Spatial Tools in Water Resource Management

Nick van de Giesen

4. Introduction Remote Sensing

Lecture 4: Intro remote sensing

TU Delft

CT5401

- GIS: Lectures 1,2,3
- Remote Sensing: Lecture 4,5,6
- Theory
- Exercise

Lecture 4: Intro remote sensing

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CT5401 2012 Lecture 4

CT5401: Remote Sensing

- Lecture 4: Introduction & image classification
- Lecture 5: Thermal imagery (Wim Bastiaanssen)
- Lecture 6: Microwave (Susan Steele-Dunne)

- Some “overlap”
- Burkina Faso

Lecture 4: Intro remote sensing

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CT5401 2012 Lecture 4

Outline

- Overview satellites & applications
- Image analysis
- Image classification
- Exercise: Mapping small reservoirs

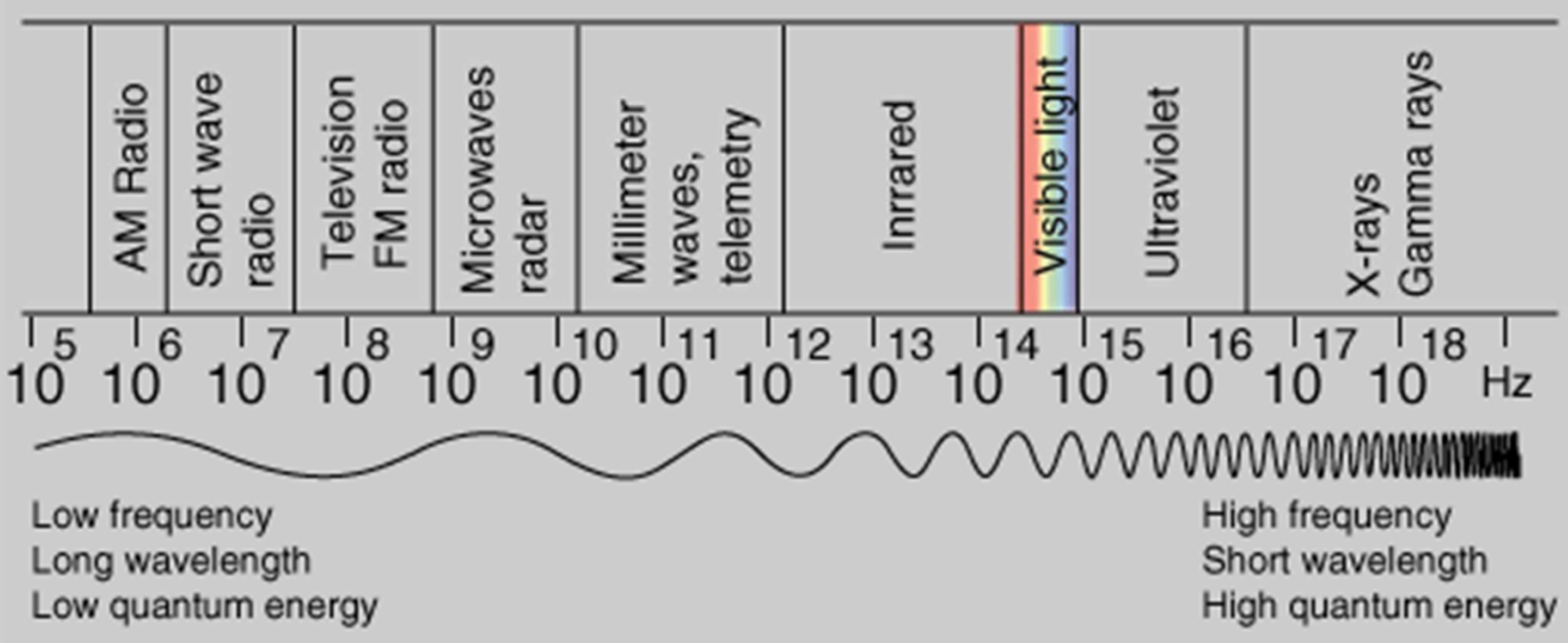
Remote Sensing

- Remote sensing (satellites)
  - Principles
  - Applications

Why?

Satellite principles

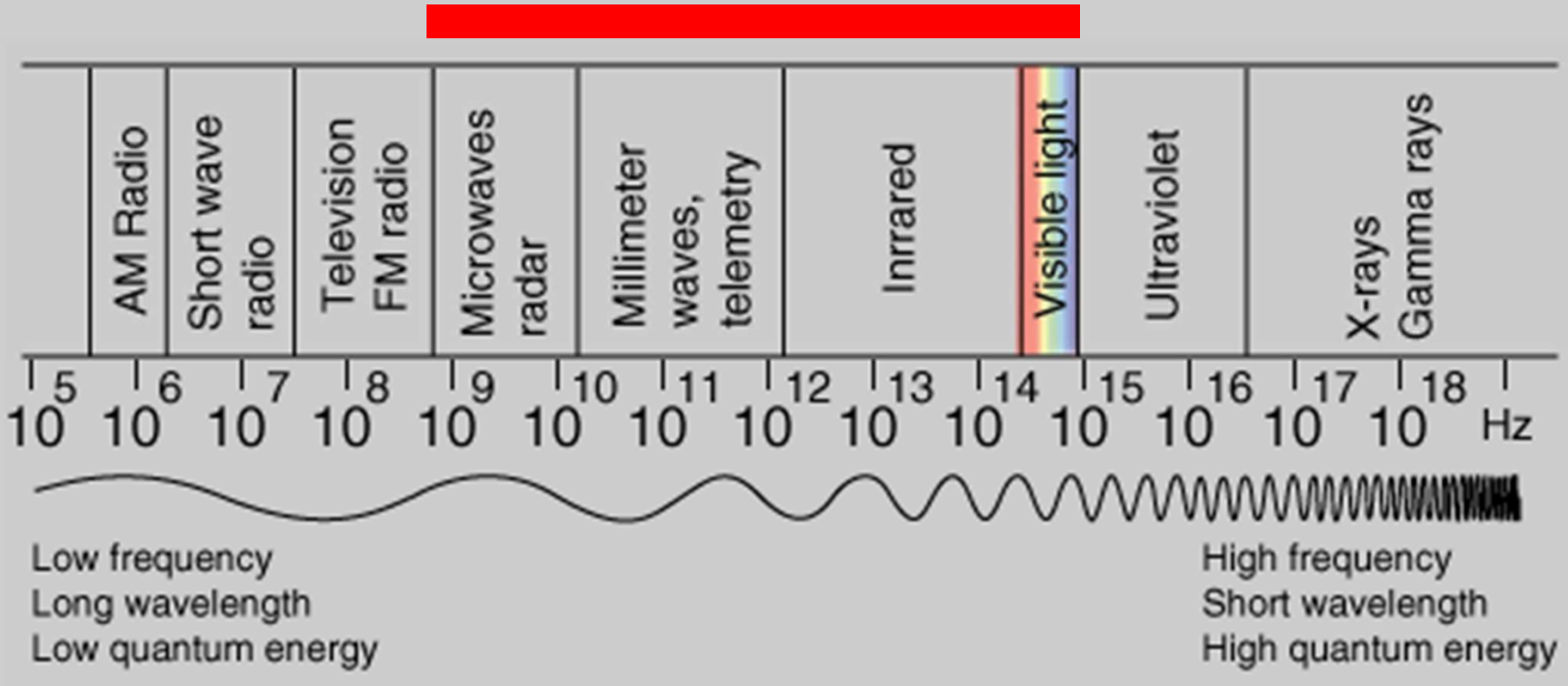
- Spectrum



[1]

Satellite principles

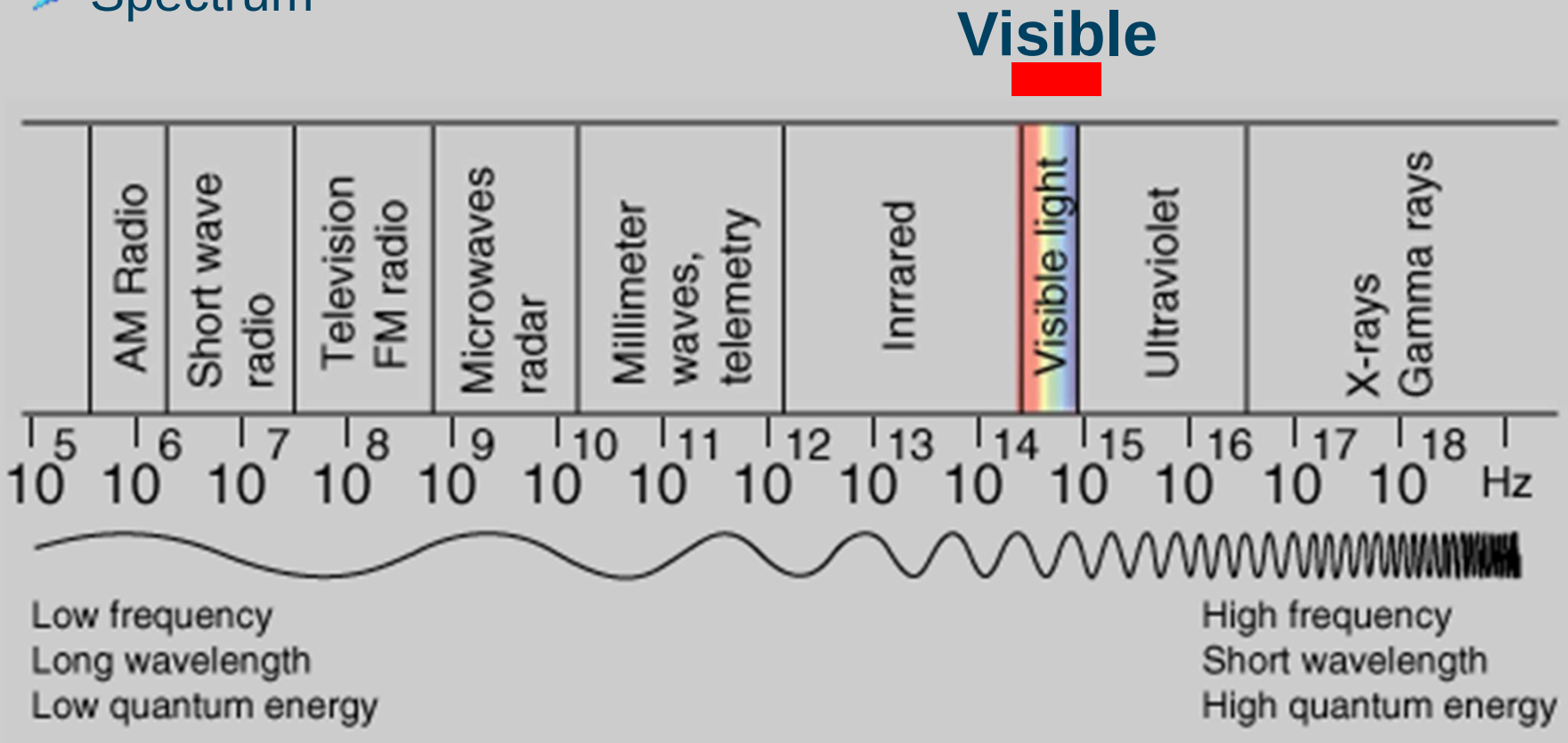
- Spectrum



[1]

Satellite principles

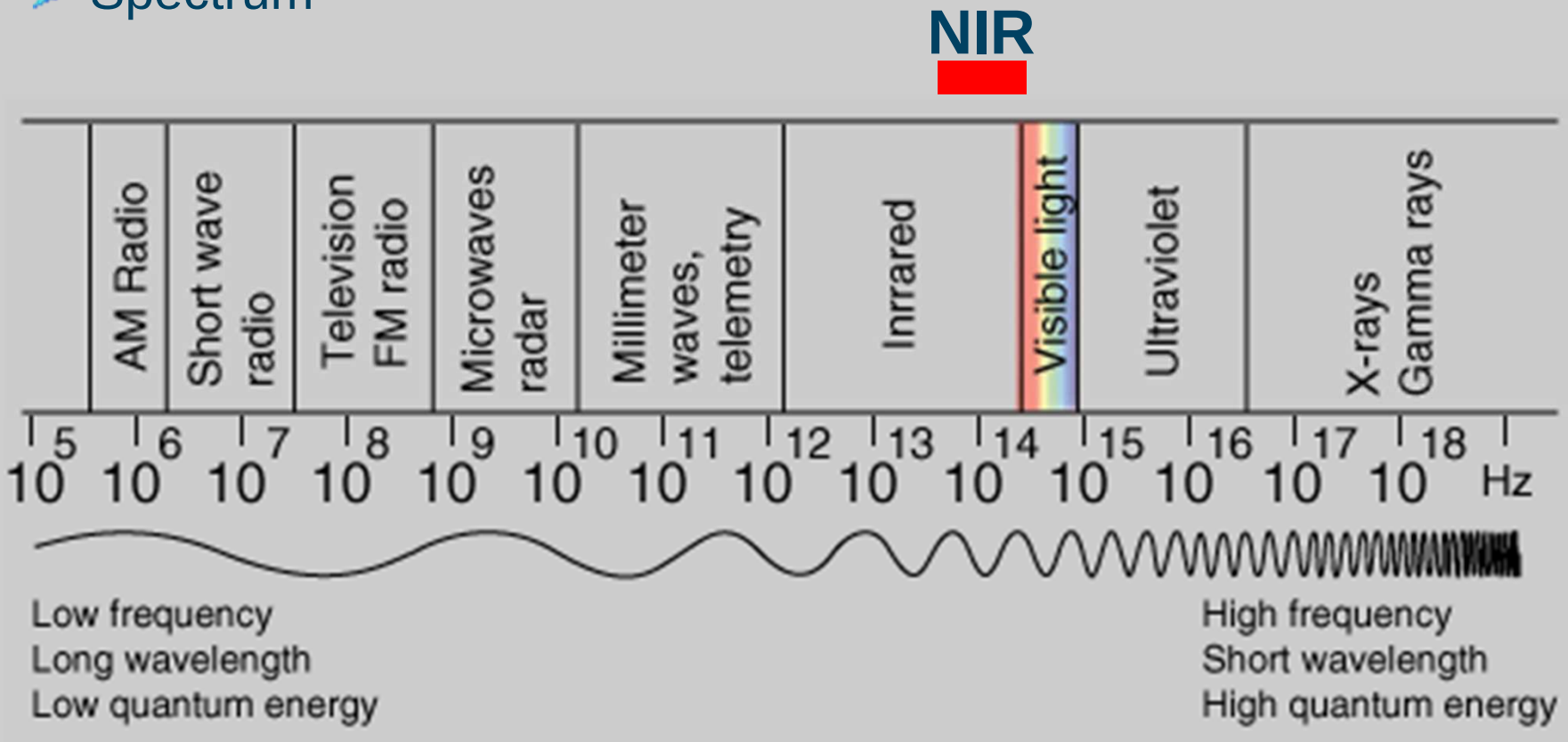
- Spectrum



[1]

Satellite principles

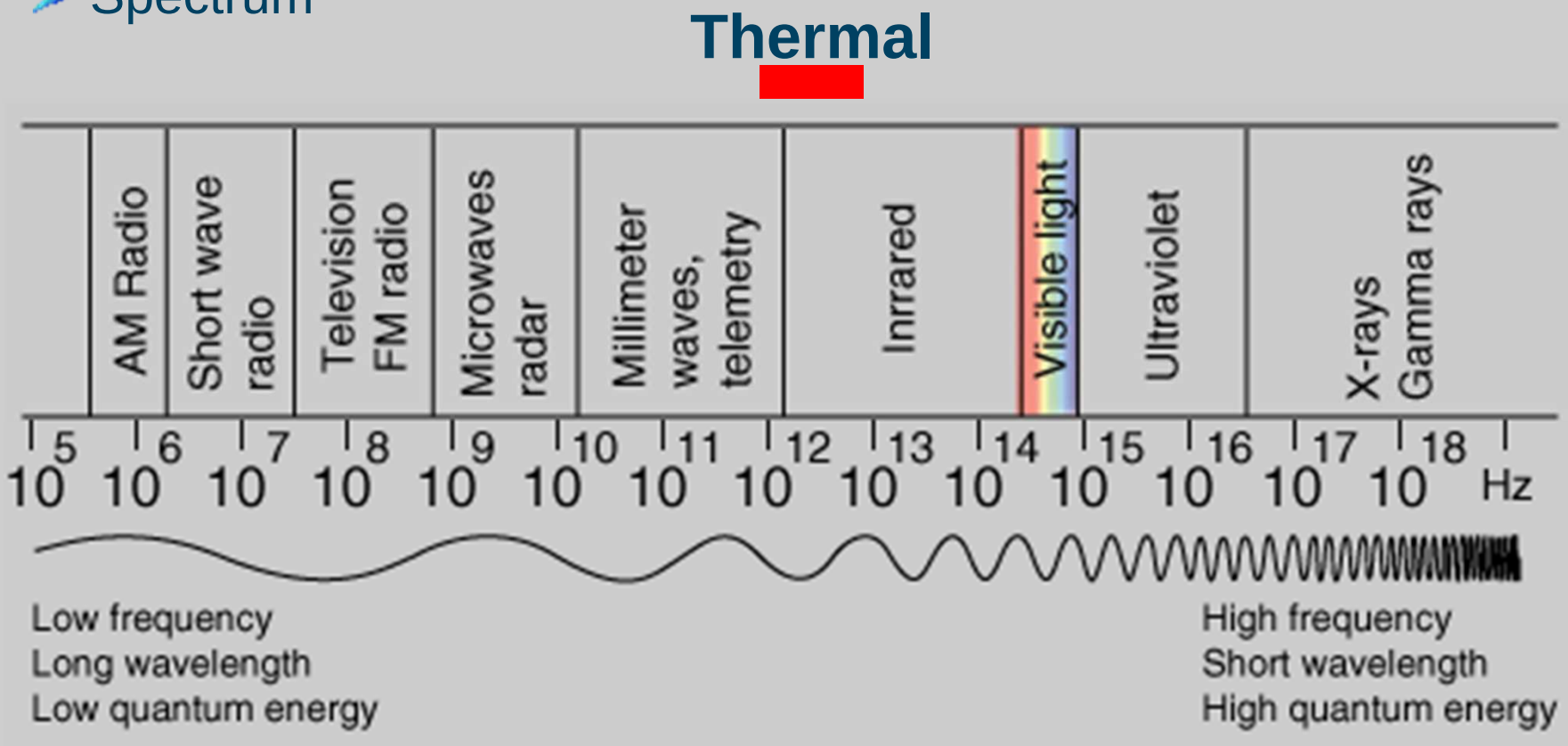
- Spectrum



[1]

Satellite principles

- Spectrum

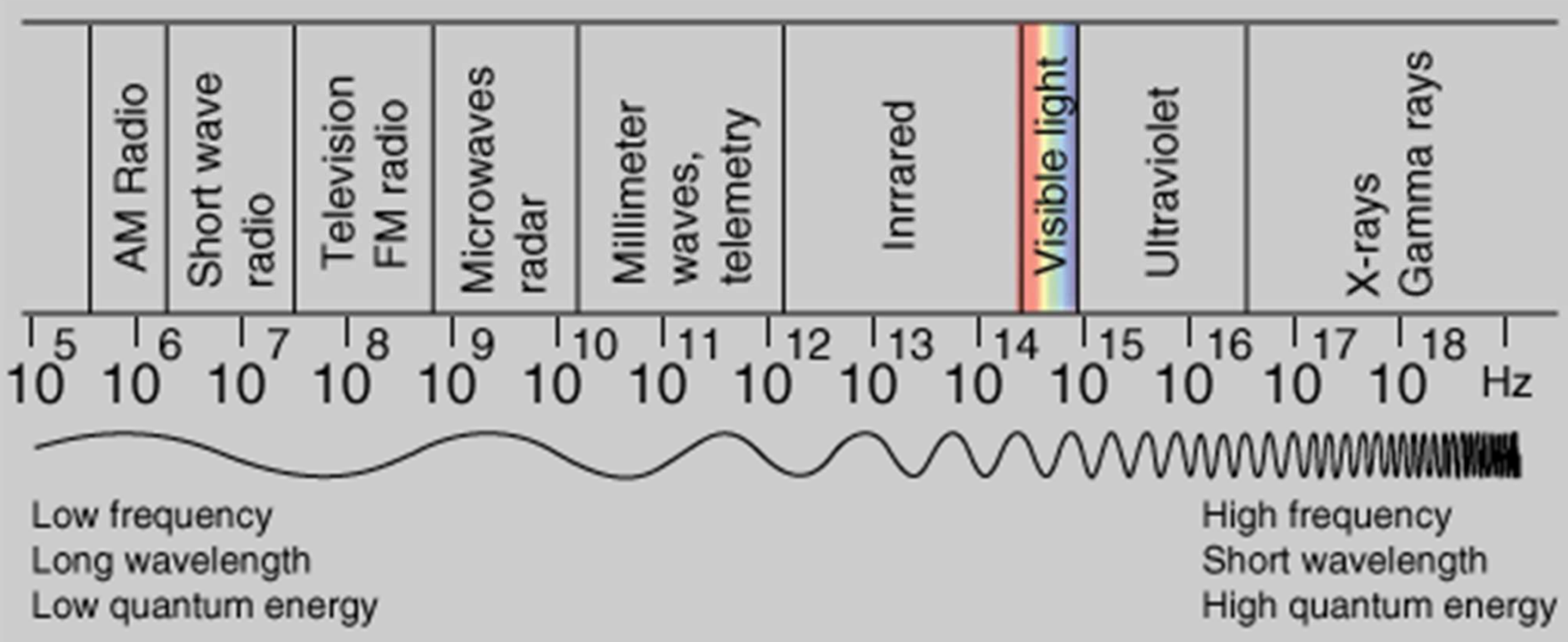


[1]

Satellite principles

- Spectrum

Microwave



[1]

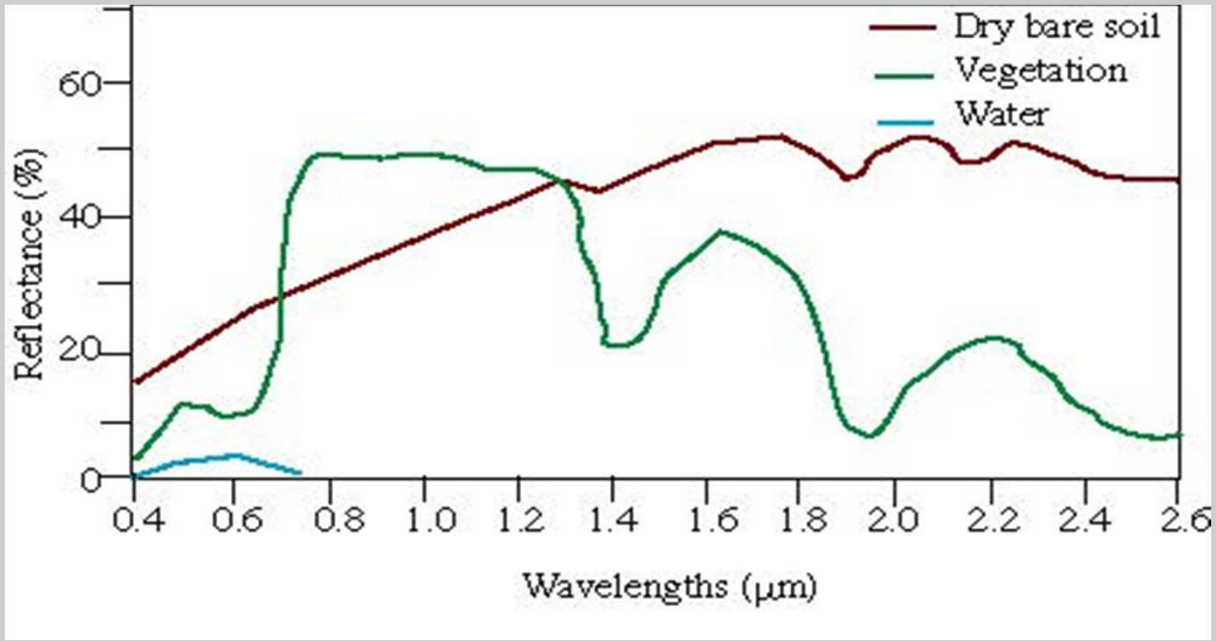
Satellite principles

- Visible/NIR
  - Easy interpret
  - Water
  - Vegetation

[2]

