HYPERSPECTRAL IMAGE PROCESSING

Pattern Recognition Module
Supplement Lecture
Inel 5046

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Overview

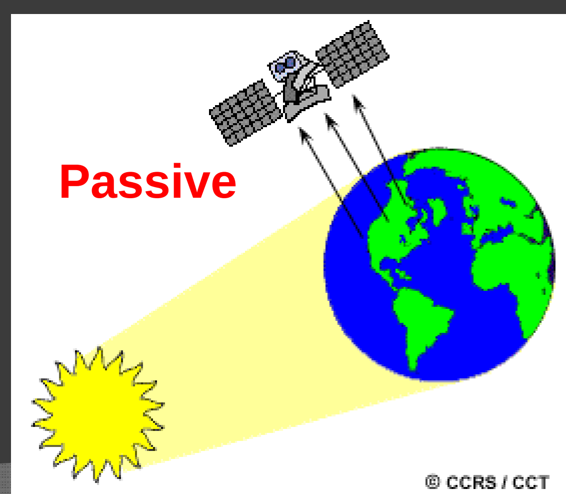
- **What is Remote Sensing?**
- **Imaging Types: MSI and HSI**
- **Sensors**
- **Applications**
- **Image Analysis Software**
- **Feature Extraction**
- **Information Extraction**
- **Post Processing**

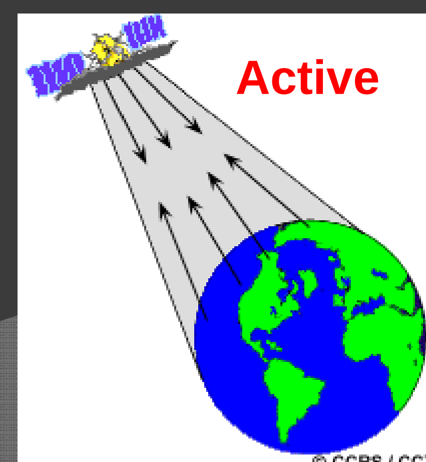
Mini Quiz?

- Some use for ultraviolet spectrum?
- Which type of radiation have the shortest wavelength?
- Why we are not damaged by x-ray from the sun?
- Name a Multispectral Sensor? Hyperspectral?
- Remote Sensing Applications?
- Types of Classification?

Remote Sensing

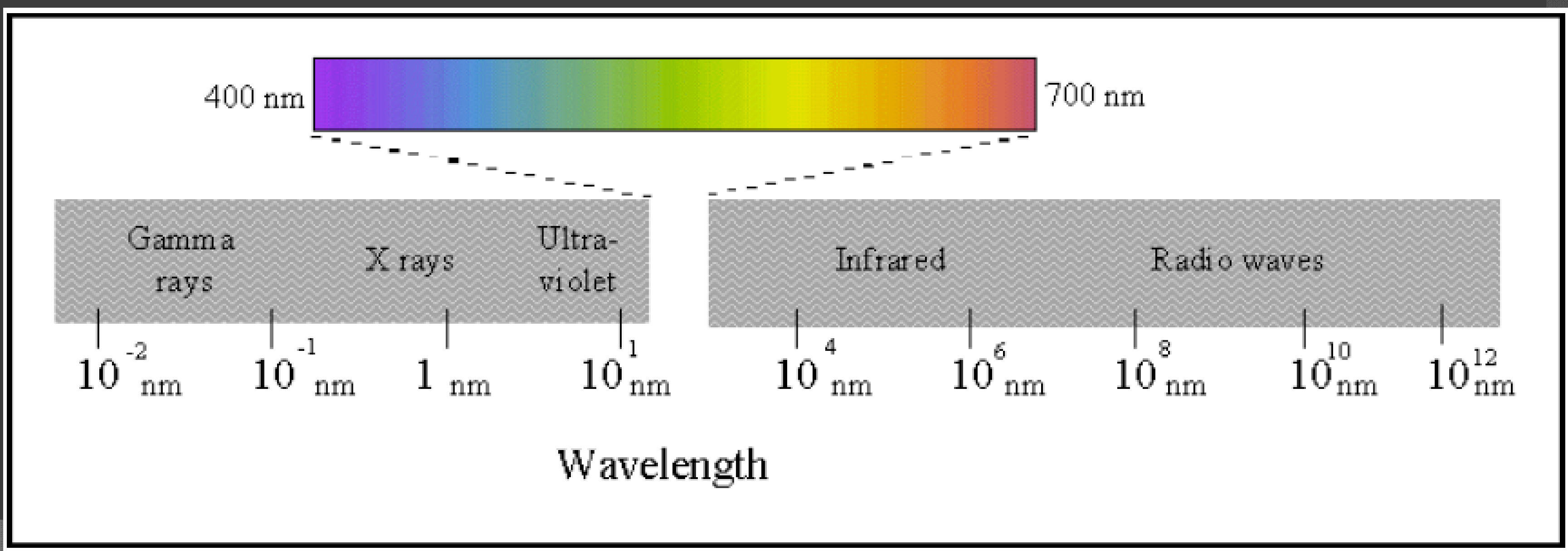
- Science and art of identifying, observing and measuring an object without coming into direct contact with it.
- RS instruments measures reflected and/or emitted electromagnetic radiation.
- RS systems
  - Passive
  - Active





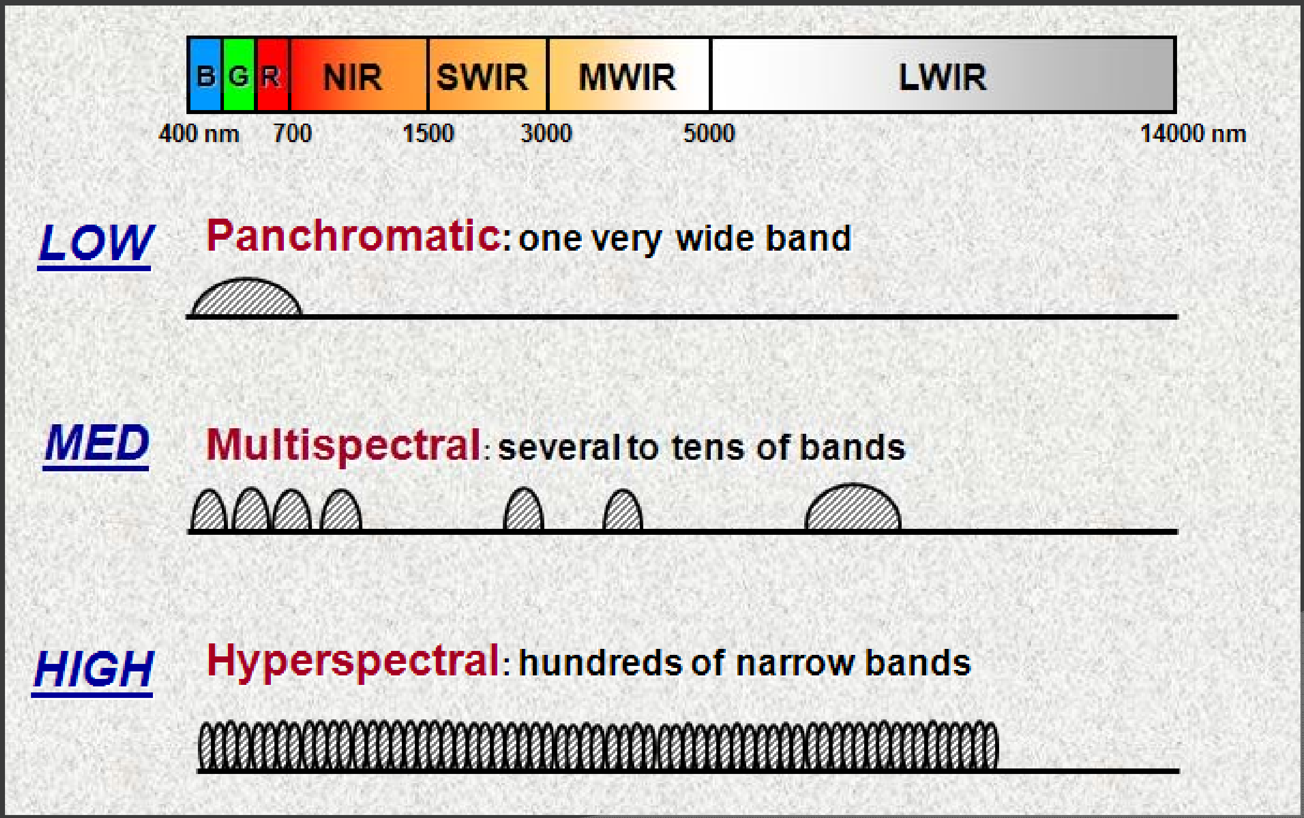
Electromagnetic Spectrum

The Electromagnetic Spectrum is the range of all possible **Electromagnetic radiation** which has an electric and magnetic field component which oscillate in phase perpendicular to each other and to the direction of energy propagation.



