Digital Image processing

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DEPARTMENT OF REMOTE SENSING

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What is remote sensing ?

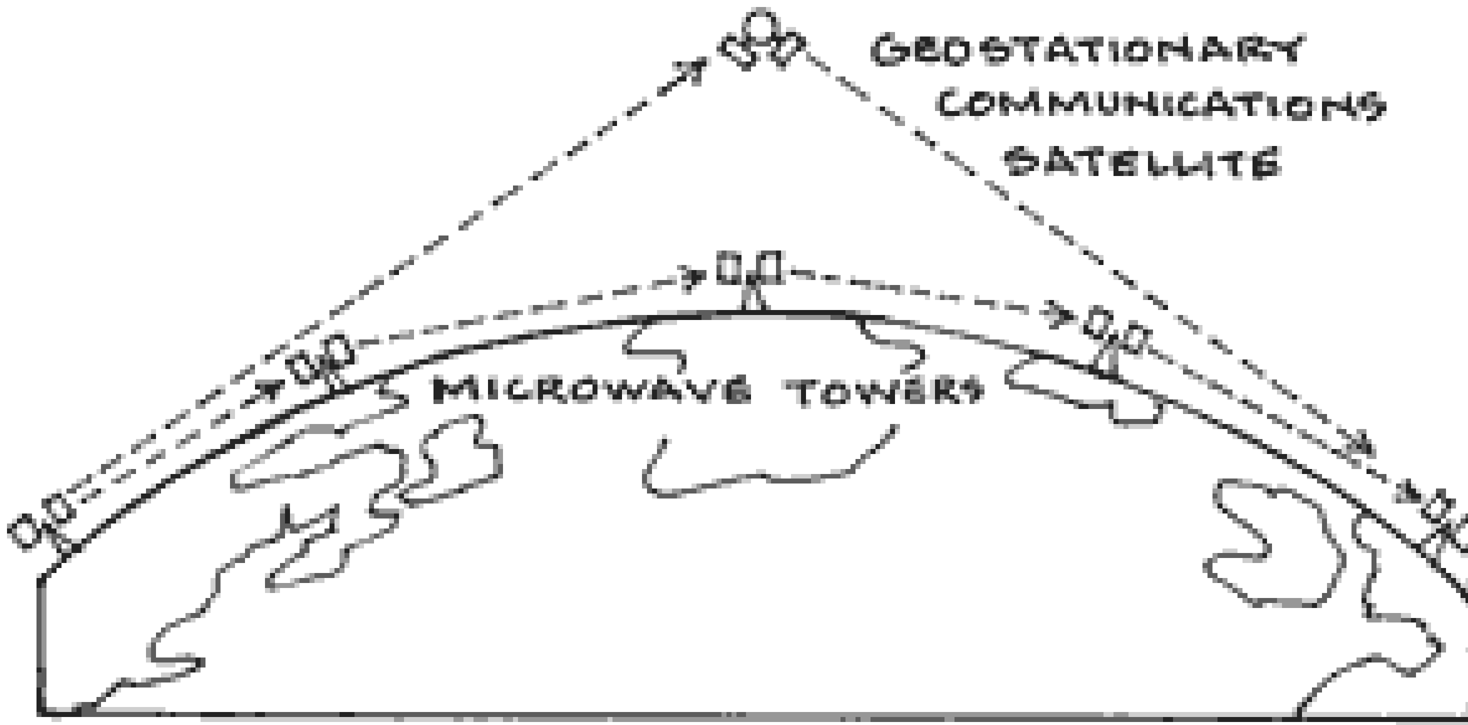
Remote sensing is

> **obtaining information about an object**
> **with a sensor which is**
> **physically separated from the object.**

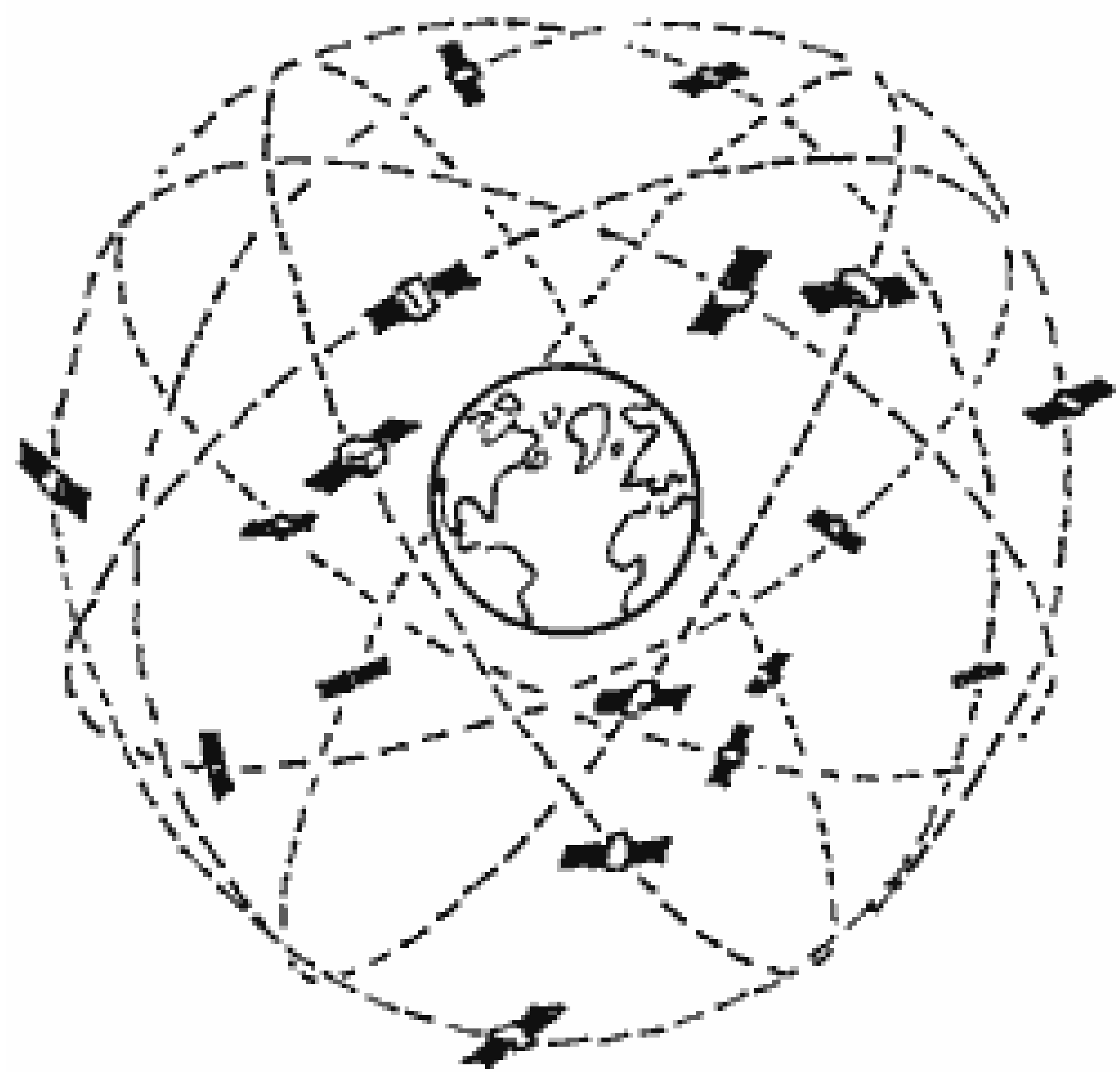
The number of satellite missions dedicated to
Earth Observation has increased significantly over the past decade, and

> will further increase over the coming decade and beyond,
> with, in particular, the incoming of very high resolution imagery.

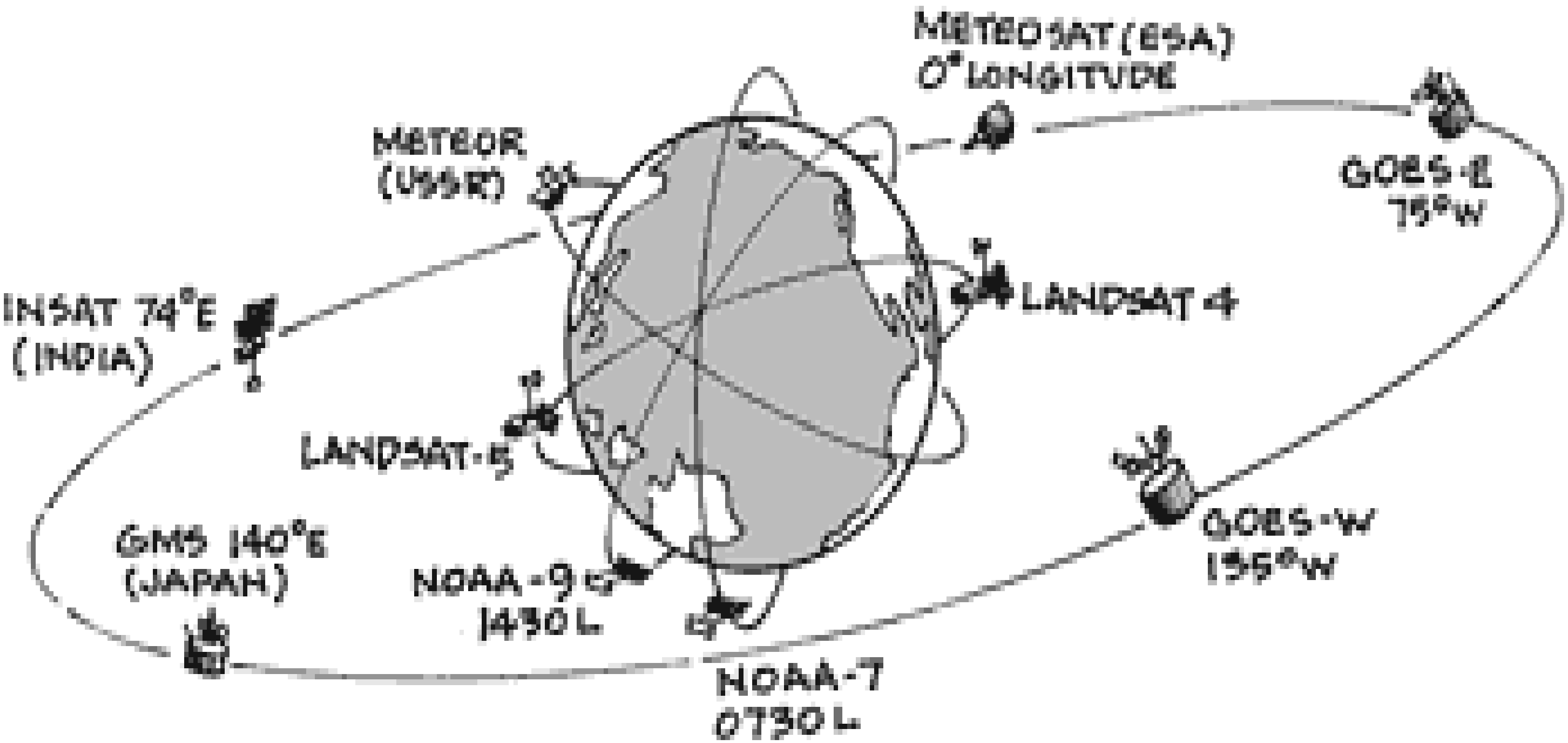
Communication Satellites



Navigation Satellites



Resource Satellites



Active remote sensing

Remote sensors rely upon the detection of energy emitted from or reflected by the object.
The source of the radiation being sensed
may or may not be independent of the sensing device.

Examples

Radar, SAR

Passive remote sensing

Examples

Aerial photography and SPOT, IRS

Active remote sensing devices direct radiation of a particular form
towards an object and then detect the amount of that energy radiated by the object.

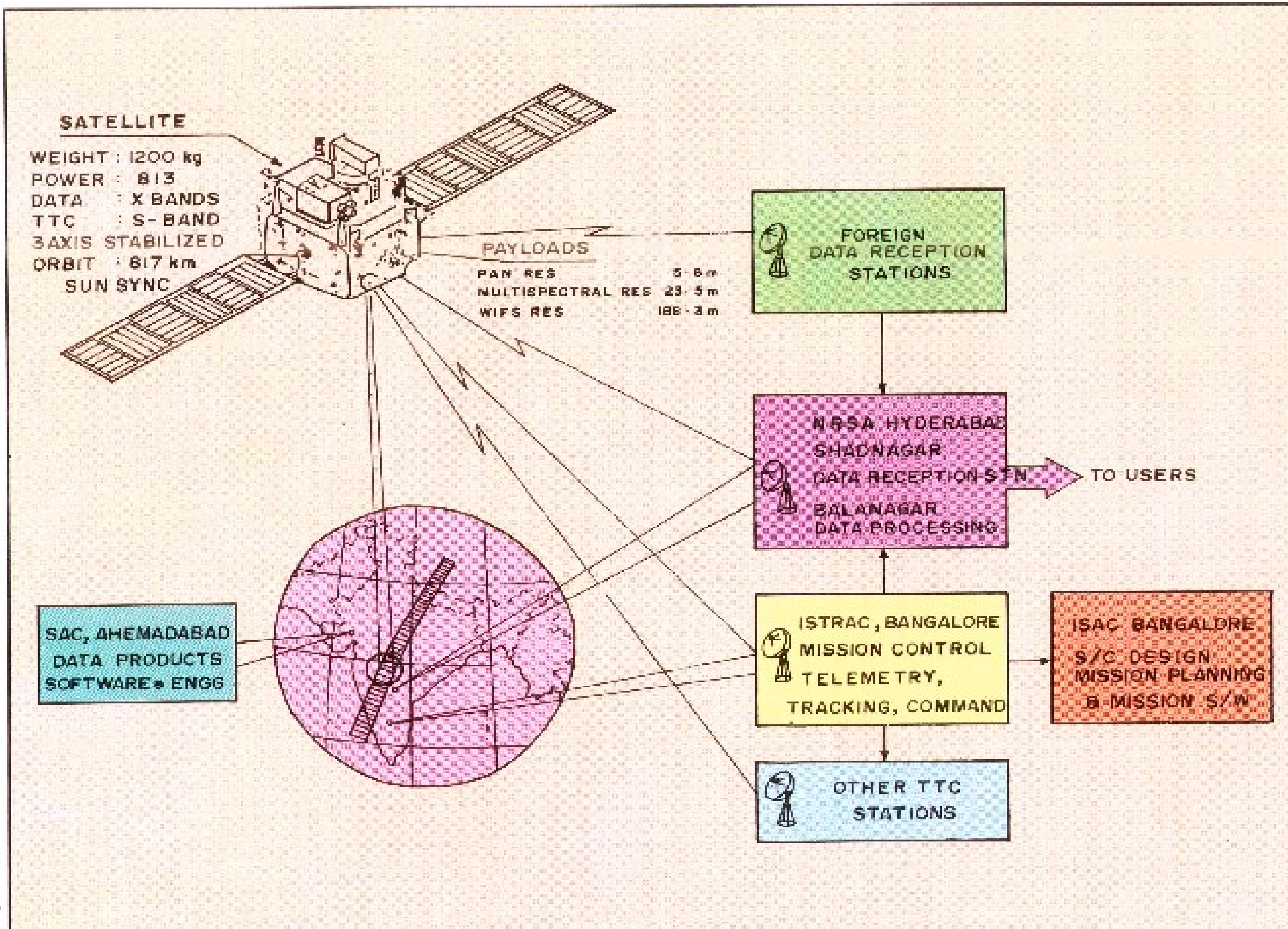
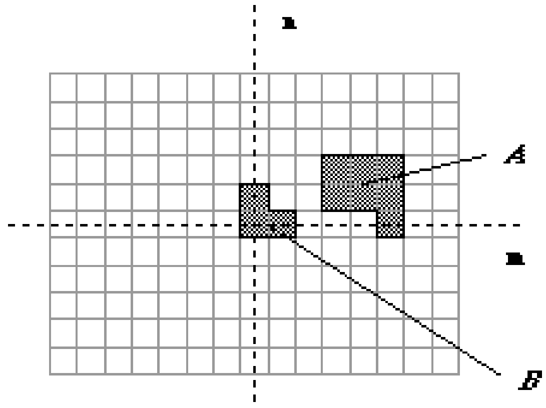


Figure 2.1.1 Overview of IRS-1D mission

Image – picture element **-pixel**

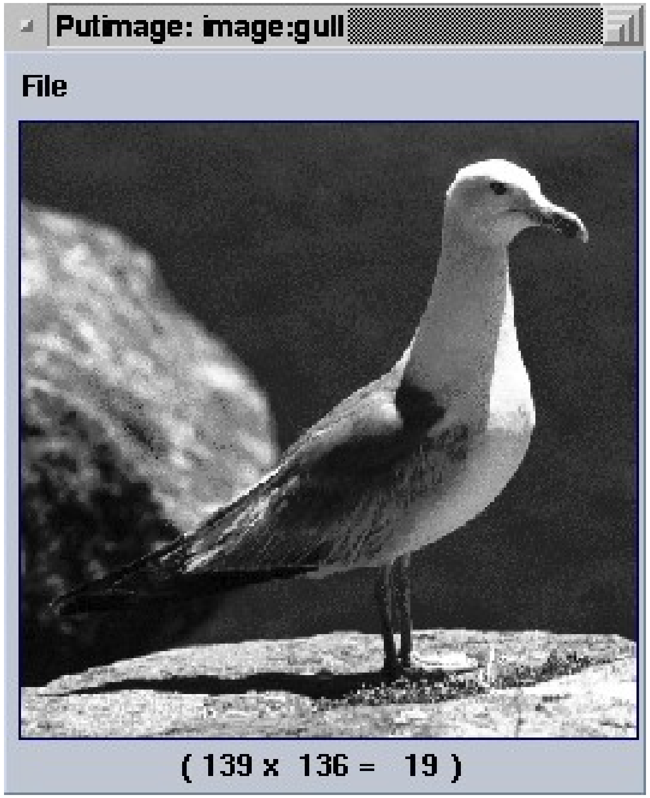


A binary image containing two object sets ***A*** and ***B***.

Pixel $\propto$ (x,y,z,t,λ)

A digital image is a two dimensional matrix where its elements are called pixels (abbreviation of picture elements).

The process of displaying an image creates a graphical representation of this matrix where the pixel values are assigned a particular grey-level (monochromatic image) or a particular color.



