Chapter 4 – Georeferencing

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- § 2 Some Non-metric Georeference Systems
- § 3 Measuring the Earth: latitude and longitude
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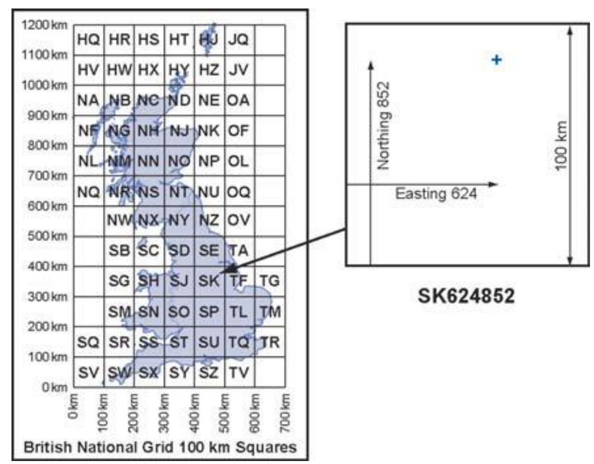
§ 1 Introduction

- Time is an optional element in geographic information, but location is essential
  - *georeference, geolocate, geocode, geo-tagging*
- To be most useful, georeferences should stay constant through time
- Metric georeferences are much more useful, because they allow maps to be made and distances to be calculated

Placenames are not necessarily unique at the global level



The National Grid of Great Britain, illustrating how a point is assigned a grid reference that locates it uniquely to the nearest 100 m

§ 1 Introduction(cont.)

Table 5.1 Some commonly used systems of georeferencing

System	Domain of uniqueness	Metric?	Example	Spatial resolution
Placename	varies	no	London, Ontario, Canada	varies by feature type
Postal address	global	no, but ordered along streets in most countries	909 West Campus Lane, Goleta, California, USA	size of one mailbox
Postal code	country	no	93117 (US ZIP code); WC1E 6BT (UK unit postcode)	area occupied by a defined number of mailboxes
Telephone calling area	country	no	805	varies
Cadastral system	local authority	no	Parcel 01452954, City of Springfield, Mass, USA	area occupied by a single parcel of land
Public Land Survey System	Western USA only, unique to Prime Meridian	yes	Sec 5, Township 4N, Range 6E	defined by level of subdivision
Latitude/longitude	global	yes	119 degrees 45 minutes West, 34 degrees 40 minutes North	infinitely fine
Universal Transverse Mercator	zones six degrees of longitude wide, and N or S hemisphere	yes	563146E, 4356732N	infinitely fine
State Plane Coordinates	USA only, unique to state and to zone within state	yes	55086.34E, 75210.76N	infinitely fine

§ 2 Some Non-metric Georeference Systems

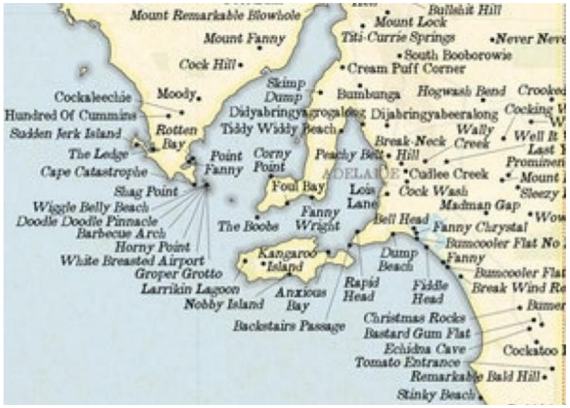
§ 2.1 Placenames

- Simplest form, earliest form of georeferenced
- Now we have complex system of naming oceans, cities, mountains, rivers, and others
- Each country maintains a system of authorized naming, often through national or state committees
- Many commonly used placenames have meanings that vary between people, and with the context in which they are used
- Language extends the power of placenames through words such as ‘between’, which serve to refine references to location, or ‘near’, which serve to broaden them

§ 2 Some Non-metric Georeference Systems(cont.)

§ 2.1 Placenames(cont.)

- Even more powerful extensions come from combining placenames with directions and distances, as in ‘200 m north of the old tree’ or ‘50 km west of Springfield’, Limitations:
  - they often have very coarse spatial resolution
  - only certain placenames are officially authorized by national or subnational agencies. Many more are recognized only locally, so their use is limited to communication between people in the local community
  - The meaning of certain placenames can become lost through time



Placenames on Map

§ 2 Some Non-metric Georeference Systems(cont.)

