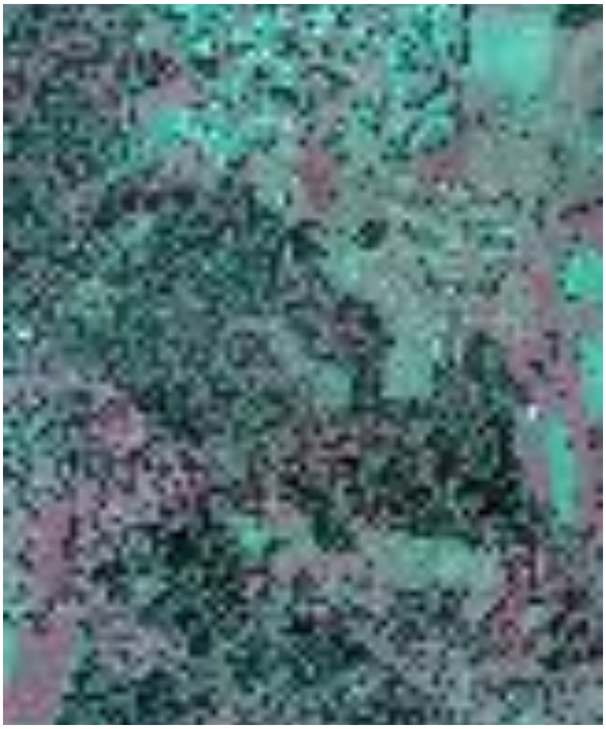
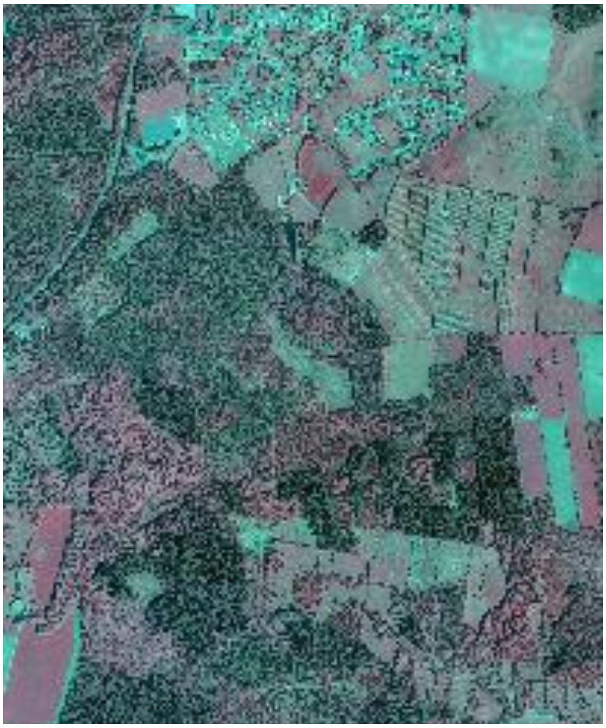
Remote sensing and image interpretation

Ulrik Mårtensson 2016





CV

- Mapping energy forest in Sweden
- Topographic map production in Sweden and the US for orienteering and recreation sites
- Photographer at LU
- Land suitability mapping in Pakistan
- Coastal zone sensitivity in Thailand and Vietnam
- Soils and erosion sensitivity in Nigeria
- Forest fires in Syria

- Roll call
- Schedule – three days vacation
- Last year evaluation – more theory
- Grading – written exam?
- Learning objectives and goals
  - Independancy
  - Own initiatives
  - Self discipline
- Practicalities – field trips, organise work
- Course philosophy - What do you need to know???

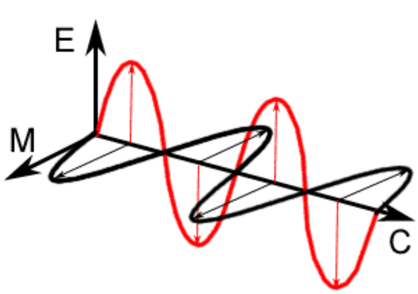
Electromagnetic radiation

- All bodies with a temperature above –273 °C (0 °K) emit energy
- A blackbody reflects no radiation. It absorbs all radiation and re-emits it
- **Emissivity (ξ) = [M/(M_b)]**
  where M is the emissivity of an object and M_b is the emissivity of a blackbody with the same temperature

Electromagnetic radiation

- Two models of explanaition

1 *Wave model*



Electric field
Magnetic field
C = Speed of light

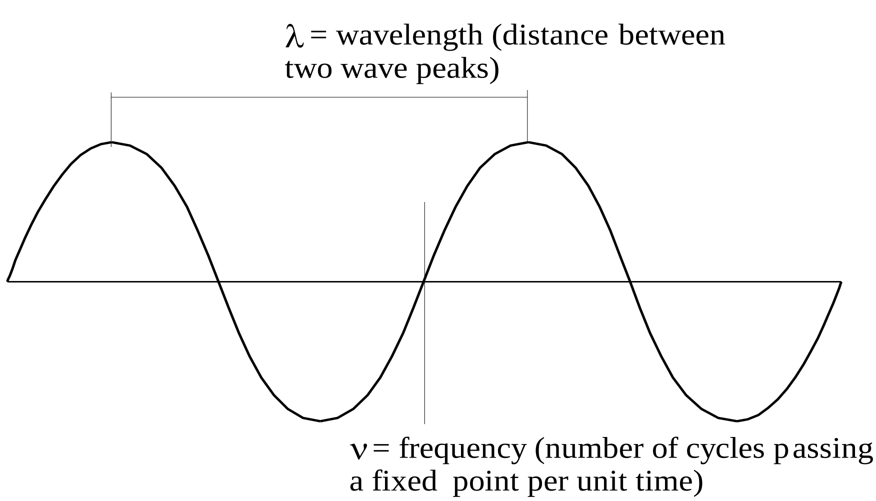
Wave length and frequency

Waves behaves as:

$$c = \nu \bullet \lambda$$

Where
c = speed of light ($3x10^8$m/sec)
ν = frequency (undulations per second (Hertz, kHz, MHz)
λ = wave length (nm μm, mm, m)

Wave length

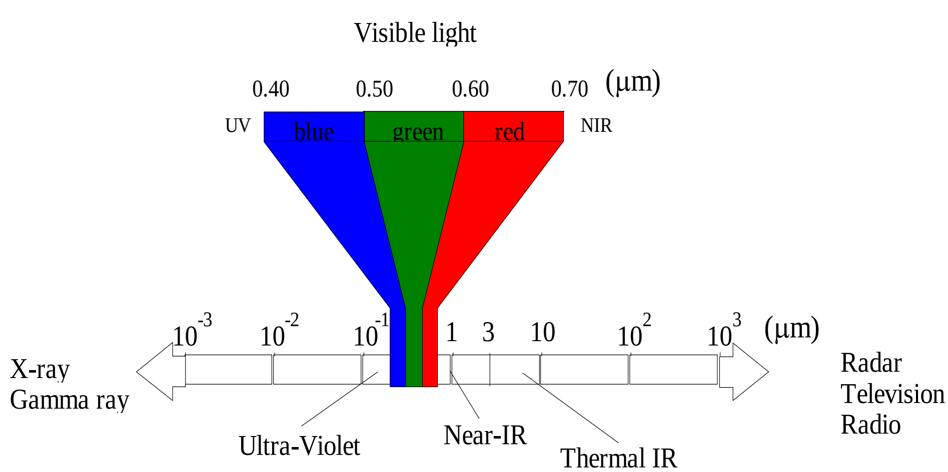


Electromagnetic radiation

Wave length (λ)

Distance from a given point in the undulation cycle to the same point in the next cycle

cm = 0.01	m = 10^{-2} m
mm =0.001	m = 10^{-3} m
μm = 0.000001	m = 10^{-6} m
nm = 0.000000001	m = 10^{-9} m



Wavebands

Optical wavebands = 0.2 μm – 15 μm

UV	0.01 μm – 0.4 μm
Visible	0.4 μm – 0.7 μm
Reflected IR	0.7 μm – 3.0 μm
Near IR (NIR)	0.7 μm – 1.3 μm
Middle IR (MIR)	1.3 μm – 3.0 μm
Thermal IR	3.0 μm – 15 μm
Far IR (FIR)	15 μm – 1000 μm

Electromagnetic radiation

2 *Flow of particles (photons)*

Energy moves as photons or quantum

The energy of a photone, $\boldsymbol{E = hv}$

where

E = energy in Joule

h = Planck's constant, 6.626×10^{-34} J.sec

v = frequency (Hz)

Electromagnetic radiation

Higher frequency => More energy

Higher frequency => shorter wave length

$$c = v \bullet \lambda$$

Stefan-Boltzmann's Law:

