Prepared By Deo Yadav

GIS Lecture Overview.pptx

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GIS Lecture Unit 03.1 ELLIPSOIDS GEOIDS DATUMS.pptx

GIS Lecture Unit 03.1 Introduction to geographic phenomena and data modeling.pptx

GIS Lecture Unit 03.1 MAP Projection based on developable surface.pptx

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Course Synopsis:

Basic concept of Geographical Information System

Goal:

- Spatial data modeling and database design
- Capturing the real world, spatial analysis and visualization
- Overview of open GIS

Reference Books:

1. Principles of Geographic Information Systems: An Introductory Text Book, International Institute for GeoInformation Science and Earth Observation, The Netherlands – By Rolf De By, Rechard A. Knippers, Yuxian Sun

2. ESRI Guide to GIS Analysis Andy Mitchell, ESRI Press, Red Lands

3. GIS Cook BOO

Unit 1: Introduction

1.1 Overview, History and concept of GIS

1.2 Scope and application areas of GIS

1.3 Purpose and benefits of GIS

1.4 Functional components of GIS

1.5 Importance of GPS and remote sensing data in GIS

Unit 2: Digital Mapping

2.1 **Map Concept:** map elements, map layers, map scales and representation

2.2 **Map projection:** coordinates system and projection system

Unit 3: **Spatial Data Modeling and Database Design**

3.1 Introduction to geographic phenomena and data modeling

3.2 Spatial relationship and topology

3.3 Scale and resolution

3.4 Vector, raster and digital terrain model

3.5 Spatial database design with the concept of geodatabase

Unit 4: Capturing the Real

4.1 Different Methods of data capture

4.2 Map projection and spatial reference

4.3 Data Preparation, Conversion and Integration

4.4 Quality aspects of Spatial Data

4.5 GPS: Global Positioning System

4.6 Remote Sensing

Unit 5: Spatial Analysis and Visualization

5.1 Spatial Analysis

- 5.1.1 Overlay
- 5.1.2 Buffering

5.2 Map outputs and its basic elements

Unit 6: Introduction to Spatial Data Infrastructure

6.1 SDI Concepts and its current trend

6.2 The concept of metadata and clearing house

6.3 Critical factors around SDIs

Unit 7: Open GIS

7.1 Introduction of Open Concept in GIS

7.2 Open Source Software for Spatial Data Analysis

7.3 Web Based GIS System

7.4 System Analysis and Design with GIS

Laboratory Work:

The lab should cover at least the concepts given in the chapters.

GIS Concept:

- Geography is the study of Earth's features and patterns of their variations in spatial location and time.
- A GIS is basically a computerized information system like any other database, but with an important difference: *all information in GIS must be linked to a geographic (spatial) reference* (latitude/longitude, or other spatial coordinates).
- The United States Geological Survey (USGS) defined "*A GIS as a computer hardware and software system designed to collect, manage, analyze and display geographically (spatially) referenced data.*"

GIS Concept:

GIS = G + IS

Geographic reference + Information system

Data of spatial coordinates on the surface of the earth (Map) – location data

Database of attribute data corresponding to spatial location and procedures to provide information for decision making

GIS = IS with geographically referenced data

Today’s Class Objectives:

Unit	Name	Method
1	**GIS Concept?**	Presentation & Demonstration
2	**What's new in Project Pro for Office365 and Sync to SharePoint Online**	Jan Kalis
3	**What's new with Microsoft's Project Portfolio Management (PPM) solution**	Christophe Fiessinger
4	**Project Online Overview**	Christophe Fiessinger
5	**Business Intelligence in Microsoft Project**	Jan Kalis
6	**Timesheet and Statusing**	Christophe Fiessinger
7	**What's new for IT Professionals - part 1 -** *Architecture*	Christophe Fiessinger
8	**What's new for IT Professionals - part 2 -** *Deployment & Upgrade*	Christophe Fiessinger
9	**What's new for IT Professionals - part 3 -** *Operations*	Christophe Fiessinger
10	**Demand Management and Workflow**	Jan Kalis
11	**Office Store Opportunity**	Jan Kalis
12	**What's new for Developers - part 1 -** *Project Desktop Extensibility*	Jan Kalis
13	**What's new for Developers - part 2 -** *Project Online and Server Extensibility*	Jan Kalis

GIS Concept:

A GIS is a computer-based system that provides the following four sets of capabilities to handle georeferenced data:

1. *Data capture and preparation*
2. *Data management*, including storage and maintenance
3. *Data manipulation and analysis*
4. *Data presentation*

WHAT A GIS CAN DO

- What exists at a particular location? Given a geographic reference (eg lat,long) for a location, the GIS must describe the features of that location
- Where can specific features be found? For example, where are the districts with rainfall greater than 500 mm and less than less than 750 mm?
- Trends or What has changed over time? For example, at what locations are the crop yields showing declining trends?
- What spatial patterns exist?
- Modelling or What if …?

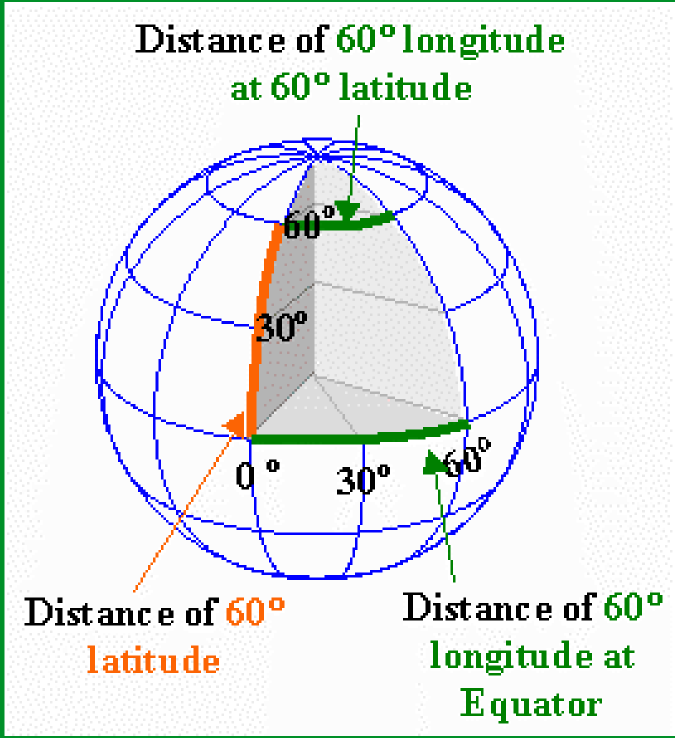
GEOGRAPHIC REFERENCING CONCEPTS

- A GIS is to be created from available maps of different thematic layers (soils, land use, temperature, etc). The maps are in two-dimensions whereas the earth's surface is a 3-dimensional ellipsoid. Every map has a projection and scale.
- To understand how maps are created by projecting the 3-d earth's surface into a 2-d plane of an analogue map, we need to understand the georeferencing concepts. Georefencing involves 2 stages: specifying the 3-dimensional coordinate system that is used for locating points on the earth's surface that is, the Geographic Coordinate System (GCS) and the Projected Coordinate System that is used for projecting into two dimensions for creating analogue maps.

Models and Representations of Real world

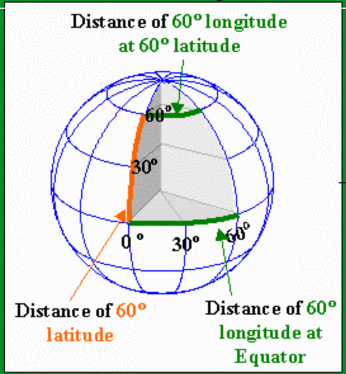
- Modelling is the process of producing an abstraction of the real world so that some part of it can be more easily handled.

Geographic Coordinate System

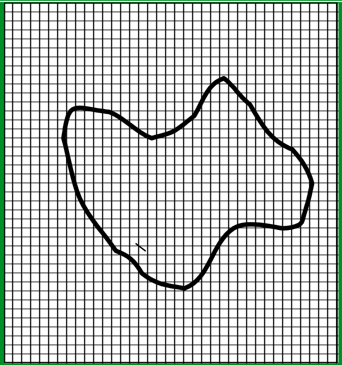


Projected Coordinate System

Geographic coordinate system

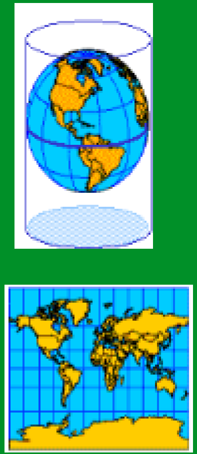


Projected coordinated system

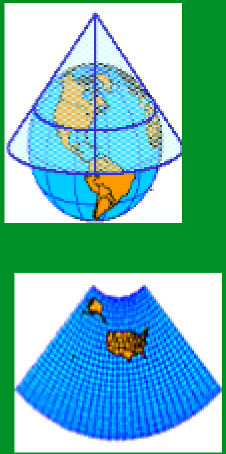


Types of Projections

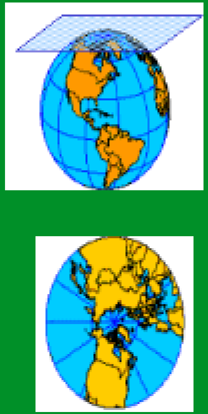
Types of Projections



Cylindrical
projection

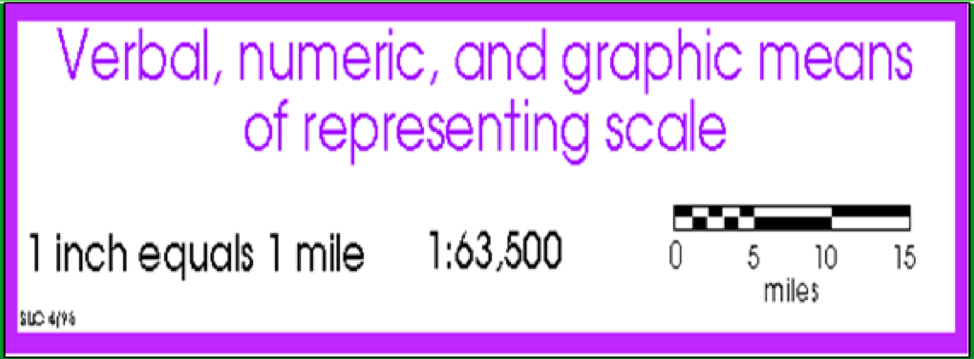


Conical
projection



Planar/azimuthal
projection

Map Scale



The standard map scales are:

- 1:1000,000 Country level or State level
- 1: 250, 000 State or District level
- 1: 50,000 District level
- 1: 12,500 Micro level

CREATING A GIS

Like for any other Information System , creating a GIS involves 4 stages:

Data input
Data Storage
Data Analysis and modelling, and
Data Output and presentation

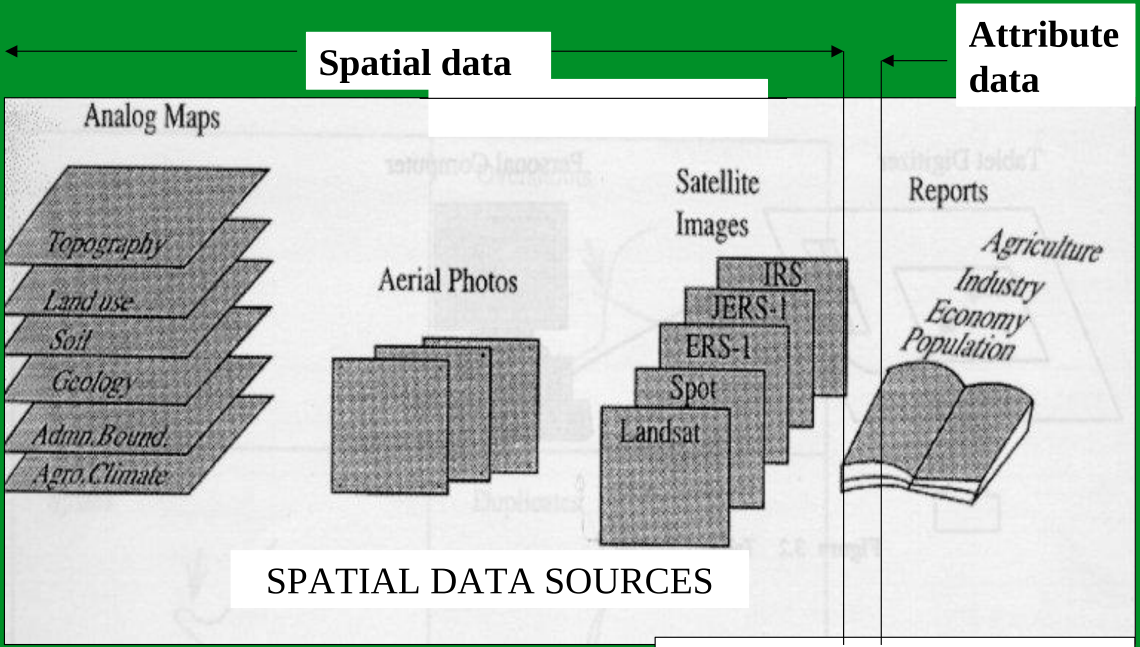
CREATING A GIS

The distinction from other Information Systems is that for a GIS the data inputs are of two types:

Spatial data (latitude/longitude for georeferencing,the features on a map, eg soil units, administrative districts), and
Attribute data (descriptive data about the features, eg soil properties, population of districts, etc.)

Components of Geographic data

Components of Geographic data

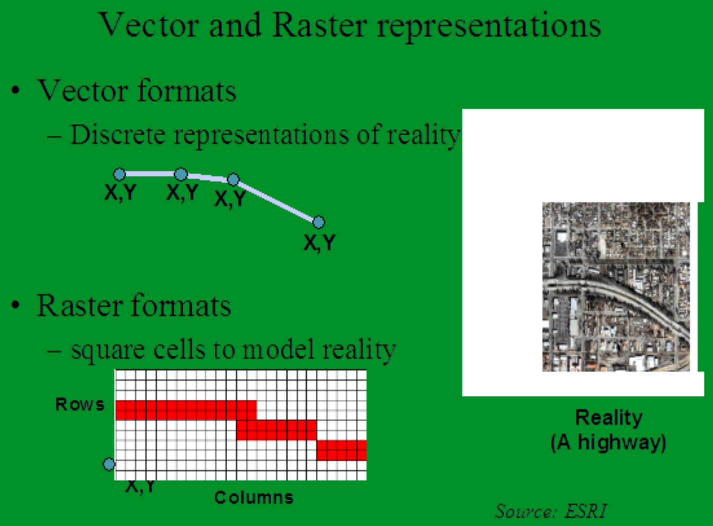


Source: (Murai and Murai, 1999))

GIS Data Input

Spatial Data capture (representing locations in a database) can be in two basic formats:

Vector format
Raster format



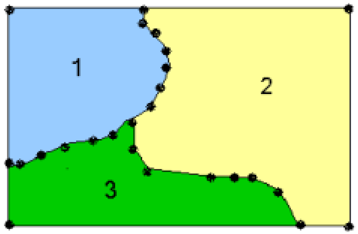
Vector Data features

any map consists of 3 basic kinds of features –

point features,
line features and
polygon or area features.

Vector Data features

Spatial data Generation in Vector Format



• discretize lines into points (nodes) and digitize as straight-line segments called vectors or arcs.

• data of X,Y coordinates of points and vectors and their connections (topology) are generated and stored in a database

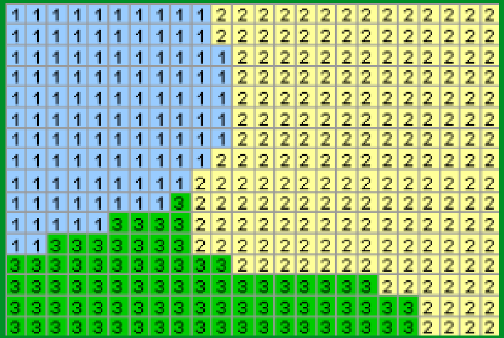
• for areas, geometry (area, perimeter) data are generated

• points, lines and areas have independent database tables

• Add attribute data to database

Raster Data

Spatial data Generation in Raster Format

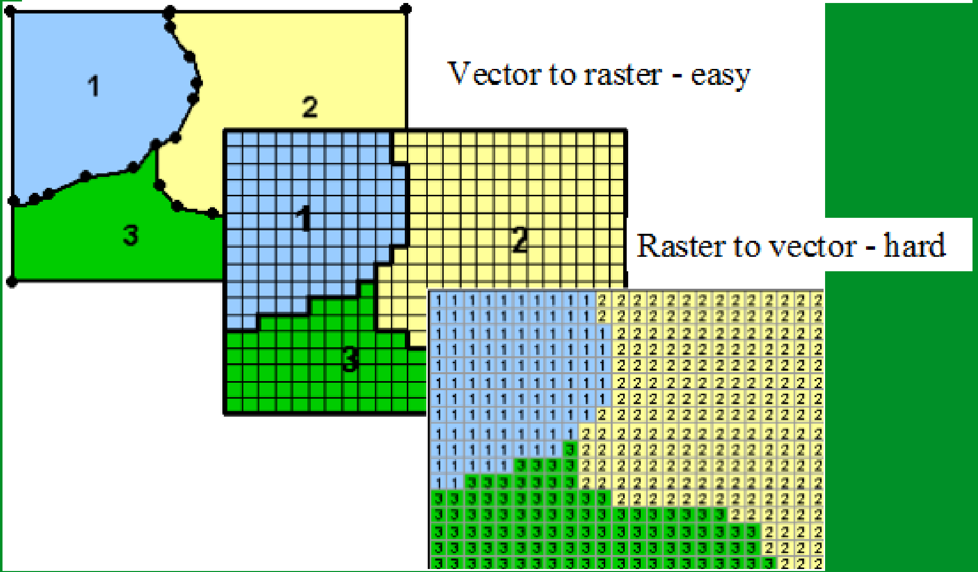


- map is represented by rectangular or square cells
- each cell is assigned a value based on what it represents
- attribute data are assigned by user to cells

Adopted from: FAO

Vector Data features

Most GIS software permit Raster-Vector format conversions:



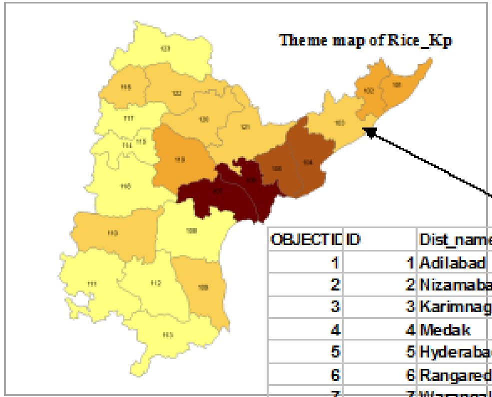
Source: FAO

Attribute data

Attribute data are descriptive data of point, line and area features. For points, this may be the name of the location, its elevation, etc. For lines attribute data could be the name of a road, or canal and other descriptions associated with them. For polygons, the attribute data may relate to name of a district and its population, area, area under specific crops in the district, etc.

Attribute data

LINKING SPATIAL AND ATTRIBUTE DATA



Attribute table of Dist

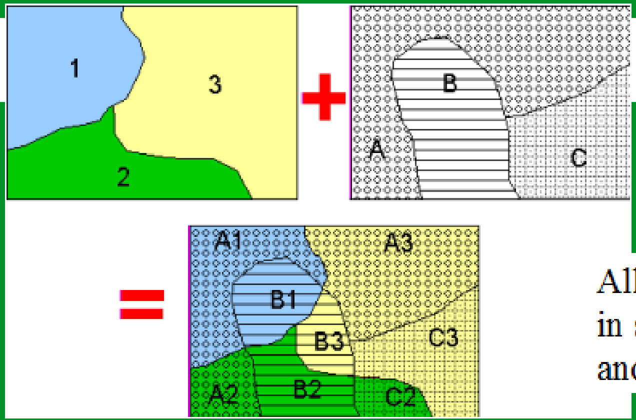
OBJECTID	ID	Dist_name	Dist_ID	Geometry	Shape_Len	Shape_Area
1	1	Adilabad	123	1Bo	753337	16838673859.80
2	2	Nizamabad	116	1BoG	430537	7655003826.81
3	3	Karimnagar	122	1BoG	662231	11771979304.40
4	4	Medak	117	1BoG	573986	9510748717.53
5	5	Hyderabad	115	1BoG	53851	203218046.01
6	6	Rangareddy	114	1BoG	587854	7813591915.82
7	7	Warangal	120	1BoG	674389	12701135906.20

Rice_1995 table

OBJECTID	DISTID	DISTNAME	NO_	YEAR_1995	RICEKA	RICEKP	RICERA	RICERP
23	123	Adilabad	113	1995	63	64	7	19
16	116	Nizamabad	78	1995	102	206	34	84
22	122	Karimnagar	108	1995	104	260	88	252
17	117	Medak	83	1995	64	111	41	78
15	115	Hyderabad	73	1995	1	1	1	1
14	114	Rangareddi	68	1995	22	47	18	35

Layer

Map Layer Overlay



All layers must be in same projection and scale

Overlay generates homogenous units – eg. agroecozones

Source: FAO

Thanks for your patience

शान्त भएर सुनिदिएकोमा
धेरै धेरै धन्यवाद

Unit 1: Introduction

1.1 Overview, History and concept of GIS

1.2 Scope and application areas of GIS

1.3 Purpose and benefits of GIS

1.4 Functional components of GIS

1.5 Importance of GPS and remote sensing data in GIS

History

- The first GIS, Canada Geographic Information System was developed in mid-1960s to identify the nation's land resources and their existing, and potential uses.
- In the late 1960s, US Bureau of the Census created the DIME program (Dual Independent Map Encoding) for all US streets to support automatic referencing and aggregation of census data.
- In late 1970s, Harvard University's Laboratory for Computer Graphics and Spatial Analysis developed a general-purpose GIS (ODYSSEY GIS).
- The first automated cartography developments occured in the 1960s, and by the late 1970s most major cartographic agencies were already partly computerized.
- GIS began to take off in the early 1980s, when the price of computing hardware had fallen to a level that could sustain a significant software industry and cost-effective applications.

History Continue…

Concept of GIS

What is a GISystem?

Many definitions of GIS have been suggested over the years, such as "a container of maps in digital form", "a computerized tool for solving geographic problems", "a tool for performing operations on geographic data that are too tedious or expensive or inaccurate if performed by hand". Let's look at some of the definitions given by the professional institutes:

Concept of GIS

What is a GISystem?

USGS (United States Geological Survey): In the strictest sense, a GIS is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information, i.e. data identified according to their locations.

ESRI (Earth Science Research Institute): GIS is a system of computer software, hardware and data, and personal to help manipulate, analyze and present information that is tided to spatial data.

Concept of GIS

What is a GISystem?

INHS (Illinois Natural History Survey): A Geographic Information System (GIS) is an organized collection of computer hardware, software, geographic data, and personnel designed to capture, store, update, manipulate, analyze, and display all forms of geographically referenced information. This System allows users to perform very difficult, time consuming, or otherwise impractical spatial analyses.

In general, we could derive the practical definition of GIS as a computerized system designed to dealing with the collection, storage, manipulation, analysis, visualization and displaying geographic information. GIS is a tool to perform the spatial analysis which will put insight to the activities and phenomena carrying out everyday.

Concept of GIS

What is GIScience?

Geographic Information Science (GIScience) is advocated to address are a set of intellectual and scientific questions which go well beyond the technical capabilities of GIS. The concept was first advocated by Michael Goodchild.

"...There is a pressing need to recognize and develop the role of science in GIS.This is meant in two senses. The first has to do with the extent to which GIS as a field contains a legitimate set of scientific questions, the extent to which these can be expressed, and the extent to which they are generic, rather than specific to particular fields of application. ... The second sense has to do with the role of GIS as a toolbox in science generally -with GIS for science rather than the science of GIS." (Goodchild, Spatial Information Science, 1990)

Concept of GIS

What is GIScience?

Thinking about the uniqueness of the spatial data, their location based characteristics, their spatial dependence, Goodchild proposed the contents for GIScience, such as data collection and measurement, spatial statistics, theories of spatial data, data structures, algorithms and processes, display and analytical tools. (Spatial Information Science, 1990)

It is known that the information science studies the fundamental issues arising from the creation, handling, storage, and use of information. So, similarly, we could infer that GIScience should also study the fundamental issues specifically arising from the special set, geographic information.

GIsystem is part of the Geographic Information whole, which also includes the fundamental issues of GIsicence. (Longley, Geographic Information System and Science, 2001)

Concept of GIS

What is GIService?

GIService is the kind of services dealing with the geographic information, such as the design and development of the GIS, geographic information retrieval, analysis, etc. For example, MapQuest (www.mapquest.com) provides a routing service for people to find the best driving route between two points.

Scope and application areas of GIS

One of the primary services provided by a GIS project is the georeferencing of various data layers for mapping projection, involving the use of satellite image data for GIS mapping including:

- Mineral Mapping
- Pipeline Corridor Mapping
- Defense Mapping
- Airport Mapping
- Land Cover Classification
- Urban Development
- Pre and post 2D/3D seismic surveys
- Environmental Impact Studies (EIS)
- Coastal erosion studies
- Cadastre Mapping
- Disaster Analysis

Purpose and benefits of GIS

Functional components of GIS

What are the major components of GISystem?

The major components of GIS is hardware, software, data, people, procedure and network.

1. **Hardware**: is the devices that the user interacts directly in carrying out GIS operations, such as the computer, digitizer, plotter, etc.
2. **Software:** normally runs locally in the user's machine, also supports user to carry out multiple spatial analysis and management.
3. **Data**: which is quite critical to GIS, contains either an explicit geographic reference, such as a latitude and longitude coordinate, or an implicit reference such as an address, postal code, census tract name, forest stand identifier, or road name.

Functional components of GIS

What are the major components of GISystem?

The major components of GIS is hardware, software, data, people, procedure and network.

4. **People** is most active components dealing with the design, programming, operation and management of GIS.
5. **Procedure:** more related to the management aspect of GIS, is referred to lines of reporting, control points, and other mechanism for ensuring the high quality of GIS.
6. **Network:** allows rapid communication and sharing digital information. The internet has proven very popular as a vehicle for delivering GIS applications.

What are data sources of GISystem?

- **Digitizing and scanning of maps**

Use the digitizer to transform the information from analog format, such as a paper map, to digital format, so that it can be stored and displayed with a computer . Or use scanner to convert the analog paper map to computer-readable form automatically.

- **Input image data**

Image data includes satellite images, aerial photographs and other remotely sensed or scanned data, which are in the raster form. Remote sensing has become a more and more important data source for GISystem.

What are data sources of GISystem?

- **Direct data entry including Global Position System (GPS)**

Surveying field data which measure the distance and angle to decide the location of other points could also be transferred into the GISystem. GPS is a set of hardware and software designed to determine accurate locations on the earth using signals received from selected satellites. Location data and associated attribute data can be transferred to mapping and GISystem.

- **Transfer data from existing sources**

Data are obtained already in digital format from Government Agencies such as Nepal Survey and Land Information Department and other sources.

What is Different Kinds of GISystem Software?

A modern GIS software system comprises an integrated suite of software components, including end user applications, geographic tools and data access components. GIS software packages could be classified as six groups based on the functionality and type.

Professional GIS

The distinctive features of professional GIS include data collection and editing, database administration, advanced geoprocessing and analysis, and other specialist tools, such as ESRI ArcInfo, Samllworld GIS.

Desktop GIS

Desktop GIS focus on data use, rather than data creation, and provide excellent tools for making maps, reports, and charts. Well-know examples include ESRI ArcView, Intergraph GeoMedia, MapInfor professional, Clark Lab's Idrisi, etc. MapInfo MapX.

- GIS viewer

GIS viewer are able to display and query popular file formats, such as ESRI ArcExplorer, Intergraph's GeoMedia, and MapInfo's ProViewer.

- Internet GIS

What is Different Kinds of GISystem Software?

Hand-held GIS
Hand-held GIS are lightweight systems designed for mobile and field use, such as Autodesk Onsite, ESRI ArcPad, and Smallworld Scout.

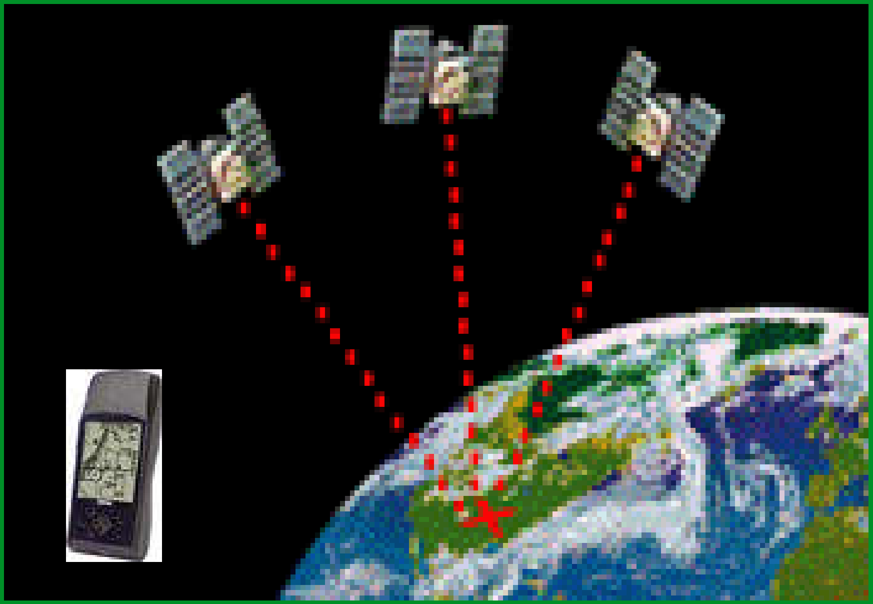
Component GIS
Component GIS are tool kits and used by knowledgeable programmers to create focused applications. Examples include Blue Marble Geographic GeoObjects, and MapInfo MapX.

GIS viewer
GIS viewer are able to display and query popular file formats, such as ESRI ArcExplorer, Intergraph's GeoMedia, and MapInfo's ProViewer.

Internet GIS
Internet GIS focus on display and query applications, as well as maping. Examples include Autodestk MapGuide, ESRI ArcIMS, Intergraph GeoMedia Web Map, and MapInfo MapXtreme.

Importance of GPS and remote sensing data in GIS

A Global Positioning System (GPS) is a tool used to collect data for a GIS. Many people get the terms GIS and GPS confused with each other.



Importance of GPS and remote sensing data in GIS

GPS stands for **Global Positioning System.**

- GPS is a system of satellites, ground stations, and receivers that allow you to find your exact location on Earth. By collecting location points you can begin compile datasets that can be used to map whatever data you are collecting.

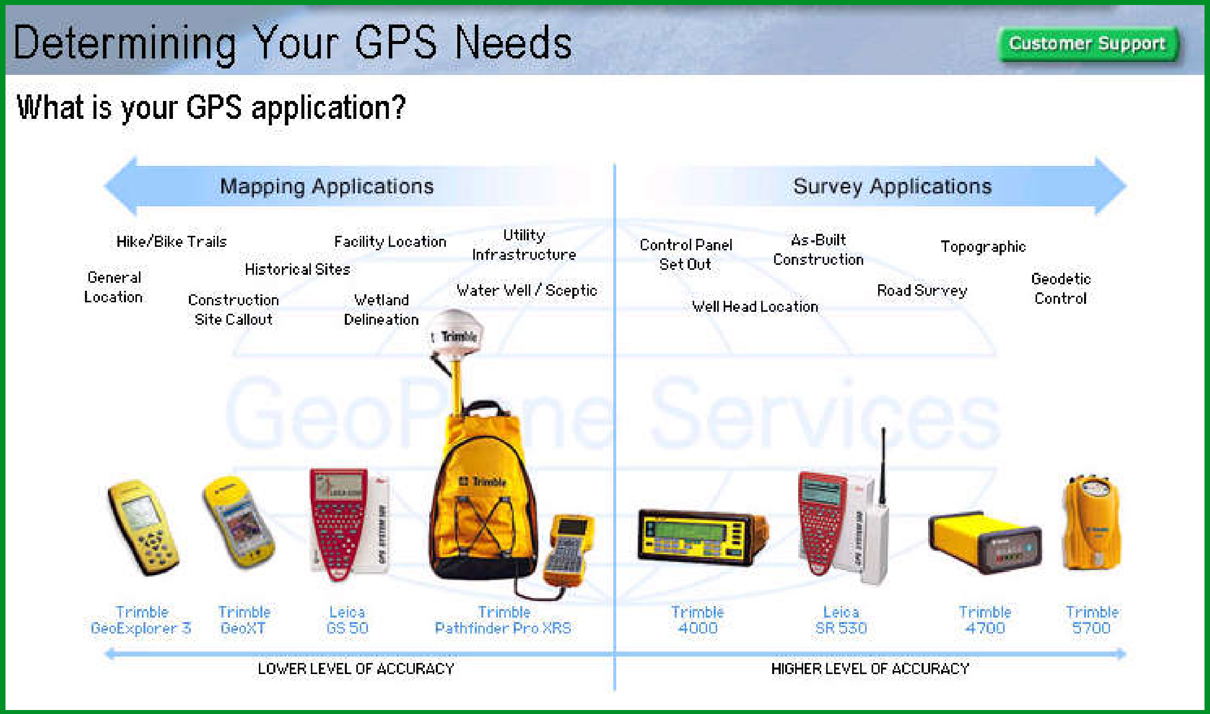
How GPS's and GIS relate to one another:

- The way a GPS works is, by connecting to three or more 24 GPS satellites that orbit 11,000 nautical miles above the earth, and are monitored by ground stations located throughout the world.
- GPS systems generate geographic reference points in the form of latitude, longitude, and elevation coordinates. Once the data is collected it can be put into a GIS and displayed digitally as it is in the real world.

Importance of GPS and remote sensing data in GIS

- Today boats and many car manufacturer's have GPS units mounted so they can track where they are at all times.
- The increased availability and affordability of handheld GPS units, makes it useful for the average person to use for activities such as backpacking, hunting, and skiing, to name a few.

Importance of GPS and remote sensing data in GIS



Remote sensing data in GIS

- RS is the science/ are the techniques of deriving information about the Earth's land and water areas from images (or point/line samples) at a distance.
- It relies upon measurement of electro-magnetic (EM) energy reflected or emitted from the objects of interest at the surface of the Earth.
- So, one is looking at the physical nature of spatially distributed features.

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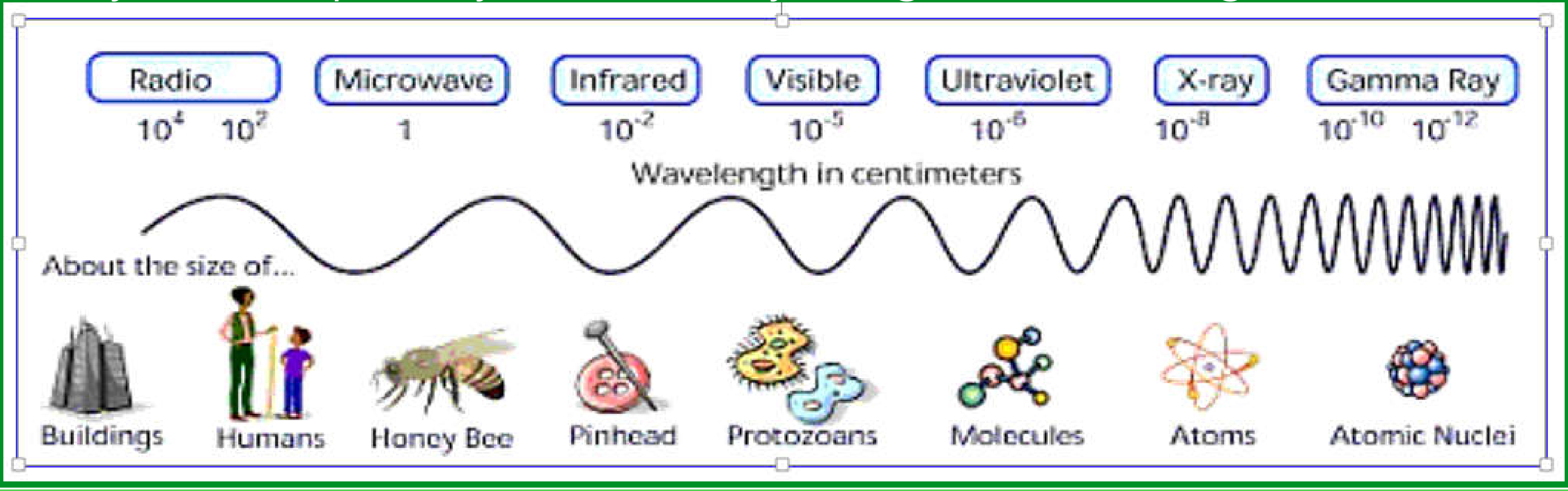
- It relies upon measurement of electro-magnetic (EM) energy reflected or emitted from the objects of interest at the surface of the Earth.
- So, one is looking at the physical nature of spatially distributed features.
- Remote Sensing is the science and art of acquiring

Remote sensing data in GIS

- In remote sensing, information transfer is accomplished by use of electromagnetic radiation (EMR).
- EMR is a form of energy that reveals its presence by the observable effects it produces when it strikes the matter.

Remote sensing data in GIS

- Using electromagnetic spectrum to image the land, ocean, and atmosphere.
- EMR is considered to span the spectrum of wavelengths from 10-10 µm to cosmic rays up to 1010 µm
- When you take a photo, you are actually doing remote sensing.



Unit 2: Digital Mapping

2.1 **Map Concept:** map elements, map layers, map scales and representation

2.2 **Map projection:** coordinates system and projection system

MAP Concept

Map Design Objectives

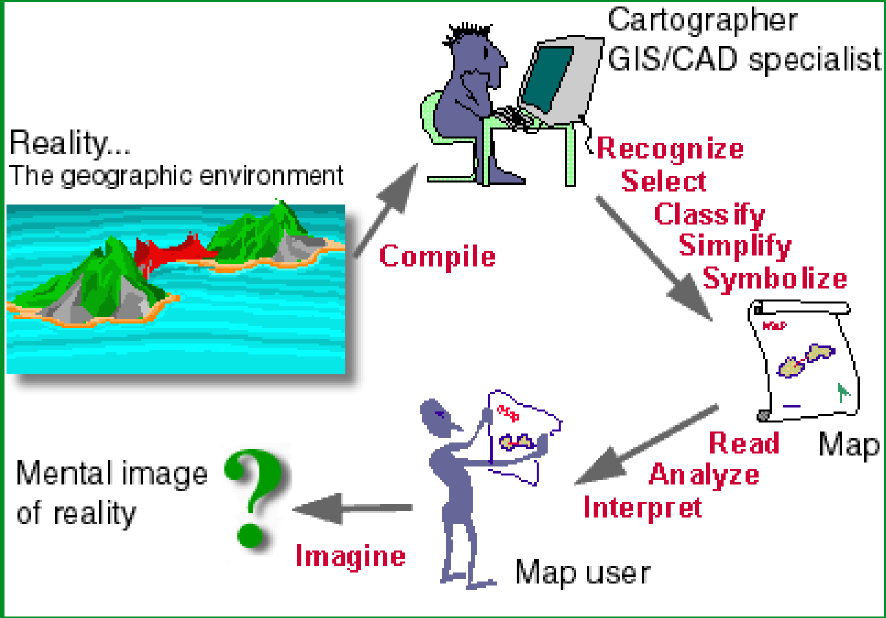
- Fulfill Intended Purpose
- Share Information
- Highlight Relationships
- Illustrate Results

Communicating with Maps

Determine what the purpose of the map is
Who is the intended audience
What features are needed
What is the best way to symbolize the map

MAP Concept

Communicating with Maps



MAP Concept

Factors Controlling Cartographic Design

- Map Objective: Will the map be in a book, hang on a wall, be folded or flat, black and white or color, etc?
- Audience: Is the audience a group of scientist or the general public.
- Scale: Controls how much detail can be on the map.
- Technical Limits: Minimum line width, Limited color palette, lack of color
- Mode of use: Will the map be used in the field? Place on a wall? Used while driving?

MAP Concept

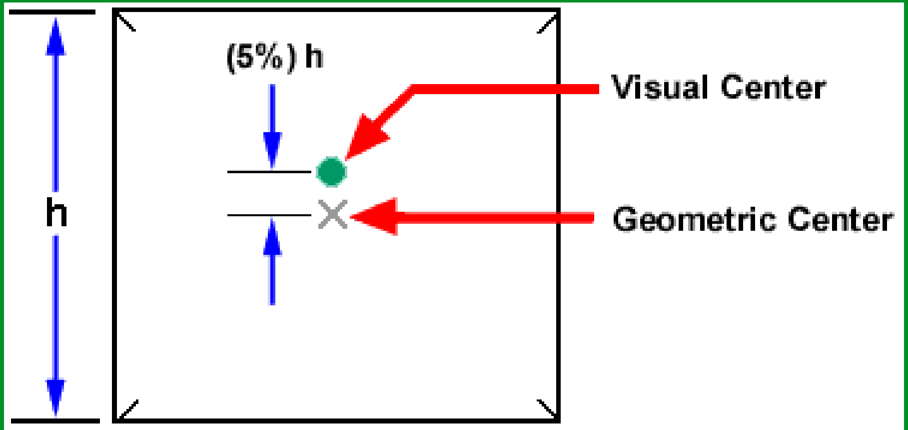
Standard Symbolization

- People are conditioned to recognize standard symbols.
- Roads Red
- Streams Blue
- Geologic Symbols Open-File Report 99-430

MAP Concept

Visual Balance

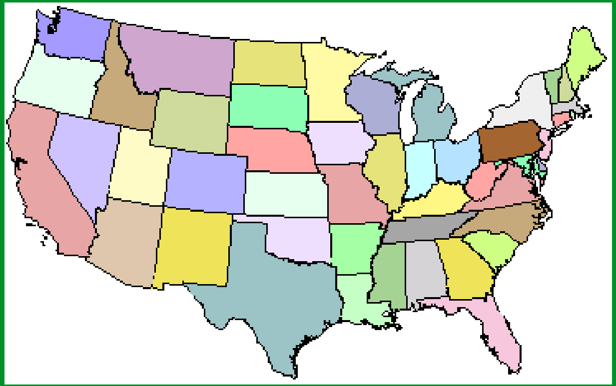
- Most people will focus on a point slightly above the image's geometric center



MAP Concept

Graphic Perception

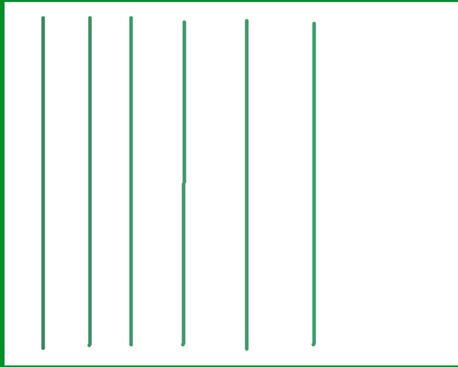
- The human eye has difficulty deciphering more than 12 colors in one view
- This map has 48 colors.
- Can you tell the difference between California and Nebraska



MAP Concept

Graphic Perception

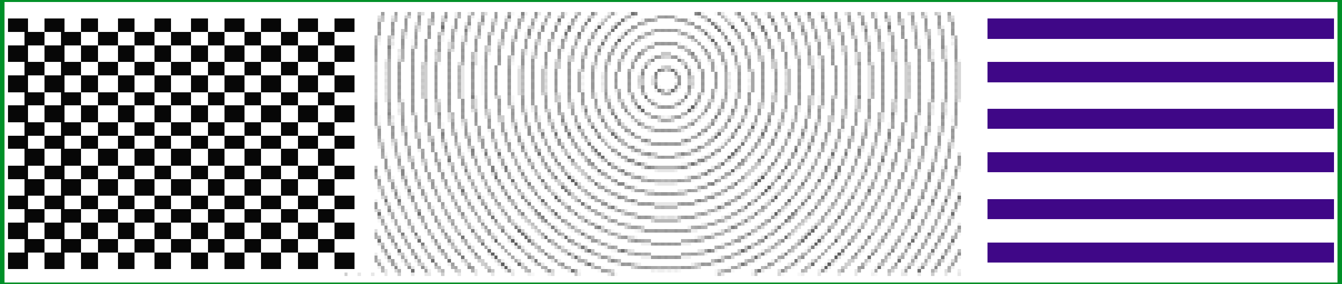
- The human eye can decipher no more than seven or eight shades form the 256 shades of one color
- All of the lines differ by 1.9%



MAP Concept

Graphic Perception

- 5 to 7% of the population is color blind
- Your map may be reproduced in Black and white.
- Texture vibration is an effect that causes some patterns to move.



MAP Concept

Annotation

- Map labels are useful but lack control.
- When you need more control use Annotation
- It is possible to create feature linked annotation in 8.3 (ArcEditor, ArcInfo)
- New product at 9.0 called Maplex has rules based labeling

MAP Concept

Geographic Features

- The map body is the main focus for the map. It should be prominently displayed. The other elements of the map should not direct attention away form it.

MAP Concept

Marginalia

- Marginalia refers to any supporting information or elements on the map.
- Title: It should be the largest text on the map but not over power the main body
- Legend: A figure to help the reader to interprate the map body.
- North Arrow
- Scale Bar
- Borders and Neatlines
- Source information and other text including projection information
- Inset maps

MAP Concept

Map Templates

- If you are making a series of maps set up the Marginalia and save the project as a template.
- You can use the template to give t feel.

Geographic phenomena and data modeling

3.1 Introduction to geographic phenomena and data modeling

Geographic phenomena and data modeling

About Earth:

- The shape of the Earth is represented as a **sphere**.
- It is also modelled more accurately as an **oblate spheroid** or an **ellipsoid**. Earth's actual shape is closer to an **oblate ellipsoid**.
- A **globe** is a scaled down model of the Earth.
- A map projection is the transformation of Earth’s curved surface (or a portion of) onto a two-dimensional flat surface by means of mathematical equations.

Geographic phenomena and data modeling

About Earth:

- During the transformation, the angular Geographic coordinates (latitude, longitude) referencing positions on the surface of the Earth are converted to Cartesian coordinates (x, y) representing position of points on a flat map.

Geographic phenomena and data modeling

The creation of a map projection involves three steps:

- Selection of a model for the shape of the Earth (Sphere, Ellipsoid, Oblate ellipsoid or Geoid).
- Transformation of Geographic coordinates (longitude and latitude) to Cartesian (x, y) Projection.
- Reduce the scale

Geographic phenomena and data modeling

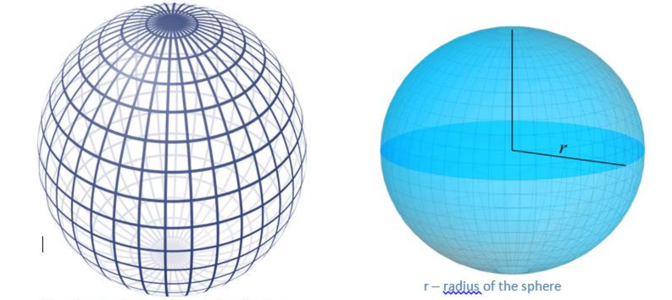
Selection of a model for the shape of the Earth

- Earth shape model selection for projection have the advantages and disadvantages.
- Spherical models are useful for small-scale maps such as world atlases and globes
- The ellipsoidal model is commonly used to construct topographic maps and for other large- and medium-scale maps that need to accurately depict the land surface.
- A third model is the geoid, a more complex and accurate representation of Earth's shape coincident with what mean sea level

Geographic phenomena and data modelling

Sphere

- A sphere is a perfectly round geometrical and circular object in three-dimensional space that resembles the shape of a completely round ball.
- A sphere is defined mathematically as the set of points that are all the same distance r from a given point in three-dimensional space.

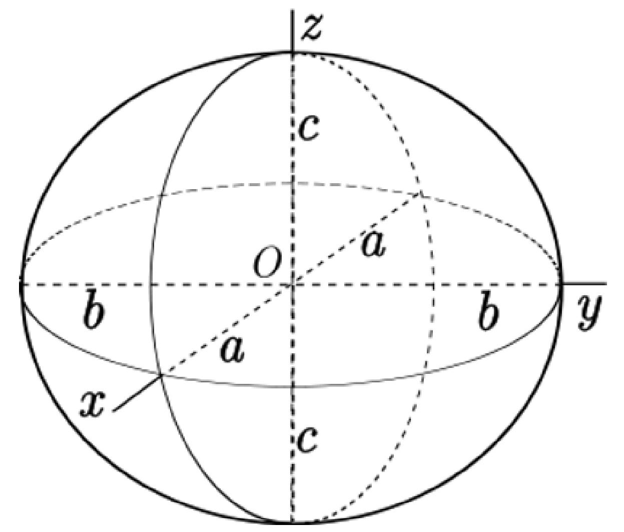


A two-dimensional perspective projection of a sphere

Ellipsoid

- An ellipsoid is a closed quadric surface that is a three-dimensional analogue of an ellipse.

Tri-axial ellipsoid with distinct semi-axis lengths



Tri-axial ellipsoid with distinct semi-axes a, b and c

Ellipsoid

- An ellipsoid is a closed quadric surface that is a three-dimensional analogue of an ellipse.

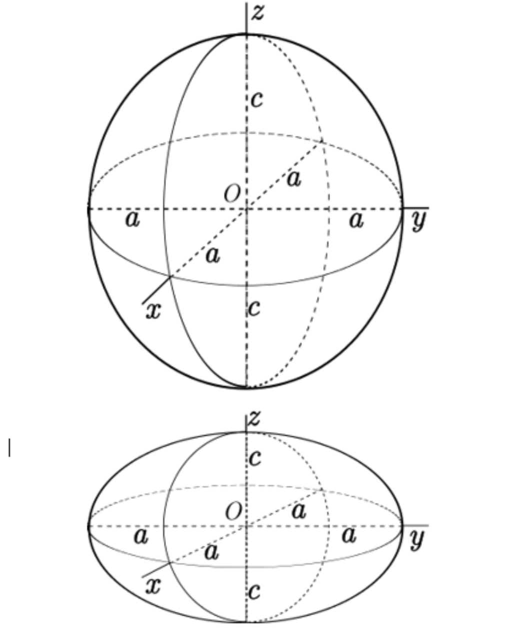
There are four distinct cases of which one is degenerate:

- $a>b>c$ = tri-axial or (rarely) scalene ellipsoid;
- $a=b>c$ = oblate ellipsoid of revolution (oblate spheroid);
- $a=b<c$ = prolate ellipsoid of revolution (prolate spheroid);
- $a=b=c$ = the degenerate case of a sphere;

Geographic phenomena and data modeling

Ellipsoid

- a=b>c = oblate ellipsoid of revolution (oblate spheroid);

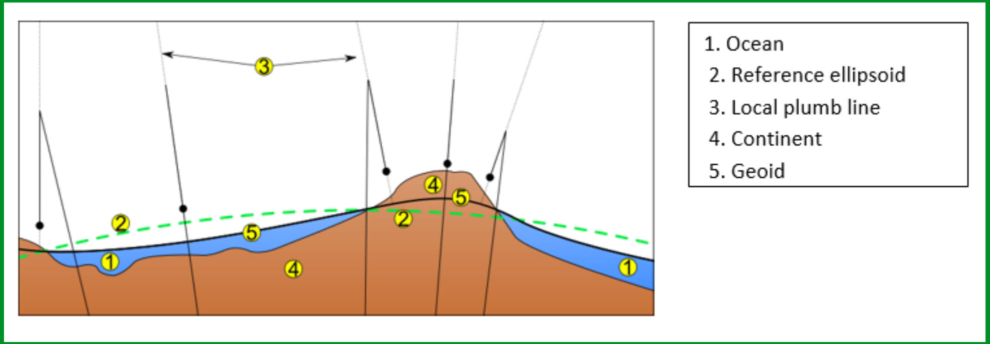


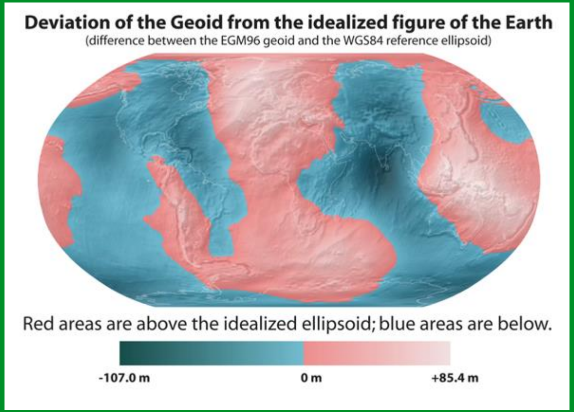
The ellipsoid is prolate (top) or oblate (bottom) as c is greater than or less than a.

Geographic phenomena and data modeling

Geoid

The geoid is the shape that the surface of the oceans would take under the influence of Earth's gravitation and rotation alone, in the absence of other influences such as winds and tides.





ELLIPSOIDS, GEOIDS, DATUMS

ELLIPSOIDS:

- Believe that the Earth was a perfect sphere until of the seventeenth century, when Newton advanced his theory of gravity.
- Newton said, if the Earth were rotating along an axis, the shape of the Earth would tend to bulge along the equator and tend to be flattened at the poles, due to the centrifugal force which confirmed by field measurements of the Earth's surface, beginning in 1735, in Peru and Lapland, and later in other areas (Snyder 1987).

ELLIPSOIDS, GEOIDS, DATUMS

ELLIPSOIDS:

- The shape of the Earth is thus referred to as an oblate ellipsoid or oblate spheroid.
- There is a 20 km difference of the Earth's most northern point on this spheroidal shape with where one would expect to find it on a perfect sphere,.

ELLIPSOIDS, GEOIDS, DATUMS

ELLIPSOIDS:

- This difference can be described as the flattening ratio (f) and is described by the relationship (a - b)la, where a is the equatorial radius and b is the polar radius.
- Technological advancements in Earth measurement collection have led to improved ellipsoid models, including the Geodetic Reference System of 1980 (GRS80) and the World Geodetic System of 1984 (WGS84).

ELLIPSOIDS, GEOIDS, DATUMS

GEOIDS:

- A further refinement and approximation of the Earth's shape can be described with a geoid.
- A geoid attempts to reconcile Earth's local irregularities with the differing gravitational forces that are caused by varying Earth densities.

ELLIPSOIDS, GEOIDS, DATUMS

GEOIDS:

- The shape of a geoid is irregular and approximates Earth's mean sea level perpendicular to the forces of gravity.
- Once can define the Earth's shape and irregularities, a control system is needed on which to base the approximate locations of landscape features.

