AMERICAN MUSEUM OF NATURAL HISTORY
CENTER FOR BIODIVERSITY AND CONSERVATION

Introduction to Geographic Information Systems

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Outline

How do we represent real world geographic information with a computer?

- What is a Geographic Information System?
- Data models – representations of geographic reality
- Location information: coordinate systems

- Georeferencing, sampling bias
- Remote Sensing

Notable GIS software

Commercial:

- ArcGIS, including ArcMap (Esri)
- IDRISI (Clark Labs)
- ERDAS IMAGINE (ERDAS Inc.)

Open source:

- **Quantum GIS**
- GRASS GIS
- MANIS tool
- GPSvisualizer
- Biogeomancer

Free (but not open source):

- DIVA GIS

What is a Geographic Information System?

- A Geographic Information System (GIS)
  - software, hardware, geographic information, spatially explicit data

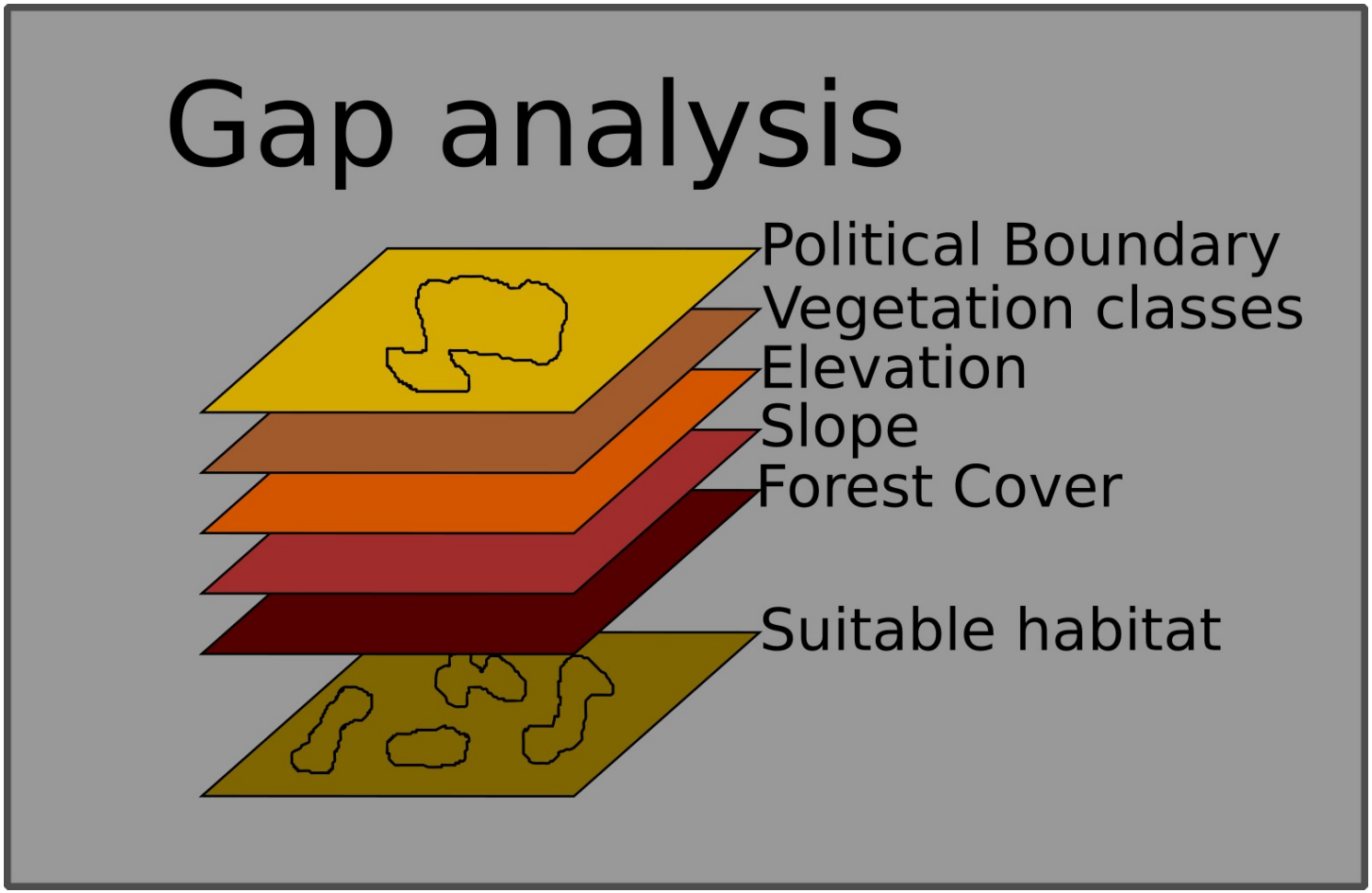
- Software can be used to store, query, manage, analyze and display spatial data.

- A GIS links cartographic, statistical, and data-basing technologies.

What is a Geographic Information System?

- Data (layers)
  - Spatial – Images, shape data, geographic information
  - Tabular – Spreadsheet data with geographic properties

Layering


Gap analysis
Political Boundary
Vegetation classes
Elevation
Slope
Forest Cover
Suitable habitat

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Two methods of GIS representation

- There are two main ways a GIS can create a logical data model of the world:
  - Raster = continuous fields
  - Vector = discrete features

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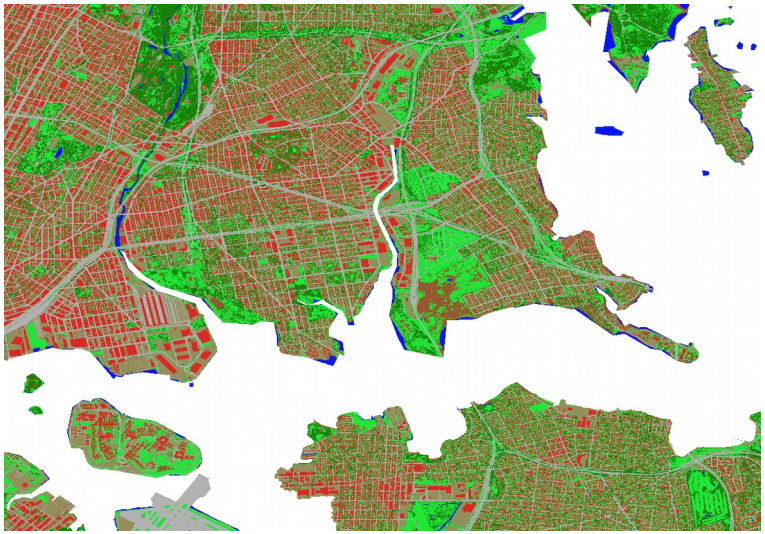

