Geodesy and Coordinate Systems

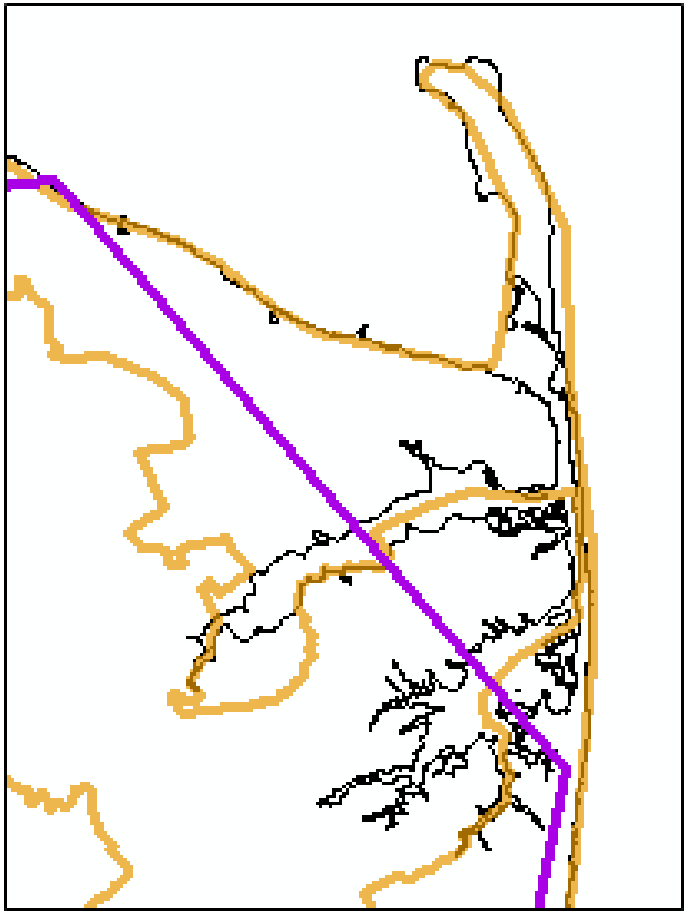
Today's Agenda

- Earth's Shape. What is it?
- Global Coordinate Systems
- Map Projections

Source scale

Data come at many scales

Need to find data at a suitable scale for your project



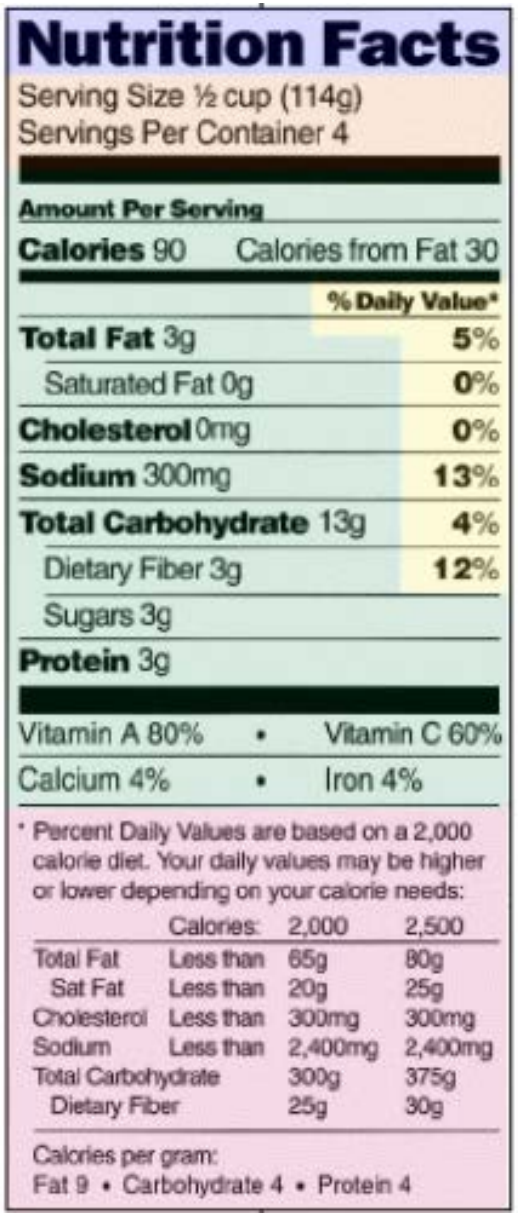
Purple scale 1:25 million

Orange scale 1:5 million

Black scale 1:50,000

Metadata

- Information about the data
- Who, what, where, when, and how of data
  - Example: USAcampgrounds feature class
    - Who: Agency or person who compiled the data
    - What: A description of the data
    - Where: The area over which the spatial data covers
    - When: The date when the dataset was last updated, and when the data was collected
    - How: How the data was compiled, the sources, etc.
- Calculations, projection and coordinate system, general description, licenses
- Travels with the dataset in associated files
- Accessed via ArcCatalog



Nutrition Facts

Serving Size ½ cup (114g)
Servings Per Container 4

Amount Per Serving

Calories 90 Calories from Fat 30

	% Daily Value*
Total Fat 3g	**5%**
Saturated Fat 0g	**0%**
Cholesterol 0mg	**0%**
Sodium 300mg	**13%**
Total Carbohydrate 13g	**4%**
Dietary Fiber 3g	**12%**
Sugars 3g	
Protein 3g	

Vitamin A 80% • Vitamin C 60%
Calcium 4% • Iron 4%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories:	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

Metadata for Massachusetts State boundary outline in ArcCatalog

ArcCatalog - C:\Users\James_Heiss\OneDrive - University of Massachusetts Lowell - UMass Lowell\GIS\outline25k\OUTLINE25K_ARC.shp

File Edit View Go Geoprocessing Customize Windows Help

C:\Users\James_Heiss\OneDrive - University of Massachusetts Lowell - UMass Lowell\GIS\outline25k

Catalog Tree

- Folder Connections
  - C:\onedrive\Teaching\ENVI301
  - C:\Users\James_Heiss\Desktop
  - C:\Users\James_Heiss\Docume
  - C:\Users\James_Heiss\OneDriv
    - cb_2017_us_state_500k
    - North_Atlantic
    - outlin
    - outline25k
      - OUTLINE25K_ARC.shp
      - OUTLINE25K_POLY.shp
    - proTest
    - Toolbox.tbx
    - Duck.mxd
    - Merrimack estuary.mxd
  - C:\Users\James_Heiss\OneDriv
  - C:\Users\James_Heiss\OneDriv
  - C:\Users\James_Heiss\OneDriv
- Toolboxes
- Database Servers
- Database Connections
- GIS Servers
- My Hosted Services
- Ready-To-Use Services

Contents Preview Description

Print Edit Upgrade Import

OUTLINE25K_ARC

Shapefile

Tags

Massachusetts 25K coast Outline political boundary boundaries 25000

Summary

Planning and analysis

Description

The outline of the Commonwealth of Massachusetts. MassGIS digitized 1:25,000 linework from U.S. Geological Survey mylar map sheets for land boundaries; a 1:25,000 coastline was extracted from the MassGIS Hydrography (1:25,000) layer. OUTLINE25K_ARC contains the line feature class.