ELLIPSOIDS, GEOIDS, DATUMS

DATUM:

- A datum is a smooth, mathematical representation of the Earth's surface that creates a "control surface," on which an ellipsoid and other location data are referenced.
- Datums are created from large numbers of measurements of the Earth's surface, typically assembled by land surveyors or others involved in Earth measurements, where the location of each point has been measured using precise control surveys.

ELLIPSOIDS, GEOIDS, DATUMS

DATUM:

- From these points, a theoretical surface of the Earth is constructed. The greater the number of point locations, the greater the datum's potential to act as a reliable surface on which one can reference other landscape features.

ELLIPSOIDS, GEOIDS, DATUMS

DATUM:

- Hundreds of datums have been developed to describe the Earth, many of which are specific to a particular country or region.
- Within North America, two datums are prorninent: the North American Datum of 1927 (NAD27) and the North American Datum of 1983 (NAD83).
- The World Geodetic System of 1984 is commonly used in conjunction with GPS data collection efforts.
-

ELLIPSOIDS, GEOIDS, DATUMS

DATUM:

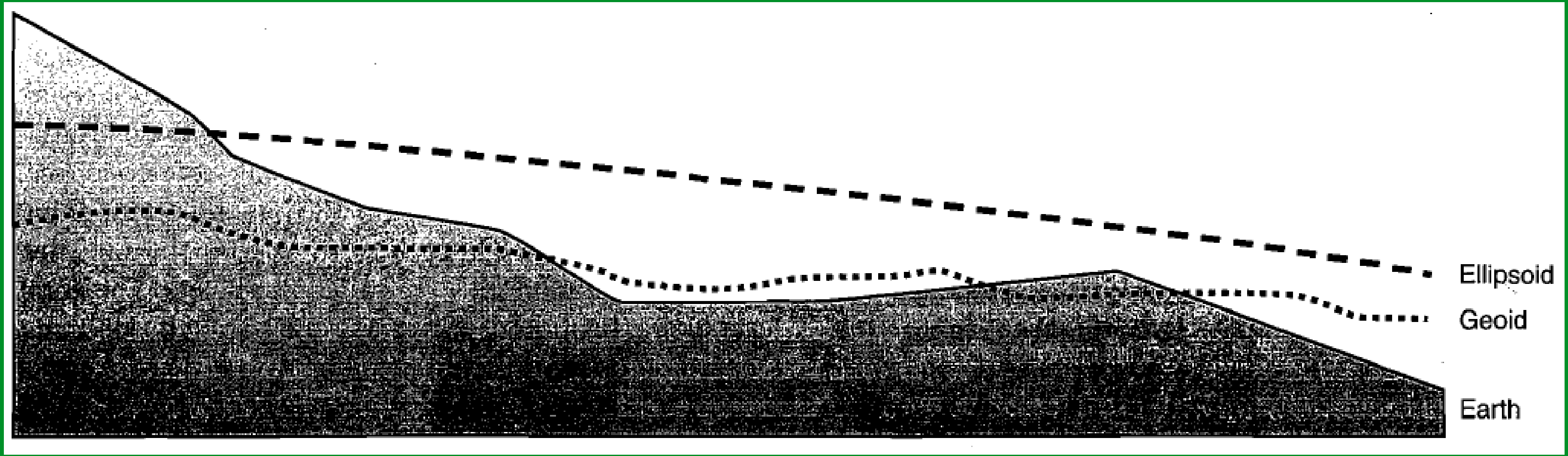
- The discussion of datums, to this point, has focused on those related to horizontal surfaces. When working with elevation data, GIS users must also be aware that datums have also been developed to describe the vertical dimension.

ELLIPSOIDS, GEOIDS, DATUMS

DATUM:

- The National Geodetic Vertical Datum of 1929 (NGVD29) was established from 26 gauging stations in the United States and Canada and forms the basis for determining mean sea level.
- The North American Vertical Datum of 1988 (NAVD88) used additional measurements from a large number of elevation profiles to create a single sea level control surface. The NAVD88 has become the preferred vertical datum.

ELLIPSOIDS, GEOIDS, DATUMS



Ellipsoid and geoid surfaces

Coordinate System

- Seventeenth-century French mathematician and philosopher, devised one of the first methods for locating landscape features on a planar surface.
- Two axes perpendicular to one another with gradations along both axes to create equal distance intervals.

Coordinate System

- The horizontal axis is termed the x-axis and the vertical is the y-axis. The location of any point on the planar surface covered by this type of grid can be defined with respect to the interval lines that it intersects.
- This basis of determining location is known as a Cartesian coordinate system.

Coordinate System

- The most common coordinate system is the system of latitude and longitude, which is sometimes referred to as the geographical coordinate system.
- This system has an origin at the center of the Earth and contains a set of perpendicular lines running through the center to approximate the x- and y-axes of the Cartesian coordinate system.

Coordinate System

- The orientation of the perpendicular lines is based on the rotation of the Earth. The Earth spins on an axis that, if extended, coincides very closely with the North Star (Polaris) and is called the axis of rotation.
- This rotation axis divides the Earth in half to create a line of longitude that approximates the y-axis. A line perpendicular to the line of longitude falls along the equator (Earth's widest extent) to create a line of latitude that is conceptually similar to the x-axis..

Coordinate System

- Latitudes are expressed to a maximum of 90°, in a north or south direction from the equator, with the equator denoting 0".
- Traveling 90" north from the equator would leave one at the most northern point of the Earth and would be noted as 90" N.
- Similarly, a position halfway between the South Pole and the equator would be referenced as 45" S.
- The equator and other lines of latitude that parallel the equator are also called parallels.

Coordinate System

Although the axis of rotation splits the Earth in half, a reference line must be established from which coordinates can start. This reference line is referred to as the prime meridian; although there are dozens in existence, the most widely recognized prime meridian circles the globe while passing across the British Royal Observatory located in Greenwich, England.

Coordinate System

Longitude measurements are made from this reference line and are designated from 0" to 180°, in a western or an eastern direction. Other lines that pass through the North and South Poles are called meridians. The conceptual collection of meridians and parallels superimposed on the Earth's surface is known as a graticule.

Coordinate System

- The geographical coordinate system can be used to locate any point on the Earth's surface. To achieve a high level of precision in locating landscape features degrees are further subdivided into minutes and seconds.
- There are 60 minutes (noted by ') within each degree and 60 seconds (noted by ") within each minute. A location that is described as 38'30' latitude indicates a line between 38" and 39".

Coordinate System

- Because this measurement system does not lend itself conveniently to mathematical calculations, conversions to the decimal degree system are common. The conversion of 38'30'45" (spoken as 38 degrees, 30 minutes, and 45 seconds) would result in 38.575" decimal degrees.
- By using this coordinate system and describing measurements to the nearest second, one can locate objects on maps that are within 100 feet of their true locations on the ground.

Coordinate System

- Although the geographical coordinate system provides a relatively straightforward solution to the complicated issue of establishing a regular system of measurements on a spherical surface, there are complications to its use.
- A primary problem is that the units of an arc (arc is used to describe angular distance-a sphere contains 360" of arc) are not constant throughout the system of geographical coordinates. Due to the convergence of the meridians at the Earth's polar areas, lo of longitude ranges from 69 miles long at the equator to 0 miles long at the poles.

Coordinate System

Latitude measurements, in contrast, differ by minor amounts but average 69 miles across the Earth. Field measurements of longitude are also difficult to collect without the use of GPS or other similar navigational technology. Whereas one can calculate latitude by measuring the distance between the horizon and the North Star (in the Northern Hemisphere), calculating longitude involves understanding the difference between one's location and the prime meridian. In addition, the calculations and conversions involved when using degreesminutes- seconds measurements are cumbersome and time-consuming.

Metric properties of maps

Many properties can be measured on the Earth's surface independently of its geography. Some of these properties are:

Area
Shape
Direction
Distance
Scale

Map projections can be constructed to preserve at least one of these properties. Each projection preserves or compromises or approximates basic metric properties in different ways.

Using globes vs. projecting on a plane

- The globe is the only way to represent the earth without distorting one or more of the above-mentioned metric properties.
- Globes have the advantage of being true to metric properties and able to provide a true picture of spatial relationships on the earth's surface.
- The disadvantages of the globe are that it is impractical to make large-scale maps with it, it is difficult to measure on a globe, one can't see the whole world at once and it is difficult to handle and transport a globe around

Using globes vs. projecting on a plane

- The flat map has the disadvantage of always distorting one or more of the metric properties.
- It is more difficult to get a true picture of the spatial relationships between objects.
- Flat maps have numerous advantages however; it is not practical to make large or even medium scale globes, it is easier to measure on a flat map, easy to carry around, and one can see the whole world at once.

Using globes vs. projecting on a plane

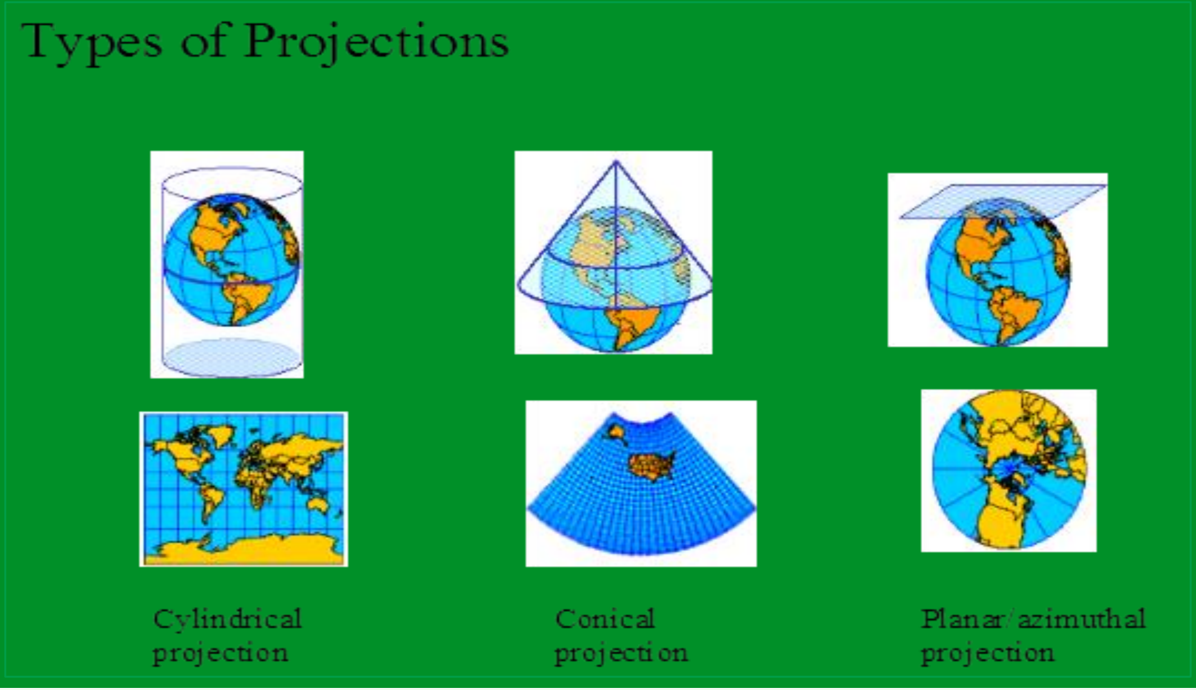
- Scale in particular is effected by the choice between using a globe vs. a plane. Only a globe can have a constant scale throughout the entire map surface and the scale for flat maps will vary from point to point
- The scale for a flat map can only be true along one or two lines or points (tangent or secant points/lines).
- The scale factor is therefore used to measure the difference between the idealized scale and the actual scale at a particular point on the map.

Choosing a projection surface

- A surface that can be unfolded or unrolled into a plane or sheet without stretching, tearing or shrinking is called a developable surface.
- The cylinder, cone and the plane are all developable surfaces.
- The sphere and ellipsoid do not have developable surfaces, so any projection of them onto a plane will have to distort the image.
- One way of describing a projection is first to project from the Earth's surface to a developable surface such as a cylinder or cone, and then to unroll the surface into a plane.

Choosing a projection surface

The projection surfaces (i.e., cylinders, cones, and planes) form the basic types of projections

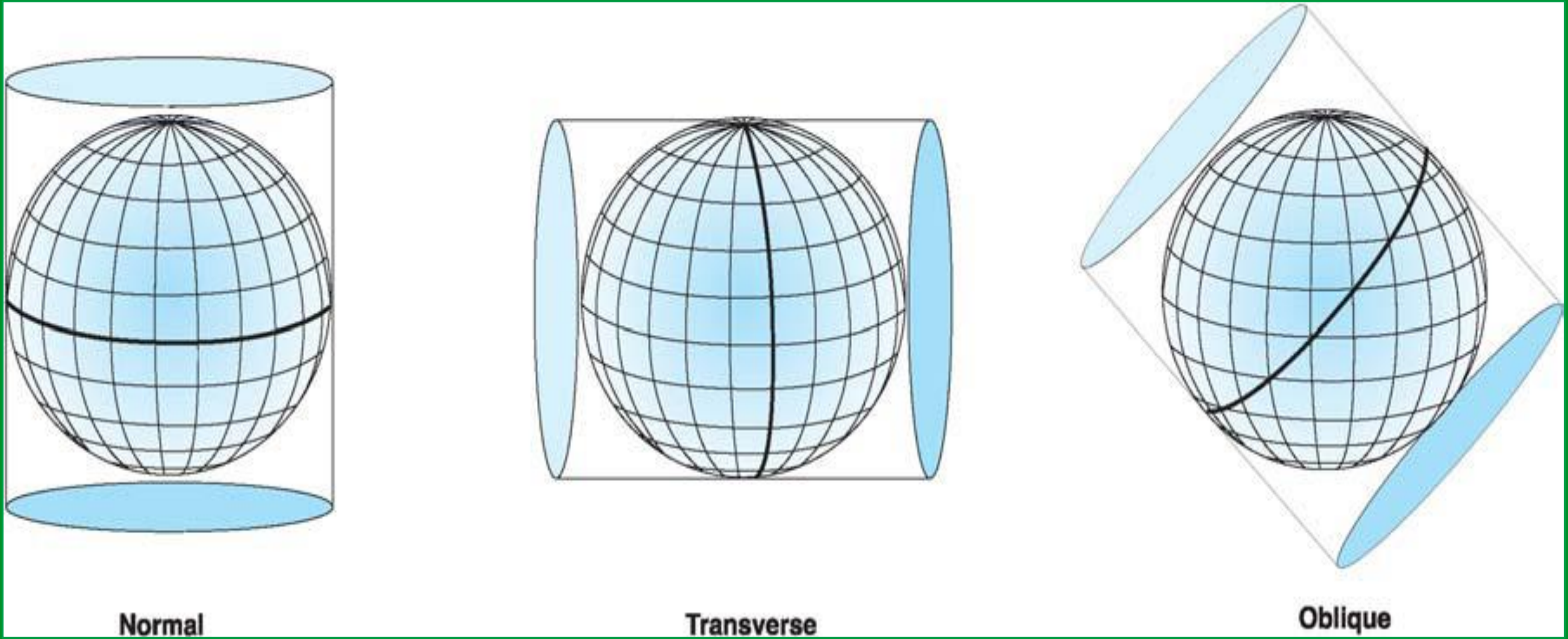


Aspects of the projection

- Once a choice is made between projecting onto a cylinder, cone, or plane, the aspect of the shape must be specified.
- The aspect describes how the developable surface is placed relative to the globe:
- It may be normal (such that the surface's axis of symmetry coincides with the Earth's axis), transverse (at right angles to the Earth's axis) or oblique (any angle in between).

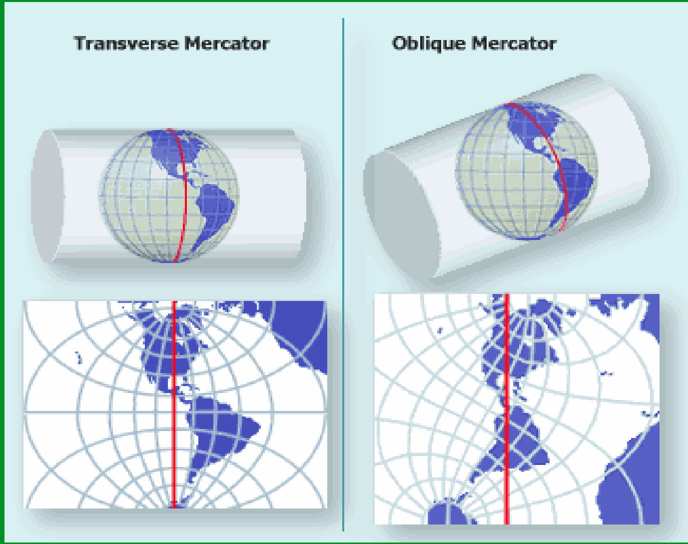
Choosing a projection surface

Three aspect of projection: Normal, Transverse and Oblique



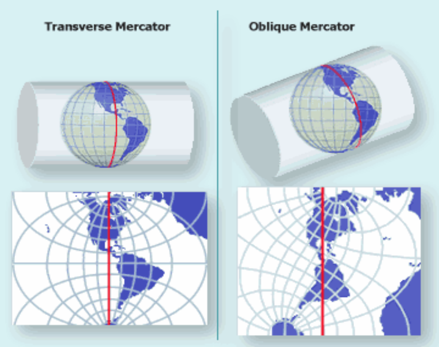
Cylinder (Transverse or equatorial)

- Once a choice is made between projecting onto a cylinder, cone, or plane, the aspect of the shape must be specified.
- The aspect describes how the developable surface is placed relative to the globe:



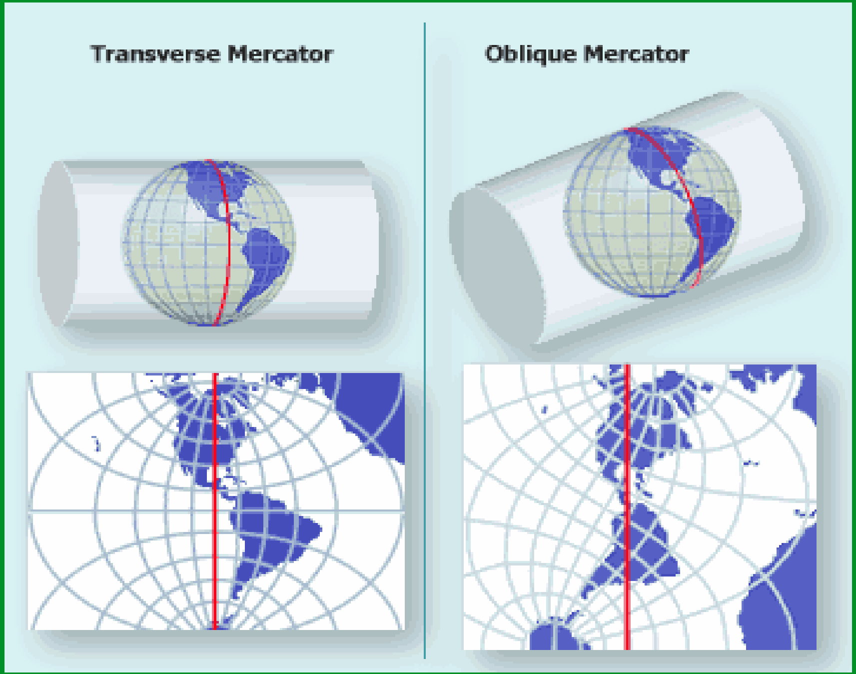
Cylinder (Transverse or equatorial)

- It may be normal (such that the surface's axis of symmetry coincides with the Earth's axis), transverse (at right angles to the Earth's axis) or oblique (any angle in between).
- The developable surface may also be either tangent or secant to the sphere or ellipsoid. Tangent means the surface touches but does not slice through the globe; secant means the surface does slice through the globe.



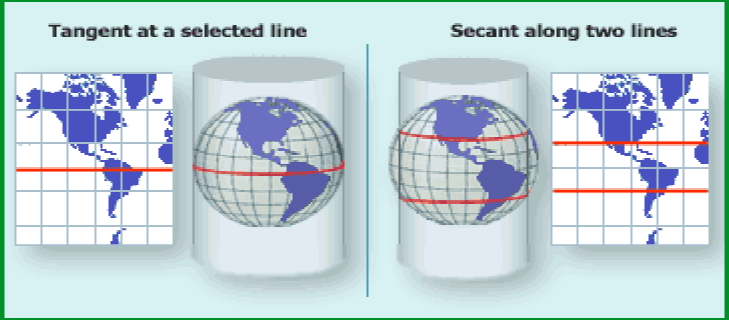
Choosing a projection surface

Cylindrical aspect – equatorial (normal), transverse, oblique



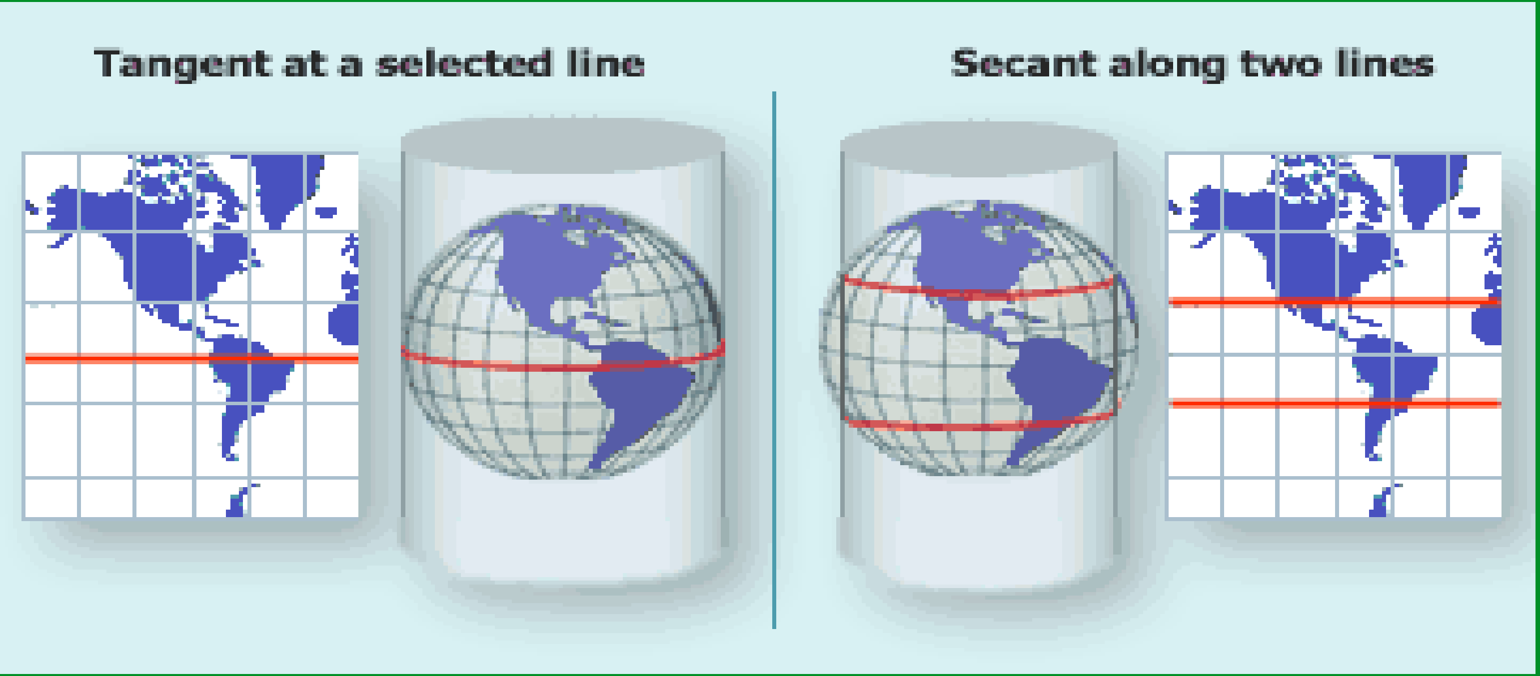
Aspects of the projection

- The developable surface may also be either tangent or secant to the sphere or ellipsoid.
- Tangent means the surface touches but does not slice through the globe.
- Secant means the surface does slice through the globe.



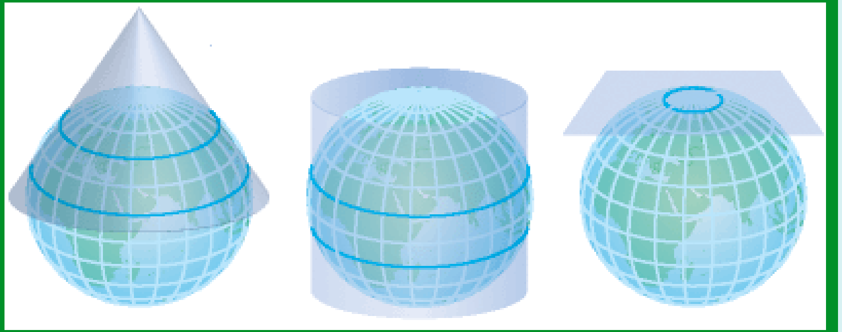
Choosing a projection surface

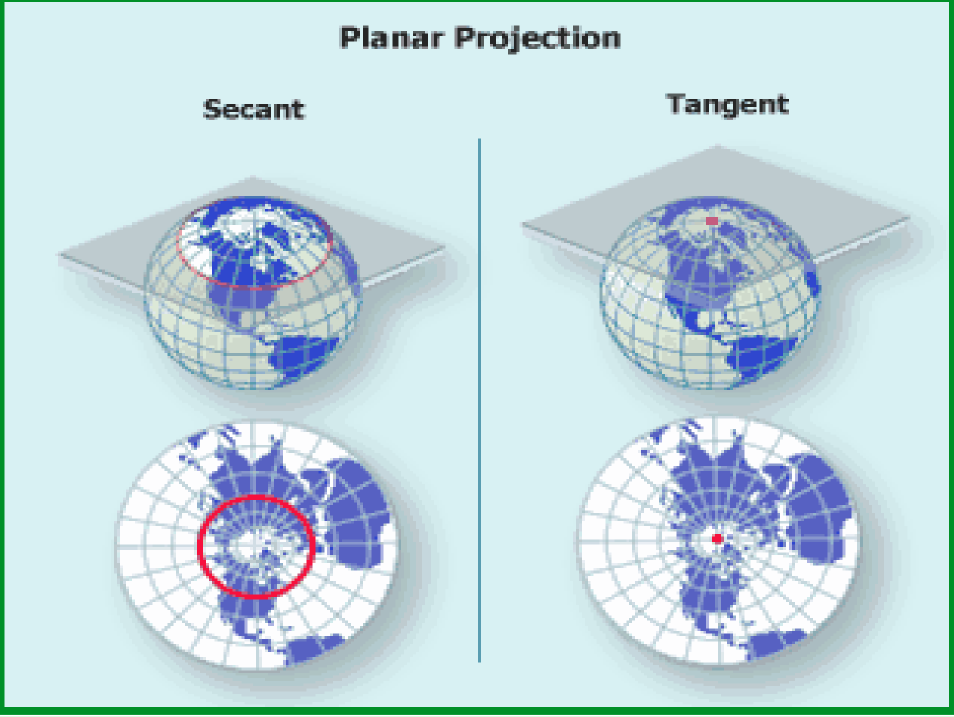
Tangent vs. secant cylindrical projection



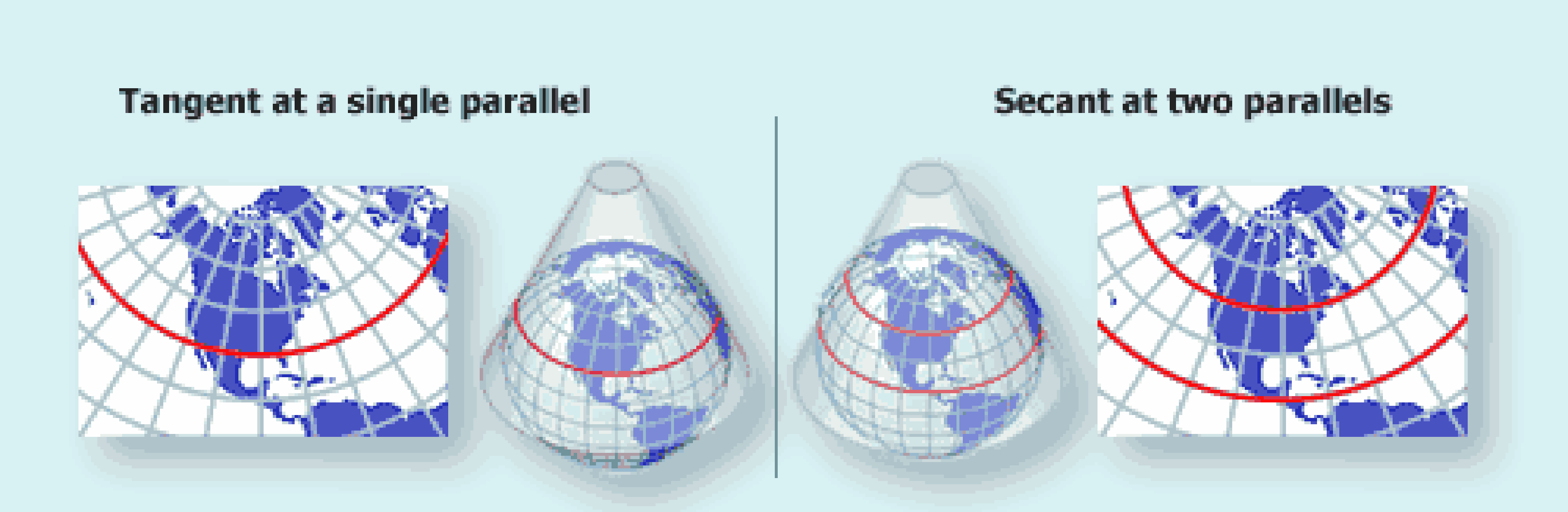
Choosing a projection surface

Tangent vs. secant planar projection





Conic



Scale (Scale factor & principal (nominal) scale)

Measuring map scale distortion – scale factor & principal (nominal) scale:

- A reference surface of the Earth is a scaled down model of the Earth.

- This scale can be measured as the ratio of distance on the reference surface (Cylinder, Cone, Plane) to the corresponding distance on the Earth.

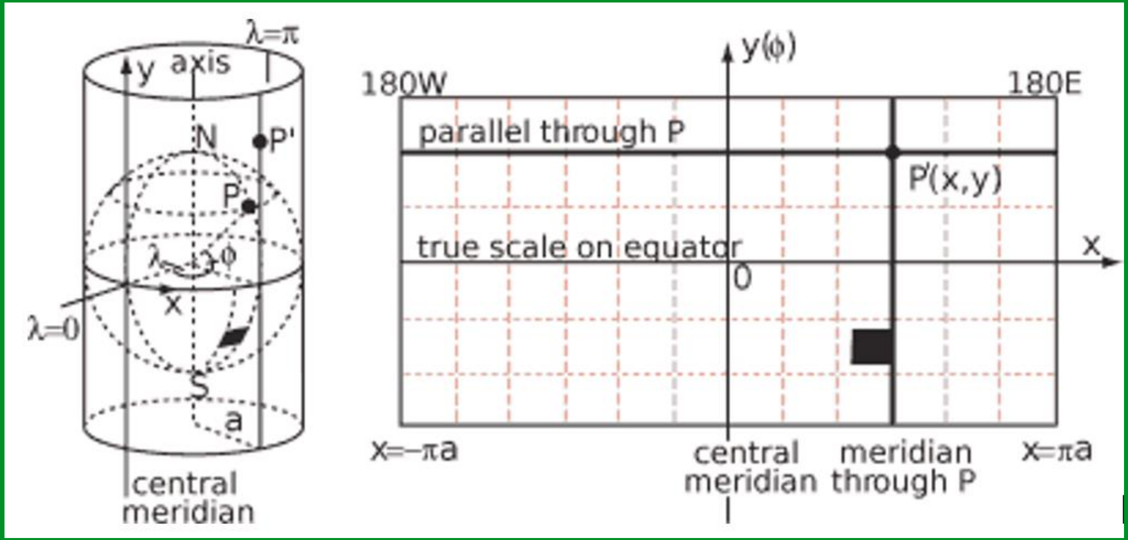
Scale (Scale factor & principal (nominal) scale)

Measuring map scale distortion – scale factor & principal (nominal) scale:

- For example, a 1:250000 representative fraction scale indicates that 1 unit (e.g. km) on the reference surface represents 250000 units on Earth.
- The principal scale or nominal scale of a flat map (the stated map scale) refers to this scale of its generating reference surface .

Scale (Scale factor & principal (nominal) scale)

Map scale distortion of a tangent cylindrical projection: SF = 1 along line of tangency

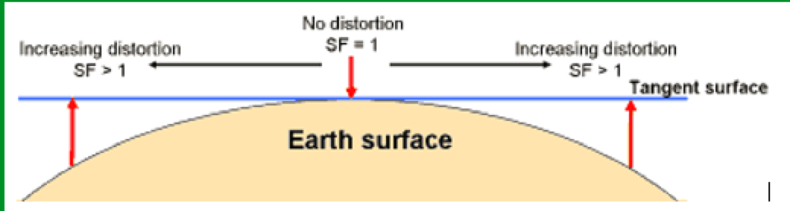


Scale (Scale factor & principal (nominal) scale)

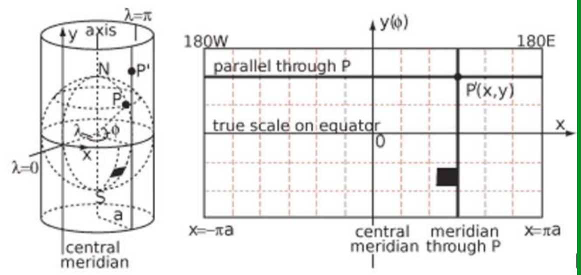
Scale distortion on a tangent surface to the globe

There is no distortion along standard lines as evident in following figures.

On a tangent surface to the reference globe, there is no scale distortion at the point (or along the line) of tangency and therefore scale factor is 1.



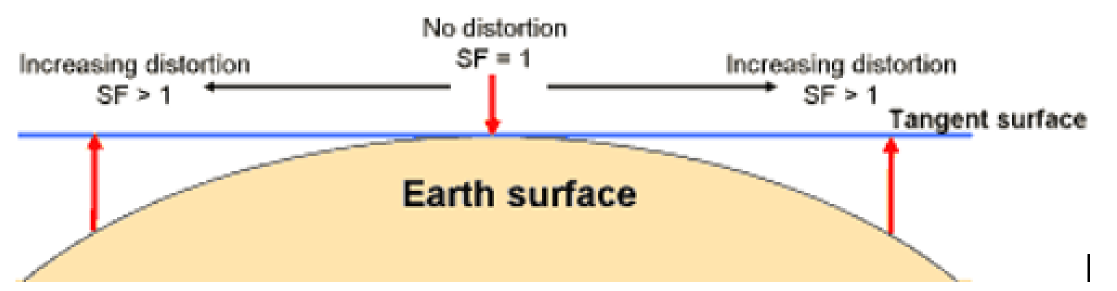
Scale distortion on a tangent surface to the globe



Scale (Scale factor & principal (nominal) scale)

Scale distortion on a tangent surface to the globe

- Distortion increases with distance from the point (or line) of tangency.



Scale distortion on a tangent surface to the globe

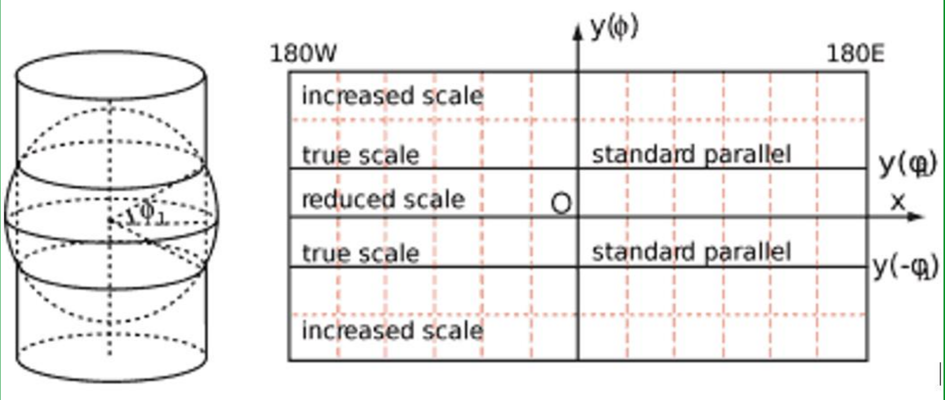
Scale (Scale factor & principal (nominal) scale)

- On a secant surface to the reference globe, there is no distortion along the standard lines (lines of intersection) where SF = 1.

- Between the secant lines where the surface is inside the globe, features appear smaller than in reality and scale factor is less than 1.

Scale (Scale factor & principal (nominal) scale)

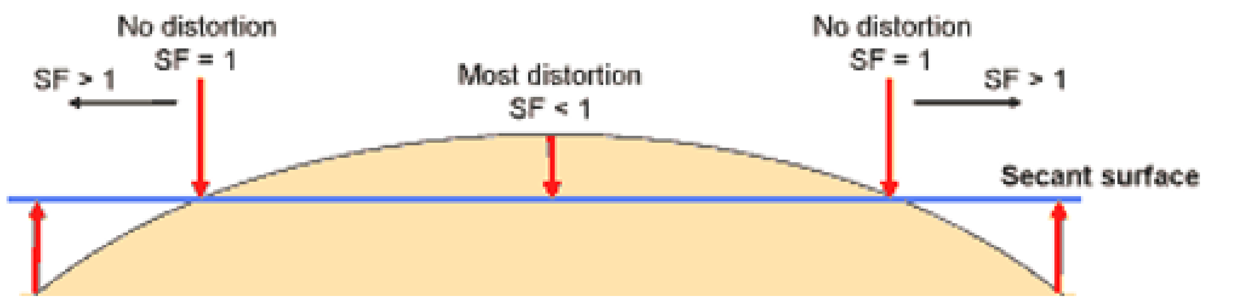
- At places on map where the surface is outside the globe, features appear larger than in reality and scale factor is greater than 1.
- A map derived from a secant projection surface has less overall distortion than a map from a tangent surface.



Map scale distortion of a secant cylindrical projection - SF = 1 along secant lines

Scale (Scale factor & principal (nominal) scale)

- At places on map where the surface is outside the globe, features appear larger than in reality and scale factor is greater than 1.
- A map derived from a secant projection surface has less overall distortion than a map from a tangent surface.



Scale distortion on a secant surface to the globe

Scale (Scale factor & principal (nominal) scale)

- The projection of the curved surface on the plane and the resulting distortions from the deformation of the surface will result in variation of scale throughout a flat map.
- In other words the actual map scale is different for different locations on the map plane and it is impossible to have a constant scale throughout the map.
- Measure of scale distortion on map plane can also be quantified by the use of scale factor.

Scale (Scale factor & principal (nominal) scale)

- Scale factor is the ratio of actual scale at a location on map to the principal (nominal) map scale (SF = actual scale / nominal scale).
- Alternatively stated as ratio of distance on the map to the corresponding distance on the reference globe.
- A scale factor of 1 indicates actual scale is equal to nominal scale, or no scale distortion at that point on the map.
- Scale factors of less than or greater than one are indicative of scale distortion. The actual scale at a point on map can be obtained by multiplying the nominal map scale by the scale factor.

Scale (Scale factor & principal (nominal) scale)

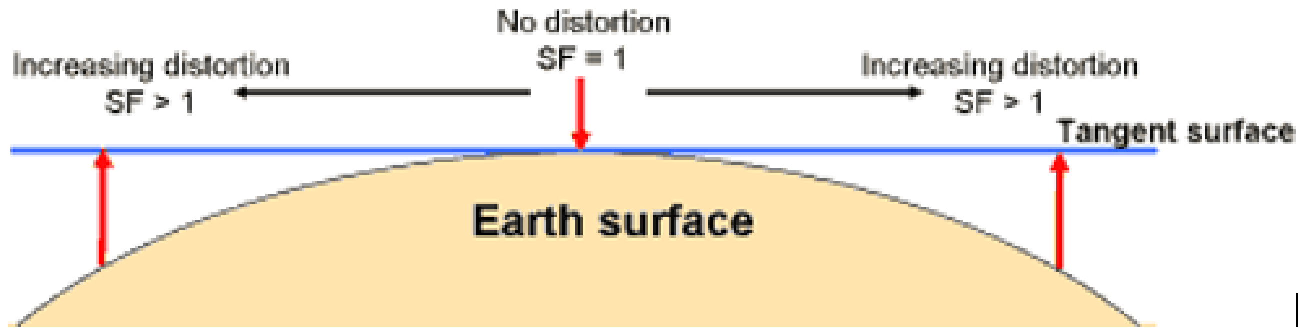
- Scale factors of less than or greater than one are indicative of scale distortion. The actual scale at a point on map can be obtained by multiplying the nominal map scale by the scale factor.
- As an example, the actual scale at a given point on map with scale factor of 0.99860 at the point and nominal map scale of 1:50000 is equal to (1:50000 x 0.99860) = (1: 50000/0.99860) = 1:50070 (which is a smaller scale than the nominal map scale).

Scale (Scale factor & principal (nominal) scale)

- Scale factor of 2 indicates that the actual map scale is twice the nominal scale; if the nominal scale is 1:4million, then the map scale at the point would be (1:4million x 2) = 1:2million.
- A scale factor of 0.99950 at a given location on the map indicates that 999.5 meters on the map represents 1000 meters on the reference globe/earth.

Scale (Measuring map scale distortion)

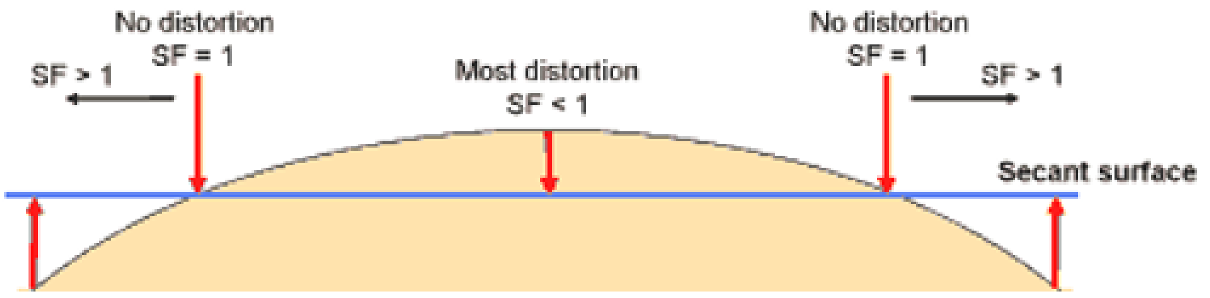
On a tangent surface to the reference globe, there is no scale distortion at the point (or along the line) of tangency and therefore scale factor is 1. Distortion increases with distance from the point (or line) of tangency.



Scale distortion on a tangent surface to the globe

Scale (Measuring map scale distortion)

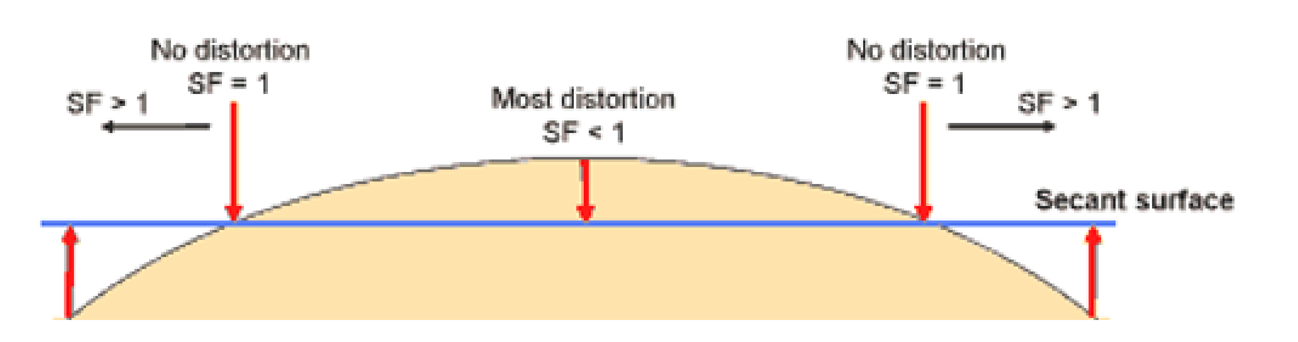
- On a secant surface to the reference globe, there is no distortion along the standard lines (lines of intersection) where SF = 1. Between the secant lines where the surface is inside the globe, features appear smaller than in reality and scale factor is less than 1.



Scale distortion on a secant surface to the globe

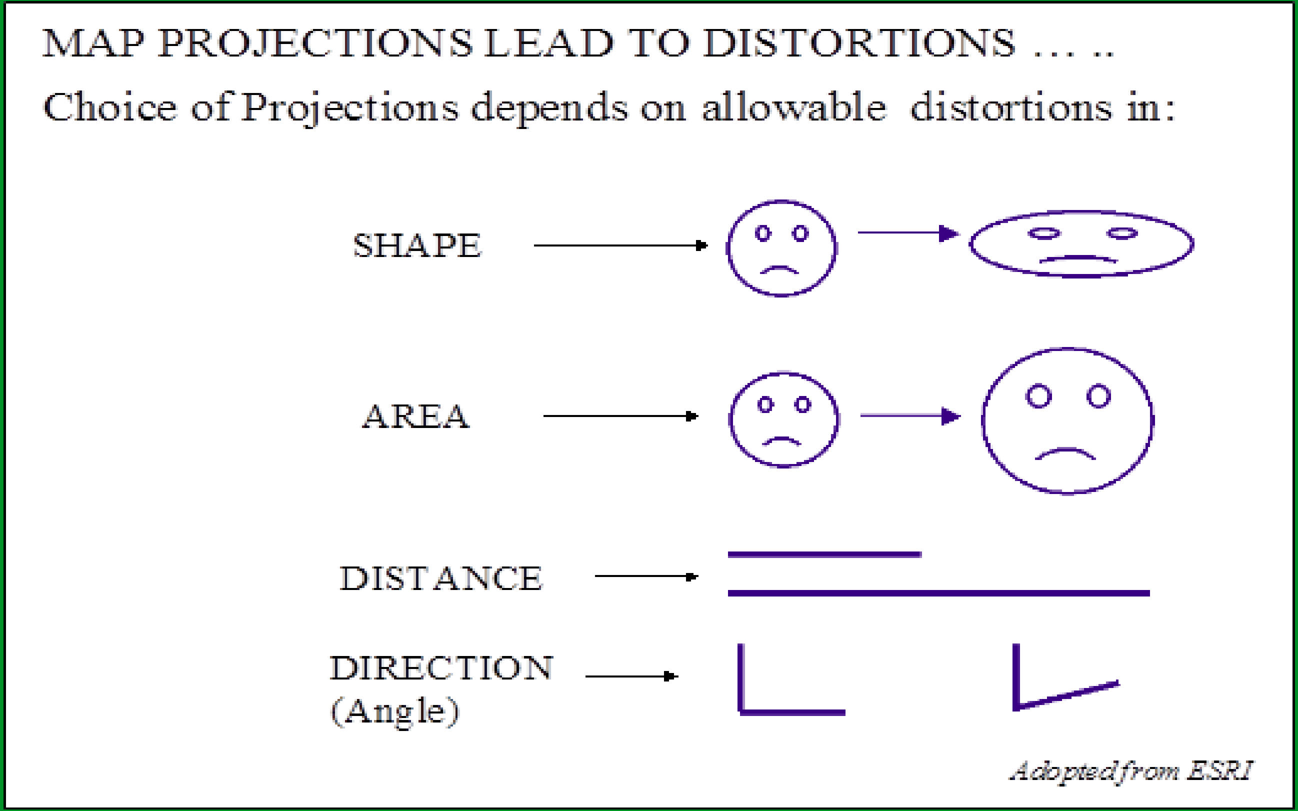
Scale (Measuring map scale distortion)

- At places on map where the surface is outside the globe, features appear larger than in reality and scale factor is greater than 1.
- A map derived from a secant projection surface has less overall distortion than a map from a tangent surface.



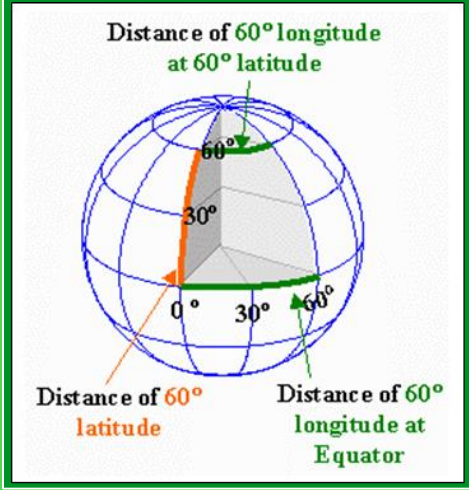
Scale distortion on a secant surface to the globe

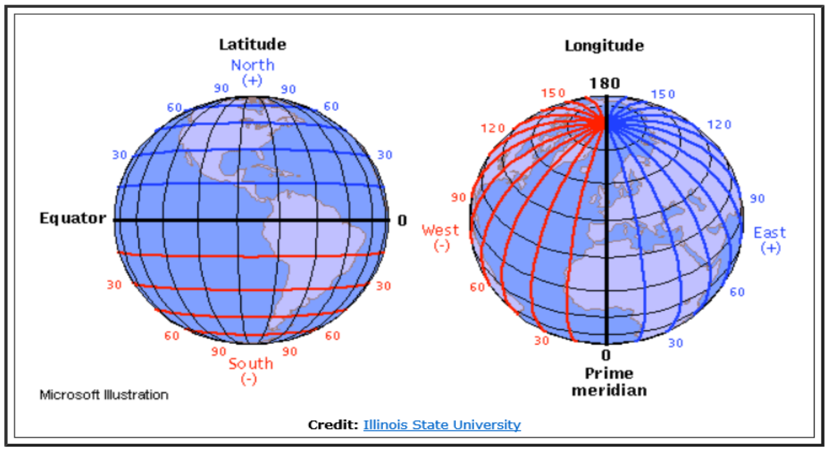
Map projections lead to distortations

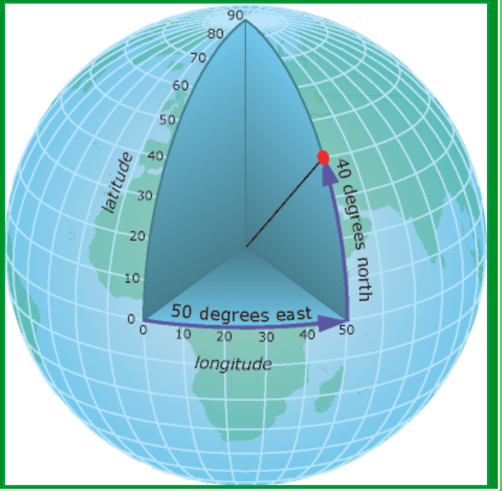


Latitude and Longitude

Latitude and Longitude determine the the Global Address of earth features. Every location on earth has a global address. A global address is given as two numbers called coordinates. The two numbers are a location's latitude number and its longitude number ("Lat/Long").

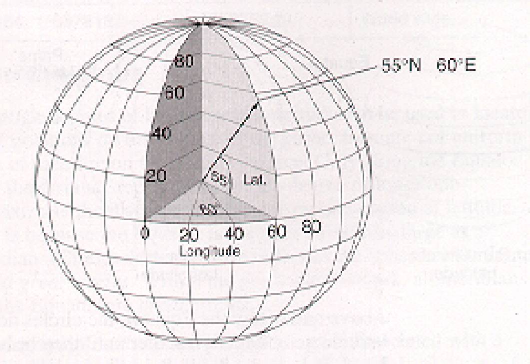


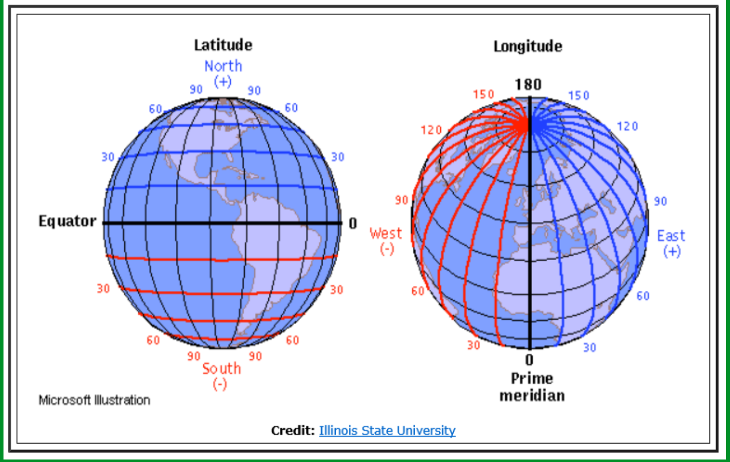


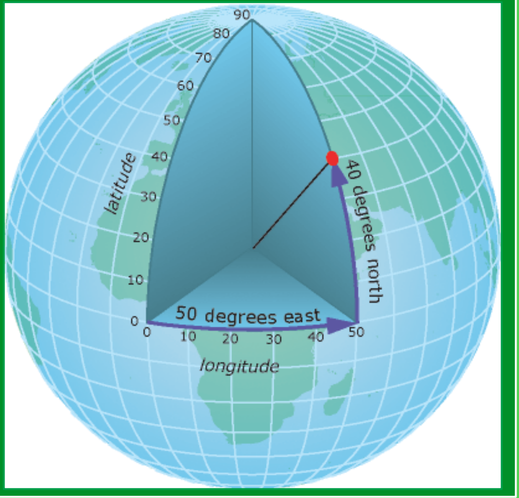


Latitude

Horizontal mapping lines on Earth are lines of latitude. They are known as "parallels" of latitude, because they run parallel to the equator.