Spectral Resolution

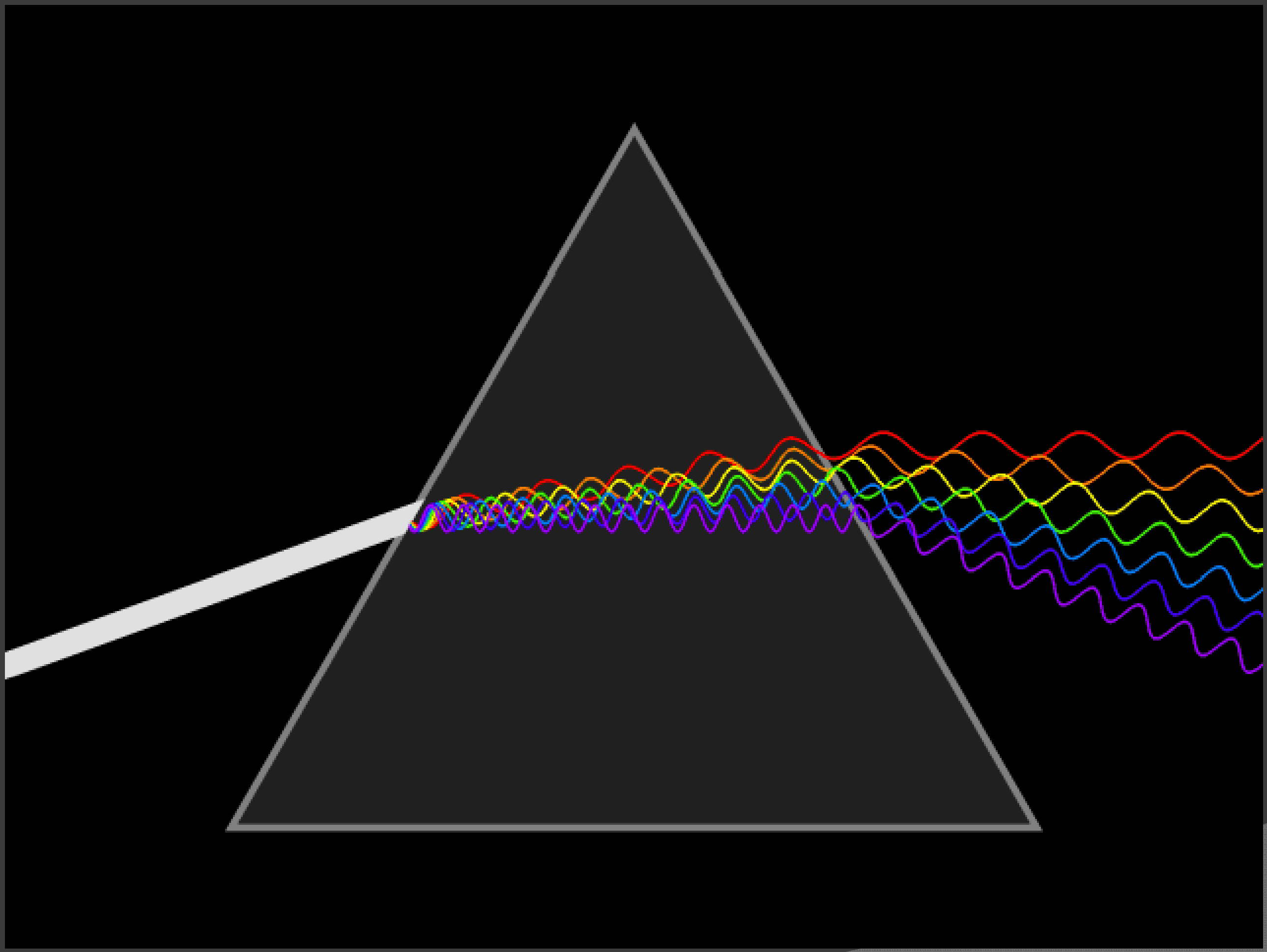
- Number and dimension of specific wavelength intervals, referred to as bands or channels.



Electromagnetic Radiations Types

- **Radio frequency**
- **Microwaves**
- **Terahertz radiation**
- **Infrared radiation**
- **Visible radiation**
- **Ultraviolet light**
- **X-rays**
- **Gamma rays**

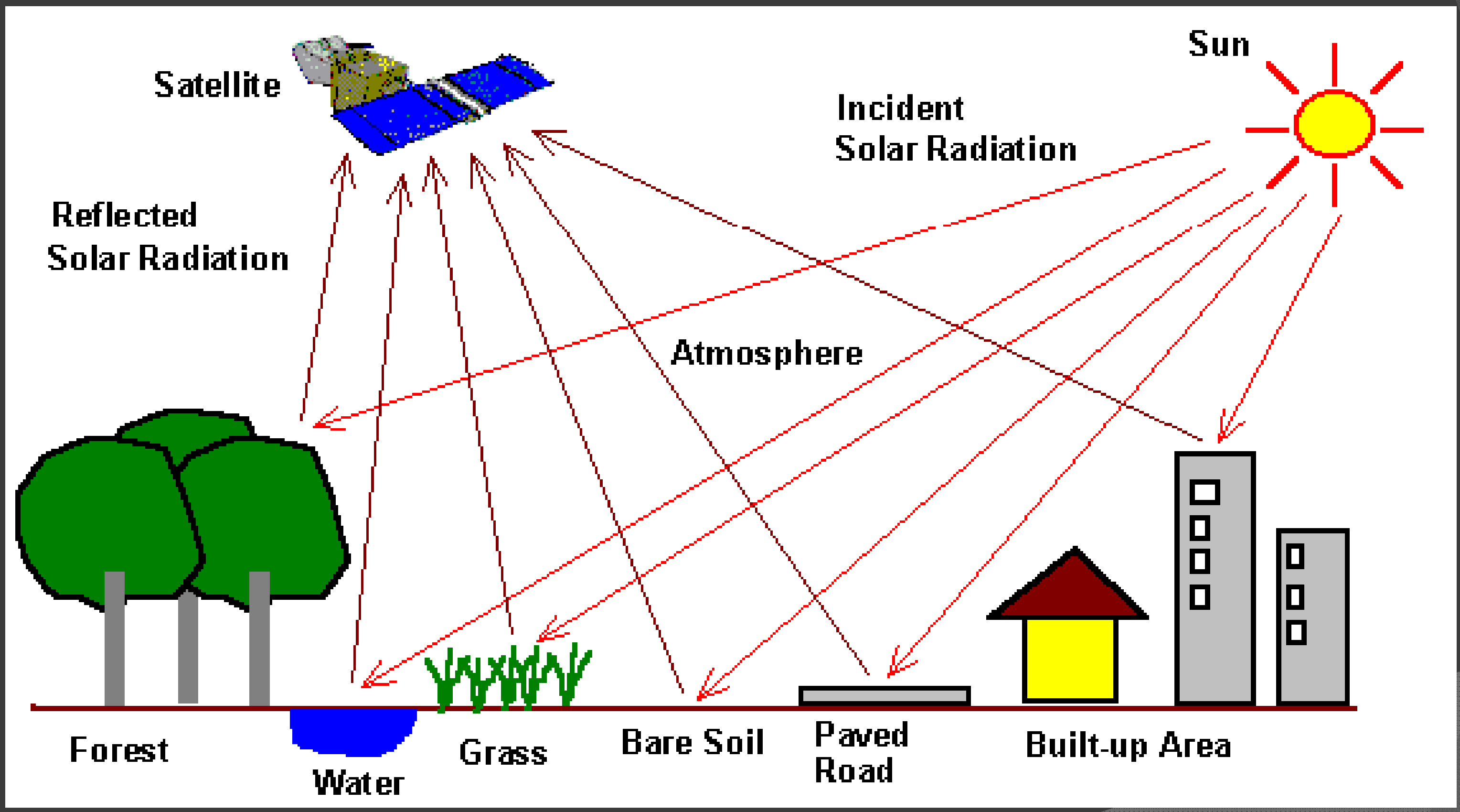
Example



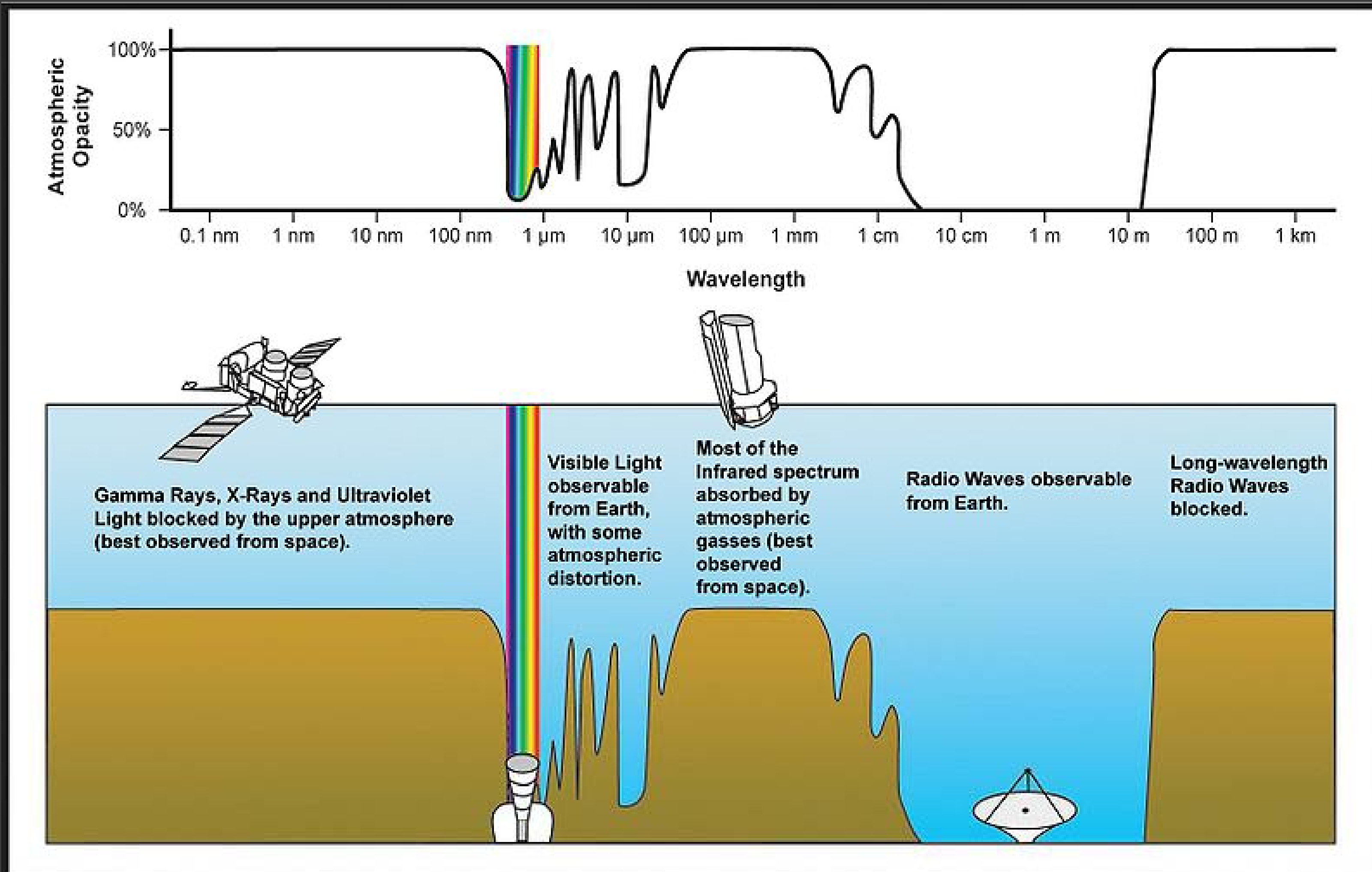
Domains of RS and its Applications

- **Gamma rays: nuclear medicine.**
- **Ultraviolet: security, sterilization, disinfecting water.**
- **Green:** 515..520-590..600 nm, used for imaging of vegetation and deep water structures.
- **Near infrared:** 750-900 nm, primarily for imaging of vegetation.
- **Mid-infrared**: 2080-2350 nm, for imaging soil, moisture, geological features and fires.
- **Radar:** related technologies, useful for mapping terrain and for detecting various objects.