§ 2.2 Postal addresses and postal codes

- Postal addresses were introduced after the development of mail delivery in the 19th century. They rely on several assumptions:
  - a potential destination for mail;
  - arrayed along paths, roads, or streets, and numbered accordingly;
  - Paths, roads, and streets have names that are unique within local areas;
  - Local areas have names that are unique within larger regions; and Regions have names that are unique within countries.
- Postal addresses work well to georeferenced dwellings and offices, but not natural feature

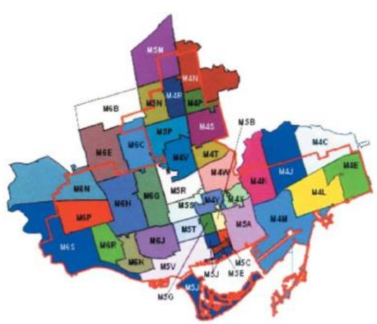
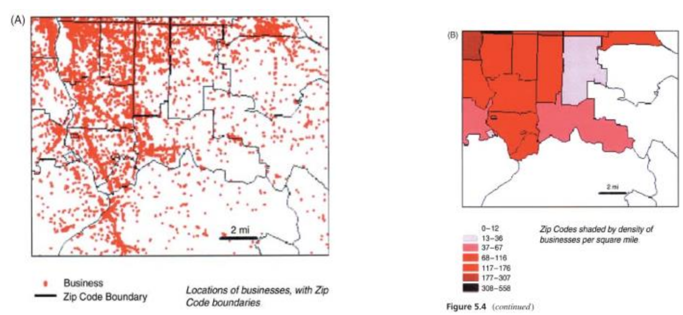


Figure 5.3 Forward Sortation Areas (FSAs) of the central part of the Toronto metropolitan region. FSAs form the first three characters of the six-character Canadian postal code



Zip code based statistics

§ 2 Some Non-metric Georeference Systems(cont.)

§ 2.3 Linear referencing systems

- A linear referencing system identifies location on a network by measuring distance from a defined point of reference along a defined path in the network
- Linear referencing systems are widely used in managing transportation infrastructure and in dealing with emergencies
- Linear referencing systems are often difficult to implement in practice in ways that are robust in all situations(urban vs rural area, multiple crossing)

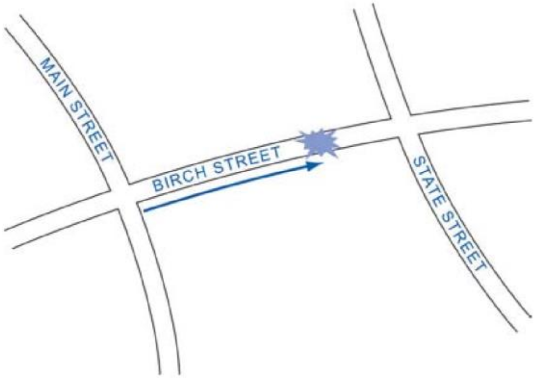
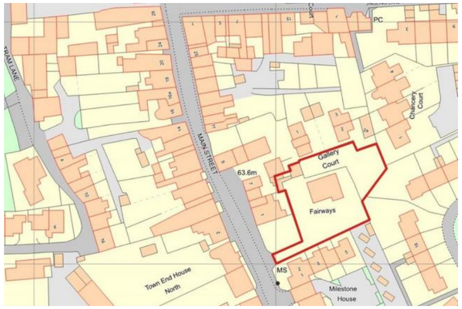


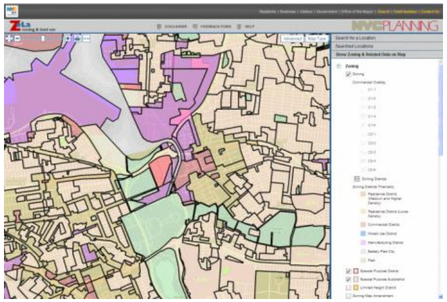
Figure 5.5 Linear referencing – an incident's position is determined by measuring its distance (87 m) along one road (Birch St) from a well-defined point (its intersection with Main St)

§ 2 Some Non-metric Georeference Systems(cont.)

§ 2.4 Cadasters

- The cadaster is defined as the map of land ownership, maintained for the purposes of taxing land, or of creating a public record of ownership
- The process of subdivision creates new parcels by legally subdividing existing ones
- Parcels of land in a cadaster are often uniquely identified, by number or by code, and are also reasonably persistent through time, and thus satisfy the requirements of a georeferencing system
- very few people know the identification code of their home parcel, and use of the cadaster as a georeferencing system is thus limited largely to local officials