Credits

There are no credits for this item.

Use limitations

None

Extent

West -73.533350 East -69.898568
North 42.888351 South 41.230598

Scale Range

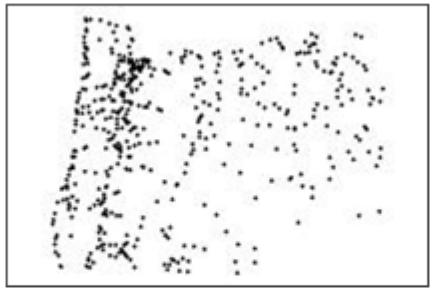
There is no scale range for this item.

You are currently using the Item Description metadata style. Change your metadata style in the Options dialog box to see additional metadata content.

Shapefile selected

U.S. National Atlas Cities

Personal GeoDatabase Feature Class



Tags

point, cities, towns, populated places, population, location, United States, Puerto Rico, U.S. Virgin Islands

Summary

U.S. National Atlas Cities provides information about the locations, names, and populations of cities and towns for conducting geographic analysis on national and large regional scales.

Description

U.S. National Atlas Cities represents cities and towns in the United States.

Credits

Access granted to Licensee only.

Access and use limitations

See legal constraints.

ArcGIS Metadata ▼

FGDC Metadata ▼

Geodesy

Olney Hall is 115 ft. above mean sea level.

What does that mean??

Coordinate systems

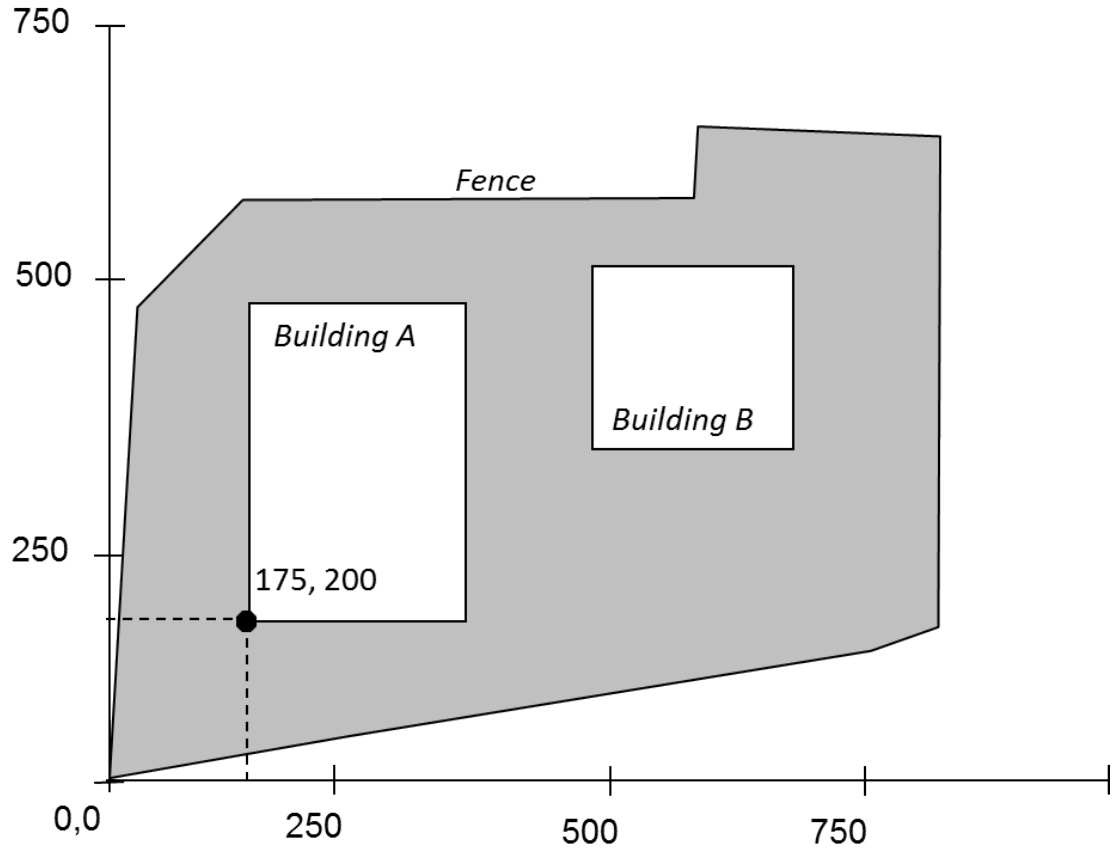
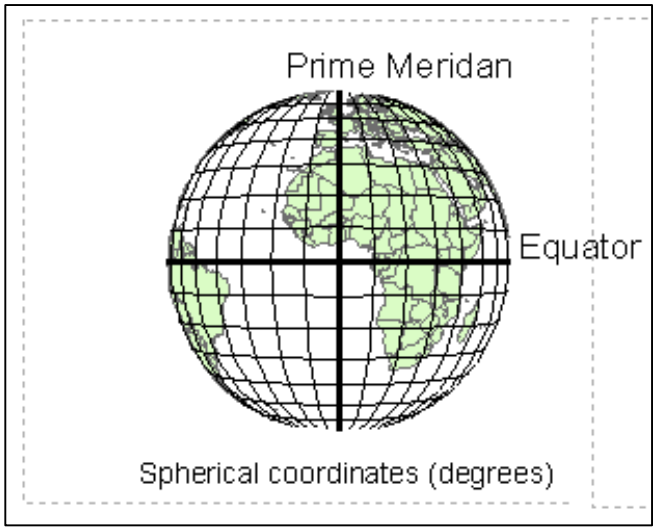
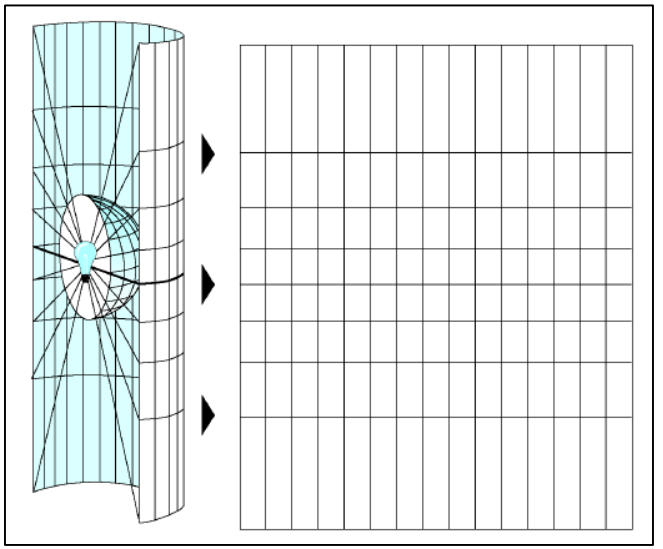