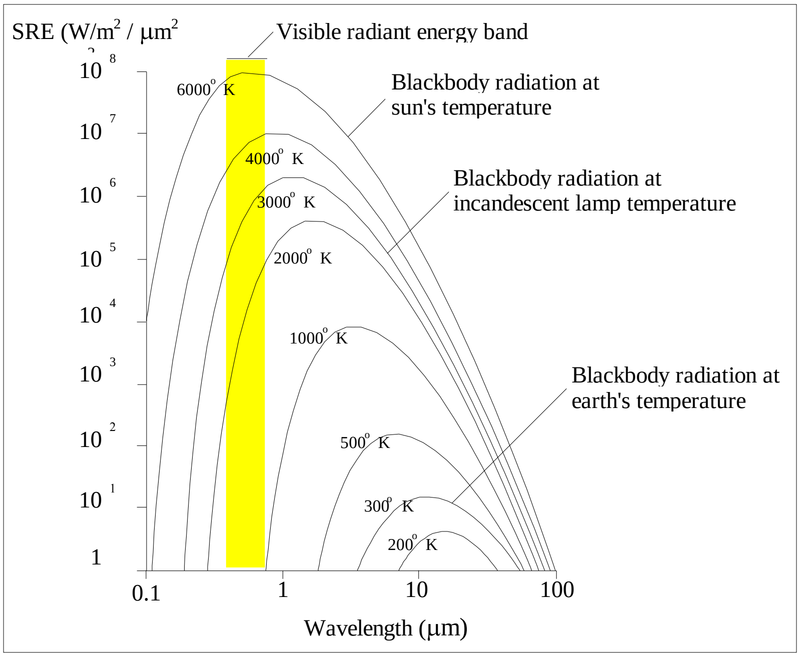
$M = \sigma \cdot T^4$

where M is the total amount of radiated energy from the surface of an object (W/m^2), σ is the Stefan-Boltzmann constant ($5.6697 \cdot 10^{-8}$ $W/m^2/°K$) and T is the absolute temperature (°K).

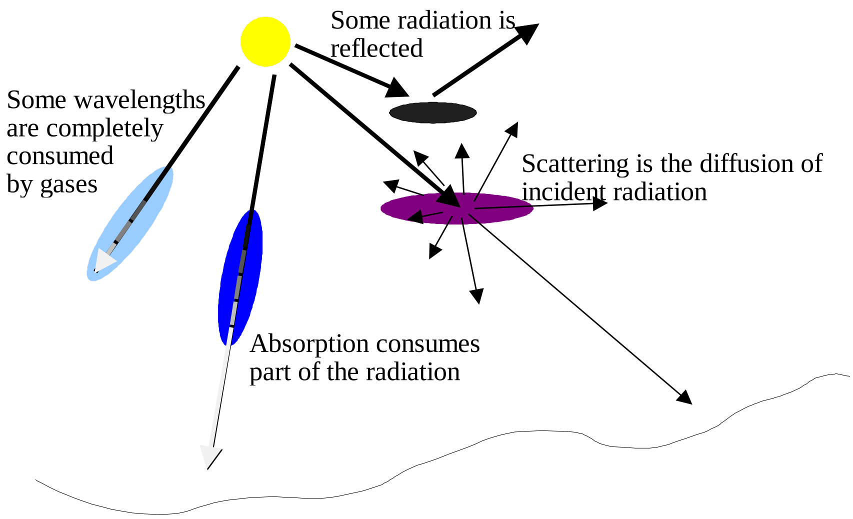
Wien's Displacement Law

$\lambda_m = A/T$

where λ_m is the wavelength with maximum radiation, A is a constant 2898 μm ºK) and T is the absolute temperature (ºK) of the object.



Radiation in the atmosphere



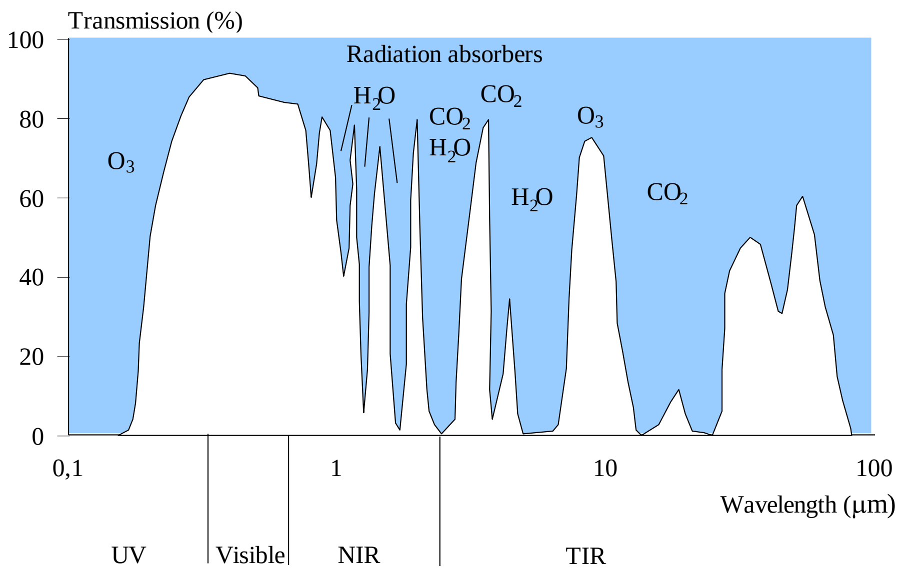
Selective scattering: *Rayleigh* (of UV and blue short wavelengths, particels smaller than wavelenght) and *Mie* (ca 5 – 100 μm caused by particles of smoke, fumes and haze of approx. same sizes as wavelengths of light being scattered)

Rayleigh scatter = Partikelkonc/λ^4

Non-selective scattering: caused by dust, fog and clouds of particle sizes >10 times wavelength of light. Scatters all wavelengths equally.

Absorption of radiation causing depletion, by O_2, N_2, O_3, CO_2 and H_2O in many atmospheric absorption bands

Atmosphere windows

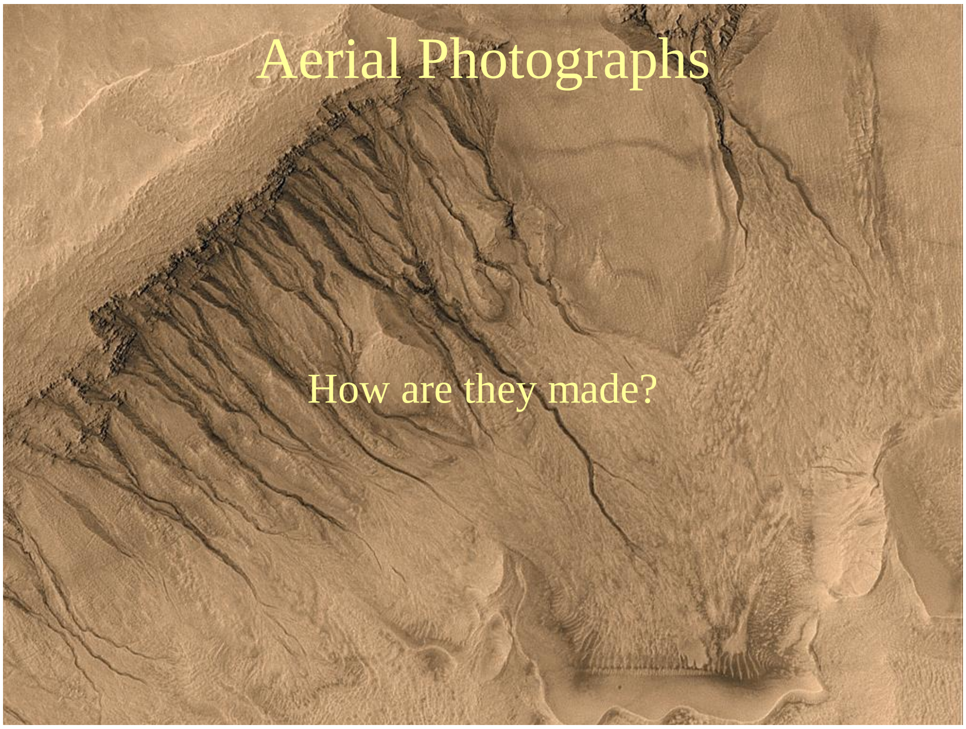


Atmosphere windows

Important atmospheric windows are

1	0.3 - 1.3 µm	*Visible, Reflective IR*
2	1.5 - 1.8 µm	*Reflective IR*
3	2.0 - 2.6 µm	*Reflective IR*
4	3.0 - 3.6 µm	*Thermal IR*
5	4.2 - 5.0 µm	*Thermal IR*
6	7.5 - 14.0 µm	*Thermal IR*

