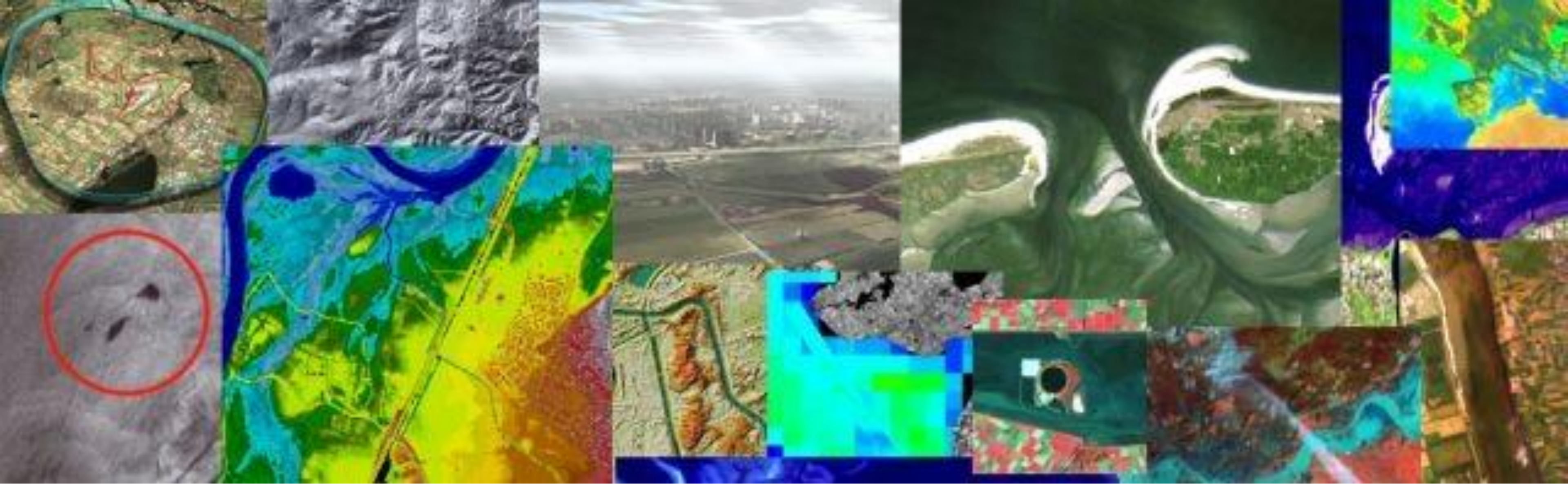
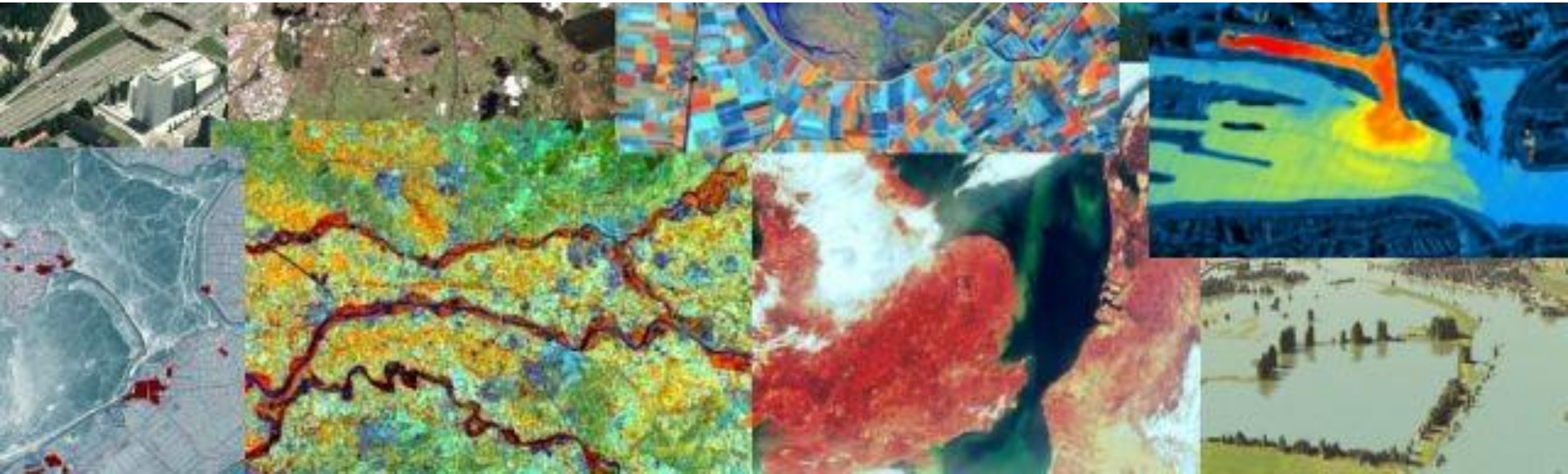


MULTI-HAZARD RISK ASSESSMENT USING GEOSPATIAL TECHNIQUES

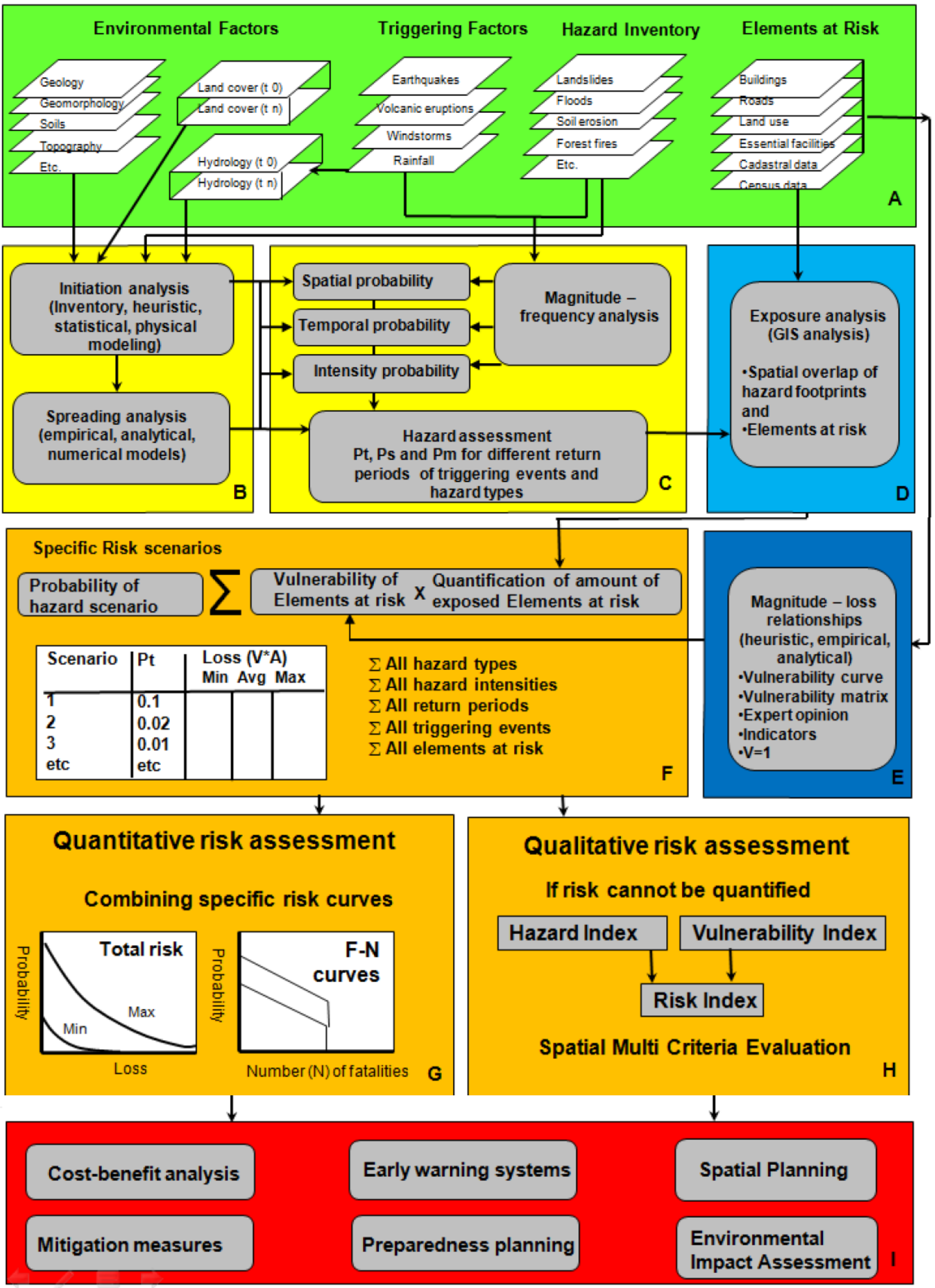


CONTENTS

- Introduction
- Multi-hazard risk framework
- Basic mapping
- Basic GIS
- Basic remote sensing
- Applications

INTRODUCTION

- Use of EO and GIS, an integrated, well developed and successful tool in disaster risk management
- Hazard and risk assessments are carried out at different scales of analysis, ranging from a global scale to a community level (each, having own objectives, and spatial data requirements)
- 3 important components of risk assessment: hazard, vulnerability, elements-at-risk

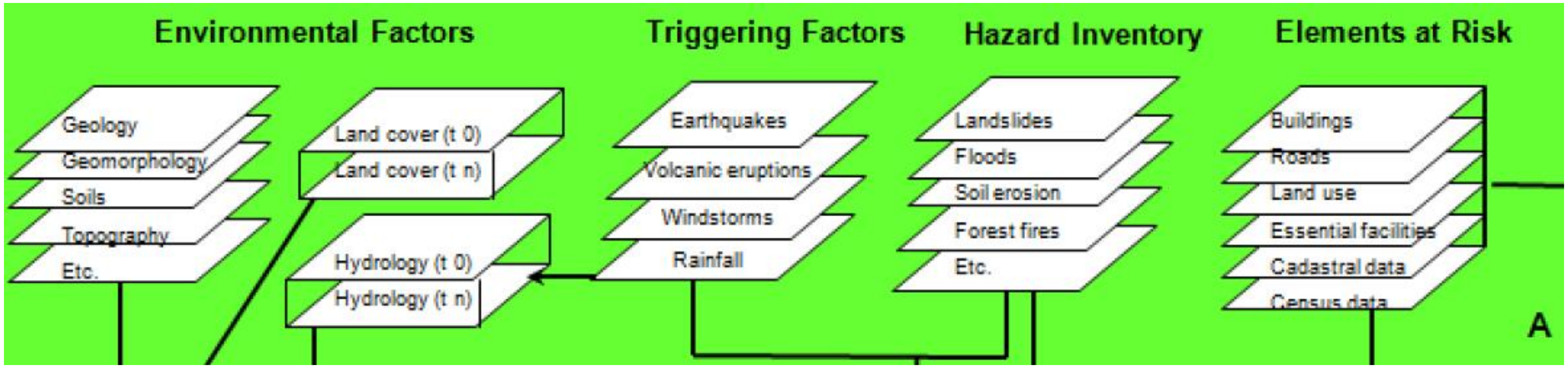


FRAMEWORK

- **A:** Input Data
- **B:** Susceptibility assessment
- **C:** Hazard assessment
- **D:** Exposure analysis
- **E:** Vulnerability assessment
- **F:** Risk assessment
- **G:** Quantitative risk assessment
- **H:** Qualitative risk assessment
- **I:** Applications

Source: Van Westen et al., 2008

INPUT DATA



- Tabular data (e.g. locations, census, etc.)
- Direct measurements (e.g. survey, observation stations, etc.)
- Satellite (e.g. automatic classification, visual interpretation, etc.)
- Models (e.g. DEM, etc.)

INPUT DATA

❖ Tabular data (e.g. locations, census, etc.)

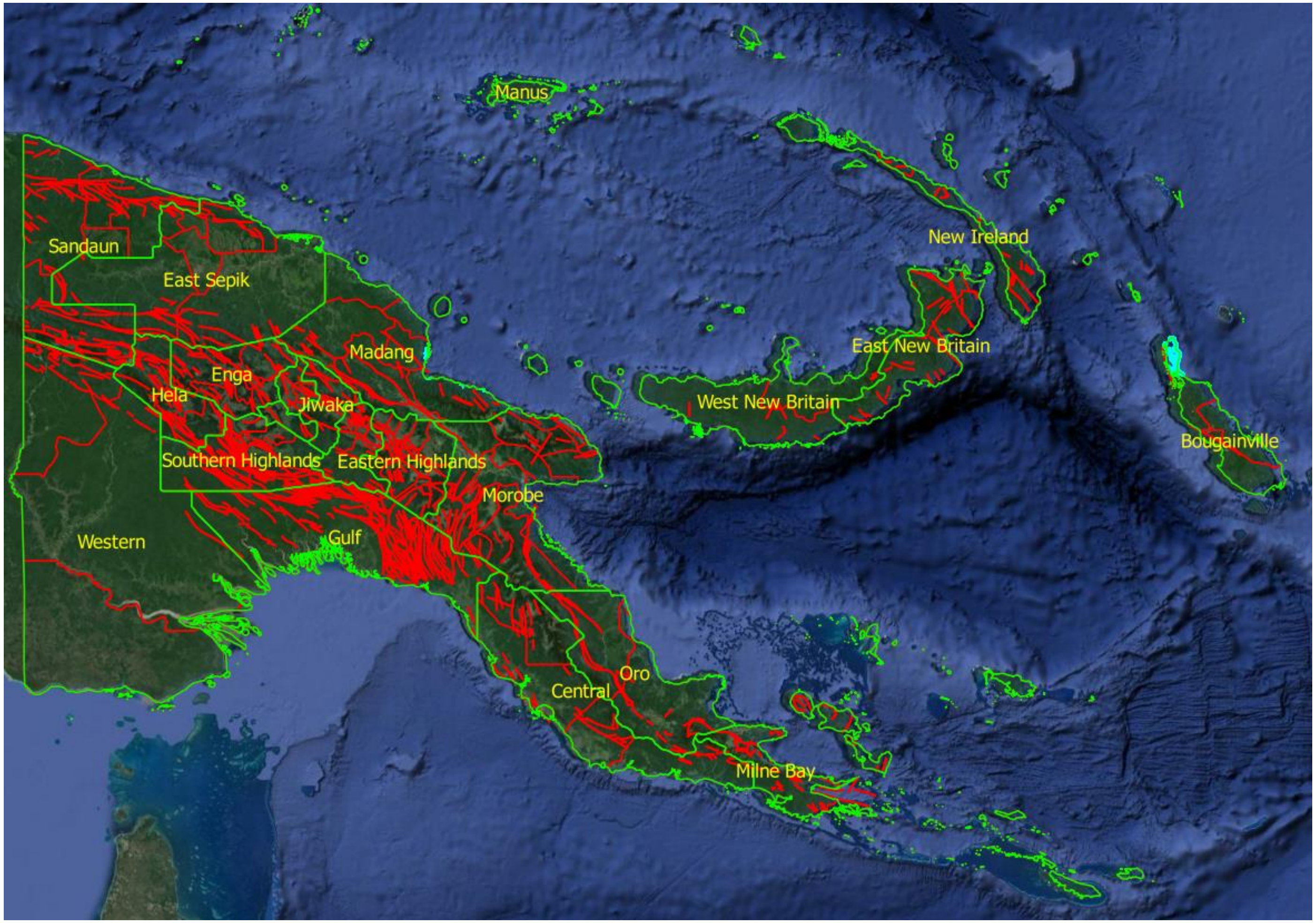
rain-20000722 :: Features total: 76, filtered: 76, selecte...