Figure 1. An arbitrary coordinate system used for surveying a site

Types of coordinate systems

- Global (3D)
  - Based on spherical globe coordinates
  - Degrees of latitude and longitude
- Projected (2D)
  - Converts spherical coordinates to planar
  - Set of mathematical equations
  - Projects 3D coordinates to 2D map



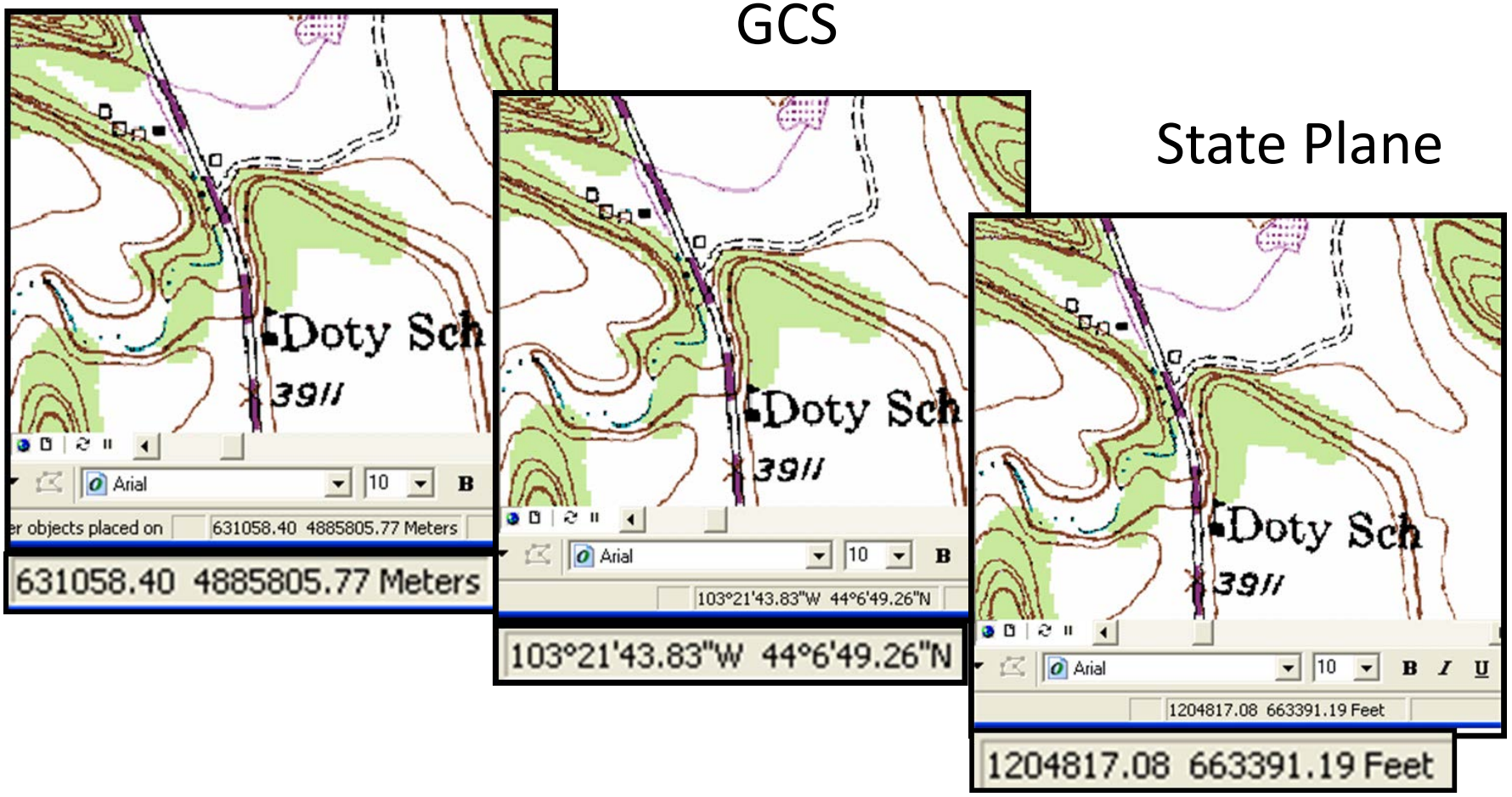


Same point—different x-y's

UTM Zone 13

GCS

State Plane



The Spatial Reference

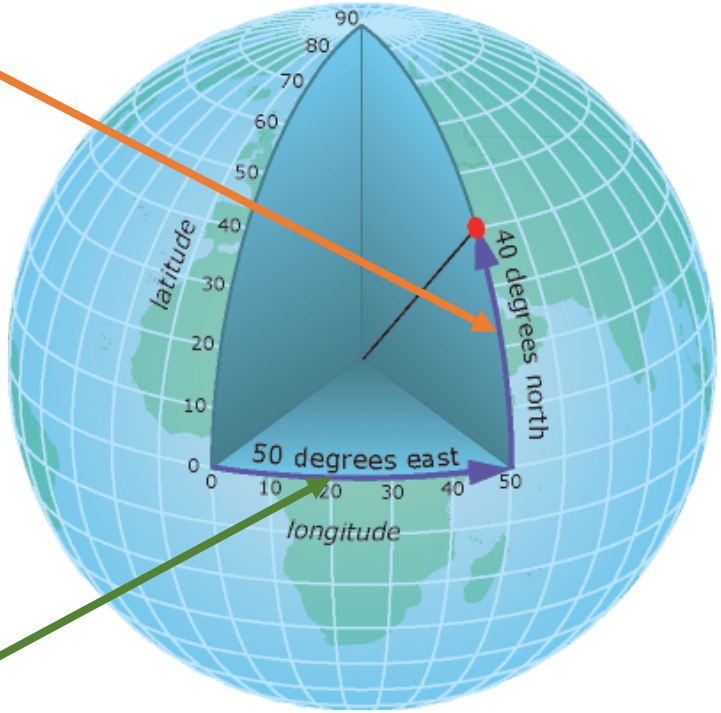
Every data set requires a complete description of its coordinate system for proper display and analysis