Light Interaction



Atmospheric Electromagnetic Transmittance



Sensor

- **Multispectral**
  - **Landsat**
  - **QuickBird**
  - **IKONOS**
  - **Spot**
- **Hyperspectral**
  - **AVIRIS**
  - **Hyperion**
  - **AISA**

Sensor

- Radar
  - Monopulse radar
  - Bistatic radar
  - Doppler radar
  - Continuous-wave radar
- Sonar
  - Sonograms
  - Underwater sonar: LIMIS and LUIS

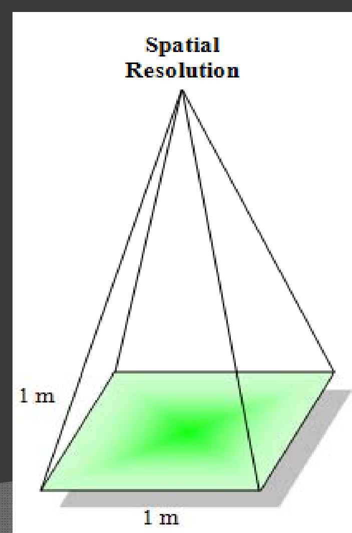
Imaging Modalities

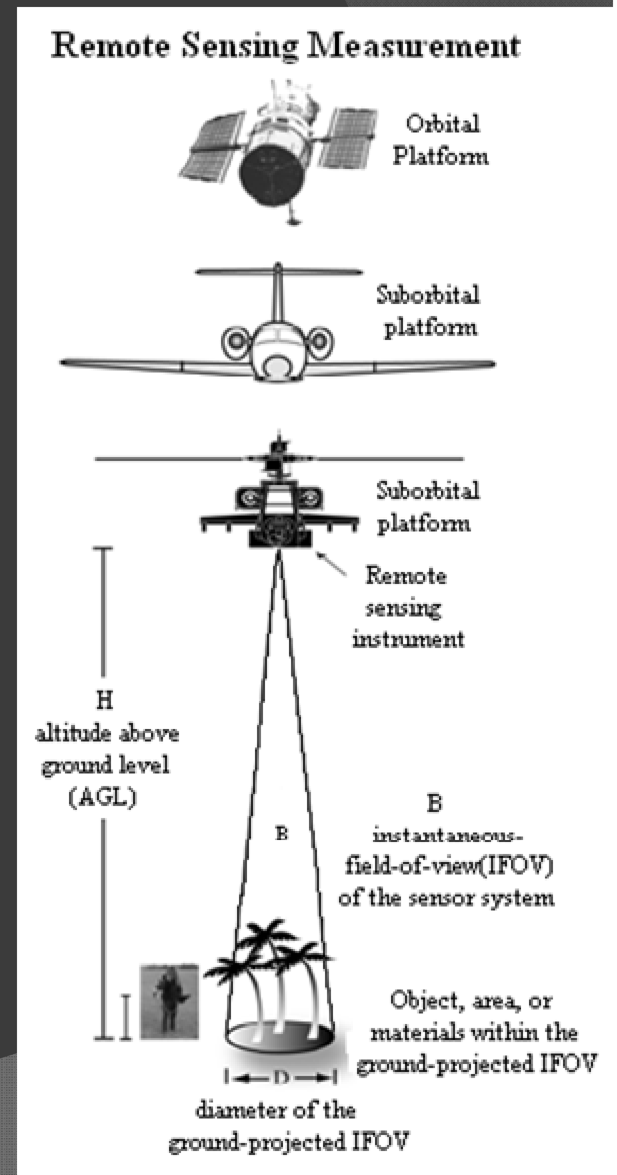
- Panchromatic
  - The sensor is a single channel detector sensitive to radiation within a broad wavelength range
- Multispectral
  - The sensor is a multichannel detector with a few spectral bands. Each channel is sensitive to radiation within a narrow wavelength band.
- Hyperspectral
  - The sensor contains hundred of detector acquiring hundred of contiguous images in the electromagnetic spectrum.

Spatial Resolution

- Spatial detail in an image.
- How much of the Earth's surface a single pixels covers.
- Depends primarily on the instantaneous field of view (IFOV)

$$Size_{Area} = IFOV \cdot H$$

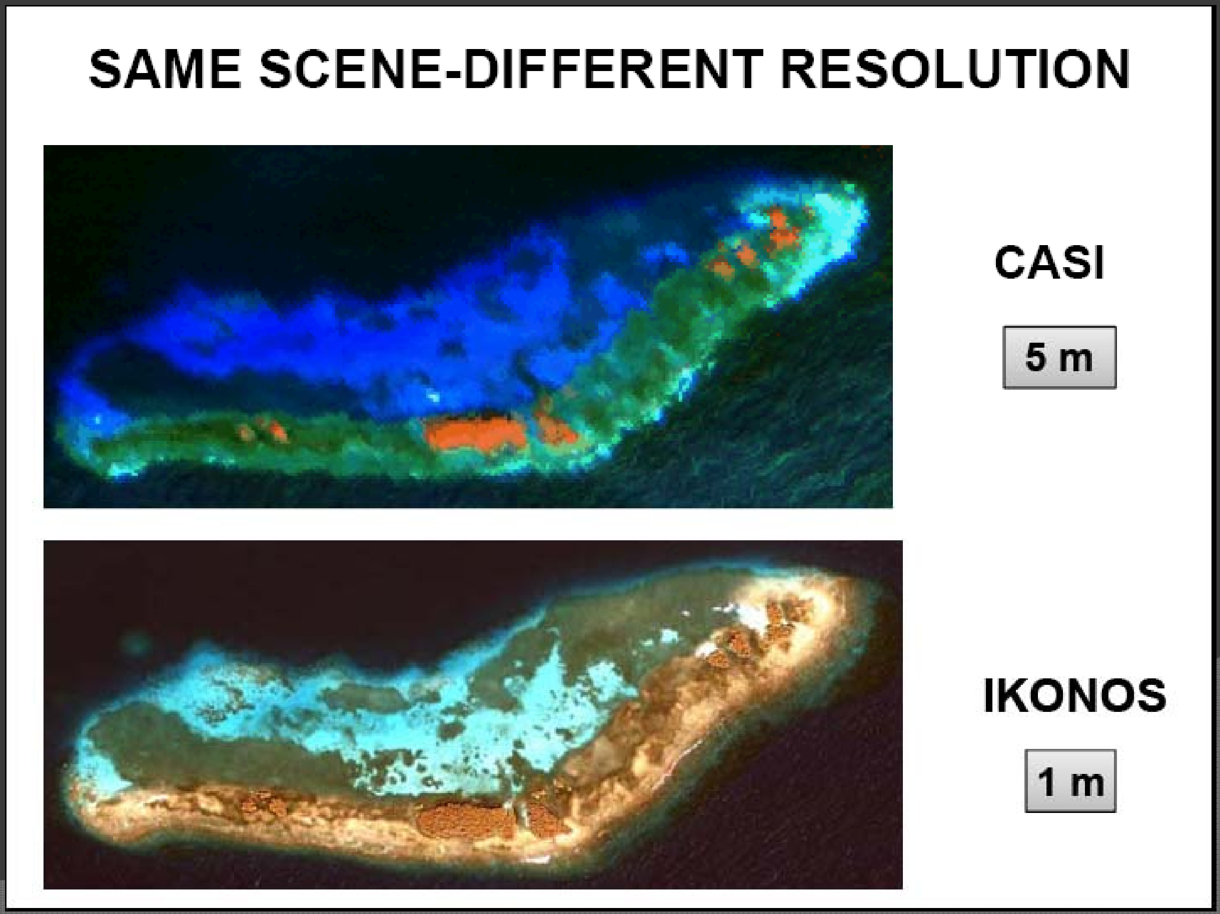




Spatial Resolution

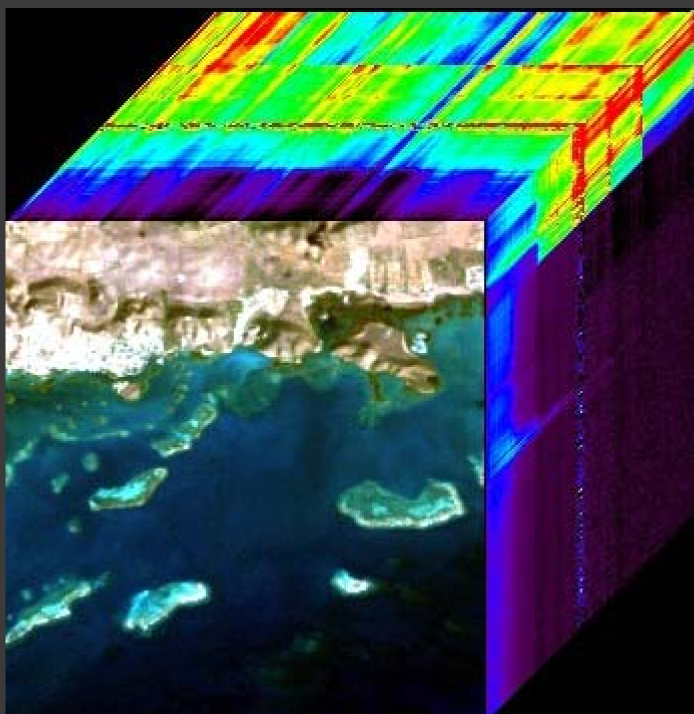
Spatial Resolution

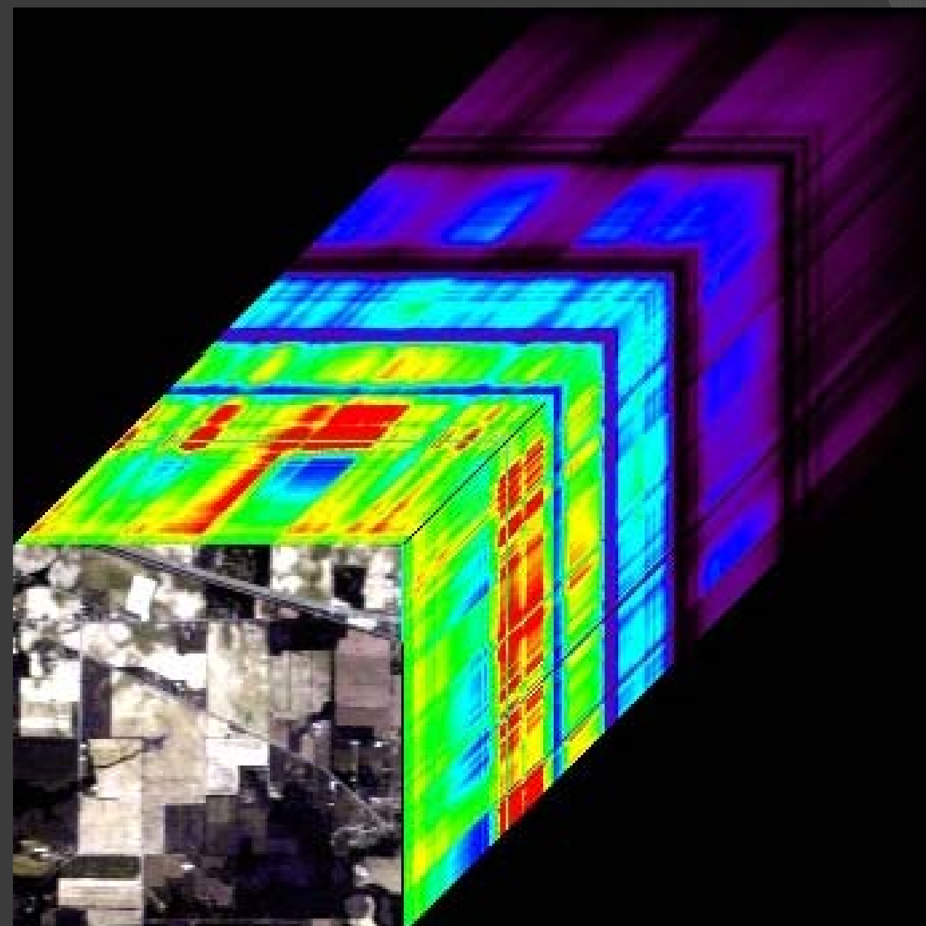
Same scene – Different spatial resolution
Enrique Reef at Lajas P.R.