Satellite principles

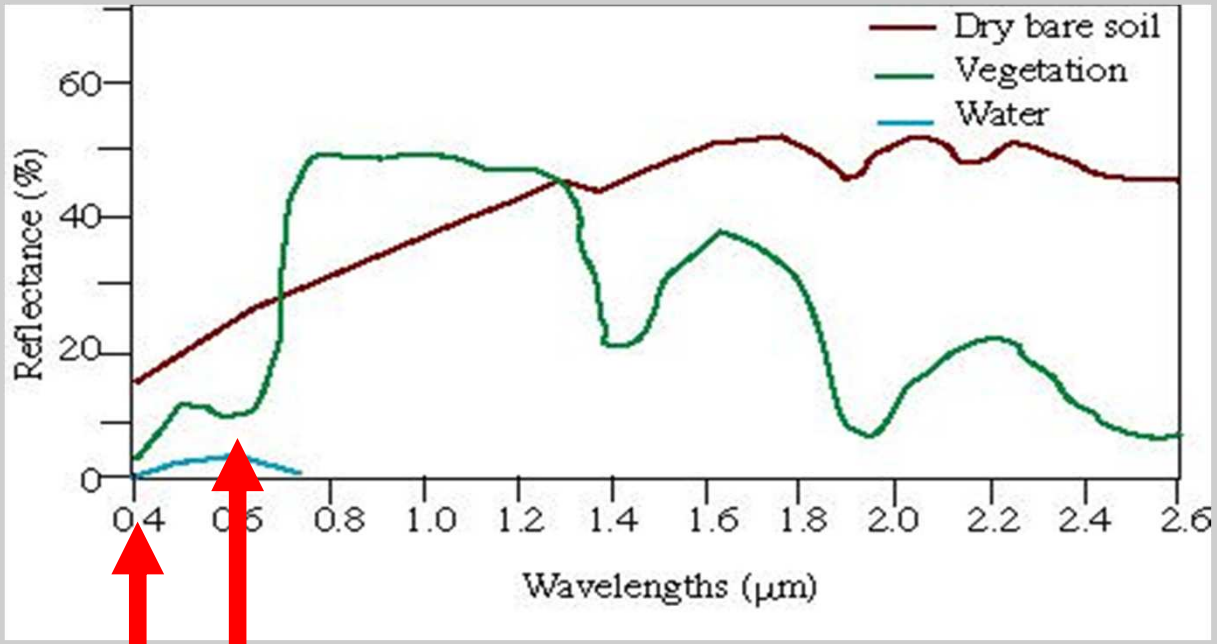
- Visible/NIR
  - Vegetation
  - NDVI



[3]

Satellite principles

- Visible/NIR
  - Vegetation
  - NDVI



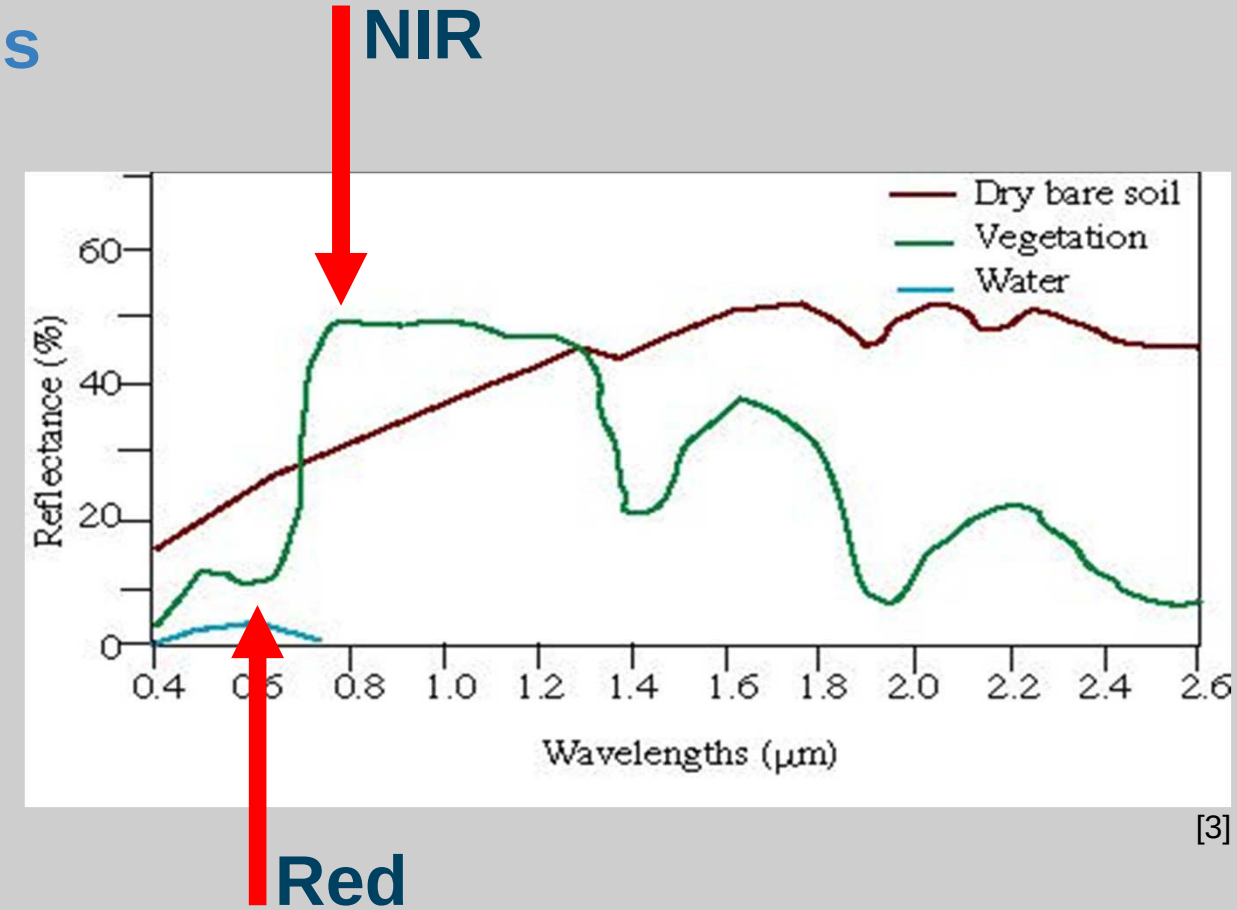
[3]

Red

Blue

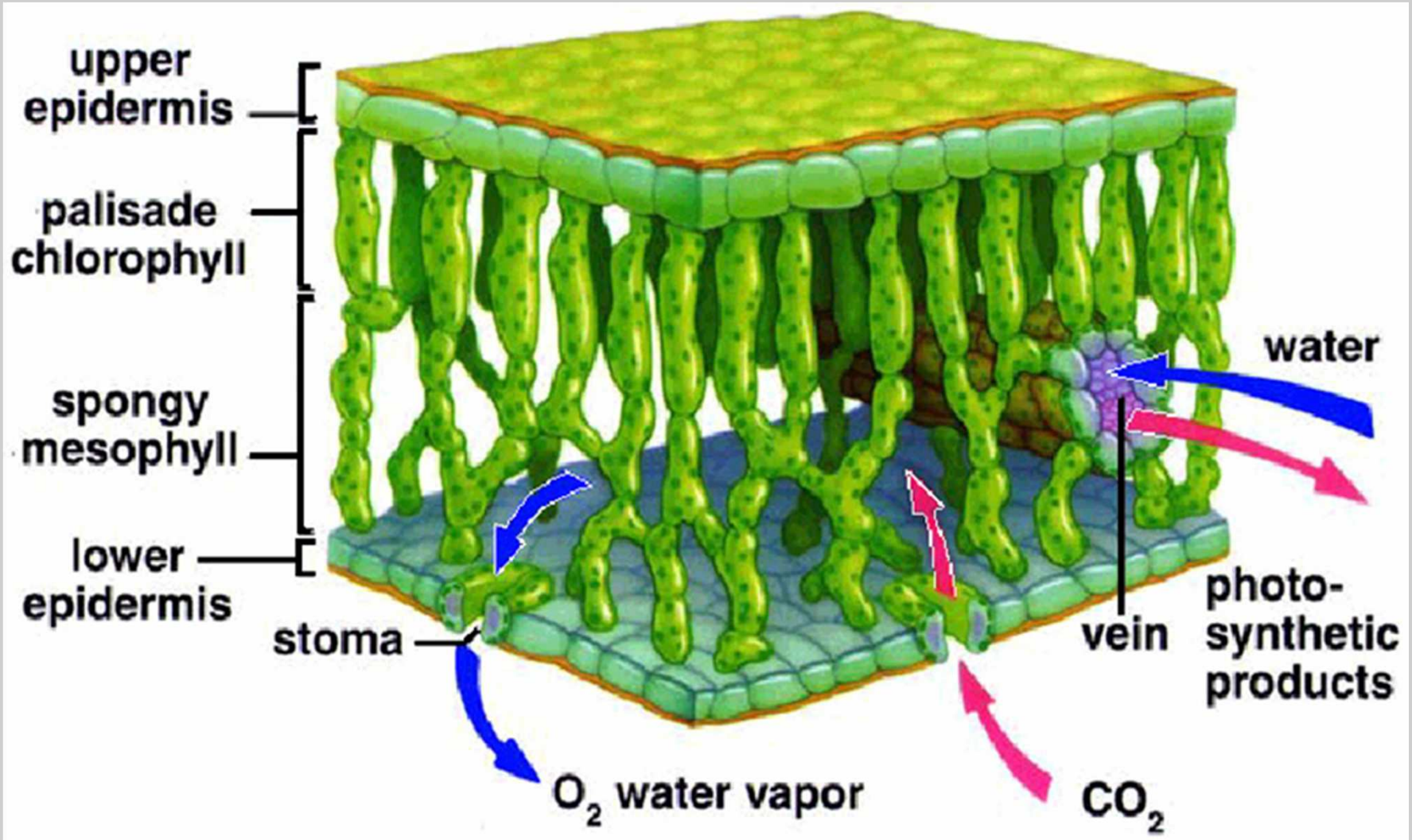
Satellite principles

- Visible/NIR
  - Vegetation
  - NDVI



[3]

NDVI=(NIR-Red) / (NIR+Red)

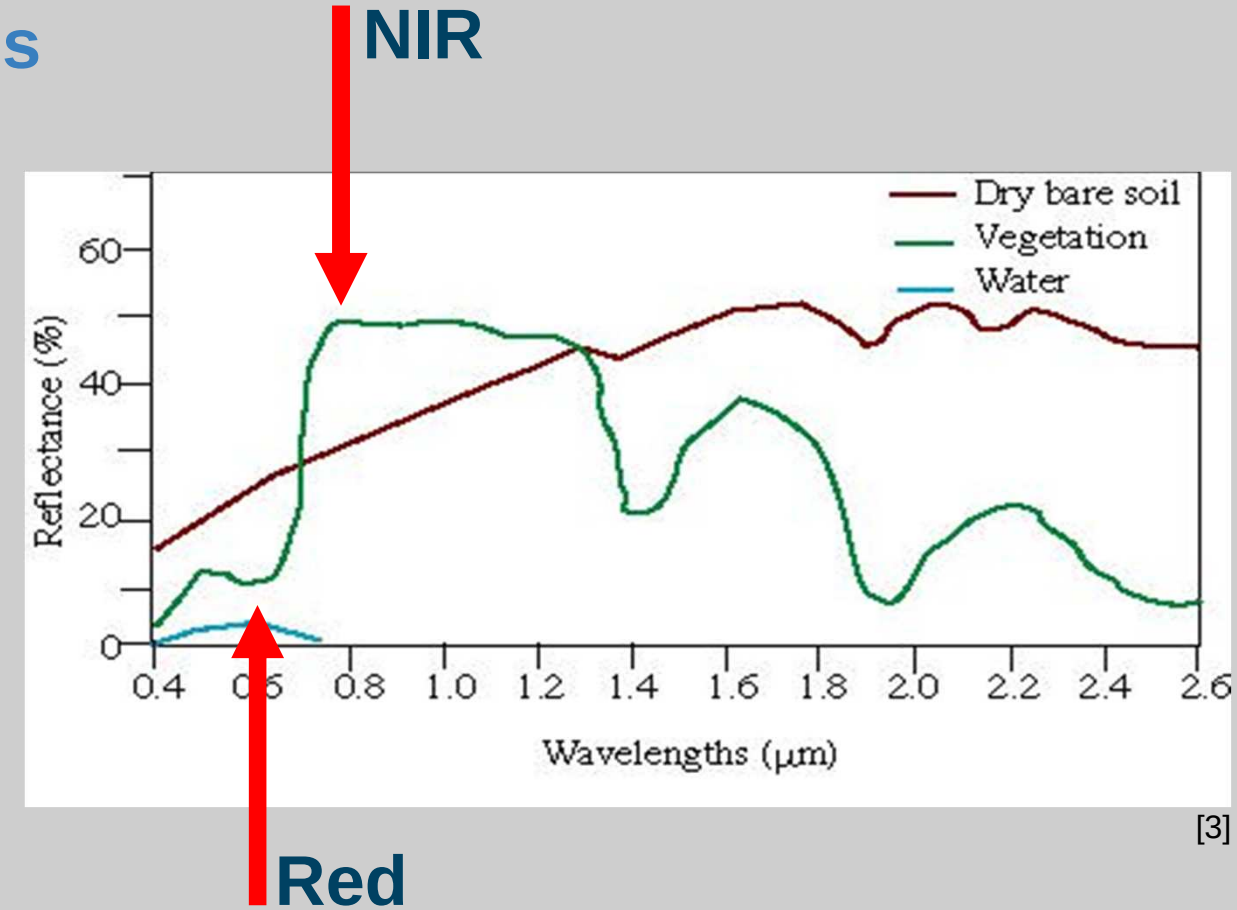


[4]

NDVI=(NIR-Red) / (NIR+Red)

Satellite principles

- Visible/NIR
  - Vegetation
  - NDVI



[3]

NDVI=(NIR-Red) / (NIR+Red)

Satellite principles

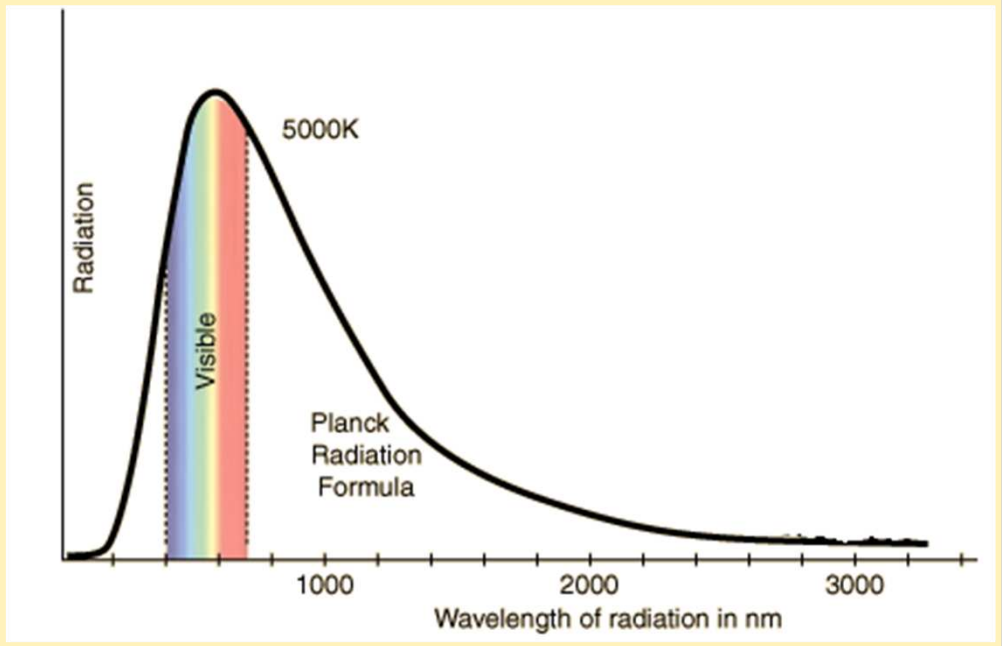
- Visible/NIR
  - Vegetation
  - NDVI

[5]

NDVI=(NIR-Red) / (NIR+Red)

Satellite principles

- Thermal IR



[6]

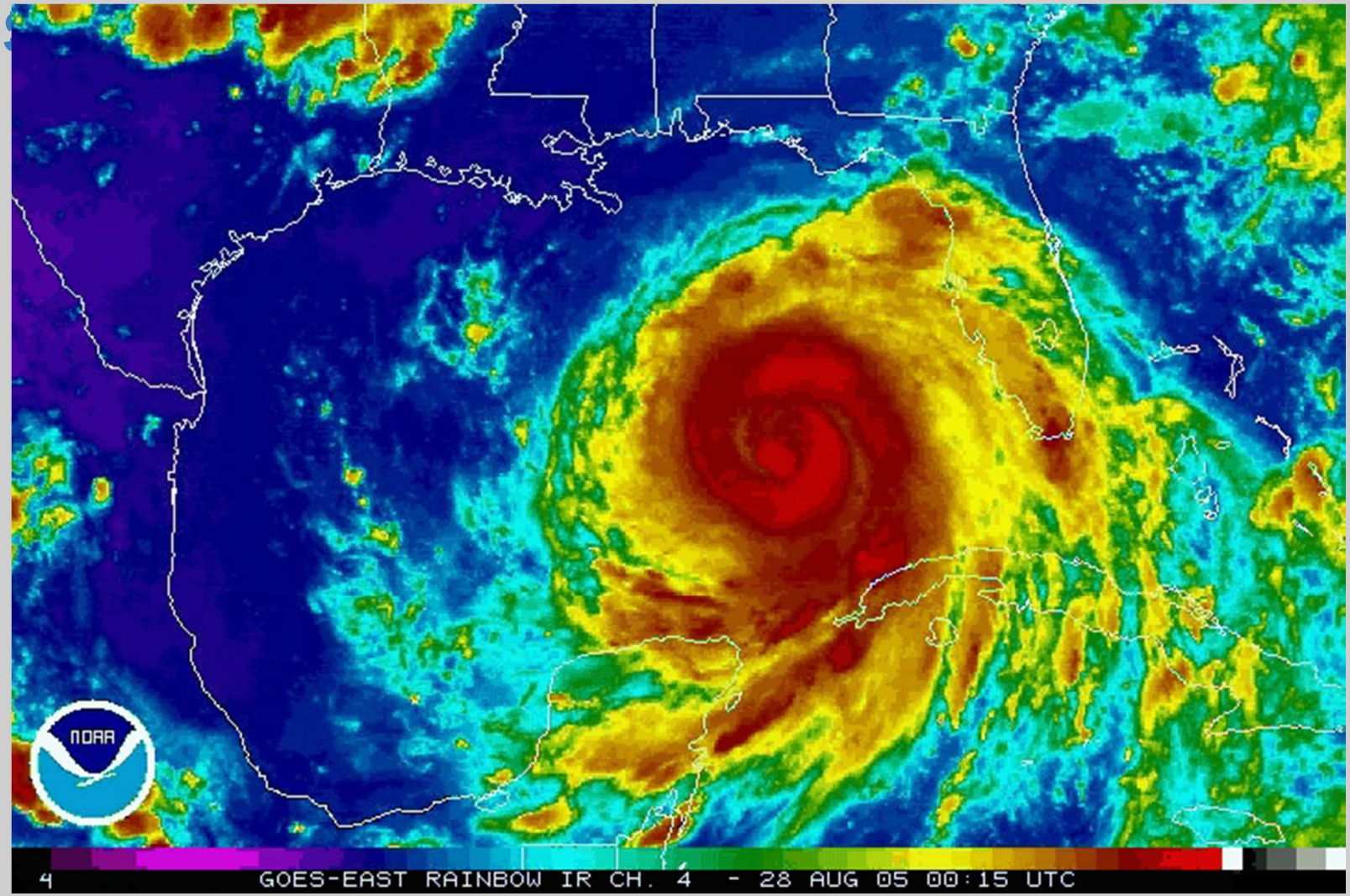
$$S_\lambda = \frac{8\pi hc}{\lambda^5}\frac{1}{e^{hc/\lambda kT}-1}$$ **Planck**

$$\lambda_{peak} = \frac{0.0029}{T}$$ **Wien**

sun: 480 nm, earth: 10 µm

$$P = \varepsilon\sigma T^4$$ **Stefan-Boltzmann**

Lecture 4: Intro remote sensing

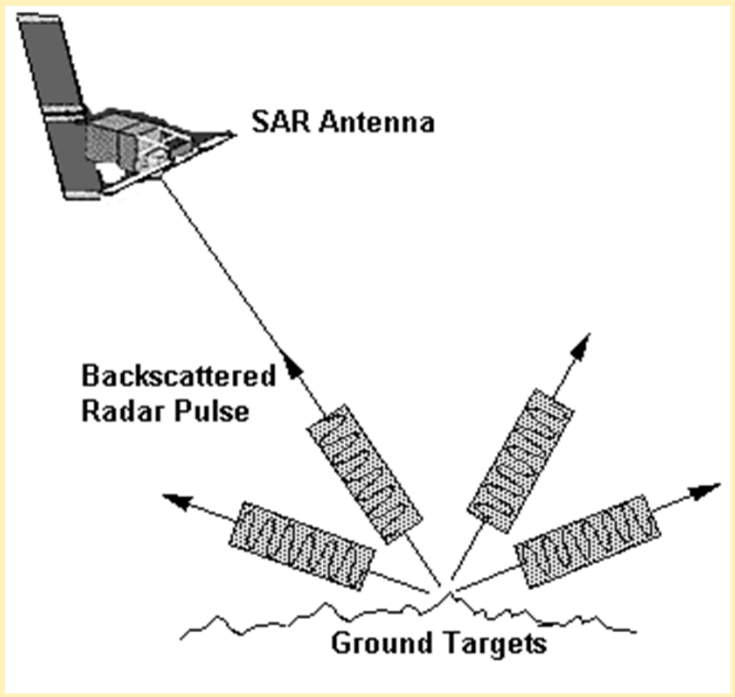


[7]

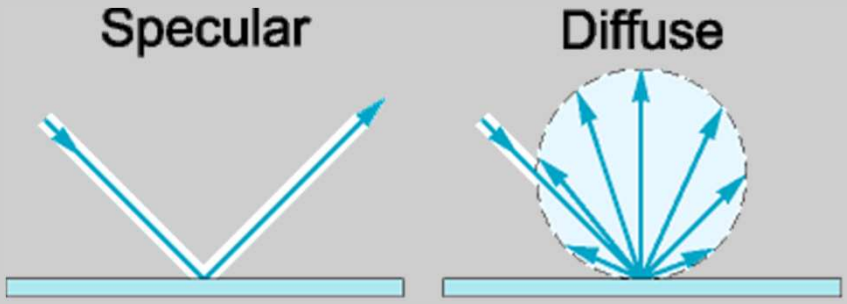
Hurricane Katrina

Satellite principles

- Radar



[8]



[9]

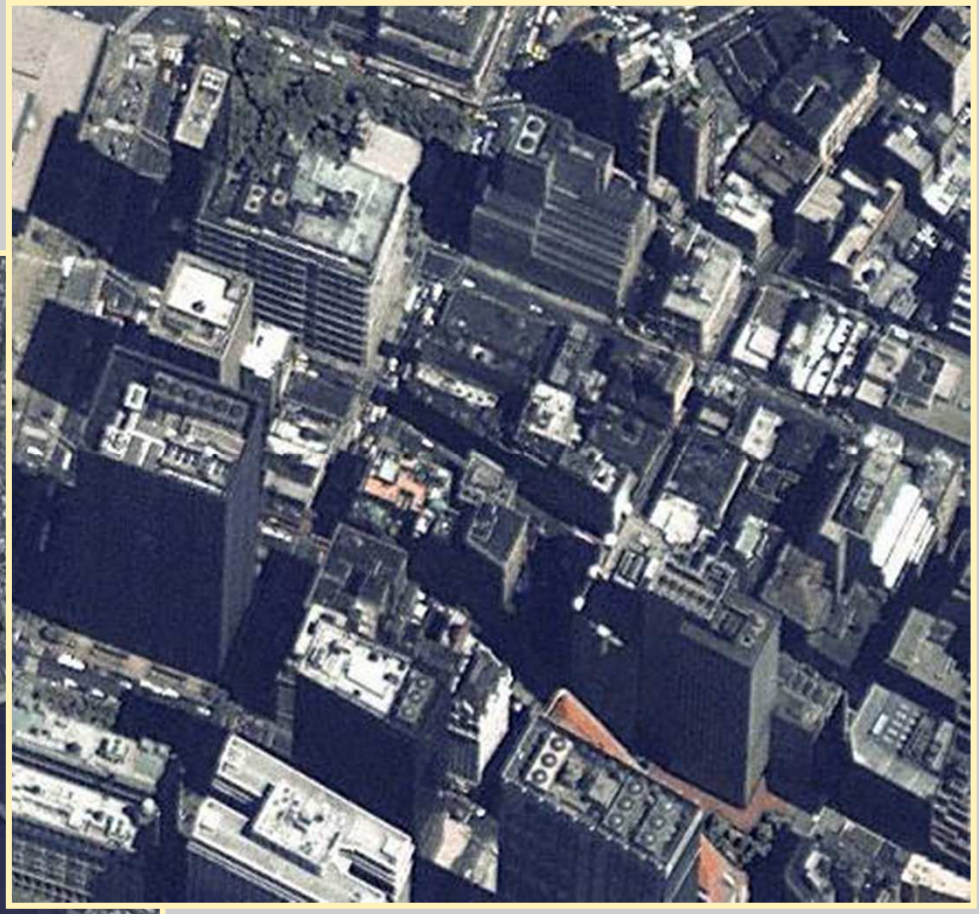
Water **Vegetation**

Satellite principles

- Radar & microwave
  - EM waves “see” > λ/4
  - Passive: like TIR (but no clouds)
  - Active: Radio Detection And Ranging
    - L-band 22 cm (soil moisture)
    - C-band 7 cm (vegetation)
    - X-band 2.5 cm (rain)