New York City landcover
classified at 3 foot resolution

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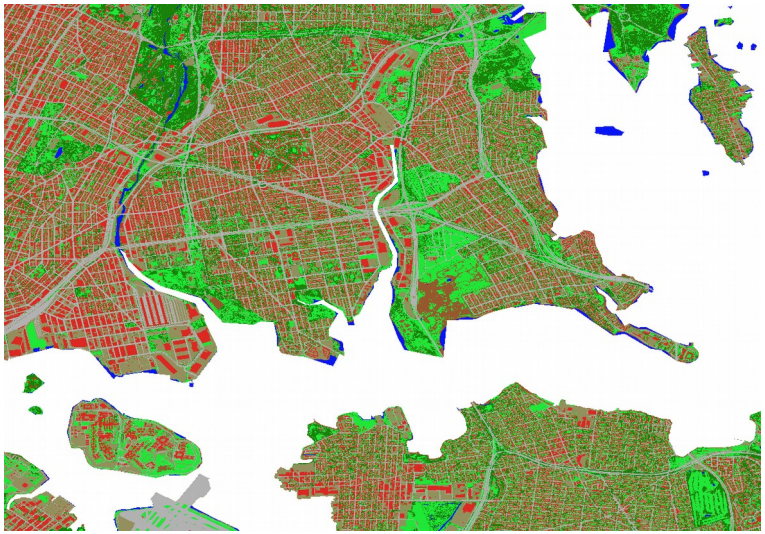
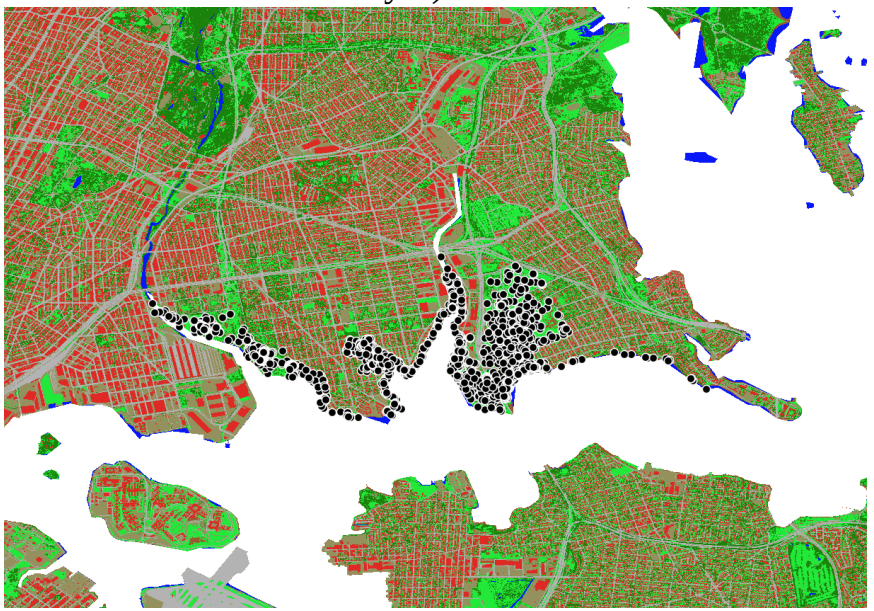


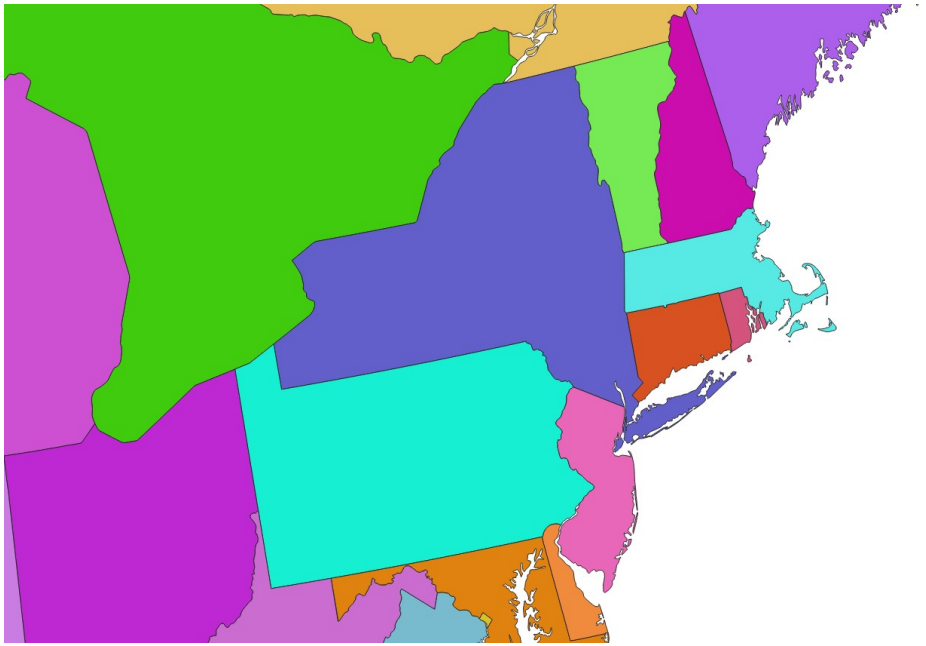
New York City landcover classified at 3 foot resolution

Coyote occurrence records (as vector layer)



Vector

- Discrete objects
  - Represents the geographic world as objects with well-defined boundaries in otherwise empty space



Data from
naturalearthdata.com

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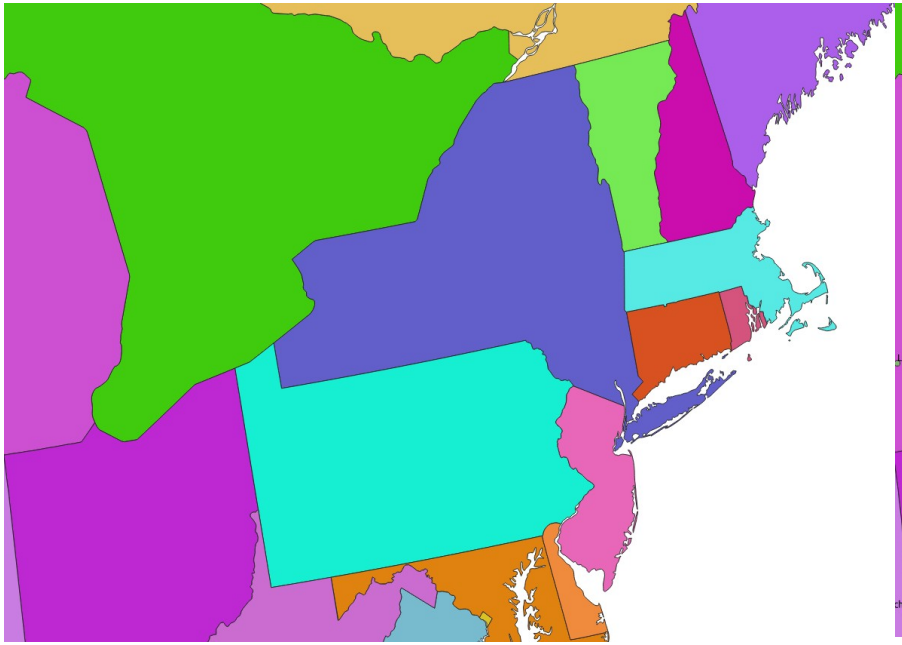

