COA 690/790 GIS in Marine Science

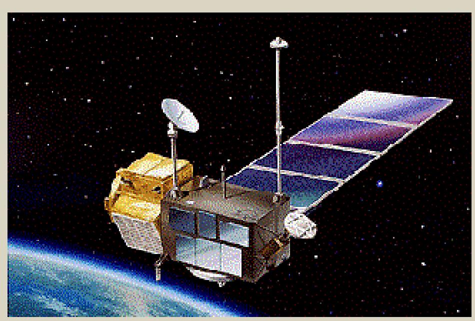
Lecture 5 Remote Sensing

Measuring an object from a distance

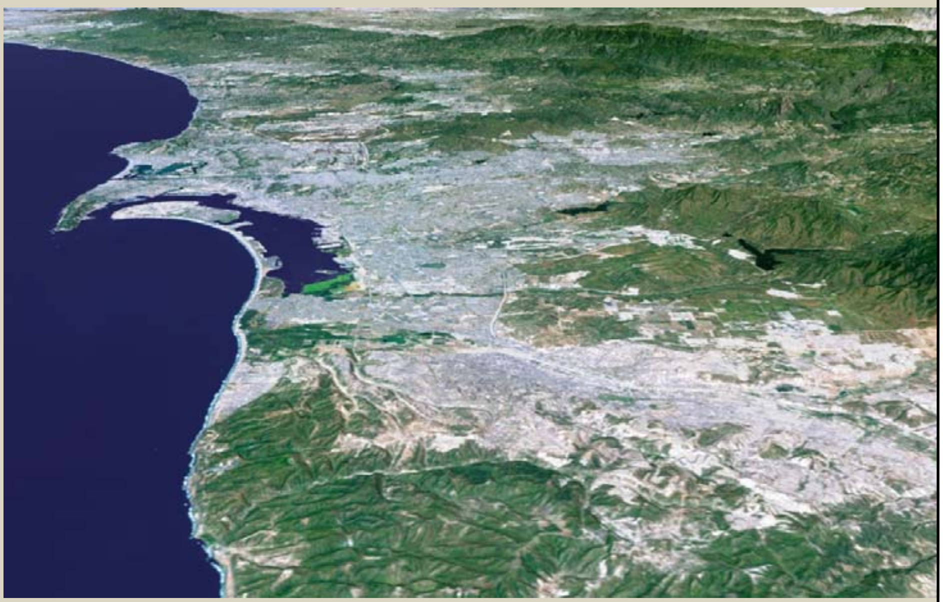
February 21, 2019

For GIS, that means using photographic or satellite images to gather spatial data

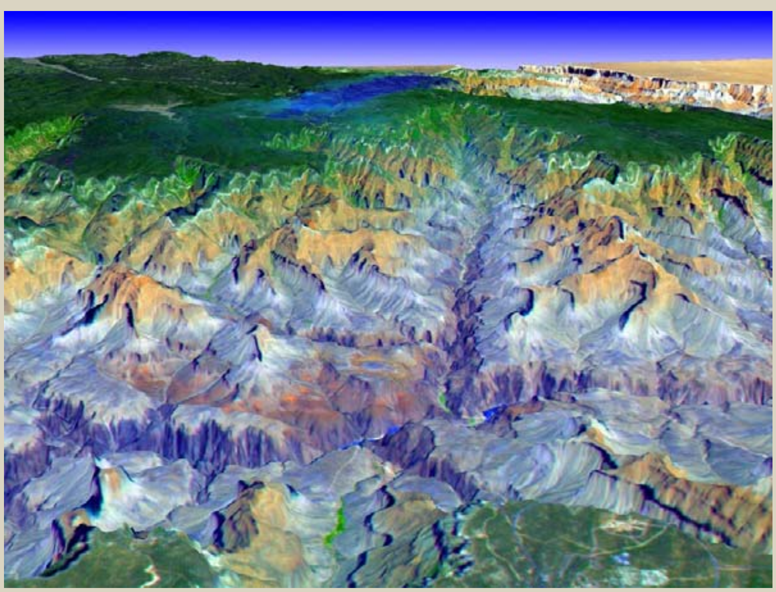
Remote Sensing measures electromagnetic energy reflected or emitted from objects – airborne or satellite-based instruments



Imagery - A Rich Data Source
NASA Aster and TM Imagery, San Diego, CA



NASA Aster and SRTM Image Data, the Grand Canyon, AZ



Broad Spectral Range
NASA MISR Data, the Hawaiian Islands

The World Changes – Images provide a permanent record

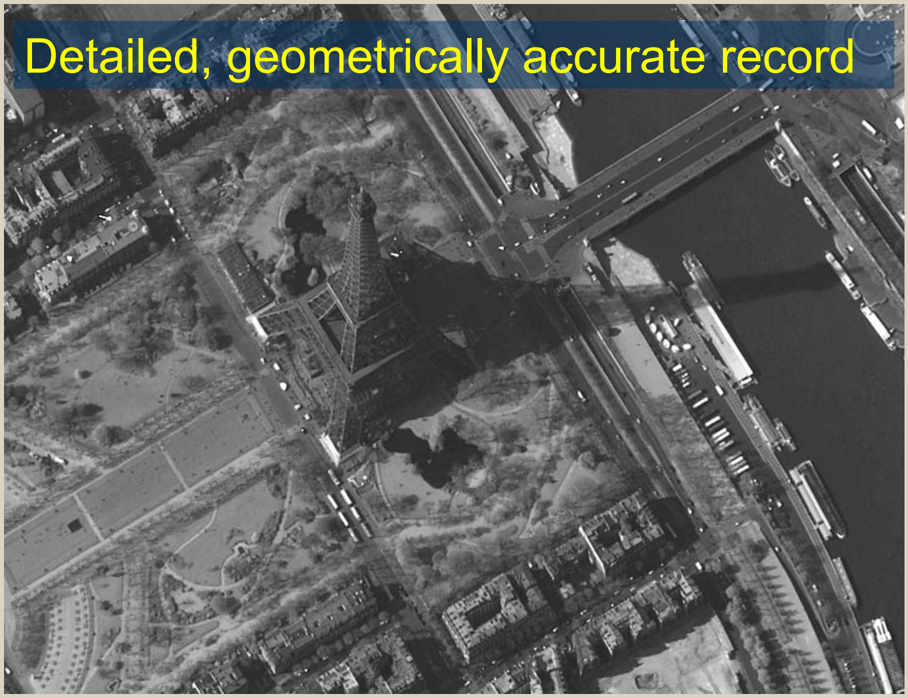
10/22/07

The World Changes – Images provide a permanent record

10/23/07

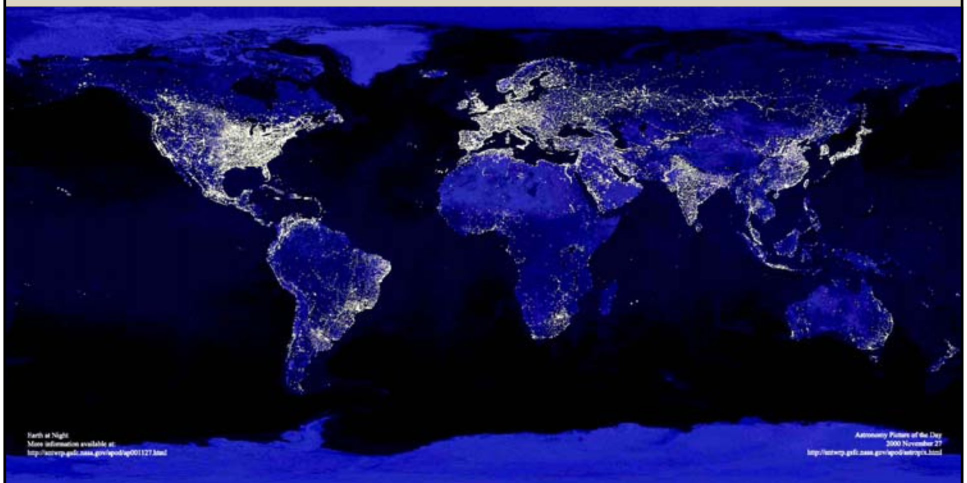
Change: Deforestation, Rondonia, Brazil (NASA Landsat Image)

