



Co-funded by the
Erasmus+ Programme
of the European Union

Introduction to Remote Sensing

Dr George P Petropoulos



UNIVERSITY OF
HOHENHEIM





Contents

Lecture 1:

- Introduce Principles, Sensors & Applications for:
 - *Optical Remote Sensing*
 - *Thermal Remote Sensing*
 - *Microwave Remote Sensing*
 - *LiDAR Remote Sensing*
- Reading List
- Practical



Remote Sensing: what is it?

Definition:

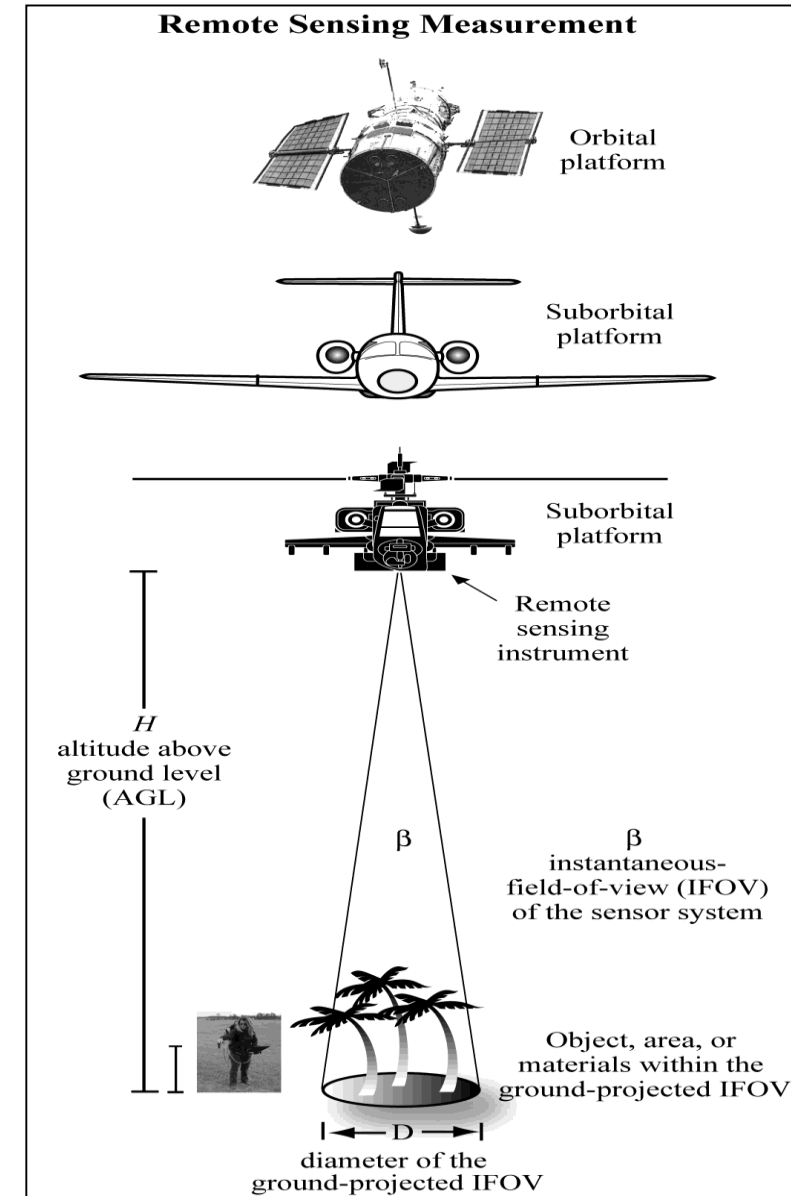
“The science of obtaining information about a feature without being in contact with it”

Remote sensing data collection involves the operation of a “sensor” that is recording the reflected or emitted energy from objects.

RS sensors are divided to:

- Optical
- Thermal
- Microwave
- LiDAR

*Overview of sensor types
& applications*





Why is it useful?

Advantages

- Information in regions beyond that of human perception (e.g., Infra-red)
- Different perspective
- Access to remote regions of the world
- Possibility for global monitoring
- Space exploration

Many different practical applications...

Optical Sensors

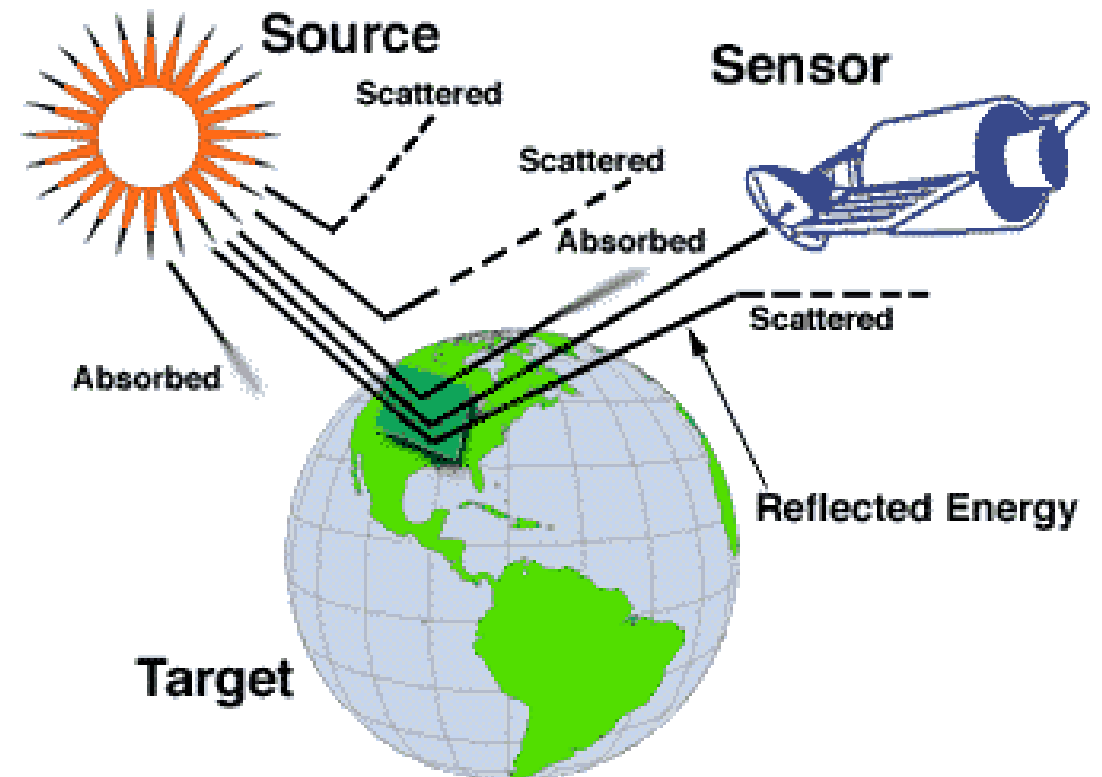


Optical sensors: Interactions

■ **Optical Sensors** record the energy that is reflected from objects at the EMR region between 0.4 to $\sim 2.5 \mu\text{m}$.

Considerations:

- *Interactions with the Atmosphere*
- *Interactions with the matter*



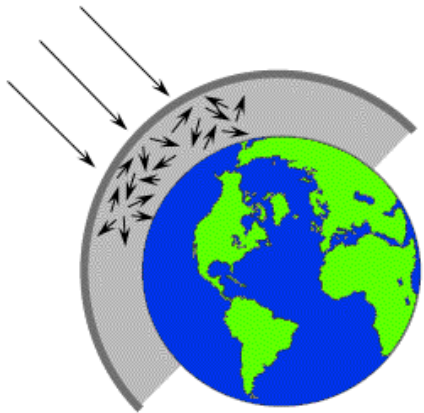


Optical sensors: Interactions

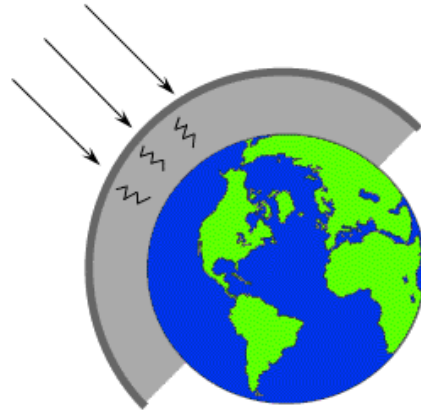
Interactions with atmosphere

⇒ **Particles and gases** in the atmosphere can affect the incoming light and radiation:

A) Scattering



B) Absorption



⇒ **Scattering** occurs when **particles or large gas molecules** in the atmosphere interact with and cause the EMR to be redirected from its original path

⇒ **Absorption** causes **molecules** in the atmosphere to absorb energy at various wavelengths.

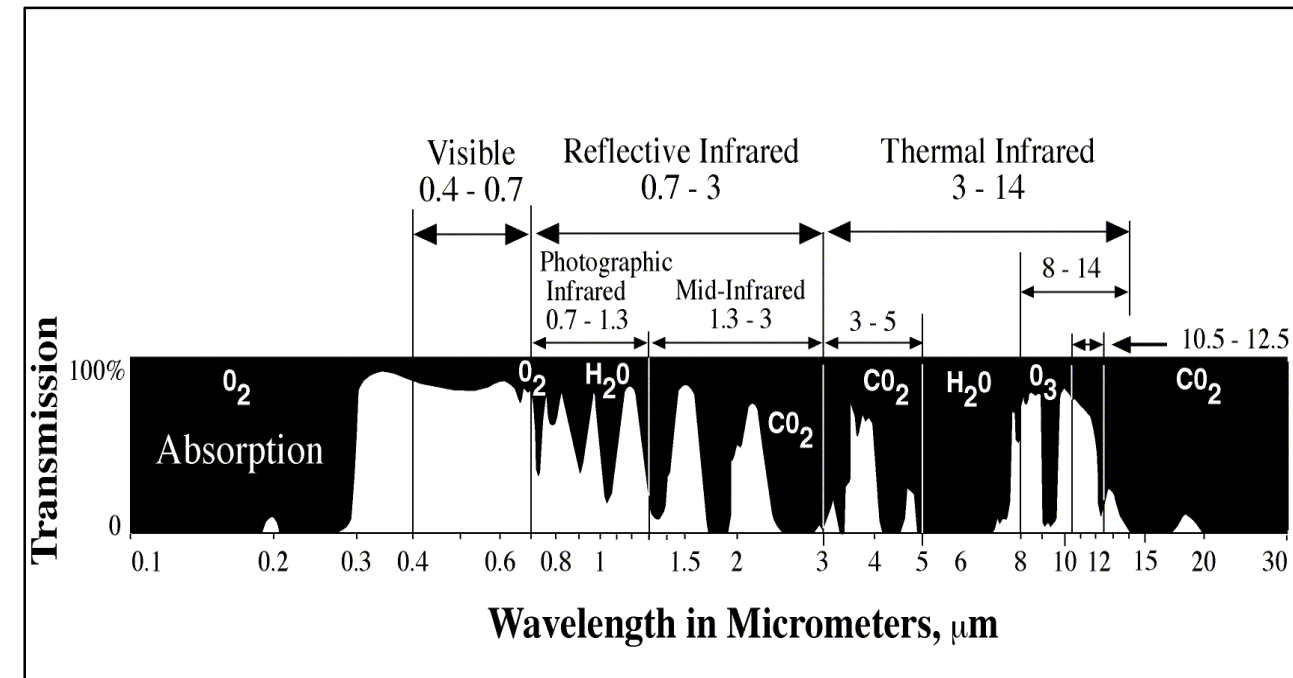


Optical sensors: Interactions

Interactions with atmosphere

- ‘Atmospheric windows’: there transmission of the EMR reflected or emitted from the Earth’s surface is strong.

Spectral Window	Radiation Type
0.3 - 1.1 μm	UV, visible, reflected IR
1.5 - 1.8 μm	Reflected IR
2.0 - 2.4 μm	Reflected IR
3.0 - 5.0 μm	Thermal IR
8.0 - 14.0 μm (below ozone layer)	Thermal IR
10.5 - 12.5 μm (above ozone layer)	Thermal IR
> 0.5 cm	Microwave





Optical sensors: Atmosphere

Interactions with the matter

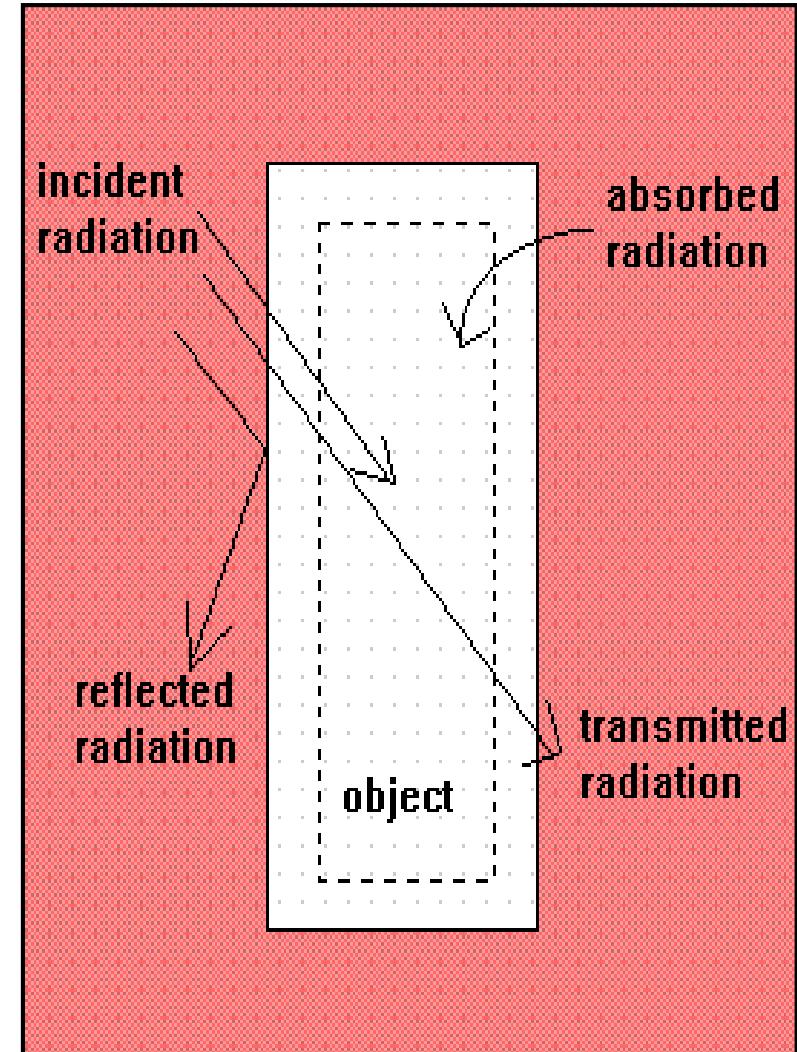
Kirchoff's Radiation Law

Conservation of energy: all radiance incident on a surface to be absorbed, reflected or transmitted:

$$\alpha_{\lambda} + r_{\lambda} + \tau_{\lambda} = 1$$

α = absorptance, r = reflectance, τ = transmittance

- **Optical systems** record the reflected component



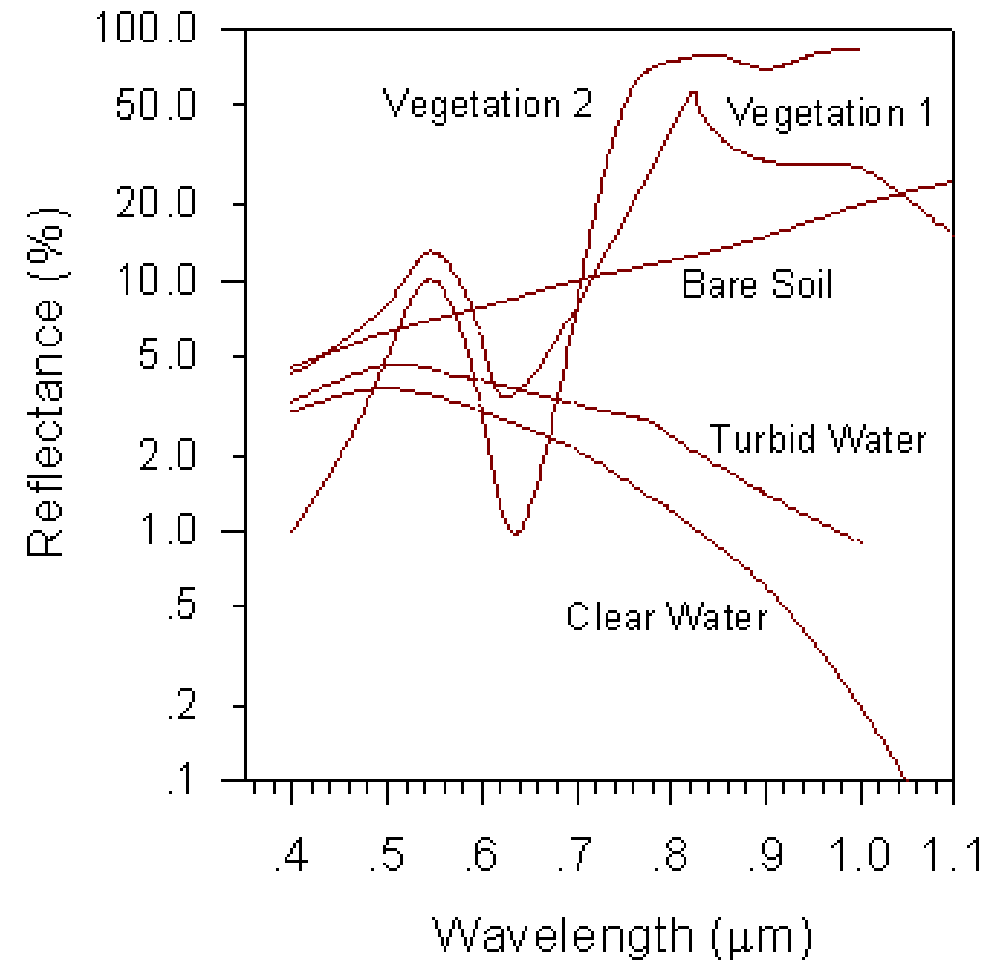


Optical sensors: Interactions

Interactions with the matter

- **Each surface has different**
 - Absorption
 - Reflectance
 - Transmission
- This creates different **spectral curves**

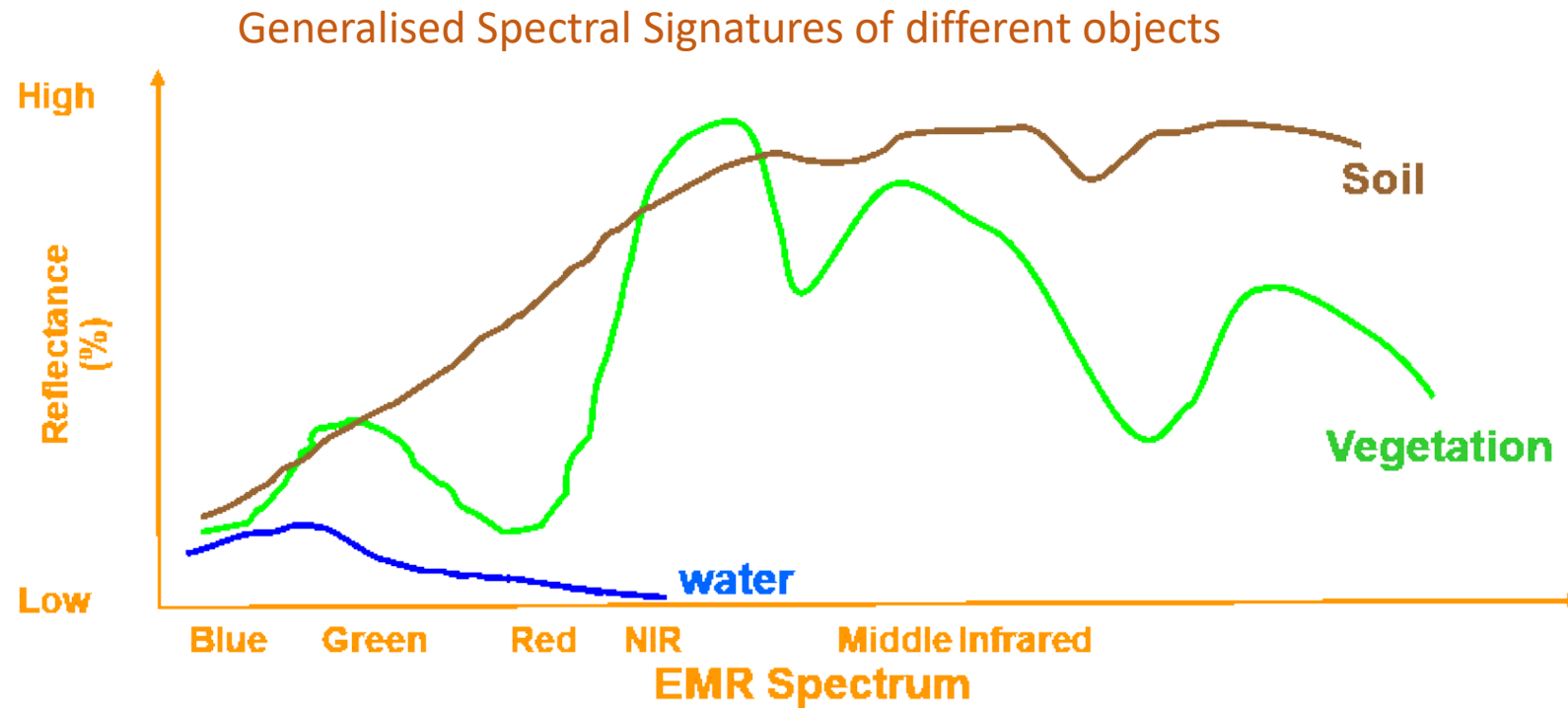
Spectral curves from visible to near infrared





Spectral Signatures

- The graphical representation of the spectral response of an object as a function of spectral wavelength is called **spectral response** - characteristic for each object.



Optical sensors operate in different regions of EMR located in the range 0.4 to 2.5 μ m.

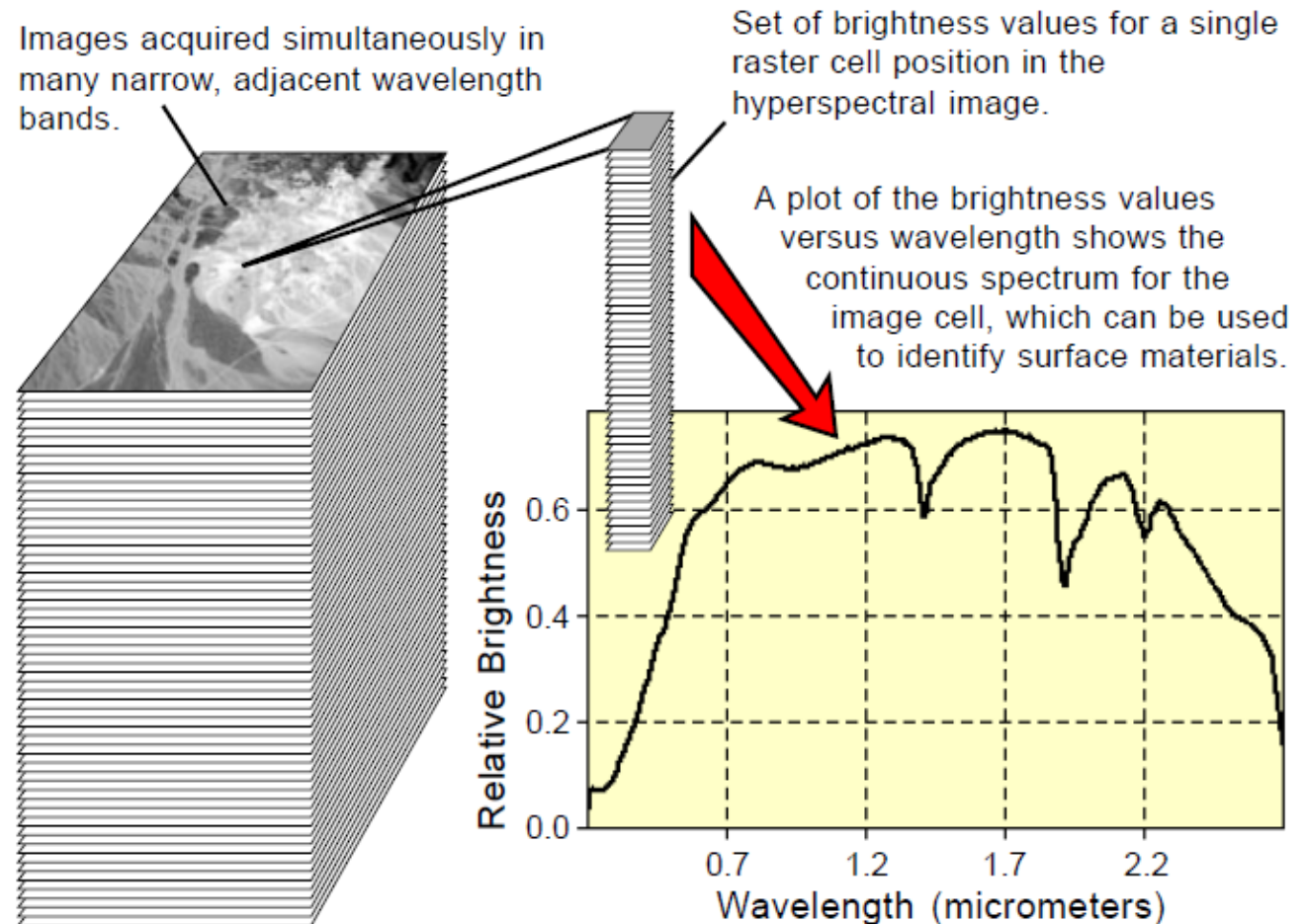


Optical sensors: Distinctions

Optical systems are divided into:

Multispectral – Many spectra (bands)

Hyperspectral – Large numbers of continuous, very narrow spectral bands

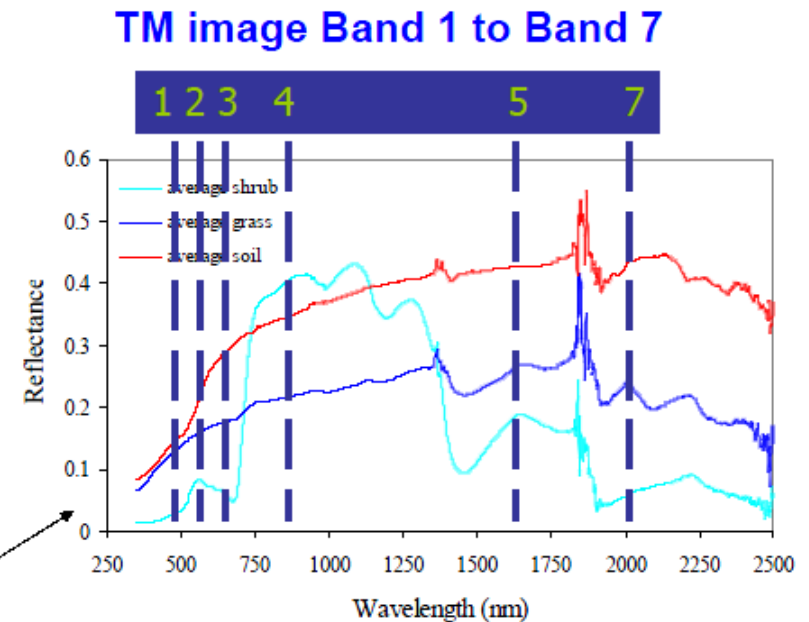




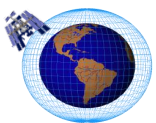
Optical sensors: Distinctions

The very high spectral resolution facilitates **discrimination between targets** based on their spectral response.

Hyper- and Multi- spectrum



Continuous hyperspectral curve for any one pixel in an image



Optical sensors: Distinctions

Field spectroscopy (non-imaging hyperspectral)

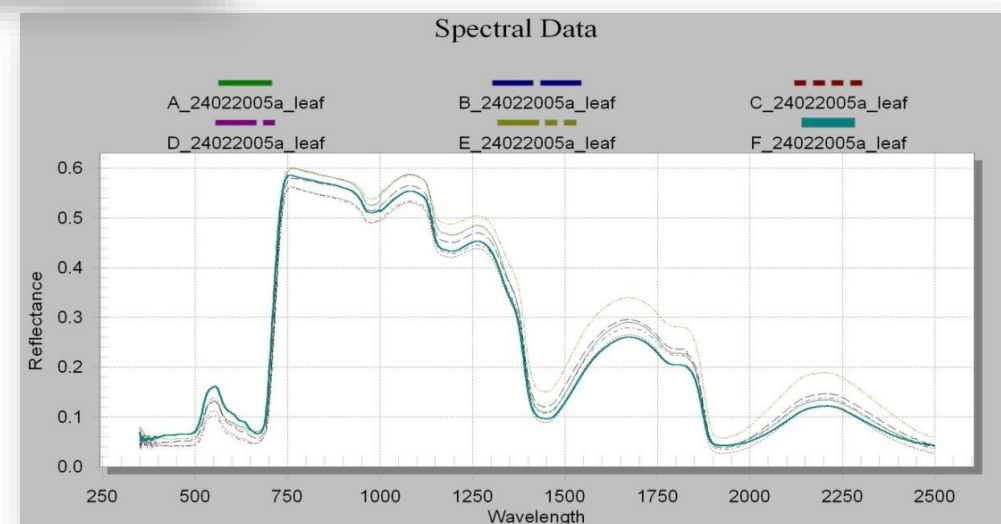
Used for:

- Collecting **spectral signatures**, known as end-members, to train your image classification
- Determine spectral differences on ground before tasking imagery
- Laboratory, field-based studies (*e.g. lead content in soils, crop yield, age of mosquitoes, etc...*)
- Determine surface reflectance values for atmospheric correction of imagery



ASD FieldSpec Pro
spectroradiometer

www.asdi.com





Optical sensors: Examples

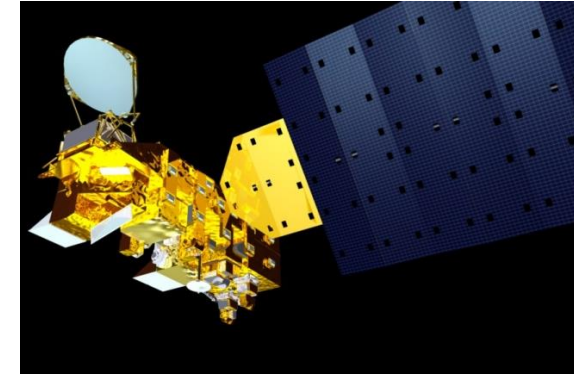
IKONOS



SPOT5



MODIS (Terra/Aqua)



CHRIS PROBA



HYPERION



MERIS ENVISAT





Optical sensors: Applications

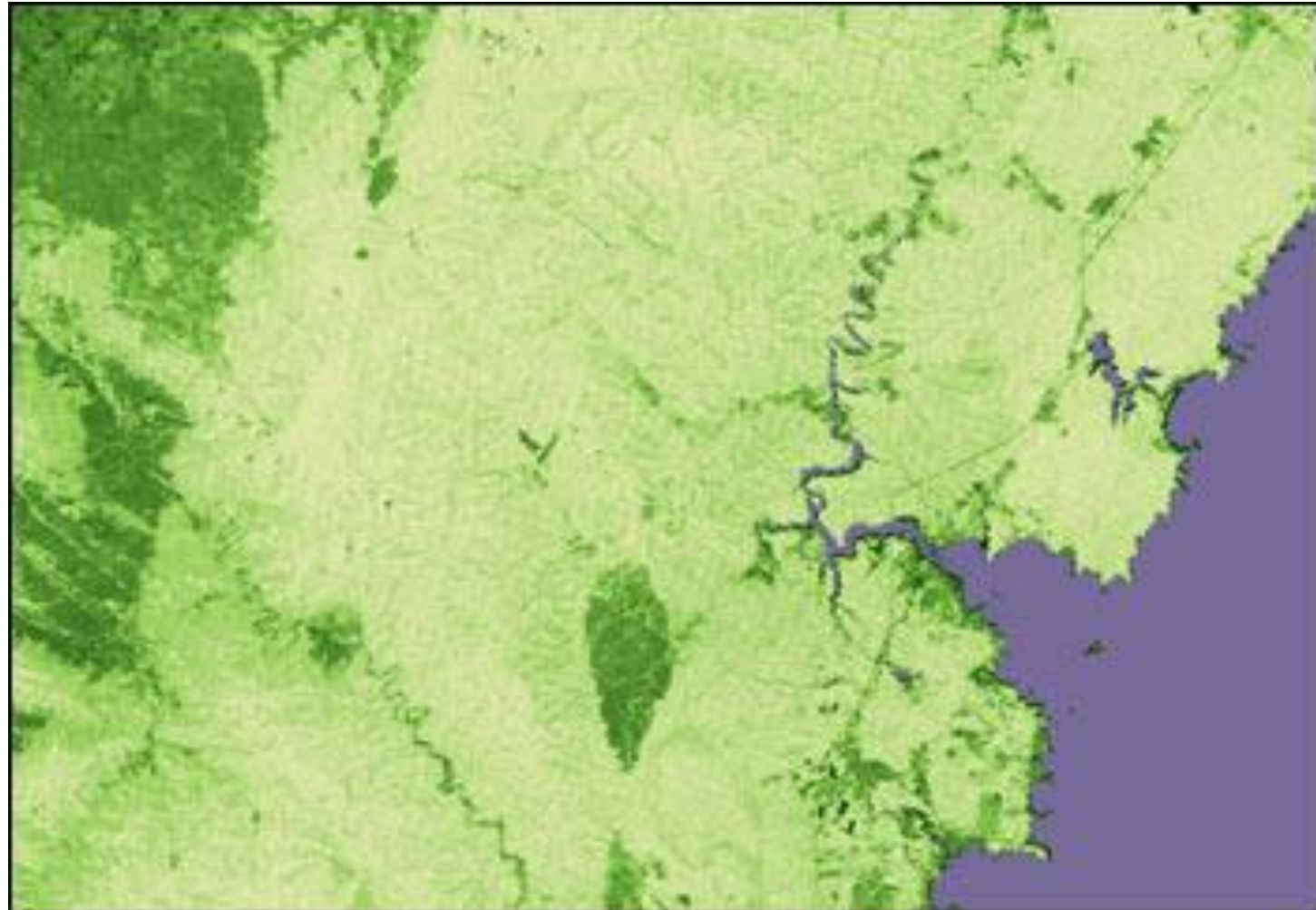
Natural Disasters Mapping: Sri Lanka tsunami, QuickBird





Optical sensors: Applications

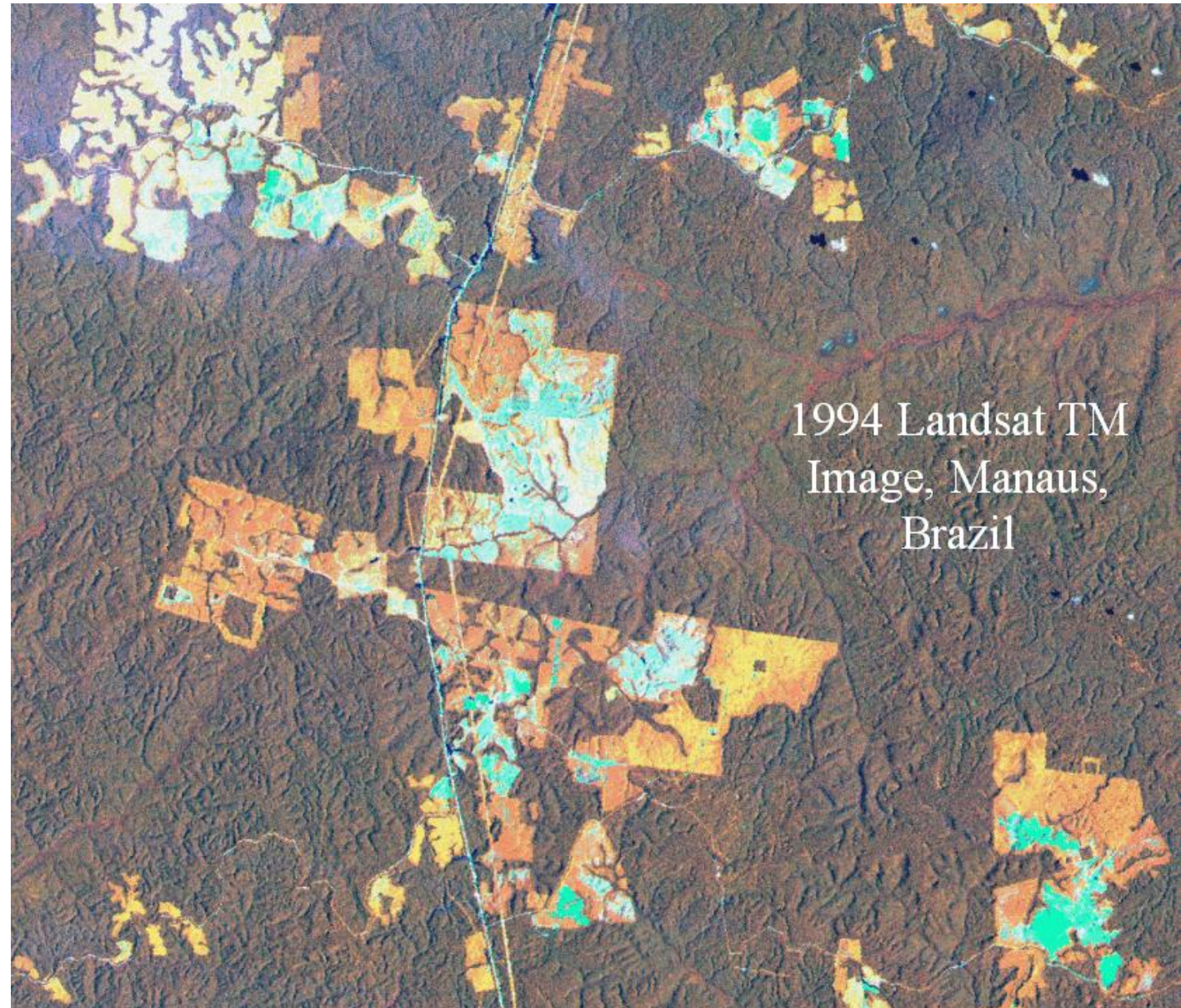
Vegetation Health: *Landsat Multi-spectral Scanner (NDVI) of eastern Australia - December 9, 1982*





Optical sensors: Applications

Deforestation mapping:
Brazil, Landsat TM



1994 Landsat TM
Image, Manaus,
Brazil

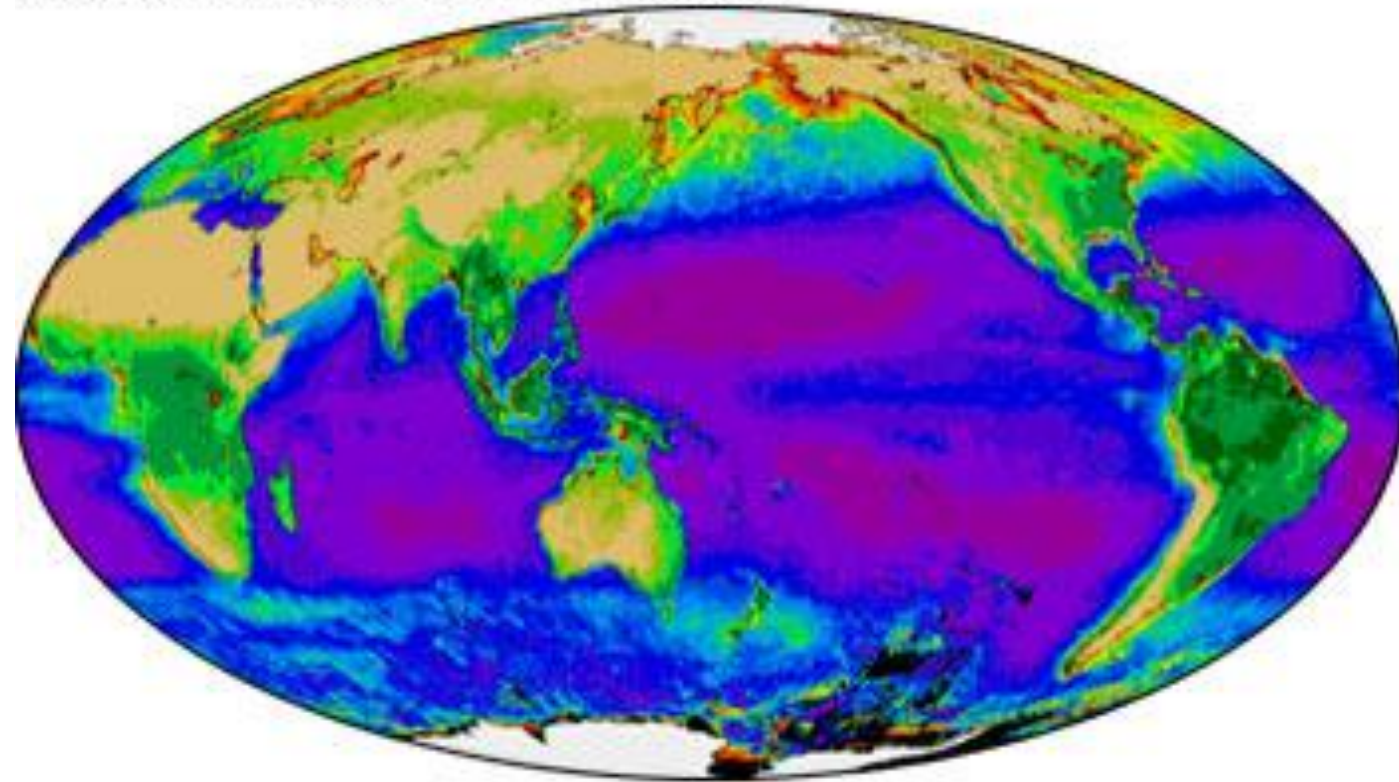


Optical sensors: Applications

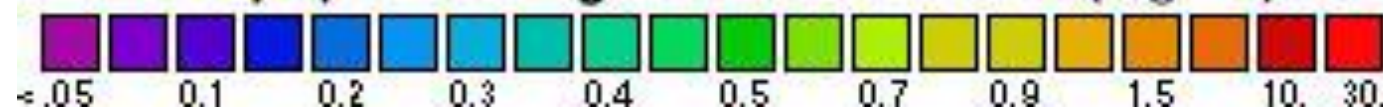
Global Productivity

- Coastal Zone Colour Scanner (CZCS)
- Advanced Very High Resolution Radiometer (AVHRR)

Global Biosphere (AVHRR & CZCS)



Phytoplankton Pigment Concentration (mg/m³)





Optical sensors: Applications

Mapping Earth surface change



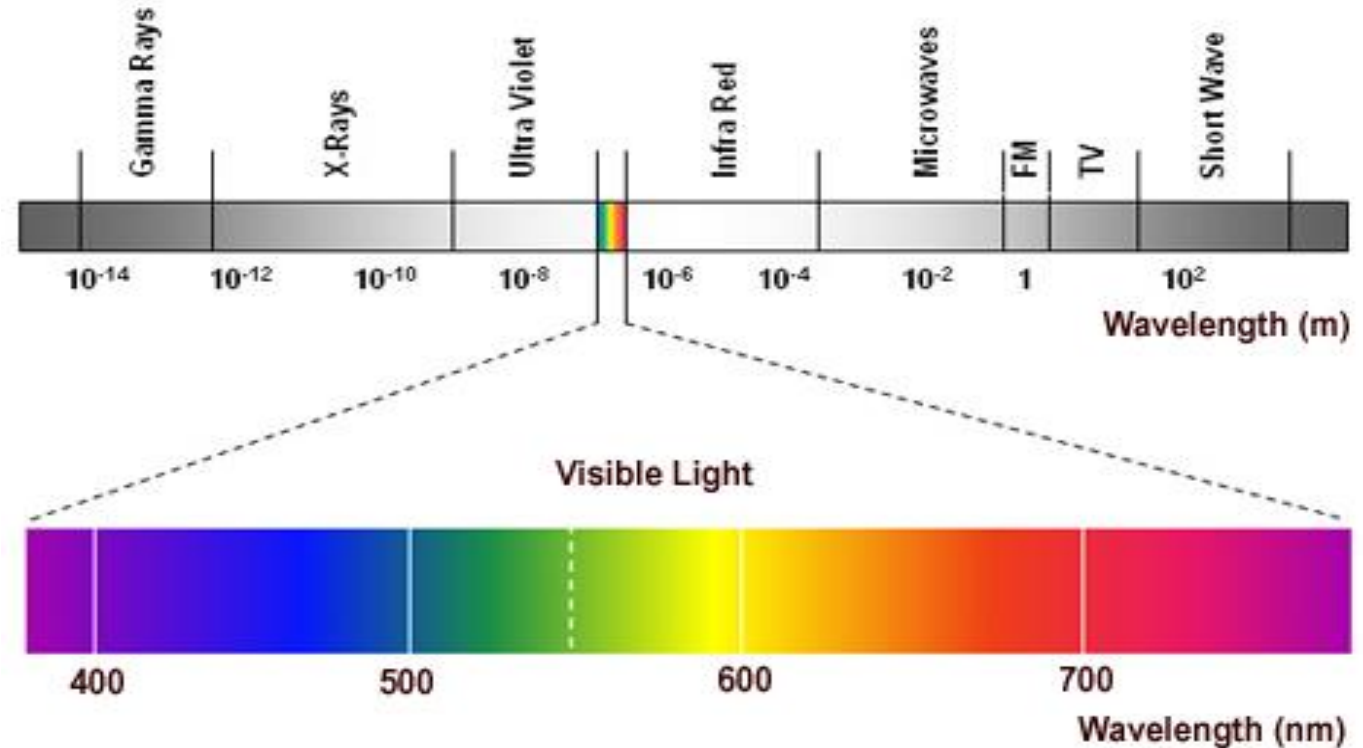
TIR Sensors



TIR: Principles

Thermal infrared energy is emitted from all objects that have a temperature greater than absolute zero. => all features in the landscape emit thermal infrared EMR.

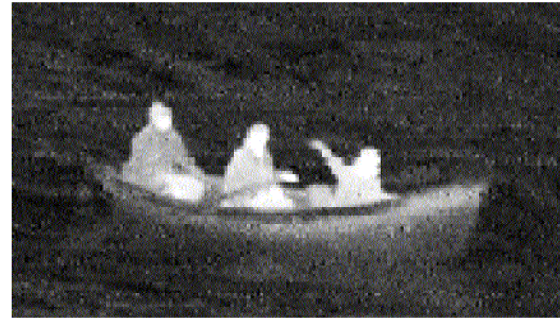
Humans eyes cannot detect differences in thermal infrared energy because are not sensitive to the reflective IR (0.7 - 3.0 μm) or thermal IR energy (3.0 - 14 μm).





