United Nations Institute for Training and Research

UNOSAT

# Recap:
# Geospatial Information Technology for Drought Risk Management

**Trainer**
Khaled Mashfiq

2 / April / 2018

Training Module A1 Session 1

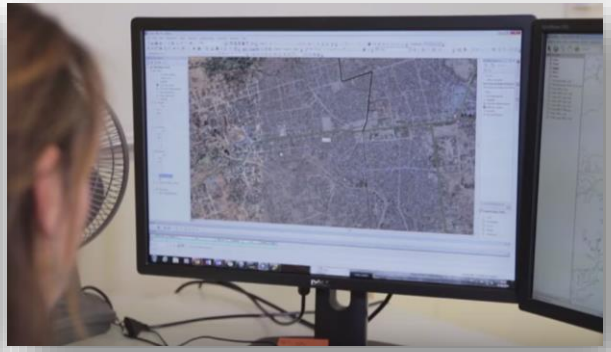
*Advanced Application of Geospatial Information technology for Decision Support related to Disaster Risk Reduction*

*Phnom Penh, Cambodia*
*2 – 6 April, 2018*

*In partnership with* UNITED NATIONS ESCAP Economic and Social Commission for Asia and the Pacific

# UNOSAT

- An operational programme of UNITAR serving UN, international organizations and governments
- Fully dedicated to satellite imagery analysis, applications of geospatial information technologies, training and capacity development
- Operational since 2001
- Currently 30 employees
- Presence: Geneva (hosted at CERN), Bangkok, Nairobi, N'Djamena



# UNOSAT's Main Activities

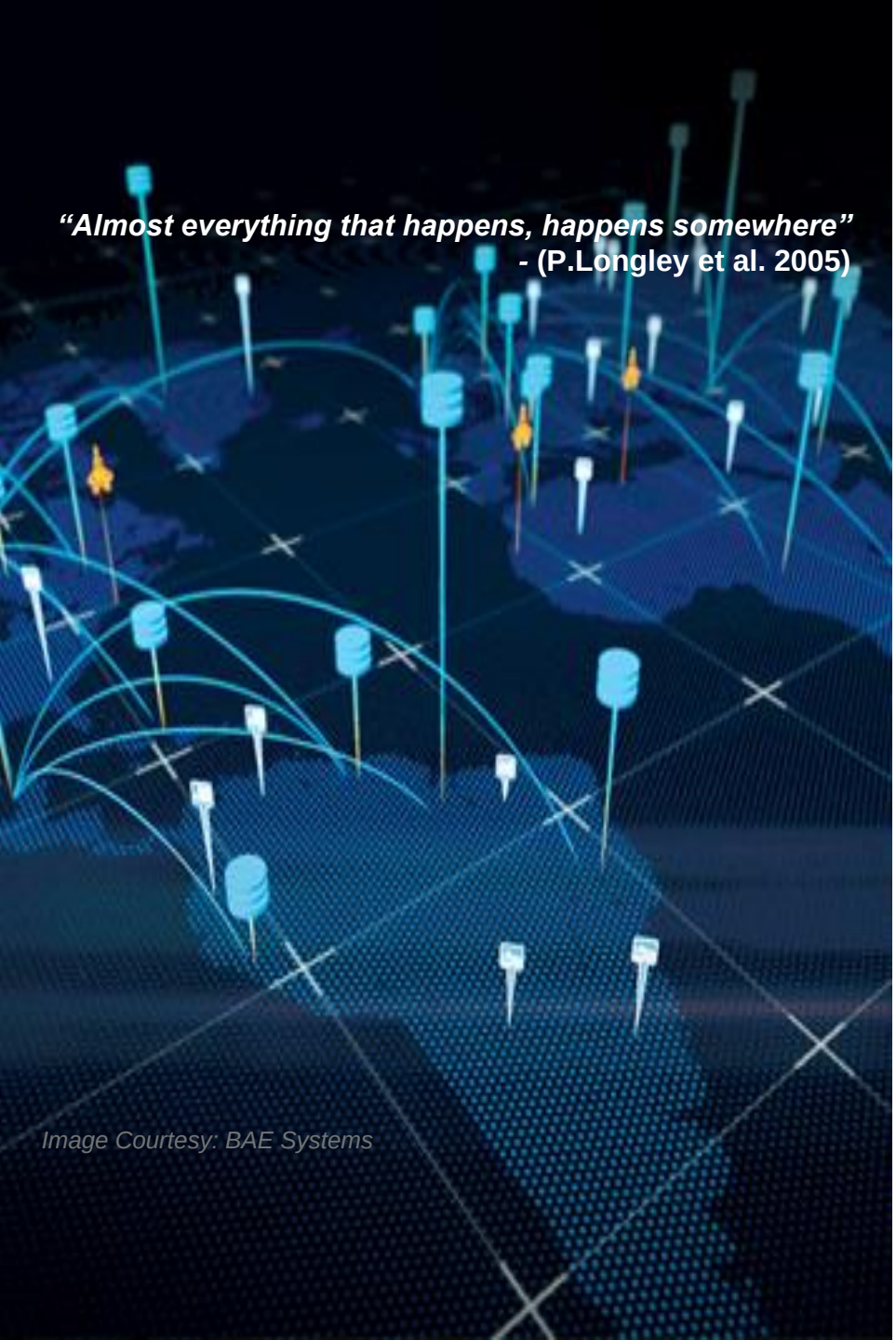
MAPPING

Analysis, Research and Innovation

TRAINING AND CAPACITY DEVELOPMENT

Hands on, National and Regional level, Technical Backstopping

Knowledge Transfer




# Everything Spatial?

Most human activities and natural phenomenon are location bound.

Ex. Driving Car, Building House, Path of a Cyclone.

Using location with information helps to articulate complete operational picture

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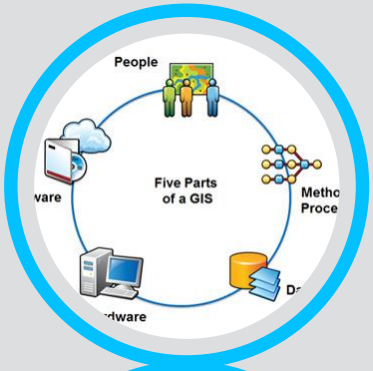
# What is Geospatial Information Technology?

Geospatial Information Technology is widely recognized as the science and technology that utilizes spatial information located on earth's surface.

Geographic Information Systems (GIS), Remote Sensing (RS), Global Positioning System (GPS) are three main types of Geospatial Information Technology that we use today.

**Geographic Information Systems (GIS)**




**Remote Sensing (RS)**

**Global Positioning System (GPS)**

*Image Courtesy: U-Spy Canada, Oregon University, NSF, ESRI, AAAS*

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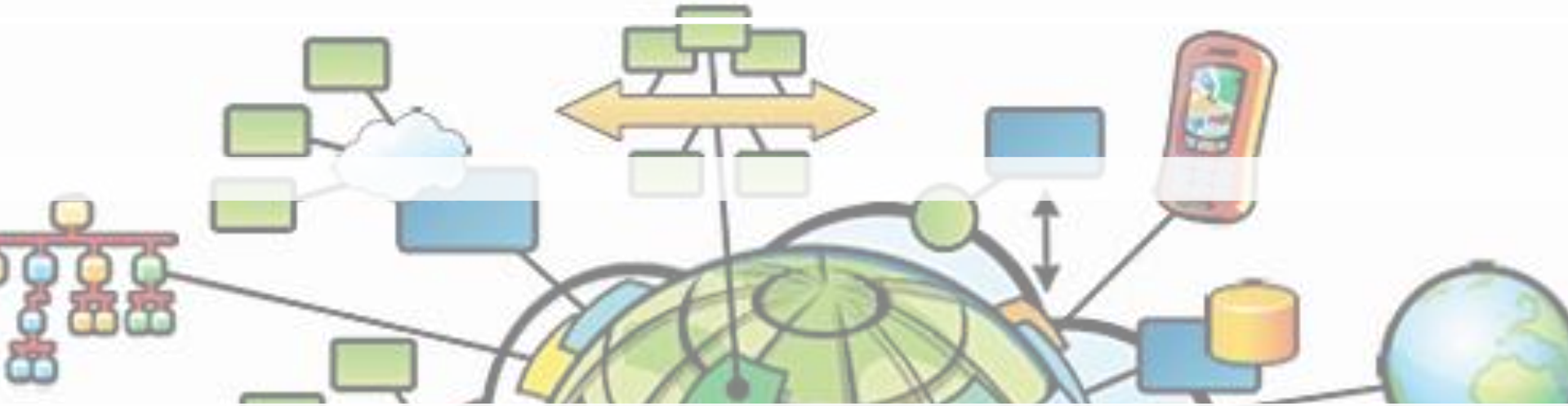
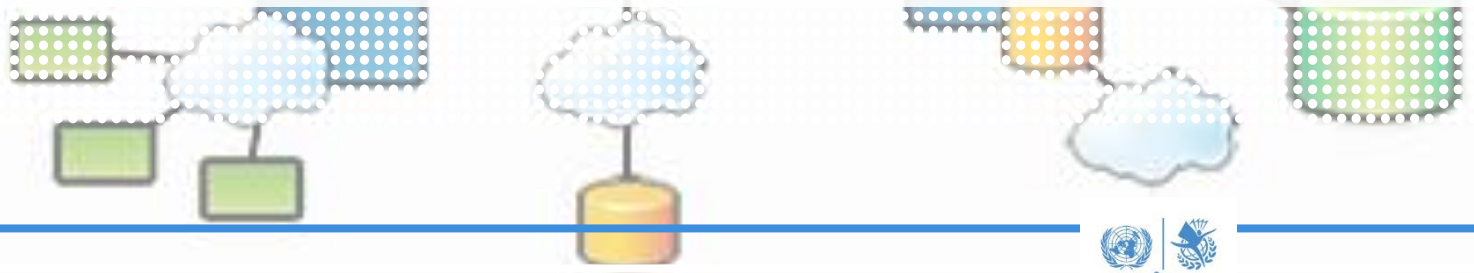


# PART A : Intro to GIS



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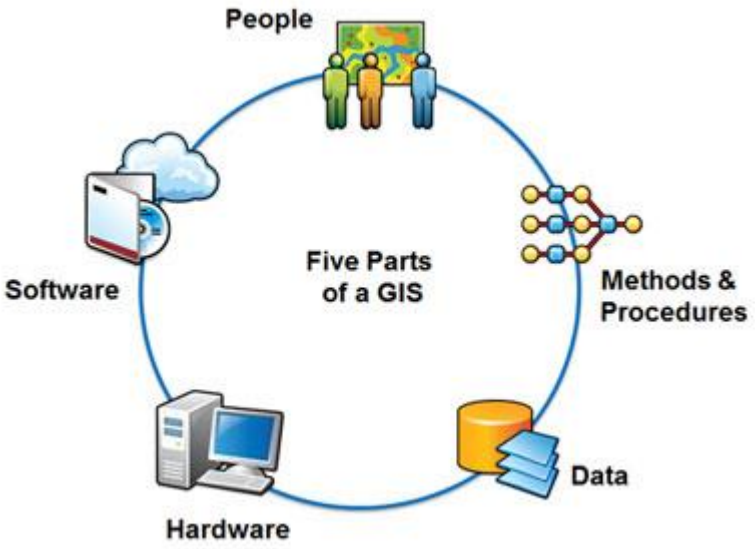
- GIS is a computation system capable of **assembling**, **storing**, **manipulating**, and **displaying** geographically referenced information (that is data identified according to their locations).




***The total GIS***

*Practitioners also regard the total GIS as including operating personnel and the data that go into the system.*

"Almost everything that happens, happens somewhere"

("P. Longley")

- Advantages of Geographic Information Systems:
  - Better decision making through spatial data analysis
  - Greater Efficiency reducing Cost, Time, Resource
  - Improved communication though mapping (paper/web)