Multispectral Sample Data

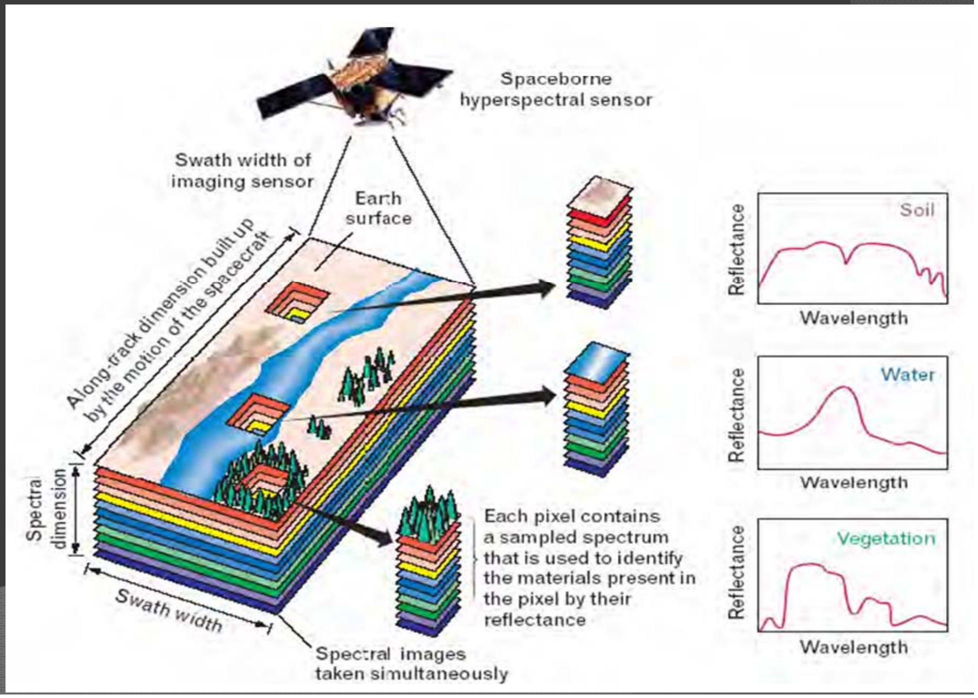
Hyperspectral Sample Data



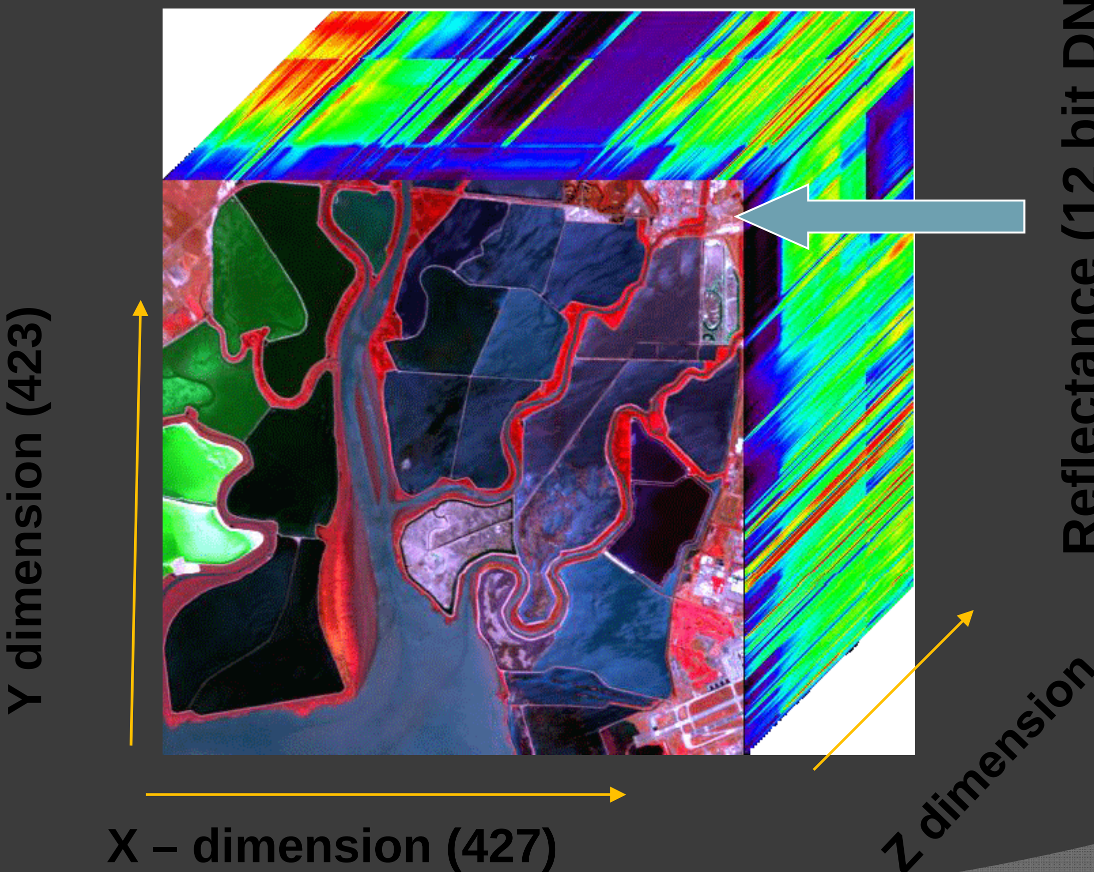


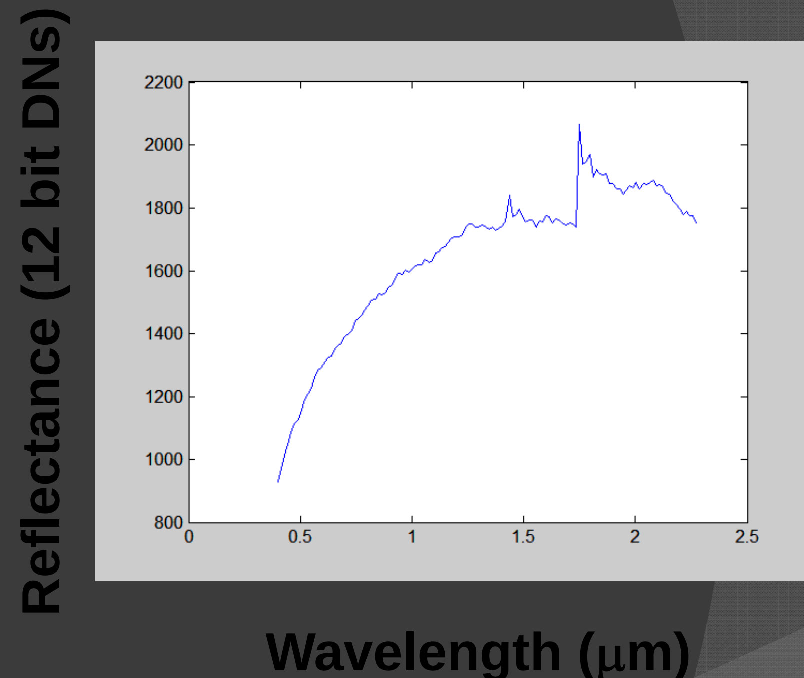
Hyperspectral Images

- Large amounts of data taken at narrow and contiguous spectral bands.
- Helps to discriminate better between different objects.
- Frequently used
  - Land cover classification
  - Detection and target recognition
  - Search and rescue operations
  - Biomedical applications



Example of Hyperspectral Image





AVIRIS data-224 spectral Bands 0.4-2.4 μm with 20m spatial resolution

Hyperspectral Sensors

SOC-700 Hyperspectral Imager

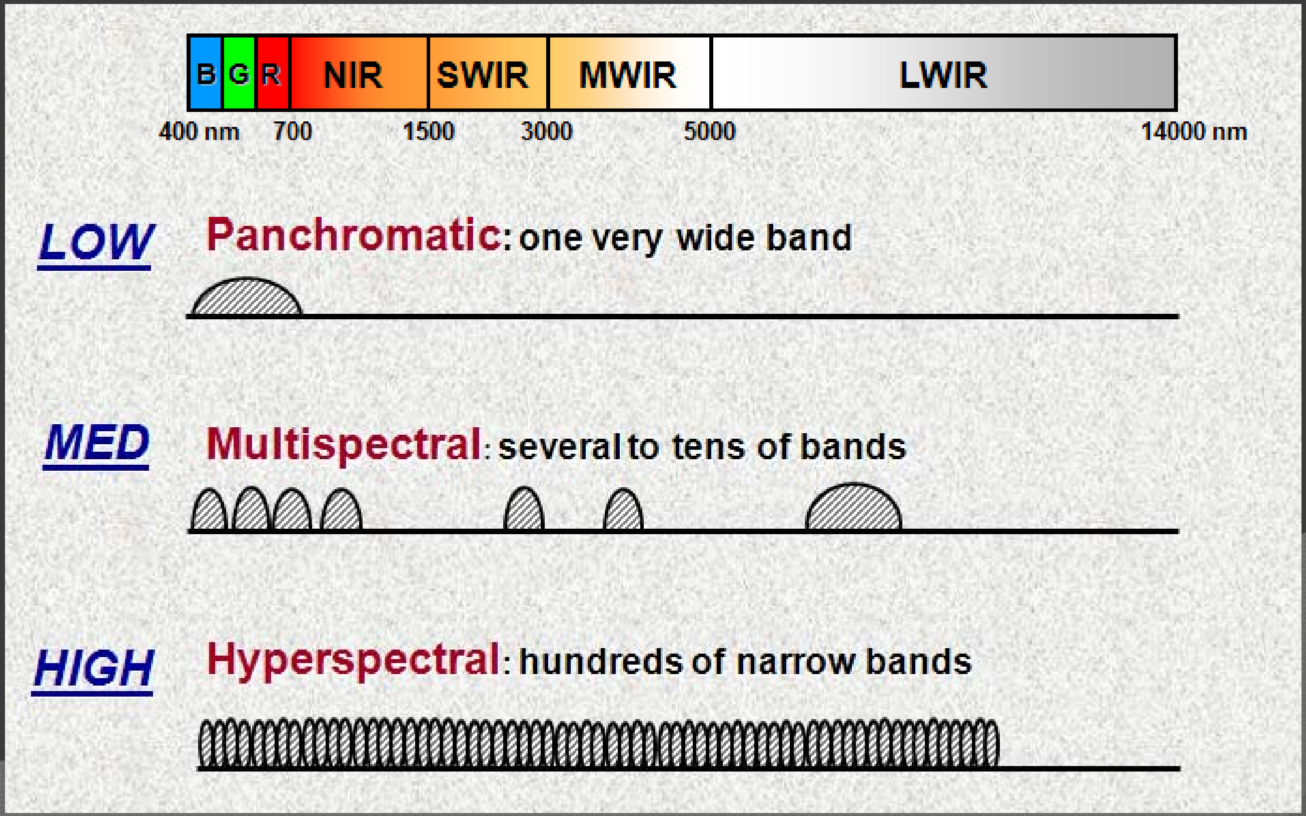
Hyperspectral Data Imagery Collection Experiment