TIR: Principles

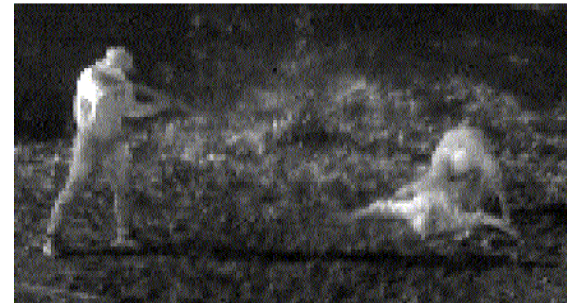
TIR detectors allow to sense an otherwise invisible world of information, as they monitor the thermal characteristics of the landscape.



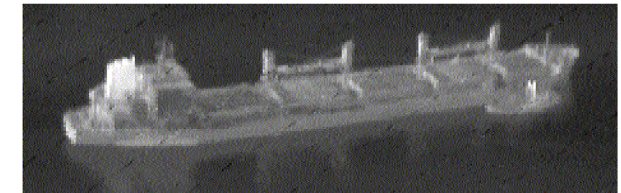
a.



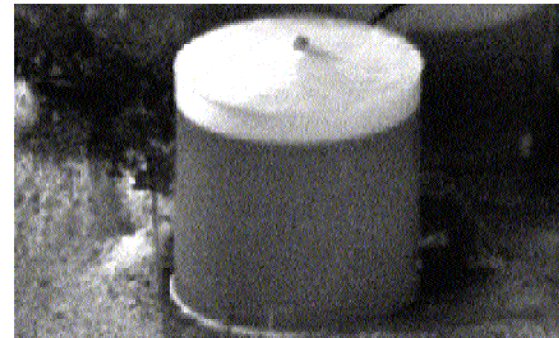
b.



c.



d.



e.

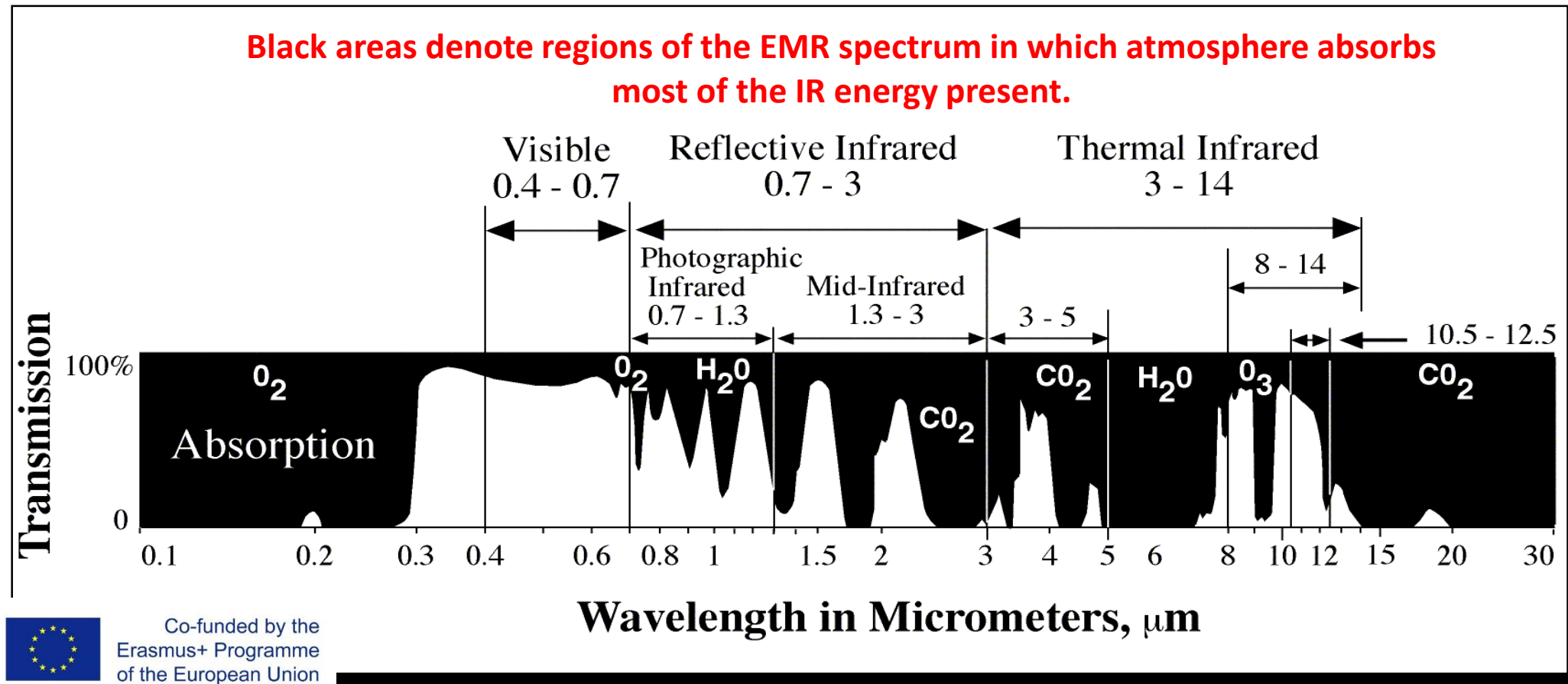


f.



TIR: Principles

- TIR region: almost no atmospheric scattering but lots of absorption by atmospheric gases (e.g., H_2O , CO_2)
–*atmospheric windows*





TIR: Principles

The Planck's Function

The **intensity of radiation emitted** by a surface unit area into a fixed direction (solid angle) from the blackbody as a function of wavelength for a fixed temperature by :

Where:

λ is wavelength (m), T is temperature (K)

L is spectral radiance (W/m²/sr/m)

h is Planck's constant (6.6×10^{-34} Ws²)

k is Boltzmann constant (5.67×10^{-8} W/m²/K⁴)

c is the velocity of light in vacuum (3×10^8 m/s)

Multiply $L(\lambda, T)$ by 10^{-6} to obtain units of W/m²/sr/μm

$$L(\lambda, T) = \frac{2hc^2}{\lambda^5 \left(\exp\left(\frac{hc}{\lambda kT}\right) - 1 \right)}$$

Blackbody: absorbs and re-radiates (emits) all the radiation that falls in to it.



TIR: Principles

Weins Displacement law

- Relates the dominant wavelength at which a blackbody radiation curve reached a maximum to its temperature:

$$\lambda_{\max} = \frac{A}{T}$$

λ_{\max} = wavelength of maximum spectral radiant exitance, μm

A = constant, equal to 2898 μm , K

T = Temperature, K

Examples:

- (i) Earth ambient temperature \sim 300 K (27 °C)

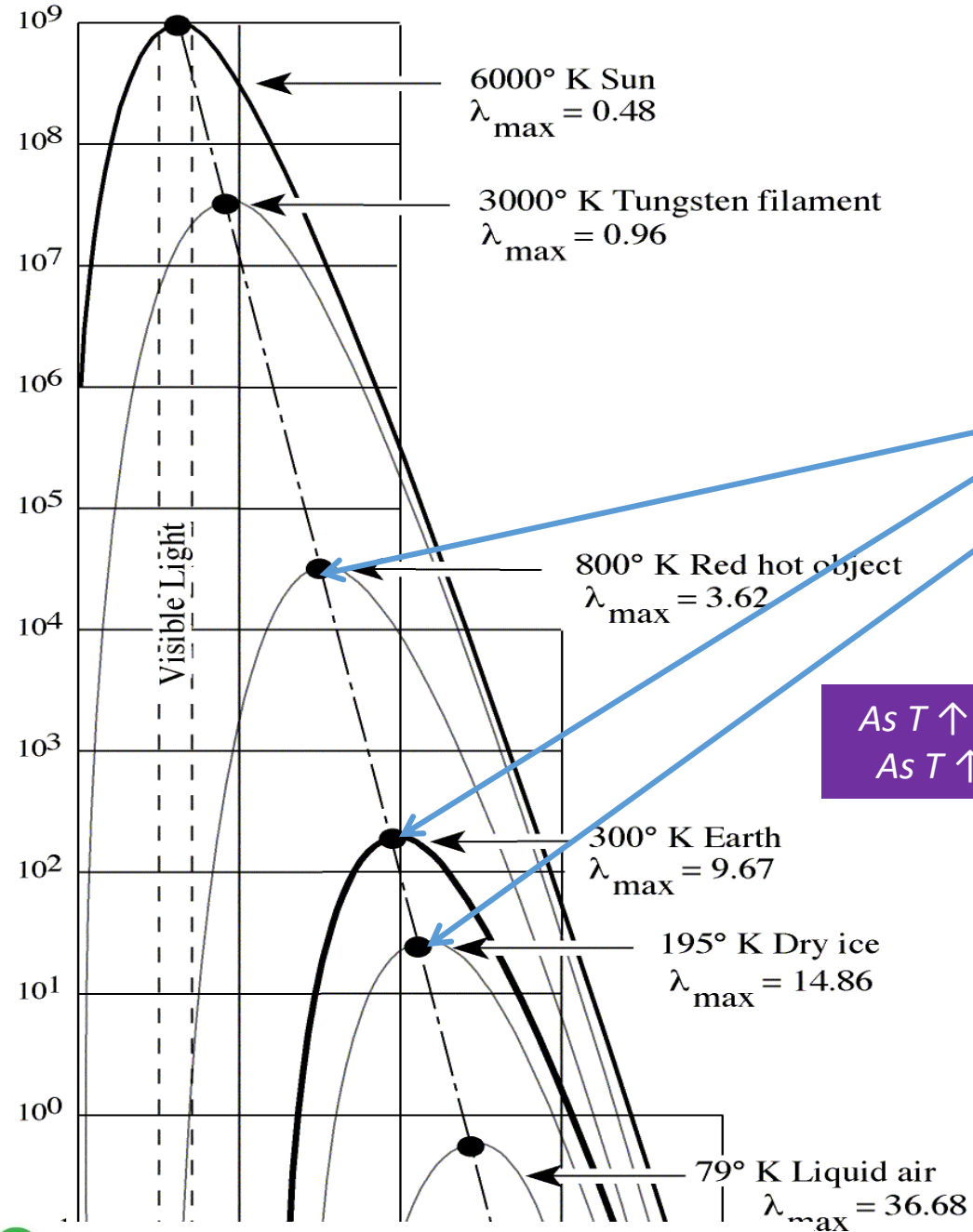
$$\lambda_{\max} = C_W / 300 \text{ (x}10^6\text{)} \mu\text{m} = 10 \mu\text{m (TIR)}$$

- (ii) **Vegetation fire temperature** \sim 850 K (577 °C)

$$\lambda_{\max} = C_W / 1000 \text{ (x}10^6\text{)} \mu\text{m} = 3.5 \mu\text{m (MIR)}$$

Blackbody Radiation Curves for Several Objects

Relative Radiated Energy



Spectral radiance exitence is the total area under the curve

As $T \uparrow \Rightarrow$ total amount of radiant energy increases
As $T \uparrow \Rightarrow$ radiant energy peaks shift to shorter λ

Q: Why is important to know λ_{max} ?

Q: What do you observe in this figure?

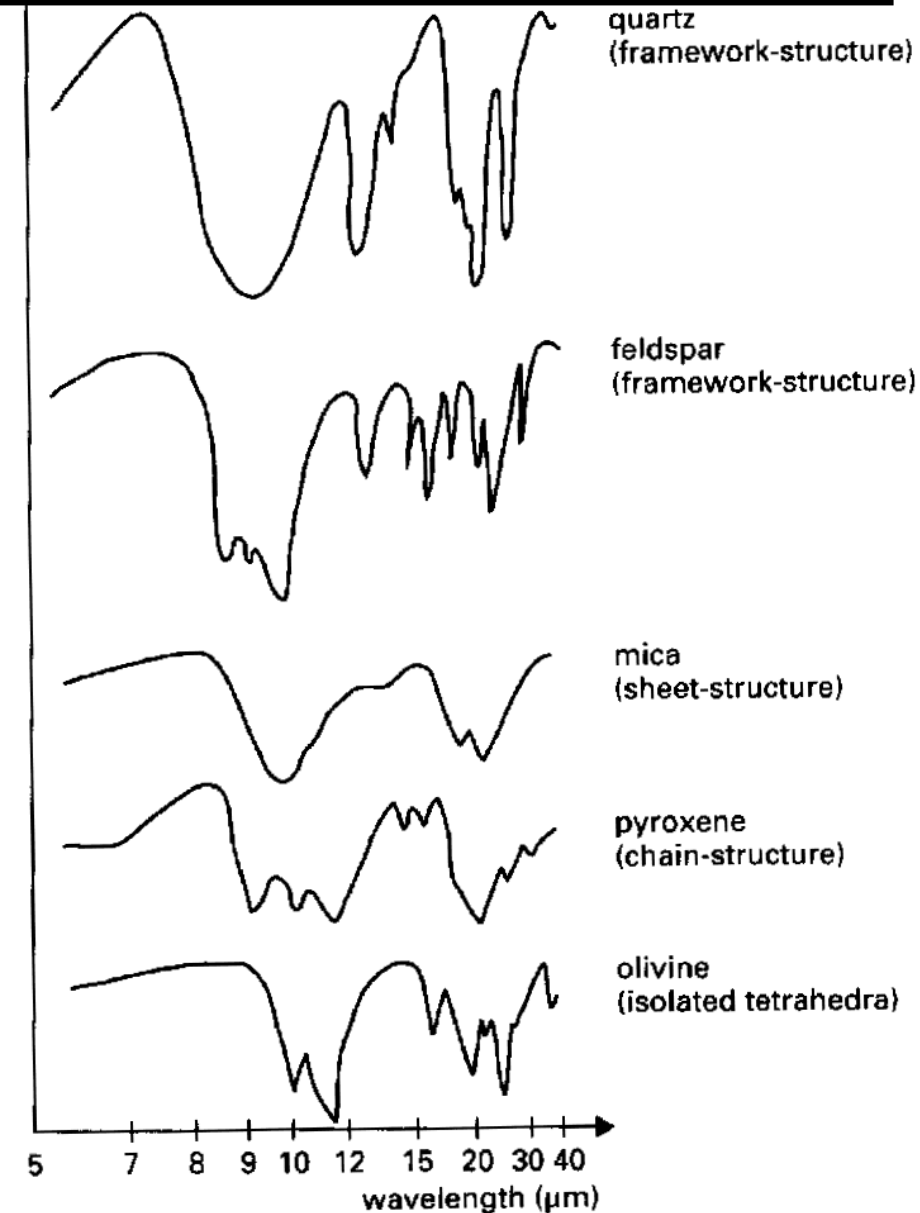


TIR: Principles

- **Emissivity** is the ratio of the emittance of an object to that of a Black Body at the same temperature:

$$\epsilon_{\lambda} = \frac{\text{spectral radiant exitance from 'real' body}}{\text{spectral radiant exitance from blackbody}}$$

- $\epsilon = 1 \Rightarrow$ body absorbs and re-emits all radiation falling upon it
- $\epsilon = 0 \Rightarrow$ reflects all radiation falling on it)
- Most vegetation: ϵ close to 1
- Many minerals: $\epsilon \ll 1$





TIR sensors: Examples

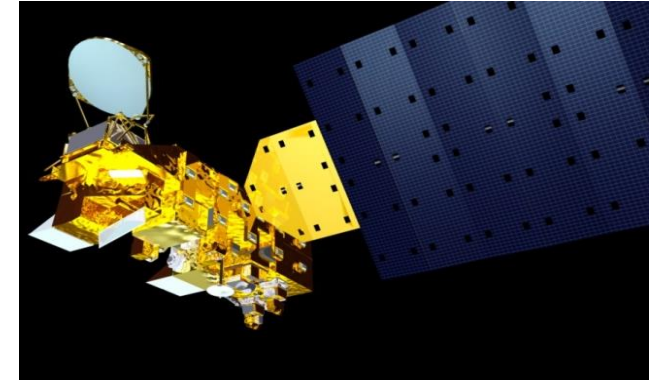
ASTER



AATSR



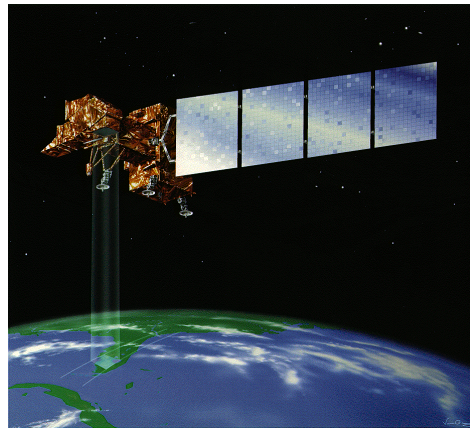
MODIS (Terra/Aqua)



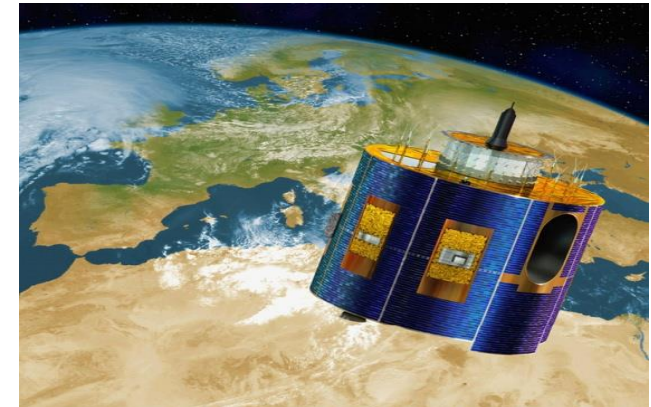
AISA Eagle-Hawk on
NERC ARSF Dornier



Landsat ETM+



MSG-2



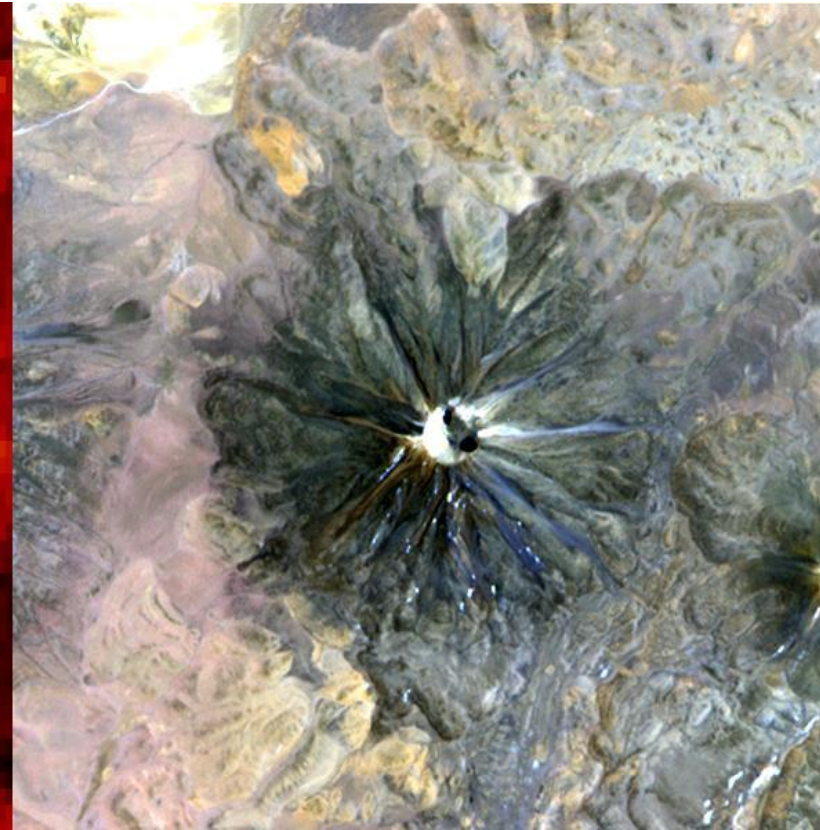
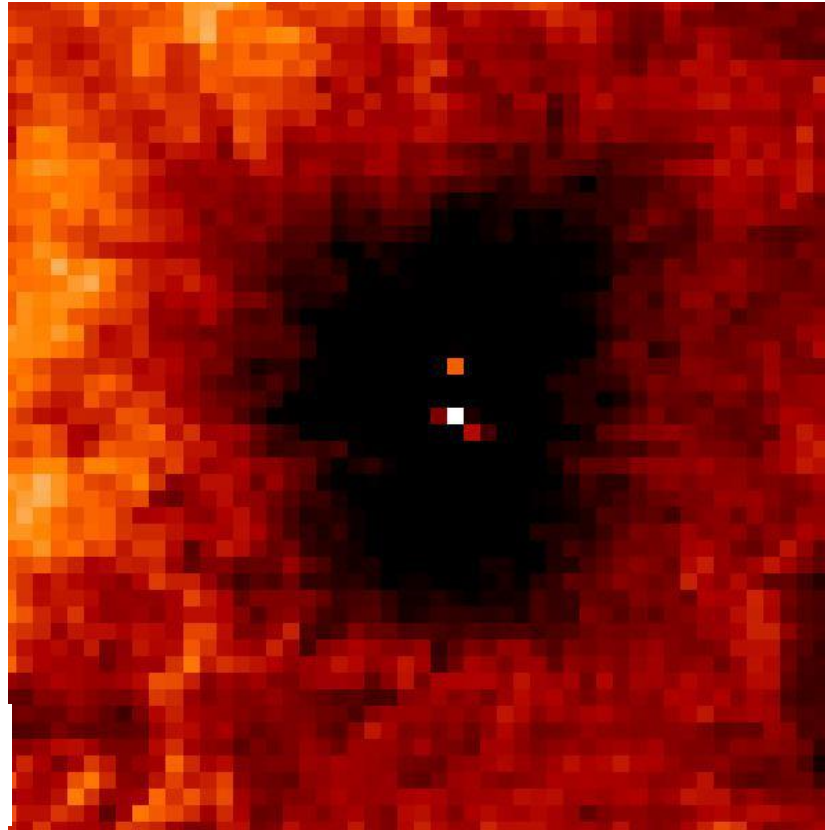


TIR sensing: Applications

TIR data: applications

Monitoring Volcanic Activity

- Right is a 7.5 x 7.5 km daytime view of Chiliques volcano.
- Left shows same volcano, showing several hot spots (white) in crater and upper flanks.
- Indicates potentially important new activity at this volcano, previously thought dormant.





TIR sensing: Applications

- Active Fire detection

Kuwait Oil Field Fires





TIR sensing: Applications

- Active Fire detection

*Brazilian
rainforest fire*

The visible light image shows only smoke, while the thermal infra-red image shows details of the fire beneath it.



Red (.657 μm)



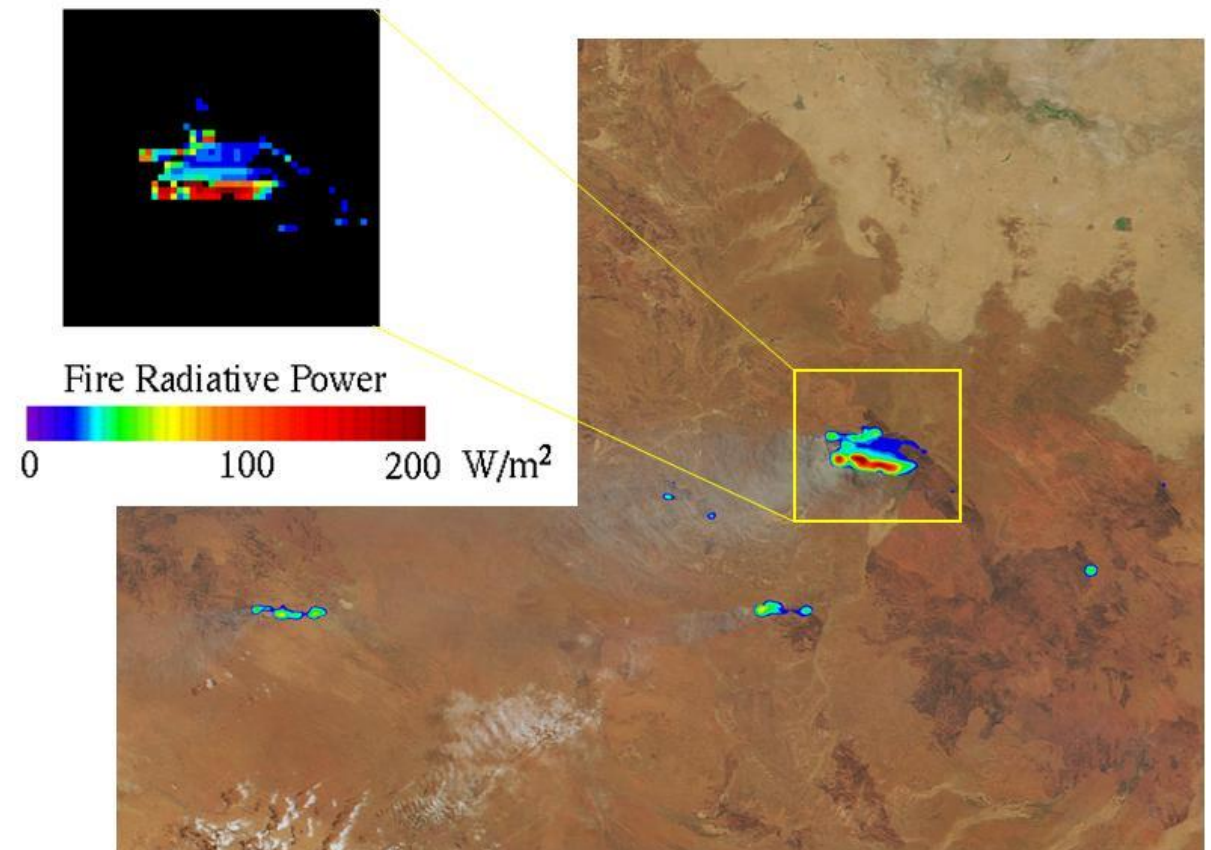
Thermal infrared (4.05 μm)



TIR sensing: Applications

- Fire Radiative Power

Large Australian Fire
2 Oct. 2000 01:40 UTC



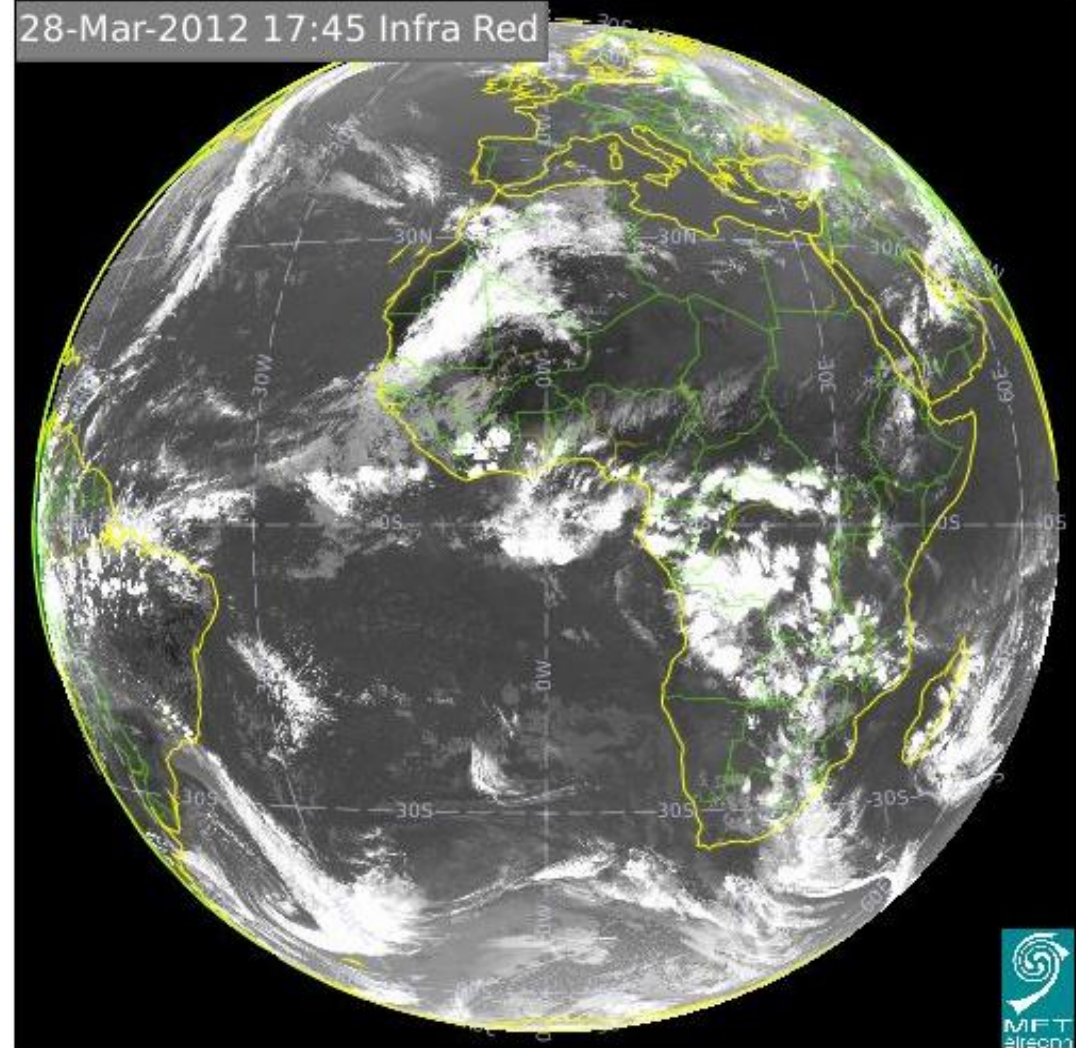


TIR sensing: Applications

- Clouds Tracking

Full Disk - Infra Red Satellite

28-Mar-2012 17:45 Infra Red



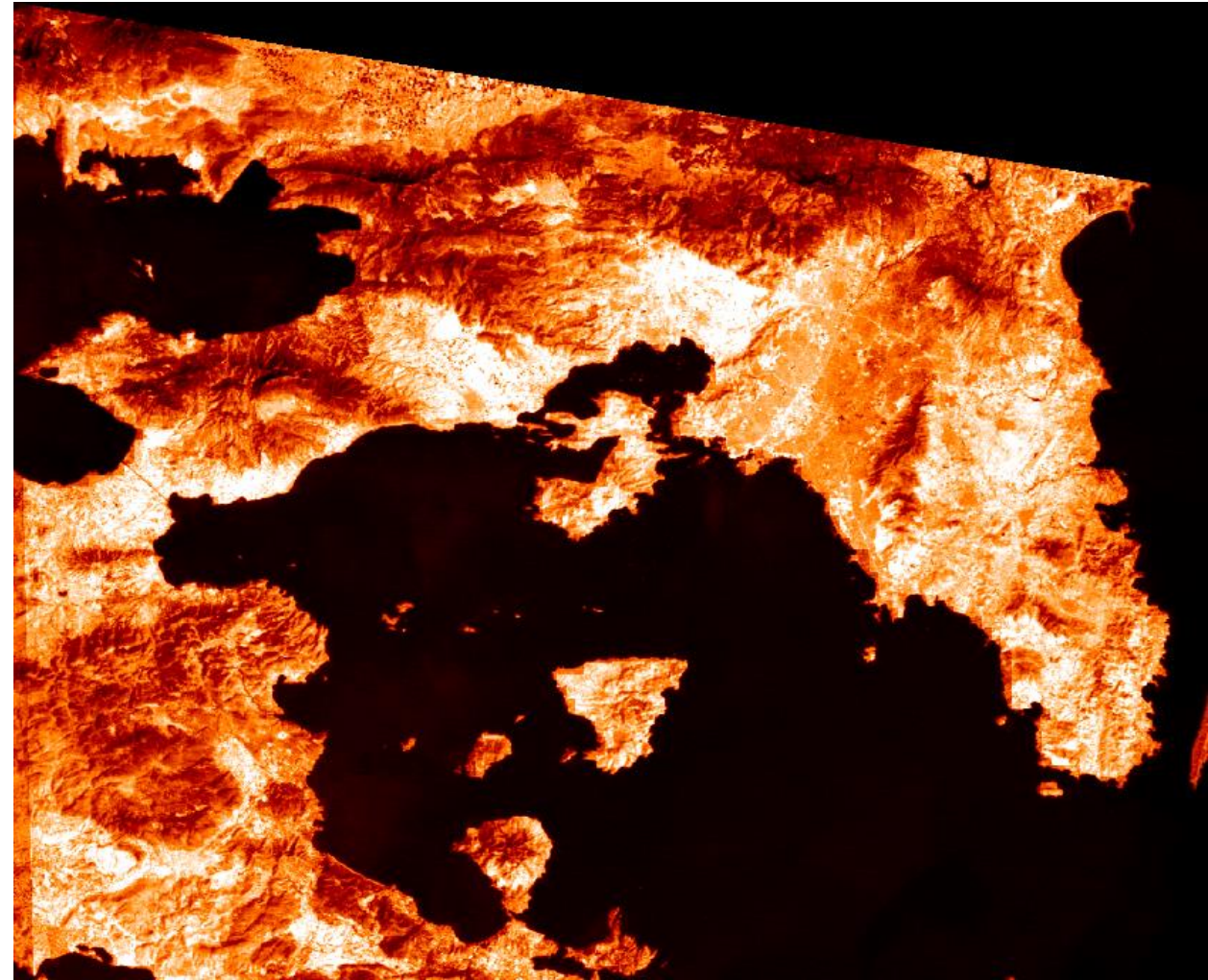


What is Soil Moisture?

TIR data: applications

- Deriving Land Surface Temperature

*LST retrieval from Landsat
TM sensor over Athens,
Greece on 24/07/09*

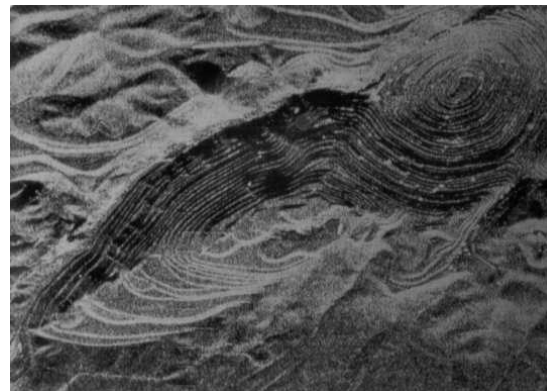
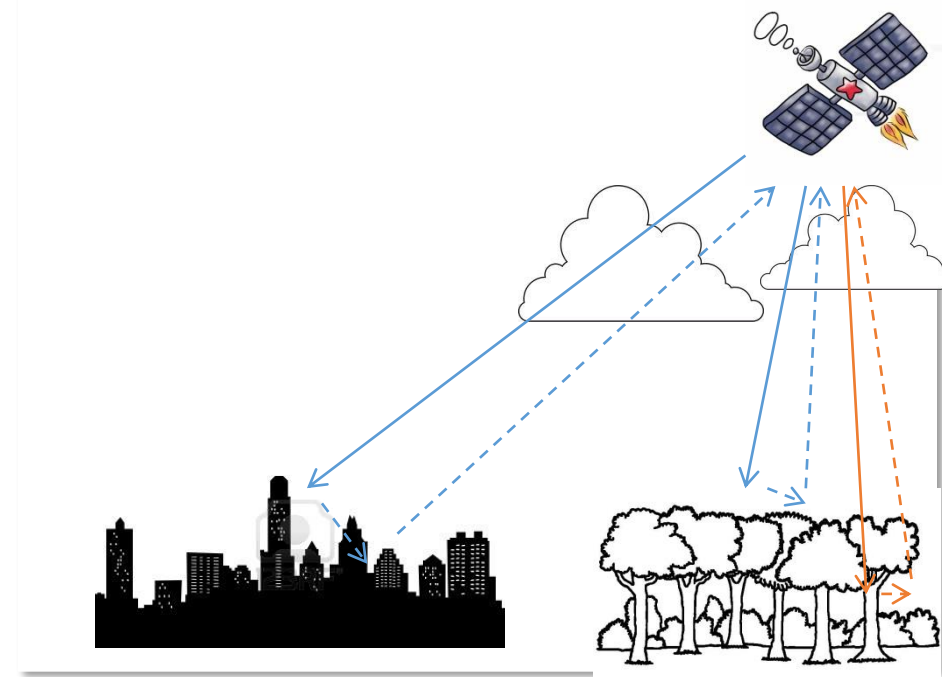


Microwave Sensors



MW sensing: Basics

- **Passive** and **active** (radar) types
- Independent of cloud/atmosphere
 - To an extent, vegetation canopies
- *Texture*
- *Elevation*
- *Soil moisture*
- ...
- *e.g. Passive: SMOS, AMSR-E*
- *e.g. Active: EnviSat, ALOS*

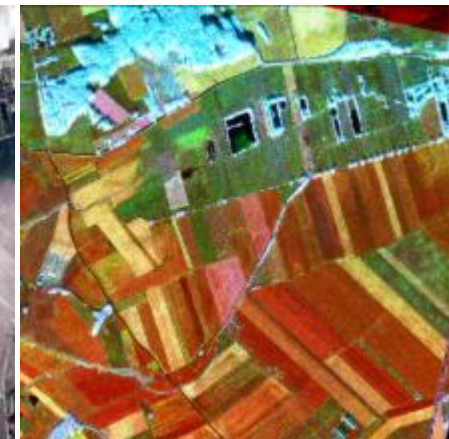


Surface texture and terrain of a copper mine

Colour photo



Processed Radar imagery





MW sensing: Basics

Microwave sensors

- **MW** defined as wavelengths **between 100 μm and 1m**
- MW are **~unaffected** by the atmosphere (even clouds)

Microwaves Wavelengths in RS

Band Designation	Wavelength (cm)	Frequency (GHz)
K	0.8 - 2.4	40.0 - 12.5
X	2.4 - 2.8	12.5 - 8.0
C	3.8 - 7.5	8.0 - 4.0
S	7.5 - 15.0	4.0 - 2.0
L	15.0 - 30.0	2.0 - 1.0
P	30.0 - 100.0	1.0 - 0.3



MW sensors: examples

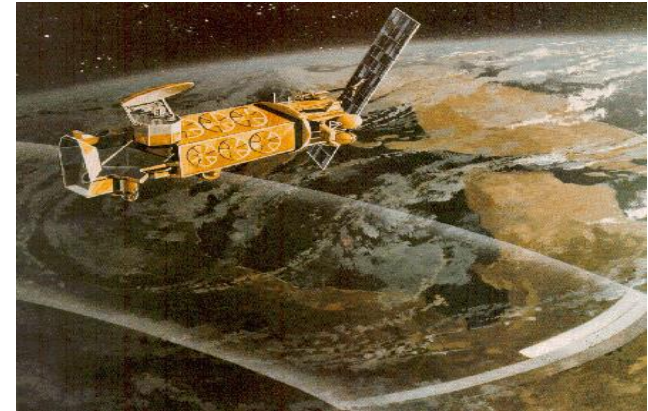
ASCAT



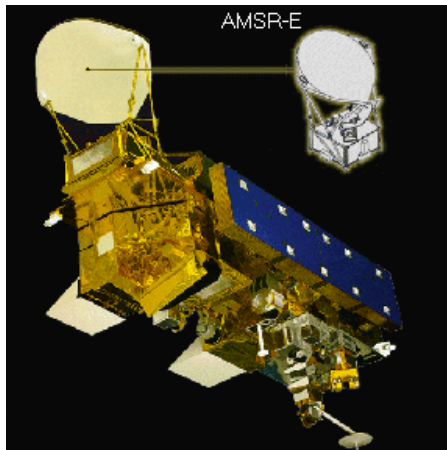
SMOS



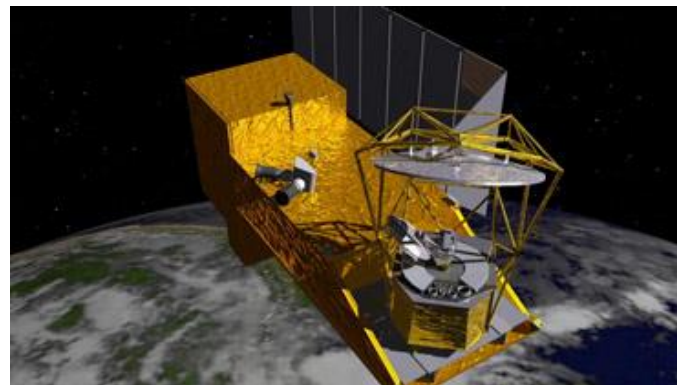
SSM/I



AMSR-E



Windsat



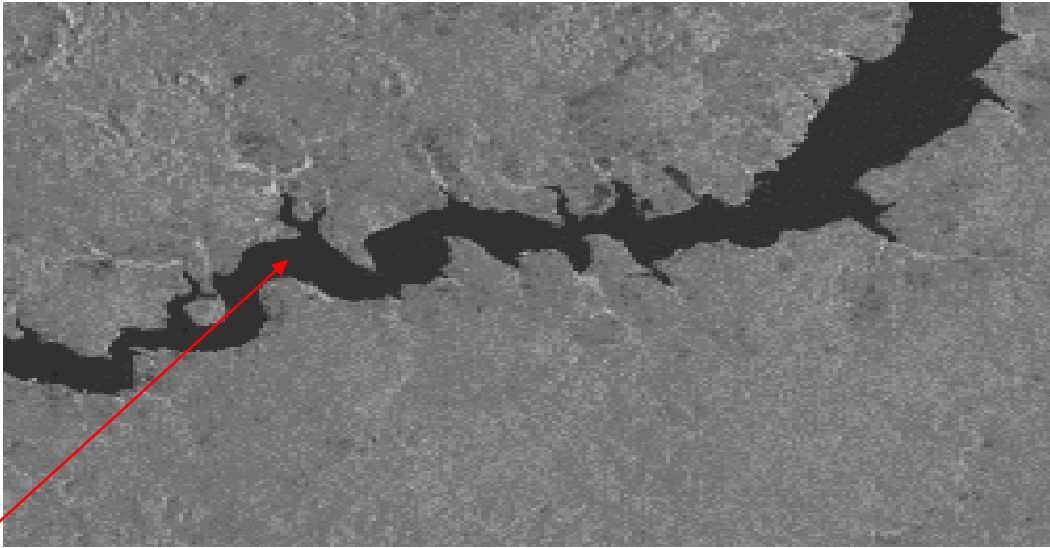
ERS-2





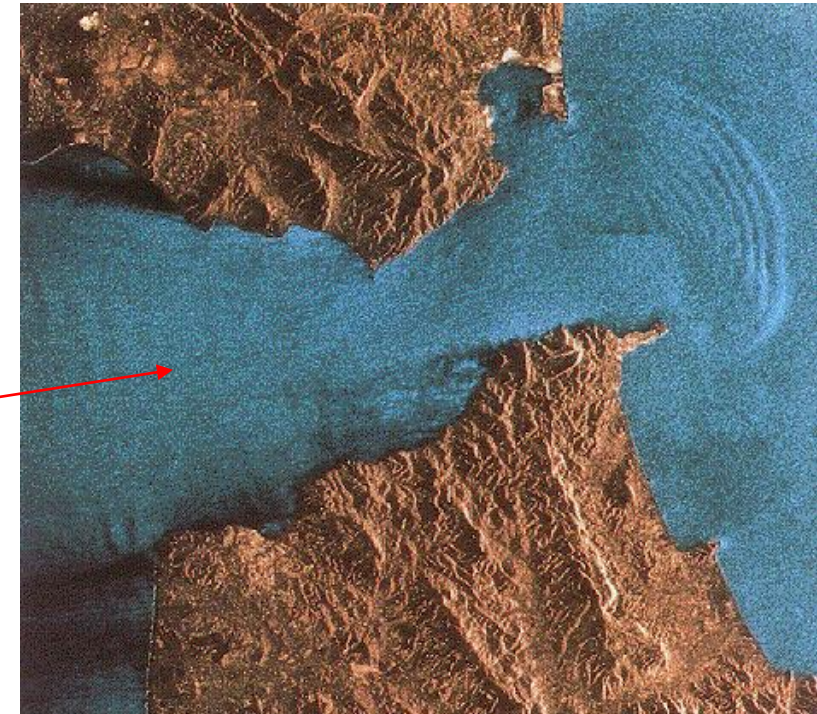
MW sensing: Applications

Water Bodies Detection



- **Water**

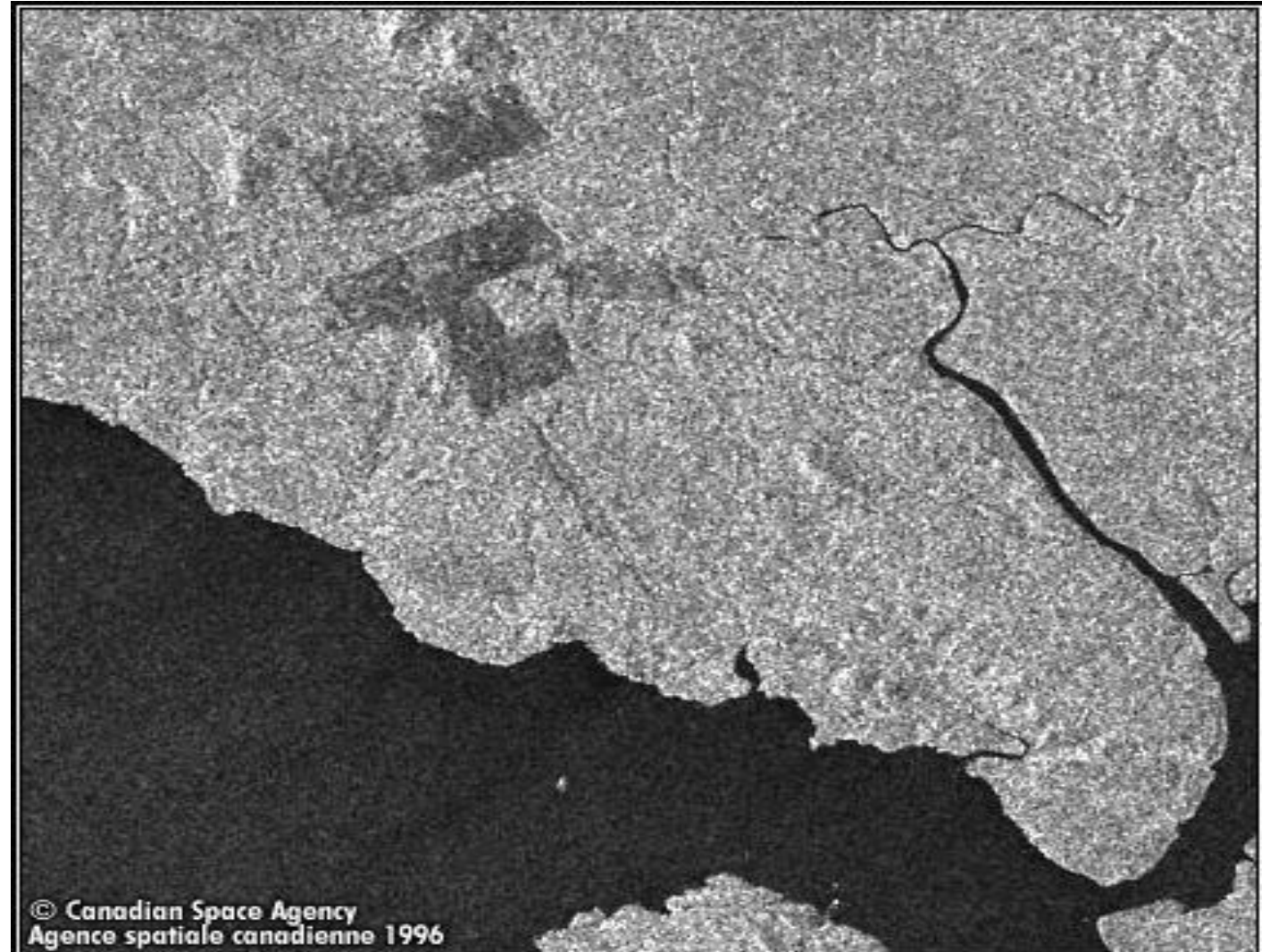
- **calm** water acts as a specular reflector
- **rough** water acts as a diffuse reflector