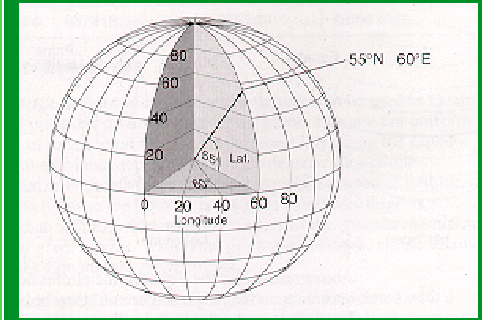


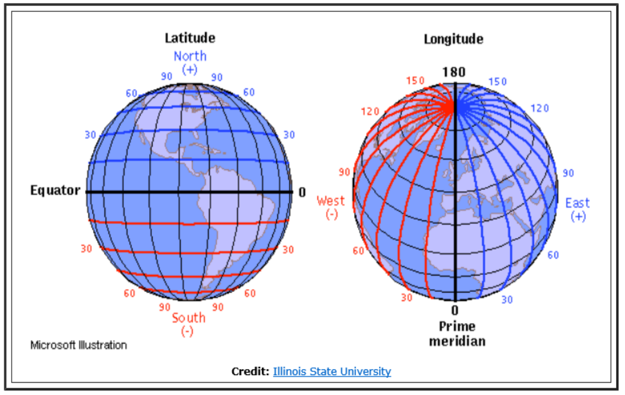


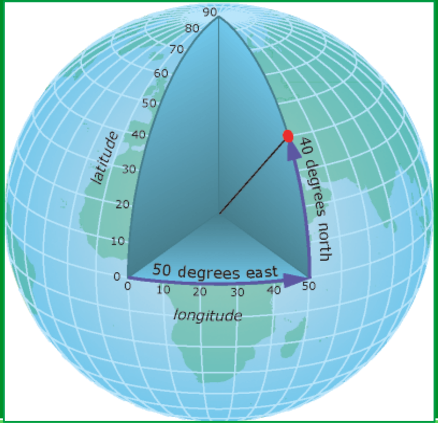


Latitude

Latitude lines are a numerical way to measure how far north or south of the equator a place is located. The equator is the starting point for measuring latitude--that's why it's marked as 0 degrees latitude. The number of latitude degrees will be larger the further away from the equator the place is located, all the way up to 90 degrees latitude at the poles. Latitude locations are given as __ degrees North or __ degrees South all geographic coordinate systems. The equator divides the globe into Northern and Southern Hemispheres.



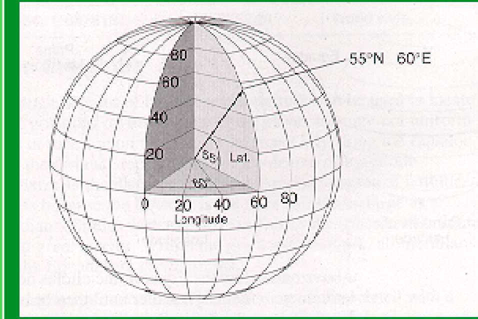


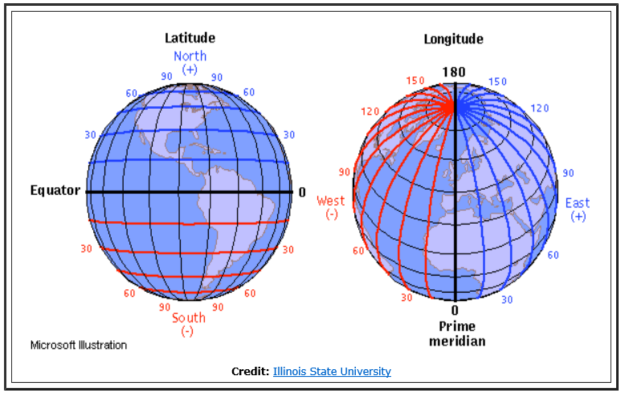


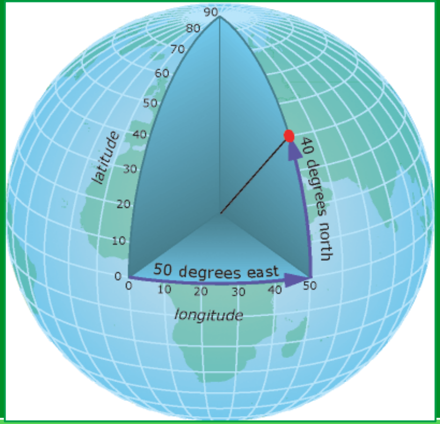
Longitude

Vertical mapping lines on Earth are lines of longitude, known as "meridians".

Longitude lines are a numerical way to show/measure how far a location is east or west of a universal vertical line called the Prime Meridian. This Prime Meridian line runs vertically, north and south, right over the British Royal Observatory in Greenwich England, from the North Pole to the South Pole. As the vertical starting point for longitude, the Prime Meridian is numbered 0 degrees longitude.

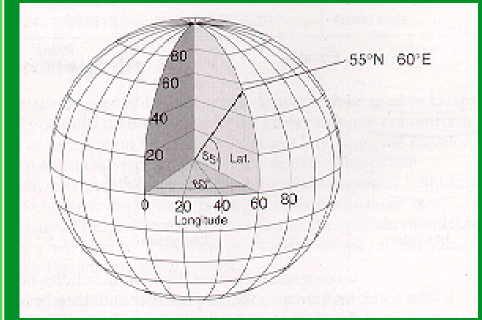


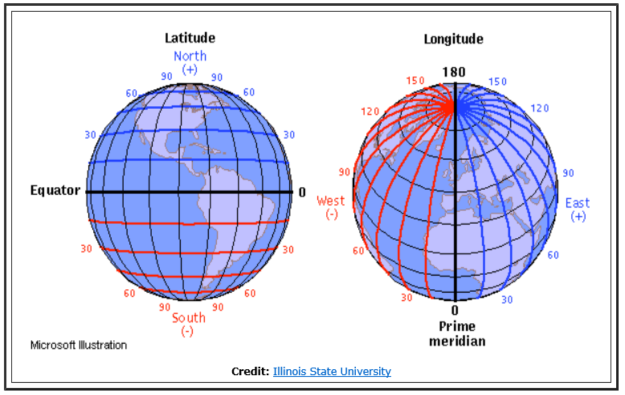


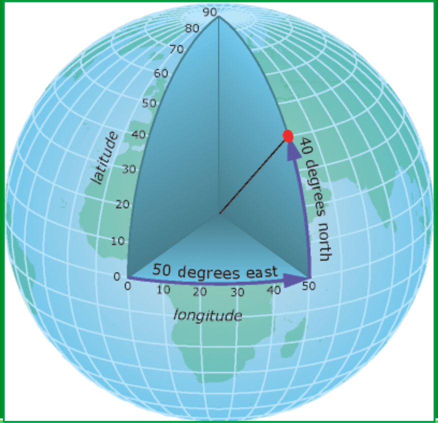


Longitude

To measure longitude east or west of the Prime Meridian, there are 180 vertical longitude lines east of the Prime Meridian and 180 vertical longitude lines west of the Prime Meridian, so longitude locations are given as __ degrees east or __ degrees west. The 180 degree line is a single vertical line called the International Date Line, and it is directly opposite of the Prime Meridian.

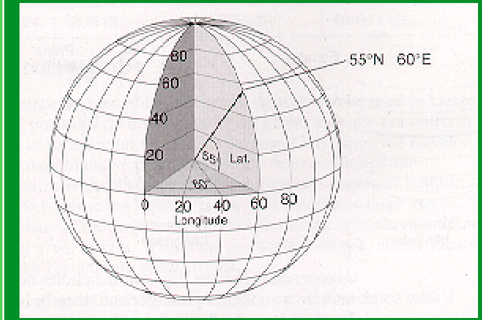


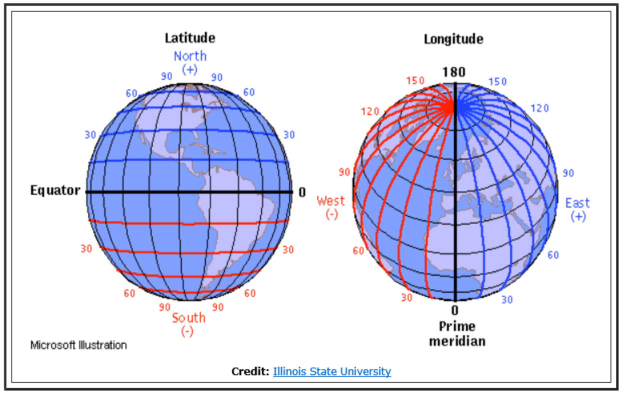


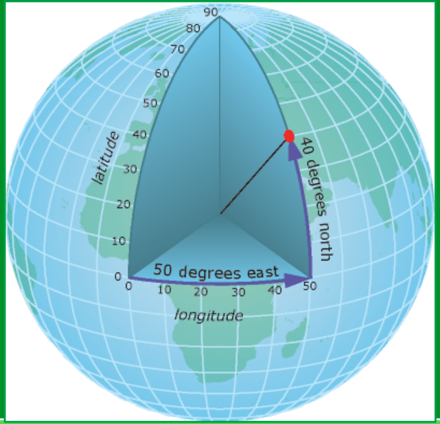


Longitude

A line, which was intended to pass through the Royal Observatory, Greenwich (a suburb of London, UK), was chosen as the international zero-longitude reference line, the Prime Meridian. Places to the east are in the eastern hemisphere, and places to the west are in the western hemisphere. The antipodal meridian of Greenwich is both 180°W and 180°E. The zero/zero point is located in the Gulf of Guinea about 625 km south of Tema, Ghana.

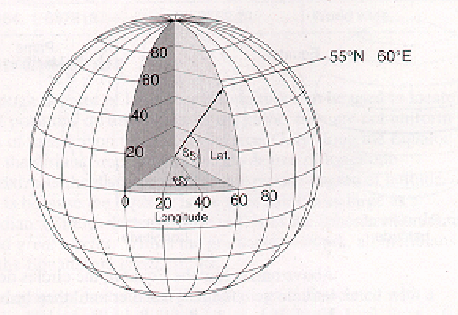


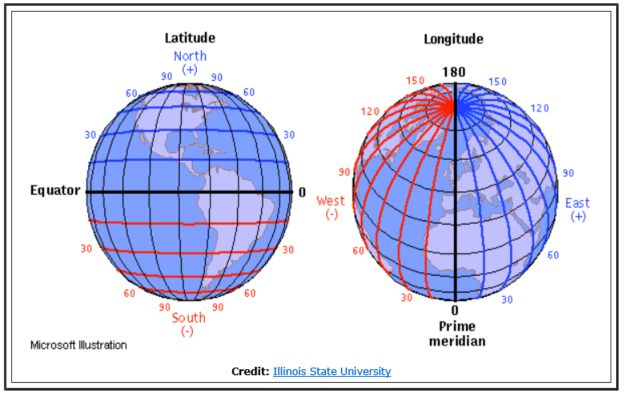


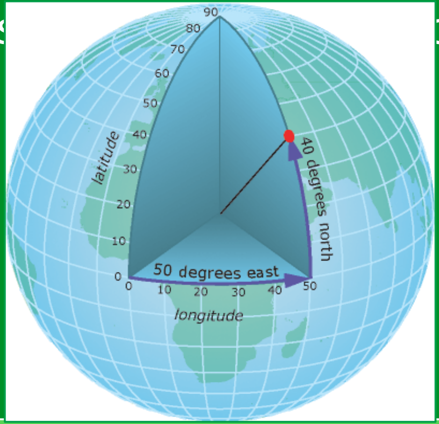


Geodetic height

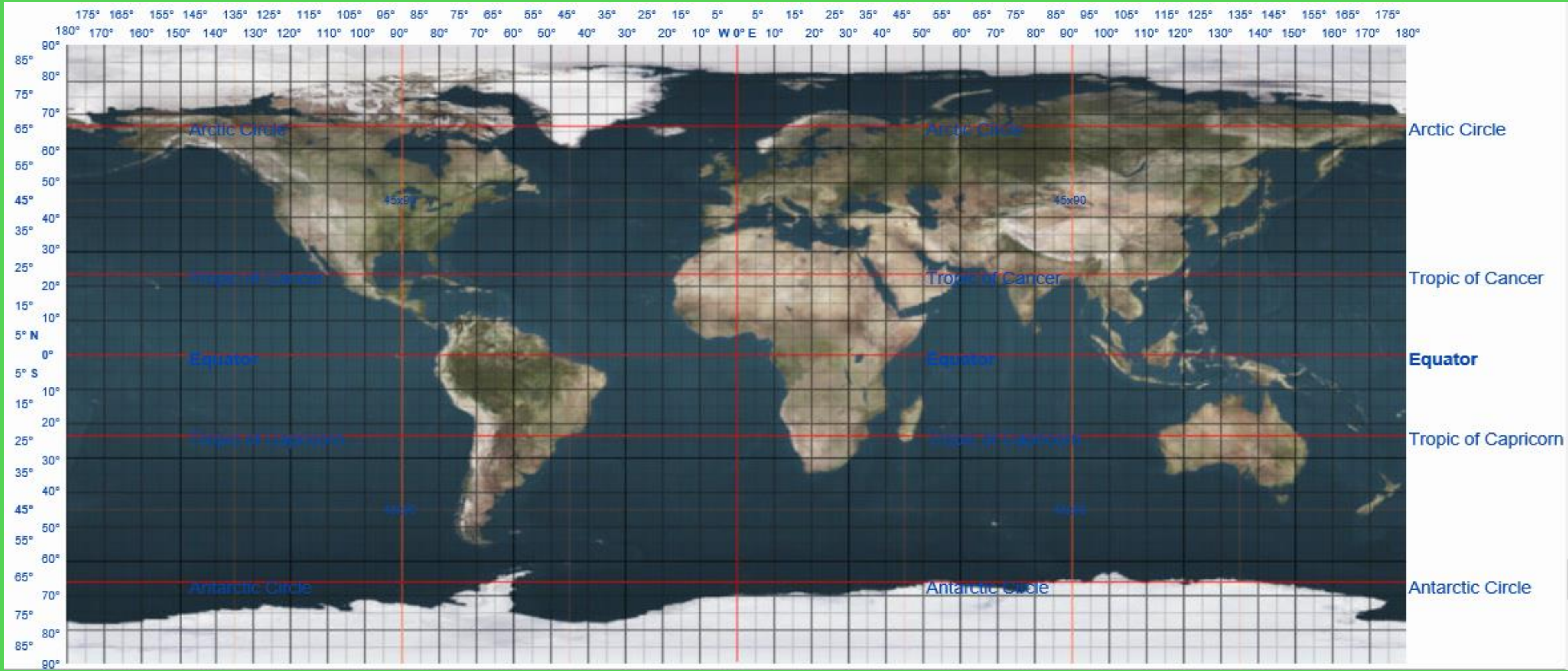
To completely specify a location of a topographical feature on, in, or above the Earth, one has to also specify the vertical distance from the centre of the Earth, or from the surface of the Earth. Because of the ambiguity of "surface" and "vertical", it is more commonly expressed relative to a precisely defined vertical datum which holds fixed some known point. Each country has defined its own datum. For example, in the United Kingdom the reference point is Newlyn, while in Canada, Mexico and the United States, the point is near Rimouski, Quebec, Canada. The distance to Earth's centre … p pos … ons







Latitude and Longitude



Geographic phenomena and data modeling

3.1 Introduction to geographic phenomena and data modeling

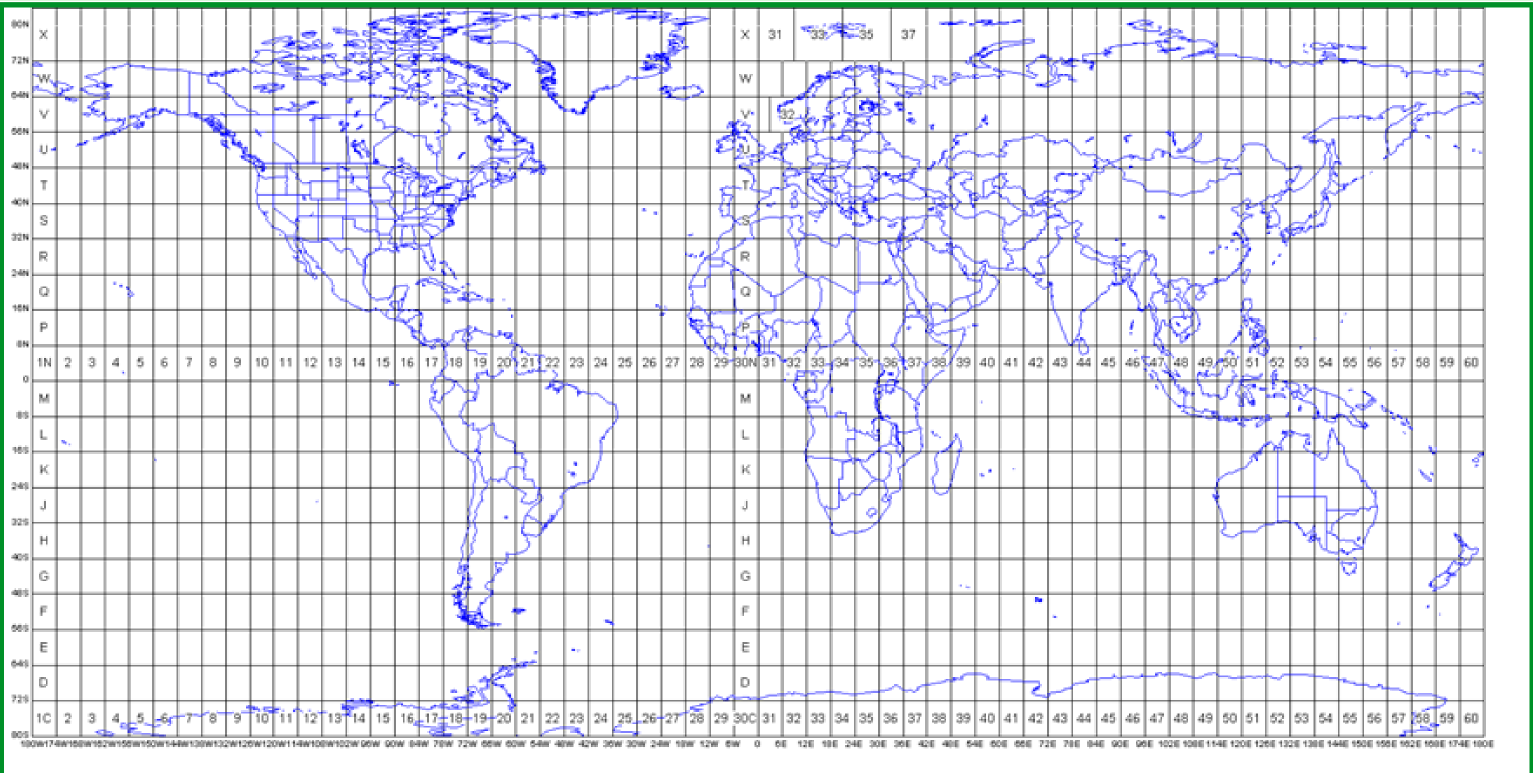
3.2 Spatial relationship and topology

3.3 Scale and resolution

3.4 Vector, raster and digital terrain model

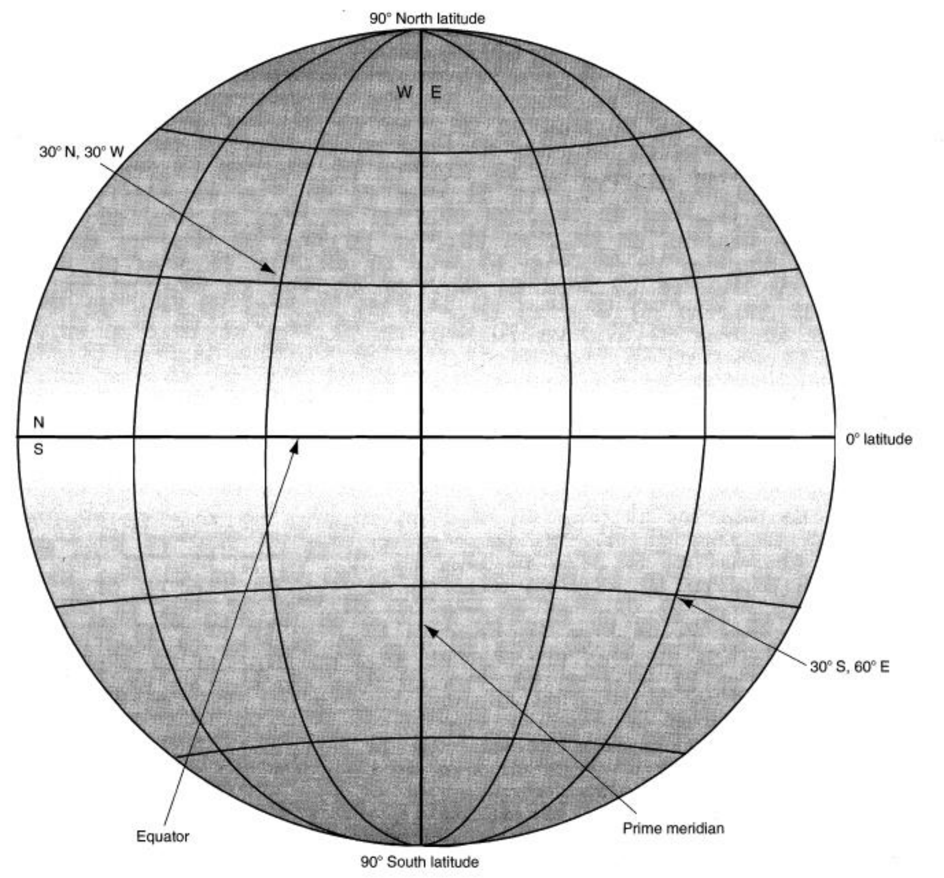
3.5 Spatial database design with the concept of geodatabase

Choosing a projection surface



Locations and grid designations in developable surfaces:

Today's Class Objectives:



Geographic coordinates as determined from angular distance from the center of the Earth and referenced to the equator and prime meridian.

Geographic phenomena and data modeling

3.1 Introduction to geographic phenomena and data modeling

Geographic phenomena and data modeling

About Earth:

- The shape of the Earth is represented as a **sphere**.
- It is also modelled more accurately as an **oblate spheroid** or an **ellipsoid**. Earth's actual shape is closer to an **oblate ellipsoid**.
- A **globe** is a scaled down model of the Earth.
- A map projection is the transformation of Earth’s curved surface (or a portion of) onto a two-dimensional flat surface by means of mathematical equations.

Geographic phenomena and data modeling

About Earth:

- During the transformation, the angular Geographic coordinates (latitude, longitude) referencing positions on the surface of the Earth are converted to Cartesian coordinates (x, y) representing position of points on a flat map.

Geographic phenomena and data modeling

The creation of a map projection involves three steps:

- Selection of a model for the shape of the Earth (Sphere, Ellipsoid, Oblate ellipsoid or Geoid).

- Transformation of Geographic coordinates (longitude and latitude) to Cartesian (x, y) Projection.

- Reduce the scale

Geographic phenomena and data modeling

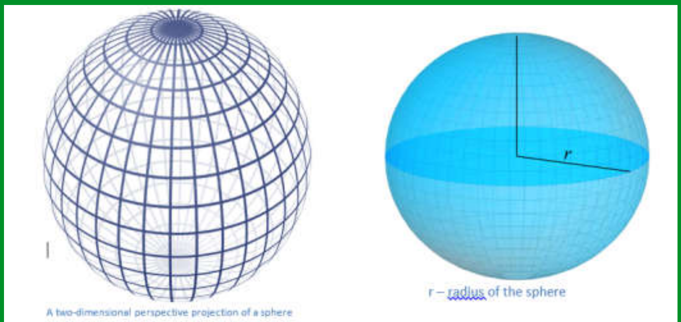
Selection of a model for the shape of the Earth

- Earth shape model selection for projection have the advantages and disadvantages.
- Spherical models are useful for small-scale maps such as world atlases and globes
- The ellipsoidal model is commonly used to construct topographic maps and for other large- and medium-scale maps that need to accurately depict the land surface.
- A third model is the geoid, a more complex and accurate representation of Earth's shape coincident with what mean sea level

Geographic phenomena and data modelling

Sphere

- A sphere is a perfectly round geometrical and circular object in three-dimensional space that resembles the shape of a completely round ball.
- A sphere is defined mathematically as the set of points that are all the same distance r from a given point in three-dimensional space.



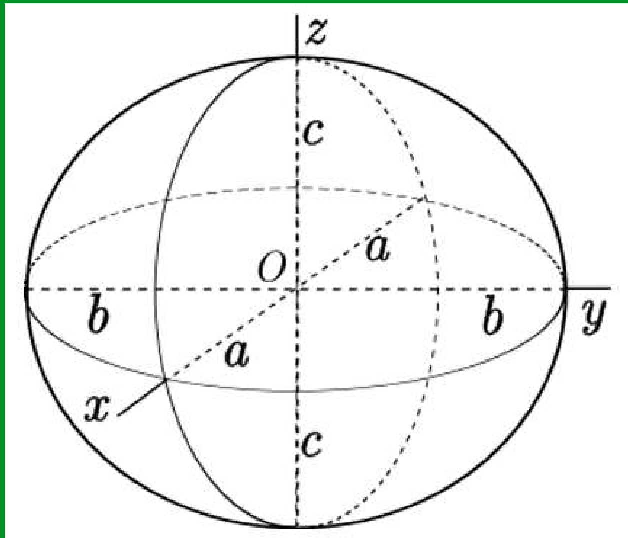
A two-dimensional perspective projection of a sphere

Geographic phenomena and data modeling

Ellipsoid

- An ellipsoid is a closed quadric surface that is a three-dimensional analogue of an ellipse.

Tri-axial ellipsoid with distinct semi-axis lengths



Tri-axial ellipsoid with distinct semi-axes a, b and c

Geographic phenomena and data modeling

Ellipsoid

- An ellipsoid is a closed quadric surface that is a three-dimensional analogue of an ellipse.

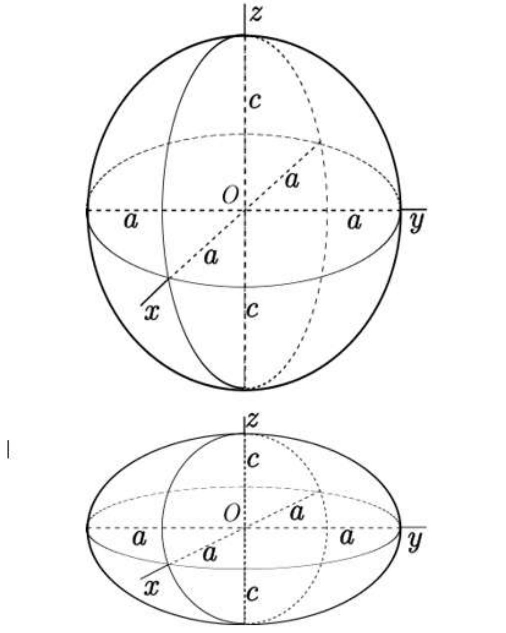
There are four distinct cases of which one is degenerate:

- $a>b>c$ = tri-axial or (rarely) scalene ellipsoid;
- $a=b>c$ = oblate ellipsoid of revolution (oblate spheroid);
- $a=b<c$ = prolate ellipsoid of revolution (prolate spheroid);
- $a=b=c$ = the degenerate case of a sphere;

Geographic phenomena and data modeling

Ellipsoid

- a=b>c = oblate ellipsoid of revolution (oblate spheroid);

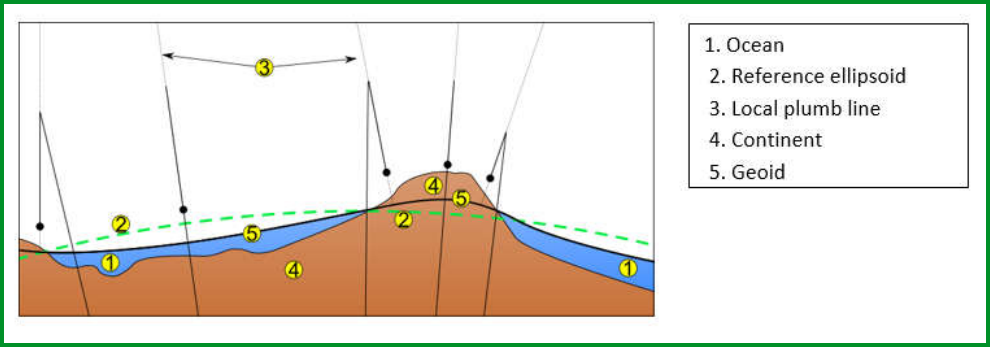


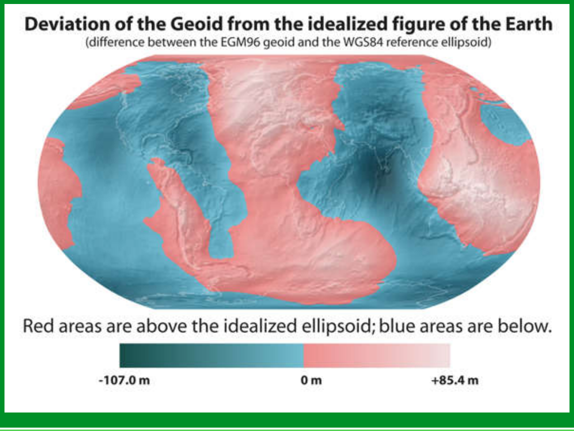
The ellipsoid is prolate (top) or oblate (bottom) as c is greater than or less than a.

Geographic phenomena and data modeling

Geoid

The geoid is the shape that the surface of the oceans would take under the influence of Earth's gravitation and rotation alone, in the absence of other influences such as winds and tides.





ELLIPSOIDS, GEOIDS, DATUMS

ELLIPSOIDS:

- Believe that the Earth was a perfect sphere until of the seventeenth century, when Newton advanced his theory of gravity.
- Newton said, if the Earth were rotating along an axis, the shape of the Earth would tend to bulge along the equator and tend to be flattened at the poles, due to the centrifugal force which confirmed by field measurements of the Earth's surface, beginning in 1735, in Peru and Lapland, and later in other areas (Snyder 1987).

ELLIPSOIDS, GEOIDS, DATUMS

ELLIPSOIDS:

- The shape of the Earth is thus referred to as an oblate ellipsoid or oblate spheroid.
- There is a 20 krn difference of the Earth's most northern point on this spheroidal shape with where one would expect to find it on a perfect sphere,.

ELLIPSOIDS, GEOIDS, DATUMS

ELLIPSOIDS:

- This difference can be described as the flattening ratio (f) and is described by the relationship (a - b)la, where a is the equatorial radius and b is the polar radius.

- Technological advancements in Earth measurement collection have led to improved ellipsoid models, including the Geodetic Reference System of 1980 (GRS80) and the World Geodetic System of 1984 (WGS84).

ELLIPSOIDS, GEOIDS, DATUMS

GEOIDS:

- A further refinement and approximation of the Earth's shape can be described with a geoid.
- A geoid attempts to reconcile Earth's local irregularities with the differing gravitational forces that are caused by varying Earth densities.
- The shape of a geoid is irregular and approximates Earth's mean sea level perpendicular to the forces of gravity.
- Within the continental United States, the geoidal surface can be found, on average, about 30 m below the GRS80 and WGS84 ellipsoids, whereas usually a few meters separates its surface from the Clarke 1866 ellipsoid.
- Once can define the Earth's shape and irregularities, a control system is needed on which to base the approximate locations of landscape features.

ELLIPSOIDS, GEOIDS, DATUMS

DATUM:

- A datum is a smooth, mathematical representation of the Earth's surface that creates a "control surface," on which an ellipsoid and other location data are referenced.
- Datums are created from large numbers of measurements of the Earth's surface, typically assembled by land surveyors or others involved in Earth measurements, where the location of each point has been measured using precise control surveys.
- From these points, a theoretical surface of the Earth is constructed. The greater the number of point locations, the greater the datum's potential to act as a reliable surface on which one can reference other landscape features.

ELLIPSOIDS, GEOIDS, DATUMS

DATUM:

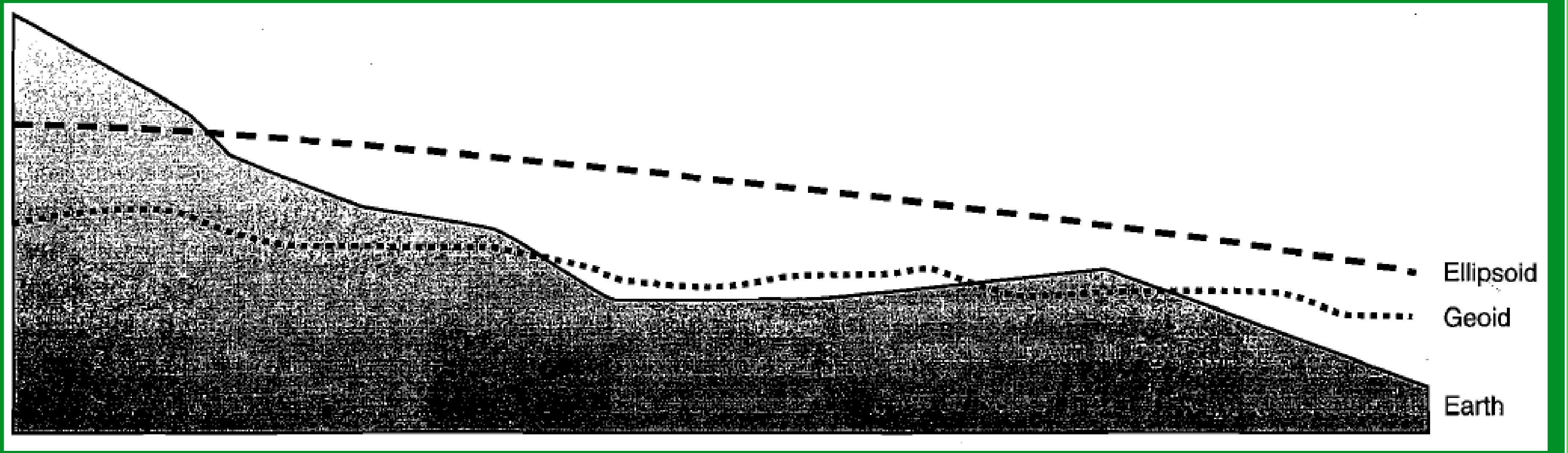
- Hundreds of datums have been developed to describe the Earth, many of which are specific to a particular country or region.
- Within North America, two datums are prorninent: the North American Datum of 1927 (NAD27) and the North American Datum of 1983 (NAD83).
- The World Geodetic System of 1984 is commonly used in conjunction with GPS data collection efforts. The NAD83 and WGS84 are very similar and are sometimes used interchangeably, although this practice may not be suitable for applications that require high data accuracy levels. The NAD83 was designed for North America, whereas the WGS84 takes a global approach in representing the Earth. The primary differences between the NAD27 and NAD83 datums are the number of longitude and latitude locations that were measured to create each datum, and the way in which the measured locations are referenced to the surface of the Earth.

ELLIPSOIDS, GEOIDS, DATUMS

DATUM:

- The discussion of datums, to this point, has focused on those related to horizontal surfaces. When working with elevation data, GIS users must also be aware that datums have also been developed to describe the vertical dimension.
- The National Geodetic Vertical Datum of 1929 (NGVD29) was established from 26 gauging stations in the United States and Canada and forms the basis for determining mean sea level.
- The North American Vertical Datum of 1988 (NAVD88) used additional measurements from a large number of elevation profiles to create a single sea level control surface. The NAVD88 has become the preferred vertical datum.

ELLIPSOIDS, GEOIDS, DATUMS



Ellipsoid and geoid surfaces

Coordinate System

Seventeenth-century French mathematician and philosopher, devised one of the first methods for locating landscape features on a planar surface. Descartes superimposed two axes, oriented perpendicular to one another, with gradations along both axes to create equal distance intervals. The horizontal axis is termed the x-axis and the vertical is the y-axis. The location of any point on the planar surface covered by this type of grid can be defined with respect to the interval lines that it intersects or most closely neighbors. This basis of determining location is known as a Cartesian coordinate system.

Coordinate System

The most common coordinate system is the system of latitude and longitude, which is sometimes referred to as the geographical coordinate system. This system has an origin at the center of the Earth and contains a set of perpendicular lines running through the center to approximate the x- and y-axes of the Cartesian coordinate system. The orientation of the perpen-dicular lines is based on the rotation of the Earth. The Earth spins on an axis that, if extended, coincides very closely with the North Star (Polaris) and is called the axis of rotation. This rotation axis divides the Earth in half to create a line of longitude that approximates the y-axis. A line perpendicular to the line of longitude falls along the equator (Earth's widest extent) to create a line of latitude that is conceptually similar to the x-axis..

Coordinate System

Latitudes are expressed to a maximum of 90°, in a north or south direction from the equator, with the equator denoting 0" (figure 2.5). Traveling 90" north from the equator would. leave one at the most northern point of the Earth and would be noted as 90" N. Similarly, a position halfway between the South Pole and the equator would be referenced as 45" S. The equator and other lines of latitude that parallel the equator are also called parallels.

Coordinate System

Although the axis of rotation splits the Earth in half, a reference line must be established from which coordinates can start. This reference line is referred to as the prime meridian; although there are dozens in existence, the most widely recognized prime meridian circles the globe while passing across the British Royal Observatory located in Greenwich, England. Longitude measurements are made from this reference line and are designated from 0" to 180°, in a western or an eastern direction. Other lines that pass through the North and South Poles are called meridians. The conceptual collection of meridians and parallels superimposed on the Earth's surface is known as a graticule.

Coordinate System

The geographical coordinate system can be used to locate any point on the Earth's surface. To achieve a high level of precision in locating landscape features degrees are further subdivided into minutes and seconds. There are 60 minutes (noted by ') within each degree and 60 seconds (noted by ") within each minute. A location that is described as 38'30' latitude indicates a line between 38" and 39". Because this measurement system does not lend itself conveniently to mathematical calculations, conversions to the decimal degree system are common. The conversion of 38'30'45" (spoken as 38 degrees, 30 minutes, and 45 seconds) would result in 38.575" decimal degrees. By using this coordinate system and describing measurements to the nearest second, one can locate objects on maps that are within 100 feet of their true locations on the ground (Muehrcke and Muehrcke 1998).

Coordinate System

Although the geographical coordinate system provides a relatively straightforward solution to the complicated issue of establishing a regular system of measurements on a spherical surface, there are complications to its use. A primary problem is that the units of an arc (arc is used to describe angular distance-a sphere contains 360" of arc) are not constant throughout the system of geographical coordinates. Due to the convergence of the meridians at the Earth's polar areas, lo of longitude ranges from 69 miles long at the equator to 0 miles long at the poles. Latitude measurements, in contrast, differ by minor amounts but average 69 miles across the Earth. Field measurements of longitude are also difficult to collect without the use of GPS or other similar navigational technology. Whereas one can calculate latitude by measuring the distance between the horizon and the North Star (in the Northern Hemisphere), calculating longitude involves understanding the difference between one's location and the prime meridian. In addition, the calculations and conversions involved when using degreesminutes- seconds measurements are cumbersome and time-consuming.

Metric properties of maps

Many properties can be measured on the Earth's surface independently of its geography. Some of these properties are:

Area
Shape
Direction
Distance
Scale

Map projections can be constructed to preserve at least one of these properties. Each projection preserves or compromises or approximates basic metric properties in different ways.

Using globes vs. projecting on a plane

- The globe is the only way to represent the earth without distorting one or more of the above-mentioned metric properties.
- Globes have the advantage of being true to metric properties and able to provide a true picture of spatial relationships on the earth's surface.
- The disadvantages of the globe are that it is impractical to make large-scale maps with it, it is difficult to measure on a globe, one can't see the whole world at once and it is difficult to handle and transport a globe around

Using globes vs. projecting on a plane

- The flat map has the disadvantage of always distorting one or more of the metric properties.
- It is more difficult to get a true picture of the spatial relationships between objects.
- Flat maps have numerous advantages however; it is not practical to make large or even medium scale globes, it is easier to measure on a flat map, easy to carry around, and one can see the whole world at once.

Using globes vs. projecting on a plane

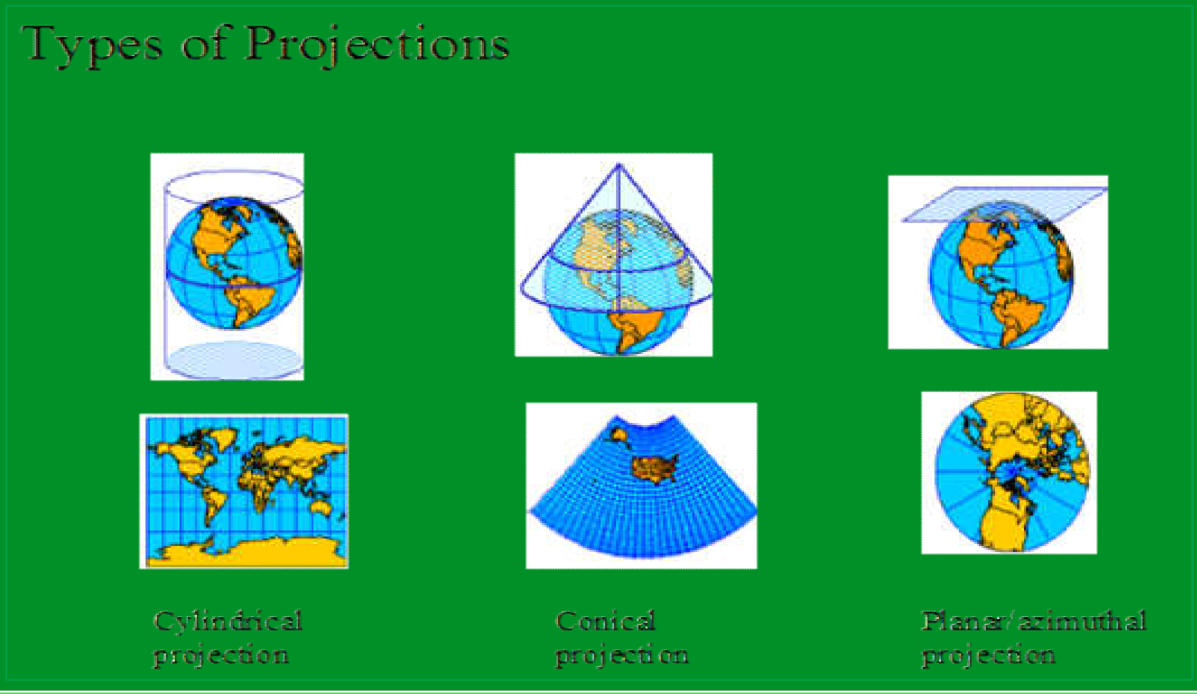
- Scale in particular is effected by the choice between using a globe vs. a plane. Only a globe can have a constant scale throughout the entire map surface and the scale for flat maps will vary from point to point
- The scale for a flat map can only be true along one or two lines or points (tangent or secant points/lines).
- The scale factor is therefore used to measure the difference between the idealized scale and the actual scale at a particular point on the map.

Choosing a projection surface

- A surface that can be unfolded or unrolled into a plane or sheet without stretching, tearing or shrinking is called a developable surface.
- The cylinder, cone and the plane are all developable surfaces.
- The sphere and ellipsoid do not have developable surfaces, so any projection of them onto a plane will have to distort the image.
- One way of describing a projection is first to project from the Earth's surface to a developable surface such as a cylinder or cone, and then to unroll the surface into a plane.

Choosing a projection surface

The projection surfaces (i.e., cylinders, cones, and planes) form the basic types of projections

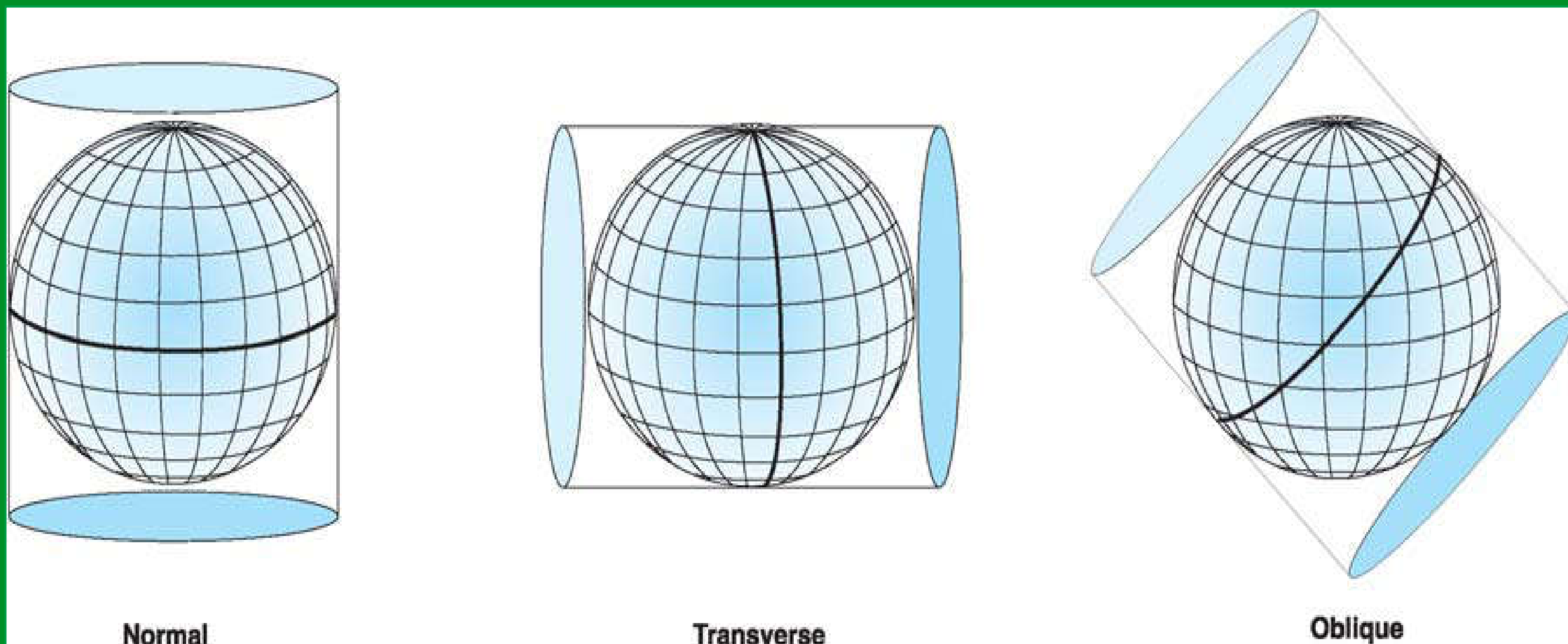


Aspects of the projection

- Once a choice is made between projecting onto a cylinder, cone, or plane, the aspect of the shape must be specified.
- The aspect describes how the developable surface is placed relative to the globe:
- It may be normal (such that the surface's axis of symmetry coincides with the Earth's axis), transverse (at right angles to the Earth's axis) or oblique (any angle in between).

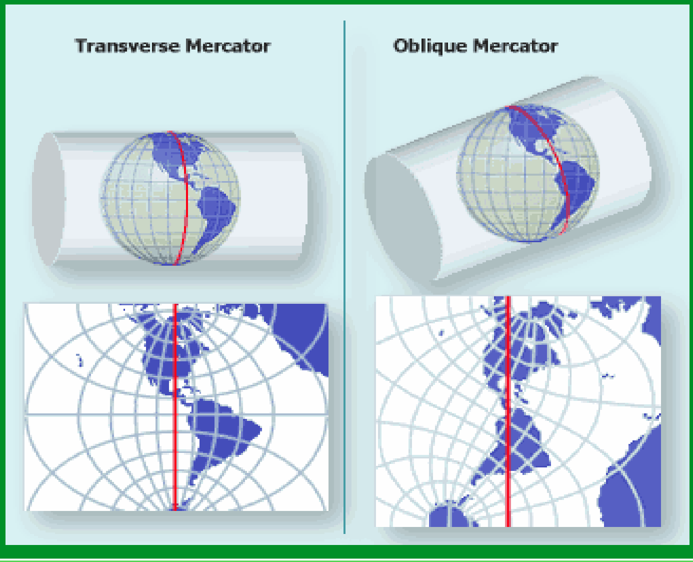
Choosing a projection surface

Three aspect of projection: Normal, Transverse and Oblique



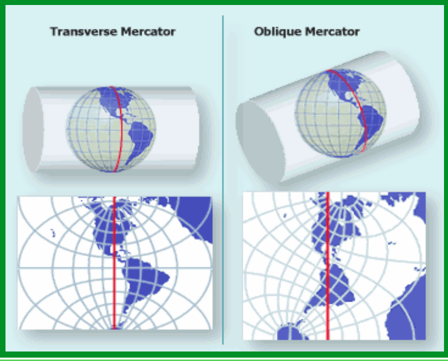
Cylinder (Transverse or equatorial)

- Once a choice is made between projecting onto a cylinder, cone, or plane, the aspect of the shape must be specified.
- The aspect describes how the developable surface is placed relative to the globe:



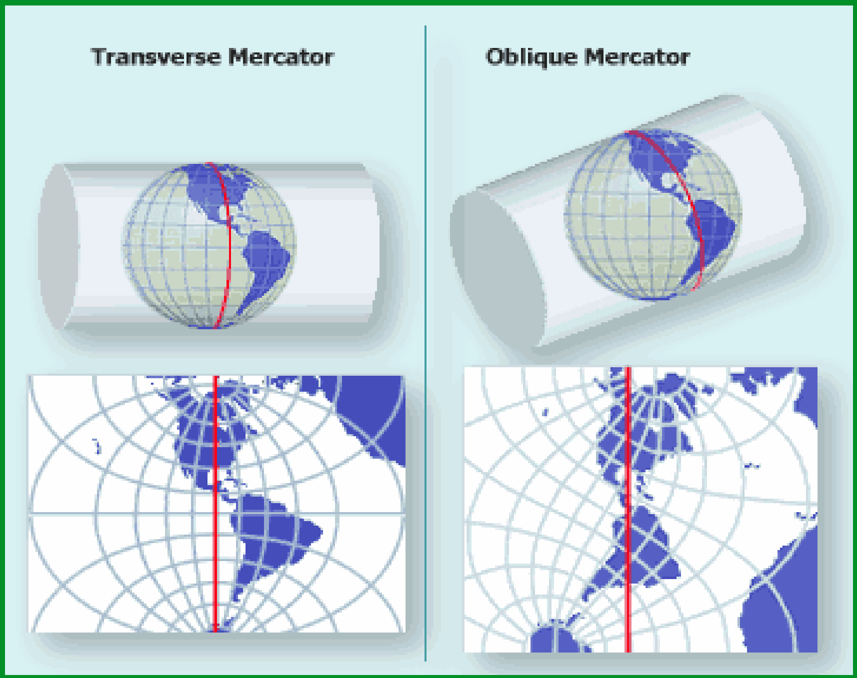
Cylinder (Transverse or equatorial)

- It may be normal (such that the surface's axis of symmetry coincides with the Earth's axis), transverse (at right angles to the Earth's axis) or oblique (any angle in between).
- The developable surface may also be either tangent or secant to the sphere or ellipsoid. Tangent means the surface touches but does not slice through the globe; secant means the surface does slice through the globe.



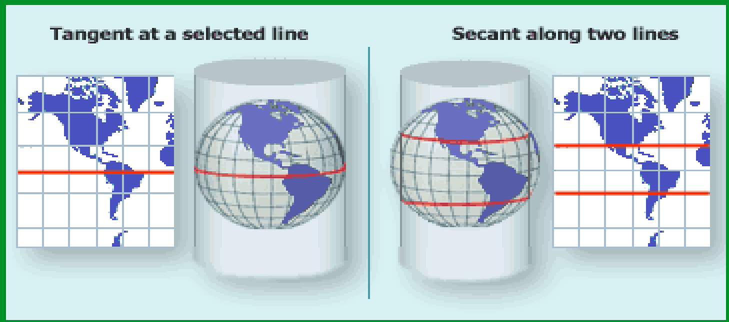
Choosing a projection surface

Cylindrical aspect – equatorial (normal), transverse, oblique



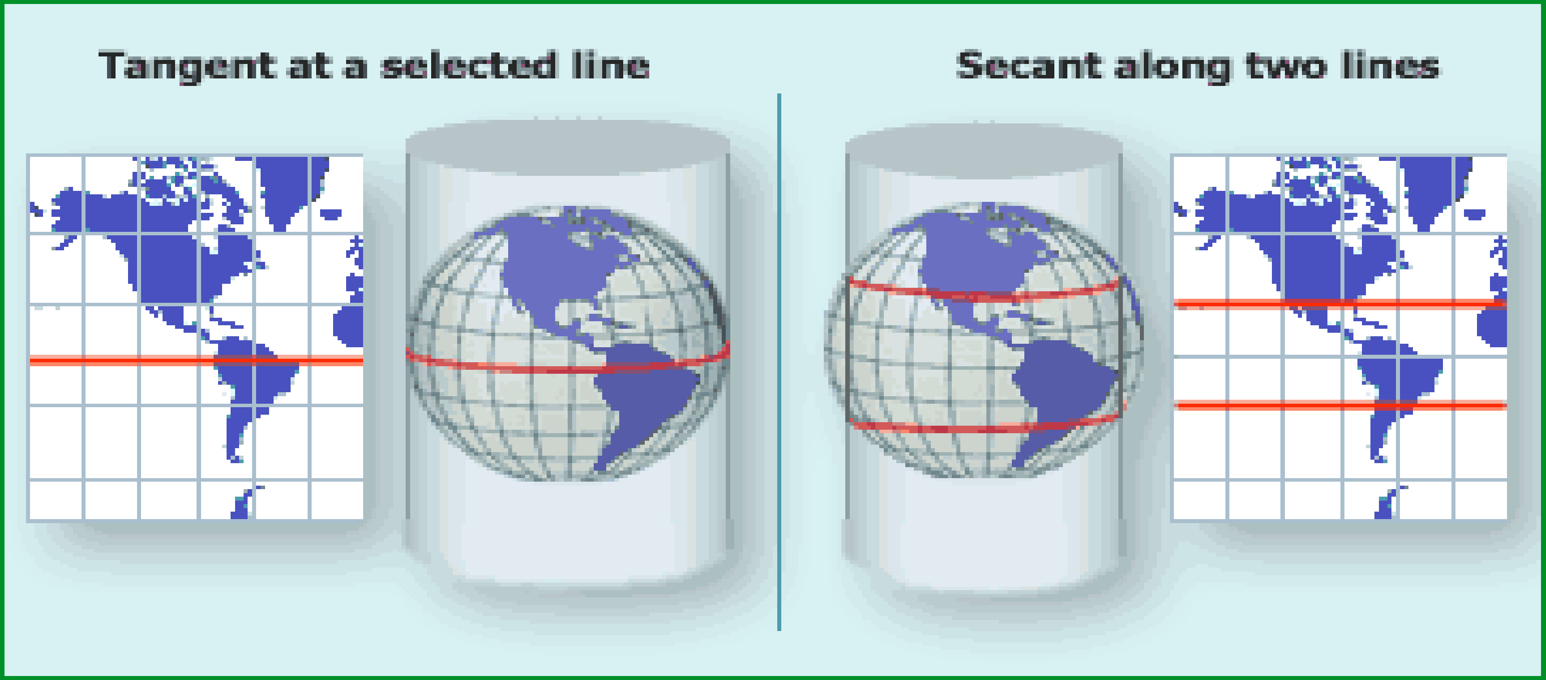
Aspects of the projection

- The developable surface may also be either tangent or secant to the sphere or ellipsoid.
- Tangent means the surface touches but does not slice through the globe.
- Secant means the surface does slice through the globe.