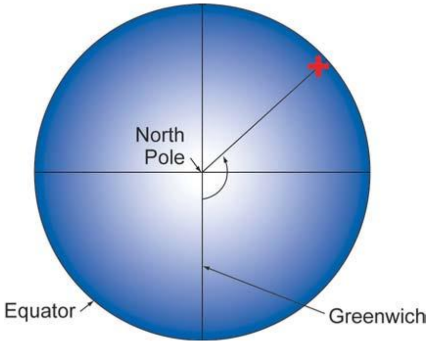


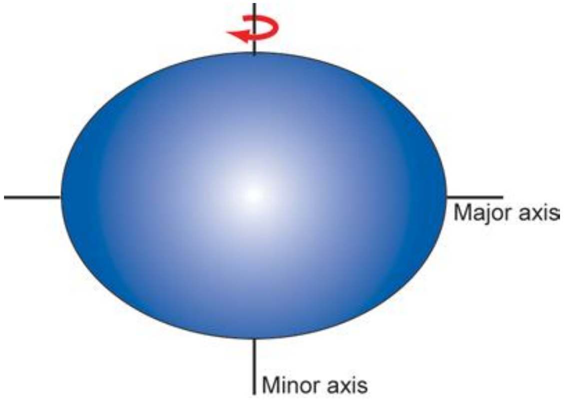


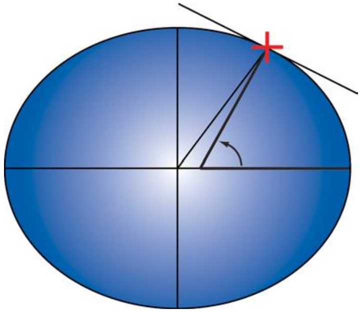
Cadaster map

§ 3 Measuring the Earth: latitude & longitude

- The system of latitude and longitude is in many ways the most comprehensive, and is often called the *geographic system of coordinates*
  - *Axis of the earth's rotation*
  - *Equator*
  - *latitude and longitude*
  - *Zero longitude*

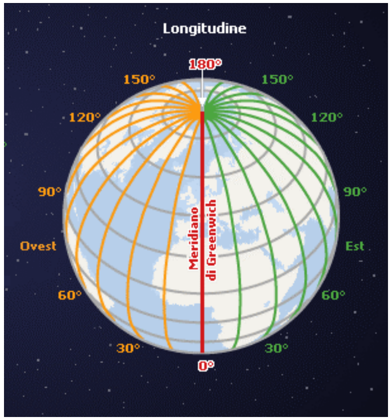






Latitude and Longitude

- The **latitude** has the symbol of *phi*, and it shows the angle between the straight line in the certain point and the equatorial plane. The latitude is specified by degrees, starting from 0° and ending up with 90° to both sides of the equator, making latitude Northern and Southern. The equator is the line with 0° latitude
- The **longitude** has the symbol of lambda and is another angular coordinate defining the position of a point on a surface of earth. The longitude is defined as an angle pointing west or east from the Greenwich Meridian, which is taken as the [Prime Meridian](). The longitude can be defined maximum as 180° east from the Prime Meridian and 180° west from the Prime Meridian

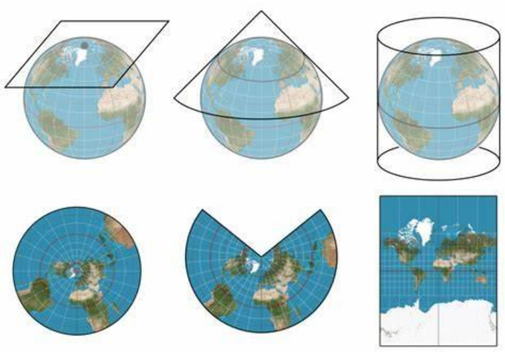


Latitude and Longitude

Prime Meridian at Greenwich

§ 4 Projections and coordinates

- The Earth is often flattened because:
  - paper is flat, and paper is still used as a medium for inputting data to GIS by scanning or digitizing , and for outputting data in map or image form;
  - rasters are inherently flat, since it is impossible to cover a curved surface with equal squares without gaps or overlaps;
  - photographic film is flat, and film cameras are still used widely to take images of the Earth from aircraft to use in GIS;
- when the Earth is seen from space, the part in the center of the image has the most detail, and detail drops off rapidly, the back of the Earth being invisible
- In order to see the whole Earth with approximately equal detail it must be distorted in some way, and it is most convenient to make it flat

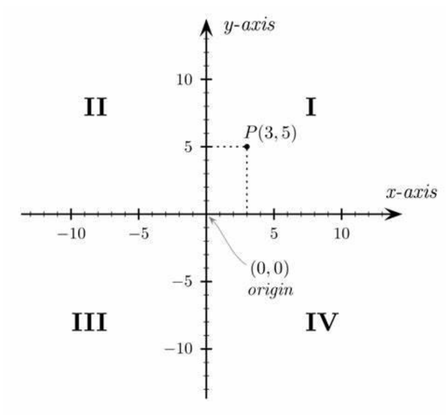


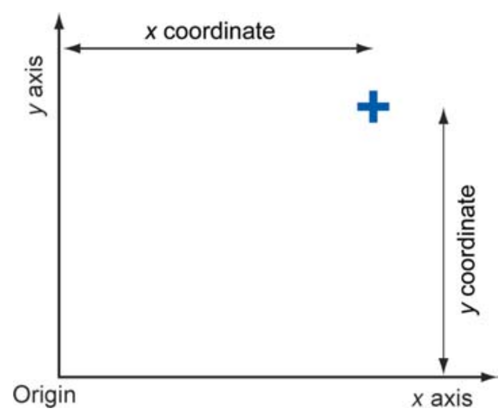
The Flattened Earth

§ 4 Projections and coordinates(cont.)