Remote sensing

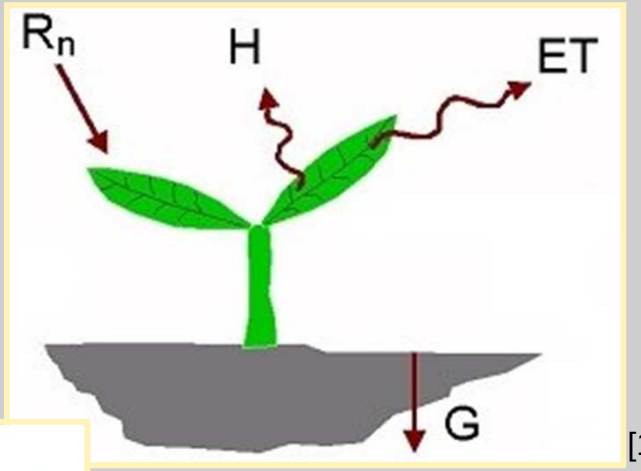
- IKONOS / QuickBird



[10]

Remote sensing

- Evaporation: SEBAL



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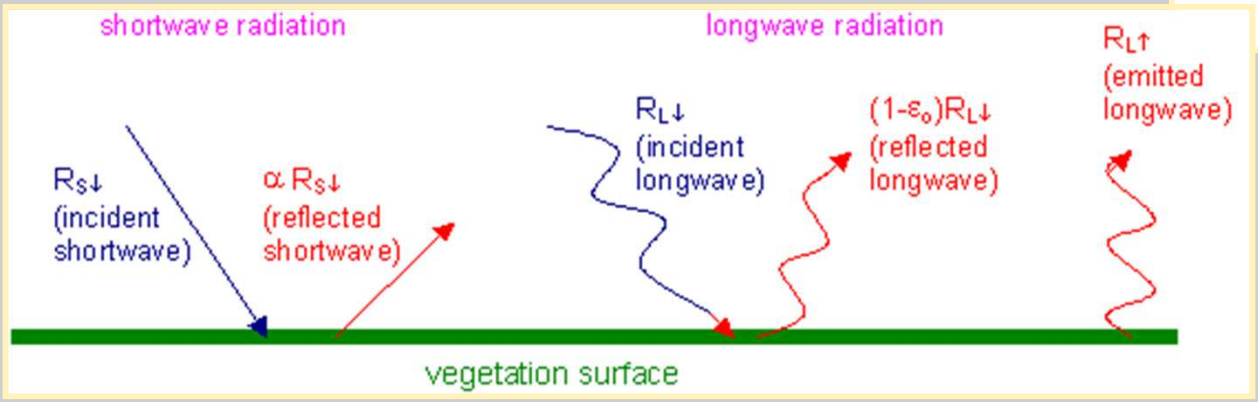


Surface Energy Balance:

$$(1-\alpha)\cdot R_{S\downarrow} + \varepsilon_0 \cdot R_{L\downarrow} - \varepsilon_0 \sigma T^4 = H + ET + G$$

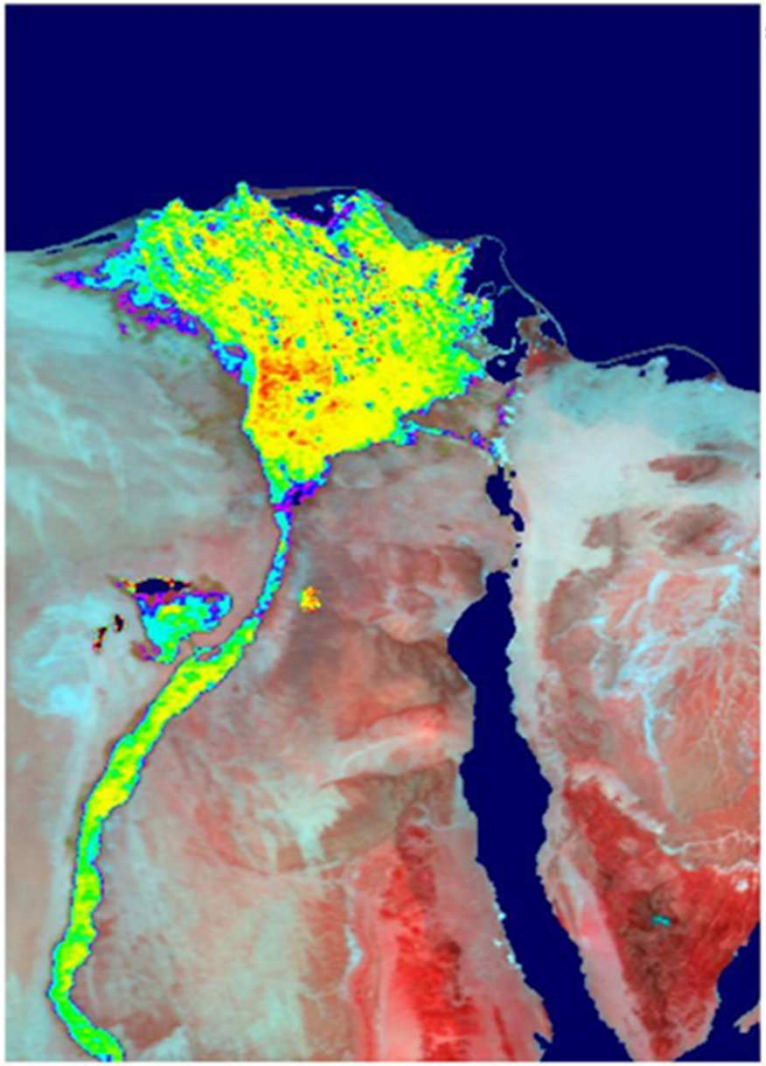
Dry & wet

Remote sensing

- Evaporation: SEBAL

Next week:

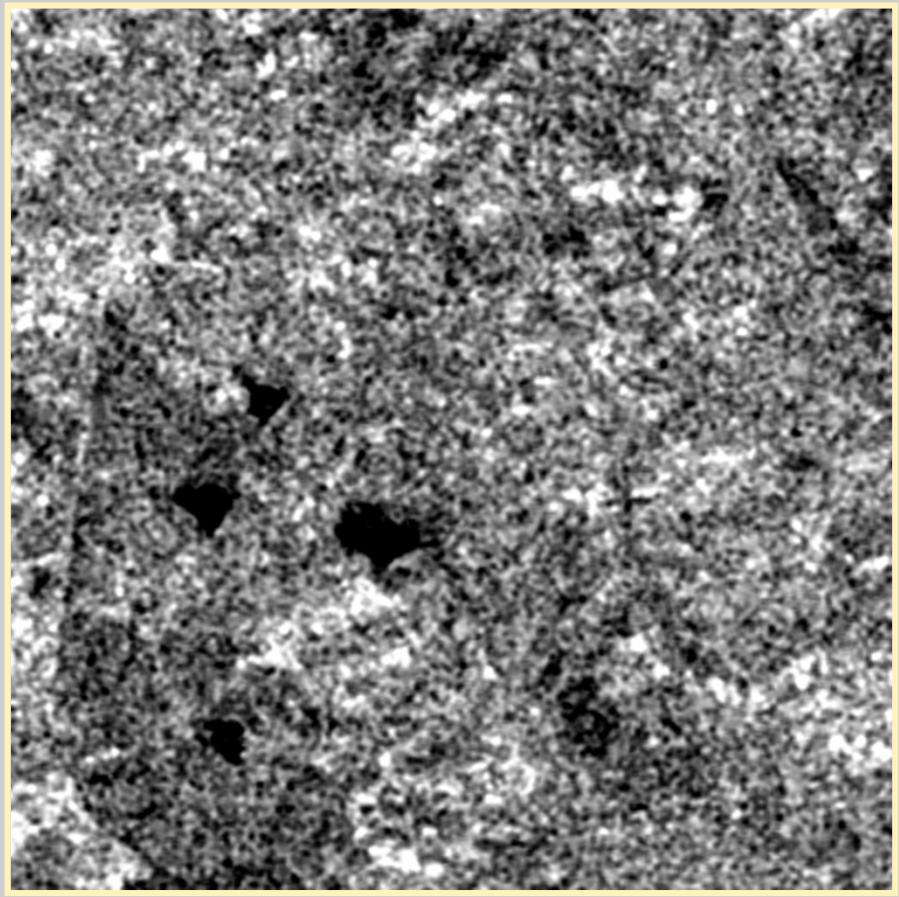
Wim Bastiaanssen

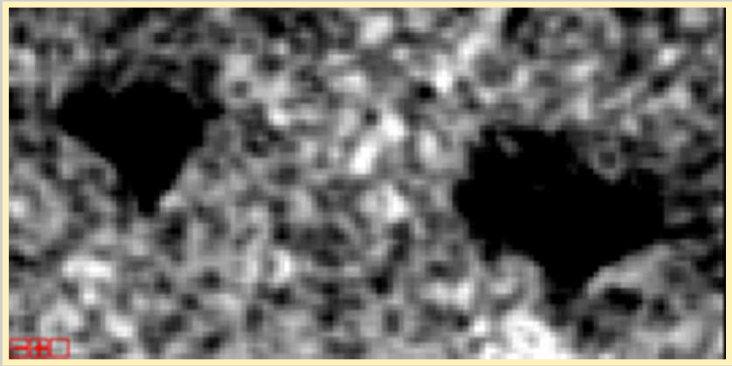


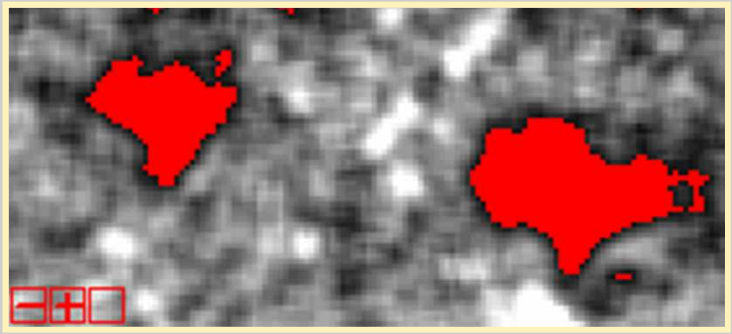
Evapotranspiration

Remote sensing

- Radar: Storage & flooding







[12]

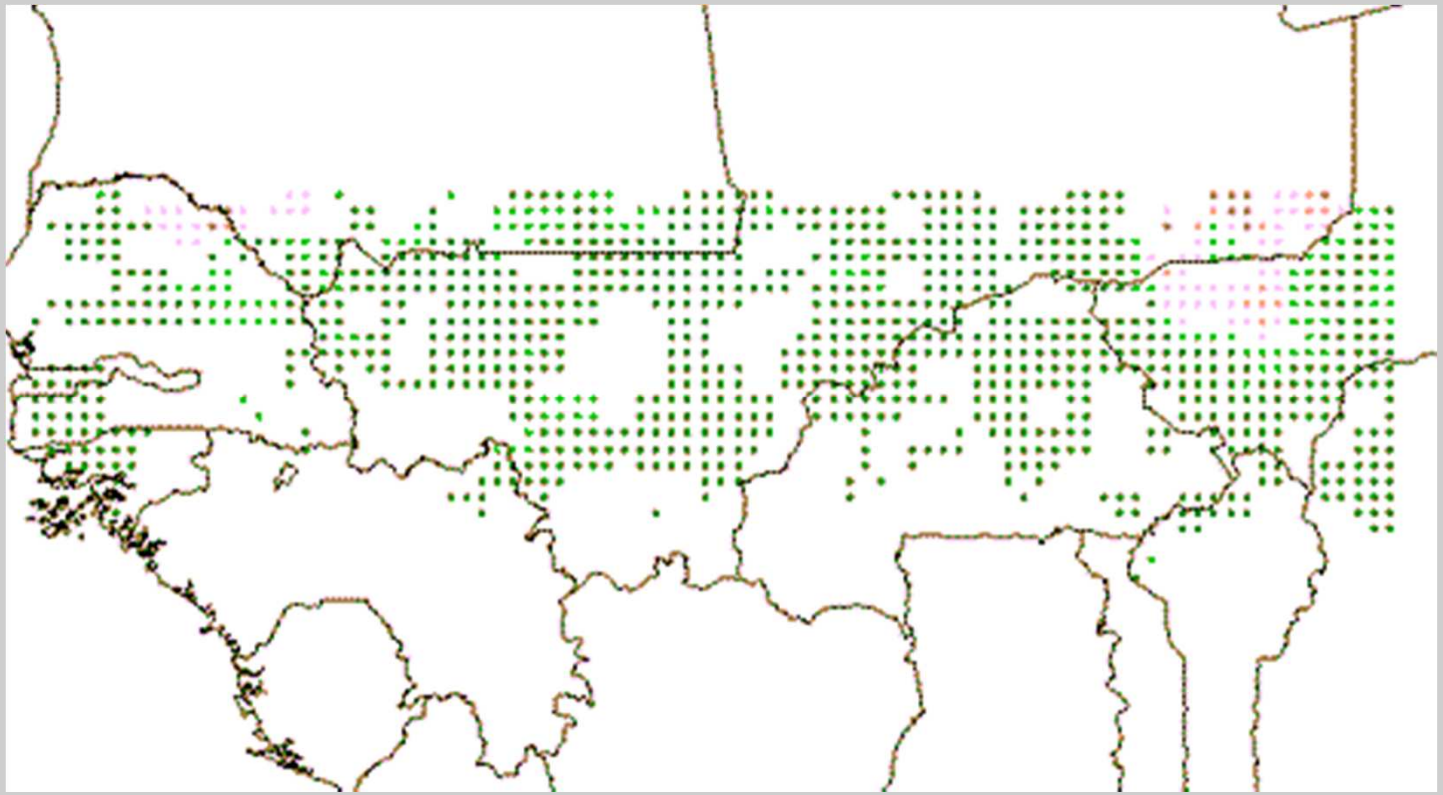
Remote sensing

- Radar: Scatterometer => Soil moisture
  - ERS
  - Envisat
  - METOP

[13]

Remote sensing

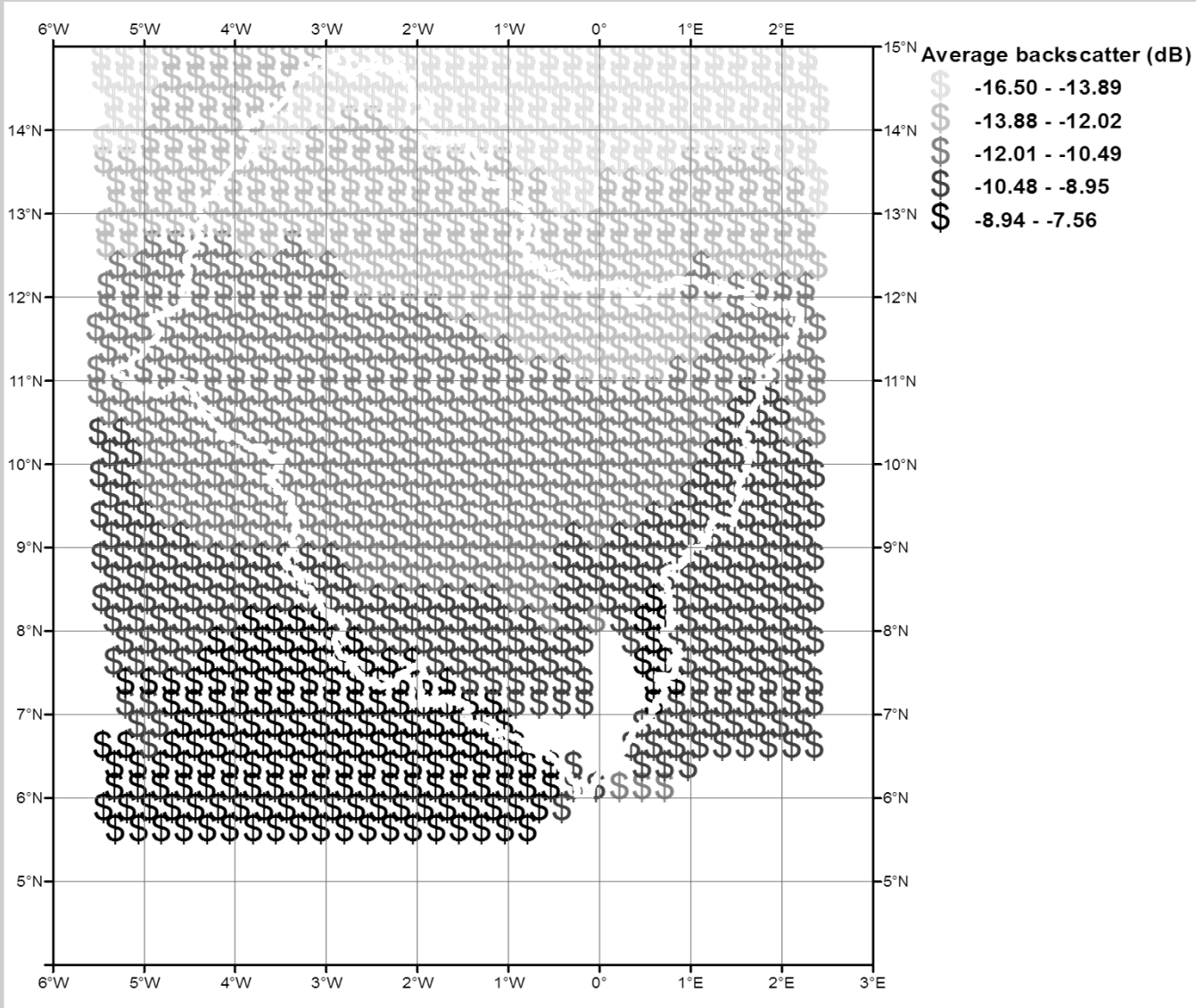
- Radar: Scatterometer => Soil moisture
  - ERS
  - Envisat
  - METOP



[14]

Remote sensing

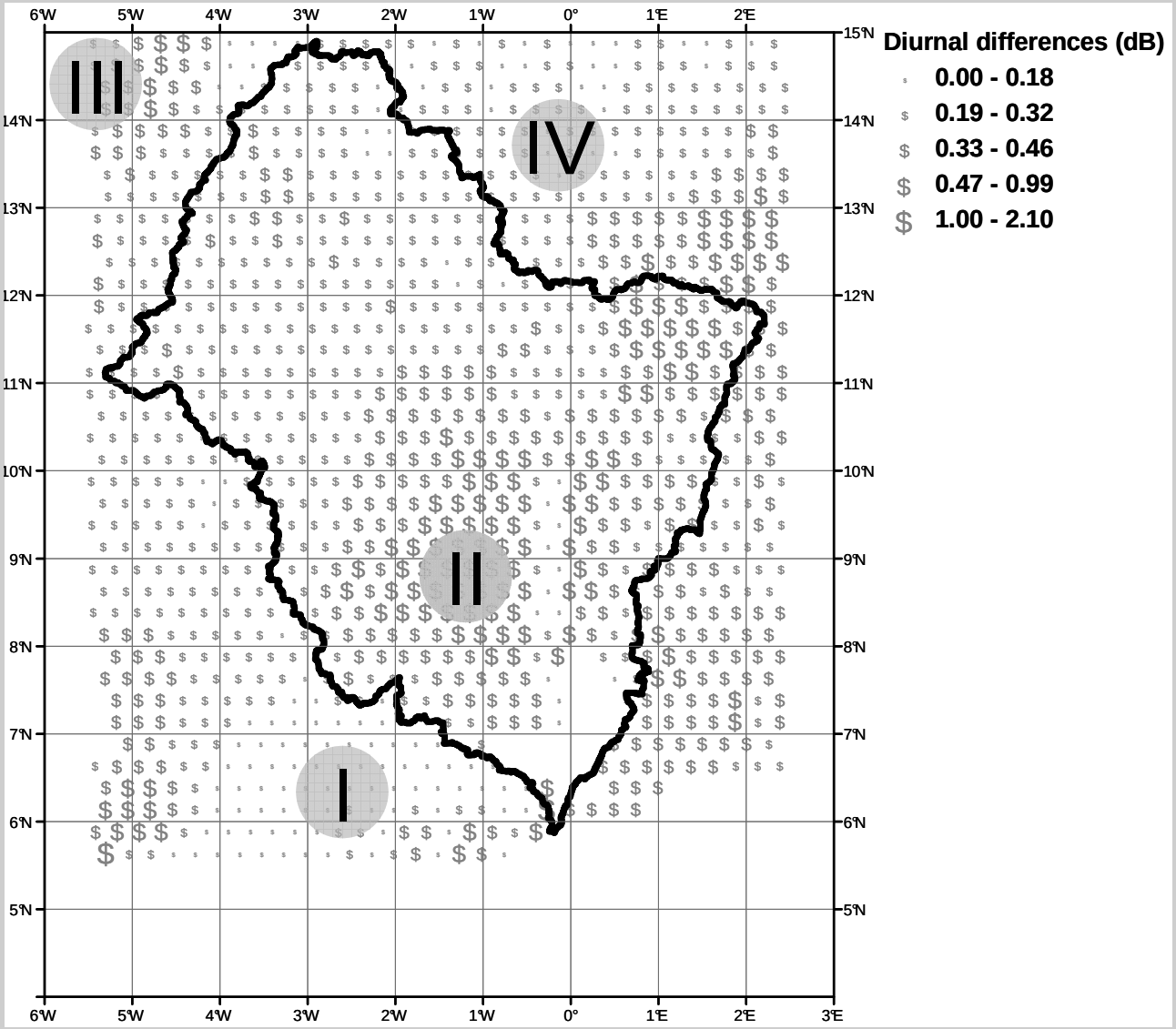
- Radar: Scatterometer => Soil moisture
  - ERS



[15]

Remote sensing

- Radar: Scatterometer => Soil moisture
  - ERS



[16]

Remote sensing

- Radar: Scatterometer => Soil moisture
  - ERS

σ_0=f(geometry, dielectric properties)

- geometry ≠ diurnal
- dielectric properties change
- water & trees

Remote sensing

- Radar: Scatterometer => Soil moisture
  - ERS

TREE WEIGHING!

Remote sensing

- SMOS
- Passive L-Band
- Low resolution (40 km)
- Accuracy?

SMOS

http://eopi.esa.int/esa/esa?e=XDqDwZWFQdQmevffklxJO2joY6jTAXK6xrEBcwkAvOBPjkKBePQifttoAPLY7Zn67UoTR1eKCPiNEoJcwF99TrmaixHyGlzTCTgmPIPCIRaMJqxZ9RMYqPGTPmHyKycmb22lL0zAVMxsjyyCkfmOME1jZC6YU4wmKXchu86F9ECVMAZF73Z4veIJMXkvWiug6OCEqjxBPJGVI26gy43TYQmu5K9K5DbGskeoQreQ9y886HsztZmgvTXsvvvLtM9ZodaN2GzRaD0

Remote sensing

- Future: SMOS & METOP!
- Combined use:

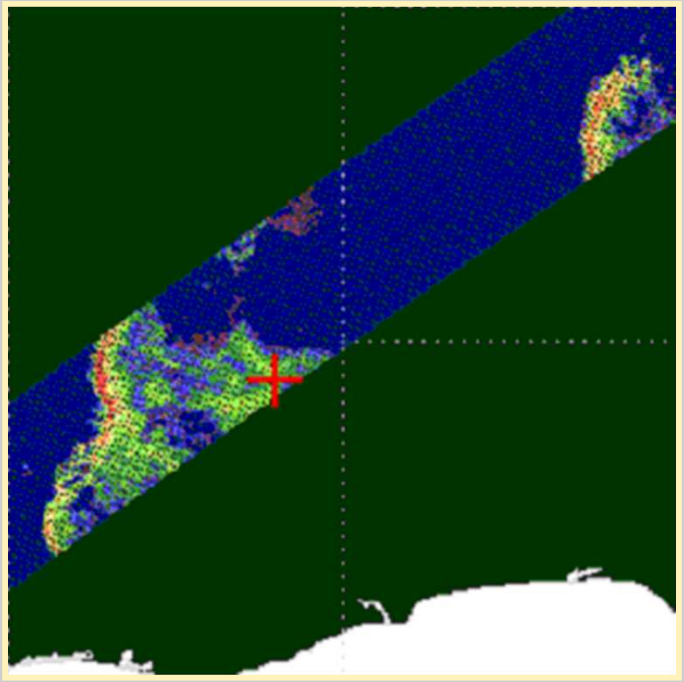
  Vegetation & soil

(MSc thesis???)