MW sensing: Applications

Clear-Cutting in Borneo

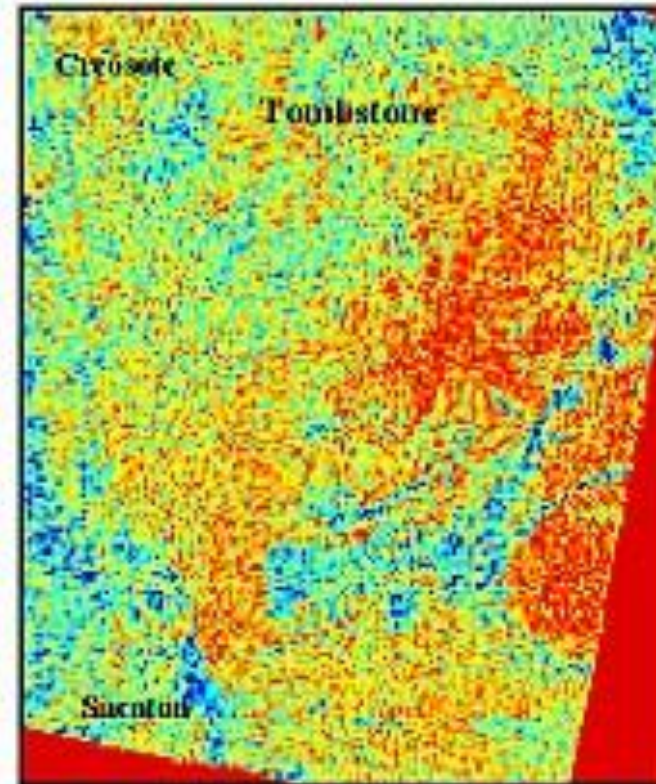


© Canadian Space Agency
Agence spatiale canadienne 1996

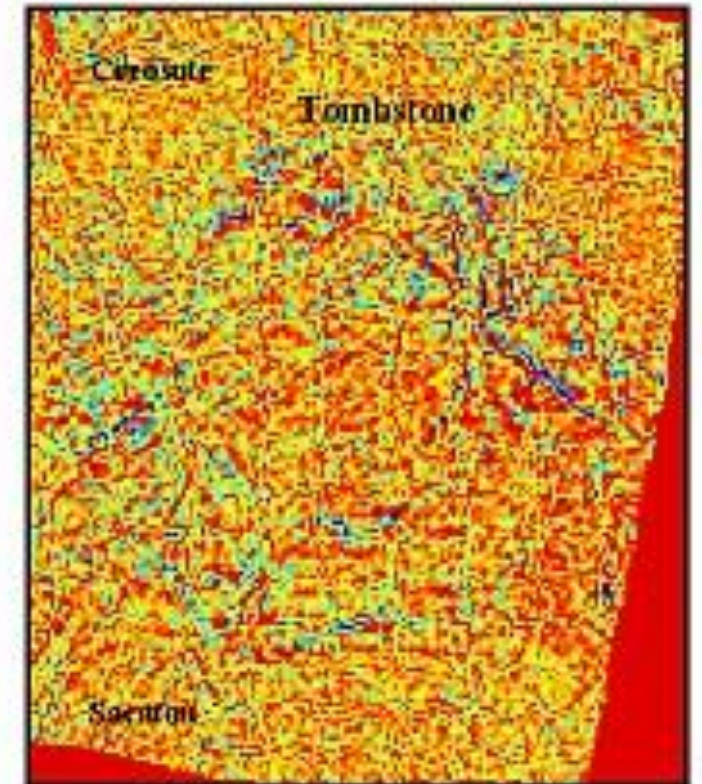


MW sensing: Applications

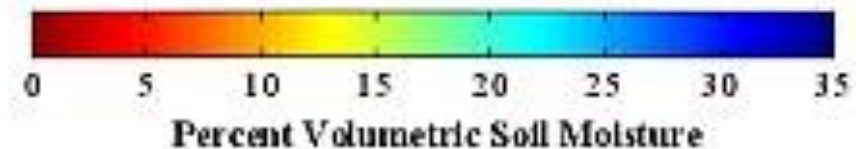
Mapping Soil Moisture



12 January 1997
Soil near saturation



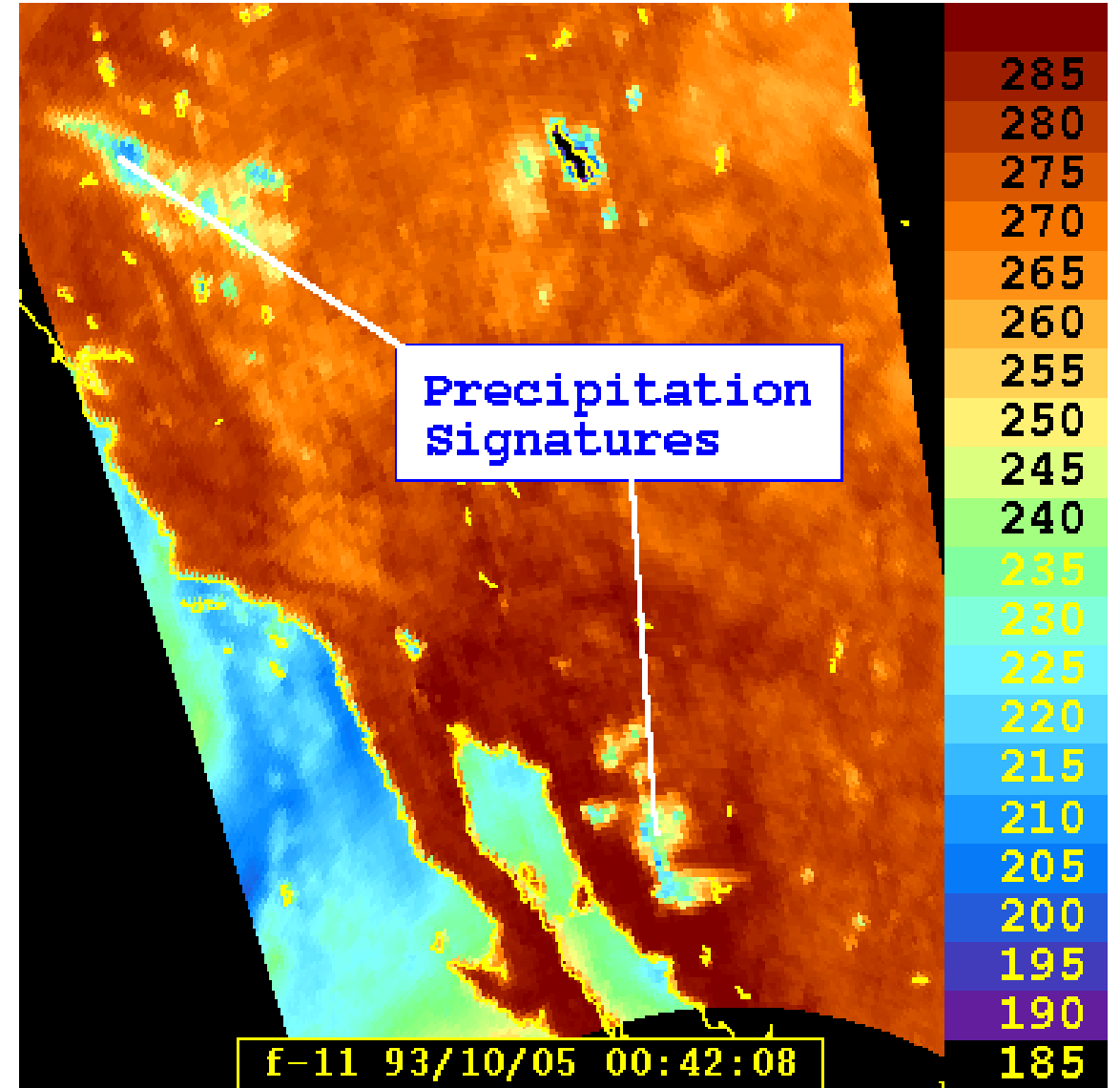
23 March 1997
Soil dry





MW sensing: Applications

Mapping Precipitation (SSM/I)



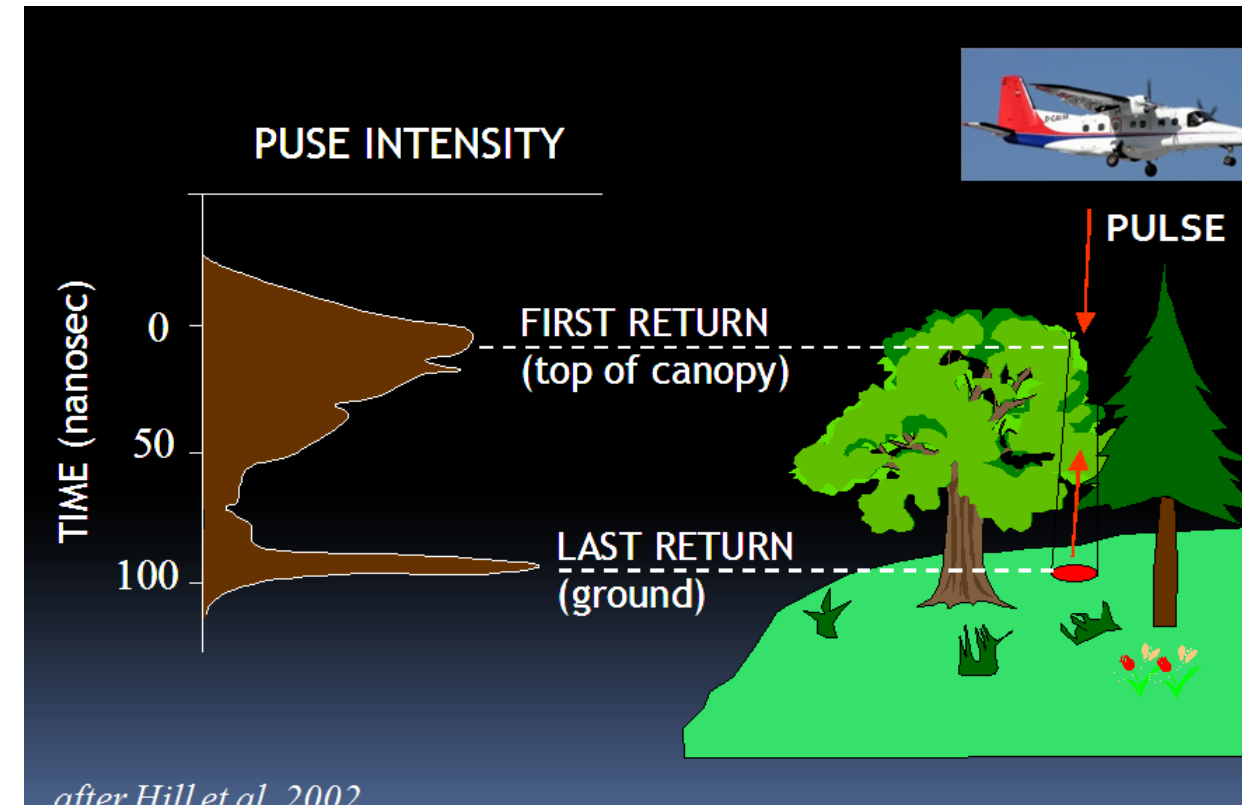
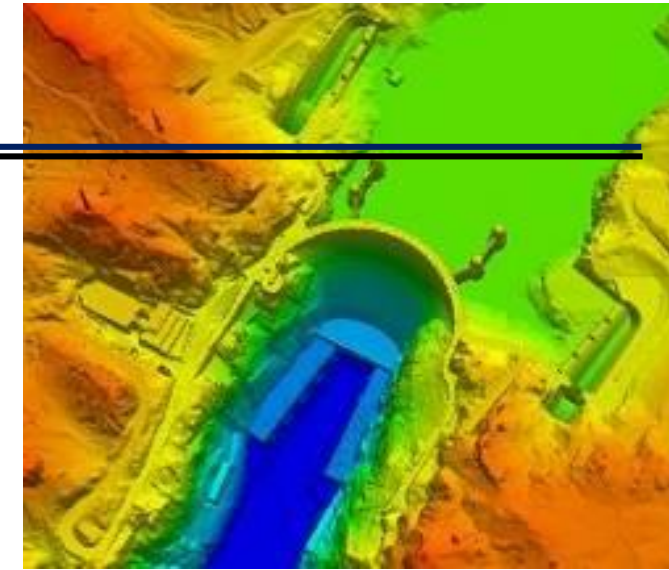
LiDAR Sensors



LiDAR sensing: Principles

LiDAR: Light Detection and Ranging

- Emits a pulse of polarised laser light
- Measures distance between object and sensor
- Records the time taken for the light to return





LiDAR sensing: types

GLAS ICESAT



NERC Airbone RS Scanner



Terrestrial Laser scanner





LiDAR sensing: Applications

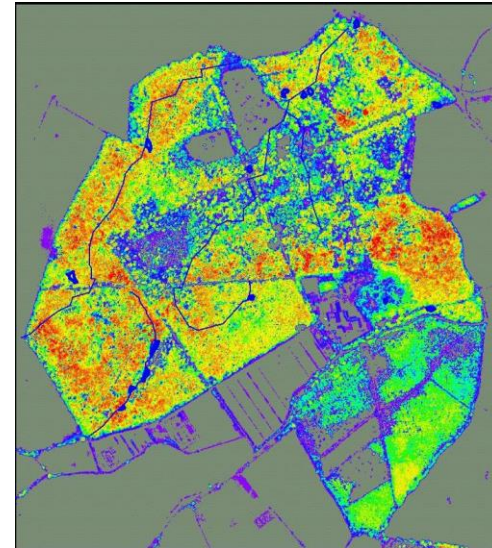
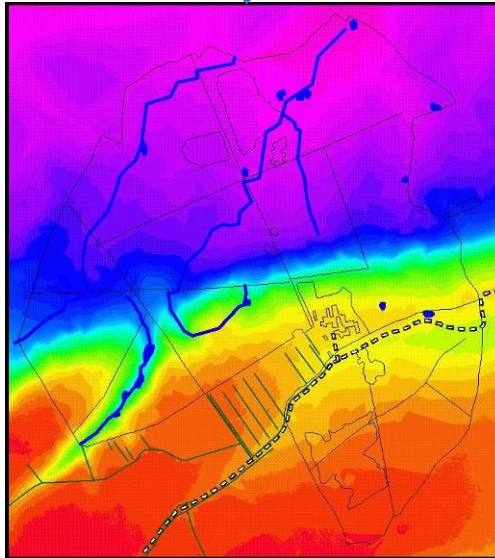
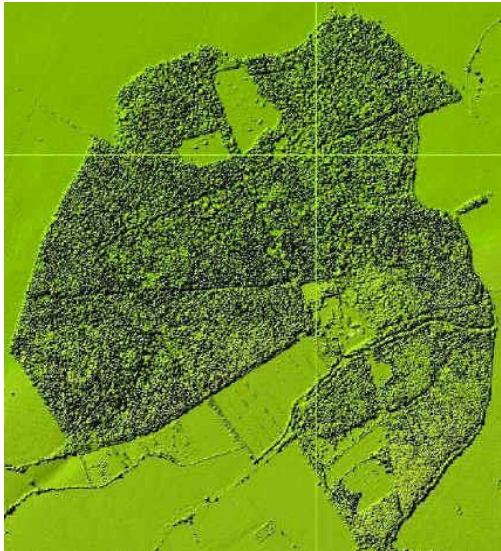
Digital Elevation Models (DEM)





LiDAR sensing: Applications

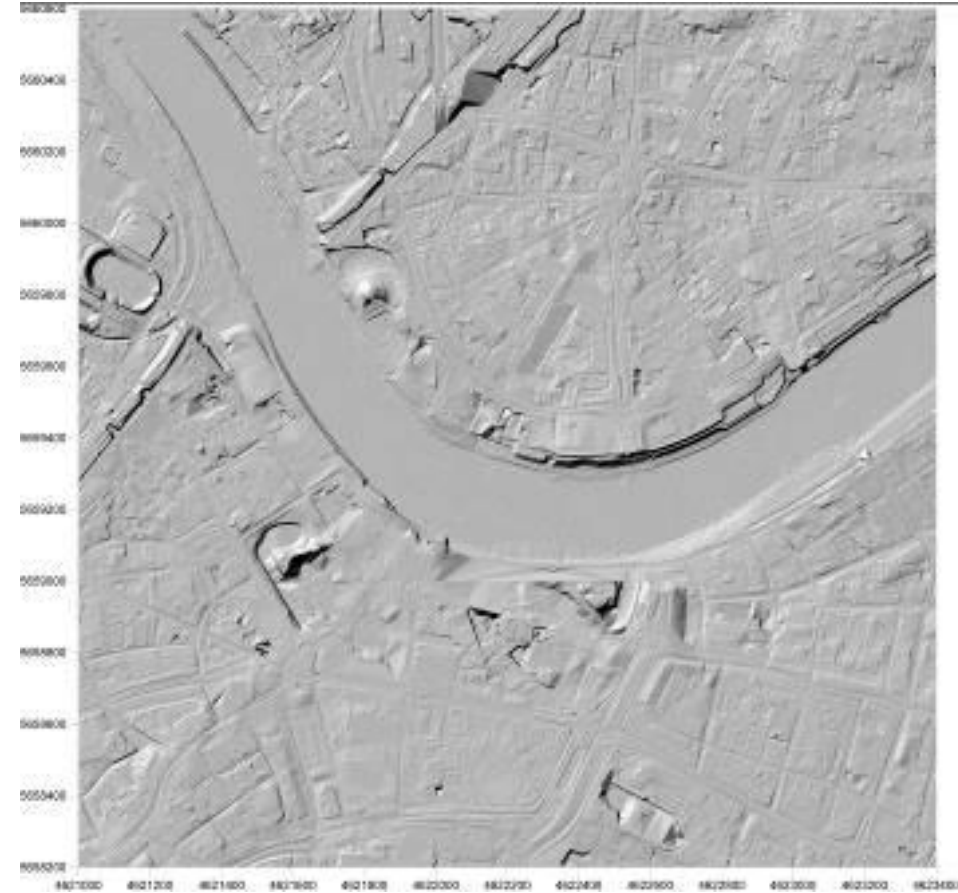
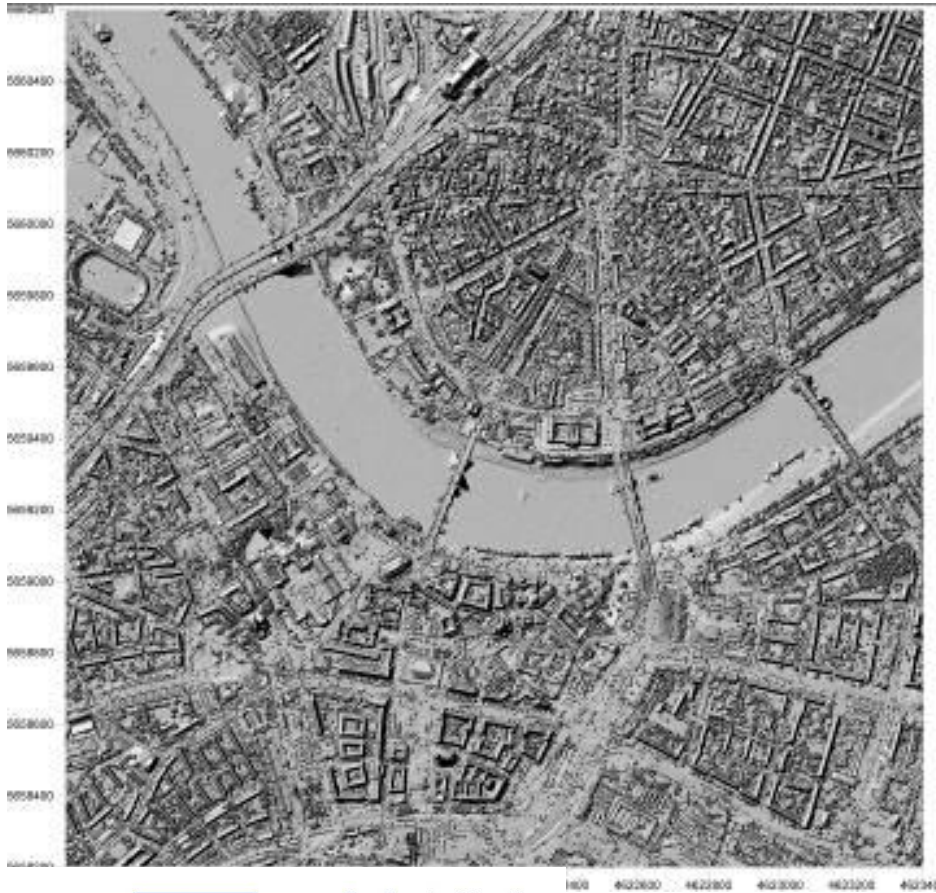
Digital Surface Model = Digital Terrain Model + Canopy Height Model





LiDAR sensing: Applications

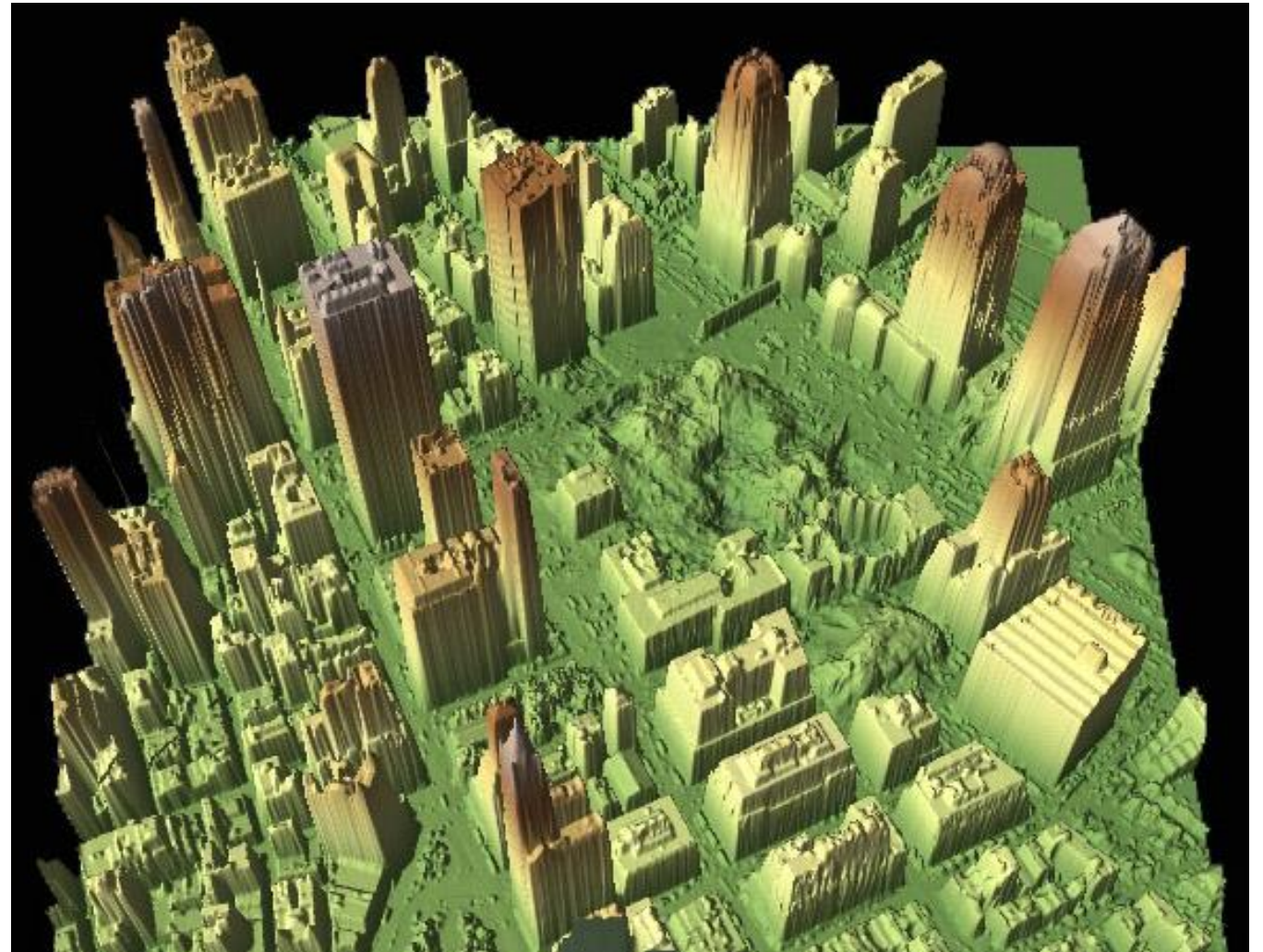
Urban Flood Modelling, disaster response





LiDAR sensing: Applications

Urban Infrastructure

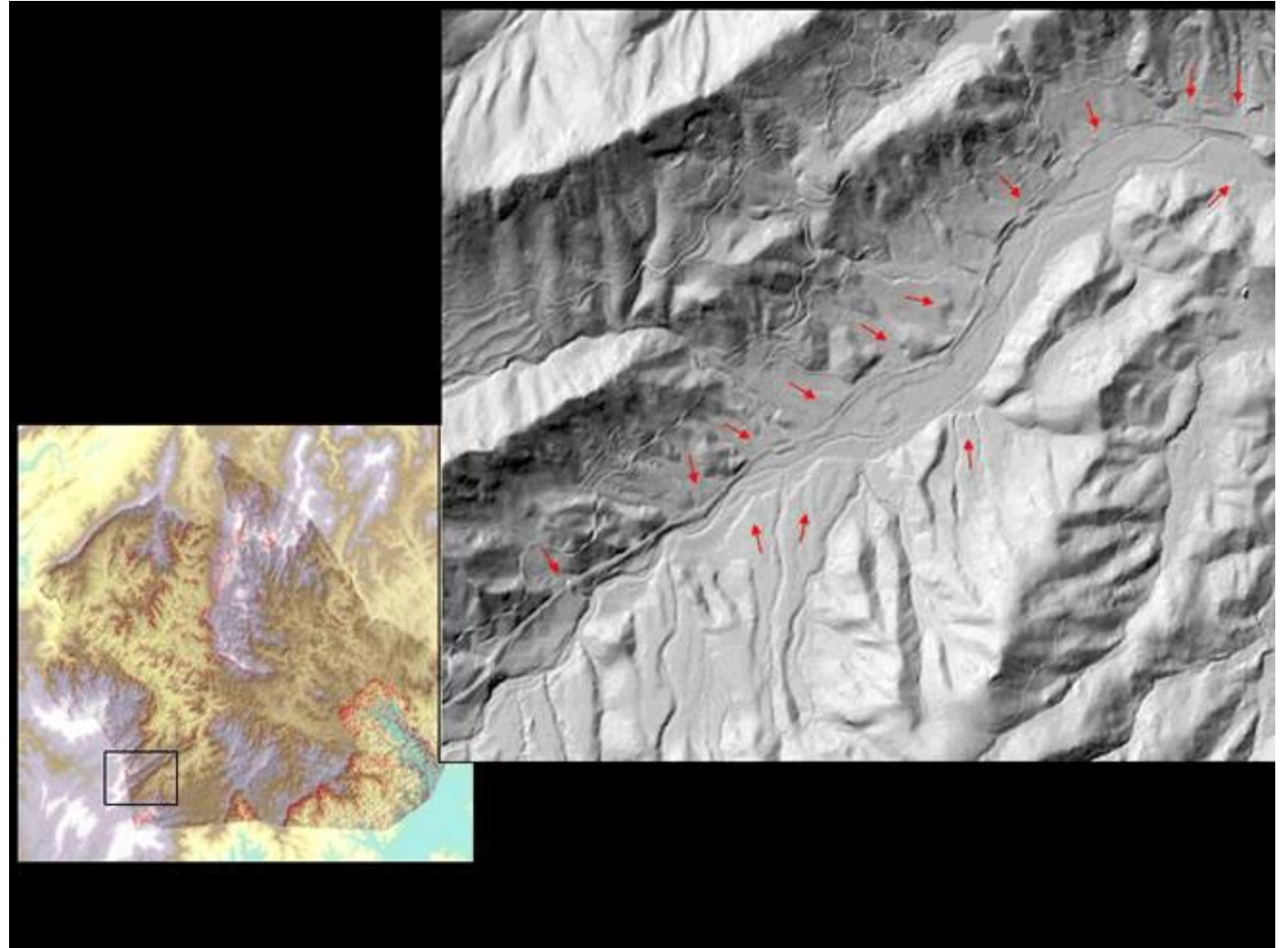




LiDAR sensing: Applications

Geology: Landslides risk

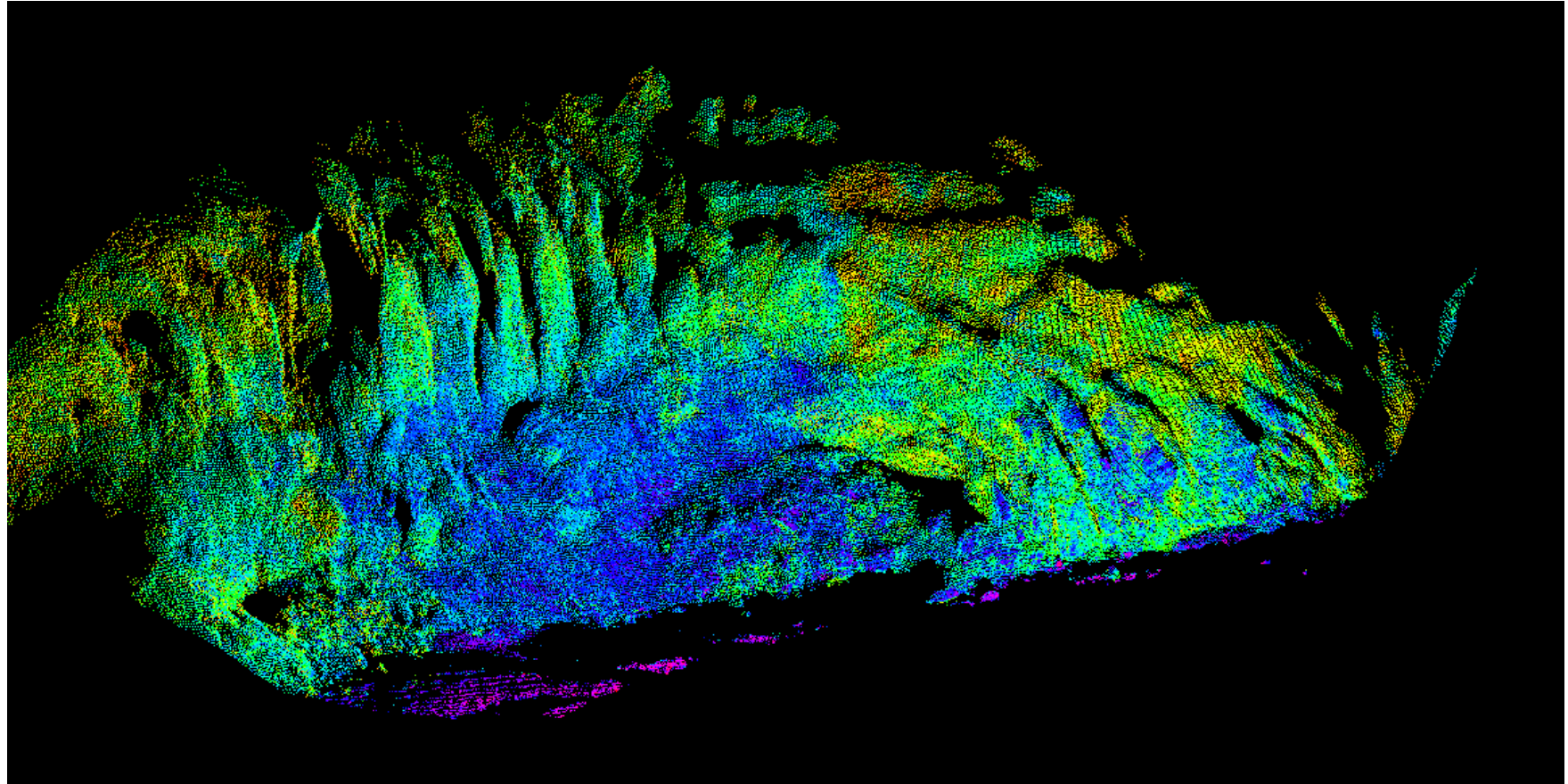
Landslide Risk – North Carolina





LiDAR sensing: Applications

Glaciology: Glacial Change & Movement





Reading List

Journals

- **International Journal of Remote Sensing**
- **Remote Sensing of Environment**
- IEEE Geoscience and Remote Sensing
- International Journal of Geographical Information Science
- Applied Earth Observation and Geoinformation
- ISPRS Journal of Photogrammetry and Remote Sensing
- Photogrammetric Record
- Application driven:
 - *Geomorphology*
 - *Journal of Glaciology*
 - *Vegetation Science*
 - *Landscape Ecology*
 - *Geospatial Health*
 - ...

Books

- **Lillesand and Kiefer**, *Remote sensing and image interpretation*.
- **Mather**, *Computer processing of remotely-sensed images*.
- Campbell, *Introduction to Remote Sensing*

Internet

- **Natural resources Canada:**

<http://www.nrcan.gc.ca/earth-sciences/geography-boundary/remote-sensing/fundamentals/1430>

- NASA

<https://www.fas.org/irp/imint/docs/rst/Front/tofc.html>

Thank you very much for your attention

Change Detection

Introduction

Change detection is important for a number of different applications including monitoring of deforestation, disaster monitoring and damage assessment, urban expansion, planning and land management. This practical will guide you through two approaches: 1) image differencing and 2) thematic change detection. The former is a pre-classification technique and the latter is a post-classification technique.

1. Image difference change detection

In this practical we will examine the impact of the 2004 Boxing Day Tsunami over an area of Indonesia using two Quickbird images from before (April 2004) and after the tsunami (January 2005).

- 1.
2. Open ENVI and explore the two images.

NOTE: Are there any noticeable differences between the two images?
--



3. From the toolbox select **Change Detection > Image Change Workflow**.

In the Time 1 field add the image tsunami_before.dat.

In the Time 2 field add the image tsunami_after.dat.

Click Next.

4. Before we conduct any change detection we must ensure that our images are correctly registered.

Fortunately ENVI has a tool which will automatically register the second image to the first.

Select the **Register Images Automatically** option and, leaving all the options as default, click Next.



NOTE: Examine the resulting image against the tsunami_before.dat image. Has the image registration improved in comparison with the original tsunami_after.dat image? TIP: Have a look at features that you would expect not to have changed, such as roads.

5. In the next window select to perform an **Image Difference** and click Next.

NOTE: Transform will perform a statistical transformation on the image such as Principal Components Analysis.

6. In the Image Difference window you can set the parameters to use for the detection of change.

NOTE:

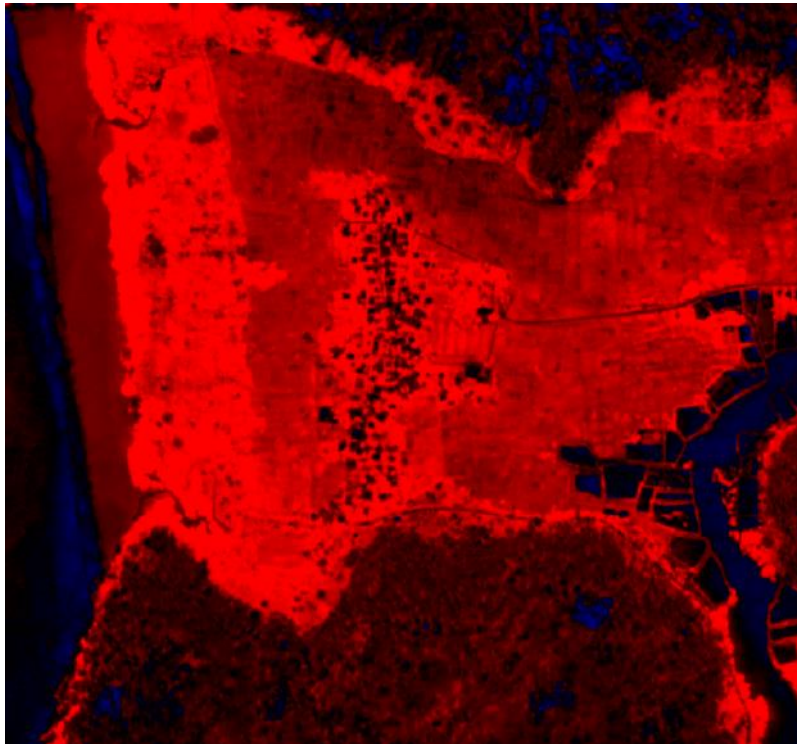
- **Difference of Input Band** will look for changes in reflectance value occurring in a particular band.
- **Feature Index** allows the user to detect changes of a specific feature such as vegetation (vegetation index), water (water index), urban areas (built-up index), or fire burn scars (burn index). Because Quickbird does not have a shortwave infrared band we are restricted to the NDVI and NDWI.
- **Spectral Angle Difference** examines the spectral signature for each pixel in the two registered images. Differences are quantified by the difference in angle between the two images. This tool can only inform you where changes have taken place, not the direction of the change.

Select **Difference of Input Band**, with band 1 as the input band and click Next.

NOTE: Zoom into an area where change has occurred near a beach. Decreases in the data value (Band 1 reflectance) appear as red and increases appear as blue. What has happened to the reflectance value over pixels that were located over sand in the before image?

7. Click Back and enable the **Difference Feature Index** and select NDVI. Again, red colours indicate a decrease in the index and blue colours indicate a decrease.

NOTE: What information is this giving you? Can you identify any areas with erroneous results?



8. We will now apply a threshold that will allow the tool to identify areas with a large change in NDVI.

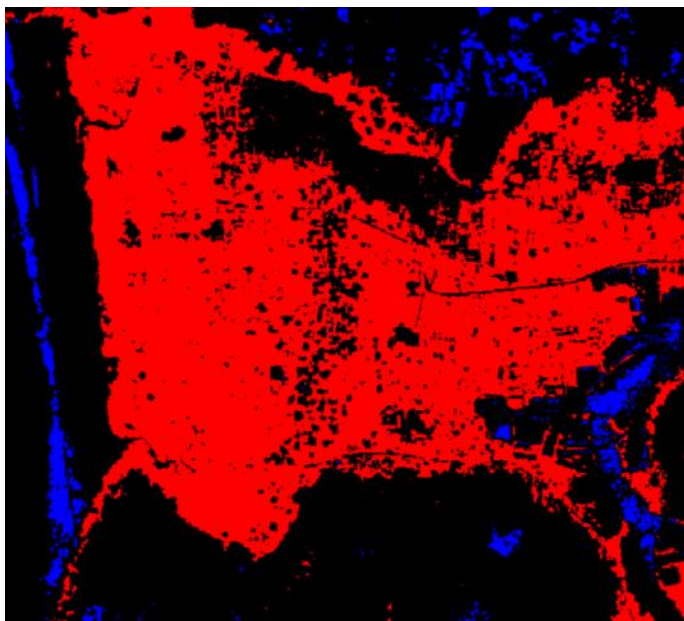
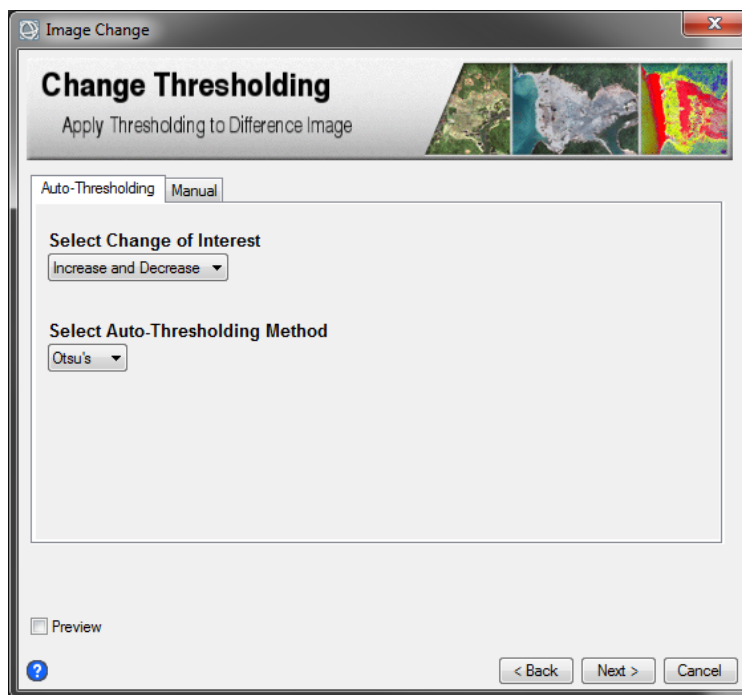
With **Apply Thresholding** selected click Next.

9. In the Change Thresholding step we can specify the changes you want to show between the two images. We can do this using pre-determine auto-thresholding techniques, or by manually adjusting the threshold.

In the **Auto-Thresholding tab**, select **Increase and Decrease**. This option shows areas of increase (in blue) and decrease (in red).

NOTE: If you are only interested in areas of vegetation decreased by the tsunami, select Decrease Only.

Under Select Auto-Thresholding Method **select Otsu's** and click Next.

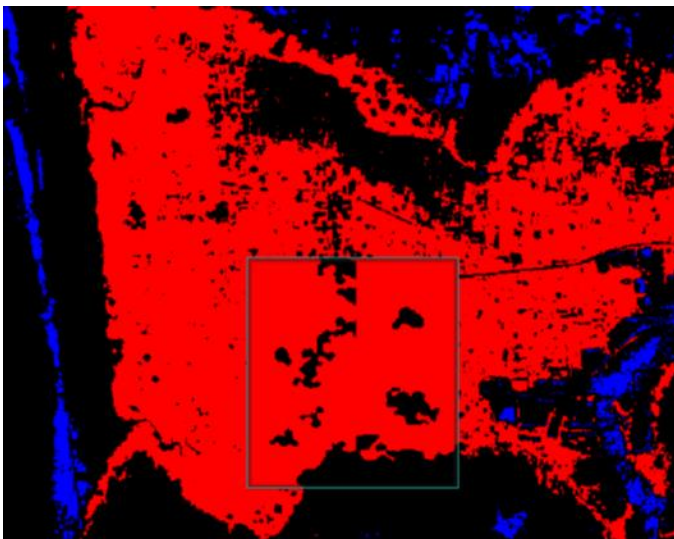


10. After viewing the resulting threshold image click Back and try **selecting one of the other thresholding options** and examine the difference. The auto-thresholding choices are:

- Otsu's: A histogram shape-based method. It is based on discriminate analysis and uses the zero and first-order cumulative moments of the histogram for calculating the value of the thresholding level.
- Tsai's: A moment-based method. It determines the threshold so that the first three moments of the input image are preserved in the output image.
- Kapur's: An entropy-based method. It considers the thresholding image as two classes of events, with each class characterized by a Probability Density Function (PDF). The method then maximizes the sum of the entropy of the two PDFs to converge on a single threshold value.
- Kittler's: A histogram shape-based method. It works on approximating the histogram as a bimodal Gaussian distribution and finds a cutoff point. The cost function is based on the Bayes classification rule.

11. In this exercise we will **use the default Otsu's thresholding method**. Select this then click Next to reach the Cleanup window.

Enable the preview portal and view the results of the cleanup methods. Click Next to apply the **smoothing and aggregation cleanup** methods.



12. Zoom out to the **image extent** and view the changes in NDVI between the two images.

NOTE: what inferences can you make from this image?

References

Otsu, N., 1979. A threshold selection method from gray-level histograms. IEEE Trans. Systems Man Cybernet. 9, 62–66.

Tsai, W., Moment-preserving thresholding. Comput. Vision Graphics Image Process. Vol. 29, pp. 377–393, 1985.

Kapur, J., Sahoo, P., Wong, A., A new method for graylevel picture thresholding using the entropy of the histogram. Comput. Vision Graphics Image Process. Vol. 29 (3), 273–285.

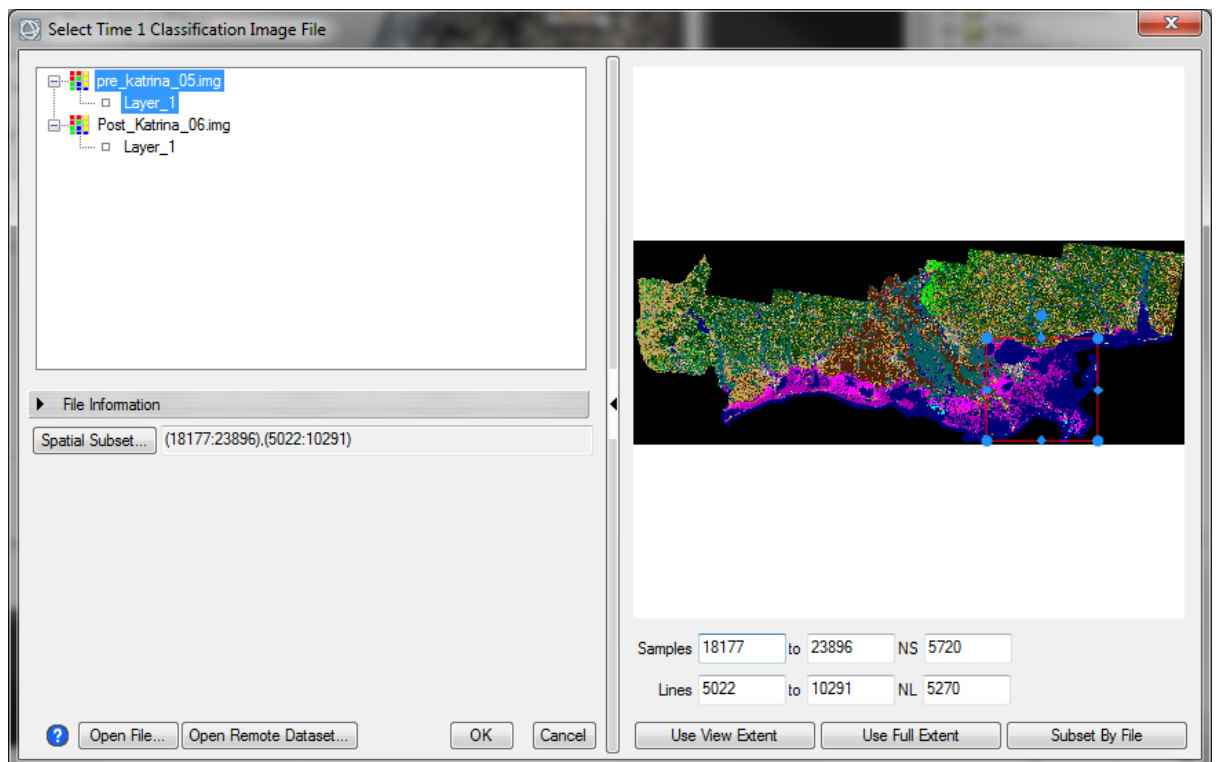
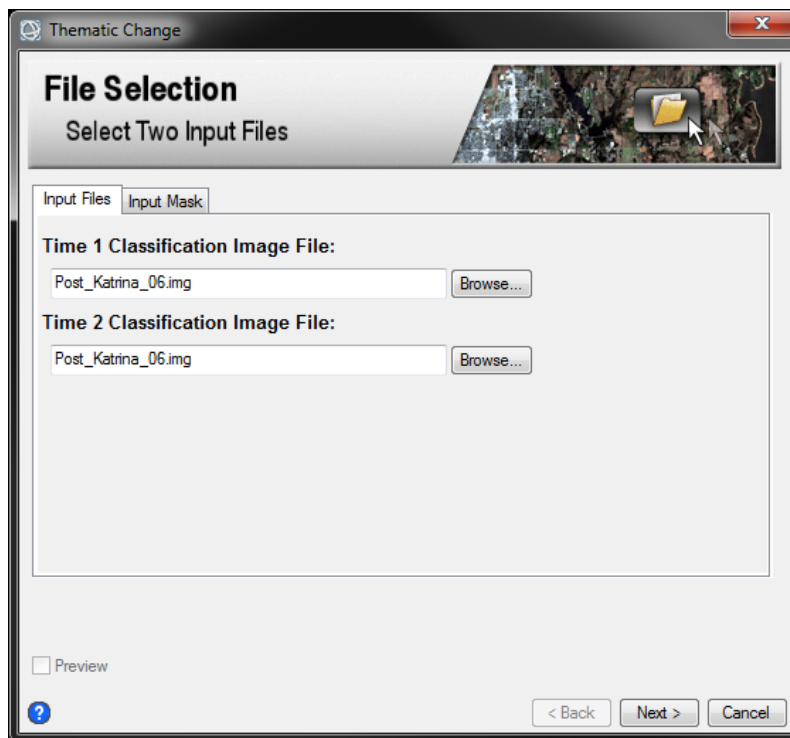
Kittler, J., Illingworth, J., Minimum error thresholding, Pattern Recogn. Vol. 19, pp. 41–47, 1986.