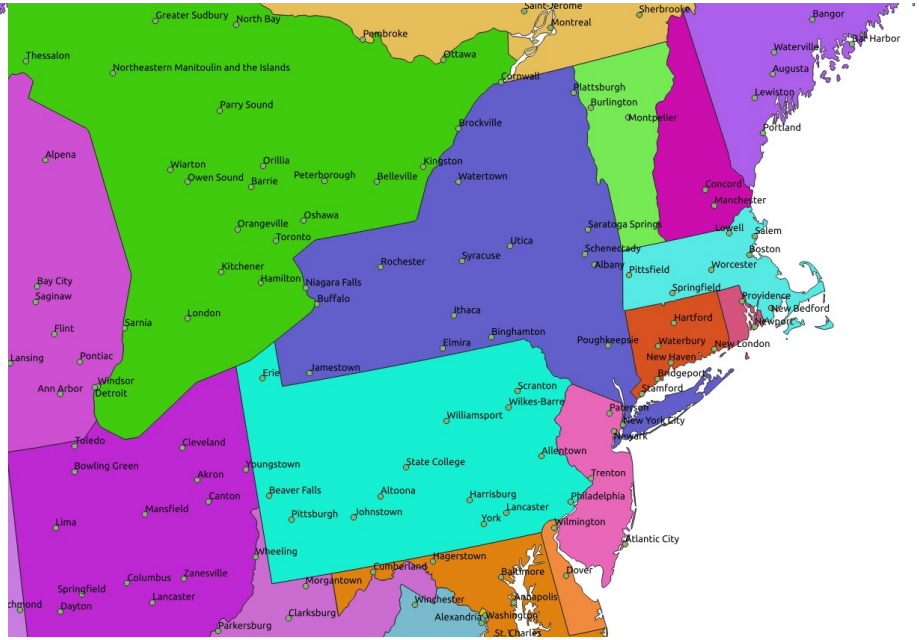

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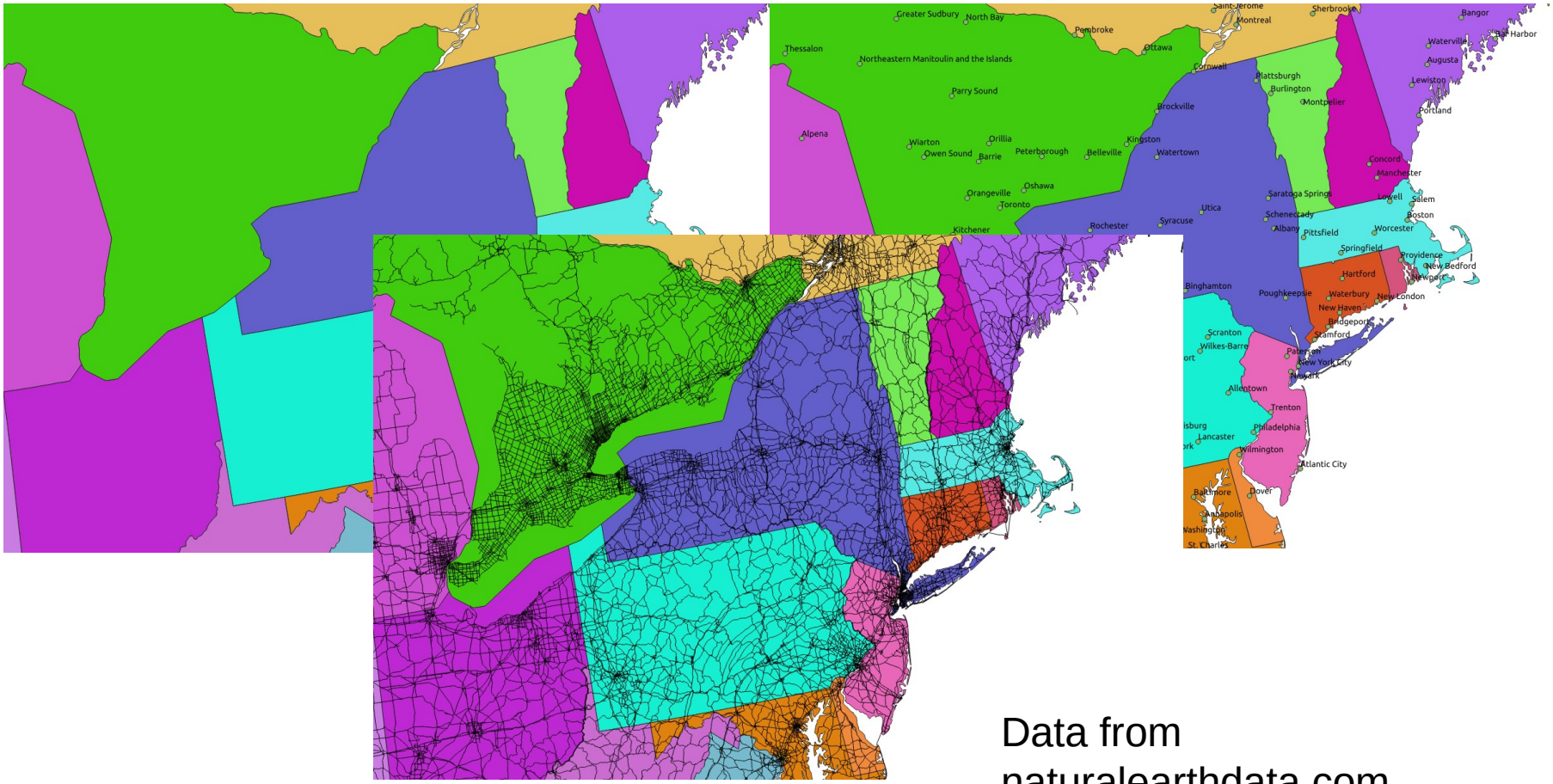
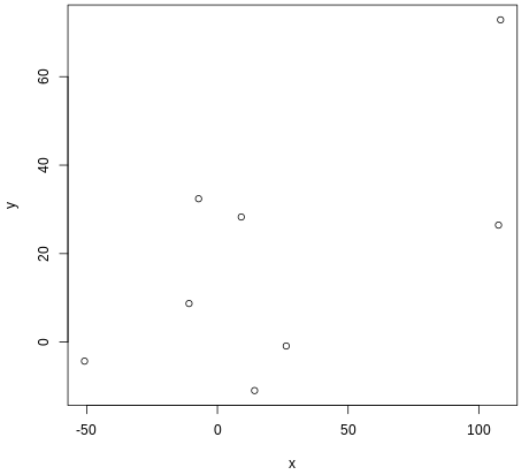
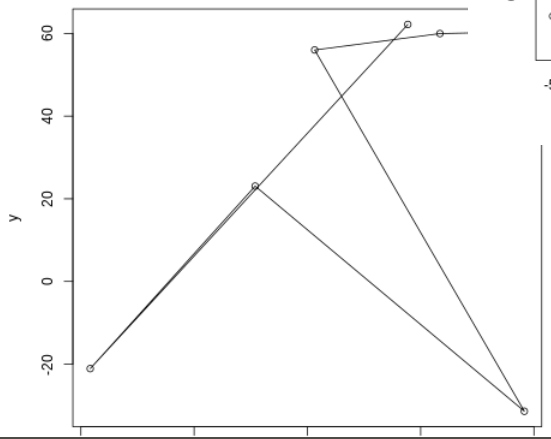


Data from naturalearthdata.com

Vector Data

- Vector data represents features as *points*, *lines*, and *polygons*.
- It is best applied to discrete objects with defined shapes and boundaries.
- It is tied with tabular data





