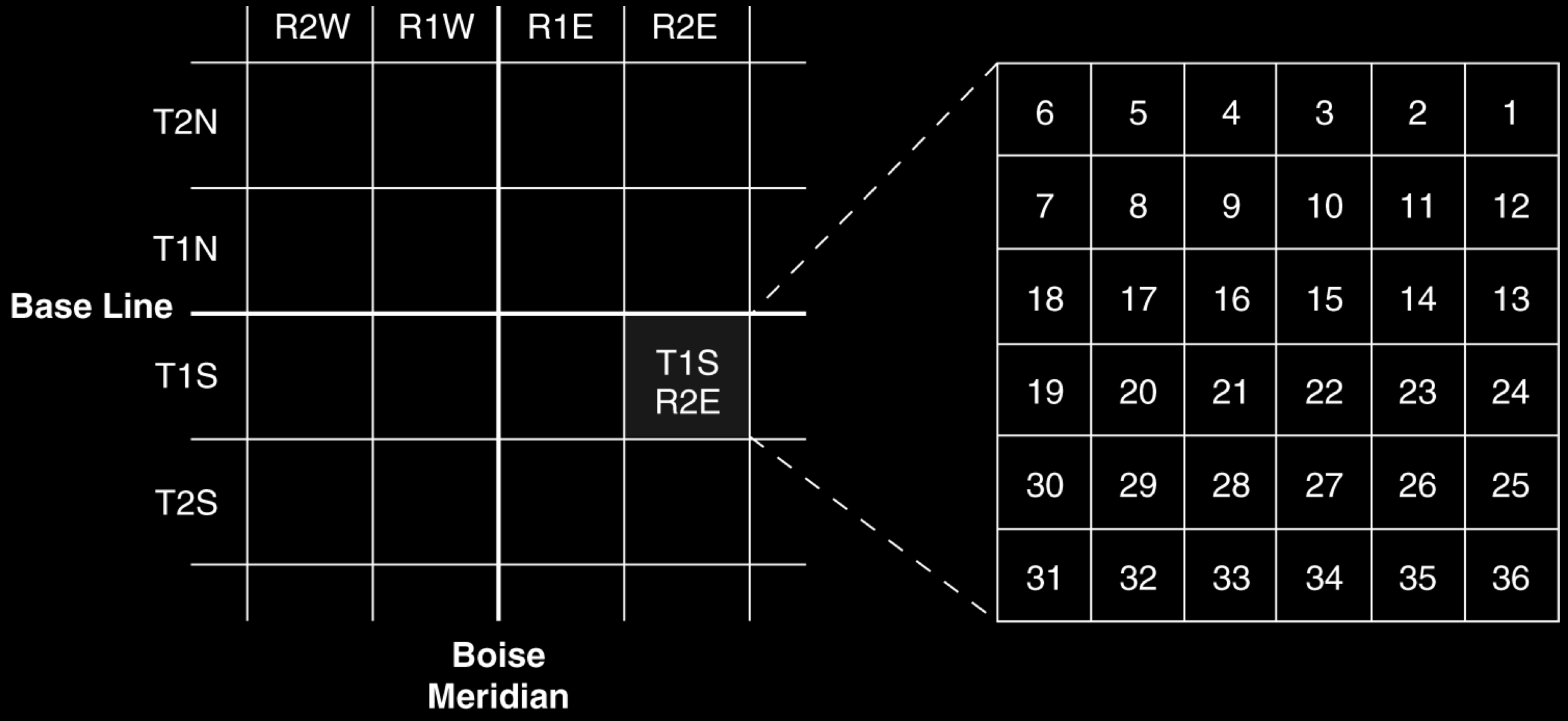
    (The smaller the area, the less important this distinction is.)