	Sta_Name	Sta_Code	Longitude	Latitude	Rain(mm)
1	Aunglan	4060	95.21667	19.36667	0.000000
2	Bago	48093	96.50000	17.33333	97.000000
3	Bhamo	48019	97.20000	24.26667	12.000000
4	Bilin	7210	97.23000	17.22000	62.000000
5	Chauk	4020	94.83333	20.90000	0.000000
6	Dothaung	7540	93.68333	18.80000	61.000000

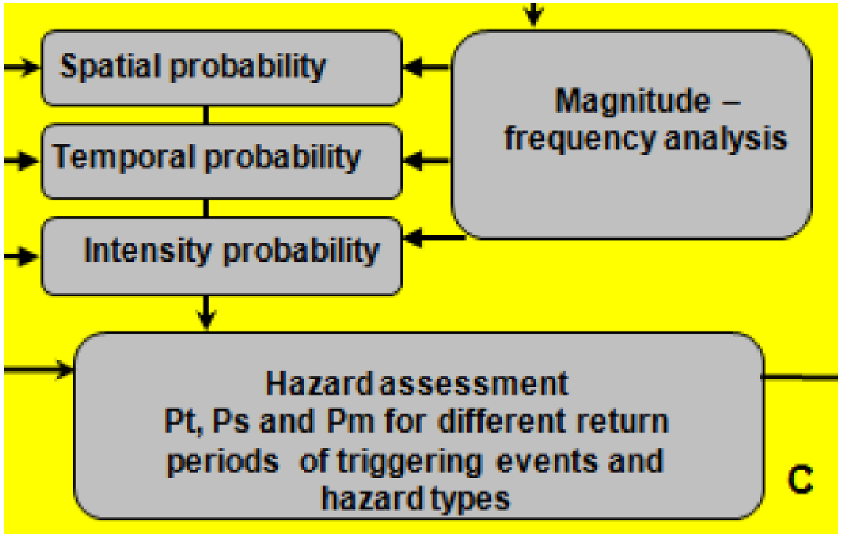
Year	Month	Day	Tmax	Tmin	Tmean
2000	1	1	27	9.6	18.3
2000	1	2	27.6	10	18.8
2000	1	3	27.6	10.6	19.1
2000	1	4	28.4	12.2	20.3
2000	1	5	28.2	12	20.1
2000	1	6	29	12.4	20.7
2000	1	7	27.8	17.7	22.75
2000	1	8	29.5	13.5	21.5
2000	1	9	29.5	12.6	21.05
2000	1	10	29.8	12.6	21.2

No.	Station		
		Lat (N)	Long (E)
1	Putao	27.33	97.43
2	Myitkyina	25.37	97.4
3	Bhamo	24.27	97.2
4	Hkamti	26	95.7
5	Homalin	24.87	94.92
6	Katha	24.17	96.33
7	Kalewa	23.2	94.3

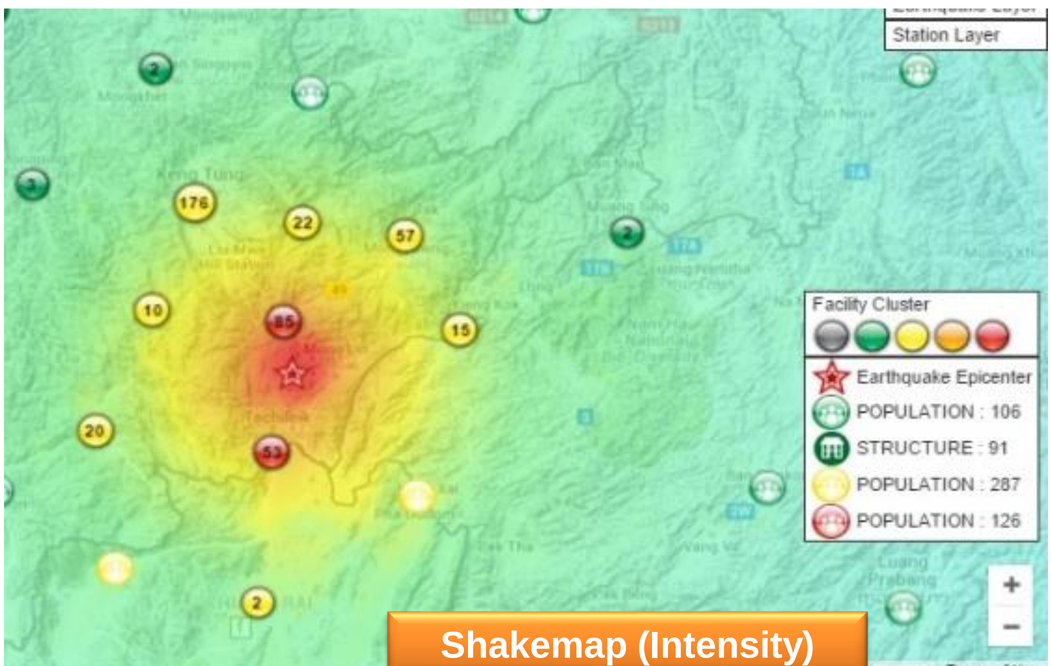
SUSCEPTIBILITY



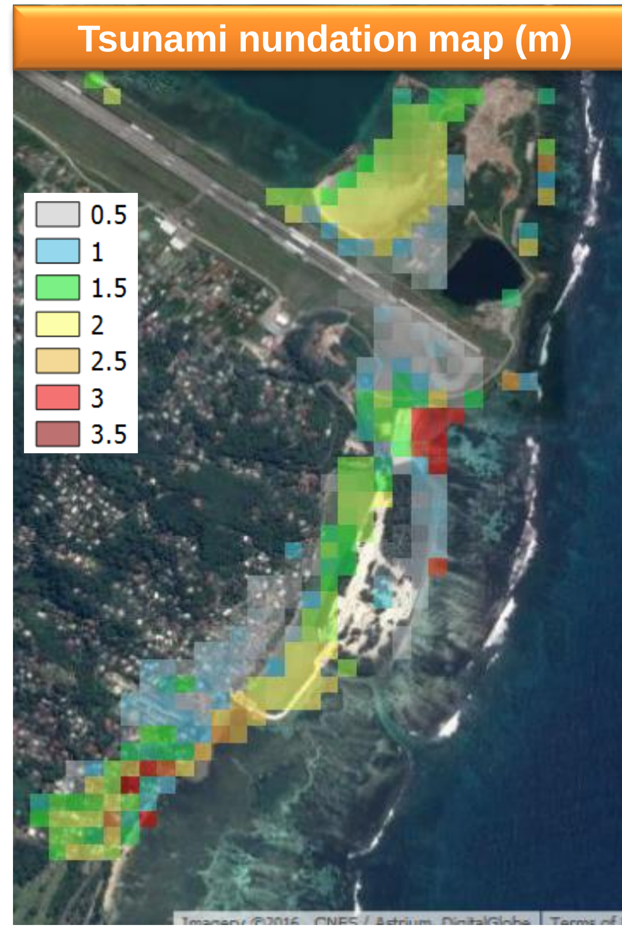
HAZARD



Spatial probability
Temporal probability
Intensity probability
Magnitude – frequency analysis
Hazard assessment
Pt, Ps and Pm for different return periods of triggering events and hazard types
C



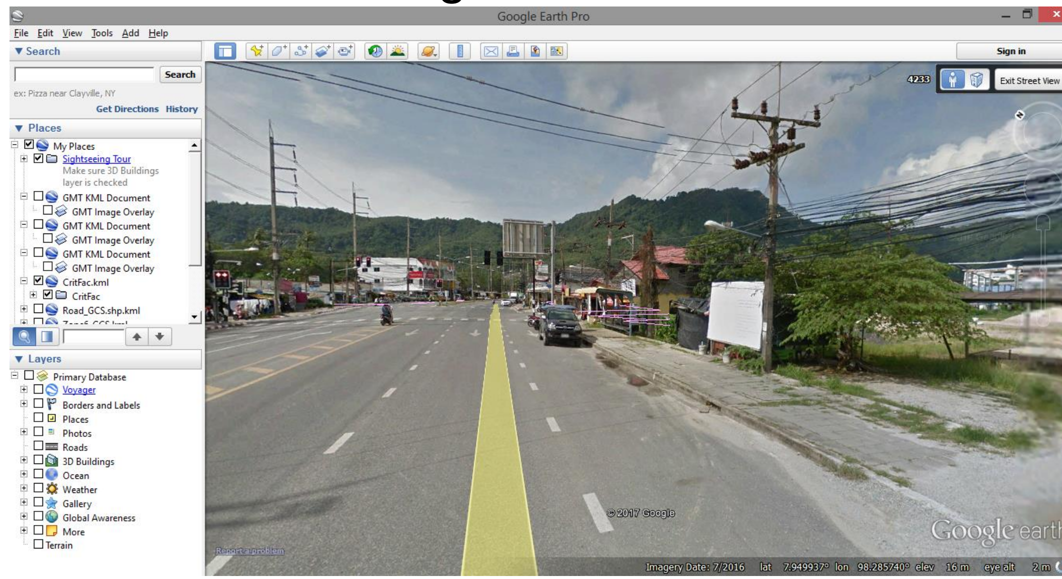
Station Layer
Facility Cluster
Earthquake Epicenter
POPULATION : 106
STRUCTURE : 91
POPULATION : 287
POPULATION : 126
Shakemap (Intensity)



Tsunami nundation map (m)
0.5
1
1.5
2
2.5
3
3.5

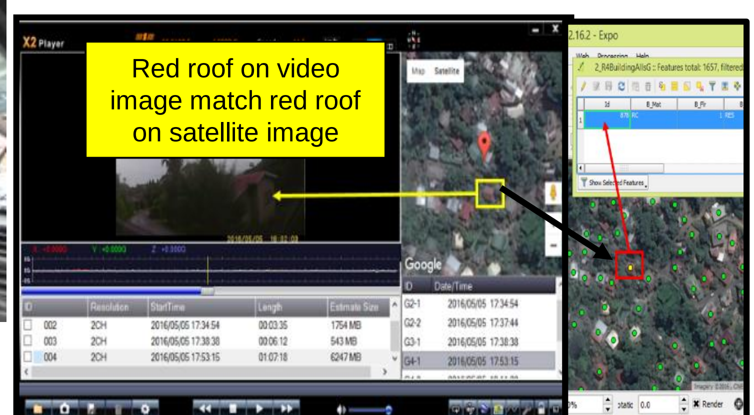
ELEMENTS-AT-RISK

Google Street View



Collect building properties using video camera with GPS installed in a vehicle

Exposure survey



QGIS

VULNERABILITY

Damage level 0 (No damage)

- There is no damage in a building.

Figure 6.1 Damage Level 0 (No damage) for engineered RC building

(a) Cracks on a wall (b) Wall punching

Figure 6.2 Damage Level 1 (Damage in secondary members only) for engineered RC building

Damage level 2 (Damage in primary members)

- There is damage in structural components, i.e. column, beam, foundation. At this damage level, there are cracks on a beam o a column, but the building is still reparable.

(a) Foundation failure (b) Bending failure of column

Figure 6.3 Damage Level 2 (Damage in primary members) for engineered RC building

Damage level 3 (Collapse)

- A building cannot sustain its gravitational load and it is non-reparable. At this damage level, a structure may fail at a major joint or absolutely collapse.

(a) Joint failure (b) Absolute destruction

Figure 6.4 Damage Level 3 (Collapse) for engineered RC building

VULNERABILITY

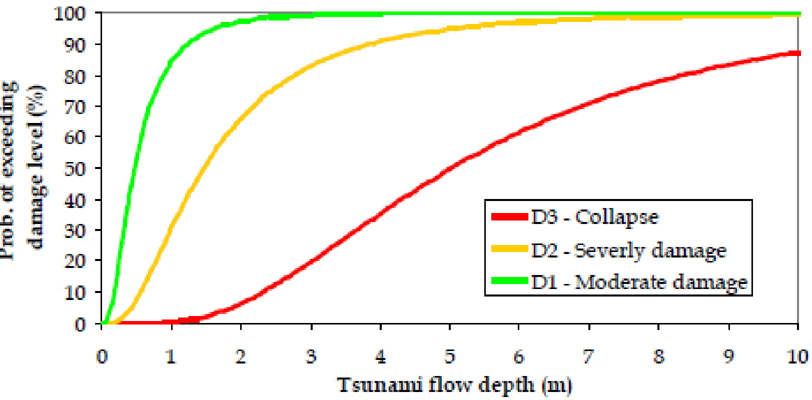


Figure 6.5 Fragility curve for RC building – 1 storey

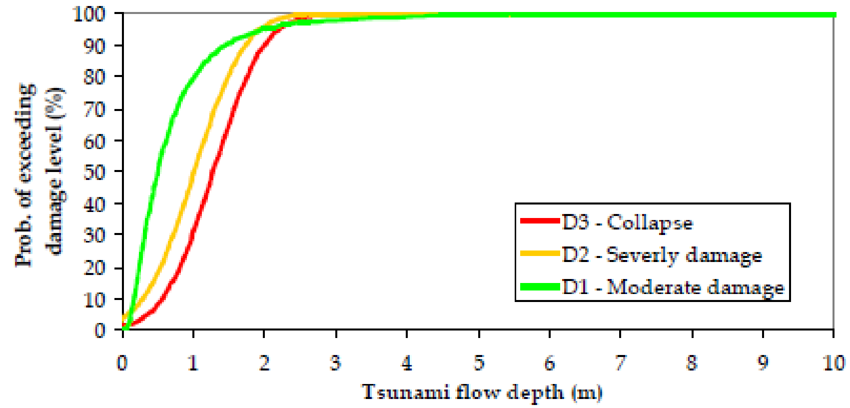


Figure 6.13 Fragility curve for non-solid buildings

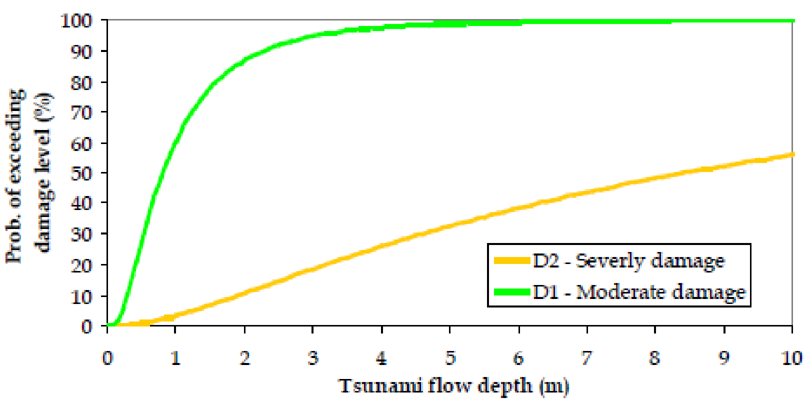


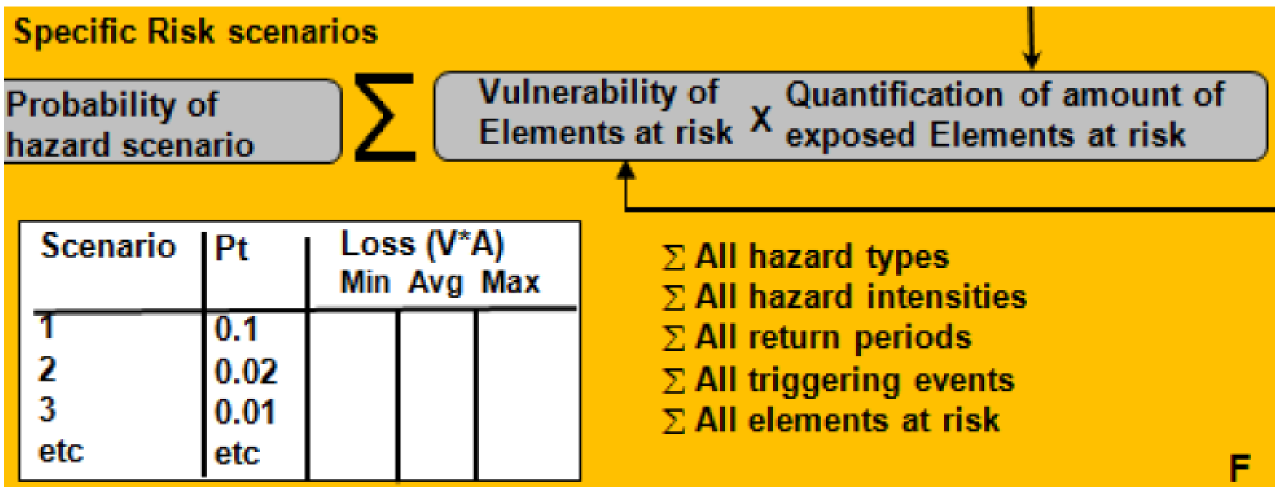
Figure 6.6 Fragility curve for RC building – taller than 1 storey