DATA REPRESENTATION

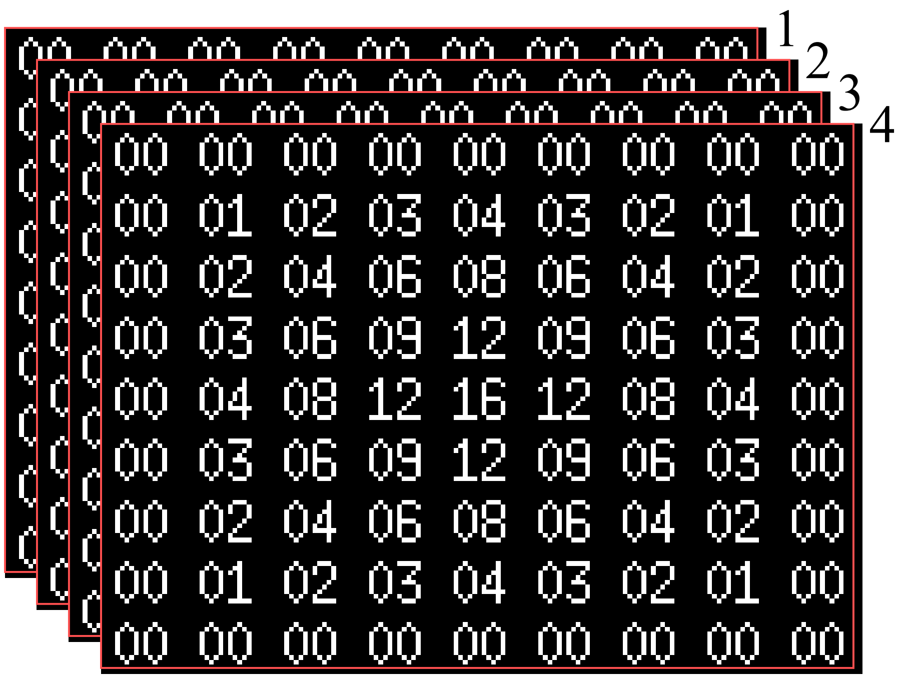
Image header Information

Dimensions: Width=256,
Height=256
Pixel type: unsigned byte
Color Model: Greyscale

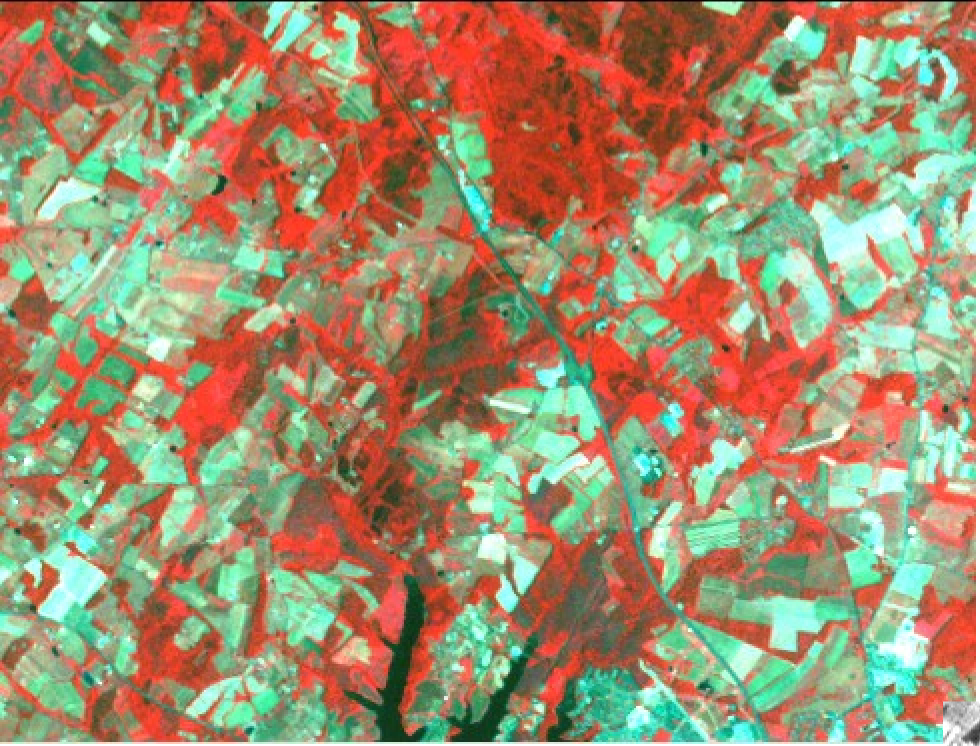
00	00	00	00	00	00	00	00	00
00	01	02	03	04	03	02	01	00
00	02	04	06	08	06	04	02	00
00	03	06	09	12	09	06	03	00
00	04	08	12	16	12	08	04	00
00	03	06	09	12	09	06	03	00
00	02	04	06	08	06	04	02	00
00	01	02	03	04	03	02	01	00
00	00	00	00	00	00	00	00	00

Size: Width=162,
Height=117
Pixel type: bit
Color Model: None

Color image, 3 elements (RGB)



Size: Width=256,
Height=256, Elements=3,
Pixel type: unsigned byte,
Color Model: RGB



MULTISPECTRAL

SINGLE BAND

IMAGE FORMATS

BIP - Band interleaved by pixels
BIL – Band interleaved by lines
BSQ – Band sequential

Band Interleaved By Pixel Format (BIP)

This format treats pixels as the separate storage unit.
Brightness values for each pixel are stored one after another.
It is practical to use if all bands in an image are to be used.

Figure 2-3.1 Band Interleaved by Pixel Format (BIP)

Line 1	Pixel **1**	Band 1		Line 1	Pixel **2**	Band 1		Line 1	Pixel **3**	Band 1
Line 1	Pixel **1**	Band 2		Line 1	Pixel **2**	Band 2		Line 1	Pixel **3**	Band 2
Line 1	Pixel **1**	Band 3		Line 1	Pixel **2**	Band 3		Line 1	Pixel **3**	Band 3
Line 1	Pixel **1**	Band 4		Line 1	Pixel **2**	Band 4		Line 1	Pixel **3**	Band 4

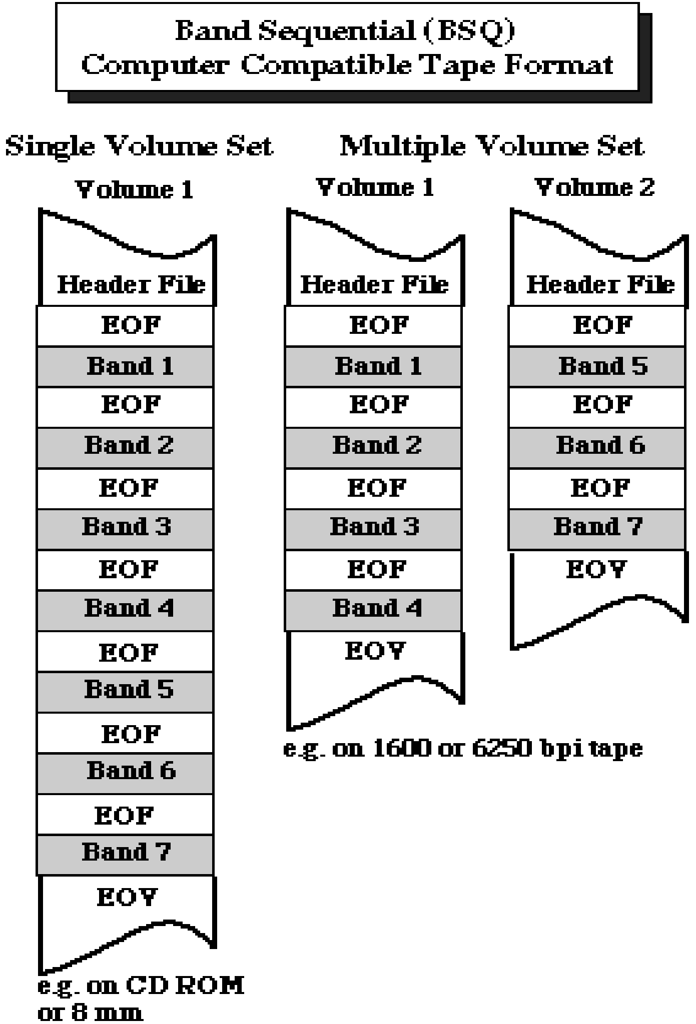
Band Interleaved By Line Format (BIL)

Just as the BIP format treats each pixel of data as the separate unit, the band interleaved by line (BIL) format is stored by lines. The logic of how the data is recorded to the computer tape in sequential values for a four band image is shown in fig.

Figure 2-3.2 Band Interleaved by Line Format (BIL)

Line **1**	Band 1	Line **1**	Band 2	Line **1**	Band 3	Line **1**	Band 4			
	Line **2**	Band 1	Line **2**	Band 2	Line **2**	Band 3	Line **2**	Band 4		
		Line **3**	Band 1	Line **3**	Band 2	Line **3**	Band 3	Line **3**	Band 4	
			Line **4**	Band 1	Line **4**	Band 2	Line **4**	Band 3	Line **4**	Band 4

Band Sequential Format (BSQ)



The band sequential format requires that all data for a single band covering the entire scene be written as one file. Many researchers like this format because it is not necessary to read serially past unwanted information if certain bands are of no value, especially when the data are on a number of different tapes.

RESOLUTIONS OF IMAGE

SPATIAL RESOLUTION

Spatial resolution is related to the resolving power to distinguish image details.

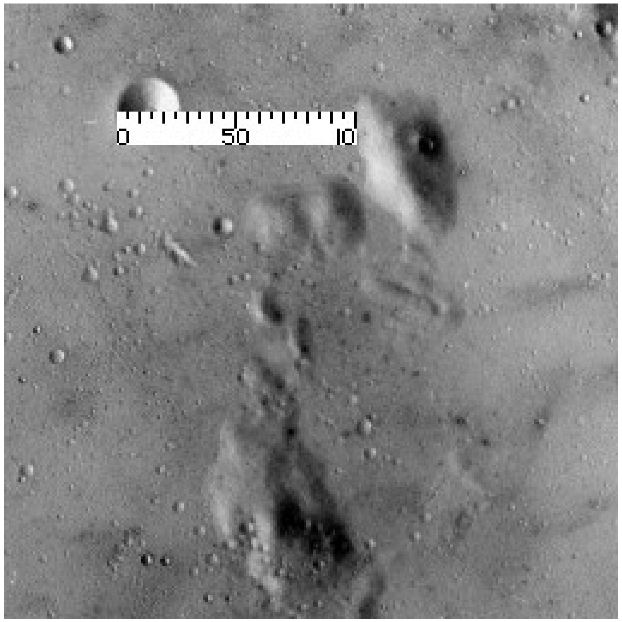
In remote sensing, spatial resolution is the size each pixel represents in the real world by the terms *ground resolution element* and *ground resolution distance*.

For example,

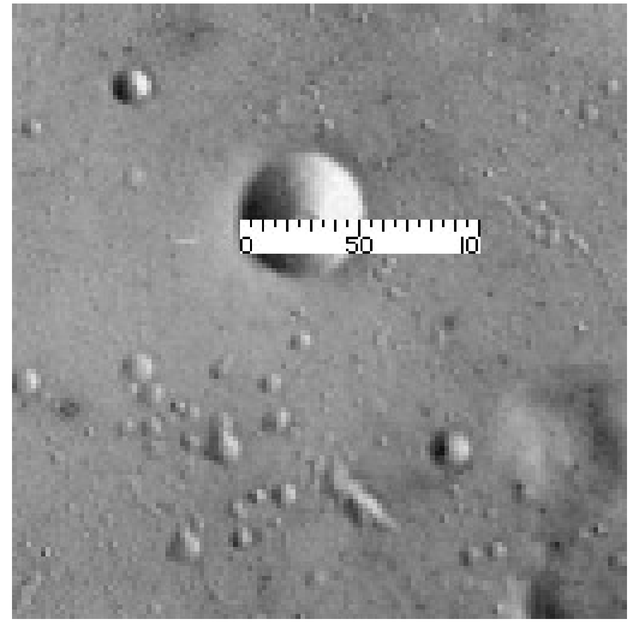
IRS 1D PAN - 5.8 m
LISS III - 23.5 m
WiFS - 188 m

smaller the resolution distance, the better one can resolve image spatial contents.

Measurement of moon



20 km/pixel



10 km/pixel

There are approximately 27 pixels across the diameter of the lunar crater shown on the first image, and approximately 55 pixels across the crater shown on the second image on the right.

Spatial Resolutions for Some Common Sensors

SPATIAL RESOLUTIONS	
Remote Sensing Instrument	**Spatial Resolution (Size of IFOV)**
Landsat TM (Thematic Mapper)	Bands 1,2,3,4,5&7: 30 m Band 6: 120 m
Landsat MSS (Multispectral Scanner)	Bands 4,5,6&7: 80 m Band 8: 237 m
SPOT HRV (Systeme Probatoire d'Observation de la Terre, High Resolution Visable)	Bands 1-3 (Multispectral): 20 m Band 4 (Panchromatic): 10 m
NOAA-AVHRR (Advanced Very High Resolution Radiometer)	Bands 1-5: 1.1 km
EOS-MODIS (Earth Observing System - Moderate Resolution Imaging Spectroradiometer)	Bands 1-2: 250 m Bands 3-7: 500 m Bands 8-36: 1 km

RADIOMETRIC RESOLUTION

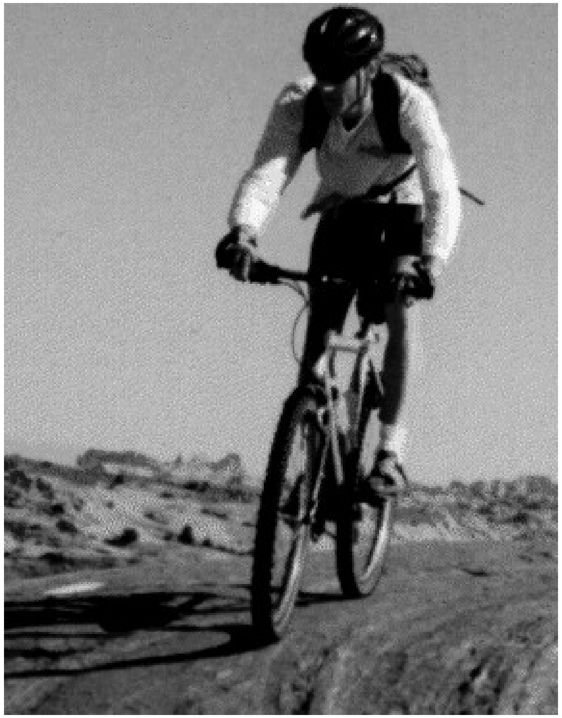
Radiometric resolution refers to the dynamic range, or the number of different output levels used to record the radiant energy for a single measurement.

The number of levels is governed by the byte size, or number of bits used by the recording medium to represent the signal generated by a single detector element for a given IFOV, or pixel.

Radiometric Resolutions for Some Common Sensors

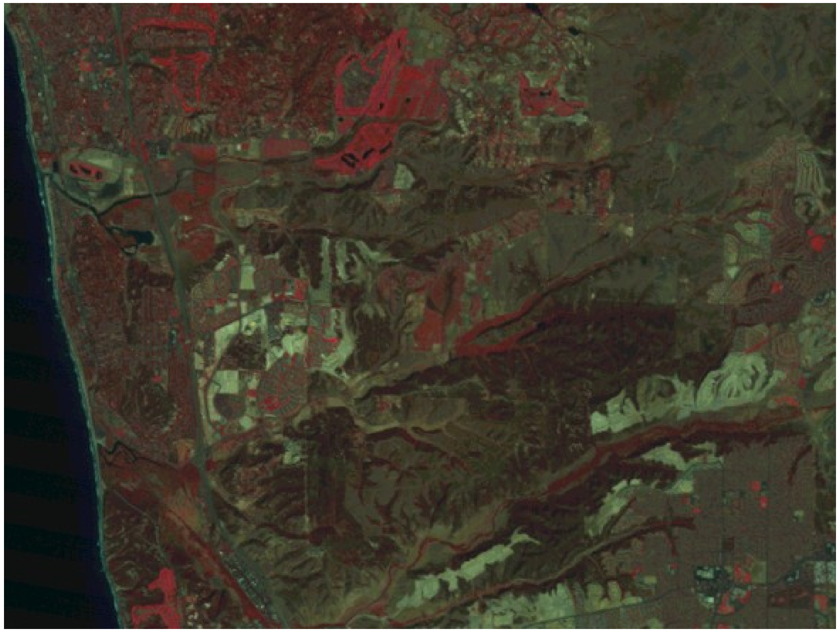
RADIOMETRIC RESOLUTIONS	
Remote Sensing Instrument	**Radiometric Resolution**
Landsats 1, 2 & 3; Multispectral Scanner	6-Bit (64 levels)
Landsats 4 & 5; Thematic Mapper and Multispectral Scanner	8-Bit (256 levels)
SPOT HRV (Systeme Probatoire d'Observation de la Terre, High Resolution Visable)	8-Bit (256 levels)
NOAA-AVHRR (Advanced Very High Resolution Radiometer)	10-Bit (1024 levels)
EOS-MODIS (Earth Observing System - Moderate Resolution Imaging Spectroradiometer)	12-Bit (4096 levels)

Digital image with 2-bit (upper left), 3-bit (upper right), 4-bit (lower left), and 7-bit (lower right) dynamic range.

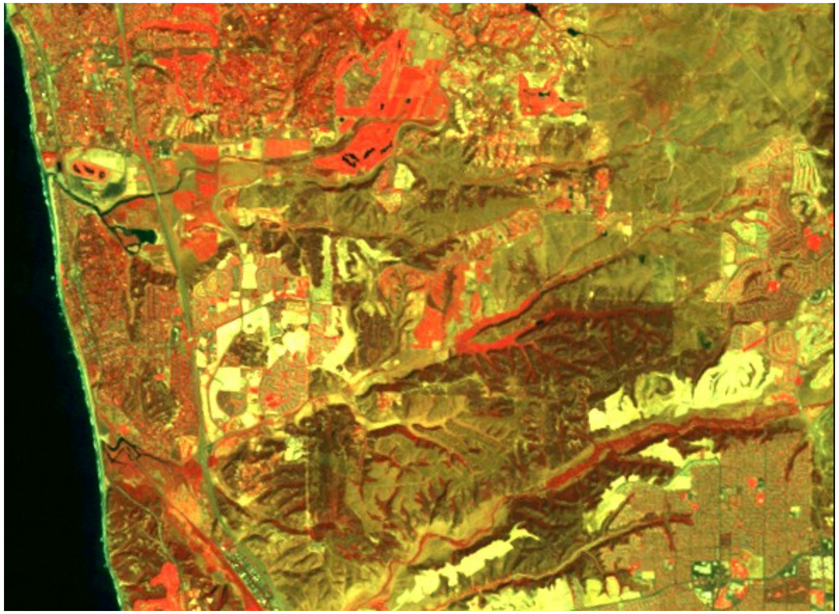


The original image in 8-bit representation.

ORIGINAL 7 BIT DATA



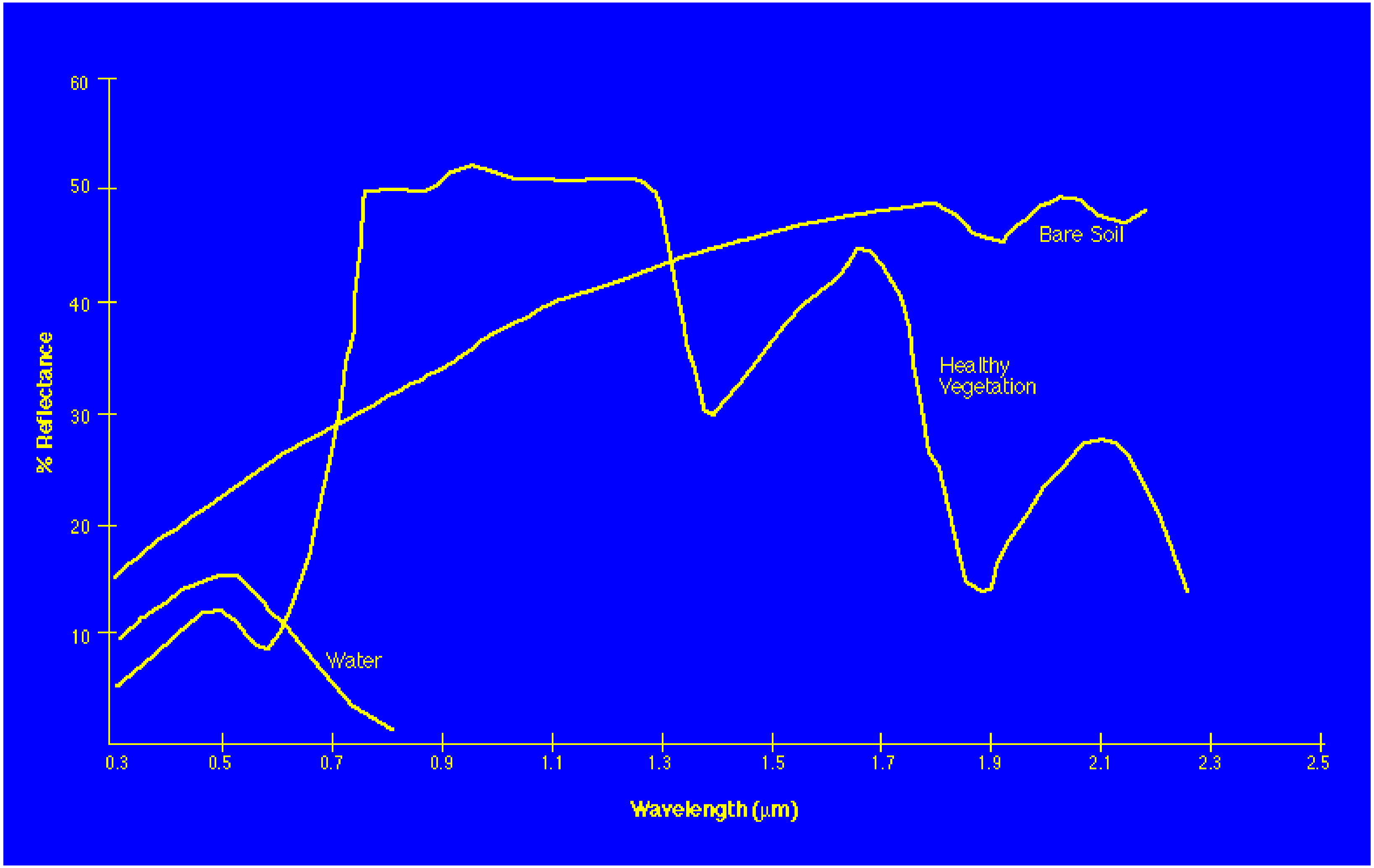
STRETCHED 8 BIT DATA



SPECTRAL RESOLUTION

In Remote Sensing,
Spectral resolution refers to the number, spacing, and width of the sampled wavelength bands along the electromagnetic spectrum.