*GIS can answer all the basic question regarding to any problem-*

*What? Where? When? Why? Who?*

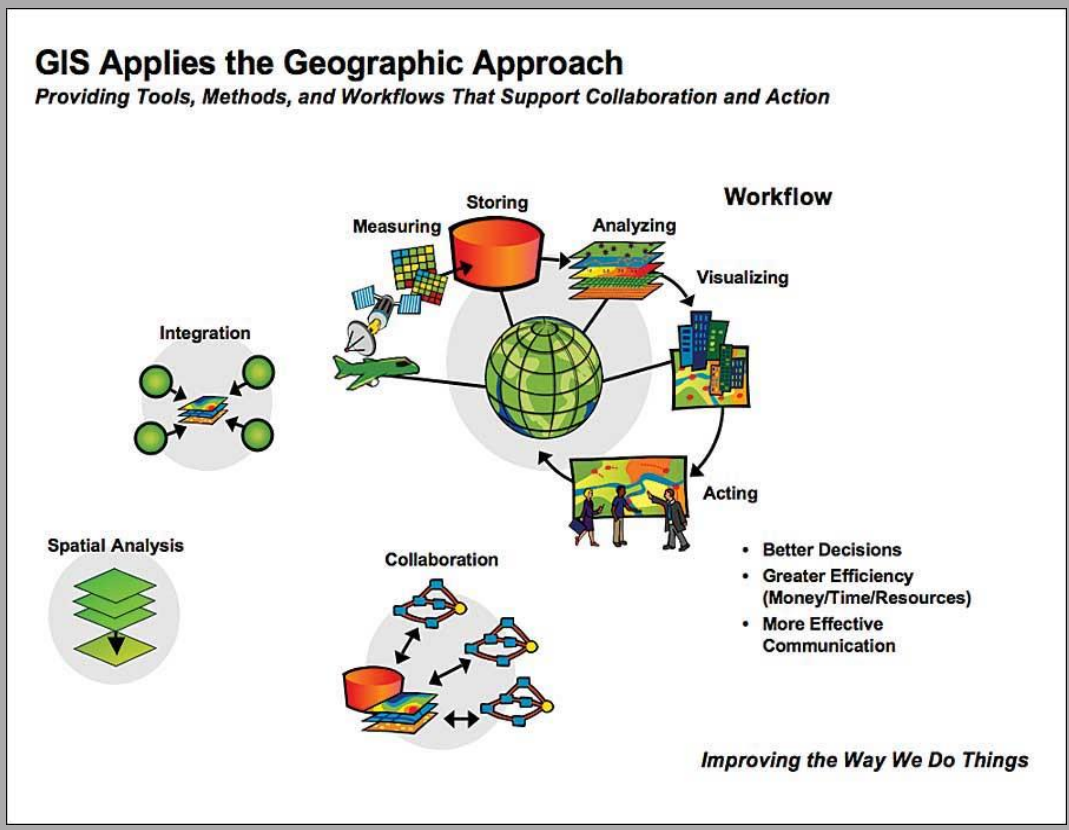





*Image Courtesy:* GIS—The Geographic Approach, *ESRI*

# Where GIS is used?

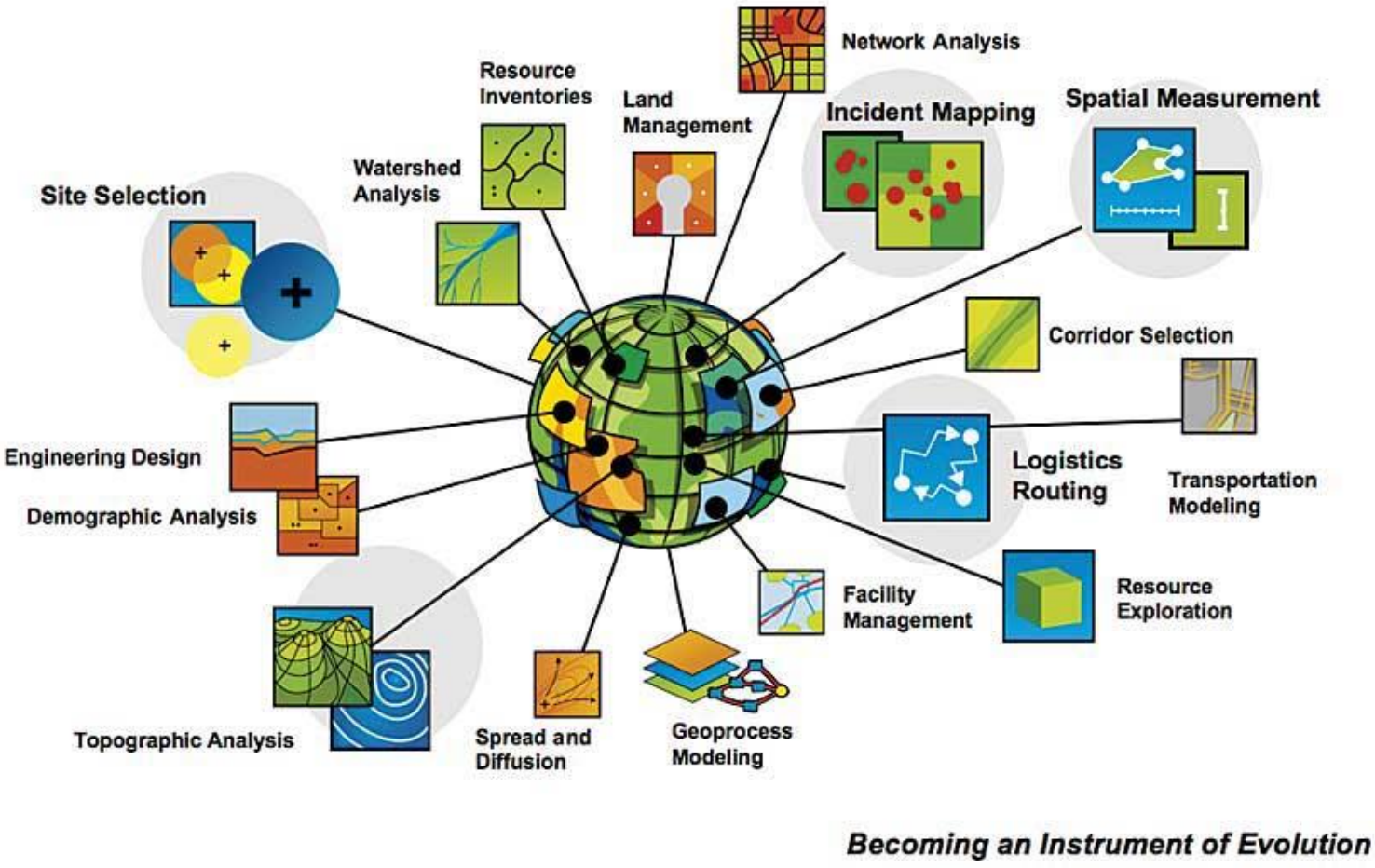





*Image Courtesy:* GIS—The Geographic Approach, *ESRI*

# Where GIS is used?

- **Geology, Natural Resources**
  - Geological mapping, mining, water resources, costal zone management, etc..
- **Agriculture**
  - Land use and rural planning, water and irrigation management , precise agriculture (optimizing agricultural production)
- **Environment**
  - Environmental monitoring and management
- **Forestry**
  - Forest management, harvesting, reforestation
- **Disaster risk management**
  - Vulnerability, Hazard, Risk Assessment
  - Preparedness, relief/emergency response, recovery, reconstruction
- **Navigation**
  - Aerial, marine, terrestrial transportation
- **Public services**
  - Urban and territorial planning, municipal facilities inventory: water, oil, electric power, sewer, transportation network
- **Epidemiology and health**
  - Mapping diseases and spatial epidemiology analysis (link to human and environmental factors)
- **Archeology**
  - Archaeology and world heritage mapping, spatial and temporal GIS modeling
- **Social studies**
  - Demographic analysis and mapping
- **Tourism**
  - Tourist's travel plans, itinerary mapping, local economy studies
- **Market studies**
  - Market and sale performance analysis, logistic, good delivery and storage

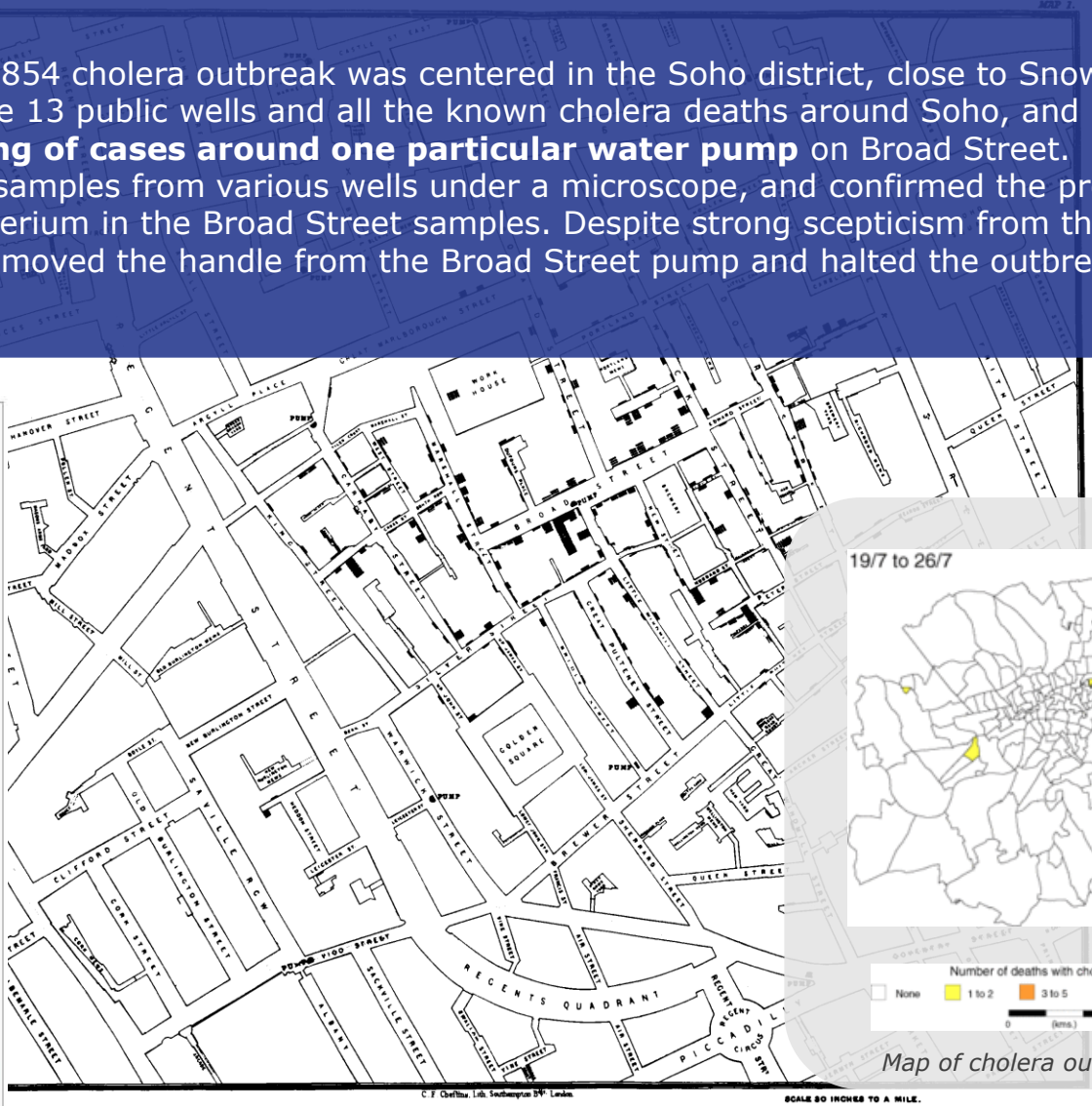
# The First Use of GIS -1854 Broad Street cholera outbreak

The September 1854 cholera outbreak was centered in the Soho district, close to Snow's house. Snow mapped the 13 public wells and all the known cholera deaths around Soho, and **noted the spatial clustering of cases around one particular water pump** on Broad Street. He examined water samples from various wells under a microscope, and confirmed the presence of an unknown bacterium in the Broad Street samples. Despite strong scepticism from the local authorities, he removed the handle from the Broad Street pump and halted the outbreak.

**John Snow**

John Snow

| | |
|---|---|
| **Born** | 15 March 1813<br>York, England |
| **Died** | 16 June 1858 (aged 45)<br>London |
| **Citizenship** | United Kingdom |
| **Nationality** | English |
| **Fields** | Epidemiology |
| **Alma mater** | University of London |
| **Known for** | Anaesthesia, locating source of a cholera outbreak, thus establishing the link between this infection and water as its vector. |

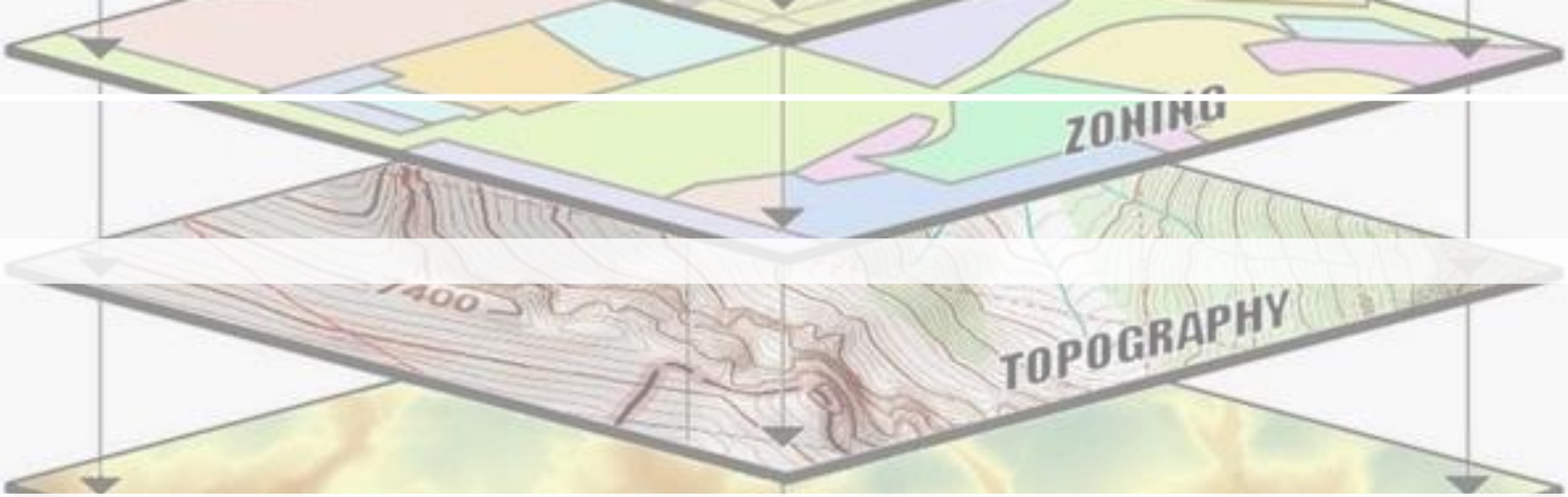






*Map of cholera outbreak in London*

*Original Mortality Dot Map Created By John Snow*




# PART B :Spatial Data Representation

The potential number of properties (attributes) of geographic objects can be extremely vast:

- Attributes can be physical, social, economic, demographic, environ., etc..

The more closely we look at the world, the more details it reveals:

- The geographic world is infinitely complex.

Humans have found ingenious ways of dealing with this problem:

- Many methods are used in GIS to create representations or **Data Models** as abstractions of real-world phenomena.

# Discrete Objects and Continuous Fields

- Discrete Objects: objects with well defined boundaries:

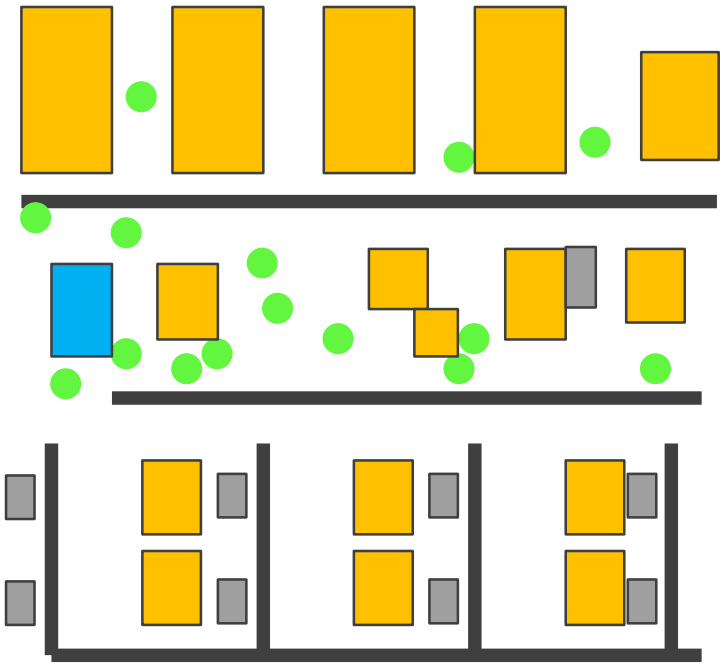
- Points, lines and areas
- Countable
- Likely persistent through time

- Continuous Fields: properties that vary continuously over space:

- Value is function of location (single value at any point)
- Property can be of any attribute type (slope, gradient, peak, soil moisture, pH, water depth, temperature, etc..)