Aerial Photographs



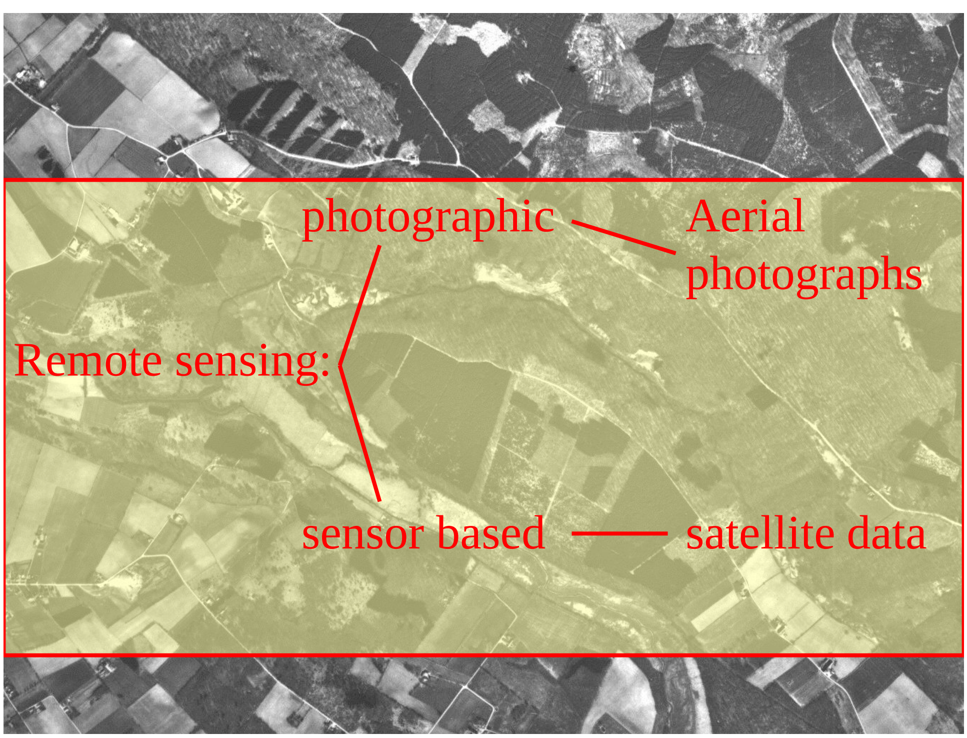
How are they made?

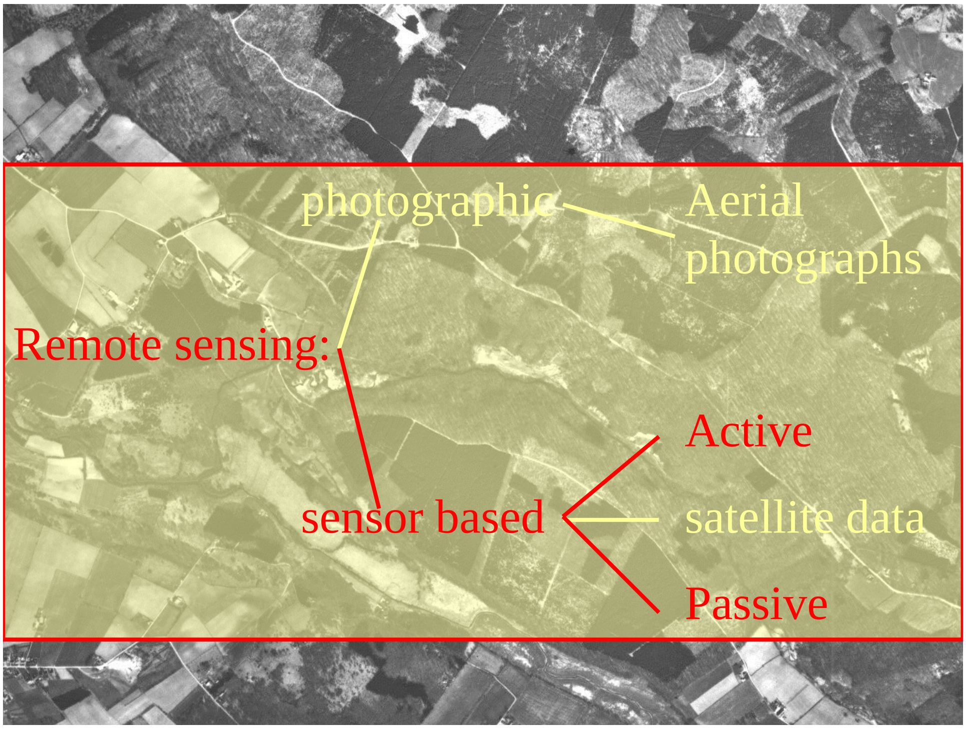
Remote Sensing

- Collect data about
- Visible
  - Invisible
- Production of thematic maps, topography
- Frequent data sourse for GIS

Remote Sensing

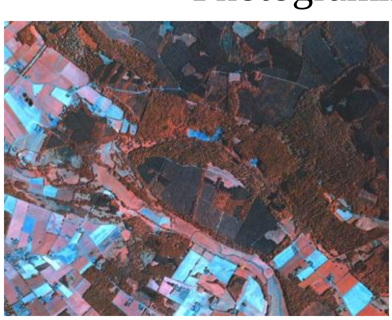
- Elektromagnetic radiation
- Different sensors – different radiation types (wave bands)
- Different platforms: Balloon, airplane, helicopter, satellite, space shuttle, space station, ship, masts, tower, car, hand held...
- Different time and date, change studies





Photographic Remote Sensing

- Image interpretation
- Photogrammetry



Aerial photo history

• Photography	1837
• Balloon	1856 (1893)
• Aircraft	1915
• New film emulusions	1930-40
• Satellite platforms	1960
• Digital Photography (sensors)	1980

What is needed?

- Camera
- Lens
- Sensor/Film
- Aircraft (platform)
- (Flash)

Airplane cameras

- Two categories of camera
  - *Metric* with strictly defined geometric attributes, used for mapping
  - *Non-metric*, used for reconnaissance and interpretation

Metric cameras

152.xx mm *wide angle* lens with 23 x 23 cm format

88.xx mm *Super-wide angle* lens with 23 x 23 cm format

- Filter fitted to allow broad or narrow spectral band photography
- Detachable magazine of capacity 200 - 1000 feet length of film
- In rotatable mount, sometimes in gimbals, to ensure verticality of camera axis when film is exposed

Metric cameras

Non-metric cameras

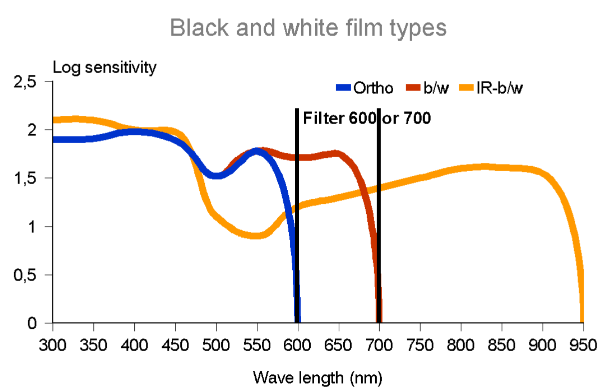
- *Non-metric*: short focal length, small format camera, small capacity magazine
  - Filter fitted
  - Same range of film types
  - Mounts for four cameras with different film/filter combinations, triggered simultaneously