2. Thematic change detection

The aim of this practical is to quantify change between two classified (thematic) images of the Gulf of Mexico region before and after hurricane Katrina (2005).

The classifications were made using 30 m Landsat TM and ETM+.

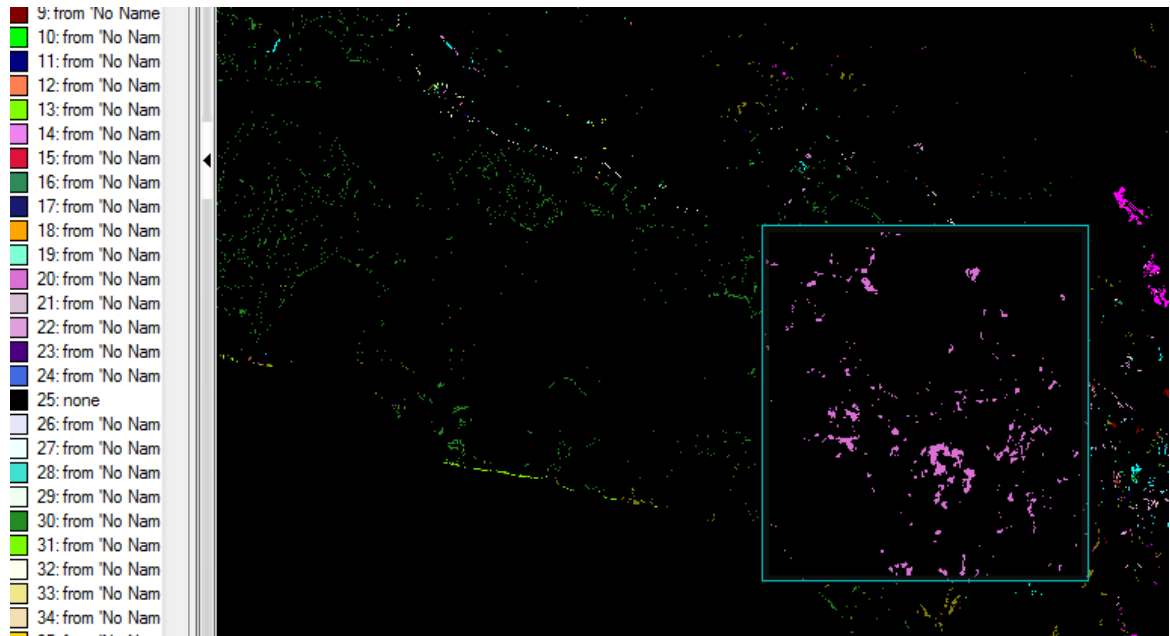
1. Start ENVI. From the toolbox open **Change Detection > Thematic Change Workflow**.
2. Under Time 1, browse to find the image pre_katrina_05.img.
Select **spatial subset** and enter the values:
Samples 18177 to 23896
Lines 5022 to 10291
3. Under Time 2, browse to find the image Post_Katrina_06.img then click Next.



4. Because the two input classified images have the same number of classes with the same name you have the option to **Only Include Areas That Have Changed**. Keep this default setting then click Next.

5. With the **Preview option checked** browse your image so you can see the subsetting portion of the image you defined earlier in Step 2.

Zoom in until the Grey preview box indicates changed pixels (in purple).



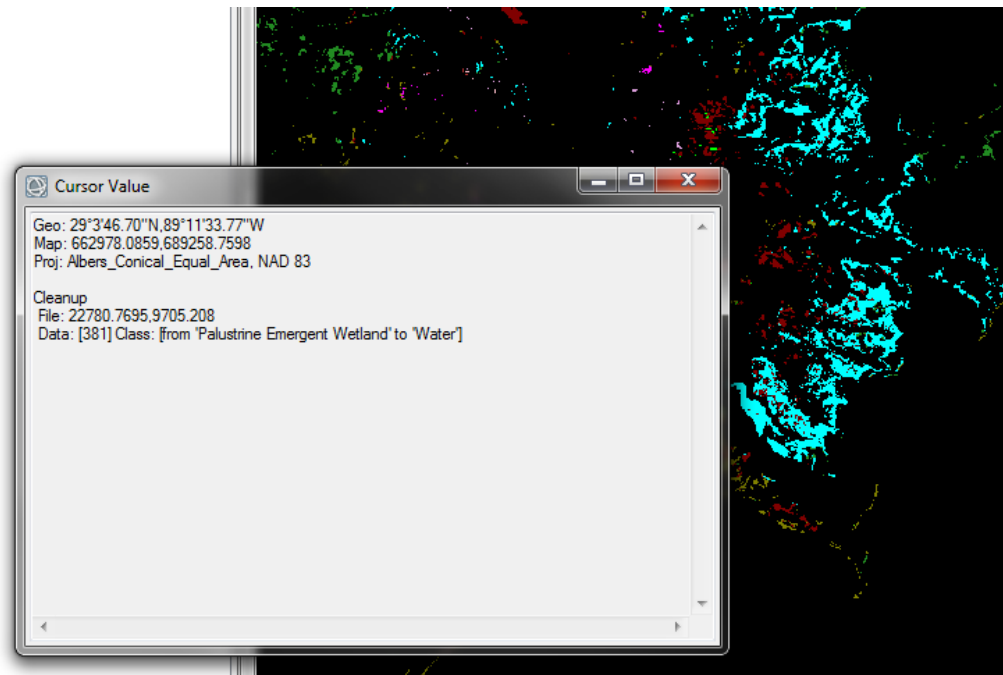
6. Test different **smoothing kernel sizes** to see the effect. Without this image smoothing step our result would appear speckled and be difficult to interpret.

Click Next to apply the change detection tool.

NOTE: This may take a few minutes to process.

7. Move to an area within the processed subset where change has taken place. Browse the layer values using **Cursor Value**. The Cursor Value identifies the relevant change in thematic class to the pixel under the cursor.

NOTE: What dominant changes took place following Hurricane Katrina?



8. Click Next to reach the **Export options**. Choose to export both the thematic change image and vector datasets. Additionally, choose to export the change statistics.

Open the statistics file in Excel and view the contents.

NOTE: Does this confirm the observations you made earlier regarding dominant changes? What other significant changes took place?

pre_katrina_05_change_stats.txt - Microsoft Excel

	A	B	C	D
1	CLASS_T1	CLASS_T2	AREA	PERCENT
2	no change	no change	26845294500	98.950734
3	Estuarine Emergent Wetland	Water	174990600	0.645009
4	Palustrine Emergent Wetland	Water	51484500	0.18977
5	Unconsolidated Shore	Water	18261000	0.067309
6	Estuarine Aquatic Bed	Water	10949400	0.040359

END



Co-funded by the
Erasmus+ Programme
of the European Union

Classification & Change detection

Dr George P. Petropoulos



UNIVERSITY OF
HOHENHEIM





Lecture Outline

- Difference between LU/LC?
 - LU & LC definitions
 - Standard approach in obtaining LU/LC mapping
 - Why Earth Observation for this?
- Supervised classification methods
 - Parametric, Non-parametric, OBIA methods
 - Non-parametric example: SVMs
 - OBIA classification: considerations in implementation
- Change Detection:
 - What do we mean by Change Detection?
 - Considerations, Pre-processing, accuracy assessment
 - Change Detection Methods



Basics in LU/LC mapping

Land Cover vs Land Use:

Land cover (LC) - *Physical and biological cover of the Earth's surface including artificial surfaces, agricultural areas, forests, (semi-)natural areas, wetlands, water bodies.*

Land use (LU) - *Territory characterised according to its current and future planned functional dimension or socio-economic purpose (e.g. residential, industrial, commercial, agricultural, forestry, Recreational).*

Source: INSPIRE Directive (2009)



Why are we interested in mapping LU/LC and its changes?

...Some good reasons include:

- ❑. Is used extensively to **derive biophysical parameters** (e.g. Fr, LAI, biomass, carbon content).
- ❑. LU/LC and its changes **reflect the underlying natural and/or social processes** => provide essential information for modeling and understanding different phenomena on Earth at different scales.
- ❑. Such information is also **critical to effective planning and management of natural resources**. Useful information in policy decision making, *e.g. when concerning environmentally or ecologically protected areas or native habitat mapping and restoration (e.g. Council Directive 92/43/EEC)*

Remote Sensing?

■ Advantages

RAPID

NON-INVASIVE

INEXPENSIVE

CONSISTENT

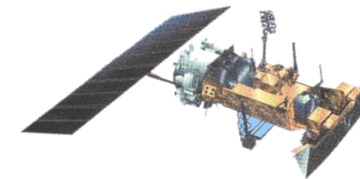
TIMELY

GLOBAL COVERAGE

REPETITIVE

**ACCESS TO REMOTE
LOCATIONS**

*Classification is the most widely researched
topic in remote sensing!*

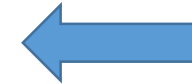




LU/LC mapping by RS

Standard Methodology to obtain a LULC Map:

- (1). Definition of the mapping approach
- (2). Geographical stratification
- (3). Image segmentation (optional)
- (4). Feature identification and selection
- (5). Training & Validation points selection
- (6). Classification technique implementation
- (7). Ancillary data integration
- (8). Post-classification processing
- (9). Accuracy assessment



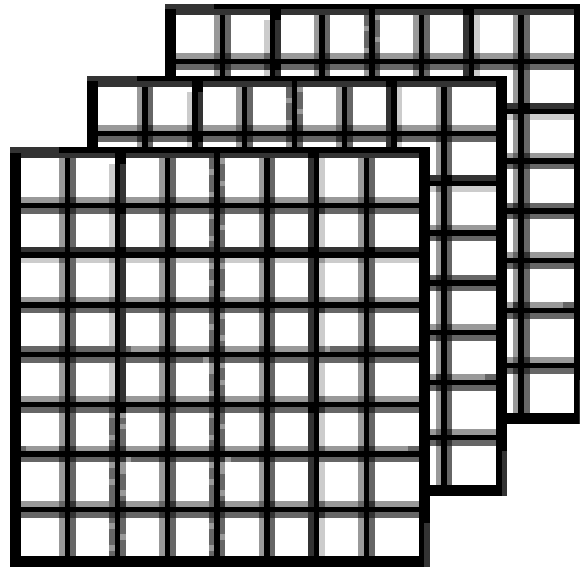
After Caetano (2009): <http://earth.eo.esa.int/landtraining09/D4L1.pdf>



What is a classification?

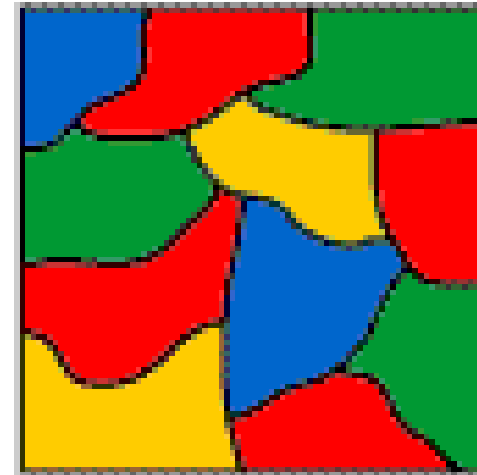
- Understanding a dataset by assigning the dataset pixels to a number groups called “classes”.

Image Data



A

Thematic Map



B



Classification Characteristics

When talking about **classes**, we need to distinguish between:

Information classes

- **categories of interest** that the analyst is actually trying to identify in the imagery (e.g. *different kinds of crops, different forest types*)

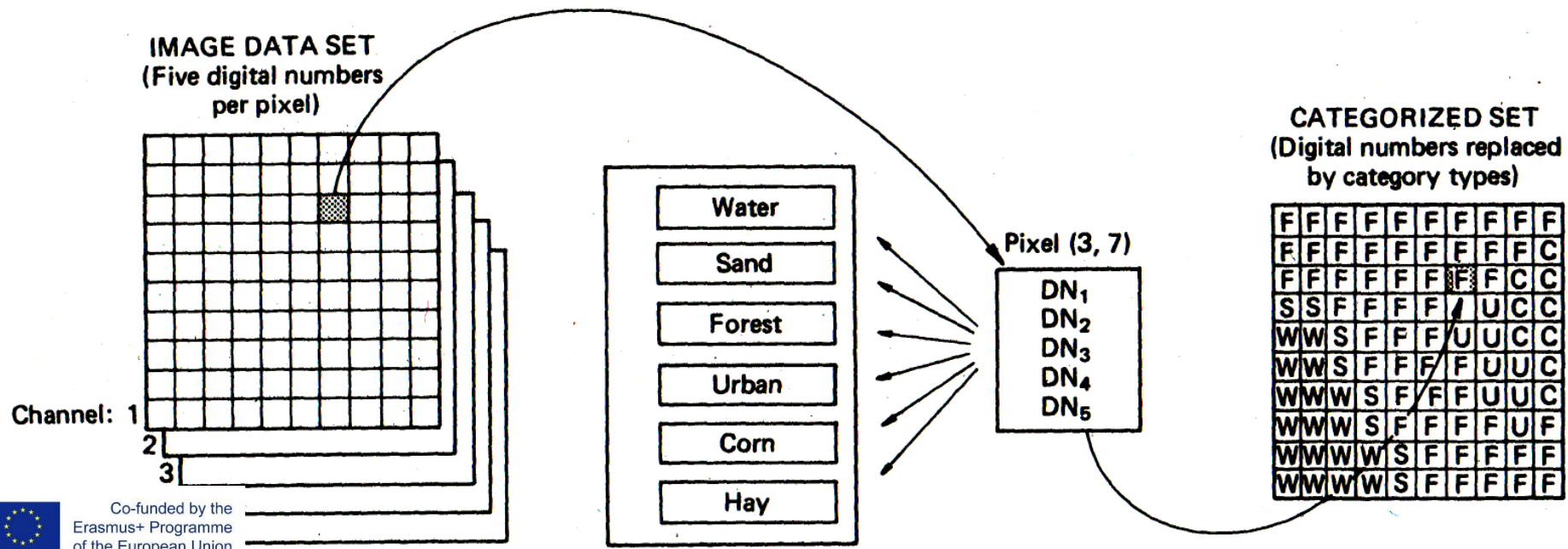
Spectral classes

- **groups of pixels** that are uniform (or near-similar) with respect to their brightness values in the different spectral channels of the data
- **The objective is to match the spectral classes in the data to the information classes of interest.**



Classification Characteristics

- A computer algorithm is used to perform classification by **spectrally** by identifying each pixel and assigning it to a class.
- Pixels are grouped into a number of **classes**.
- Each pixel in the image is labelled with a **class name**.





Example: image classification

Landsat TM subscene



Classification

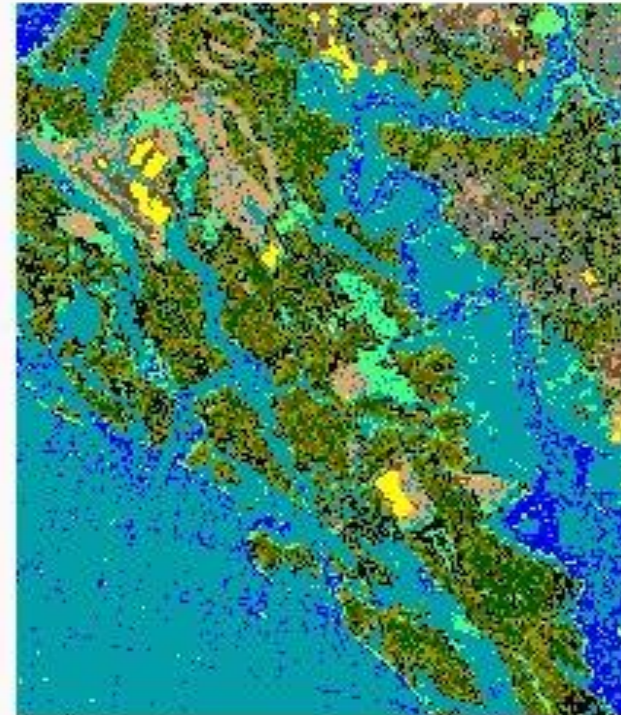




Image classification methods?

What *classification methods* have we already covered?

- Unsupervised vs supervised
- Rule-based classification (decision tree classifiers)
- Hard vs Soft classifiers
- Object Oriented Classification

We have also covered:

- Classification accuracy assessment
 - *Error matrix, Kappa...*

...More on this at a later session of the module...



Image classification methods?

LU/LC mapping methods can also generally be divided based on their assumption on PDFs of classes into:

1. Parametric methods

- *e.g. Maximum Likelihood, Minimum Distance*

2. Non-parametric methods

- *e.g. Spectral Angle Mapper, Artificial Neural Networks, Support Vector Machines*

3. Object-based methods

- *e.g. Membership functions decision tree, Nearest Neighbour*

READ: *Lu, D. and Weng, Q., 2007. A survey of image classification methods and techniques for improving classification performance. Intern. Jour. Remote Sensing, 28 (5), 823-870*



Supervised classification

PARAMETRIC & NON-PARAMETRIC METHODS

■ ADVANTAGES:

- *Implementation based on spectral information using training, Computationally fast and cost-effective option*

■ DISADVANTAGES:

- *Results dependent on algorithm selection, misclassification errors difficult to handle (without introducing a hybrid approach), salt & pepper effect, not easy to process in GIS environment, Hughes effect (for hyperspectral data)*

OBJECT-BASED METHODS

■ ADVANTAGES:

- *More sophisticated approach, deals better with large number of classes*
- *Often higher classification accuracy can be obtained, more easily manipulated in a GIS environment*

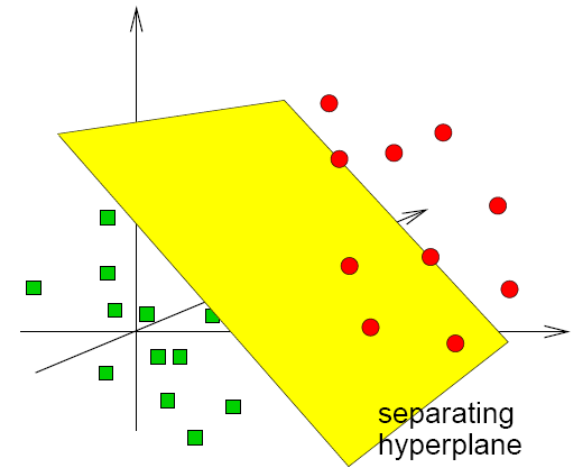
■ DISADVANTAGES:

- *Computationally and in development time more expensive, transferability to other regions care needed, highly trained staff expertise*



Non-parametric classifier: example

- ❏ **Support Vector Machines (SVMs)** is a supervised **machine learning** method that performs classification based on statistical learning theory (Vapnik, 1995)
- ❏ It is a binary classification method that provides a separation of classes by fitting a hyperplane to a set of training data that maximises the separation between the classes



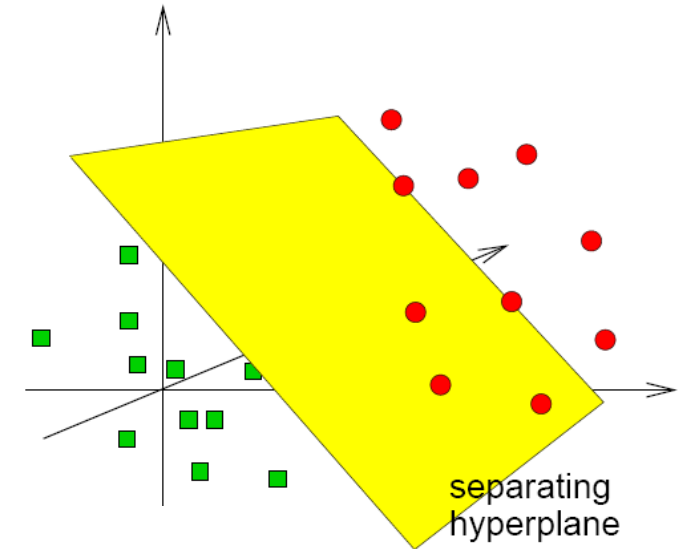
Why interested for SVMs ?

Make no assumptions on the probability distribution of training set, Are able to perform classification using less training points, Produce high classification accuracy results, Easy development of architectural design, Are easy to implement , Efficient in dealing with data of high dimensionality, Can easily adapt to different types of data and input structures



Support Vector Machines

- ❑ Essentially, the hyperplane is the decision surface on which the optimal class separation takes place.
- ❑ SVMs, although is a binary classifier in its simplest form, it can function as well as a multiclass classifier, by combining several binary SVMs classifiers. Classes separation is done using kernels.



Linear:

$$K(x_i, x_j) = x_i^T x_j$$

Polynomial:

$$K(x_i, x_j) = (\gamma x_i^T x_j + r)^d, \gamma > 0$$

Radial Basis Function:

$$K(x_i, x_j) = \exp(-\gamma \|x_i - x_j\|^2), \gamma > 0$$

Sigmoid:

$$K(x_i, x_j) = \tan H(\gamma x_i^T x_j + r)$$

where: γ is the gamma term, d is the degree of polynomial, r is the bias term.



Support Vector Machines

- ❏ Except the type of kernel, other parameters that generally need to be set include:
 - ❏ Penalty parameter: allows a certain degree of misclassification (important for non-separable training sets)
 - ❏ Pyramid levels: sets the number of hierarchical processing levels to apply during SVM training and classification
 - ❏ Classification probability threshold: sets the probability for reporting pixels with all probability values less than this value as unclassified



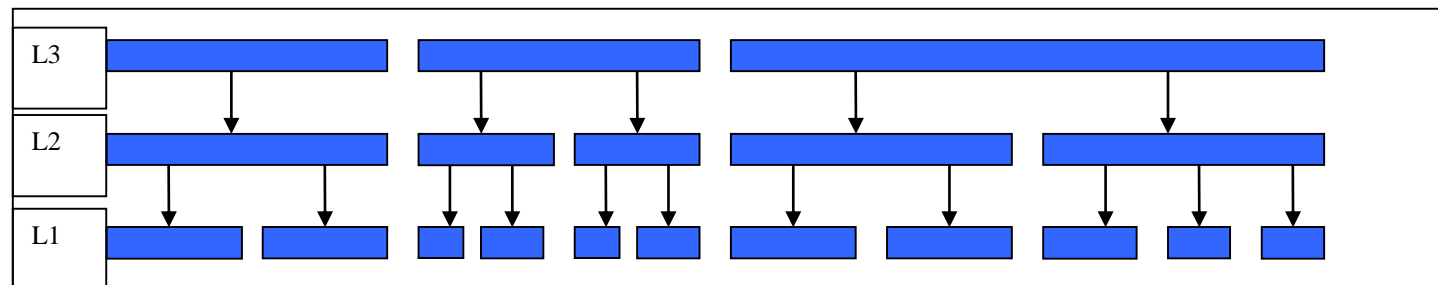
Object-based classification

- Rather than classifying pixels they are grouped into objects at different scales.
- Objects have more information than pixels: e.g. Mean, Standard Deviation, Adjacency, Shape
- These objects provide a better representation of the landscape.
E.g., Fields, Building, Trees.



Why do we want to use OBIA?

- Pixels have one value only
- Objects have:
 - Mean, standard deviation and other statistical descriptors
 - Area, perimeter and shape
 - Proximity and relative borders
 - Enclosing/enclosed
 - Relations to parent and child objects
- Hierarchical layers of objects





OBIA: Steps

1. Prepare Imagery
2. Segmentation
3. Calculation of segment statistics
(most software packages do that on the fly)
4. Classification of the segments
5. Merge the classified segments.

Implementation is done in software such as:
eCognition & RSGLib



Image Segmentation

- Image segmentation creates the objects.
- It is implemented hierarchically and can be implemented at different scales..
- The scene is divided into representative units.
- Many segmentation algorithms have been developed which aim at:
 - *Edge identification*
 - *Spectral similarity*
 - *Image gradients*



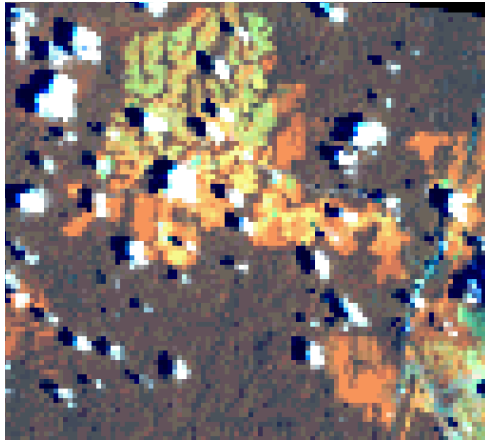
E.g. Segmentation within eCognition

- Overview of segmentation process:
 - Chessboard
 - Quadtree
 - Multi-resolution
 - Scale factors
 - Colour & shape parameters
 - Spectral Difference

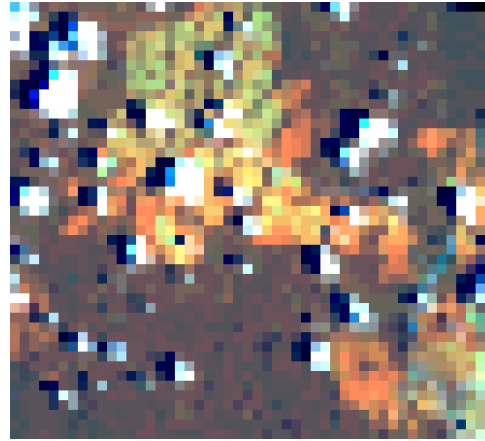


e.g. Chessboard

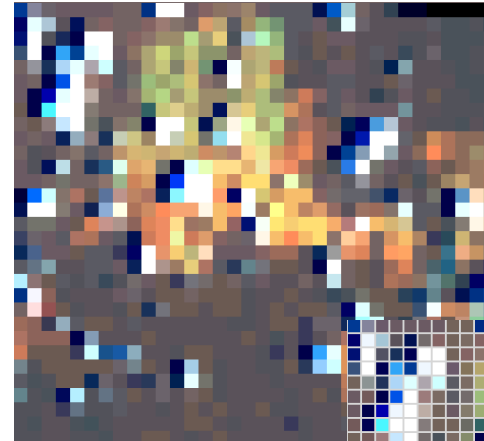
- Simply divides the image into **equally sized square** objects:
 - Single parameter: object size (in pixels)



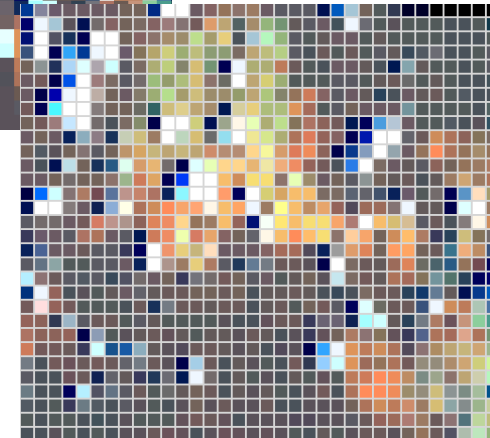
5 x 5 pixels



10 x 10



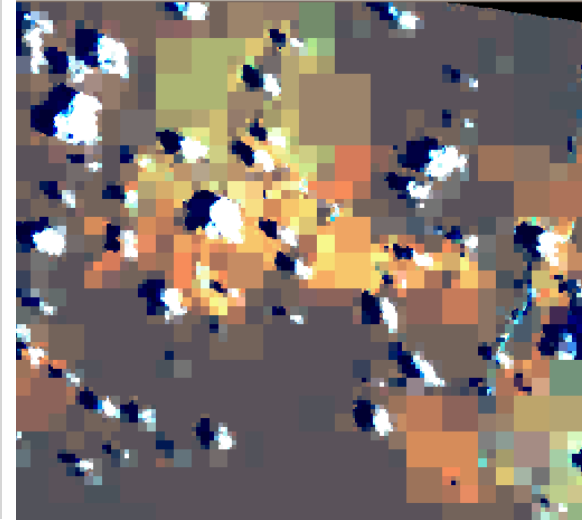
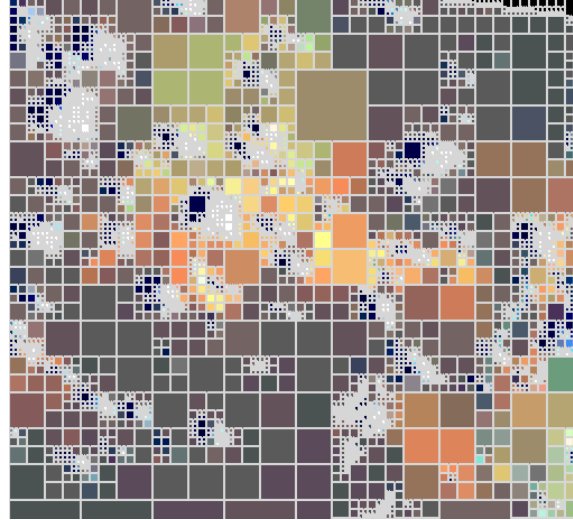
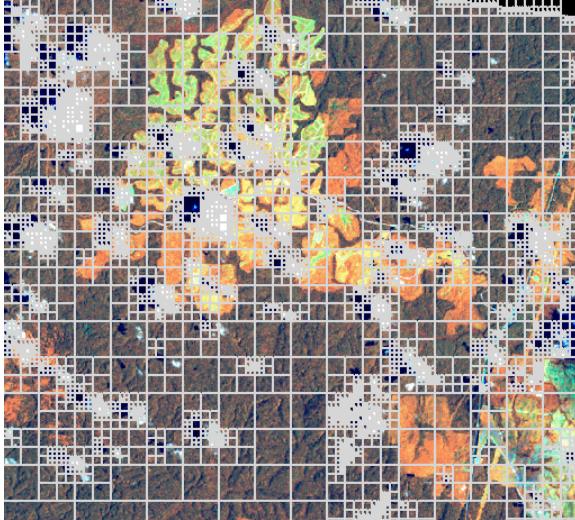
15 x 15





e.g. Quadtree

- Similar to the chessboard segmentation but **uses spectral homogeneity** to define how the image should be divided (i.e., into squares)
 - Single parameter: Spectral Homogeneity.





Multi-resolution segmentation

Segmentation [?] [X]

Edit layer weights

Layer name	Layer stddev.	Weight
Layer 1	(13.3)	1.0
Layer 2	(16.5)	1.0
Layer 3	(17.3)	1.0
Layer 4	(19.0)	1.0
Layer 5	(21.2)	1.0
Layer 6	(24.2)	1.0
Layer 7	(28.8)	1.0
Layer 8	(27.8)	1.0

Image layers Edit weights: 1

Level

- entire scene
- new level
- Level 2**
- new level
- Level 1
- new level
- pixel level

Level Name: Level 1

Segmentation Mode: Multiresolution Segmentation

Class Domain: all objects

Overwrite existing level ☐

Scale parameter: 10

Composition of homogeneity criterion:

Color: 0.9 Shape: 0.1

Compactness: 0.5 Smoothness: 0.5

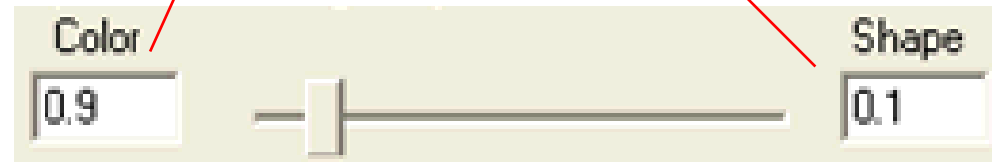
Start Cancel



Multi-resolution segmentation

- The **scale factor** is compared to the weighted sum of shape and colour.

$$f = w \cdot h_{color} + (1 - w) \cdot h_{shape}$$



- ◆ Where f is greater than the scale factor, objects are not merged.



Multi-resolution segmentation

- ◆ **Colour** (or spectral homogeneity)

- The sum of the standard deviations of spectral values in each layer weighted by user defined weights

$$h = \sum_c w_c \cdot \sigma_c$$



- ◆ **Shape** is defined by the weighted sum of compactness and smoothness.

$$h_{shape} = w_{compact} \cdot h_{compact} + (1 - w_{compact}) \cdot h_{smooth}$$

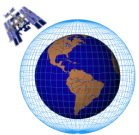


- **Compactness** relates to a ratio of the perimeter length and the square root of the number of pixels forming the image object (\sim object area)

$$h = \frac{l}{\sqrt{n}}$$

- **Smoothness** relates to a ratio of the perimeter length to the perimeter of the bounding box.

$$h = \frac{l}{b}$$

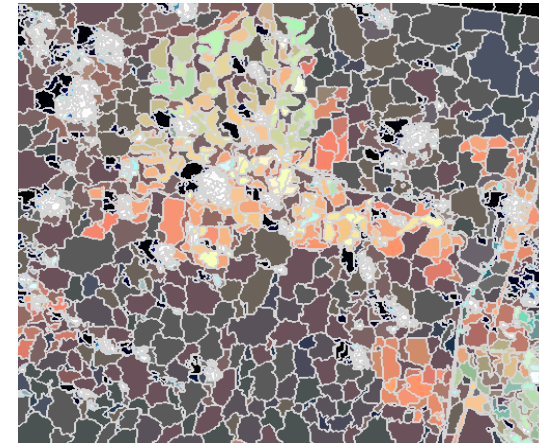
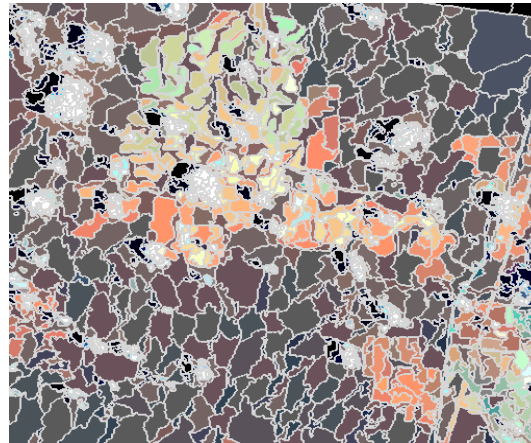
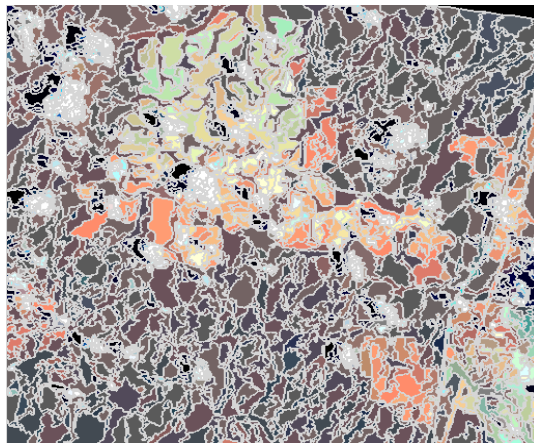


Smoothness

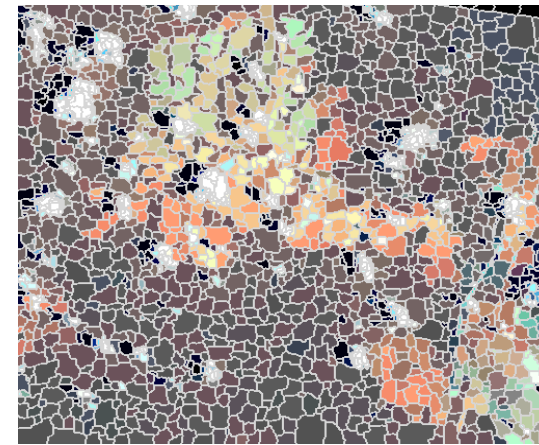
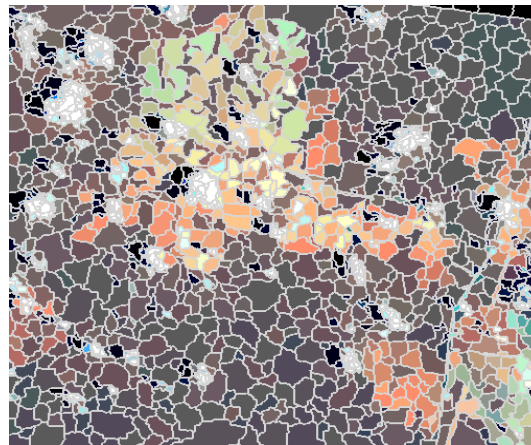
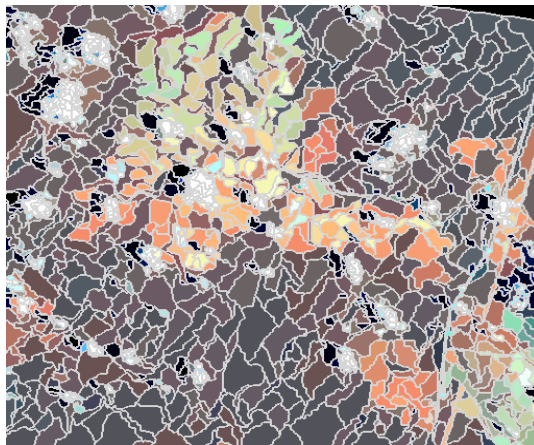


Compactness

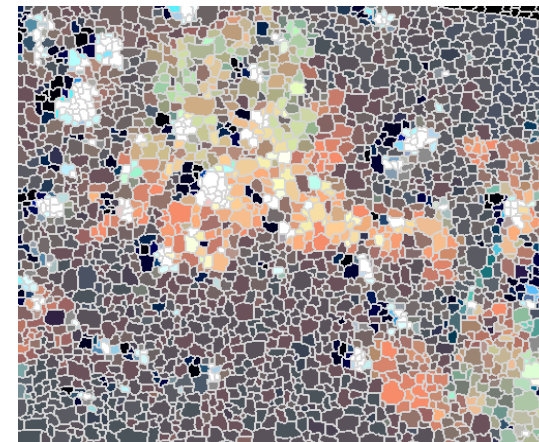
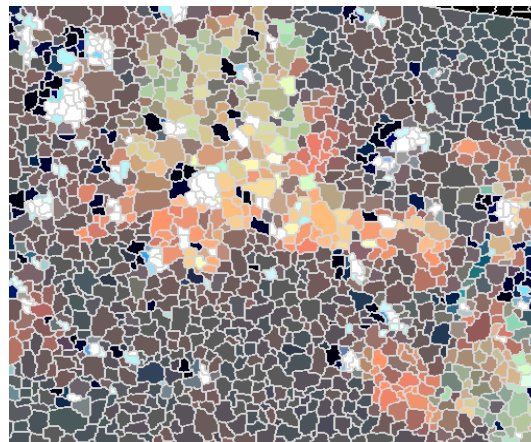
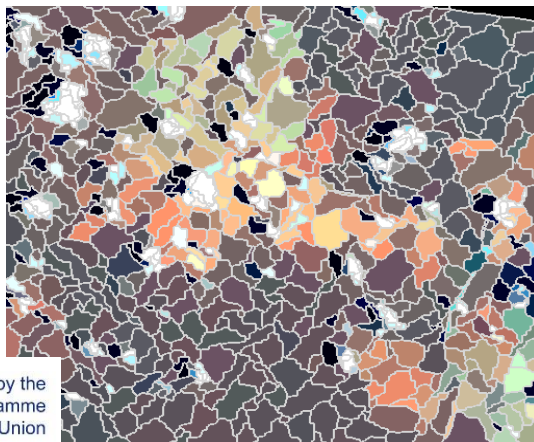
**Shape
0.1**



**Shape
0.5**



**Shape
0.9**





How to compare segmentation results?

- Not an easy thing to do...
- For feature extraction techniques reference segments can be drawn for comparison.
- For general segmentations then they need to be 'fit for purpose'.
 - There is no one 'best' segmentation but each has it's pluses and minuses.
 - Visually assess it for your application.



Classification

- The same algorithms are available as for pixels.
 - Gaussian Maximum likelihood
 - Discriminant Analysis
 - Support Vector Machines
 - Random Forests
 - Rule based



Rule-based Classification

...Advantages:

- Results can be cross-examined to find the rules which 'fitted' to produce the classification
 - *Explanation and accountability*
 - *Can make expert users happier to accept the output.*

...Disadvantages:

- Considerable analyst effort => **time consuming and complex to define** a rule-base for all required classes.
- More complex, not necessarily more accurate...
- **Optimum separation maybe difficult** to define...
- Data-dependent => a new tree must be designed for each new application...



LULC Change Detection in Earth Observation



Change Detection

- What do we mean by change?
 - Alterations in surface components at varying rates
- Why is land cover/use change important?
 - Deforestation
 - Damage assessment
 - Disaster monitoring
 - Urban expansion
 - Planning
 - Land management



Quickbird: Before/after the
Boxing day Tsunami 2004



Key considerations

- Principle of change detection in RS:

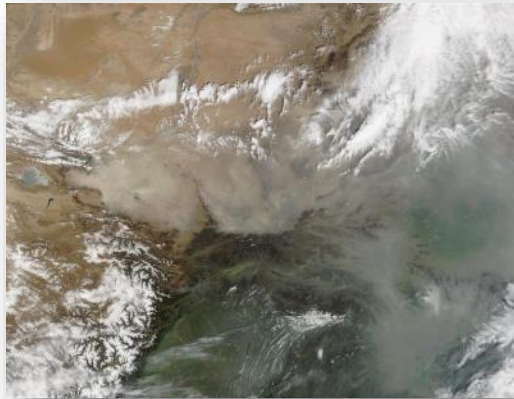
Land cover change will change the spectral properties of an area

- NOTE: This needs to be independent of:

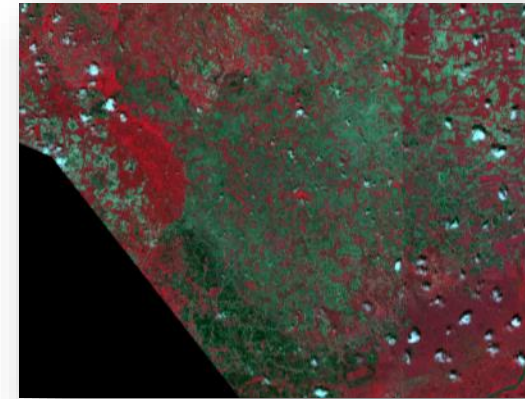
- Atmospheric conditions
- Illumination and viewing angles
- Soil moisture



Sun angle



Haze conditions



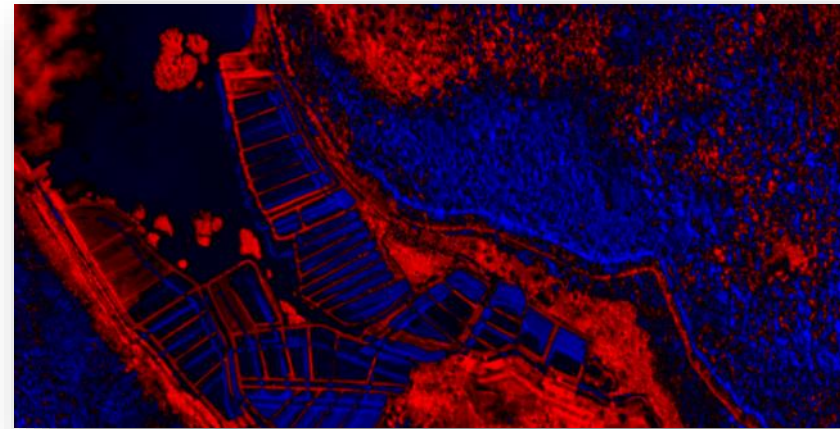
Soil moisture

What do we need to consider??



Key considerations

- Pre-processing
 - Radiometric, atmospheric, topographic corrections, **image registration**
 - Sub-pixel level registration accuracy required
- Best to use the **same sensor, near anniversary dates**
 - Difficult, especially considering cloud cover



Changes in field boundaries or images
not properly registered?