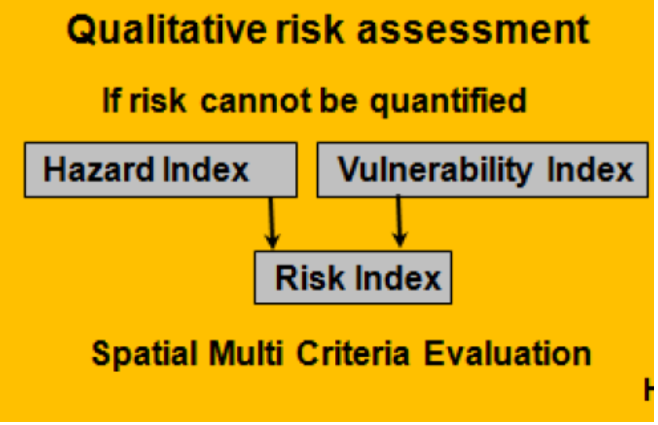
ID	Building Type	Damage Level	μ	σ	μ'	σ'
1	Reinforced Concrete (1 Floor) *Foytong and Ruangrassamee (2007)*	1			-0.7620	0.7572
		2			0.3813	0.7572
		3			1.6150	0.6031
2	Reinforced Concrete (>1 Floor) *Foytong and Ruangrassamee (2007)*	1			0.2186	0.8135
		2			2.1322	1.1559
3	Non-Solid *Garcin et al (2007)*	1	0.6201	0.6302		
		2	1.0109	0.5546		
		3	1.2626	0.5454		
4	Visual Interpretation from Satellite Image *Koshimura et al (2009)*	1	2.9900	1.1200		

Note:

μ = mean based on standardized normal distribution
σ = standard deviation based on standardized normal distribution
μ' = mean based on lognormal distribution
σ' = standard deviation based on lognormal distribution

RISK


Specific Risk scenarios
Probability of hazard scenario
∑
Vulnerability of Elements at risk
X
Quantification of amount of exposed Elements at risk
Scenario
Pt
Loss (V*A)
Min Avg Max
1
0.1
2
0.02
3
0.01
etc
etc
∑ All hazard types
∑ All hazard intensities
∑ All return periods
∑ All triggering events
∑ All elements at risk
F



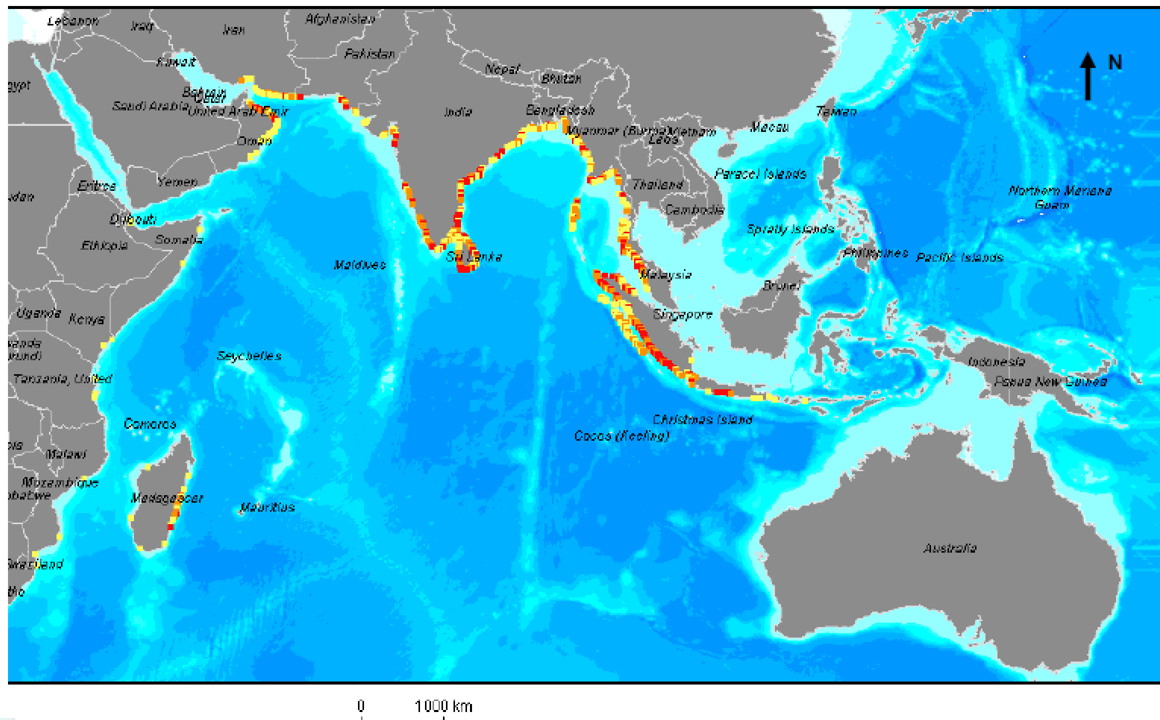
RISK

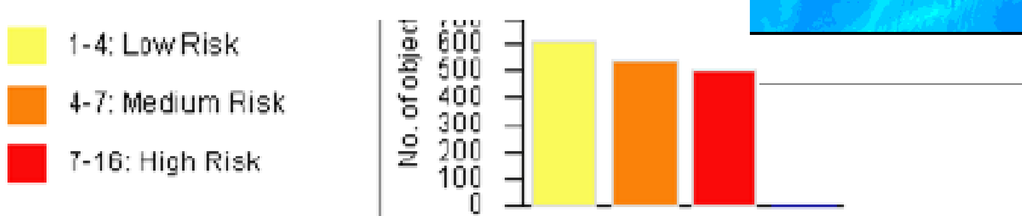
Table 1. Risk level on population from tsunami inundation

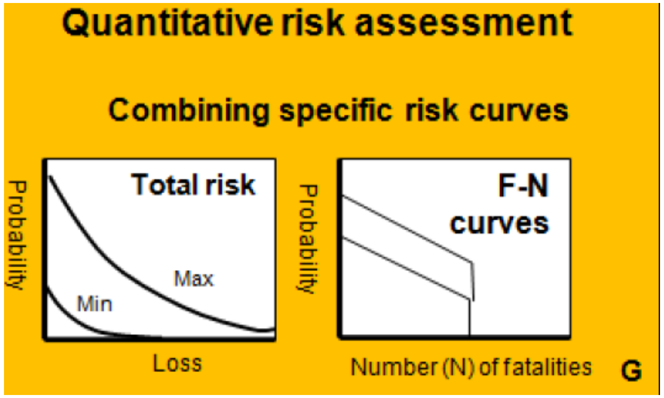
Inundation (m)	Degree of Threat (Score)	Population Density/ Exposure (Score)			
		<500 Low (1)	500 to 999 Medium (2)	1,000 to 5,000 High (3)	>5,000 Very high (4)
0.5 to 1.0	Low (1)	1	2	3	4
1.0 to 1.5	Medium (2)	2	4	6	8
1.5 to 3.0	High (3)	3	6	9	12
>3.0	Very high (4)	4	8	12	16

Note: Risk level of 1-4: low risk
Risk level of 4-7: medium risk
Risk level of 7-16: high risk

- Preliminary assessment
- Data availability is scarce



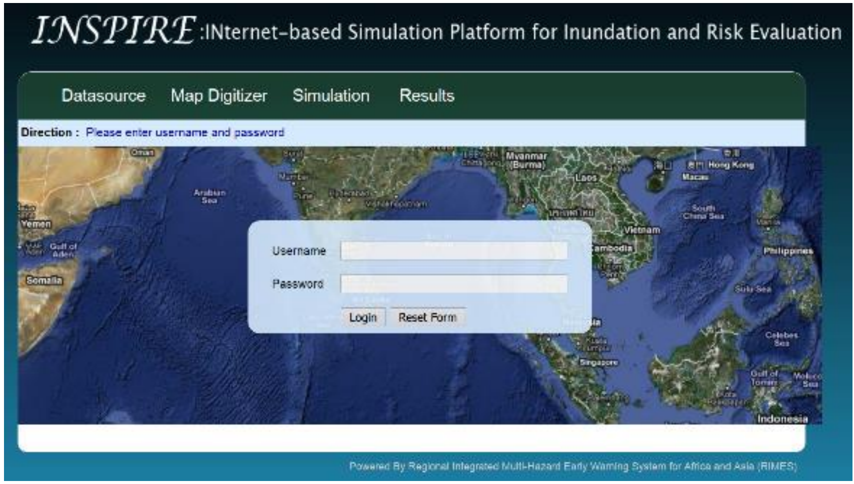




RISK

- Where is the area and extent of inundation?
- What is the impact on facilities?
- How many people will be at risk?

- "What if" scenarios



Risk to building type 2 (%)

Risk to population (%)

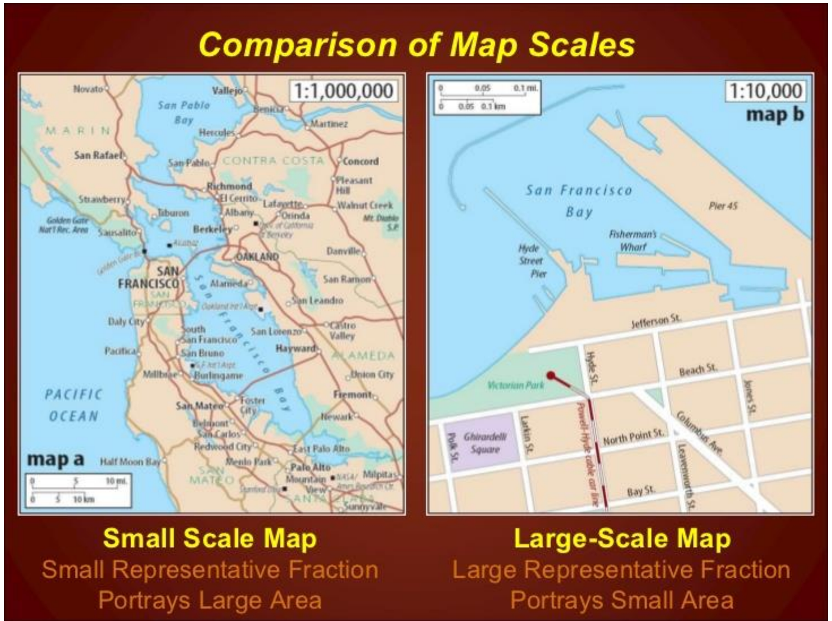
MAPPING

- Scale
- Resolution
- Projection

MAPPING

❖ Scale

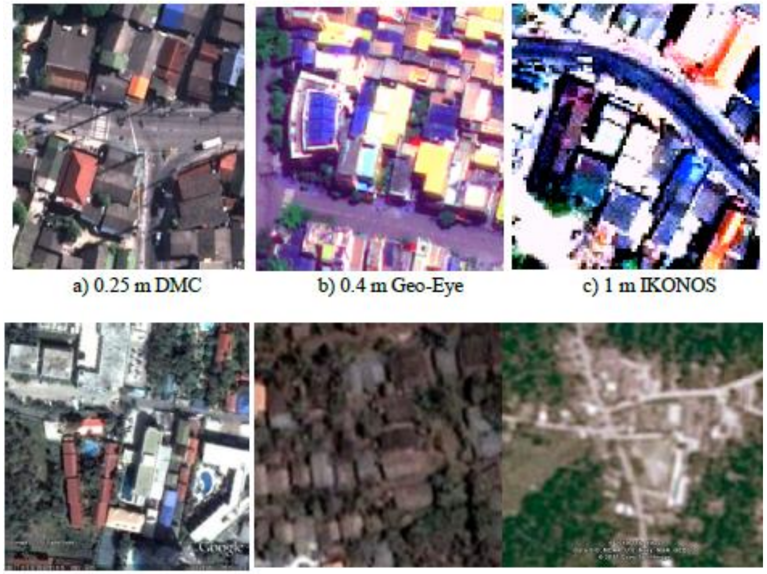
- It is the ratio in which the real objects are reduced on to a map illustration
  - 1 cm = 1000 m
  - 1 cm = 100, 000 cm
  - 1 : 100, 000
    - 1 unit on map equivalent to how many units on Earth



MAPPING

❖ Resolution

- How accurately the location and shape of map features can be depicted for a given map scale
- In larger scale maps - features more closely matches real world features



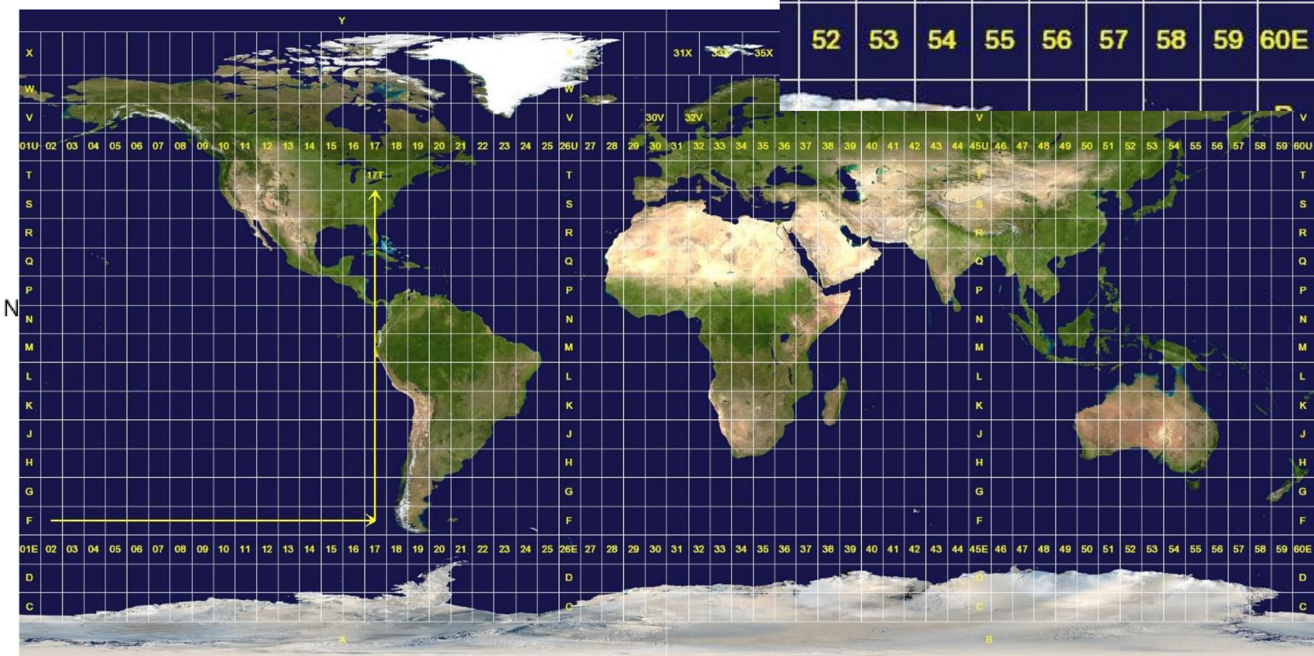
a) 0.25 m DMC b) 0.4 m Geo-Eye c) 1 m IKONOS

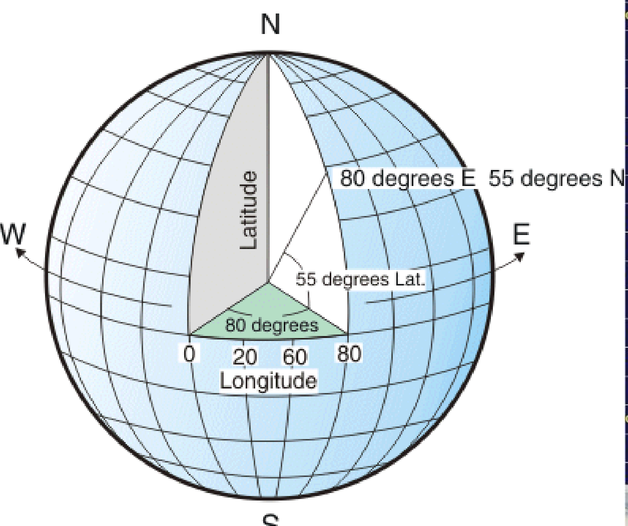
d) Google Earth 1 e) Google Earth 2 f) Google Earth 3