Vertical image, measurable

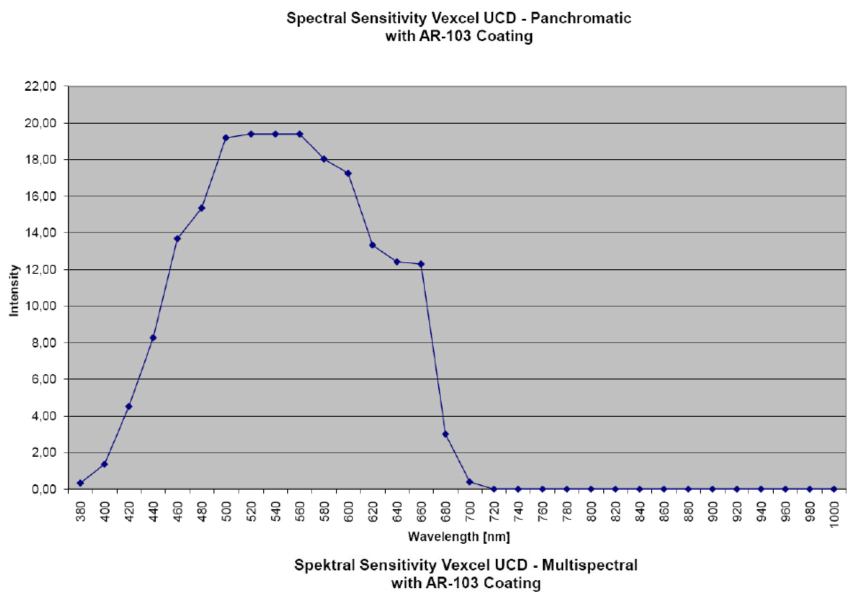
Obligue image, not measurable

Film types

- Ortochromatic
- Panchromatic
- IR-black/white

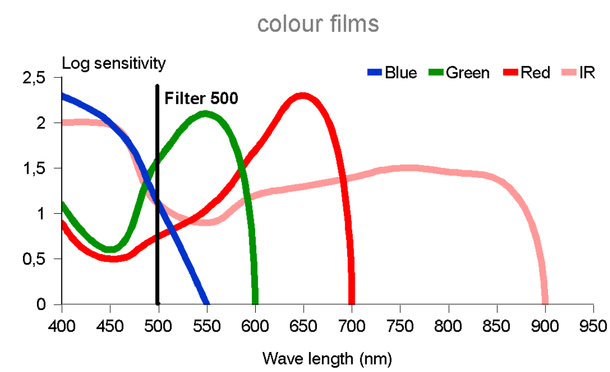


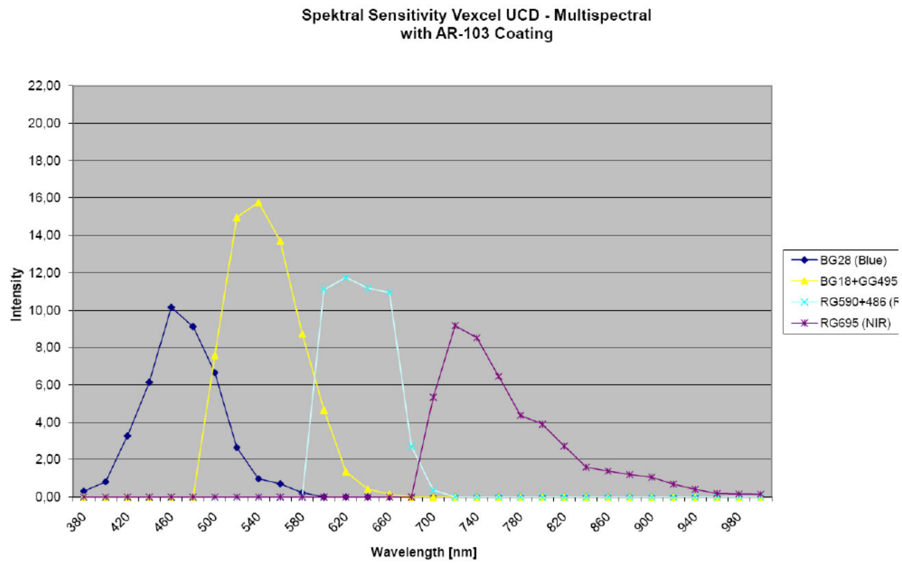
Spectral Sensitivity

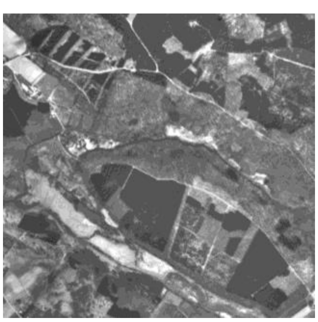


Film types

- Colour
- IR-colour




Spektral Sensitivity Vexcel UCD - Multispectral
with AR-103 Coating
Intensity
Wavelength [nm]
22,00
20,00
18,00
16,00
14,00
12,00
10,00
8,00
6,00
4,00
2,00
0,00
380
420
460
500
540
580
620
660
700
740
780
820
860
900
940
980
BG28 (Blue)
BG18+GG495
RG590+486
RG695 (NIR)



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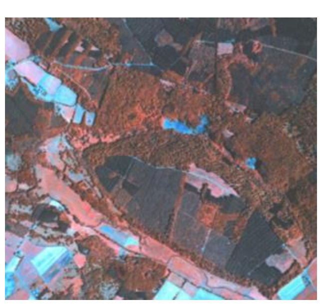
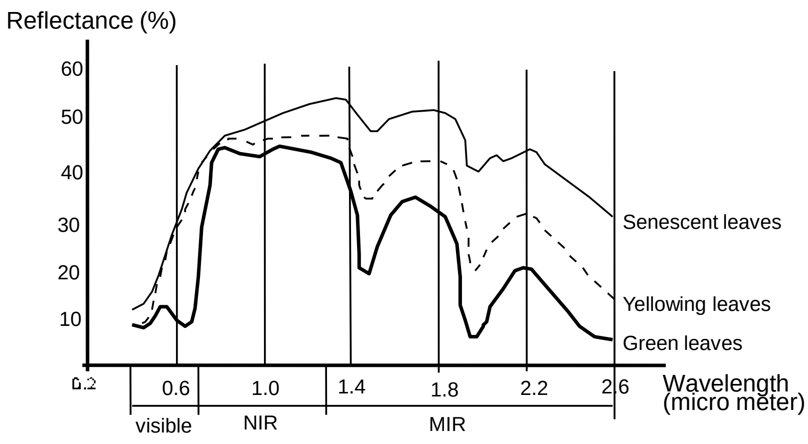
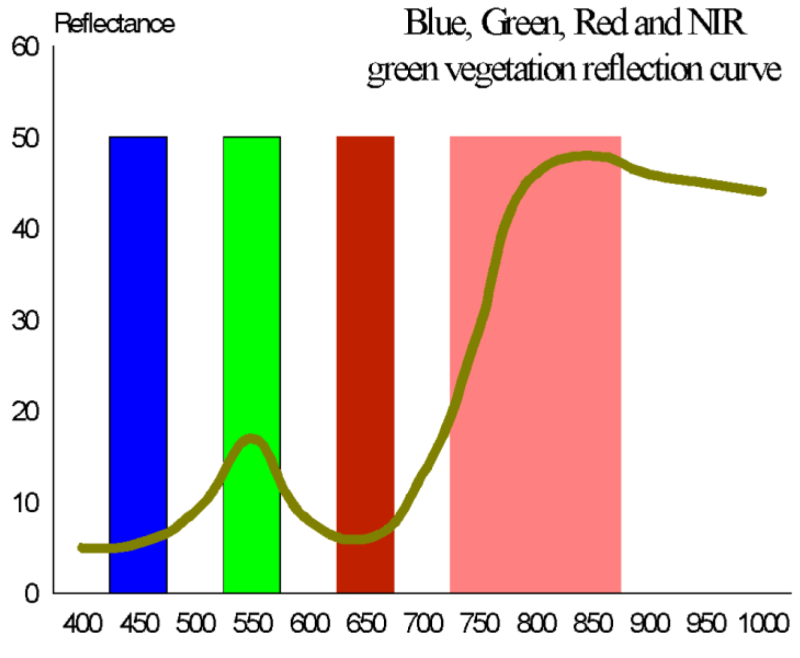


Why IR-sensitive?





Why colour film?

- Regular colour film – objects are depicted as we are used to see them (in colour)
- 20 – 120 shades of gray
- 20000 – 120000 colours and shades

Film

B/W	50-125 lp/mm
Colour	40-50 lp/mm
IR B/W	50 lp/mm
IR-colour	32 lp/mm

Approximately 0.3 m for B/W and about 1.0 m for IR-colour in scale 1:30000

Film

- **B/W** Good geometric resolution, cheap
- **Colour** Better spectral resolution, but less geometrical, less quality on high altitude
- **IR-B/W** OK geometric resolution, certain penetration in haze, harsh shadows
- **IR-färg** OK spectral resolution, haze penetration, good for vegetation mapping, harsh shadows, very treatement sensitive, expensive

Sensors

- Geometry sensor controlled
- Record in 4 bands
- Visible normally higher geometric resolution – WHY?
- Combine panchromatic mode with IR
- Orthographic projection standard