- The Cartesian coordinate system assigns two coordinates to every point on a flat surface, by measuring distances from an origin parallel to two axes drawn at right angles

René Descartes (1596-1650)





Cartesian Coordinate System

§ 4 Projections and coordinates(cont.)

- One way to think of a map projection, therefore, is that it transforms a position on the Earth's surface identified by latitude and longitude (φ, λ) into a position in Cartesian coordinates (x, y)
- Every recognized map projection, of which there are many, can be represented as a pair of mathematical functions:

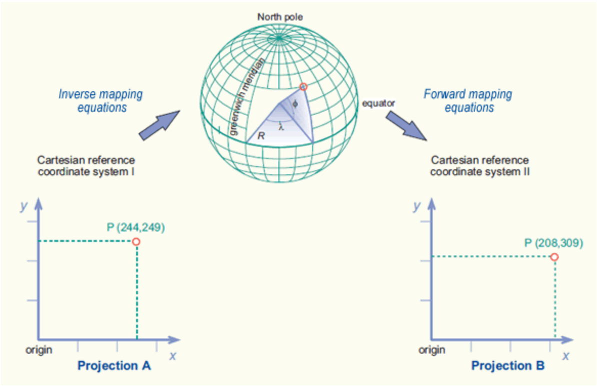
$$x = f(\phi, \lambda)$$

$$y = g(\phi, \lambda)$$

- For example, the famous Mercator
- projection uses the functions:

$$x = \lambda \qquad \lambda = x$$

$$y = \ln \tan[\phi/2 + \pi/4] \qquad \phi = 2 \arctan e^{y} - \pi/2$$



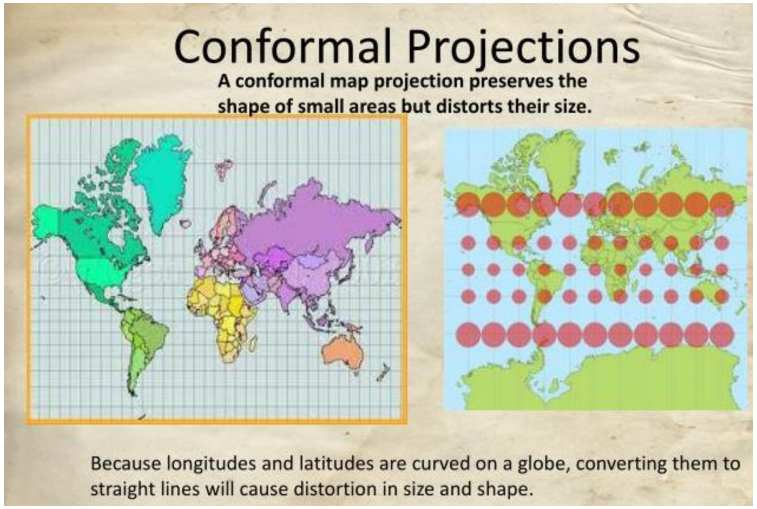
Map between (φ, λ) and (x, y)

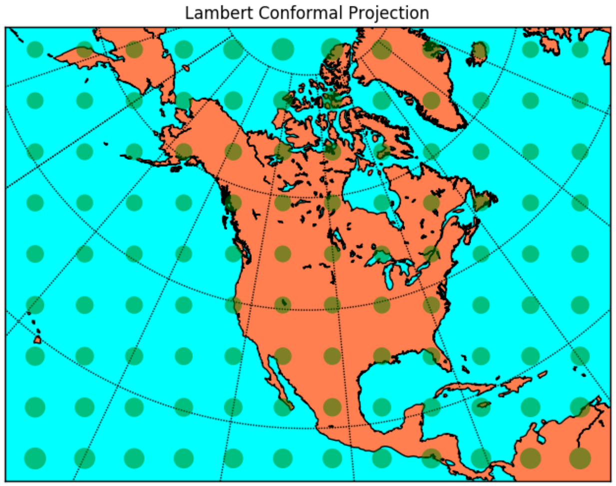
- Distortion ellipses help us to visualize what type of distortion a map projection has caused, how much distortion occurred, and where it occurred

Classifications of Map Projections(I)

Conformal Projections

- maintains proper angular relationship in map so that shape of small areas are preserved, distort their size
  - Impossible to depict true shapes for large areas like continents
  - Biggest problem is that they must distort size, esp. in the higher latitudes