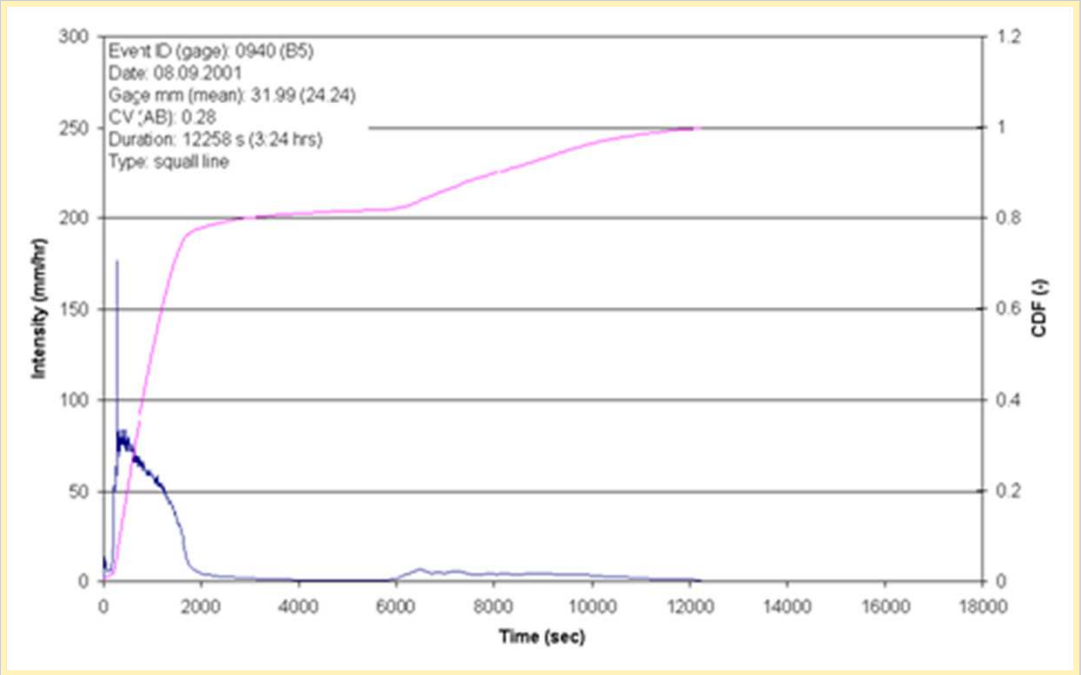
SMOS

Remote sensing

- Radar: Rainfall



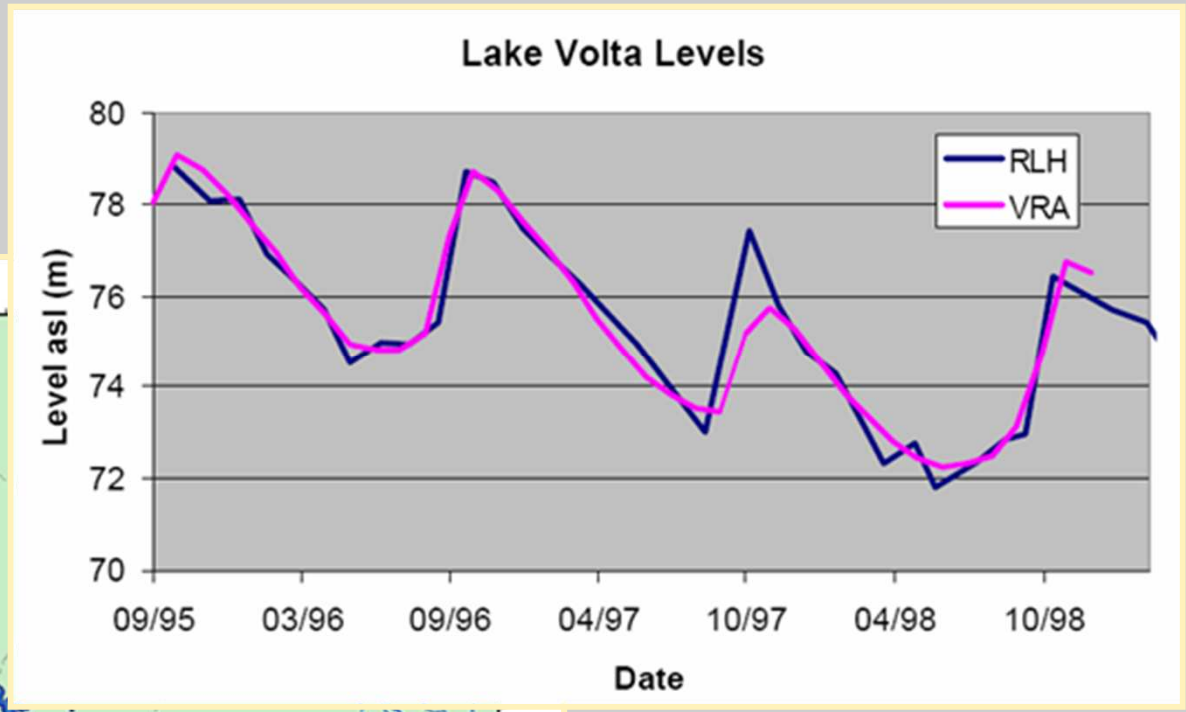
TRMM

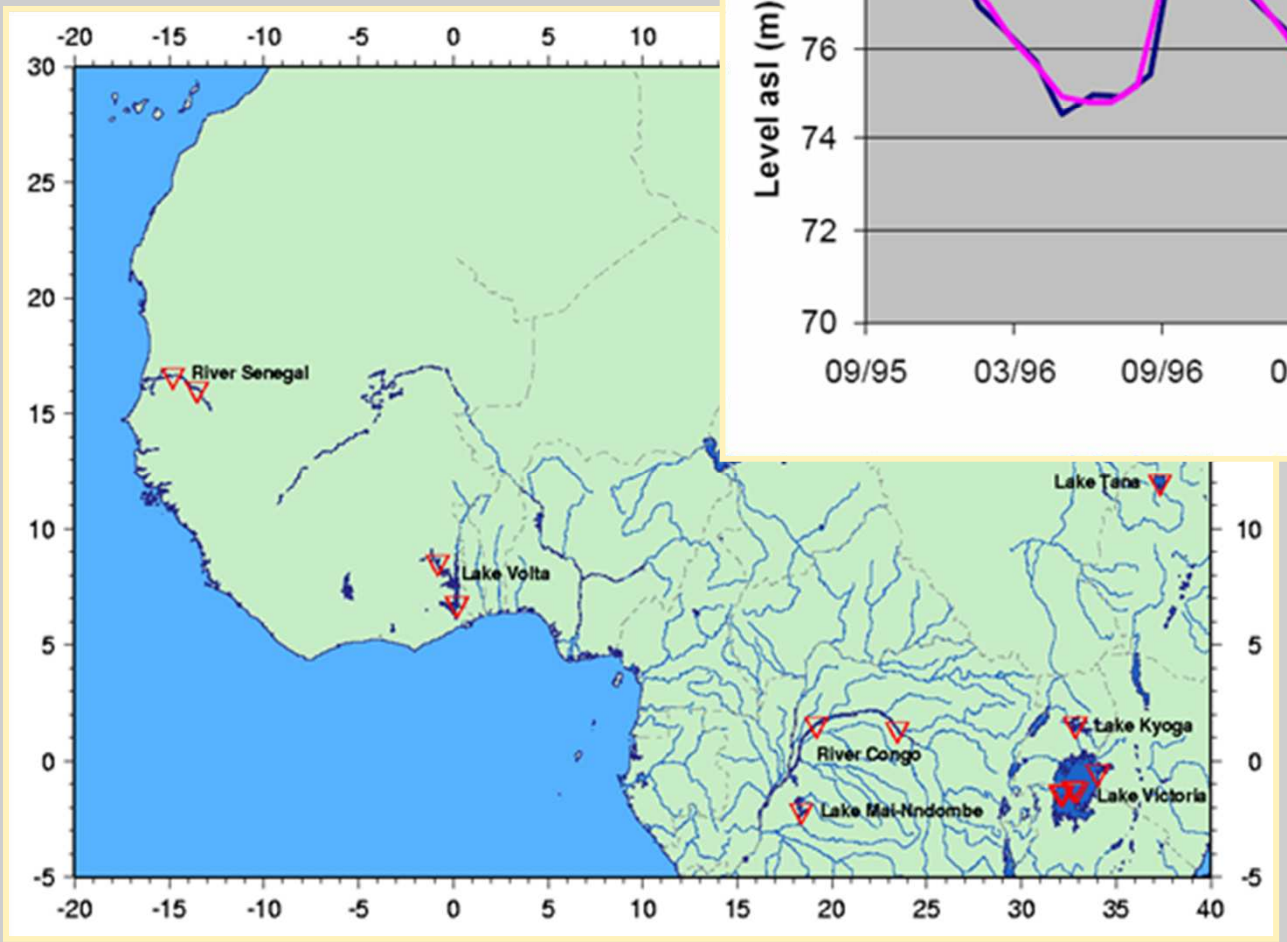


Ground

Remote sensing

- Radar: Altimetry
- Lidar: Altimetry ICE



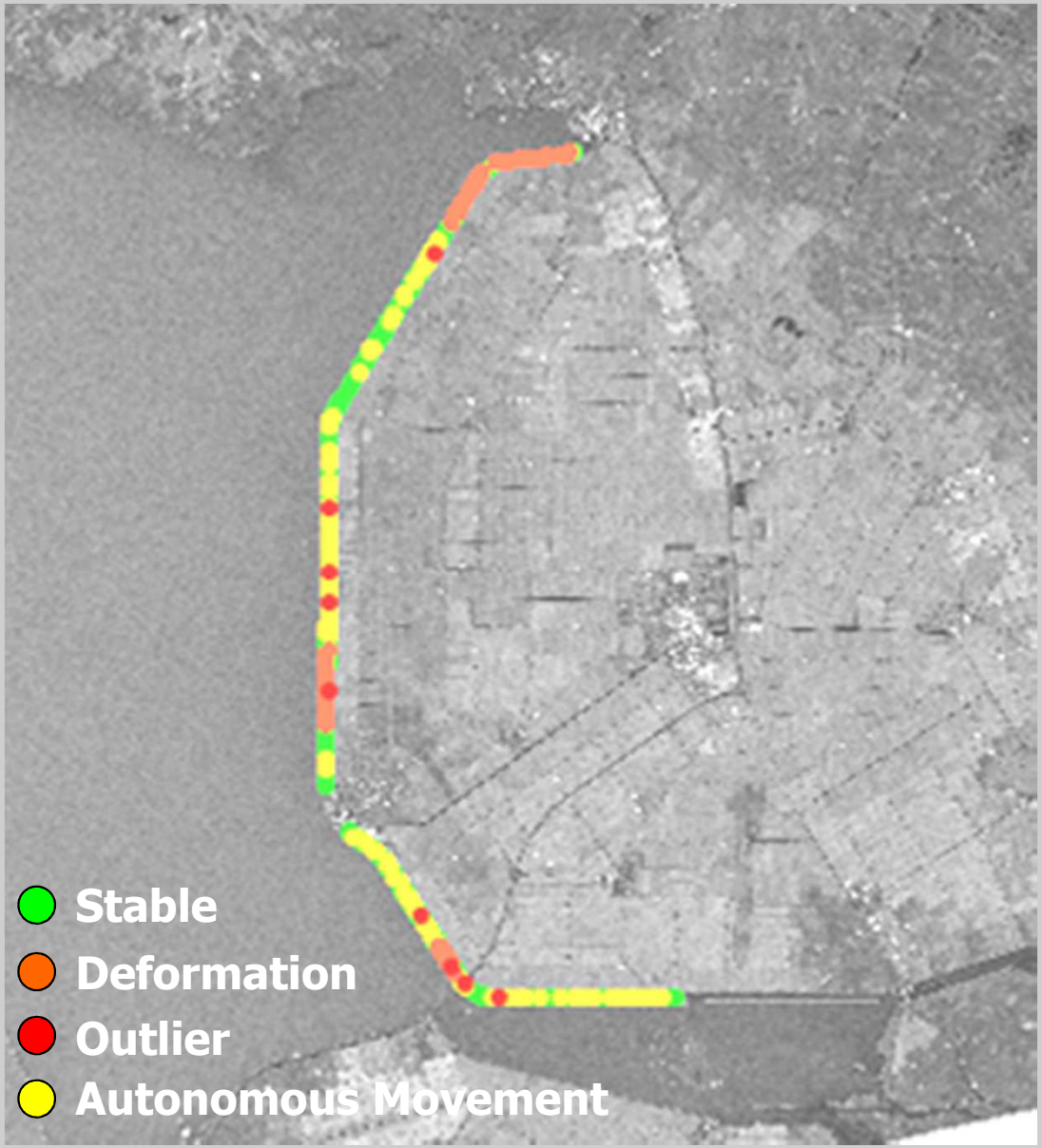


earth.esa.int/riverandlake

Remote sensing

- Radar: Interferometry

Ramon Hanssen



Remote sensing

- Radar: Storage & flooding

New research:

ALOS: L-band radar

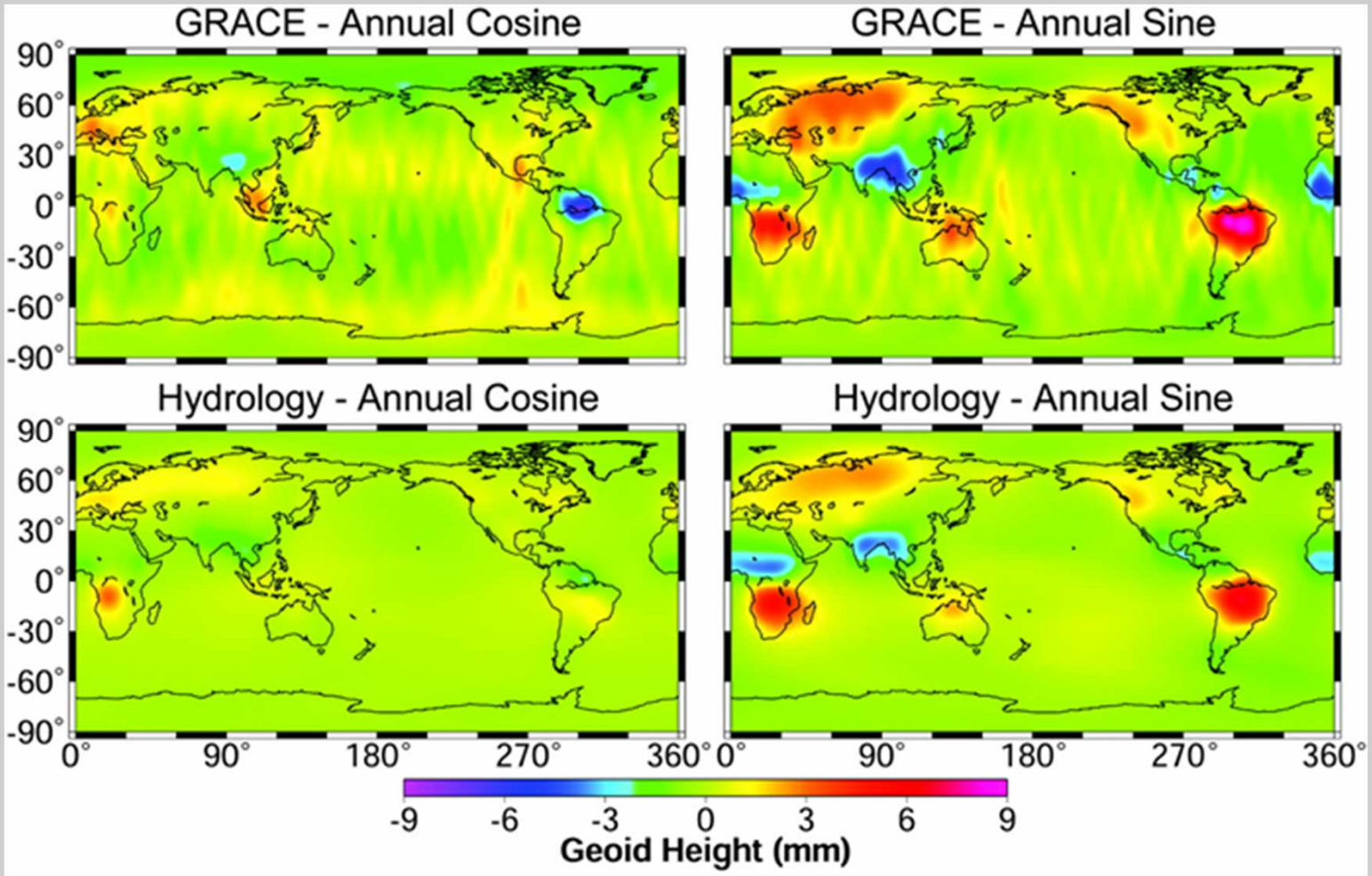
Biesbos

Casamance

[17]

Remote sensing

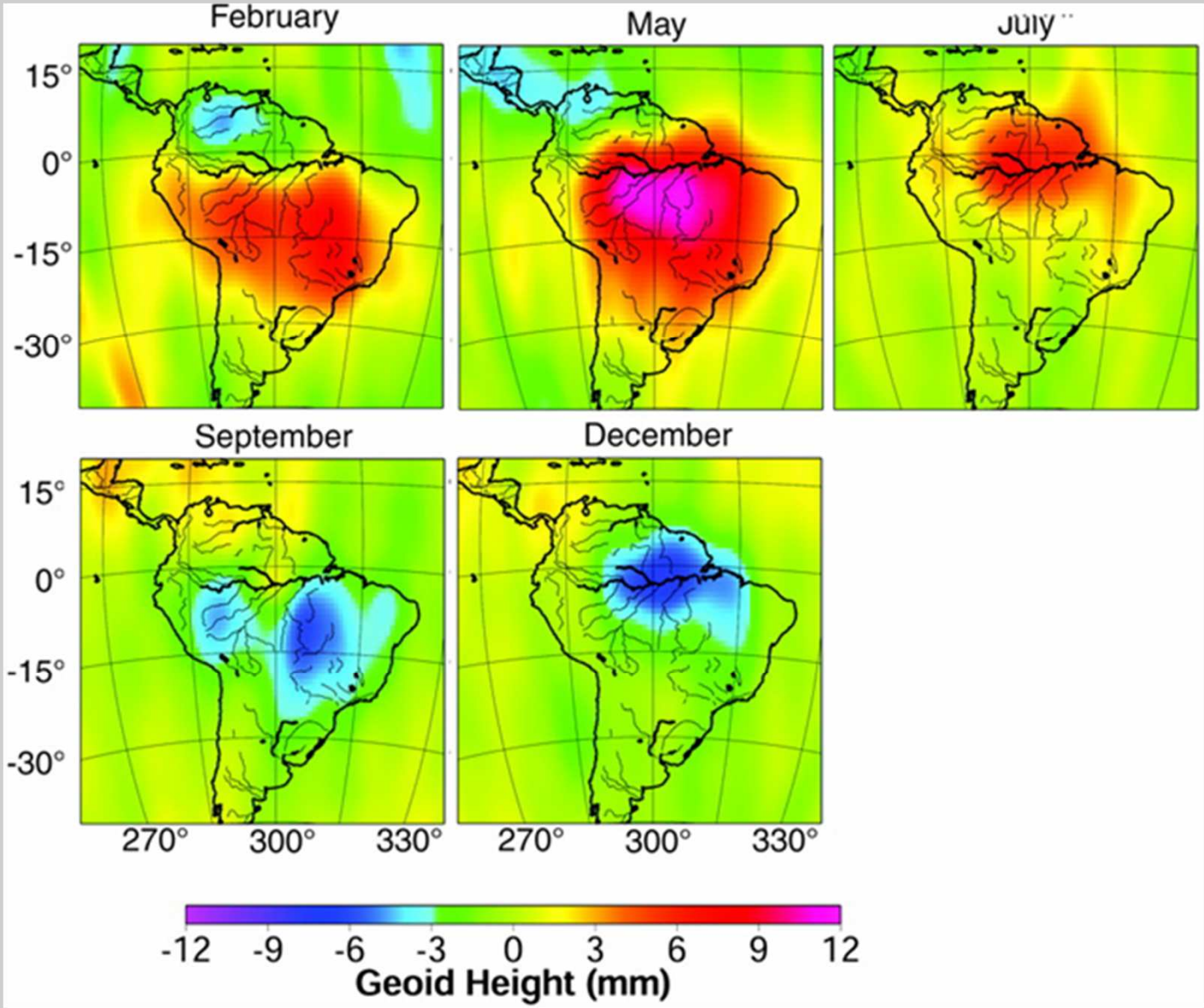
- Gravity: GRACE



[18]

Remote sensing

- Gravity: GRACE



[18]

Overview satellites

Variable	Satellite	Principle	Resol.	Qual.
Rain	MeteoSat, NOAA, …	Cloud Tem	2km+	Med
	TRMM	Rain radar	4km	Good
Evaporation	Landsat, ASTER, MODIS, …	SEBAL, ..	30m-1km	Med
Soil moisture	ERS, ENVISAT	C-Band	1 km+	Poor
	Landsat, ASTER, MODIS, …	Thermal inertia	30m-1km	Poor
	TRMM	Passive multi	45km	Good
	SMOS	Passive L-band	50 km	???
	METOP	Scatterometer C	25 km	Good
Storage	Optical, radar	Reflection H_20	30m	High
Level	TOPEX-POSEIDON, ENVISAT	Radar altimetry	NA	High
Groundwater	GRACE	Gravity	400km	High

Image analysis

Image analysis

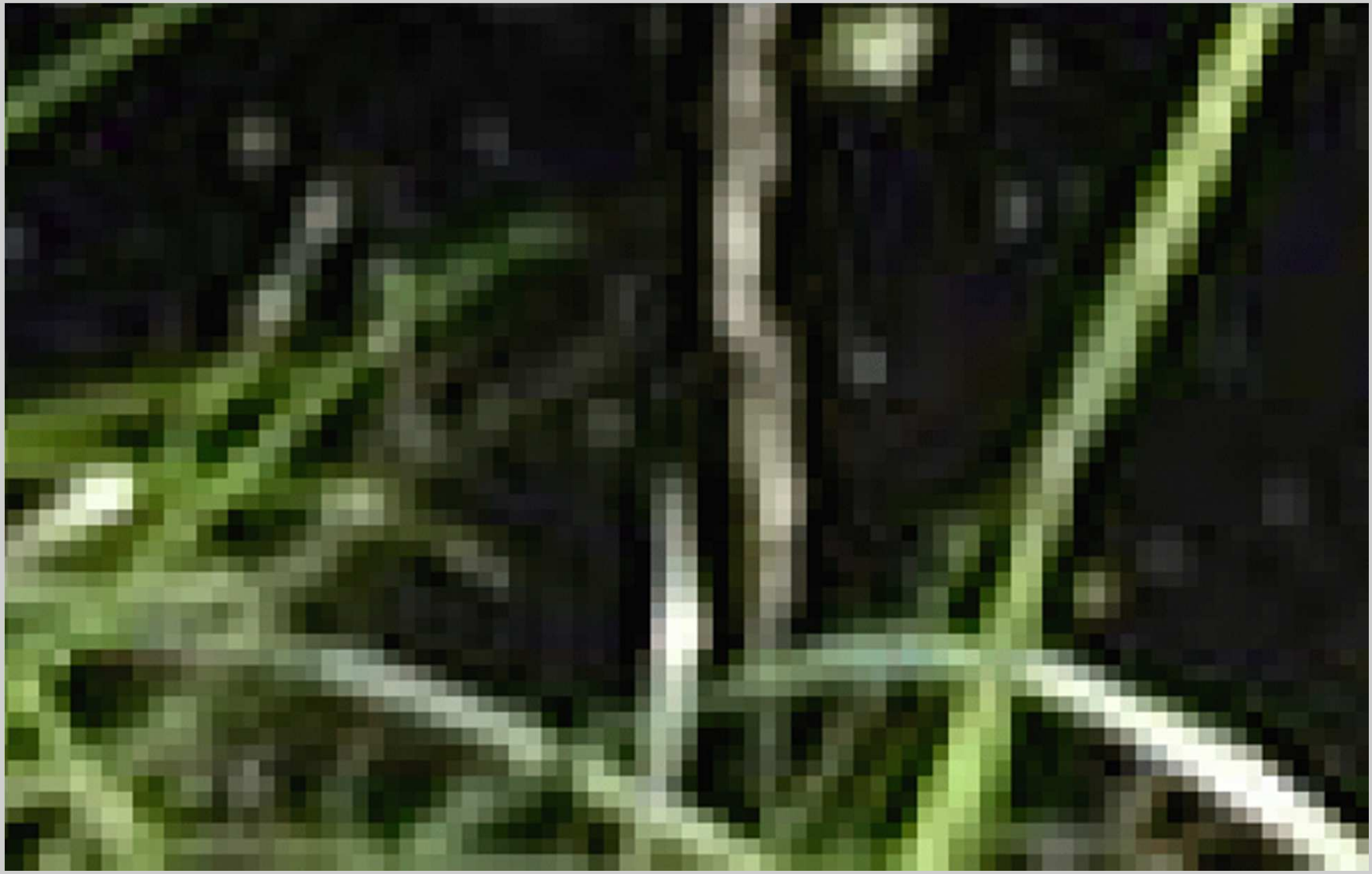


Image analysis

Image => Matrix

Row => Horizontal line

Column => Vertical line

Entry => Picture element (pixel)