1938, scanned from negative, 1 m, panchromatic

1989, scanned from negative, 1 m, panchromatic

2007, scanned from positive, 1 m, colour

2010, digital camera, 0.25 m, colour

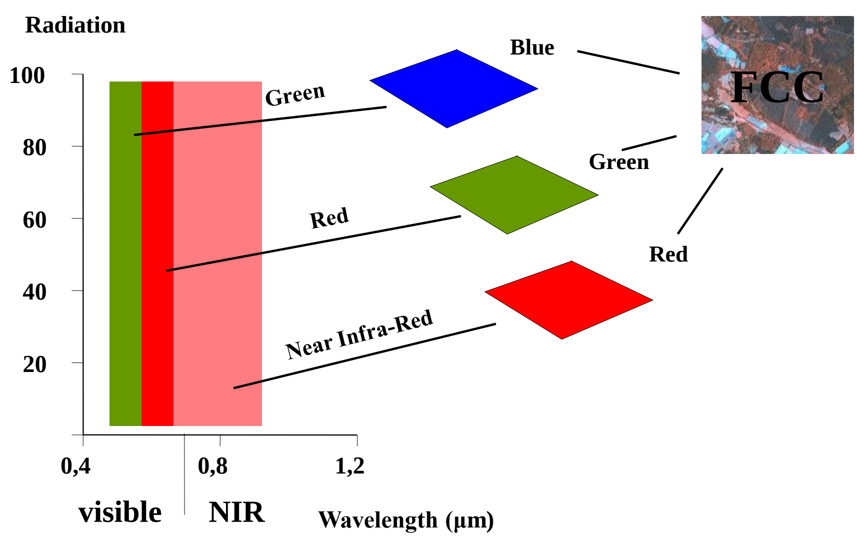
2010, digital camera, 0.25 m, IR-colour

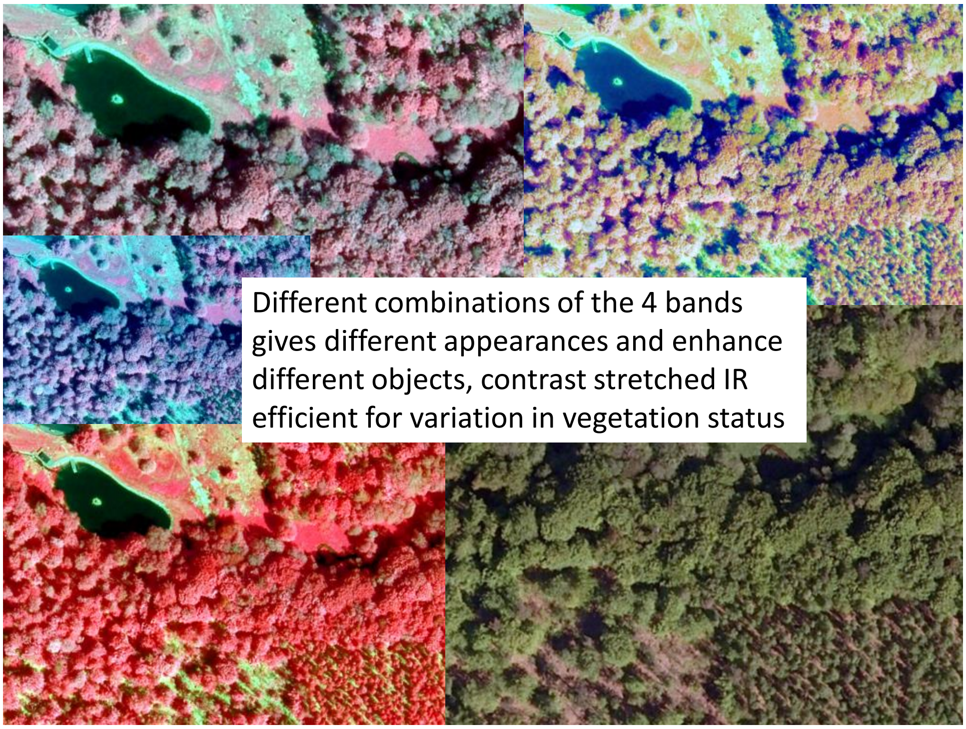
2010, digital camera, 0.25 m, IR-colour, contrast stretched and saturation increased

1 m, 2007,
colour

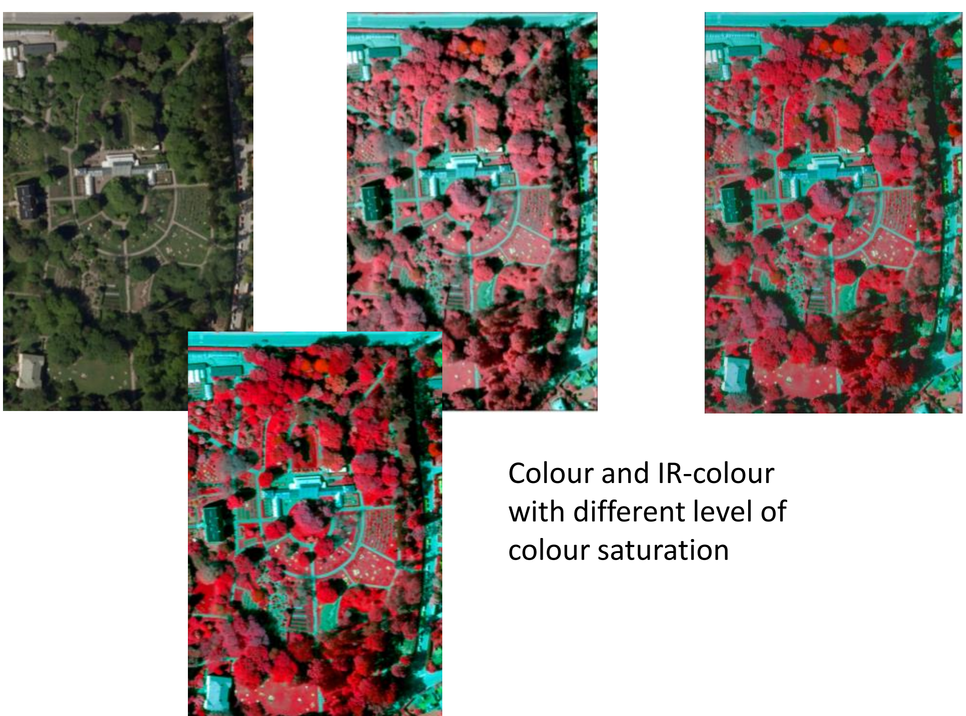
0.25 m, 2010,
colour

0.25 m, 2010,
IR- colour

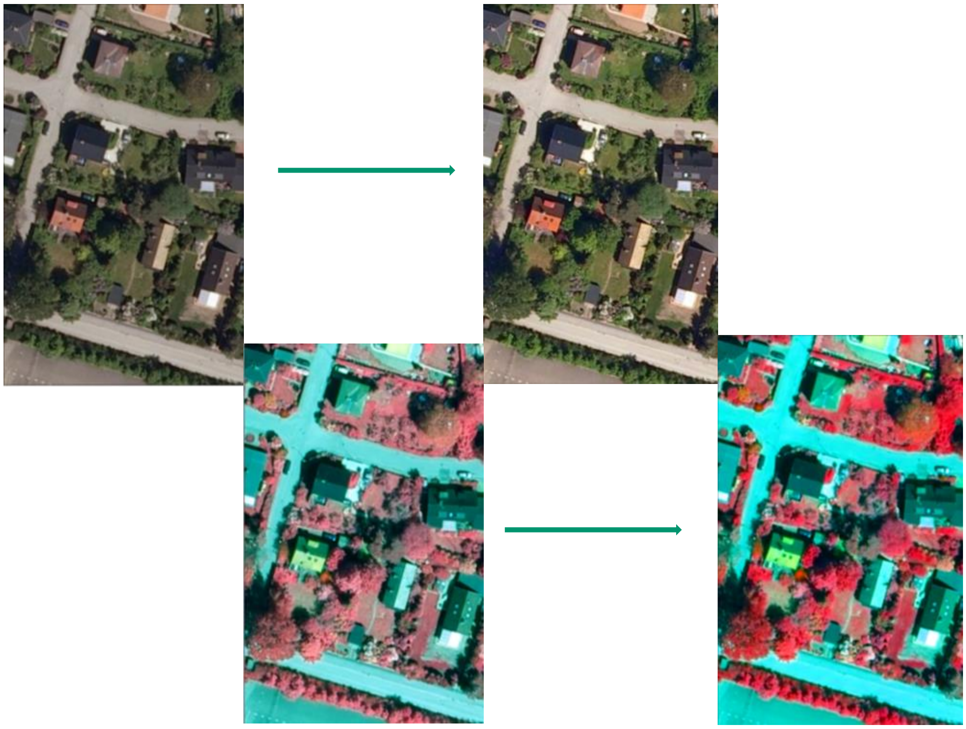




Different combinations of the 4 bands gives different appearances and enhance different objects, contrast stretched IR efficient for variation in vegetation status