- Examples include:
  - GPS points
  - Roads
  - Protected areas

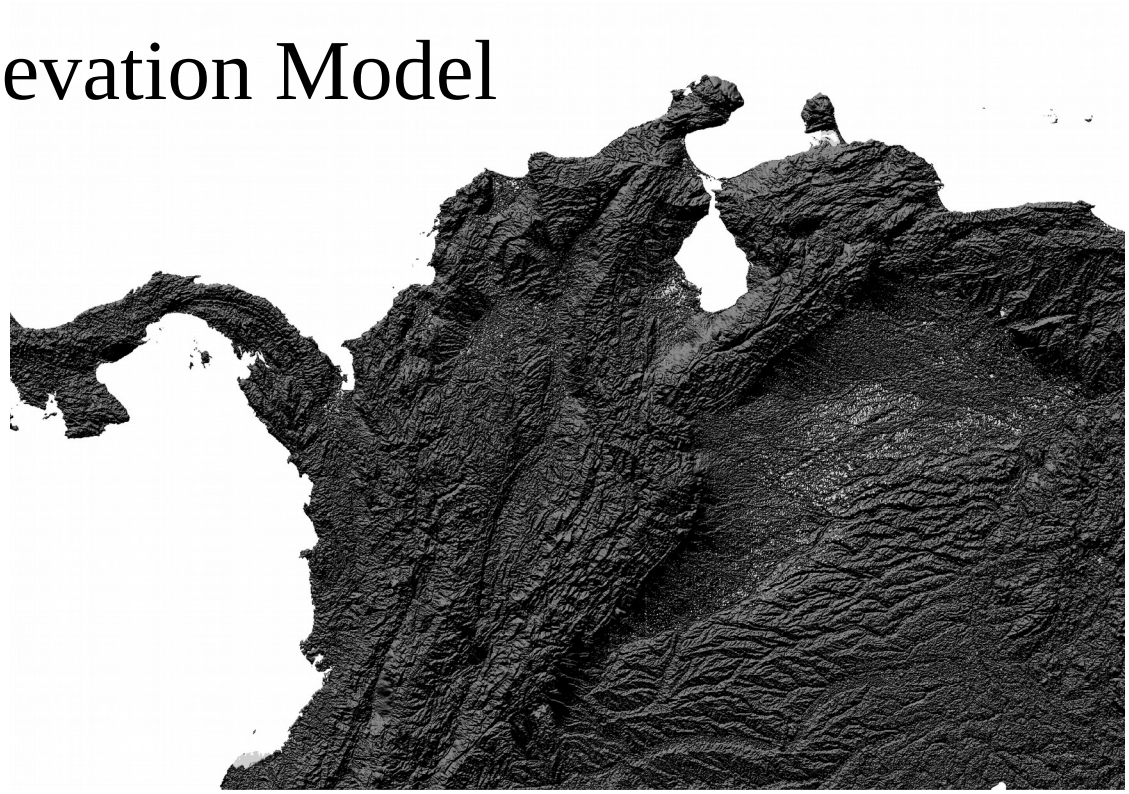
ne_10m_roads_north_america :: Features Total: 49183, Filtered: 49183, Selected: 0

	prefix	number	class	type	divided	country	state
1			Other	Unpaved		United States	California
2			Other	Other Paved		United States	Nevada
3		S2	Other	Other Paved		Mexico	
4		S1	Other	Other Paved		United States	California
5		S1	Other	Secondary	Undivided	United States	California
6			Other	Secondary	Undivided	United States	California
7			Other	Other Paved		Mexico	Puebla
8			Other	Other Paved		Mexico	Puebla

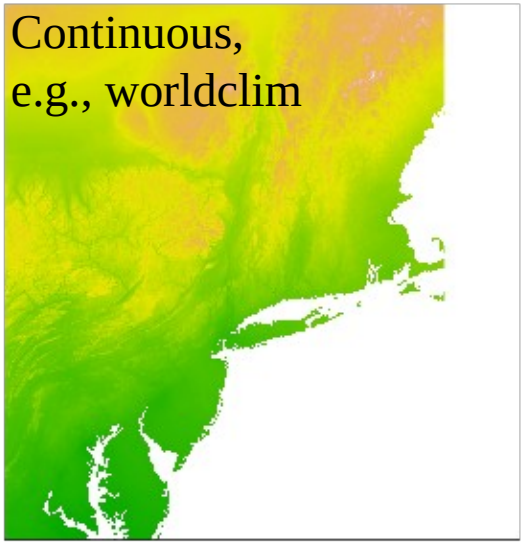
Show All Features

Raster

- Continuous fields
  - Represents the real world as a finite number of variables, each one defined at every possible position.
- E.g. a Digital Elevation Model

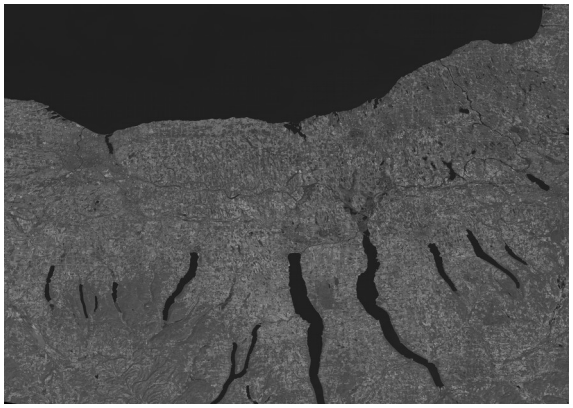


Raster Data

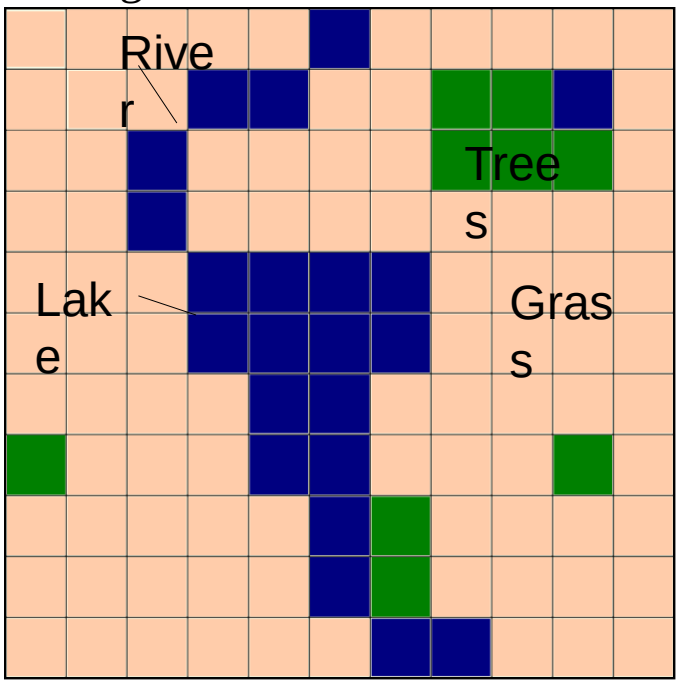


A raster model represents the world as a surface that is divided into a regular grid of cells, each of which are assigned a value.

Raster data includes images and grids. aerial photograph, a satellite image, or a scanned map, are often used for generating raster datasets.



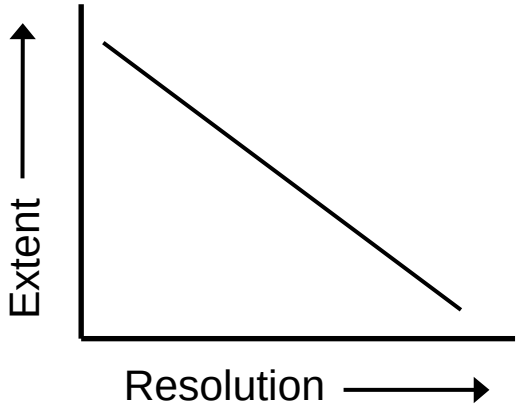
Categorical



General data issues: spatial scale

Spatial scale has two elements: **resolution** and **extent**

Resolution and extent
tend to be
inversely related



Vector data

- Advantage
  - precise representation of points, boundaries, and linear features
    - defining spatial relationship (connectivity and adjacency) between coverage features
    - network analysis (for example to find an optimal path between two nodes in a complex transport network)
- Disadvantage
  - boundaries of the resulting map polygons are discrete/enclosed by well-defined boundary lines. In reality the map polygons may represent continuous gradation or gradual change, as in soil maps
  - Resolution is not clear – how many points were used to make up a line?