Detailed, geometrically accurate record

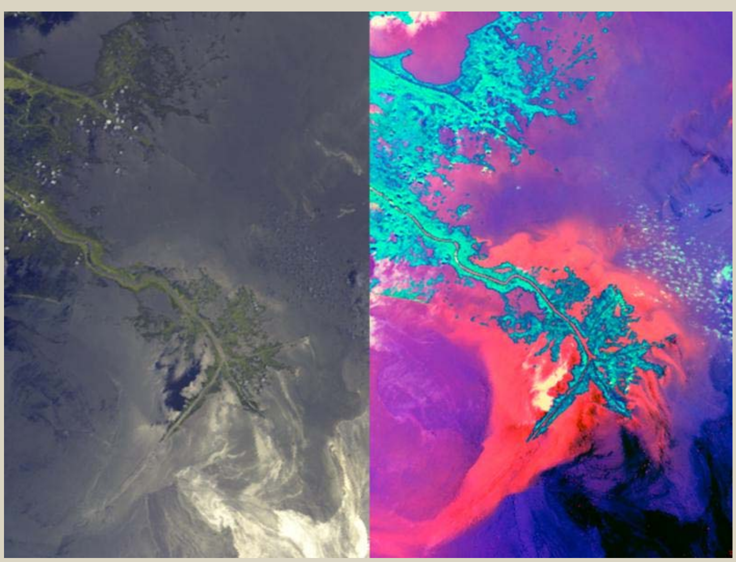


Broad Area Coverage

Broad Area Coverage

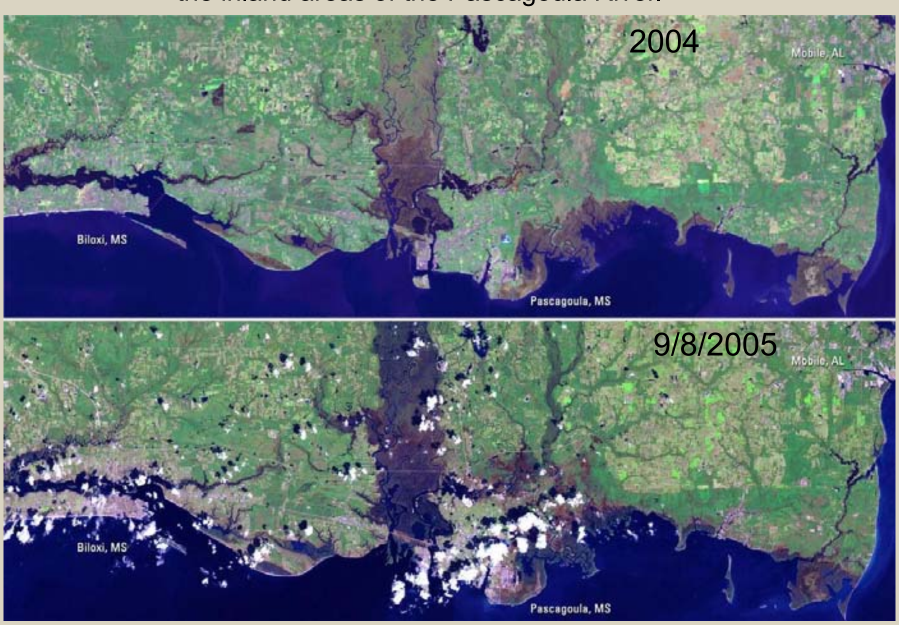


Multiple cameras on JPL's MISR instrument on NASA's Terra spacecraft were used to create two unique views of oil moving into Louisiana's coastal wetlands.



The MODIS on NASA’s Terra satellite captured this image on May 24, 2010

Hurricane Katrina not only affected the coastline, but also reached the inland areas of the Pascagoula River.



Why remotely-sensed images

•Large area coverage
•Extended spectral range
•Geometric accuracy
•Permanent record

Background

Light (300,000 km per second)

Light waves consist of **electric** and **magnetic** fields

Electromagnetic radiation is composed of many discrete units called "**photons**"

Electromagnetic radiation behaves like a **wave** *or traveling energy*

Measured by **wavelength** (peak to peak)

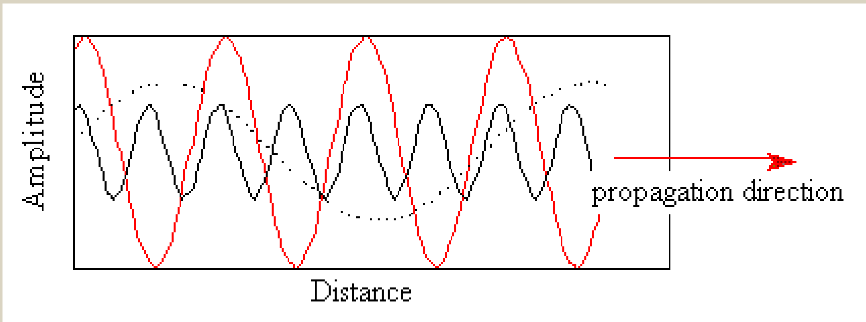
or **frequency** *(how many waves pass a point in space per second)*

wavelength and frequency are related
wavelength x frequency = Speed of Light

$$\lambda \times f = C$$

http://science.howstuffworks.com/light3.htm

Electromagnetic energy is a mixture of waves with different frequencies

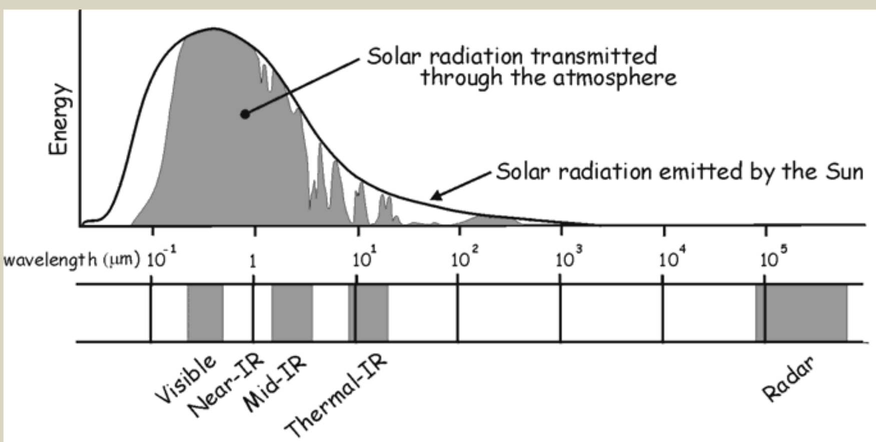


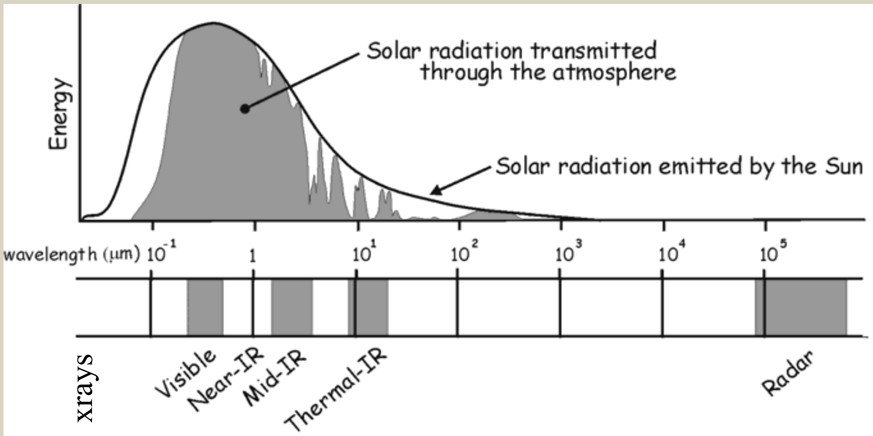
Each wave represents energy that varies at a given frequency.

Source:http://www.cnr.berkeley.edu/~gong/textbook/chapter2/html/sect21.htm

Radiation (electromagnetic energy) is emitted by the Sun, and attenuated by the atmosphere.

Specific bands of wavelengths are used for remote sensing





Blue .4 to.5 µm (micrometers)

Green .5 to .6 µm (micrometers)

Red .6 to .7 µm (micrometers)

Visible Light - How we see colors

Addition of light waves of different frequencies

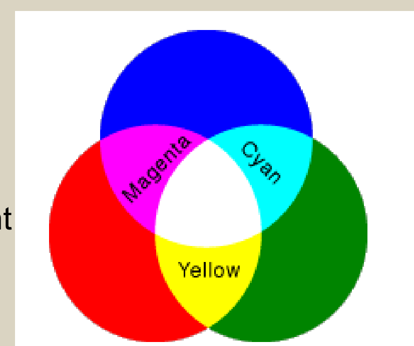
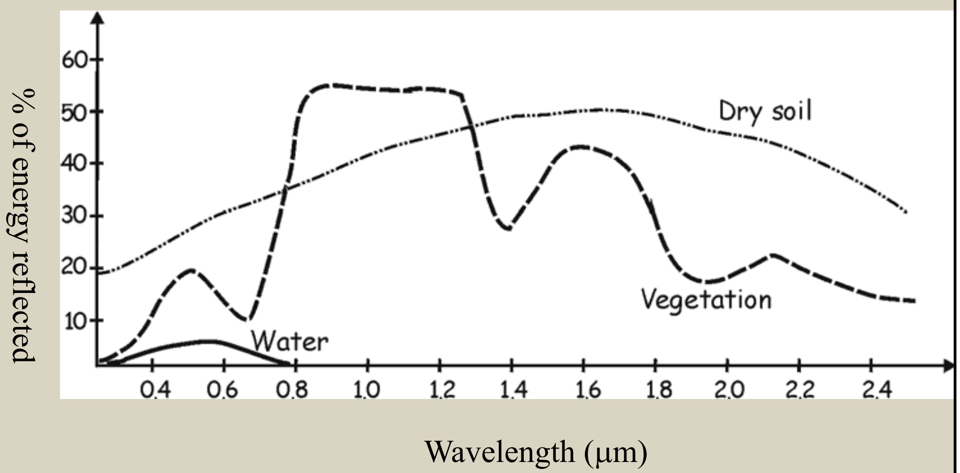