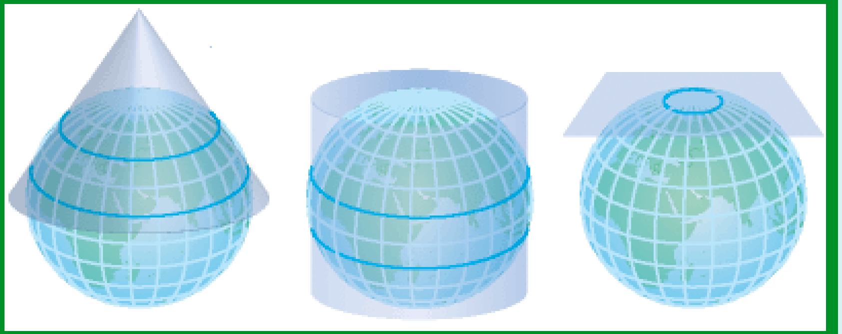
Choosing a projection surface

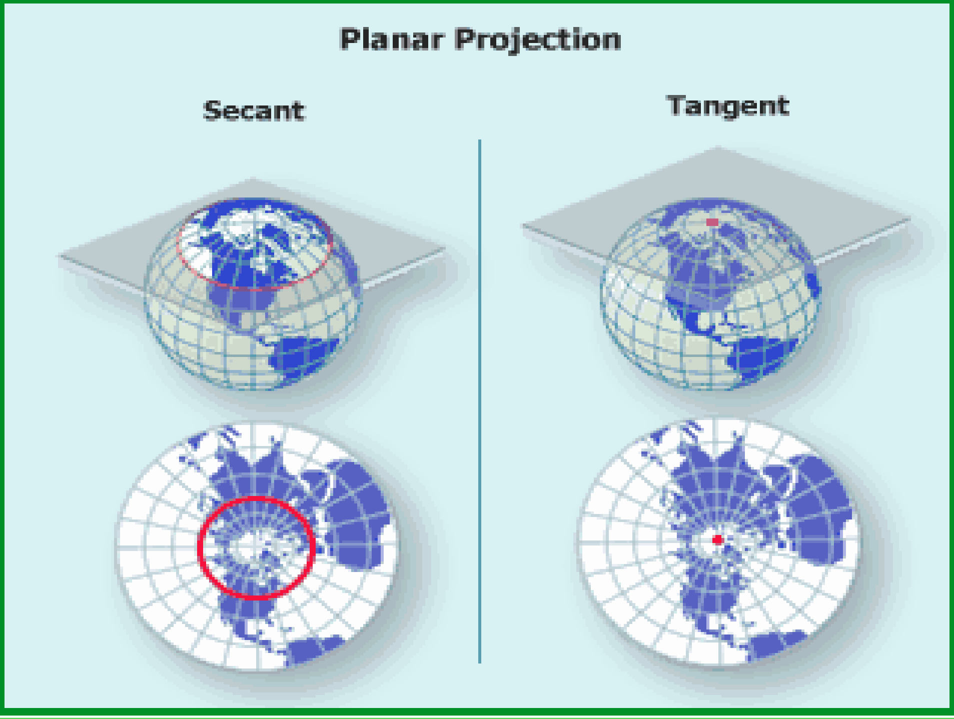
Tangent vs. secant cylindrical projection



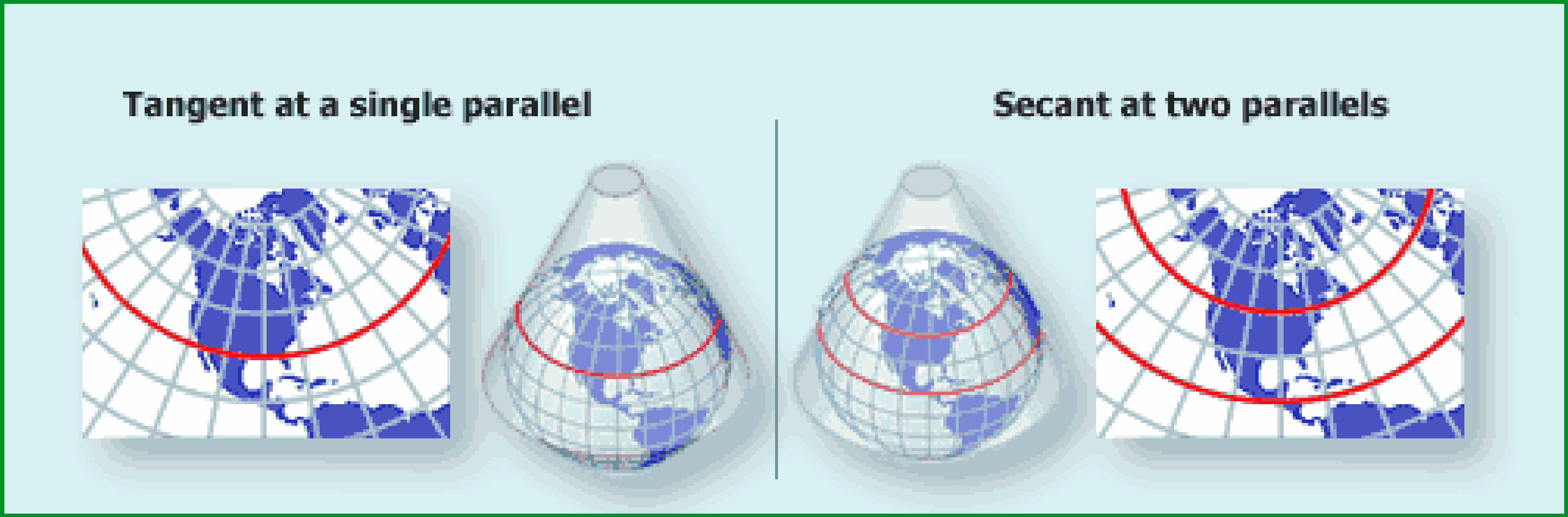
Choosing a projection surface

Tangent vs. secant planar projection





Conic



Scale (Scale factor & principal (nominal) scale)

Measuring map scale distortion – scale factor & principal (nominal) scale:

- A reference surface of the Earth is a scaled down model of the Earth.
- This scale can be measured as the ratio of distance on the reference surface (Cylinder, Cone, Plane) to the corresponding distance on the Earth.

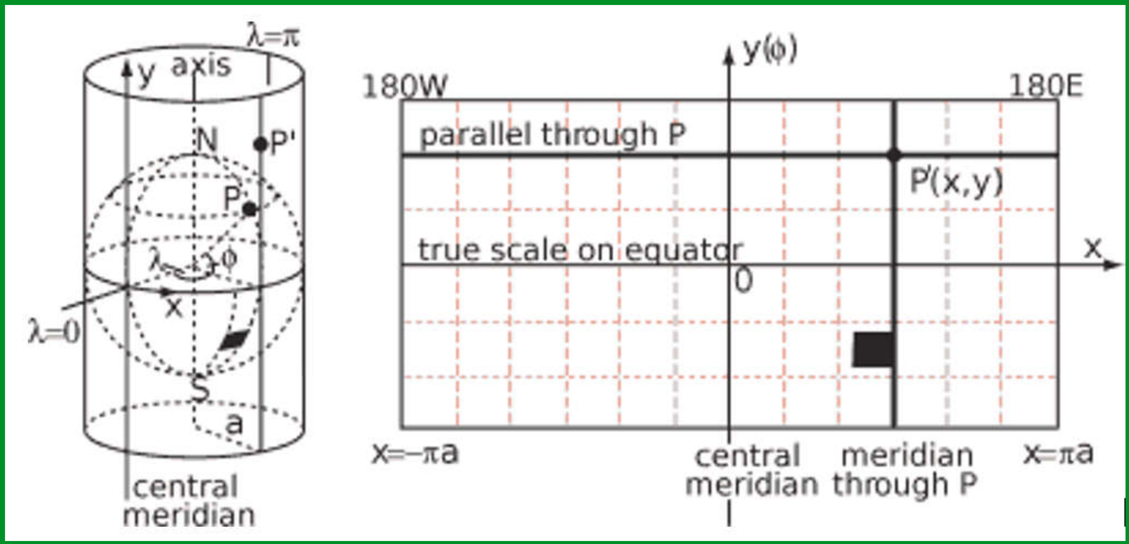
Scale (Scale factor & principal (nominal) scale)

Measuring map scale distortion – scale factor & principal (nominal) scale:

- For example, a 1:250000 representative fraction scale indicates that 1 unit (e.g. km) on the reference surface represents 250000 units on Earth.
- The principal scale or nominal scale of a flat map (the stated map scale) refers to this scale of its generating reference surface .

Scale (Scale factor & principal (nominal) scale)

Map scale distortion of a tangent cylindrical projection: SF = 1 along line of tangency

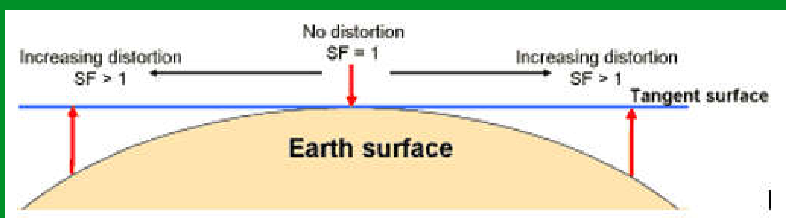


Scale (Scale factor & principal (nominal) scale)

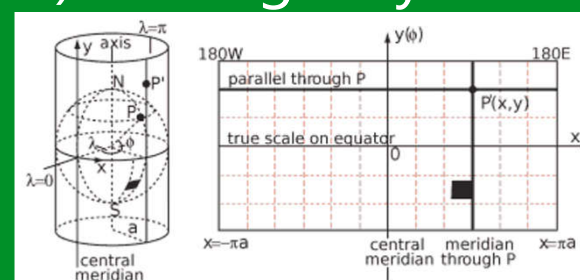
Scale distortion on a tangent surface to the globe

There is no distortion along standard lines as evident in following figures.

On a tangent surface to the reference globe, there is no scale distortion at the point (or along the line) of tangency and therefore scale factor is 1.



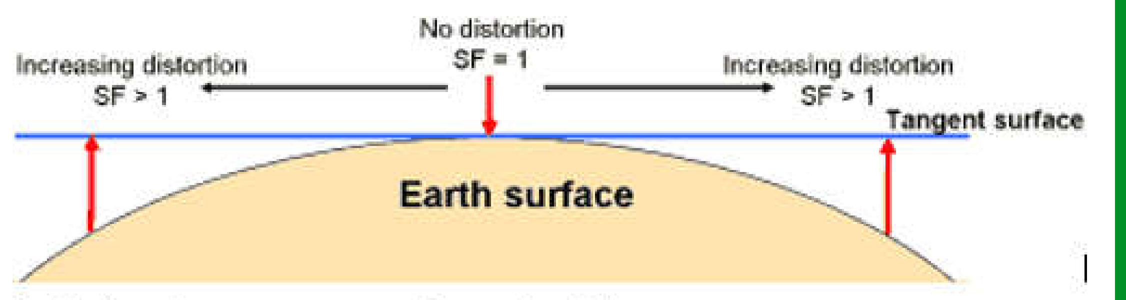
Scale distortion on a tangent surface to the globe



Scale (Scale factor & principal (nominal) scale)

Scale distortion on a tangent surface to the globe

- Distortion increases with distance from the point (or line) of tangency.



Scale distortion on a tangent surface to the globe

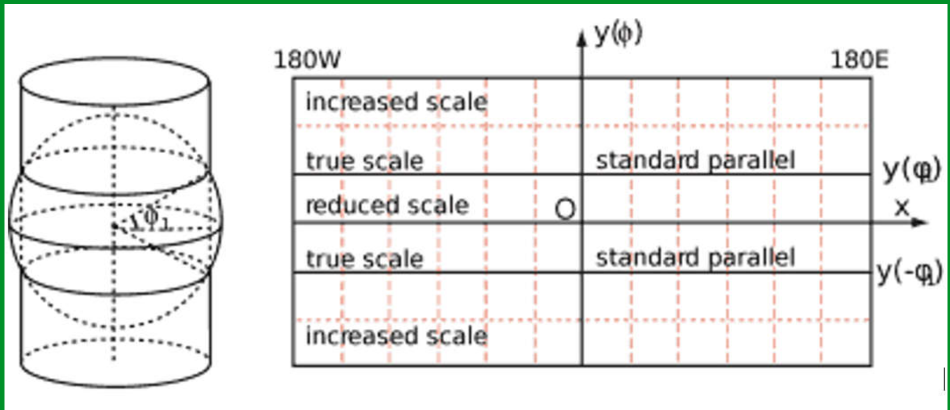
Scale (Scale factor & principal (nominal) scale)

- On a secant surface to the reference globe, there is no distortion along the standard lines (lines of intersection) where SF = 1.

- Between the secant lines where the surface is inside the globe, features appear smaller than in reality and scale factor is less than 1.

Scale (Scale factor & principal (nominal) scale)

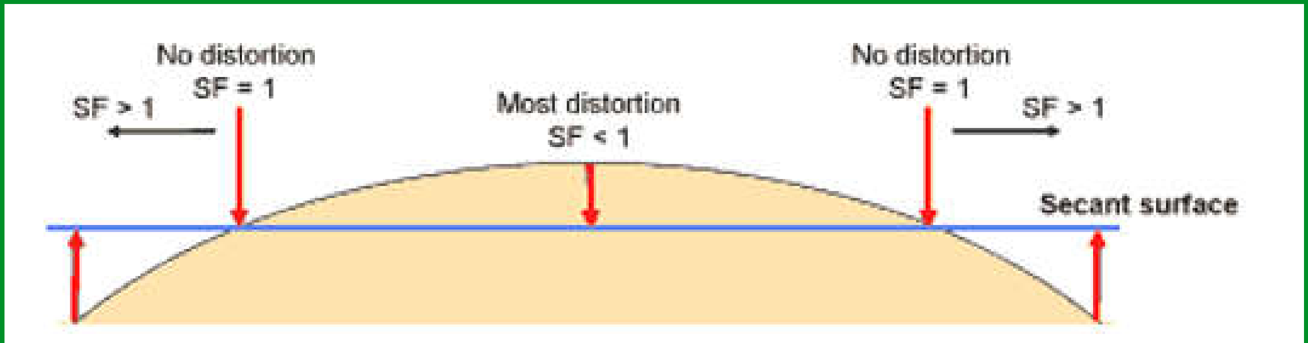
- At places on map where the surface is outside the globe, features appear larger than in reality and scale factor is greater than 1.
- A map derived from a secant projection surface has less overall distortion than a map from a tangent surface.



Map scale distortion of a secant cylindrical projection - SF = 1 along secant lines

Scale (Scale factor & principal (nominal) scale)

- At places on map where the surface is outside the globe, features appear larger than in reality and scale factor is greater than 1.
- A map derived from a secant projection surface has less overall distortion than a map from a tangent surface.



Scale distortion on a secant surface to the globe

Scale (Scale factor & principal (nominal) scale)

- The projection of the curved surface on the plane and the resulting distortions from the deformation of the surface will result in variation of scale throughout a flat map.
- In other words the actual map scale is different for different locations on the map plane and it is impossible to have a constant scale throughout the map.
- Measure of scale distortion on map plane can also be quantified by the use of scale factor.

Scale (Scale factor & principal (nominal) scale)

- Scale factor is the ratio of actual scale at a location on map to the principal (nominal) map scale (SF = actual scale / nominal scale).
- Alternatively stated as ratio of distance on the map to the corresponding distance on the reference globe.
- A scale factor of 1 indicates actual scale is equal to nominal scale, or no scale distortion at that point on the map.
- Scale factors of less than or greater than one are indicative of scale distortion. The actual scale at a point on map can be obtained by multiplying the nominal map scale by the scale factor

Scale (Scale factor & principal (nominal) scale)

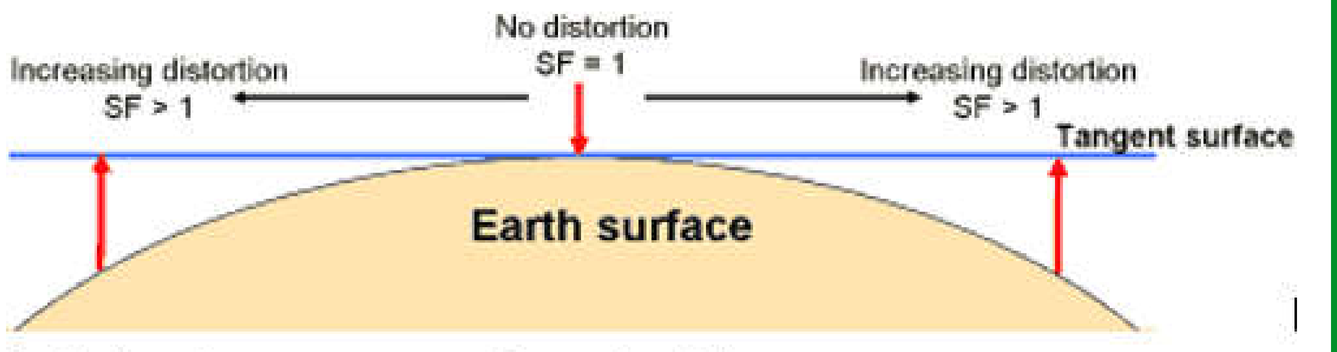
- Scale factors of less than or greater than one are indicative of scale distortion. The actual scale at a point on map can be obtained by multiplying the nominal map scale by the scale factor.
- As an example, the actual scale at a given point on map with scale factor of 0.99860 at the point and nominal map scale of 1:50000 is equal to (1:50000 x 0.99860) = (1: 50000/0.99860) = 1:50070 (which is a smaller scale than the nominal map scale).

Scale (Scale factor & principal (nominal) scale)

- Scale factor of 2 indicates that the actual map scale is twice the nominal scale; if the nominal scale is 1:4million, then the map scale at the point would be (1:4million x 2) = 1:2million.
- A scale factor of 0.99950 at a given location on the map indicates that 999.5 meters on the map represents 1000 meters on the reference globe/earth.

Scale (Measuring map scale distortion)

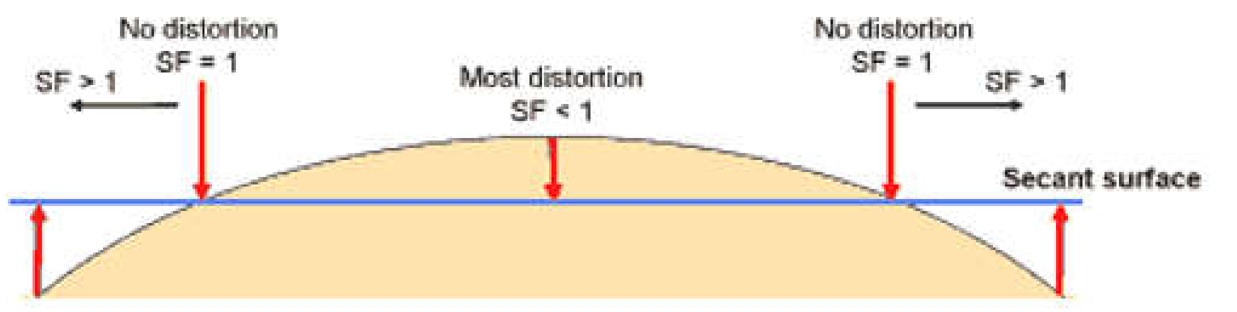
On a tangent surface to the reference globe, there is no scale distortion at the point (or along the line) of tangency and therefore scale factor is 1. Distortion increases with distance from the point (or line) of tangency.



Scale distortion on a tangent surface to the globe

Scale (Measuring map scale distortion)

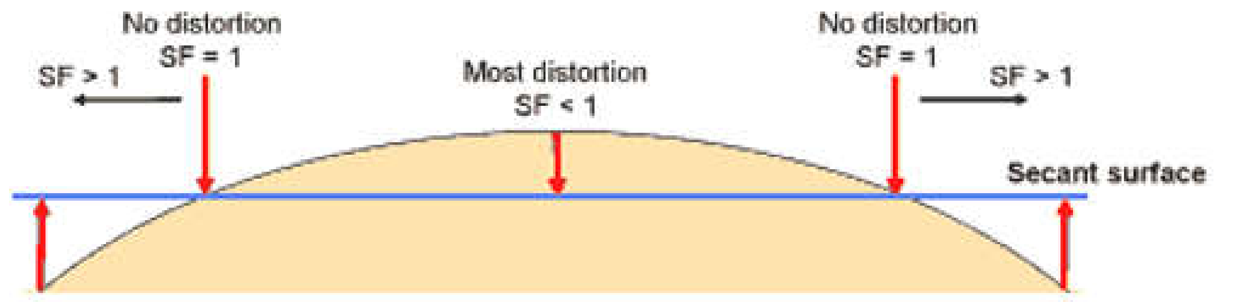
- On a secant surface to the reference globe, there is no distortion along the standard lines (lines of intersection) where SF = 1. Between the secant lines where the surface is inside the globe, features appear smaller than in reality and scale factor is less than 1.



Scale distortion on a secant surface to the globe

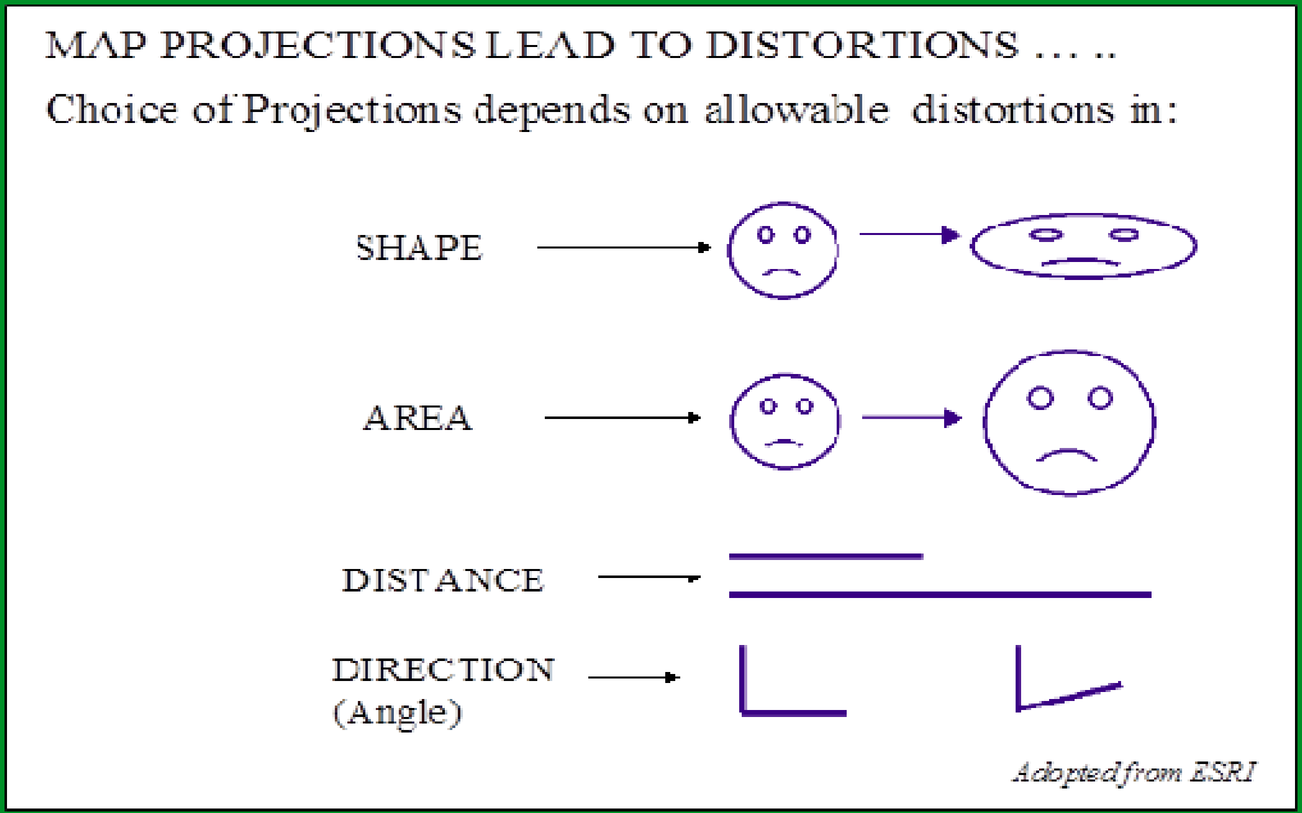
Scale (Measuring map scale distortion)

- At places on map where the surface is outside the globe, features appear larger than in reality and scale factor is greater than 1.
- A map derived from a secant projection surface has less overall distortion than a map from a tangent surface.



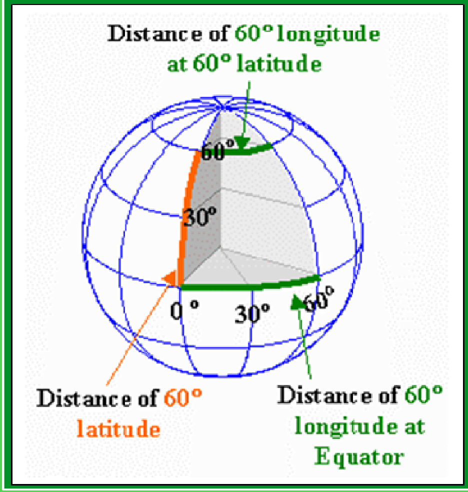
Scale distortion on a secant surface to the globe

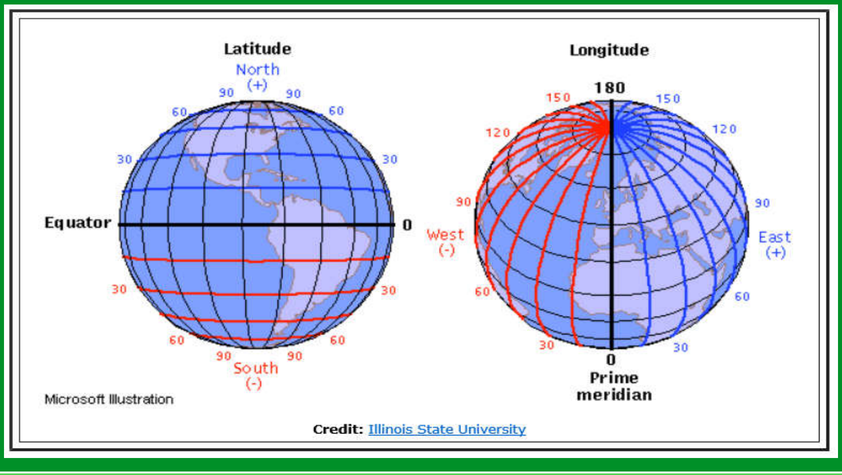
Map projections lead to distortations

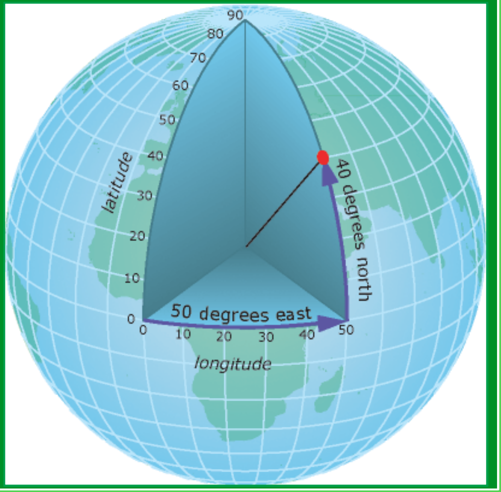


Latitude and Longitude

Latitude and Longitude determine the the Global Address of earth features. Every location on earth has a global address. A global address is given as two numbers called coordinates. The two numbers are a location's latitude number and its longitude number ("Lat/Long").

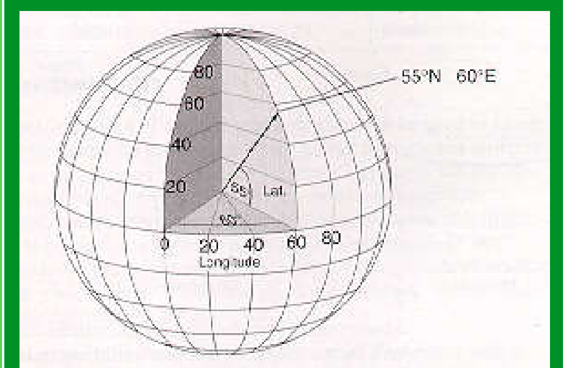


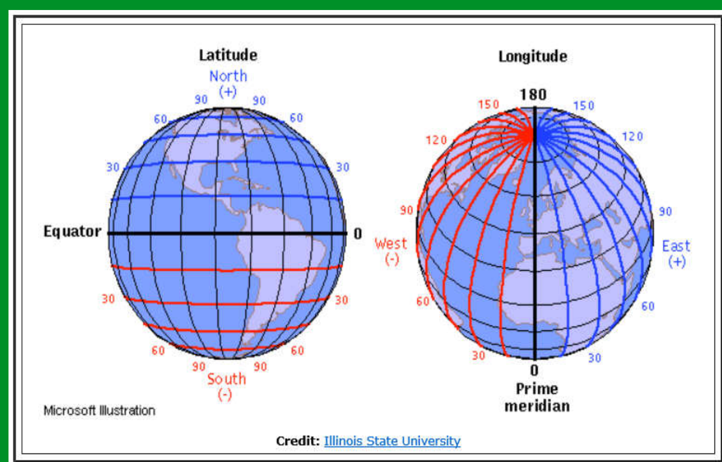


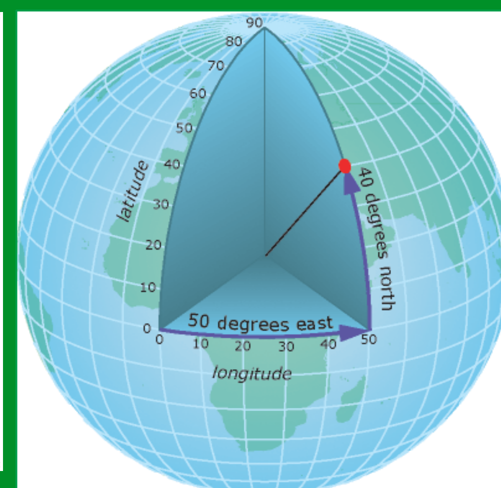


Latitude

Horizontal mapping lines on Earth are lines of latitude. They are known as "parallels" of latitude, because they run parallel to the equator.

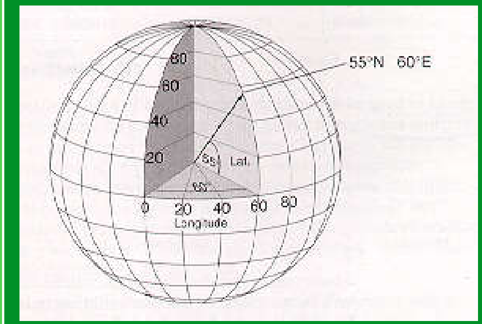


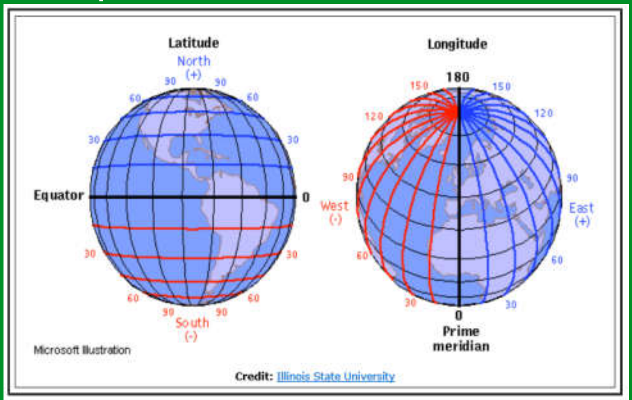


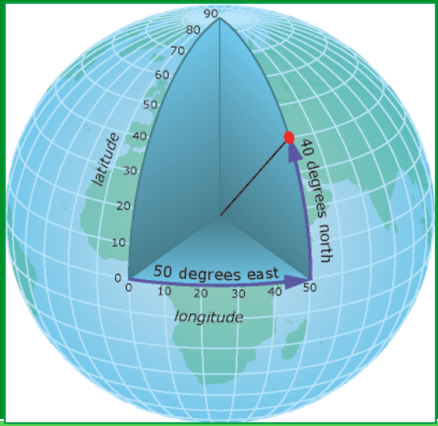


Latitude

Latitude lines are a numerical way to measure how far north or south of the equator a place is located. The equator is the starting point for measuring latitude--that's why it's marked as 0 degrees latitude. The number of latitude degrees will be larger the further away from the equator the place is located, all the way up to 90 degrees latitude at the poles. Latitude locations are given as __ degrees North or __ degrees South all geographic coordinate systems. The equator divides the globe into Northern and Southern Hemispheres.



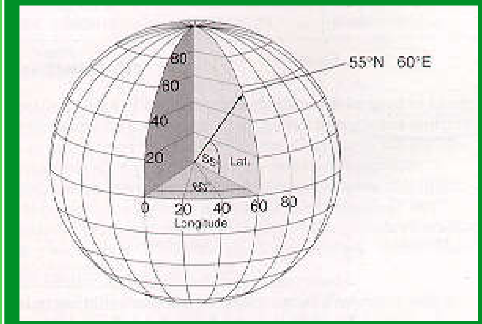


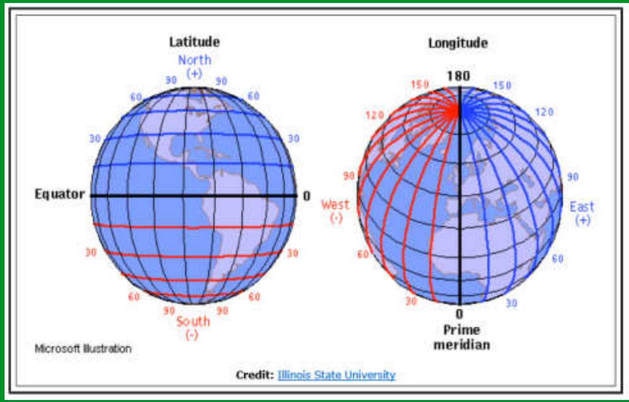


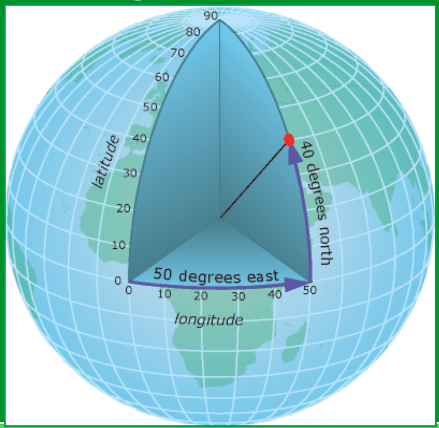
Longitude

Vertical mapping lines on Earth are lines of longitude, known as "meridians".

Longitude lines are a numerical way to show/measure how far a location is east or west of a universal vertical line called the Prime Meridian. This Prime Meridian line runs vertically, north and south, right over the British Royal Observatory in Greenwich England, from the North Pole to the South Pole. As the vertical starting point for longitude, the Prime Meridian is numbered 0 degrees longitude.

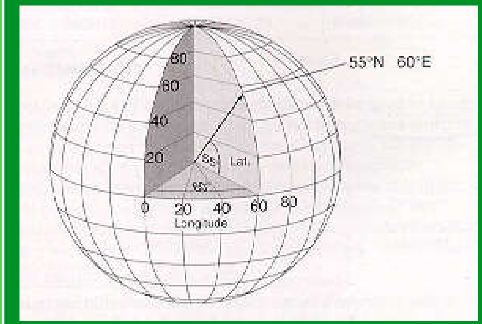


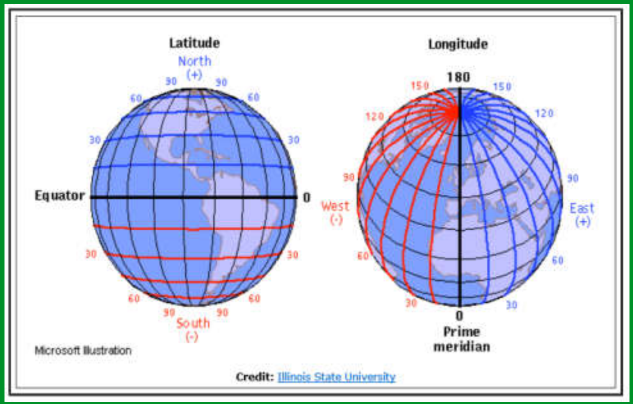


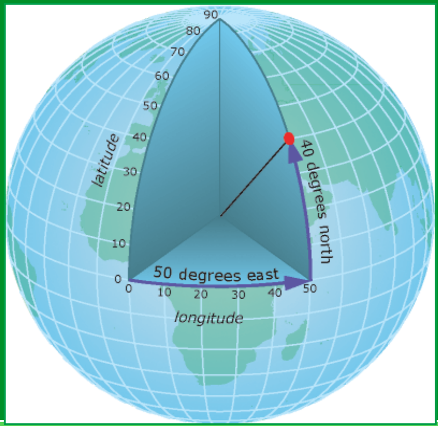


Longitude

To measure longitude east or west of the Prime Meridian, there are 180 vertical longitude lines east of the Prime Meridian and 180 vertical longitude lines west of the Prime Meridian, so longitude locations are given as __ degrees east or __ degrees west. The 180 degree line is a single vertical line called the International Date Line, and it is directly opposite of the Prime Meridian.

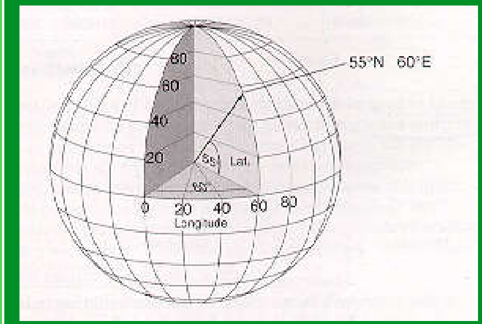


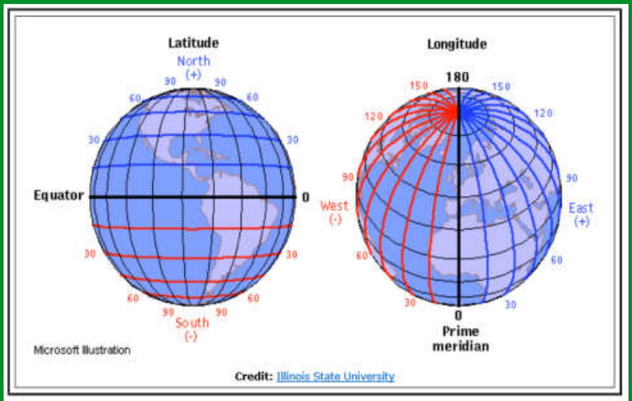


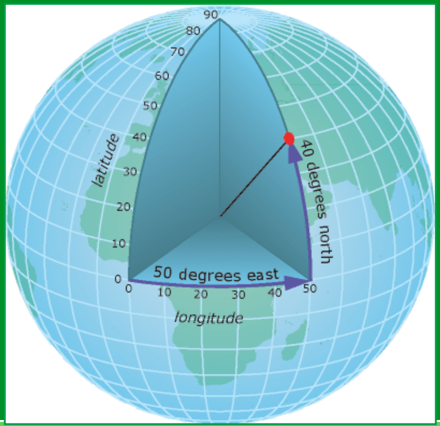


Longitude

A line, which was intended to pass through the Royal Observatory, Greenwich (a suburb of London, UK), was chosen as the international zero-longitude reference line, the Prime Meridian. Places to the east are in the eastern hemisphere, and places to the west are in the western hemisphere. The antipodal meridian of Greenwich is both 180°W and 180°E. The zero/zero point is located in the Gulf of Guinea about 625 km south of Tema, Ghana.

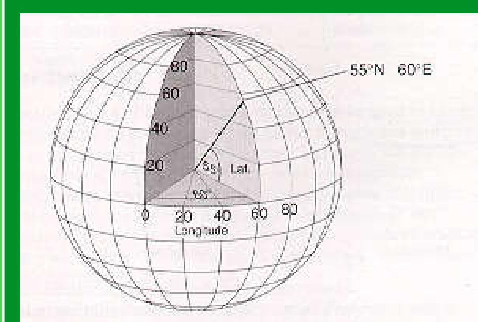


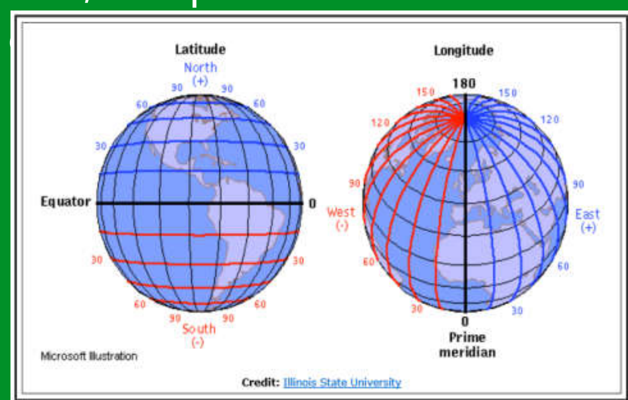


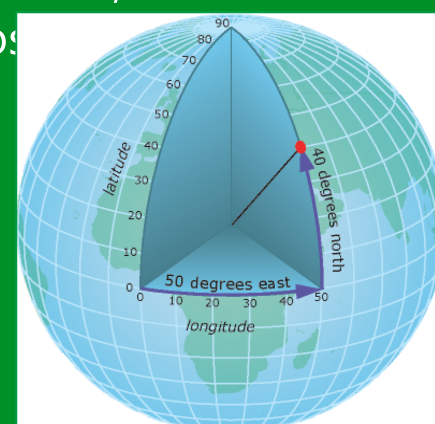


Geodetic height

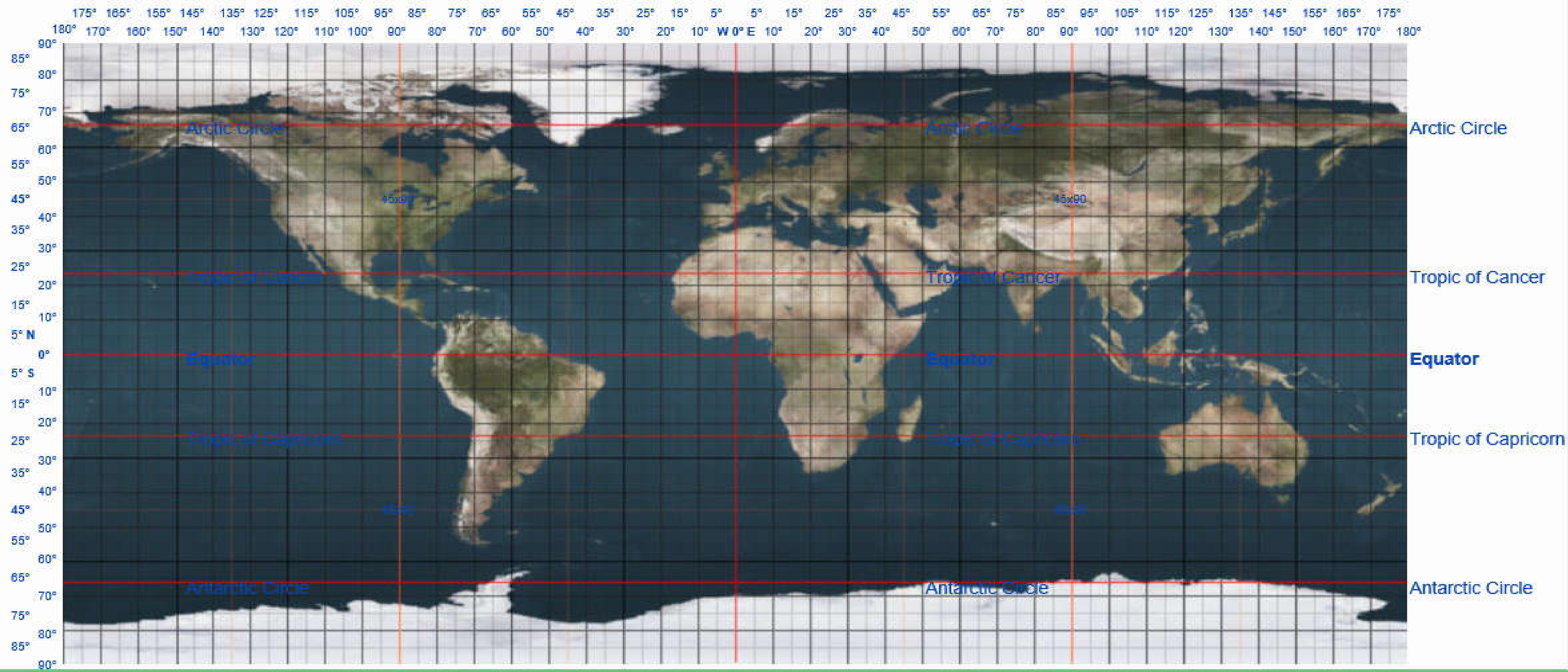
To completely specify a location of a topographical feature on, in, or above the Earth, one has to also specify the vertical distance from the centre of the Earth, or from the surface of the Earth. Because of the ambiguity of "surface" and "vertical", it is more commonly expressed relative to a precisely defined vertical datum which holds fixed some known point. Each country has defined its own datum. For example, in the United Kingdom the reference point is Newlyn, while in Canada, Mexico and the United States, the point is near Rimouski, Quebec, Canada. The distance to Earth's centre p pos ons







Latitude and Longitude



Geographic Information Systems

Geographic phenomena and data modeling

3.1 Introduction to geographic phenomena and data modeling

3.2 Spatial relationship and topology

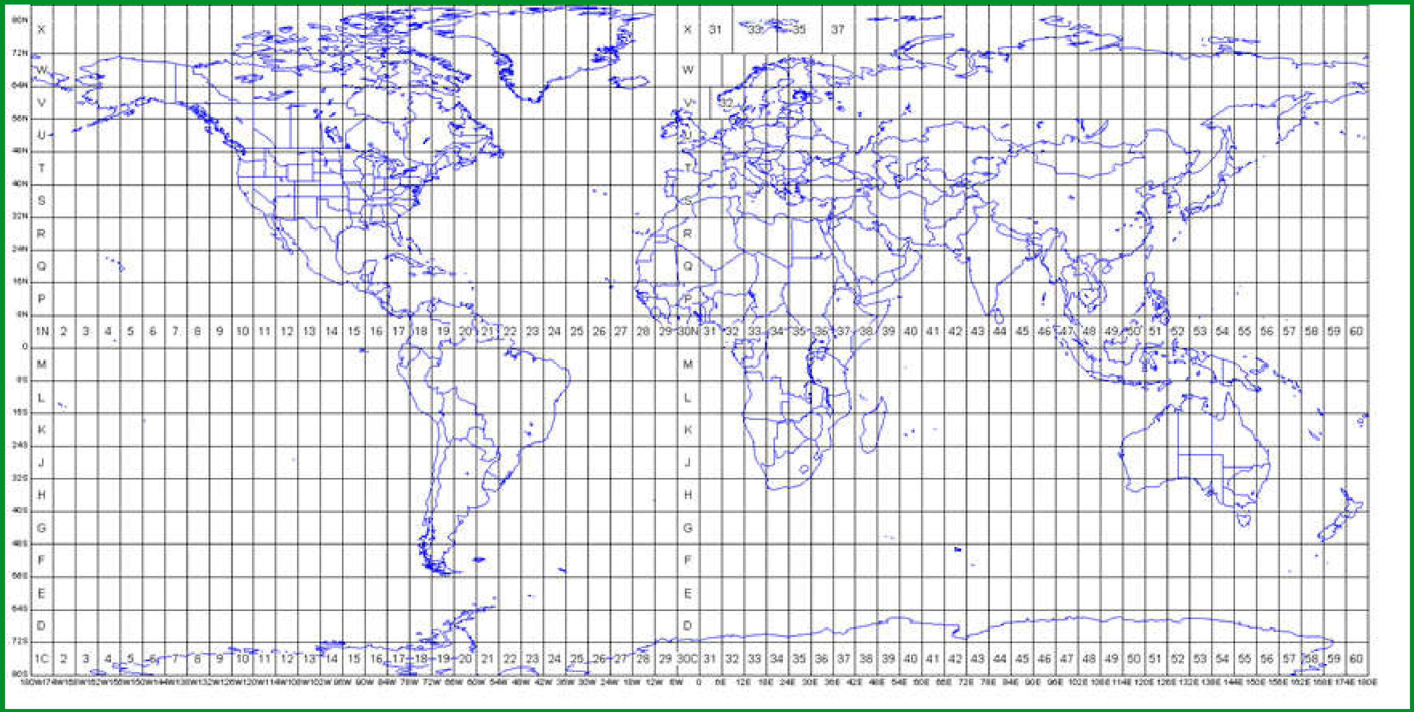
3.3 Scale and resolution

3.4 Vector, raster and digital terrain model

3.5 Spatial database design with the concept of geodatabase

Choosing a projection surface

Locations and grid designations in developable surfaces:



Map Projection

- A map projection is the transformation of Earth's curved surface (or a portion of) onto a two-dimensional flat surface by means of mathematical equations.
- During such transformation, the angular geographic coordinates (latitude, longitude) referencing positions on the surface of the Earth are converted to Cartesian coordinates (x, y) representing position of points on a flat map.

Map Projection

The map projection process :

1. Measurements collected from the Earth's surface are placed on a globe that reflects the reduced scale on which one wishes to visualize the measurements. This conceptual globe is called a reference globe.

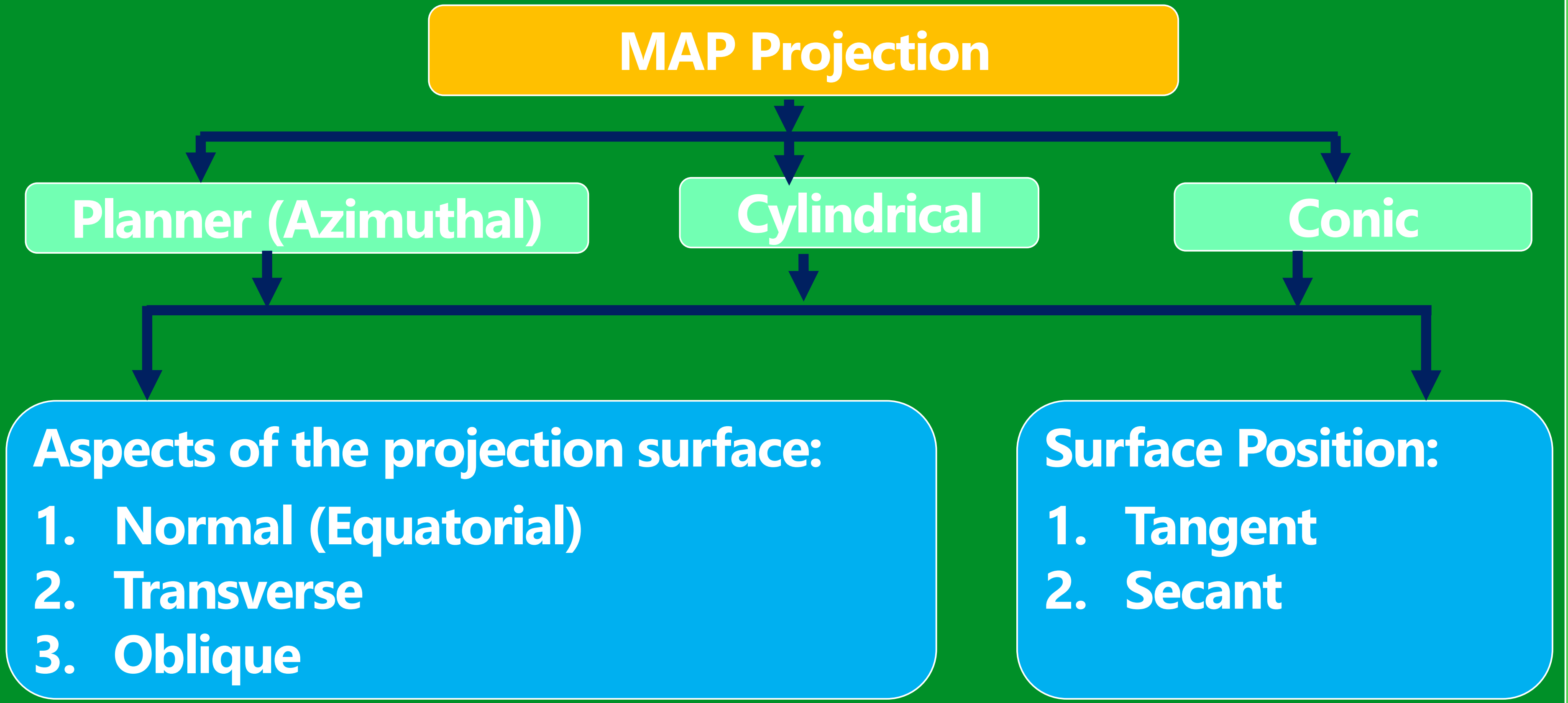
2. The second step is to take the mapped measurements from the three dimensional reference globe and place them onto a two-dimensional, flat surface.

Type of Map Projection

The map projection classification :

1. Based on developable surface
2. Based on distortion characteristics.

MAP Projection based on developable Surface?



MAP Projection based on distortion characteristics?

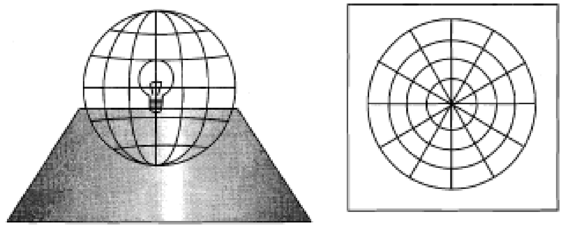
- There are hundreds of types of map projections, and they can be classified according to how they manage the distortion related to the shape and direction of mapped landscape features.
- Three such classifications are
  - Conformal projection
  - Equal area projection
  - Azimuthal projection.

MAP Projection based on distortion characteristics?

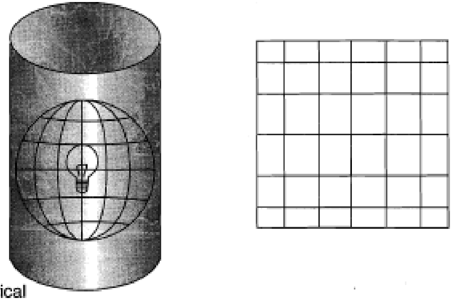
- Each of these classifications has strengths and limitations when illustrating landscape features.
- Users must decide which of these classifications is the most appropriate for their GIS databases.