# Vector Data Model

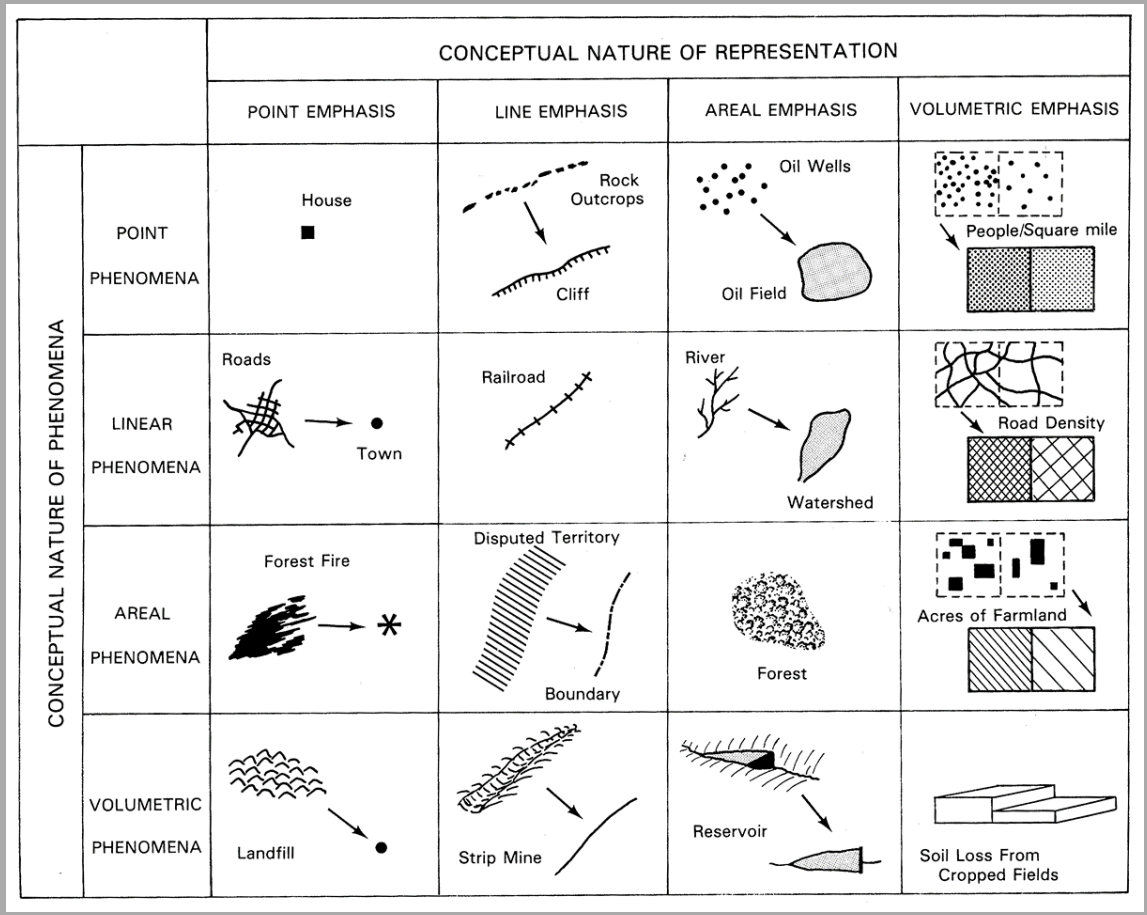
- Used to **represent discrete objects** as points, lines, and areas
- Point locations recorded as coordinates (e.g. trees)
- Lines as polylines
  - Straight lines between points (e.g. roads)
- Areas as polygons
  - Straight lines between points, connecting back to the start (e.g. buildings)



# Which Type of Vector Data model to use where?

**Point/Line/Polygon ??**

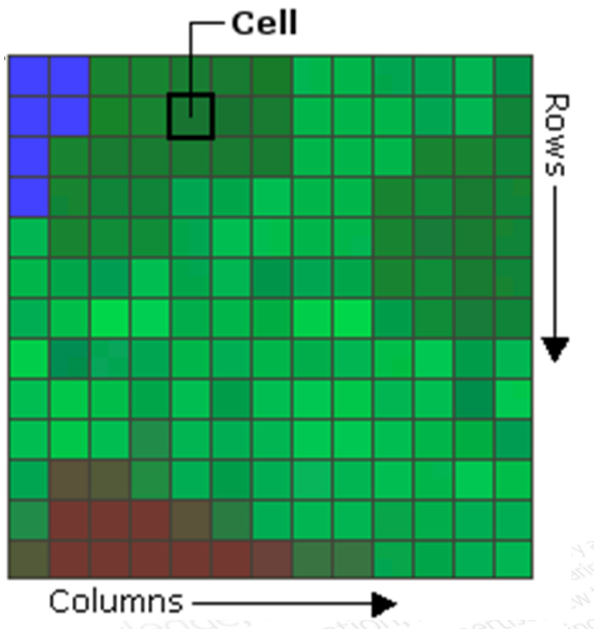
**Depends on what you want to show**
**or**
**what is the purpose of the visualization**



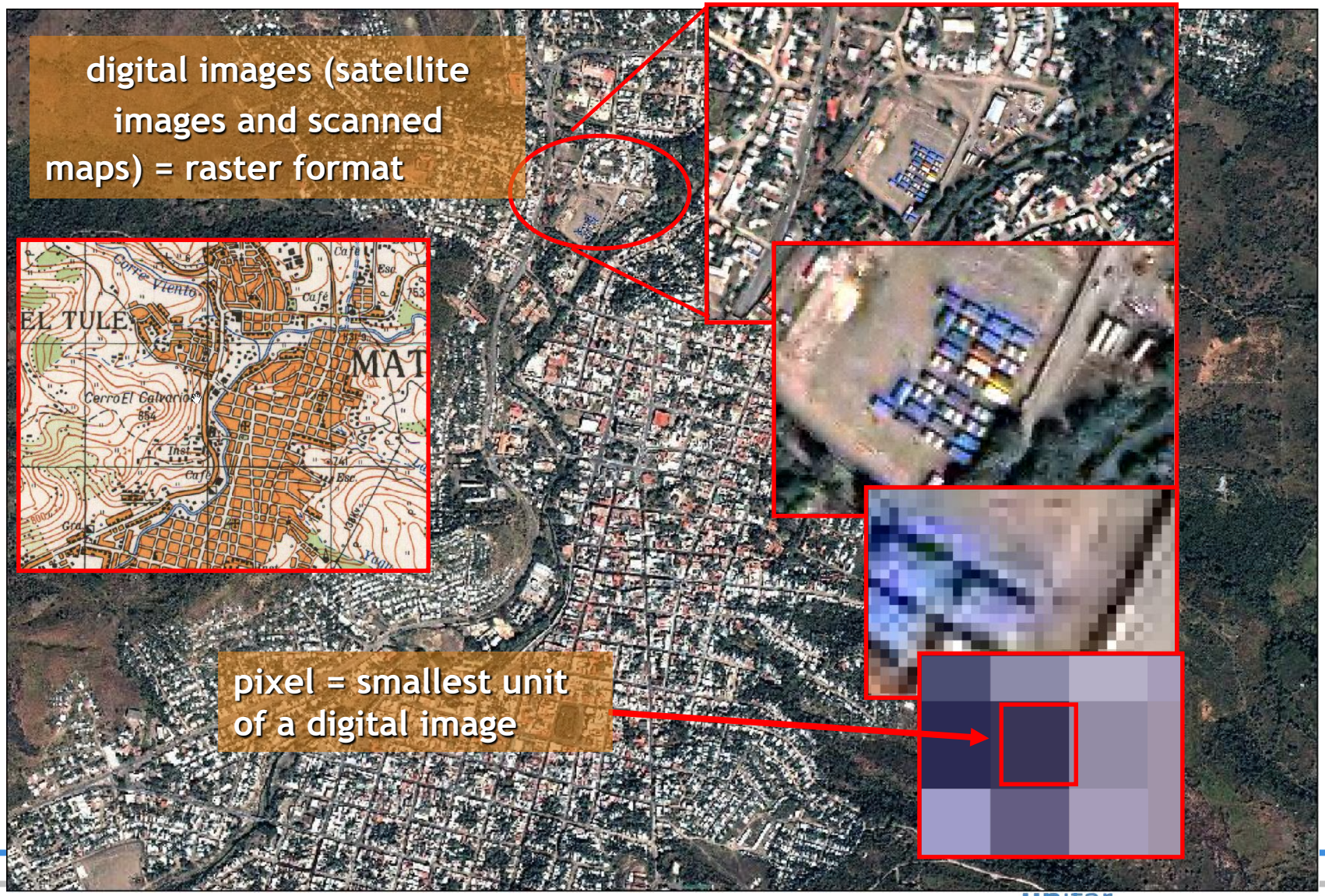
# Raster Data Model

Commonly used to **represent continuous fields**: real-world phenomena divided into square cells

- Whole geographic area is divided into grids of small cell/pixel
- One pixel has one value
- Represent discrete objects as collections of one or more cells
- Represent fields by assigning attribute values to cells

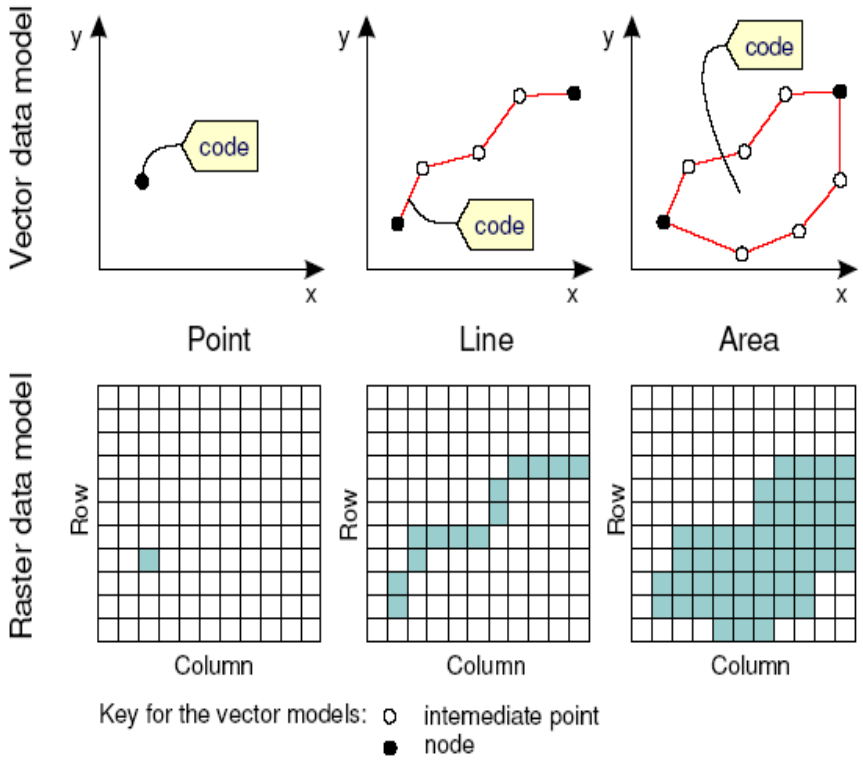


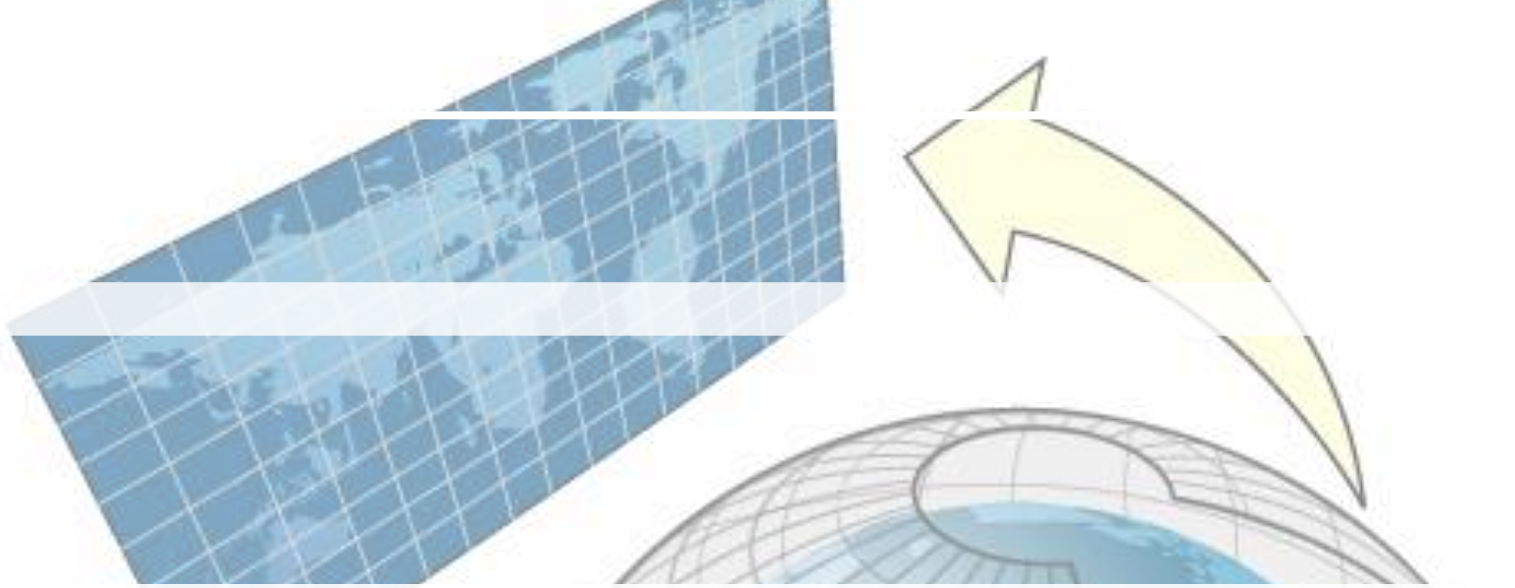
## Example Raster Data Model



# GIS data models - Vector Vs Raster

- Computing resource usage
  - Raster becomes more voluminous as cell size decreases, and vector data gets slow to process and display in any GIS with the increase of number of features
- Source of data
  - Remote sensing, elevation data come in raster format
  - Vector favored for administrative data
- Software
  - Some GIS better suited to raster, some to vector
- Purpose
  - Vector can be converted to raster vie-versa depending on the outcome and analysis needs





# PART C :Datum, Coordinate Systems and Map Projections

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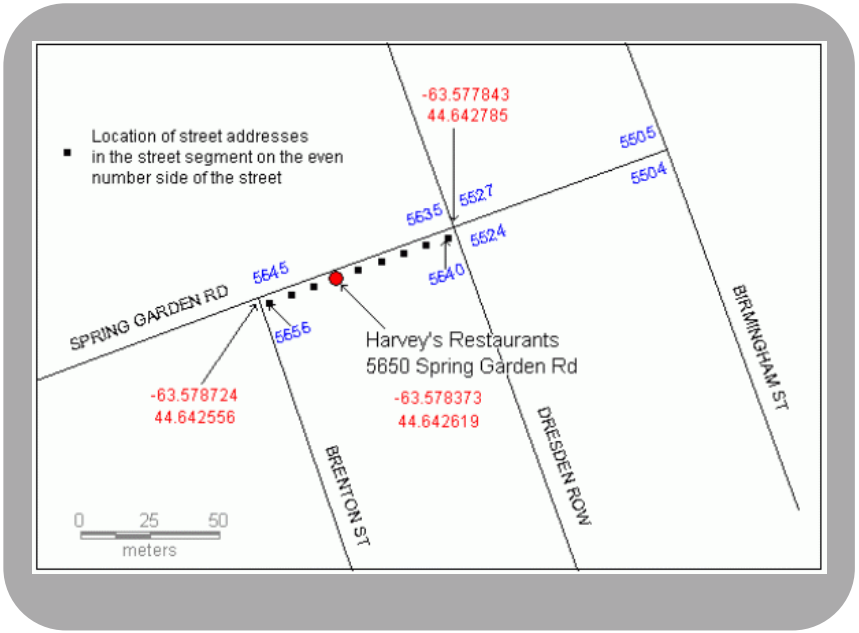
## Defines where the feature or object is located on earth

What is geolocation and how its done?

- **Geolocation** is the identification of the real-world geographic location of an object
- Most common way of representing location is using coordinates (Lat/Long, Northing/Easting)
- Can be done through geocoding (Address , street name)

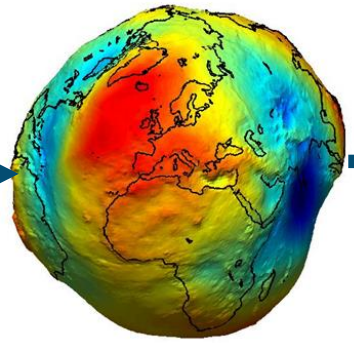



Geocoding also finds associated geographic coordinates (often expressed as latitude and longitude) from other geographic data. So we need to know how coordinates are generated to give a specific location on earth.

# ELLIPSOID

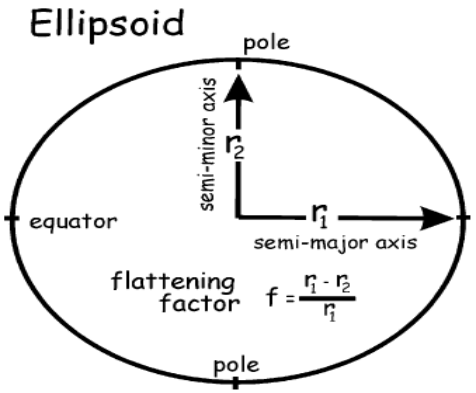
- Definition of coordinate systems is not a trivial issue due to the irregular nature of the Earth's shape!