Raster data

- Advantage
  - Represent indistinct boundaries
    - thematic information on soil types, soil moisture, vegetation, ground temperatures
  - Reconnaissance satellites and aerial surveys use raster-based scanners
    - scanned images can be directly incorporated into GIS
- Potential disadvantage
  - The higher the grid resolution, the larger the data file is going to be
  - If converting from vector to raster can lose information:

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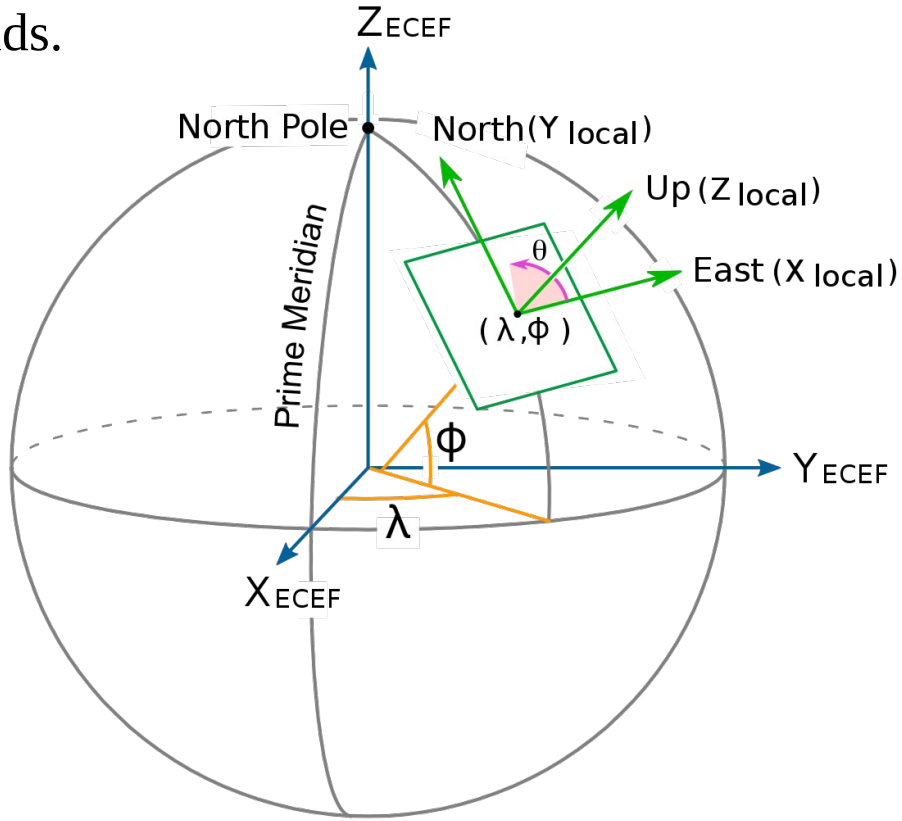
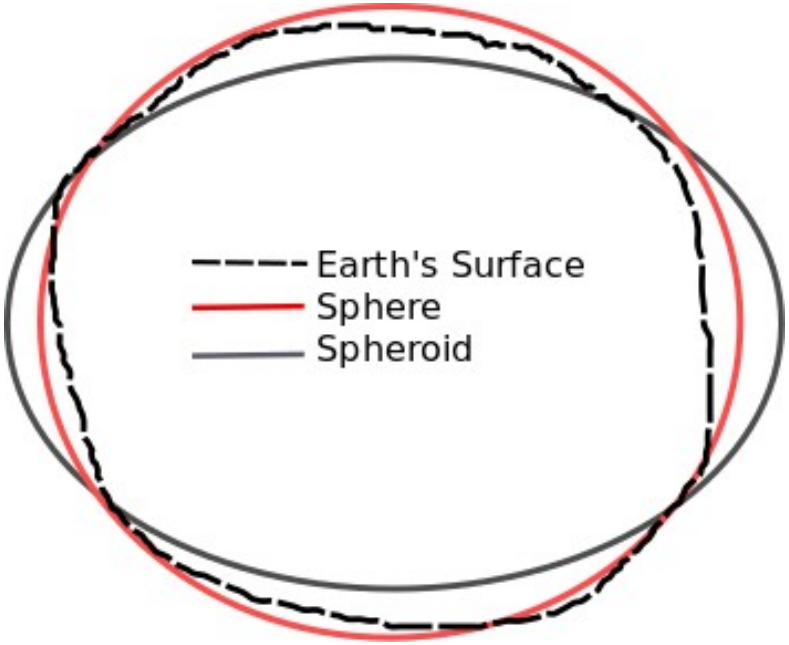
GIS fundamentals: Geographic coordinate systems (GCS)

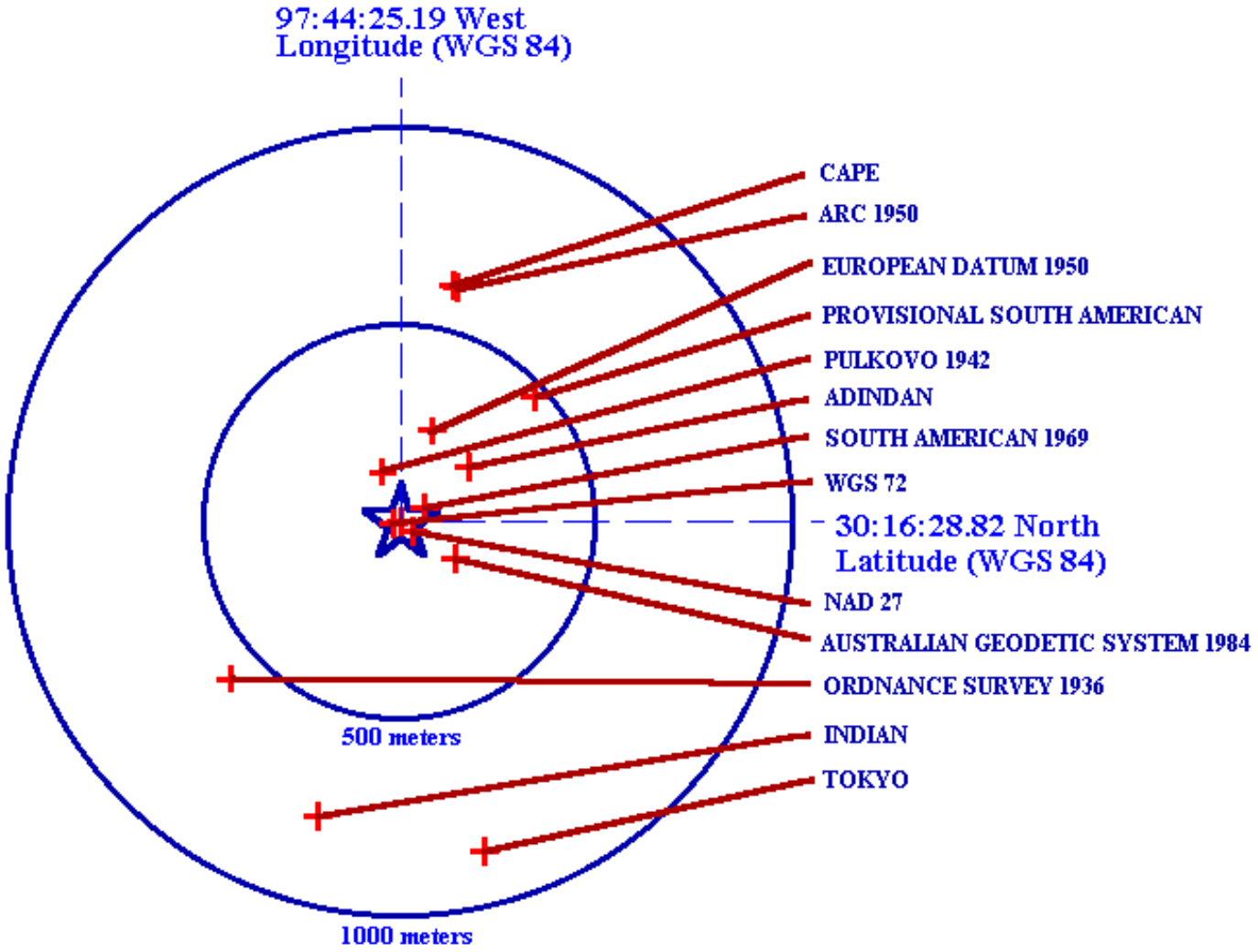
- A point is referenced by its *longitude* and *latitude*, which are angles measured from the Earth's center to a point on its surface.
  - Latitude is also the angle from Polaris to horizon (in N. hemisphere)
- Latitude and longitude are measured either in decimal degrees or in degrees, minutes and seconds.