Sensor	Spectral Resolution	Spatial Resolution	No. of Bands	Spectral range
SOC-700	4 nm	high [a]	120	400-900 nm
HYDICE	10 nm	1-4 m	210	400-2500 nm

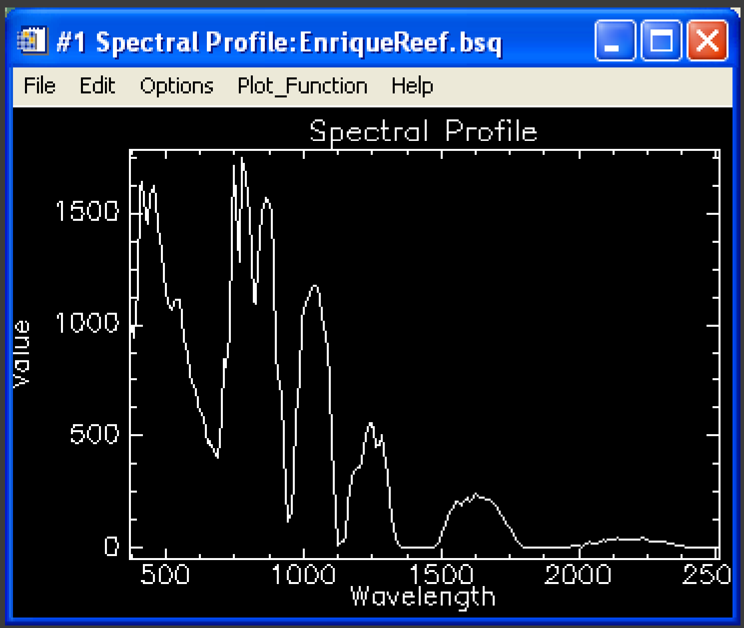
[a] Depends on the IFOV of the sensor system and on the distance from the ground to the sensor (H). The IFOV of the SOC-700 is 0.0078125. $Size_{AREA}$ = IFOV x H

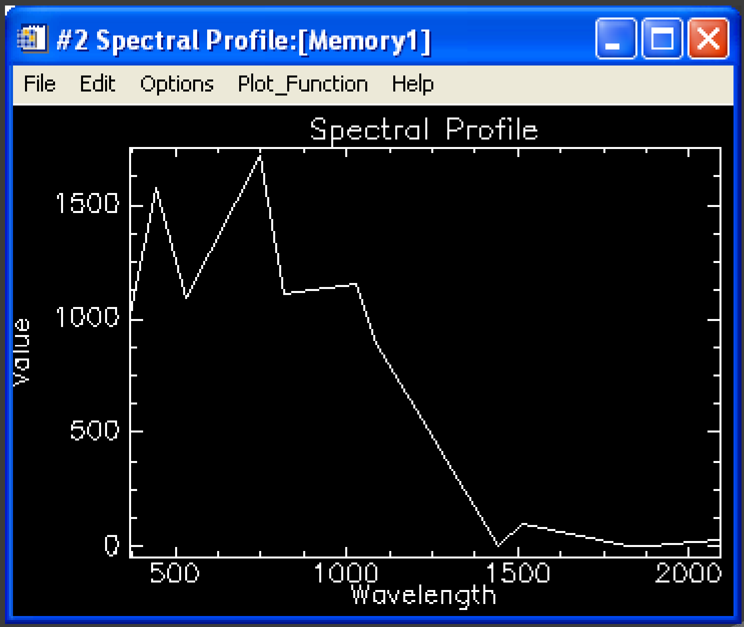
Spectral Resolution

- Number and dimension of specific wavelength intervals, referred to as bands or channels.

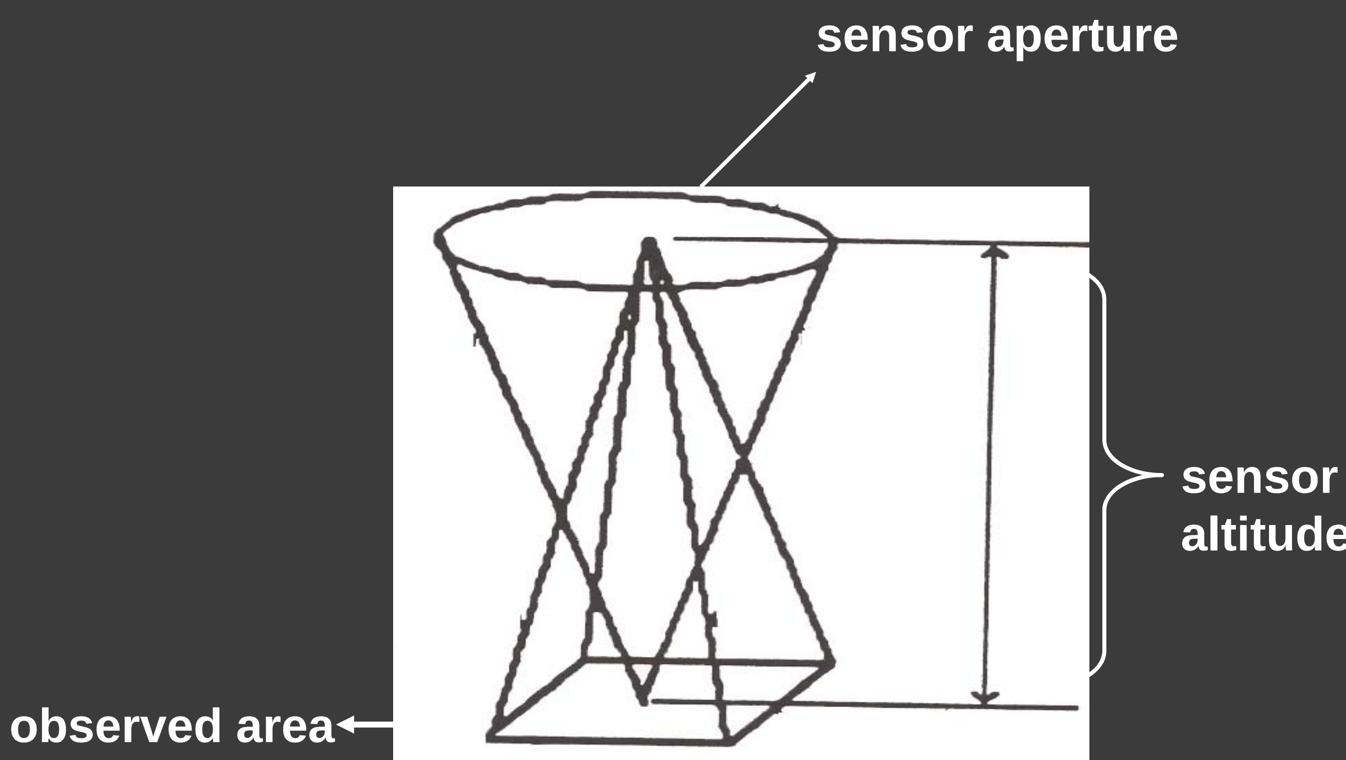


Spectral Resolution





Spectral and Spatial Trade of



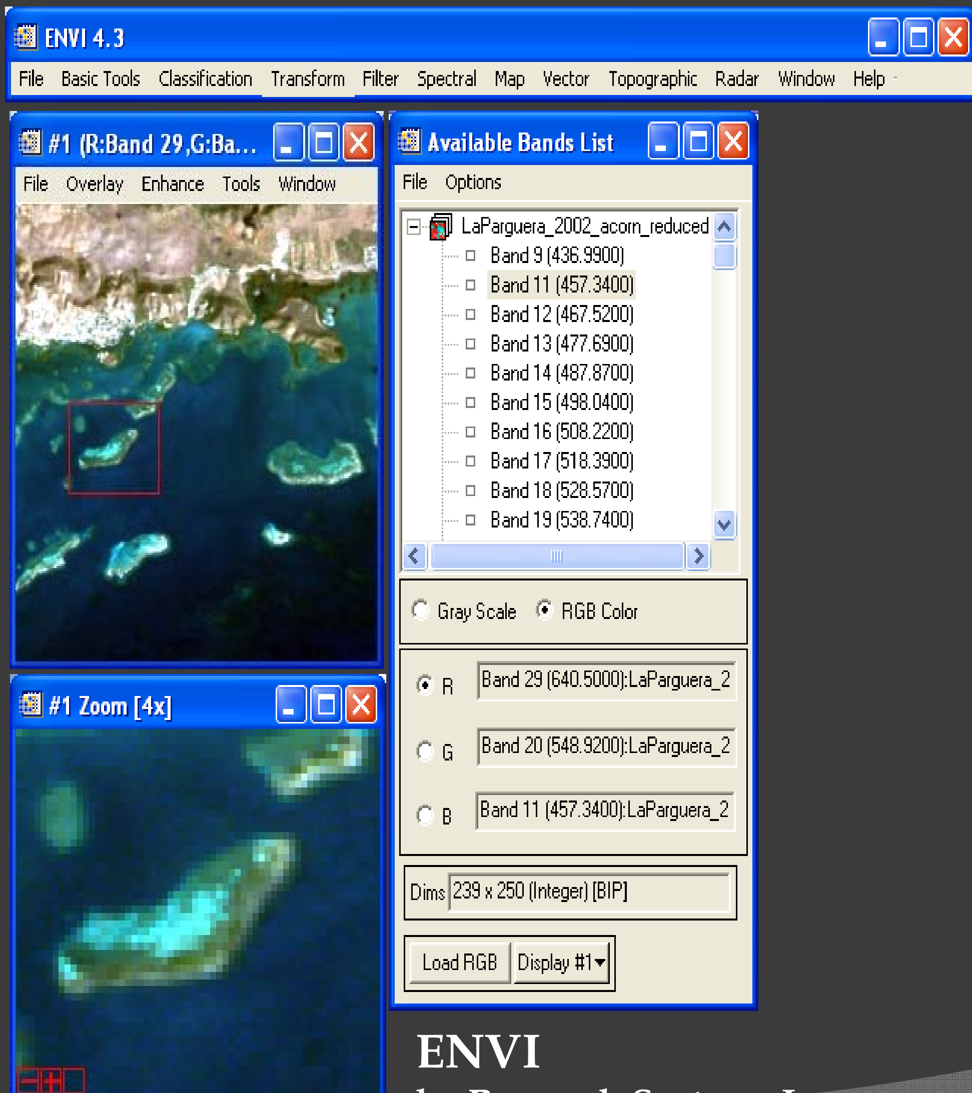
Multispectral vs Hyperspectral

- HSI images
  - High spectral resolution
  - The measured spectra is the contribution of the spectral signatures of the objects in the field of view of the sensor.
- MSI
  - High spatial resolution
  - Low spectral profile
  - Specifically derived applications