Accuracy of change detection

- **Dependent upon:**

- Geometric registration between images
- Calibration or normalisation between images
- Availability of quality ground truth
- Knowledge of study area
- Complexity of the study area
- Change detection method or algorithm used
- Time and cost

READ: *Lu, D., et al. (2004): "Change detection techniques." International journal of remote sensing 25.12, 2365-2401.*



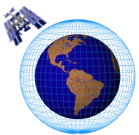
Change detection methods

1. Algebra
2. Transformation
3. Classification
4. Advanced models
5. Others



1. Algebra

- **Examples:**
 - Image differencing, image regression, image ratioing, vegetation index differencing, change vector analysis
- **Advantages...**
 - Relatively simple, easy to interpret
 - Can handle illumination effects
 - Yet, do not fully exploit the spatial context of real-world objects...
- **Success reliant on ...:**
 - Selecting suitable band or indices
 - Selecting suitable thresholds



Example: Quickbird, Before/after the Boxing day Tsunami 2004

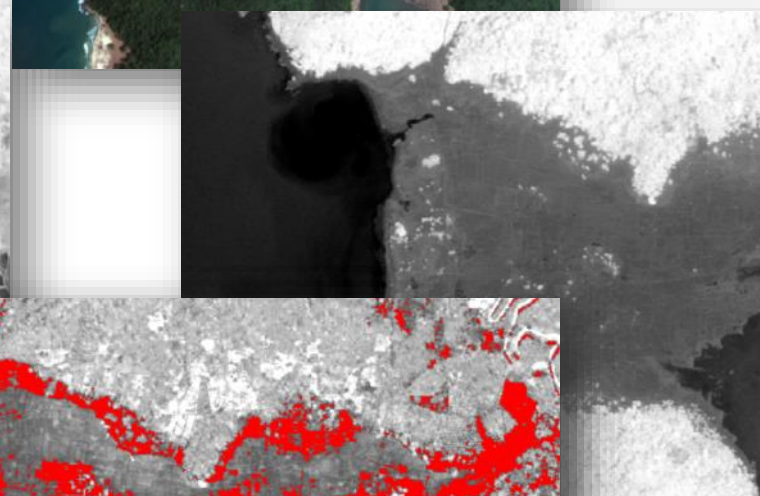
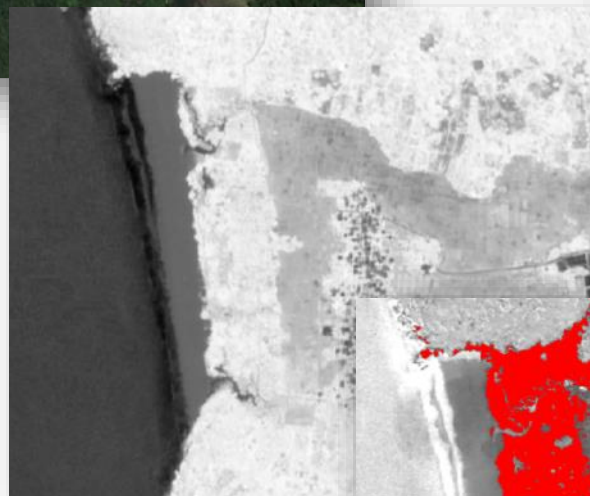
Before



After



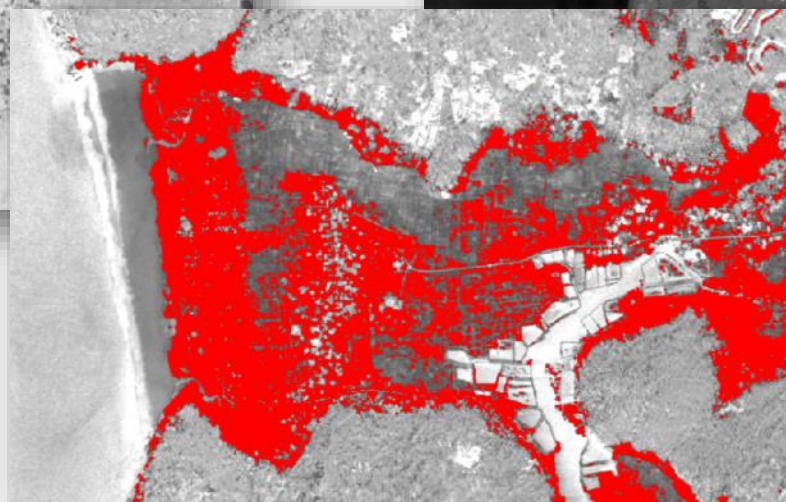
NDVI



NDVI difference

Threshold < -0.4

i.e. big drop in vegetation
cover





2. Transformations

- Examples:
 - Principal components analysis, tasselled-cap transformation
- Advantages...
 - Reduces data redundancy
 - Good for data from multiple sensors
- Disadvantages...
 - Require thresholds to identify changed areas
 - Difficult to interpret change information in transformed images



Example: Quickbird, Before/after the Boxing day Tsunami 2004

Before



After



**PCA transformed,
component 1**





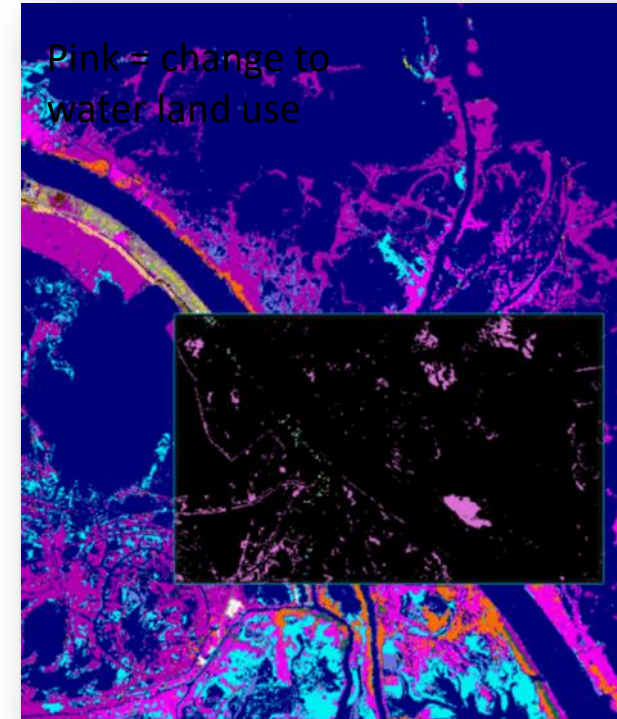
3. Classification

■ Advantages

- Reduces impact of atmosphere, sensor and environment
- Provides information on the nature of change

■ Disadvantages

- Requires accurate training data
- Final accuracy dependent of accuracy of classification
- Time-consuming

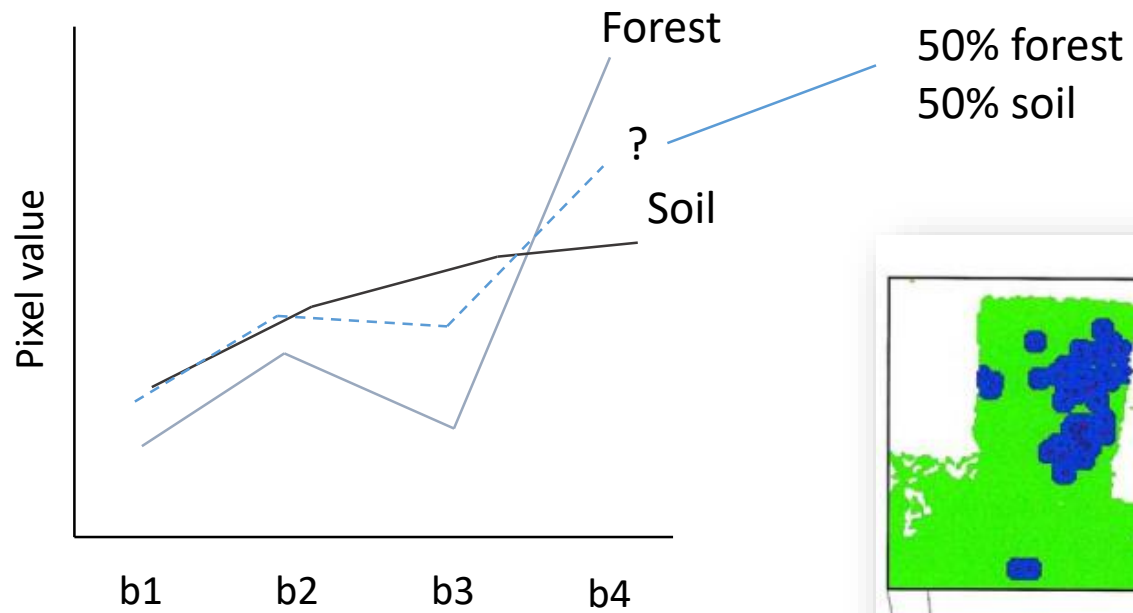


Example from the practical:
post-Katrina land use change



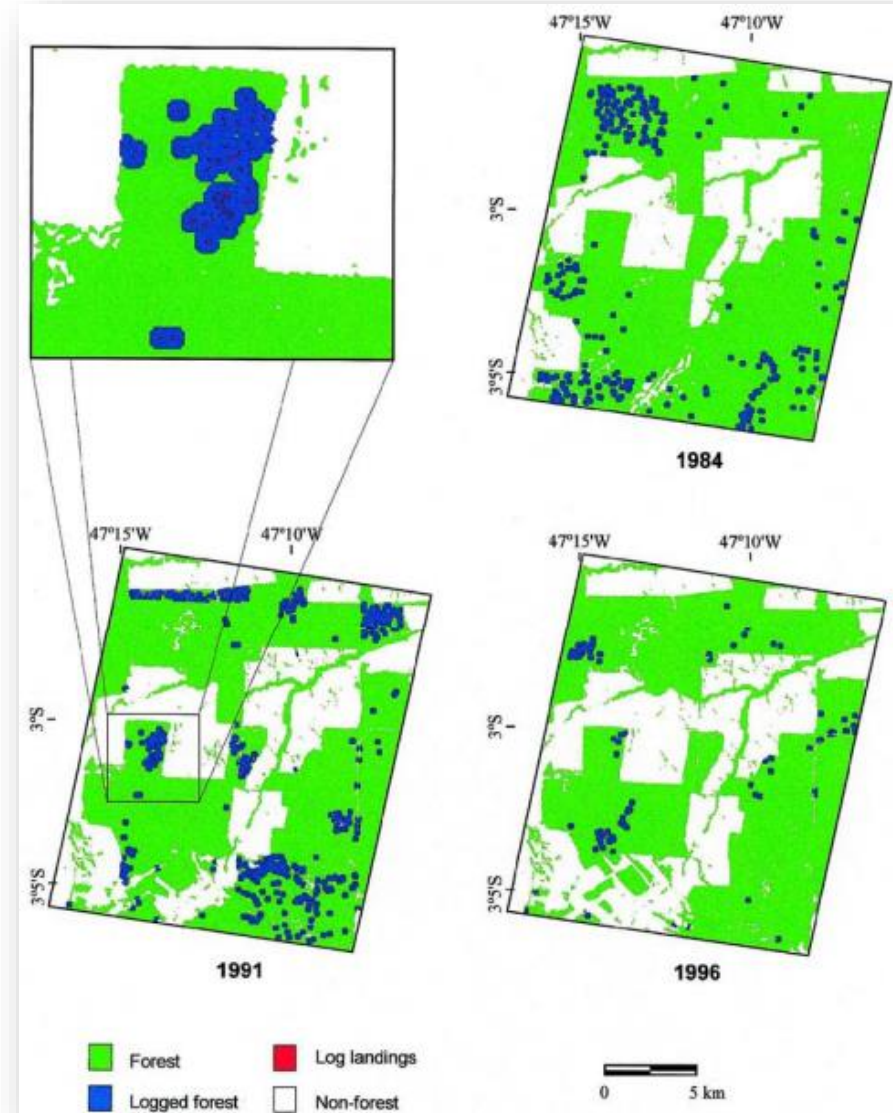
4. Advanced models

- **Examples:**
 - Spectral mixture models
 - Image reflectance values converted to physically based parameters (e.g. 10% forest, 20% mangrove, 70% water)
- **Advantages...**
 - Precise information about the type and nature of change
- **Disadvantages...**
 - Time-consuming
 - Difficult to develop initial reflectance-biophysical parameter models



Example:

Fractions of soil in pixels used to identify logging areas in the Brazilian rainforest



SOUZA, C. JR, and BARRETO, P., 2000,



Co-funded by the
Erasmus+ Programme
of the European Union

Journal of Remote Sensing, 21, 173–179.



5. Others

- **Visual analysis**

- Texture, shape, size, patterns

- **Object-based**

- Object extracted from one image and searched for in the second image
 - Straight forward but dependent of accuracy of segmentation

- **GIS-based**

- Image overlaying and binary masking
- Land fragmentation analysis softwares (e.g. FRAGSTATS @)

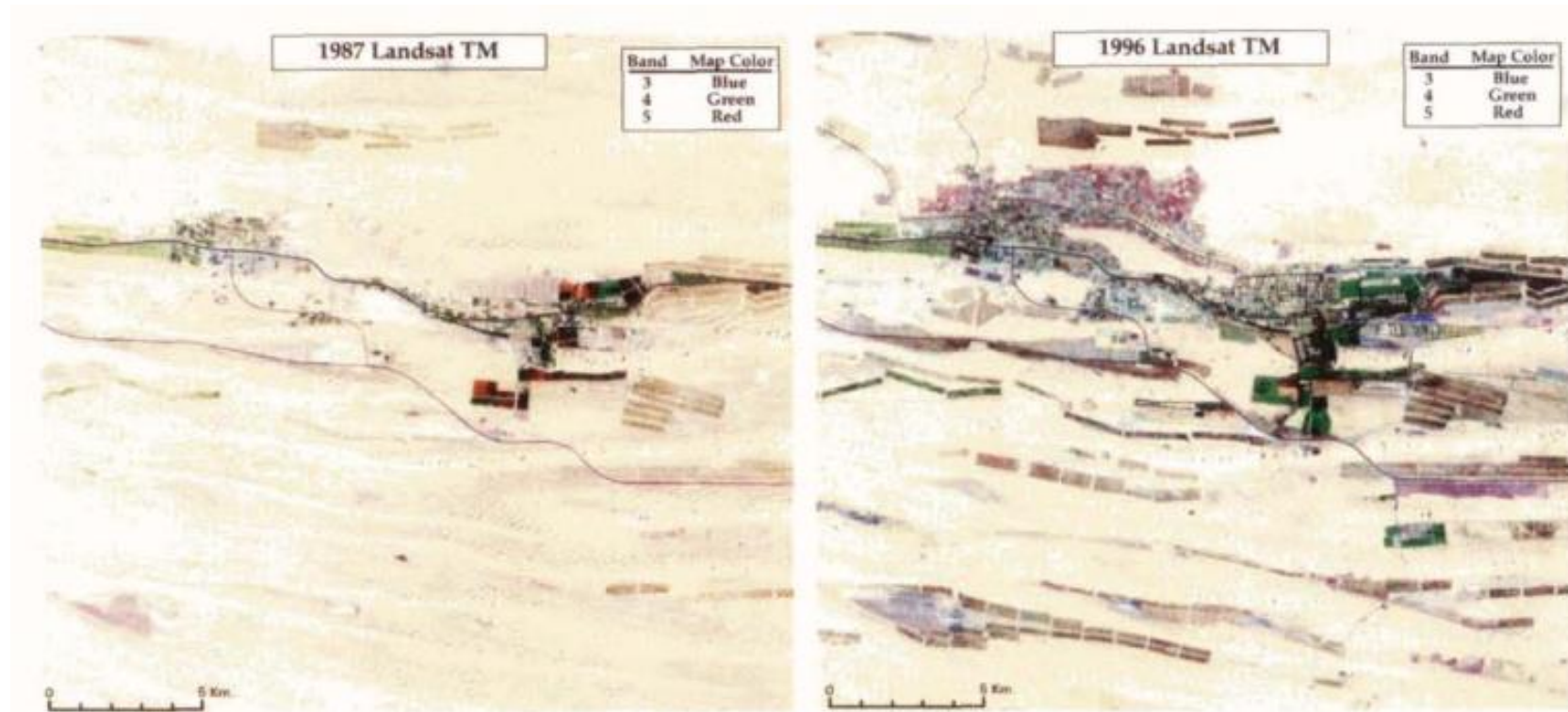
- **Data mining**

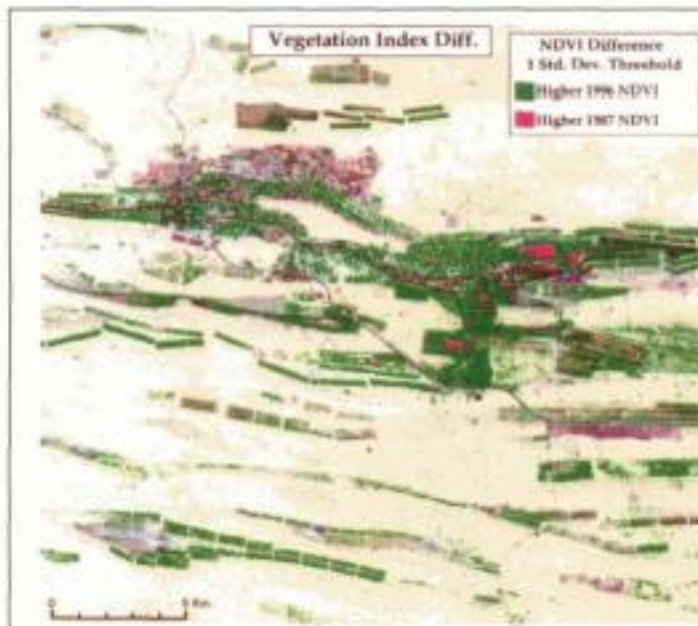
- Spatial clustering (Moran's I index), machine learning, multivariate modelling (generalised linear modelling)



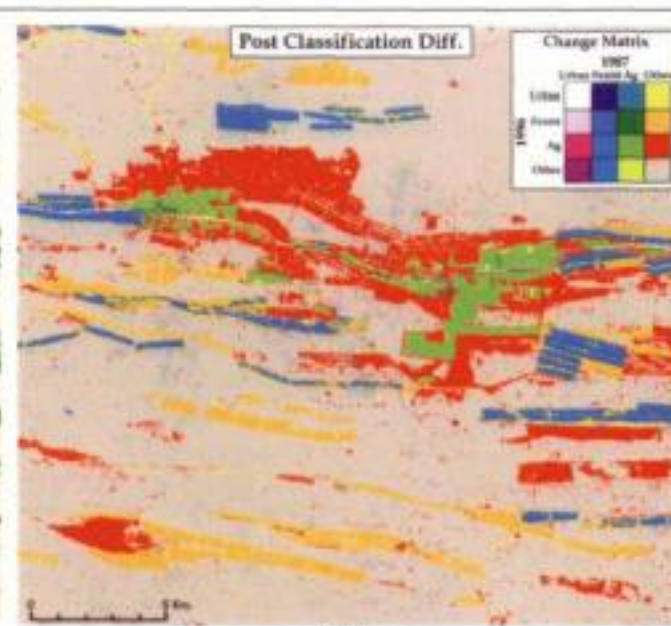
EXAMPLES...

United Arab Emirates: Sohl et al. (1999)





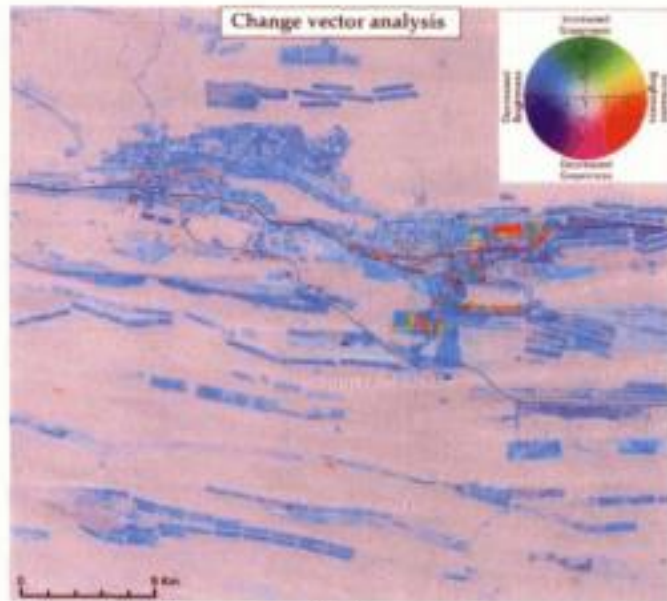
(a)



(b)

Change Matrix
1987

	Urban	Forest	Ag	Other
Urban	White	Dark Blue	Light Blue	Yellow
Forest	Light Purple	Dark Blue	Dark Green	Orange
Ag	Red	Blue	Green	Red
Other	Purple	Blue	Yellow	Light Grey



(c)

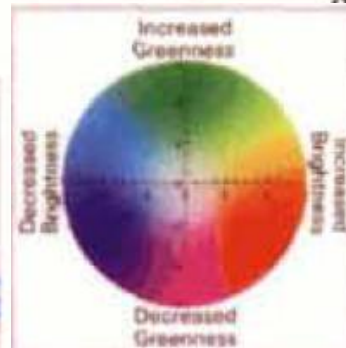


Plate 2. (a) Change image from the vegetation index differencing approach. (b) Change image from the post-classification differencing approach. (c) Change image from the change-vector analysis approach.

- a) Veg index
- b) Post-classification
- c) Vector analysis

United Arab Emirates:
Sohl et al. (1999)



EXAMP

1986

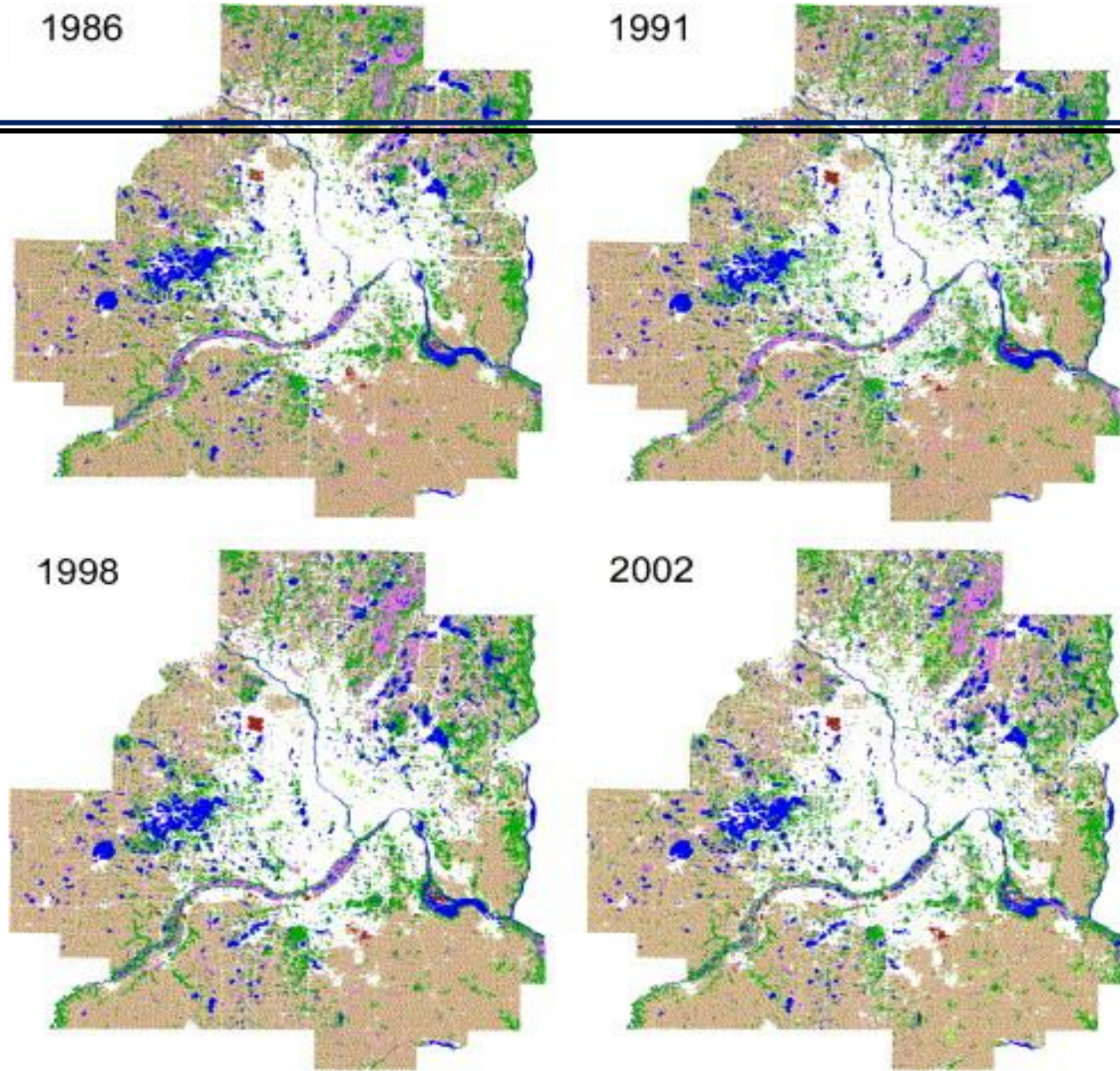
1991

**Twin Cities,
Minnesota:
Yuan et al. (2005)**

Landsat
classifications

1998

2002



Wetland
Water

Grass
Forest

Extraction
Agriculture

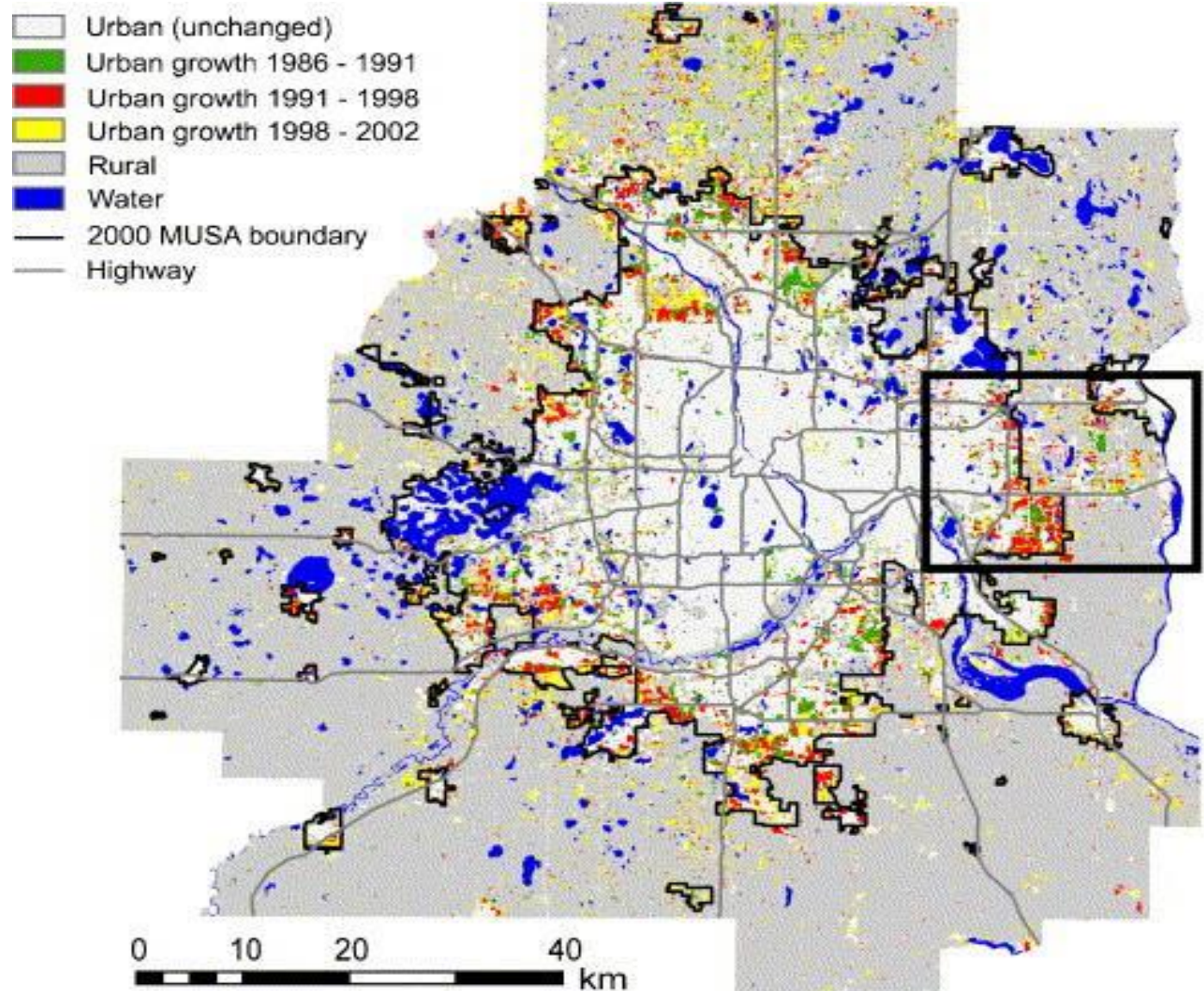
Urban



EXAMPLES...

Thematic map differencing

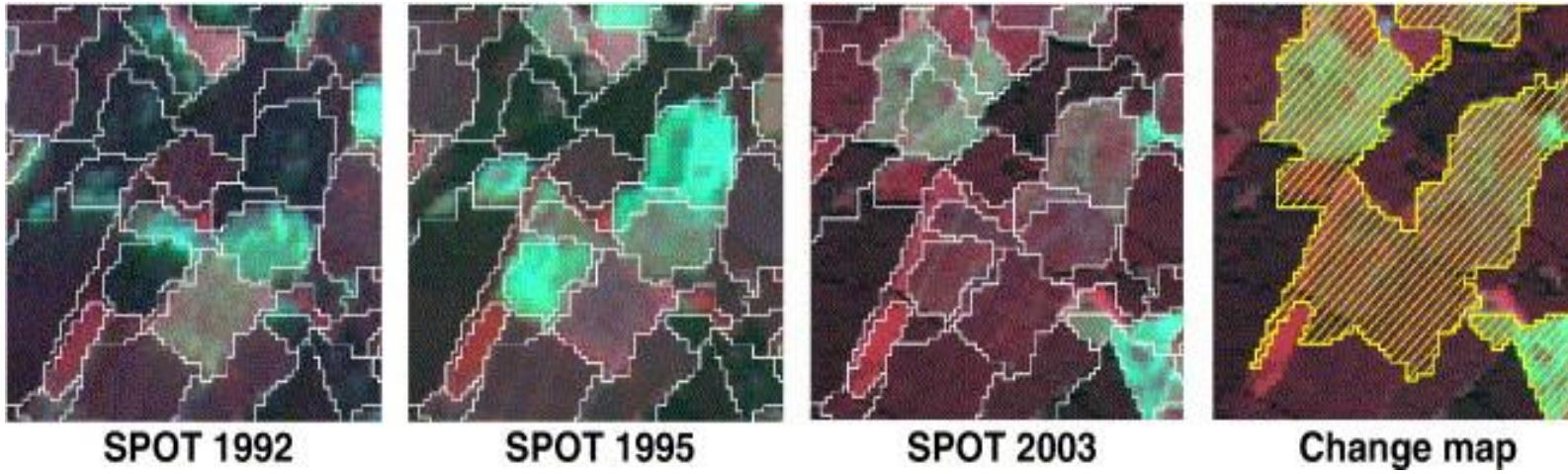
Gives the nature of change (although this study is only concerned with change to urban)





EXAMPLES...

Forest change eastern Belgium: Desclée et al. (2006)



False color composite subsets (RGB = NIR–Red–Green) of each image of the SPOT time series (1992–1995–2003) overlaid by the multivariate segmentation result.

Bright objects are clear-cuts while regions in reddish grey are regenerating areas. The hatched...

Thank you very much for your attention

EO: Radiometric Indices

Dr George P. Petropoulos



Contents

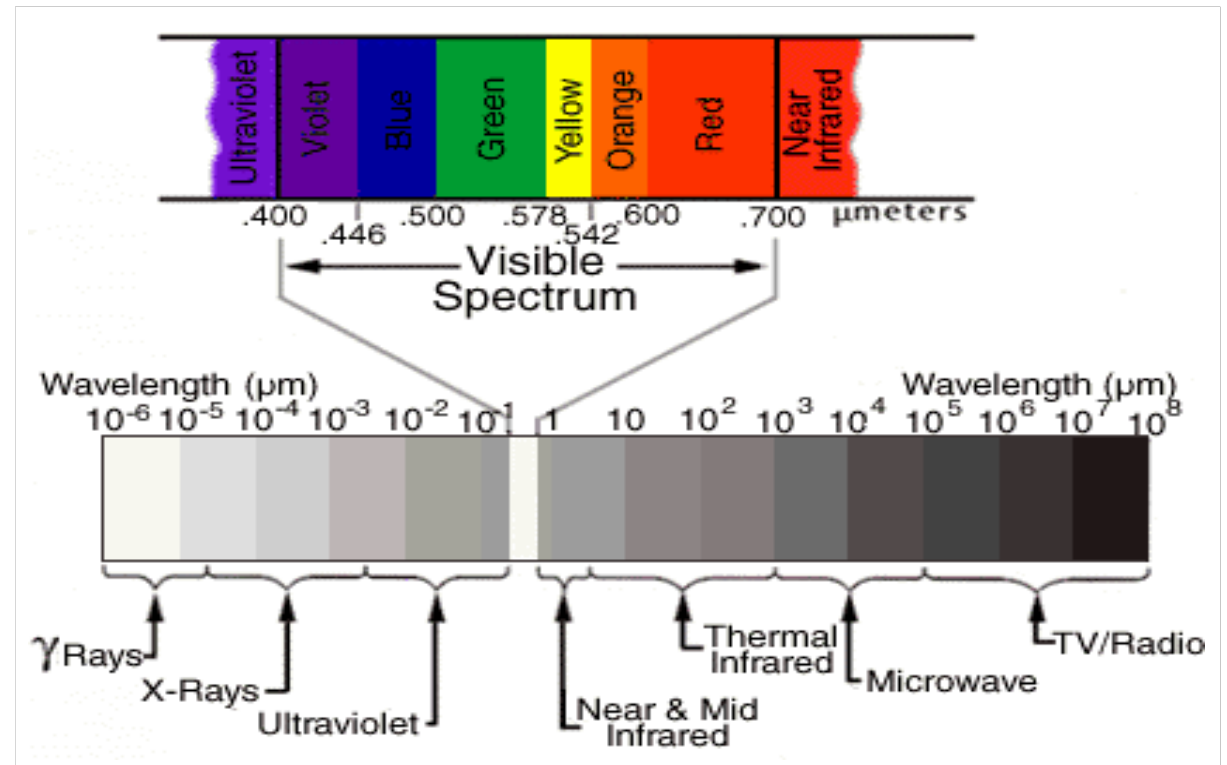
- Spectral characteristics of vegetation reflection
- Radiometric Indices in Remote Sensing



Remote sensing & EMR Spectrum

Remote sensing is defined as the use of electromagnetic spectrum (EMF) radiation to obtain information about an object without any physical contact with it.

There are several areas of the EMR spectrum that are useful for Remote Sensing

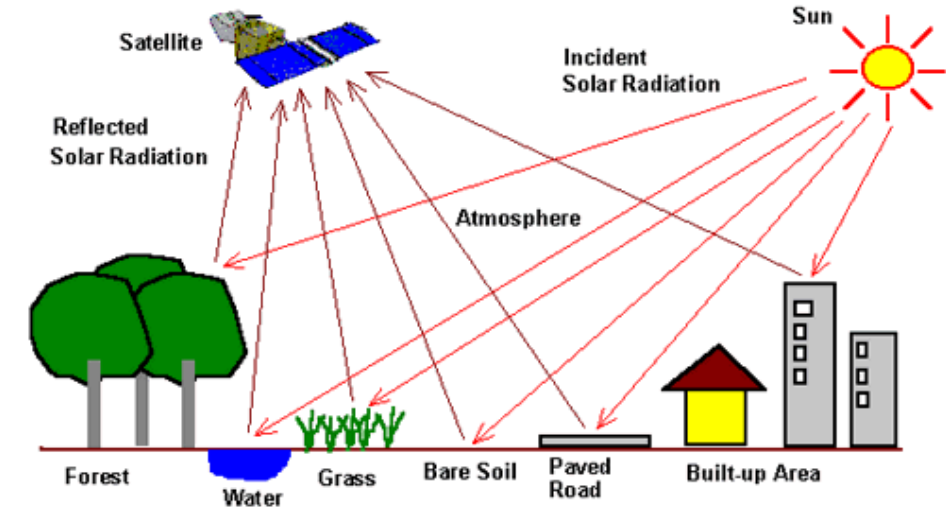
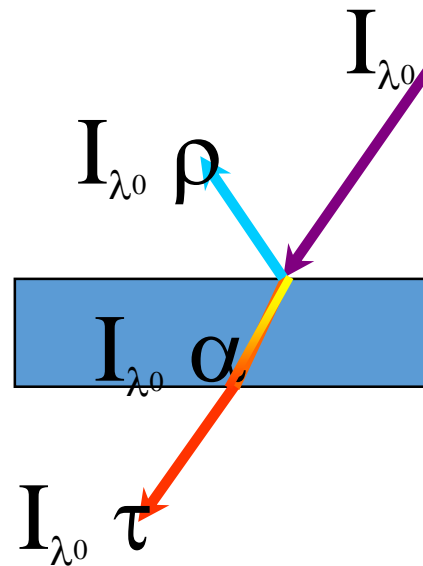




EMR Interactions with Matter

When electromagnetic energy hits any target on the earth's surface, three energy-targeted interactions are possible:

- Reflection
- Absorption
- Transmission





EMR Interactions with Matter

Those interactions are linked as follows:

$$E_i(\lambda) = E_r(\lambda) + E_a(\lambda) + E_t(\lambda)$$

E_i = Incident energy

E_r = Reflected Energy

E_a = Absorbed Energy

E_t = Transmitted Energy

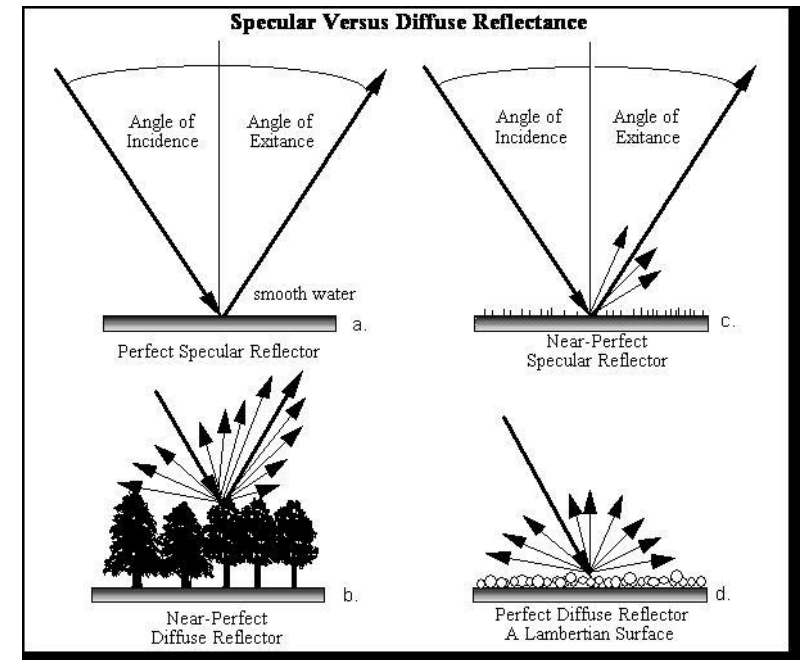
- The % of energy reflected, absorbed, and transmitted depend on the nature of the incident surface, the wavelength of the energy, and the angle of incidence.

• Remote sensing usually uses the part that reflects and examines the properties of a surface through the characteristic spectrum of reflected radiation.



EMR Interactions with Matter

- The nature of reflection depends on the geometric way in which an object reflects energy. In general, there are two broad categories of body surface reflection:
 - Most bodies on the Earth's surface lie somewhere between perfectly specular or **isotropic (diffuse)** reflectors.
 - Whether a target will reflect mirrors or isotropically or somewhere in between depends on the surface roughness of the feature compared to the wavelength of the incoming radiation.



Reflection types



Reflectance

- The reflection characteristics of material bodies on the surface of the earth can be quantified by measuring the percentage of incident radiation that is reflected.
- This is called **reflection** and it is defined as follows:

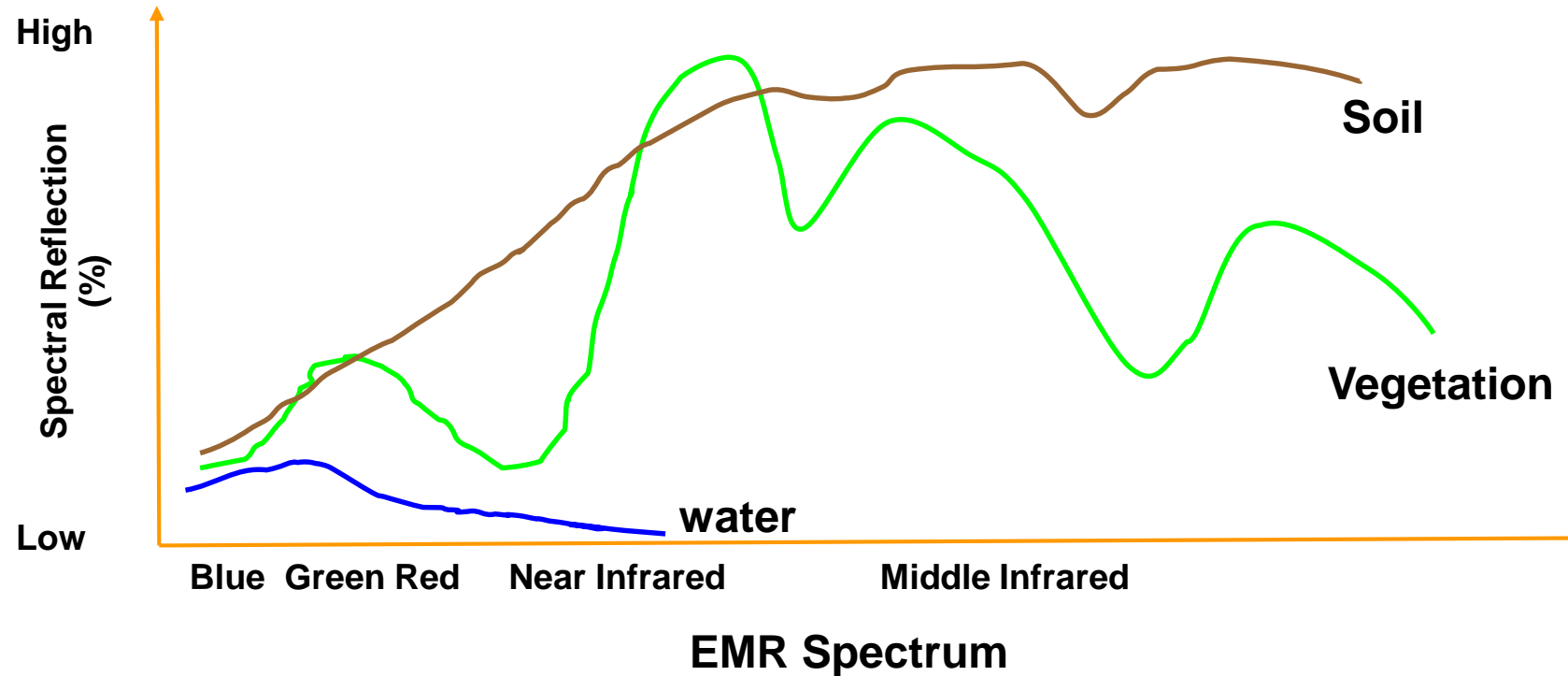
$$\frac{\text{radiation reflected from a body in a specific wavelength}}{\text{radiation incident to the body at the same wavelength}} \times 100$$

- The graph of the spectral reflection of an object as a function of wavelength is called the spectral response curve and is characteristic of any physical object.



Reflectance

Generalised Spectral Signatures of Different Targets

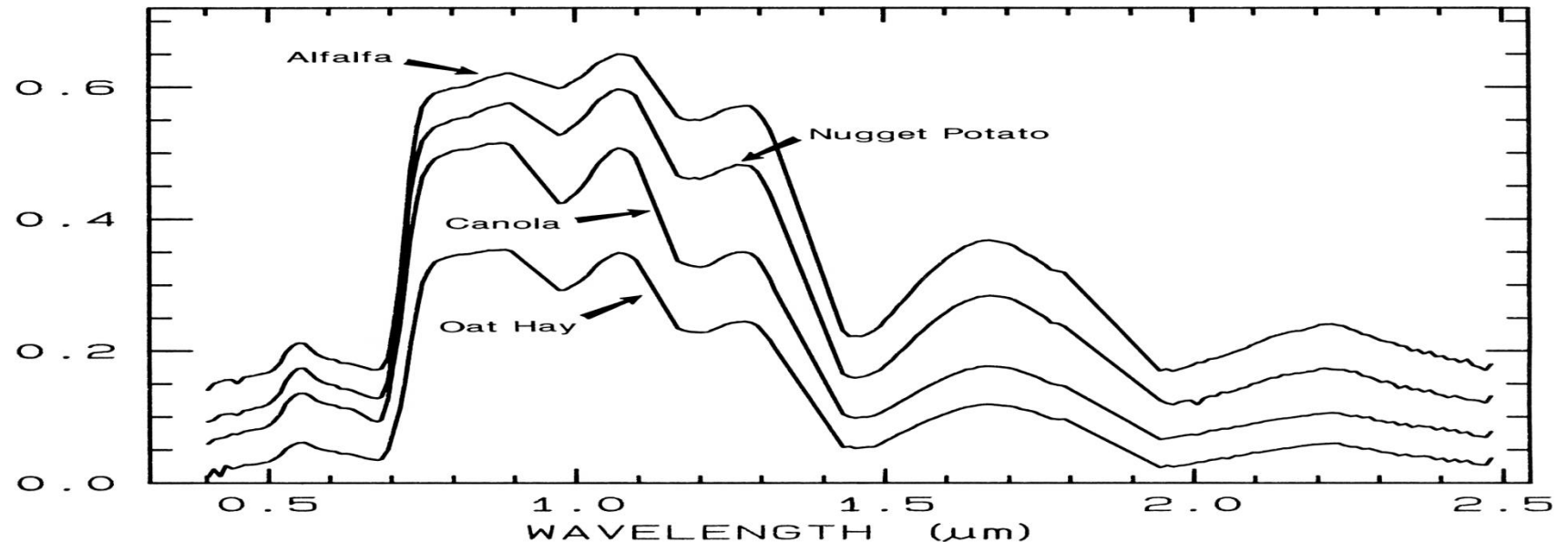


Spectral reflectance curves are usually collected prior to a remote sensing survey to help identify both different bodies but also to select the appropriate remote sensing sensors to be used for their observation.



Spectral Signatures

Generalised Spectral Signatures of Different Targets



Λυμήνη

Μπλέ Πράσινο Κόκκινο Εγγύς Υπέρυθρο

Μέσο Υπέρυθρο

Ηλεκτρομαγνητικό Φάσμα

Spectral reflectance curves are usually collected prior to a remote sensing survey to help identify both different bodies but also to select the appropriate remote sensing sensors to be used for their observation.