GIS fundamentals: Geographic coordinate systems (GCS)

- The shape and size of a GCS's surface is defined by a sphere or a spheroid
- In fact, the Earth is neither a perfect sphere nor spheroid (the South Pole is closer to the equator than the North pole!)
- A *datum* defines the origin and orientation of latitude and longitude lines.
- Changing a GCS's spheroid or datum changes all values!
- The standard global system is called World Geodetic System 1984 (WGS1984)





Position Shifts from Datum Differences

Texas Capitol Dome Horizontal Benchmark

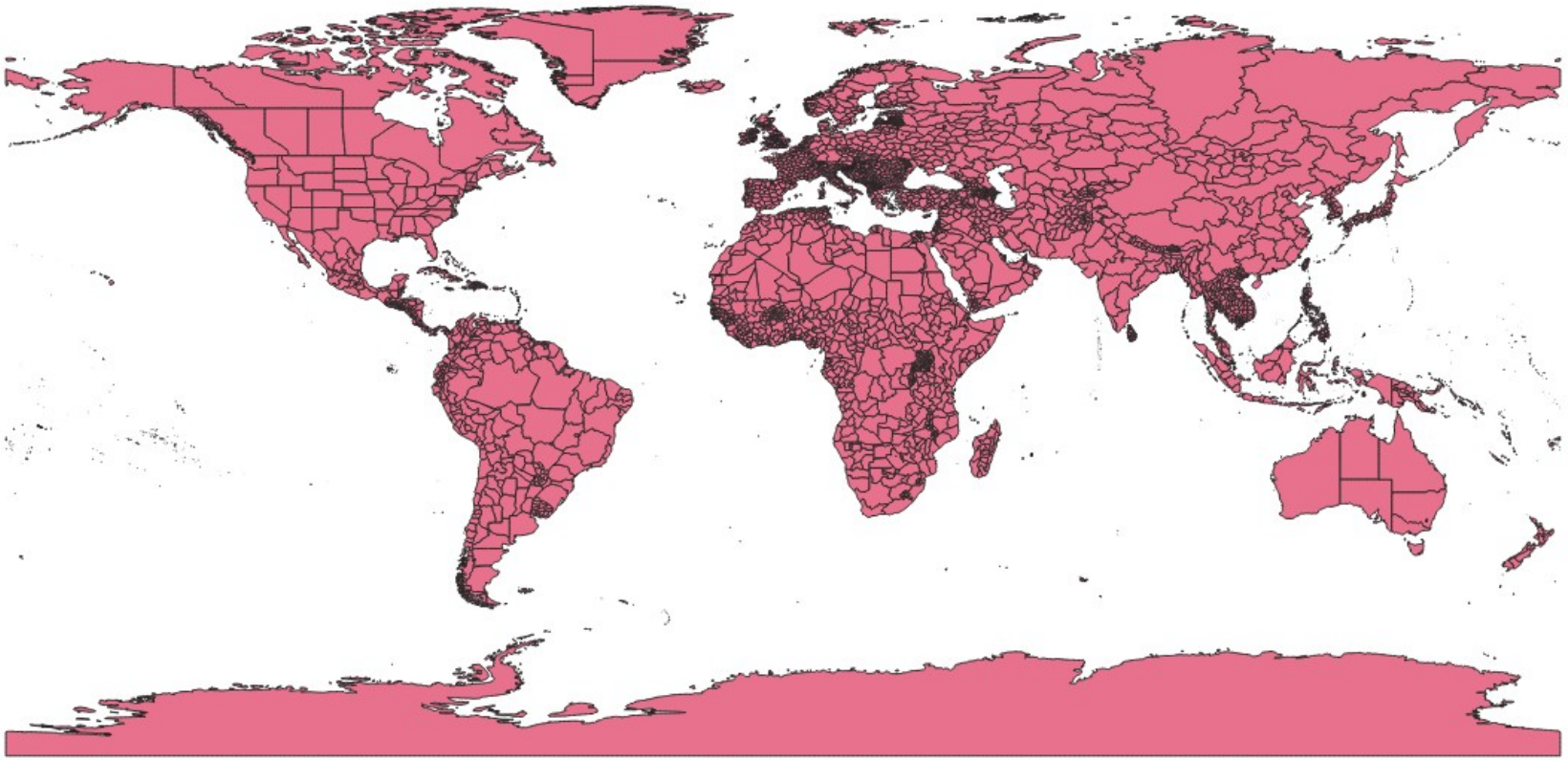
Peter H. Dana 9/1/94

GIS fundamentals: Geographic coordinate systems (GCS)

- WGS84
  - Default Datum for GPS units
  - Pretty good for global measurements
  - Small changes in landmass movements can be significant at global scale
    - Melting glaciers cause rising elevation
    - Tectonic movements
  - Local datums are better for local maps (e.g., North American Datum; NAD83) and reduce significance of landmass movements.

GIS fundamentals: Geographic coordinate systems (GCS)

- WGS84 – Unprojected: Distortion near extents of map



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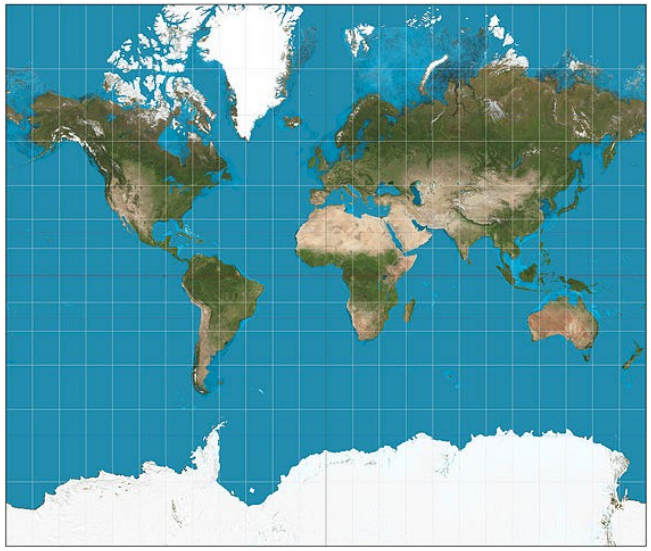
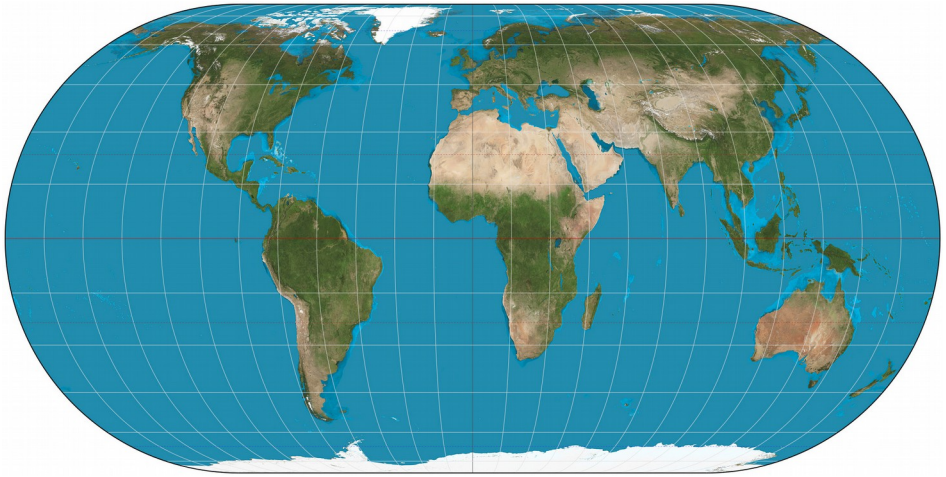
GIS fundamentals: Projected coordinate systems (PCS)

- Representing the earth's surface in two dimensions causes distortion in the shape, area, distance, or direction of the data.
  - Impossible to show spherical object in 2 dimensions without distortion
- A map projection uses mathematical formulas to relate spherical coordinates on the globe to flat, planar coordinates.
- Different projections are designed to minimize different distortions.