Figure 3

$E_I(\lambda) = E_R(\lambda) + E_A(\lambda) + E_T(\lambda)$

Natural objects appear to be the color they most reflect

Spectral Reflectance Curves



Upland forest just beginning growing season

Cool season grass

(brome, fescue)

True Color

False Color

April

False Color IR and True Color

http://www.emporia.edu/nasa/epscor/ft_leav/epscor.htm#ir

Upland forest with full canopy

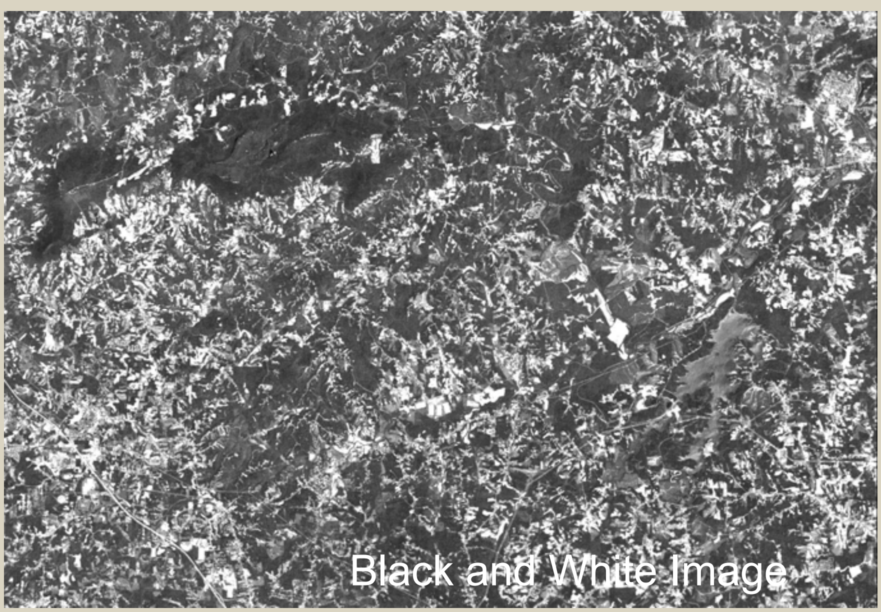
True Color

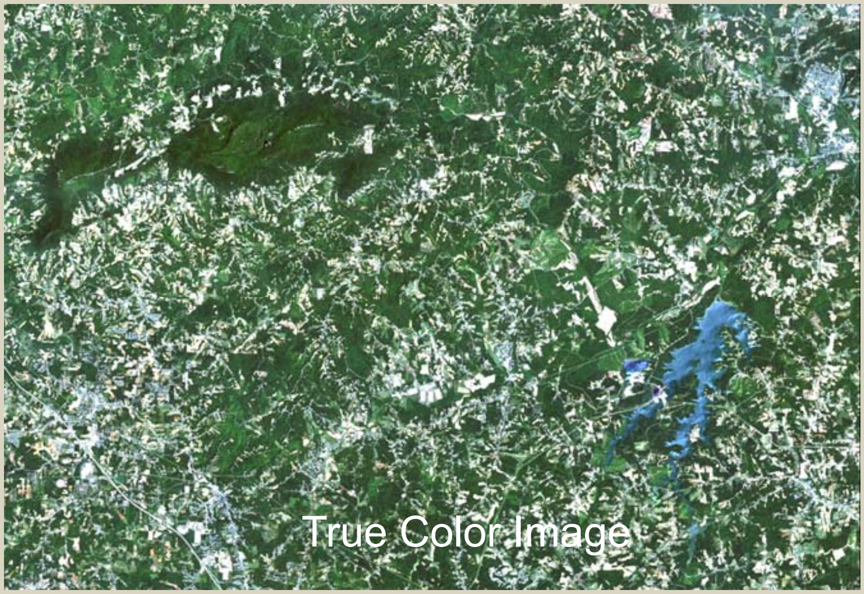
False Color

May

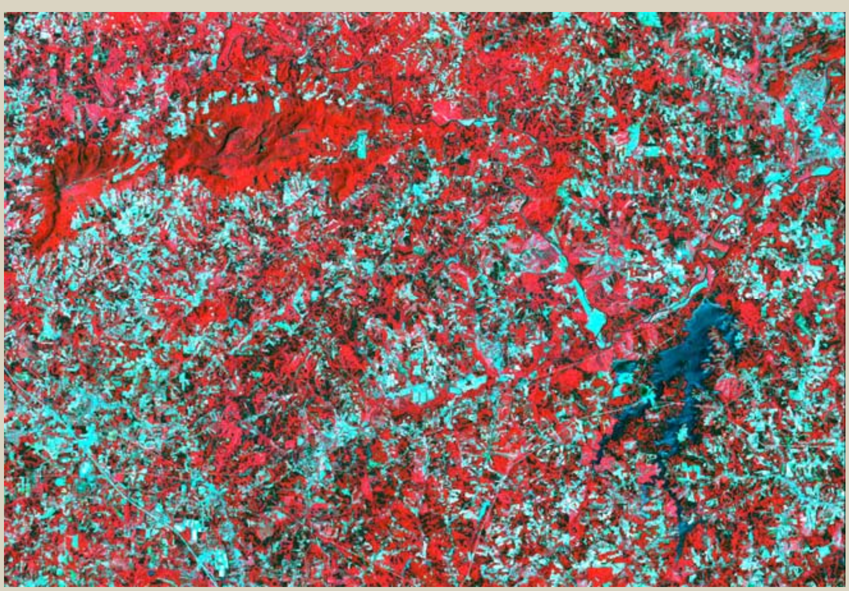
False Color IR and True Color

http://www.emporia.edu/nasa/epscor/ft_leav/epscor.htm#ir

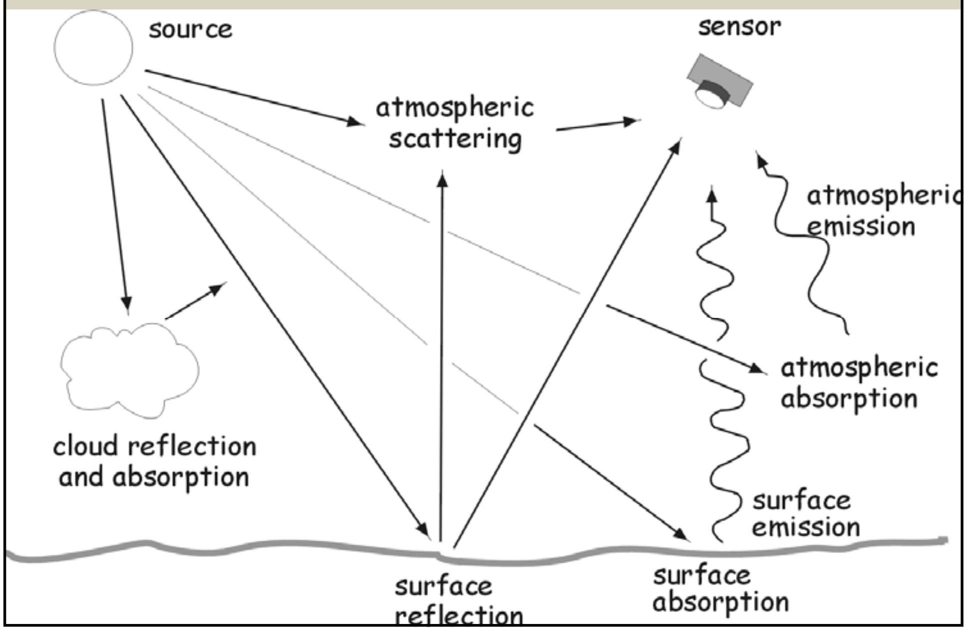




Color Infrared



Energy, Atmosphere, and Surface Interactions



Attributes of remotely sensed data

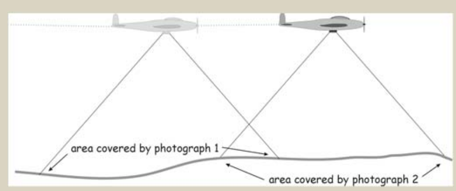
- Scale: 1:15,840
- Extent – the area covered by an image
- Resolution – smallest object that can reliably be detected by the image

What Information Can Be Remotely Sensed ?