Earth's shape in not a sphere



Geoid = It is the shape that the surface of the oceans would take under the influence of Earth's gravitation and rotation alone

Ellipsoid = mathematical model to describe 3D shape of the Earth




Ellipsoidal model of the Earth's shape (also referred to as spheroid)

***It is the hypothetical mean sea level surface!***

not suitable for measurements

suitable for measurements

# Datum

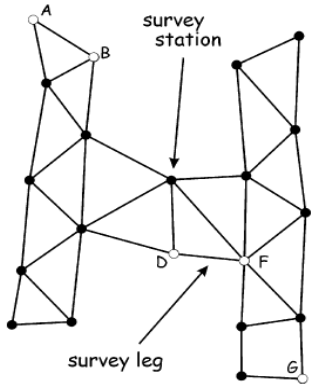
Many countries have established governmental bodies to make precise geodetic surveys and to define local or national geodetic datums (upon which topographic survey are based on).

- Geodetic datum :
  - Datum defines the size and shape of the ellipsoid and the origin (or position) and orientation (or direction) with respect to the Earth
  - specification of a given ellipsoid with a fixed position:

    ellipsoid parameters (a, b, r); geographic coordinates of the fundamental point (λ, ϕ, h) and angle between the fundamental point and another given point).

Geodetic survey to define datum locations

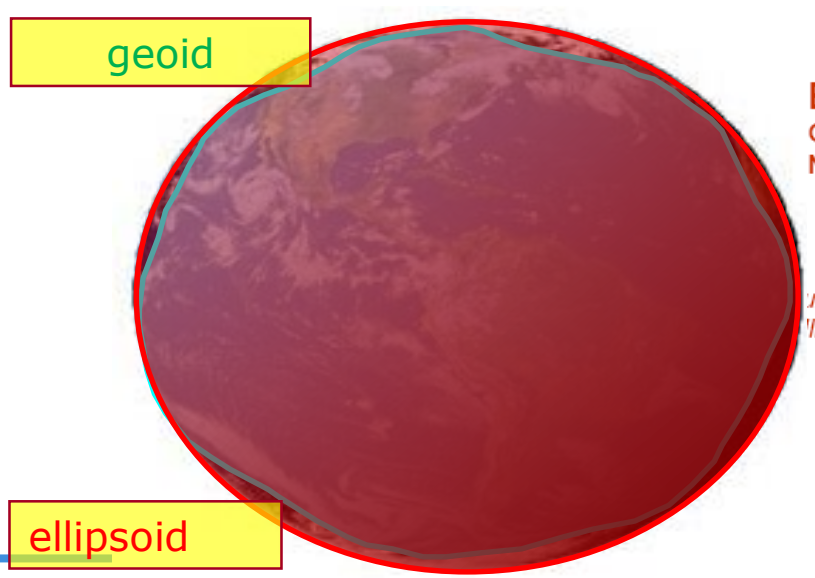

Geodetic point (benchmarks)

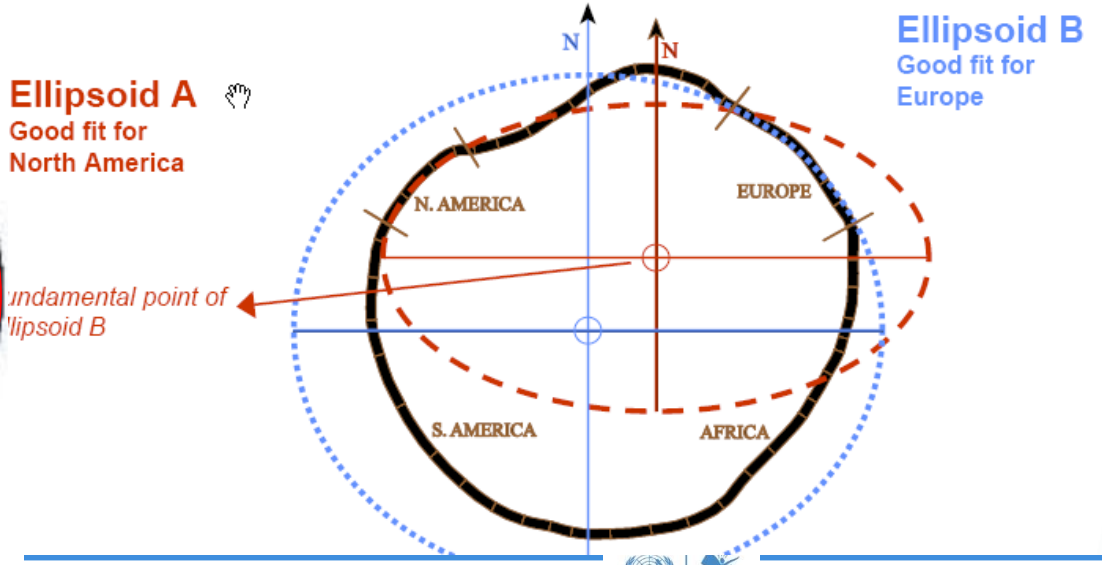



Triangulation survey network

# Local and global datum

- Different ellipsoids were adopted in various parts of the world to best fit the real shape of the Earth reflecting:
  - Different survey methods and measurement units used
  - Different local geoid's undulations



# EXAMPLES OF GLOBAL AND LOCAL DATUM

WGS 84
World
Geodetic
System
1984

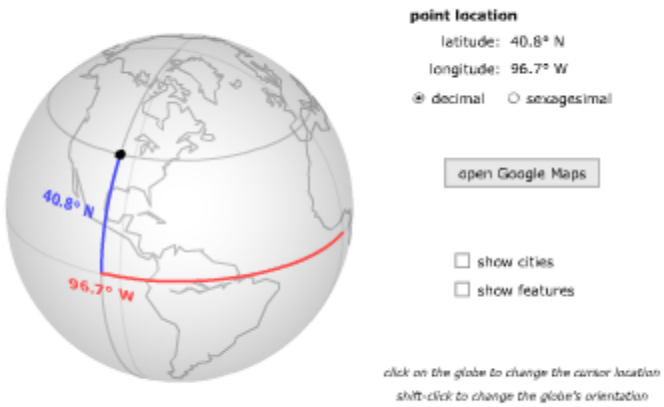
A global datum commonly used is the World Geodetic System (WGS84)


A Common datum used for East Africa is Arc1960

# Geographic Coordinates Systems

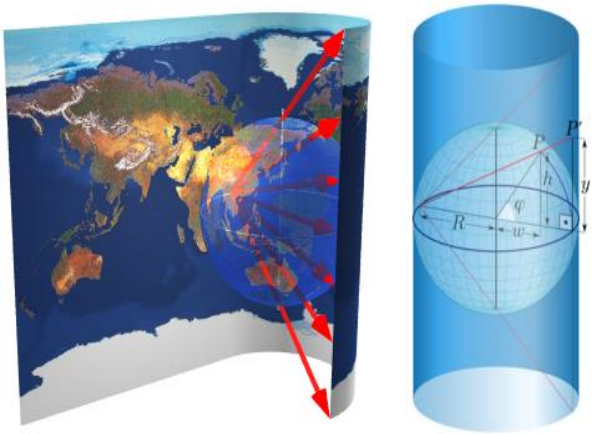
A coordinate grid as reference system is required to specify the position of features on the ellipsoidal surface.

- Within a geographic coordinate system, a point on the surface of the ellipsoid can be uniquely described by two variables:
  - The "latitude" (abbreviation: Lat., φ, or phi) of a point on the Earth's surface is the angle between the equatorial plane and the straight line that passes through that point and is normal to the surface of a reference ellipsoid which approximates the shape of the Earth
  - The "longitude" (abbreviation: Long., λ, or lambda) of a point on the Earth's surface is the angle east or west from a reference meridian to another meridian that passes through that point.




http://astro.unl.edu/classaction/animations/coordsmotion/longlat.html

# Projected Coordinates Systems

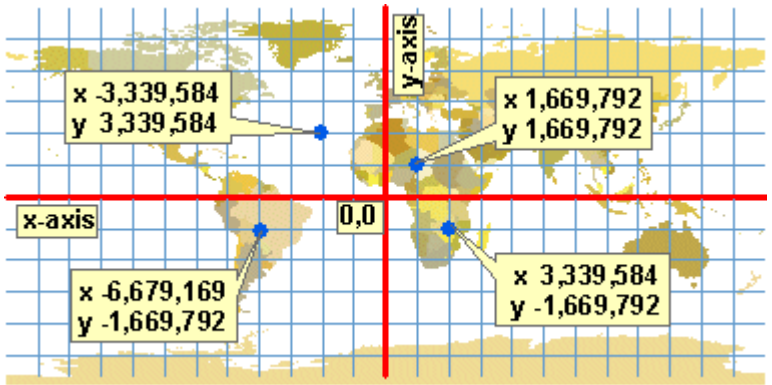


*A map projection uses mathematical formulas to convert geographic coordinates on the spherical globe to planar coordinates on a flat map.*

A projected coordinate system (PCS) is defined on a flat, two-dimensional surface which is generated through map projection.

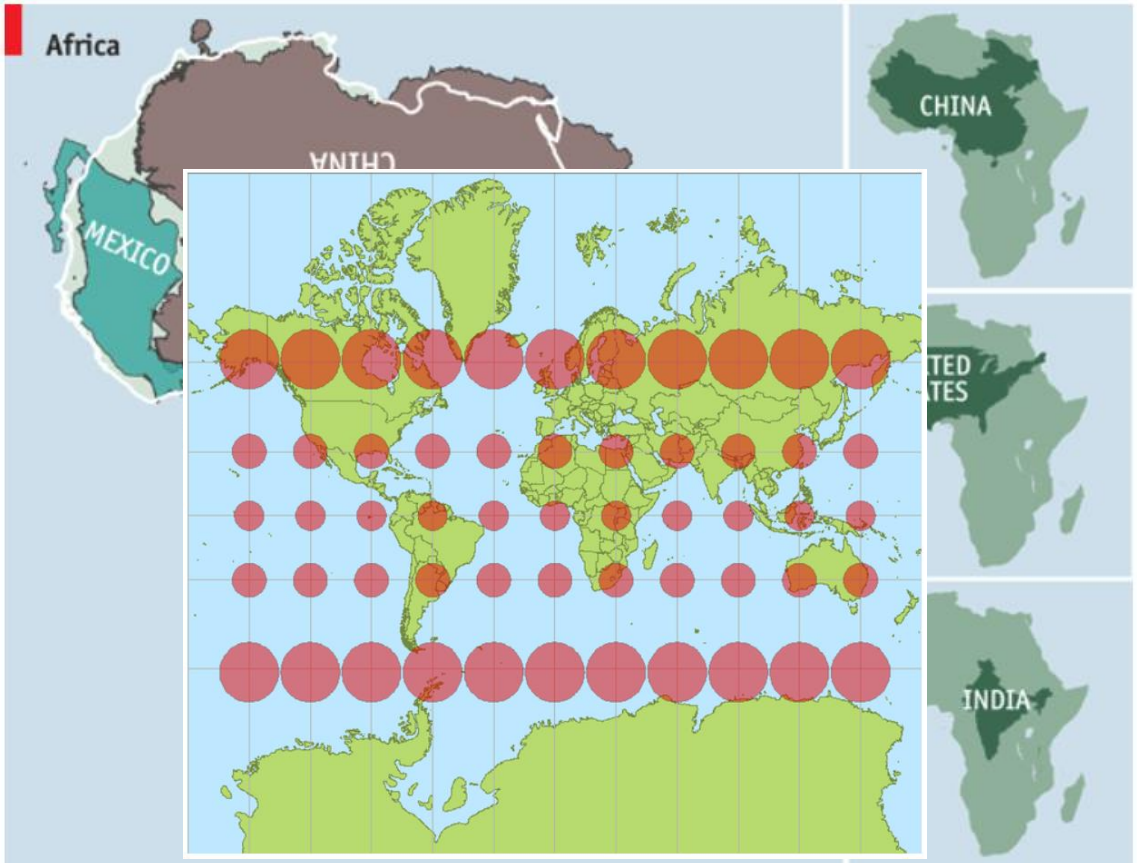
Projected coordinate systems, which are based on Cartesian coordinates, have an origin, an x and a y axis, and a unit for measuring distance.

- Why Geographic Coordinate System is not sufficient?
  - Not easy to make measurements (distances, areas, angles)
  - Most of the communication medium are 2D. Hence, the representation of geographic coordinate system in 2D space will give wrong idea about distance are and shape of objects



# Map Projections and Distortion

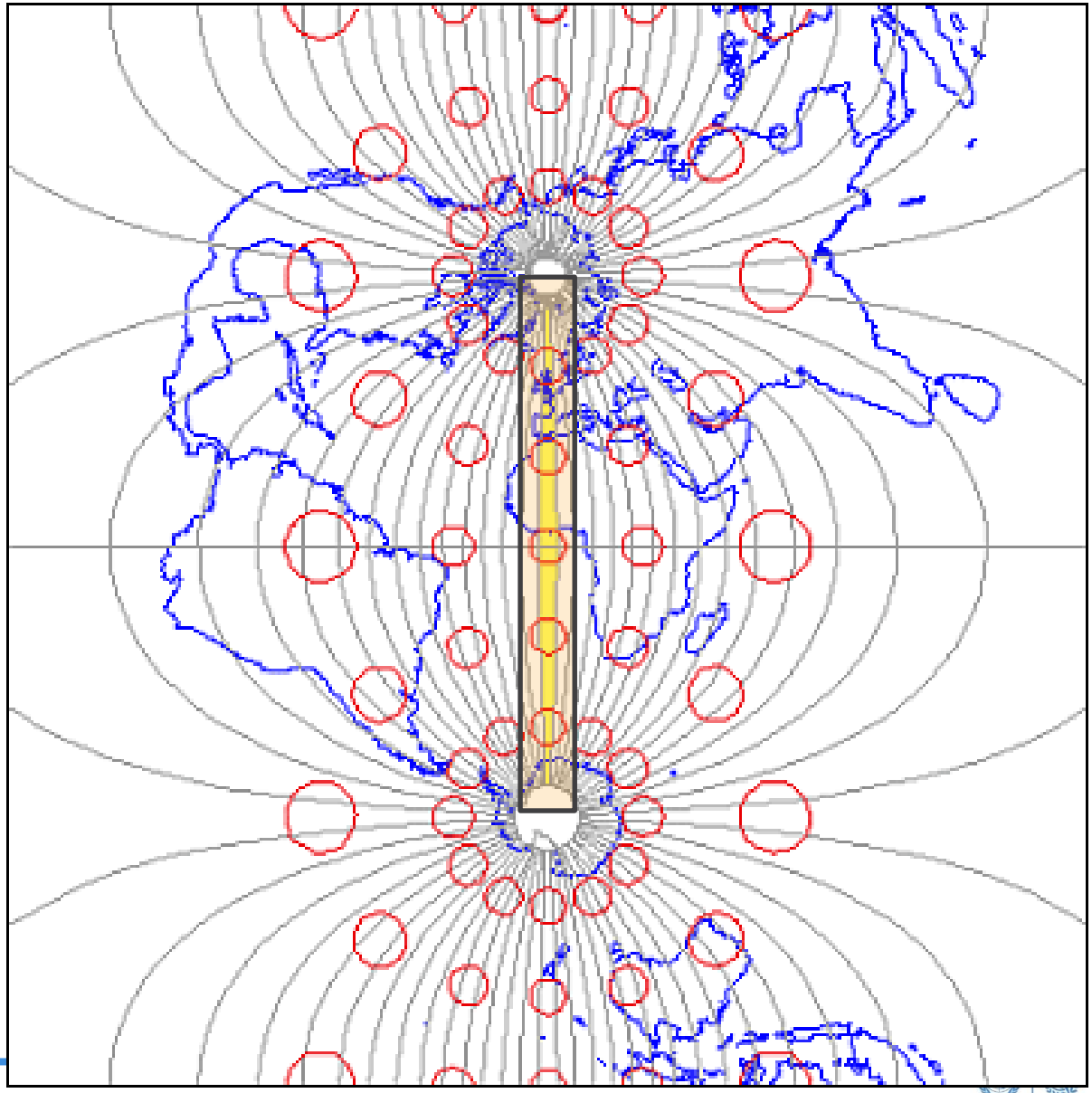
- A sphere cannot be represented on a flat plane without distortion, which means all map projections




; or scales, vice-versa!