MAPPING

❖ Projection

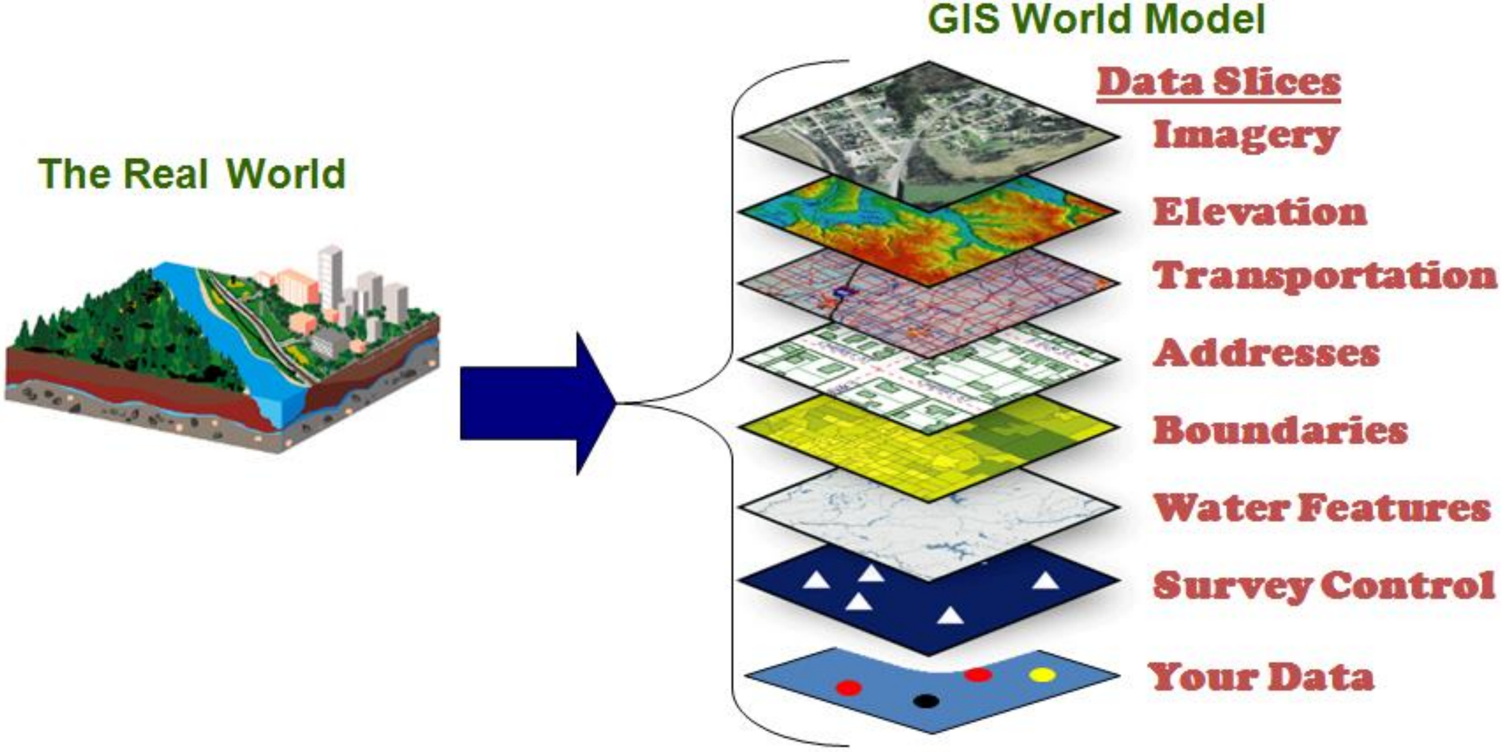
- Geographic Coordinate System (EPSG: 4326)
- Projection Systems
    - Universal transverse Mercator (UTM54S, 55S, 56S)
    - Pseudo Mercator (EPSG: 3857)

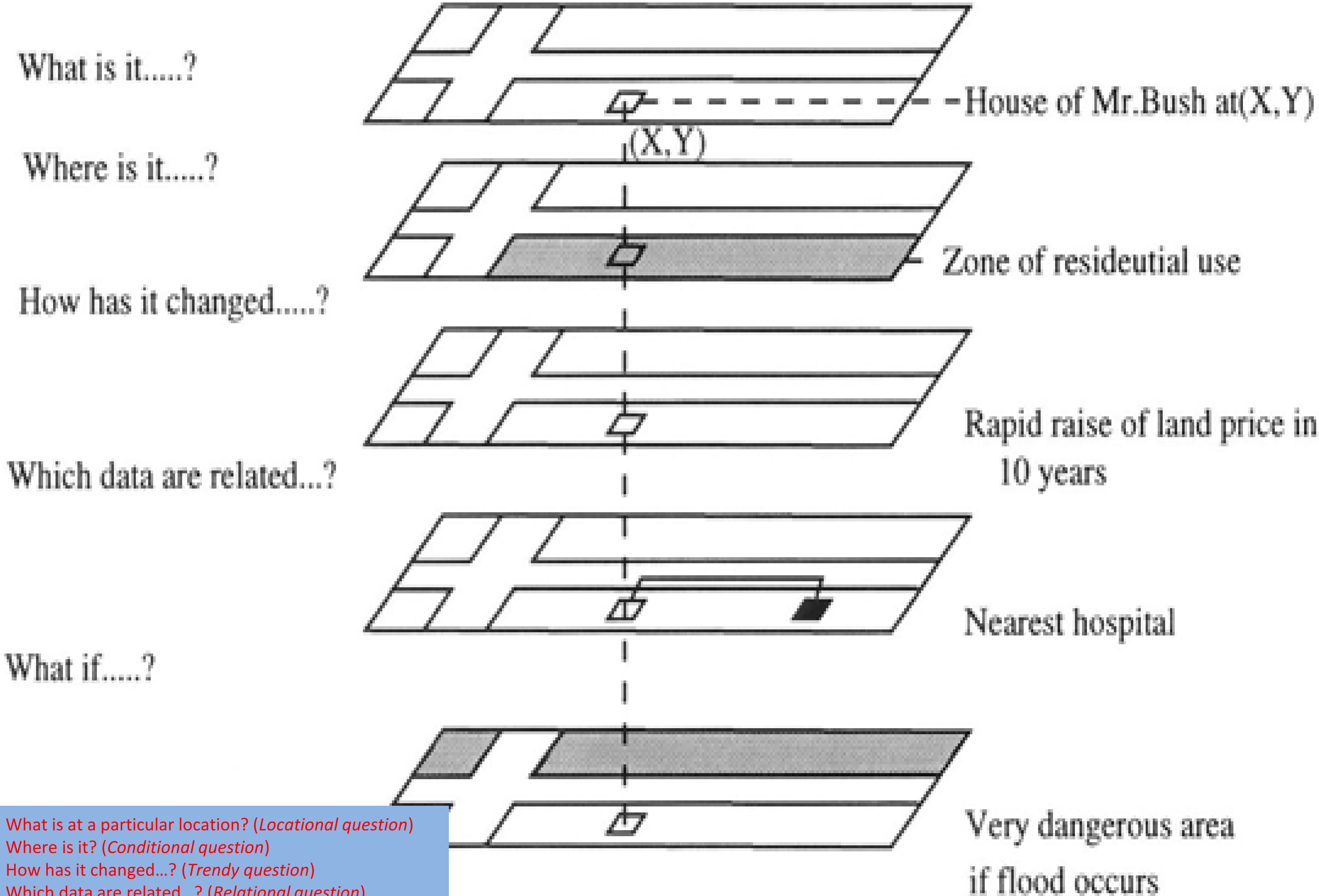




GIS

- An organized collection of computer hardware, software, geographic data, and personnel designed to efficiently *capture, store, update, manipulate, analyze and display* all forms of geographically referenced information



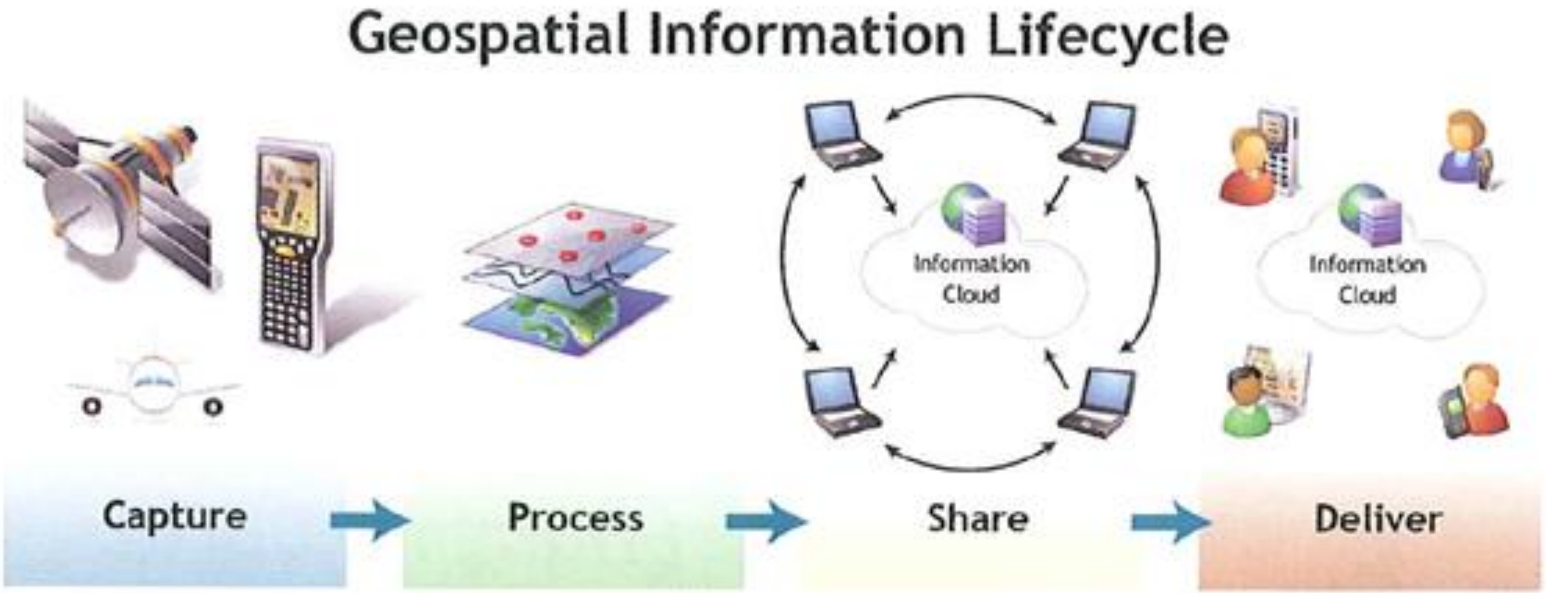


1. What is at a particular location? (*Locational question*)
2. Where is it? (*Conditional question*)
3. How has it changed…? (*Trendy question*)
4. Which data are related…? (*Relational question*)
5. What if …? (*Model-based question*)

Figure 1.4 Required Functions of GIS

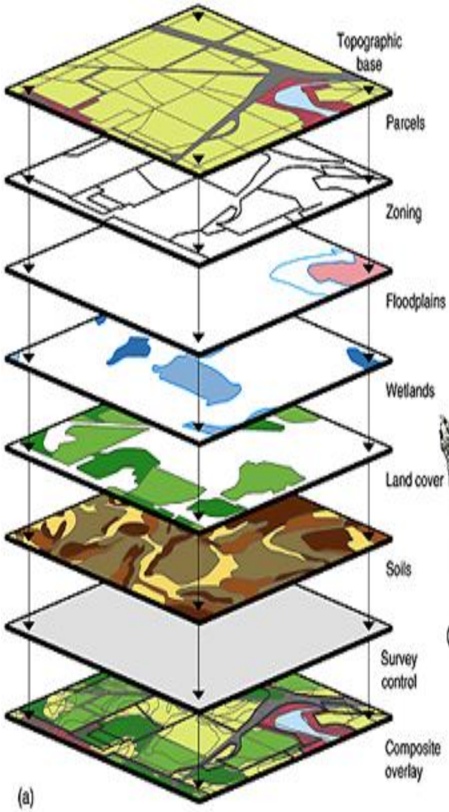
GIS

- Data Acquisition
- Data Processing
- Data Management
- Data Manipulation and Analysis
- Data Product Generation



GIS CAPABILITIES

- *Convert data into digital format*, so constraints such as scale, is no longer a limitation
- *Easier revision, update, query, analysis, manipulation and representation* of geographic data
- *Different thematic layers can be overlayed* such as in suitability analysis
- *Data sharing and networking* is possible since data storage and transfer is easy
- *Computation is precise* and takes only a little time
- *Multidisciplinary* science



GIS LIMITATIONS

- *One-time cost* for the initial phase of acquiring hardware (PC, plotter, scanner, GIS software, personnel, etc.)

- *Lack of tranined professionals* in the field

- Drawback for high temporal resolution image, which is crucial in disaster monitoring, is low spatial resolution; *hence lesser detail*

- GIS professionals should not only need to know how to process data using GIS but should also have knowledge in the different fields such as in disaster management, the physical, social, economic, management, planning, etc. since GIS is *multidiscplinary*

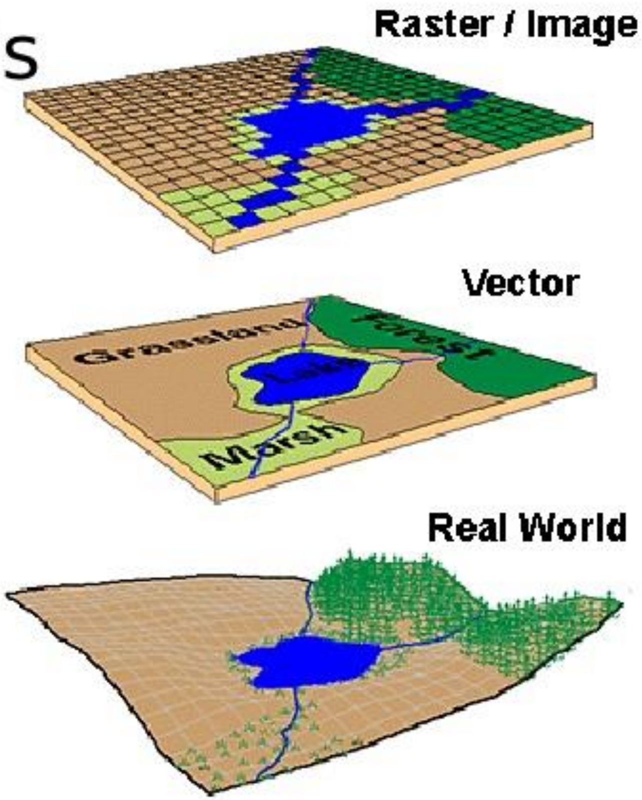
"The level of technology required of a GIS professional takes years… It's not one specialty, you need to be broad based."