Fundamental Variables

- Planimetric (x,y) location and dimensions
- Topographic (z) location
- Color (spectral reflectance)
- Surface Temperature
- Texture
- Surface Roughness
- Moisture Content
- Vegetation Biomass

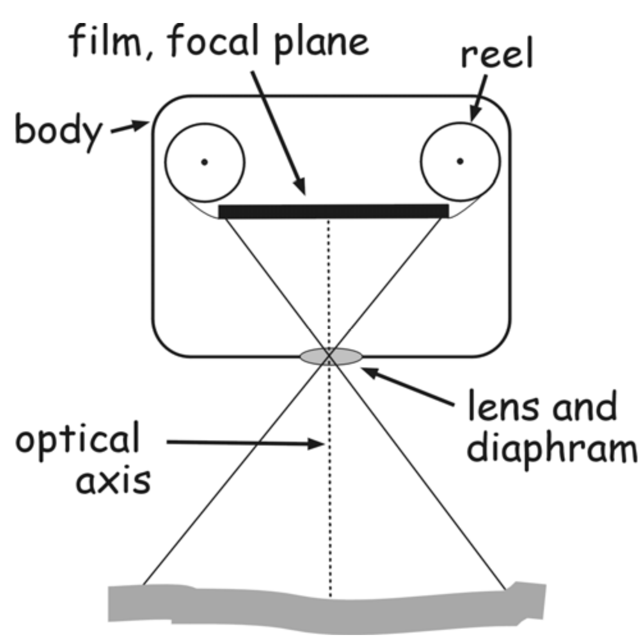
Aerial Photographs



Primary uses:
1) Basis for surveying and topographic mapping
2) Image interpretation may be used to categorize or assign attributes to surface features
3) Background for maps of other features

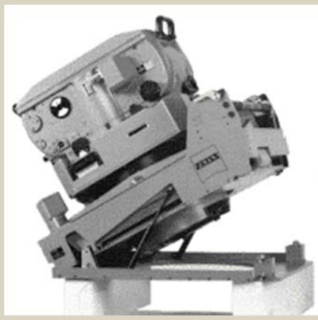
Aerial Photographs – from an Aerial Camera

Figure 6-8 A large-format camera (courtesy Z/I Imaging Systems).



Large format

Small format



Photos are usually scanned and converted to digital images for on-screen display and measurements

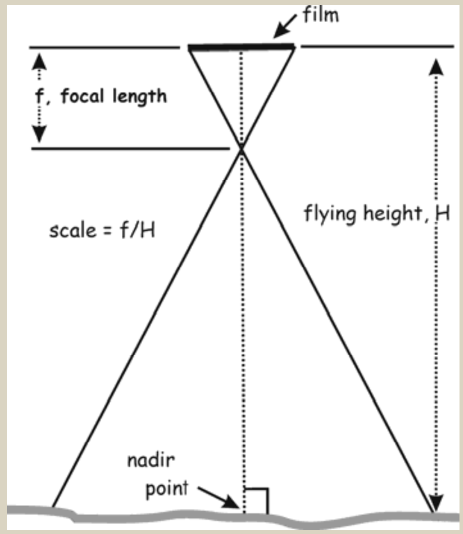
Scale most commonly controlled by

1. flying height
2. lens focal length

Scale is approximately equal to f / H
f = focal length
H = flying height

Photo Scale

- Set by flying height, focal length
- Most mapping cameras use 6” lens
- Reduce scale by flying higher



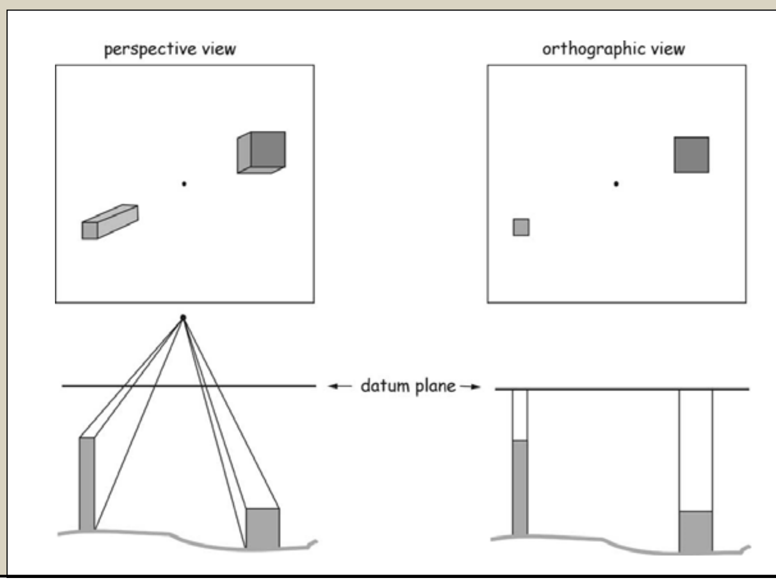
Increasing flying height reduces scale *(objects get smaller, area covered by each photo increases)*

Increasing focal length increases scale *(objects get larger, area covered decreases)*

Scale is NOT Constant

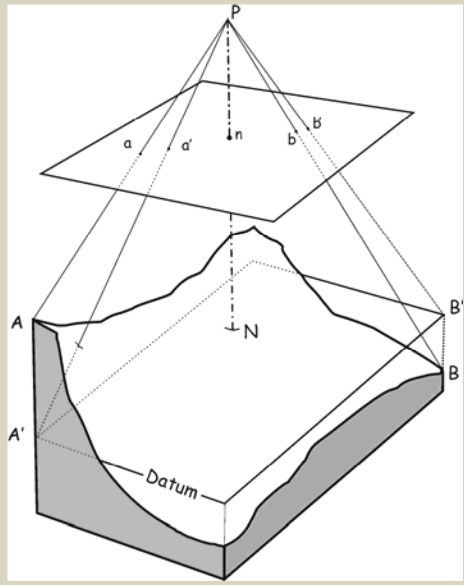
- Can be over flat terrain with perfectly vertical photographs - rarely occurs
- Terrain - some objects are closer to lens, hence larger scale
- Tilt - causes perspective distortion

Perspective vs. Orthographic Views



Terrain Variation – Causes Relief Displacement

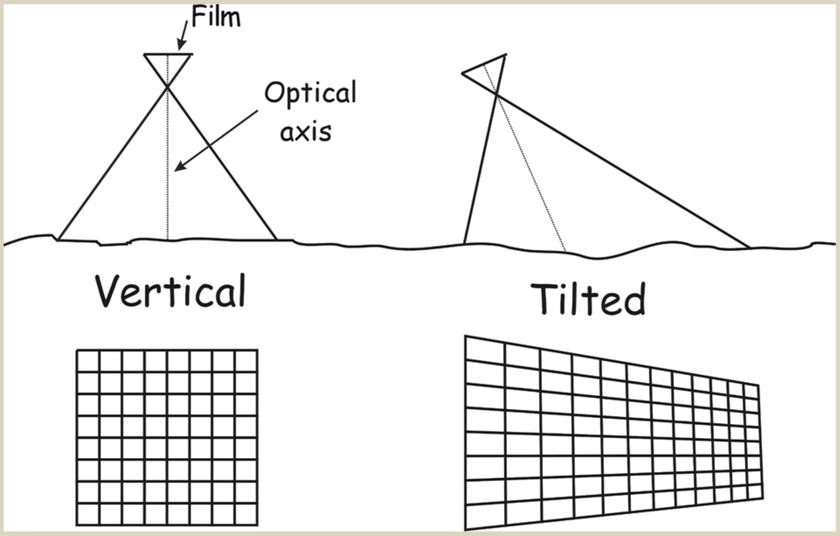
Features are displaced radially from their planimetric position due to differences in relative elevation



Characteristics of terrain distortion

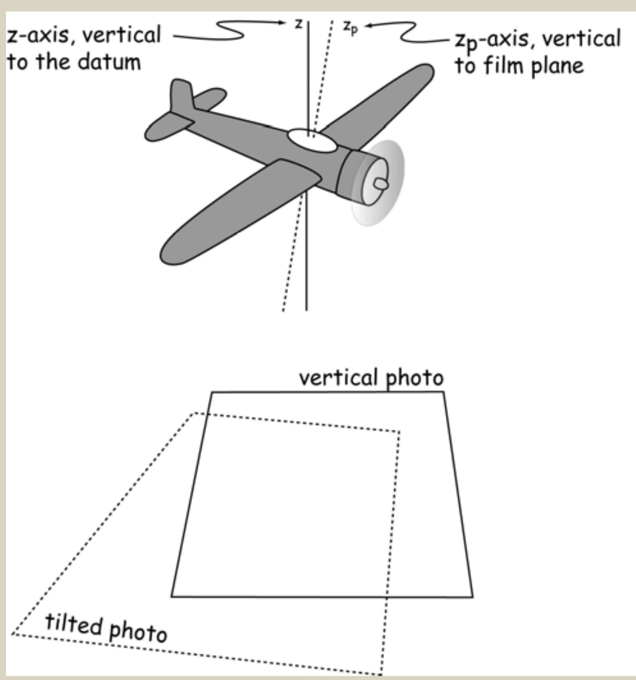
- Radial
- Affect angles and distances
- Scale is not constant
- Not orthographic