Vegetation Spectral Properties

Vegetation Spectral Reflection is dependent on:

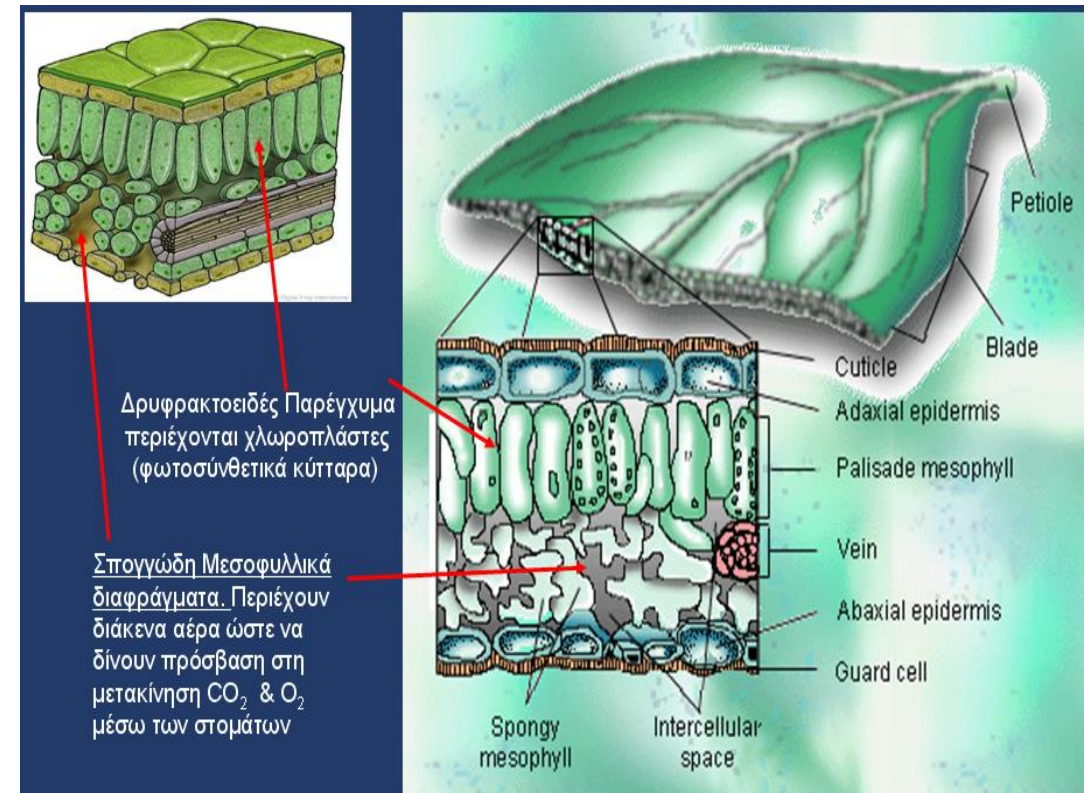
Pigments inside the plants:

- chlorophyll
- carotene και carotene

Cell physiology of the plant:

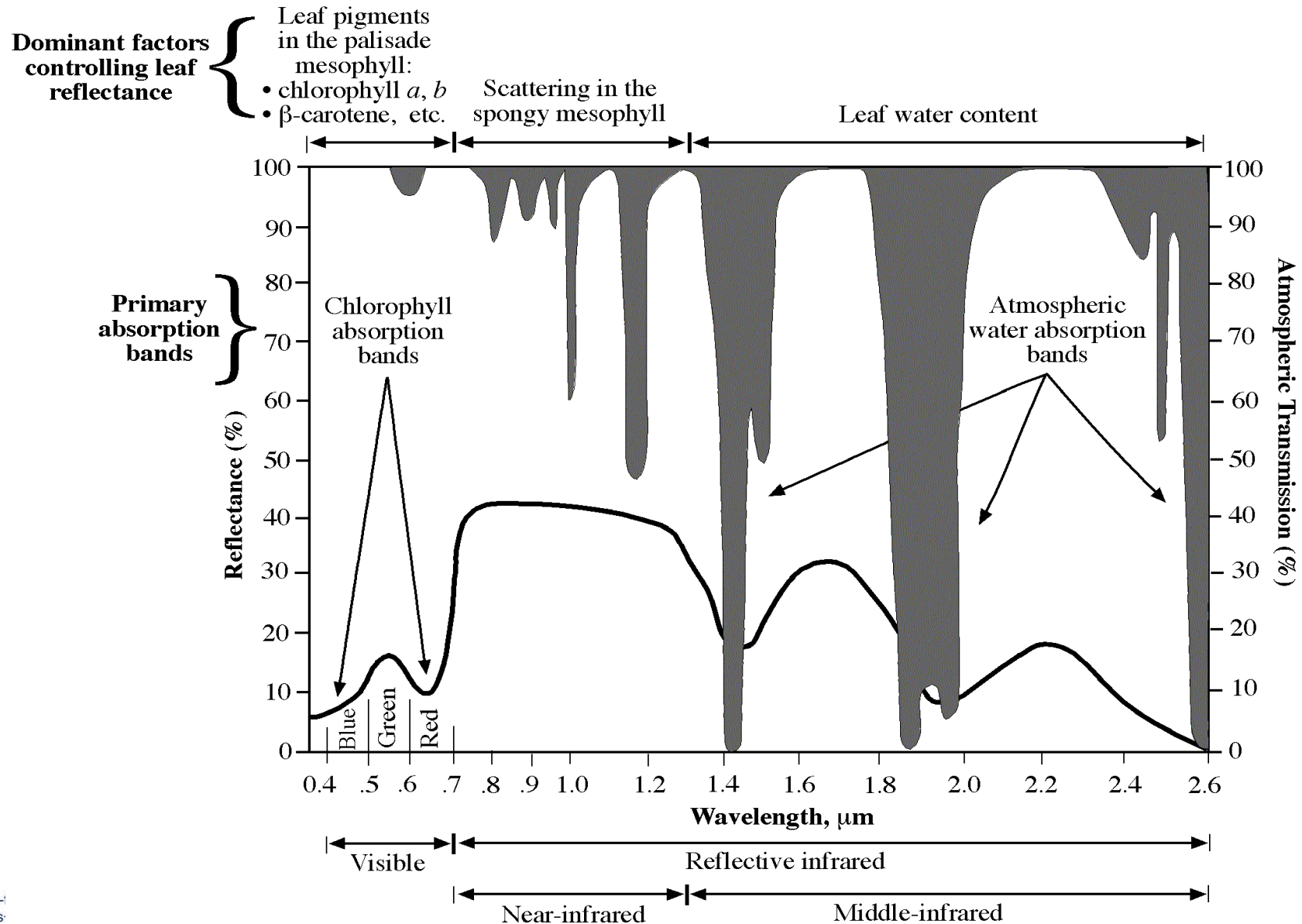
- Spongy Mesophyll cells
- Epidermis

Concentration of water in the plant



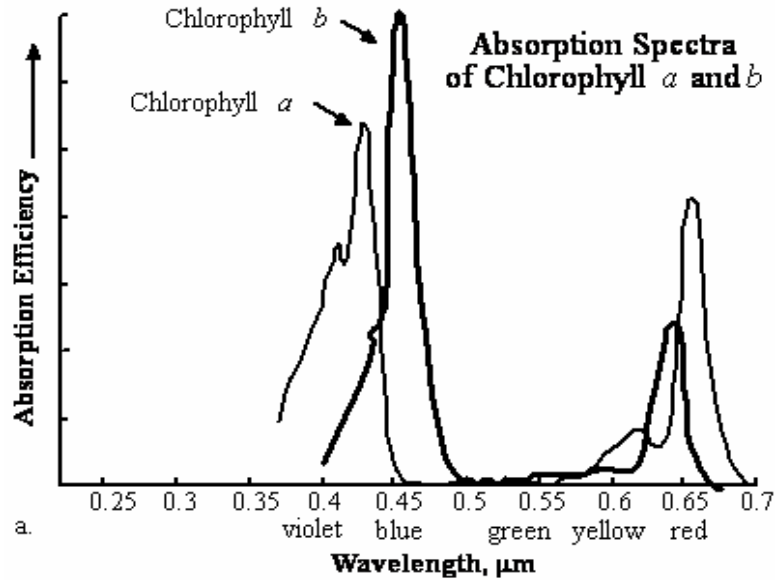


Vegetation Spectral Properties



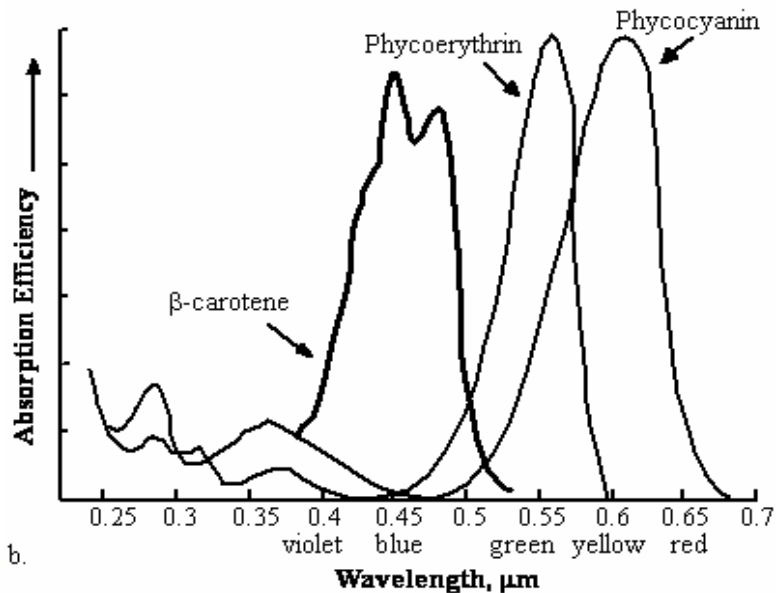


Vegetation Spectral Properties



Different pigments within the plant cells absorb at different wavelengths the visible light with different efficiency.

- Chlorophyll *a* has a maximum absorption at 0.43 and 0.66 μm and chlorophyll *b* at 0.45 and 0.65 μm .



- Carotene and xanthophyll also have high absorption at 0.45 μm .

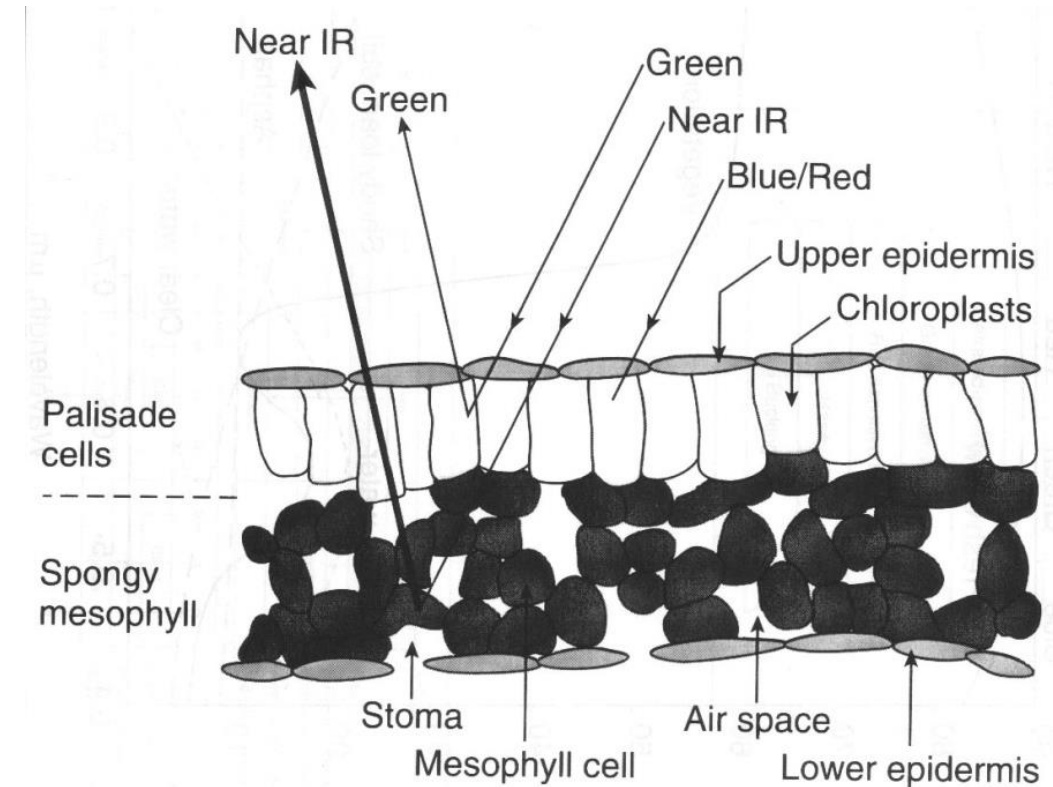
- Phycocyanin & Phycoerythrin are also mainly absorbed in the green and red areas of the EMR



Vegetation Spectral Properties

The very high reflection of vegetation in the near-infrared is due to multiple internal reflections between the hydrated cell walls and the intracellular air of the intervertebral spongy tissues.

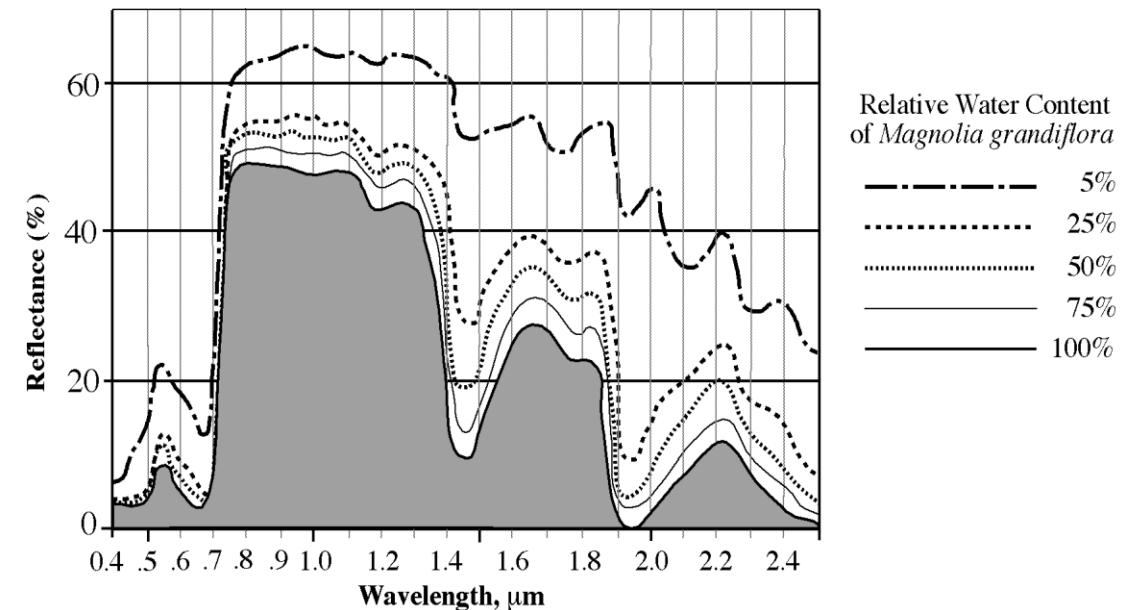
- The leaf surface reflects **40–60%** of incident radiation from the spongy intervertebral portion of the leaf cell tissue.
- The remaining **45 - 50%** of the incident energy is propagated through the leaf and is reflected back to the leaf below it.





Vegetation Spectral Properties

- In mid-infrared (MIR), vegetation reflectance is maximal in 2 areas, at about $1.6\ \mu\text{m}$ and $2.2\ \mu\text{m}$. This is related to the concentration of water in the leaves of the vegetation.
- The more swollen the leaves of the plant, the weaker the reflection in the MIR region. On the contrary, the lower the amount of water in the intercellular spaces of the leaf, the more the incident MIR will diffuse into the intercellular walls, resulting in a higher leaf reflectance coefficient.



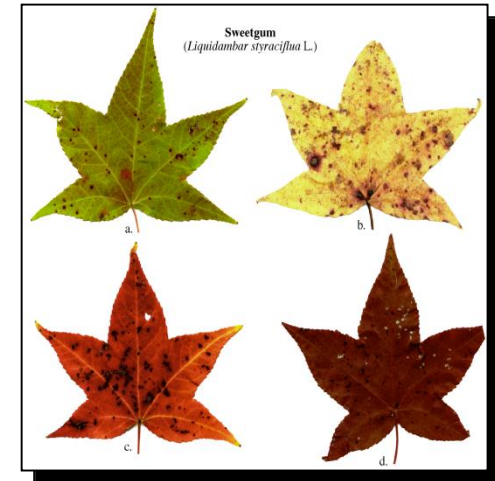
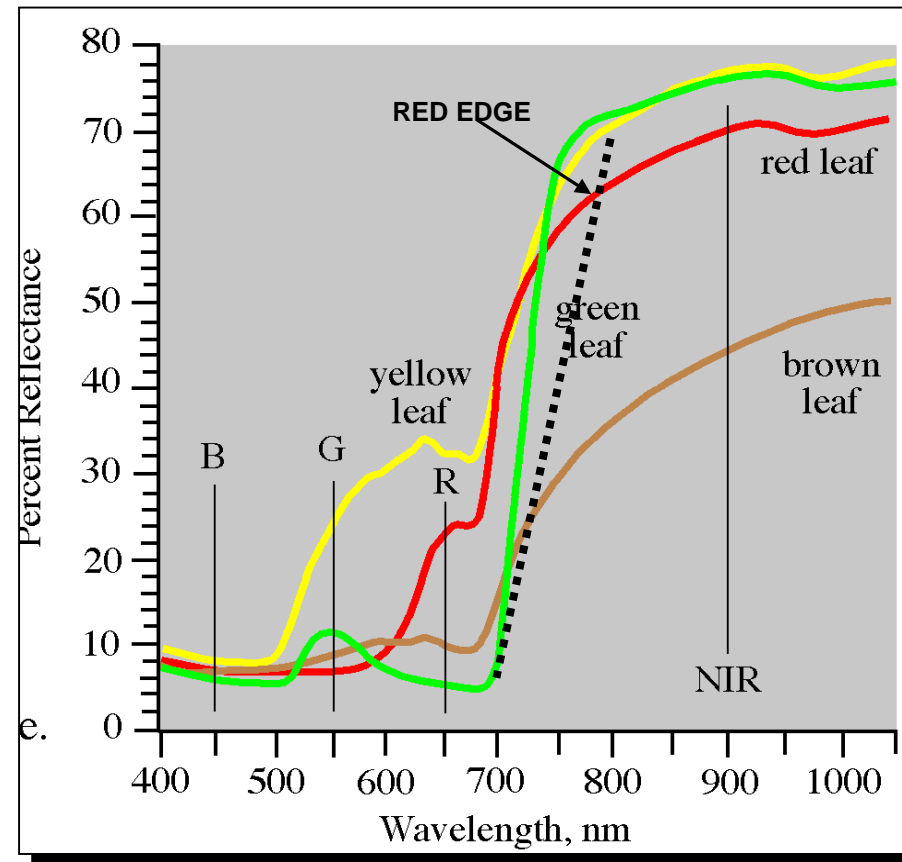


Vegetation Spectral Properties

A healthy green leaf has very low reflectance coefficients in red due to chlorophyll absorption in the optical and very high reflectance coefficients in near-infrared.

When the vegetation begins to "get sick", the internal structure of the cell begins to break down.

The reflection coefficient begins to decrease to near infrared and increases to red

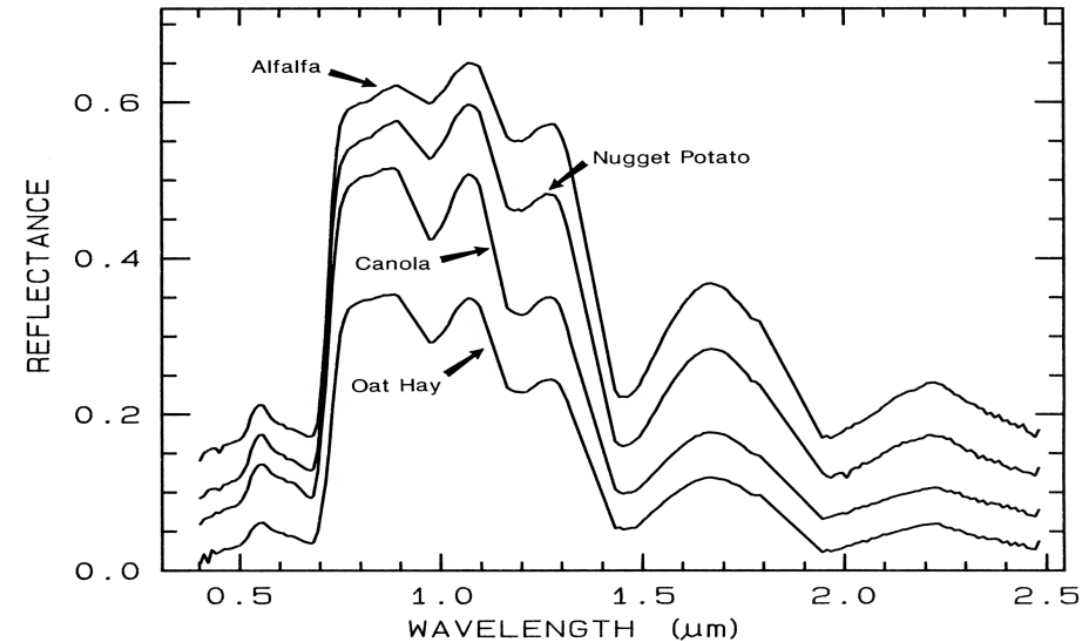
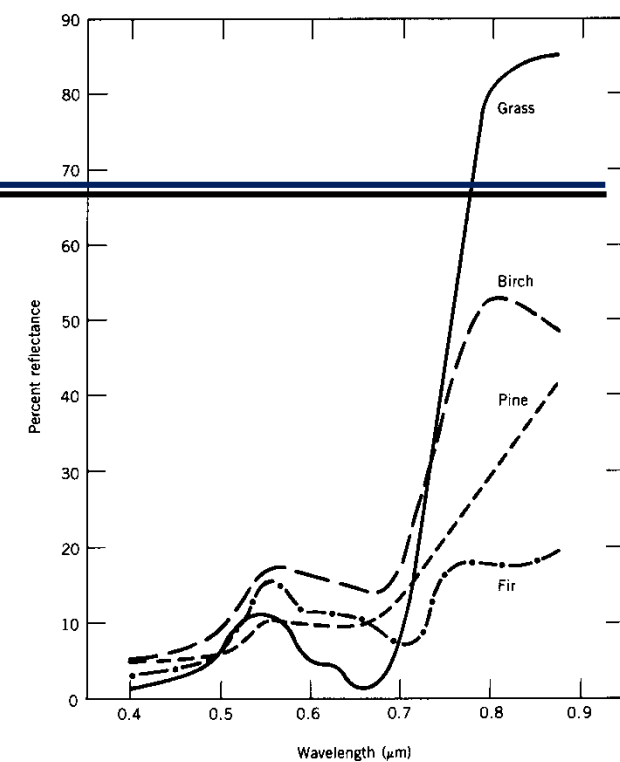




Vegetation Spectral Properties

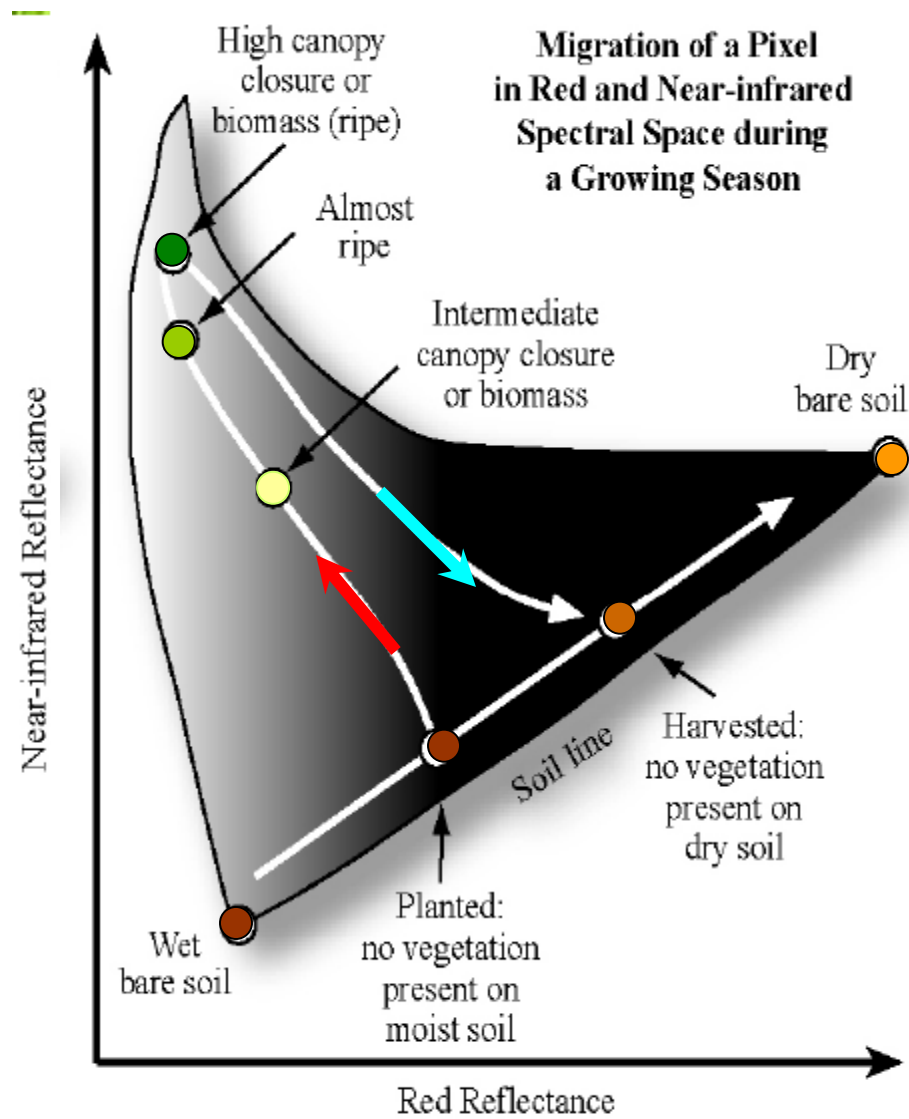
What are the differences in spectral signatures between different vegetation types?

- Cellular differentiation (protein, cellulose and lignin, water, pigments, etc.)
- Leaf characteristics (leaf angle and shape), leaf cover (LAI)
- Trunk, stem and branch variations (size, number, color)
- Vegetation size and form of vegetation cover



Distribution of pixels in a Scene in RED and NIR multispectral Feature Space

Increased biomass and / or vegetation cover results in increased reflection in the near infrared and reduced reflection in red.

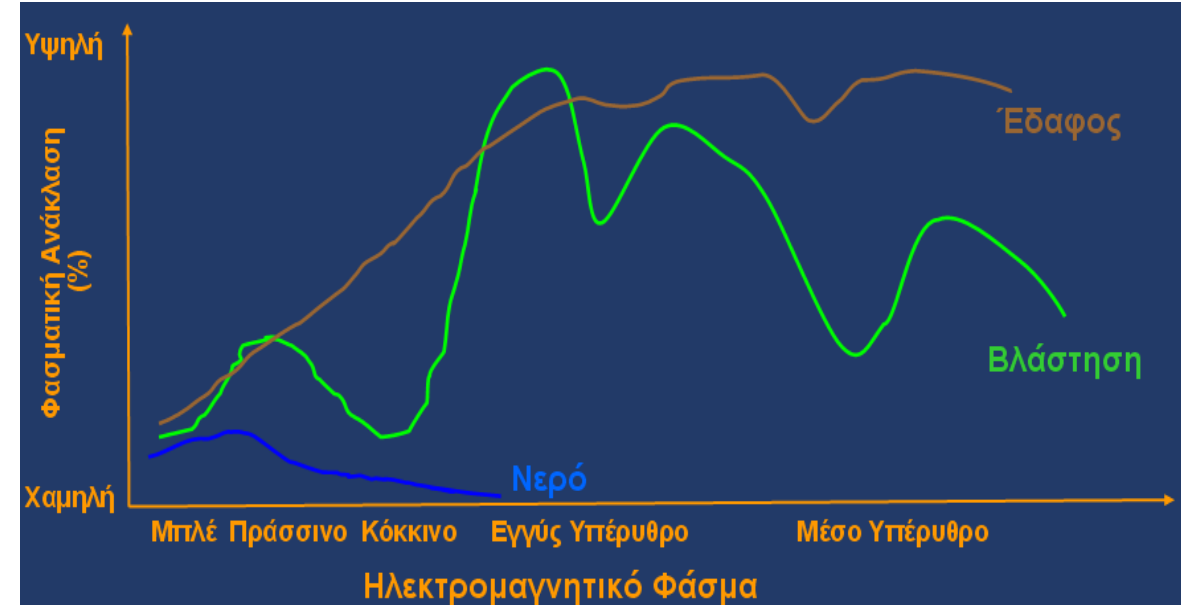


b.



Soils Spectral Properties

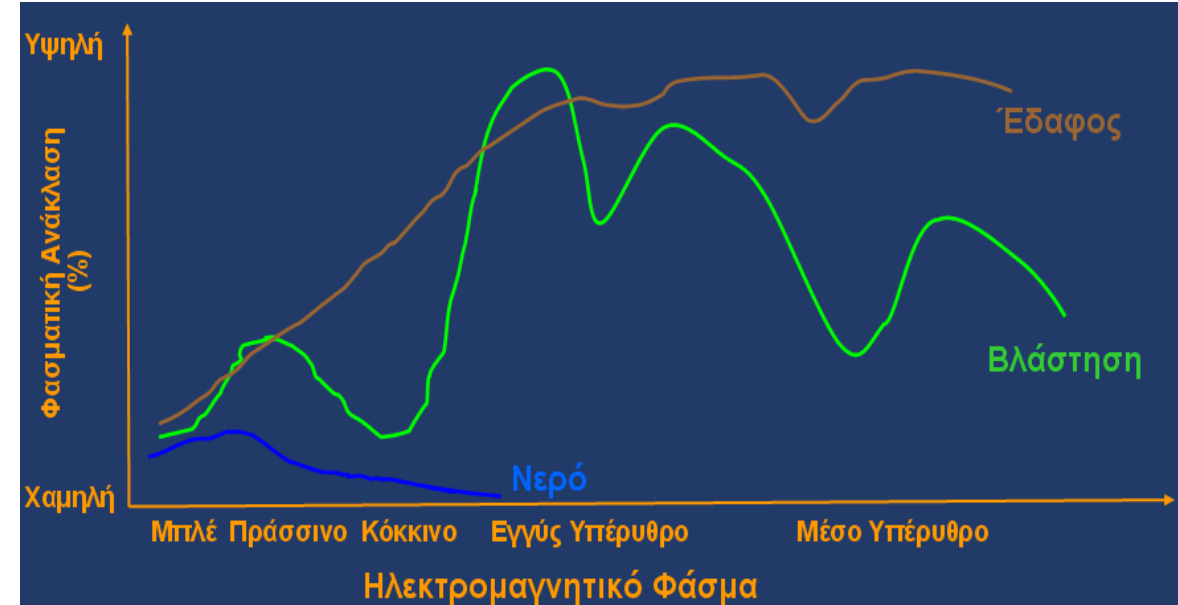
- Most of the incident radiation on the ground is either absorbed or reflected while only a very small portion of it is diffused.
- The reflectance of most soil types is similar and increases as a function of EM wavelength.
- The main factors affecting the reflection of a soil are:
 - **Moisture content**
 - **Organic substance**
 - **Texture and structure of soil**





Water Spectral Properties

- In the visible spectrum, only a very small part is reflected (<5%), most of the incident radiation diffuses.
- In the near- and mid-infrared portion of the EMF, the water strongly absorbs the incident radiation, leaving only a very small part of the radiation reflected or diffused.
- The main factors affecting water reflection are:
 - Depth of water
 - Materials in the water
 - Surface roughness of water





Vegetation Indices: Definition

Huete (1994) gave the following definition for vegetation indices

“ VI's are dimensionless, radiometric measures usually involving a ratio and/or linear combination of the red and near infrared (NIR) portions of the EM spectrum.

VI's may be computed from digital counts, at-satellite radiances, apparent reflectances, land leaving radiances, or surface reflectances and require no additional ancillary information other than the measurements themselves...

What VIs specifically measure remains unclear. They serve as indicators of relative growth and/or vigor of green vegetation, and are diagnostic of various biophysical vegetation parameters”.

...Therefore:

- **A vegetation index is a spectral transformation of two or more regions of the EM spectrum - a "synthetic image plane" - to enhance the "vegetation signal".**

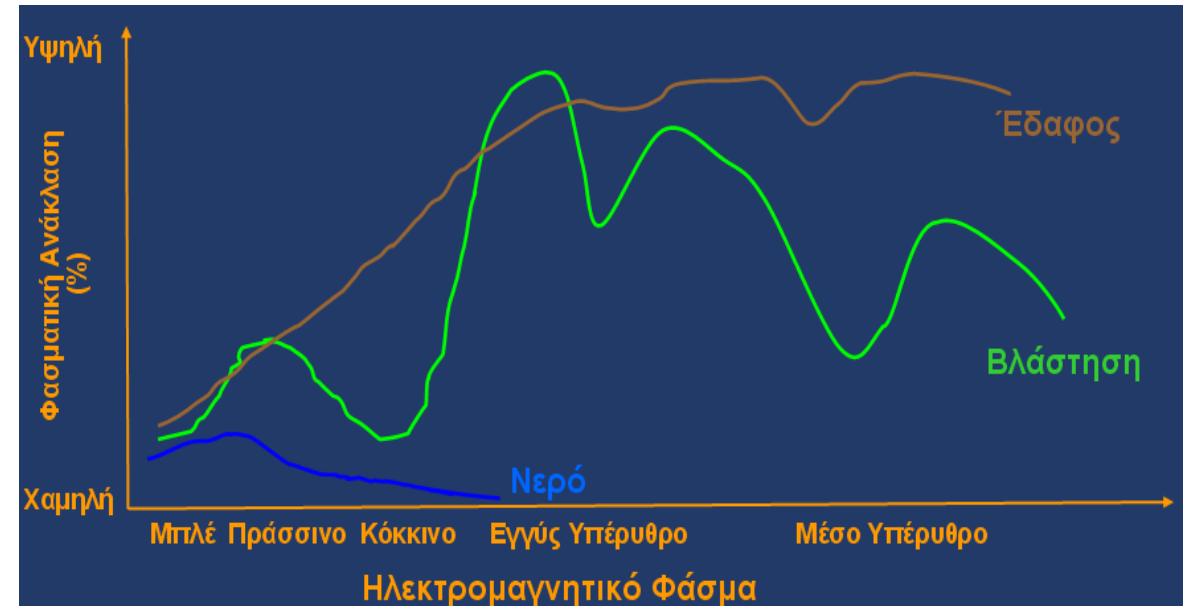


Simple Ratio

Simple ratio (SR)

This indicator is based on the inverse relationship between chlorophyll uptake in the NFR region and the increased reflectance coefficient in the near infrared, as is the case in healthy vegetation.

$$\text{Simple Ratio} = \frac{\rho_{RED}}{\rho_{NIR}}$$



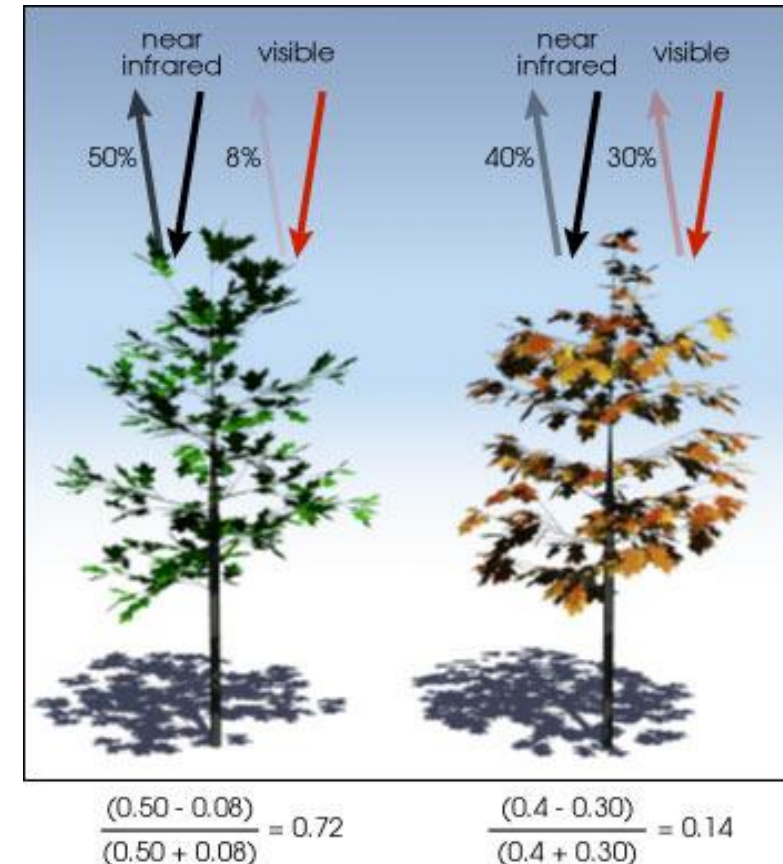


NDVI

Normalized Difference Vegetative Index (NDVI)

- Compared to SR, it is less sensitive to the effect of the atmosphere and to changes in incident radiation.
- NDVI has been used in methods developed to:
 - **monitoring the phenological cycle of different vegetation types**
 - **evaluation of drought periods**
 - **identification of ecological zones**

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}}$$





Fractional Vegetation Cover

1. Wittich & Hansing (1995)
Gutman & Ignatov (1998)

$$FVC = NDVI^*$$

$$NDVI^* = \frac{NDVI - NDVI_{\min}}{NDVI_{\max} - NDVI_{\min}}$$

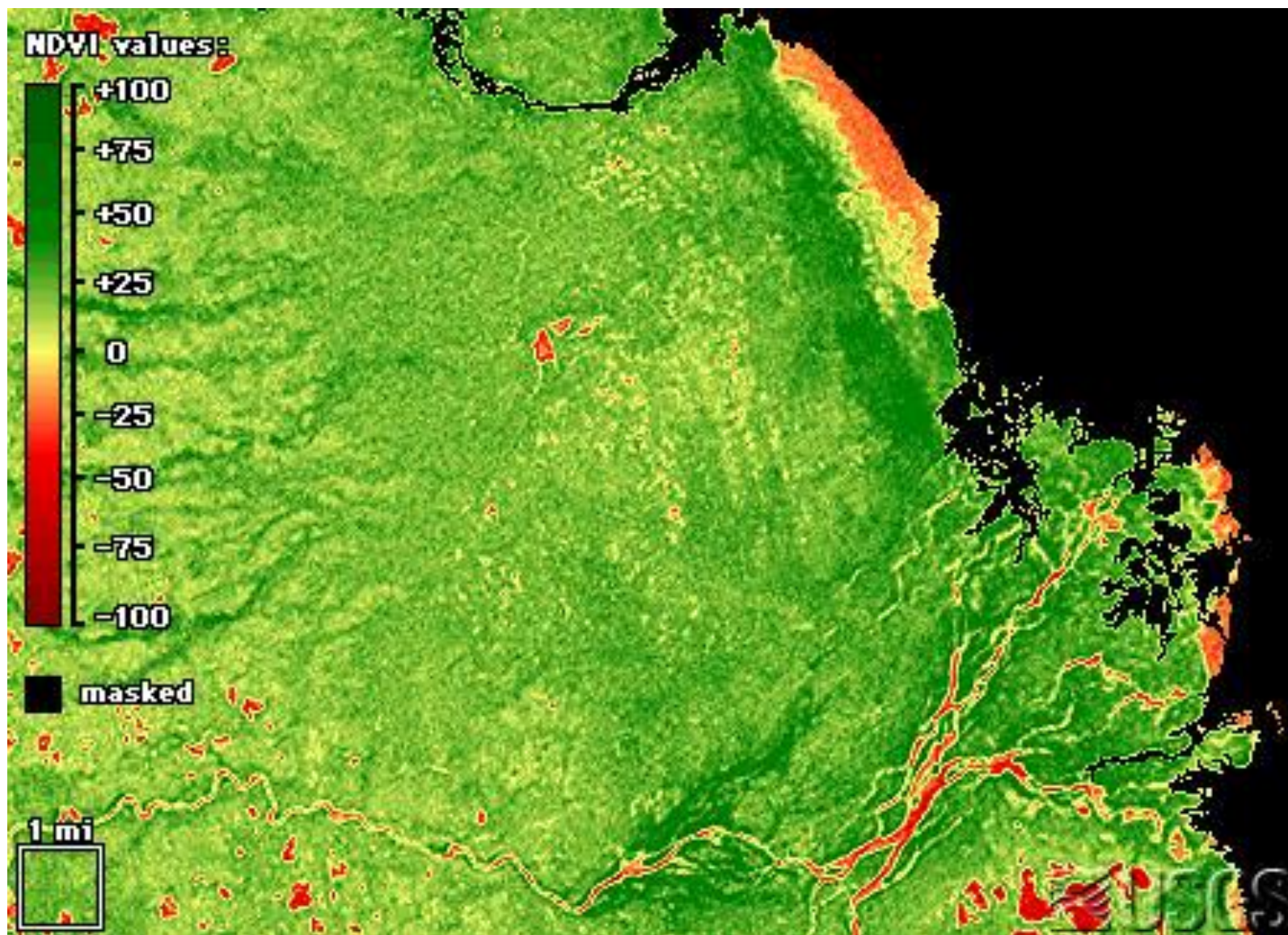
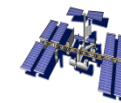
2. Carlson & Ripley (1995)

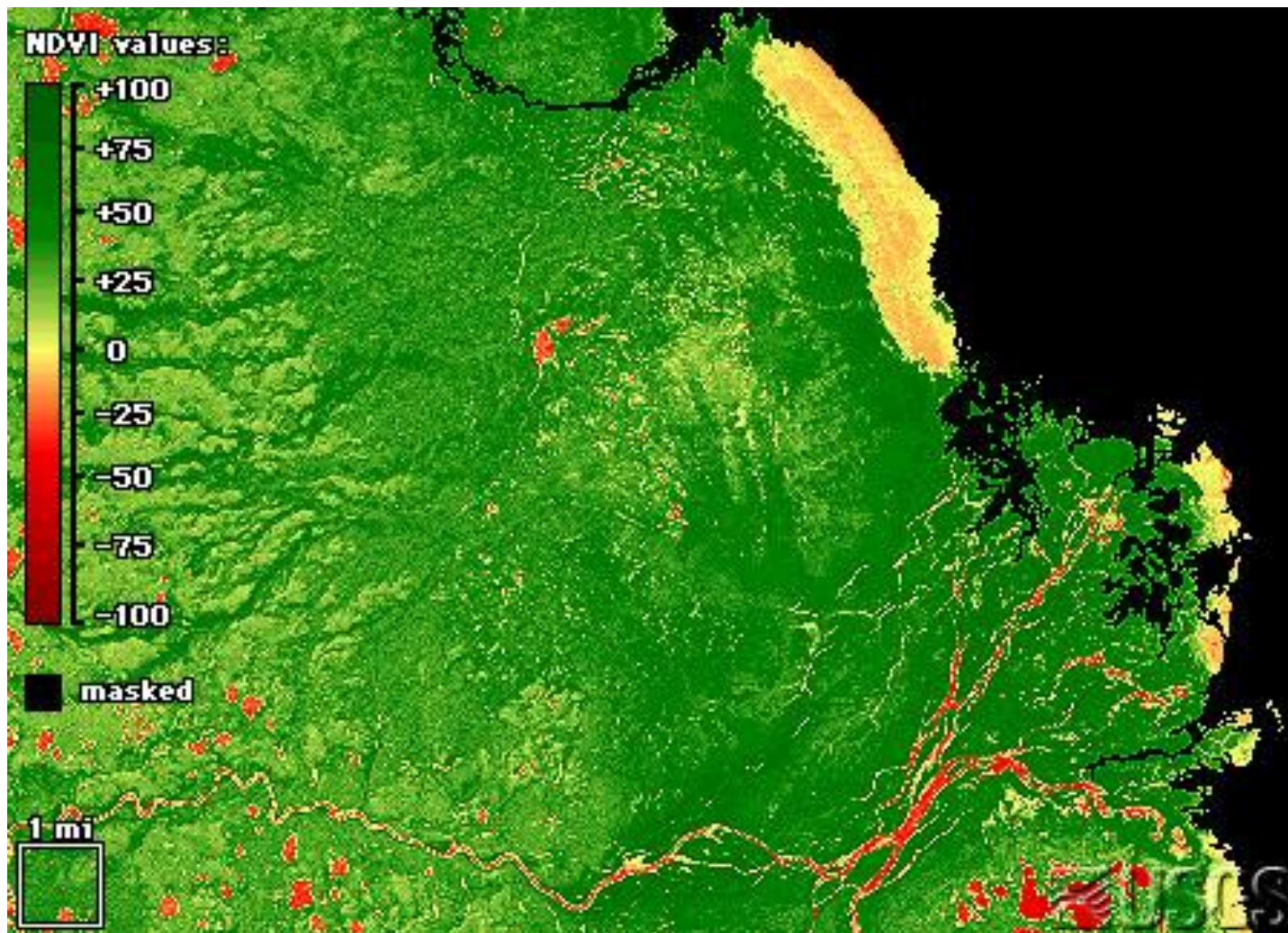
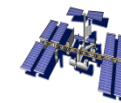
$$FVC = (NDVI^*)^2$$