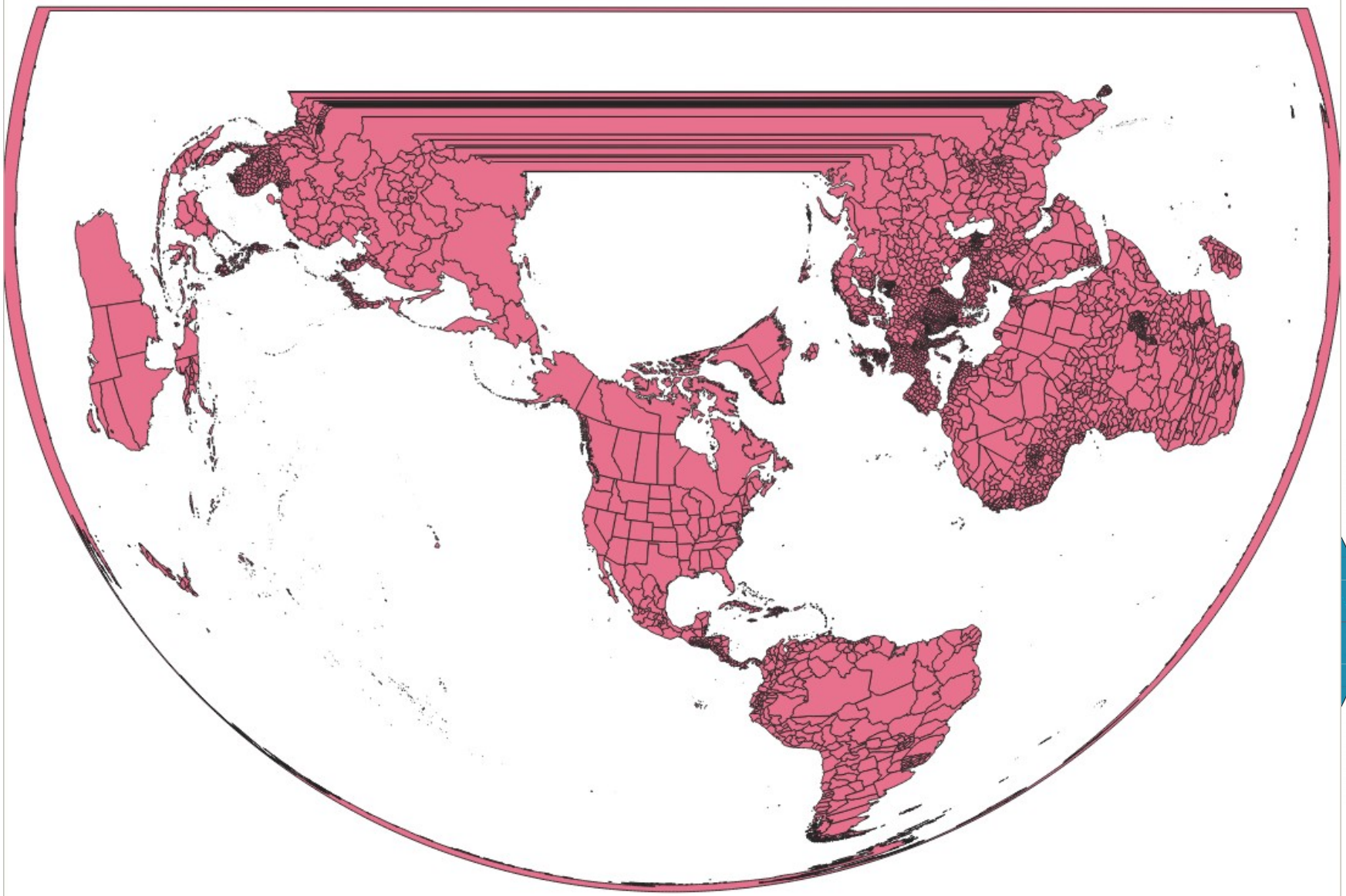


Mercator: maintains direction

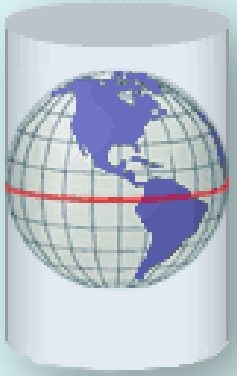


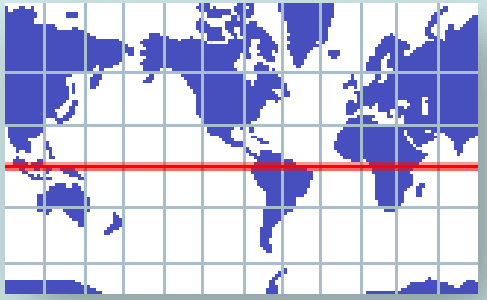
Eckert IV: maintains area

GIS fundamentals: Projected coordinate systems (PCS)



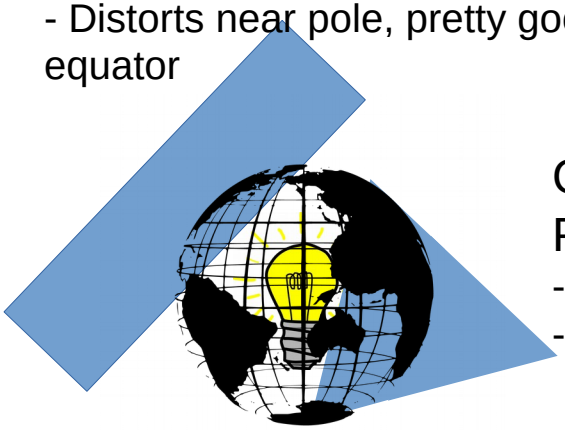
GIS fundamentals: Projected coordinate systems (PCS)





Mercator Projection

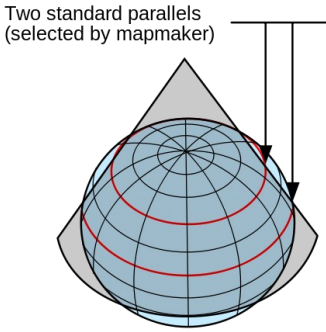
- Maintains direction
- Good for navigating
- Distorts near pole, pretty good near equator