Tilt Distortion



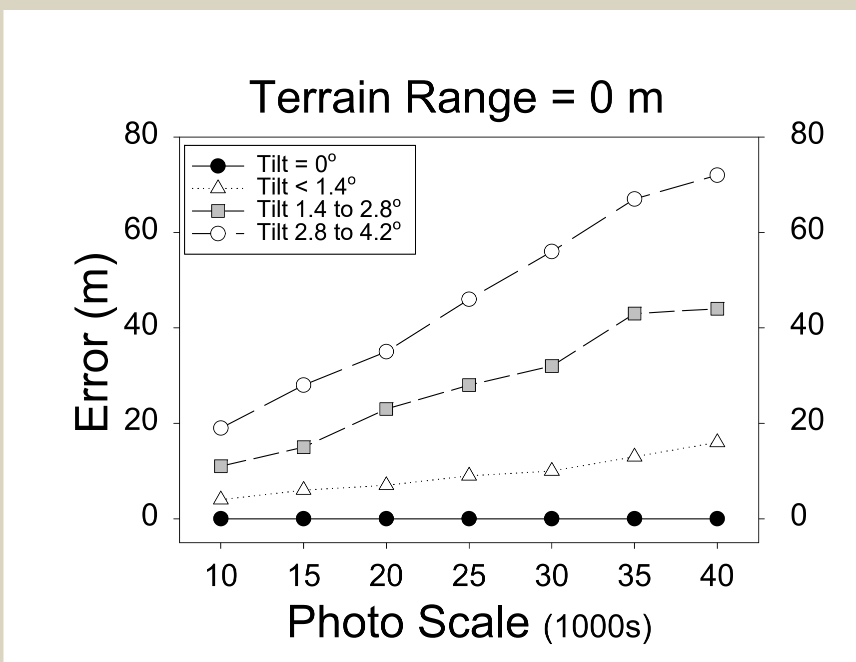
Tilt measured as the angle between a line perpendicular to the film and a line perpendicular to the datum.

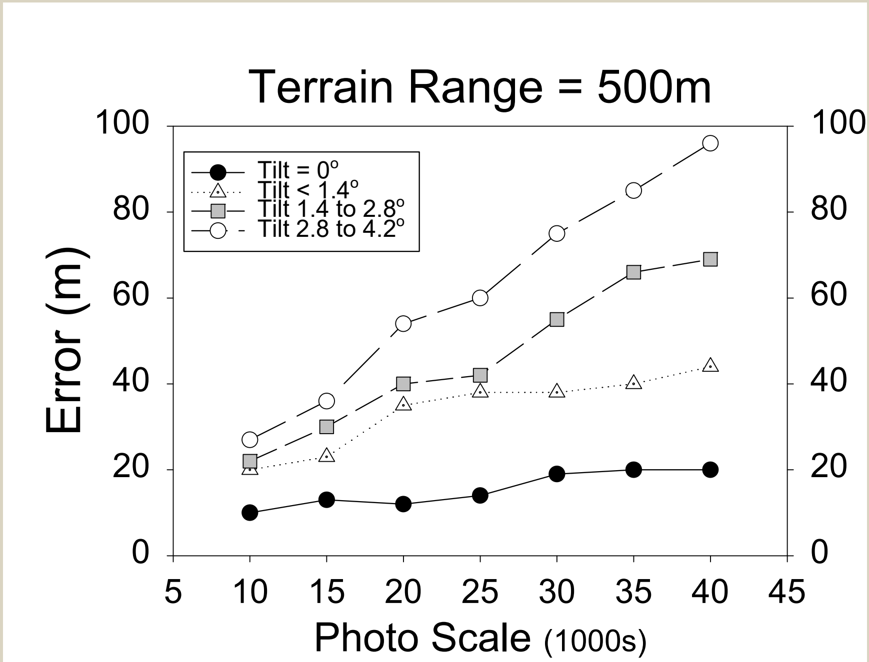
Typically specified to be less than 3^o on vertical aerial photos.



How Big Are Tilt and Terrain Errors?

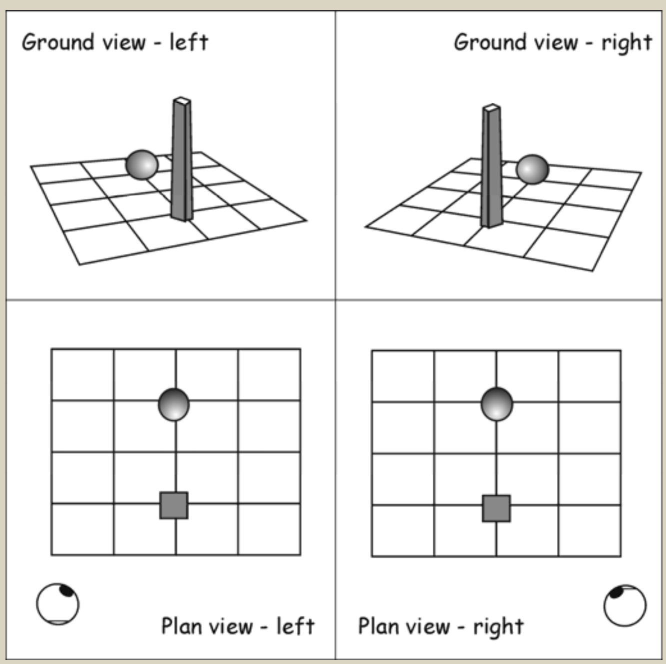
- Larger errors with more tilt (even under 3^o)
- Larger errors with more relief (proportional to elevation difference)
- Larger at smaller scale



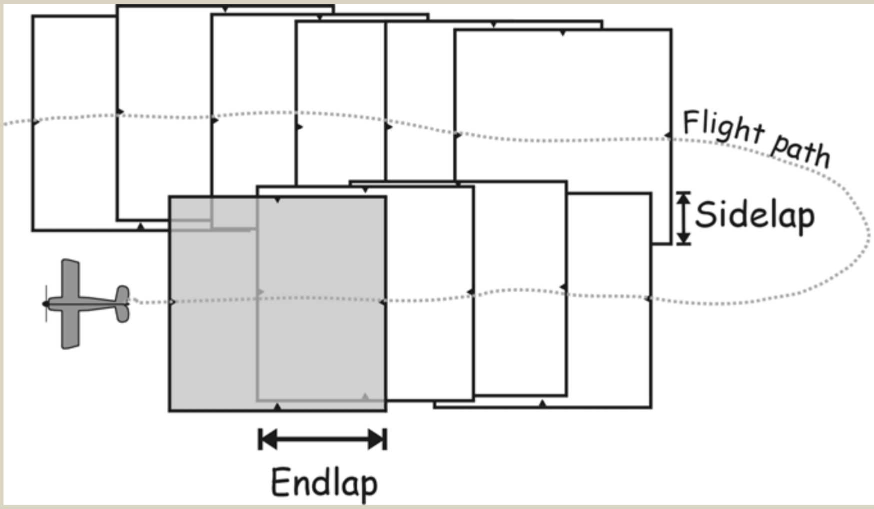


Parallax - Relative shift in position with a change in viewing location.

Closer (taller) objects shift more.
We measure parallax to estimate height.



Overlapping Stereophotographs to create parallax shifts



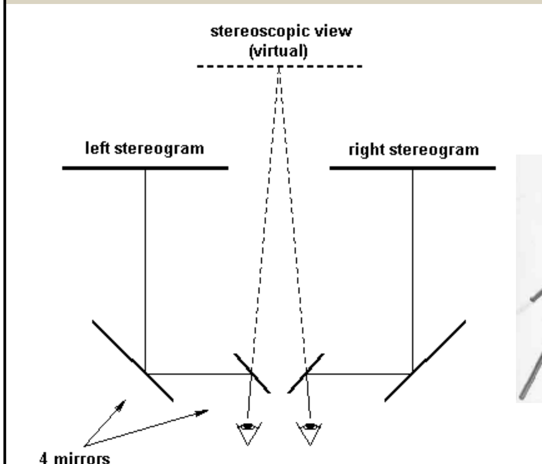


Fig. 4 - Mirror stereoscope. View from the top (schematic).

Source:http://www.2spi.com/catalog/stereo-3D/mstereo.html

Source:http://www.funsci.com/fun3_en/stscp/stscp.htm

Relief Displacement – Height affects horizontal position

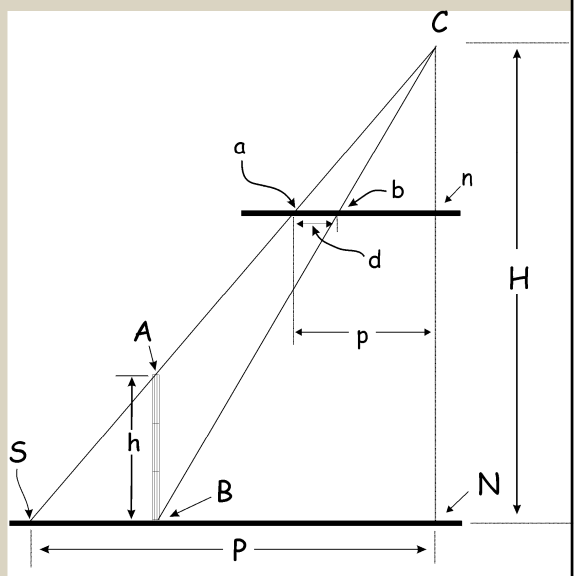
Displacement are radial
higher – outward shift
Lower – inward shift

In a planimetric map, A should occur at the same location as B

But is displace by d

Question: how much is d?