Map Projection

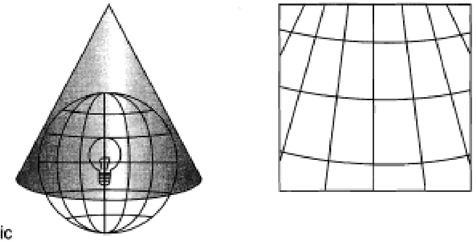
- Perhaps the easiest way to understand this concept is to picture a transparent plastic globe with a **graticule** placed on its surface. If a light bulb is placed within the globe, the outline of the **graticule** will be projected onto any surrounding surface.



Azimuthal



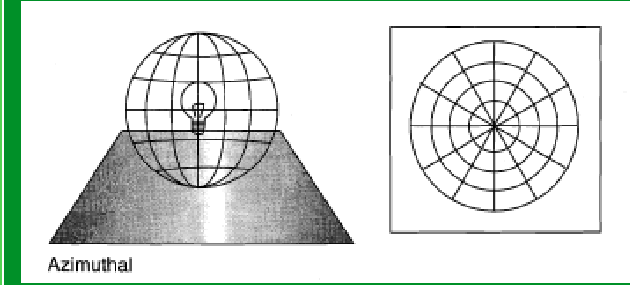
Cylindrical

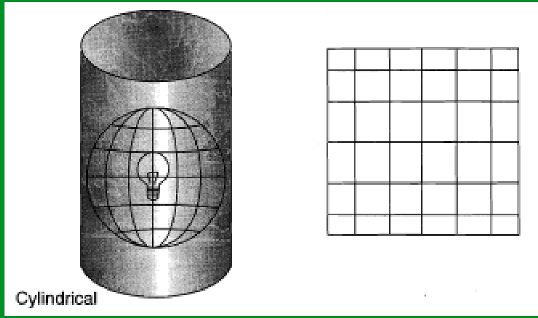


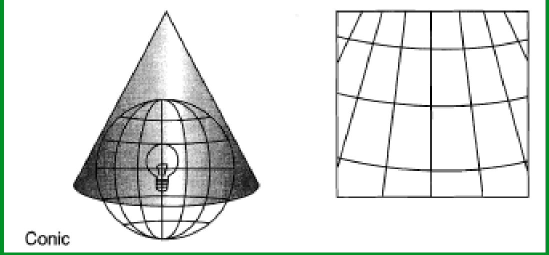
Conic

Map Projection

Map projections on these surfaces are referred to as **Planner (azimuthal)**, **cylindrical**, and **conic**, respectively



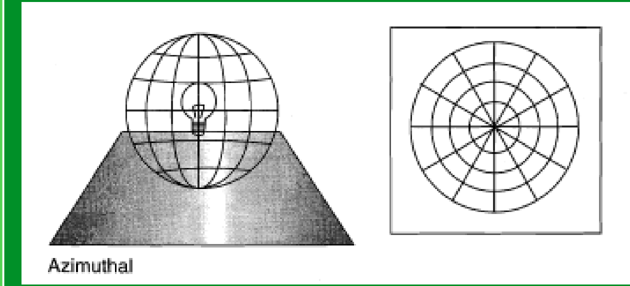


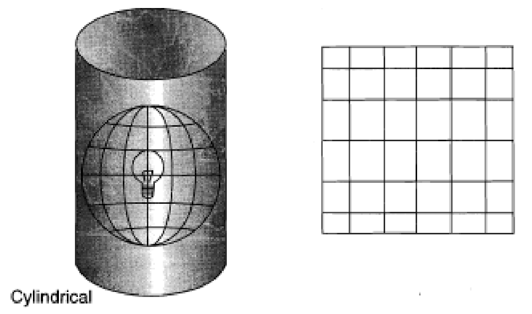


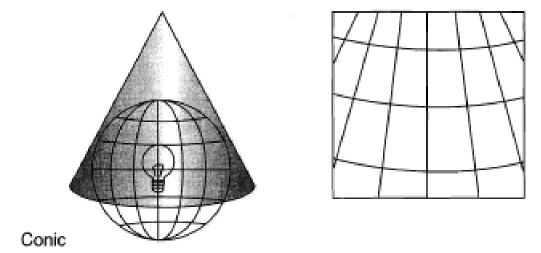
Earth's graticule projected onto azimuthal, cylindrical, and conic surfaces.

Map Projection

With all 3 surfaces, a graticule on a map will appear in a different location than it does on a globe, and a graticule will appear in a different location on each surface.





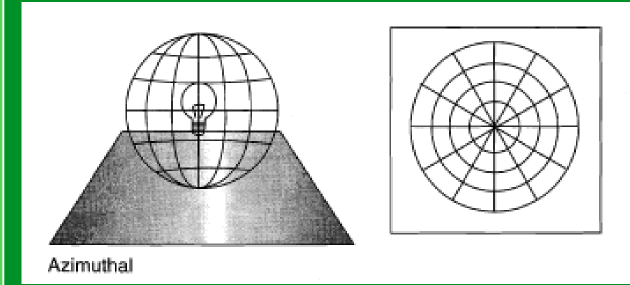


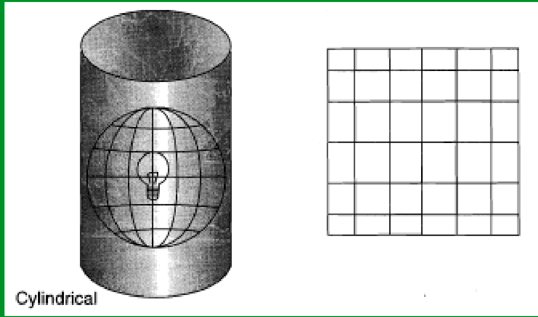
Earth's graticule projected onto azimuthal, cylindrical, and conic surfaces.

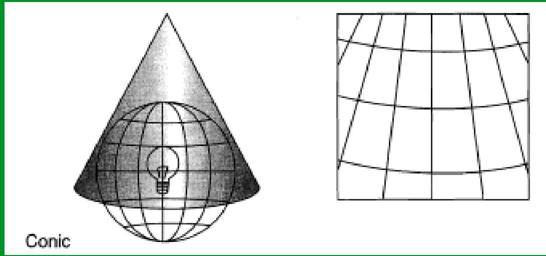
Map Projection

one would see that a projected graticule appears more distorted along the edges of the maps, away from the point or line(s) where a globe actually coincides with the map surface.

In fact, the areas where a globe and a map surface meet are the places where distortion is minimized.







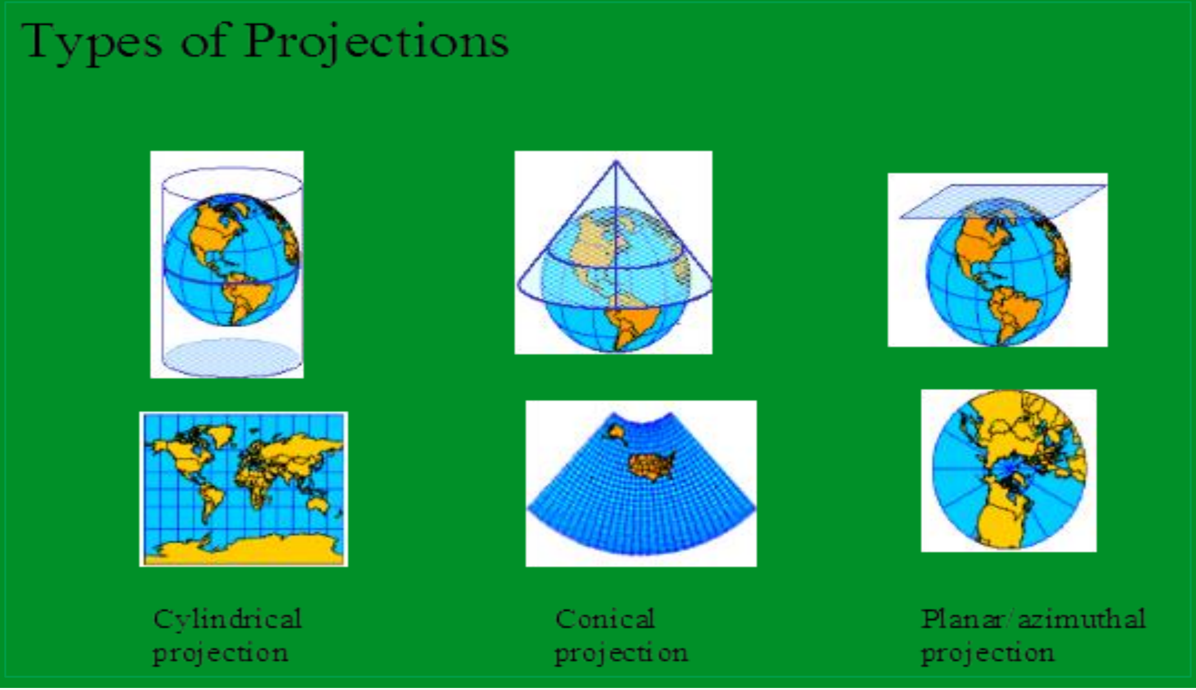
Earth's graticule projected onto azimuthal, cylindrical, and conic surfaces.

Choosing a projection surface

- A surface that can be unfolded or unrolled into a plane or sheet without stretching, tearing or shrinking is called a developable surface.
- The cylinder, cone and the plane are all developable surfaces.
- The sphere and ellipsoid do not have developable surfaces, so any projection of them onto a plane will have to distort the image.
- One way of describing a projection is first to project from the Earth's surface to a developable surface such as a cylinder or cone, and then to unroll the surface into a plane.

Choosing a projection surface

The projection surfaces (i.e., cylinders, cones, and planes) form the basic types of projections

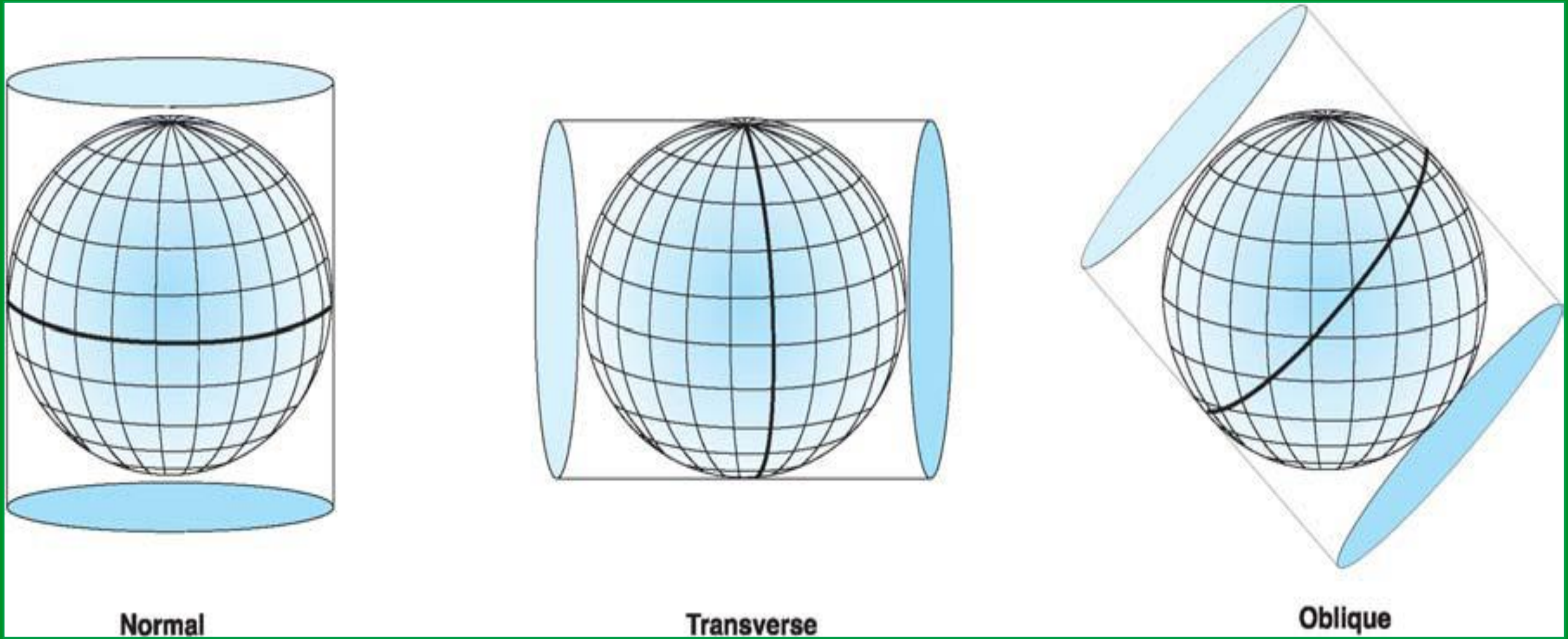


Aspects of the projection

- Once a choice is made between projecting onto a cylinder, cone, or plane, the aspect of the shape must be specified.
- The aspect describes how the developable surface is placed relative to the globe:
- It may be normal (such that the surface's axis of symmetry coincides with the Earth's axis), transverse (at right angles to the Earth's axis) or oblique (any angle in between).

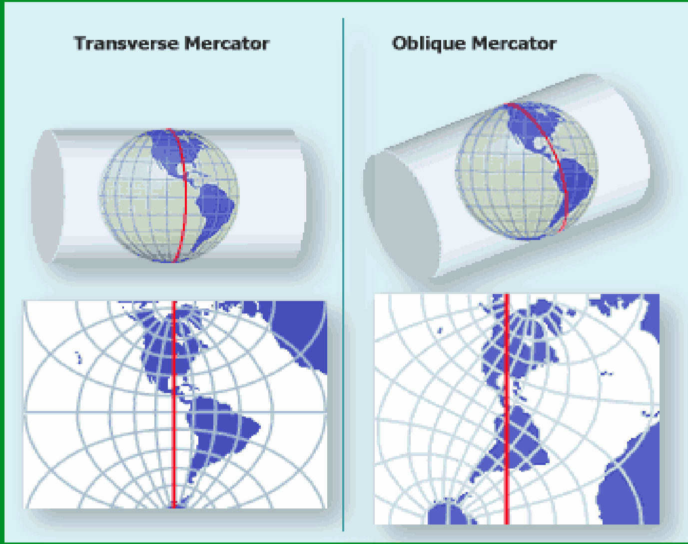
Choosing a projection surface

Three aspect of projection: Normal, Transverse and Oblique



Cylinder (Transverse or equatorial)

- Once a choice is made between projecting onto a cylinder, cone, or plane, the aspect of the shape must be specified.
- The aspect describes how the developable surface is placed relative to the globe:



Cylinder (Transverse or equatorial)

- It may be normal (such that the surface's axis of symmetry coincides with the Earth's axis), transverse (at right angles to the Earth's axis) or oblique (any angle in between).
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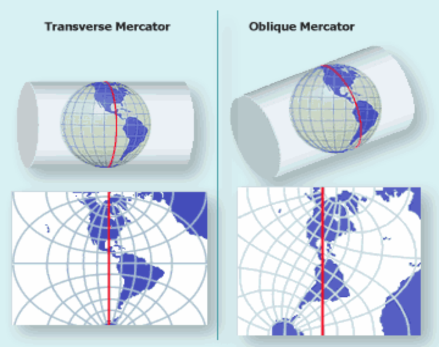
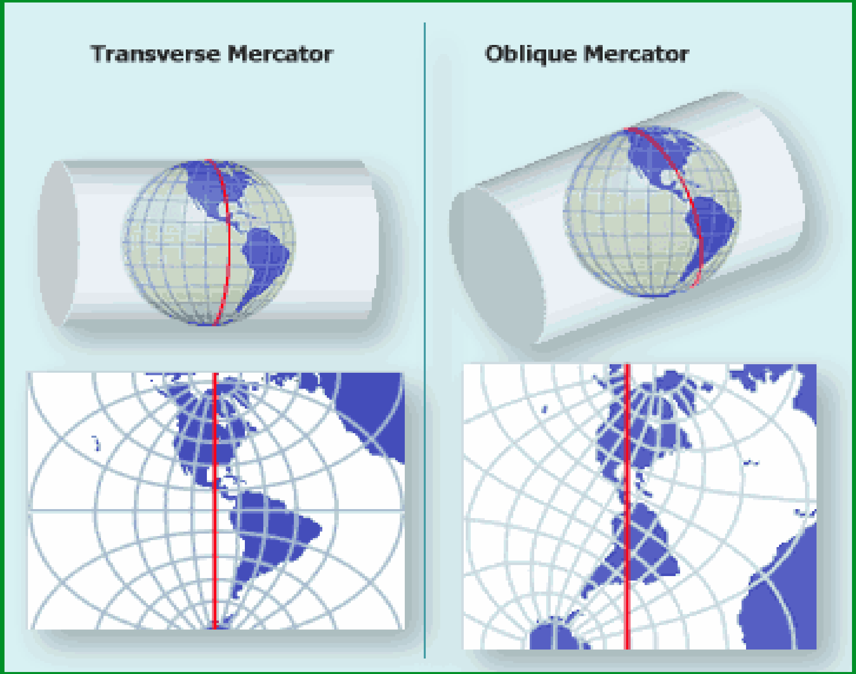


Choosing a projection surface

Cylindrical aspect – equatorial (normal), transverse, oblique



Aspects of the projection

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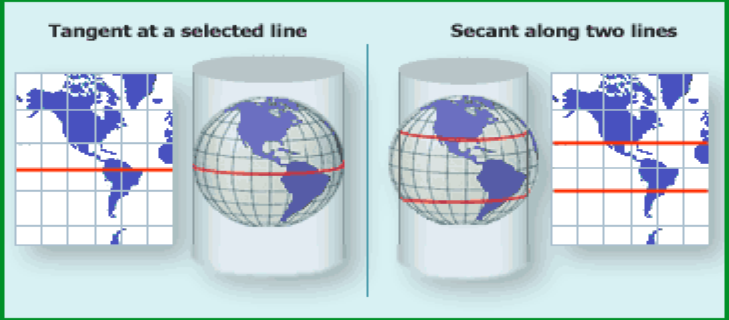
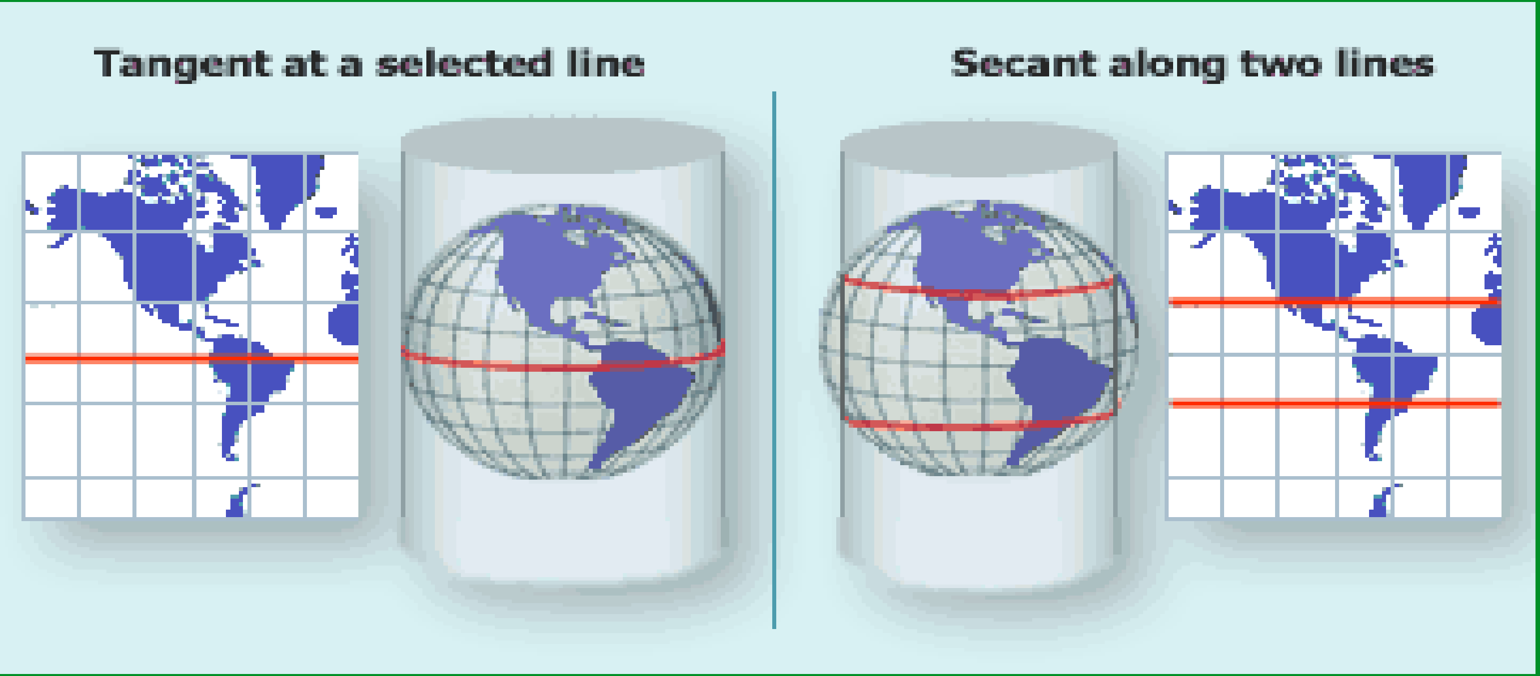


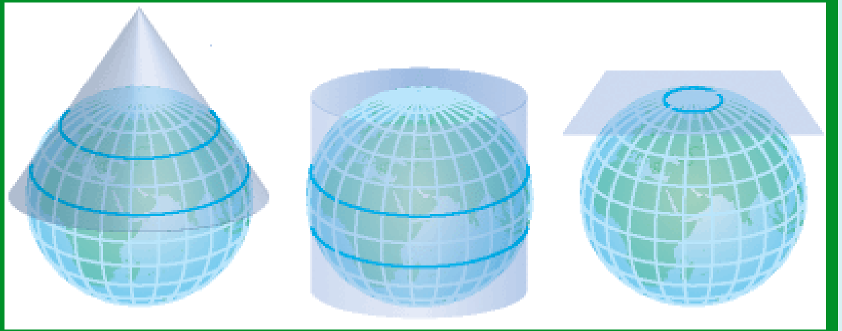
Choosing a projection surface

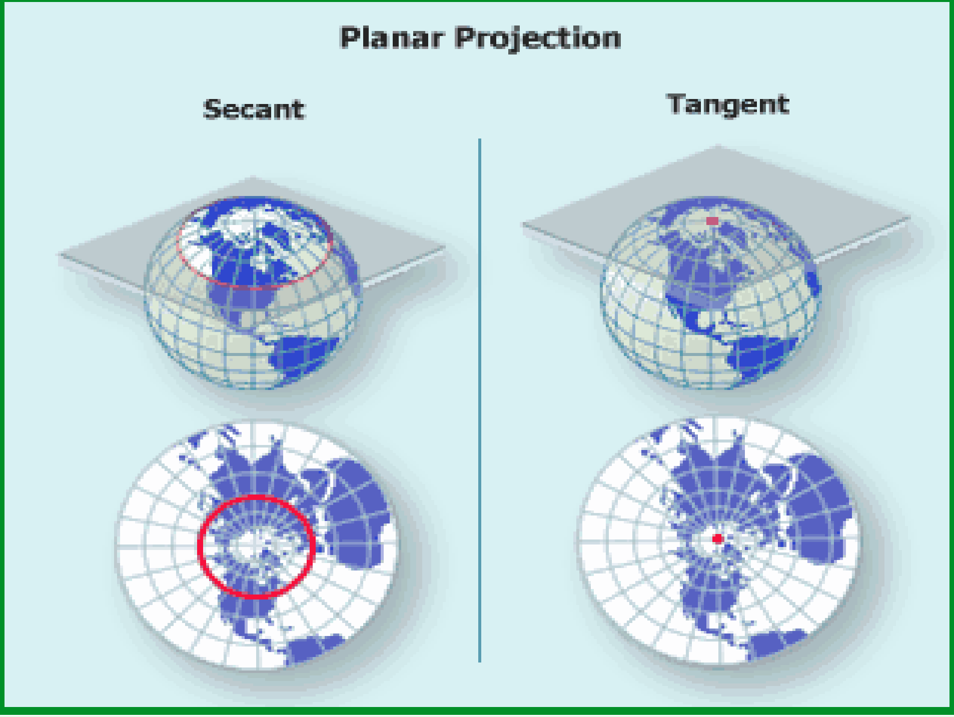
Tangent vs. secant cylindrical projection



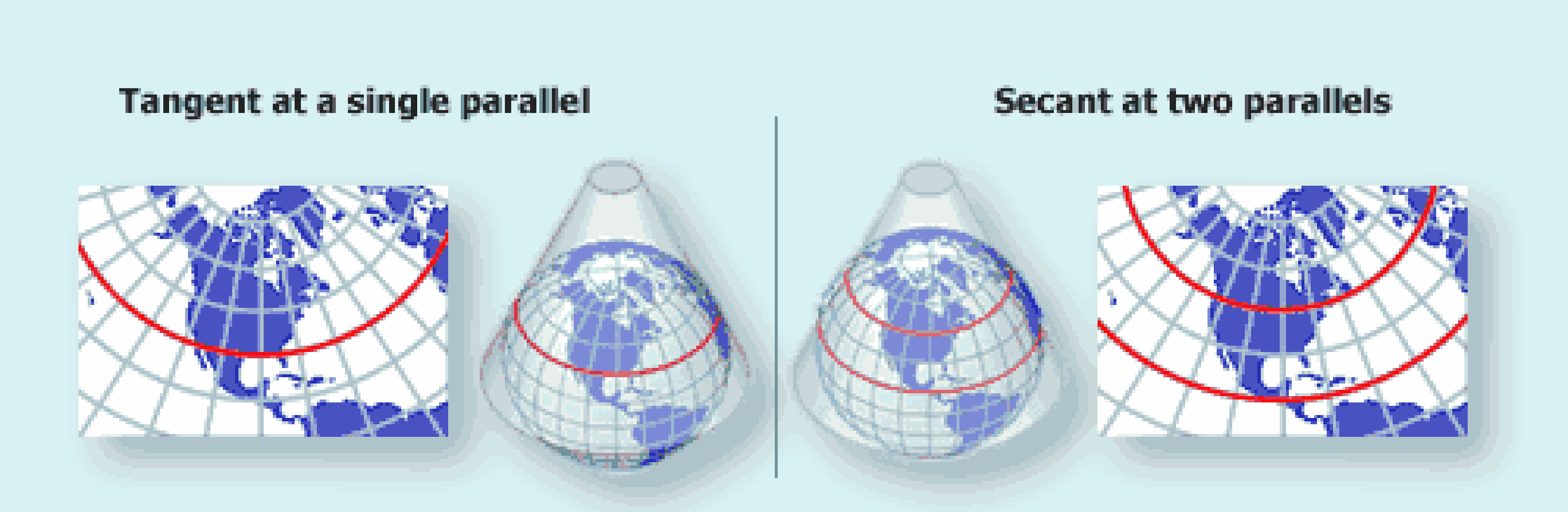
Choosing a projection surface

Tangent vs. secant planar projection





Conic



Map Projection

- A map projection is the transformation of Earth's curved surface (or a portion of) onto a two-dimensional flat surface by means of mathematical equations.
- During such transformation, the angular geographic coordinates (latitude, longitude) referencing positions on the surface of the Earth are converted to Cartesian coordinates (x, y) representing position of points on a flat map.

Map Projection

The map projection process :

1. Measurements collected from the Earth's surface are placed on a globe that reflects the reduced scale on which one wishes to visualize the measurements. This conceptual globe is called a reference globe.

2. The second step is to take the mapped measurements from the three dimensional reference globe and place them onto a two-dimensional, flat surface.

MAP Projection Classifications?

MAP Projection Classification

- Based on developable surface
- Based on distortion characteristics.

MAP Projection based on developable Surface?

MAP Projection

- Planner (Azimuthal)
- Cylindrical
- Conic

Aspects of the projection surface:

1. Normal (Equatorial)
2. Transverse
3. Oblique

Surface Position:

1. Tangent
2. Secant

MAP Projection based on distortion characteristics?

- There are hundreds of types of map projections, and they can be classified according to how they manage the distortion related to the shape and direction of mapped landscape features.
- Three such classifications are
    - Conformal projection
    - Equal area projection
    - Azimuthal projection.

MAP Projection based on distortion characteristics?

- Each of these classifications has strengths and limitations when illustrating landscape features.
- Users must decide which of these classifications is the most appropriate for their GIS databases.

MAP Projection based on Distortion?

MAP Projection based on Distortion

- **Conformal**
  1. Mercator Projection
  2. Transverse Mercator
  3. Lambert Conformal Conic
- **Equal area**
  1. Albert's Equal Area
  2. Lambert Equal Area
- **Azimuthal**
  1. Lambert Equal Area
  2. Stereographic
  3. Orthographic
  4. Gnomic
- **Compromise**

MAP Projection based on distortion characteristics?

Conformal Projection

1. Mercator Projection
2. Transverse Mercator Projection
3. Lambert Conformal Conic Projection

MAP Projection based on distortion characteristics?

Conformal Projection

- Conformal projections are most useful when the determination of directions or angles between objects is important.
- Applications of conformal projections include navigation and topographic maps.
- Examples include the Mercator projection, the transverse Mercator projection, and the Lambert conformal conic projection.

MAP Projection based on distortion characteristics?

1. Mercator projection:

- The Mercator projection is a cylindrical projection, originally created for nautical navigation, and is probably the most widely recognized projection in the world.
- One useful feature of this projection system map, as it relates to navigational purposes, is that a line of constant azimuth or direction (called a rhumb line) will appear as a straight line.

MAP Projection based on distortion characteristics?

2. Transverse Mercator projection:

- The transverse Mercator rotates the cylinder, so that it is aligned with a parallel rather than a meridian.
- The transverse Mercator projection is useful for navigational purposes in areas that have an extensive north-south orientation but are limited in their east-west orientation. The transverse Mercator has served as the base map projection for the USGS topographic map series and as the basis for the universal transverse Mercator coordinate system, "Planar Coordinate Systems."

MAP Projection based on distortion characteristics?

3. Lambert Conformal Conic:

- The Lambert conformal conic projection is useful for mid latitude areas of the world with an extensive east-west orientation and a limited north-south orientation. When a secant method is used for small areas, the Lambert conformal conic projection can provide a highly accurate description of directions and shapes of landscape features. Large areas of land, however, will include distorted shapes when mapped with a conformal projection.

MAP Projection based on distortion characteristics?

3. Lambert Conformal Conic:

- Applications of the Lambert conformal conic projection include those related to aerial navigation, meteorological uses, and topographic maps. Detailed applications of this projection system should focus on smaller land areas, since maintaining angular integrity across large areas is difficult.

MAP Projection based on distortion characteristics?

Equal area

- Equal area, or equivalent, projections are well suited for maintaining the relative size and shape of landscape features when size comparisons are of interest.
- Equal area projections preserve the size and shape of landscape features but sacrifice linear and distance relationships in doing so.

MAP Projection based on distortion characteristics?

Equal area

- A tenet of map projection techniques and an important distinction between equal area and conformal projections is that areas and angles cannot both be maintained simultaneously-one must decide which is more important than the other. One example of the equal area projection is the Albers' equal area projection.

MAP Projection based on distortion characteristics?

Equal area

- This projection is widely used and is typically based on a secant conic map surface. As in the Lambert conformal conic projection, mid-latitude areas that have extensive east-west orientations are better candidates. This projection system has been selected by many U.S. agencies as a base map projection. The Lambert equal area projection is another commonly used equal area projection, yet it is based on an azimuthal map surface

MAP Projection based on distortion characteristics?

Azimuthal Projection

- Azimuthal projections are useful for maintaining direction on a mapped surface. Azimuthal projections can be based on one (tangent) or two (secant) points of reference. With one point of reference, distortion will occur radially from the reference point, but directions near the reference point should remain true. For this reason, the azimuthal projection is appropriate for maps that have relatively the same amount of area in north-south and east-west orientations.

MAP Projection based on distortion characteristics?

Azimuthal Projection

- When using two points of reference, directions emanating from either reference point should be true. The azimuthal equidistant projection offers the unique ability of maintaining uniform direction and distance from reference points. Azimuthal projections are useful for demonstrating the shortest route between two points. Applications include those related to air navigation routes, radio wave ranges, and descriptions of celestial bodies. Azimuthal projections include Lambert's equal area, stereographic, orthographic, and gnomic.

MAP Projection based on distortion characteristics?

Compromise projection

MAP Projection based on distortion characteristics?

Equal Area Projection

1. **Albert's Equal Area**
2. **Lambert Equal Area**

MAP Projection based on distortion characteristics?

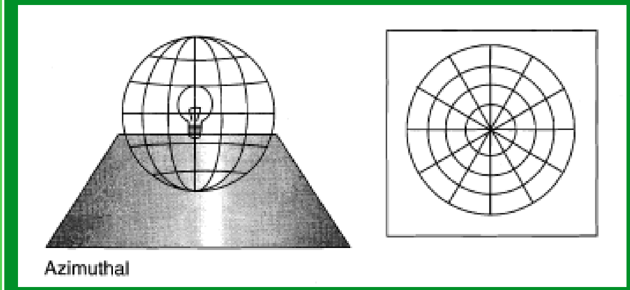
MAP Projection based on distortion characteristics?

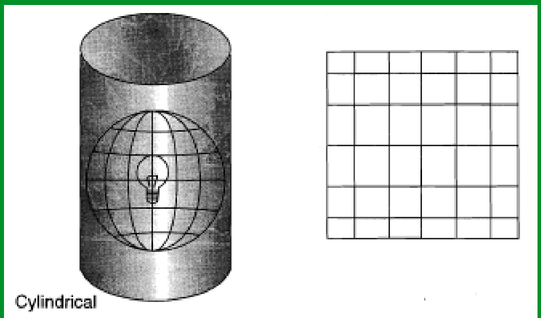
Azimuthal Projection

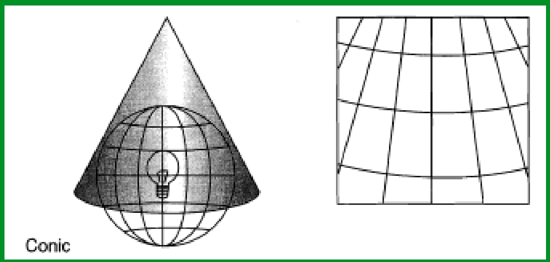
1. Lambert Equal Area
2. Stereographic
3. Orthographic
4. Gnomic

Map Projection

- Perhaps the easiest way to understand this concept is to picture a transparent plastic globe with a **graticule** placed on its surface. If a light bulb is placed within the globe, the outline of the **graticule** will be projected onto any surrounding surface.

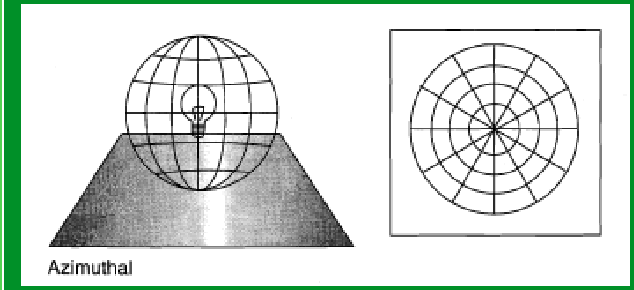


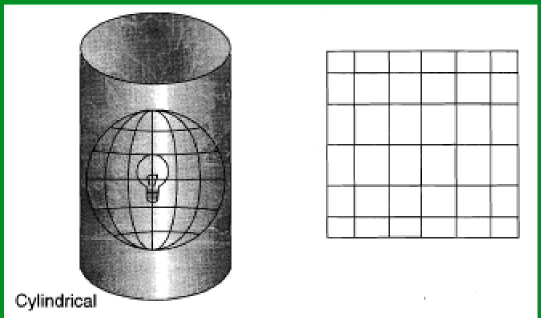


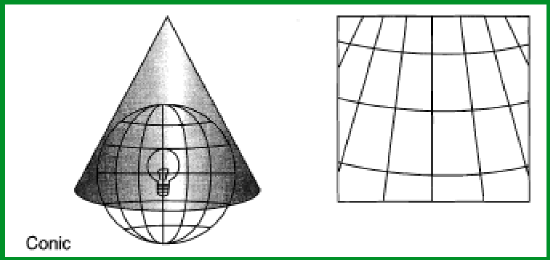


Map Projection

Map projections on these surfaces are referred to as **Planner (azimuthal)**, **cylindrical**, and **conic**, respectively



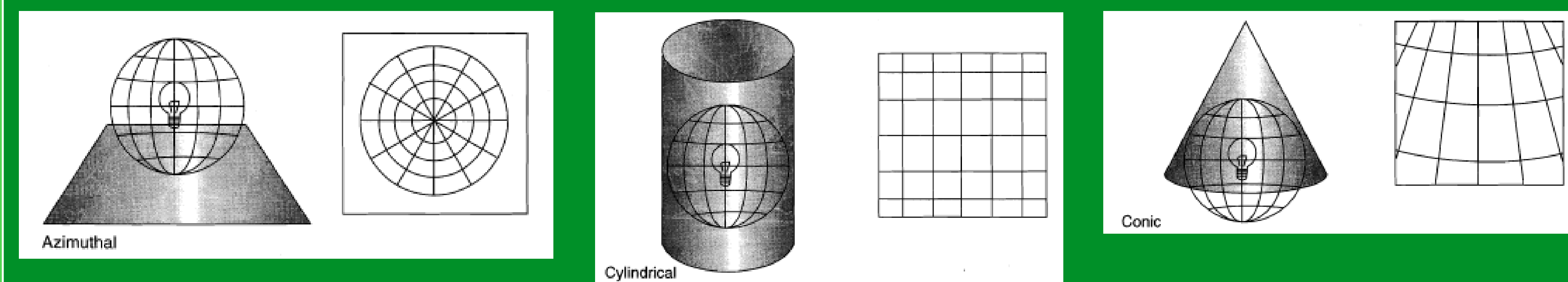




Earth's graticule projected onto azimuthal, cylindrical, and conic surfaces.

Map Projection

With all 3 surfaces, a graticule on a map will appear in a different location than it does on a globe, and a graticule will appear in a different location on each surface.

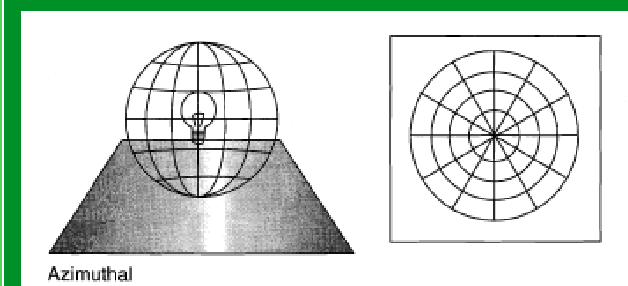


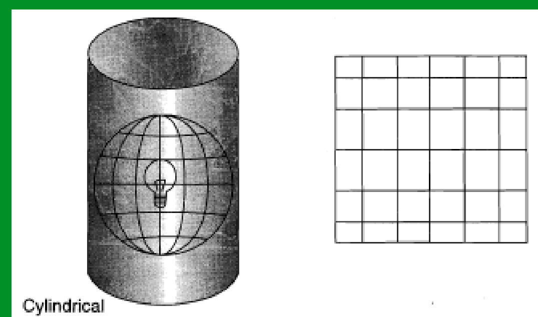
Earth's graticule projected onto azimuthal, cylindrical, and conic surfaces.

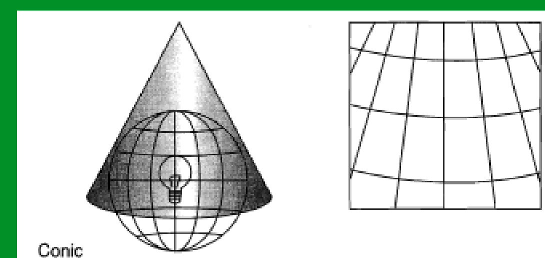
Map Projection

one would see that a projected graticule appears more distorted along the edges of the maps, away from the point or line(s) where a globe actually coincides with the map surface.

In fact, the areas where a globe and a map surface meet are the places where distortion is minimized.







Earth's graticule projected onto azimuthal, cylindrical, and conic surfaces.

Choosing a projection surface

- A surface that can be unfolded or unrolled into a plane or sheet without stretching, tearing or shrinking is called a developable surface.
- The cylinder, cone and the plane are all developable surfaces.
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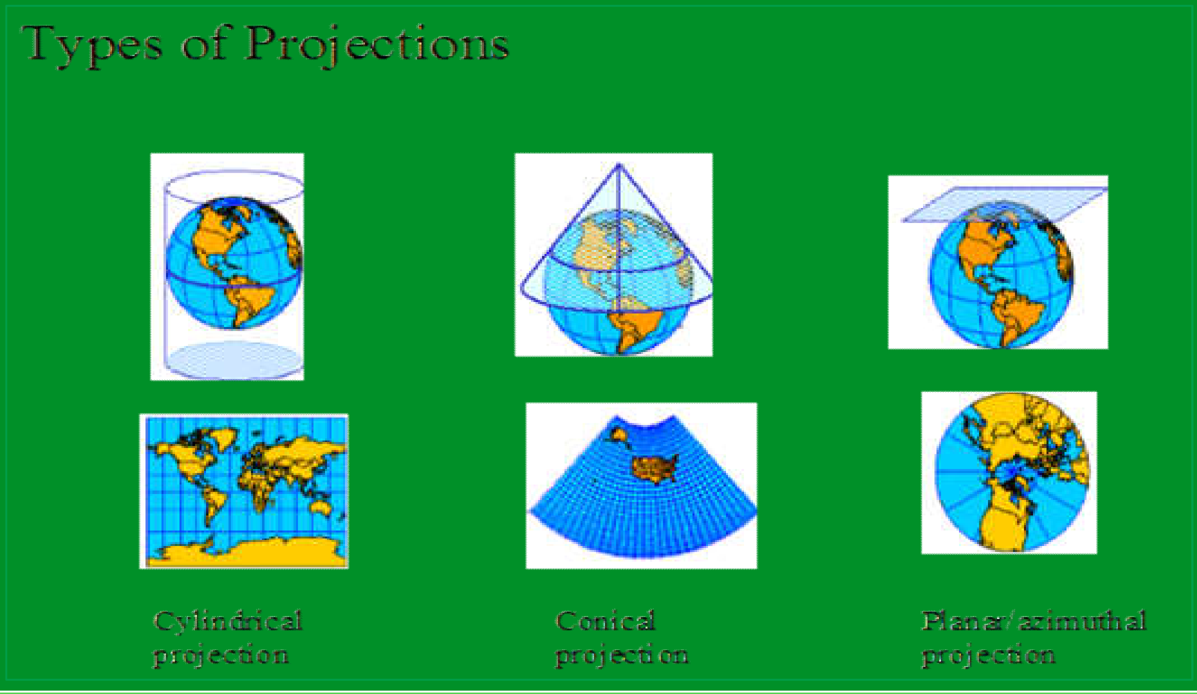
- One way of describing a projection is first to project from the Earth's surface to a developable surface such as a cylinder or cone, and then to unroll the surface into a plane.

Choosing a projection surface

The projection surfaces (i.e., cylinders, cones, and planes) form the basic types of projections

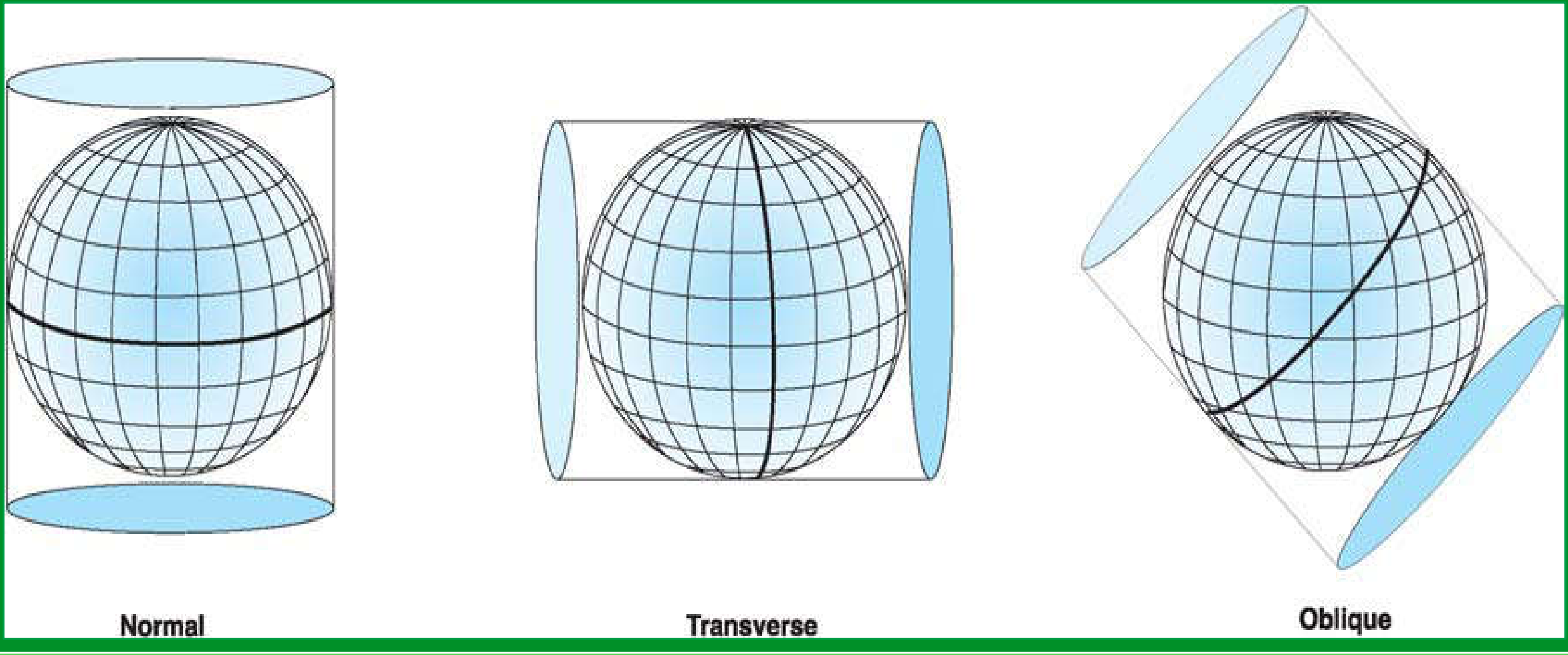


Aspects of the projection

- Once a choice is made between projecting onto a cylinder, cone, or plane, the aspect of the shape must be specified.
- The aspect describes how the developable surface is placed relative to the globe:
- It may be normal (such that the surface's axis of symmetry coincides with the Earth's axis), transverse (at right angles to the Earth's axis) or oblique (any angle in between).

Choosing a projection surface

Three aspect of projection: Normal, Transverse and Oblique



Cylinder (Transverse or equatorial)

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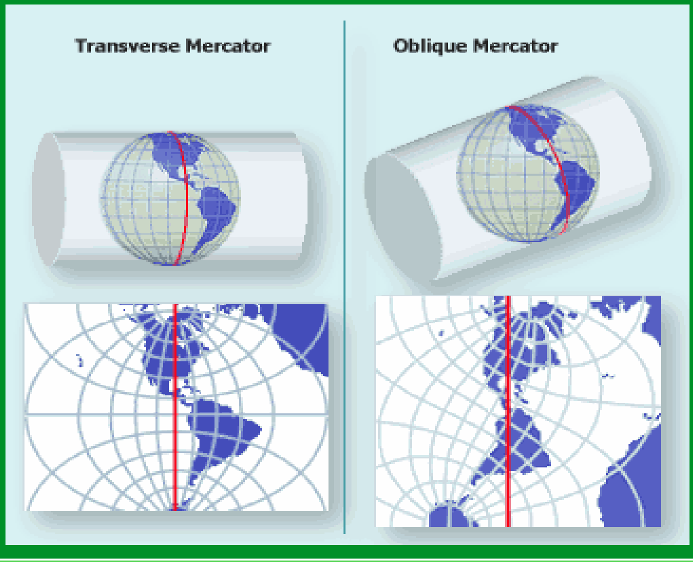

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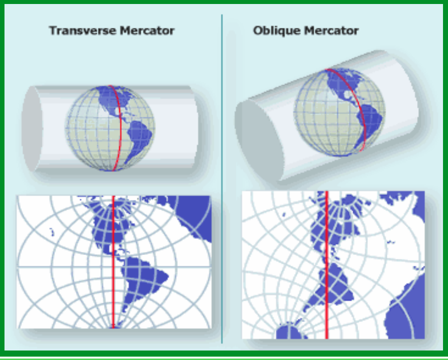
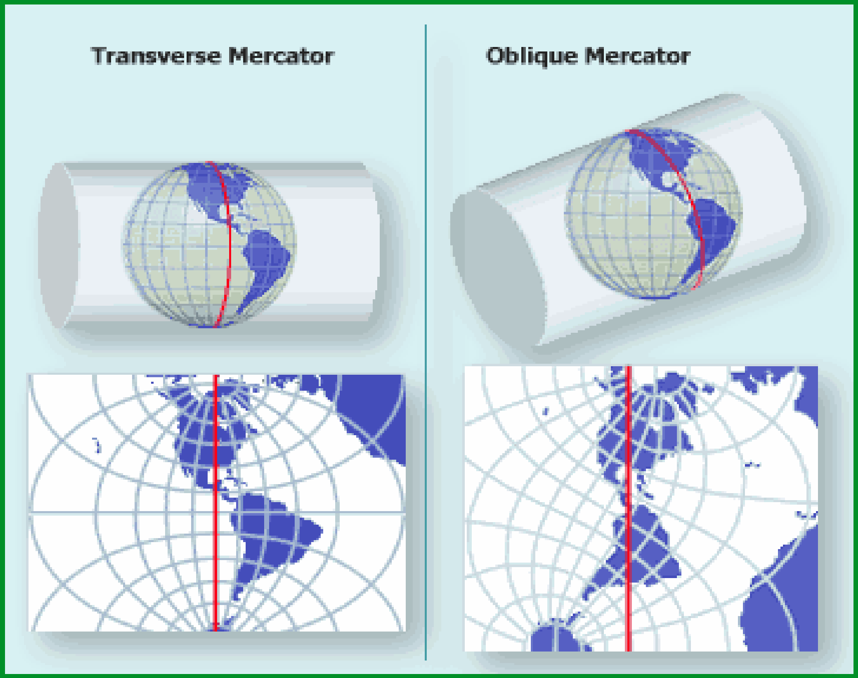


Choosing a projection surface

Cylindrical aspect – equatorial (normal), transverse, oblique



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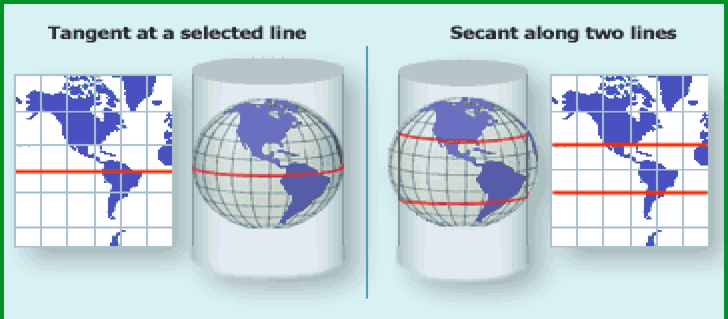
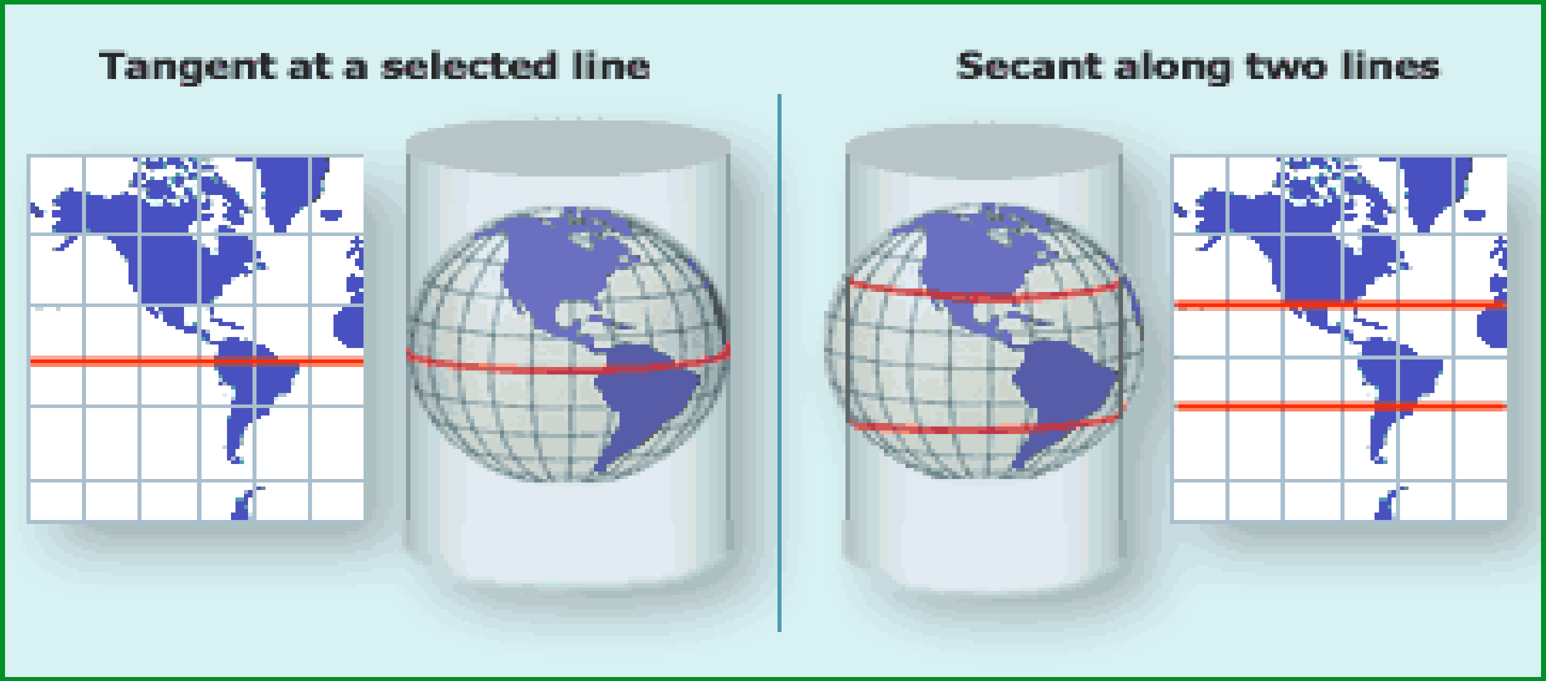


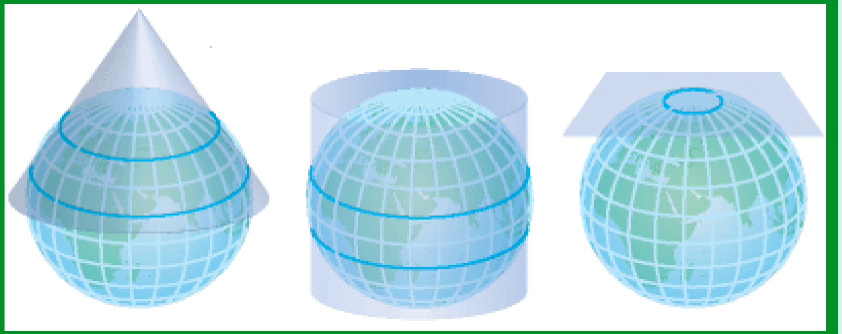
Choosing a projection surface

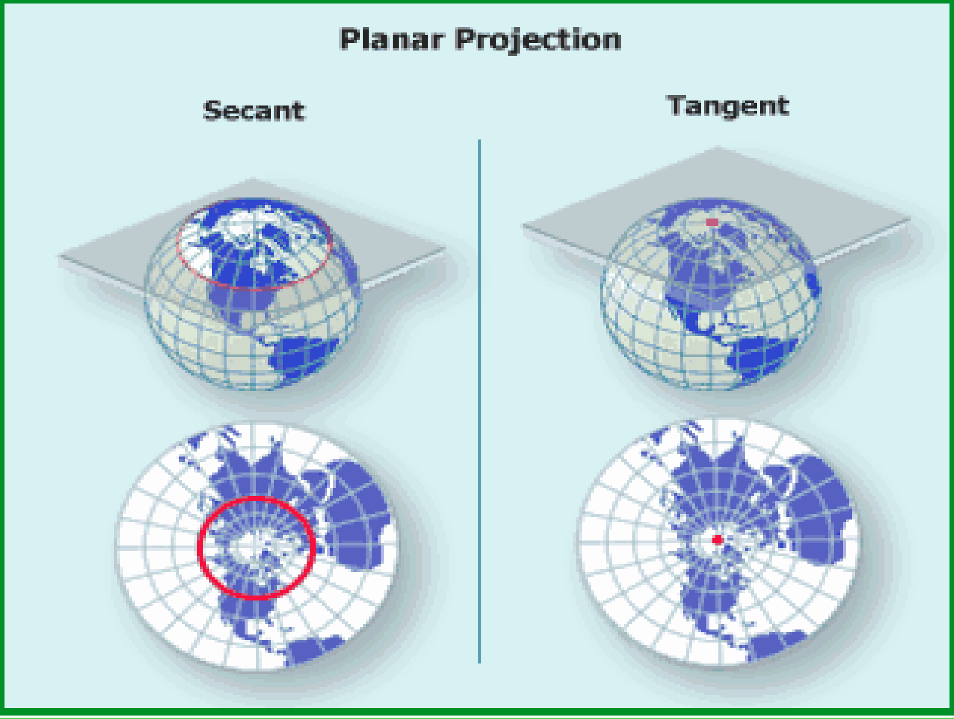
Tangent vs. secant cylindrical projection



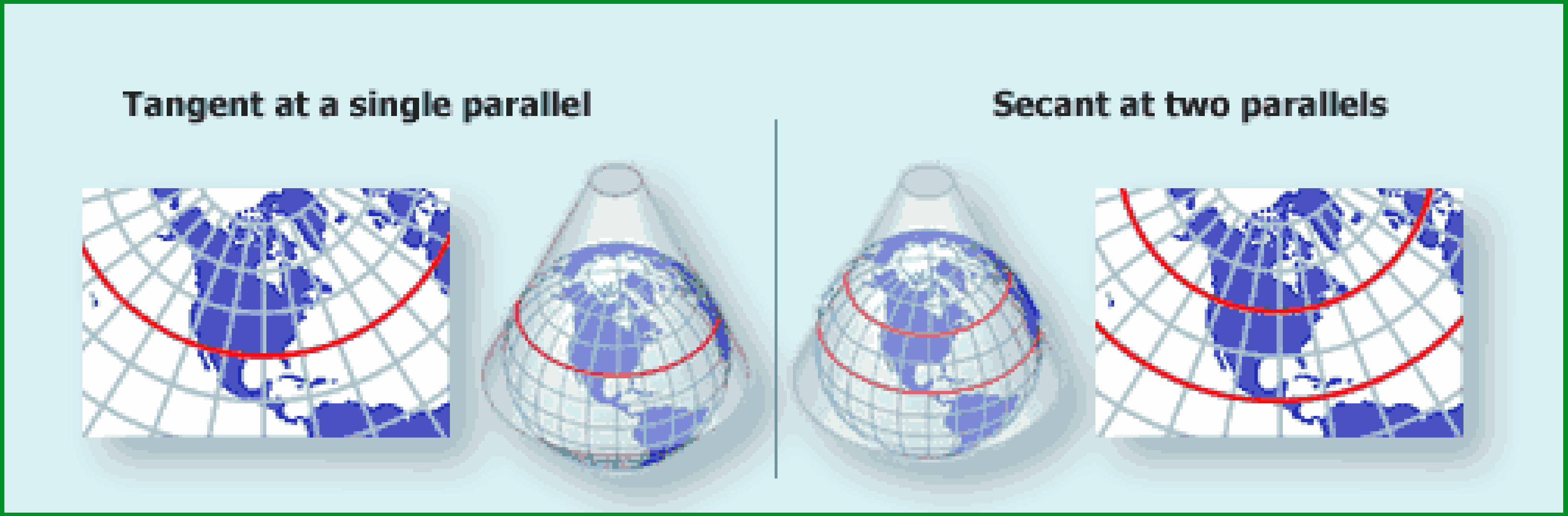
Choosing a projection surface

Tangent vs. secant planar projection





Conic



Geographic phenomena and data modeling

3.1 Introduction to geographic phenomena and data modeling

3.2 Spatial relationship and topology

3.3 Scale and resolution

3.4 Vector, raster and digital terrain model

3.5 Spatial database design with the concept of geodatabase

Geographic phenomena and data modeling

3.3 Scale and resolution

Landscape Features (Spatial Data Types)?