Colour and IR-colour with different level of colour saturation




Dead tree
Pink flowers on Japaneese cherry tree
Bush with desease
Different species, different tonality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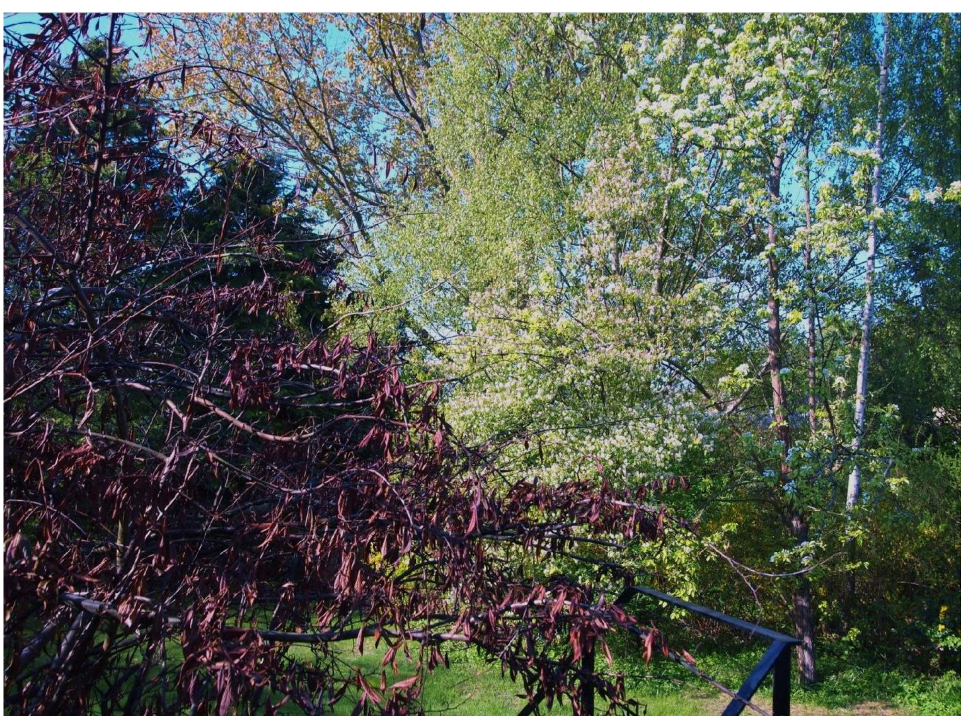
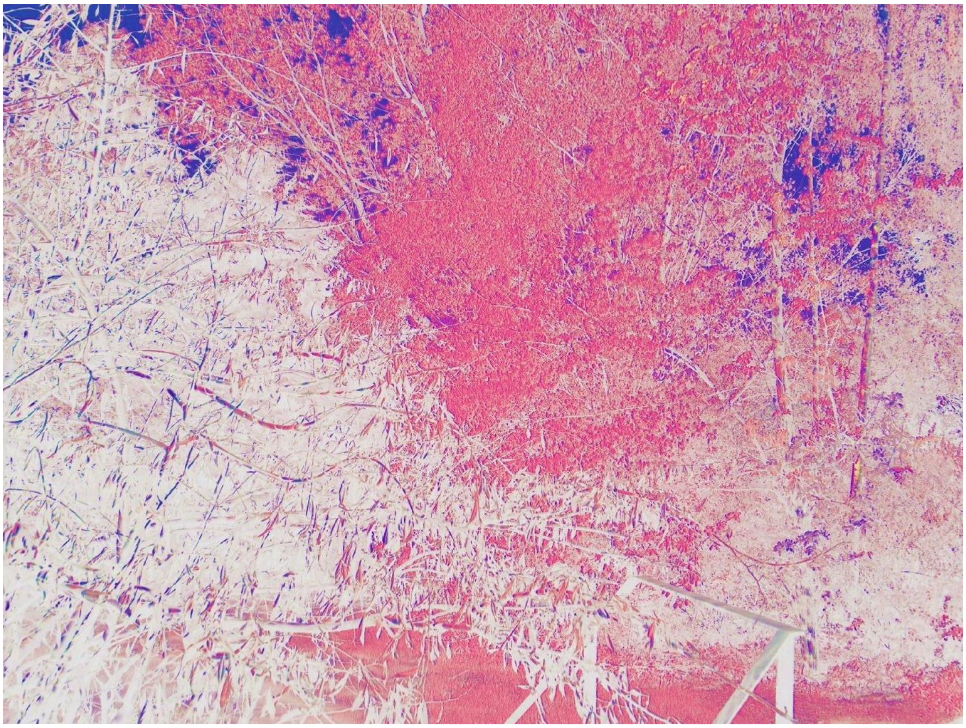




Digital images

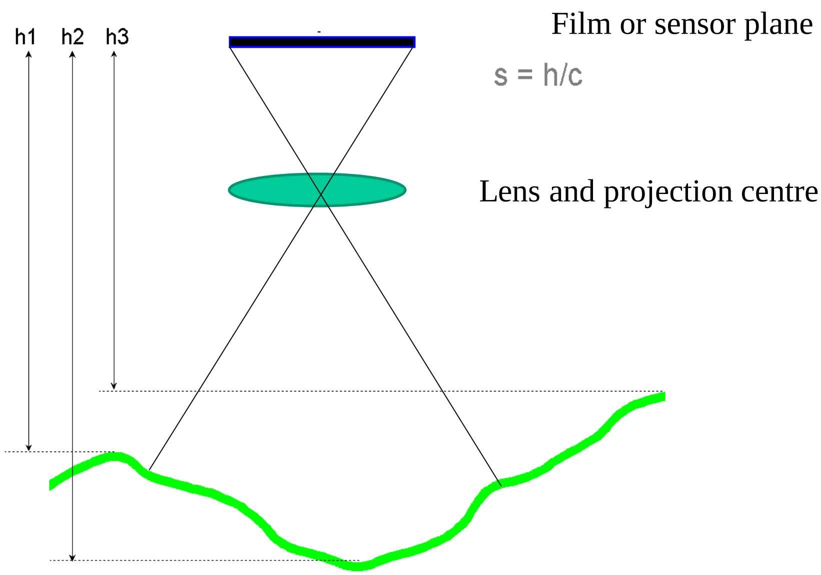
- Satellite sensors
- Airborne radiometers
- Digital aerial images
  - Scanned aerial photographs from negatives
  - Fixed geometrical resolution, pixel
  - Often 256 gray levels (8 bits)
  - Today digital aerial cameras
  - Archiving an issue

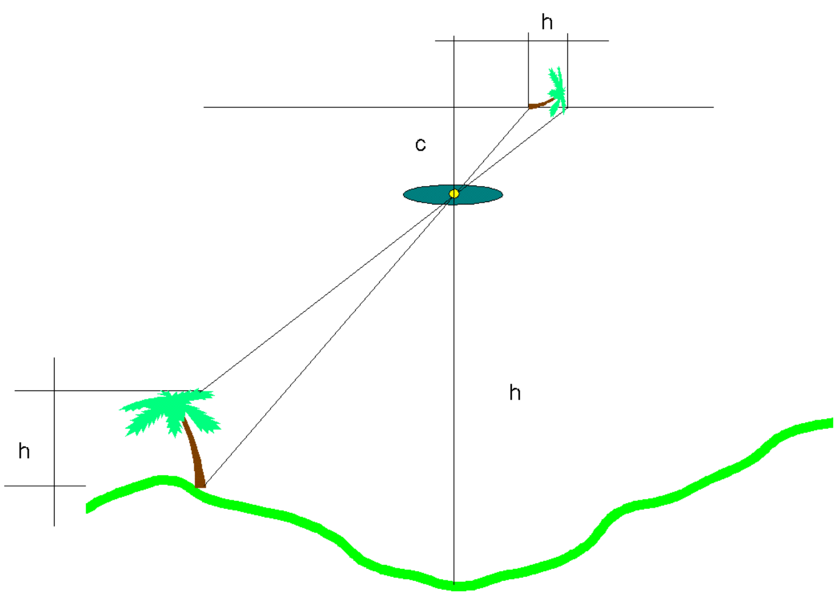
Image quality

- Camera
- Lens
- Image carrier (film or sensor)
- Atmospheric conditions

Geometry

- Airphotos are a photographs, NOT a map
- Scale vary with flight altitude and terrain elevation, indicative scal on photo is average on reference level
- Central projektion, projection centre
- Radial displacements increase with distance from image centre
- Difference in elevation generate displacements that can be used for measuring elevation


h1
h2
h3
Film or sensor plane
s = h/c
Lens and projection centre


h
c
h
h

Stereo model

- General photography 60 % overlap
- Two viewing angles
- Three dimensional, virtual image
- Stereoscope
- Anaglyph
- Polarisation
- Blink

Stereo model

- Measurements in aerial images developed after WW1- Photogrammetry
- All topographic mapping done ever since
- Improves interpretation results, e.g. shadowed areas, shapes and topography

Photogrammetry

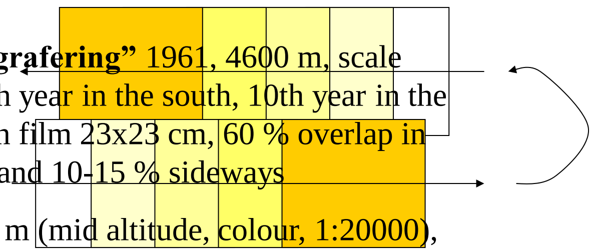
- Ortho-photo maps
  - Rectification and correction of image to adjust to a map reference system, uses computer assistance
  - Priviously use optical-mechanical instruments for this, e.g. stereoaviographs as A8, B8
- Rectification require access to Ground Control Points (GCP's) with known x, y och z-coordinates
- ”Rubber sheet”, 2nd and higher order polynoms to adjust positions