Use similar triangles to find out

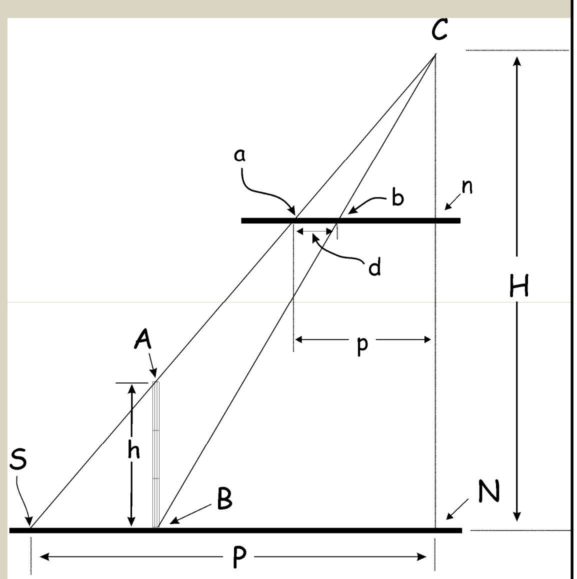


Similar Triangles

Strategy:
Measure d and p (from photo)
We know H (from flight record)

We can get h (e.g., from DEM)

We need to relate d to p, h, and H



Big triangle – CNS

Small triangle 1 - Cna

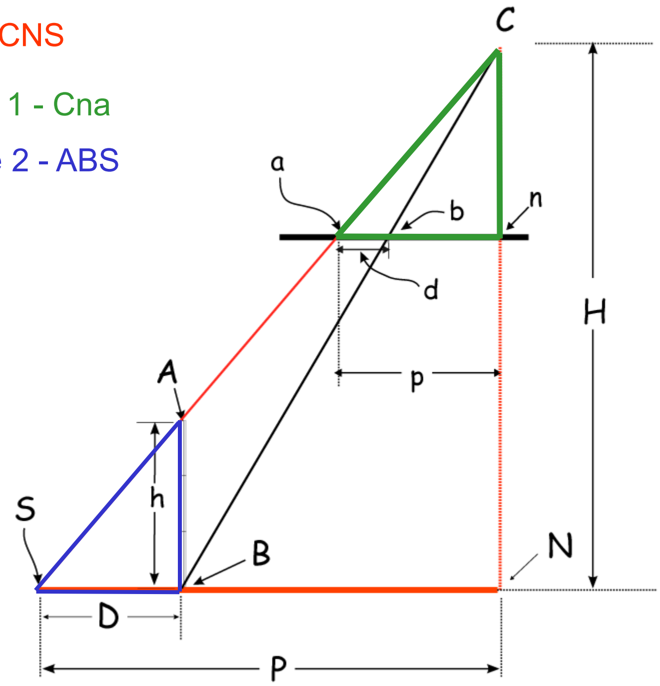
Small triangle 2 - ABS

We may see:
D/P = d / p

and
D/P = h/H

So
d/p = h/H

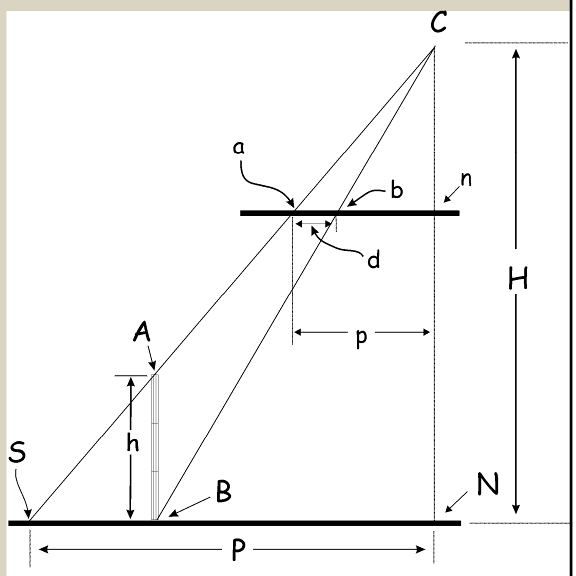
d=p*h/H



So
We know H
Measure p on photo
Know h from DEM
Apply equation

$d = p * h/H$

Apply for every spot (cell, pixel) on the photo, yielding an ortho-corrected image



What about tilt?

Tilt plus terrain distortion complicates the equations, e.g.,

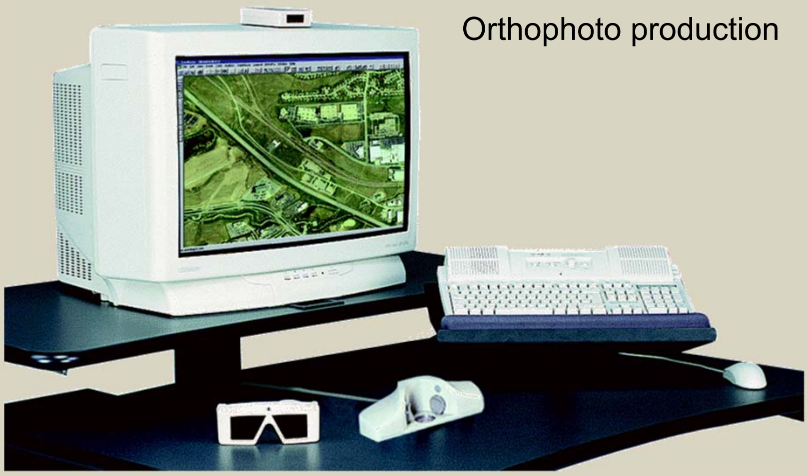
Photo $x = x0 - f\,[\, m11(Xp-XL) + m21(Yp-YL) + m13(-ZL) \ldots$

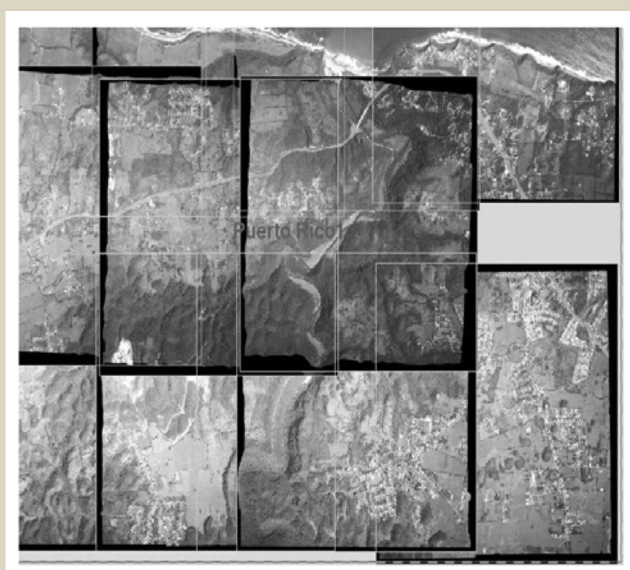
Where $m11 = \cos\phi * \cos\kappa$, $m21 = -\cos\phi * \cos\kappa$, etc.

The idea is the same – photo measurement are used with knowledge of flying height, ground height, and now tilt (ω, ϕ, κ) to calculate and remove displacement.

Softcopy Photogrammetric Workstations

Orthophoto production





An orthophotograph or orthoimage – tilt/terrain distortion removed

Besides geometric fidelity, we are also interested in the photo information content

How do we interpret the photographs?