Spatial Data Scaling

- Scale factor
- MAP Scale and Resolution
- Precision and Accuracy

Geographic phenomena and data modeling

Map Scale and resolution:

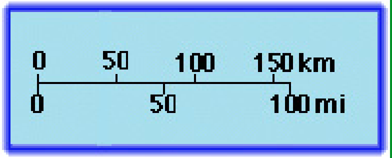
- Scale refers to the relationship or ratio between a distance on a map and the distance on the earth it represents.
- Maps should display accurate distances and locations, and should be in a convenient and usable size.
- Map scales can be expressed as

  representative fraction or ration:
- 1:100,000 or 1/100,000

Geographic phenomena and data modeling

Map Scale and resolution:

- graphical scale:



- verbal-style scale:

1 inch in map equal to 2000 feet on the ground or

1 inch = 2000 feet

Geographic phenomena and data modeling

Map Scale and rese

DMA: Saigon, Vietnam, 1968
City Map, Series L909
Scale 1:15,000

DMA: ONC G-4, 1986
Operational Navigation Chart
Scale 1:1,000,000

Large Scale *Small Scale*

Figure 7: Illustration of different map scales

Table 3: Representative distances for map scales:

Scale:	1 inch on map represents:	1 centimeter on map represents:
1:24,000	2,000 feet	240 meters
1:50,000	4,166 feet	500 meters
1:63,360	1 mile	633.6 meters
1:100,000	1.6 miles	1 kilometer
1:250,000	4 miles	2.5 kilometers
1:500,000	8 miles	5 kilometers
1:1,000,000	16 miles	10 kilometers

Geographic phenomena and data modeling

Map Scale and resolution:

A useful rule of thumb for features on paper maps

Map scale	accuracy, or resolution (corresponding to 0.5 mm map distance)
1:1,250	0.625 m
1:2,500	1.25 m
1:5,000	2.5 m
1:10,000	5 m
1:24,000	12 m
1:50,000	25 m
1:100,000	50 m
1:250,000	125 m
1:1,000,000	500 m
1:10,000,000	5 km

Geographic phenomena and data modeling

Map Scale and resolution:

- Since a paper map is always the same size, its data resolution is tied to its scale. Resolution also limits the minimum size of feature that can be stored. Generally, a line cannot be drawn much narrower than about 1/2 a millimeter. Therefore, on a 1:20,000 scale paper map, the minimum distance which can be represented (resolution) is about 10 meters. On a 1:250,000-scale paper map, the resolution is 125 meters.

Geographic phenomena and data modeling

Map Scale and resolution:

GIS is Scaleless

- In GIS, the scale can be easily enlarged and reduced to any size that is appropriate. However, if we get farther and farther from the original scale of the layer, problems appear:
    - details no appear in an enlarged map
    - too dense in a reduced map

Geographic phenomena and data modeling

Map Scale and resolution:

Scale in attention

- The scale of the original map determines the largest map scale at which the data can be used.
- Road map 1:50,000 scale can NOT be used accurately at the 1:24,000 scale.
- Water coverage at 1:250,000 scale can NOT be used accurately at the 1:50,000 scale.

Geographic phenomena and data modeling

Map Scale and resolution:

The earth on a computer screen

- Computer screen ~ 1 million pixels
- If entire earth displayed, each pixel would represent about 10 km x 10 km (100 km2)
- Entire city of Pokhara less than one pixel.
- Spatial resolution is 10 km so Anything less than 10 km across cannot be seen

Geographic phenomena and data modeling

Precision and Accuracy:

- Data are often described in terms of their precision and accuracy, two terms often confused.
- Precision relates to the degree of specificity to which a measurement is described.
- A measurement that is described with multiple decimal places, such as an area measurement of 2.6789 hectares, is considered a very precise measurement.

Geographic phenomena and data modeling

Precision and Accuracy:

- If this measurement were derived from a property boundary where distances were gathered by counting paces, and angles were measured using a handheld compass, the measurement should not be described this precisely.
- Precision can also be described in terms of the relative consistency among a set of measurements. For instance, if the measurements related to a property boundary were taken multiple times through the use of a sophisticated surveying instrument, such as a totalstation, and the resulting variation among measurements were small, one could describe the measurements as being precise.

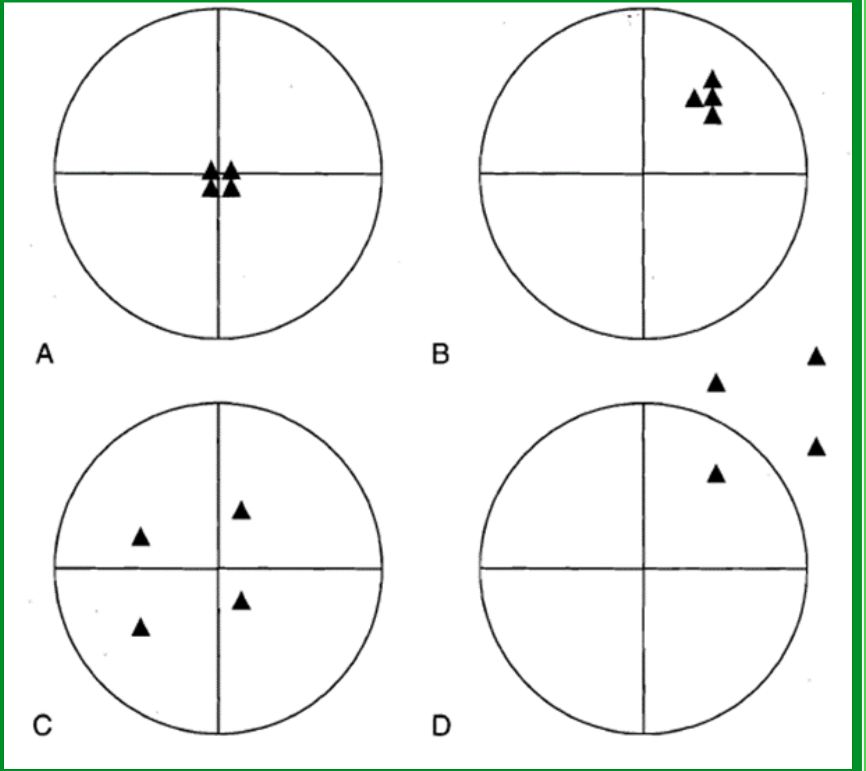
Geographic phenomena and data modeling

Precision and Accuracy:

- Accuracy is the ability of a measurement to describe a landscape feature's true location, size, or condition.
- Accuracy is typically described in terms of a range, or threshold of values, and attempts to answer the following question: how close are the measurements to their true value? Examples of accuracy levels include distance measurements of +/- 0.5 m or angle measurements of +/- 1 second.

Geographic phenomena and data modeling

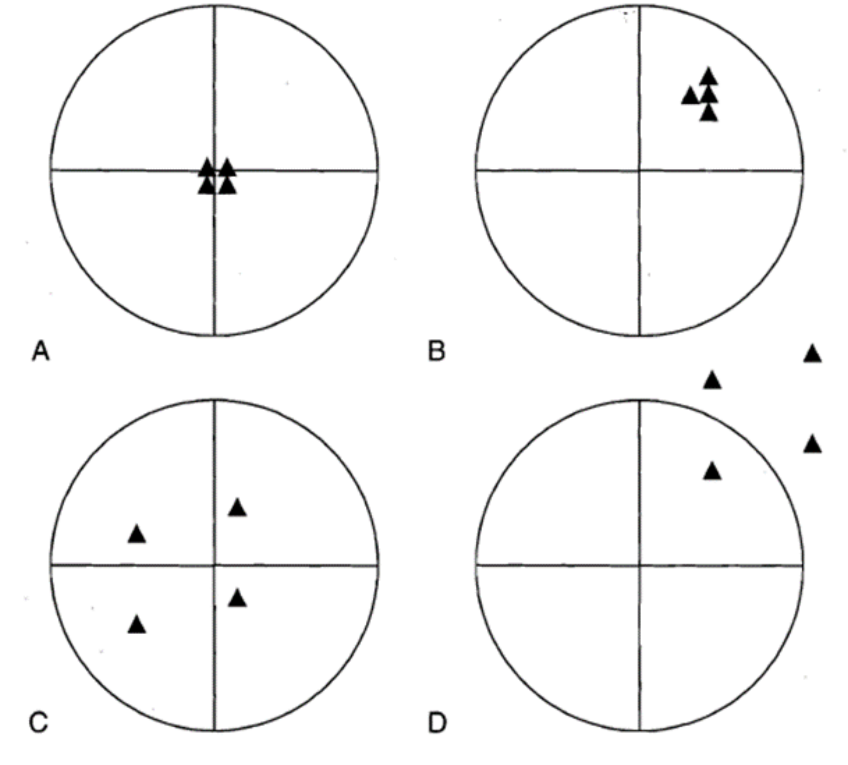
Part A shows accurate and precise locations of data around the circle center;



Geographic phenomena and data modeling

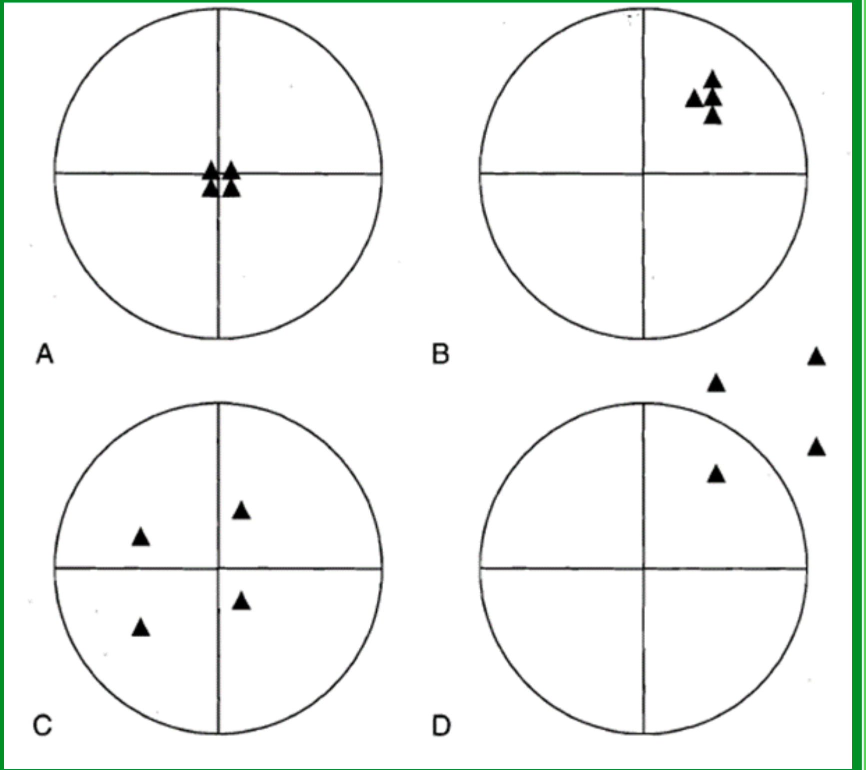
Part B shows precise

but not very accurate data;



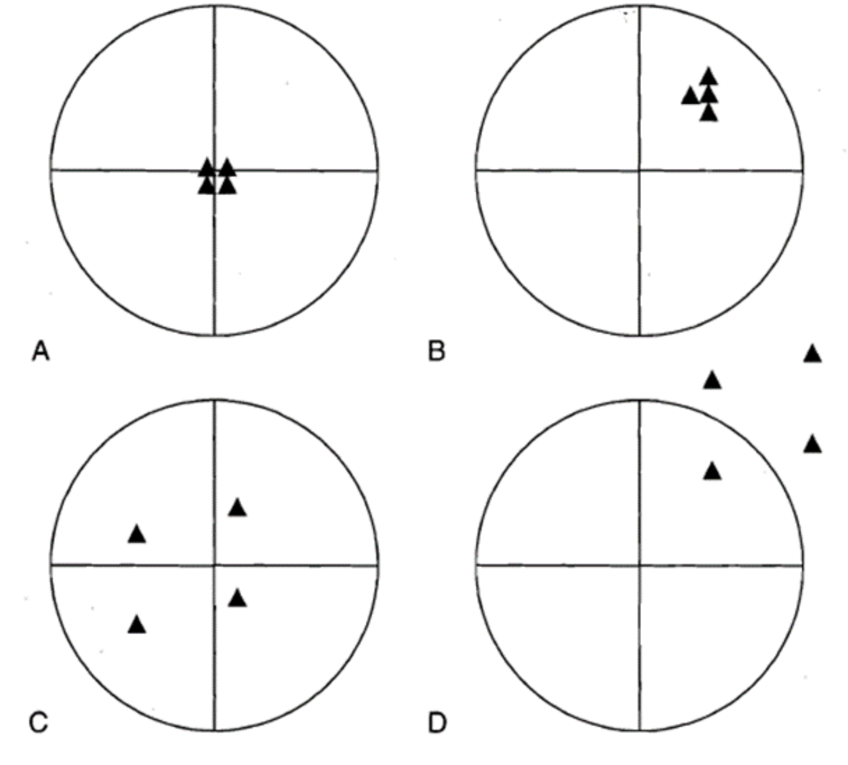
Geographic phenomena and data modeling

Part C shows accurate
but not very precise data;



Geographic phenomena and data modeling

Part D shows neither precise nor accurate data around the circle center.



Geographic phenomena and data modeling

Geometric Transformation:

- Geometric transformation is the process of converting a digital map from one coordinate system to another by using a set of control points and transformation equations.
- There are 5 types of transformations.

Geographic phenomena and data modeling

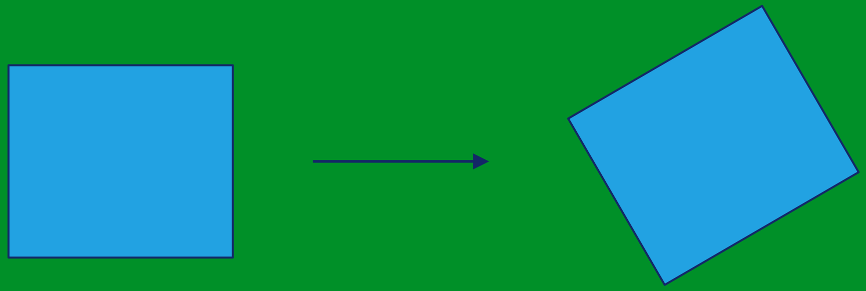
Control Points:

- Links that define common points in each coordinate system.
- The corners of a map are very often used
- Control points should be distributed over the area of interest.

Geographic phenomena and data modeling

Equiarea Transformation:

- The method allows rotation of the rectangle and preserves its shape and size.



Geographic phenomena and data modeling

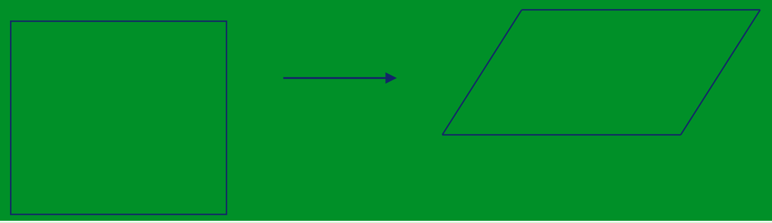
Similarity Transformation:

- The method allows rotation of the rectangle and preserves its shape but not size.

Geographic phenomena and data modeling

Affine Transformation:

- The method allows angular distortion but preserves the parallelism of lines.
- While preserving line parallelism, the affine transformation allows rotation, translation, skew, and differential scaling on the rectangular object.



Geographic phenomena and data modeling

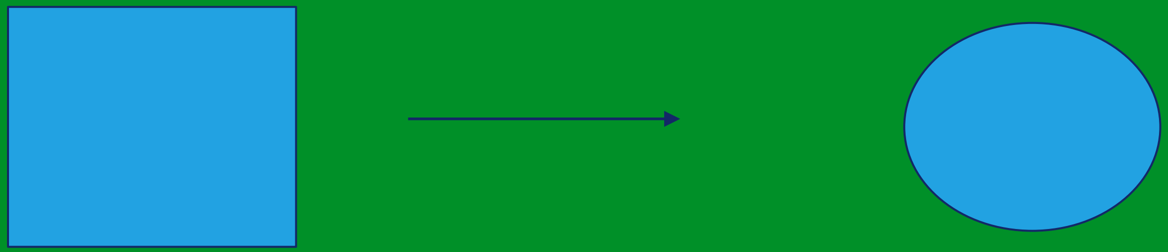
Projective Transformation:

- The method allows angular and length distortion, thus allowing the rectangle to be transformed into an irregular quadrilateral.

Geographic phenomena and data modeling

Topological Transformation:

- The method preserves the topological properties of an object but not shape, thus allowing the rectangle to be transformed into a circle.



Scale (Scale factor & principal (nominal) scale)

Measuring map scale distortion – scale factor & principal (nominal) scale:

- A reference surface of the Earth is a scaled down model of the Earth.

- This scale can be measured as the ratio of distance on the reference surface (Cylinder, Cone, Plane) to the corresponding distance on the Earth.

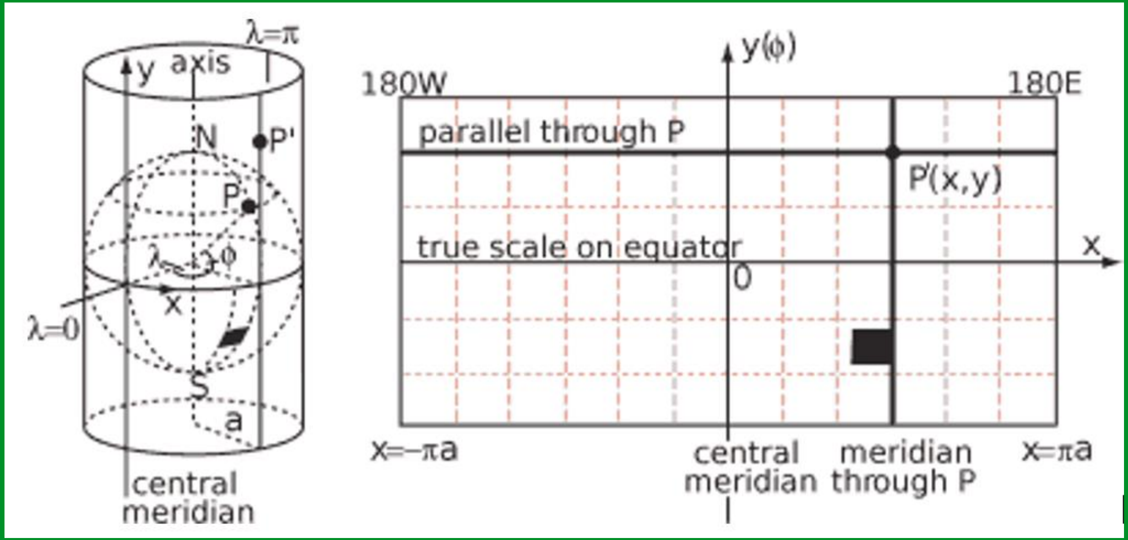
Scale (Scale factor & principal (nominal) scale)

Measuring map scale distortion – scale factor & principal (nominal) scale:

- For example, a 1:250000 representative fraction scale indicates that 1 unit (e.g. km) on the reference surface represents 250000 units on Earth.
- The principal scale or nominal scale of a flat map (the stated map scale) refers to this scale of its generating reference surface .

Scale (Scale factor & principal (nominal) scale)

Map scale distortion of a tangent cylindrical projection: SF = 1 along line of tangency

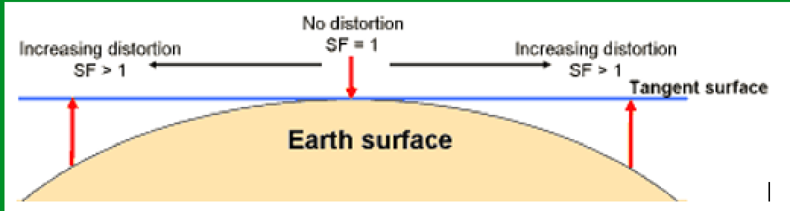


Scale (Scale factor & principal (nominal) scale)

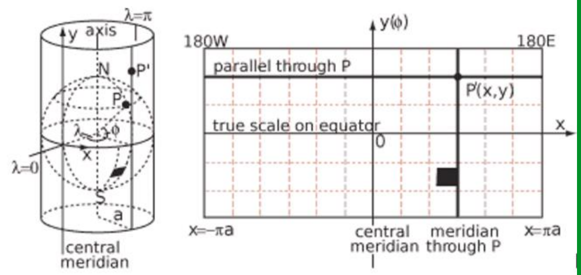
Scale distortion on a tangent surface to the globe

There is no distortion along standard lines as evident in following figures.

On a tangent surface to the reference globe, there is no scale distortion at the point (or along the line) of tangency and therefore scale factor is 1.



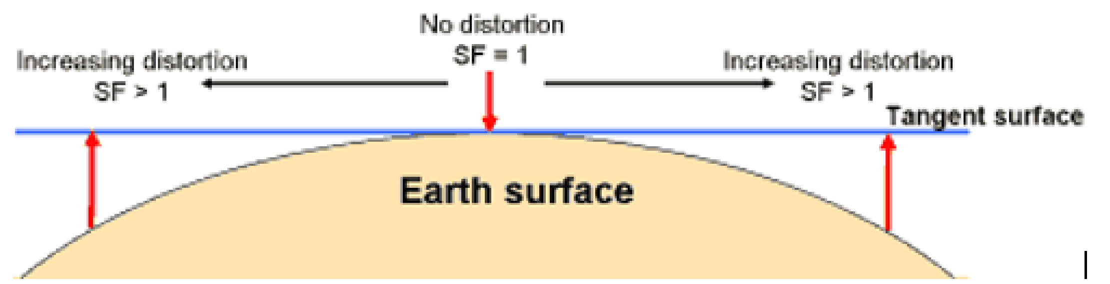
Scale distortion on a tangent surface to the globe



Scale (Scale factor & principal (nominal) scale)

Scale distortion on a tangent surface to the globe

- Distortion increases with distance from the point (or line) of tangency.



Scale distortion on a tangent surface to the globe

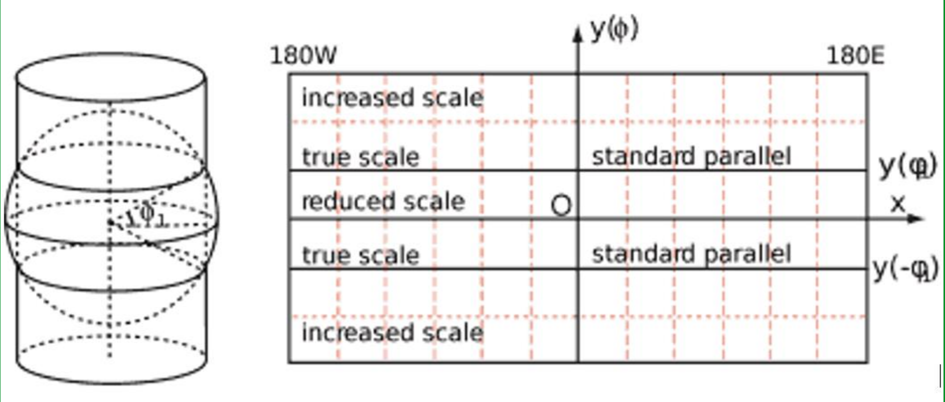
Scale (Scale factor & principal (nominal) scale)

- On a secant surface to the reference globe, there is no distortion along the standard lines (lines of intersection) where SF = 1.

- Between the secant lines where the surface is inside the globe, features appear smaller than in reality and scale factor is less than 1.

Scale (Scale factor & principal (nominal) scale)

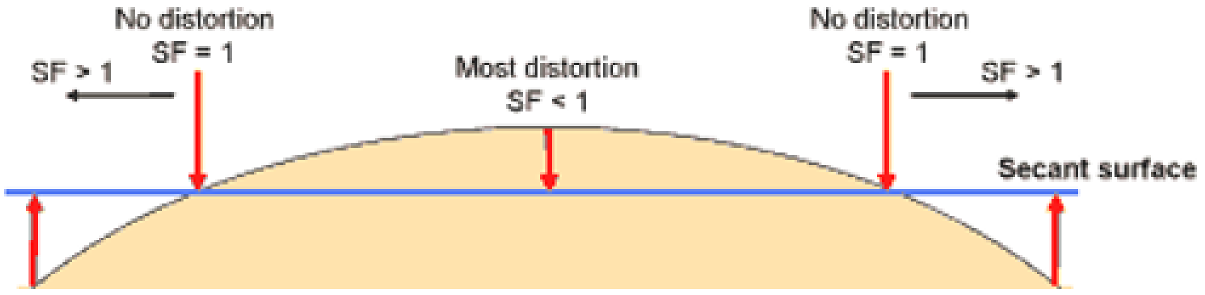
- At places on map where the surface is outside the globe, features appear larger than in reality and scale factor is greater than 1.
- A map derived from a secant projection surface has less overall distortion than a map from a tangent surface.



Map scale distortion of a secant cylindrical projection - SF = 1 along secant lines

Scale (Scale factor & principal (nominal) scale)

- At places on map where the surface is outside the globe, features appear larger than in reality and scale factor is greater than 1.
- A map derived from a secant projection surface has less overall distortion than a map from a tangent surface.



Scale distortion on a secant surface to the globe

Scale (Scale factor & principal (nominal) scale)

- The projection of the curved surface on the plane and the resulting distortions from the deformation of the surface will result in variation of scale throughout a flat map.
- In other words the actual map scale is different for different locations on the map plane and it is impossible to have a constant scale throughout the map.
- Measure of scale distortion on map plane can also be quantified by the use of scale factor.

Scale (Scale factor & principal (nominal) scale)

- Scale factor is the ratio of actual scale at a location on map to the principal (nominal) map scale (SF = actual scale / nominal scale).
- Alternatively stated as ratio of distance on the map to the corresponding distance on the reference globe.
- A scale factor of 1 indicates actual scale is equal to nominal scale, or no scale distortion at that point on the map.
- Scale factors of less than or greater than one are indicative of scale distortion. The actual scale at a point on map can be obtained by multiplying the nominal map scale by the scale factor.

Scale (Scale factor & principal (nominal) scale)

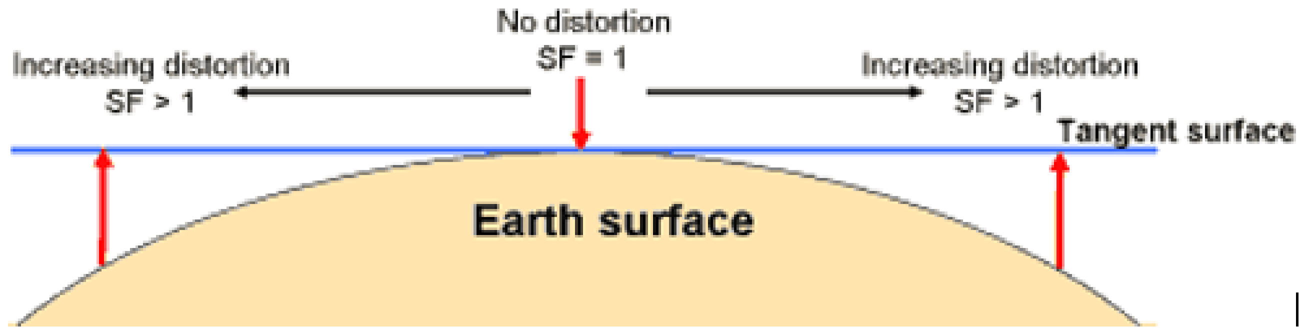
- Scale factors of less than or greater than one are indicative of scale distortion. The actual scale at a point on map can be obtained by multiplying the nominal map scale by the scale factor.
- As an example, the actual scale at a given point on map with scale factor of 0.99860 at the point and nominal map scale of 1:50000 is equal to (1:50000 x 0.99860) = (1: 50000/0.99860) = 1:50070 (which is a smaller scale than the nominal map scale).

Scale (Scale factor & principal (nominal) scale)

- Scale factor of 2 indicates that the actual map scale is twice the nominal scale; if the nominal scale is 1:4million, then the map scale at the point would be (1:4million x 2) = 1:2million.
- A scale factor of 0.99950 at a given location on the map indicates that 999.5 meters on the map represents 1000 meters on the reference globe/earth.

Scale (Measuring map scale distortion)

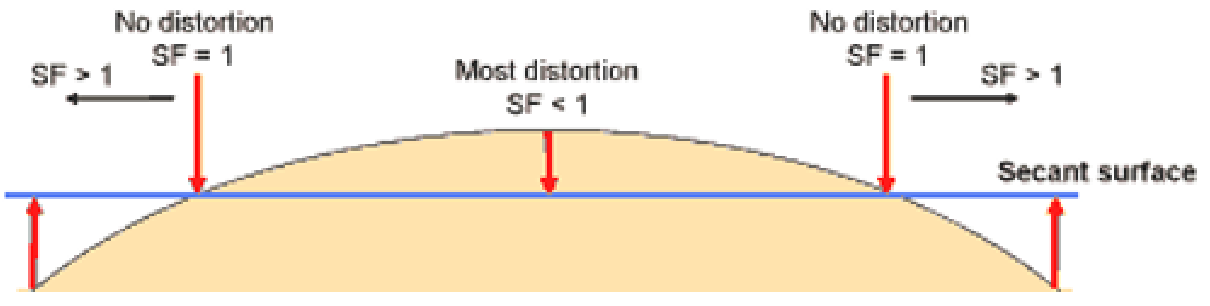
On a tangent surface to the reference globe, there is no scale distortion at the point (or along the line) of tangency and therefore scale factor is 1. Distortion increases with distance from the point (or line) of tangency.



Scale distortion on a tangent surface to the globe

Scale (Measuring map scale distortion)

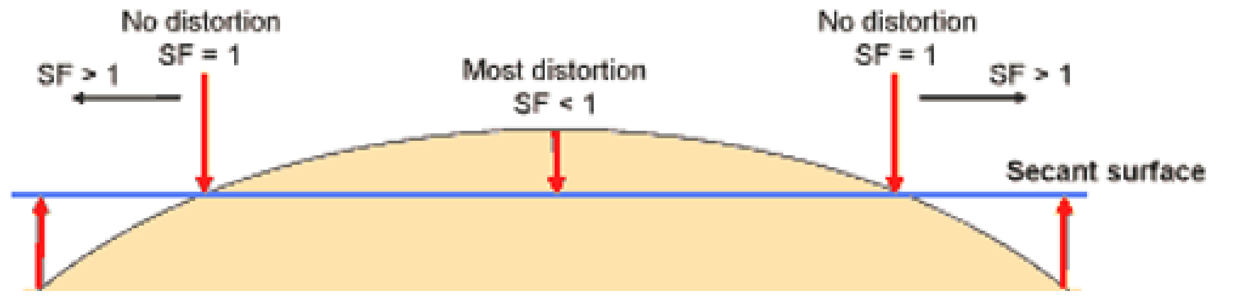
- On a secant surface to the reference globe, there is no distortion along the standard lines (lines of intersection) where SF = 1. Between the secant lines where the surface is inside the globe, features appear smaller than in reality and scale factor is less than 1.



Scale distortion on a secant surface to the globe

Scale (Measuring map scale distortion)

- At places on map where the surface is outside the globe, features appear larger than in reality and scale factor is greater than 1.
- A map derived from a secant projection surface has less overall distortion than a map from a tangent surface.



Scale distortion on a secant surface to the globe

Landscape Features (Spatial Data Types)?

Database

Database

Spatial Database / Geo-database

Basic level object types:

1. Point
2. Line
3. Polygon

Higher Level Objects types:

4. Triangular Irregular Networks (TINs)
5. Network
6. Region

Spatial Relationship and Topology

GIS:

- With GIS, users can create, maintain, and analyse geographic or spatial data.
- Spatial data not only describes the landscape features (eg. road, structure of forest, settlement) but also reference the location of that features in the earth.
- The point, line, and polygon vector data structure provides a method for representing irregularly shaped Earth features.

Spatial Relationship and Topology

GIS:

- GIS stores spatial data in computer as a digital database files and often referred to as GIS databases.
- Software like Database management, graphics and CAD also performs GIS like tasks but does not describe with reference to earth location.

Spatial Relationship and Topology

Topology:

- Spatial Database maintain, store and analyse also some extra earth features like Point, Line and Polygon .
- Topology is the arrangement for how point, line, and polygon features share geometry.
- Topology describes the spatial relationships between geographic elements eg points, lines, and polygons.
- It is a very important consideration when conducting spatial query and analyses.

GIS Database Structure/ Database Model

Topology:

- Topology allows one to determine such things as the distance between points, whether lines intersect, or whether a point (or a line) is located within the boundary of a polygon.

GIS Database Structure/ Database Model

Topology:

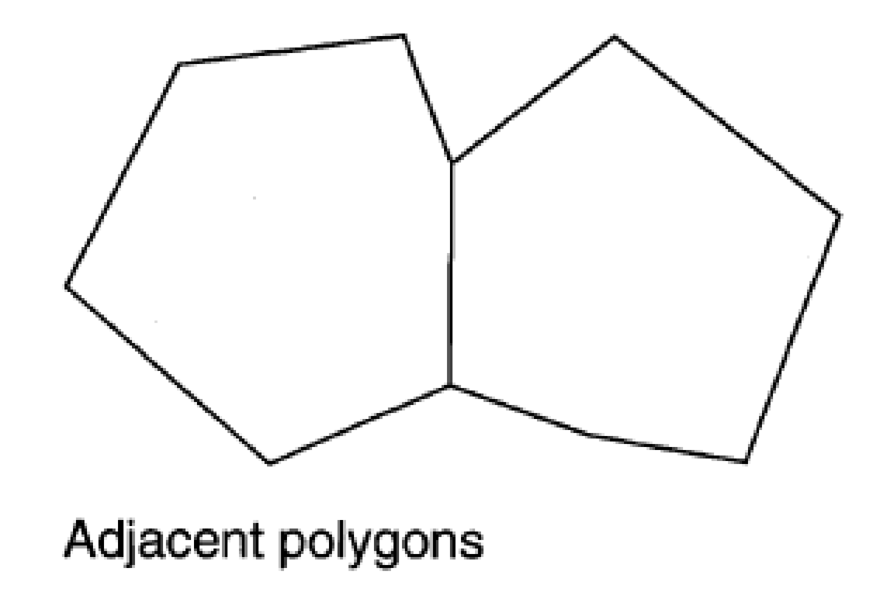
- Topology can be defined in a number of ways, but the most common definitions involve aspects of adjacency, connectivity, and containment.

- Adjacency is used to describe a landscape feature's neighbors.

- Adjacency relationships use to describe polygons that share borders or to identify the lines that make up a polygon (area).

GIS Database Structure/ Database Model

Topology: (Adjacency)



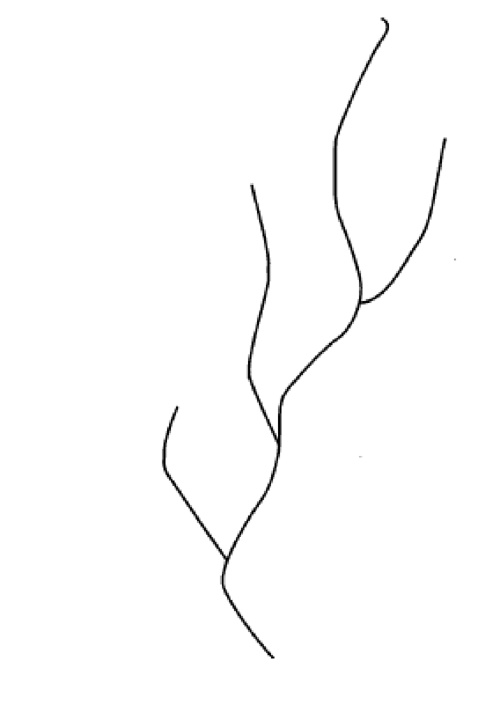
GIS Database Structure/ Database Model

Topology:

- Connectivity is typically used to describe linear networks, such as a network of culverts that might be connected by drainage ditches.
- Connectivity would allow one to trace the flow of water through a stream system. One can also incorporate direction into a description of connectivity.

GIS Database Structure/ Database Model

Topology: (Connectivity)



Connected stream network

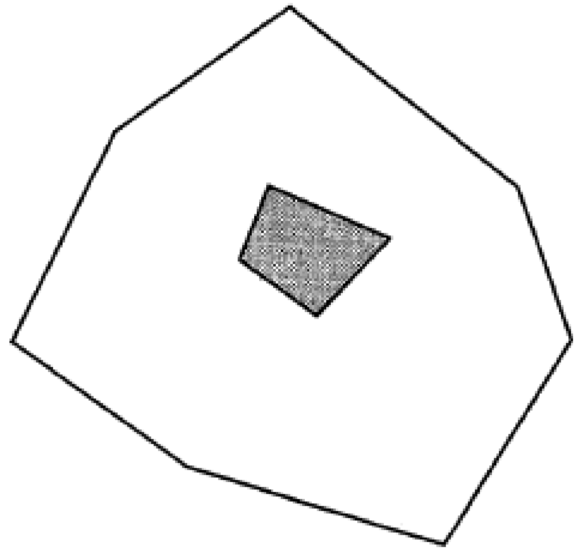
GIS Database Structure/ Database Model

Topology:

- Containment allows one to describe which landscape features are located within, or intersect, the boundary of polygons.
- Containment information can use to describe the well locations (points) or the power lines (lines) that are located within a proposed urban growth boundary.

GIS Database Structure/ Database Model

Topology: (Containment)



One polygon contained inside
another polygon

GIS Database Structure/ Database Model

Topology:

- A system for coding topology that can be understood and manipulated by a computer must also exist.
- With GIS databases containing point features, there is little need for anything more than a file of coordinate pairs (X, Y coordinates), since all points are ideally separated from one another and, thus, there are no issues of adjacency, connectivity, and containment to resolve.

GIS Database Structure/ Database Model

Topology:

- However, more detail is needed in describing feature locations and linkages when using GIS databases containing line and polygon features.
- The spatial integrity of lines and polygons is maintained by managing the nodes, vertices, and links of each feature.

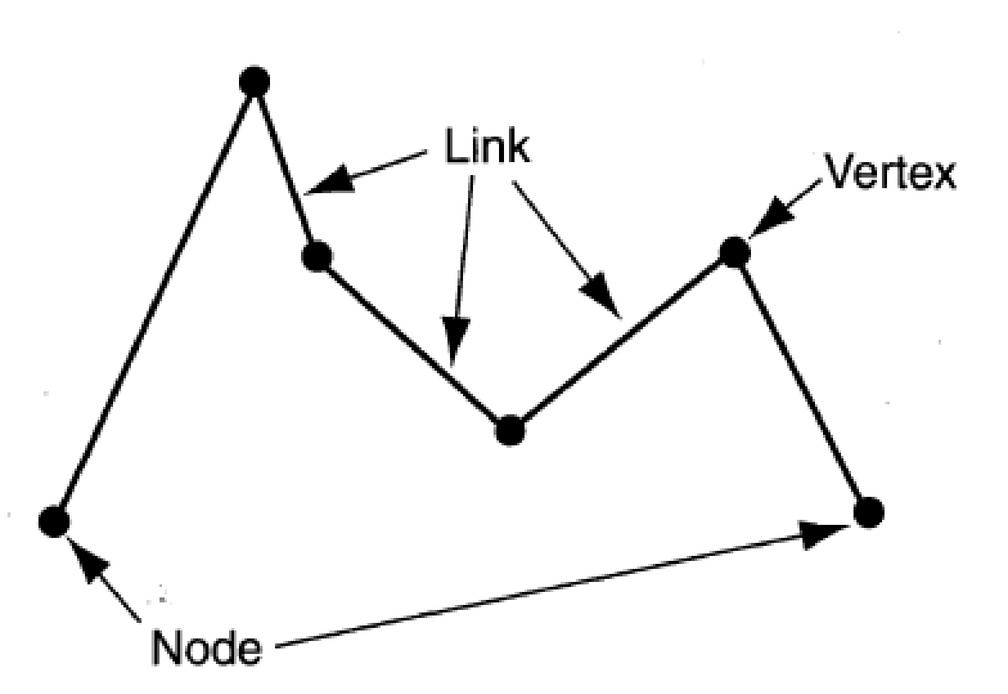
GIS Database Structure/ Database Model

Topology:

- A node is the starting and ending point of a line, and may represent the intersection of two or more lines.
- A vertex is any point that is not a node but specifies a location or creates a directional change in a line.
- A link, sometimes called an arc, is a line that connects points as defined by nodes and vertices.
- Nodes, Vertices, and Links are usually numbered and maintained in a GIS database file to maintain topology.

GIS Database Structure/ Database Model

Examples of nodes, links, and vertices



GIS Database Structure/ Database Model

Topology:

- In a network of lines and polygons, this would involve using numeric codes for network pieces (nodes and links) to identify the node locations, the nodes that are attached to each link, and the polygons that may form on either side of each link.

GIS Database Structure/ Database Model

Topology:

- Topology also allows one to inspect the spatial integrity-containment of lines and polygons.
- For instance, one can use topological information to determine whether any breaks or gaps occur in lines that are meant to represent streams.

GIS Database Structure/ Database Model

Topology:

- From a polygon perspective, topology would allow one to determine whether a polygon forms a closed boundary or whether an extraneous polygon exists inside, or along the outside border, of another polygon.

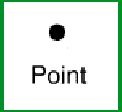
GIS Database Structure/ Database Model

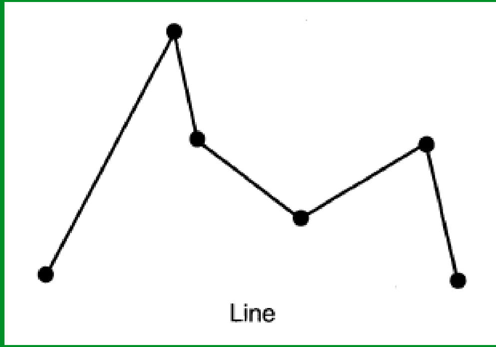
Topology:

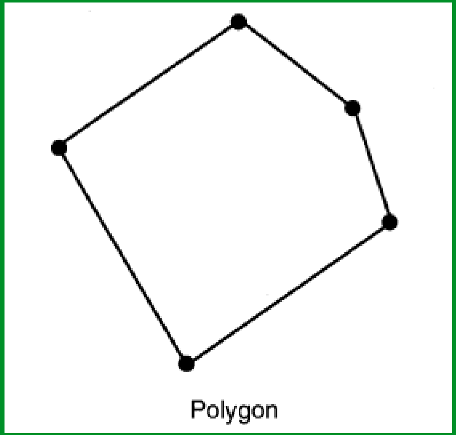
- The point, line, and polygon vector data structure provides a method for representing irregularly shaped Earth features.

GIS Database Structure/ Database Model

Point, line, and polygon vector shapes.

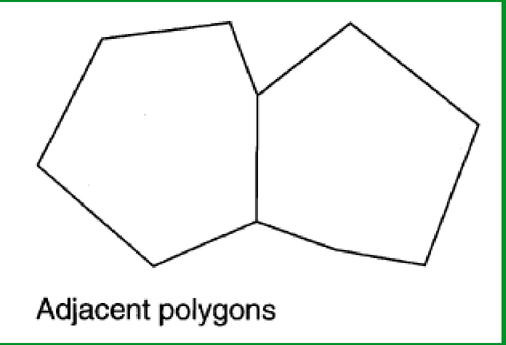


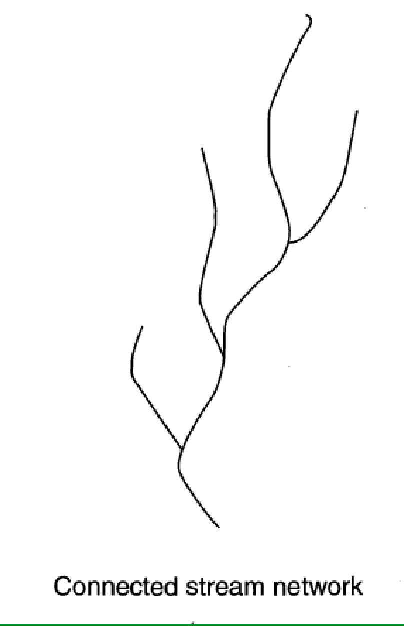


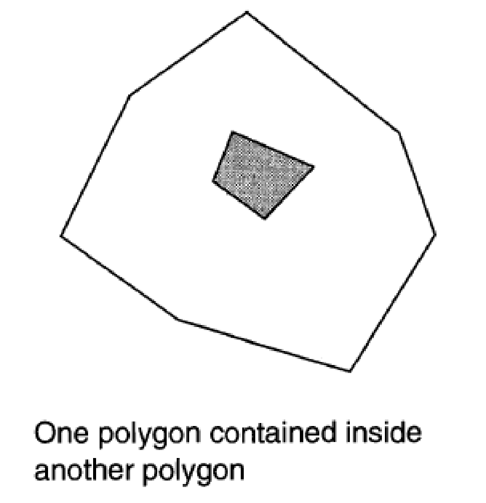


GIS Database Structure/ Database Model

Adjacent polygons, Connected stream network, One polygon contained inside another polygon

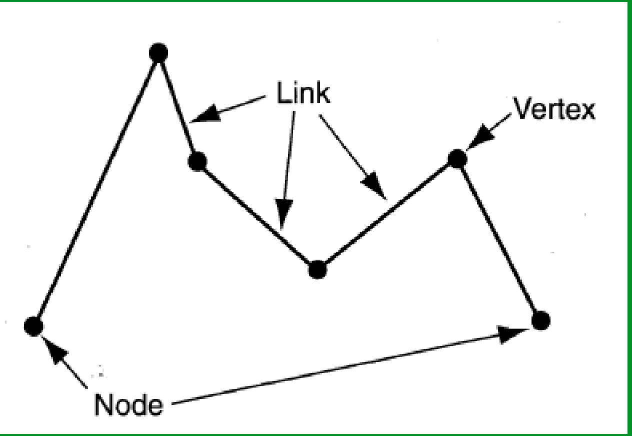






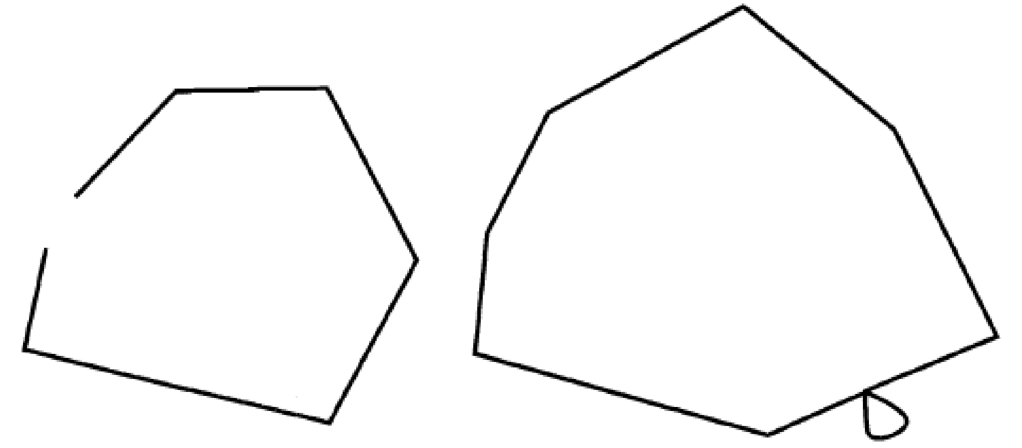
GIS Database Structure/ Database Model

Examples of nodes, links, and vertices



GIS Database Structure/ Database Model

Examples of topological errors

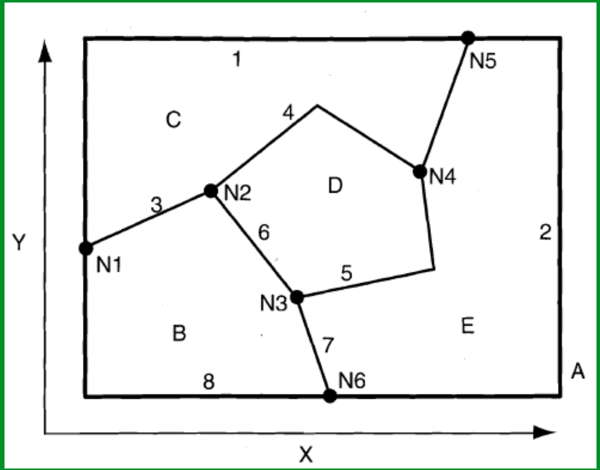


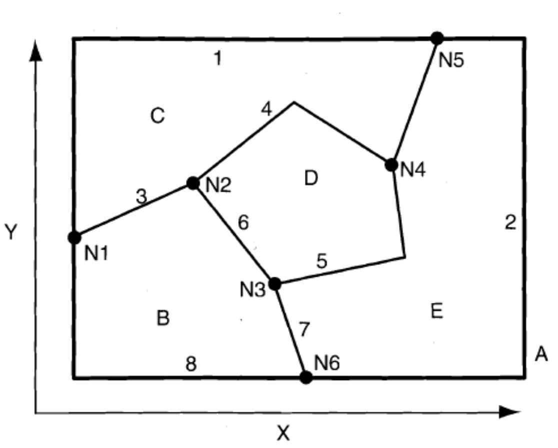
a. An unclosed polygon b. An extraneous polygon

GIS Database Structure/ Database Model

Vector topological data:

network of nodes links, and polygons (a); node coordinate file (b); and topological relationship file (c).