Aerial photography history

- First vertical image in Sweden 1920ies
- First national cover 1957/58, 10000 m
- Most countries in the world 1950-1960
- National cover IR-colour 1978-88 (4 600 in the south, 9200 in the north

Aerial photography history

- **”Omdrevsfotografering”** 1961, 4600 m, scale 1:30000, s/v, 5th year in the south, 10th year in the north, 7x7km on film 23x23 cm, 60 % overlap in flight direction and 10-15 % sideways
- Later also 3000 m (mid altitude, colour, 1:20000), 9200 m (high altitude, 1:60000), 13200 m (extreme high altitude, 1:150000, 4:e år från 1984) och colour and IR-colour
- Consulting, on demand, national and international, also extreme low altitudes 1500-600m
- Currently also commercial actors



Omdrevsfotografering

- Thematic mapping (vegetation, soils, geology)
- Physical planning
- Topografic mapping
- Up-dating existing maps
- Environment, agriculture, forestry
- Flight path maps and image information, Survey Department, National Mapping Agency (LMV)

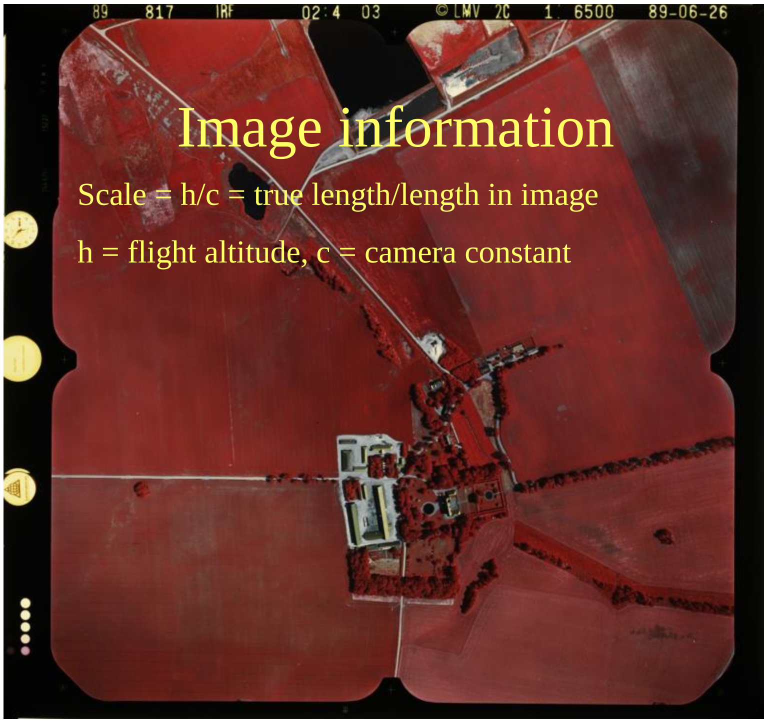


Image information
Scale = h/c = true length/length in image
h = flight altitude, c = camera constant

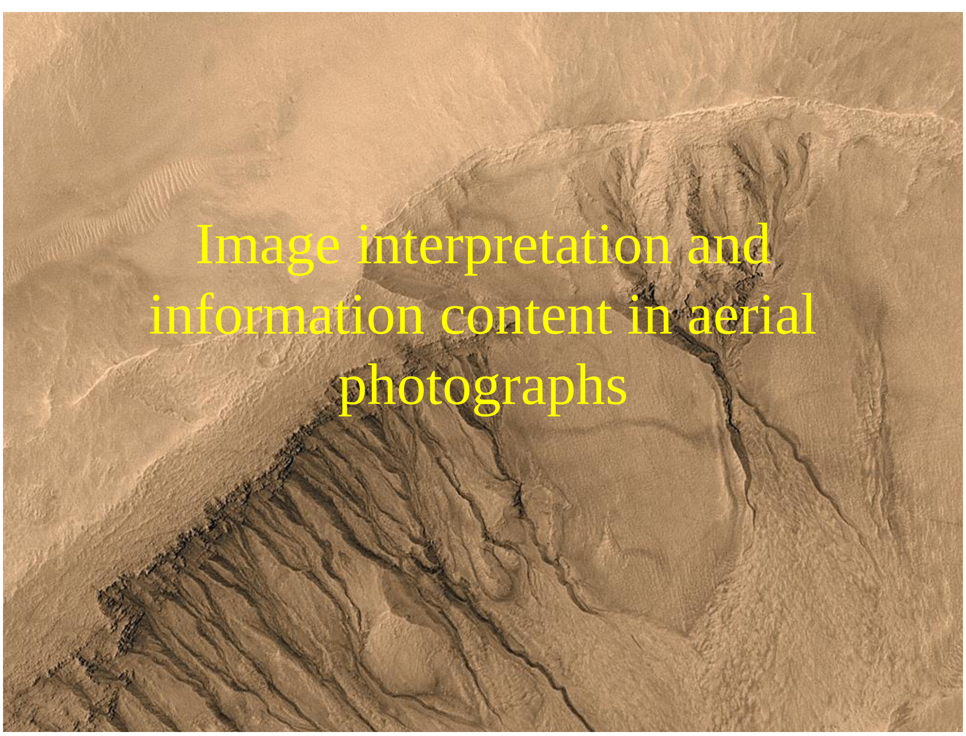


Image interpretation and information content in aerial photographs

Photo interpretation

- Intuitive analytic process
- Experience important
- Thematic knowledge of the features to interpret
- Field experience
- Craftsmanship”ish” process
- Orthophoto interpretation on screen most common, sometimes supported by analogue stereo images

Image interpretation process

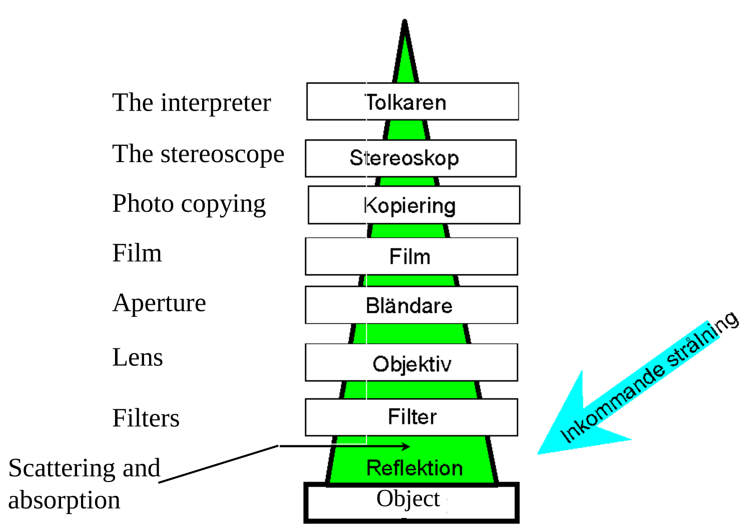


Image interpretation process

- Incoming radiation characteristics
- Reflection characteristics of the object
- Image quality
- The interpreter’s skills and ability

Image interpretation process

1. Study existing information
2. Select image material depending on purpose and scale for presentation
3. Create an interpretation key, what should be included and how it looks like – definitions, including smallest mapping unit (area, width, length)
4. Collect training data
5. Identify object, classify
6. Quantify, e.g. vegetation cover, surface boulders tree crown cover
7. Collect evaluation data
8. Calculate map accuracy
9. Produce final results and reports

Interpretation

- Colour and tone
- Shape and texture
- Geometry
- Placement and context
- *Additional information*

Colour and tone

- Many object are very similar
- Many object present seasonal variations, due to e.g. phenology and humidity
- Many object looks different in different environments

Shape och texture

- Natural shapes often not exactly similar
- Texture relative wave lengths
- Texture and patterns could be important clues, such as right angles imply human influence
- Many shapes together gives connections that could support interpretation, e.g. a river will end in a delta
- Shadows help interpretation of features with a vertical extention (such as trees)

Image geometry (non-digital images)

- Obstruction generated by central projection. Most important towards edges
- Larger image overlap reduce problem (two viewing angles)
- Same sized objects may appear different in size due to variations in scale due to e.g. topography
- Stereo imaging normally increase interpretation accuracy
- Elevation exaggeration improves estimation of object height

Placement and context

- Where in the landscape – wet land on a hill top?
- How relate to other objects – farmland in the city?
- Environment indicators – bed rock in the surface
- Exceptions exsist – riding range in the city – grazing land?
- Climate (placement) could rule out certain interpretations – trees in the desert?

Additional information

- ?
- ?
- ?
- ?
- ?
- ?
- ?