- **Geographic coordinate system / datum**
- **Projection** (if one is used)
- **Storage units** used to store the x-y values (degrees, feet, etc.)
- **Domain**, or maximum allowable x-y values
- **Resolution**, or the x-y precision

Geographic coordinate systems

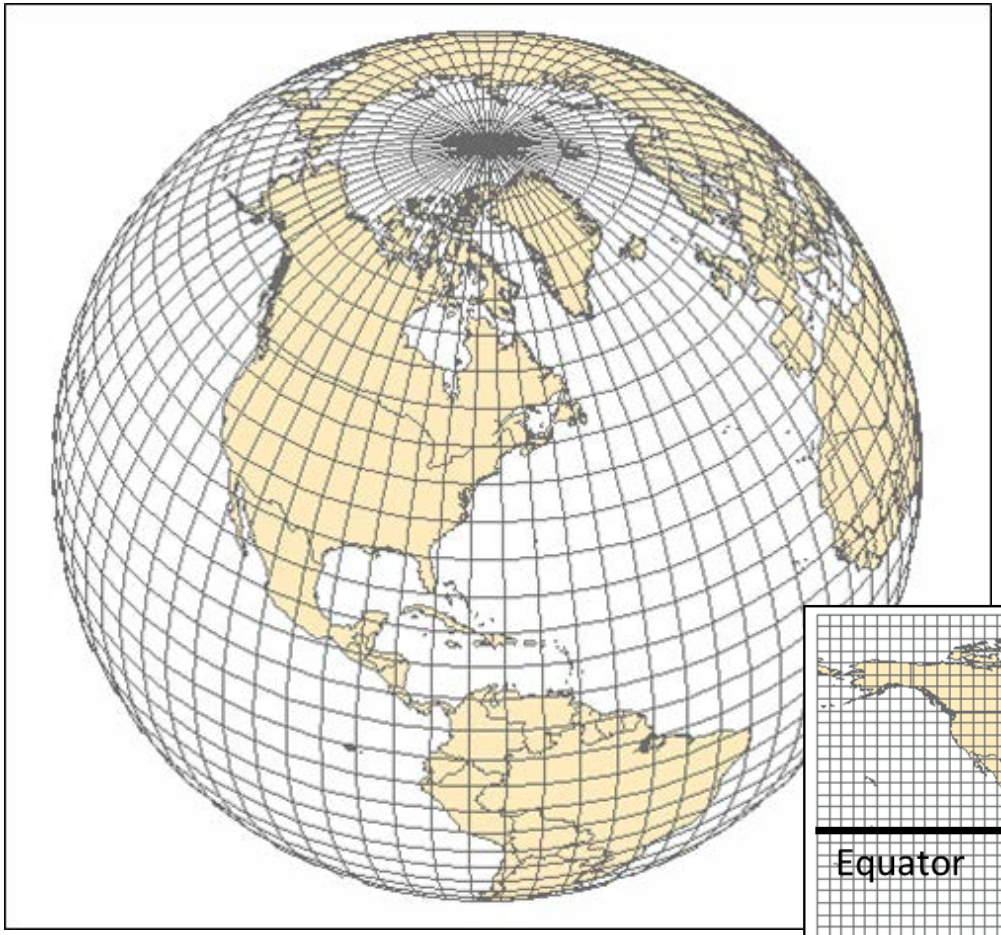
Geographic coordinate systems
Units: Degrees

Latitude measures the angle from the horizontal. It represents north-south distance from the equator.



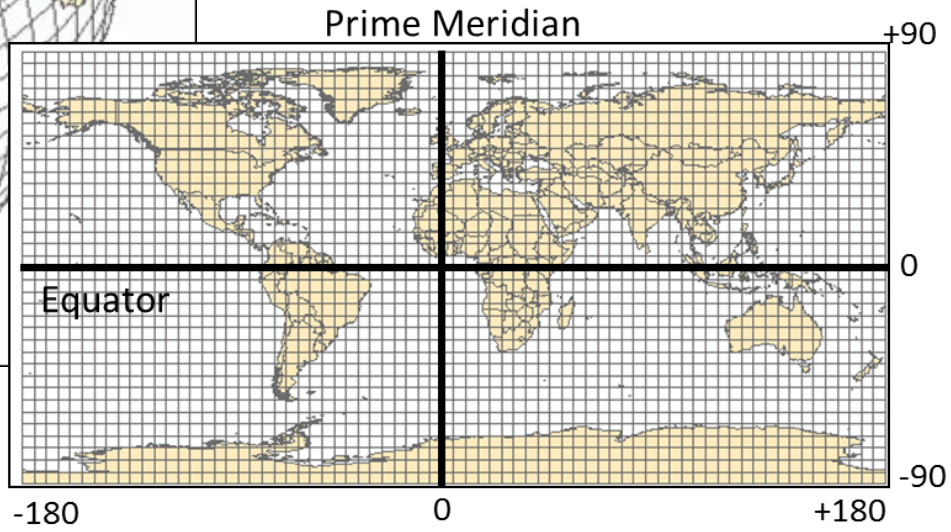
Longitude measures around the circle of the equatorial plane. It represents east-west distance from Prime Meridian.