-Colleen Messel

GIS

Basic Data Models

- **Vector Data Model (entities)**
- **Raster Data Model (fields)**

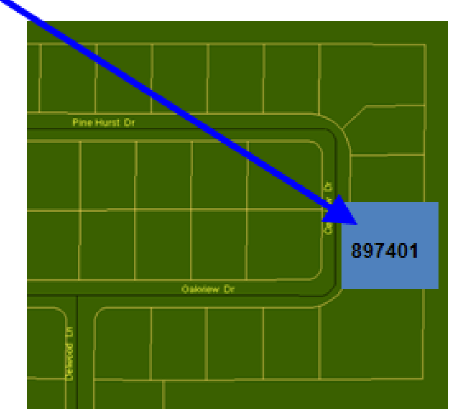


GIS

❖ Feature vs. attribute table

Parcel ID	897401
Owner	Jane Doe
Address	110 E Oak
City	Anywhere
State	Indiana
Zip	46060
Property Value	$72,000

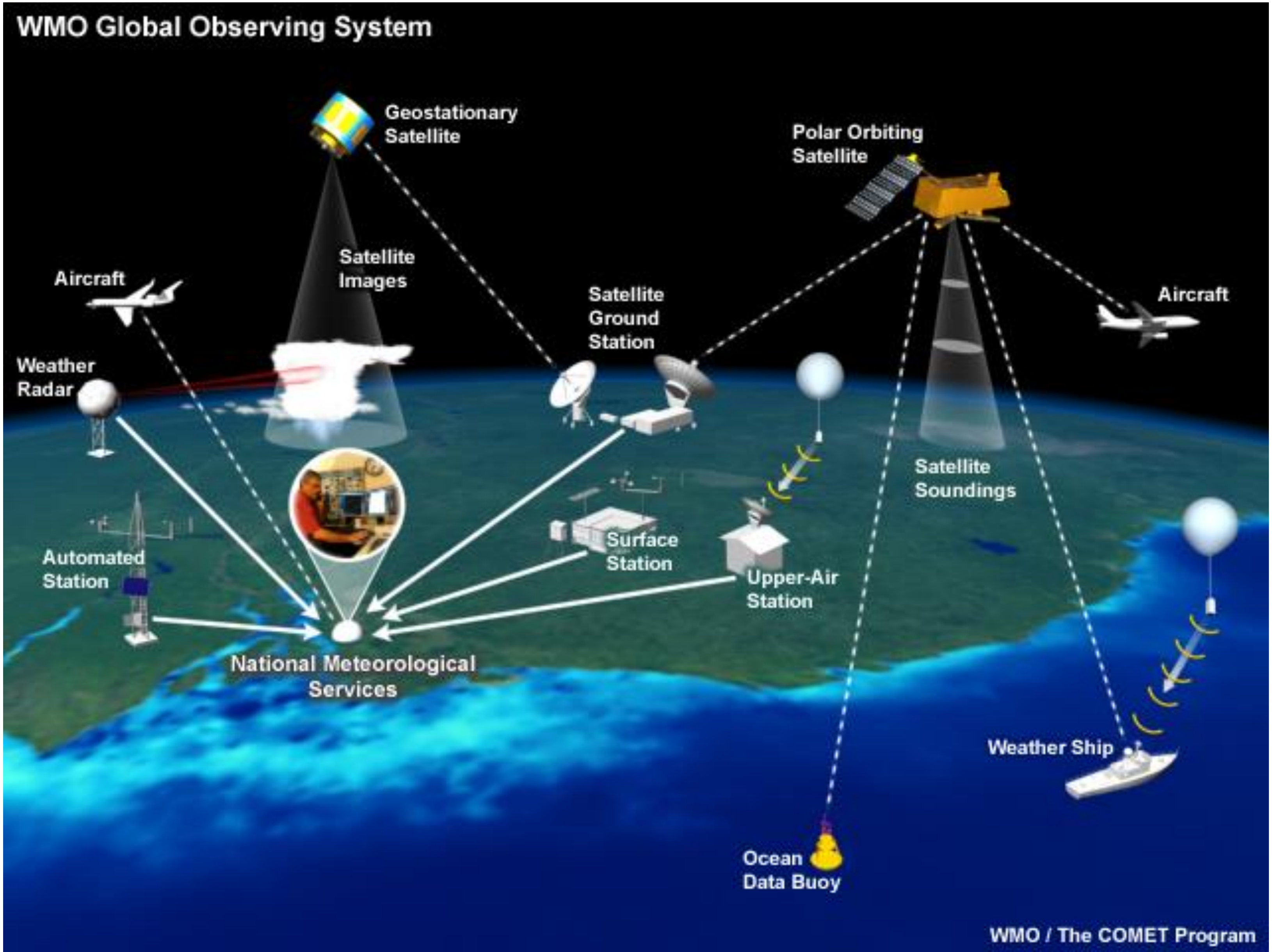
Name	Jane Doe
Phone	776-6300
School Dist	Center
Fire Dist	No. 12
Police Dist	Centertown
Zip	46060

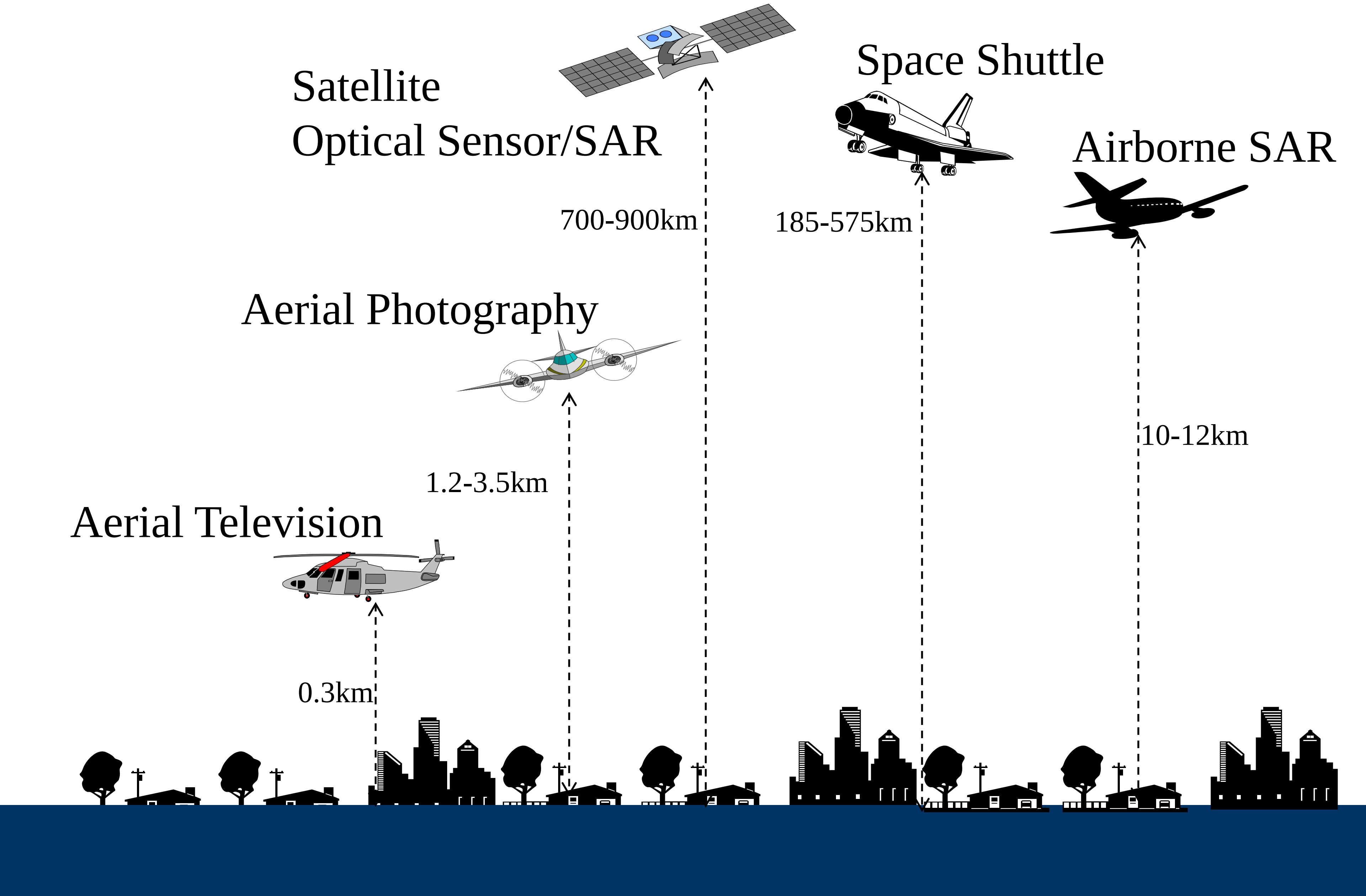


REMOTE SENSING

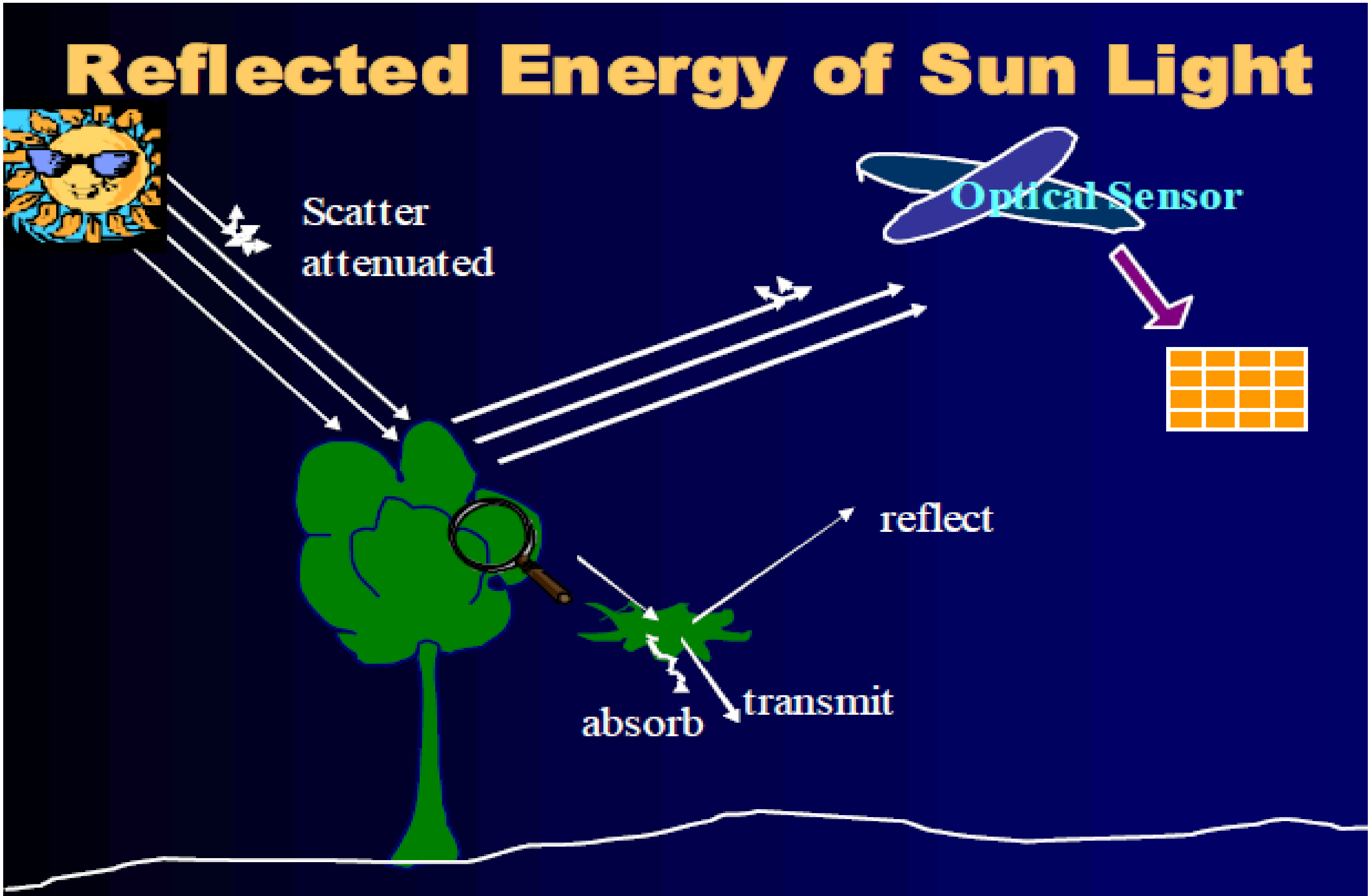
The science and art of *identifying, observing, and measuring an object without coming into direct contact with it*

REMOTE SENSING



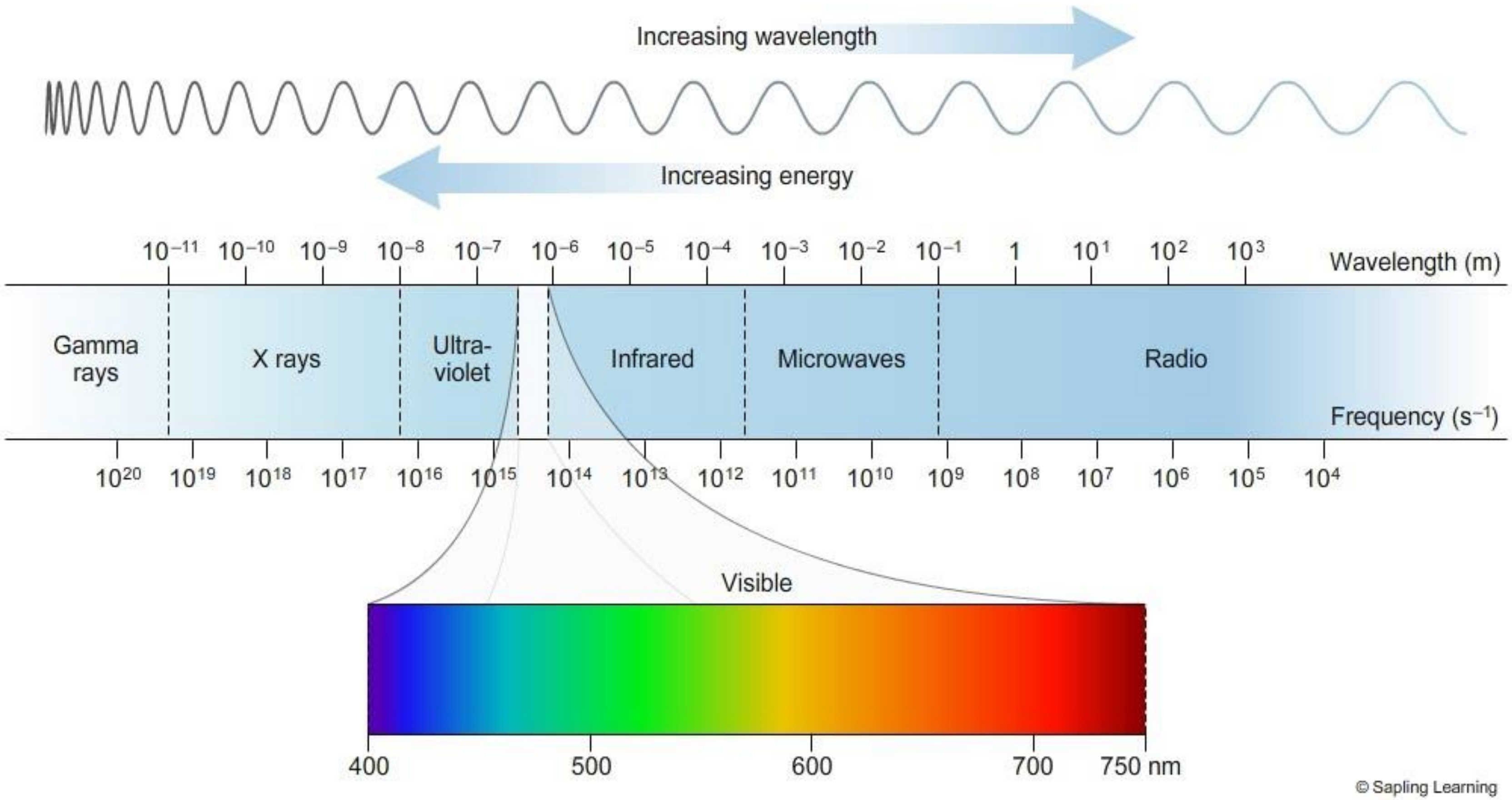

Satellite
Optical Sensor/SAR
Space Shuttle
Airborne SAR
700-900km
185-575km
Aerial Photography
10-12km
1.2-3.5km
Aerial Television
0.3km