Image analysis

- Pre-processing:
  - Georeferencing
  - Atmospheric correction
  - Image enhancement
- Processing
  - NDVI
  - Surface temperature
  - Classification

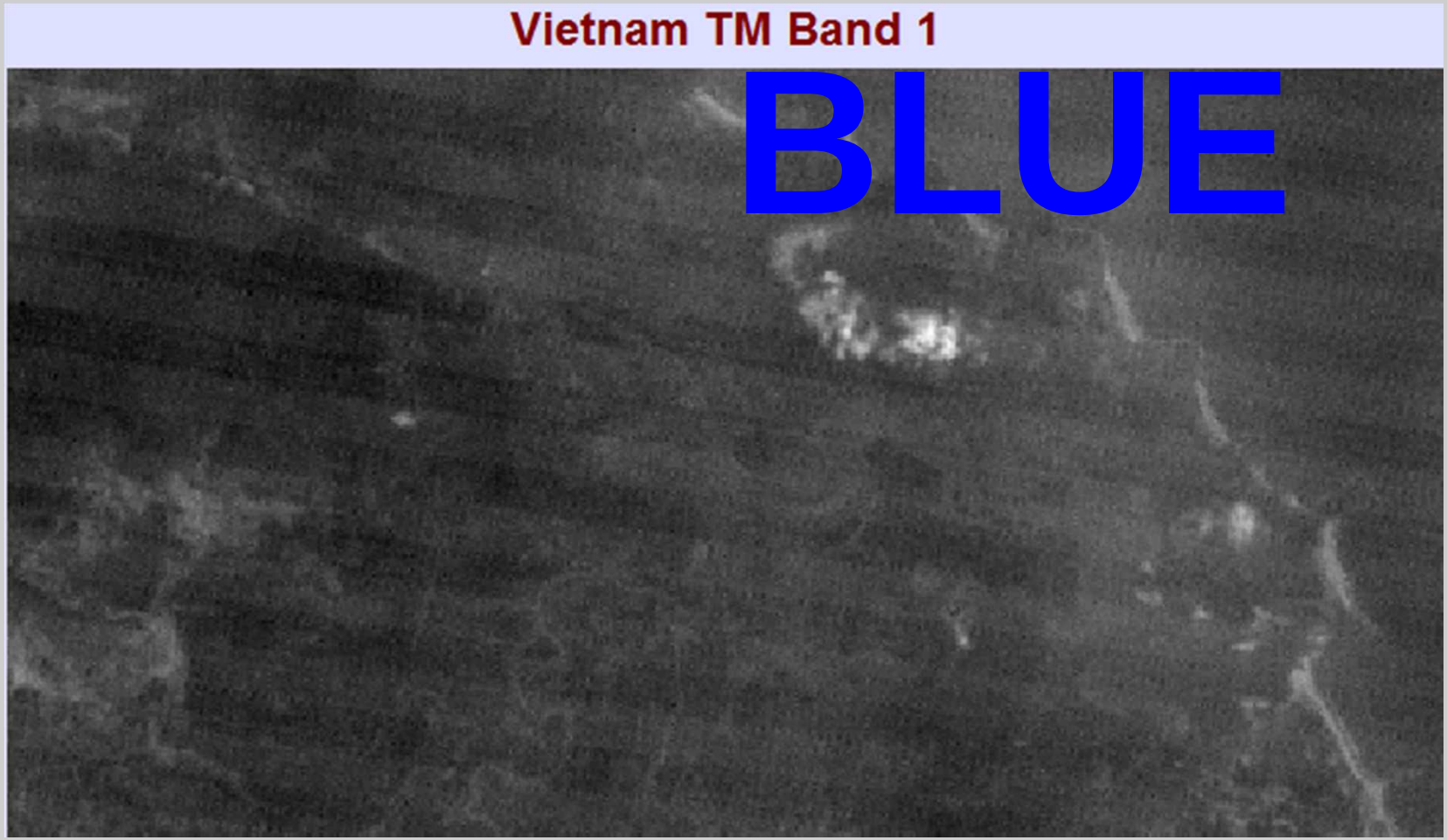
Image analysis

Color

Pixel => Number (DN), greyscale

[19]

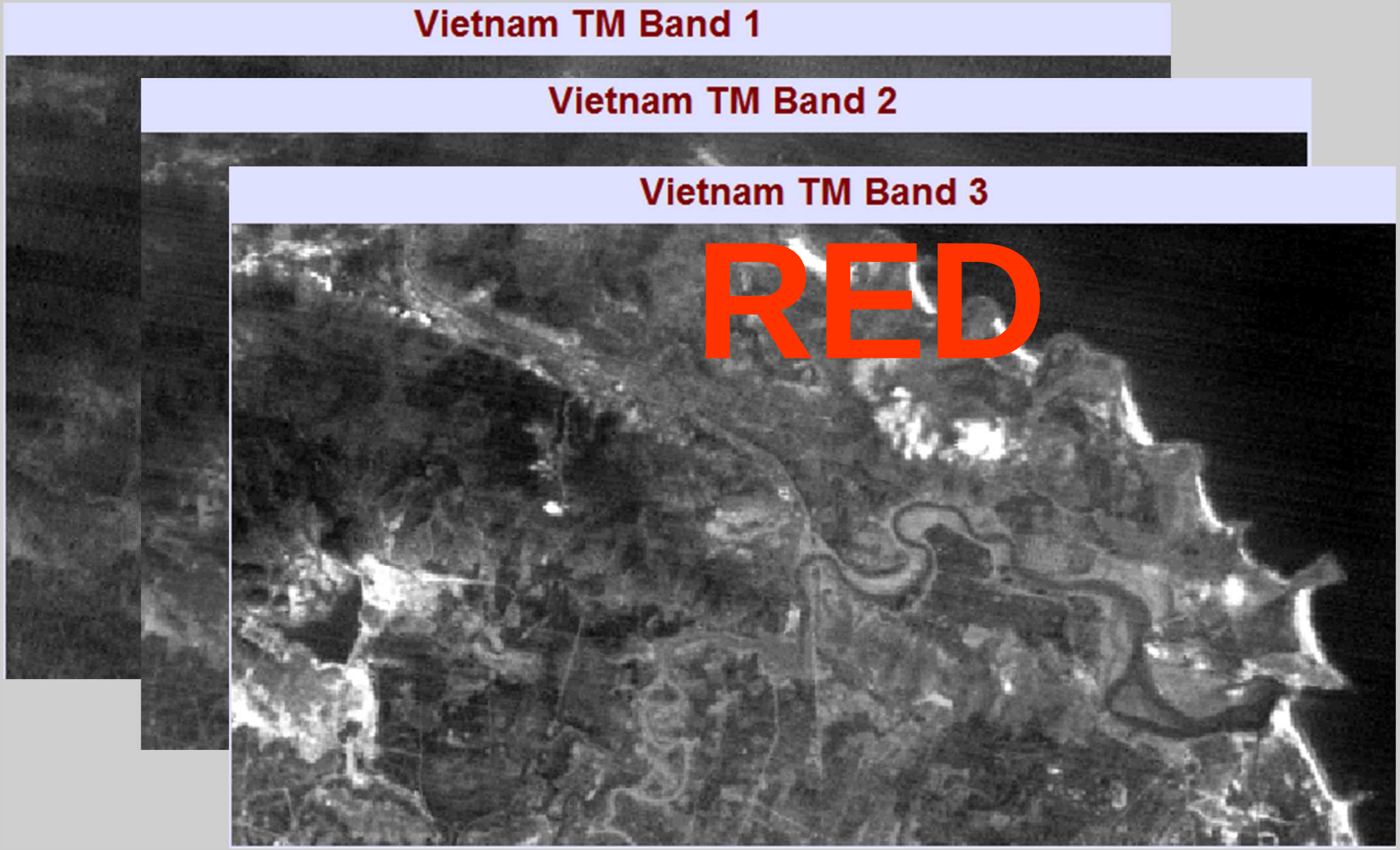
Image analysis



[20]

Image analysis

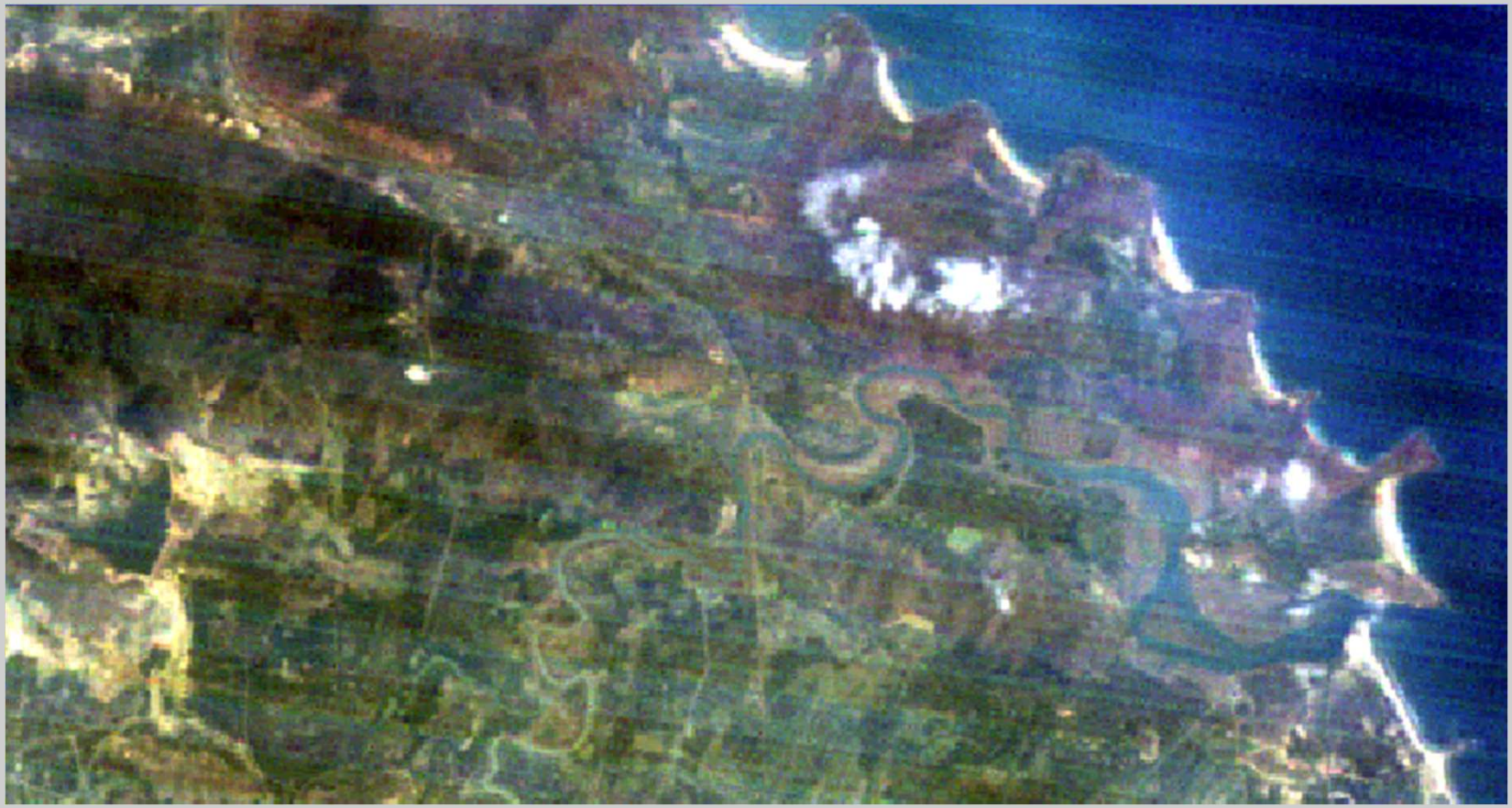
Image analysis



[21]

Image analysis

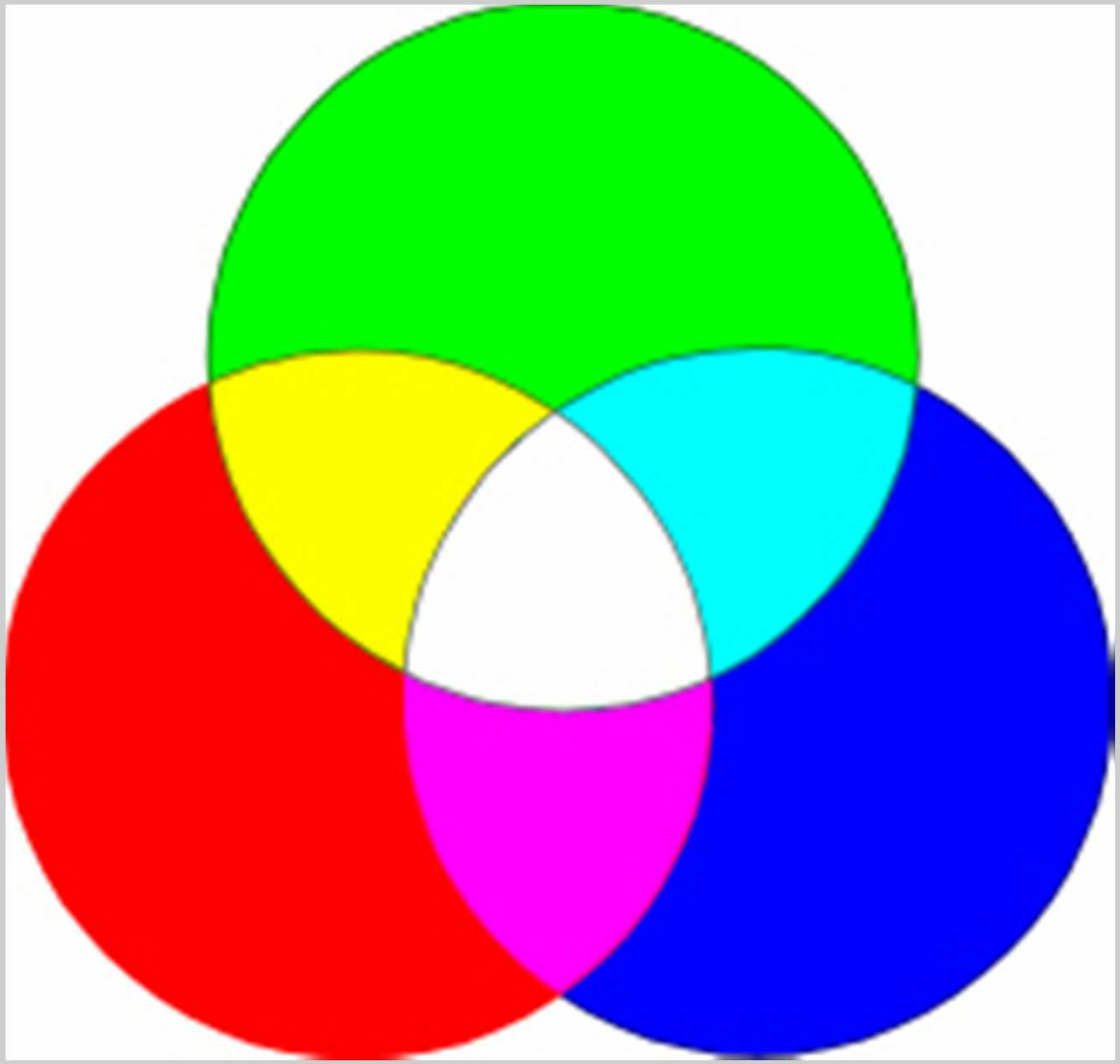
Color



[22]

Image analysis

Color



[23]

Image analysis

Color

Green => Blue, Red => Green, NIR => Red

[24]

Image analysis

Landsat 7 (ETM+) bands (wavelengths in micrometers)

Band 1	0.45-0.52	Blue-Green
Band 2	0.53-0.61	Green (often mapped to Blue)
Band 3	0.63-0.69	Red (often mapped to Green)
Band 4	0.75-0.90	Near IR (often mapped to Red)
Band 5	1.55-1.75	Mid-IR
Band 6	10.4-12.5	Thermal IR
Band 7	2.09-2.35	Short Wave IR
Band 8	0.52-0.90	Panchromatic

Image analysis

Operators

Multiply, add, subtract, …

If …, then … (Boolean)

Convolution / filters

Almost like matrix math (pixel by pixel)

Image analysis

Operators

Red

Image analysis

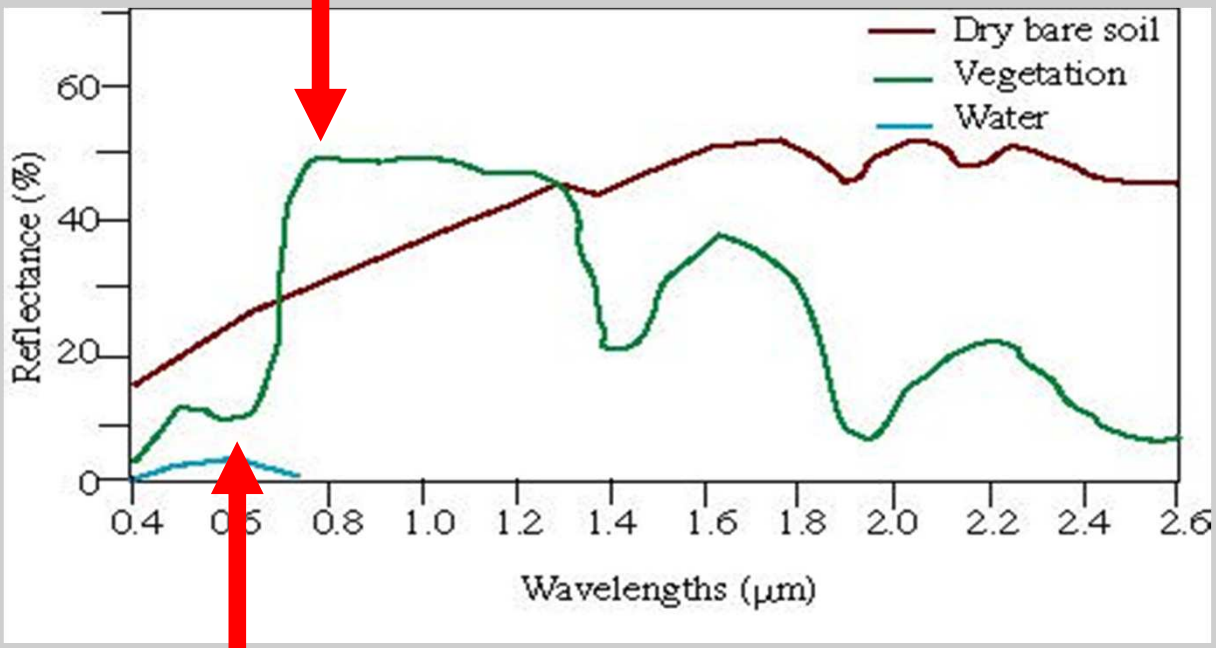
Operators

Near Infrared (NIR)

Image analysis

Operators

NIR



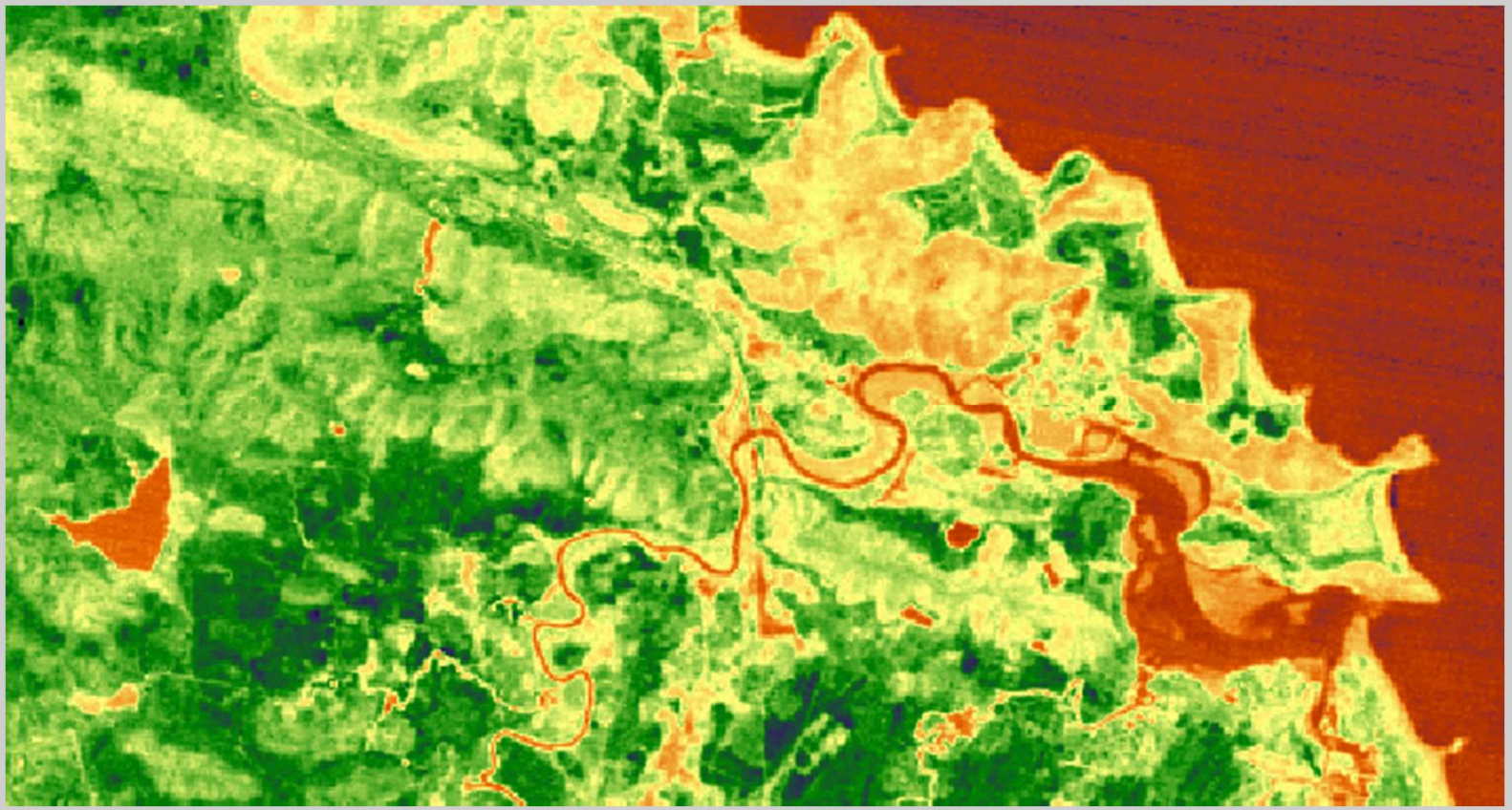
[3]

Red

NDVI=(NIR-Red) / (NIR+Red)

Image analysis

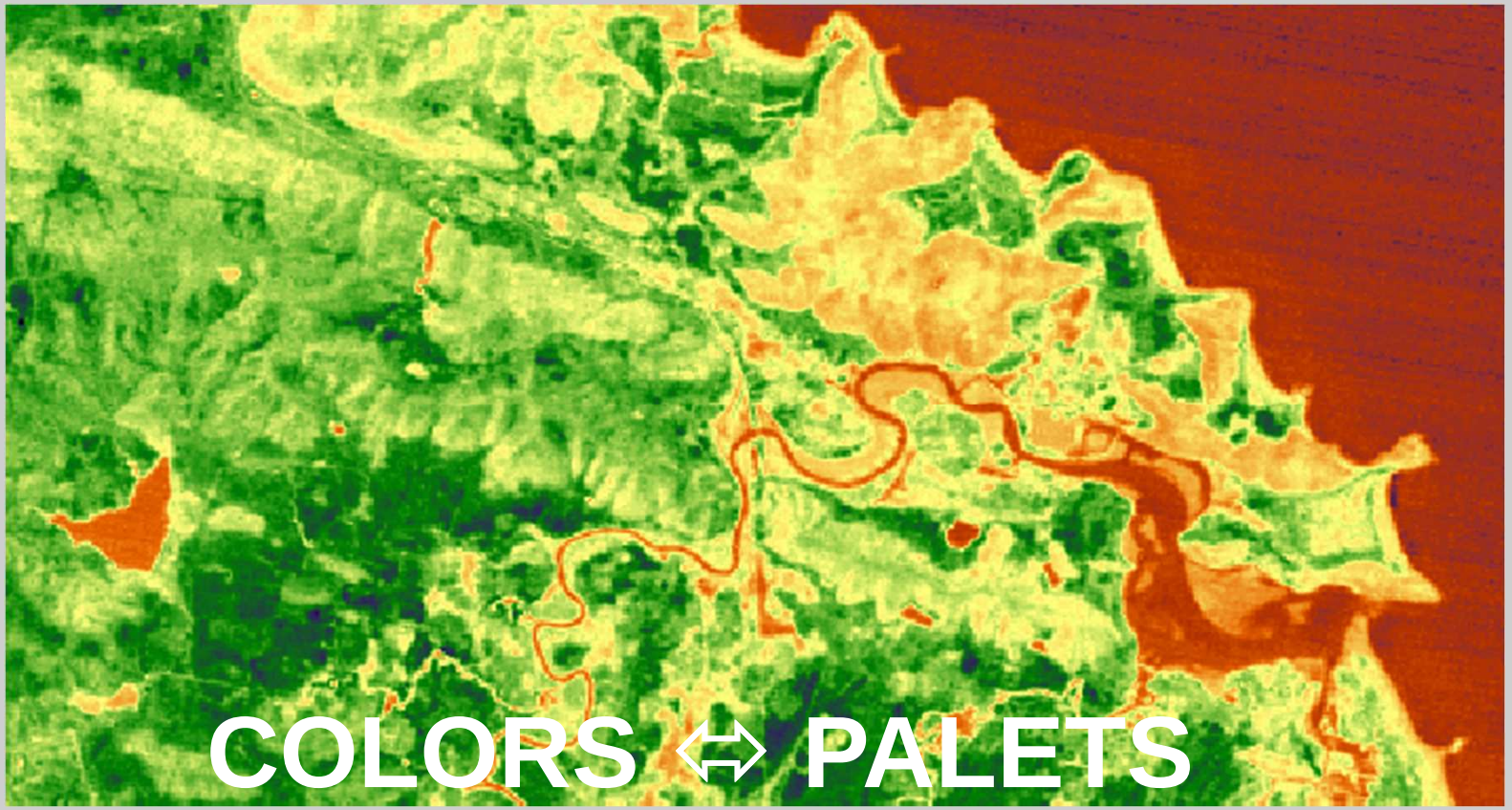
Operators



NDVI=(NIR-Red) / (NIR+Red)