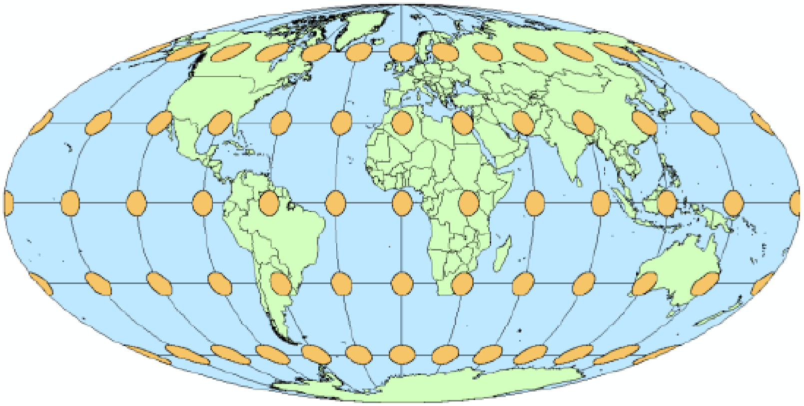


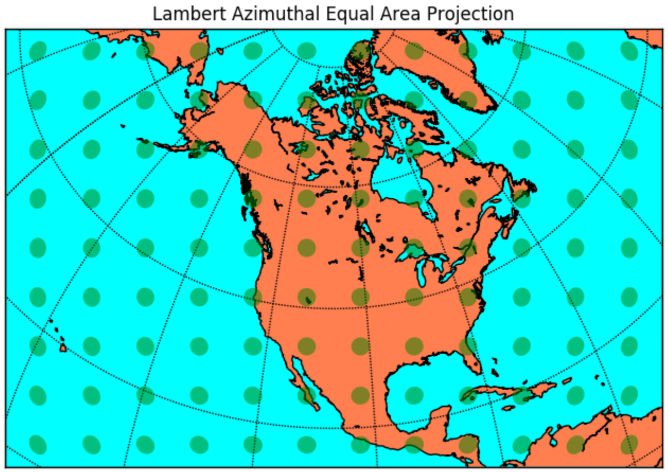


Classifications of Map Projections(I)

Equal-Area / Equivalent Projections

- Maintain accurate relative sizes which allows for accurate area calculations
- Good to show global distribution
- Shape distorted

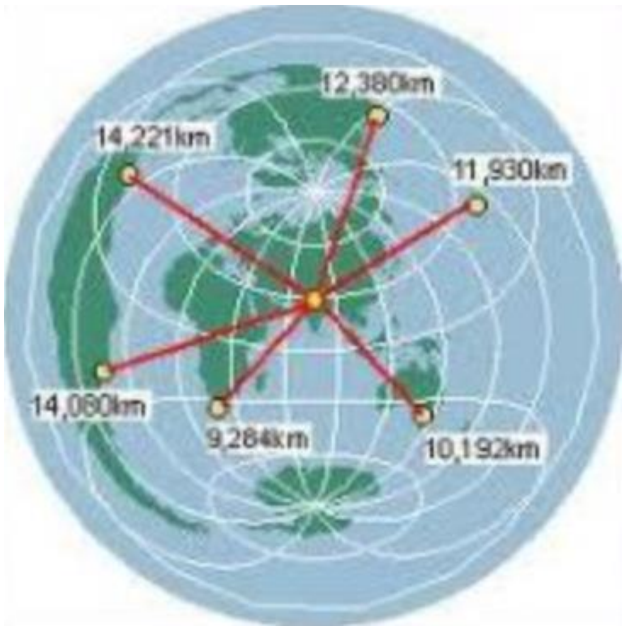


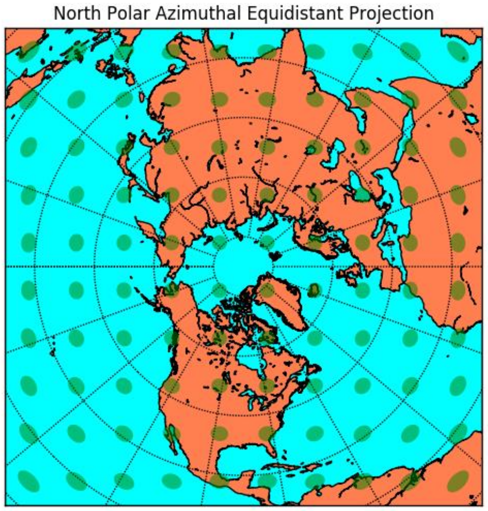


Classifications of Map Projections(I)

Equidistant Projections

- distance from a single location to all other locations are preserved
- All other distances are incorrect
- Distortion of areas and shapes increase dramatically