The higher the *spectral resolution*, the more completely and precisely the *spectral signature* of each individual IFOV will be sampled, and the more readily different scene elements can be classified or discriminated based on those signatures.

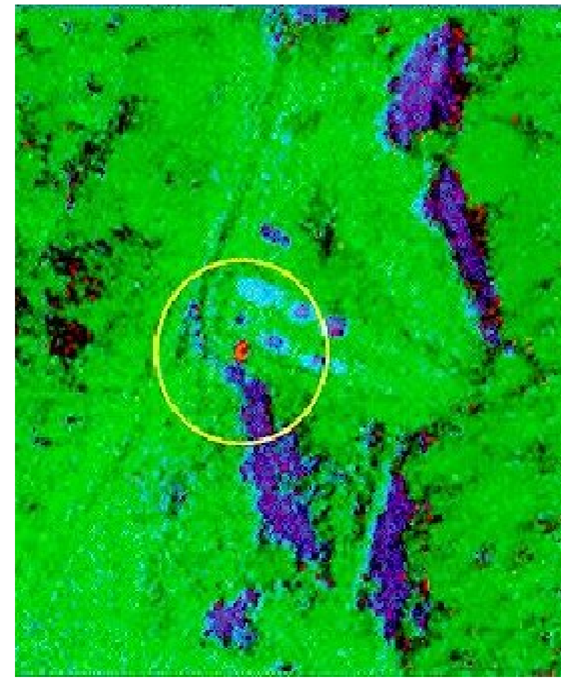


Generic spectral signatures for three common materials are shown. Notice in particular how these three spectra differ in the red and near-infrared regions. Sampling reflected energy in these critical regions can help discriminate objects because of these differences.

SPECTRAL RESOLUTION

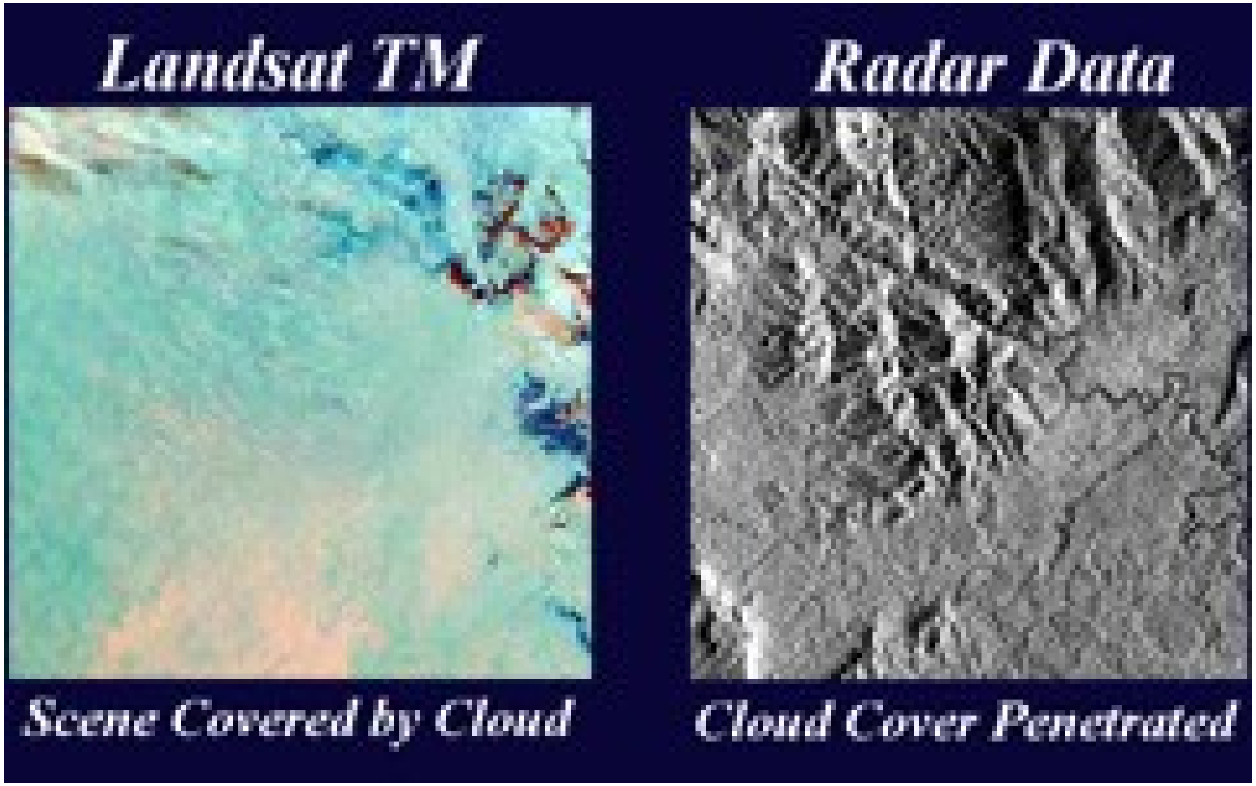
PAN IMAGE

IKONOS



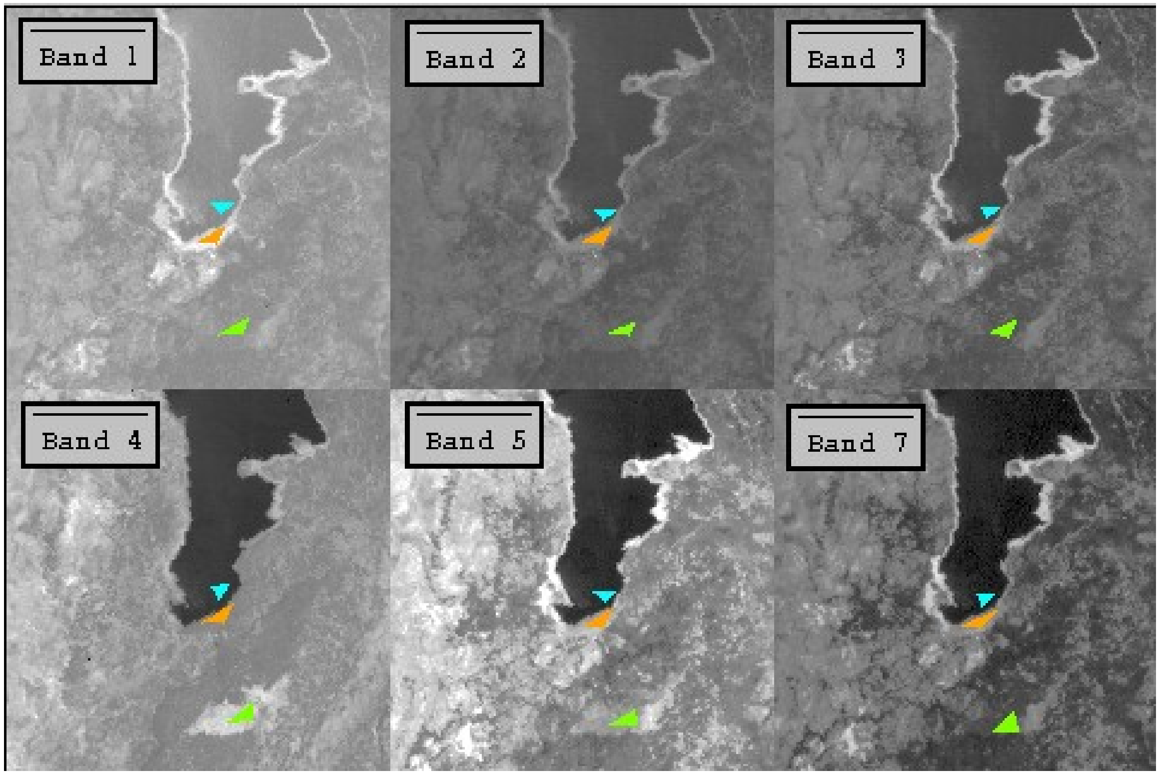
HYPERSPECTRAL

LANDSAT and RADAR comparison

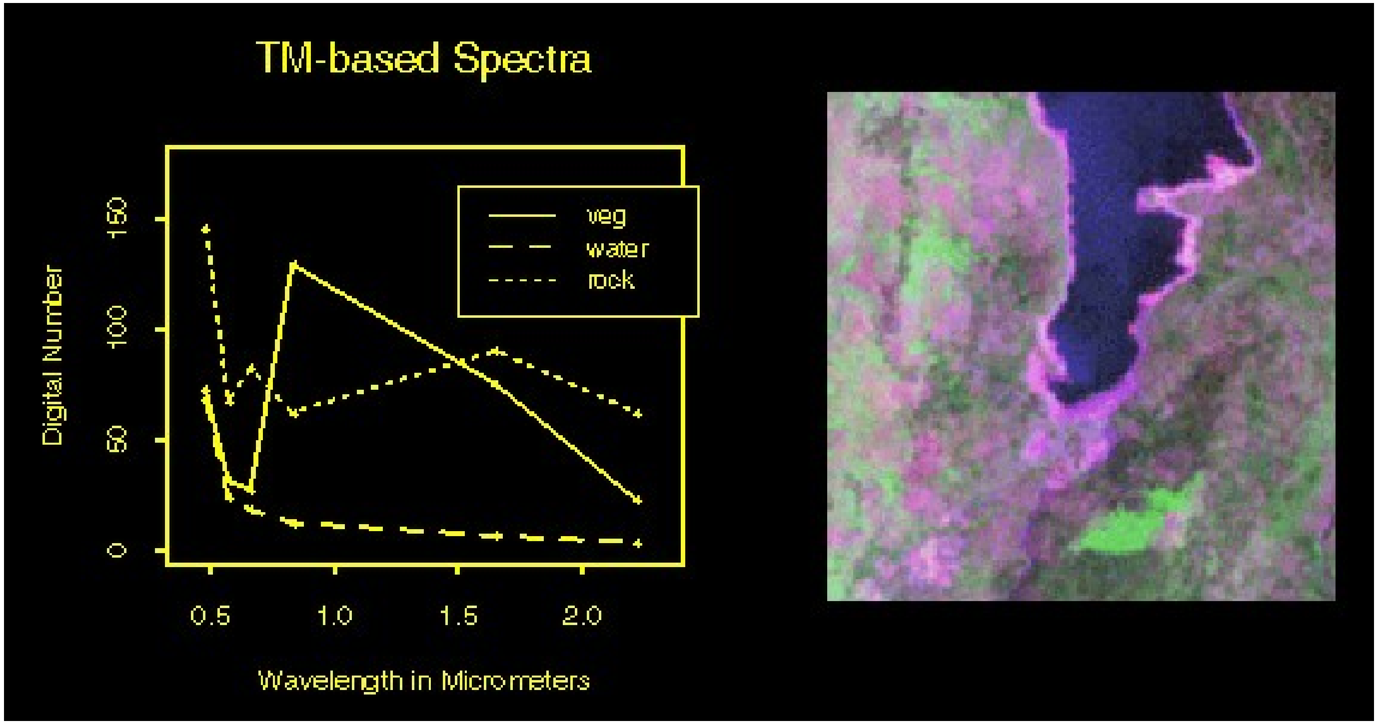


SPECTRAL RESOLUTIONS

Remote Sensing Instrument	Spectral Bands (in micrometers)
Landsat TM (Thematic Mapper)	1. 0.45 - 0.52 (Blue) 2. 0.52 - 0.60 (Green) 3. 0.63 - 0.69 (Red) 4. 0.76 - 0.90 (Near-Ifrared) 5. 1.55 - 1.75 (Middle-Infrared) 6. 10.4 - 12.5 (Thermal) 7. 2.08 - 2.35 (Middle-Infrared)
Landsat MSS (Multispectral Scanner)	4. 0.5 - 0.6 (Green) 5. 0.6 - 0.7 (Red) 6. 0.7 - 0.8 (Near-Infrared) 7. 0.8 - 1.1 (Near-Infrared) 8. 10.4 - 12.6 (Thermal)
SPOT HRV (Systeme Probatoire d'Observation de la Terre, High Resolution Visable)	1. 0.50 - 0.59 (Green) 2. 0.61 - 0.68 (Red) 3. 0.79 - 0.89 (Near-Infrared) 4. 0.51 - 0.73 (Panchromatic)
NOAA-AVHRR (Advanced Very High Resolution Radiometer)	1. 0.58 - 0.68 (Red) 2. 0.72 - 1.10 (Near-Infrared) 3. 3.55 - 3.93 (Middle-Infrared) 4. 10.3 - 11.3 (Thermal) 5. 11.5 - 12.5 (Thermal)



Landsat Thematic Mapper bands 1, 2, 3, 4, 5, and 7 for a small region of the Stanislaus National Forest in the northern Sierra Nevada Mountains in California.



Pixel spectral values are extracted for three classes to produce the spectral signatures seen in Figure 3b below. The three classes, indicated by the small colored polygons are: Aqua = Water; Orange = Rock; Green = Vegetation.

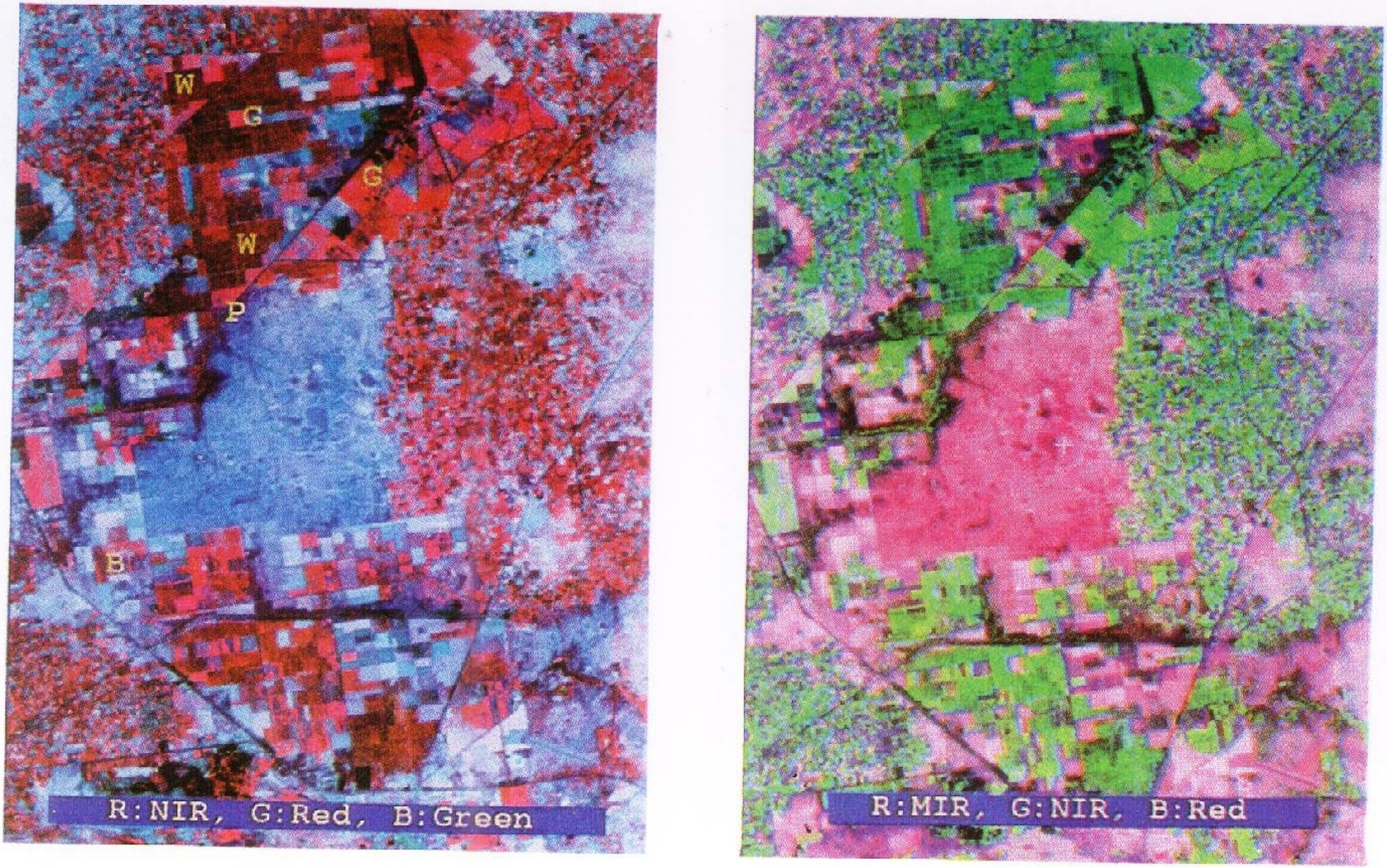


Figure 6.3.2.3 LISS-III FCCs with different band combinations

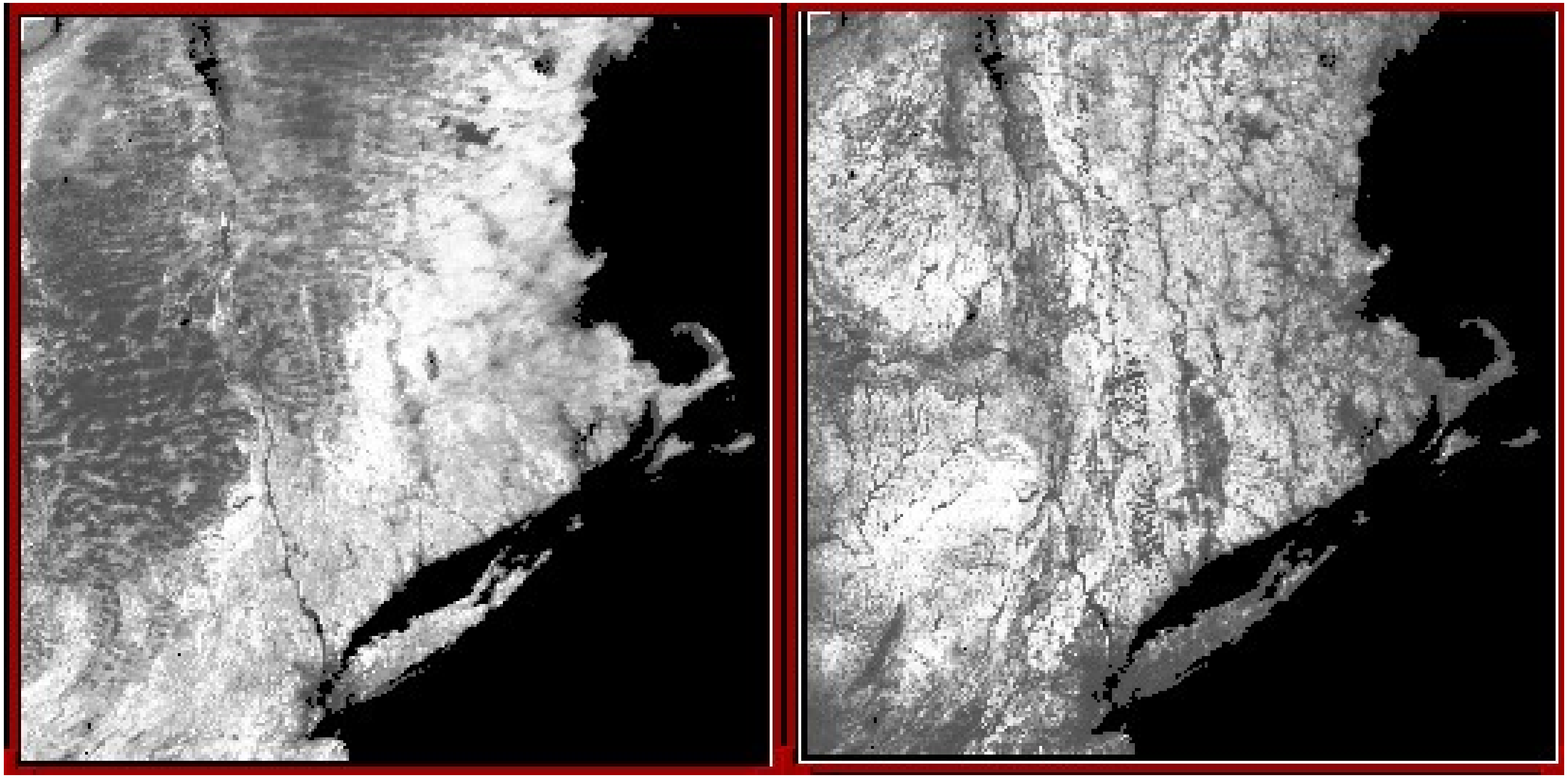
TEMPORAL RESOLUTION

Temporal resolution refers to the temporal frequency with which a given ground location will be sampled by an individual sensor. It is controlled by the orbital characteristics of the satellite and the swath width of the instrument.