GCS properties



Measured in degrees

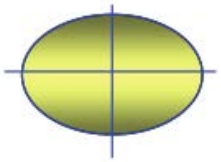
In a GIS, the 2D surface introduces distortion



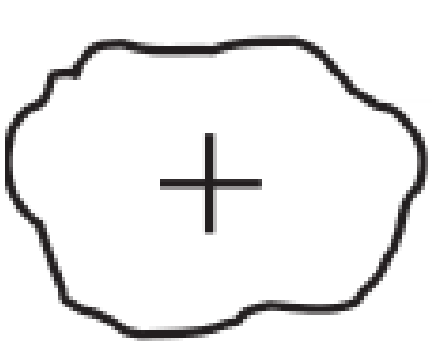
Earth's Shape. What is it?

Earth is not a sphere

Earth is not an ellipsoid



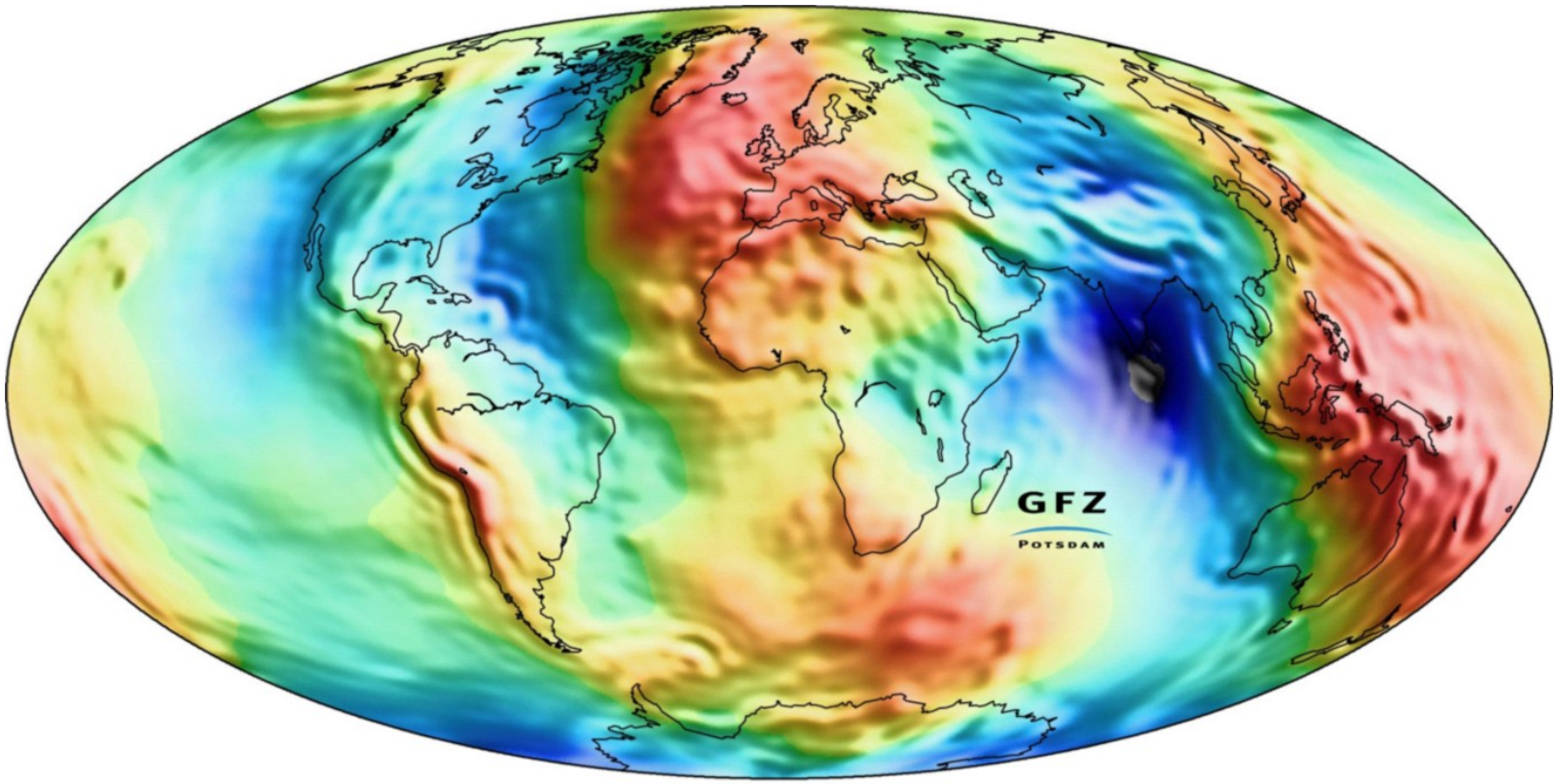
So what shape it?



Geoid

Credit: NASA/JPL

Earth's Geoid



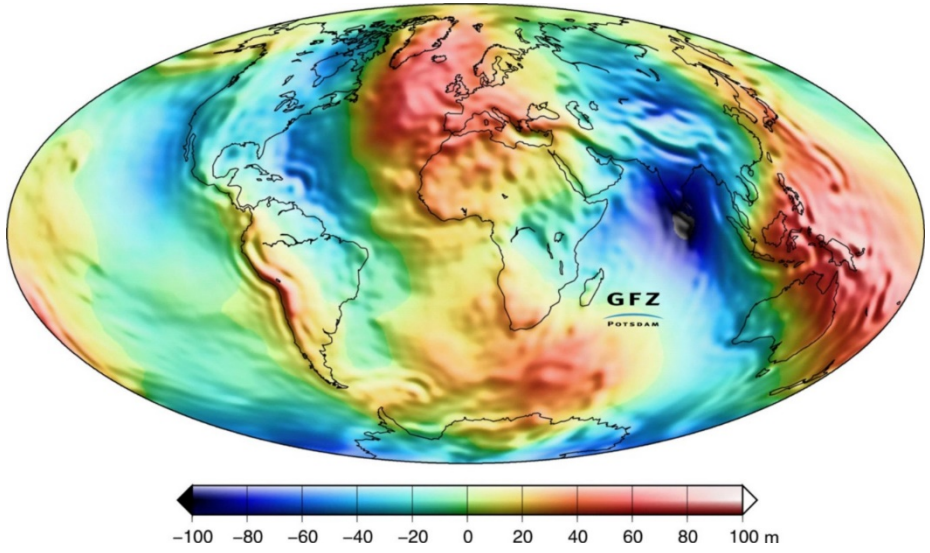
How to we assign an X, Y, and Z location to a point on the geoid?