REMOTE SENSING



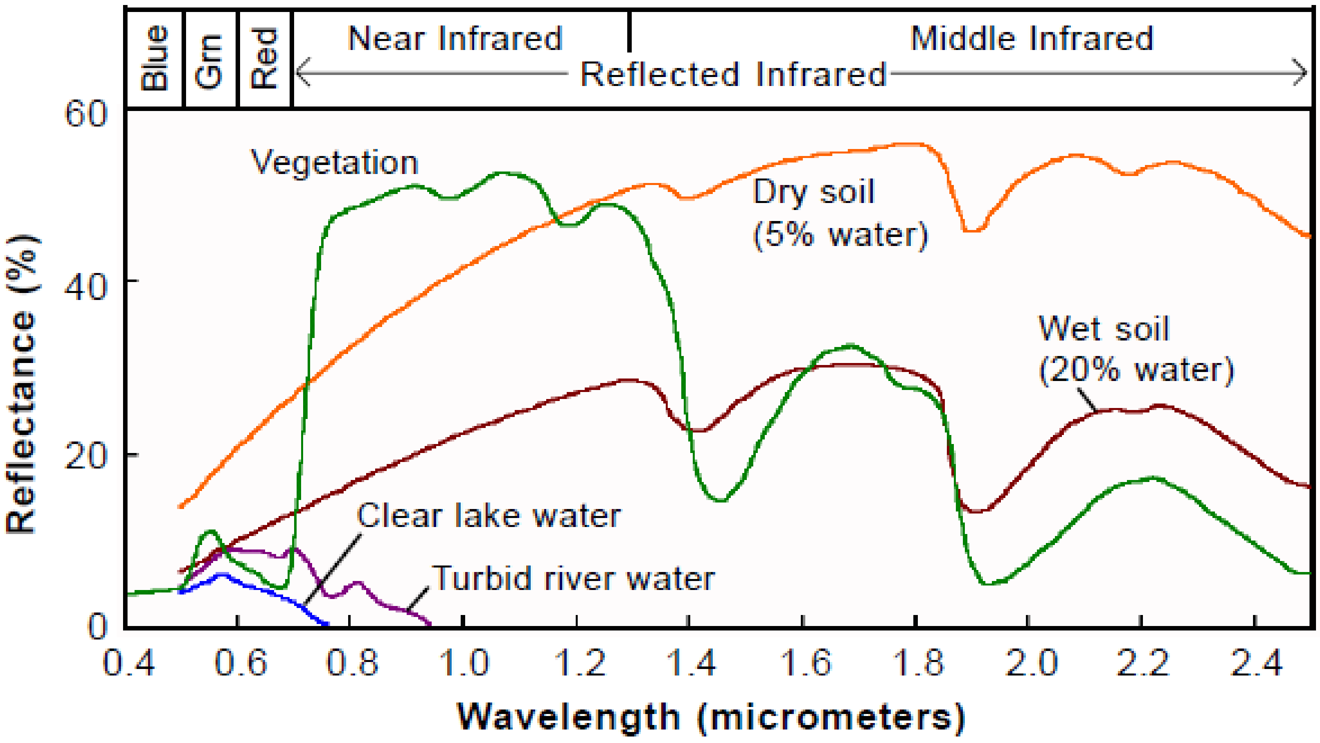
REMOTE SENSING

❖ *Different objects reflect and emit differently over the range of the electromagnetic spectrum*, this particular characteristic of objects distinct to its kind, is called the object's *spectral signature*



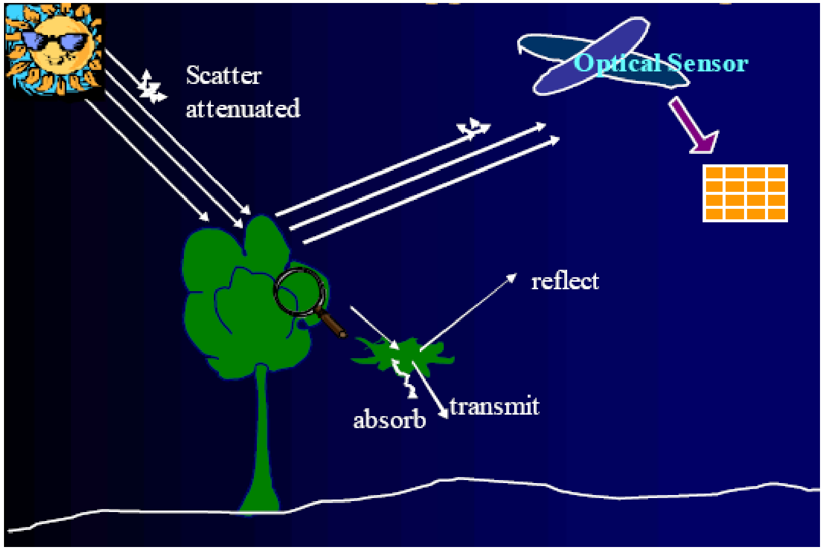
REMOTE SENSING

- *Vegetation* is characterized by a very unique spectral signature



OPTICAL REMOTE SENSING

- Operate in the visible region
- Detect reflectance of sunlight on different objects
- Good for *assessment of patterns and extent of damage*



Landsat 7 ETM+ Image around Lake Titicaca, Bolivia/Peru

LANDSAT 8

- Operational Land Imager (OLI)
- Temporal resolution: 16 days

Panchromatic

Natural Color

False Color Infrared

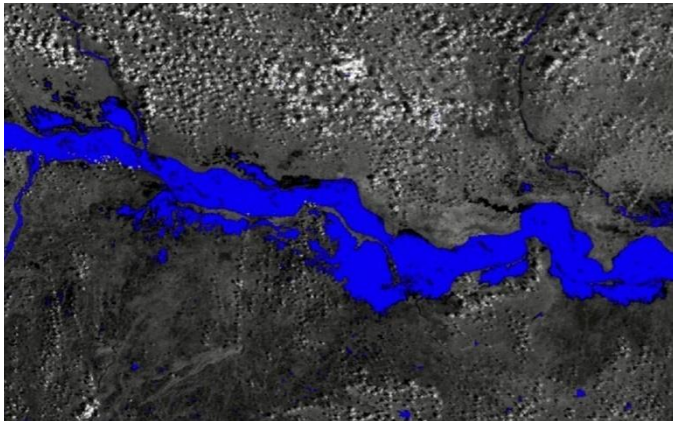
Spectral Band	Wavelength	Resolution	Solar Irradiance
Band 1 - Coastal / Aerosol	0.433 – 0.453 μm	30 m	2031 W/(m²μm)
Band 2 - Blue	0.450 – 0.515 μm	30 m	1925 W/(m²μm)
Band 3 - Green	0.525 – 0.600 μm	30 m	1826 W/(m²μm)
Band 4 - Red	0.630 – 0.680 μm	30 m	1574 W/(m²μm)
Band 5 - Near Infrared	0.845 – 0.885 μm	30 m	955 W/(m²μm)
Band 6 - Short Wavelength Infrared	1.560 – 1.660 μm	30 m	242 W/(m²μm)
Band 7 - Short Wavelength Infrared	2.100 – 2.300 μm	30 m	82.5 W/(m²μm)
Band 8 - Panchromatic	0.500 – 0.680 μm	15 m	1739 W/(m²μm)
Band 9 - Cirrus	1.360 – 1.390 μm	30 m	361 W/(m²μm)

OLI Spectral Bands [15][*citation needed*]

SENTINEL 2

- Temporal resolution: 5 days

Sentinel-2 Bands	Central Wavelength (µm)	Resolution (m)	Bandwidth (nm)
Band 1 – Coastal aerosol	0.443	60	20
Band 2 – Blue	0.490	10	65
Band 3 – Green	0.560	10	35
Band 4 – Red	0.665	10	30
Band 5 – Vegetation Red Edge	0.705	20	15
Band 6 – Vegetation Red Edge	0.740	20	15
Band 7 – Vegetation Red Edge	0.783	20	20
Band 8 – NIR	0.842	10	115
Band 8A – Narrow NIR	0.865	20	20
Band 9 – Water vapour	0.945	60	20
Band 10 – SWIR – Cirrus	1.375	60	20
Band 11 – SWIR	1.610	20	90
Band 12 – SWIR	2.190	20	180

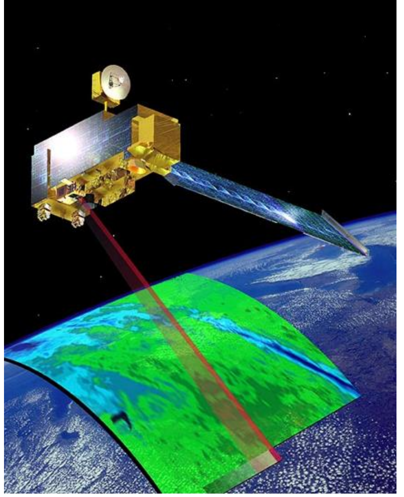


MODIS

- Moderate-resolution imaging spectroradiometer
- Temporal resolution: 1-2 days

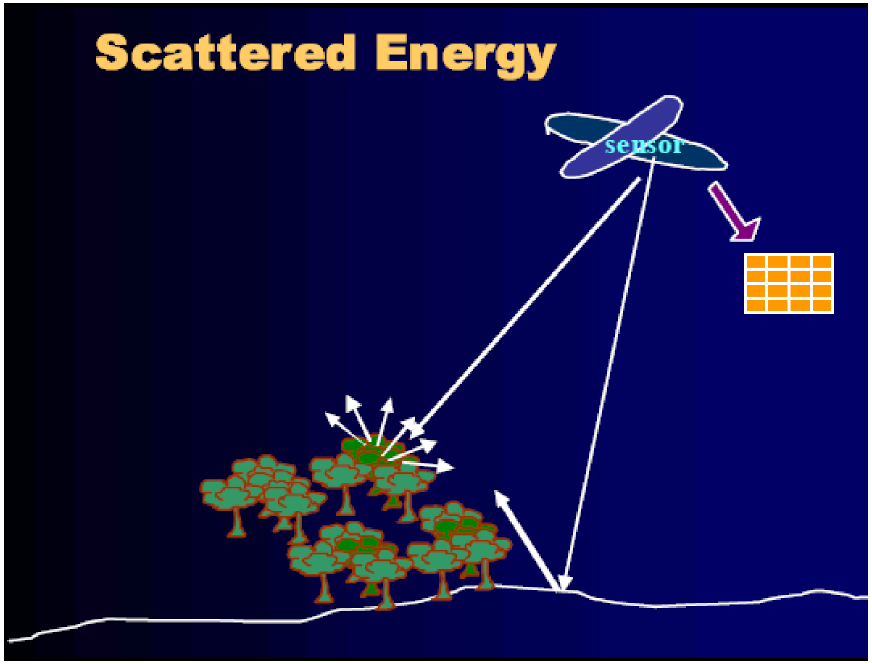
Band	Wavelength (nm)	Resolution (m)	Primary Use
1	620–670	250	Land/Cloud/Aerosols Boundaries
2	841–876	250	
3	459–479	500	Land/Cloud/Aerosols Properties
4	545–565	500	
5	1230–1250	500	
6	1628–1652	500	
7	2105–2155	500	
8	405–420	1000	Ocean Color/ Phytoplankton/ Biogeochemistry
9	438–448	1000	
10	483–493	1000	
11	526–536	1000	
12	546–556	1000	
13	662–672	1000	
14	673–683	1000	
15	743–753	1000	
16	862–877	1000	
17	890–920	1000	Atmospheric Water Vapor
18	931–941	1000	
19	915–965	1000	

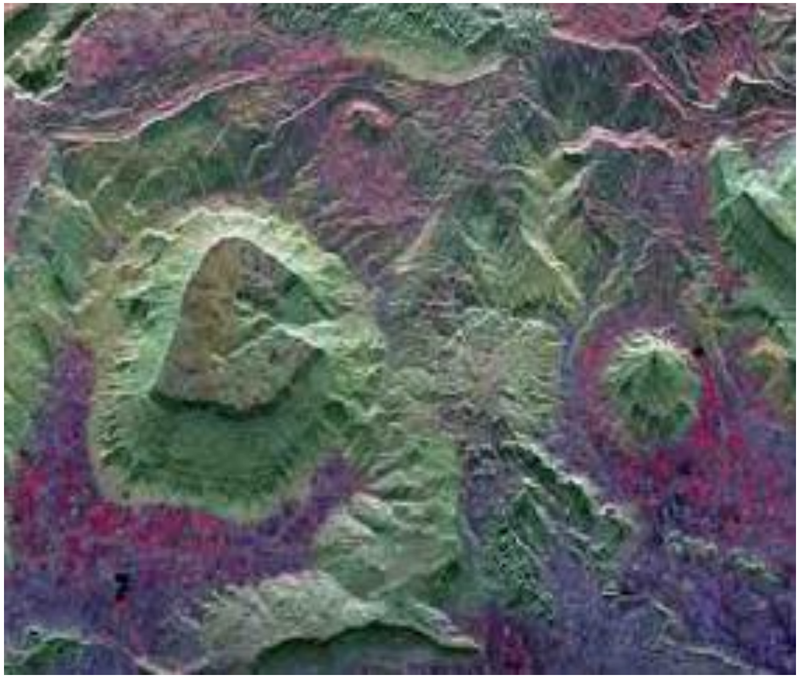
Band	Wavelength (µm)	Resolution (m)	Primary Use
20	3.660–3.840	1000	Surface/Cloud Temperature
21	3.929–3.989	1000	
22	3.929–3.989	1000	
23	4.020–4.080	1000	
24	4.433–4.498	1000	Atmospheric Temperature
25	4.482–4.549	1000	
26	1.360–1.390	1000	Cirrus Clouds Water Vapor
27	6.535–6.895	1000	
28	7.175–7.475	1000	
29	8.400–8.700	1000	Cloud Properties
30	9.580–9.880	1000	Ozone
31	10.780–11.280	1000	Surface/Cloud Temperature
32	11.770–12.270	1000	
33	13.185–13.485	1000	Cloud Top Altitude
34	13.485–13.785	1000	
35	13.785–14.085	1000	
36	14.085–14.385	1000	



RADAR REMOTE SENSING

- Operates in the *microwave region*
- Detect scattered energy sent by satellite on different objects
- *Can penetrate* clouds, rain, local darkness
- Show texture and patterns of objects
- Good for assessment/monitoring in *weather obscured areas*