*Under the Mercator projection Africa looks about the same size as Greenland, for example, even though it is in fact 14 times bigger!!*

# UTM DISTORTIONS



## Recommended projections for maps of continents and smaller areas

| Characteristics of Map Projections | | |
|---|---|---|
| **Projection Category** | **Properties** | **Common Uses** |
| Conformal | Preserves local shapes and angles | Topographic maps, navigation charts, weather maps |
| Equal Area | Preserves areas | Dot density maps, thematic maps |
| Equidistant | Preserves distance from one or two specified points to all other points on the map | Maps of airline distances, seismic maps showing distances from an earthquake epicenter |
| Azimuthal | All directions are true from a single specified point (usually the center) to all other points on the map | Navigation and route planning maps |
| Compromise | No point is completely distortion free; distortion is minimized near the center and along the equator | World maps |

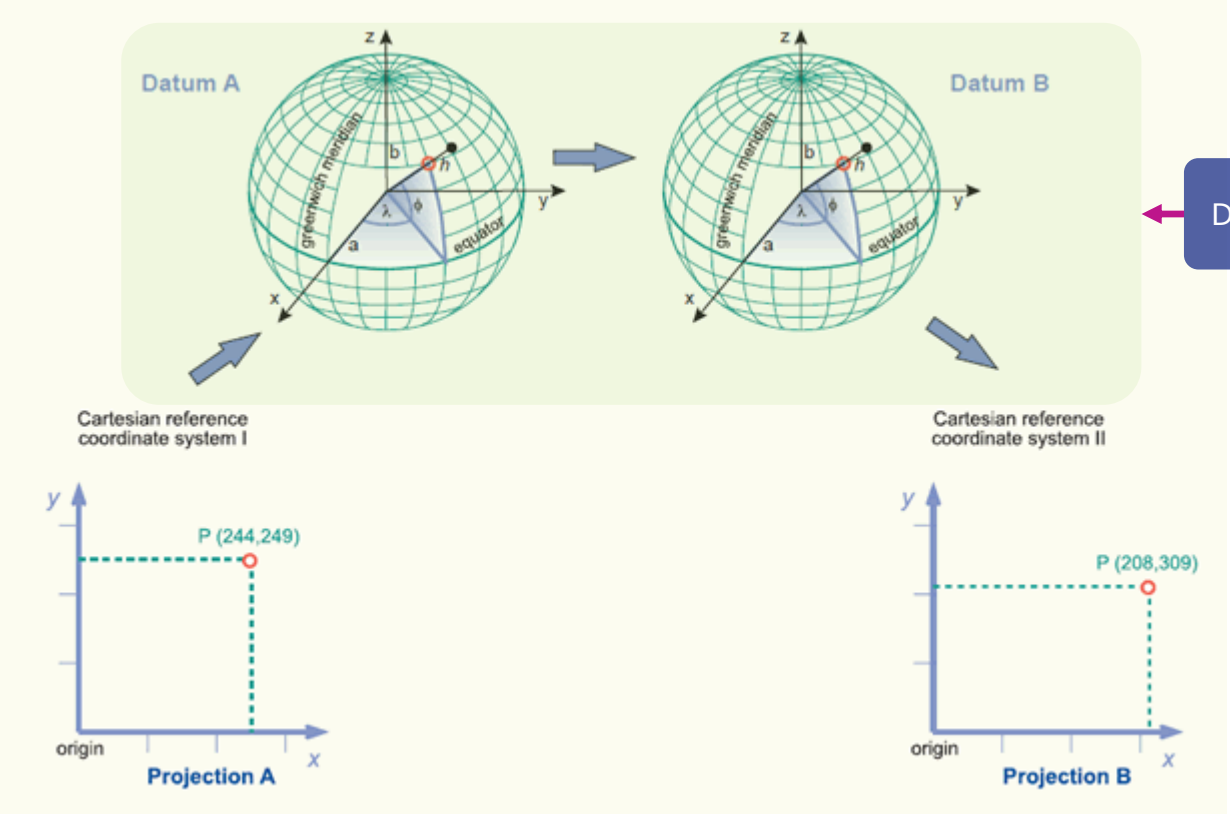
# Recommended projections for maps of continents and smaller areas

| Property | Area of interest extends mainly … | | | | | | |
|---|---|---|---|---|---|---|---|
| | **north to south** | **east to west …** | | **equally in all directions …** | | | **obliquely** |
| | | *along equator* | *away from equator* | *centered on pole* | *on or along equator* | *between pole and equator* | |
| Conformal | Transverse Mercator | Mercator | Lambert Conformal Conic | Stereographic (polar) | Stereographic (equatorial) | Stereographic (oblique) | Hotine Oblique Mercator |
| Equal-area | Sinusoidal | Cylindrical Equal Area | Albers Equal Area Conic | Lambert Azimuthal Equal Area (polar) | Lambert Azimuthal Equal Area (equatorial) | Lambert Azimuthal Equal Area (oblique) | |

| Property | Center of projection is … | | |
|---|---|---|---|
| | **at pole** | **at equator** | **between pole and equator** |
| Equidistant (true scale on meridians) | Azimuthal Equidistant (polar aspect) | Plate Carree | Equidistant Conic |

# IF I HAVE TWO DATA IN DIFFERENT DATUM?

Datum transformations are transformations from a 3D coordinate system (i.e. horizontal datum) into another 3D coordinate system.




Datum transformation

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}^B = \begin{bmatrix} c_x \\ c_y \\ c_z \end{bmatrix} + (1 + s \times 10^{-6}) \cdot \begin{bmatrix} 1 & -r_z & r_y \\ r_z & 1 & -r_x \\ -r_y & r_x & 1 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}^A$$

Example 7 parameter datum transformation

# PART D :Query in GIS

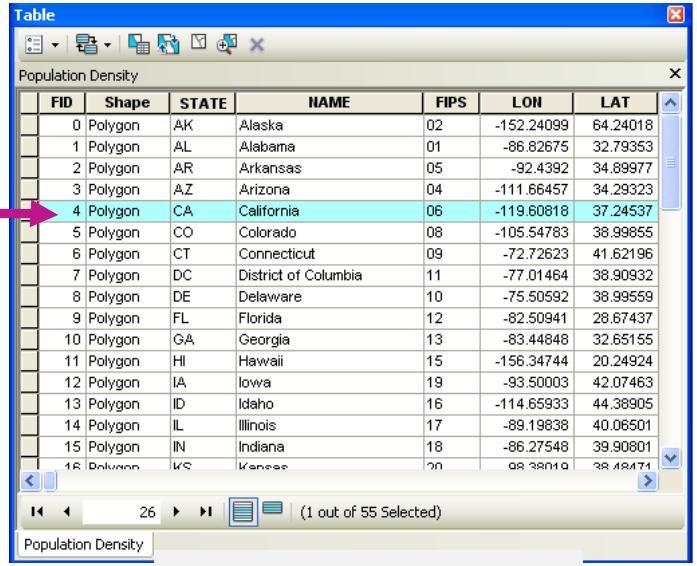
## Query can be utilised to extract required information in GIS

- There are two main kinds of query -
  - Non-Spatial Query ( Select by attribute)
  - Spatial Query ( Select by location)

The advantage of GIS database over a normal database is that, it can also select by the spatial relationship between objects

Geometry

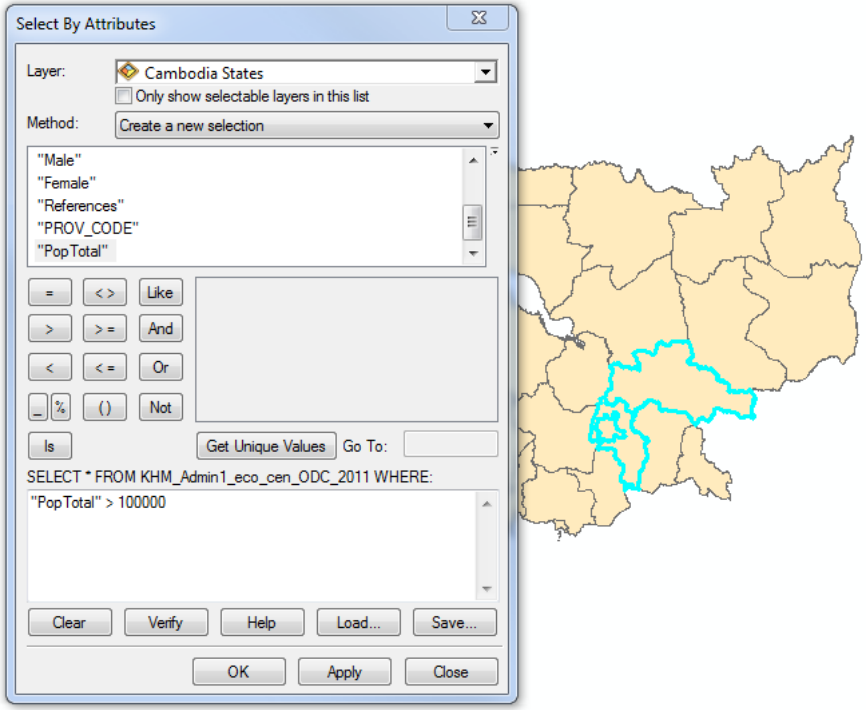
SPATIAL DATA




Attribute table

# Query by attributes

- Query by attributes are used in GIS to select a subset of features and table records based on their specified attribute.
- Select By Attributes allows you to provide a SQL query expression that is used to select features that match the selection criteria



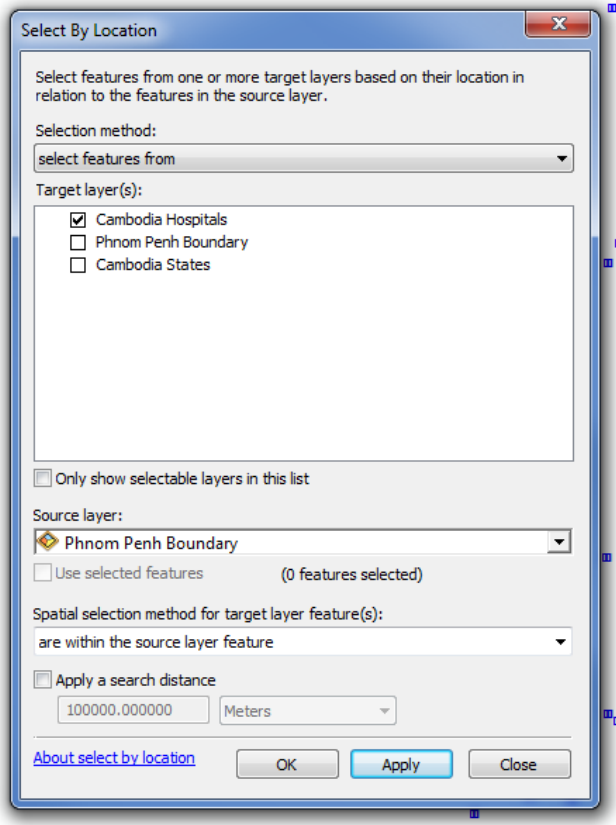

*SQL STATEMENT : "PopTotal" > 100000*

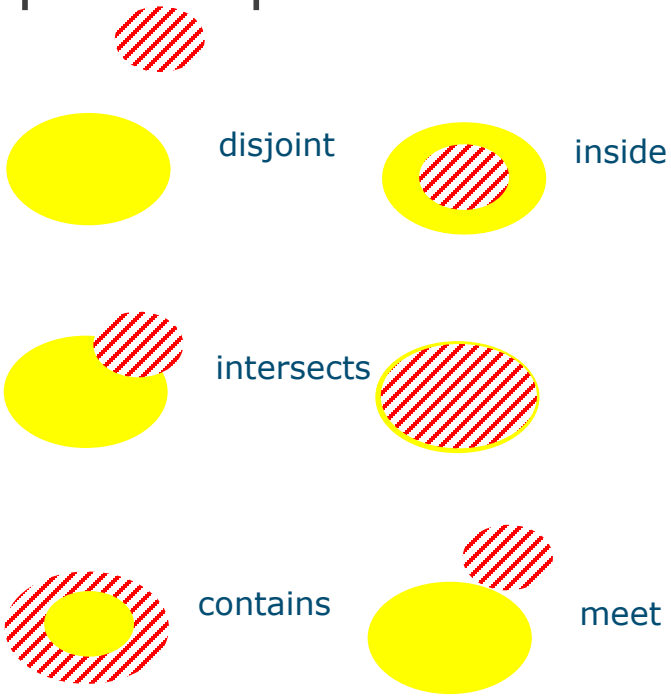
***Equivalent Human Instruction:***

***Find All the states having more than 100000 people***

# Query by location

- Query by attributes are used in GIS to select a
  n specific spatial



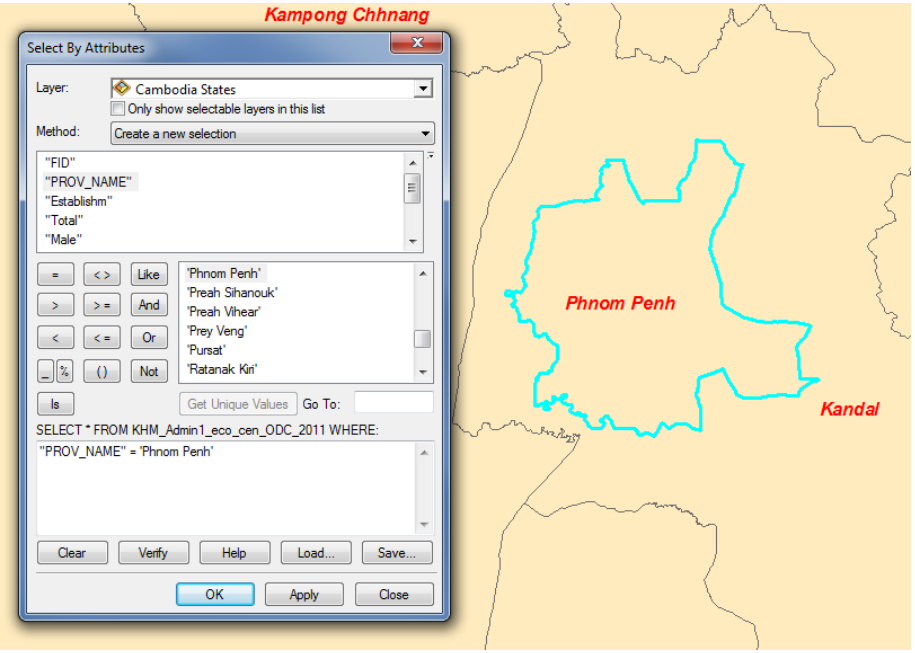

Spatial relationships between objects

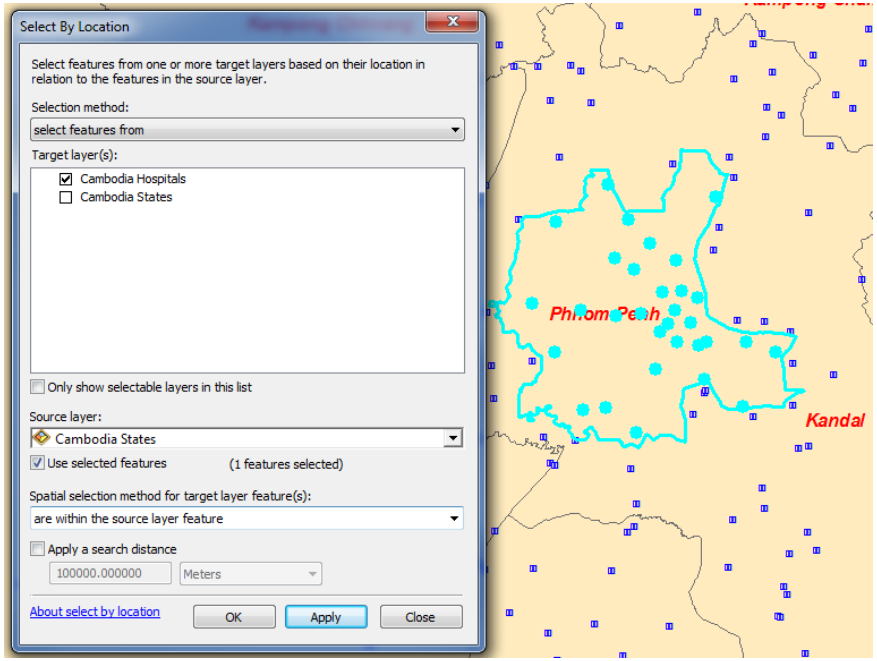
***Equivalent Human Instruction:***
***Find All the hospitals inside my area of interest***