Earth's Geoid

Earth's geoid is defined as: "the theoretical ocean surface of the Earth, if the oceans were in equilibrium, at rest, and extended through the continents"

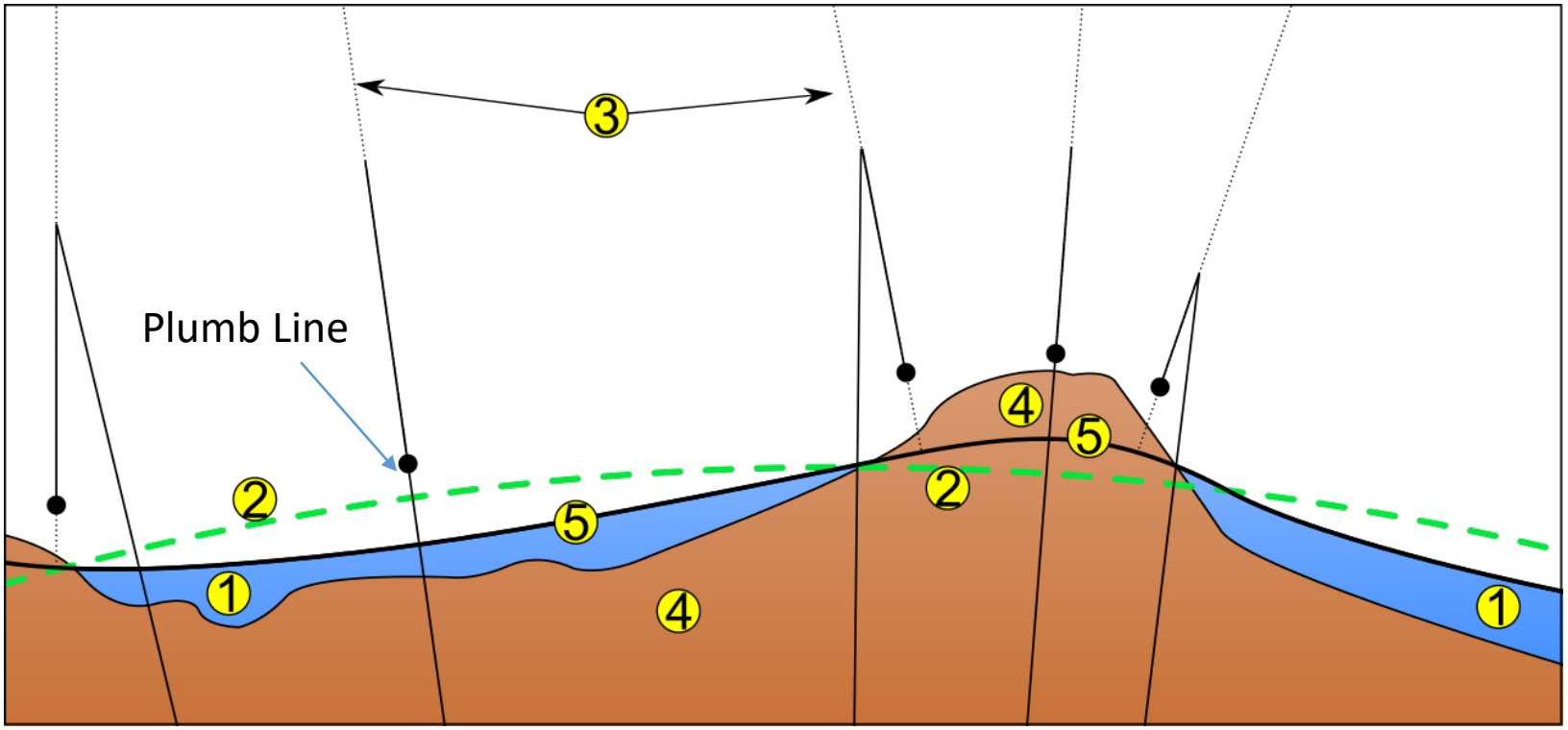
Remove the continents, but keep their gravity, and extend the ocean into those areas. Also remove tides, waves, currents

The geoid is the shape of the ocean surface if the entire earth were covered by ocean, but still subjected to the gravity caused by the continents



The geoid is 0 elevation

Earth's Geoid



1. Ocean
2. Reference ellipsoid
3. Local plumb line
4. Continent
5. Geoid

Plumb lines are always perpendicular to the geoid

Geoids are complex!

$$V = \frac{GM}{r}\left(1 + \sum_{n=2}^{n_{\max}}\left(\frac{a}{r}\right)^n \sum_{m=0}^{n} \overline{P}_{nm}(\sin\phi)\left[\overline{C}_{nm}\cos m\lambda + \overline{S}_{nm}\sin m\lambda\right]\right),$$

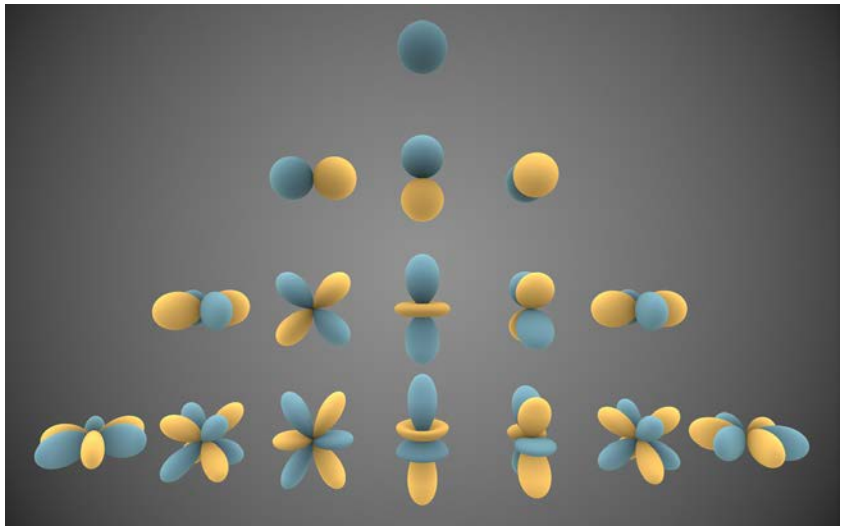
$$\sum_{n=2}^{n_{\max}}(2n+1) = n_{\max}(n_{\max}+1) + n_{\max} - 3 = 130317 \text{ using the EGM96 value of } n_{\max} = 360 .$$