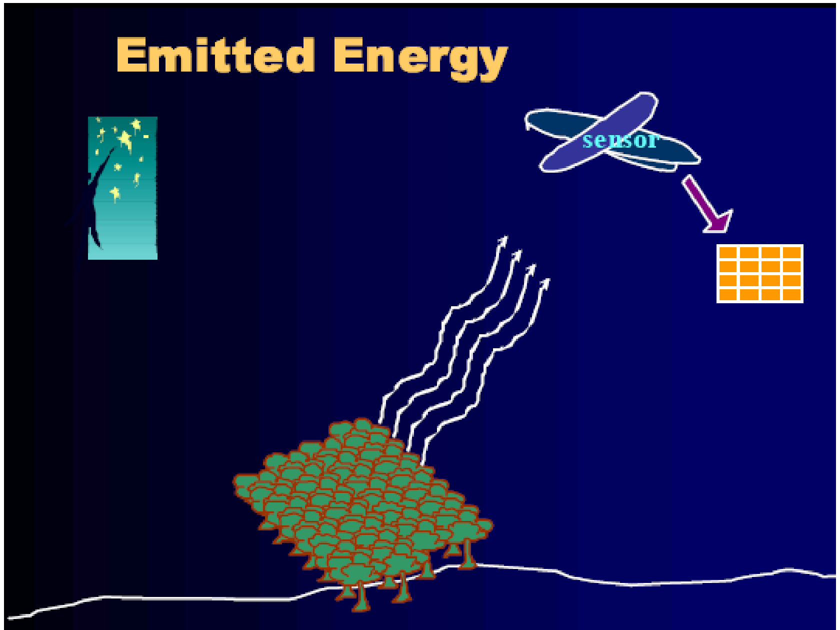


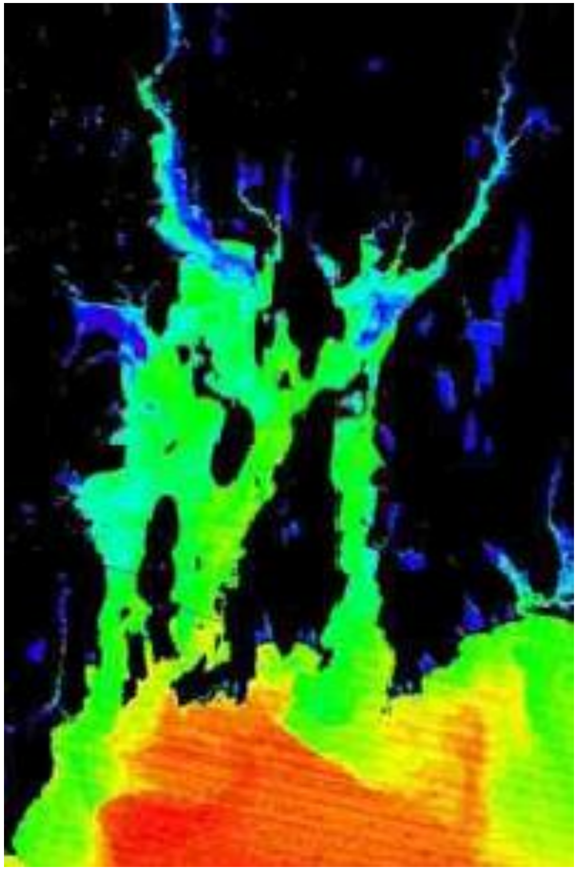


- *Phang Hoei Range*

THERMAL REMOTE SENSING

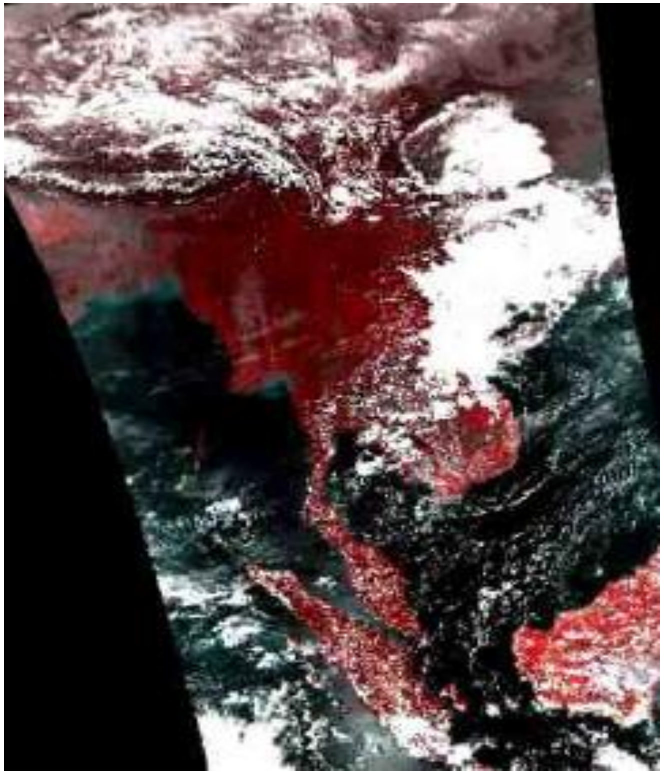
- Operates in the *Infrared region*
- Detects energy emitted from an object
- NIR sensitive to vegetation, Thermal to temperature
- Good for detection of aerial extent of *forest fires and assistance in non-urban search and rescue activities*





Landsat image showing temperature of the water surface

HIGH/LOW RESOLUTION



- High Resolution IKONOS (0.61m)
- Ideal for detailed assessment

- Low Resolution NOAA (1.1km)
- Ideal for monitoring and global extent

CAPABILITIES

- *Major sources* for detection during monitoring and assessment of disaster and damages (pre-, during, post disaster activities)

- *Local and global scale* of the disaster area (spatial resolution from 0.44 m to 1km)

- *Good temporal resolution* from a geostationary satellite like NOAA AVHRR that is ideal for monitoring fire or cyclone

LIMITATIONS

- *Ground data* still needed to achieve more useful information (using *GPS camera or manual inspection*)

- *High cost* for high spatial resolution imagery like Quickbird which costs $18/km^2

- Drawback for high temporal resolution image, which is crucial in disaster monitoring, is low spatial resolution; *hence lesser detail*

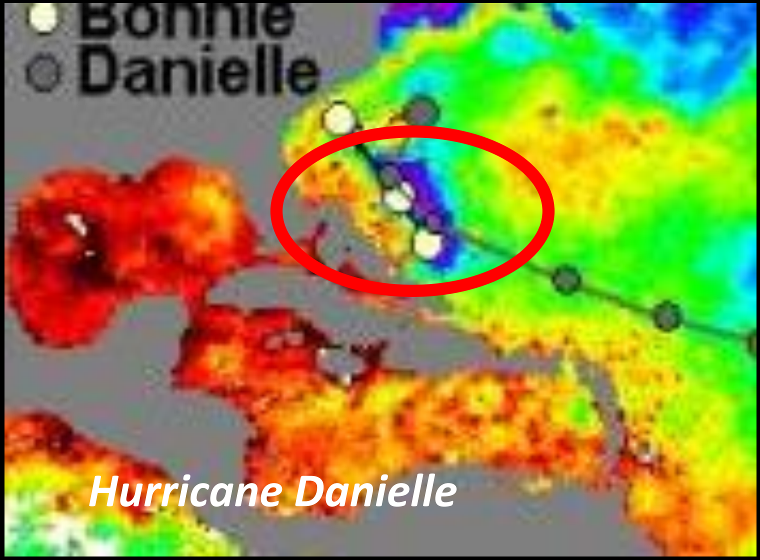
- Drawback for high spatial resolution image like GeoEye-1, which are good in mapping detail of impact of disaster, is low temporal resolution; *hence not good for monitoring disaster*

APPLICATIONS

Cyclone

- RS instruments such as IR sensors (polar-orbit satellites) provide day-and-night observations during daytime while geostationary satellites (NOAA, INSAT) provide *continuous coverage during daytime*
- Low resolution satellite (NOAA) provides a *full extent* of the cyclone
- *Cold temperatures* in the middle of an otherwise homogeneous area of normal temperature in thermal images can signify a cyclone in the area


Hurricane Katrina

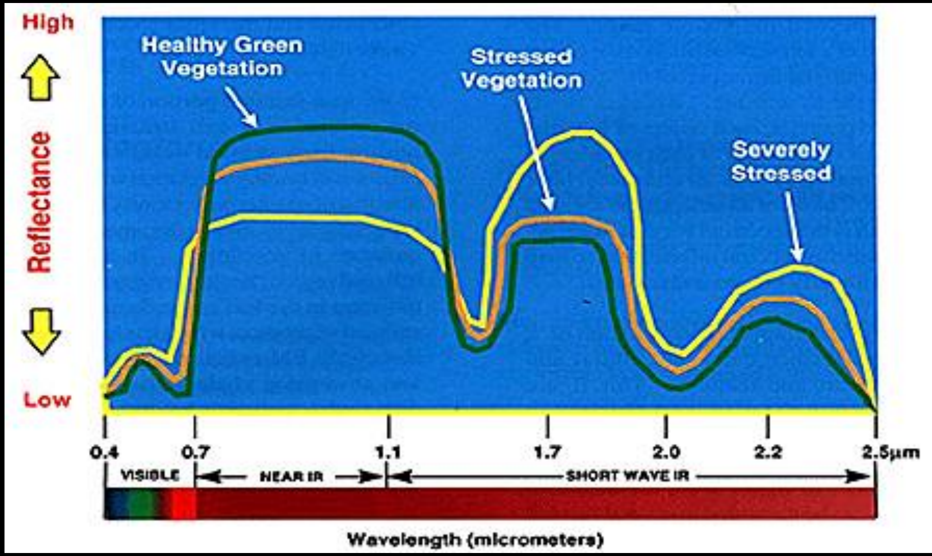


Hurricane Danielle

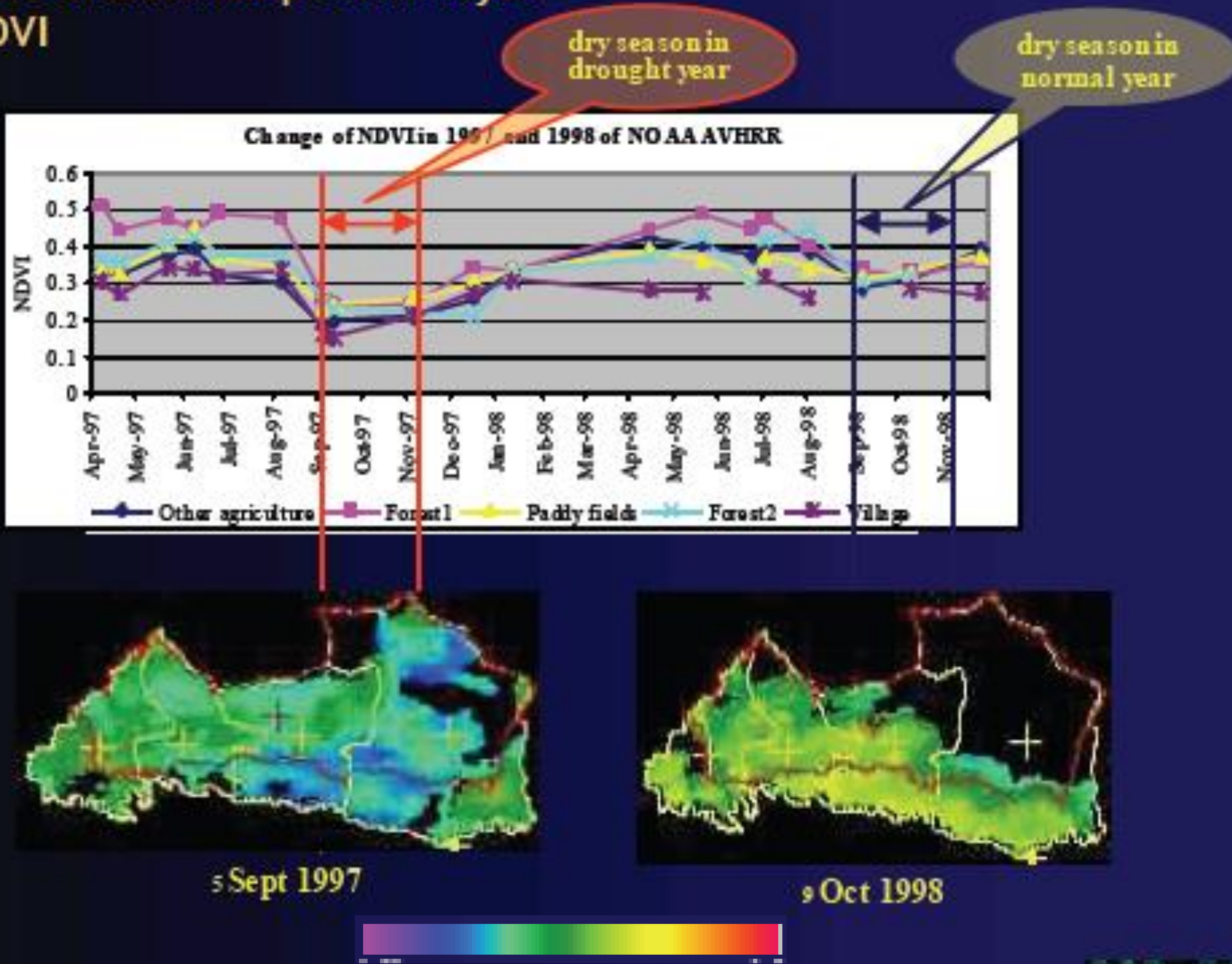
Drought

- RS data can provide *major sources of input* to rainfall predictions, NDVI, atmospheric, land and ocean parameters (temperature, pressure, wind)
- Monitoring may be done by *assessment of NDVI* which is sensitive to stress in vegetation

Winter Wheat (Cape Town, South Africa)



Graphic of Multi temporal analysis for NDVI

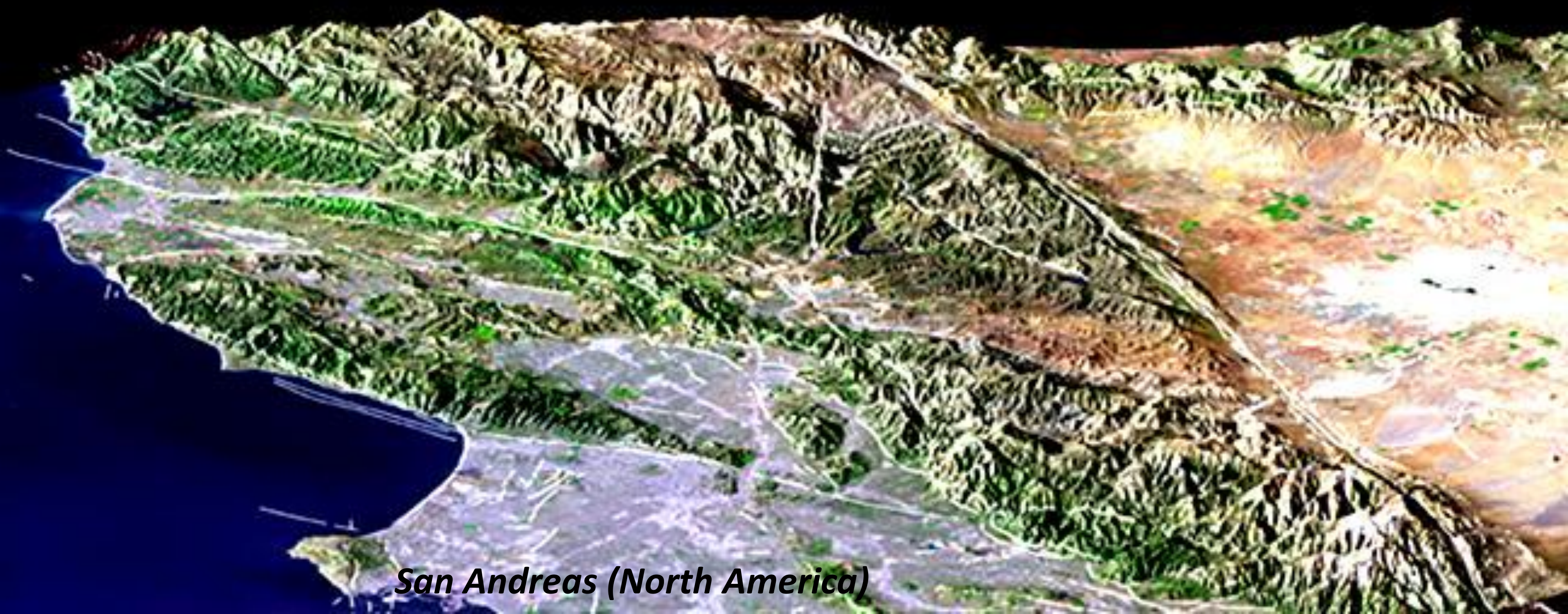


5 Sept 1997

9 Oct 1998

Earthquake

- RS is useful in *seismic analysis* wherein active faults may be distinguished as distinct breaks on the ground along known active faults