Many ground objects have characteristic temporal signatures. This refers to how the reflectance for a given object in a given waveband, or band combination, changes through time.

Temporal Resolutions for Some Common Sensors

TEMPORAL RESOLUTIONS	
Remote Sensing Instrument	**Temporal Resolution**
Landsat 1,2, and 3 (Both TM and MSS)	18 Days (Every 251 Orbits)
Landsat 4,5, and 6 (Both TM and MSS)	16 Days (Every 233 Orbits)
SPOT HRV (Systeme Probatoire d'Observation de la Terre, High Resolution Visable)	26 Days
NOAA-AVHRR (Advanced Very High Resolution Radiometer)	12 Hours
EOS-MODIS (Earth Observing System - Moderate Resolution Imaging Spectroradiometer)	2 Days



NDVI images for the same two dates as shown above. Notice how the image from the first period (the one dominated by off-nadir viewing) has a blurred appearance, the second image, which is sampled from near nadir, has greater sharpness of detail.

IMAGE PRE-PROCESSING

Radiometric Corrections

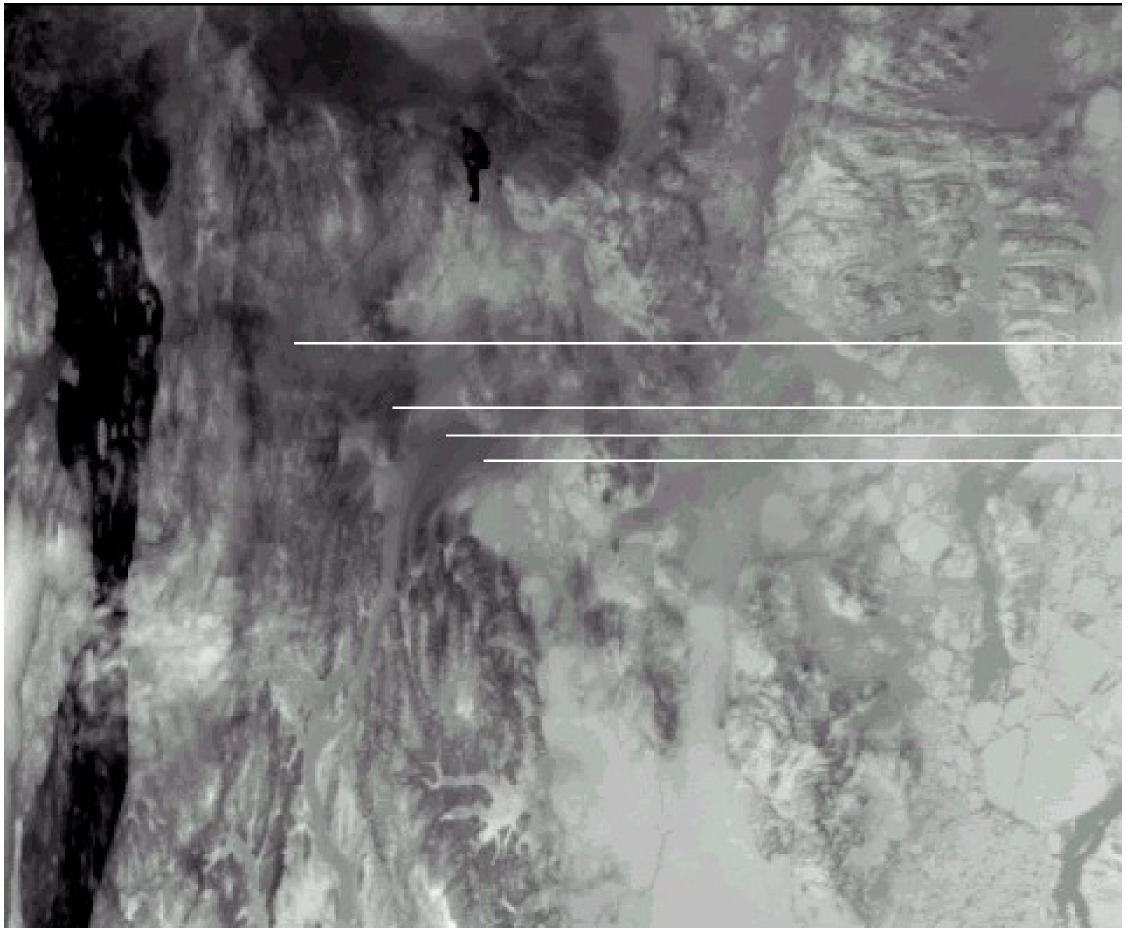
Radiometric distortions arise due to the following factors:

i. Non-uniform response of the detectors and detector elements.
ii. Specific detector element failure.
iii. Data losses during communication or archival/ retrieval
iv. Narrow dynamic range.
v. Image to image variations.

Geometric Corrections

Geometric distortions arising due to the following reasons are corrected:

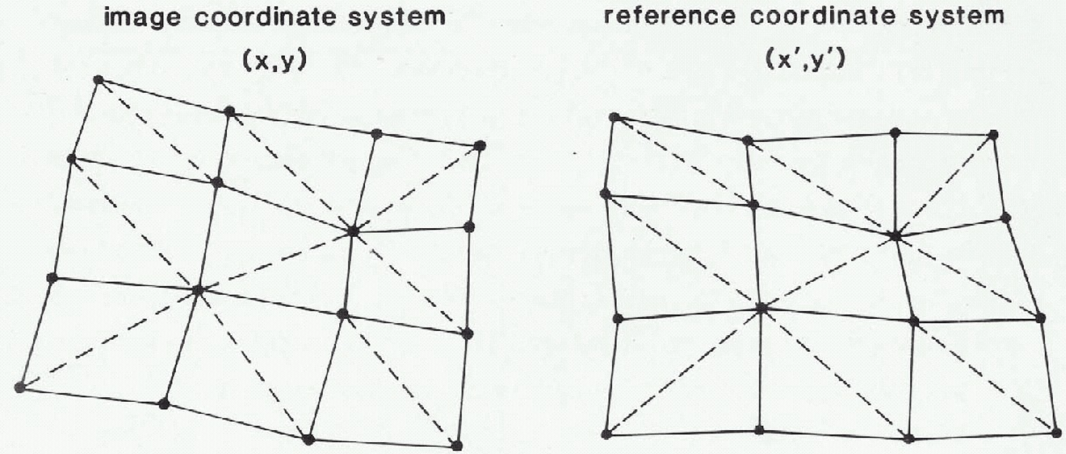
i. Scene related.
ii. Sensor related.
iii. Spacecraft related.
iv. Measurement / Calibration Errors.



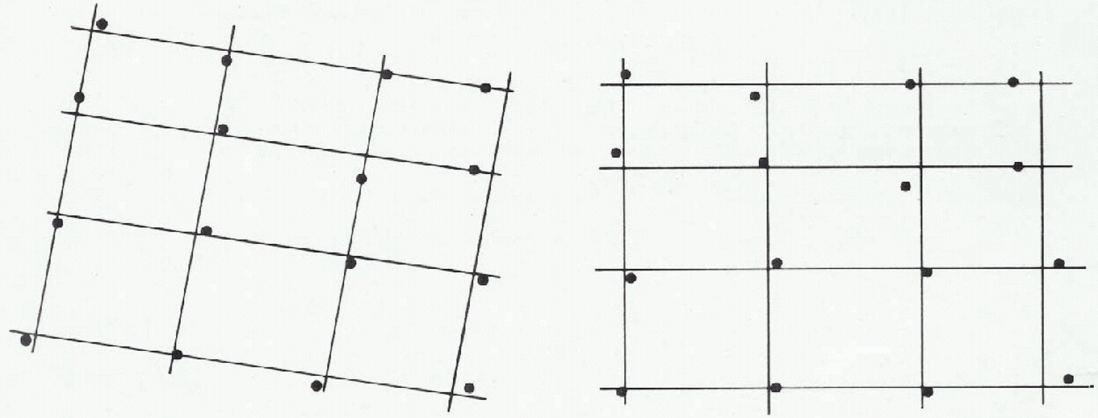
BADLINES

Image geometric and locational errors arise from a number of sources. These sources include:

- **the rotation of the earth during image acquisition**
- **the finite scan rate of some sensors**
- **the wide field of view of some sensors**
- **the curvature of the earth**
- **sensor non-idealities**
- **variations in platform altitude, attitude and velocity**
- **panoramic effects related to the imaging geometry**
- **uncertainty in the exact location of the satellite at the time of image acquisition**

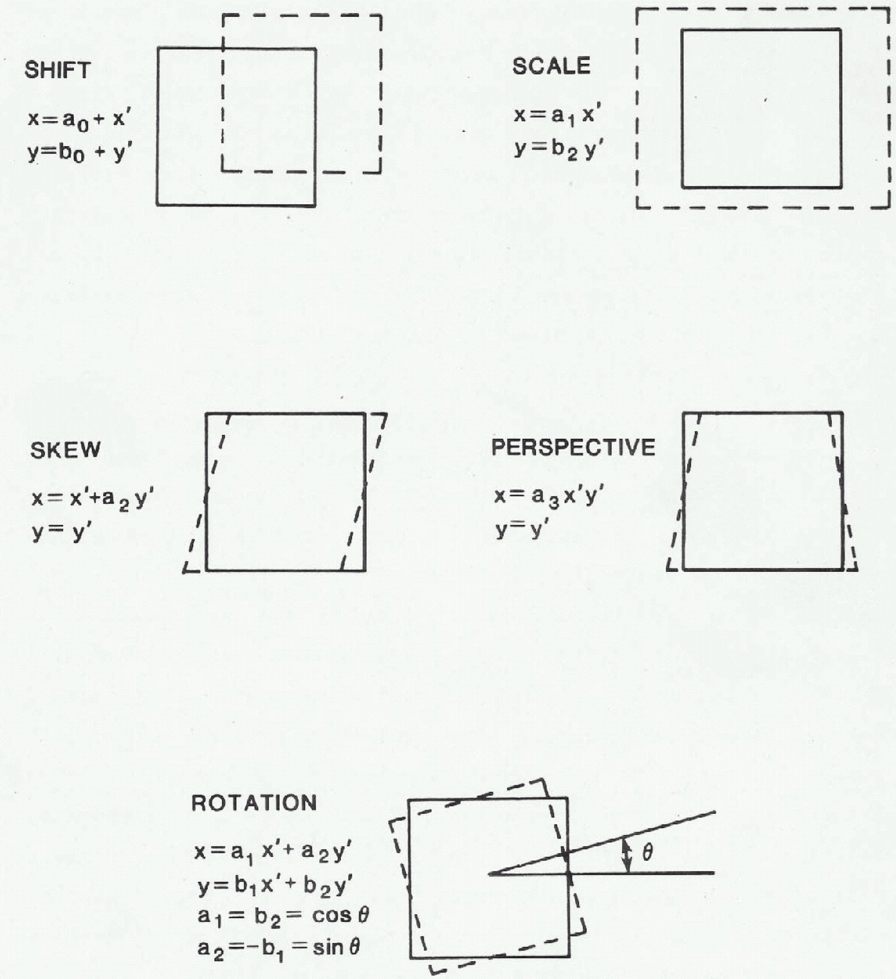


(a) PIECEWISE APPROXIMATION WITH QUADRILATERALS (——) OR TRIANGLES (– – –)



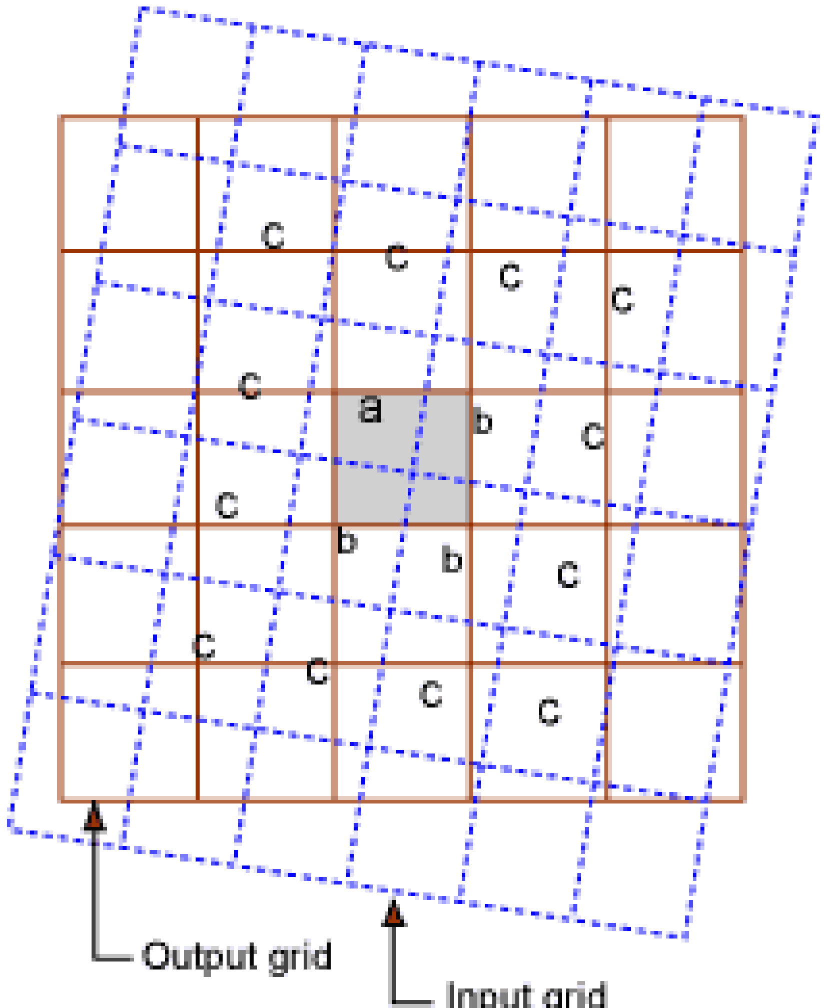
(b) GLOBAL APPROXIMATION WITH LEAST SQUARES, LINEAR POLYNOMIAL

Distortion Models using Control Points



SIMPLE GEOMETRIC TRANSFORMATION

RESAMPLING



Grid of geometrically correct output pixels superimposed on the original, uncorrected input pixels

DATA PRODUCTS

LEVEL 0
Not corrected for both geometry and Radiometry

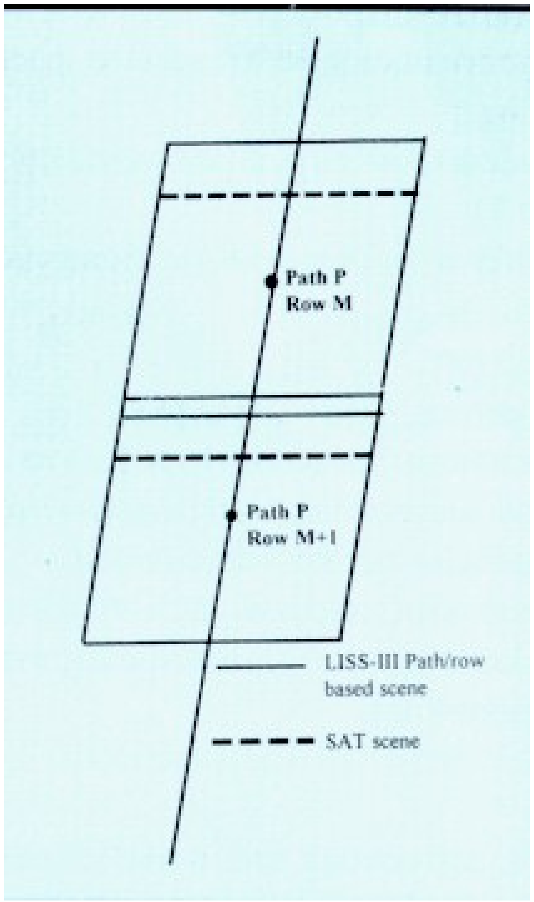
LEVEL I
Corrected for Radiometry

LEVEL II
Corrected for Radiometry and Geometry

LEVEL IV
Special processing

STANDARD PRODUCTS:

PATH / ROW PRODUCTS
SHIFT ALONG TRACK PRODUCTS
QUADRANT PRODUCTS
BASIC STEREO PRODUCTS
GEOCODED PRODUCTS



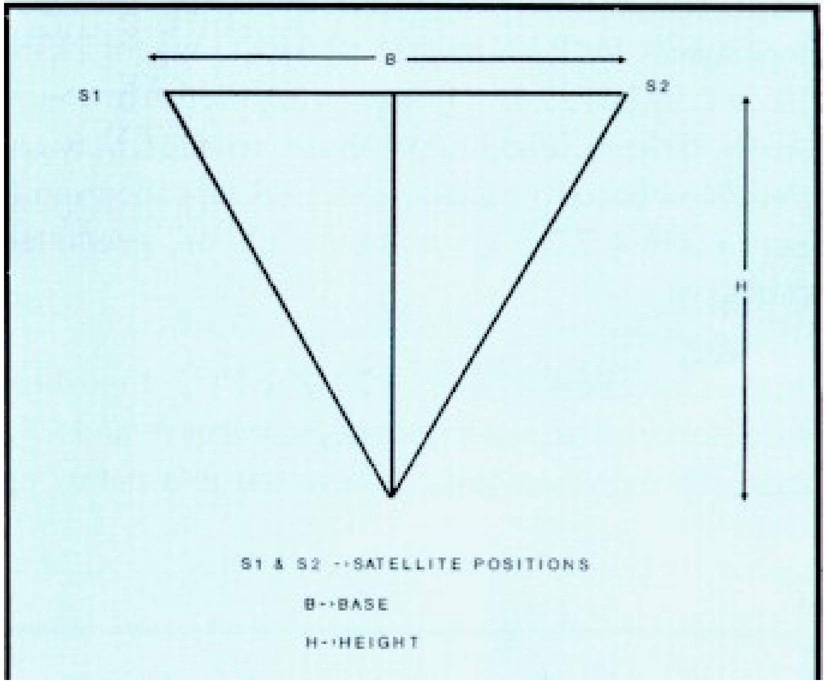
Concept of SAT scene

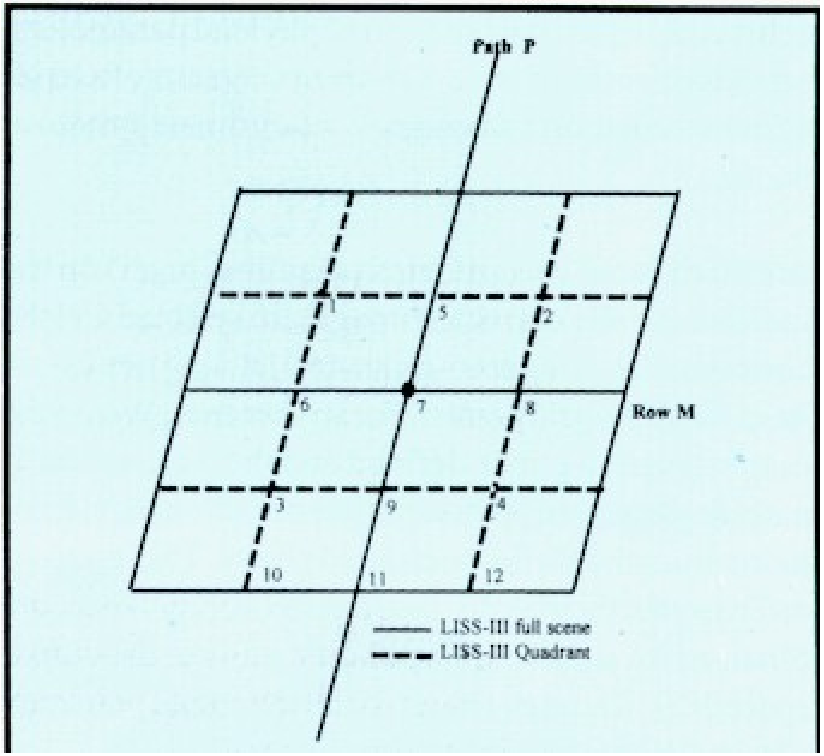
WiFS DATA+

PAN DATA

LISS III DATA

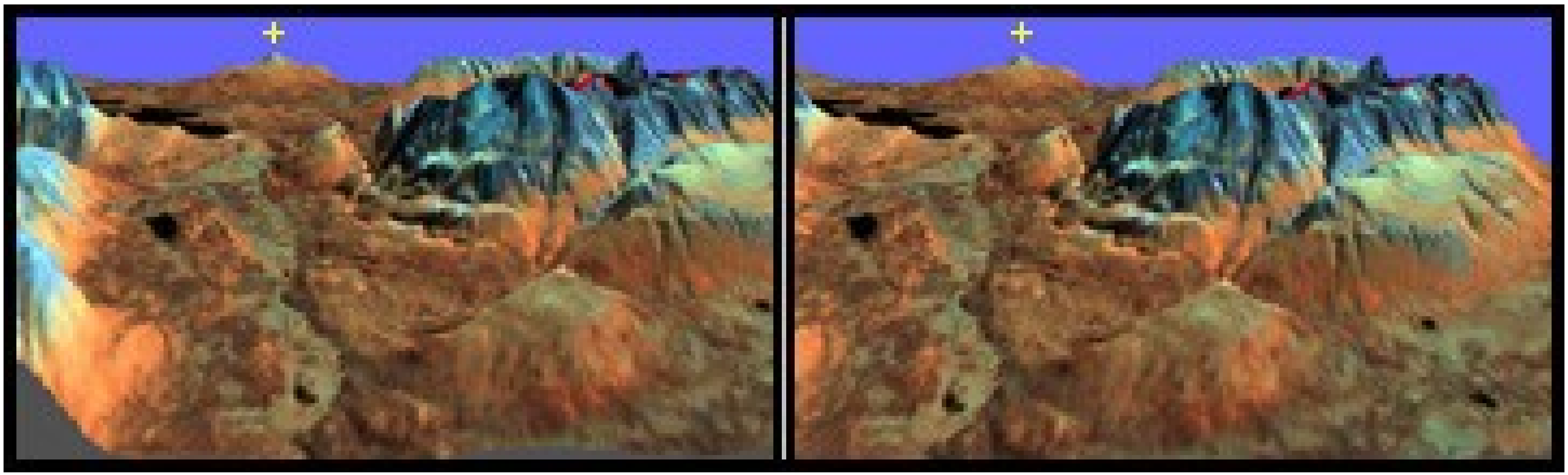
Concept of Stereo Pairs



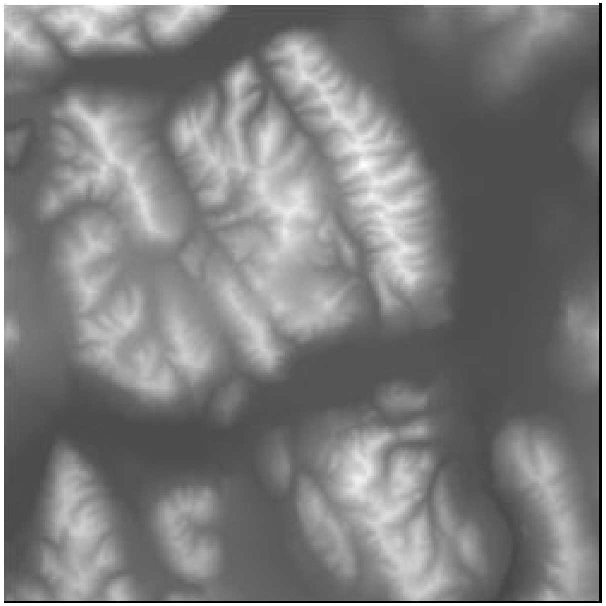


LISS III Quadrants

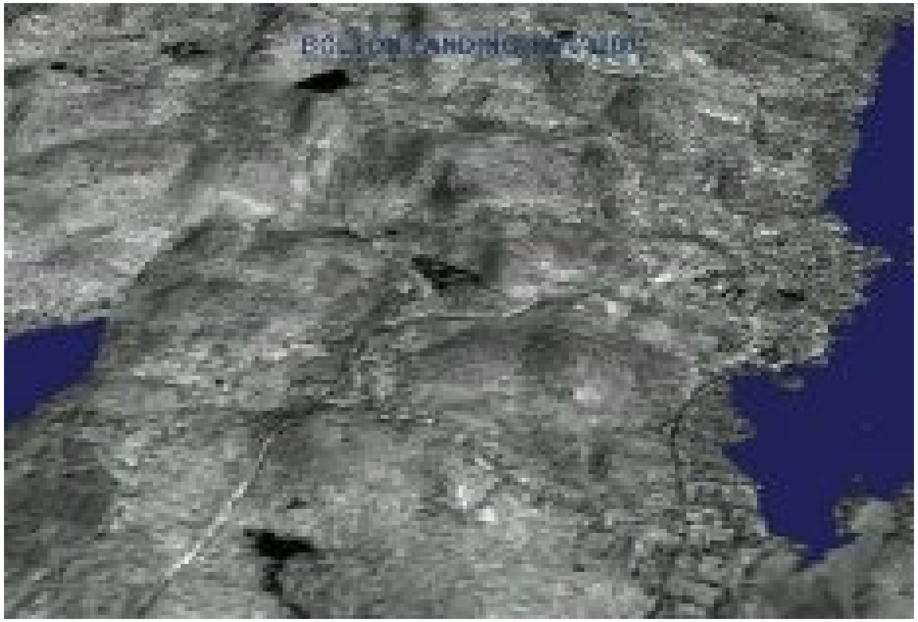
Kluane National Park,
South of Haines Junction,
Yukon Territory



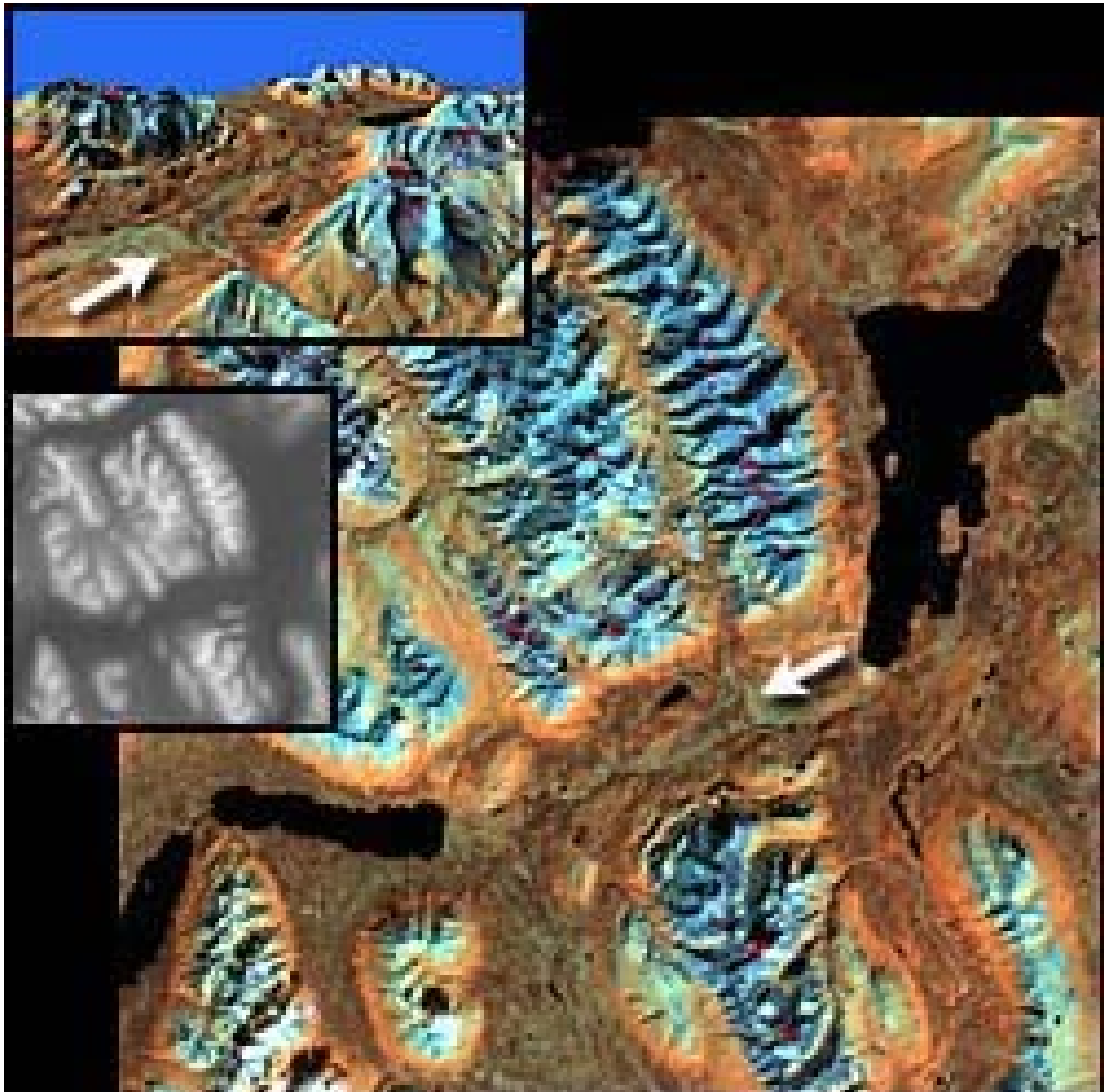
stereo-pair of Landsat images showing a portion of Kluane National Park in the Yukon

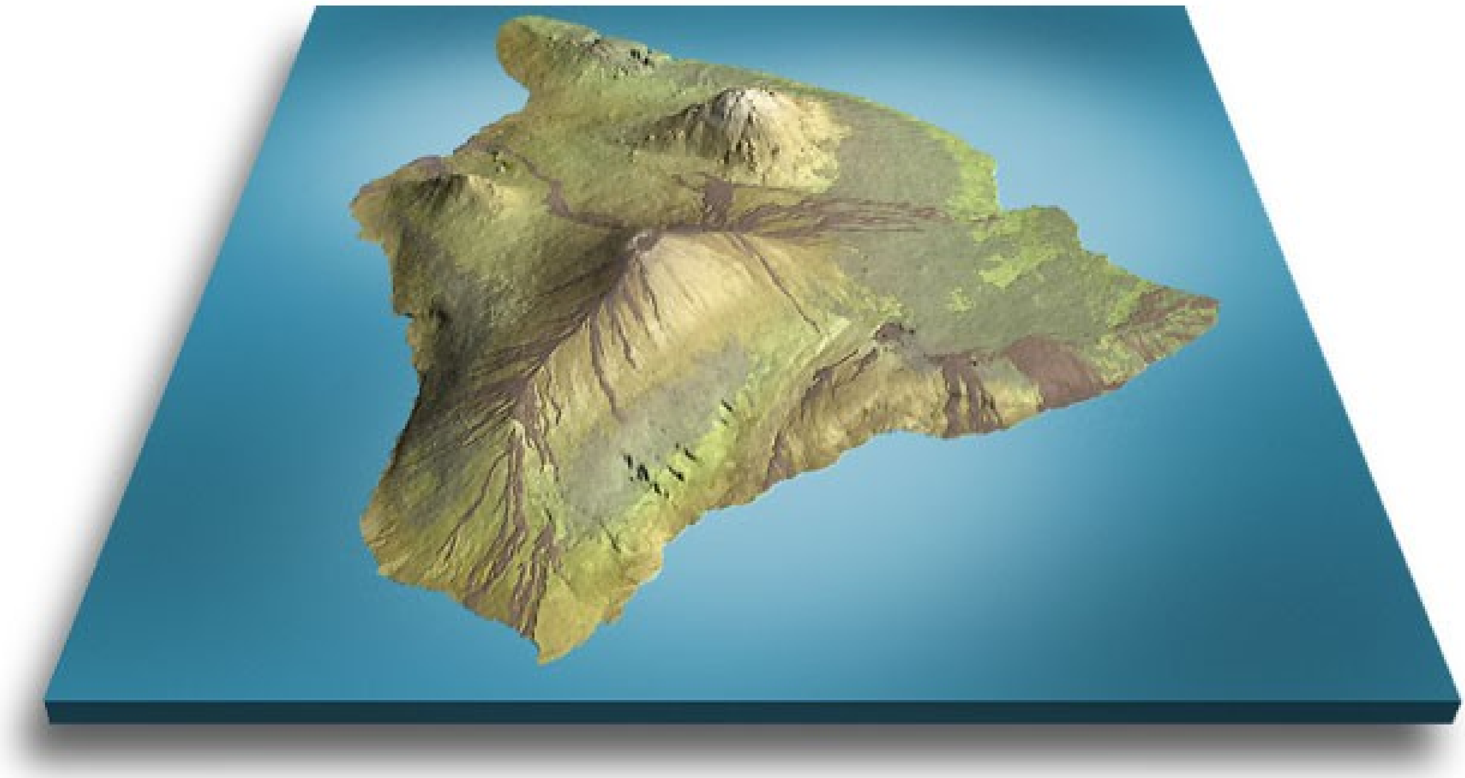


DIGITAL ELEVATION MODELS



DRAPING MULTISPECTRAL DATA ON DEM



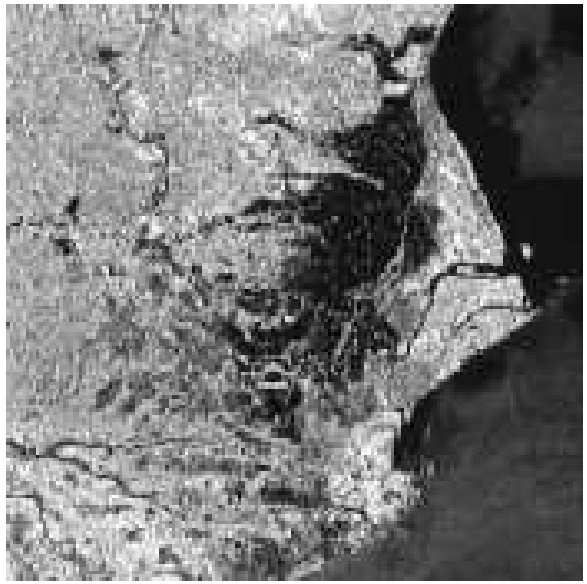


ISLAND OF HAWAI   FLY THROUGH

Special Products

1. PAN + LISS-III Merged products
2. Ortho image
3. MOSAICK

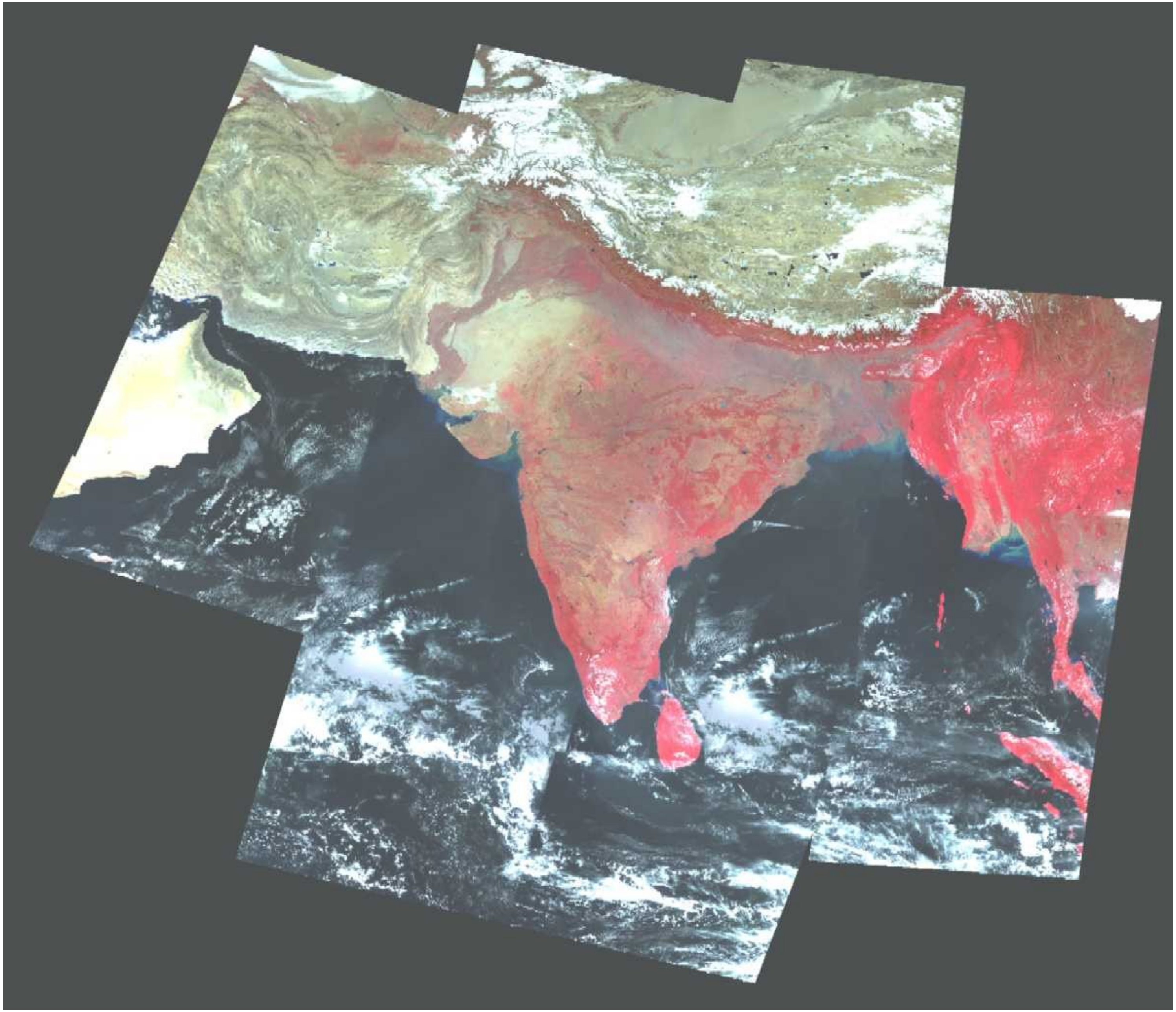
LISS III +PAN



RADARSAT

MOSAICK

IRS P4 OCM MOSAICK OF INDIA



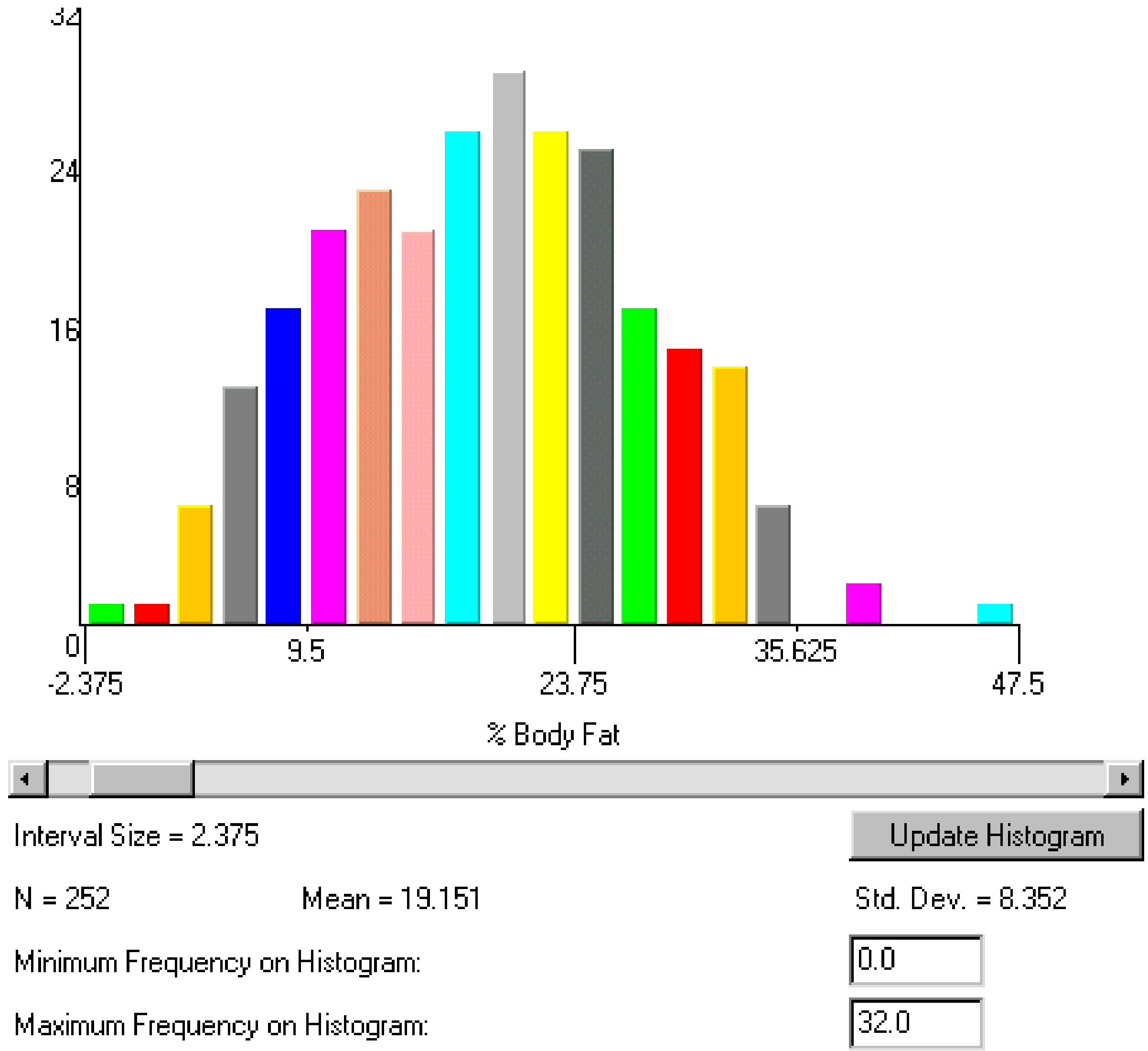
Histogram:

A histogram is a specialized graph or plot used in statistics.