$$\nabla^2 f = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial f}{\partial r}\right) + \frac{1}{r^2\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial f}{\partial\theta}\right) + \frac{1}{r^2\sin^2\theta}\frac{\partial^2 f}{\partial\varphi^2} = 0.$$

$$V(\mathbf{x}) = \sum_i \frac{m_i}{|\mathbf{x}_i - \mathbf{x}|}.$$

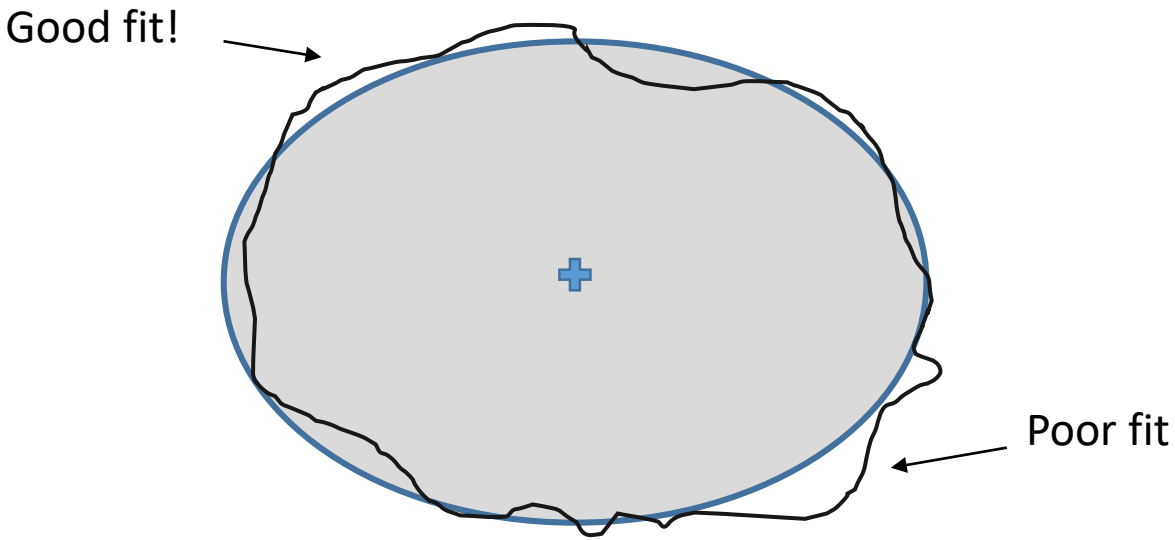
$$\frac{1}{|\mathbf{x}_1 - \mathbf{x}|} = P_0(\cos\gamma)\frac{1}{r_1} + P_1(\cos\gamma)\frac{r}{r_1^2} + P_2(\cos\gamma)\frac{r^2}{r_1^3} + \cdots$$

$$\mathbf{L}^2 = -r^2\nabla^2 + \left(r\frac{\partial}{\partial r} + 1\right)r\frac{\partial}{\partial r}$$



Let’s use ellipsoids instead (phew)

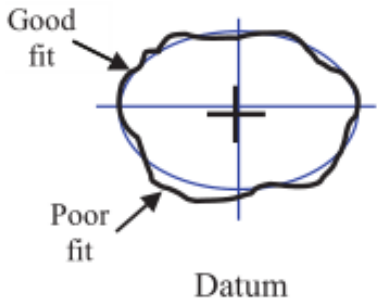
Let’s use an ellipsoid and shift it to the left and tilt it so part of it overlays with the geoid



An ellipsoid and its shift is a **datum**

Datums

A datum is a specific ellipse that has been shifted so that it's surface aligns with the geoid in a particular location



Datums North America:

North American Datum 1927 (NAD 1927 or NAD27)

- Based on Clarke 1866 spheroid, common until the 1980's and still used for some data sets.

North American Datum 1983 (NAD 1983 or NAD83)

- Current popular datum for most mapping. GRS80 spheroid.
- First choice if you must assume an unknown datum for a set of undocumented data.

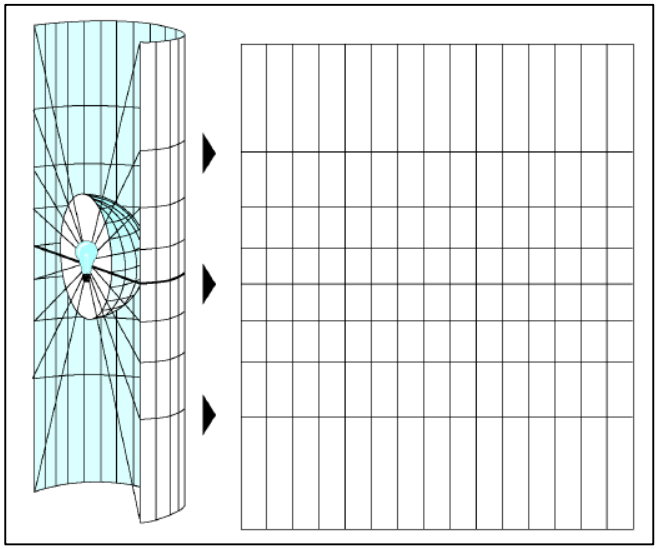
North American Datum 1983 HARN (NAD 1983 HARN)

- Updates NAD83

World Geodetic Survey 1984 (WGS84)

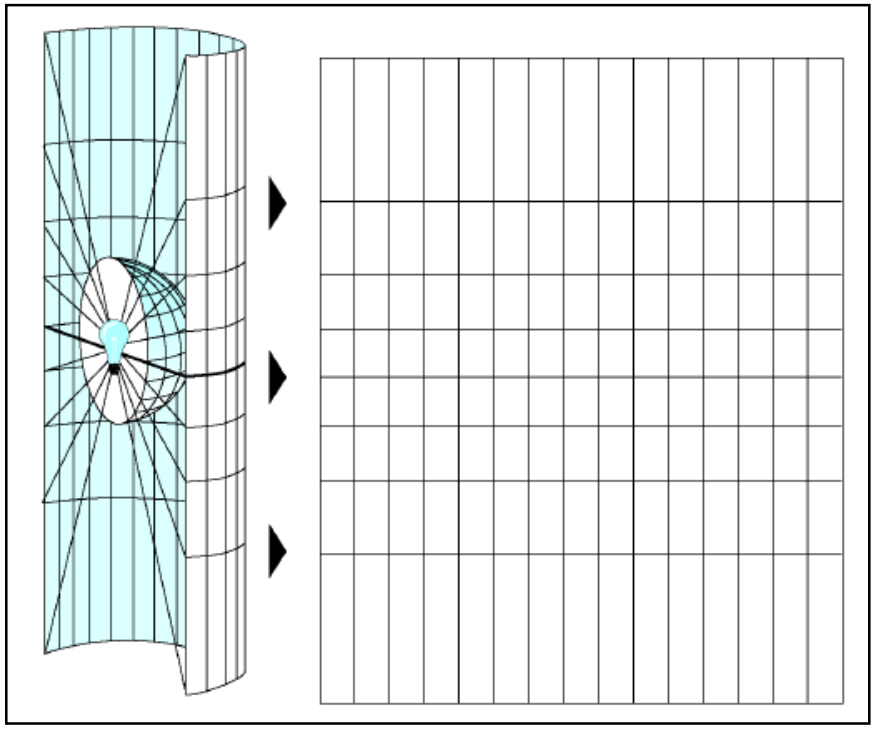
- Geocentric datum
- Default datum for many GPS units.