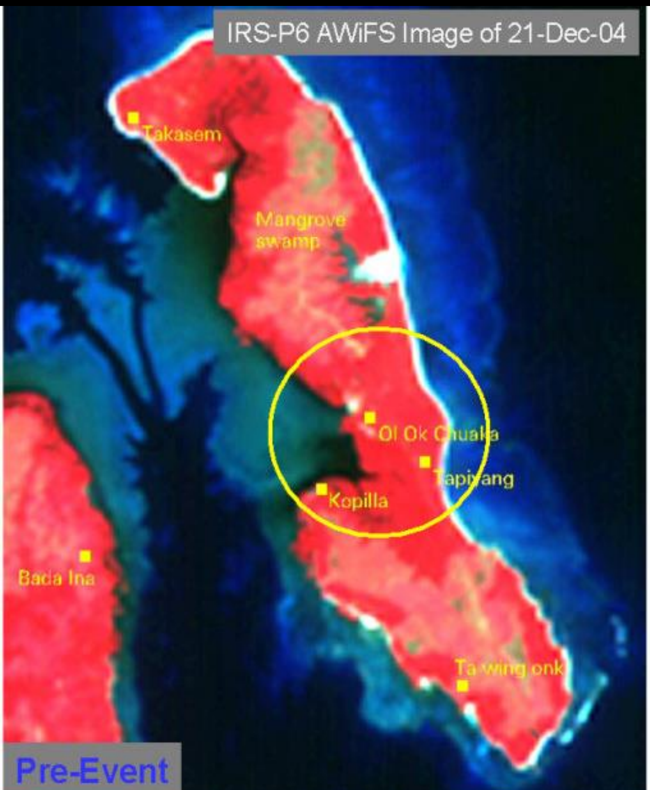


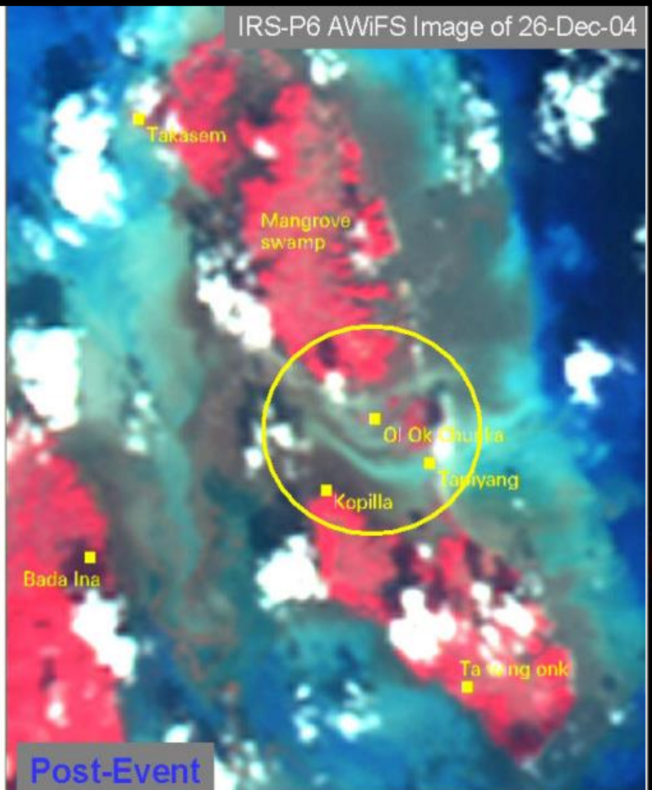
San Andreas (North America)

Earthquake

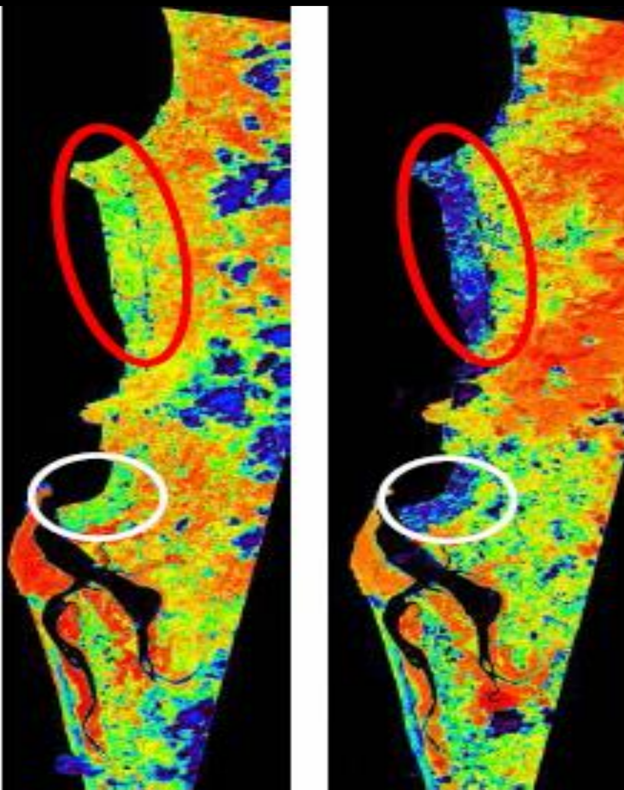
- Optical data such as false color IRS can show the extent of flooding and damage in the area caused by a tsunami
- NDVI can detect a decrease in vegetation due to flooding

Trinkat Island, 2004

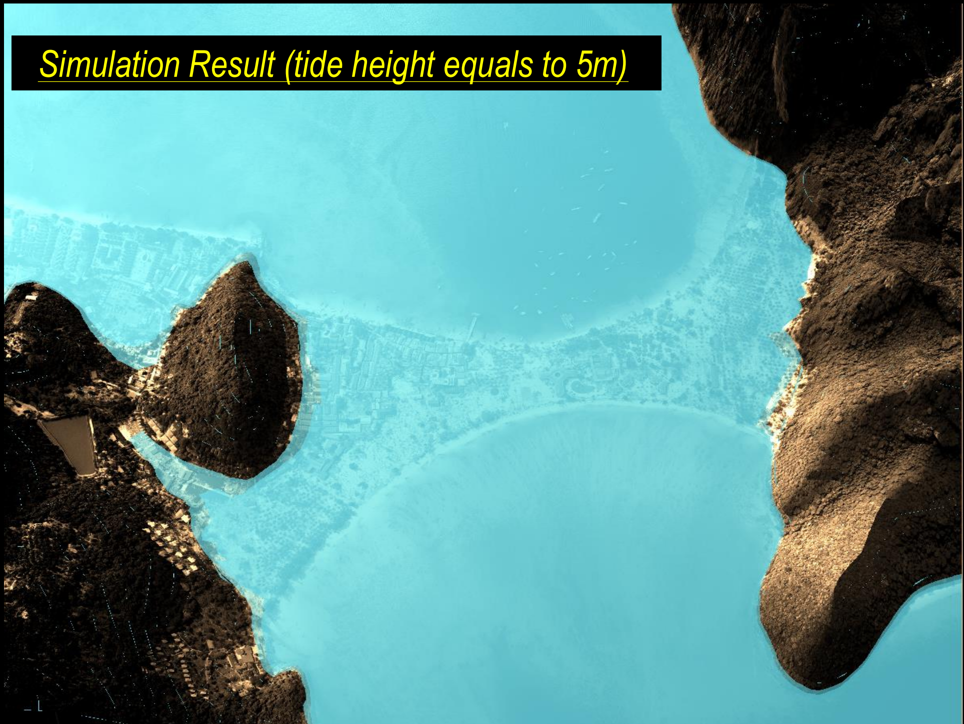




NDVI assessment



Phi-Phi Island, Thailand



Fire

- **High temporal, global coverage (NOAA) images and high spatial, low temporal IRS data can be used to detect fires that break, monitor conditions and provide information on affected areas**

- **GIS can help in the preparation of *forest fire risk assessment* by integrating different data that influence the occurrence of this phenomenon such as *land use, vegetation type, soil moisture and previously mapped burned areas***

Flood

- Optical and microwave (radar) such as Landsat and ERS help map and monitor flood events before, during and after it occur
- Near IR band is the optimum band for flood monitoring
- Significant advantage of microwave RS is its ability to penetrate through clouds, rain or local darkness, hence a good source of all-weather data
- GIS helps in the integration of these data with land use, topographic, hydrologic, and flood plain maps to form *flood risk maps*

Flooding of Mississippin River Basin

Flooding of Inn River (Branau, German/Austrian border)

3-D Flood Model (Great Britain)

Landslide

- RS limited only to recognizing landslide from ***previous disasters***

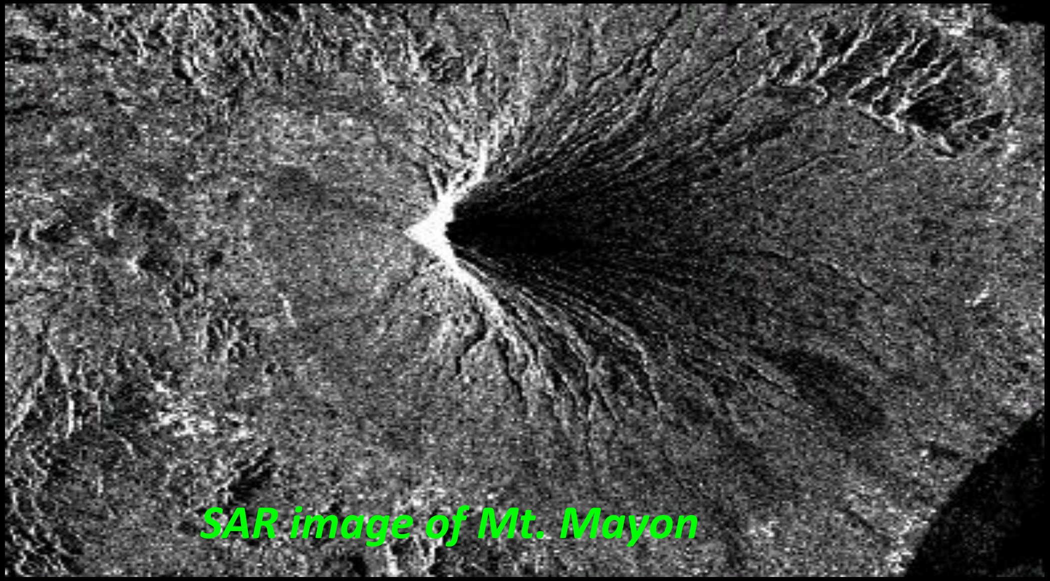
- ***High resolution optical satellite data*** **such as Quickbird, IKONOS, SPOT-5, radar or aerial photographs can be used to detect these features**

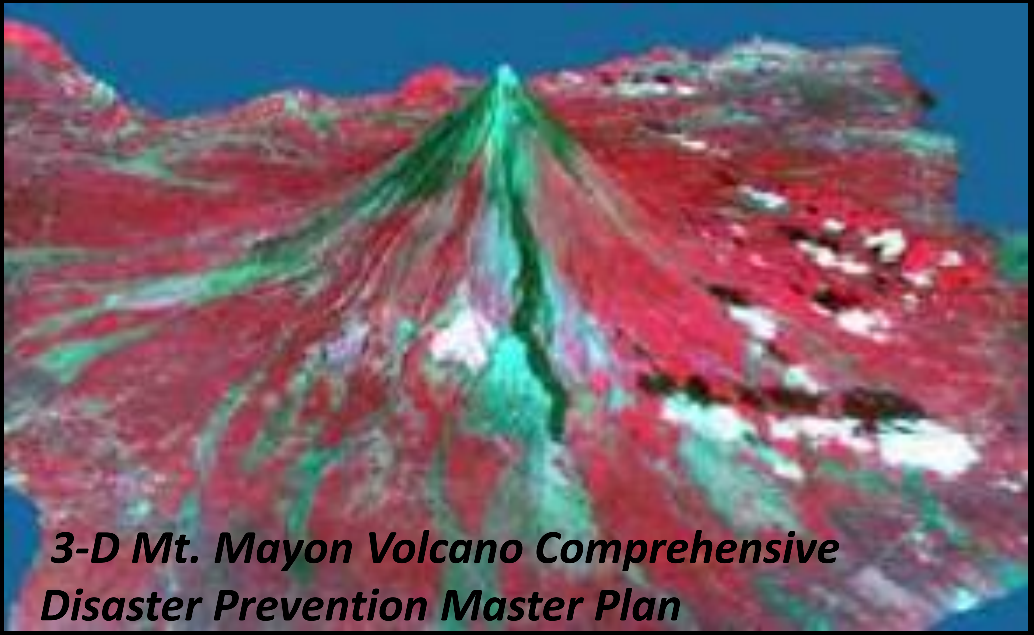
- **Since high soil moisture is a major characteristic of landslides,** ***thermal IR images can detect differences in damp ground*** **associated with landslides**

Landslide (Pakistan)

Volcanic Eruption

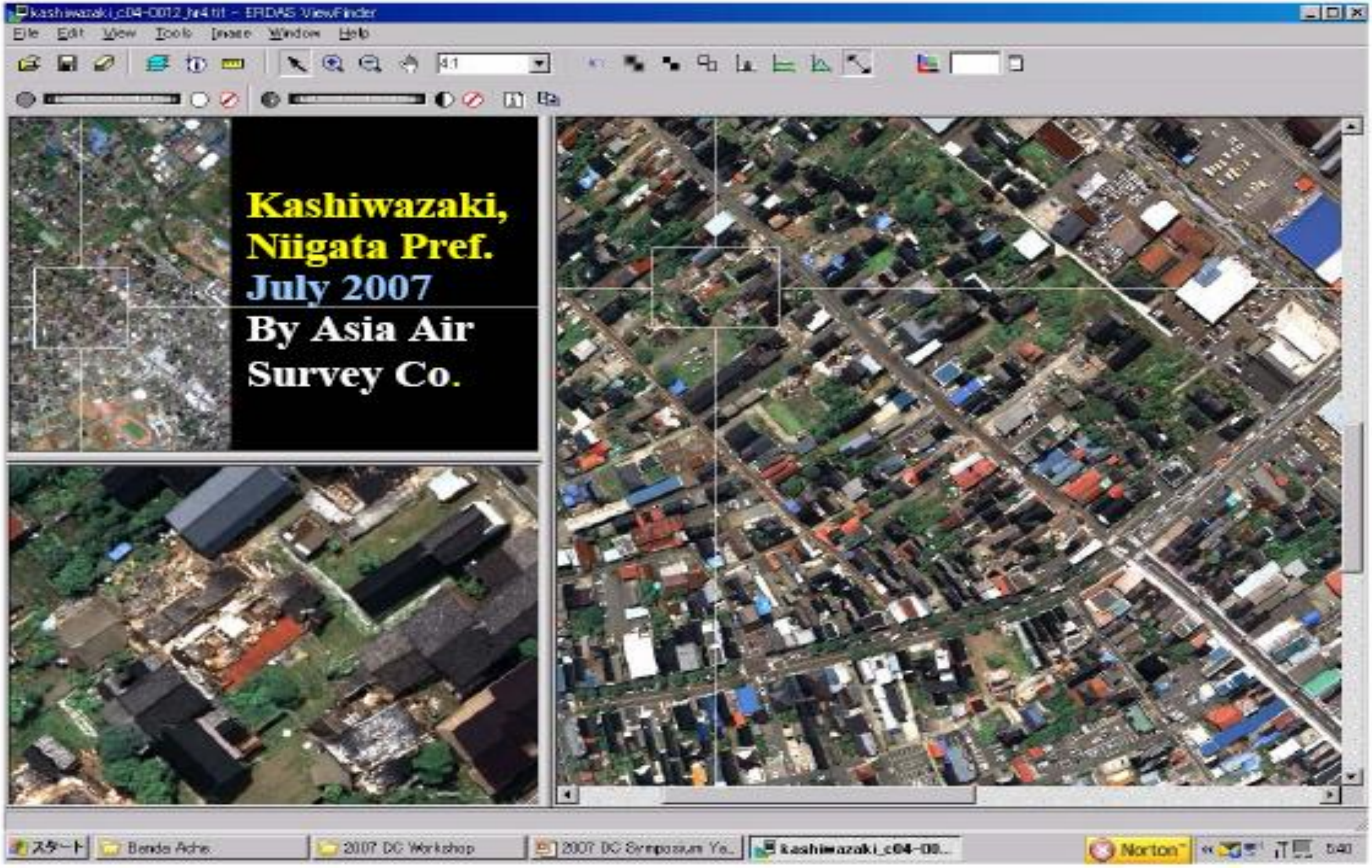
- Earthquakes caused by magma intrusion can be sensed by *seismometers*
- *Changes in shape* of volcano can be seen on aerial photographs
- *Steam-driven ejection of old rock and ash* can be monitored by visual observation, photographs, radar observation
- *Ground temperature* may be measured directly with probes or remotely by thermal infrared scanners and radiometer


SAR image of Mt. Mayon


3-D Mt. Mayon Volcano Comprehensive Disaster Prevention Master Plan

Pre-disaster image of residential areas (Bam, Iran)

Post-disaster image of residential areas (Bam, Iran)



Damage Assessment using GIS

Thank you for your attention

RIMES Website: http://www.rimes.int/