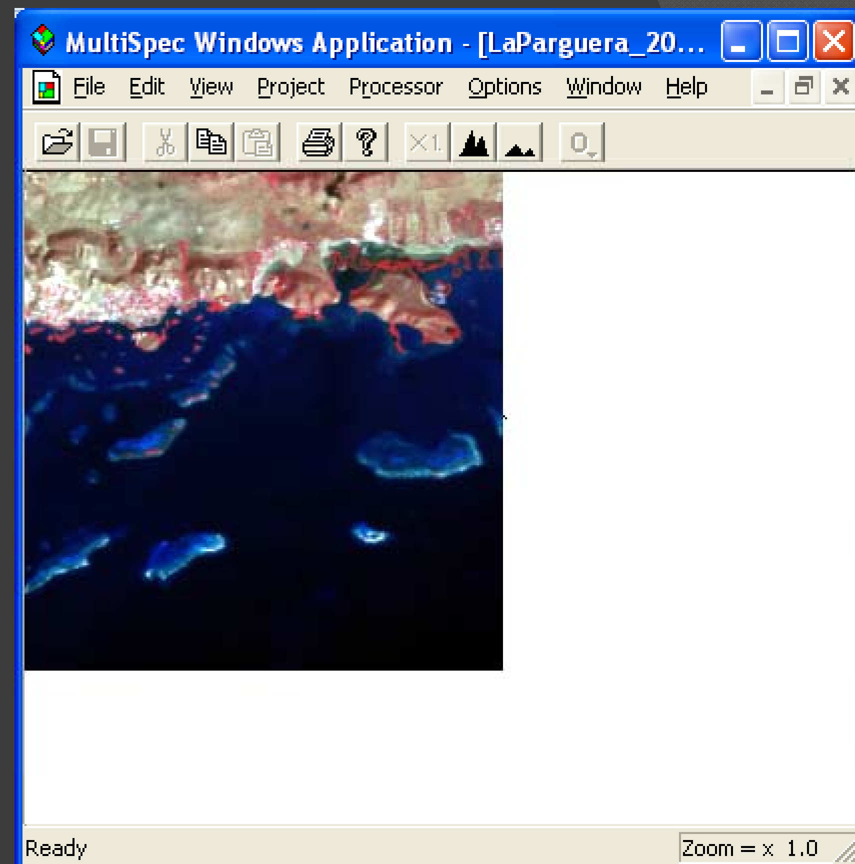
Remote Sensing Applications

- Multispectral
  - Mapping
  - Forestry
  - Resource management
  - Oceanography
- Hyperspectral
  - Geology
  - Mining
  - Mapping
  - Ecology
  - Surveillance

State of the Art in HSI Software Tools



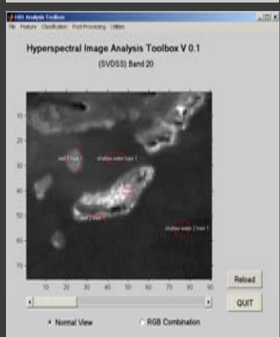
ENVI
by Research Systems Inc., a ITT subsidiary.

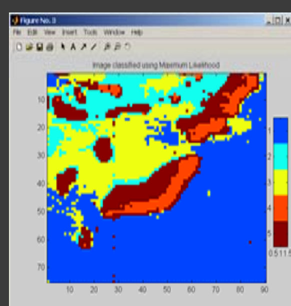


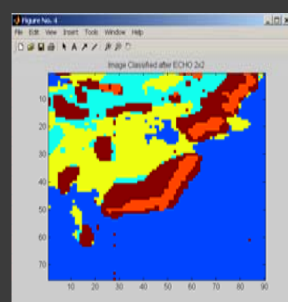
MultiSpec
developed at Purdue University by Dr. David Landgrebe and the Remote Sensing research group in Purdue's LARS

Hyperspectral Image Analysis

MATLAB Toolbox







Hardware Implementation in FPGA/DSP and GPUs

Laboratory #1

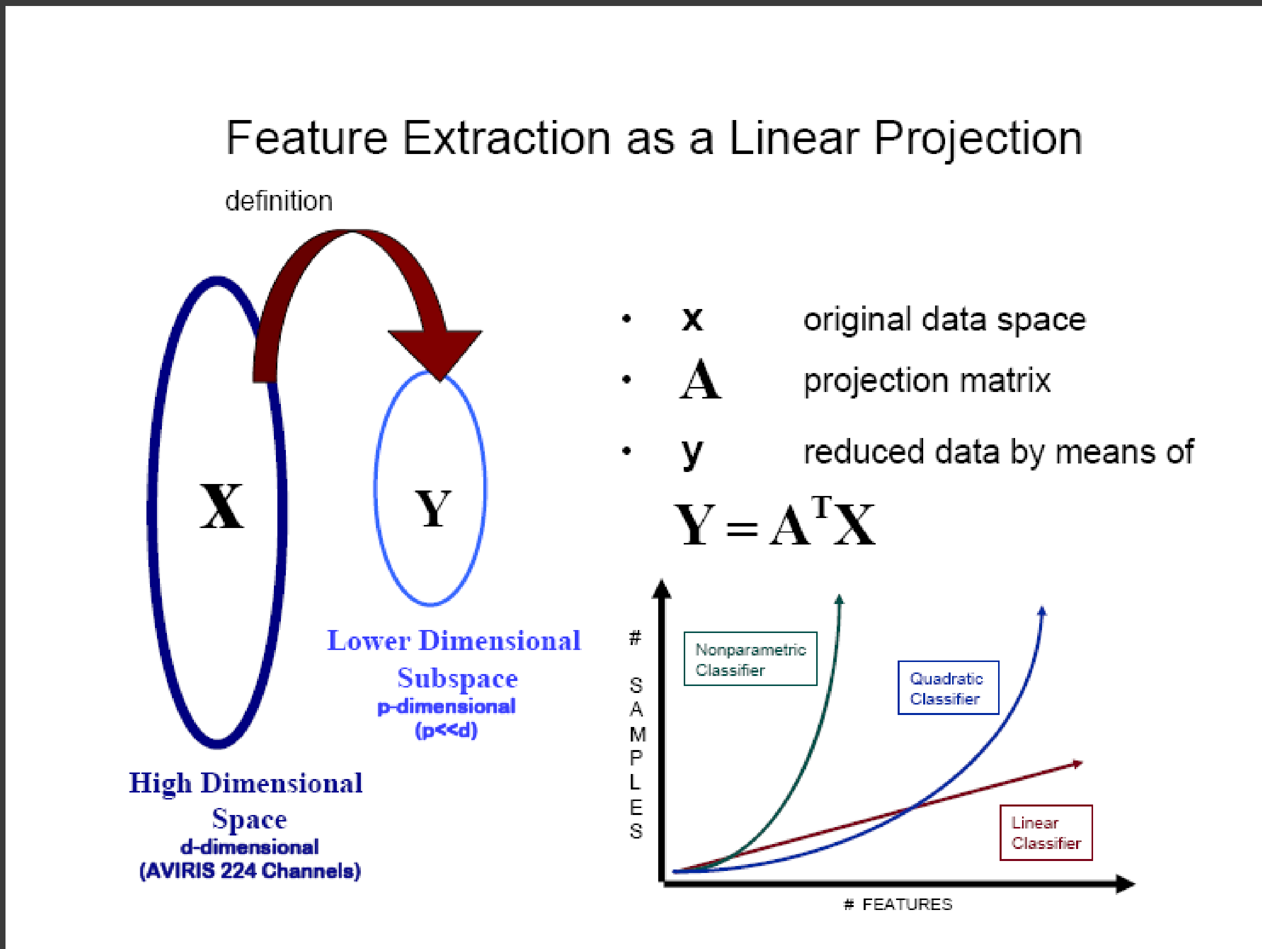
Basic image analysis and applications

- Introduction to ENVI
- Learning to use the basic operations
- Image Manipulation
  - Loading images
  - Displaying different bands
  - Displaying pixel information
  - Merging data sets

Data Reduction

- HSI contains hundreds of bands.
- High Dimensionality in HSI.
  - Curse of dimensionality.
- High Computational time.