Image analysis

Operators

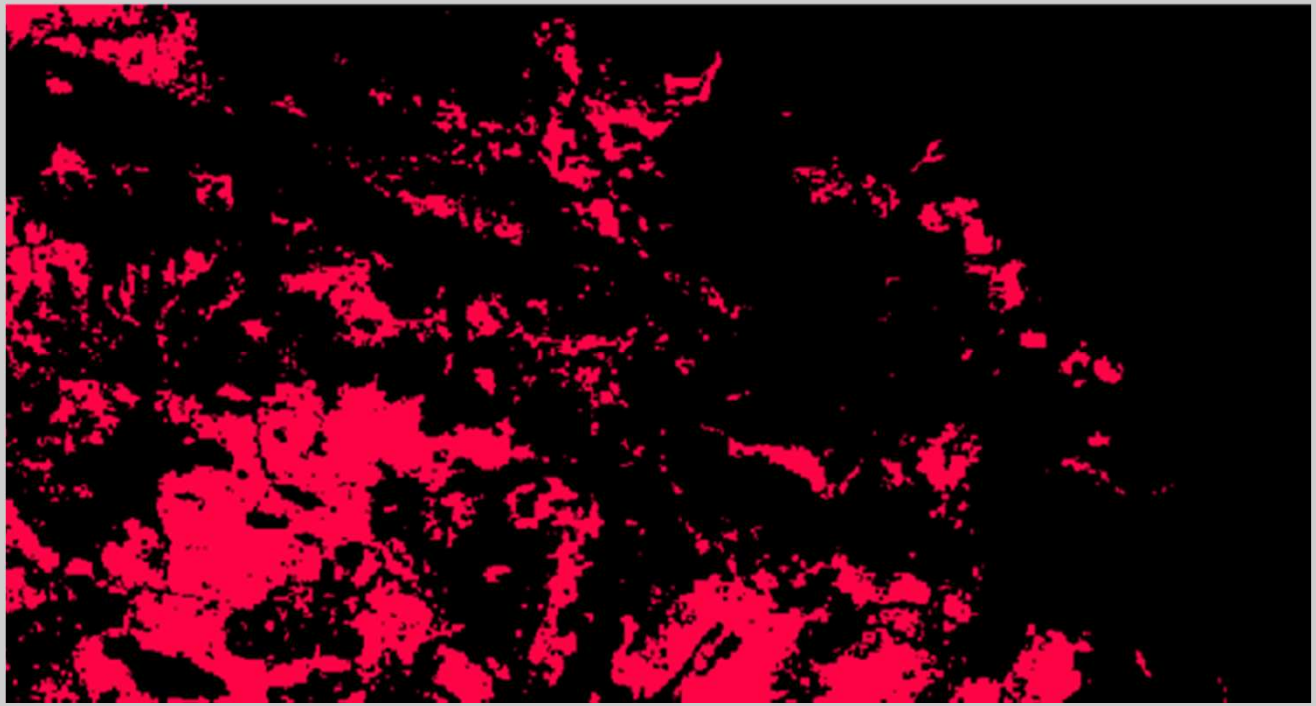


NDVI=(NIR-Red) / (NIR+Red)

Image analysis

Operators

Density slicing => classification



NDVI>0.15 => Forest (red)
NDVI<0.15 => Other (black)

Image analysis

Classification

Histogram

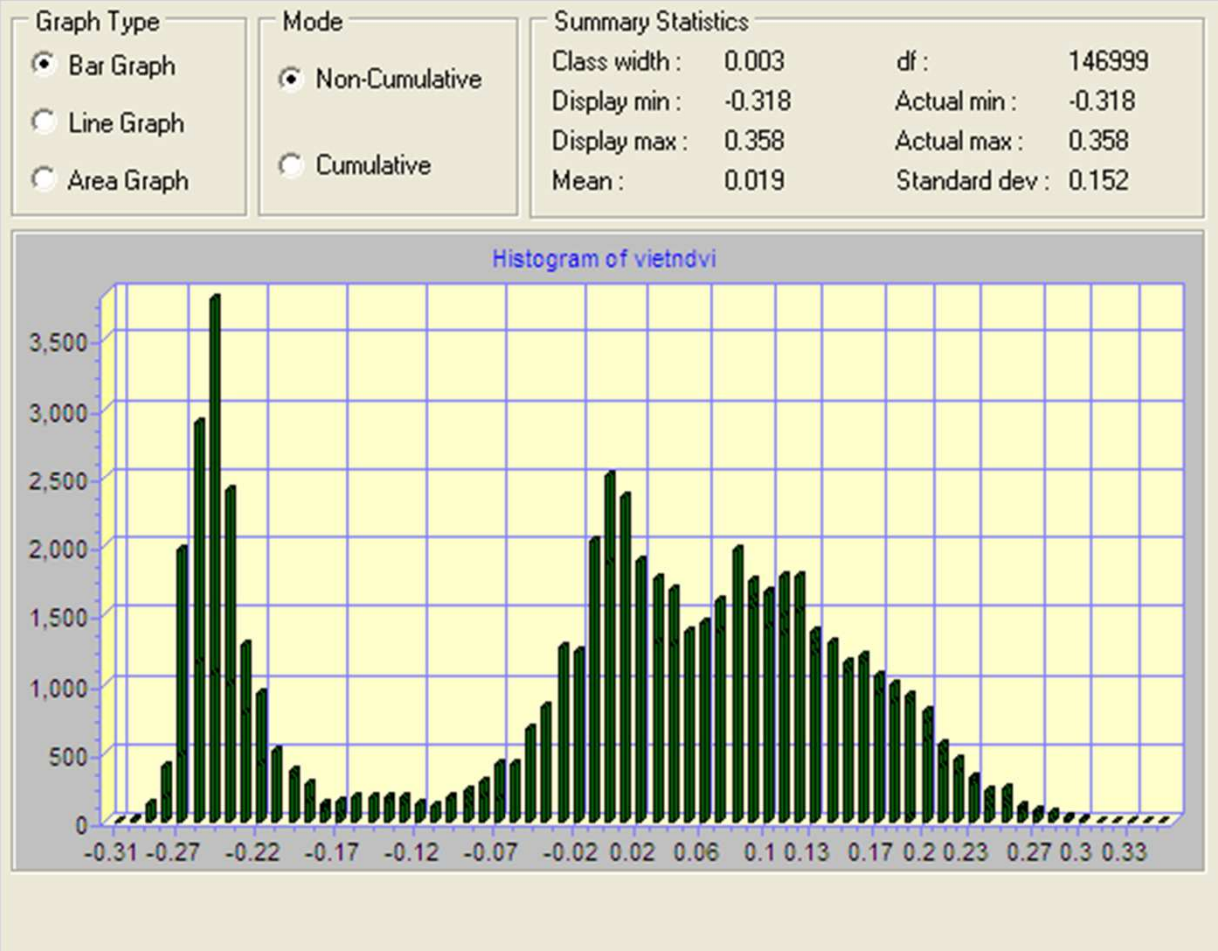


Image analysis

Classification

Histogram

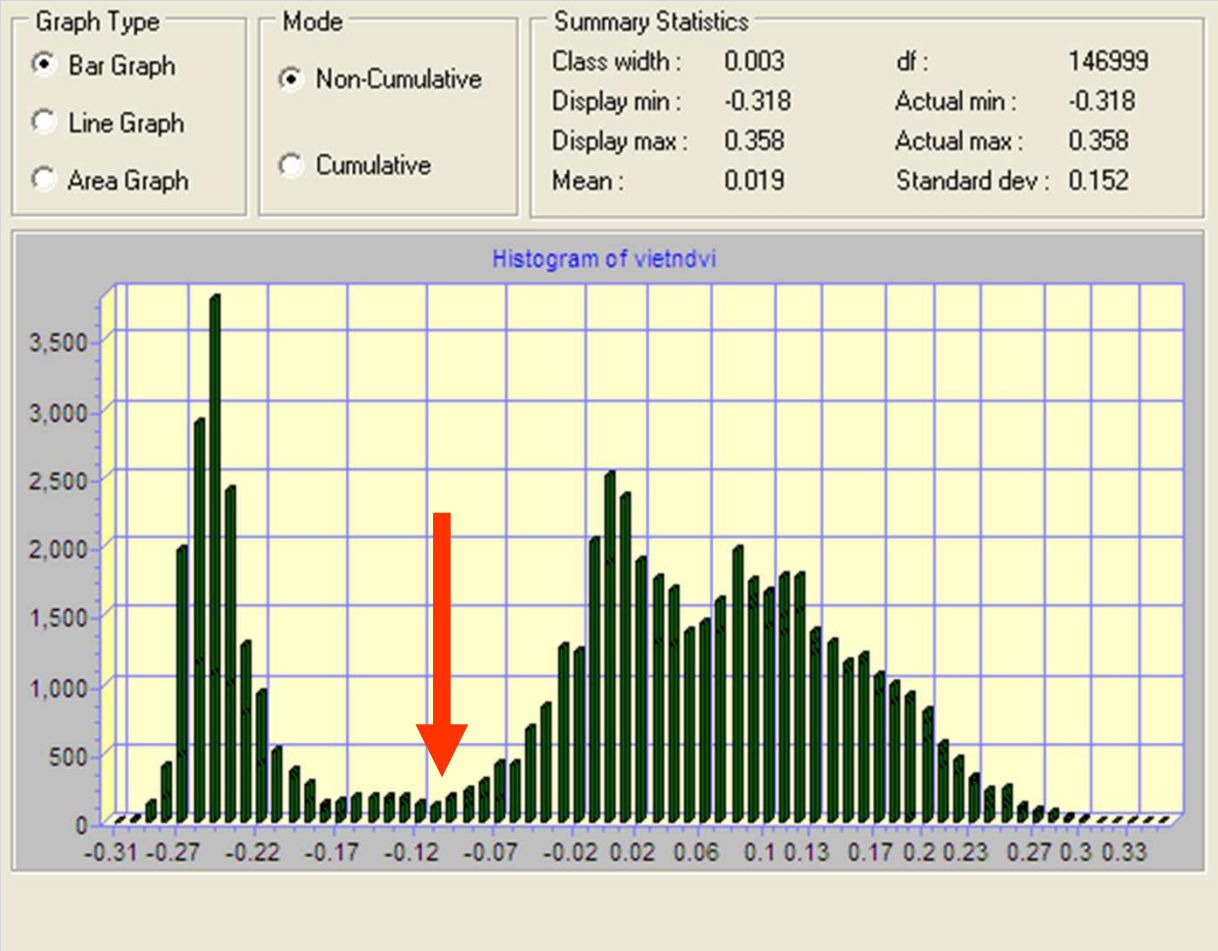
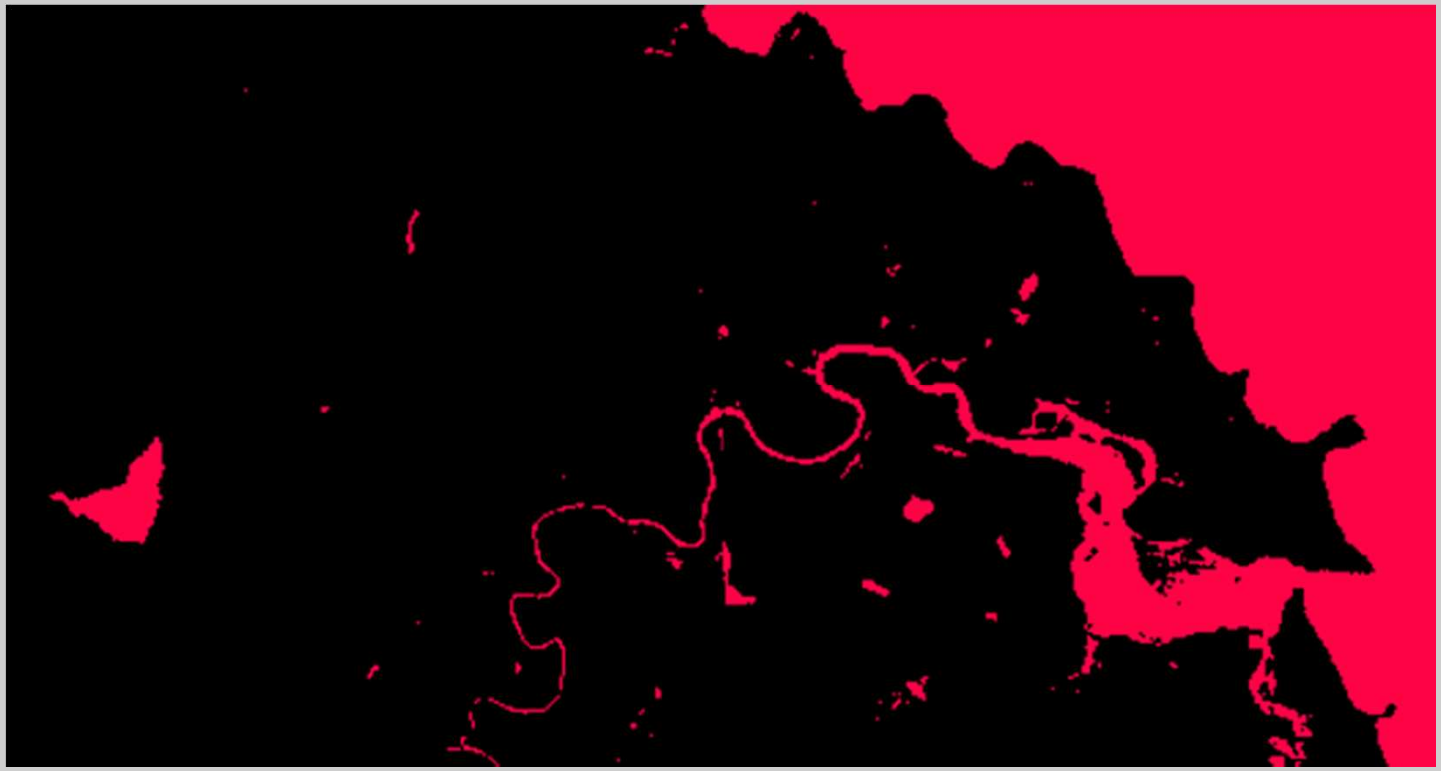


Image analysis

Classification

Histogram



NDVI<-0.15 => Water (red)
NDVI>-0.15 => Other (black)

Image analysis

Classification

- Automatic (cluster analysis)
- Supervised
  - Parallelepiped
  - Minimum distance
  - Maximum Likelihood

Image analysis

Classification / Maximum Likelihood

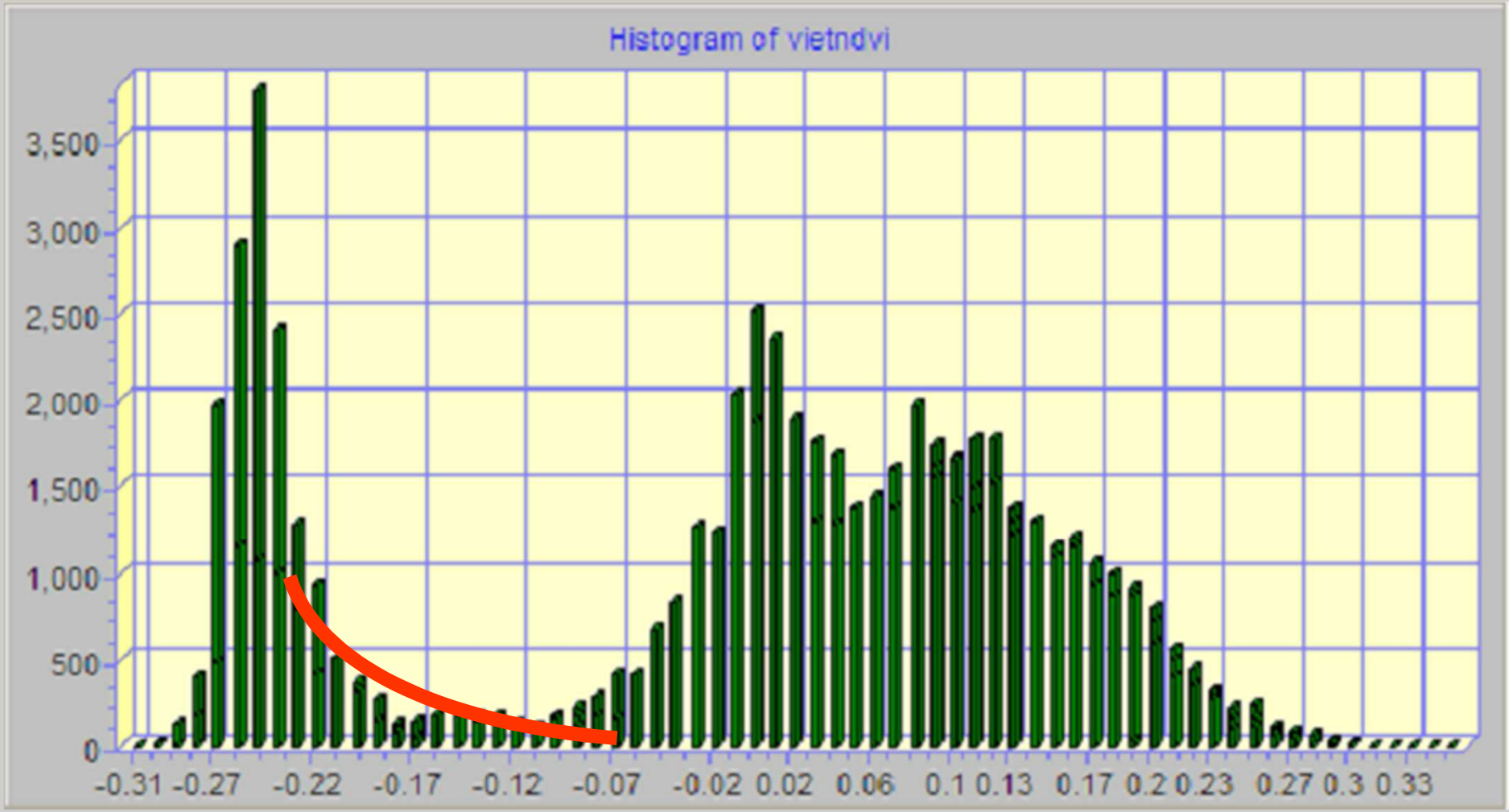


Image analysis

Classification / Maximum Likelihood

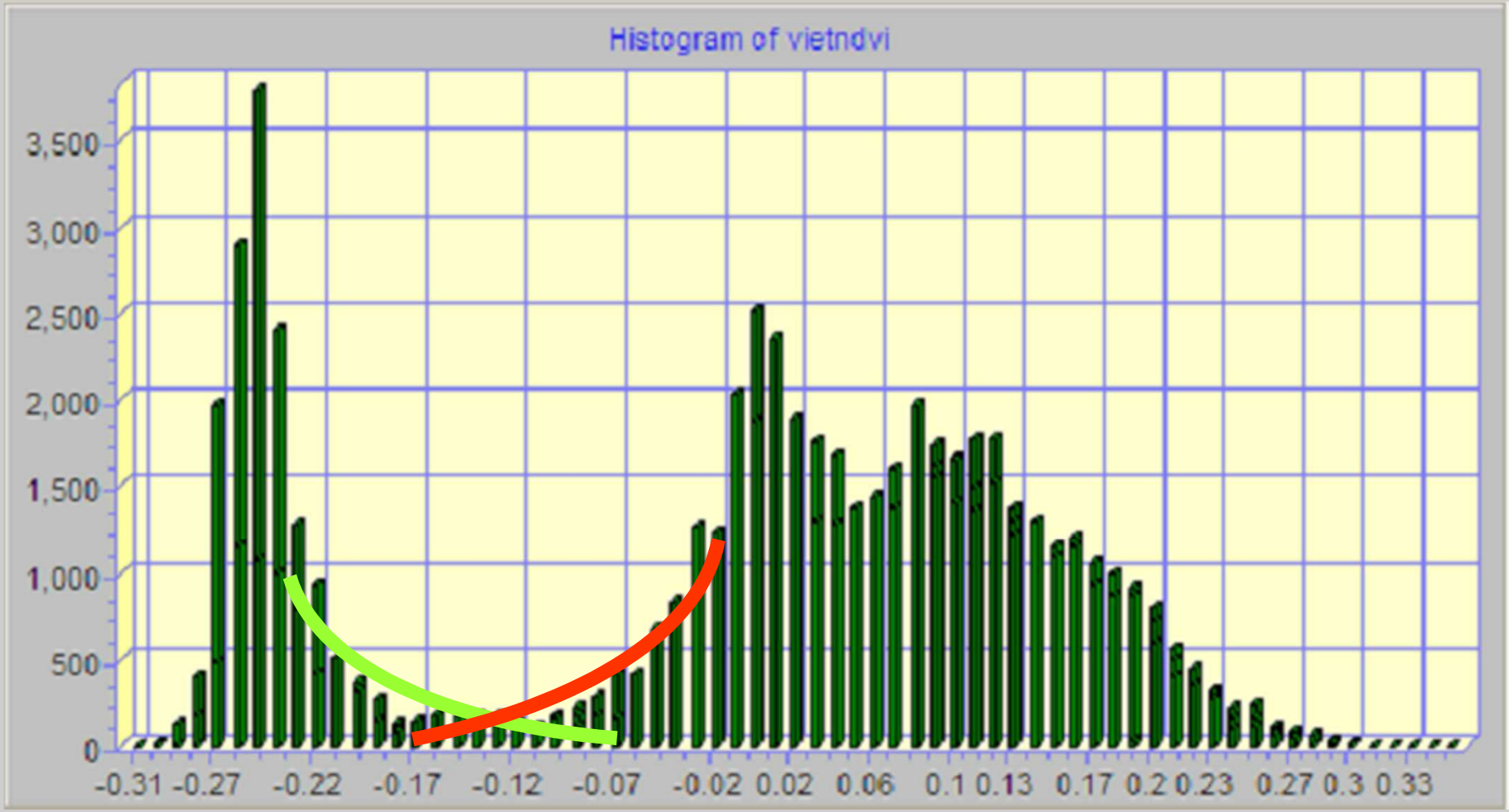


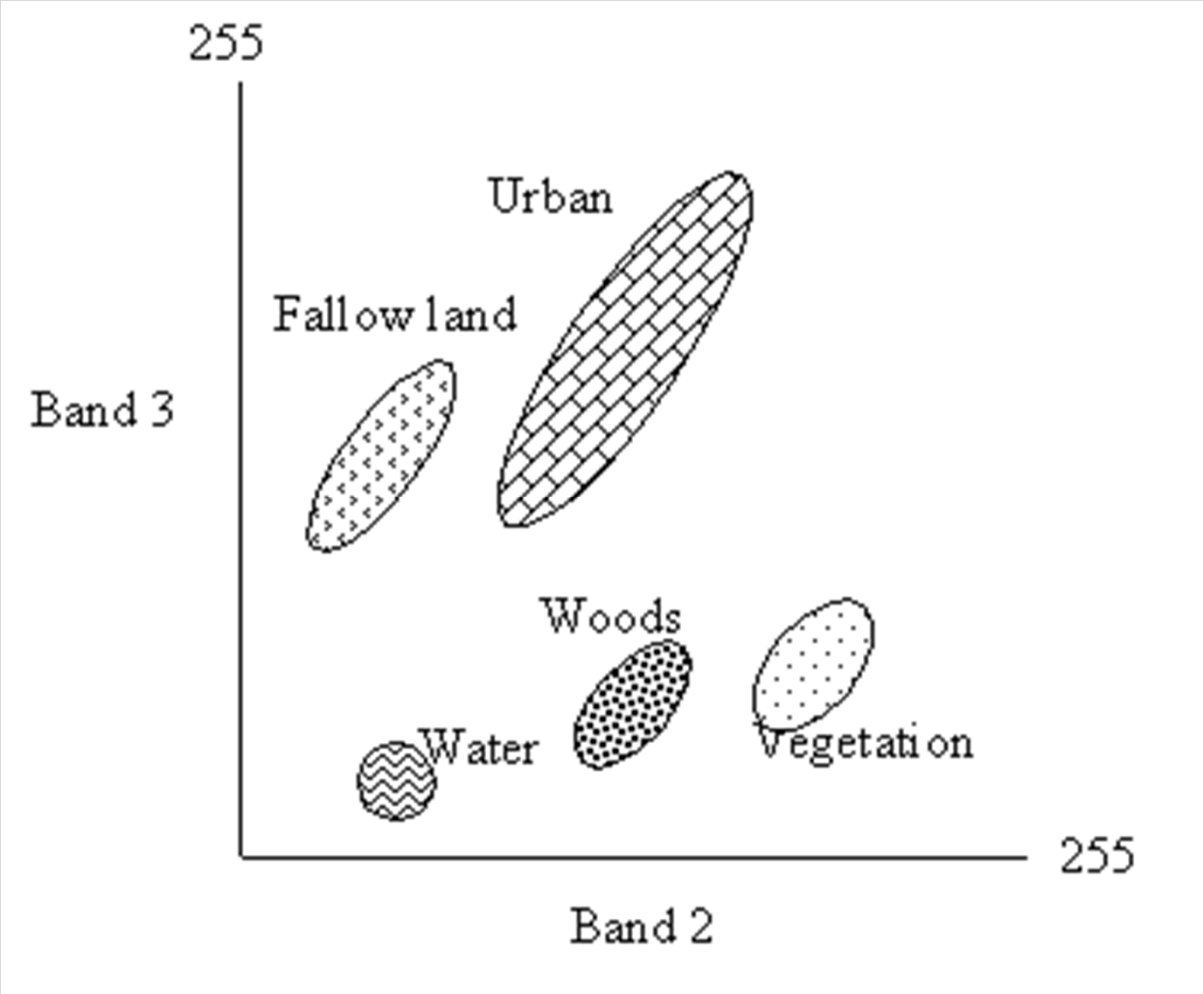
Image analysis

Classification / Maximum Likelihood

- Multi-band analysis
- Assume normal distribution
- Use training sets => avg, sd, cov
- Determine likelihoods per class (take max)
- Some pixels may remain undetermined