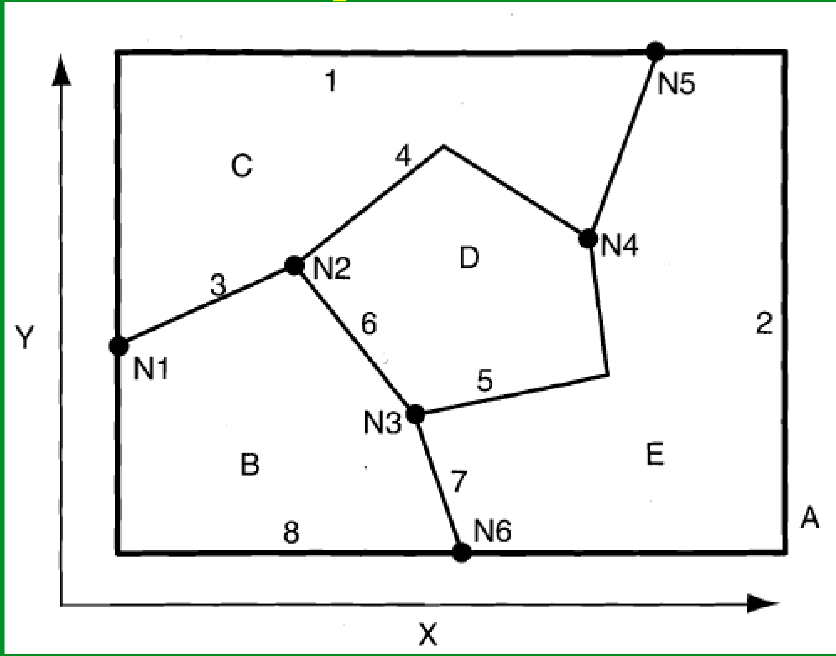




a. Network of nodes, links, and polygons
(polygon A is outside the rectangle)

GIS Database Structure/ Database Model

Node Representation file:

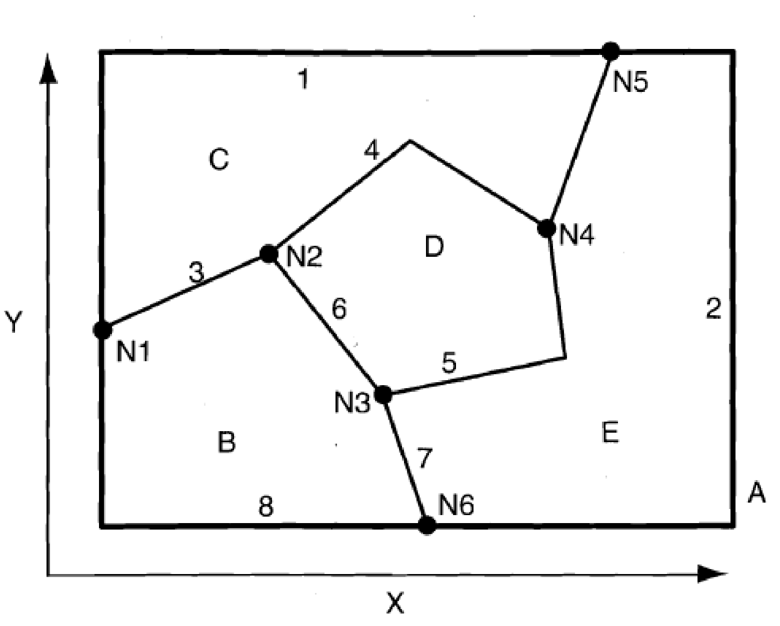


Node	X	Y
N1	0.5	2.4
N2	2.1	3.1
N3	3.2	1.7
N4	4.7	3.3
N5	5.4	5.0
N6	3.6	0.5

b. Node coordinate file

GIS Database Structure/ Database Model

Topological relationship file:



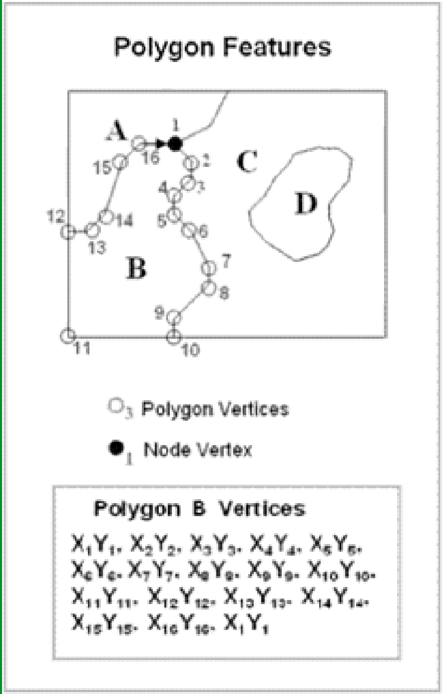
a. Network of nodes, links, and polygons
(polygon A is outside the rectangle)

Link	Begin node	End node	Left polygon	Right polygon
1	N1	N5	A	C
2	N5	N6	A	E
3	N1	N2	C	B
4	N2	N4	C	D
5	N4	N3	E	D
6	N3	N2	B	D
7	N3	N6	E	B
8	N1	N6	B	A

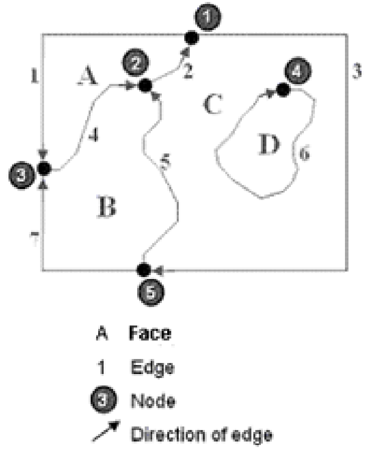
c. Topological relationship file

GIS Database Structure/ Database Model

Topological relationship file:



Topological Elements and Relationships



Face	Edges	Nodes
A	1, 2, 4	1, 2, 3
B	4, 5, 7	2, 5, 3
C	2, 3, 5, 0, 6	1, 5, 2, 0, 4
D	6	4

Edge	Left Face	Right Face	From-Node	To-Node
1	A	---	1	3
2	A	C	2	1
3	---	C	1	5
4	A	B	3	2
5	B	C	5	2
6	C	D	4	4
7	---	B	5	3

GIS Database Structure/ Database Model

Spatial Data Types:

Systems of spatial data types, or spatial algebras, can capture the fundamental abstractions for point, line and region described above together with relationships between them and operations for composition (e.g. forming the intersection of regions). We have stated in Section 1 that they are a mandatory part of the data model for a spatial DBMS, so that indeed, all proposals for models and query languages as well as prototype systems (see Section 5) offer them in some form.

GIS Database Structure/ Database Model

Spatial Data Model:

Data Model - An abstraction of the real world which incorporates only those properties thought to be relevant to the application at hand, define specific groups of entities, and their attributes and the relationships between these entities.

GIS Database Structure/ Database Model

Spatial Data Model:

- A data model is independent of a computer system. Any time you wish to deal with geographic data, you must choose a geographic data model by which to do it.

- The choice of data model will yield benefits in terms of simplifying real-world features enough to deal with them easily, but will also incur costs in terms of oversimplifying or misrepresenting different aspects.

GIS Database Structure/ Database Model

Spatial Data Model:

- Data Model: An abstraction of the real world which incorporates only those properties thought to be relevant to the application at hand, define specific groups of entities, and their attributes and the relationships between these entities.
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GIS Database Structure/ Database Model

Spatial Data Model:

- Any time you wish to deal with geographic data, you must choose a geographic data model by which to do it.
- The choice of data model will yield benefits in terms of simplifying real-world features enough to deal with them easily, but will also incur costs in terms of oversimplifying or misrepresenting different aspects.

GIS Database Structure/ Database Model

Spatial Data Model:

- Most of the confusion about data models arises from their diversity. Some data models are more abstract/theoretical while others are made with specific database types in mind.
- For example, the vector data model and the raster data model are very general, whereas the geo-relational data model and geodatabase data model are made to fit specific categories of database software.

GIS Database Structure/ Database Model

Spatial Data Model:

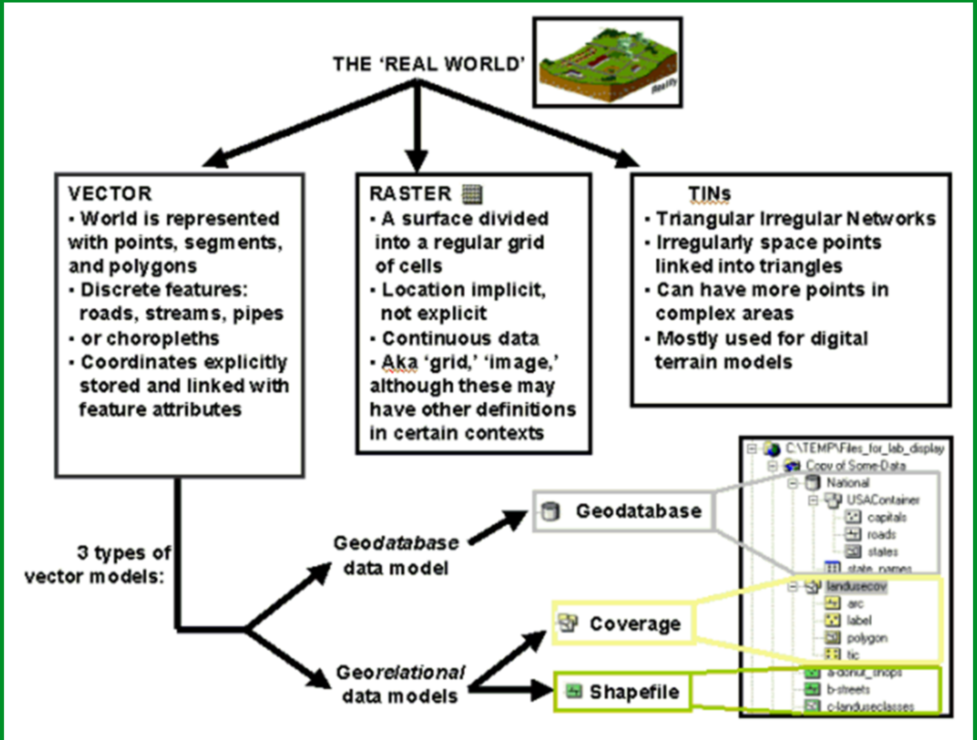
- Furthermore, a given data model may belong to more than one category: a coverage is both a vector data model (general) and a georelational data model.

GIS Database Structure/ Database Model

Spatial Data Model:

The many types of data models are easier to think about if one pictures of them as being part of a general hierarchy. Below is a figure showing the hierarchy of ArcGIS's data models:

GIS Database Structure/ GIS Database Model



GIS Database Structure/ Database Model

Spatial Data Model:

The data models go from most general at the top level (vector, raster, TIN) to most specific at the bottom level (shapefile, coverage, geodatabase). It is important to note that a geodatabase can handle all three general models, not just the vector model. Geographic data models have evolved under the influences of technology (e.g., increasing storage space and processing power, networking, or software evolution) and even history (e.g., ESRI introduced the "coverage" data model in 1980).

GIS Database Structure/ Database Model

Spatial Data Model:

Every GIS software package will be capable of supporting a number of data models, but will also have it's own proprietary format (that none of the others will read). The capabilities of the data models may change with new versions of the software, and compatibility issues may arise between different GIS software, and even between different versions of the same software. Certain functions will be accessible using data in the form of one data model but not another.

GIS Database Structure/ Database Model

Data Structures vs. Data Models:

- The specific format with which the data are stored on the computer is known as the data structure.
- To illustrate, consider a basic vector data model. The vector model represents features as consisting of lines which individually link together a start node, vertices in between, and an end node.

GIS Database Structure/ Database Model

Data Structures vs. Data Models:

- To draw and analyze features represented this way, the computer needs information on the locations of each node and vertex of the lines.
- This could be provided in the form of a table listing the coordinates of these points, and indicating which line(s) go through them.
- This table would be the basic data structure. Coverages and shapefiles use this type of structure.

GIS Database Structure/ Database Model

Data Structures vs. Data Models:

In Figure 1 above, the lower left box titled "DATABASE (relational tables)" represents the data structure. In it you can see numbered rows and columns with labels, this is the 'structure' of the data. Some columns have only numbers, some have only text and some have both.

GIS Database Structure/ Database Model

Data Structures vs. Data Models:

Several different types of data structures can potentially be used to represent the same data model.
For example, you could represent a vector data model using coverages, shapefiles, or geodatabases. Although these all take the same basic approach in representing the model, there are still significant differences between them; 1) data models do not necessarily imply any particular data structures; and 2) data structures can represent the same data model while still being very different from one another.

GIS Database Structure/ Database Model

Spatial Relationships:

- Among the operations offered by spatial algebras, spatial relationships are the most important ones.
- For example, they make it possible to ask for all objects in a given relationship with a query object, e.g. all objects within a window.

GIS Database Structure/ Database Model

Spatial Relationships:

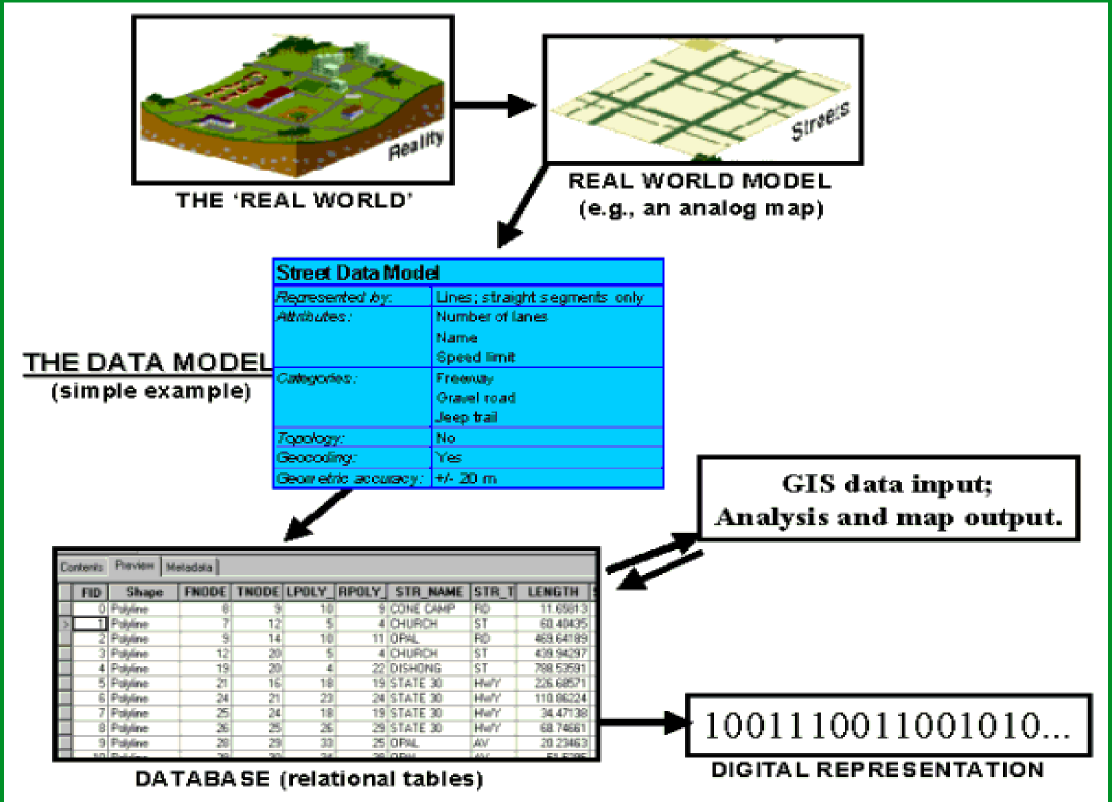
- **Topological relationships:** such as adjacent, inside, disjoint, are invariant under topological transformations like translation, scaling, and rotation.
- **Direction relationships:** for example, above, below, or north_of, southwest_of, etc.
- **Metric relationships**: e.g. "distance < 100".

GIS Database Structure/ Database Model

Integrating Geometry into the DBMS Data Model:

The central idea for integrating geometric modeling into a DBMS data model is to represent “spatial objects” (in the sense of application objects such as river, country, city, etc.) by objects (in the sense of the DBMS data model) with at least one attribute of a spatial data type. Hence the DBMS data model must be extended by SDTs at the level of atomic data types (such as integer, string, etc.), or better be generally open for user-defined types.

GIS Database Structure/ GIS Database Model



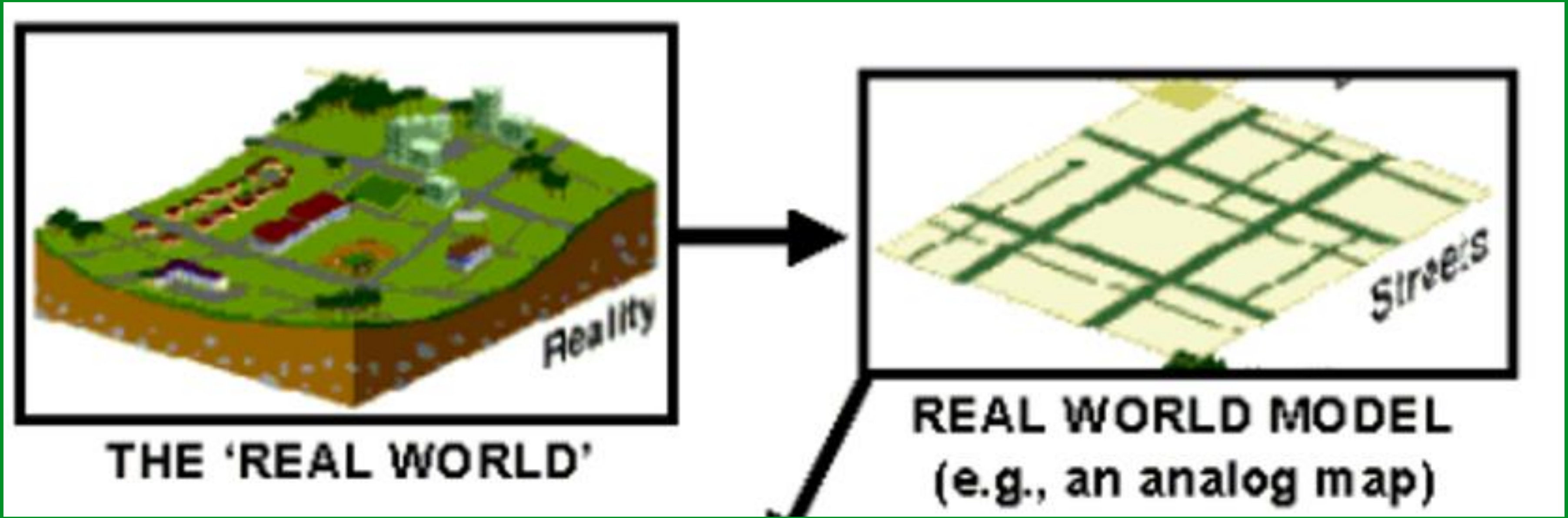
GIS Database Structure/ Database Model

Spatial Data Model:

- An abstraction of the real world which incorporates only those properties thought to be relevant to the application at hand, define specific groups of entities, and their attributes and the relationships between these entities.
- A data model is independent of a computer system.

GIS Database Structure/ Database Model

Spatial Data Model:



GIS Database Structure/ Database Model

Spatial Data Model:

- The choice of data model will yield benefits in terms of simplifying real-world features enough to deal with them easily.
- Data modelling incur costs in terms of oversimplifying or misrepresenting different aspects.

GIS Database Structure/ Database Model

So what needs to be represented?

There are two important alternative views of what needs to be represented:

Objects in space: We are interested in distinct entities arranged in space each of which has its own geometric description.

Space: We wish to describe space itself, that is, say something about every point in space.

GIS Database Structure/ Database Model

So what needs to be represented?

- The first view allows one to model, for example, cities, forests, or rivers.

- The second view is the one of thematic maps describing e.g. land use or the partition of a country into districts.

GIS Database Structure/ Database Model

How the entities(Landscape features) in space/earth to be represented ?

Landscape Features (Spatial Data Types)?

**Spatial Data Structure/
Real World Spatial Features**

Raster data

Vector Data

Basic level object types:

1. Point
2. Line
3. Polygon

Higher Level Objects types:

4. Triangular Irregular Networks (TINs)
5. Network
6. Region

GIS Database Structure

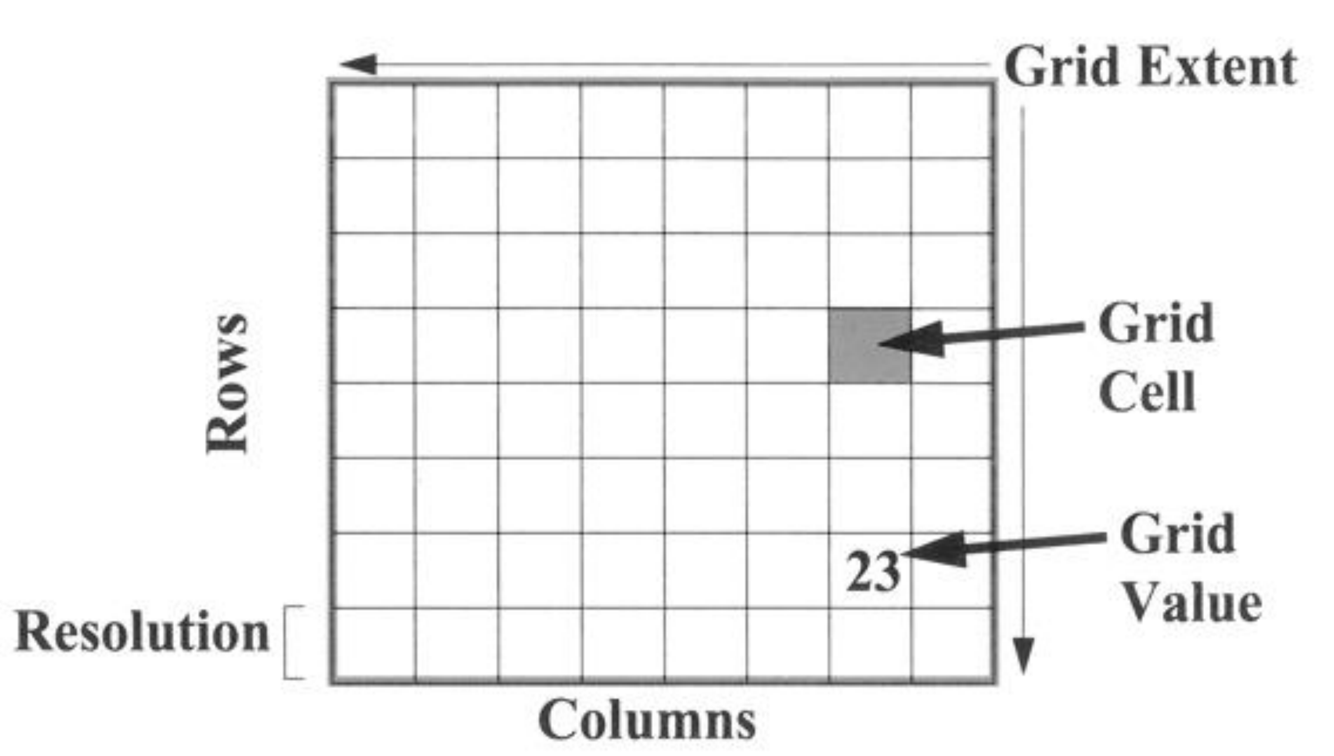
Raster Data:

- Raster data structures are generally made up of what can be considered grid cells, or pixels, that are organized and referenced by their row and column position in a database file.
- Raster data structures attempt to divide up and represent the landscape through the use of regular shapes.
- The shape that is almost exclusively used is the square
- Other shapes, such as triangles, hexagons, and octagons, can also cover the Earth completely and regularly.

GIS Database Structure

Raster Data:

Example



GIS Database Structure

Raster Data:

- A simple raster data set is a regular grid of cells divided into rows and columns.
- Data values for a given parameter are stored in each cell – these values may represent an elevation in meters above sea level and so forth.
- The spatial resolution of the raster data set is determined by the size of the cell.

GIS Database Structure

Raster Data:

- Each Grid Cell holds one value even if it is empty.
- A cell can hold an index standing for an attribute.
- Cell resolution is given as its size on the ground.
- Point and Lines move to the center of the cell.
- Minimum line width is one cell.
- Rasters are easy to read and write, and easy to draw on the screen.

GIS Database Structure

Raster Data:

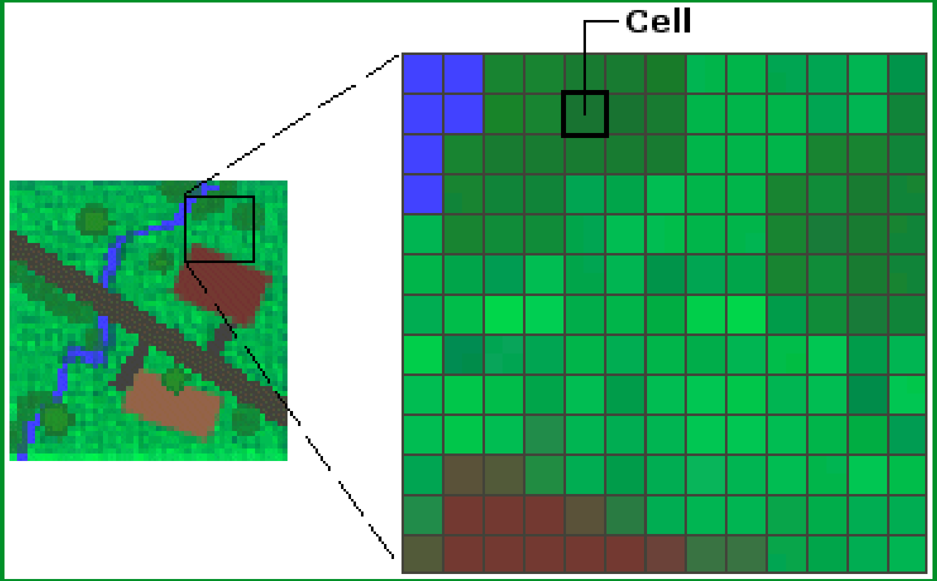
Example:

- Some common raster GIS databases are those related to Satellite imagery, Digital elevation models, Digital orthophotographs, and digital raster graphs

GIS Database Structure

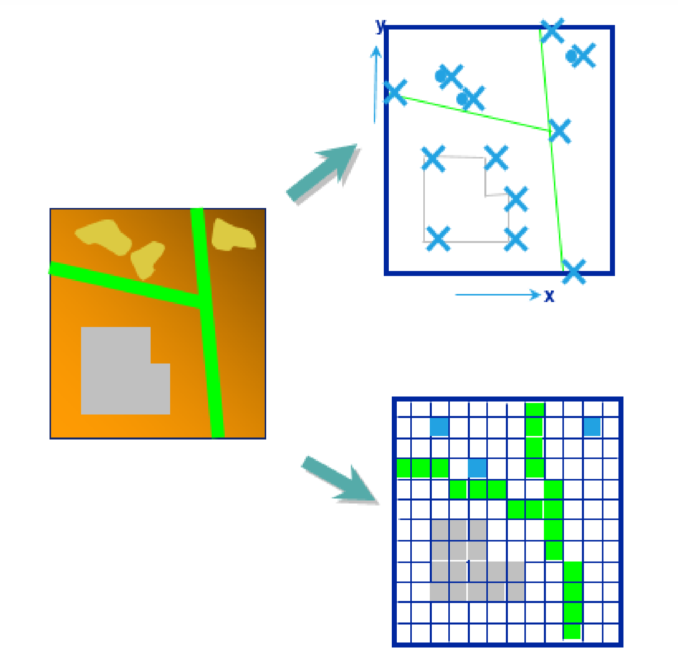
Raster Data:

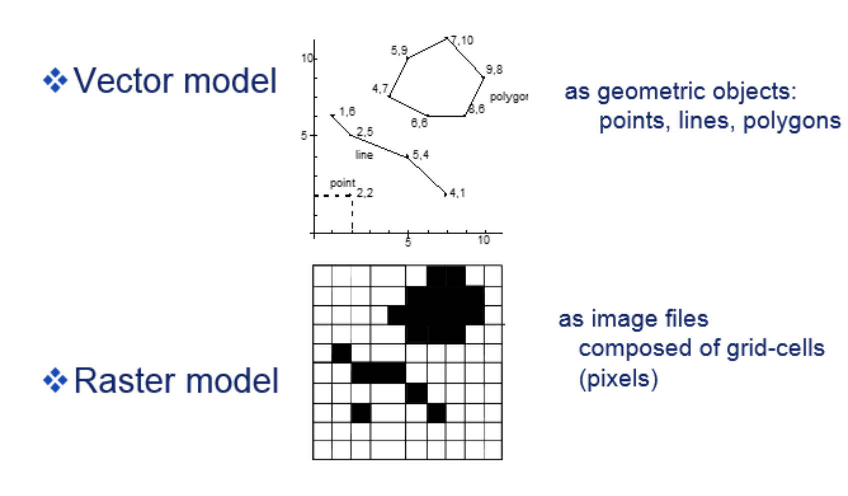
Example:



GIS Database Structure

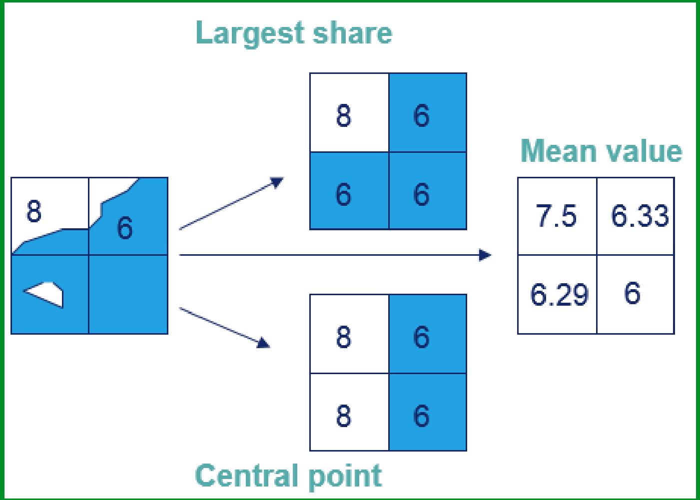
Raster Data:

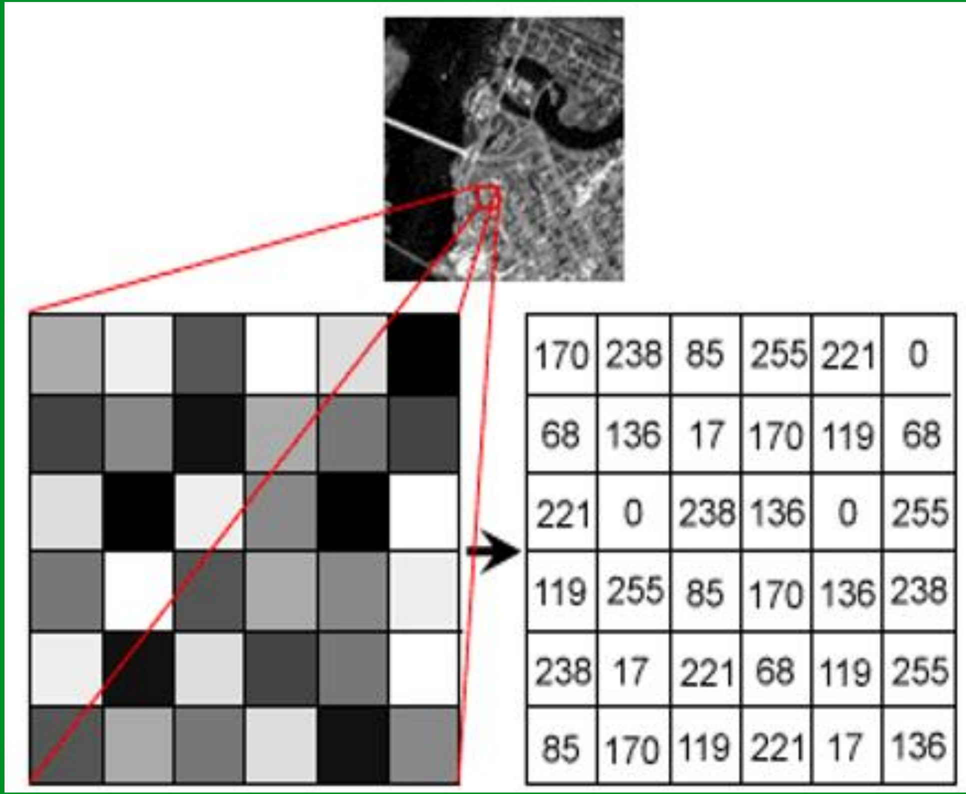




Geographic phenomena and data modeling

Raster

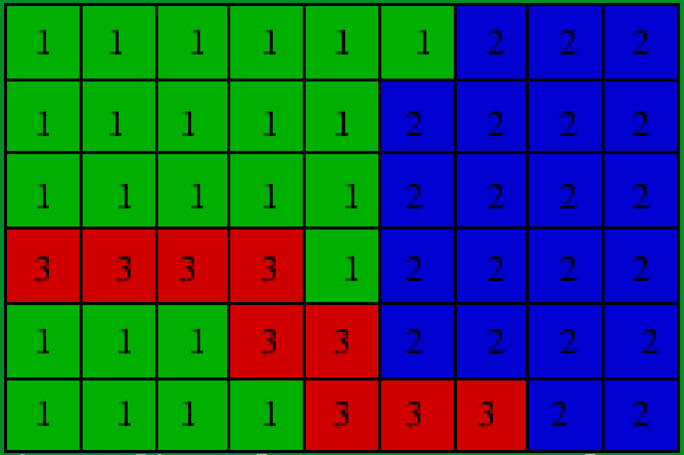




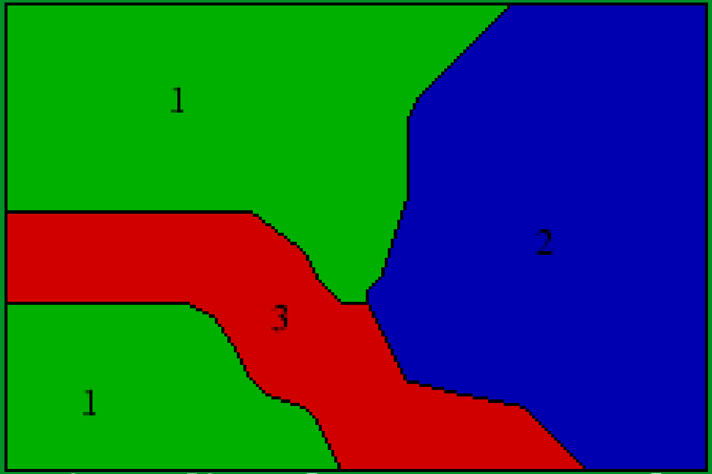
170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

GIS Database Structure

Raster Data:



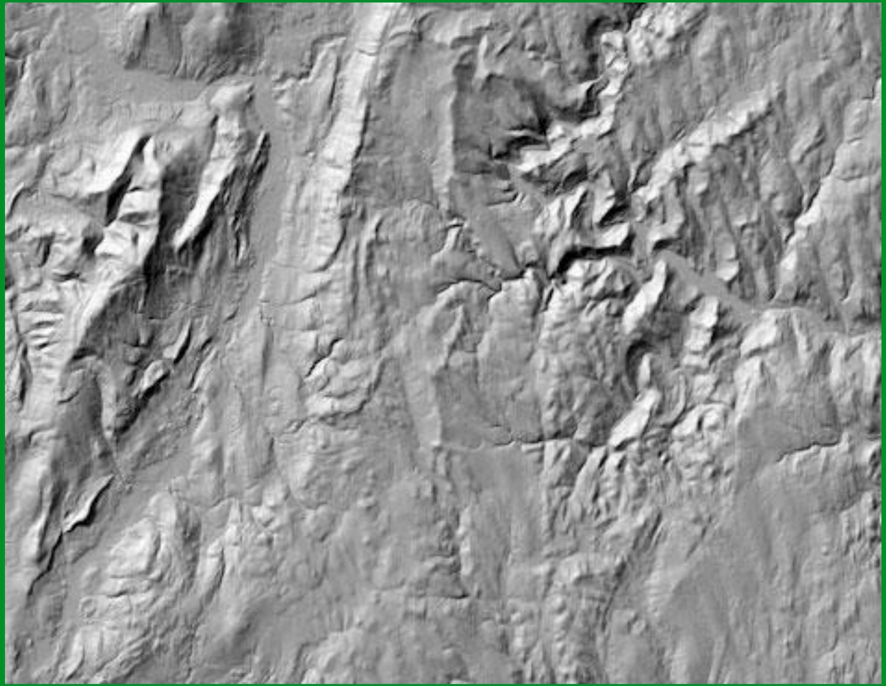
Visualised as raster data



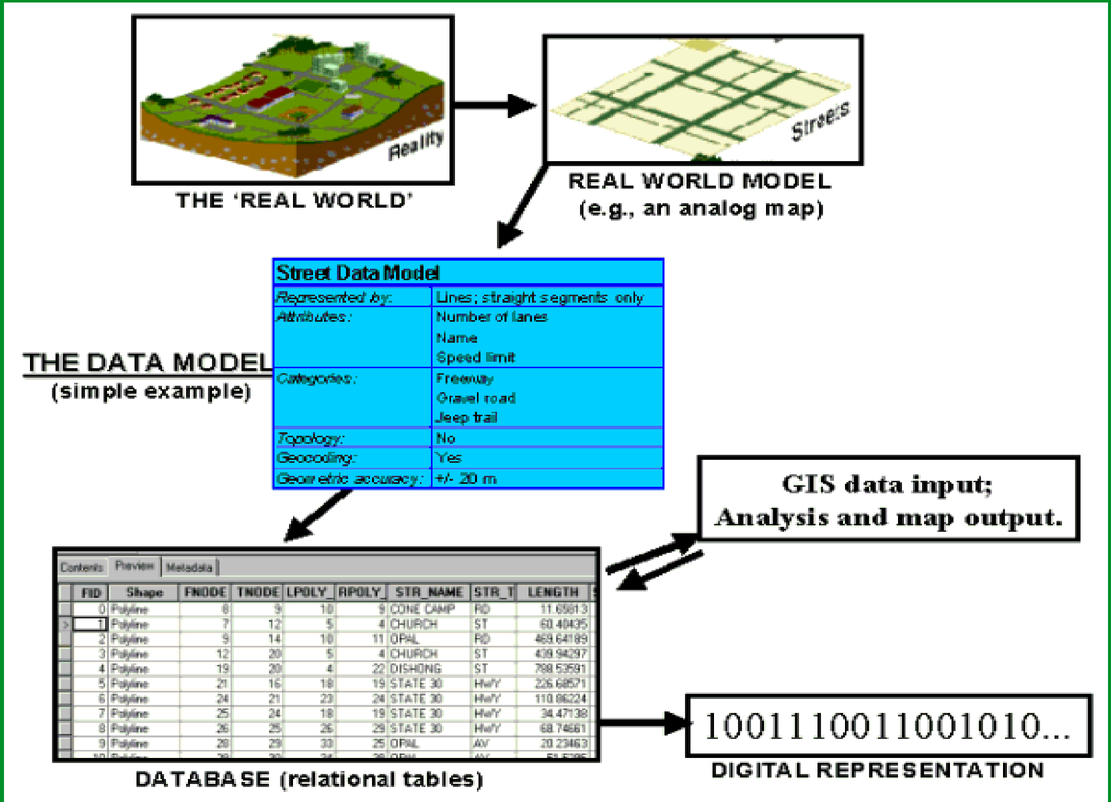
Visualised as vector data

GIS Database Structure

Raster Data:



GIS Database Structure/ GIS Database Model



GIS Database Structure/ Database Model

Vector Data:

- Vector data, as compared with raster data, are generally considered "irregular." This is not a comment on the quality or usefulness of vector data structures but, rather, a characterization of the type of data they represent.
- Vector data are generally grouped into three categories: **points**, **lines**, or **polygons**. Almost any landscape feature on the Earth can be described using one of these three shapes, or a combination of the shapes.

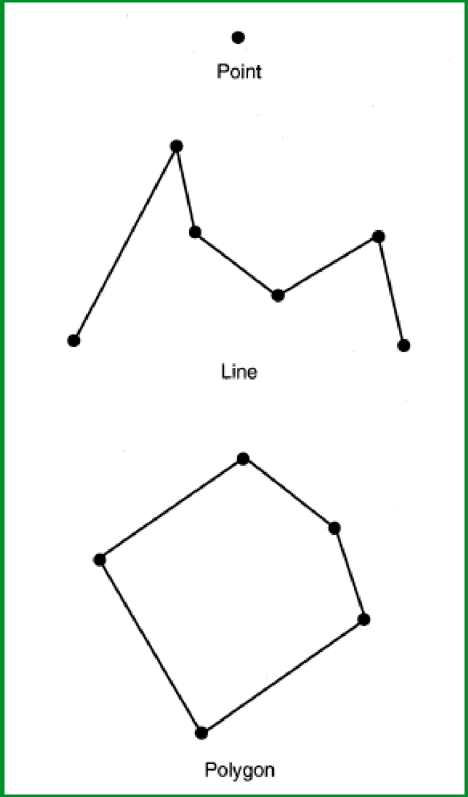
GIS Database Structure/ Database Model

Vector Data:

- Points are the most basic of the shapes but define the essence of all three forms.
- A line , is a set of connected points.
- A polygon is a collection of lines that forms a closed loop.

GIS Database Structure/ Database Model

Vector Data: (Example)



Point, line, and polygon vector shapes

GIS Database Structure/ Database Model

Vector Data: (Example)

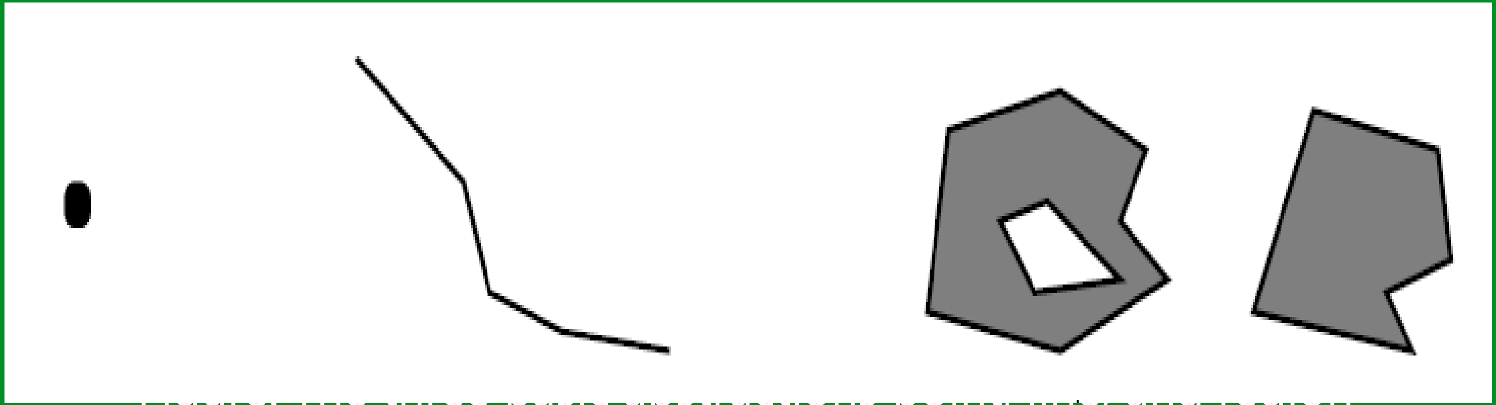
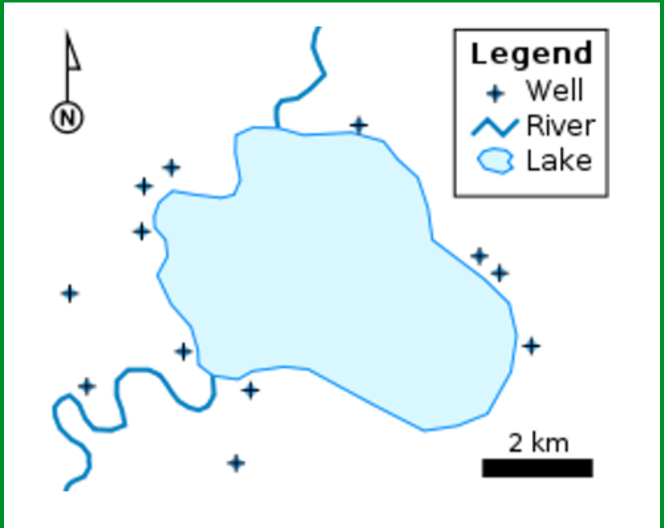


Figure: The three basic abstractions point, line, and region

GIS Database Structure/ Database Model

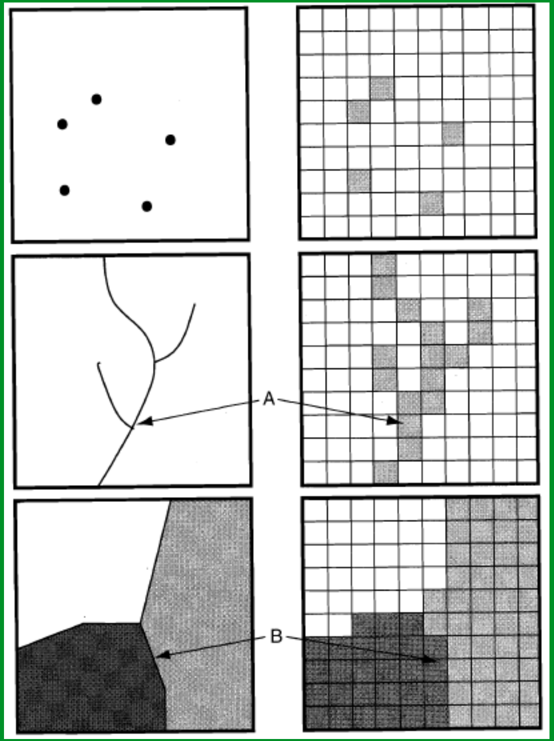
Data Model –

A simple vector map, using each of the vector elements: points for wells, lines for rivers, and a polygon for the lake



GIS Database Structure

Raster vs Vector Data:



Point, line, and polygon features represented in vector and raster data structares.

GIS Database Structure/ Database Model

Comparison of Raster and Vector Data Structure:

TABLE 2.1 Comparison of Raster and Vector Data Structures

	Raster	Vector
Structure complexity	Simple	Complex
Location specificity	Limited	Not limited
Computational efficiency	High	Low
Data volume	High	Low
Spatial resolution	Limited	Not limited
Representation of topology among features	Difficult	Not difficult

GIS Database Structure/ Database Model

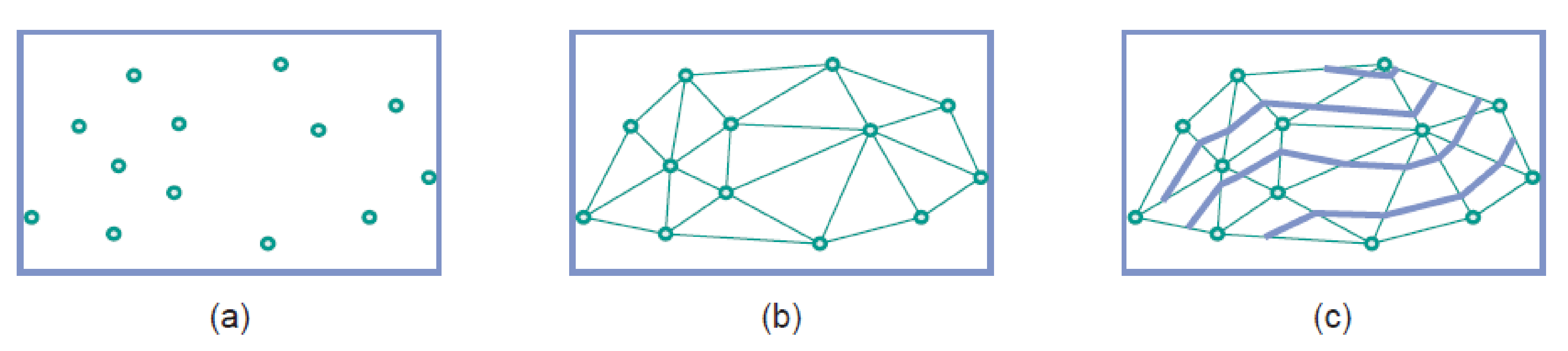
Alternative Data Structures:

Although points, lines, and polygons represent the most common forms of vector GIs data, several other forms of vector GIs data may also be useful in representing landscape features. These other data structures include triangular irregular networks (TINs), dynamic segmentation of networks, and regions.

1. Triangular irregular networks (TINs)
2. Dynamic segmentation of networks
3. Regions

GIS Database Structure/ Database Model

Triangulated irregular network:



TIN overlaid with contour lines

GIS Database Structure/ Database Model

Triangulated irregular network:

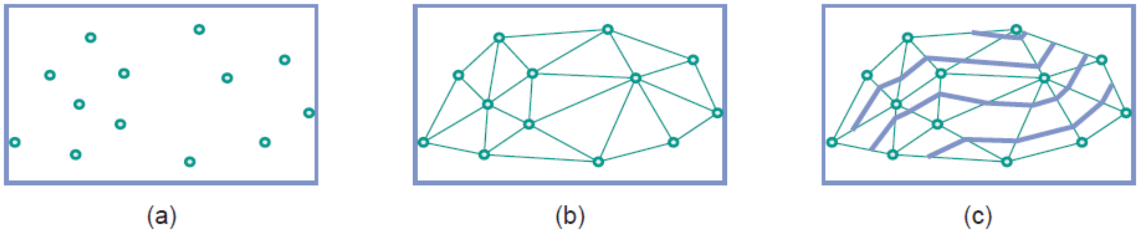
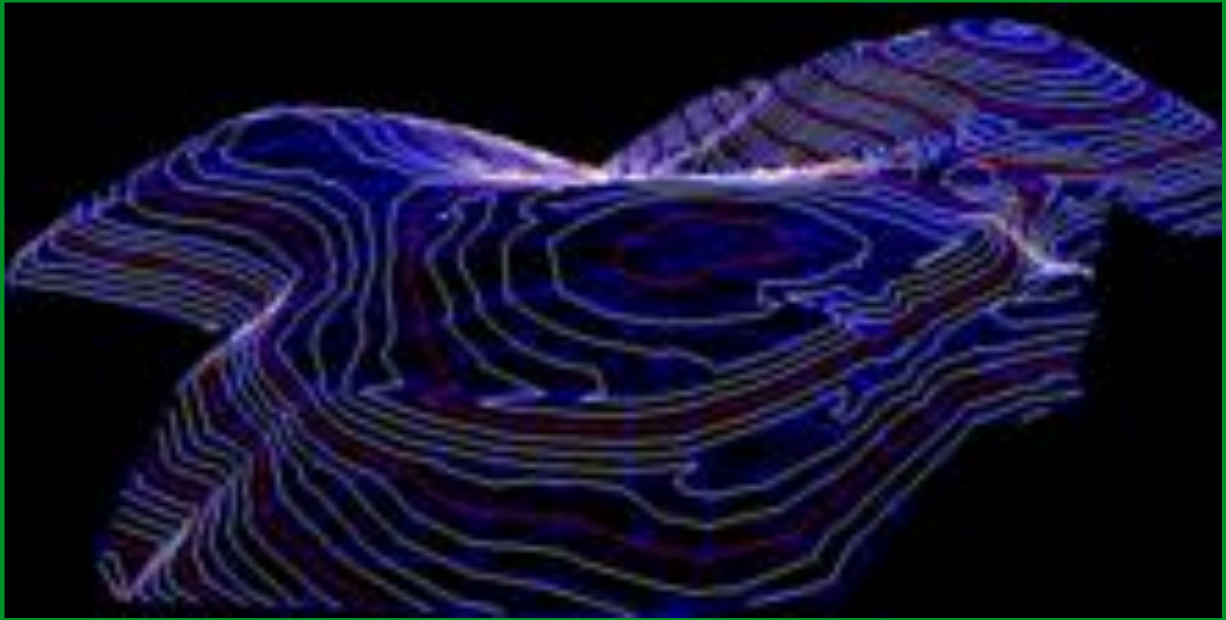


Figure 5.16: Triangulation as a means of interpolation. (a) known point measurements; (b) constructed triangulation on known points; (c) isolines constructed from the triangulation.

TIN overlaid with contour lines

GIS Database Structure/ Database Model

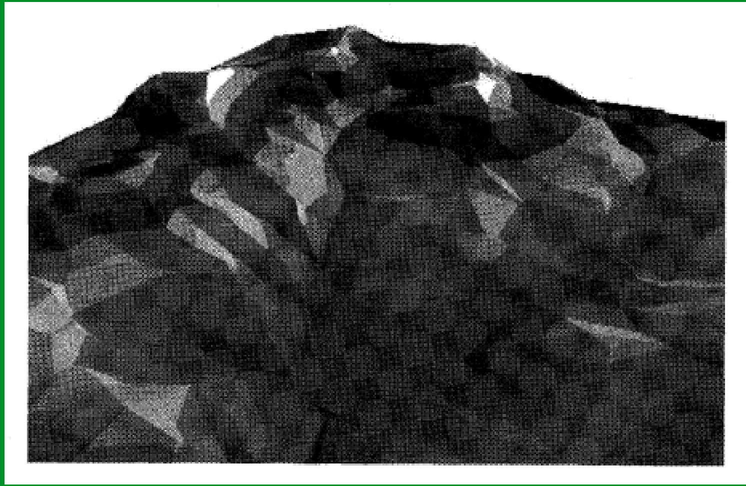
Triangulated irregular network:



TIN overlaid with contour lines

GIS Database Structure/ Database Model

Triangulated irregular network:



TIN representation of an elevation surface

GIS Database Structure/ Database Model

Triangular Irregular Networks (TINs):

- A triangulated irregular network (TIN) is a digital data structure used in a geographic information system (GIS) for the representation of a surface.
- A TIN is a vector-based representation of the physical land surface or sea bottom, made up of irregularly distributed nodes and lines with three-dimensional coordinates (x, y, and z) that are arranged in a network of nonoverlapping triangles.