In its most common form, the independent variable is plotted along the horizontal axis, and the dependent variable (usually a percentage) is plotted along the vertical axis.

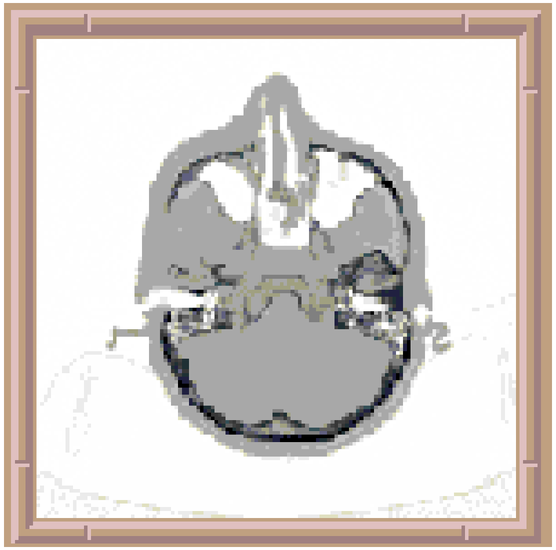
The independent variable can attain only a finite number of discrete values (for example, five) rather than a continuous range of values. The dependent variable can span a continuous range.

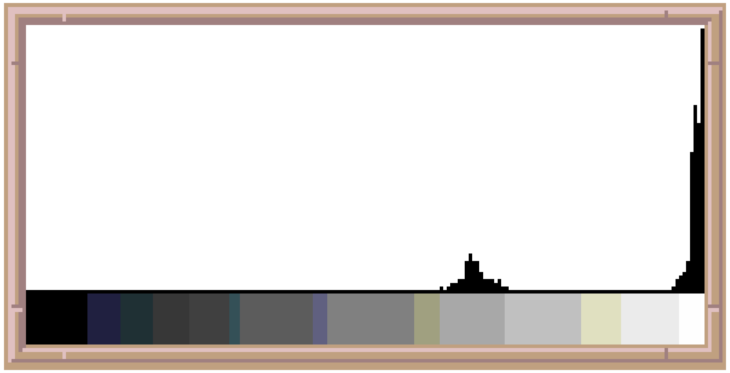
HISTOGRAM



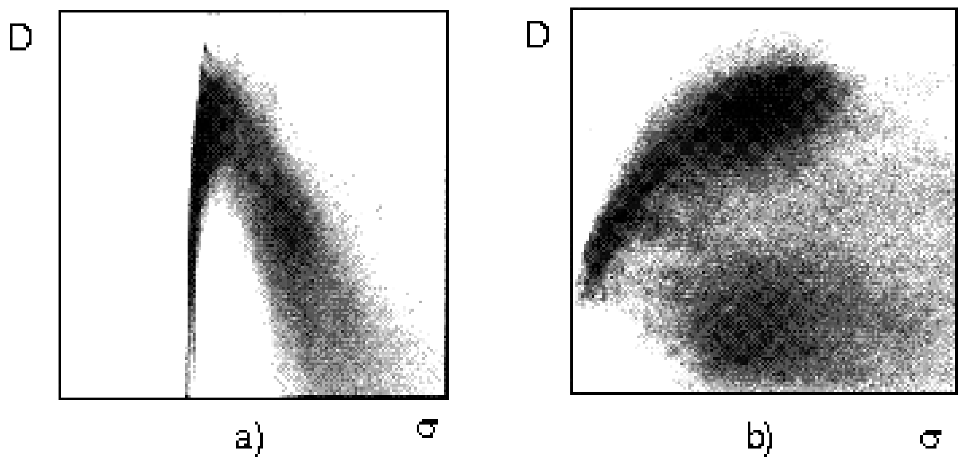
32
24
16
8
0
-2.375
9.5
23.75
35.625
47.5
% Body Fat
Interval Size = 2.375
Update Histogram
N = 252
Mean = 19.151
Std. Dev. = 8.352
Minimum Frequency on Histogram:
0.0
Maximum Frequency on Histogram:
32.0

An image at it's histogram (gray value distribution).



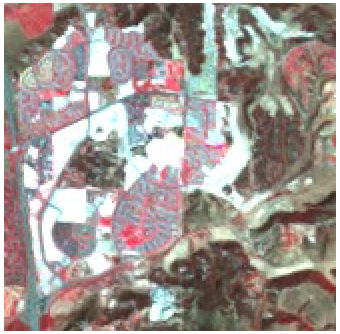


SCATTEROGRAM



Scatterogram of the standard deviation of elevation data vs. fractal dimension for the topographic DEM b) Scatterogram of the standard deviation of elevation data vs. fractal dimension for the interferometric DEM

ZOOM OUT BY 2



ORIGINAL

ZOOM IN BY 2

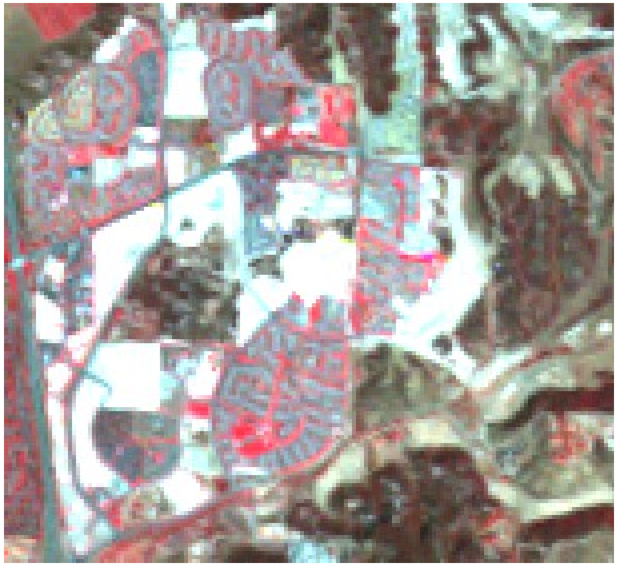
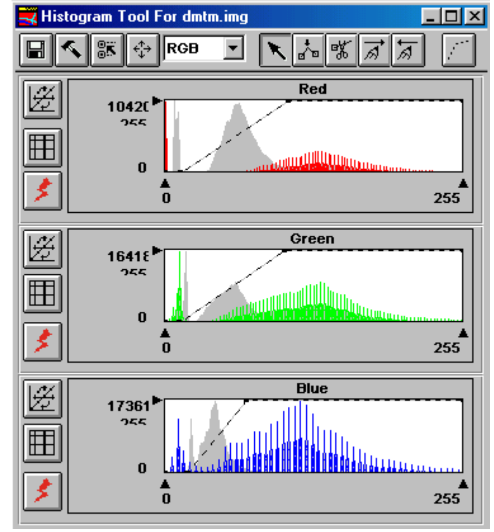


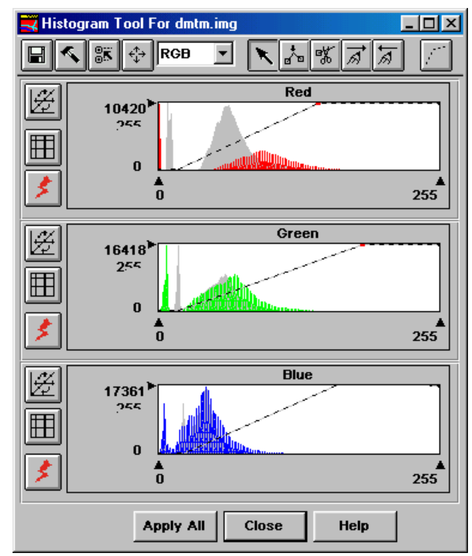
IMAGE ENHANCEMENT TECHNIQUES

$$b[m,n] = \begin{cases} 0 & a[m,n] \le p_{\text{low}}\% \\ \left(2^{B}-1\right) \bullet \dfrac{a[m,n] - p_{\text{low}}\%}{p_{\text{high}}\% - p_{\text{low}}\%} & p_{\text{low}}\% < a[m,n] < p_{\text{high}}\% \\ \left(2^{B}-1\right) & a[m,n] \ge p_{\text{high}}\% \end{cases}$$



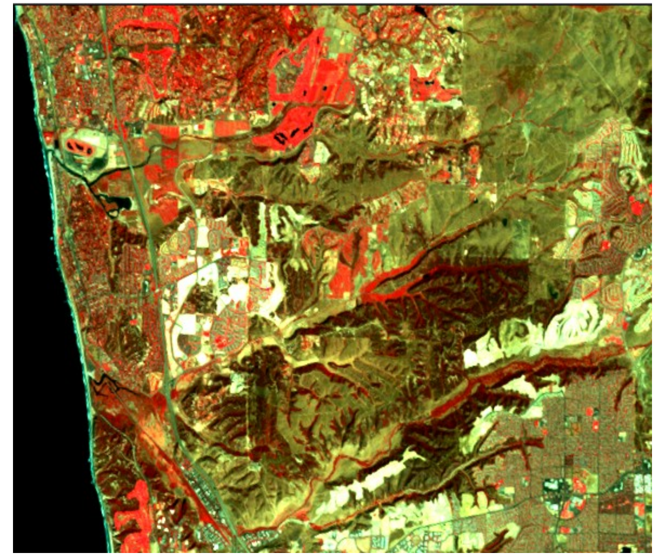
Original Image

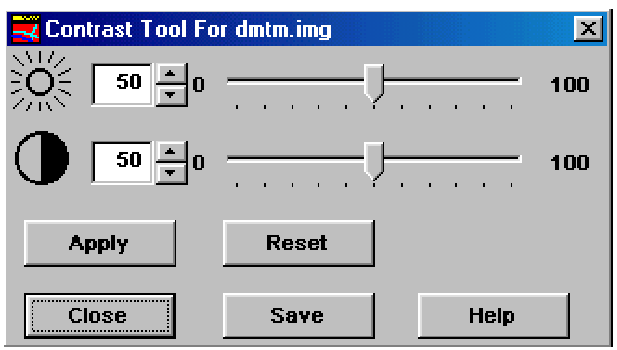
Histogram Equalized Image

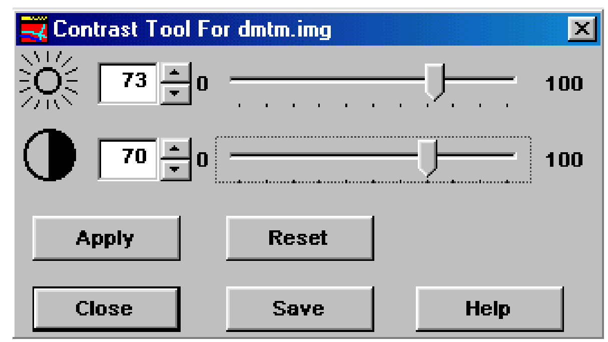


Histograms

Adjusting the image histogram to improve image contrast




Contrast Tool For dmtm.img
50
0
100
50
0
100
Apply
Reset
Close
Save
Help


Contrast Tool For dmtm.img
73
0
100
70
0
100
Apply
Reset
Close
Save
Help

HISTOGRAM EQUALISATION

For a "suitable" function (*) the relation between the input probabil density function, the output probability density function, and the function (*) is given by:

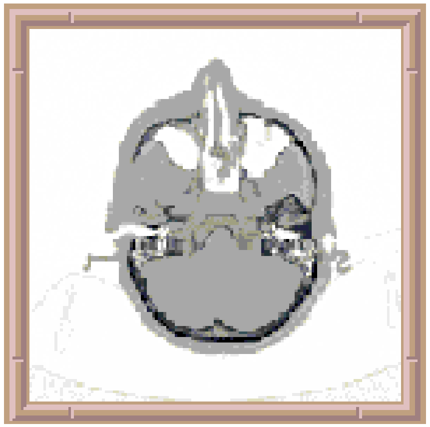
$$p_b(b)db = p_a(a)da \quad \Longrightarrow \quad df = \frac{p_a(a)da}{p_b(b)}$$

For histogram equalization we desire that $p_b(b)$ = constant and this means that:

$$f(a) = \left(2^B - 1\right) \bullet P(a)$$

Where P(a) is the probability distribution function

Original image and equalized image



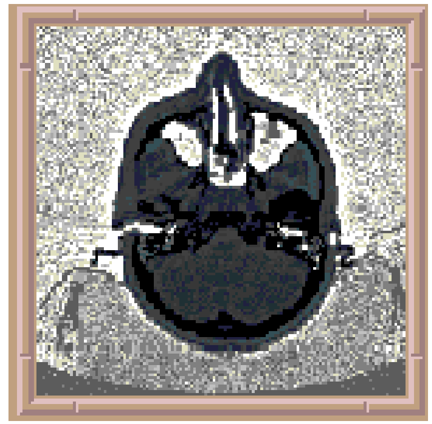
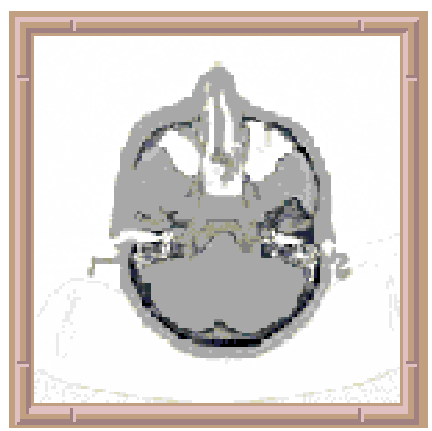
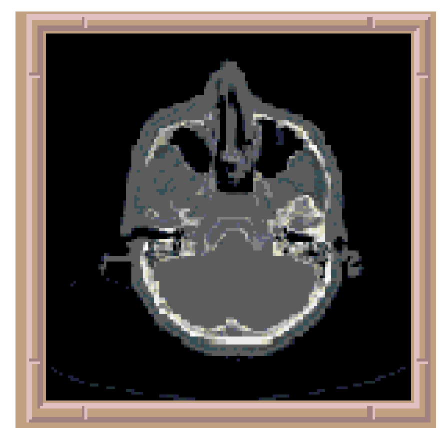
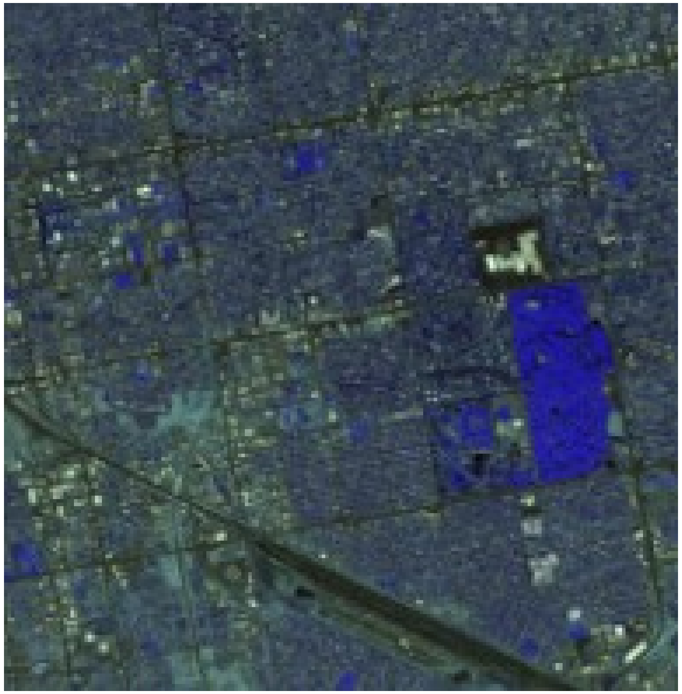


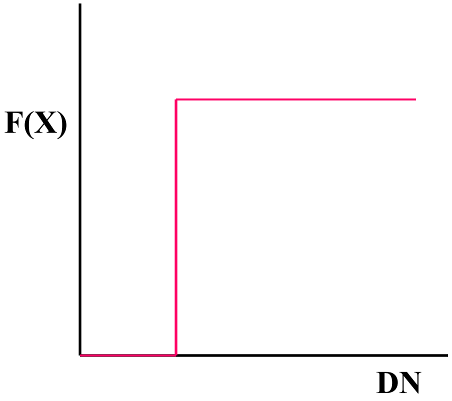
Image before and after REVERS





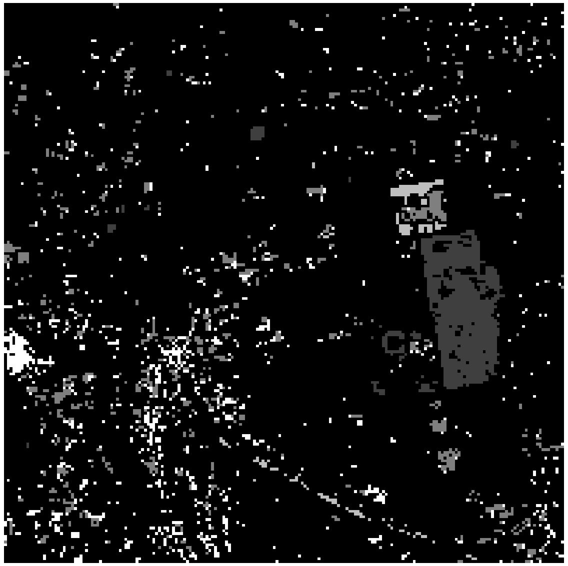
ORIGINAL





THRESHOLD

DENSITY SLICE



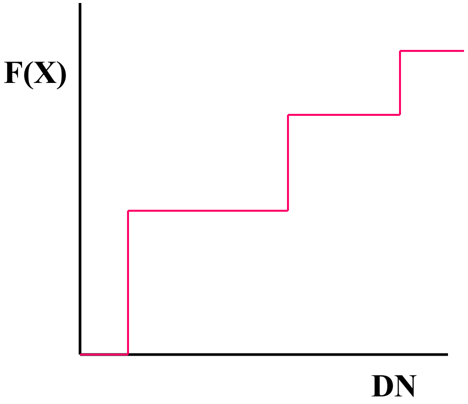


IMAGE OPERATORS

- **Point operators – stretch**
- **Local operators - filters**
- **Global operators - transformations**