Image analysis

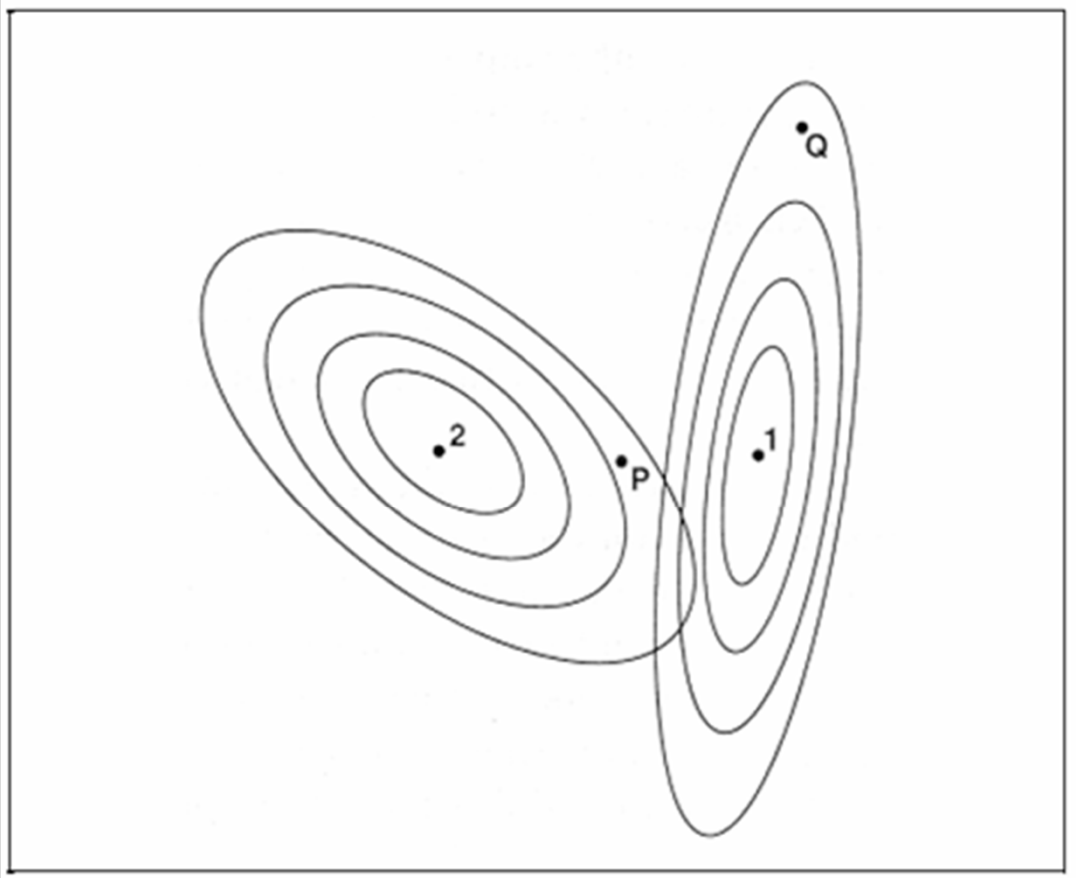
Classification / Maximum Likelihood



[25]

Image analysis

Classification / Maximum Likelihood

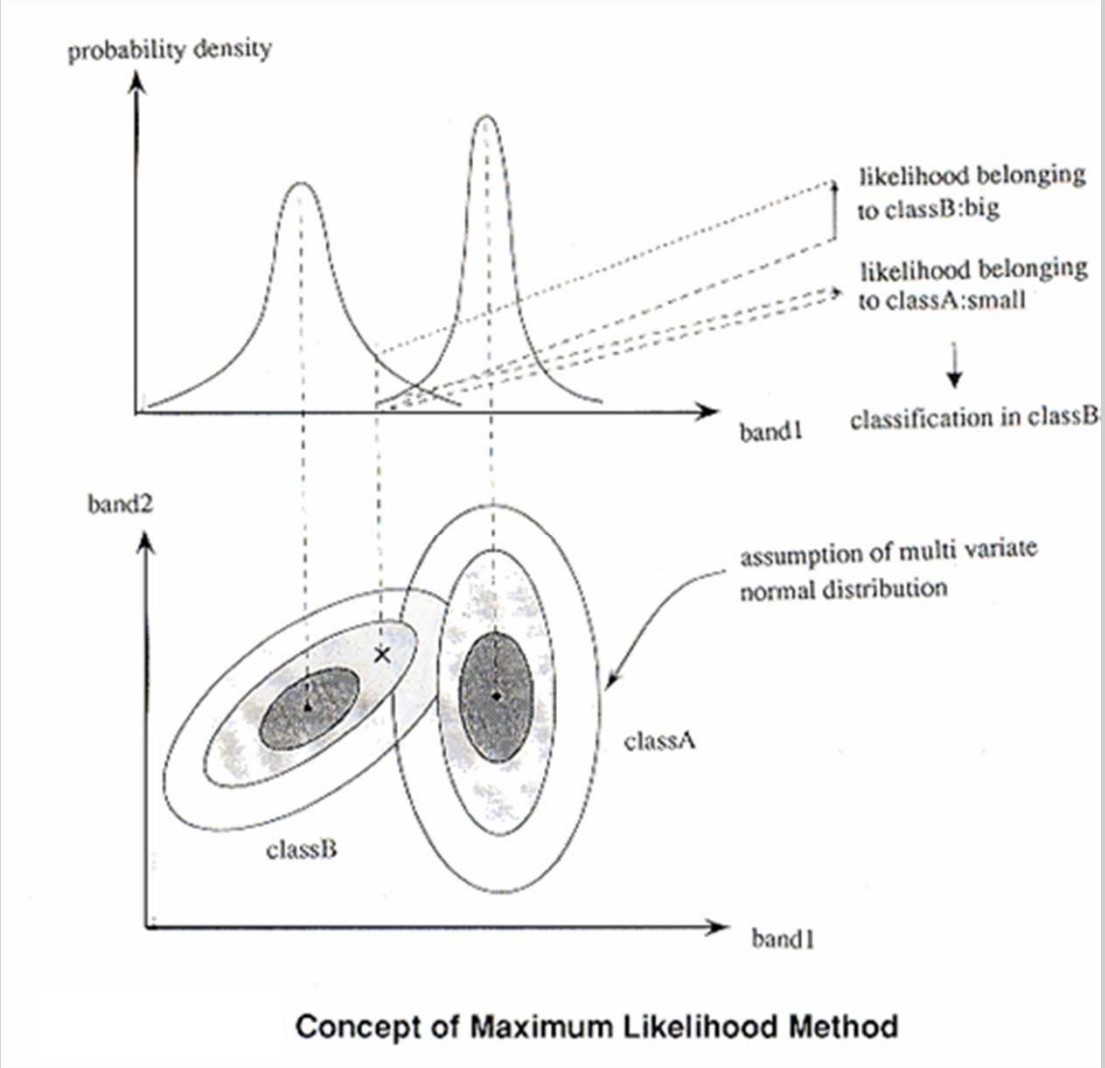


Equi-probability contours as used in Maximum Likelihood classification

[26]

Image analysis

Classification / Maximum Likelihood



Concept of Maximum Likelihood Method

[27]

Image analysis

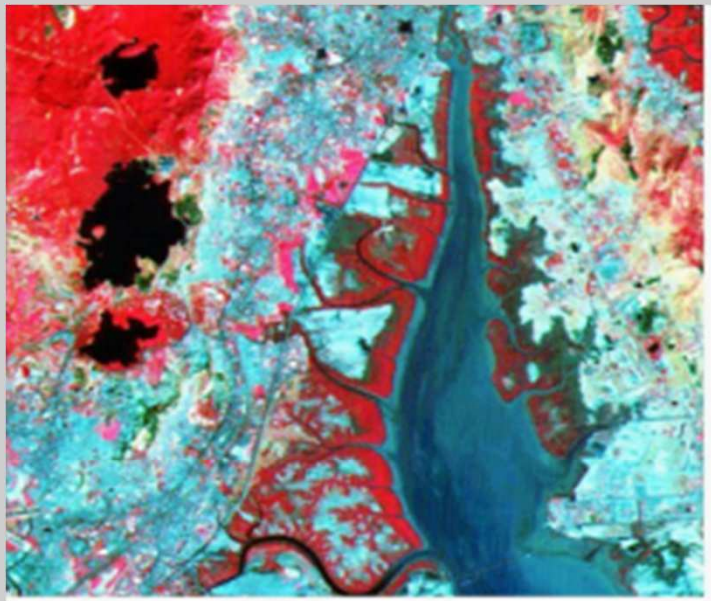
Classification / Maximum Likelihood

Steps

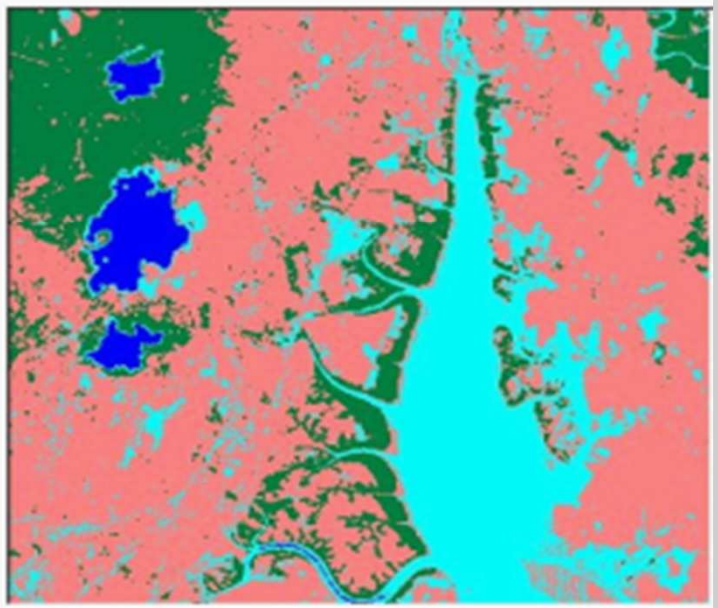
1. Select test sets
2. Determine statistics
3. Classify complete image

Image analysis

Classification / Maximum Likelihood



Original Image



Classified Image

[28]

Typical result

Exercise

Mapping small reservoirs in Burkina Faso

- Assignment on Blackboard (Lecture3)
- Read assignment
- Make assignment

Exercise

Mapping small reservoirs in Burkina Faso

Why:

www.smallreservoirs.org

Exercise

Mapping small reservoirs in Burkina Faso

Why:

Jens Liebe

Exercise

Mapping small reservoirs in Burkina Faso

Many shapes…

Exercise

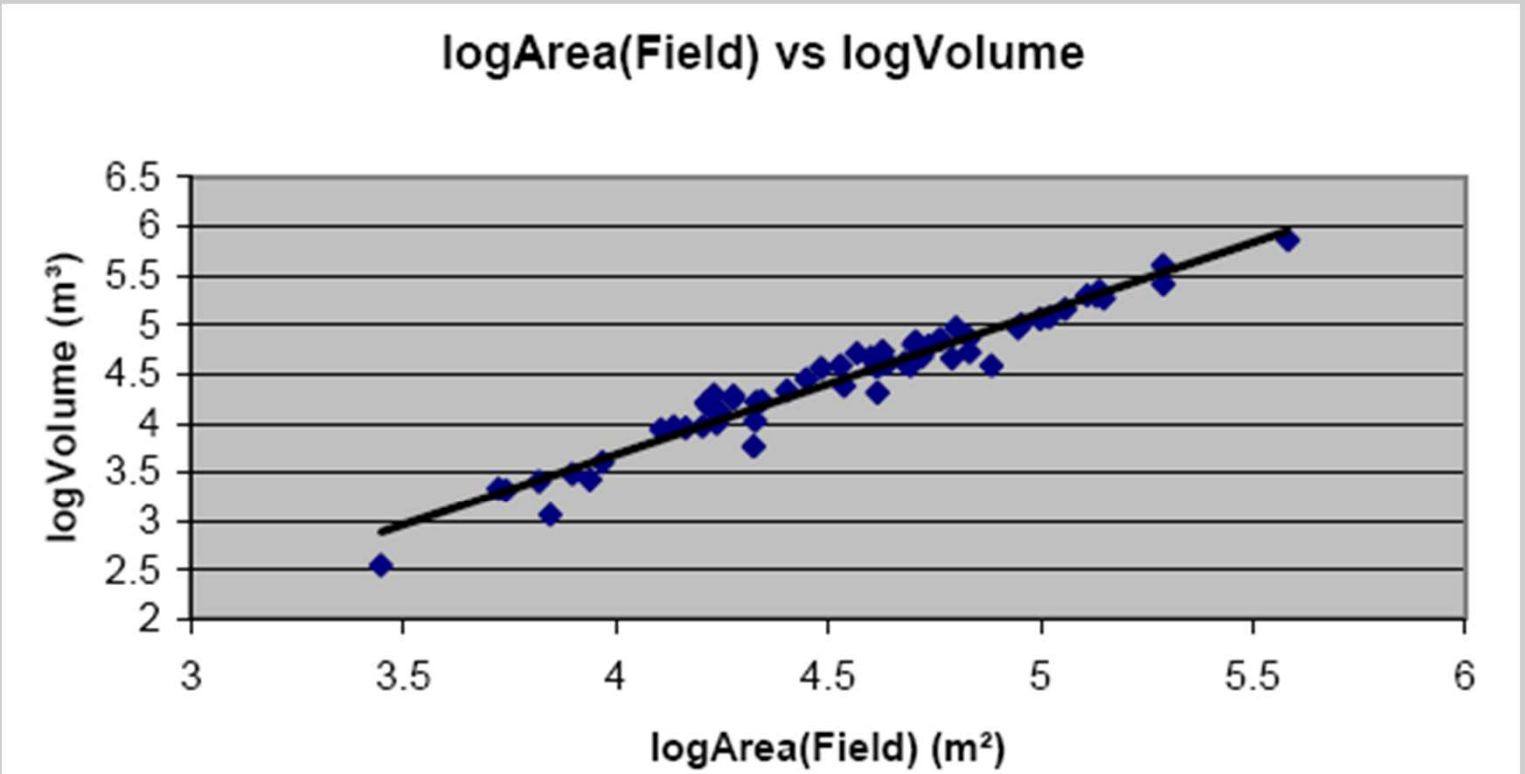
Mapping small reservoirs in Burkina Faso

Bathymetric survey of sixty reservoirs

Exercise

Mapping small reservoirs in Burkina Faso

Many shapes… one equation!



$$\text{Volume} = 0.00857 * \text{Area}^{1.4367} \quad [\text{m}^3]$$

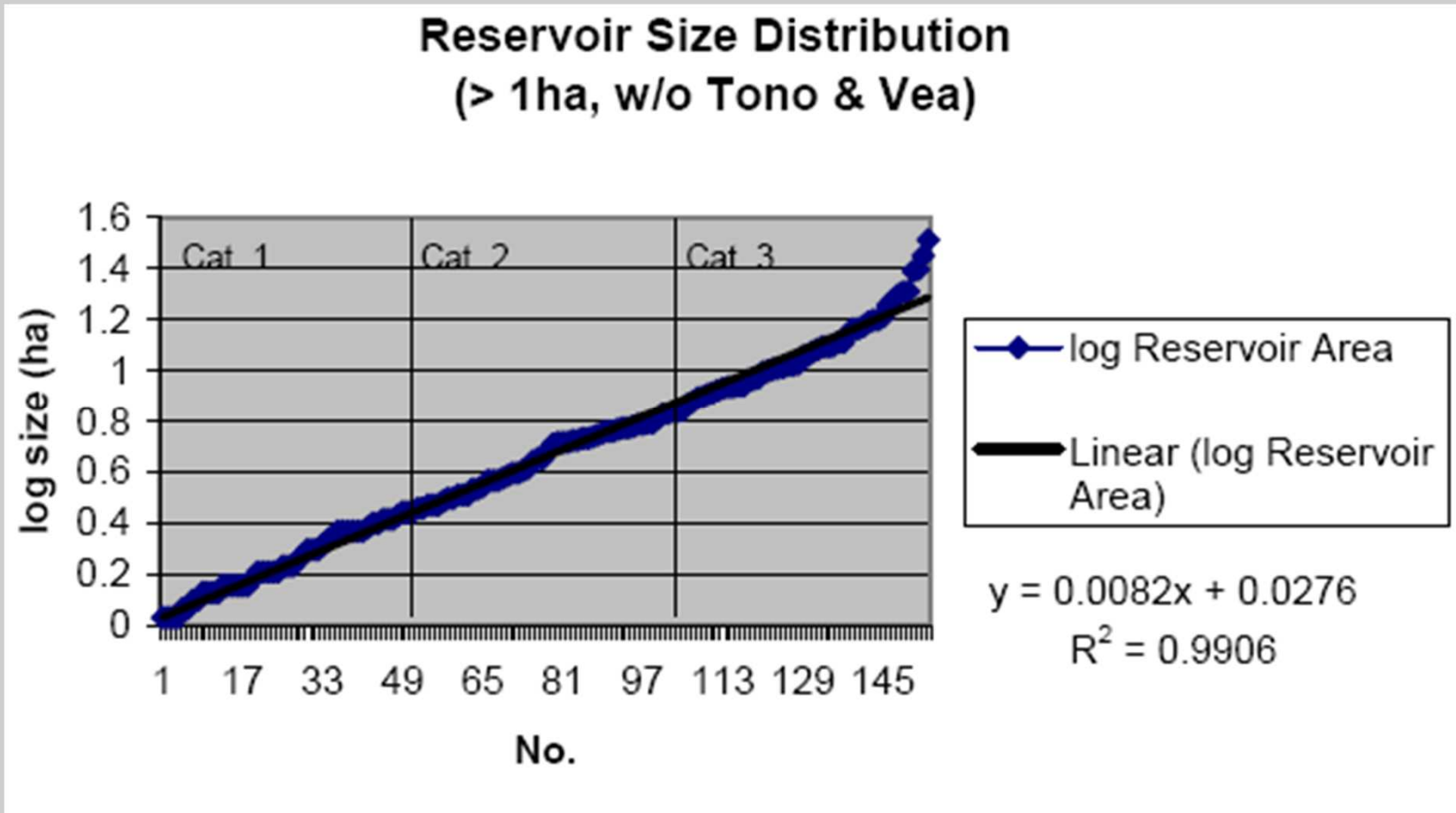
Exercise

Mapping small reservoirs in Burkina Faso

Remote sensing (Landsat, radar) => Volume!

Exercise

Mapping small reservoirs in Burkina Faso



Pareto

Exercise

How to map open water?

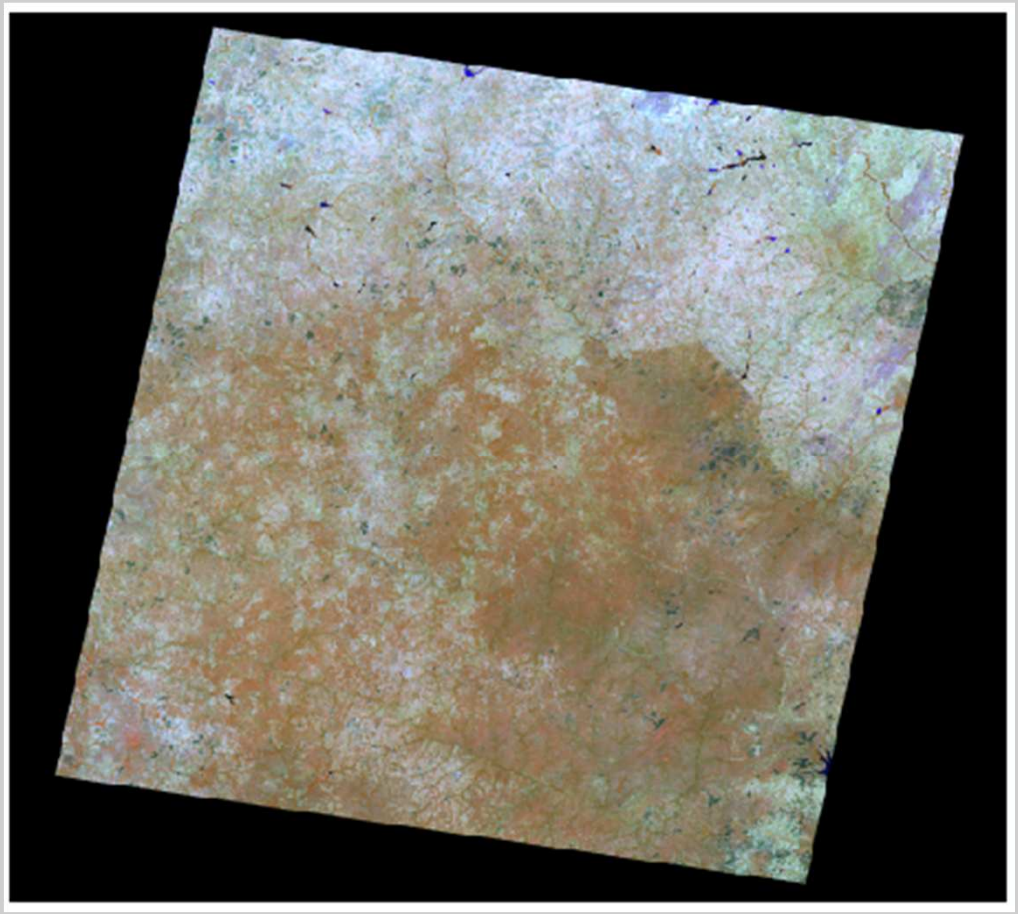
- Color composite
- Test areas (many!)
- Maximimum Likelihood
- Contiguity
- Hand check…

Exercise

How to map open water?

Color composite

- **Band 4 => Blue**
- **Band 5 => Green**
- **Band 3 => Red**



(Windows)

Exercise

How to map open water?