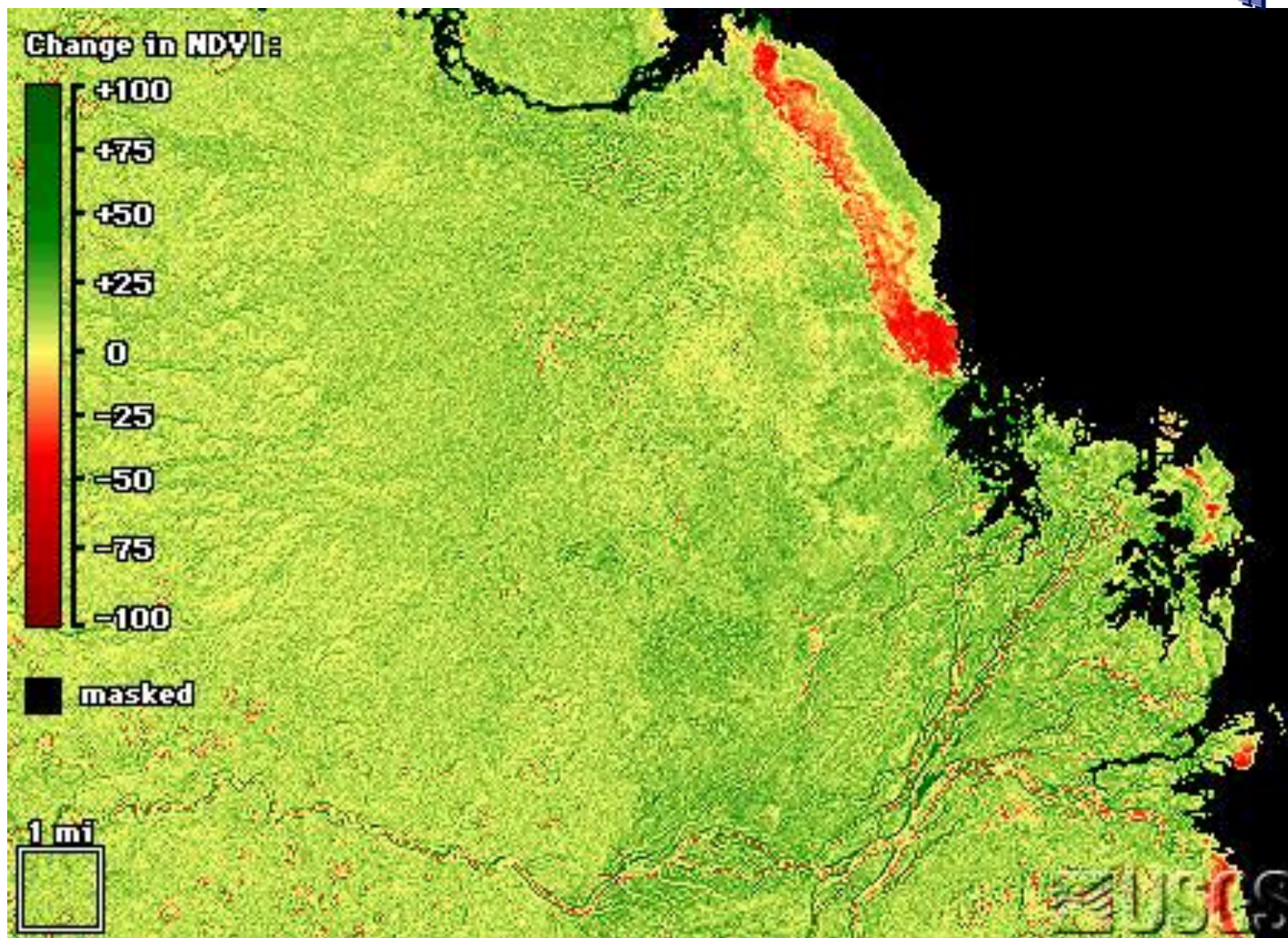
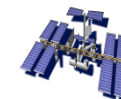
3. Valor & Caselles (1996)

$$FVC = \frac{\left(1 - \frac{NDVI}{NDVI_{\min}}\right)}{\left(1 - \frac{NDVI}{NDVI_{\min}}\right) - \kappa \left(1 - \frac{NDVI}{NDVI_{\max}}\right)}$$

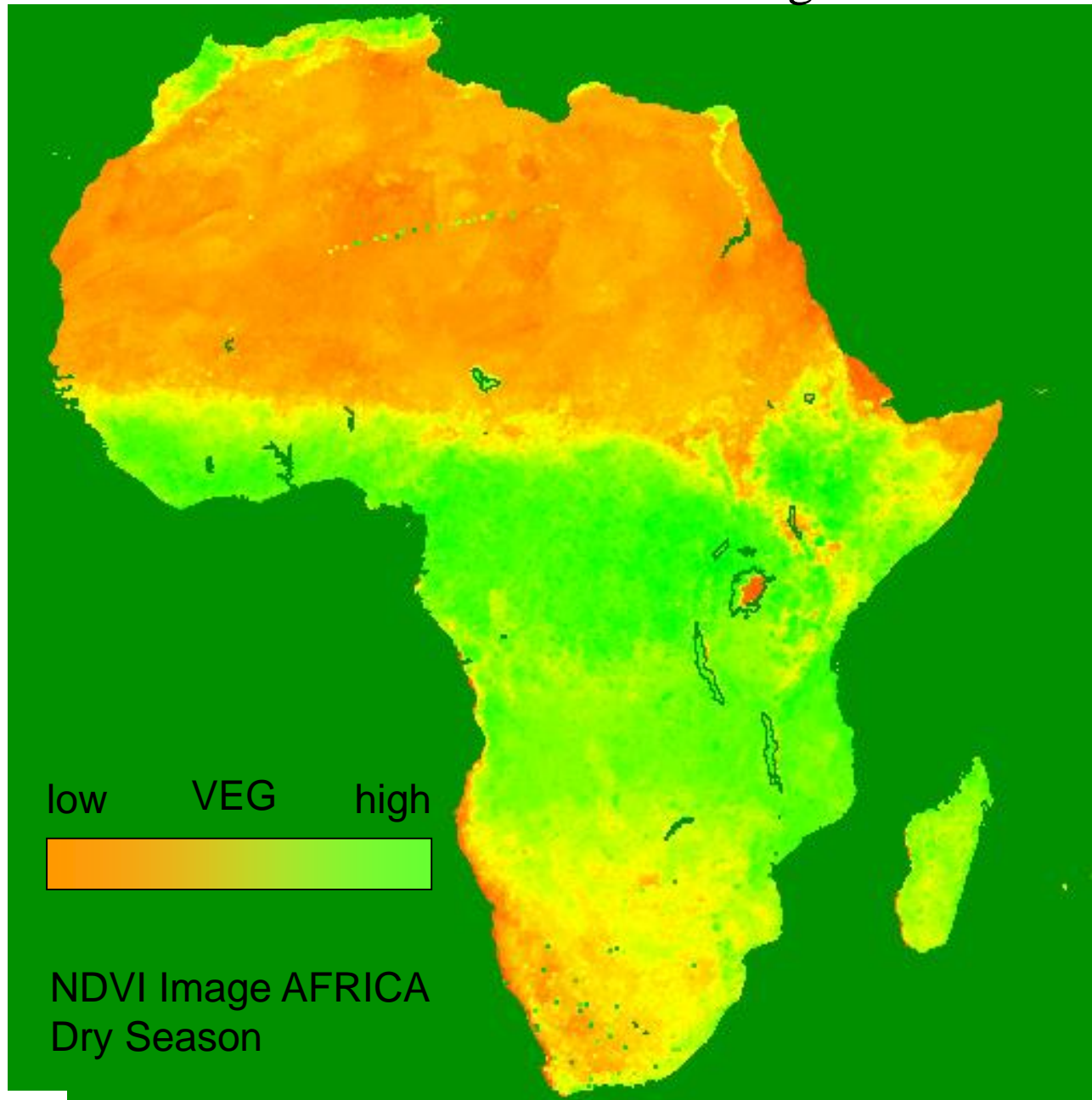
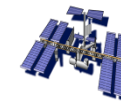
$$k = \frac{IRC_{veg} - R_v}{IRC_s - R_s}$$

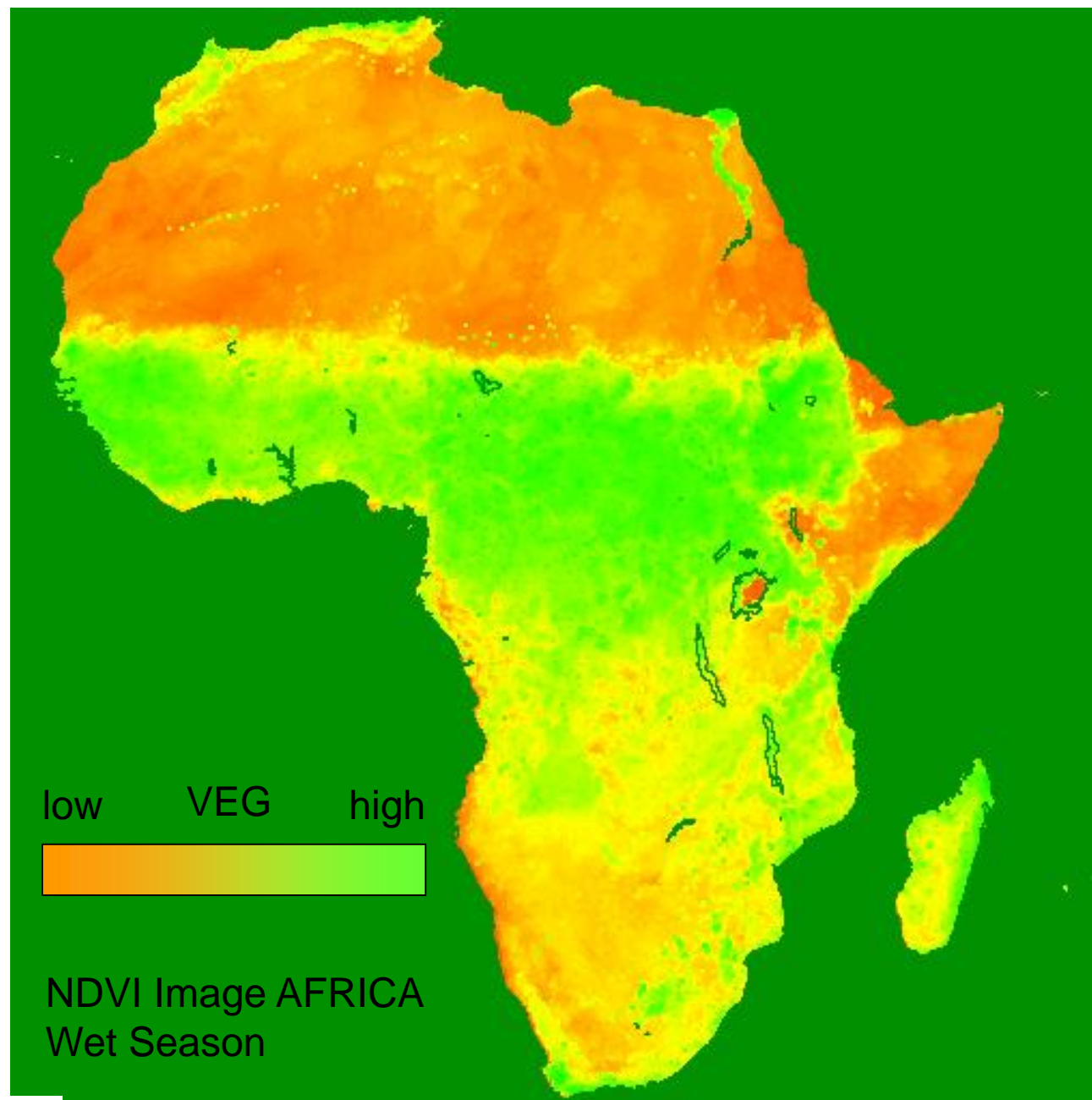
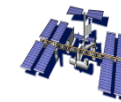


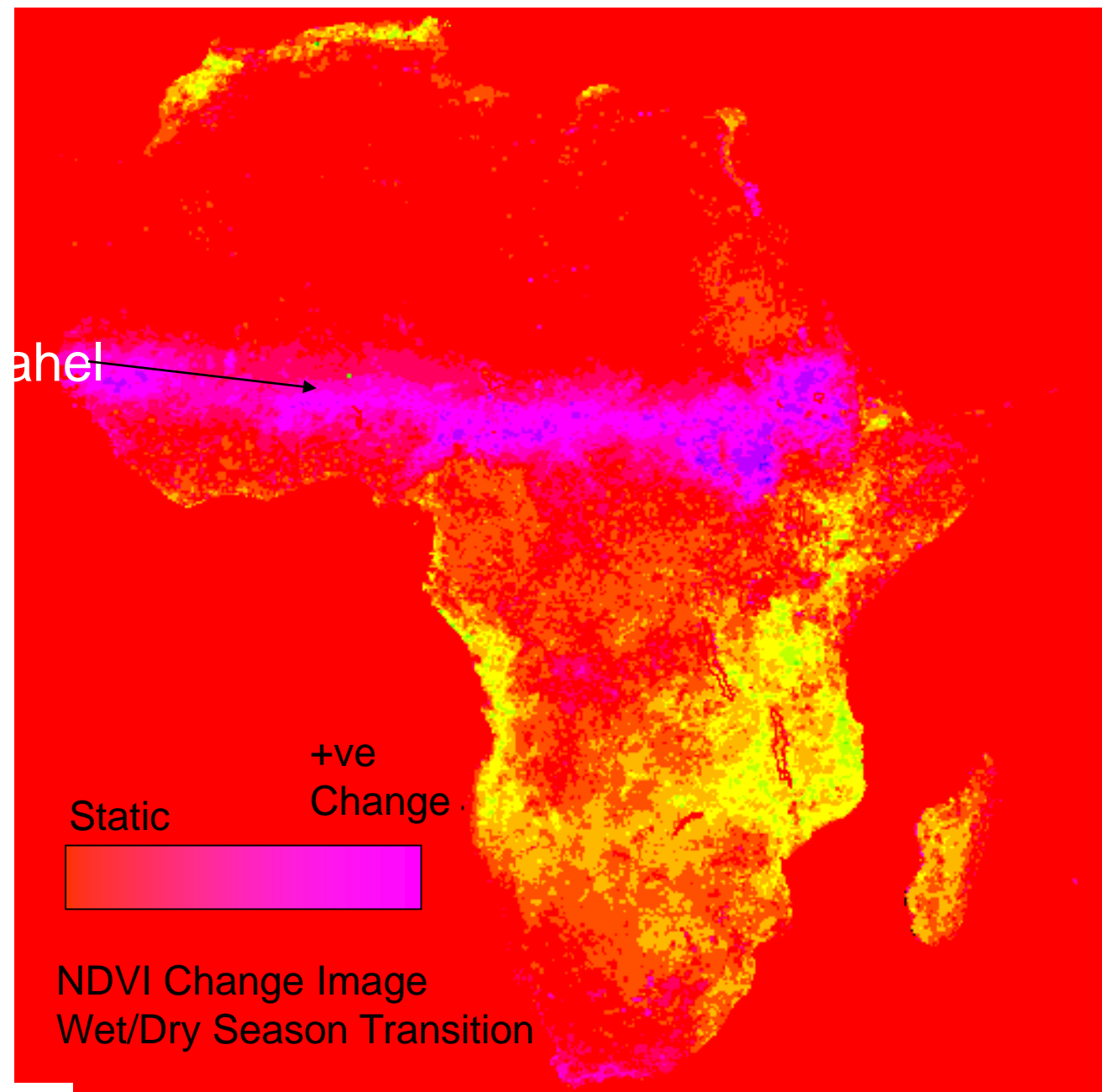
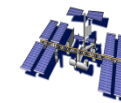




Continental Scale Changes









Soil Adjusted Vegetative Index (NDVI)

- It is an improved index, which introduces a soil calibration factor, L , into the NDVI equation to minimize the effects of soil resulting from spectral interactions between soil and vegetation.
- The value of $L = 0.5$ has been found to minimize variations in soil luminosity & eliminates the need for additional scoring for different types of soils.

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}}$$



$$SAVI = \frac{(1 + L)(\rho_{NIR} - \rho_{RED})}{\rho_{NIR} + \rho_{RED} + L}$$

Atmospherically Resistant Vegetation Index (ARVI)

- It is more sensitive than the SAVI index to the influence of the atmosphere
- Application of this indicator requires correction for the molecular diffusion and absorption of O₃ in the blue, red and near infrared region

$$ARVI = \frac{\rho^* nir - \rho^* rb}{\rho^* nir + \rho^* rb}$$

$$\rho^* rb = \rho^* RED - \gamma(\rho^* BLUE - \rho^* RED)$$



Visible Atmospherically Resistant Index (VARI)

- It is a continuation of the index (ARVI)
- This indicator is slightly sensitive to the influence of the atmosphere and allows the calculation of the fraction of photosynthetic vegetation with a <10% error

$$VARI_{green} = \frac{\rho_{GREEN} - \rho_{RED}}{\rho_{GREEN} + \rho_{RED} - \rho_{BLUE}}$$



Enhanced Vegetation Index (EVI)

- Has increased sensitivity in areas with high biomass
- It offers improved monitoring of vegetation biomass through the separation of the EM vegetation signal and a reduction in the effects of the atmosphere on the radiometric signal.

$$EVI = 2.5 \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + C_1 \rho_{RED} - C_2 \rho_{BLUE} + L}$$

L, is a regulating factor and C1 and C2 are coefficients used to correct for the effect of EM diffusion due to atmospheric diffusion.

The coefficients, C1, C2, and L, are empirically determined as 6.0, 7.5, and 1.0, respectively.



EVI

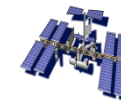
NDVI

EVI

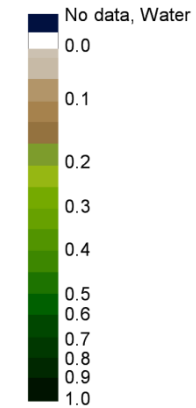


EVI shows better dynamic range, less saturation

MODIS 500 m Vegetation Indices

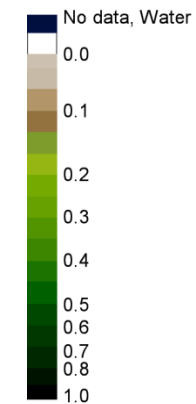


NDVI



**MOD13A1 16 day
Composite**

EVI



MODLAND/Huete et al



NDMI

Normalized Difference Moisture or Water Index (NDMI or MDWI)

- The indicator (NDMI or MDWI) is closely related to the content of vegetation in water.

$$NDMI = \frac{NIR - SWIR}{NIR + SWIR}$$

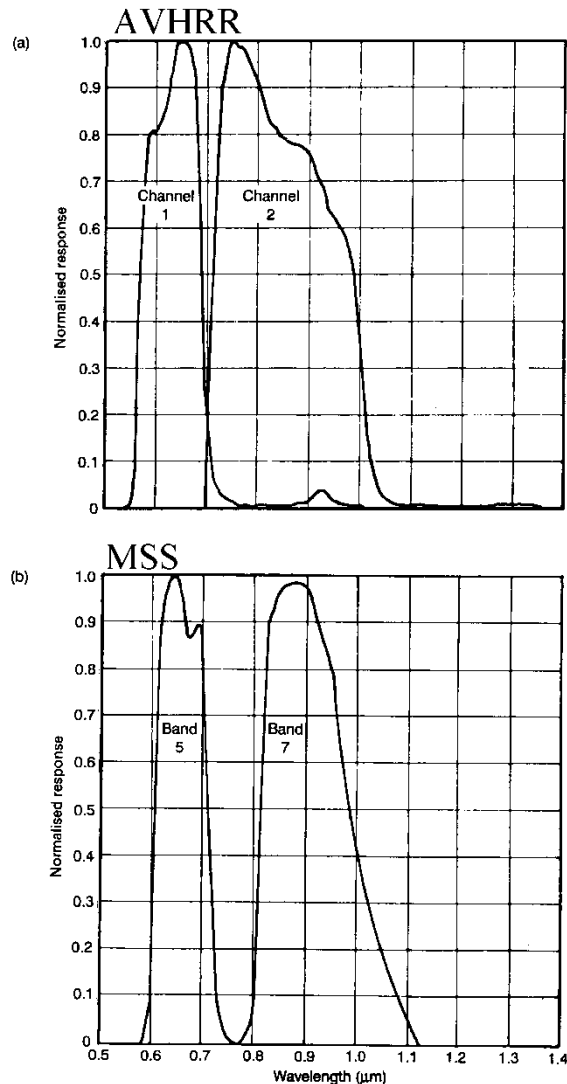


Factors Affecting VIs

- Various factors (other than vegetation itself) can influence observation by radiometric vegetation indices:
 - **Impact of the atmosphere**
 - **Differences in instantaneous incident solar radiation**
 - **Dimensions of the unit surface on which the% reflectance measurement is attempted**
 - **The speed of the air**
 - **The zenith angle of the receiver (off-nadir viewing effects)**
 - **Differences in satellite**
 - **Changes in the radiometric characteristics of the satellite**
 - **Gradual degradation of the satellite sensor**

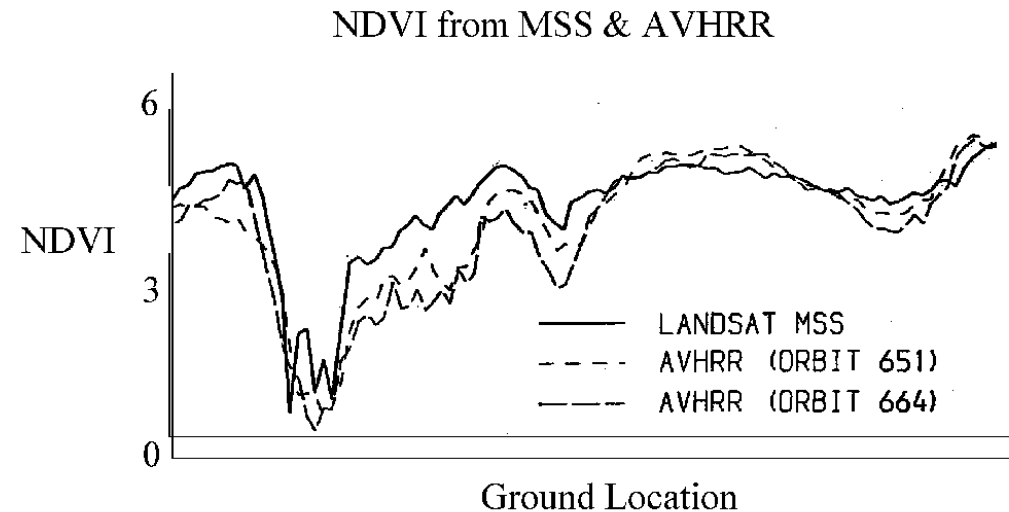


Factors Affecting VIs



Example:

Performance of different spectral response in red and near infrared between sensors results in different NDVI values





Factors Affecting VIs

Example 2:

The change of the satellite sensor and its gradual deterioration affect the relationship between DN and radiance / reflectance and consequently NDVI values.

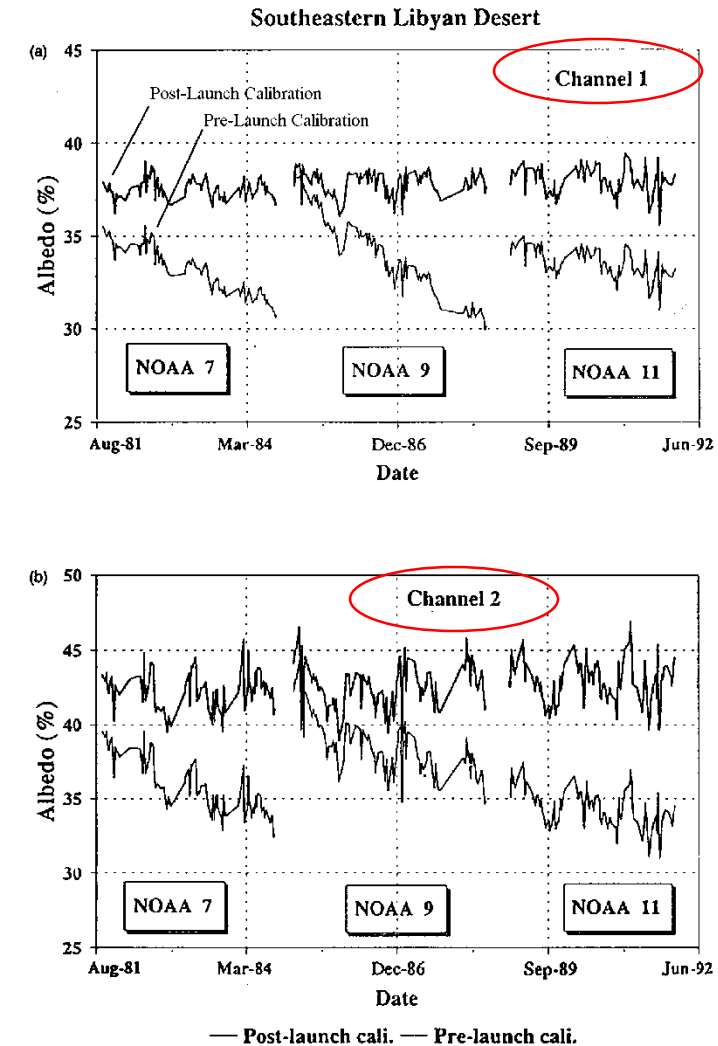


Figure 2.18 Isotropic albedo in (a) channel 1 and (b) channel 2 of the southeastern Libyan desert (Rao and Chen 1994).

Top 10 cited VI papers

rank	Published work	citations
1	Tucker 1979, Remote Sens. Environ. 8:127-150	780
2	Schlesinger et al. 1990, Science 247:1043-1048	559
3	Turner 1989, Annual Review Ecology and 20:171-197	558
4	Myneni et al. 1997, Nature 386:698-702	525
5	Noilhan J. 1989, Monthly Weather Review 117:536-549	480
6	Holben B.N., 1986, Intl. J.Remote Sens. 7:1417-1434	476
7	Tucker et al. 1985, Science 227:369-375	401
8	Justice et al. 1985, Intl. J.Remote Sens. 6:1271-1318	384
9	Walther et al. 2002, Nature 416:389-395	384
10	Potter et al. 1993, Global Biogeochem. Cycles 7:811-841	375

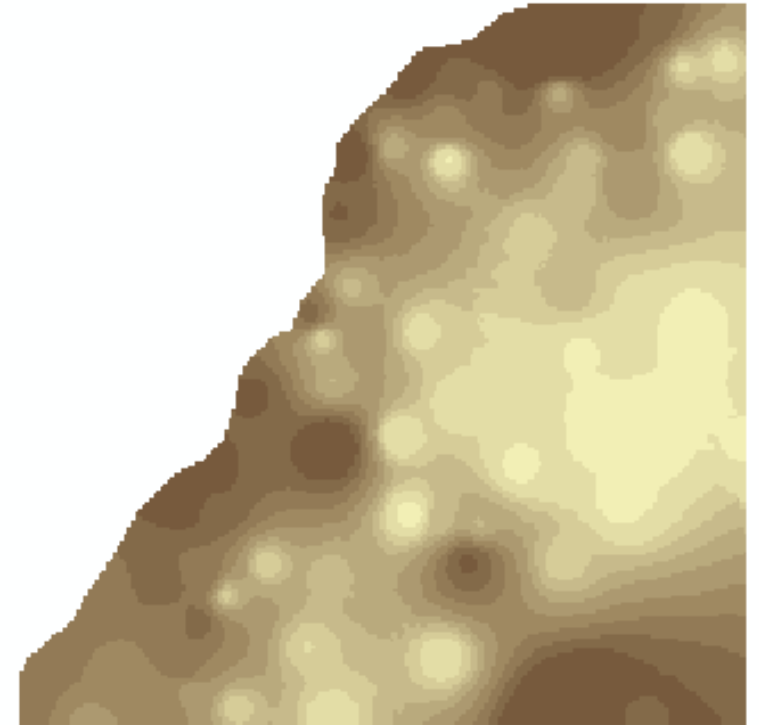
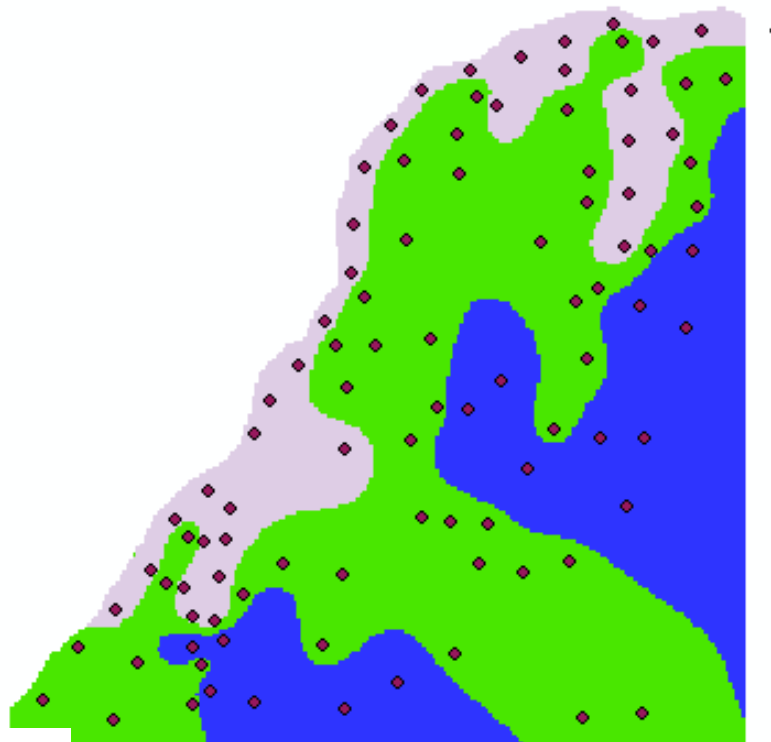
Thank you very much for your attention

Interpolimi Hapsinor

Dr. George P. Petropoulos

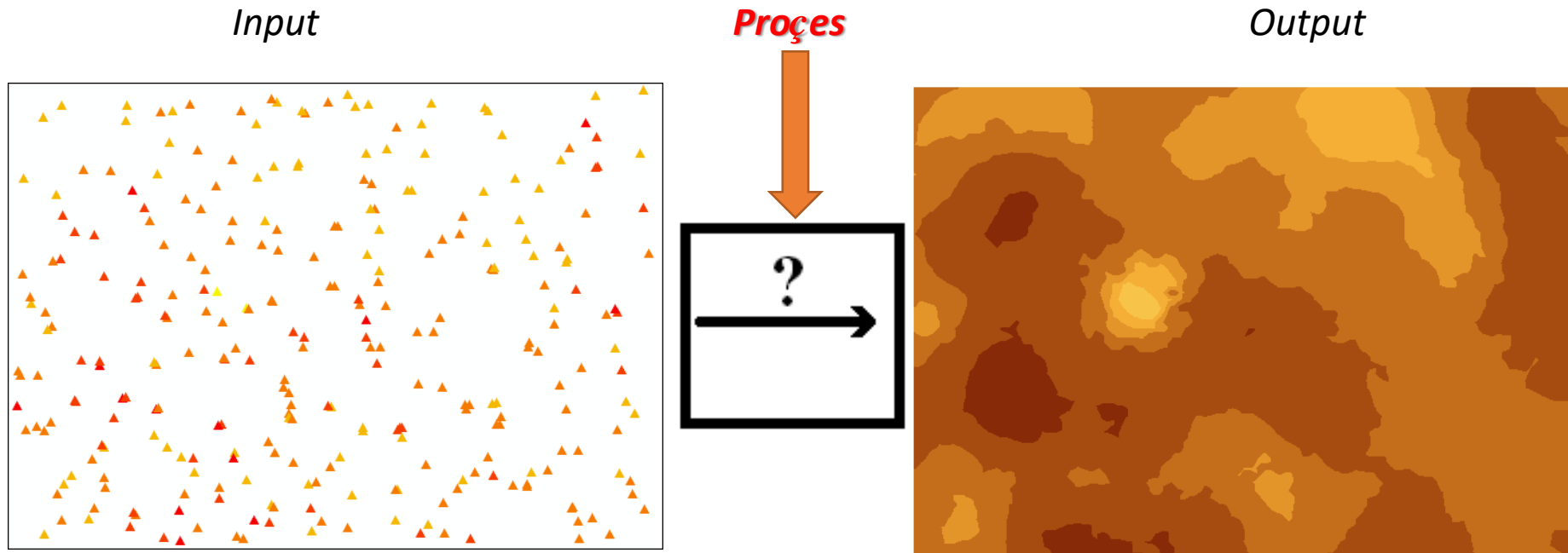


Interpolimi Hapsinor wshtw llogaritja e vlerws sw tipareve tw stacioneve tw ndryshme brenda zonws sw mbuluar nga vrojtimet ekzistuese.



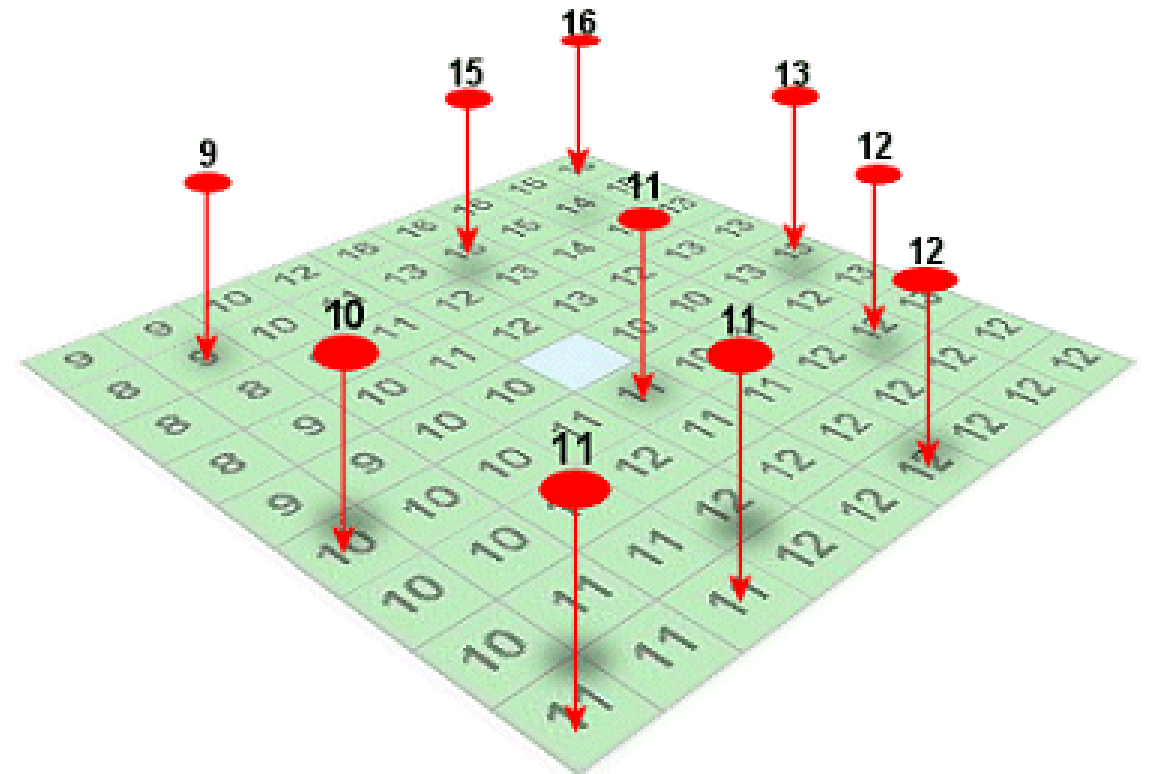


Interpolimi Hapsinor wshtw llogaritja e vlerws sw tipareve tw stacioneve tw ndryshme brenda zonws sw mbuluar nga vrojtimet ekzistuese.





Zakonisht Racional: pikat qe jane me afer njeri-tjetrit kane mundesi te kene vlera te ngjashme krahasuar me pikat me te largeta (Ligji i Toblerit)





Ligji i Parw nw Gjeografi

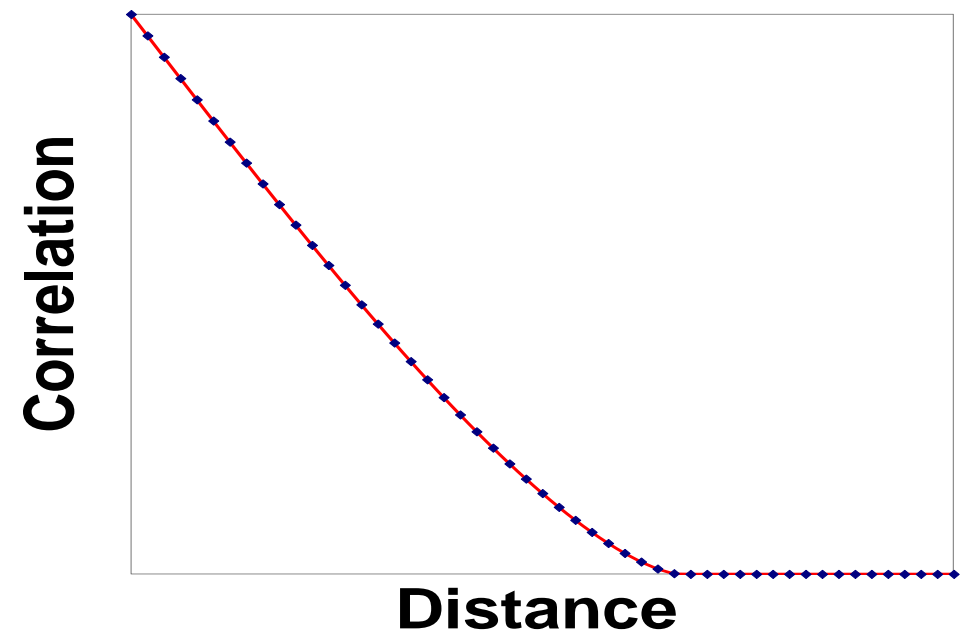
- *“Çdo gje eshte e lidhur me diçka tjeter,por gjerat me te aferta jane me shume te lidhura sesa gjerat qe ndodhen me larg”Waldo Tobler (1970)*
- Kjo perben nje premise bazike mbrapa interpolimit dhe pikat me te aferta zakonisht marrin peshe me te madhe sesa pikat me te largeta.





Ligji i Parw nw Gjeografi

“Çdo gje eshte e lidhur me diçka tjeter, por gjerat me te aferta jane me shume te lidhura sesa gjerat qe ndodhen me larg” Waldo Tobler (1970).





Interpolimi vs Ekstrapolimit

Supozon njw siperfaqe te vazhdueshme qe merret si model.

Interpolimi

- Vleresimi i vlerave atribut te vendodhjeve qe gjenden **brenda games se vlerave ekzistuese** duke perdorur vlera te te dhenave te njohura.

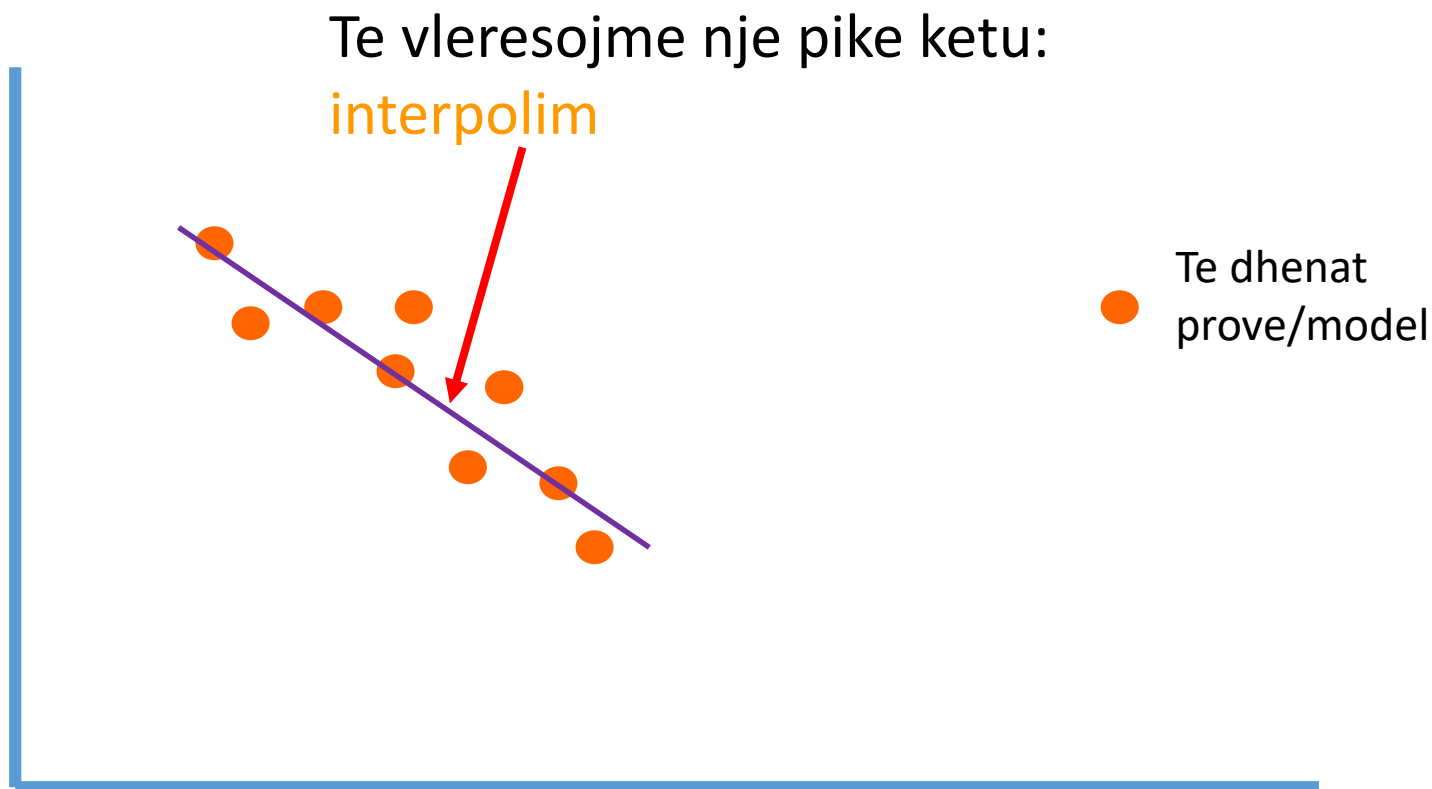
Ekstrapolimi

- Vleresimi i vlerave atribut te vendodhjeve qe gjenden **jashte games se vlerave ekzistuese** duke perdorur vlera te te dhenave te njohura.



Interpolimi vs Ekstrapolimit

Interpolimi





Interpolimi vs Ekstrapolimit

Ekstrapolimi





Kur nevojitet Interpolimi ?

Per te konvertuar te dhenat nga vrojtime ne forme pike ne fusha te vazhdueshme, modelet hapsinore te perzgjedhur nga keto matje mund te krahasohen me modelet hapsinore ose entitetet e tjera hapsinore.

Kur sipërfaqja diskrete ka një nivel të ndryshëm rezolucioni, madhësi qelizash ose orientim nga ajo që kërkohet.

Psh. Konvertimi i imazheve të skanuara (dokumentave, fotove ajrore ose imazheve satelitore) nga një mozaik i rrjësuar me një madhësi të dhene/ose orientim tjetër. Kjo procedurë njihet si përdredhje (convolution)

Kur një sipërfaqe e vazhdueshme përfaqësohet nga një model të dhënash që është i ndryshëm nga ai që kërkohet.

Psh: poligon vektor në raster.

Kur të dhënat që kemi nuk mbulojnë fushën e interesit plotësisht (psh janë mostra/kampione).

Psh: Shndërrimi i të dhënave nga grupe të pikave prove në një sipërfaqe të vazhdueshme diskrete.



Vizualizimi i Siperfaqeve te Panderprera

Siperfaqet e vazhdueshme/panderprera qe vijne nga interpolimi hapsinor jane perdorur zakonisht individualisht ose si mbivendisje shtresash ne GIS qe perfaqsohen nga **imazhe** ose **vija**.

Metodat e imazheve perfshijne ndertimin e rrjeteve te rregullt ose te ç'rregullt ku variacioni i vlerave te attributeve te hartografuara paraqitet nepermjet zonat e shkallezuara sipas niveleve te ngjyrave te ndryshme ose ngjyres gri.

Perfaqsimi nepermjet vijave perfshin **izovijat** (vija me vlera te barabarta), nderprerjet vertikale(profilet) dhe vijat kritike si: kreshtat, rrjedhiet ujore, vijen bregdetare dhe thyerjet e shpateve.

...Metoda me vija dhe e imazheve mund te kombinohen te dyja per te rritur shkallen e perceptimit....



Burimet e te dhenave per Interpolimin

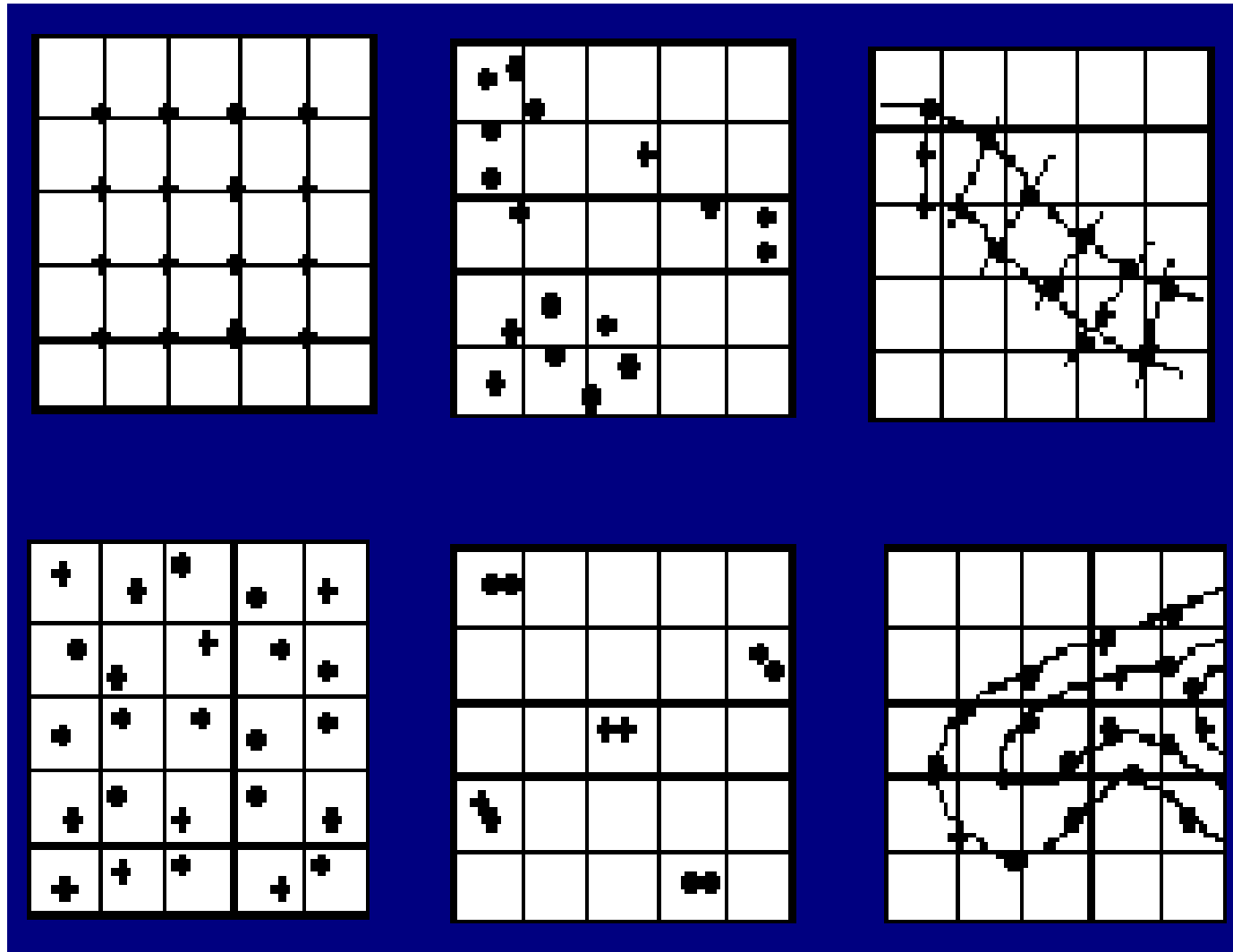
Shume te dhena per interpolim vijne nga **kampionimi** i nje modeli kompleks i variacionit bazuar ne pak pika. Keto matje njihen shpesh si: “ **te dhena te veshtira**”

Burimet e te dhenave per siperfaqet e vazhdueshme perfshijne:

1. Fotot ajrore stereo
2. Fotot ajrore qe mbivendosin imazhet satelitore duke perdorur fotogrametrine.
3. Skanerat ne satelitet ose aeroplanet dhe skanerat e dokumentave.
4. Pikat prove/kampion e attributeve te matura direkt ose indirekt ne terren ratesisht,e strukturuar ose modelet e kampionimit linear si transektet e rregullta ose konturet e dixhitalizuara.
5. Poligonet e dixhitalizuara/Hartat.