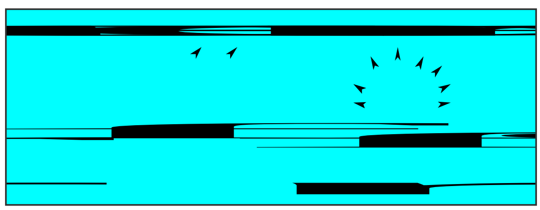
Reflection characteristics of different objects

Critical role of *reflectors*, which are distinguished theoretically as

a) *Specular*: flat, mirror-like surface

b) *Diffuse*: (rough) surface

Most actual earth surfaces fall between the two



Reflection characteristics of different objects

- Knowledge of energy/target interactions is central to effective use of remote sensing
- In visible and reflective IR portions of spectrum, knowledge of *spectral reflectance* is the key

Reflection characteristics of different objects

- Detection of
  - → Incoming short wave solar radiation
    - 99 % radiated energy between 0.2 - 5.6 µm
    - 44 % between 0.4 - 0.7 µm
  - → Longwave terrestial radiation emitted over broad range from 5.0 µm : also by atmospheric gases and heated objects on ground

Reflection characteristics of different objects

Albedo: average percentage of incident radiation reflected

- Fresh snow 80-85%
- Old snow 50-60%
- Asphalt 5-10%
- Water (sun near horizon) 50-80%
- Light soil 25-45%
- Deciduous forest 15-20%
- Coniferous forest 10-15%

Reflection characteristics of different objects

- Albedo values are generalisations
- Albedo values disregard variations in reflectance with wavelength (λ)
- Each sensor functions in one or more narrow parts of the E-M spectrum
- Thus important to know value of reflectance at specific λ

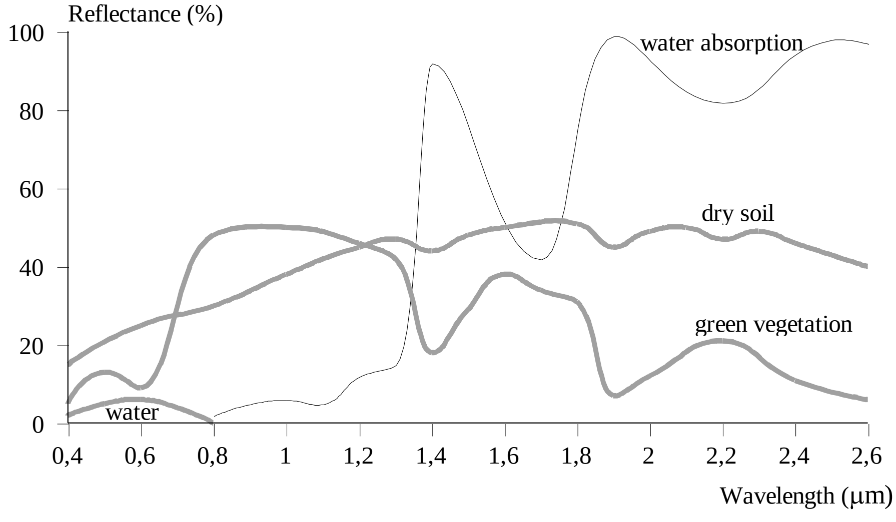
Reflection characteristics of different objects

- Many variables affect reflectance e.g. with *trees*:
  - Species
  - Texture/colour of exposed leaves
  - Morphology of tree crown
  - Health of tree
  - Spaces between tree crowns
  - Spectral composition and intensity of light
  - Atmospheric conditions

Reflection characteristics of different objects

- Soil type and moisture
- Relief and drainage
- Slope and aspect
- Weather conditions
- Date and time of observation
- Direction of observation relative to illumination

Reflection characteristics of different objects



Reflection characteristics

Influenced also by:

- Shadows
- Light distribution
- Time for photographing

Shadows

- Aerial photography is avoided when the length of shadows are over 1.5 times the object height
- Shadows obscure vision
- Shadows alters colour charateristics (re-emitted radiation from the atmosphere contra direct sun light)
- Could revail shape of e.g. a tree crown

Light distribution

- View angle related to light source angle yeald different reflection characteristics (looking on the shadow or sun side of an object)
- Topografy also influence
- Shadow from clouds
- Mirror reflex => over saturated image

Time for photographing

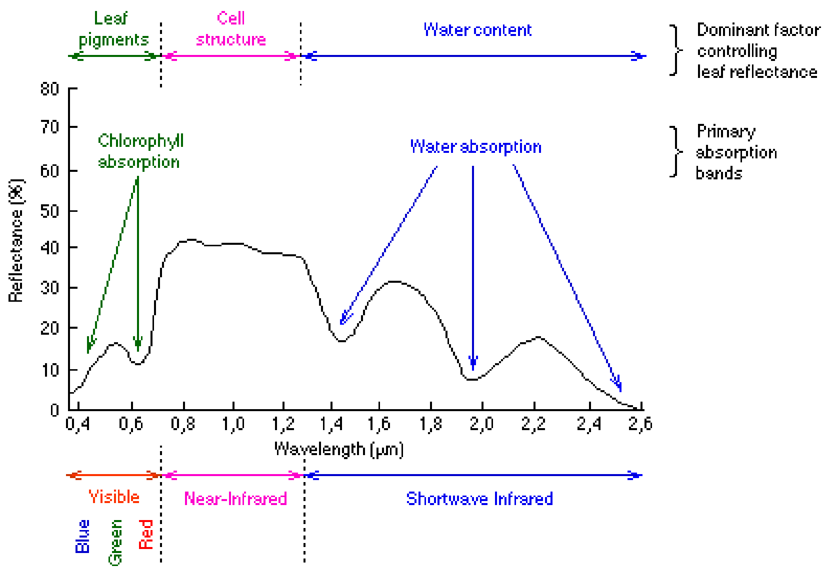
- Time of the day controls shadows, low angle could be useful for acheologic applications
- Time of the year
  – Different light
  – Different phenological development
  – Vegetation or no vegetation
  – Snow and ice

1. Spring, before leaves develop, ground visibility, topography soils, geomorphology, humidity variations, clay is speckled, organic soils, field cover, decidious trees on trunk and branch shapes
2. Spring, after leaves developed. The actual timing of leaves break out can be used to differentiate species and decidious and conifers

3. Summer, limited vision, dense vegetation, few shadows, good for open areas and cultivated areas, from August good separability Spruce-Pine, water vegetation, algae blooming
4. Autumn before leaves are falling, decidious-conifer separation, also Spruce-Pine separation, after harvest – soils and humidity in cultivated areas, IR – forest damages

5. Autumn, after leaves have fallen, dark, heavy shadows, archeology applications, similar to early spring
6. ´Winter, military applictions? Snow mapping

Vegetation



Conifers

- Easy seprable in scale 1:10000 – crown shape
- Difficult in 1:30 000
- Best spring before new branches on spruce in spring
- Shadow crucial for separability
- Wave bands 1.3 – 3.0 µm best for separation of species

Decidious forest

- Ash – like oak but more and thinner branches
- Birch – very thin fine crown, slim and distinct
- Beech – broad, flat crown, regularly shapede, often in single stand forest
- Oak – broad crown, few but thick branches that gives and irregular shape, shadow on open ground
- Mixed decidious forest
- ”Noble decidious forests” Oak, Beech, Ash; Elm, Fagus

Open

- Cultivated = immense number of crops impossible to separate, field contact important, climate zone helps
- Patterns important, square angles – cultivated if smooth, could be grazed if trees and stony
- After harvest – naked soil, good for soil mapping
- Wet lands – humidity visible

Soils and Geology

- Multispektral recording often better
- Humidity reduce reflectance
- Dry soils have higher reflectance in longer wave bands (λ)
- Texture - ytskrovlighet *(surface roughness*), fine texture gives higher reflectance
- Organic content, iron oxides, etc.

Soils and Geology

- Both soils and geology – lots of indirect indicators
- Drainage pattern – karst under ground, pattern indicators for fissures and weaknesses
- Drainage density
- Fissures, faulting and tectonics
- Basement complex difficult to separate type of rock
- Basement complex and sanstones often softer shapes, limestone and shale sharper
- Vegetation important indicator
- Possible to map borders without deciding on type (needs feild check)

Soils and Geology

- Early spring and late autumn
- Geomorfology – shapes important
- Geometric resulution important
- Processes are indicators for soils, e.g. slide angle in clay is steeper than for silt or sand, dunes are sandy material, etc.
- Cultivated or grazed, clayey moraine or sandy stone moraine
- Stone fences indicate moraine

Water

- Water has low reflectance between
  0.4 - 0.8 μm.
- No reflection >0.8 μm (all absorbed)
- Quantifies atmosphere influence
- Detect pollution as algae bloom, sedimets load, oil spill

SPECTRAL REFLECTANCE

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- Kalensky and Wilson. 1975. Spectral signatures of forest trees. *Proceedings, 3rd Canadian Symposium on Remote Sensing*. 155-171.