Test areas

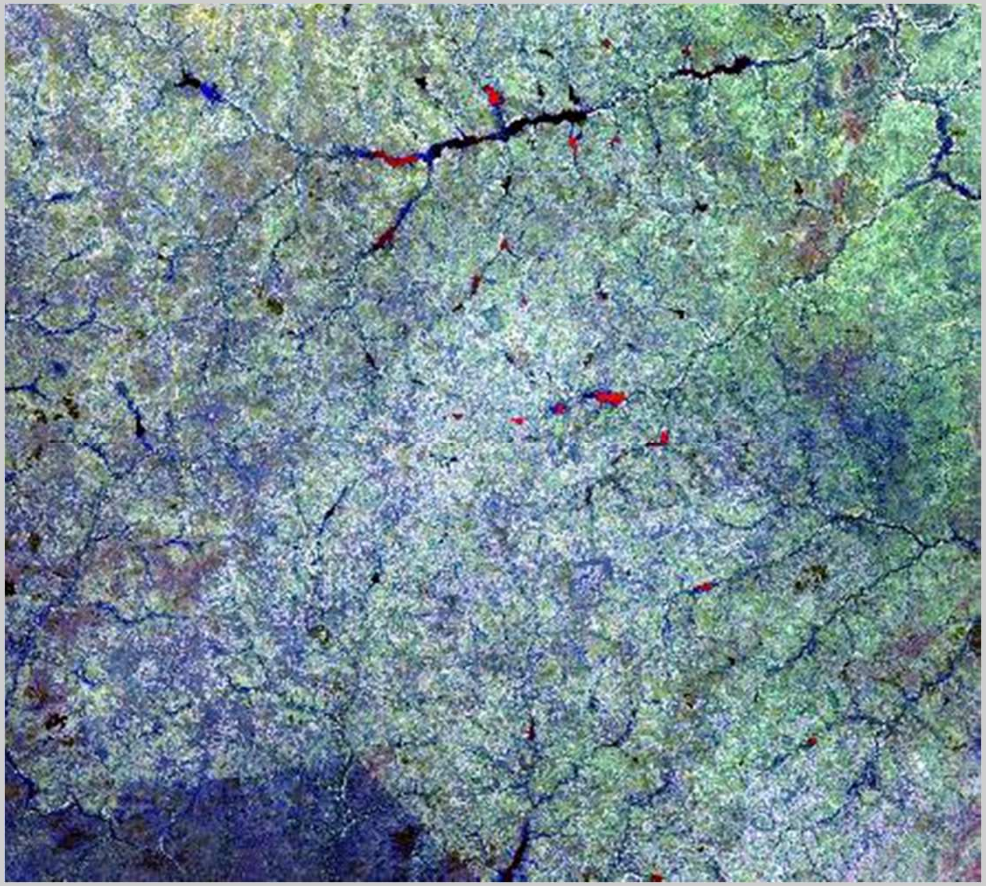
- **Sediment**
- **Clear water**
- **Non-water!**
- **Shades & burn scars**

Exercise

How to map open water?

Test areas

- **Use database**

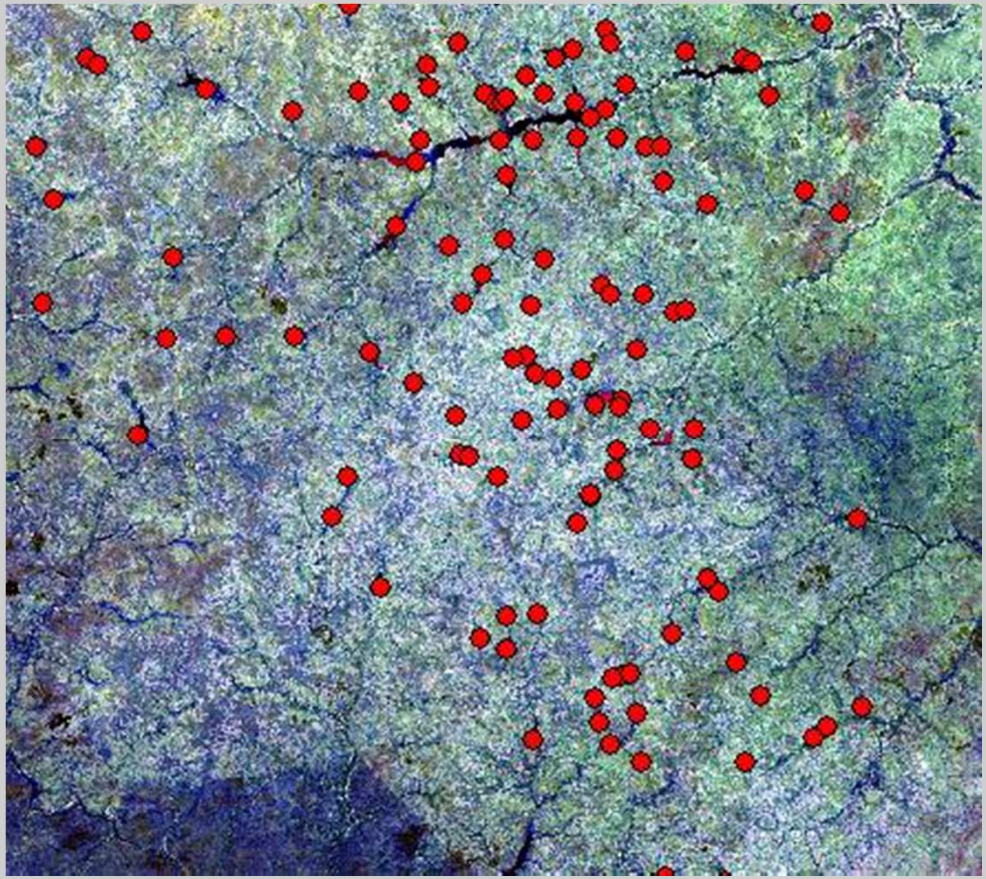


Exercise

How to map open water?

Test areas

- **Use database**

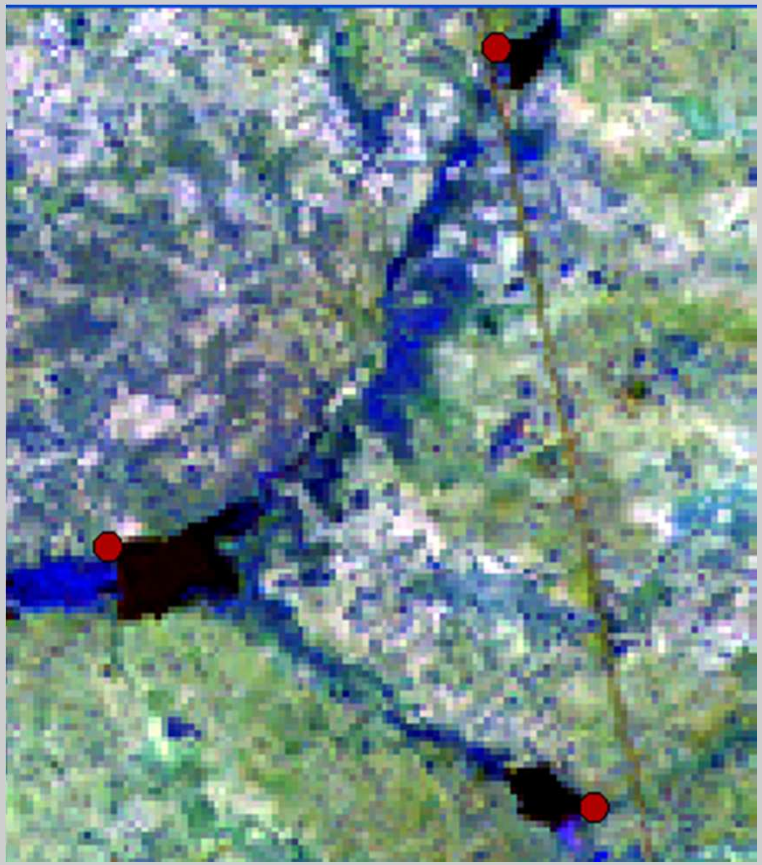


Exercise

How to map open water?

Test areas

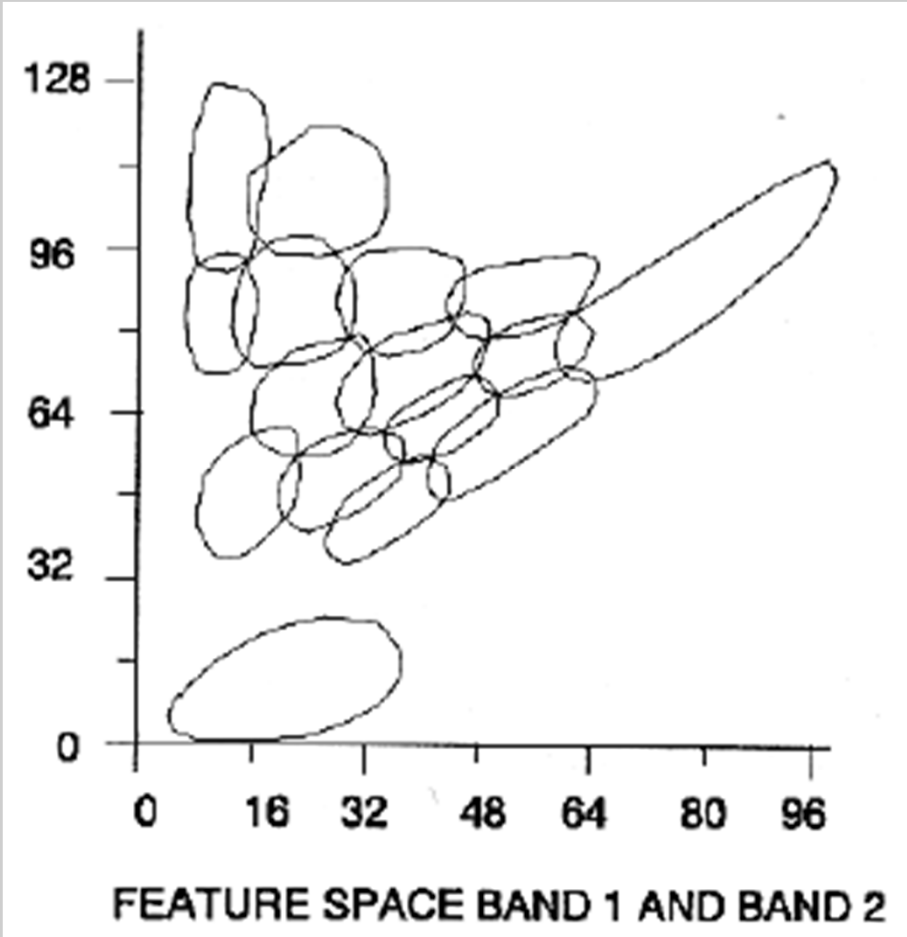
- **Use database**
- **Zoom in**



Exercise

How to map open water?

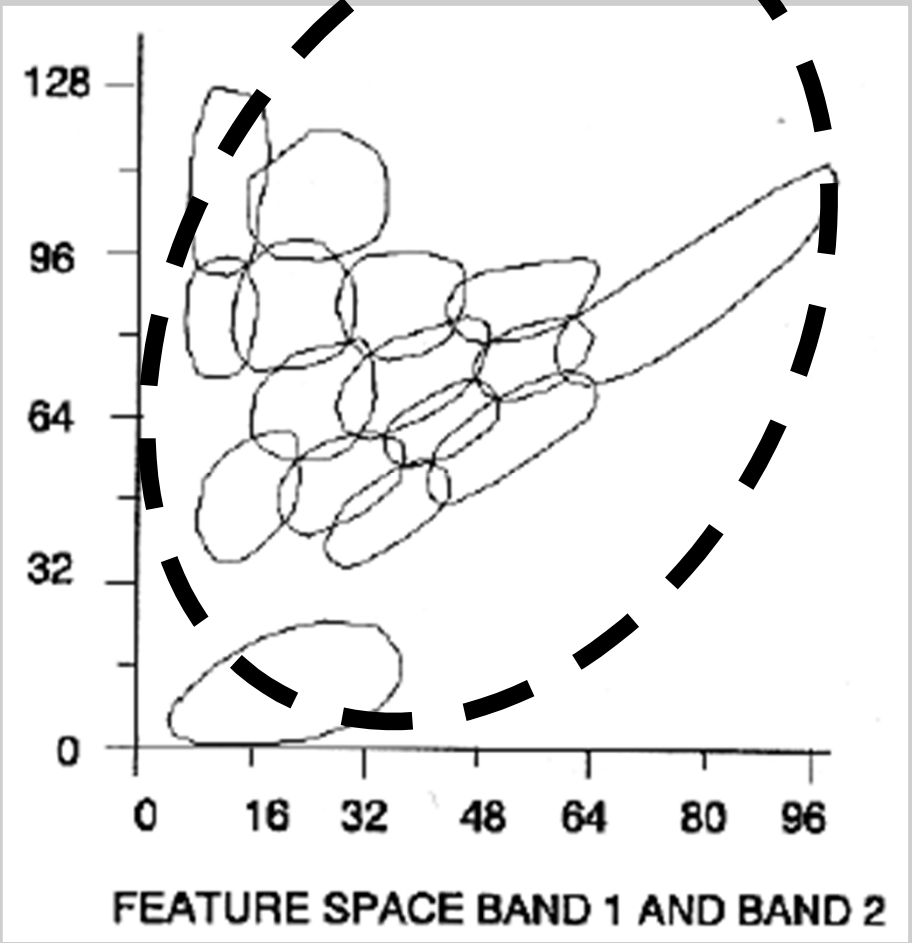
Test areas: MANY different ones!



Exercise

How to map open water?

Test areas: MANY different one! (Gaussian)

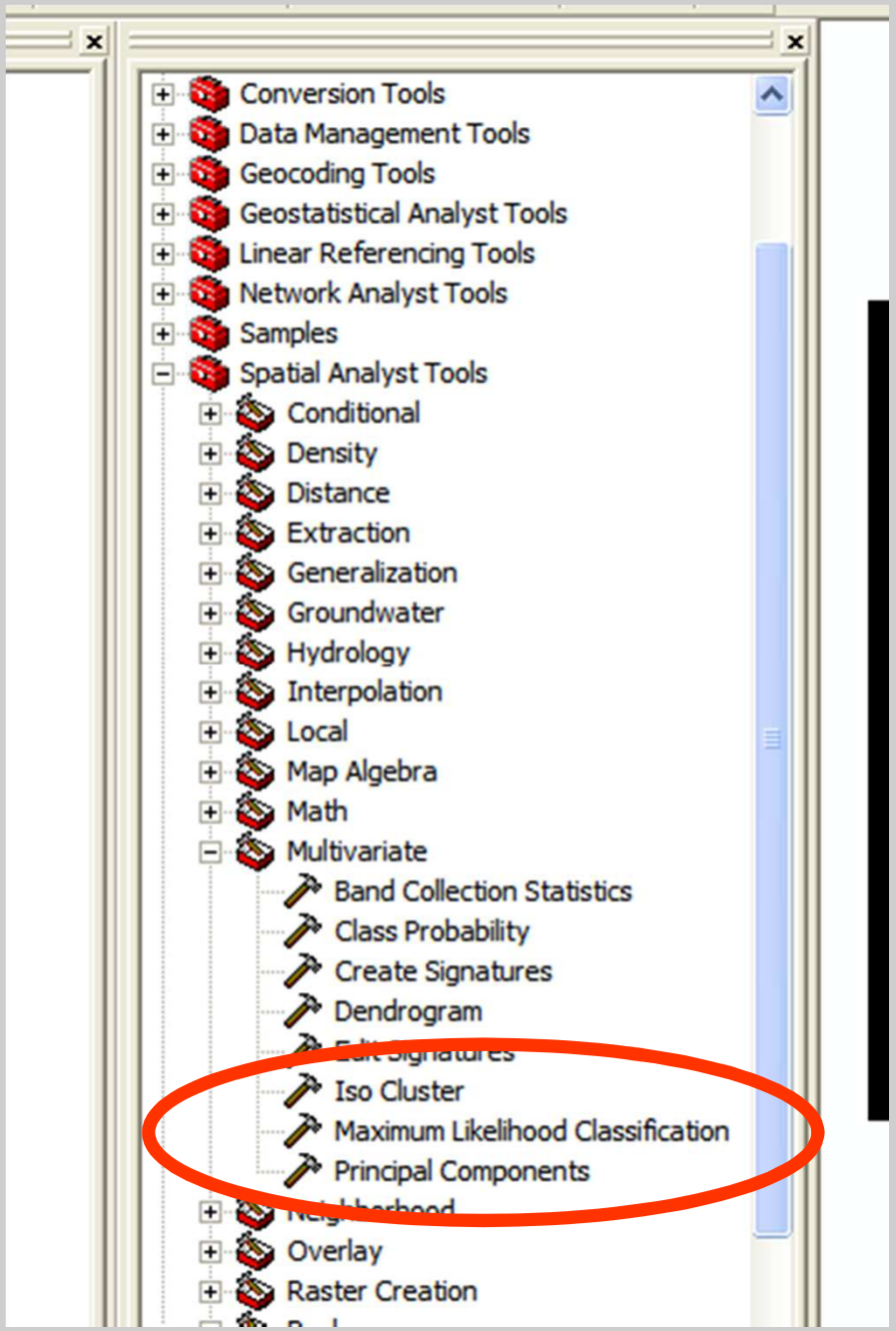


Exercise

How to map open water?

Use test areas

for maximum likelihood…

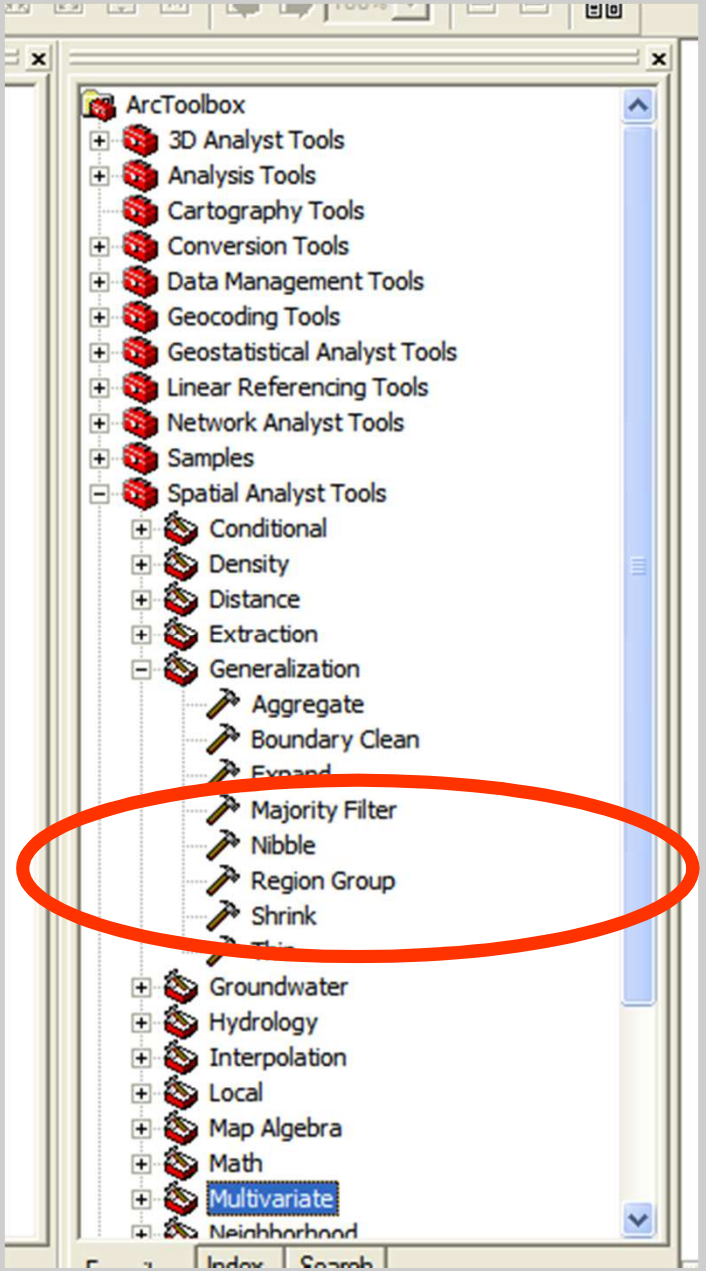


Exercise

How to map open water?

Small reservoirs:

- **Contiguous set of "water" pixels**
- **Find contiguous sets (disgard rest)**
- **"Region Groups"**



Exercise

How to map open water?

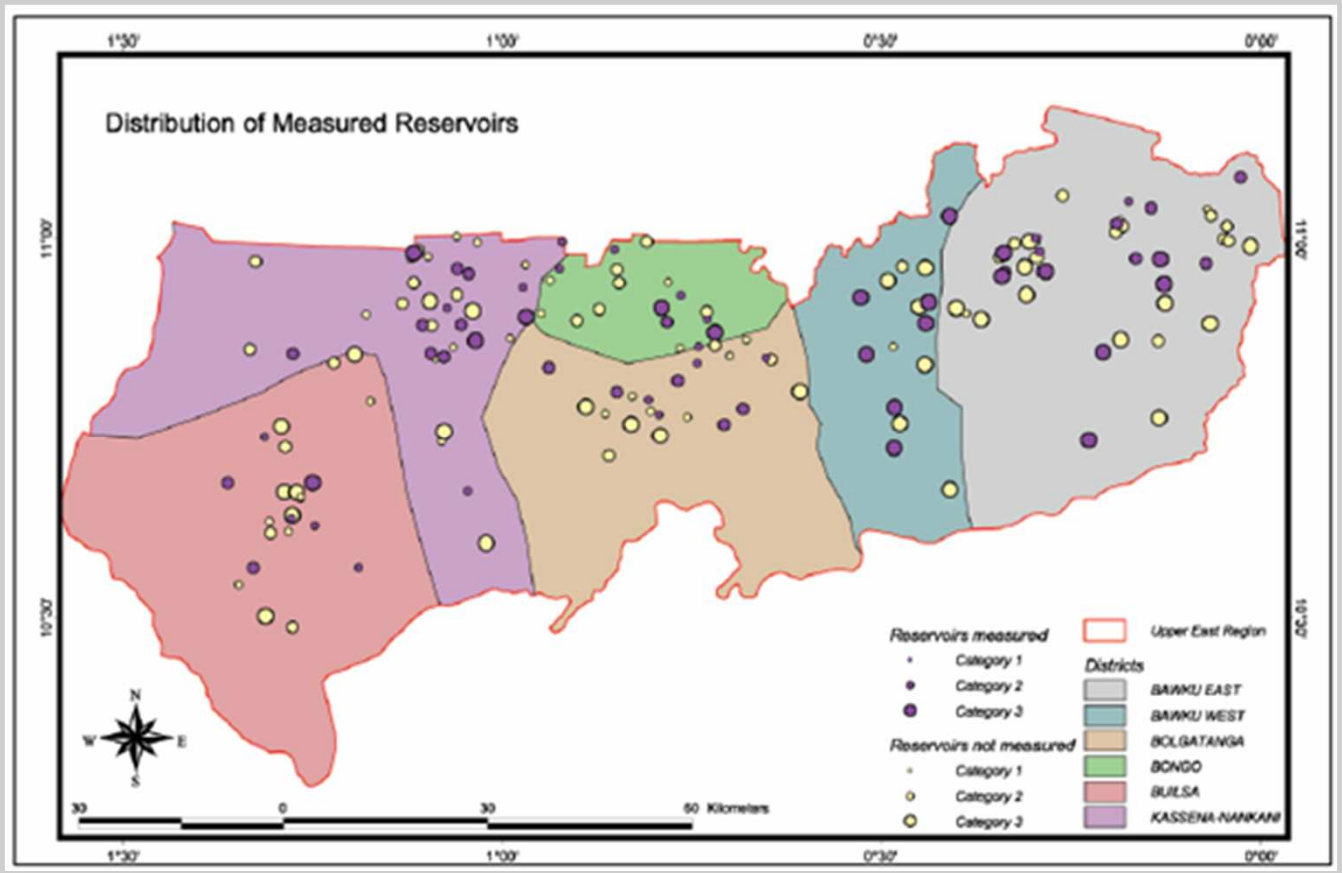
Small reservoirs, sometimes:

- **Single (noisy) pixels**
- **Rivers**
- **Reservoirs “cut” in two**
- **(Burn scars / dark objects)**

} **Hand check!**

Exercise

How to map open water?



FINAL PRODUCT… (table)

Sources images

[1] The Electromagnetic Spectrum, source: HyperPhysics Georgia State University, image courtesy of C.R. Nave
[2] Near Infrared Satellite image, source: unknown
[3] Spectral reflectance, source: University of Calgary
[4] Photosynthesis, source: unknown
[5] Africa, source: unknown
[6] Visible spectrum from Planck's formula, source: HyperPhysics
[7] Radar image of hurricane Katrina, source: ncdc.noaa.gov
[8] Synthetic Aperture Radar (SAR), source: CRISP, Singapore
[9] Reflections from a surface, source: Light Measurement Handbook, Alex Ryer
[10] Images from the IKONOS Quickbird satellite, source: Satellite Imaging Corporation
[11] Evaporation, source: WaterWatch
[12] Radar images, source: unknown
[13] MetOp satellite, source: ESA
[14] Crop performance, source: Drymon.biz
[15] Average backscatter of soil moisture, source: unknown
[16] Diurnal differences of soil moisture, source: unknown
[17] Casamance, source: unknown
[18] Images from the GRACE satellite, source: NASA & DLR
[19] Satellite image of Vietnam with TM band 3, source: unknown
[20] Satellite image of Vietnam with TM band 1, source: unknown
[21] Satellite image of Vietnam with TM band 2, source: unknown
[22] Satellite image of Vietnam in color, source: unknown
[23] Additive color, source: unknown
[24] Satellite image of Vietnam with Near Infrared, source: unknown
[25] Maximum Likelihood Supervised Classified procedure, source: Eastman, 2001
[26] Equi-probability contours, source: unknown
[27] Maximum likelihood method, source: Remote Sensing Notes, JARS 1999
[28] Image Classification using Maximum likelihood classification technique, source: bhugolgis.com