Select a photographic system appropriate to the task,

i.e., scale, coverage, time of year, and film type which best renders the details of interests

Scale
Without magnification, you are stuck at about 2 - 3 mm

To identify individual trees -10 m across

without magnification scale = 2 mm / 10,000 mm, or about 1:5,000

Coverage

Scale and format determines area per photo,

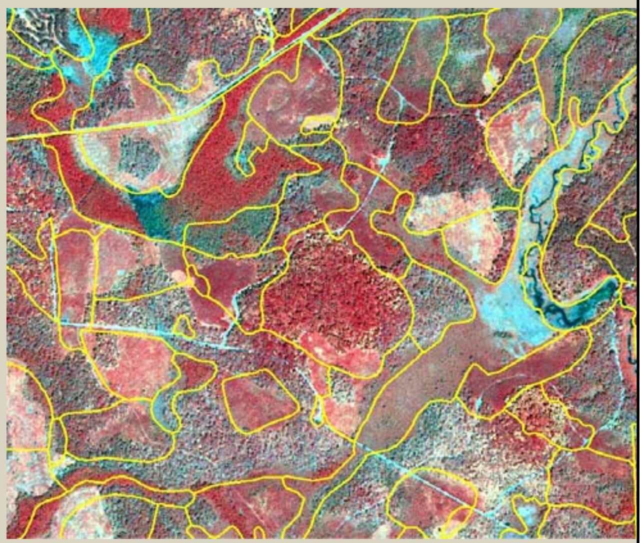
e.g. 9" photo @ 1:10,000 scale yields photos which contain 7,500 feet on edge

9" = 0.75 ft * 10,000 ground feet/photo feet

= 7,500 ft

Photo Interpretation

This is the process of identifying and mapping the features that appear on the photos



Use characteristics of the objects observed, plus knowledge of acquisition (scale, time of year, film type) to identify features

Characteristics used include:

- Shape
- Size
- Color (or tone)
- Texture
- Shadows
- and Context

Satellite Images

Advantages

- High view, little relief displacement
- Ultra-stable satellites, little tilt distortion
- Extended spectral range, from radar to far infra-red
- Low cost per unit area (for large study areas)
- Digital images, which may be easily enhanced, integrated into a GIS

Satellite Images

Disadvantages

- Limited acquisition flexibility, fixed schedules
- Expensive for small areas, due to fixed frame size
- Limited scale/resolution
- Requires sophisticated, moderately expensive systems to take advantage of digital image

Different resolutions

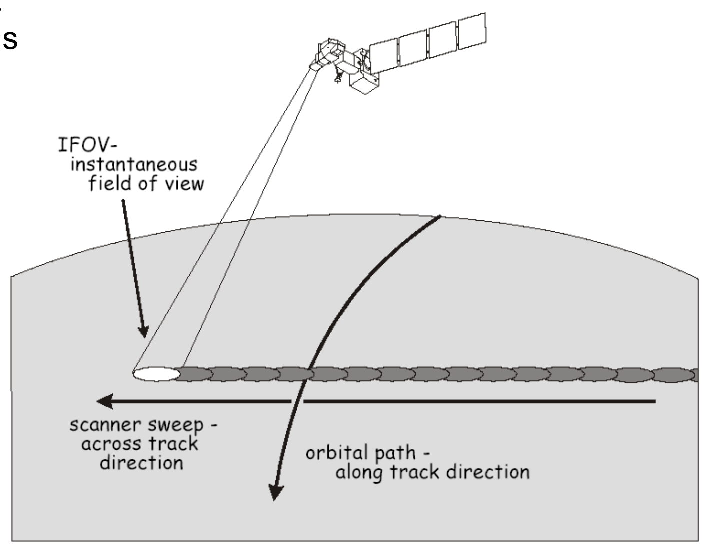


Figure 6-17: A point scanning system, as aboard Landsat. The scanner sweeps an instantaneous field of view (IFOV) in an across-track direction to record a multispectral response. Subsequent sweeps in an along-track direction are captured as the satellite moves forward along the orbital path.

Systems

Ikonos, Quickbird

Ikonos: 1 meter panchromatic and 4 meter visible / infrared (1-3 day revisit)

Quickbird: 0.65 (panchromatic) to 2.44 meter (3-band color) resolution (Three to five day repeat visit)

Images 10 to 30 km on a side

Spot

Panchromatic, 2.5 to 10 m resolution

3-band color, 5 to 20 m resolution

Returns from every 5 to 26 days, depending on requirements and latitude

Image 60 km on a side

Thematic Mapper (TM)

7 bands, 30 m resolution

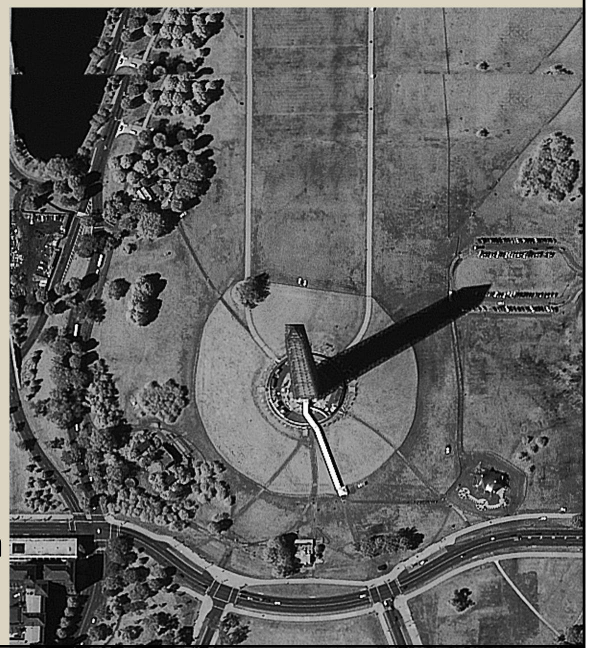
Return time of 16 days

Image approximately 185 km on a side

High-Resolution Satellite Systems

IKONOS (1999)

High resolution system
680 km orbit
Revisit times are typically 1- 3 days
1 meter panchromatic
4 meter visible/infrared
Scan width of 13 km – pointable.



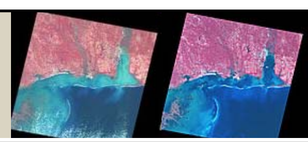
Quickbird (2000)

61 cm (2 foot) pan.
2.44 meter mulitpsectral
Image side 16.5 km
1-3 day revisit

Primary Uses for High Resolution Satellite Data

- On-screen digitizing – similar to aerial photographs
- Infrastructure mapping (roads, etc.)
- Detail landuse mapping
- Topographic mapping
- Disaster assessment (fire, hurricane, flooding)
- Habitat and other mapping

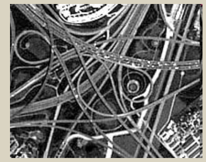
Landsat



Sensor	Mission	Sensitivity (µm)	Spatial Resolution (m)
RBV	1, 2	0.475 - 0.575	80
		0.580 - 0.680	80
		0.690 - 0.830	80
	3	0.505 - 0.750	30
MSS	1- 5	0.5 - 0.6	79 / 82
		0.6 - 0.7	79 / 82
		0.7 - 0.8	79 / 82
		0.8 - 1.1	79 / 82
	3	10.4 - 12.6	240
TM	4, 5	0.45 - 0.52	30
		0.52 - 0.60	30
		0.63 - 0.69	30
		0.76 - 0.90	30
		1.55 - 1.75	30
		10.4 - 12.5	120
		2.08 - 2.35	30
ETM[c]	6	above TM bands	30 (120 m thermal band)
		plus 0.50 - 0.90	15
ETM+	7	above TM bands	30 (60 m thermal band)
		plus 0.50 - 0.90	15

Lillesand et al. – Remote sensing and imaging interpretation 2007

SPOT



Mission	Lauched	High Res. Instruments	Spectral bands (µm)	Spatial Resolution (m)
1 - 3	21-Feb-86	2 HRVs	1 pan (0.51 – 0.73)	10
	21-Jan-90		Green (0.50 -0.59)	20
	25-Sep-93		Red (0.61 – 0.68)	20
			NIR (0.79 – 0.89)	20
4	23-Mar-98	2 HRVIRS And vegetation instrument (VI)	1 pan	10
			Blue (VI only) (0.43 – 0.47)	1000
			Green (HRVIR only)	20 / 1000
			Red (HRVIR / VI)	20 / 1000
			NIR (HRVIR / VI)	20 / 1000
			Mid IR (HRVIR / VI) (1.58 – 1.75)	20 / 1000
5	3-May-02	2 HRGs, 1 HRS, and 1 VI	Pan (HRG / HRS) (0.48 – 0.71 / 0.49 – 0.69)	2.5 or 5 / 5 or 10
			Blue (HRS only) (0.45 – 0.52)	1000
			Green (HRG only) (0.50 – 0.59)	10 / 1000
			Red (HRG / HRS) (0.61 – 0.68)	10 / 1000
			NIR (HRG / HRS) (0.78 – 0.89)	10 / 1000
			Mid IR (HRG / HRS) (1.58 – 1.75)	20 / 1000