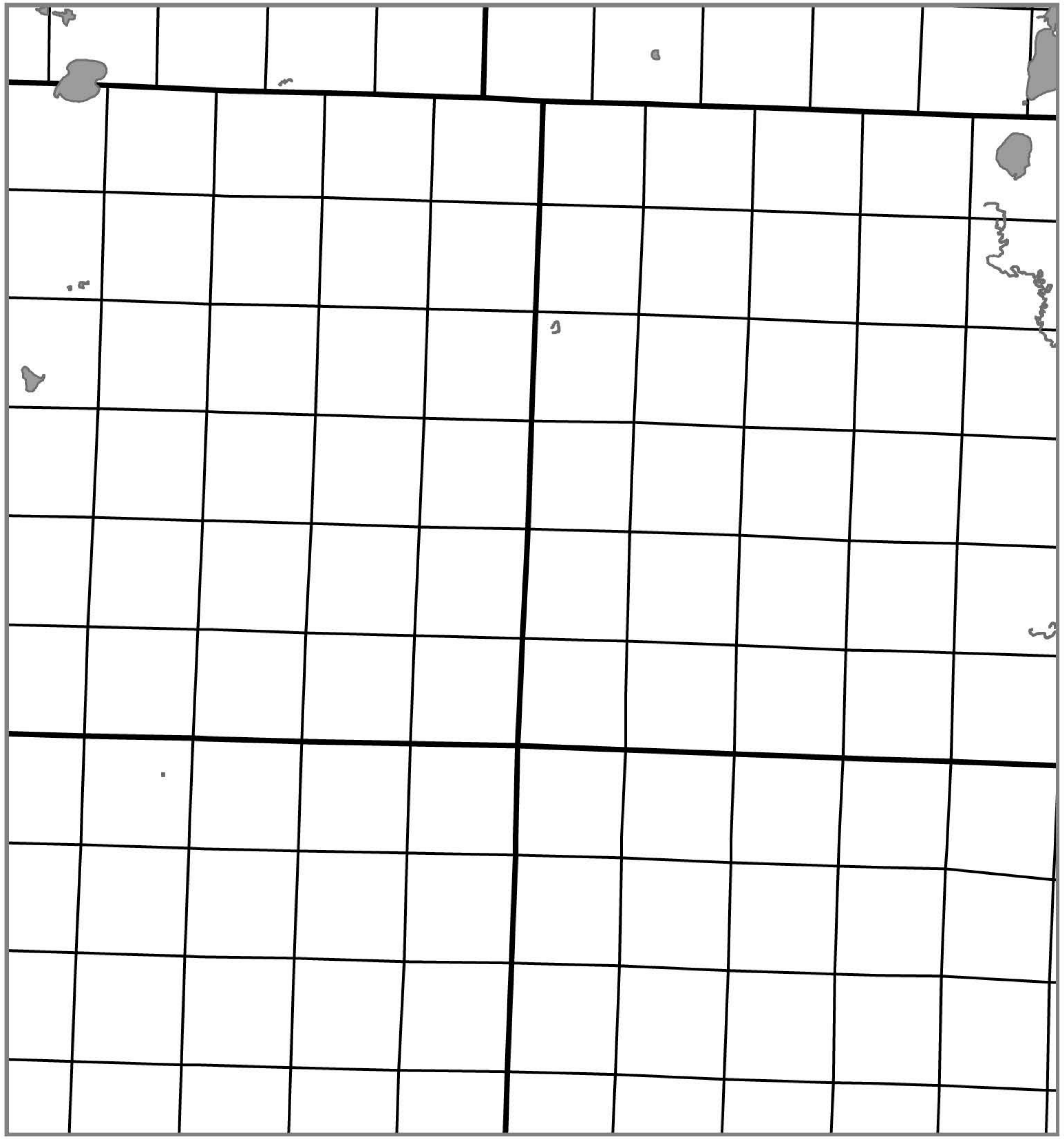
Cadasters

- 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

Township and Range System (PLSS)

- land ownership in most of western US
- townships laid out in six mile squares on either side of accurately surveyed Principal Meridian.
- Square mile sections within township numbered as shown east of PM, reversed west the Principal Meridian.



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 **iff** 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
    - Texas A&M
- Gazetteer
  - database of: place = (name, location, type)
    - U.S. Board on Geographic Names
    - GeoNames