Filters	**-**	**convolution filters**
		statistical filters
		gradient filters

Convolution

$$c[m,n] = a[m,n] \otimes h[m,n] = \sum_{j=0}^{J-1} \sum_{k=0}^{K-1} h[j,k]\,a[m-j, n-k]$$

Convolution in spatial domain

$$c[0,0] = \sum_{j=-J_o}^{+J_o} \sum_{k=-K_o}^{+K_o} h[j,k]\,a[-j,-k] \qquad J_o = \frac{(J-1)}{2}, \;\; K_o = \frac{(K-1)}{2}$$

Linear Filters

$$h_{rect}[j,k] = \frac{1}{25}\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

$$h_{circ}[j,k] = \frac{1}{21}\begin{bmatrix} 0 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 0 \end{bmatrix}$$

Uniform filters for image smoothing

$$h_{rect}[j,k] = \frac{1}{81}\begin{bmatrix} 1 & 2 & 3 & 2 & 1 \\ 2 & 4 & 6 & 4 & 2 \\ 3 & 6 & 9 & 6 & 3 \\ 2 & 4 & 6 & 4 & 2 \\ 1 & 2 & 3 & 2 & 1 \end{bmatrix}$$

Pyramidal filter (J=K=5)

$$h_{circ}[j,k] = \frac{1}{25}\begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 2 & 2 & 2 & 0 \\ 1 & 2 & 5 & 2 & 1 \\ 0 & 2 & 2 & 2 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix}$$

Cone filter (R=2.5)

Triangular filters for image smoothing

Original image

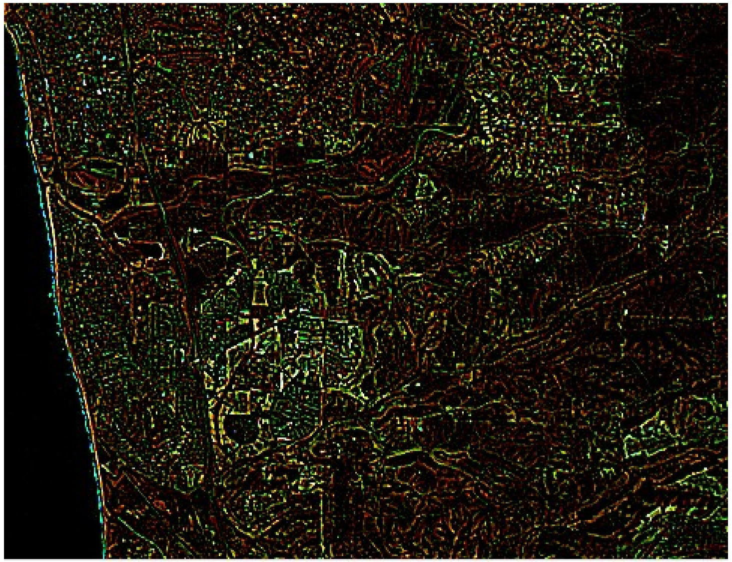
Low pass filters

Original image

High pass filters

Original image

Edge detect filters



Gradient filters

$$[\mathbf{h}_x] = \frac{1}{3}\begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} \bullet \begin{bmatrix} 1 & 0 & -1 \end{bmatrix}$$

$$[\mathbf{h}_y] = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 \\ 0 \\ -1 \end{bmatrix} \bullet \begin{bmatrix} 1 & 1 & 1 \end{bmatrix}$$

Prewitt filters

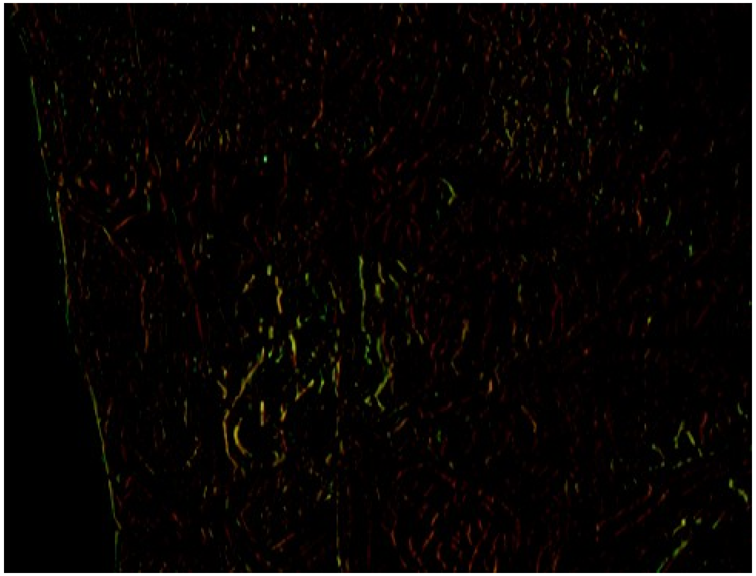
Sobel filters

$$[\mathbf{h}_x] = \frac{1}{4}\begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} = \frac{1}{4}\begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix} \bullet \begin{bmatrix} 1 & 0 & -1 \end{bmatrix}$$

$$[\mathbf{h}_y] = \frac{1}{4}\begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} = \frac{1}{4}\begin{bmatrix} 1 \\ 0 \\ -1 \end{bmatrix} \bullet \begin{bmatrix} 1 & 2 & 1 \end{bmatrix}$$

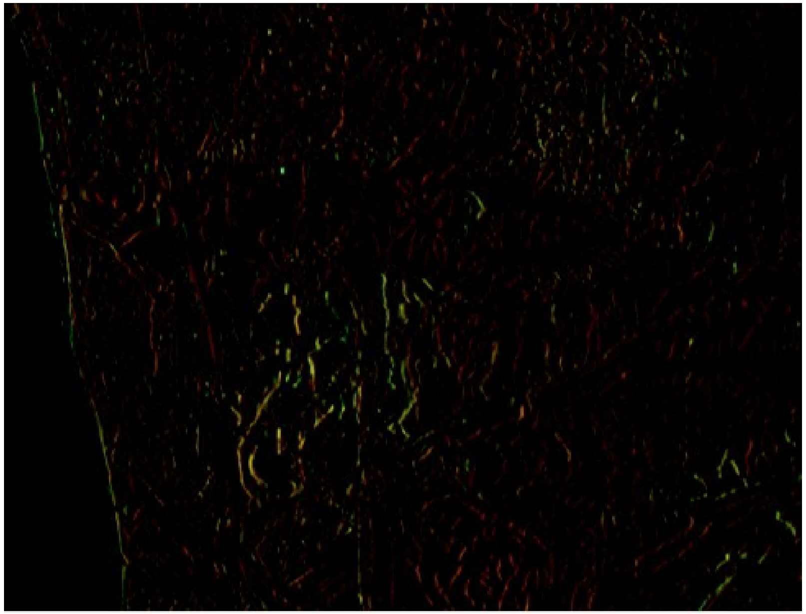
Prewitt filters

Original image



Sobel filters

Original image



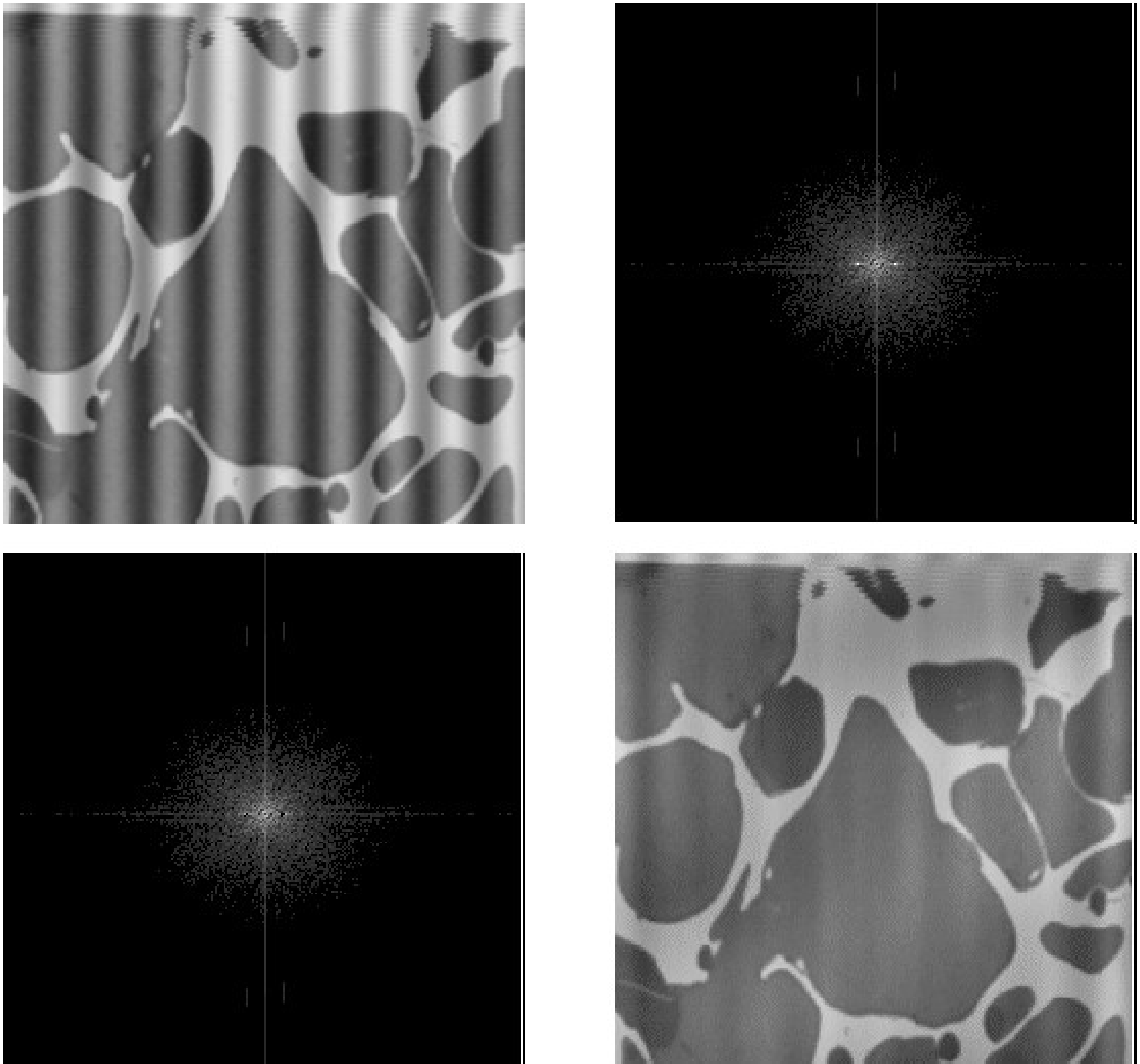
Convolution in frequency domain

i) Compute $A(\Omega,\Psi) = F\{a[m,n]\}$

ii) Multiply $A(\Omega,\Psi)$ by the *precomputed* $(\Omega,\Psi) = F\{h[m,n]\}$

iii) Compute the result $c[m,n] = F^{-1}\{A(\Omega,\Psi)*(\Omega,\Psi)\}$

Application of the 2-dimensional Fast Fourier Transform

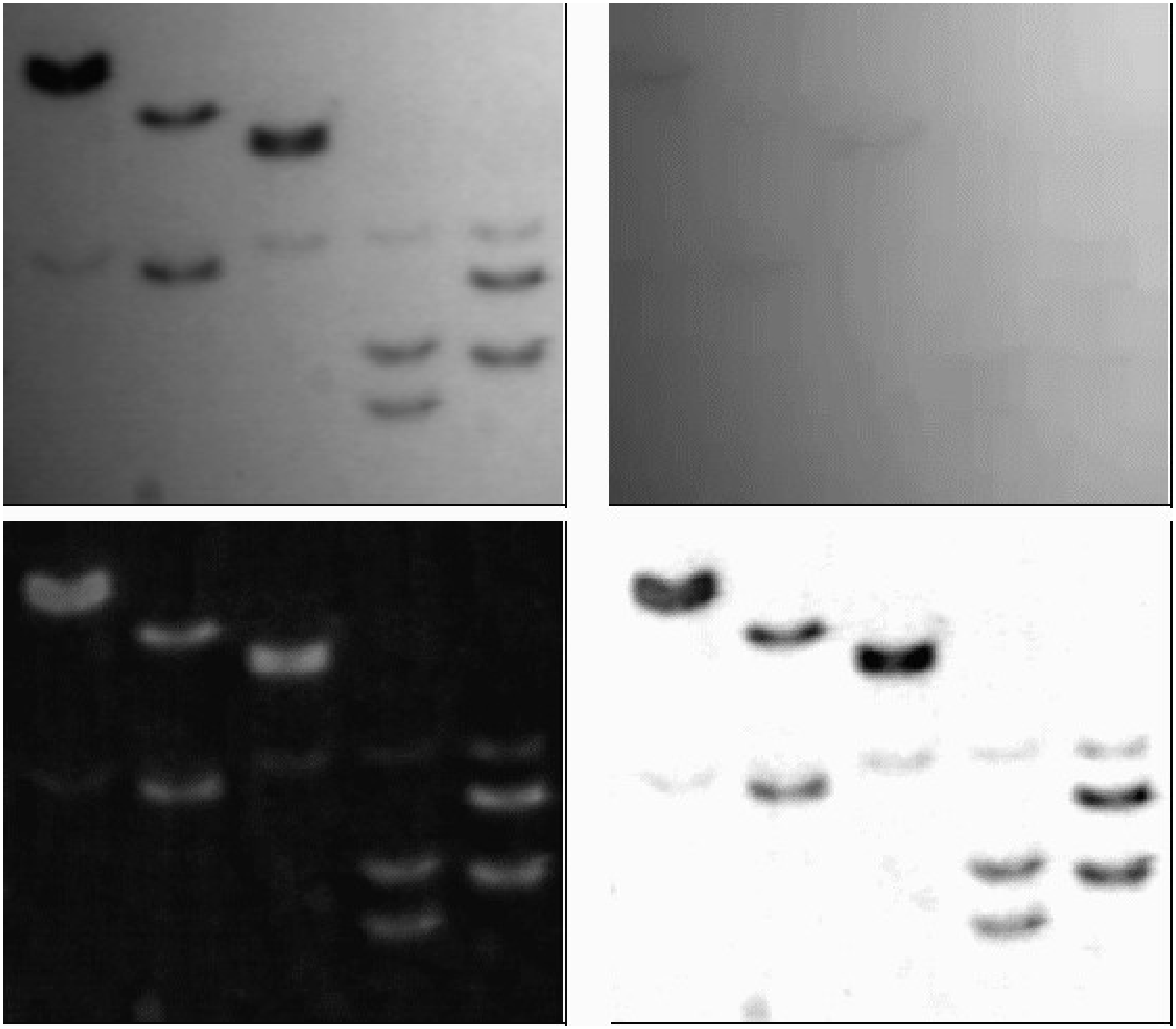


Non-Linear Filters

A median filter is based upon moving a window over an image (as in a convolution) and computing the output pixel as the median value of the brightness within the input window.

Application of the median filter

Correcting for a background gradient



Thresholding an image and applying a Watershed Separation Filter

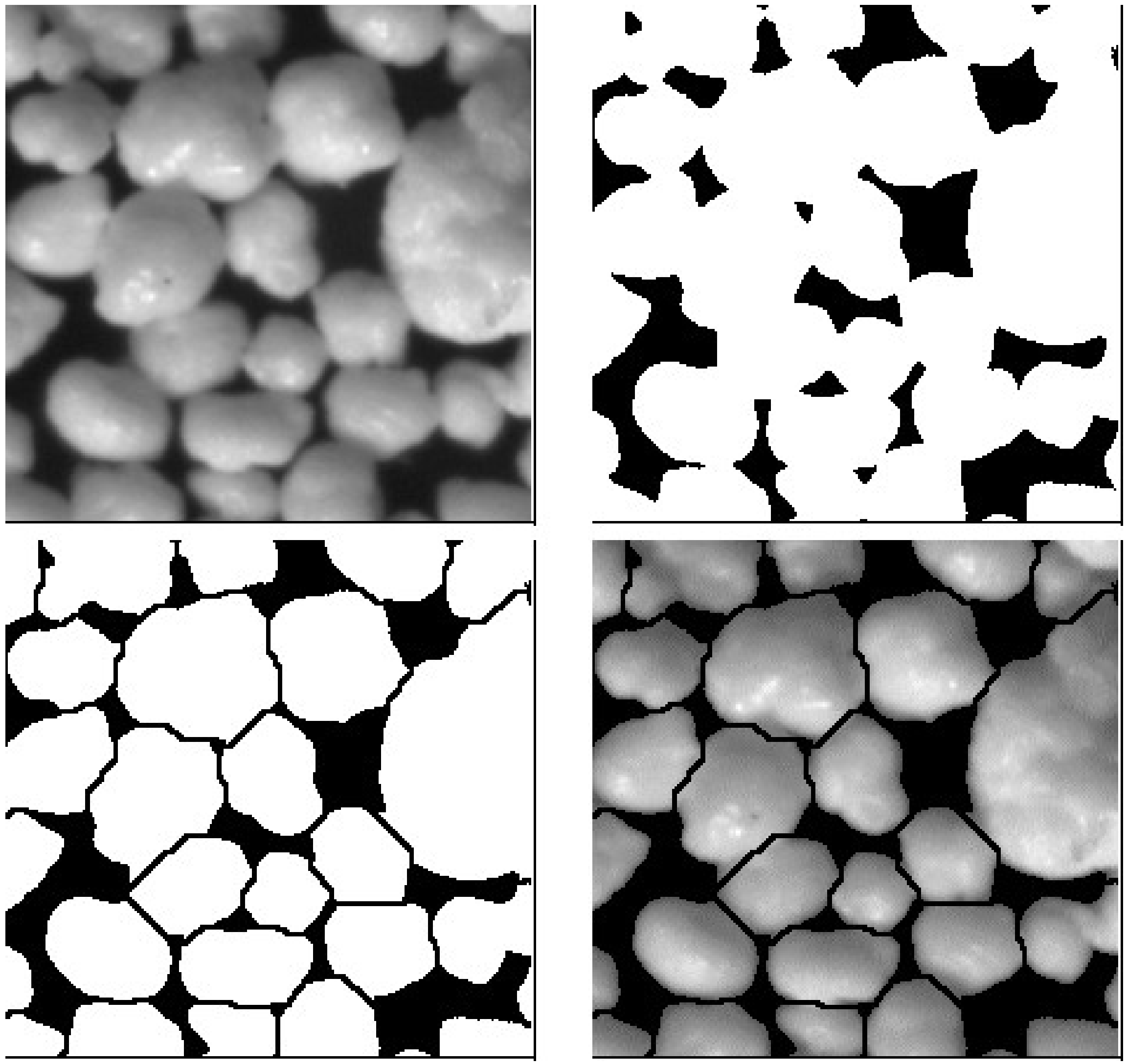
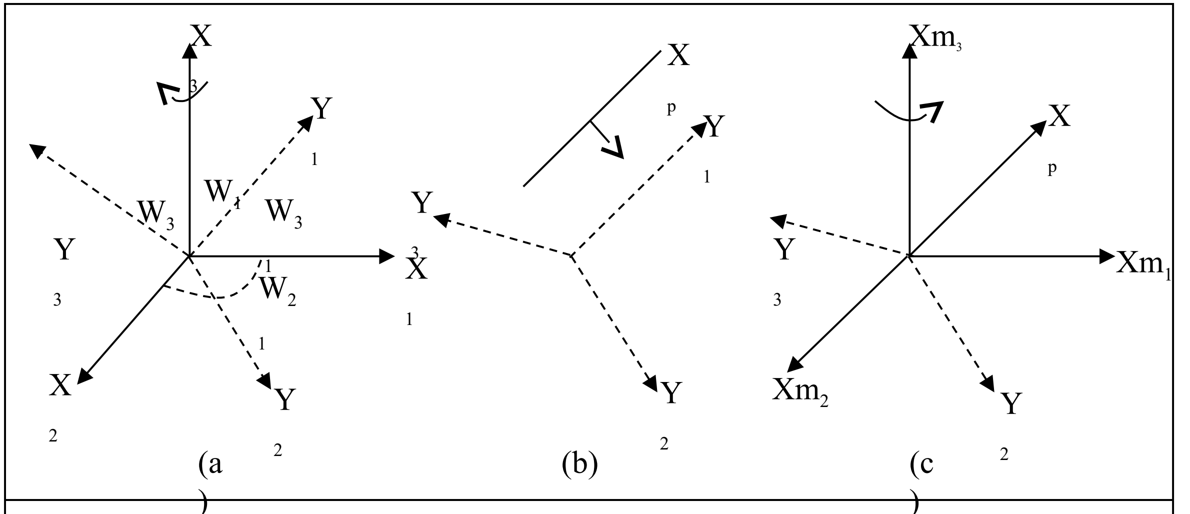