Data Projection



Feature Extraction

- Principal Component Analysis
- Discriminant Analysis
- Projection Pursuit

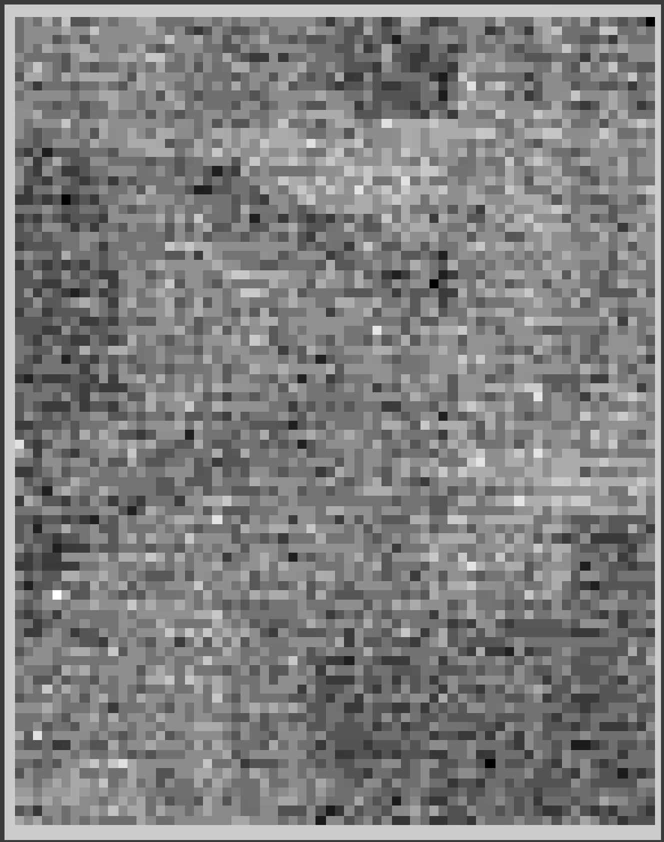
PCA Definition

- PCA is mathematically defined as an orthogonal linear transformation that transforms the data to a new coordinate system such that the greatest variance by any projection of the data comes to lie on the first coordinate (called the first principal component), the second greatest variance on the second coordinate, and so on.

$$Y = XW = VU$$

- Where VUW is the singular value decomposition of X

PCA Example



HSI Data

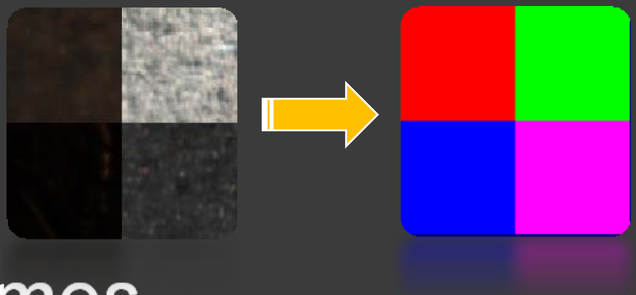
HSI data using PCA

Information Extraction

- Classification
  - Supervised
  - Unsupervised
- Unmixing
  - Abundance Estimation
  - Full Unmixing

Image Classification

- Process of assigning all pixels in a digital image to particular classes according to their characteristics.
- Result: Thematic Map



- Main Classification Schemes
  - Unsupervised
  - Supervised

Semi-Supervised

Classification of hyperspectral image

Hyperspectral dataset

3-dimensional raw data

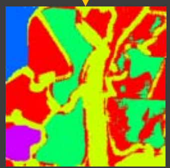
Preprocessing

Atmospheric and radiometric correction:
reduce distortion and enhance dataset

Feature extraction

Reduce bands using principal components
reduce data dimensionality

Classification



Use feature image (reduced bands) pixels to perform classification using distance classifiers (supervised or unsupervised):
identify pixels

Supervised Classification

- Uses samples of known identity - Training data - to classify pixels of unknown identity.
- Testing samples are used to evaluate the accuracy of the classifier.
- Different Supervised Classification Methods
  - Maximum Likelihood
  - Minimum Distance
  - Mahalanobis Distance
  - Neural Networks
  - Support Vector Machines (SVMs)

Supervised Classification

- Analyst identifies in the imagery homogeneous representative samples of the different surface cover types or classes of interest.
- These samples data are referred to as **training areas**. The analyst is "supervising" the categorization of a sets of specific classes.
- The numerical information in all spectral bands for the pixels comprising these areas are used to "train" the algorithms to recognize spectrally similar areas for each class.
- Once the algorithms has determined the statistics for each class, each pixel in the image is compared each class statistics and labeled as the class it most closely "resembles" to create a **Class Map**.

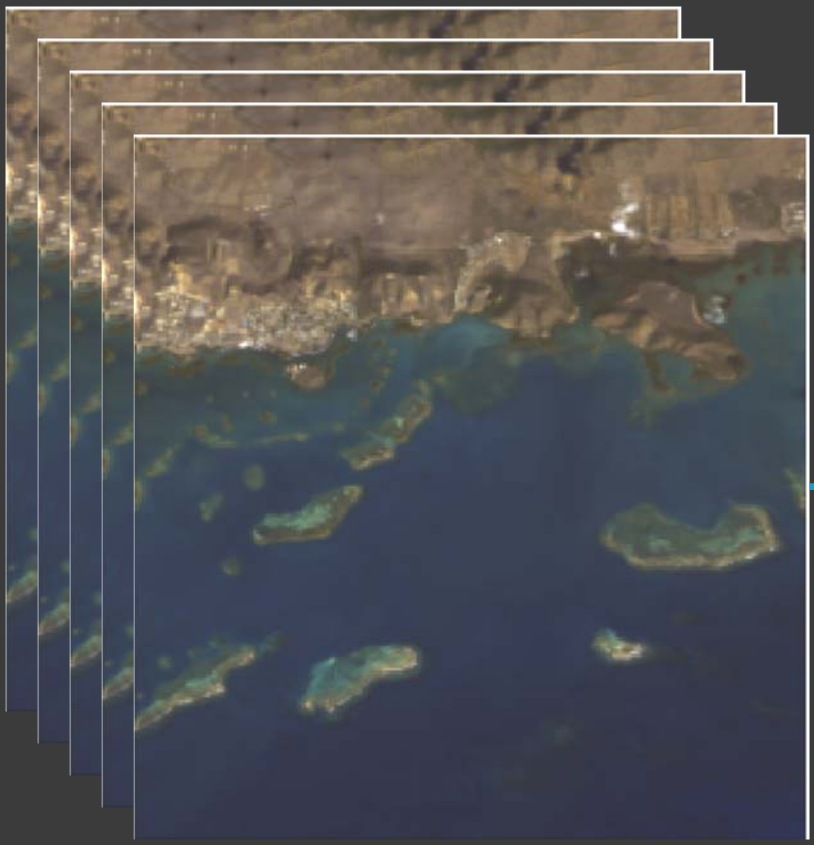
Unsupervised Classification

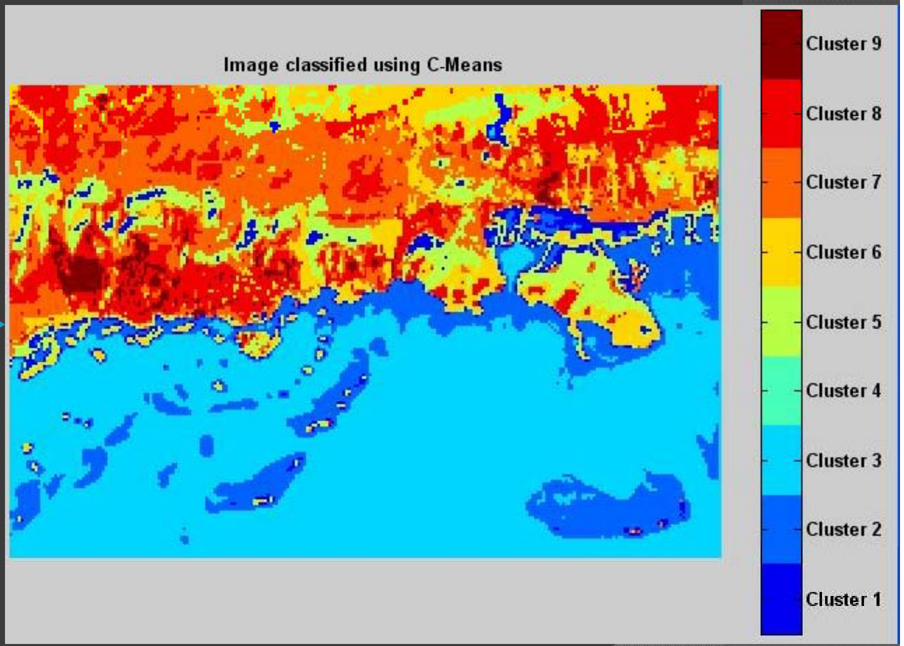
- Identification of natural groups
- Based only on the dataset statistics
  - No previous knowledge about the classes
- User inputs the number of classes
  - User must then name each class
- Main unsupervised classification methods
  - K-Means
  - Isodata (Iterative Self-Organizing Data Analysis Technique)

Unsupervised Classification

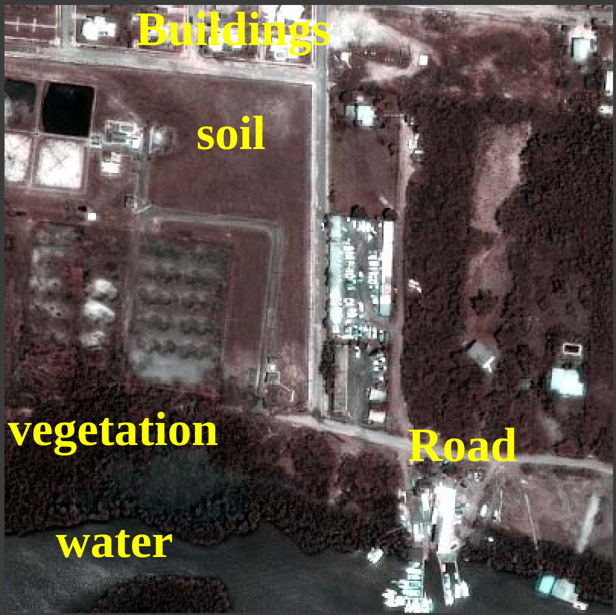
- **Clusters** (similar as classes), group similar pixels based on the natural data statistics.
- Different measurement create different clusters.
- The analyst specifies how many groups or clusters are to be looked for in the data.
- Analyst also specify parameters related to the separation distance among the clusters and the variation within each cluster.
- The final result is a **Cluster Map or Class Map**.