# Combination of Query

- Attribute query and spatial query can be combined to get complex selections

***Objecttive:***
***Find All the hospitals inside "Phnom Penh" Province***



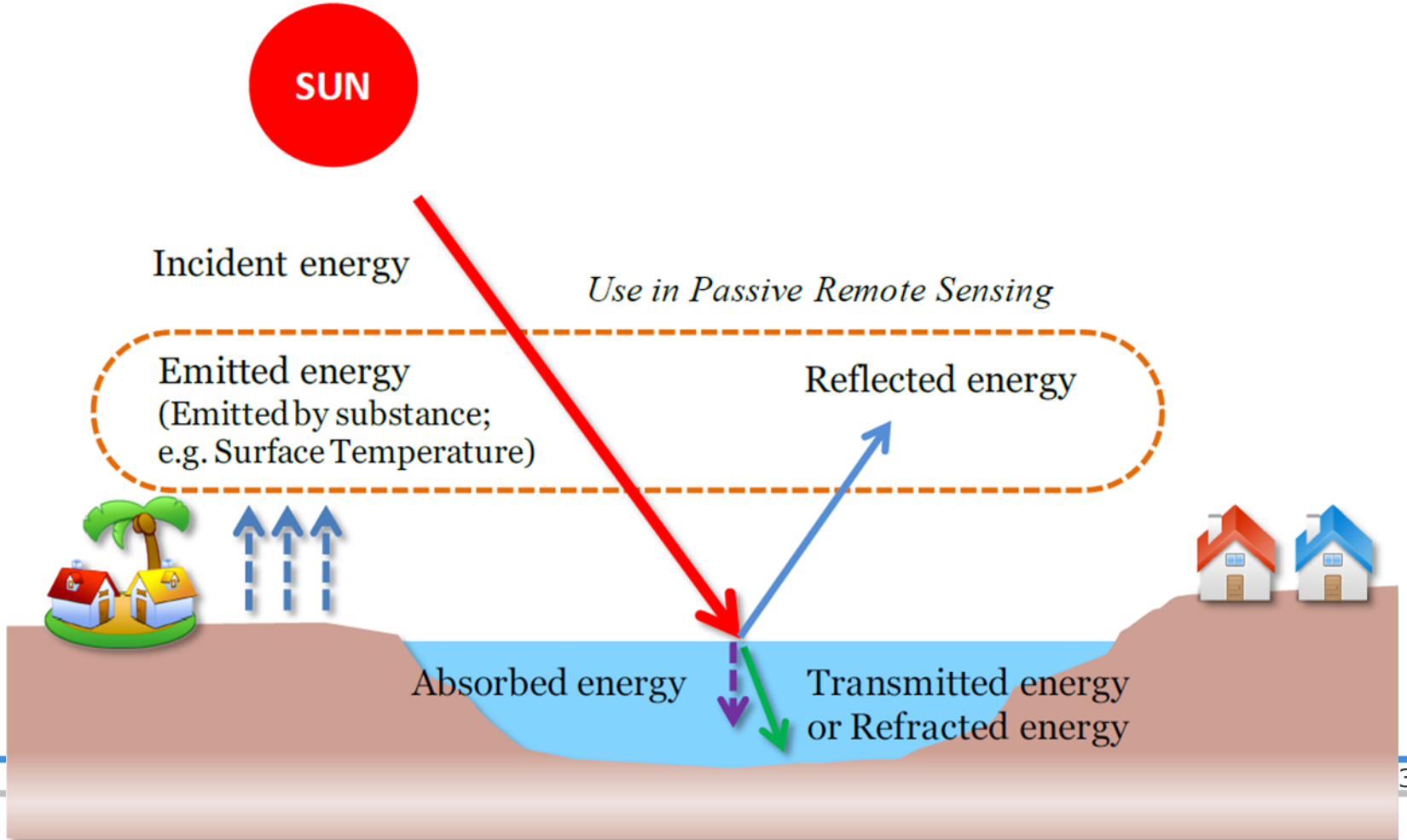




***Query 1:***
***Find Province named "Phnom Penh"***
***Type = Attribute query***

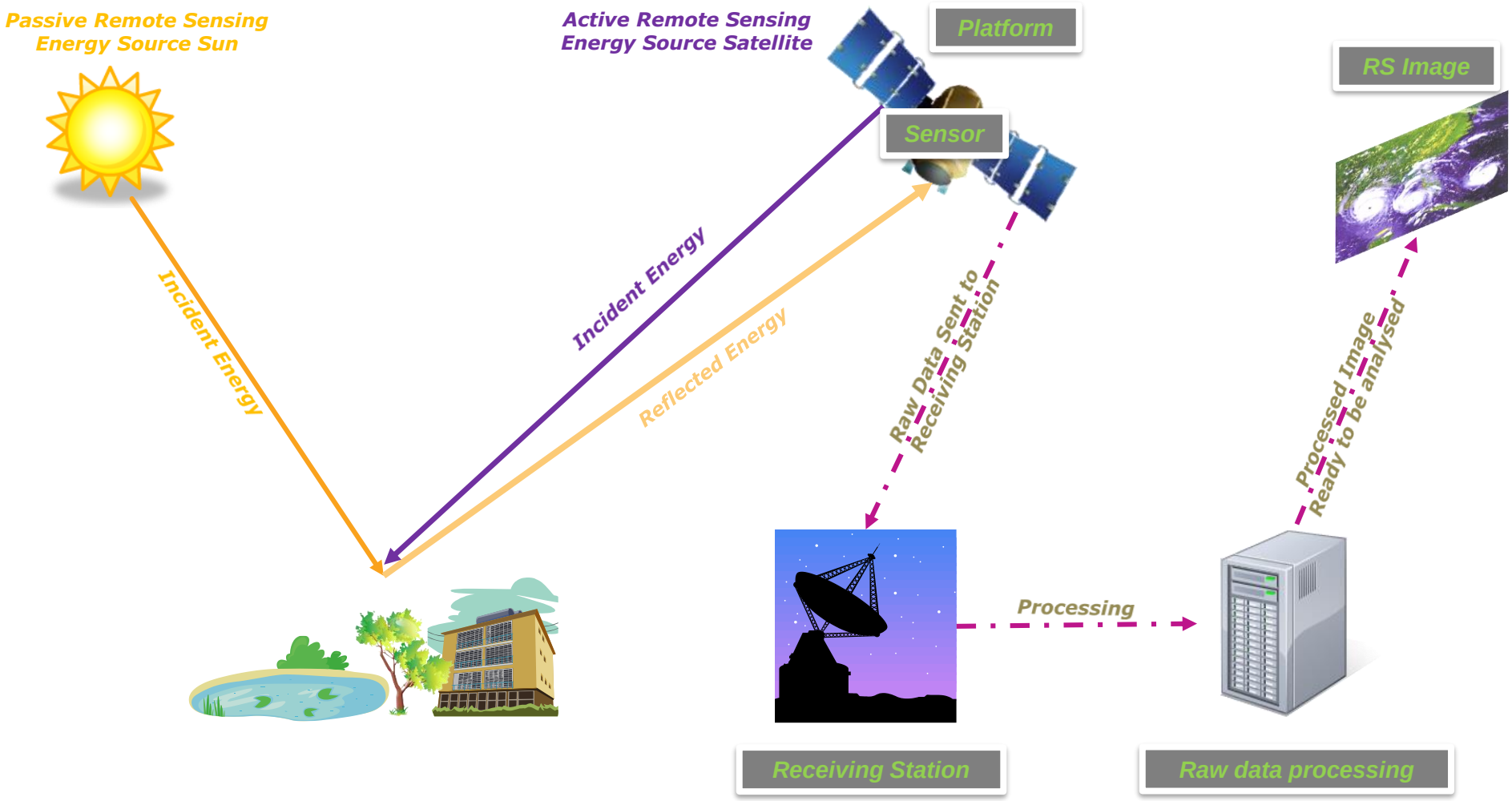
***Query 2:***
***Find All the hospitals that are inside***
***"area selected by Query 1"***

# PART E :
# Intro to RS

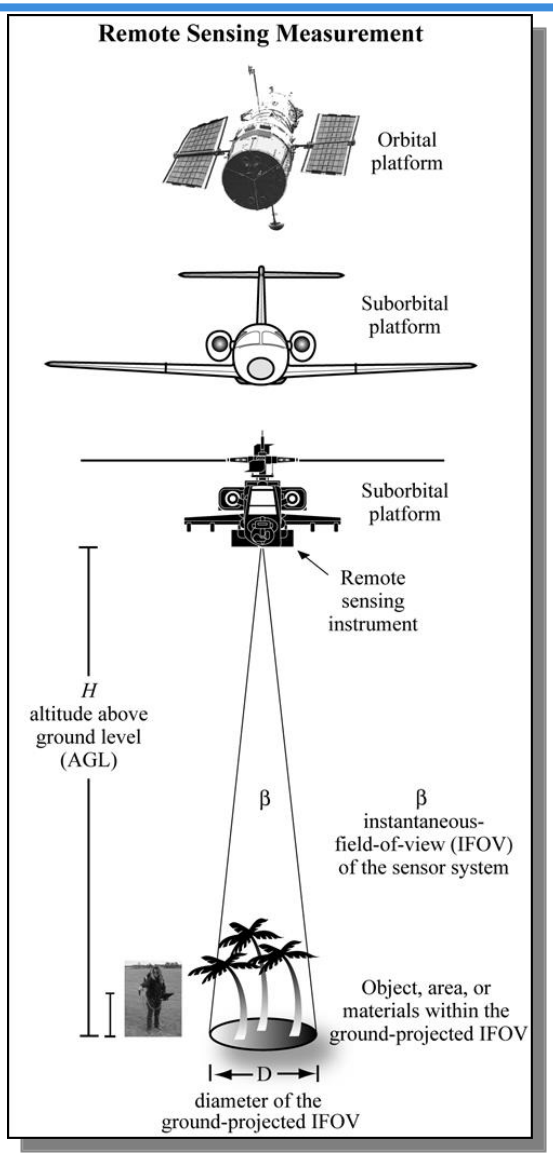
"Remote Sensing is defined as the science and technology by which **characteristics of objects** of interest can be **identified without direct contact**"



# ELEMENTS OF REMOTE SENSING



# REMOTE SENSING PLATFORMS AND SENSORS



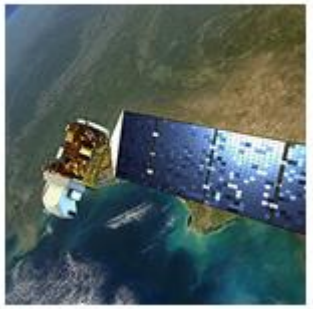

## PLATFORMS

## PASSIVE SENSORS

WorldView-2 (0.46m)

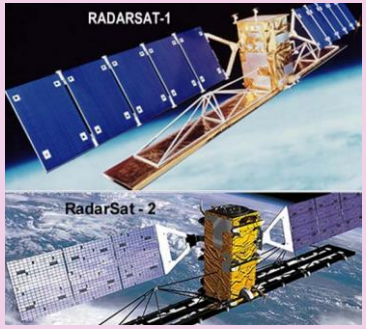
SPOT-6 (1.5m)

Landsat 8 (15m)



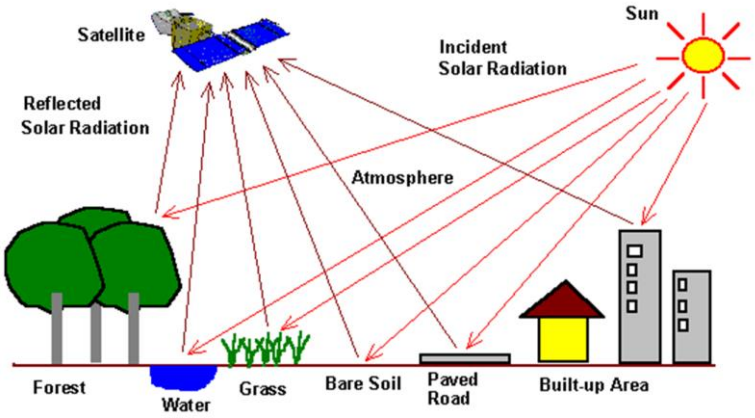
## ACTIVE SENSORS

RADARSAT1,2



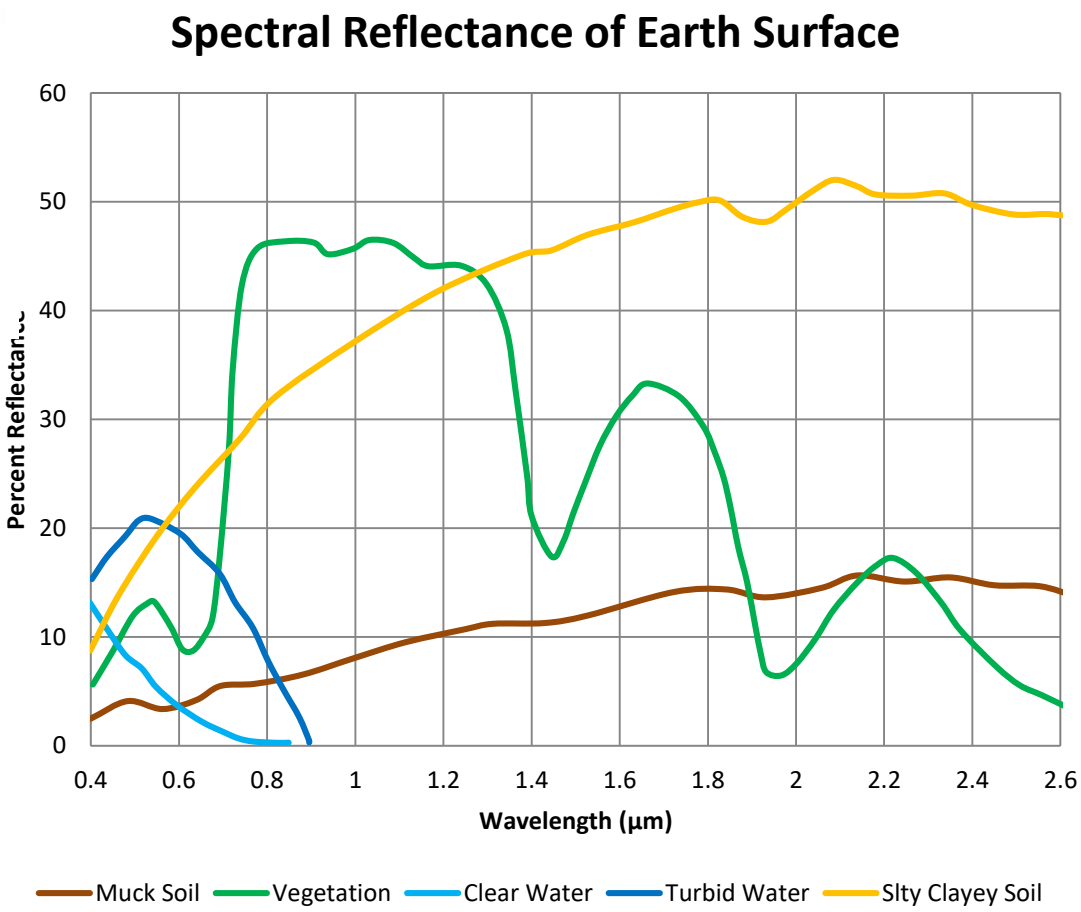

TerraSAR-X

LIDAR



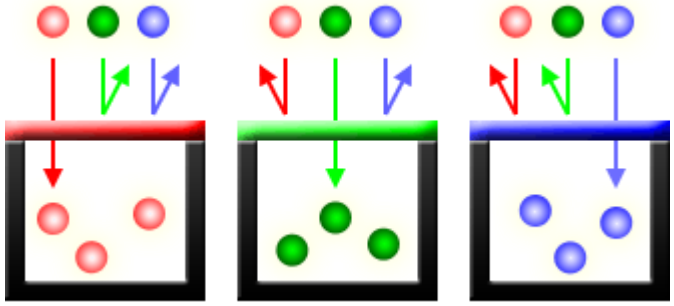

*Different surface cover exhibits different amount of reflectance in different wavelength of electro magnetic spectrum*