Lillesand et al. – Remote sensing and imaging interpretation 2007

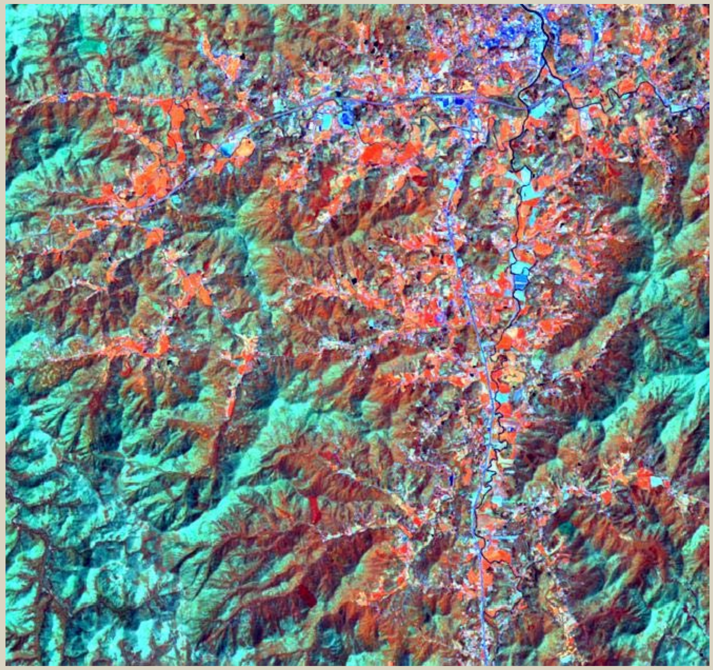
Medium Resolution Sening Systems

Landsat Thematic Mapper (TM, ETM+)
7 spectral bands
30 meter resolution multispectral, 15 meter panchromatic
16-day repeat cycle – data since 1984
Historical importance, new collections difficult

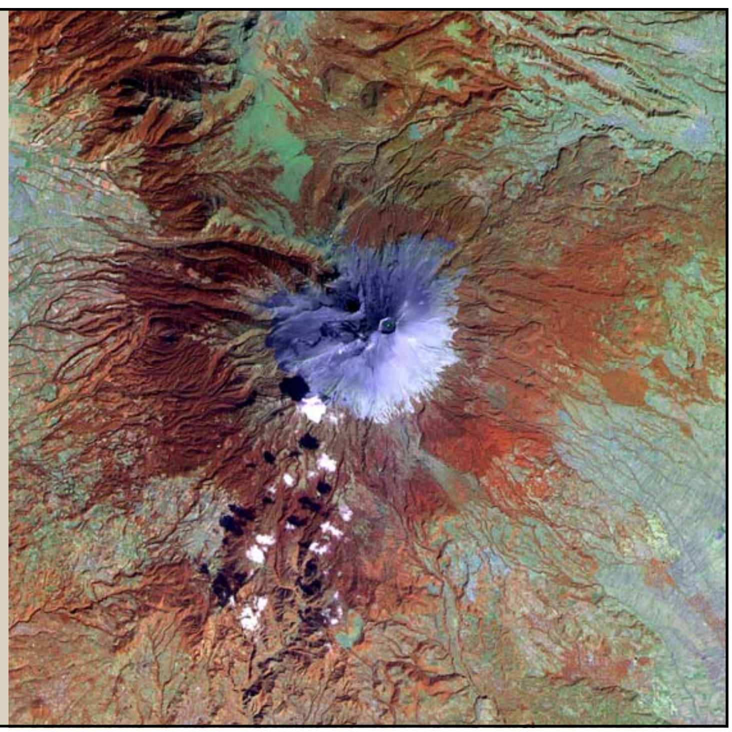
Multispectral Scanner (MSS)
4 spectral bands
80 meter resolution
16-day repeat cycle – data since 1972

SPOT – coarse modes
5 spectral bands
10 to 20 meter resolution
1-3 day repeat cycle

TM Data – Good for regional, some local analyses – typically can't distinguish objects smaller than 25 meters wide



SPOT 20 meter
More detail than Landsat, but smaller imaged area

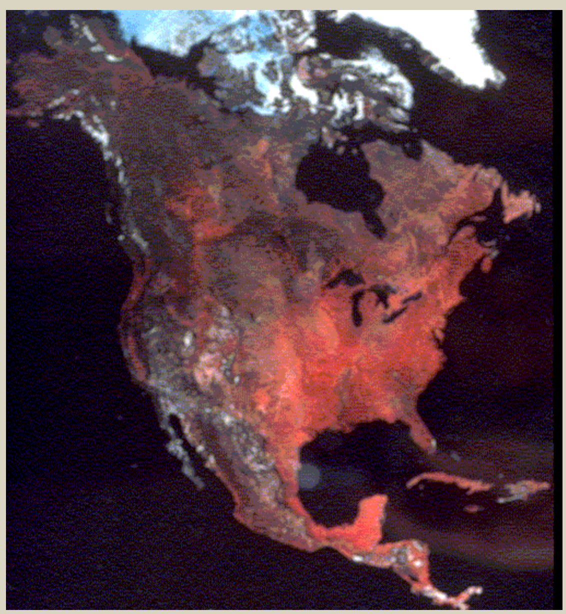


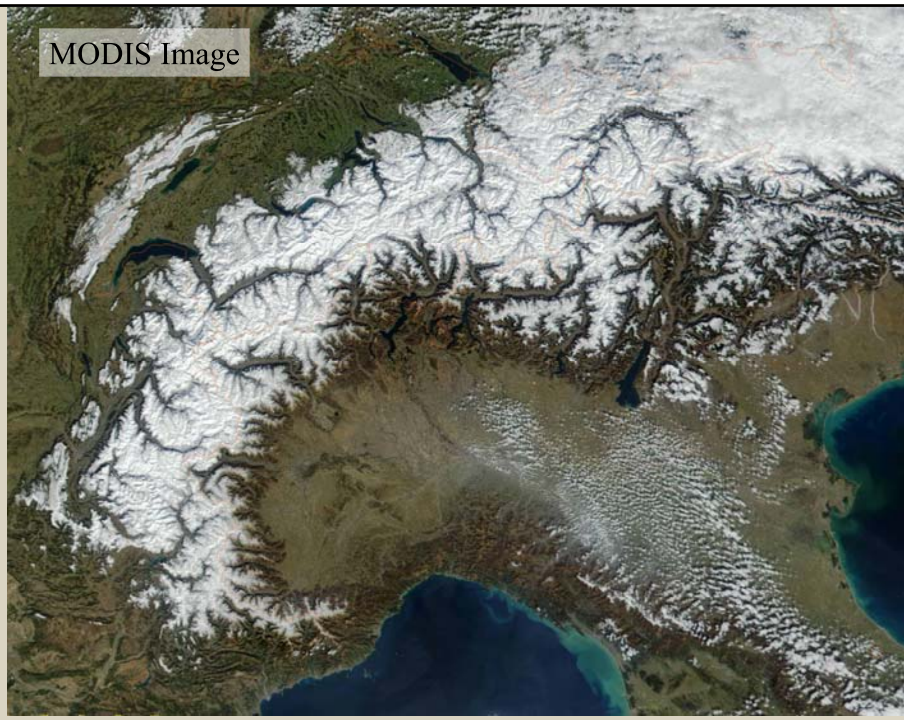
COARSE RESOLUTION LAND SENSORS

AVHRR (since the 1970s)
Advanced Very High Resolution Radiometer
5 spectral bands
1.1 km resolution
12 hour repeat cycle

MODIS
Moderate Resolution Imaging Sensor
36 spectral bands
1 km, 500m and 250 m resolutions
1 to 2 day repeat cycle

NOAA AVHRR Imagery

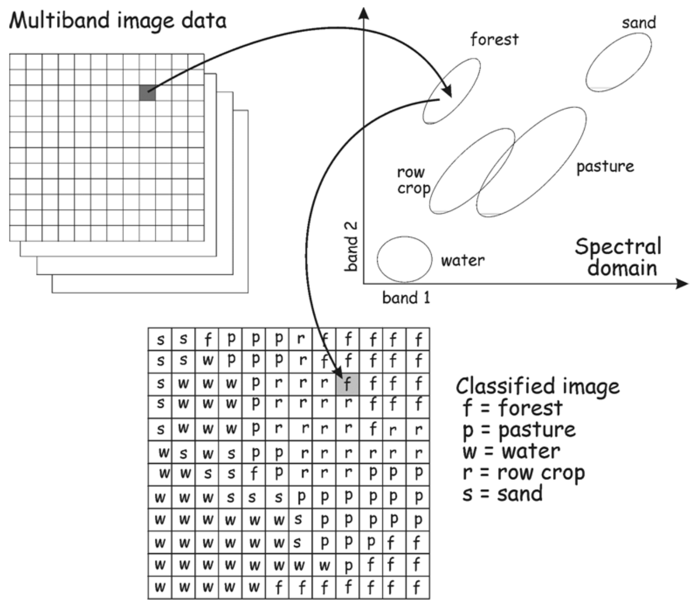




Most common useful applications

- •Landcover mapping, large areas
  e.g., wetlands, urban, forest
- •Disaster evaluation, management
- •Crop monitoring
- •Change detection *(for example, deforestation)*
- •Snow monitoring, runoff estimation
- •Geologic prospecting
- •Vegetation health monitoring

Image Classification from Multispectral Data



Satellite vs. Photos – Which to Use?

Satellites
- Lower detail (barely)
- Expanded spectrum
- Inherently digital
- Stable platform
- Higher flight path
- Inexpensive for large areas

Aerial Photos
- Higher detail
- Less expensive for small areas
- Flexible repeat time
- Fly under clouds
- Simple handling