Classified Image

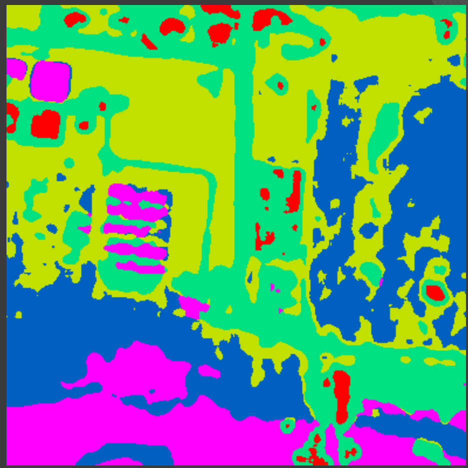


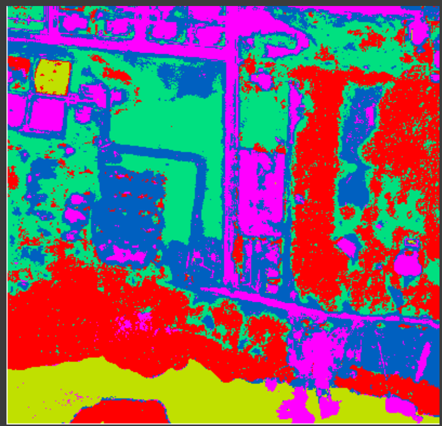


Classifications of IKONOS image (La Parguera)



4 bands
– R, Near IR, G, B

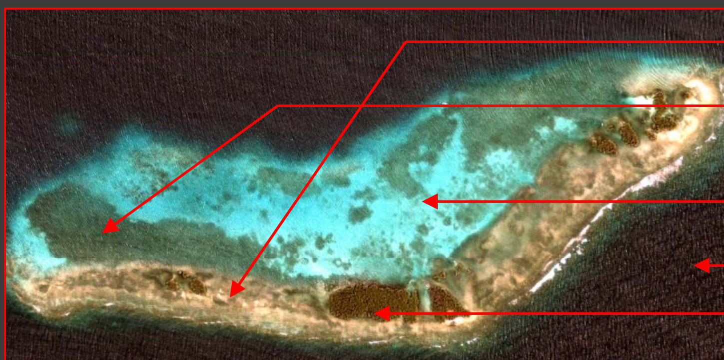




Total features= 4
(Band R spectral value and 3
Statistical features)
8x8 regions
Accuracy (testing) =99%

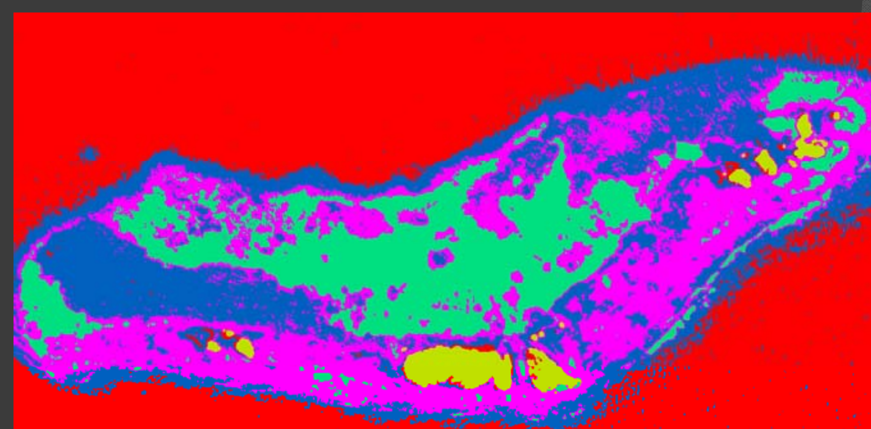
Maximum likelihood classification using 4 bands of spectral values

Coastal classification IKONOS image



4 bands – R,NIR, G and B
Resolution -1mt.

Class map – using spectral and gray level statistical features -3x3 regions
Total features = 5(NIR band and 4 statistical features)
Accuracy (testing samples) = 95.0745%



Laboratory # 2

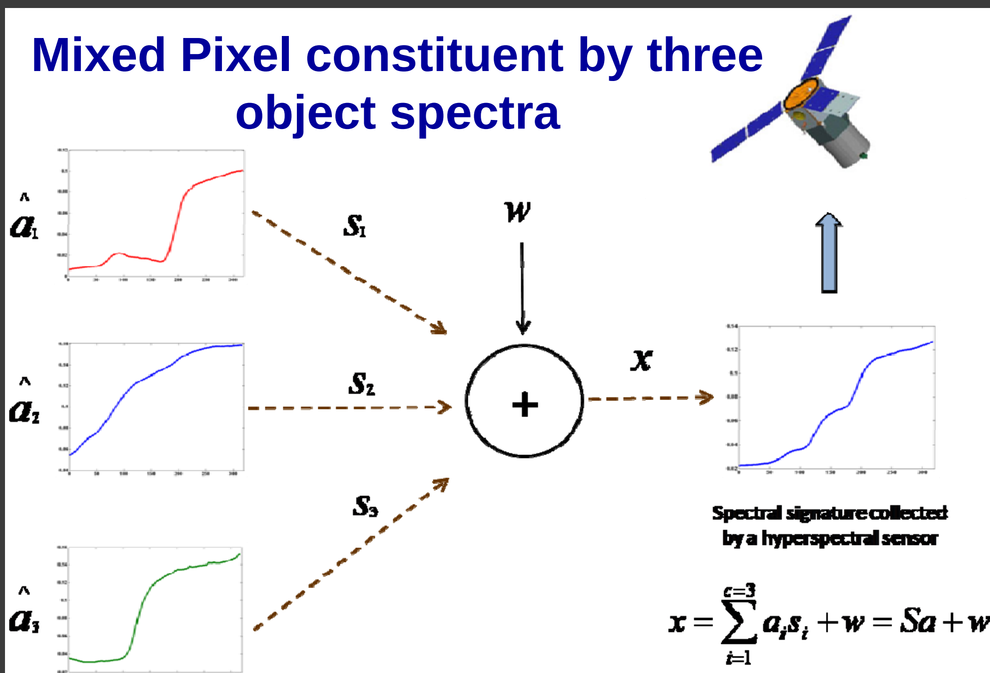
Feature Extraction and Information Extraction

- Use of different feature extraction technique
- Comparison of images projected
- Basic Classifier
  - Supervised
- Class Map comparison and accuracy

Unmixing

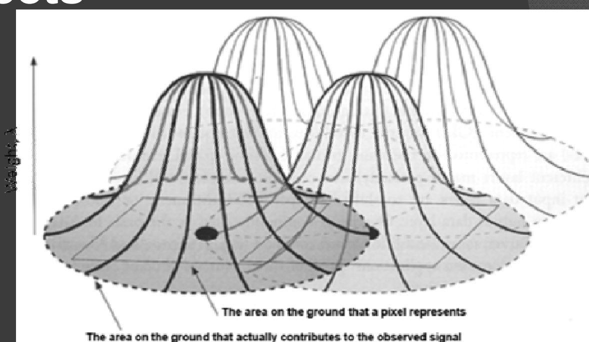
- **Spectral unmixing** is the processing is to decompose the mixed pixels into the materials that contribute to the pixel, *endmember and a set of corresponding fractions* of the spectral signature in the pixel, *abundances.*

Mixed pixels are an important problem in information extraction from remote sensed imagery

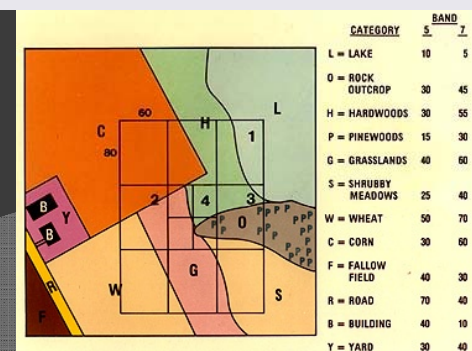


Low spatial resolution sensors

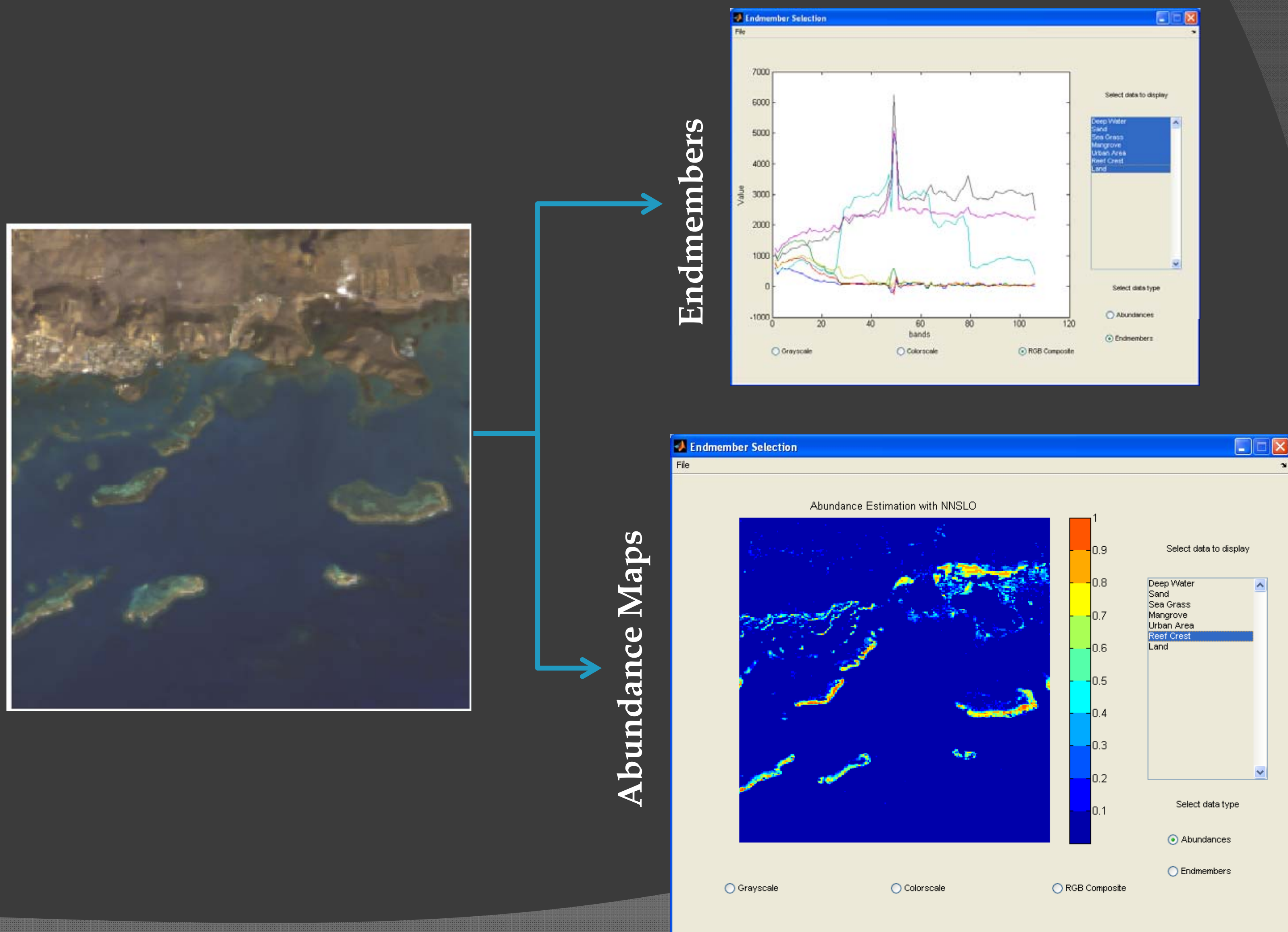
PSF effects



Boundaries among classes



Unmixed Image



Post Processing

- Techniques for class map enhancement
  - Base on contextual information of the image classes
  - Using spatial and spectral information of pixel neighborhood to enhance the final map
- Common use is for removing class map anomalies
- In addition, for class smothness

Laboratory #3
Post processing & Unmixing

- Use of basic post processing algorithms for class map improvement.
- Class map comparison.
- Accuracy of the different maps.
- Using Unmixing Algorithms for Information Extraction