Projected Coordinate Systems



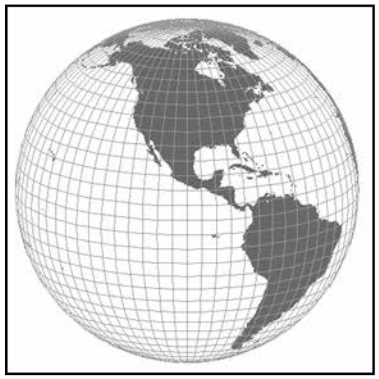
Projections

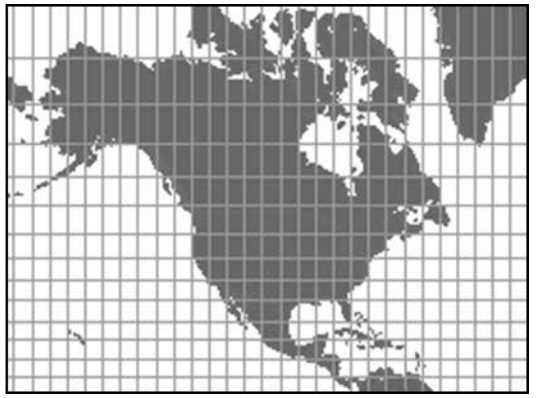
A projection is a mathematical conversion of a 3D surface to a 2D surface



What is a Projection?

Projecting changes the x-y values from degrees to meters or feet





-103.567,44.628

-103.678,44.653

-103.765,44.732

…

Units in decimal degrees

2445678,654321

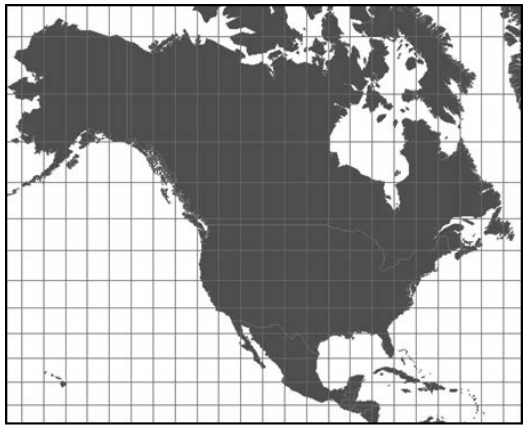
2445021,650001

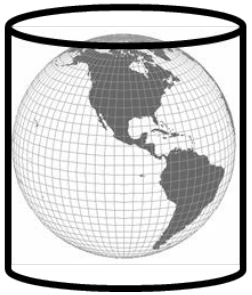
2444823,649200

….

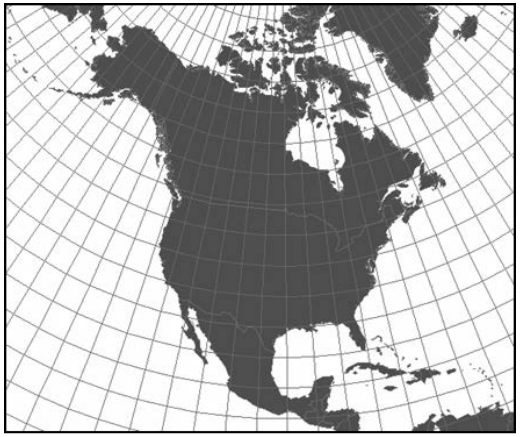
Units in meters

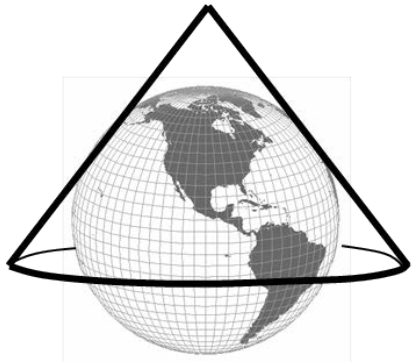
Types of projections



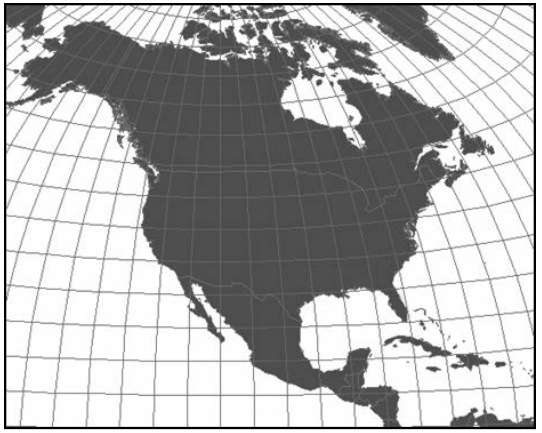


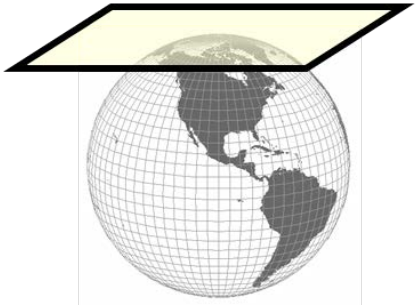
Cylindrical





Conic





Azimuthal

Distortion

All map projections introduce distortion

Type and degree of distortion varies with map projection

When using a projection, one must take care to choose one with suitable properties