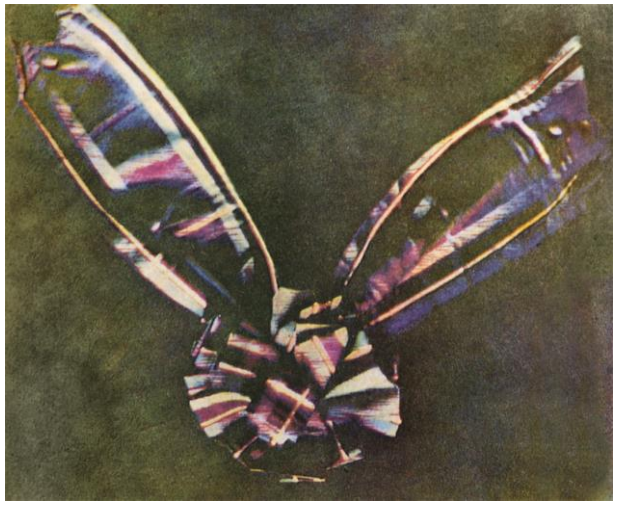



$$Reflectance = \frac{Reflected\ Energy}{Incident\ Energy}$$

The three-color method, which is the foundation of virtually all practical color processes whether chemical or electronic, was first suggested in an 1855 paper on color vision by Scottish physicist James Clerk Maxwell.

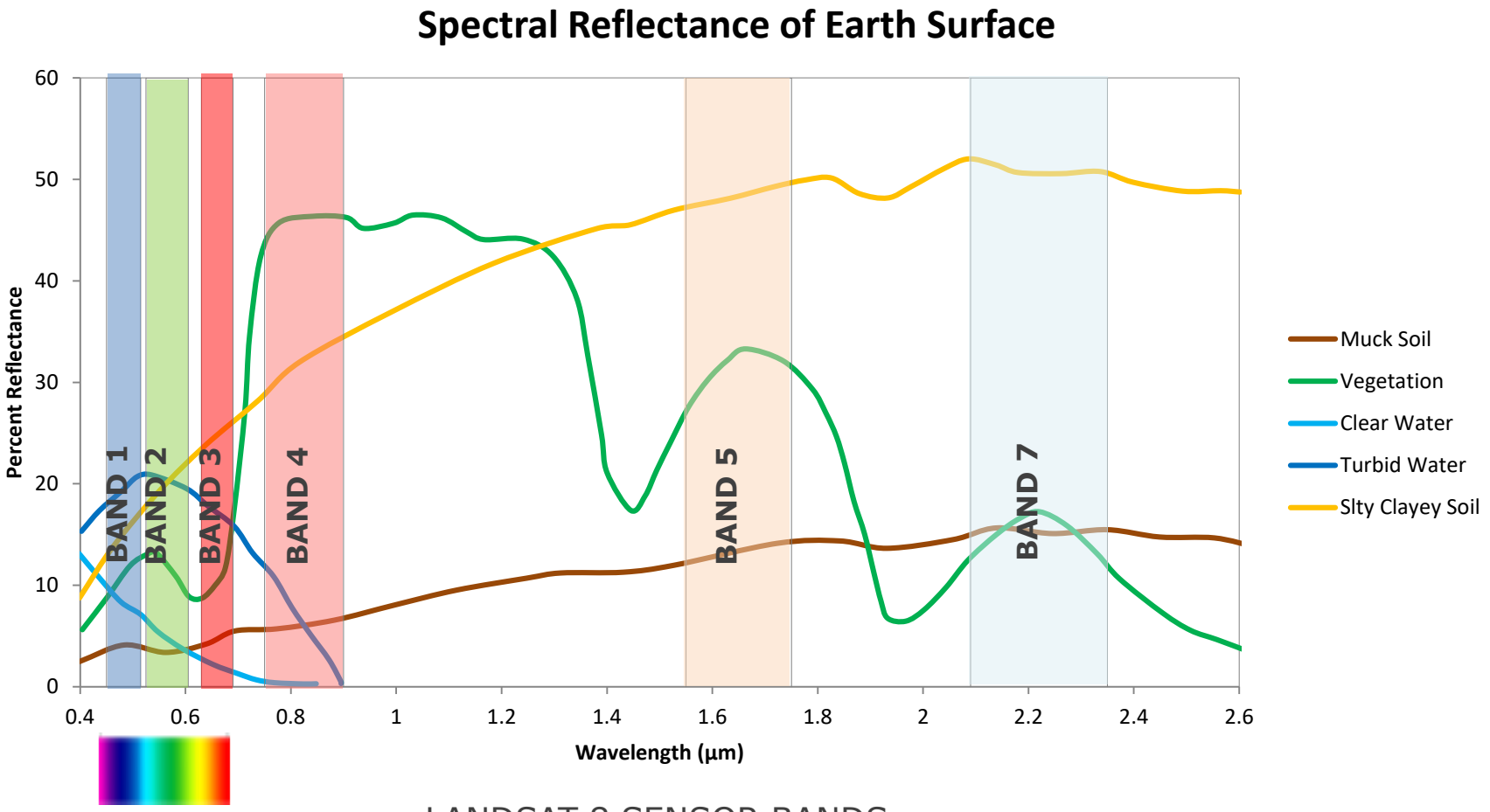


***Color separation with filters***



The first color photograph made in 1861 by Thomas Sutton. The subject is a colored ribbon, usually described as a tartan ribbon.


Emir of Bukhara, 1911.Prokudin-Gorsky photographed the upper, middle and lower images through blue, green and red filters.



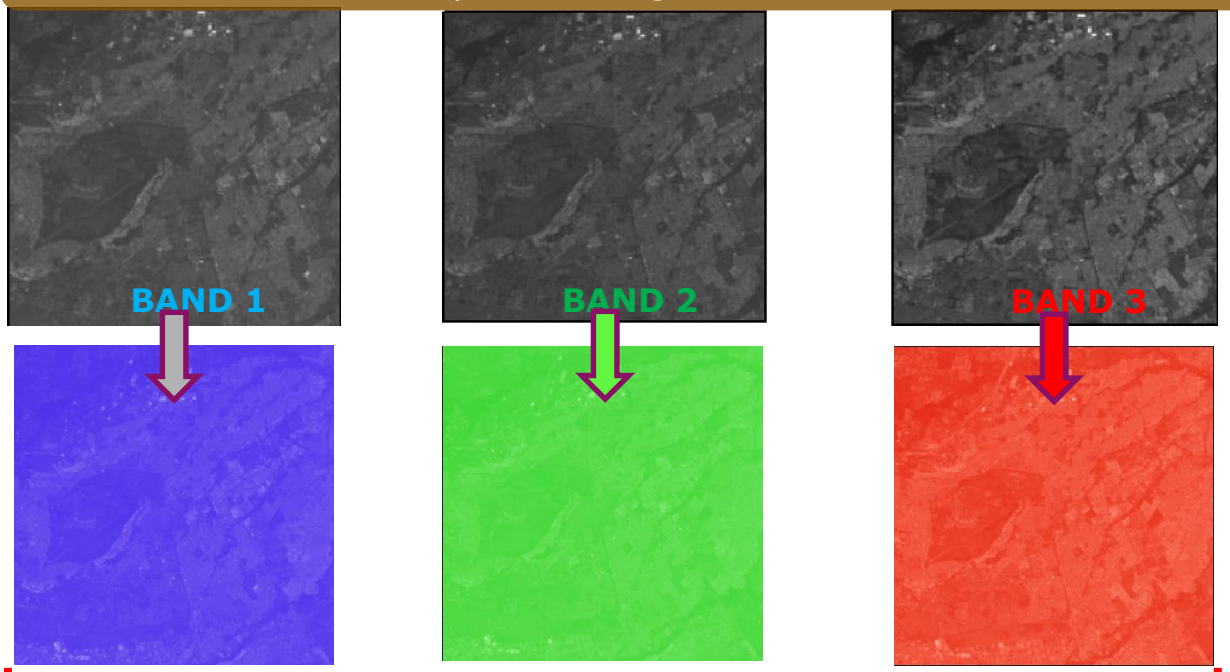

LANDSAT 8 SENSOR BANDS

*Visible part of the spectrum*

***Spectral bands are like windows of electromagnetic spectrum through which data is recorded!***

***And each of the bands reveal different property of different object on earth!***

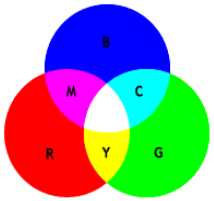
*Associating each spectral band (not necessarily a visible band) to a separate primary colour results in a colour composite image.*




*For visualization if blue, green and red channel band are assigned to Blue, Green, Red colors respectively, the result would be a true color composite.*

*This color composite will closely resemble what our eye percieve*

**COLOR MIXING**

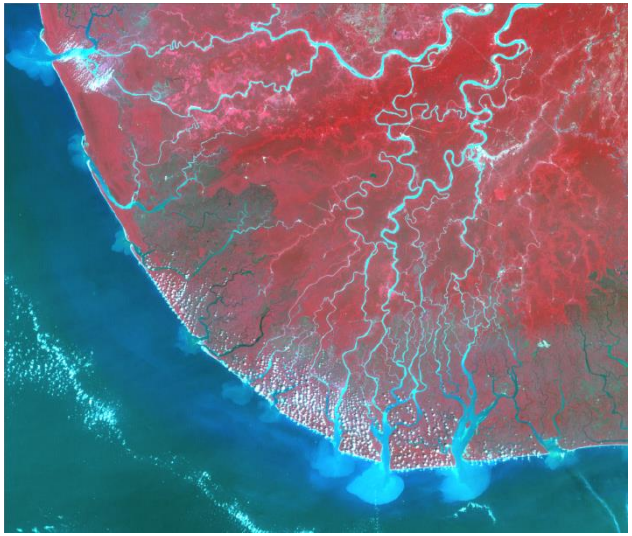



**TRUE COLOR COMPOSITE**
**BAND 3,2,1 (R,G,B)**

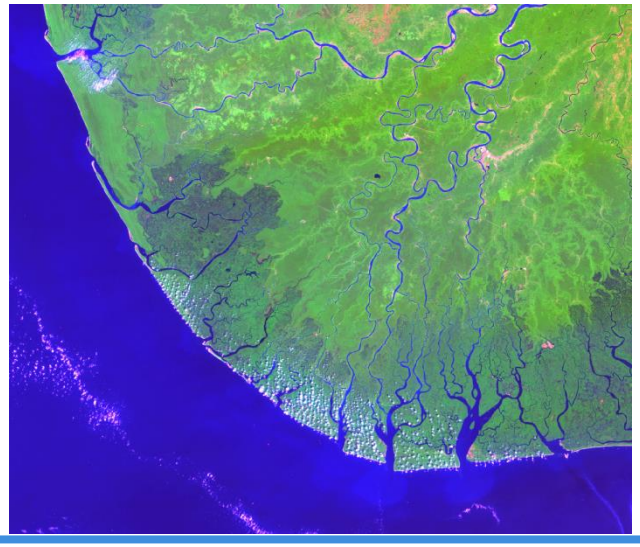
*Any other color composites are called false color composite.*