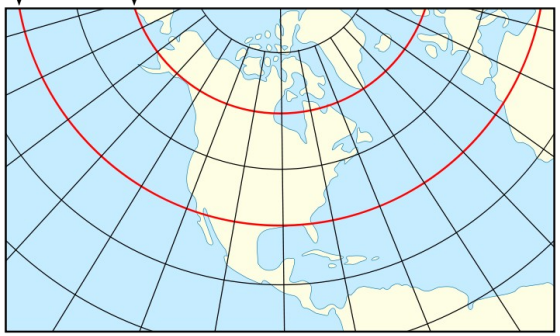


Gall-Peters Projection

- Maintains relative areas
- High distortion

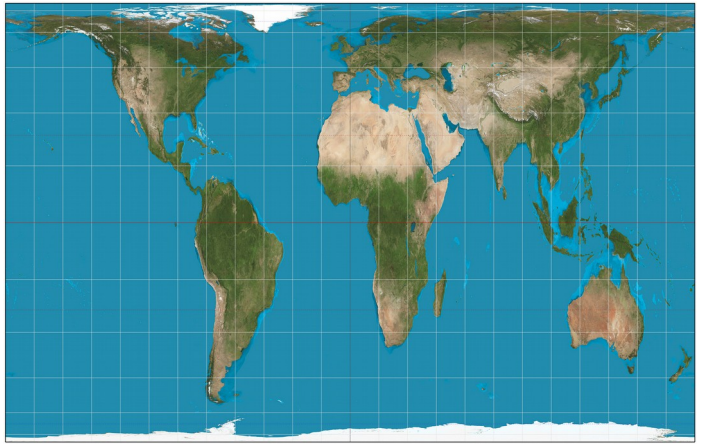
https://thetruesize.com/





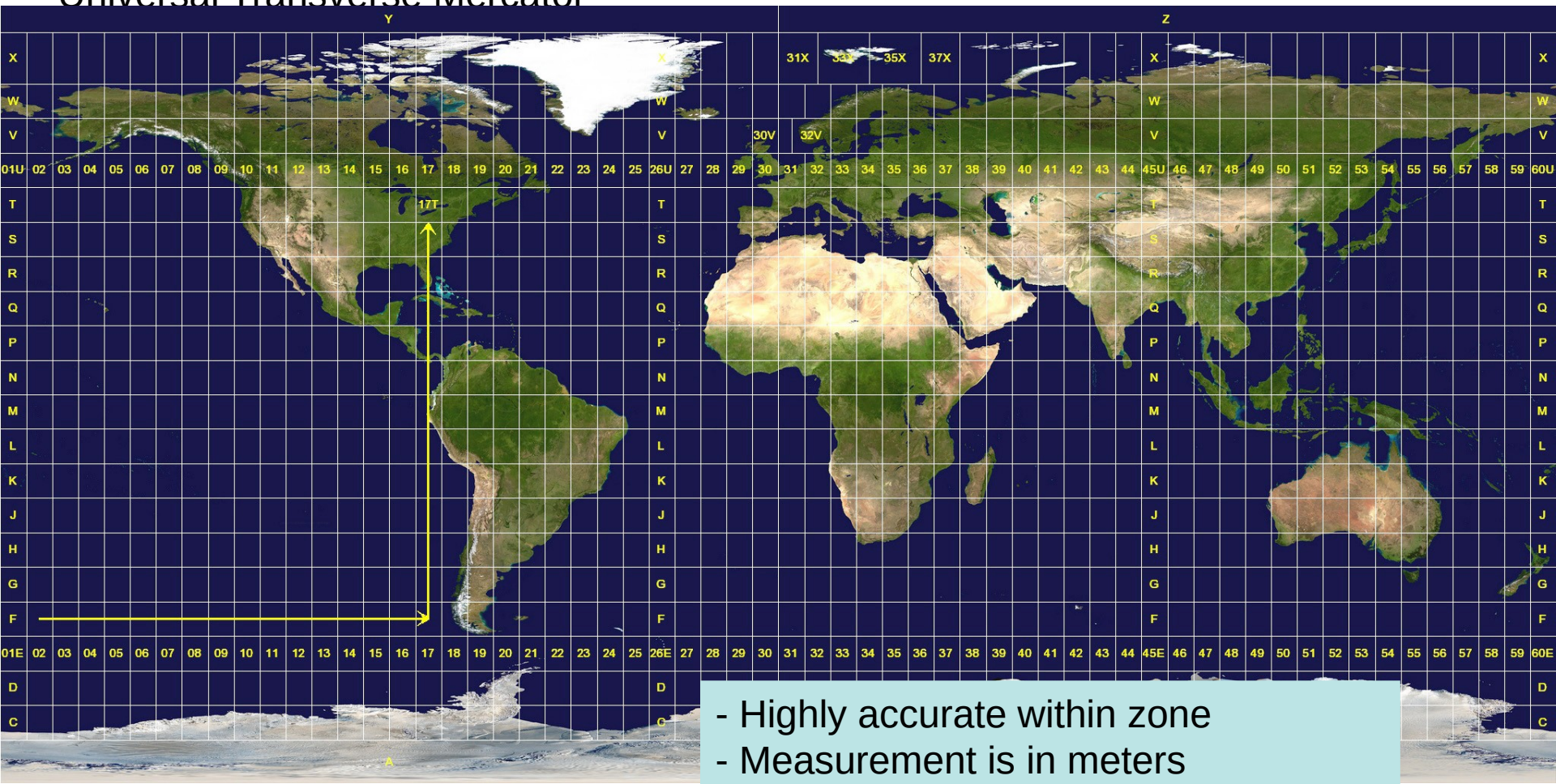
Conic Projection

- Maintains area near center
- Distortion near edges
- Good for east/west because distortion constant



GIS fundamentals: Projected coordinate systems (PCS)

Universal Transverse Mercator -



- Highly accurate within zone
- Measurement is in meters
  - intuitive
- Not great for large areas (across zones)

GIS fundamentals: Geographic and Projected coordinate systems

- Modern GIS make dealing with coordinate systems relatively straightforward; however:

IT IS ESSENTIAL TO KNOW THE COORDINATE SYSTEM OF ANY DATA WITH WHICH YOU ARE WORKING!

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Species' distribution data: possible sources

- Personal collection during field surveys (e.g., using a GPS receiver or smartphone)
- Extracting data from large surveys (e.g., North American Breeding Bird Survey)
- Digitizing atlases (e.g. *The new atlas of breeding birds in Britain and Ireland: 1988-1991*)
- Collections in natural history museums
- On-line distributed databases (e.g. GBIF, HerpNET, FishNET, ORNIS)

Georeferencing

- Woodbury, NY
- Near Woodbury
- 5 miles from Woodbury
- 1 mile east of Woodbury
- 10 minutes along the path leading out of Woodbury

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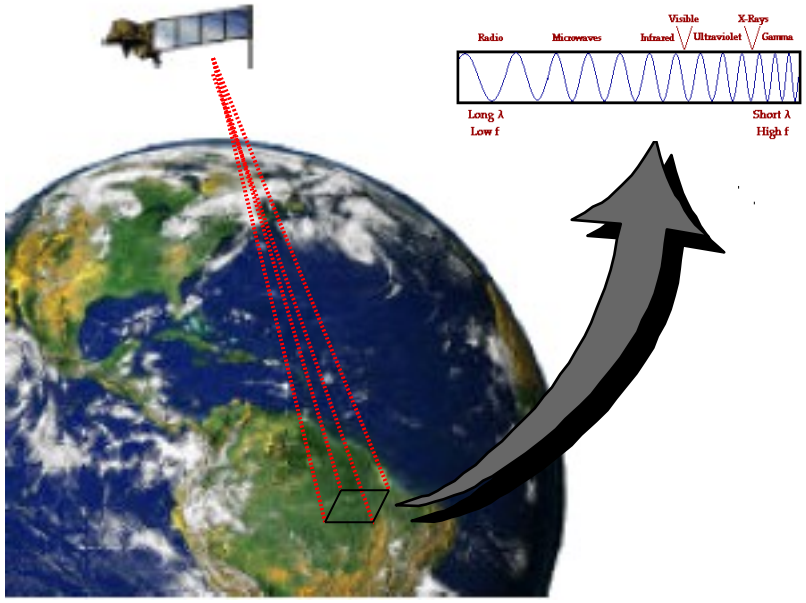
What is Remote Sensing?



Source: P. Ersts, July 2004

General definition: *Acquiring information about an object without physical contact.*

Definition in context of Earth observation: *A technology for sampling reflected and emitted electromagnetic (EM) radiation of features on the Earth's land surface, oceans, and atmosphere.*