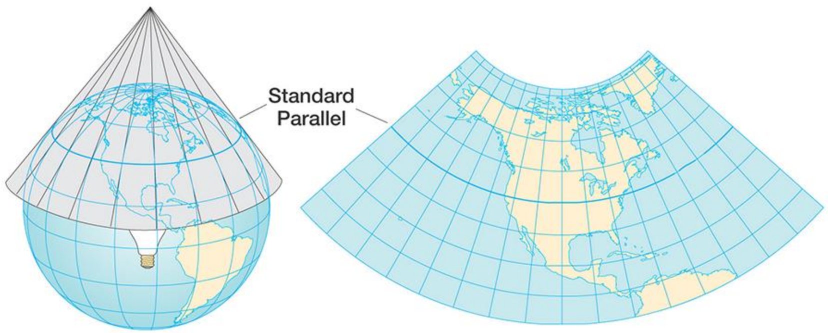


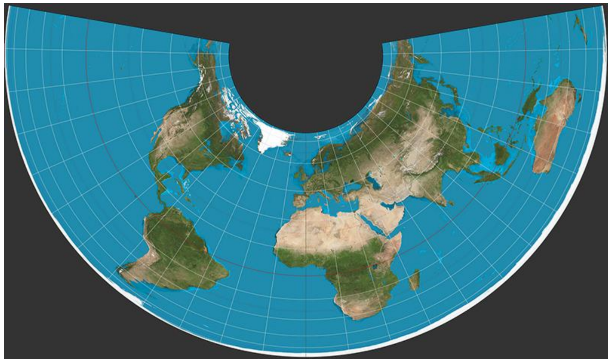


Classifications of Map Projections(II)

Conic Projections

- Earth intersects the cone at two (or one) circle(s)
- Locations are projected onto the surface of the cone which is then unwrapped and laid flat
- all points along both (or the)circle(s) have no scale distortion

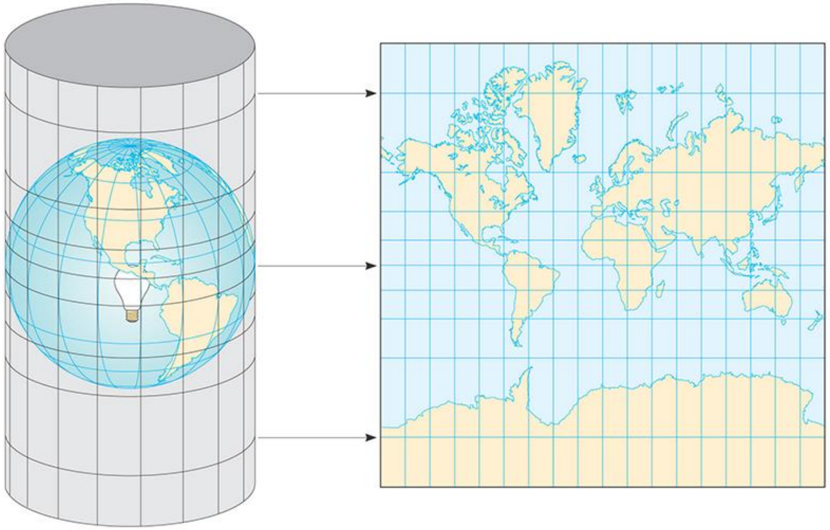


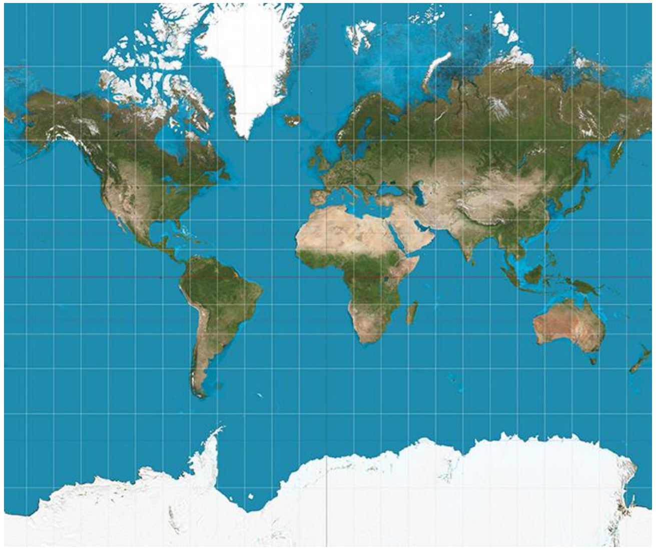


Classifications of Map Projections(II)

Cylindrical Projections

- Earth intersects the cylinder on two small (or one) circle(s).
- All points along both(or the) circle(s) have no scale distortion