*Each of the composite will reveal certain property of earths surface*

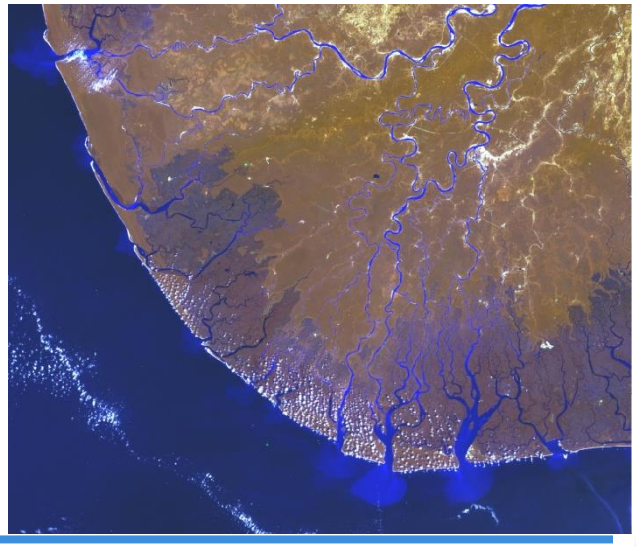
321



432



751



375

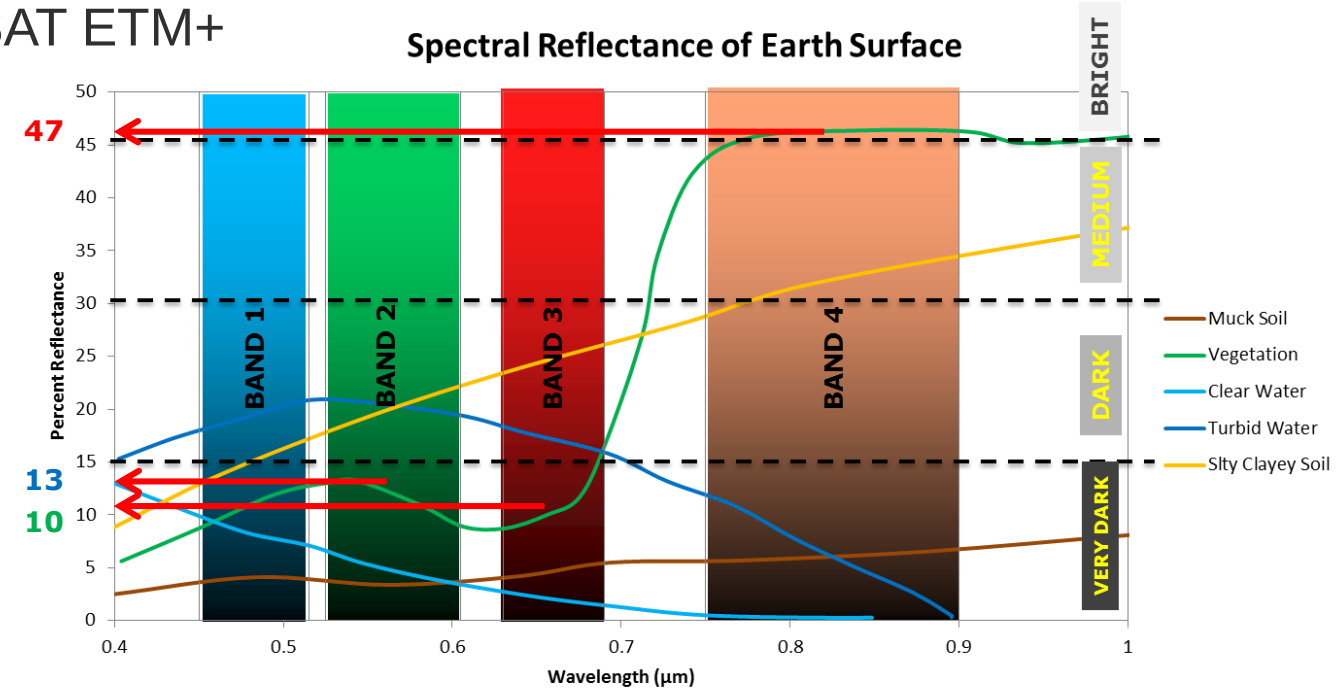
LANDSAT 7

Different band combinations accentuate different land covers



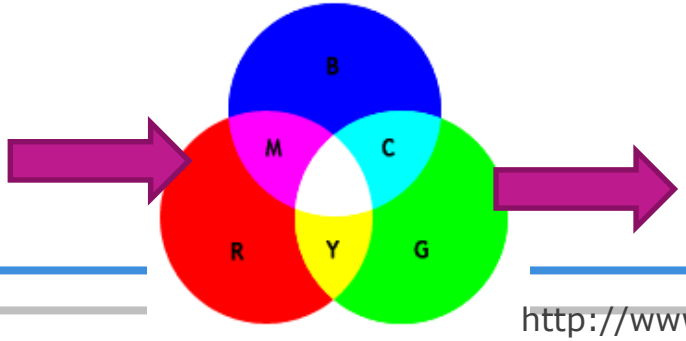
Photo: NASA

# WHAT WILL BE THE COLOR OF VEGETATION IN 4,3,2(RGB) OF LANDSAT ETM+




LANDSAT ETM+ SENSOR BANDS

Red = 47
Green = 10
Blue = 13

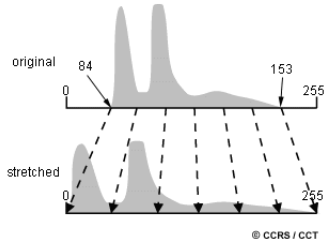


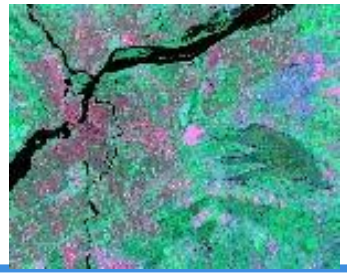

Red/Brown?

http://www.colortools.net/color_mixer.html

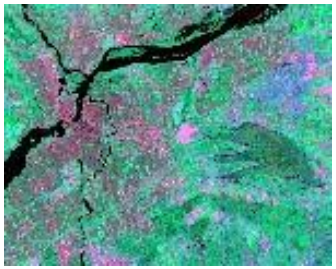
Image enhancement is the modification of an image to alter its impact on the viewer.
Most enhancement operations distort the original digital values

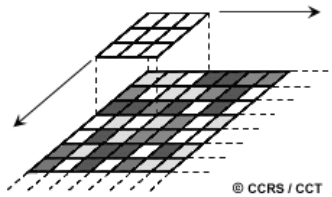
RADIOMETRIC ENHANCEMENT

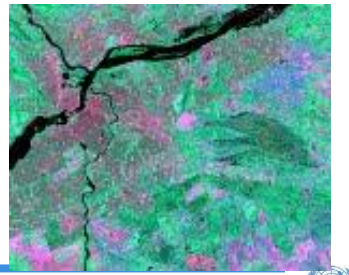


SPATIAL ENHANCEMENT







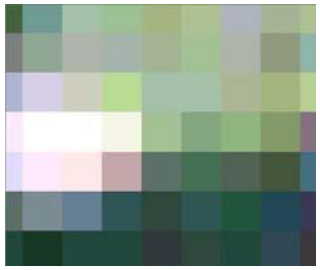
http://www.nrcan.gc.ca/earth-sciences/geography-boundary/remote-sensing/fundamentals/2187

# RESOLUTION TERMS USED IN REMOTE SENSING

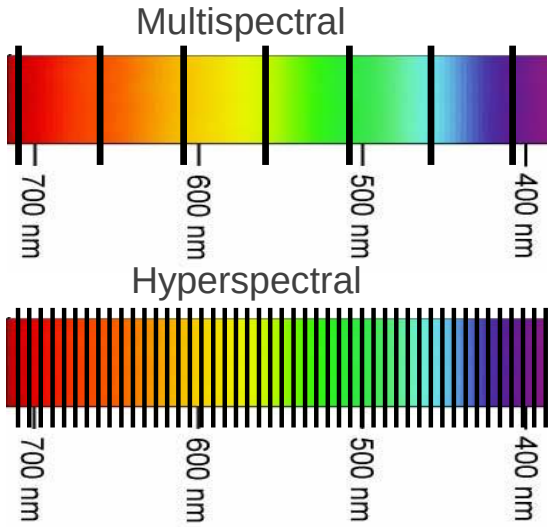
## Spatial resolution: The ground area represented by each pixel in an image

High resolution

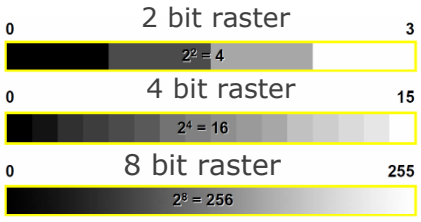
Low Resolution



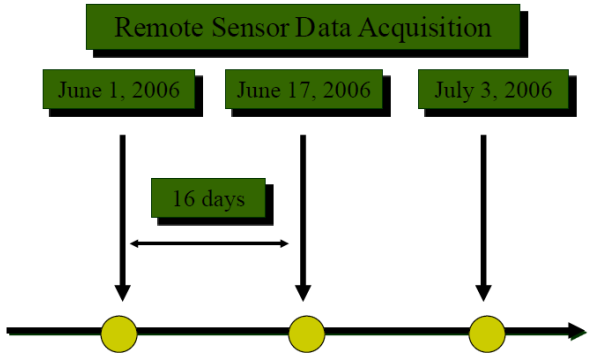
## Spectral resolution: Ability of sensor to separate EM into small intervals (bands)

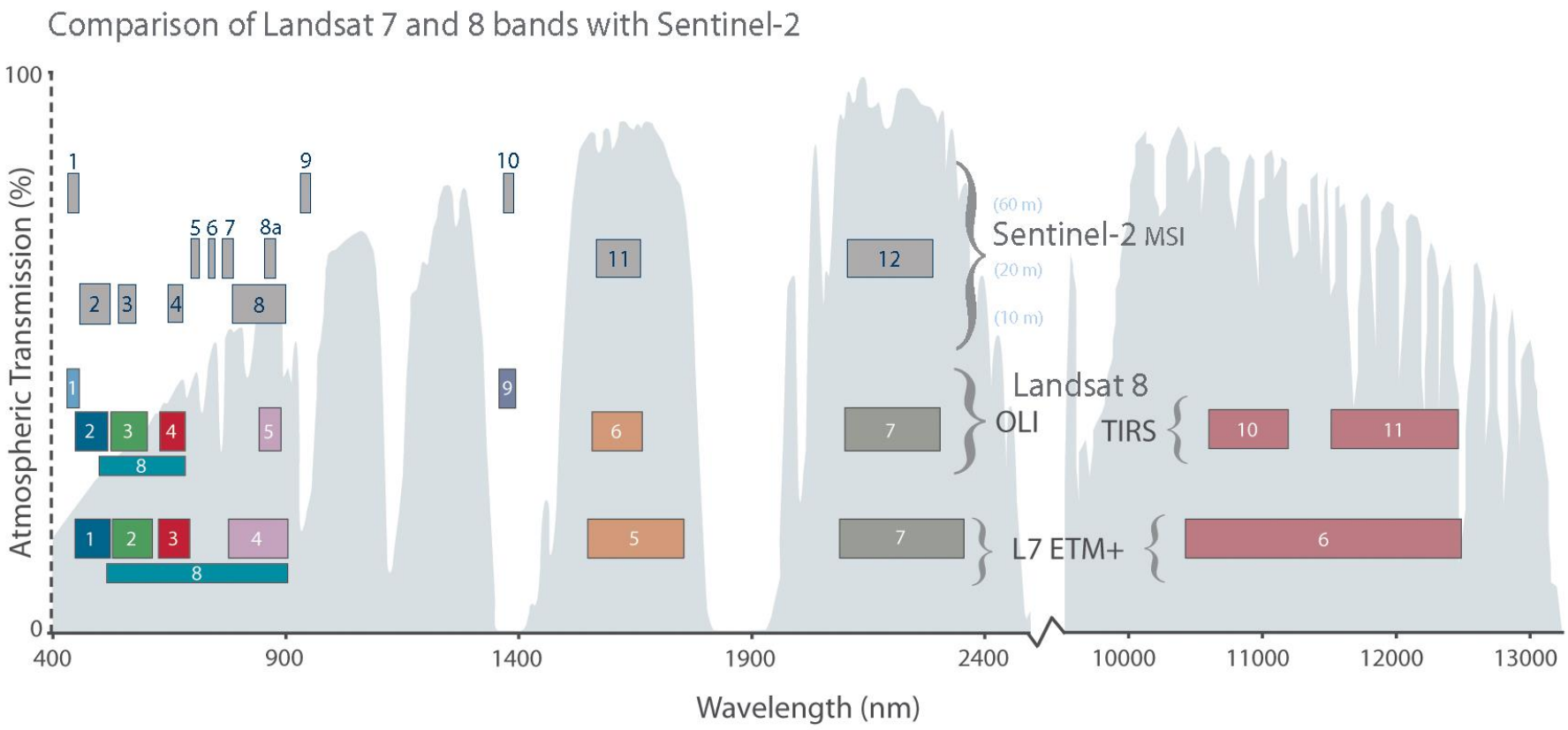



## Radiometric resolution: Ability to discriminate slight differences in energy

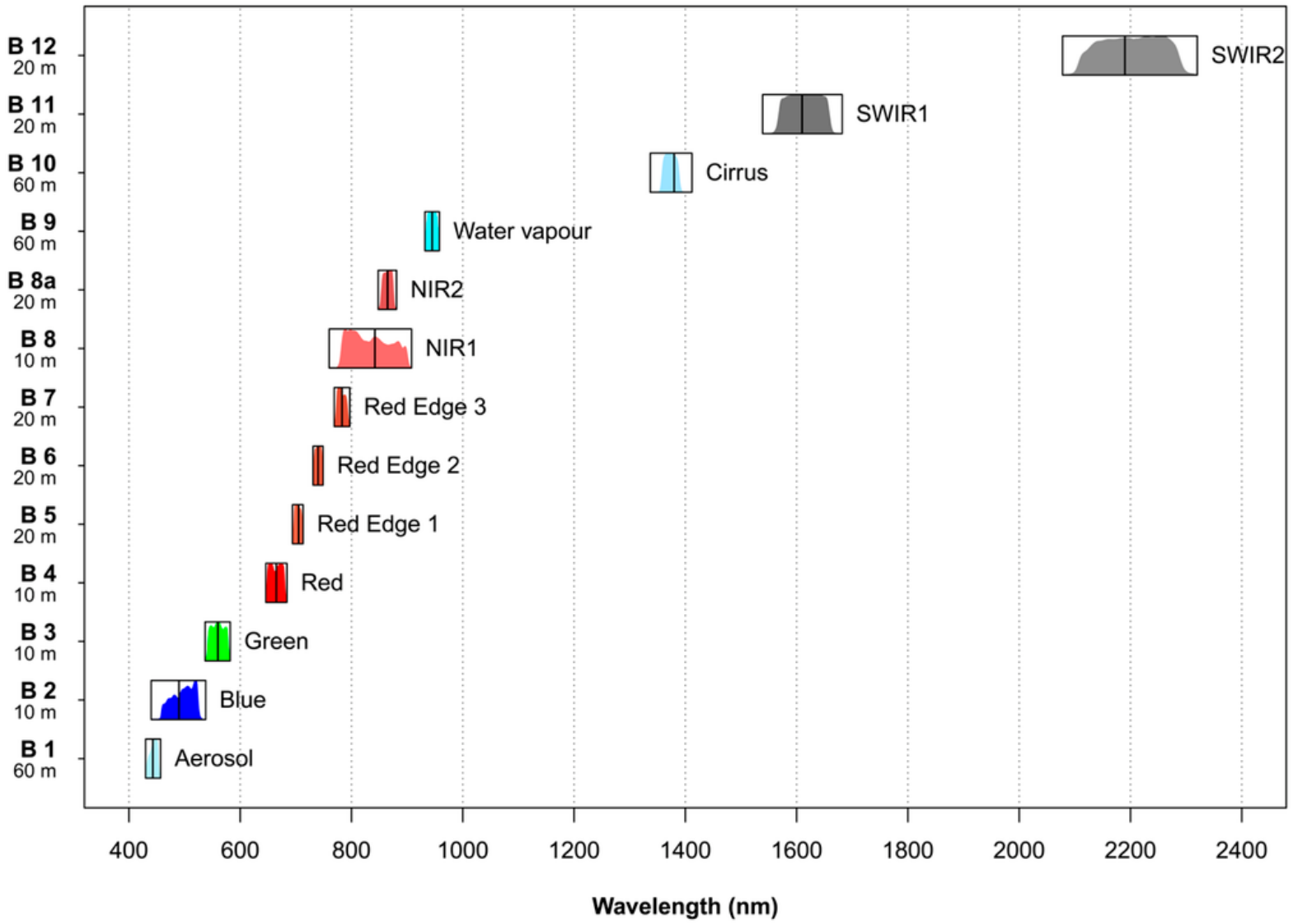



**Temporal resolution:** How often is the target sampled (orbital characteristics, swath width, flight campaigns)




Comparison of Landsat 7 and 8 bands with Sentinel-2
Atmospheric Transmission (%)
100
0
400
900
1400
1900
2400
10000
11000
12000
13000
Wavelength (nm)
1
9
10
5 6 7
8a
2
3
4
8
11
12
(60 m)
Sentinel-2 MSI
(20 m)
(10 m)
Landsat 8
OLI
TIRS
L7 ETM+
5
6
7
10
11

# Sentinel 2 Bands



# Can we define drought?

**Drought** is a relative condition between normal precipitation and demand of water within a watershed; a protracted period of deficient precipitation resulting in extensive damage to crops, resulting in loss of yield and adversely affecting the population

*Drought is a normal, recurrent event that occurs virtually in all climate zones throughout the world and occurs in any season, anywhere, anytime*



Source: http://www.icrisat.org/vasat/learning_resources/drought/html/m1l2/index.html

# Geospatial Drought Indicators

Temperature

Humidity

Wind

Precipitation

Streamflow

Soil Moisture

# Challenges

*Past can no longer be an indicator of the future*

Climate change related issues makes it harder to be effectively predict weather conditions

Investment in creating an early warning system

Inadequate capacity at national level for providing effective climate services

# Where to start?

1. Continuous monitoring using geospatial and insitu data
2. Improved climate services at local level
3. Drought Information Statements
4. Timely Information for Preparedness
5. Timely Forecast of weather conditions
6. Drought Plan
7. Local Drought Team
8. Frequent Press Release
9. Meetings with collaborators
10. Local drought webpage




Source: Startups.co.uk

United Nations Institute for Training and Research


United Nations Institute for Training and Research
Institut des Nations Unies pour la Formation et la Recherche
Instituto de las Naciones Unidas para Formación Profesional e Investigaciones
Учебный и научно-исследовательский институт
Организации Объединенных Наций
معهد الأمم المتحدة للتدريب والبحث
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