GIS Database Structure/ Database Model

Triangular Irregular Networks (TINs):

- TINs are often derived from the elevation data of a rasterized digital elevation model (DEM).
- An advantage of using a TIN over a raster DEM in mapping and analysis is that the points of a TIN are distributed variably based on an algorithm that determines which points are most necessary to an accurate representation of the terrain.

GIS Database Structure/ Database Model

Dynamic Segmentation of Networks:

A data structure that uses dynamic segmentation is based on a network of lines and, thus, is a variation of the vector data structure. The dynamic segmentation data structure is designed to represent linear features, and traditional uses of this structure include modelling efforts related to river systems, utility distributions, and road networks.

GIS Database Structure/ Database Model

Dynamic Segmentation of Networks:

Dynamic segmentation attempts to link a network of lines, based on a common attribute, so that the lines are grouped into categories of interest. An example of this approach might relate to a streams GIS database. A typical streams GIS database uses a series of lines to represent a stream network.

GIS Database Structure/ Database Model

A **network** can be viewed as a graph embedded into the plane, consisting of a set of point objects, forming its nodes, and a set of line objects describing the geometry of the edges. Networks are ubiquitous in geography, for example, highways, rivers, public transport, or power supply lines.

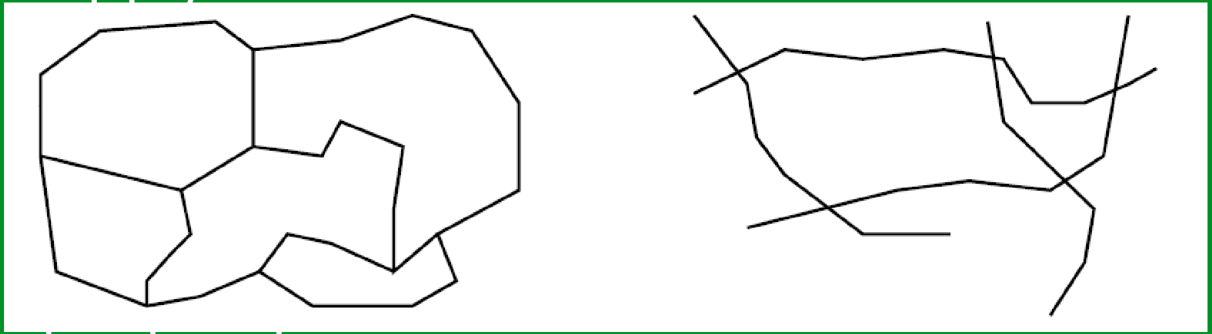


Figure: Partitions and networks

GIS Database Structure/ Database Model

Region:

Another alternative vector data structure is called the region.

This data structure is based on polygons or approximations of areas, such as stand boundaries or ownership parcels.

GIS Database Structure/ Database Model

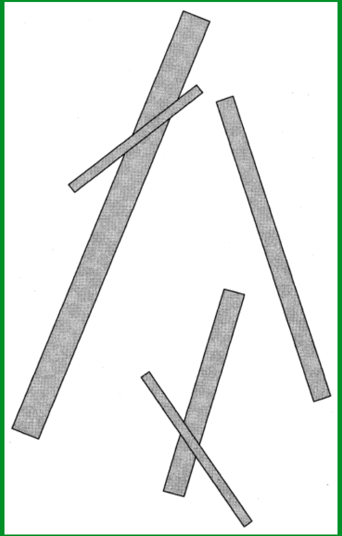
Region:

One of the characteristics of a "topologically correct" polygon structure is that polygon features do not overlap, but, when they do, a new polygon is created to represent the overlapping.

A region data structure will allow the existence of overlapping polygons yet will also maintain topology

GIS Database Structure/ Database Model

Regions:



Example of the region data structure used to - capture the placement of downed woody debris in a stream channel- Typical polygon topology would create 11 polygons to represent the 5 woody debris pieces. Regions allow for polygons to overlap and lead to 5 shapes in a database, or 1 for each piece.

GIS Database Structure/ Database Model

Region:

Another alternative vector data structure is called the region. This data structure is based on polygons or approximations of areas, such as stand boundaries or ownership parcels. One of the characteristics of a "topologically correct" polygon structure is that polygon features do not overlap, but, when they do, a new polygon is created to represent the overlapping area (some desktop GIs software programs do not allow one to determine whether polygons are topologically correct). A region data structure will allow the existence of overlapping polygons yet will also maintain topology

GIS Database Structure/ Database Model

Dynamic Segmentation of Networks:

The dynamic segmentation data model can associate information with any portion or segment of a linear feature. Events can be associated with each line or a single point on a line. This information can then be stored, queried, analyzed, and displayed without affecting the structure of the original vector GIs database. Dynamic segmentation attempts to link a network of lines, based on a common attribute, so that the lines are grouped into categories of interest. An example of this approach might relate to a streams GIs database. A typical streams GIs database uses a series of lines to represent a stream network. Each of the lines has a set of nodes, or beginning and ending points, placed at all tributary junctions along the stream network. Depending on the size of the stream network, hundreds or thousands of lines might exist. A stream ecologist interested in analyzing the stream system, for example, could associate all lines that are used to represent the main channel of a river.Dynamic Segmentation of Networks:

GIS Database Structure/ Database Model

Dynamic Segmentation of Networks:

The dynamic segmentation data model can associate information with any portion or segment of a linear feature. Events can be associated with each line or a single point on a line. This information can then be stored, queried, analyzed, and displayed without affecting the structure of the original vector GIs database. Dynamic segmentation attempts to link a network of lines, based on a common attribute, so that the lines are grouped into categories of interest. An example of this approach might relate to a streams GIs database. A typical streams GIs database uses a series of lines to represent a stream network. Each of the lines has a set of nodes, or beginning and ending points, placed at all tributary junctions along the stream network. Depending on the size of the stream network, hundreds or thousands of lines might exist. A stream ecologist interested in analyzing the stream system, for example, could associate all lines that are used to represent the main channel of a river.Dynamic Segmentation of Networks:

GIS Database Structure/ Database Model

Dynamic Segmentation of Networks:

A data structure that uses dynamic segmentation is based on a network of lines and, thus, is a variation of the vector data structure. The dynamic segmentation data structure is designed to represent linear features, and traditional uses of this structure include modeling efforts related to river systems, utility distributions, and road networks (ESRI 1994). Dynamic segmentation allows GIs users to create routes to represent the movement or presence of an entity along a linear network. The routes are actually stored as information within a vector GIs database. Dynamic segmentation eliminates the need to create a separate GIs database for each route and facilitates advanced data handling and manipulation of GIs databases. Underlying the route structure are sections and events. Sections are the linear components or segments that, when added together, form a route. Events are the data sources, or attribute tables, that are connected to the routes.

GIS Database Structure/ Database Model

Dynamic Segmentation of Networks:

Any attributes that are used to describe the main channel, such as length, depth, or temperature, can then be summarized. The stream ecologist might use this dynamic segmentation approach for the entire stream network to create a new GIs database that groups all lines based on an attribute, such as the stream name. Dynamic segmentation allows GIs users to organize a GIs database so that analysis and storage can be easier and more effiicient. Dynamic segmentation can also be used to assist in scheduling forest harvest operations or in planning or tracking almost any phenomenon that is associated with a linear network.

GIS Database Structure/ Database Model

Regions:

Another alternative vector data structure is called the region. This data structure is based on polygons or approximations of areas, such as stand boundaries or ownership parcels. One of the characteristics of a "topologically correct" polygon structure is that polygon features do not overlap, but, when they do, a new polygon is created to represent the overlapping area (some desktop GIs software programs do not allow one to determine whether polygons are topologically correct).

GIS Database Structure/ Database Model

Regions:

A region data structure will allow the existence of overlapping polygons yet will also maintain topology (ESRI 1995). One application in which regions might be useful is when a forest scientist is interested in capturing the locations of fallen logs within a stream channel (figure 2.23). Polygons can be used to represent the lengths and widths of the logs, but any logs that are stacked on top of each other, as one might expect to find in a log jam, will not be represented accurately in a topologically correct polygon structure.

GIS Database Structure/ Database Model

Regions:

Two logs that overlap each other might result in multiple topologically correct polygons: one or more polygons to represent the non-overlapping areas of logs and other polygons for each of the overlapping areas of logs. For the 5 objects (logs) displayed in figure 2.23, enforcing correct topology for these landscape features would create a total of 11 polygons, resulting not only in a loss of information but also in a larger set of database records than might be appropriate to describe the logs. With the use of the region data structure, one can retain individual log data records, while associating the overlapping logs with one another.

Geographic phenomena and data modeling

3.1 Introduction to geographic phenomena and data modeling

3.2 Spatial relationship and topology

3.3 Scale and resolution

3.5 Spatial database design with the concept of geodatabase

Geographic phenomena and data modeling

Raster

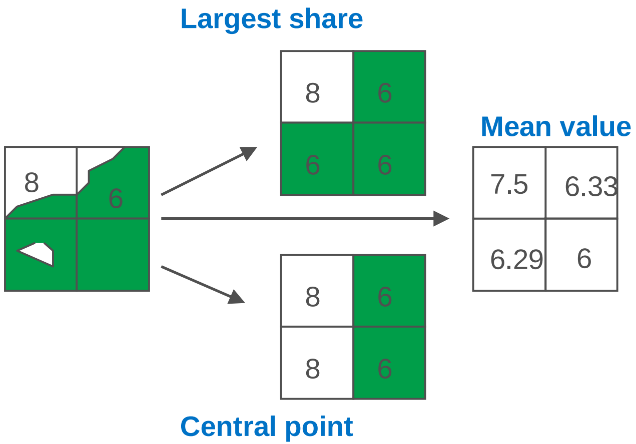
- Because of the distortions due to flattening, cells in a raster can never be perfectly equal in size on the Earth's surface.
- When information is represented in raster form all detail about variation within cells is lost, and instead the cell is given a single value. largest share, central point (f.g. USGS DEM), and mean value (f.g. remote sensing imagery)

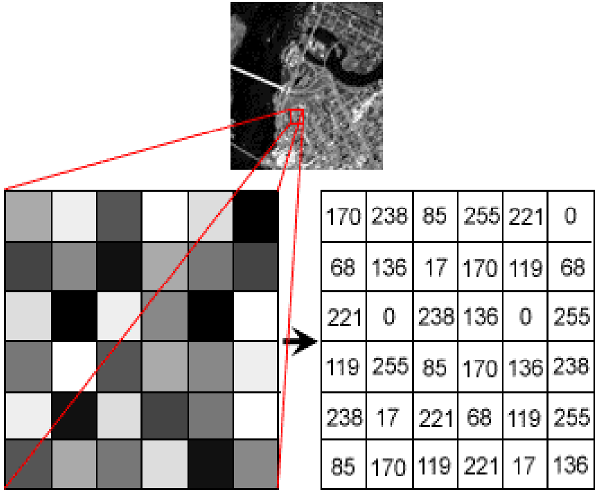
Error in raster

- raster

  - because of the distortions due to flattening, cells in a raster can never be perfectly equal in size on the Earth's surface.

  - when information is represented in raster form all detail about variation within cells is lost, and instead the cell is given a single value. **largest share**, **central point** (f.g. USGS DEM), and **mean value** (f.g. remote sensing imagery)





GIS Database Structure/ Database Model

Point, Line , Polygon (Area):

The fundamental abstractions are point, line, and region (Area or polygon).

A point represents an object for which only its location in space, but not its extent, is relevant. For example, a city may be modelled as a point in a model describing a large geographic area (a large scale map).

A line (in this context always to be understood as meaning a curve in space, usually represented by a polyline, a sequence of line segments) is the basic abstraction for facilities for moving through space, or connections in space (roads, rivers, cables for phone, electricity, etc.). single objects.

GIS Database Structure/ Database Model

For modeling single objects:

A region is the abstraction for something having an extent in 2d-space, e.g. a country, a lake, or a national park. A region may have holes and may also consist of several disjoint pieces. Figure shows the three basic abstractions for single objects.

.

GIS Database Structure/ Database Model

The two most important instances of spatially related collections of objects are partitions (of the plane) and networks.

A partition can be viewed as a set of region objects that are required to be disjoint. The adjacency relationship is of particular interest, that is, there exist often pairs of region objects with a common boundary. Partitions can be used to represent thematic maps.

GIS Database Structure/ Database Model

Data Model –

In a GIS, geographical features are often expressed as vectors, by considering those features as geometrical shapes. Different geographical features are expressed by different types of geometry:

GIS Database Structure/ Database Model

Data Model –

There are three basic spatial data types used with GIS (points, lines, and areas):

1. *Points represent anything that can be described as a discrete x, y location

2. *Lines represent anything having a length

3. *Areas, or polygons, describe anything having boundaries

A simple vector map, using each of the vector elements: points for wells, lines for rivers, and a polygon for the lake

GIS Database Structure/ Database Model

Points:

Zero-dimensional points are used for geographical features that can best be expressed by a single point reference—in other words, by simple location. Examples include wells, peaks, features of interest, and trailheads. Points convey the least amount of information of these file types. Points can also be used to represent areas when displayed at a small scale. For example, cities on a map of the world might be represented by points rather than polygons. No measurements are possible with point features.

GIS Database Structure/ Database Model

Lines or polylines

One-dimensional lines or polylines are used for linear features such as rivers, roads, railroads, trails, and topographic lines. Again, as with point features, linear features displayed at a small scale will be represented as linear features rather than as a polygon. Line features can measure distance.

GIS Database Structure/ Database Model

Polygons

Two-dimensional polygons are used for geographical features that cover a particular area of the earth's surface. Such features may include lakes, park boundaries, buildings, city boundaries, or land uses. Polygons convey the most amount of information of the file types. Polygon features can measure perimeter and area.

GIS Database Structure/ Database Model

Attributes:

Each of these geometries are linked to a row in a database that describes their attributes. For example, a database that describes lakes may contain a lake's depth, water quality, pollution level. This information can be used to make a map to describe a particular attribute of the dataset. For example, lakes could be coloured depending on level of pollution. Different geometries can also be compared. For example, the GIS could be used to identify all wells (point geometry) that are within one kilometre of a lake (polygon geometry) that has a high level of pollution.

Remote sensing data in GIS

- RS is the science/ are the techniques of deriving information about the Earth's land and water areas from images (or point/line samples) at a distance.
- It relies upon measurement of electro-magnetic (EM) energy reflected or emitted from the objects of interest at the surface of the Earth.
- So, one is looking at the physical nature of spatially distributed features.

Remote sensing data in GIS

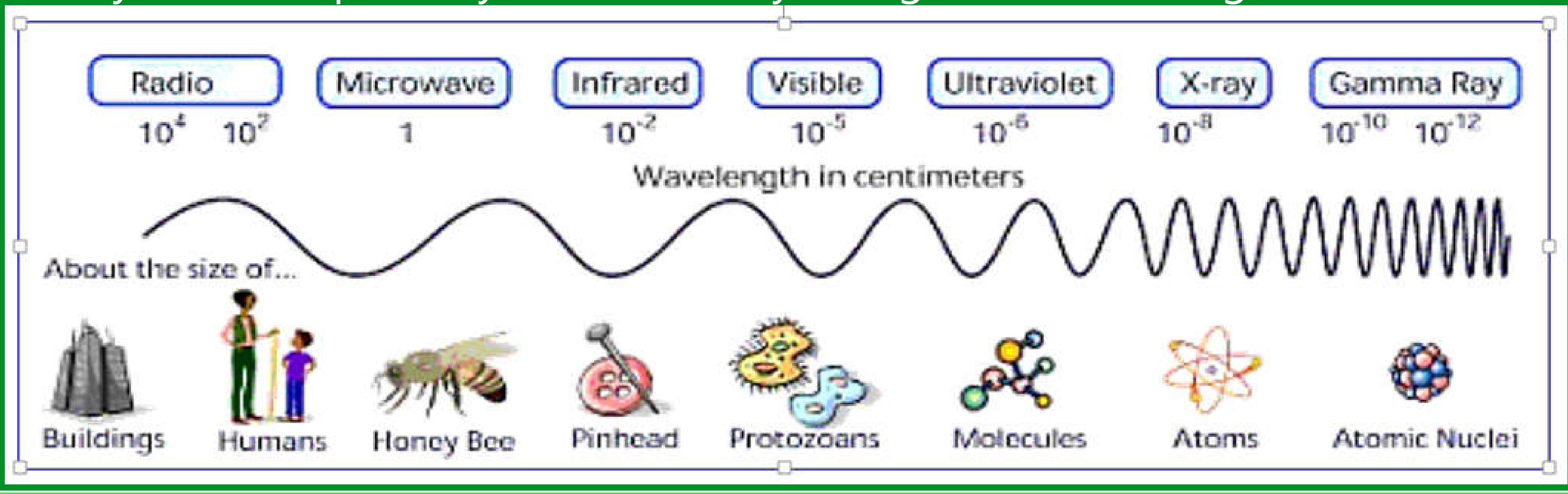
- Remote Sensing is the science and art of acquiring information (spectral, spatial, temporal) about material objects, area, or phenomenon, without coming into physical contact with the objects, or area, or phenomenon under investigation.

Remote sensing data in GIS

- In remote sensing, information transfer is accomplished by use of electromagnetic radiation (EMR).
- EMR is a form of energy that reveals its presence by the observable effects it produces when it strikes the matter.

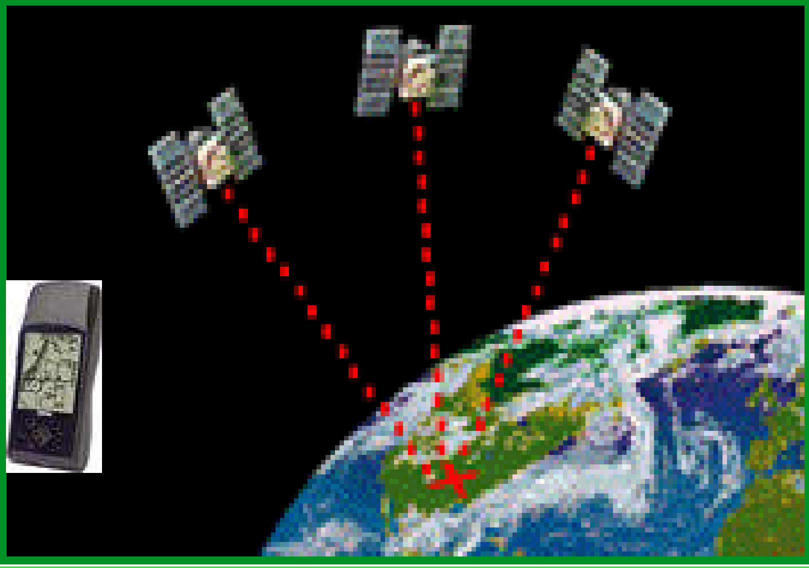
Remote sensing data in GIS

- Using electromagnetic spectrum to image the land, ocean, and atmosphere.
- EMR is considered to span the spectrum of wavelengths from 10-10 µm to cosmic rays up to 1010 µm
- When you take a photo, you are actually doing remote sensing.



Importance of GPS and remote sensing data in GIS

A Global Positioning System (GPS) is a tool used to collect data for a GIS. Many people get the terms GIS and GPS confused with each other.



Importance of GPS and remote sensing data in GIS

GPS stands for **Global Positioning System.**

- GPS is a system of satellites, ground stations, and receivers that allow you to find your exact location on Earth. By collecting location points you can begin compile datasets that can be used to map whatever data you are collecting.

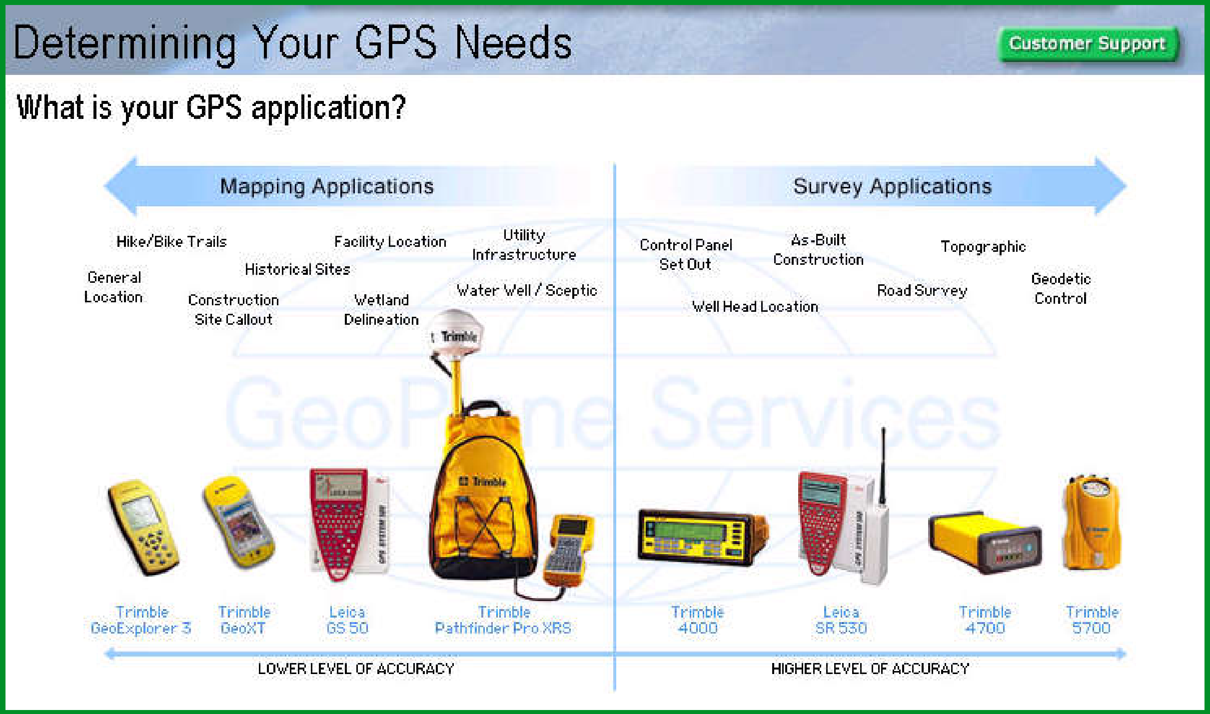
How GPS's and GIS relate to one another:

- The way a GPS works is, by connecting to three or more 24 GPS satellites that orbit 11,000 nautical miles above the earth, and are monitored by ground stations located throughout the world.
- GPS systems generate geographic reference points in the form of latitude, longitude, and elevation coordinates. Once the data is collected it can be put into a GIS and displayed digitally as it is in the real world.

Importance of GPS and remote sensing data in GIS

- Today boats and many car manufacturer's have GPS units mounted so they can track where they are at all times.
- The increased availability and affordability of handheld GPS units, makes it useful for the average person to use for activities such as backpacking, hunting, and skiing, to name a few.

Importance of GPS and remote sensing data in GIS



Map projection and spatial reference

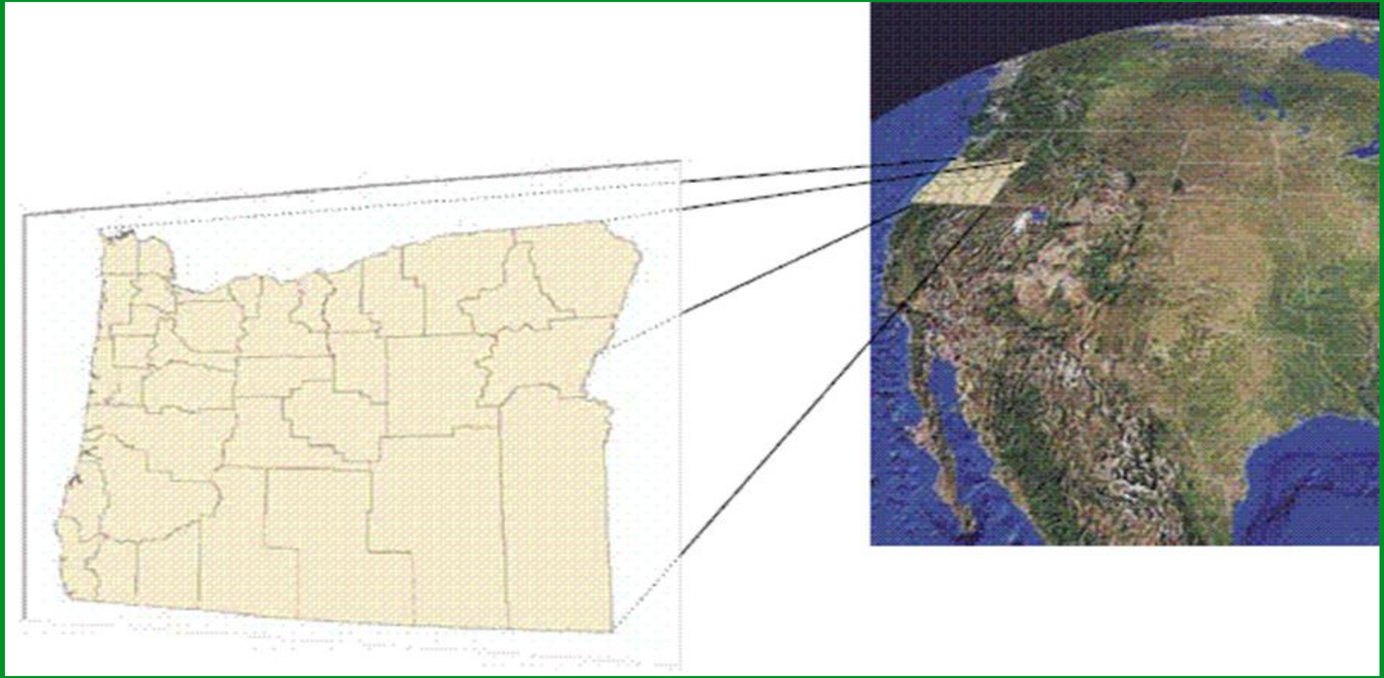
Georeferencing and coordinate systems

Georeferencing: Assigning map coordinates and spatial location

- All the elements in a map layer have a specific geographic location and extent that enables them to be located on or near the earth's surface. The ability to accurately describe geographic locations is critical in both mapping and GIS. This process is called georeferencing.

Map projection and spatial reference

Georeferencing and coordinate systems



Map projection and spatial reference

Georeferencing and coordinate systems

- Describing the correct location and shape of features requires a framework for defining real-world locations. A geographic coordinate system is used to assign geographic locations to objects. A global coordinate system of latitude-longitude is one such framework. Another is a planar or Cartesian coordinate system derived from the global framework.

Map projection and spatial reference

Georeferencing and coordinate systems

- Maps represent locations on the earth's surface using grids, graticules, and tic marks labeled with various ground locations (both in measures of latitude-longitude and in projected coordinate systems (such as UTM meters). The geographic elements contained in various map layers are drawn in a specific order (on top of one another) for the given map extent.

Unit 4: Capturing the Real World

There are two methods for spatial data acquisition

1. Primary methods
   Surveying, Photogrammetry, GPS, and Remote Sensing

   Digitization (Digitizing Tablet); Automatic line following; Scanning; On Screen Digitizing; Text Files; COGO (Coordinate Geometry)

2. Secondary methods

Unit 4: Capturing the Real World

There are two methods for spatial data acquisition

2. Secondary Methods

   Large amount of data is now available from others
   Free data from the government
   Internet map server
   Commercial data
   Data from other GIS users

Unit 4: Capturing the Real World

Spatial data features:

- Data input to a GIS involves encoding both the locational and attribute data
- The locational data is encoded as coordinates on a particular Cartesian Coordinate System
- Source maps may have different projections and scales

Unit 4: Capturing the Real World

Spatial data features:

- Several stages of data transformation may be needed to bring all data to a common coordinate system
- Attribute data is often obtained and stored in tables (Database Management System)

Primary Data Capture

Field Data Collection (Surveying):

Field collection techniques for the creation of GIS databases have advanced tremendously over the past 20 years and are now fully enmeshed in the digital age.

Field data collection processes are using digital data collection techniques.

Primary Data Capture

Field Data Collection (Surveying):

Current technology includes the ability to capture not only distance measurements but also the angles between objects. In addition, the measurements are stored in a digital database.

GPS equipment has also become more affordable and useable in recent years. GPS requires that a receiver, located on the Earth's surface, collect and record signals transmitted by a constellation of satellite that orbit the Earth.

Primary Data Capture

Photogrammetry:

- Photogrammetry is the collection of measurements from the image of an object or a resource.
- Through various techniques, photogrammetry facilitates the interpretation and measurement of features captured on photographs.

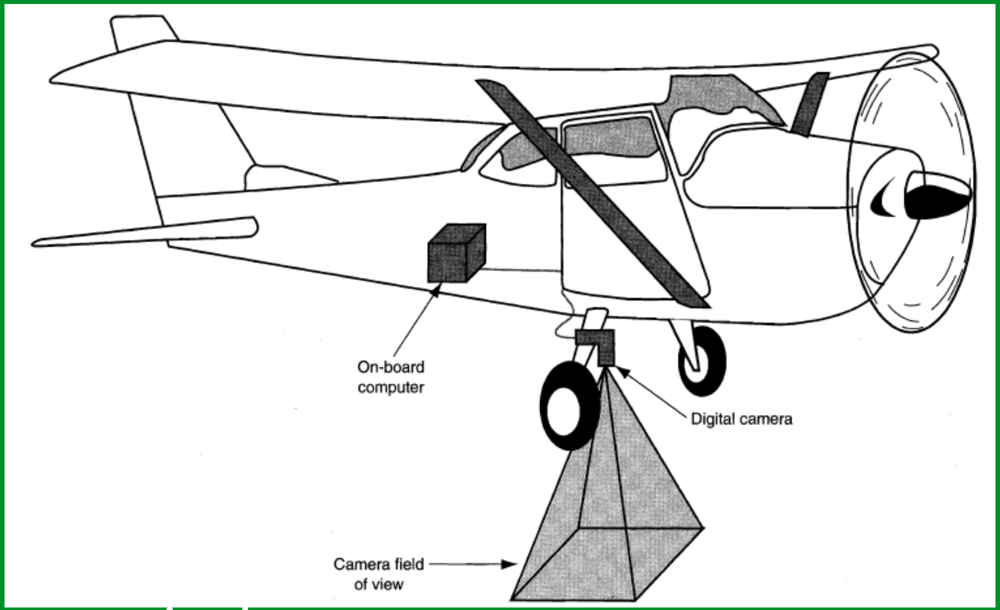
Primary Data Capture

Photogrammetry:

- It requires a firm understanding of photography Photograminetry is perhaps the primary method used for the creation of spatial data in forestry and natural resource management.

Primary Data Capture

Photogrammetry:



Digital camera mounted on an airplane

Primary Data Capture

Remote Sensing:

Remote sensing devices capture electromagnetic energy, perhaps generated by the sun or another device (such as a radar transmitter), that is reflected off of landscape features.

Primary Data Capture

Remote Sensing:

- A relatively new technology called light detection and ranging (LIDAR) allows for the collection of topographic or elevation data. LIDAR systems are mounted on an aircraft and include a laser, an inertial navigation system, a Global Positioning System (GPS) receiver, and an on-board computer for processing.

Primary Data Capture

Remote Sensing:

- Remote sensing involves the use of a sensor that is not in physical contact with its subject of interest.
- Remote sensing technology in natural resource management frequently refers to the use of satellites or cameras mounted on airplanes.

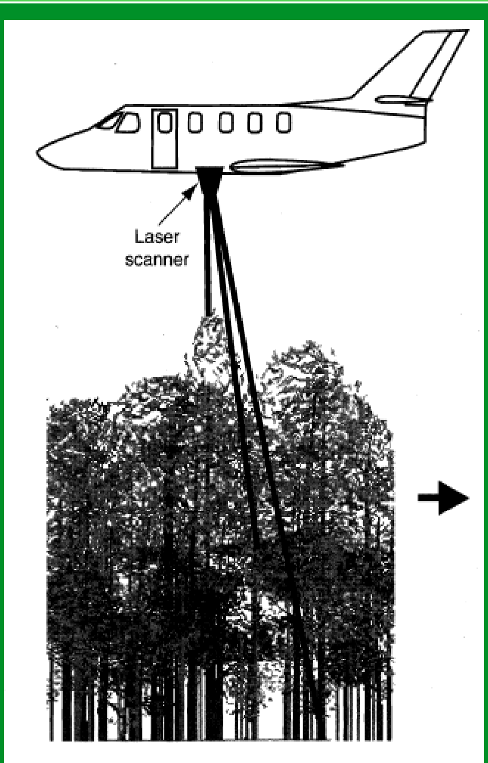
Primary Data Capture

Remote Sensing:

- Remote sensing devices capture electromagnetic energy, perhaps generated by the sun or another device (such as a radar transmitter), that is reflected off of landscape features.

Primary Data Capture

Remote Sensing:



LIDAR system on aircraft.

Primary Data Capture

Manual Map Digitizing:

The ability to encode vector maps manually using a digitizing table and associated software has been available since the late 1960s.

Paper maps are taped down to a digitizing table, in which is embedded a fine mesh of copper wire.

Primary Data Capture

Manual Map Digitizing:

- Known reference points on the maps are identified using the digitizing table's "puck (similar to a computer mouse), which sends a signal to the wire mesh within the table.
- Once the reference points have been identified, all other landscape features can be encoded in a coordinate system and related to the reference points.

Primary Data Capture

Scanning:

- Scanning involves the examination of maps by a computer process that seeks to identify (and convert to digital form) changes in map color or tone that identify landscape features.

- Flat-bed scanners allow one to convert a picture or map, such as an aerial photograph or a topographic map, to digital form.

Primary Data Capture

Scanning:

- The resulting images are described by the raster data structure and include pixels or grid cells that may be encoded (or attributed) differently, depending on how the scanner interprets the color or tone of each feature.

Primary Data Capture

Scanning:

- A second method of scanning involves the use of digital cameras. An array of photo-detectors located within digital cameras allows one to capture and store an image.

- The images are saved with a raster data structure and can be transferred to a computer system and used in manners similar to the scanned images.

Primary Data Capture

- **Digitizing Tablet**
- Sends an electrical impulse from the edges that is read by the puck to determine Location.
- Accuracy of tablets ranges form .01" to .002"

Primary Data Capture

On Screen Digitizing:

- The original is scanned and Georeferenced
- Features are captured using the mouse
- Less fatigue than using a tablet

Primary Data Capture

Text Files:

- If you have a text file or table with X,Y values you can directly import them into ArcGIS.
- GPS Data

Primary Data Capture

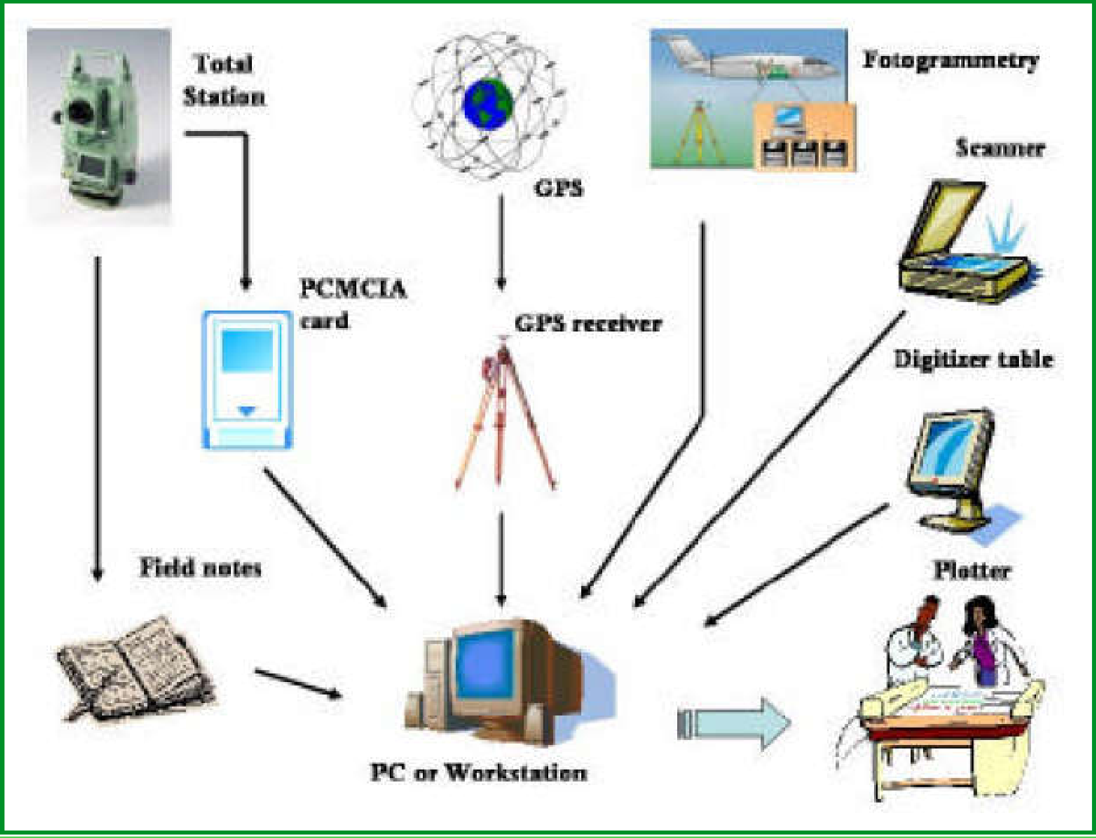
(Coordinate Geometry) COGO and Survey Analyst:

- COGO (Coordinate Geometry)
- Extension for Command line ArcInfo
- Tracking Analyst
- ArcGIS Extension
- Both extensions allow direct input of survey data

Secondary Data

- Large amount of data is now available
- Always check for existing data before creating it
- Several groups of data exist
    - Free data from the government
    - Government data available for a fee
    - Internet map servers
    - Commercial data
    - Data from other GIS users

Different Methods of data capture



Unit 4.6: Remote sensing

In this chapter , will explain about

What is remote sensing ?

Types of remote sensing ?

Components of remote sensing ?

GPS: Global Positioning System

Unit 4.6: Remote sensing

What is remote sensing ?

- Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object and thus in contrast to on site observation.
- In modern usage, the term generally refers to the use of aerial sensor technologies to detect and classify objects on Earth (both on the surface, and in the atmosphere and oceans) by means of propagated signals (e.g. electromagnetic radiation).

Unit 4.6: Remote sensing

Types of remote sensing ?

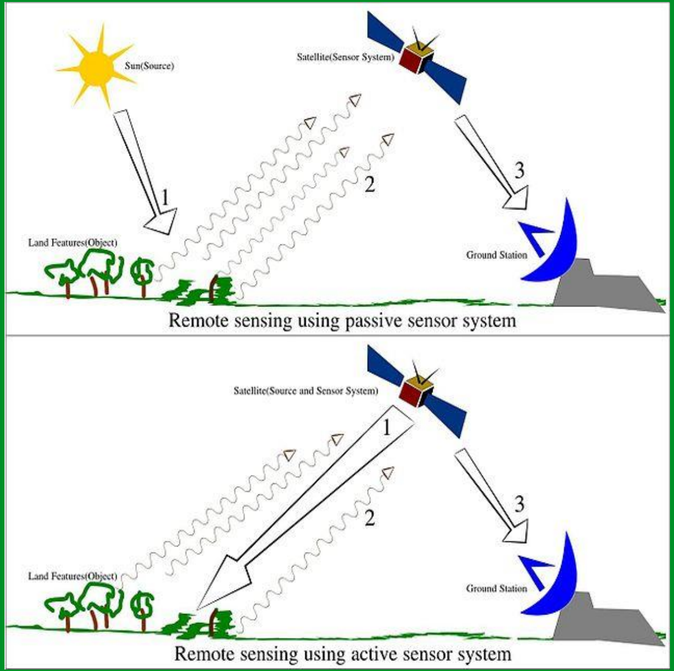
In respect to the type of Energy Resources:

- **Passive Remote Sensing:** Makes use of sensors that detect the reflected or emitted electro-magnetic radiation from natural sources.
- **Active remote Sensing:** Makes use of sensors that detect reflected responses from objects that are irradiated from artificially-generated energy sources, such as radar.

Unit 4.6: Remote sensing

Types of remote sensing ?

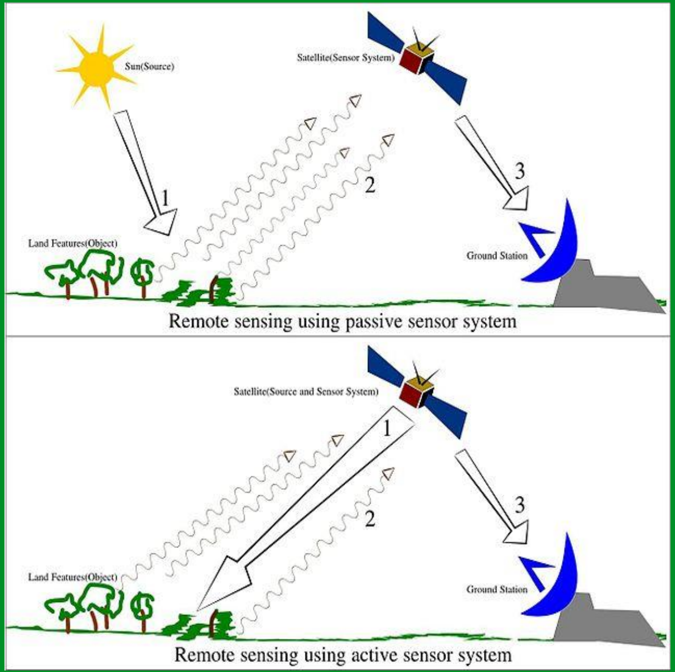
It may be split into active remote sensing (when a signal is first emitted from aircraft or satellites) or passive (e.g. sunlight) when information is merely recorded.



Unit 4.6: Remote sensing

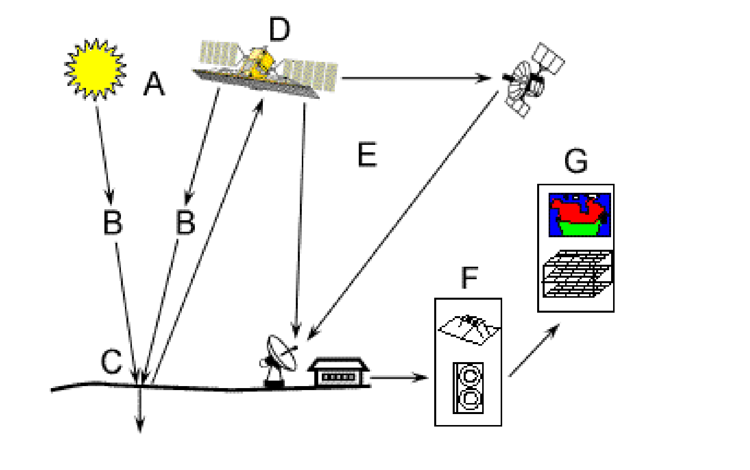
Types of remote sensing ?

Passive sensors gather natural radiation that is emitted or reflected by the object or surrounding areas. Reflected sunlight is the most common source of radiation measured by passive sensors.



Unit 4.6: Remote sensing

A. the Sun: energy source
C. target
D. sensor: receiving and/or energy source
E. transmission, reception, and pre-processing
F. processing, interpretation and analysis
G. analysis and application



Unit 4.6: Remote sensing

Components of remote sensing ?

1. **Energy Source**

- Passive System: sun, irradiance from earth's materials;
- Active System: irradiance from artificially generated energy sources such as radar.

2. **Platforms:** (Vehicle to carry the sensor) (truck, aircraft, space shuttle, satellite, etc.)

3. **Sensors:** (Device to detect electro-magnetic radiation) (camera, scanner, etc.) universities, etc.).

Unit 4.6: Remote sensing

Components of remote sensing ?

4. Detectors: (Handling signal data) (photographic, digital, etc.)

5. Processing:(Handling Signal data) (photographic, digital etc.)

6. Institutionalisation: (Organisation for execution at all stages of remote-sensing technology: international and national orrganisations, centres, universities, etc.).

Unit 4.6: GPS

What is GPS?

- The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense.
- GPS was originally intended for military applications, but in the 1980s, the government made the system available for civilian use.

Unit 4.6: GPS

What is GPS?

- GPS works in any weather conditions, anywhere in the world, 24 hours a day. There are no subscription fees or setup charges to use GPS.

Unit 4.6: GPS

How it works ?

- GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth.
- GPS receivers take this information and use triangulation to calculate the user's exact location.
- Essentially, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received.

Unit 4.6: GPS

How it works ?

- The time difference tells the GPS receiver how far away the satellite is.
- Now, with distance measurements from a few more satellites, the receiver can determine the user's position and display it on the unit's electronic map.
- A GPS receiver must be locked on to the signal of at least three satellites to calculate a 2D position (latitude and longitude) and track movement.

Unit 4.6: GPS

How it works ?

- With four or more satellites in view, the receiver can determine the user's 3D position (latitude, longitude and altitude).

- Once the user's position has been determined, the GPS unit can calculate other information, such as speed, bearing, track, trip distance, distance to destination, sunrise and sunset time and more.

Unit 4.6: GPS

The GPS satellite system ?

- The 24 satellites that make up the GPS space segment are orbiting the earth about 12,000 miles above us.
- They are constantly moving, making two complete orbits in less than 24 hours.
- These satellites are travelling at speeds of roughly 7,000 miles an hour.

Unit 4.6: GPS

The GPS satellite system ?

Unit 4.6: GPS

The GPS satellite system ?

- GPS satellites are powered by solar energy.
- They have backup batteries on board to keep them running in the event of a solar eclipse, when there's no solar power.
- Small rocket boosters on each satellite keep them flying in the correct path.

Unit 4.6: GPS

Some other interesting facts about the GPS satellites.

GPS satellites (also called NAVSTAR, the official U.S. Department of Defense name for GPS):

- The first GPS satellite was launched in 1978.
- A full constellation of 24 satellites was achieved in 1994.
- Each satellite is built to last about 10 years. Replacements are constantly being built and launched into orbit.

Unit 4.6: GPS

Some other interesting facts about the GPS satellites.

- A GPS satellite weighs approximately 2,000 pounds and is about 17 feet across with the solar panels extended.
- Transmitter power is only 50 watts or less.

Unit 5: Spatial Analysis and Visualization

What is Spatial Database system ?

Types of Spatial Relationships ?

What is Spatial Analysis or classification of different function of Spatial Data Types ?

What is Spatial Database system/design ?

The spatial database design reflects following view:

1. Spatial database system is a full-fledged database system with additional capabilities for handling spatial data.
2. It offers spatial data types (SDTs) in its data model and query language.

What is Spatial Database system/design ?

- Spatial information is in practice always connected with “non-spatial” (e.g. alphanumeric) data.

- It supports spatial data types in its implementation, providing at least spatial indexing and efficient algorithms for spatial join.

What is Spatial Database system/design ?

- Spatial data types, e.g. POINT, LINE, REGION, provide a fundamental abstraction for modeling the structure of geometric entities in space as well as their *relationships* (*l intersects r*), *properties* (*area*(*r*) > 1000), and *operations* (*intersection*(*l*, *r*) – the part of *l* lying within *r*).

What is Spatial Database system/design ?

- A system must at least be able to retrieve from a large collection of objects in some space those lying within a particular area without scanning the whole set.
- Therefore spatial indexing is mandatory.

Unit 5: Spatial Analysis and Visualization

Spatial Data Types/Algebra?

- Systems of spatial data types, or spatial algebras, can capture the fundamental abstractions for Point, line and region together with relationships between them and operations for composition (e.g. forming the intersection of regions).

Unit 5: Spatial Analysis and Visualization

Spatial Relationships?

- *Topological relationships*, such as inside, intersects, adjacent, overlap are invariant under topological transformations like translation, scaling, and rotation.
- *Direction relationships*, for example, above, below, or north_of, southwest_of, etc.
- *Metric relationships*, e.g. "distance < 100".

Unit 5: Spatial Analysis and Visualization

Spatial Analysis:?

- The analysis functions of a GIS use the spatial and non-spatial attributes of the data in a spatial database to provide answers to users questions.
- GIS functions are used for maintenance of the data, and for analysing the data in order to infer information from it.

Unit 5: Spatial Analysis and Visualization

Spatial Analysis:?

- So Spatial Analysis of data can be defined as computing new information that provides new insight from the existing, stored spatial data.
- The exact nature of the analysis will depend on the application requirement, but computations and analytical functions operate on both spatial and non-spatial data.

Unit 5: Spatial Analysis and Visualization

Classification of analytical GIS Capabilities

1. Retrieval, Classification and Measurement function
2. Overlay functions
3. Neighbouring functions
4. Connectivity functions

Classification of analytical GIS Capabilities?

The analytical functions of a GIS are as:

1. Retrieval, Classification and measurement functions:

All functions in this category are performed on a single (vector or raster) data layer, often using associated attribute data.

Classification of analytical GIS Capabilities?

- Retrieval functions allow the selective search of data. We might thus retrieve all agricultural fields where potato is grown.
- Generalization is a function that joins different classes of objects with common characteristics to a higher level (Generalized) class.

Classification of analytical GIS Capabilities?

- Classification allows the assignment of features to a class on the basis of attribute values or attribute ranges. On the basis of reflectance characteristics found in a raster, pixels may be classified as representing different crops, such as potato and maize.

Unit 5: Spatial Analysis and Visualization

Classification of analytical GIS Capabilities?

- Measurement functions allow the calculation of distances, length, or areas.

Classification of analytical GIS Capabilities?

2. Overlay functions:

These belong to the most frequent used functions in a GIS application. They allow the combination of two or more spatial data layers comparing them position by position, and treating areas of overlap – and of non-overlap- in distinct ways.

Classification of analytical GIS Capabilities?

2. Overlay functions:

Example: Union, intersection and complement functions are used to select the layer from the many layers. ie. Select the field (soils) where potato or maize is the crop (Union function)

Classification of analytical GIS Capabilities?

3. Neighbouring functions:

Whereas overlays combine features at the same location, neighbourhood functions evaluate the characteristics of an area surrounding a feature’s location. A neighbourhood functions scan the neighbourhood of the given feature(s), and performs a computation on it.

Classification of analytical GIS Capabilities?

4. Connectivity functions:

These function work on the basis of networks, including road networks, water courses in coastal zones, and communication lines in mobile telephony. These networks represent spatial linkages between features.

Classification of analytical GIS Capabilities?

4. Connectivity functions:

Example:

Analysis of such networks may entail shortest path computations (in term of distance or travel time) between two points in a network for routing purposes.

Today's Class Objectives:

SN	Descriptions
1	SDI Concepts and its current trend
2	What is a SDI?
3	Components of SDIs
4	
5	
6	
7	
8	

Unit 6: Introduction to Spatial Data Infrastructure

- **What is a SDI?**
- “The Global Spatial Data Infrastructure supports ready global access to geographic information. This is achieved through the coordinated actions of nations and organisations that promote awareness and implementation of complimentary policies, common standards and effective mechanisms for the development and availability of interoperable digital geographic data and technologies to support decision making at all scales for multiple purposes.”

Unit 6: Introduction to Spatial Data Infrastructure

- **What is a SDI?**
- "An SDI is a coordinated series of agreements on *technology standards*, *institutional arrangements*, and *policies* that enable the discovery and use of geospatial information by users and for purposes other than those it was created for."
- Another definition is "the technology, policies, standards, human resources, and related activities necessary to acquire, process, distribute, use, maintain, and preserve spatial data"

Unit 6: Introduction to Spatial Data Infrastructure

- **What is a SDI?**
- A spatial data infrastructure (SDI) is a data infrastructure implementing a framework of geographic data, metadata, users and tools that are interactively connected in order to use spatial data in an efficient and flexible way.

Unit 6: Introduction to Spatial Data Infrastructure

- **What is a SDI?**
- Some of the main principles are that data and metadata should not be managed centrally, but by the data originator and/or owner, and that tools and services connect via computer networks to the various sources.[3] A GIS is often the platform for deploying an individual node within an SDI. To achieve these objectives, good coordination between all the actors is necessary and the definition of standards is very important.

Unit 6: Introduction to Spatial Data Infrastructure

- **Over all Goal of SDI?**
- The goal of SDI is to reduce duplication of effort among agencies, improve quality and reduce costs related to geographic information, to make geographic data more accessible to the public, to increase the benefits of using available data, and to establish key partnerships with states, counties, cities, academia and the private sector to increase data availability.

Unit 6: Introduction to Spatial Data Infrastructure

- **Over all Goal of SDI?**
- Sharing geographic data among all users could produce significant savings for data collection and use and enhance decision making.

Unit 6: Introduction to Spatial Data Infrastructure

- **Over all Goal of SDI?**
- The NSDI has come to be seen as the technology, policies, criteria, standards and people necessary to promote geospatial data sharing throughout all levels of government, the private and non-profit sectors, and academia.

Unit 6: Introduction to Spatial Data Infrastructure

- **What is a SDI?**

- At the European side, INSPIRE is a European Commission initiative to build a European SDI beyond national boundaries and ultimately the United Nations Spatial Data Infrastructure (UNSDI) will do the same for over 30 UN Funds, Programmes, Specialized Agencies and member countries.

Unit 6: Introduction to Spatial Data Infrastructure

- **Software components?**
- A SDI should enable the discovery and delivery of spatial data from a data repository, via a spatial service provider, to a user. As mentioned earlier it is often wished that the data provider is able to update spatial data stored in a repository. Hence, the basic software components of an SDI are:

Unit 6: Introduction to Spatial Data Infrastructure

- **Software components?**

- Software client - to display, query, and analyse spatial data (this could be a browser or a desktop GIS)
- Catalogue service - for the discovery, browsing, and querying of metadata or spatial services, spatial datasets and other resources
- Spatial data service - allowing the delivery of the data via the Internet

Unit 6: Introduction to Spatial Data Infrastructure

- **Software components?**
- Processing services - such as datum and projection transformations
- (Spatial) data repository - to store data, e.g., a spatial database
- GIS software (client or desktop) - to create and update spatial data

Unit 6: Introduction to Spatial Data Infrastructure

- **Critical factors around SDIs ?**

Unit 6: Introduction to Spatial Data Infrastructure

- **The concept of metadata and clearing house?**