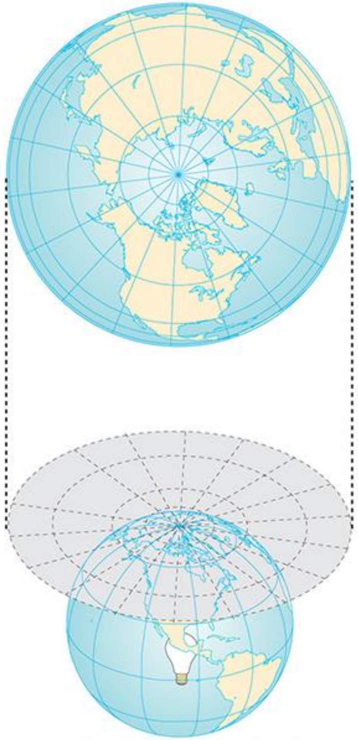


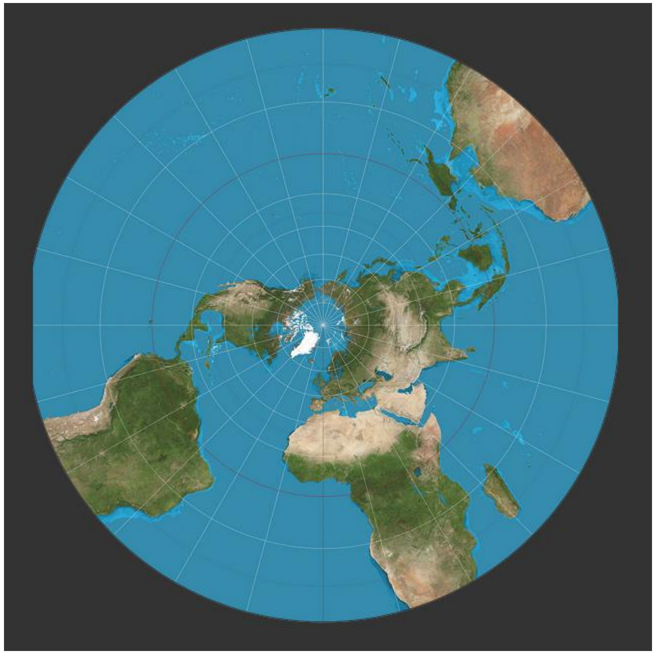


Classifications of Map Projections(II)

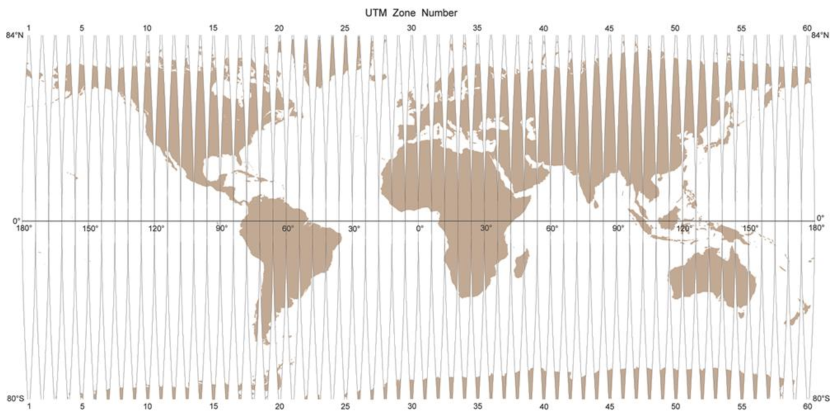
Planar or azimuthal Projections

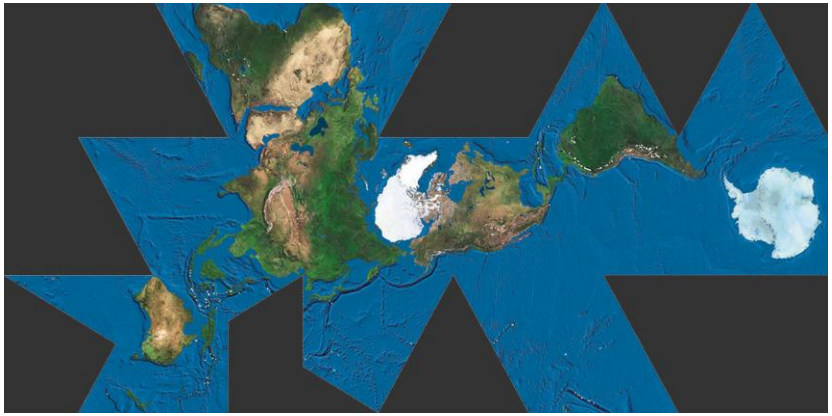
- Earth intersects the plane on a small circle
- All points on circle have no scale distortion