Metodat e Zgjedhjes/kampionimit



1. Rregullt
2. Rastesishme
3. Terthorazi
4. Rastesisht shtresezuar
5. Ne tufa
6. Konture

e



Klasifikimi i Metodave te Interpolimit

- ☐. Linear – Jo Linear
- ☐. Global – Lokal
- ☐. E sakte – E perafert
- ☐. Deterministike – Stokastike
- ☐. Graduale / Menjehershme



Interpolimi Linear

Te dhena per vleresima

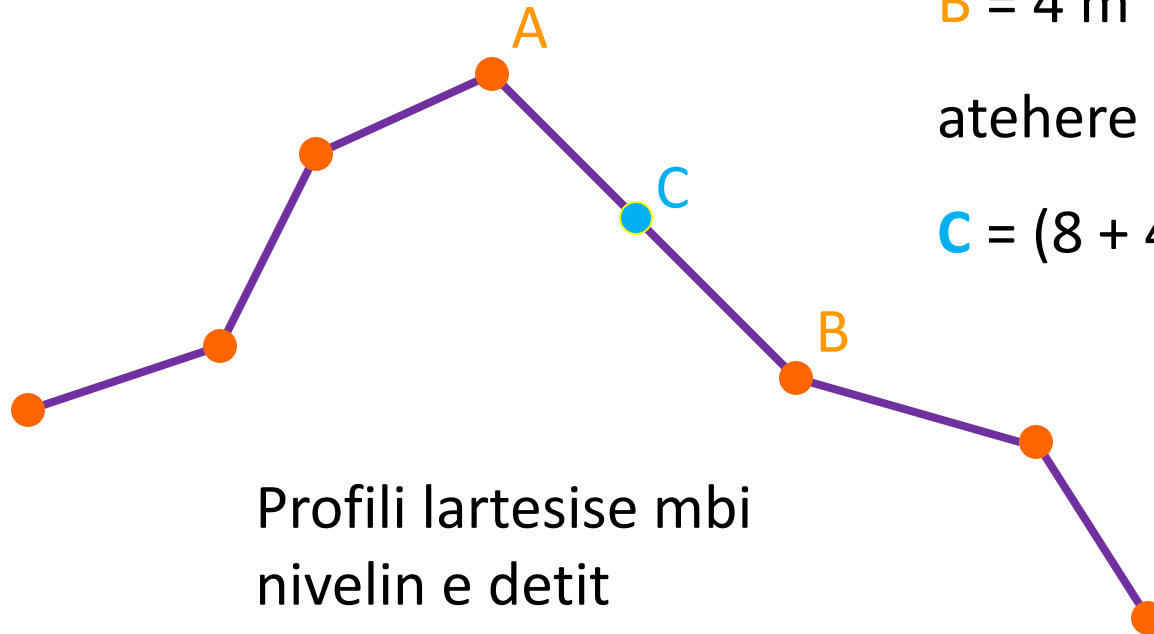
Nese

$A = 8 \text{ m}$ dhe

$B = 4 \text{ m}$

atehere

$C = (8 + 4) / 2 = 6 \text{ m}$



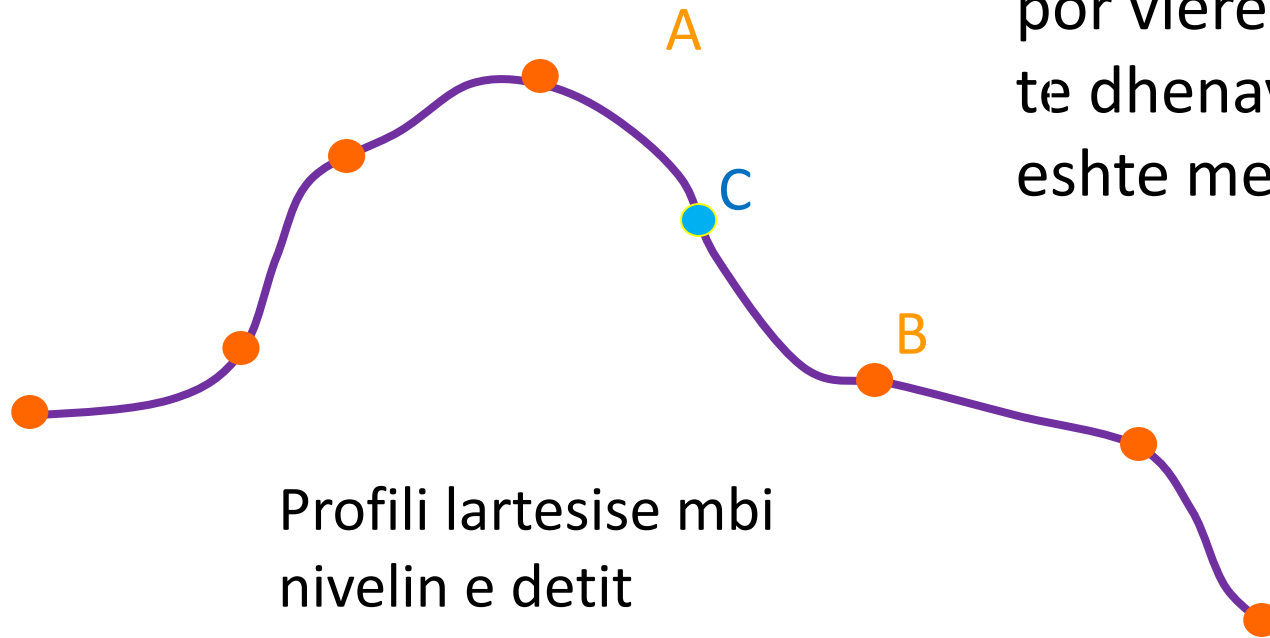
Profili lartese mbi
nivelin e detit



Interpolimi Jo-linear

- Te dhenat prove

Shpesh rezulton ne nje interpolim me realistik, por vleresimi i vlerave te te dhenave qe mungojne eshte me kompleks.

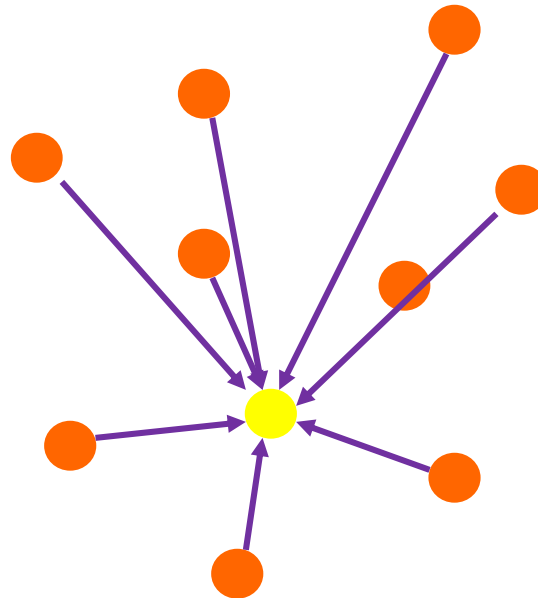




Interpolimi Global

Perdor **te gjitha pikat e zgjedhura** per te llogaritur vleren e nje pike me vendodhje te ndryshme.

Percaktohet nje funksion i vetem i cili perdoret permes te gjithe rajonit (psh: trendi i siperfaqes) .



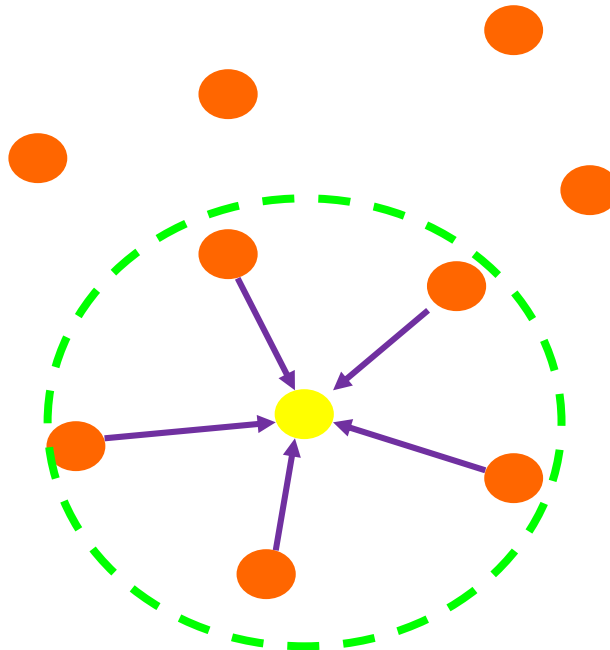
● Te dhenat
prove



Interpolimi lokal

Perdorimi i **pike prove fqinje** per te vleresuar nje vlere ne nje vendodhje jo te zgjedhur.

Perdoret nje algoritem ne menyre te perseritur ne nje numer te vogel pikash nga grupi total i pikave (psh: distanca e ponderuar e anasjellte).



- Te dhenat/pikat prove

Perdoret nje pike **fqinje** lokale per te llogaritur vleren: psh: n pikat me te aferta ose brenda nje rreze te dhene.



Interpolimi i sakte kundrejt interpolimit te perafert

❑. Interpoluesit e sakte nderojne te gjitha pikat e te dhenave

✓ psh. *Distanca e ponderuar e anasjellte.*

❑. Interpoluesit e perafert perpiqen ti afrohen te gjitha pikave te te dhenave.

✓ Psh. *Trendi i siperfaqes*



Interpolimi Gradual/i menjehershëm

- ❑. Interpoluesit gradual marrin ne konsiderate sjellien e vazhdueshme ose te bute te te dhenave kudo.
- ❑. Interpoluesit e menjehershem lejojnë ndryshime te papritura ne te dhenat per shkak te kufijve ose derivateve te papërcaktuara.

METODAT GLOBALE



Analiza e Tendences se Siperfaqes

Gjetja e siperfaqes qe pepruthet me pikat prove duke perdorur **metoden e regresionit te katroreve minimal/me te vegjel**.Percaktohet nje ekuacion polinomial per te gjithë siperfaqen. Eshte nje interpolator **jo i sakte** dhe mund te jete **linear** ose **jo linear**.

Kjo rezulton ne nje siperfaqe qe minimizon variacionin e siperfaqes ne lidhje me vlerat e perdorura ne llogaritje.

Siperfaqja eshte ndertuar dhe per çdo pike, totali i differences midis vlerave aktuale dhe vlerave te llogaritura (psh: varianca) do jete sa me e vogel te jete e mundur.



Analiza e Tendences/Trendit te Siperfaqes

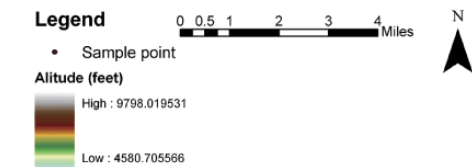
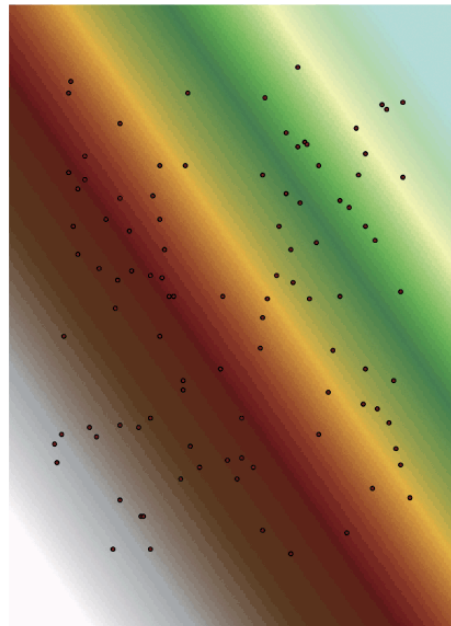
Kjo metode zbulon tendendcen **ne te dhenat prove** dhe eshte e ngjashme me fenomenet natyrrore qe tipikisht variojne bute.

Ajo zbulon pjese te nje zone studimi qe ka edhe shmangien me te madhe nga nje tendence e pergjithshme.

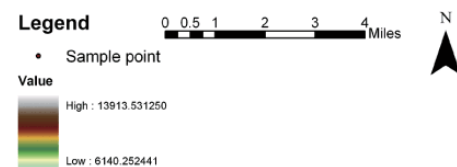
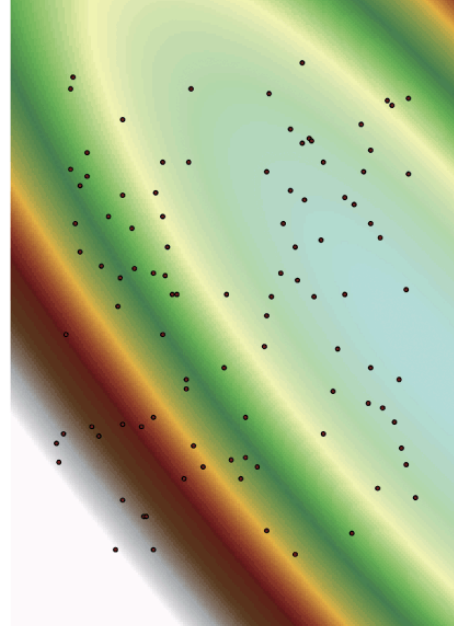
Perdorimi kryesor ne analizen e trendit te siperfaqes, nuk eshte ai i interpoluesit brenda nje rajoni, por **si nje menyre per te larguar vecori/tinare te shumta te te dhenave** perpara se te perdoren interpolues



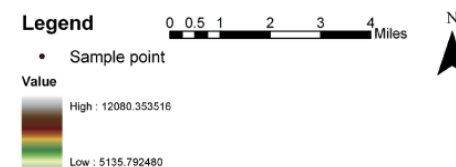
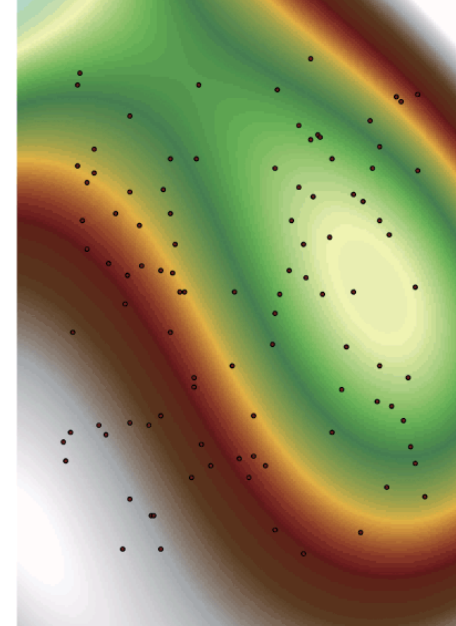
Analiza e Tendences/Trendit te Siperfaqes



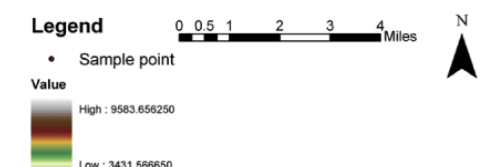
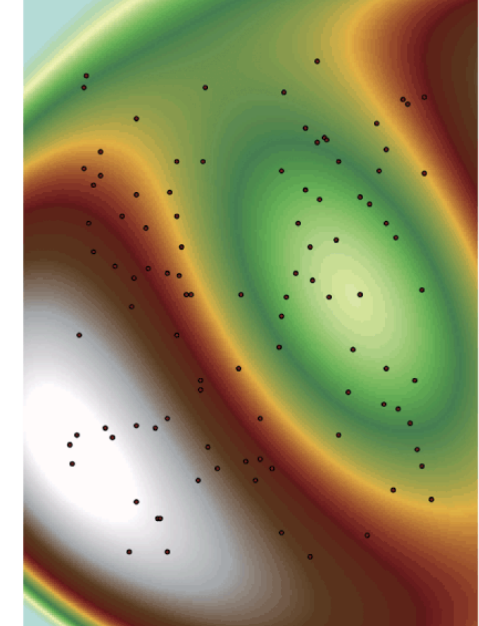
(c) Trend surface 1st order polynomial



(d) Trend surface 2nd order polynomial



(e) Trend surface 3rd order polynomial



(f) Trend surface 4th order polynomial

Burimi: Heywood et al., 2011



Metodat Globale – Modelet e Regresionit

Ajo ben lidhjen midis variablit te varur me nje numer variablash te pavarur ne nje ekuacion linear (nje interpolues), i cili mund te perdoret per parashikimin ose vleresimin.

Ne mund te parashikojme variacionin hapsinor te nje prone, nese dime variacionin hapsinor e nje ose me shume veçorive/tipareve qe lidhen me kete prone.

Modeli i regresionit qe do perdoret eshte i formes:

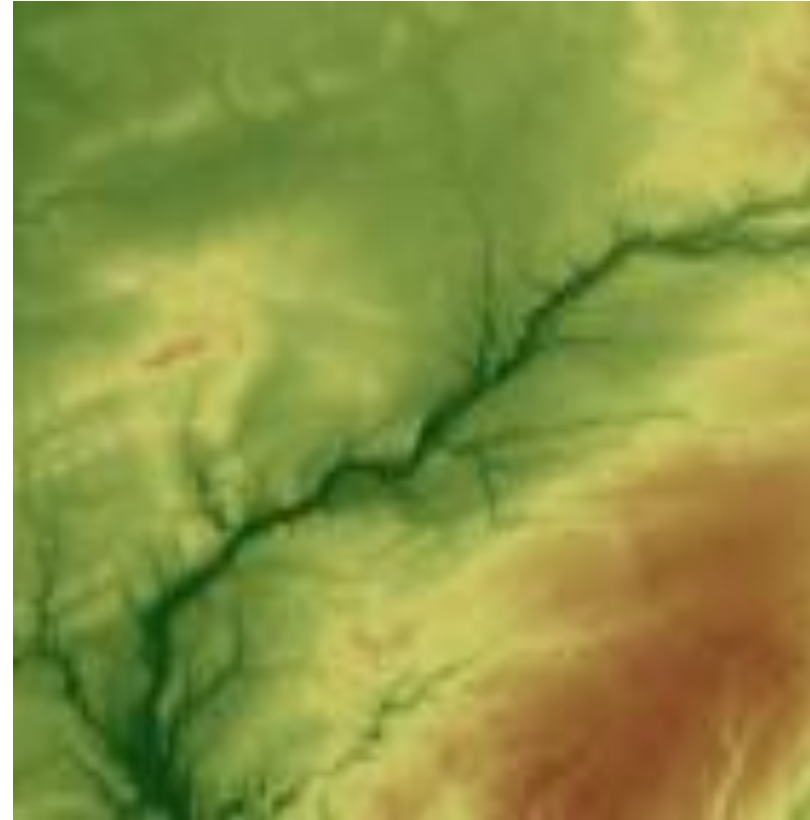
$$Z(x) = \sum b_i * P_i + \epsilon$$

ku: **b_i** = koeficienti i regresionit

P_i = karakteristikat e pavarura



Metodat Globale – Modelet e Regresionit



METODAT LOKALE



Metodat Lokale

Percaktohet vlera e nje karakteristike te nje pike nga nje numer i kufizuar i pikave te tjera qe jane te aferme me te.

Procedura e pergjithshme eshte:

1. Percaktojme nje zone kerkimi ose fqinje perreth pikes qe do parashikohet.
2. Gjejme pikat e te dhenave brenda kesaj zone fqinje
3. Zgjedhim nje funksion matematik per te perfaqshuar variacionin mbi kete numer te kufizuar pikash.
4. Vleresojeni ate bazuar ne piken qe i perket nje rrjeti te rregullt.
5. Procedura perseritet derisa te gjitha pikat ne rrjet te jene llogaritur.



Metodat Lokale

❖ Metodat deterministike/lokale per interpolim duhet te adresojne çeshtjet e meposhtme:

- ✓ Llojin e funksionit te interpolimit qe do perdoret.
- ✓ Madhesine, formen dhe orientimin e pikave fqinje
- ✓ Numrin e pikave qe i perkasin te dhenave
- ✓ Shperndarjen e pikave te te dhenave: rrjet i rregullt ose shperndarje e ç'rregullt.
- ✓ Perfshirja e mundshme e informacionit te jashtem ne tendencen ose fusha te ndryshme.

❖ Metodat qe perdoren me shume jane:

Fqinji me i afert

Distanca e ponderuar e anasjellte

Funksionet Spline

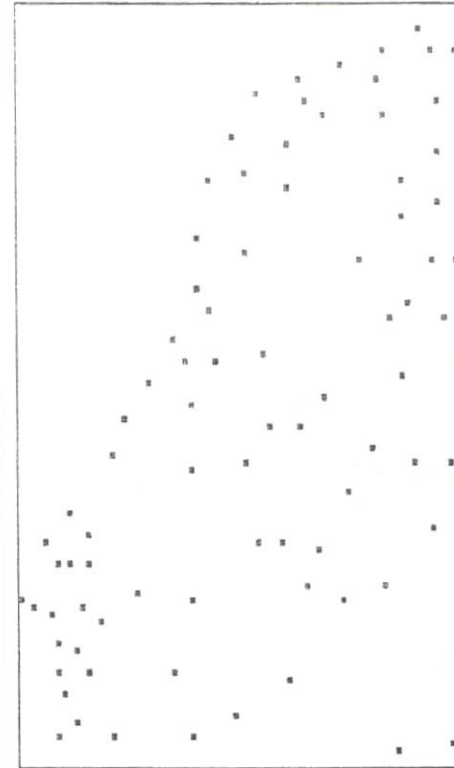


Metoda e fqinjit me te afert/Poligonet Thiessen

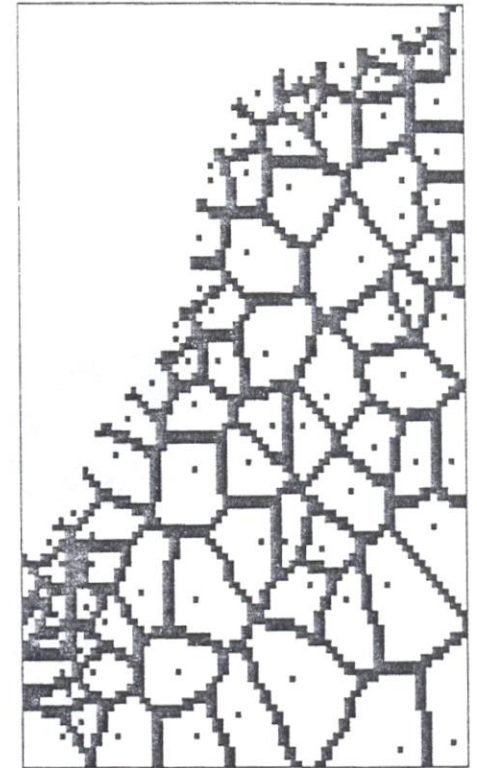
Me metoden e fqinjit me te afert (e njohur edhe si **poligonet Thiessen, Dirichlet ose Voronoi**), sipërfaqja e studimit ndahet në poligone ku secili prej tyre përmban një pikë që ekzistojnë të dhënat.

Nëse të dhënat shtrihen mbi një sipërfaqe të rregullt katrore, atëherë poligonet Thiessen janë të gjithë të barabartë, qeliza të rregullta me ane të barabarta me hapsirën e rrjetit. Nëse të dhënat janë të shpërndara në mënyrë të ç'rregullt, atëherë një rrjetë e ç'rregullt e poligoneve do të rezultojë.

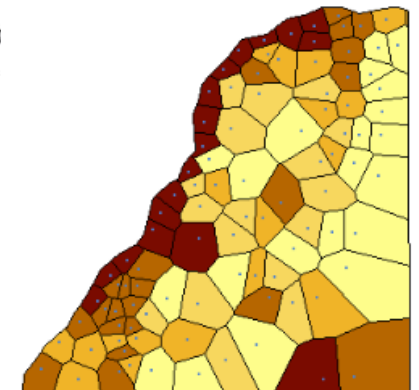
Kjo është metoda **lokale, e sakte dhe deterministike** => e lehtë & metode e shpejte



(a) Data locations



(b)



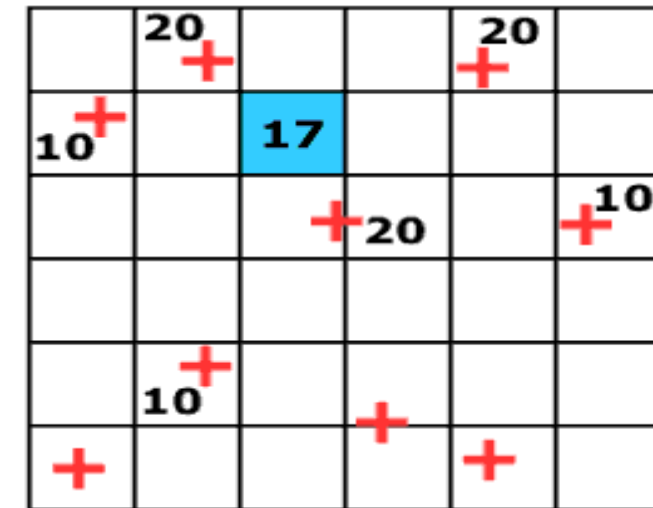



Distanca e Ponderuar Inverse (IDW)


Distanca e ponderuar inverse supozon se **secila pike prove ka nje ndikim lokal qe dobesohet me distancen**. Ne llogaritjen e vleres per nje qelize te dhena, kjo metode i jep peshe me te madhe pikave qe jane me afer me qelizen sesa ato qe jane me larg.

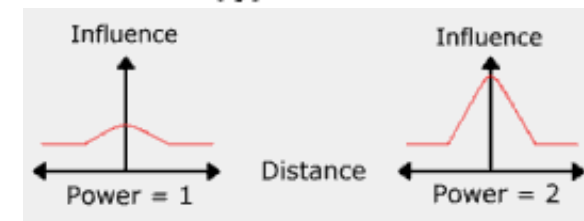
Termi “distance inverse” rrjedh nga supozimi qe **pesha eshte anasjelltas proporcionale me distancen midis qendres se qelizes dhe pikes se matur ne fuqi “r”**.

Zakonisht $r=2$, prodhon nje distance te anasjellte ne katror, por rastesisht vlera te tjera te r jane zgjidhur.



 Cell value being estimated

 Samples of x, y, z values



Pesha (ndikimi) e vleres se te dhenave prove eshte anasjelltas proporcionale me distancen e tij nga vlera e llogaritur



Distanca e Ponderuar Inverse (IDW)

(Shembull)

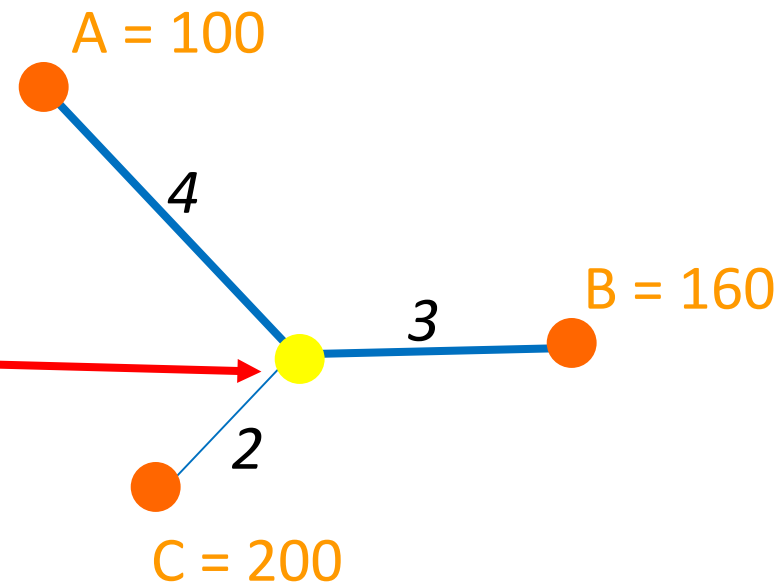
	Koef e peshes	Koef e peshes * vlera
A	$1 / (4^2) = 0.0625$	$0.0625 * 100 = 6.25$
B	$1 / (3^2) = 0.1111$	$0.1111 * 160 = 17.76$
C	$1 / (2^2) = 0.2500$	$0.2500 * 200 = 50.00$

$$Z_j = \frac{\sum_i \frac{Z_i}{d_{ij}^n}}{\sum_i \frac{1}{d_{ij}^n}}$$

Totali = 0.4236

$$6.25 + 17.76 + 50.00 = 74.01$$

$$74.01 / 0.4236 = \mathbf{175}$$





Distanca e Ponderuar Inverse (IDW)

- ☐. Esencialisht, metoda e mesatareve levizese, vlereson bazuar ne afersine e pikave me te dhena te njohura.
- ☐. Interpolues i **sakte**
- ☐. Rezultatet me te mira nga IDW perftohen kur kampionimi eshte mjaftueshem i dendur ne lidhje me variacionin lokal qe ju perpiqeni te stimuloni.
- ☐. Nëse zgjedhja e pikave eshte e rralle ose e pabarabarte, rezultatet mund te mos perfaqsojne mjaftueshem siperfaqen e deshiruar.



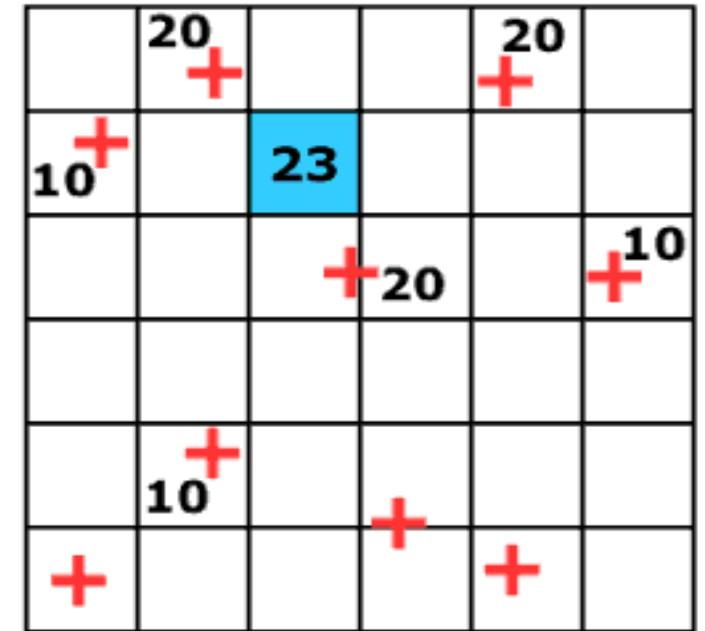
Splines


Ndryshe nga IDW, e cila interpolon vlerat nga pika te perzgjedhura prane qelizave te perpunimit, modelet spline formojne nje funksion matematik mbi fushen perkatese.


Spline synon qe te pershtase **nje siperfaqe minimale te kurbeuar ndaj pikave prove te perzgjedhura**. Siperfaqja kalon ekzaktesisht neper pikat prove.

Duke qene se gjeneron siperfaqe te zmusuara, metoda Spline pershtatet me se miri me te dhenat prove qe variojne pakez.

Nuk eeshte e pershtatshme te perdoret nese ka ndryshime shume te medha ne vlere brenda nje distance te shkurter horizontale. Shpejt duhet te llogarisim dhe te percaktojme **metoden e rillogaritjes**.



 Cell value being estimated

 Samples of x, y, z values



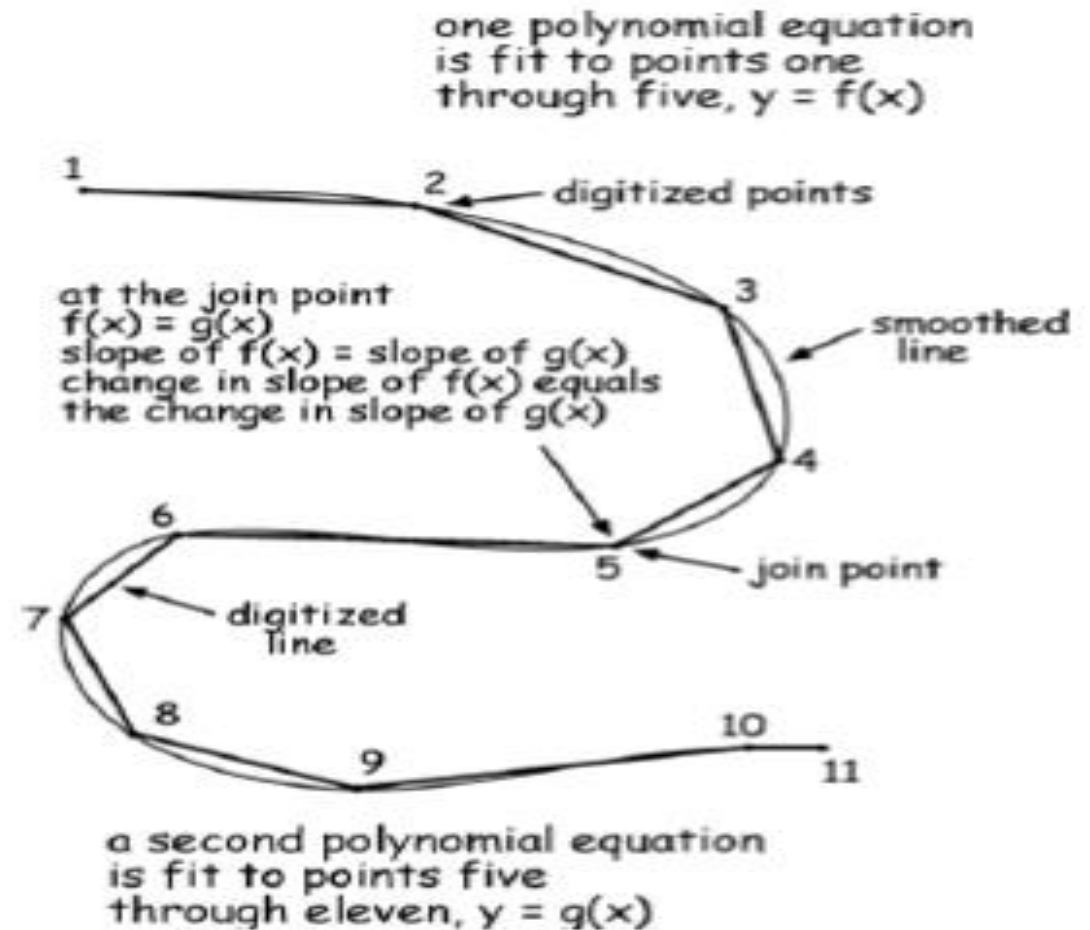
Llogaritja e Splines

Funksionet Spline jane ndertuar nga nje grup I **funksioneve polinomial te bashkuar.**

Funksionet polinomiale pershtaten per **segmente te shkurter**

Metoda e sakte e katroreve minimale/me te vegjel percakton drejtezat qe kalojne ne pikat ne secilin segment.

Normalisht kemi polinome te **rendit te I-re, II-te dhe te III-te.**





Llogaritja e Splines

- ☐ Ekuivalenti matematik i perdorimit te nje vizoreje fleksibile (e quajtur spline).
- ☐ Polinomet pershtaten duke kaluar ne te dhenat (interpolues lokal).
- ☐ Mund te perdoret si nje interpolues i sakte ose i perfaert ne varesi te shkalleve te lirise (psh: rendit te polinomit).
- ☐ Me i mire per grupet e te dhenave dhe mund te shkaktoje



Interpoluesit Stokastik (Gjeostatistik)

- ☐ . **Teknikat Gjeostatistike** krijojne sipërfaqe duke inkorporuar veçoritë statistike të të dhënave të matura.
- ☐ . Prodhon jo vetëm parashikimin e sipërfaqeve por edhe pasigurite në parashikim.
- ☐ . Mjaft metoda bazohen tek gjeostatika por janë të gjitha në familjen kriging.



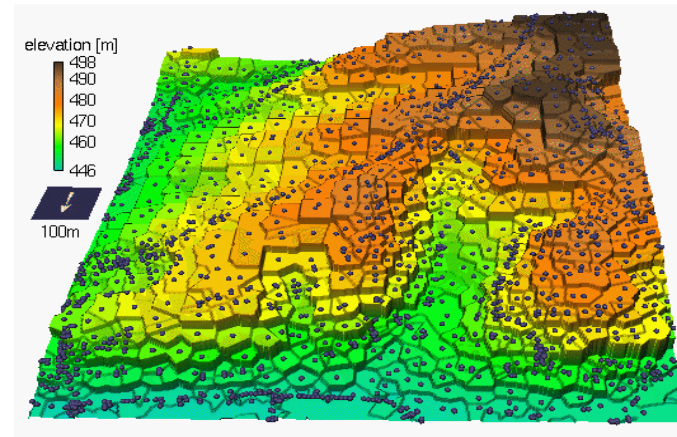
Interpolimi Hapsinor – cili eshte me i miri ?

- ☐ Sa e **sheshte** doni qe te jete siperfaqja dhe cila eshte me e pershtatshmja ?
- ☐ A keni nevojte qe pikat e te dhenave **te ruhen** ne vendodhjen e tyre perkatese ?
- ☐ Mund te mendojme per ndonje **varesi** midis te dhenave si funksion **I distances** ?
- ☐ Cilat jane **trendet/tendencat Globale** ?
- ☐ Si mund ti **validoni**,mundeni ju sado pak ?
- ☐ Ndonje prej te dhenave qe mund te **permirsojne llogaritjet** ?

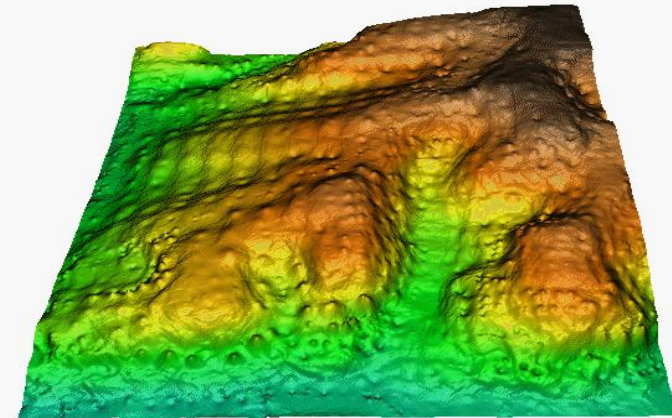


Interpolimi Hapsinor – cili eshte me i miri ?

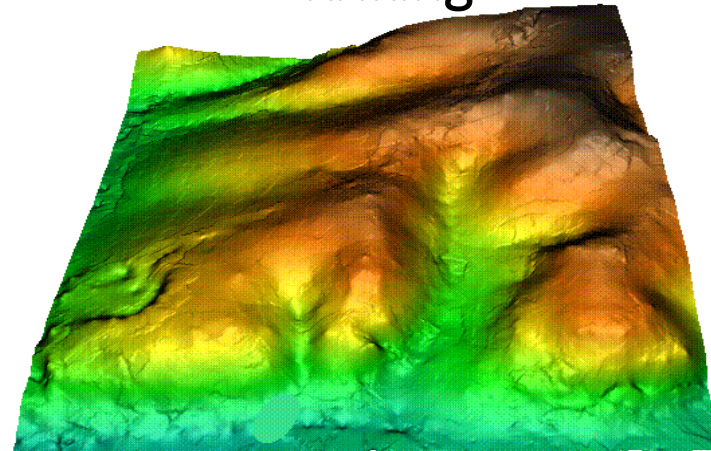
Poligoni Theissen



Distanca e Anasjellte e Ponderuar



Kriking





Nje krahasim i Metodave te Interpolimit Hapsinor

❖ Pervec bollekut te metodave qe mund te kryejne interpolimin hapsinor, **veshtiresia e vertete bie ne zgjedhjen e metodes me te pershtatshme** per secilin rast.

❖ **Secila metode ka avatnatzhe qe varen dukshem ne te dhenat fillestare.** Kjo nenkupton qe nje metode jep rezultatet shume te mira ne nje grup specifik te pikash prove por qe mund te kete pak saktesi ne nje grup tjetër te dhenash ose ne fusha te ndryshme te se njejtes siperfaqe

❖ Diferencat qe mund te ngrihen midis metodave te interpolimit hapsinor jane rezultat i **natyres se vecorive qe po studiohet, vlerave te tyre ne pikat e zgjedhura dhe kriteret e zgjedhura per vleresim sesa nga vete metoda.**

Permbledhje e Interpolatoreve

(Nga Analisti Gjeostatik i ESRI)

Method	Deterministic/ Stochastic	Output Surface Types	Computing Time/ Modeling Time ¹	Exact Interpolator	Advantages	Disadvantages	Assumptions ²
Inverse Distance Weighted	Deterministic	Prediction	Fast/Fast	Yes	Few parameter decisions	No assessment of prediction errors; produces "bulls eyes" around data locations	None
Global polynomial	Deterministic	Prediction	Fast/Fast	No	Few parameter decisions	No assessment of prediction errors; may be too smooth; edge points have large influence	None
Local polynomial	Deterministic	Prediction	Moderately Fast/Moderate	No	More parameter decisions	No assessment of prediction errors; may be too automatic	None
Radial basis functions	Deterministic	Prediction	Moderately Fast/Moderate	Yes	Flexible and automatic with some parameter decisions	No assessment of prediction errors; may be too automatic	None
Kriging	Stochastic	Prediction; Prediction Standard Errors; Probability; Quantile	Moderately Fast/Slower	Yes without measurement error; No with measurement error	Very flexible; allows assessment of spatial autocorrelation; can obtain prediction standard errors; many parameter decisions	Need to make many decisions on transformations, trends, models, parameters, and neighborhoods	Data comes from a stationary stochastic process, and some methods require that the data comes from a normal distribution
Cokriging	Stochastic	Prediction; Prediction Standard Errors; Probability; Quantile	Moderate/ Slowest	Yes without measurement error; No with measurement error	Very flexible; can use information in multiple datasets; allows assessment of spatial cross- correlation; many parameter decisions	Need to make many decisions on transformations, trends, models, parameters, and neighborhoods	Data comes from a stationary stochastic process, and some methods require that the data comes from a normal distribution

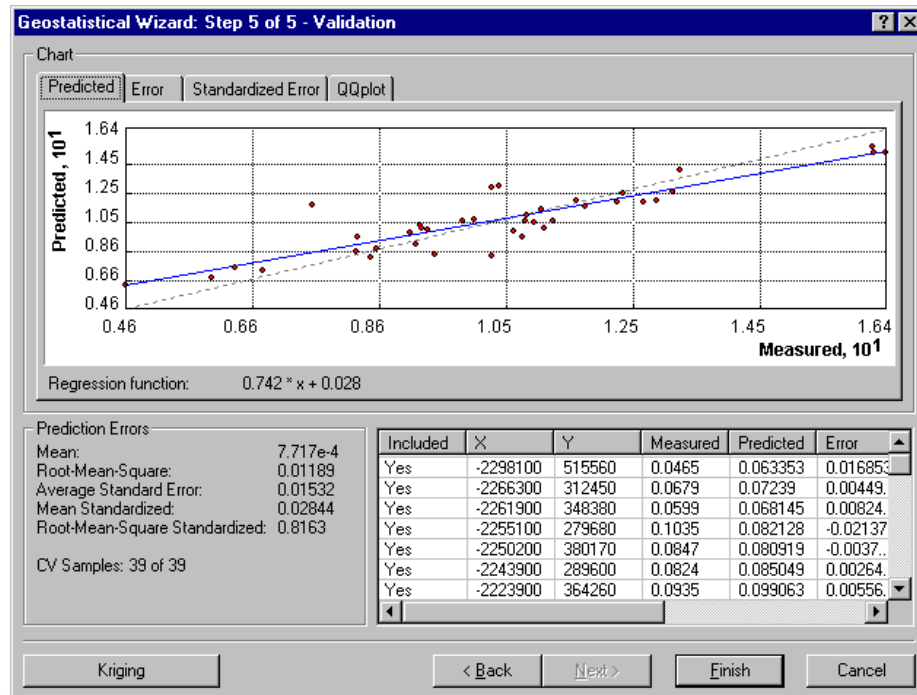


Diagnostika

Validimi

Sa mire eshte parashikimi ?

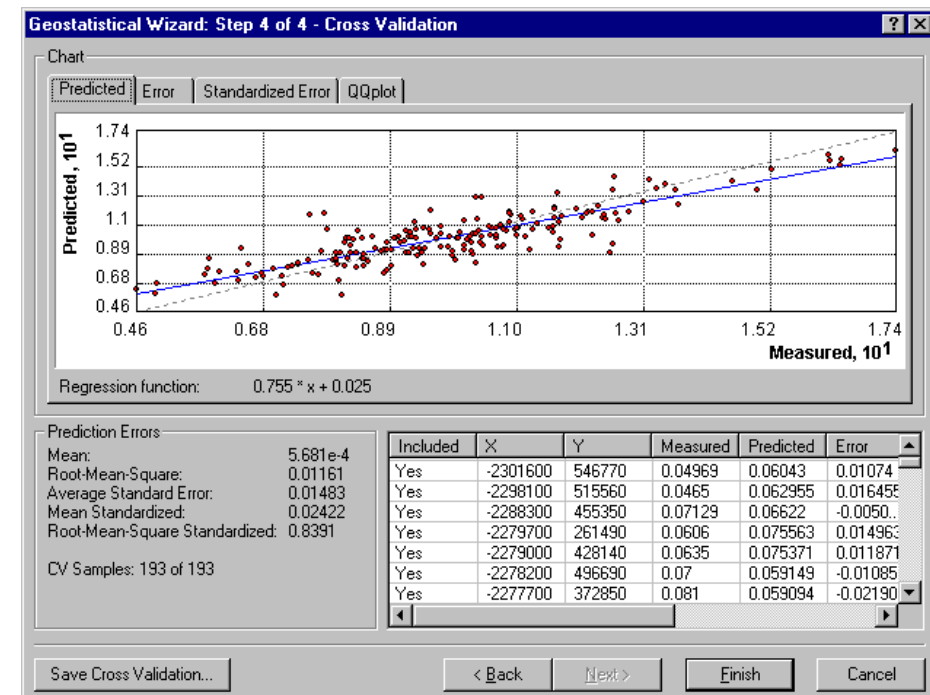
- Parashikimet jane krahasuar me nje grup perfaqshues te dhenash qe jane perjashtuar nga interpolimi.



Kross-validimi

Sa i mire eshte modeli ?

- Refuzimi I nje pike te dhenash dhe matja e gabimit.; pika zevendesohet, pika e re e zgjedhur dhe e njeta gje perseritet.





Konkluzione

Metodat e Interpolimit varen ne:

- Karakterin e te dhenave
- Supozimin tuaj per sjellien e te dhenave

Kur eshte e mundur, menyra me e mire per te krahasuar metodat eshte:

1. Provo disa metoda
2. Sigurohuni se e kuptoni teorine mire
3. Permirëso metoden me te mire

Faleminderit per vemendjen !

Dr. George P. Petropoulos

Technical University of Crete & Hellenic Agricultural Organisation (HAO)
“Demeter”, Greece