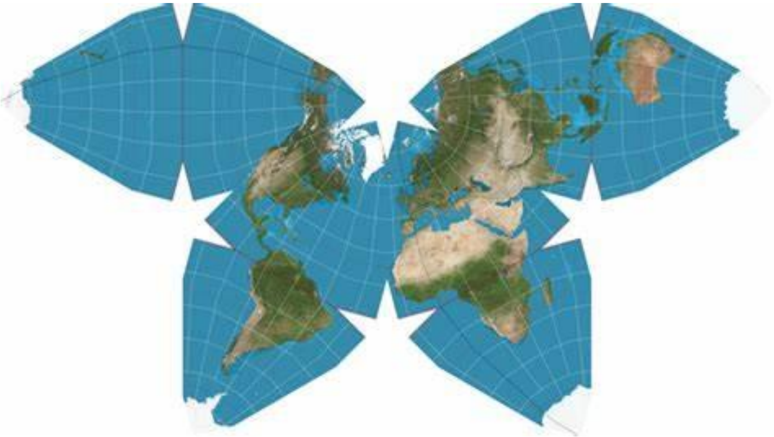




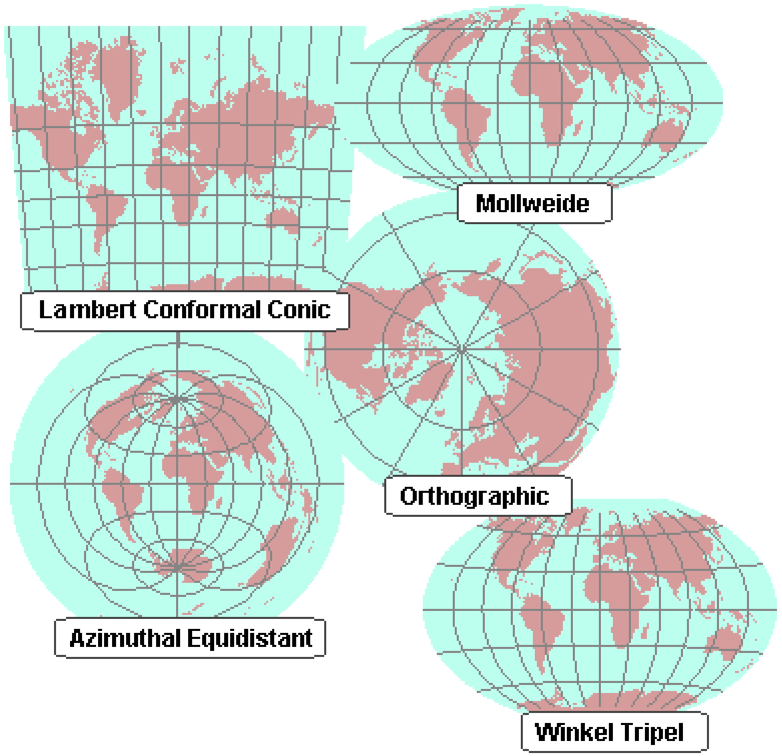
Kinds of Map Projections

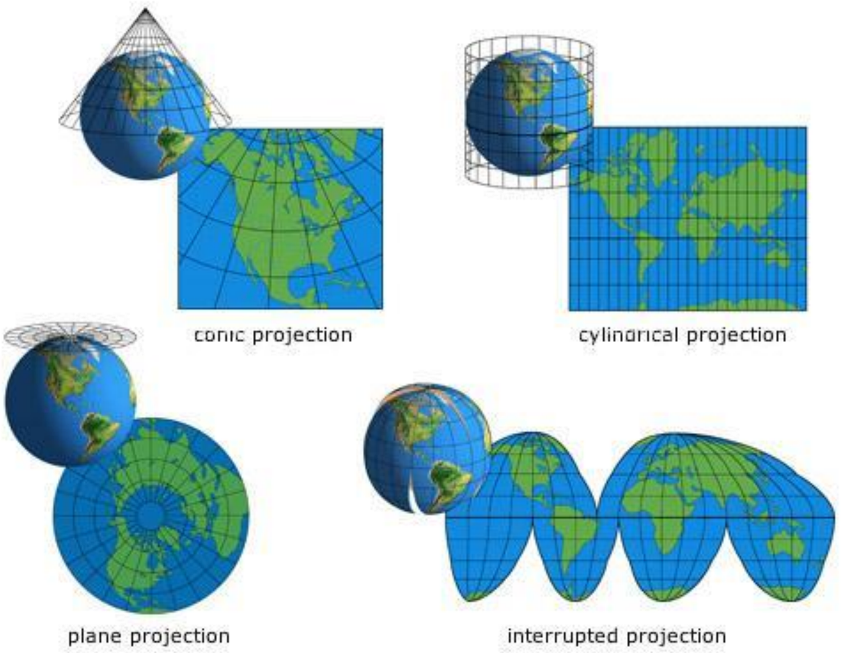






Combinations of Projections





§ 5 Converting georeferences

- Converting between georeferences are important for:
  - converting lists of customer addresses to coordinates for mapping or analysis
  - combining datasets that use different systems of georeferencing
  - converting to projections that have desirable properties for analysis, e.g., no distortion of area;
  - searching the Internet or other distributed data resources for data about specific locations;
  - positioning GIS map displays by recentering them on places of interest that are known by name (these last two are sometimes called locator services
- Conversion between different map projections
- Geocoding,addrss matching services

§ 6 Summary

- Any form of geographic information must involve some kind of georeference, and so it is important to understand the common methods, and their advantages and disadvantages
- with modern methods of measurement, it is possible to direct another person to a point on the other side of the Earth to an accuracy of a few centimeters
- But georeferences can never be perfectly accurate, and it is always important to know something about spatial resolution