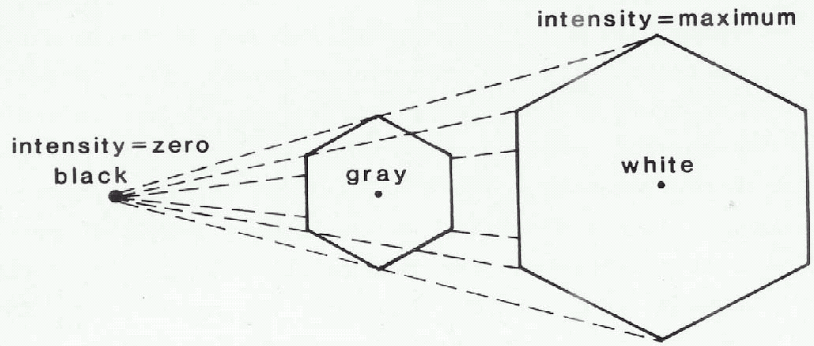
IMAGE TRANSFORMATIONS



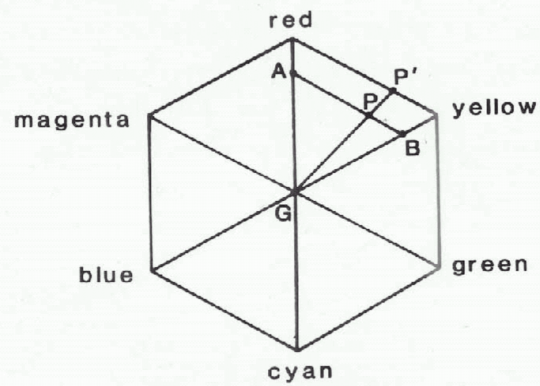
(a) Transform from the original space X_1, X_2, X_3 to the replace space Y_1, Y_2, Y_3

(b) Replacement of the component Y_i by the high resolution panchromatic data X_p

(c) Retransform to the original data space Xm_1, Xm_2, Xm_3



(a) GENERATION OF THE HEXCONE

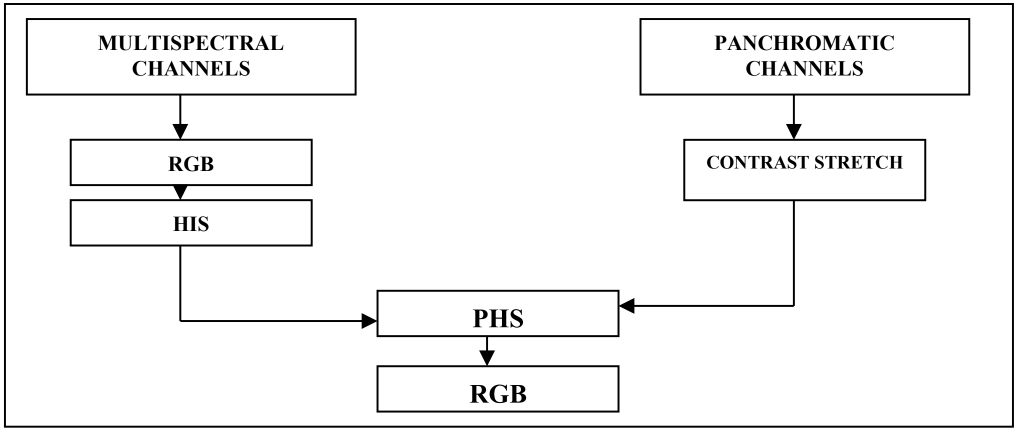


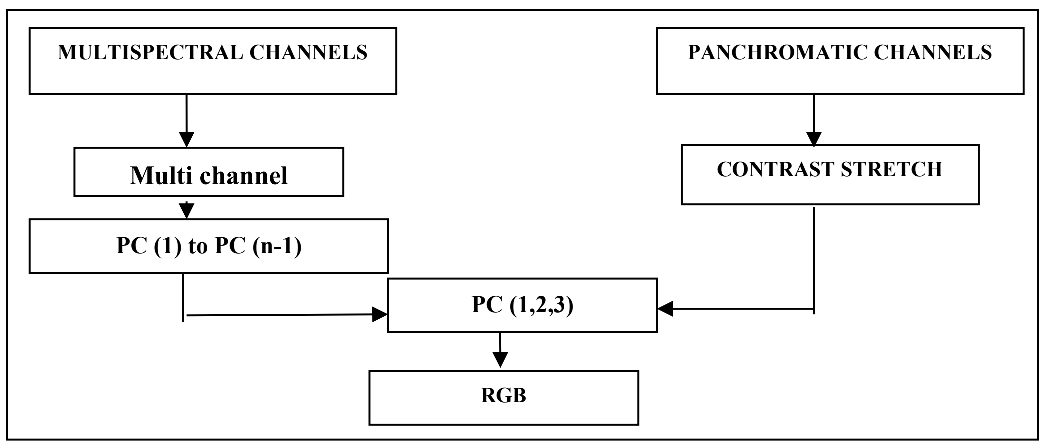
hue = |AP| / |AB|

saturation = |GP| / |GP'|

(b) DEFINITION OF COLOR COMPONENTS FOR A PIXEL VECTOR WITH NON-ZERO INTENSITY AT POINT P

The Hexcone color Model

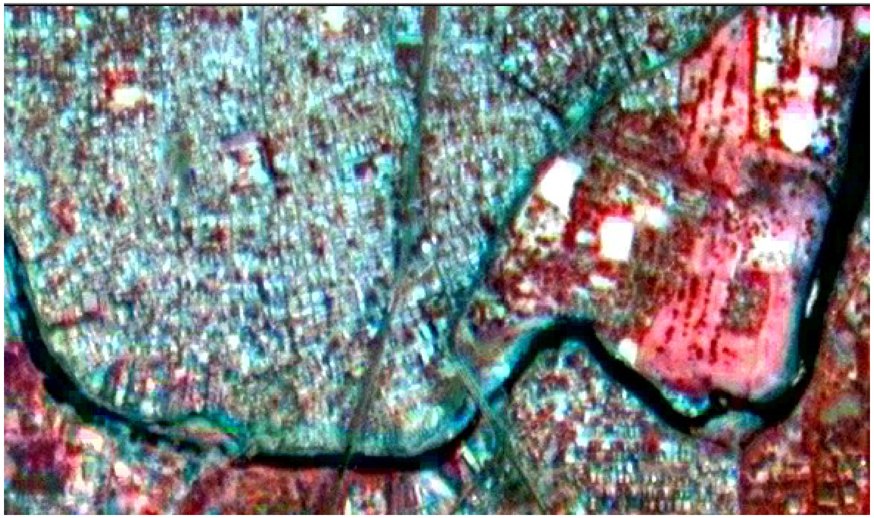

MULTISPECTRAL CHANNELS
PANCHROMATIC CHANNELS
RGB
CONTRAST STRETCH
HIS
PHS
RGB


MULTISPECTRAL CHANNELS
PANCHROMATIC CHANNELS
Multi channel
CONTRAST STRETCH
PC (1) to PC (n-1)
PC (1,2,3)
RGB

LISS III IMAGE

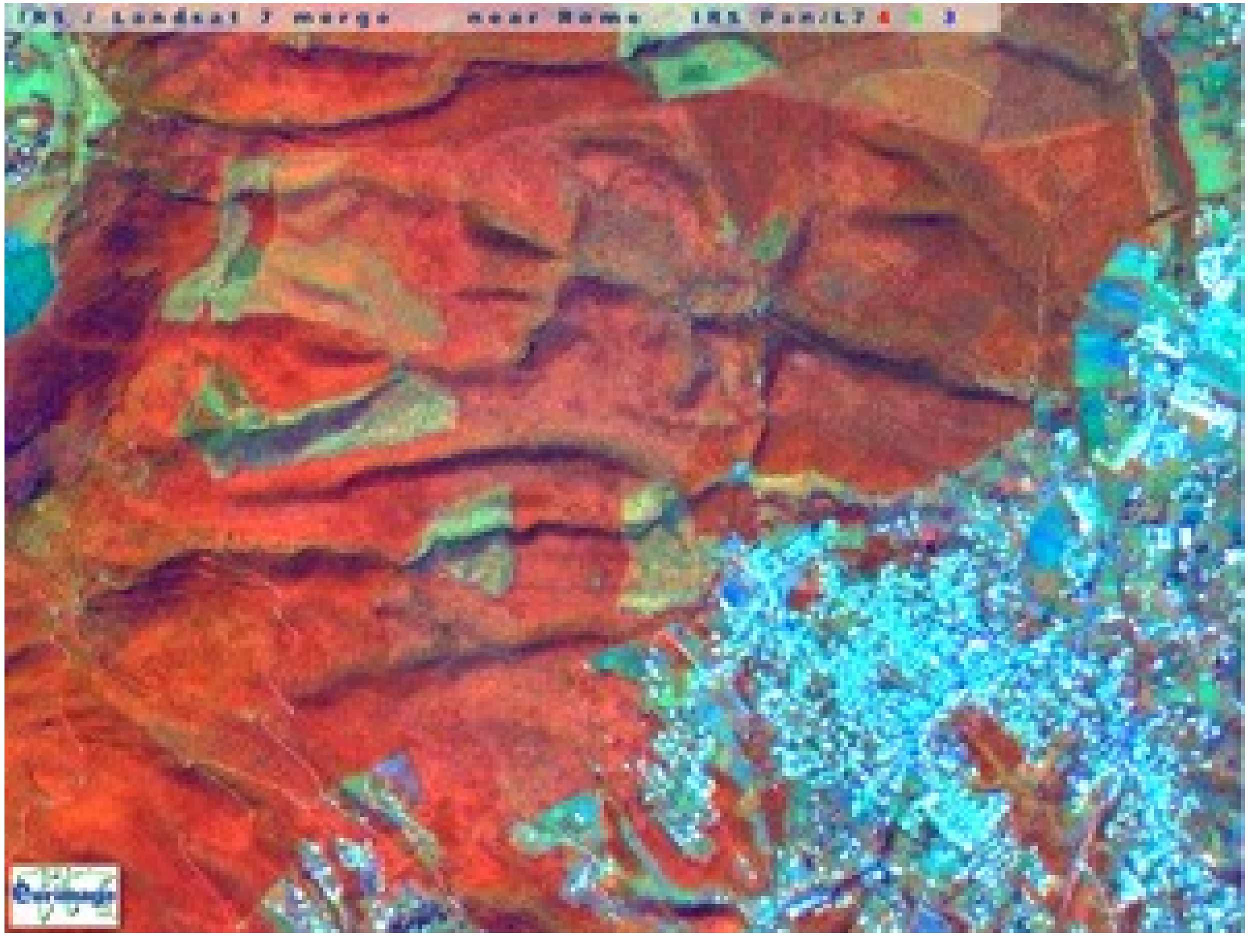
PAN IMAGE

IHS MERGE DATA PRODUCT



PC MERGED PRODUCT

IRS 1D + LANDSAT MERGED



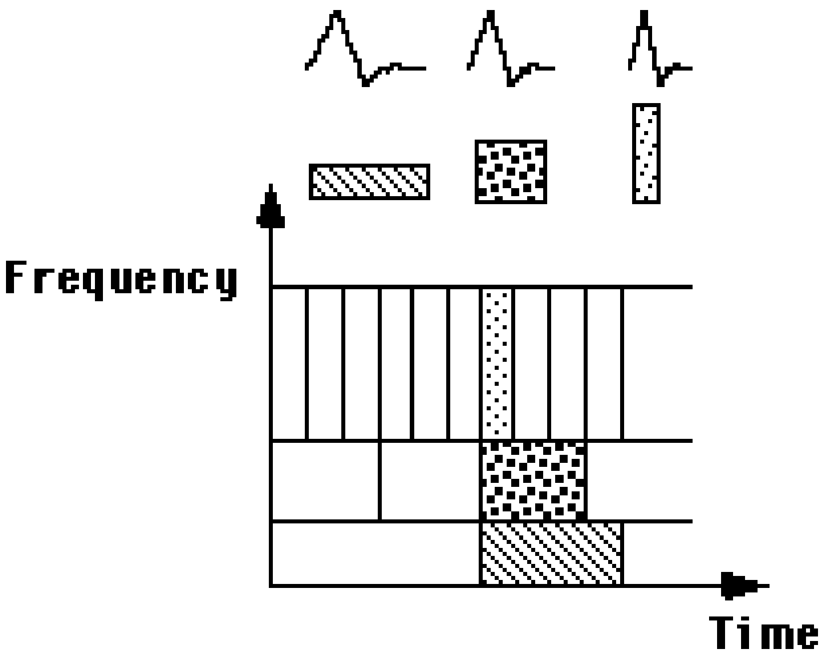
Multi-spectral
Resolution, 4 metres

Panchromatic
Resolution, 1 metre

Pan-sharpened
Resolution, 1 metre

WAVELET TRANSFORMATION:

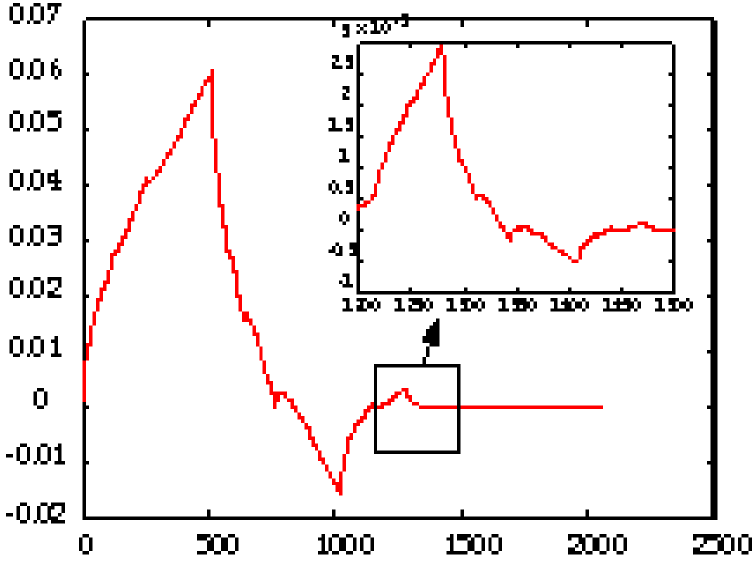
The fundamental idea behind wavelets is to analyze according to scale



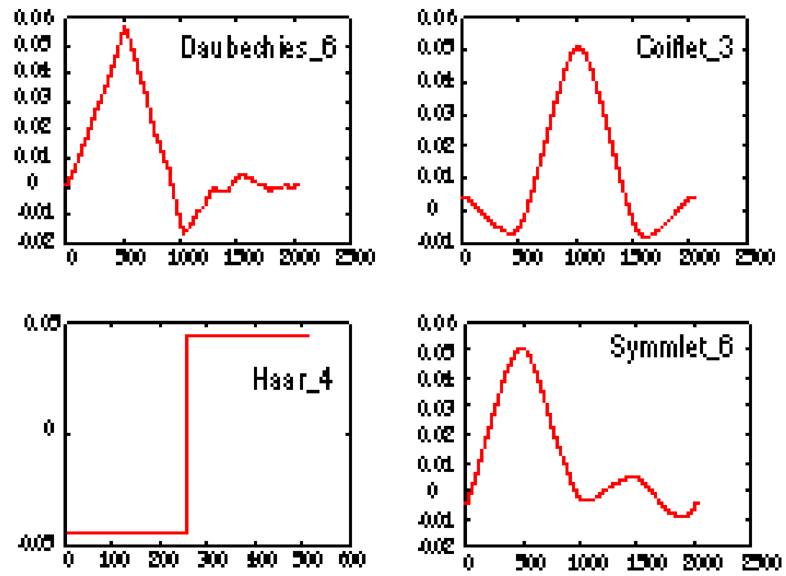
Wavelets are functions that satisfy certain mathematical requirements and are used in representing data or other functions

What do Some Wavelets Look Like?

Wavelet transforms comprise an infinite set. The different wavelet families make different trade-offs between how compactly the basis functions are localized in space and how smooth they are



Daubechies mother wavelet



Several different families of wavelets.

Wavelet Analysis

The Discrete Wavelet Transform

Dilations and translations of the "Mother function," or "analyzing wavelet" define an orthogonal basis, our wavelet basis:

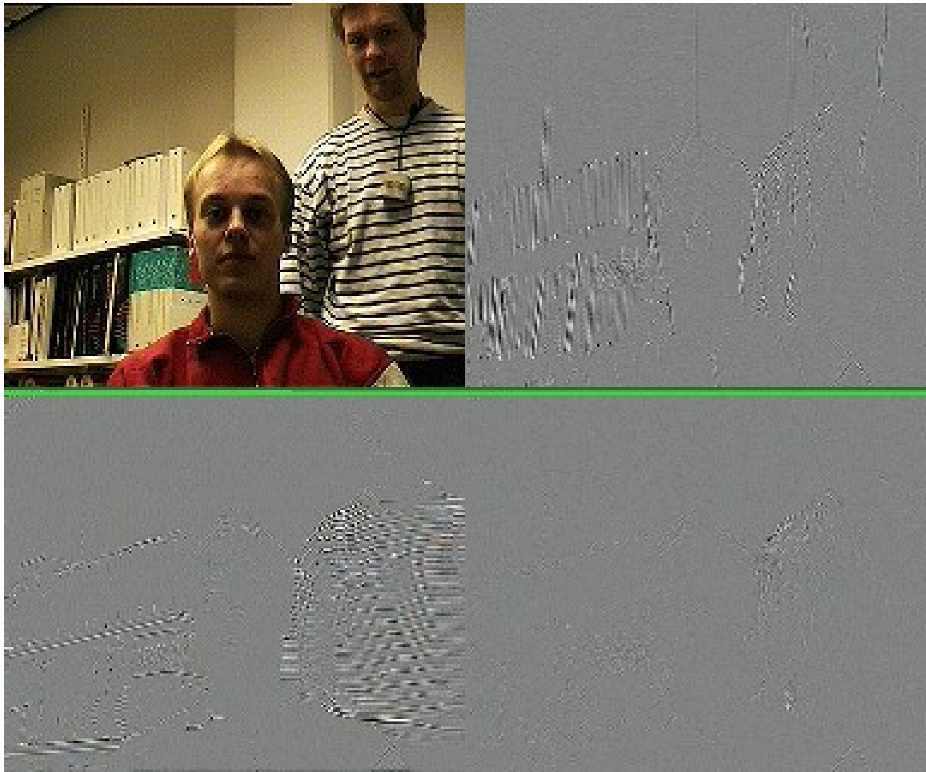
$$\Phi_{(s,l)}(x) = 2^{\frac{-s}{2}}\Phi\left(2^{-s}x - l\right) \qquad (3)$$

$$W(x) = \sum_{k=-1}^{N-2}(-1)^k c_{k+1}\Phi(2x+k) \qquad (4)$$

$$\sum_{k=0}^{N-1} c_k = 2 \quad , \quad \sum_{k=0}^{N-1} c_k c_{k+2l} = 2\,\delta_{l,0}$$

ORIGINAL IMAGE

Wavelet transformed image.
LL, HL, LH, HH



RECONSTRUCTION

WITH LL

ORIGINAL

WITH LL & HL

LL& HL &LH

WITH ALL

TRANFORMED

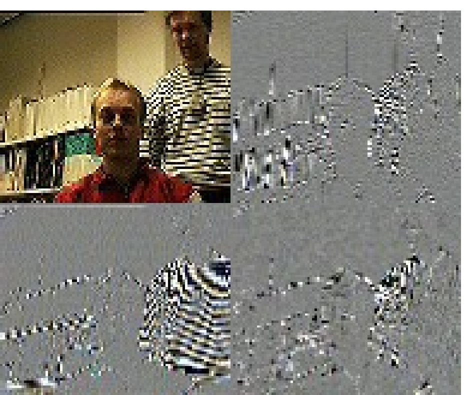
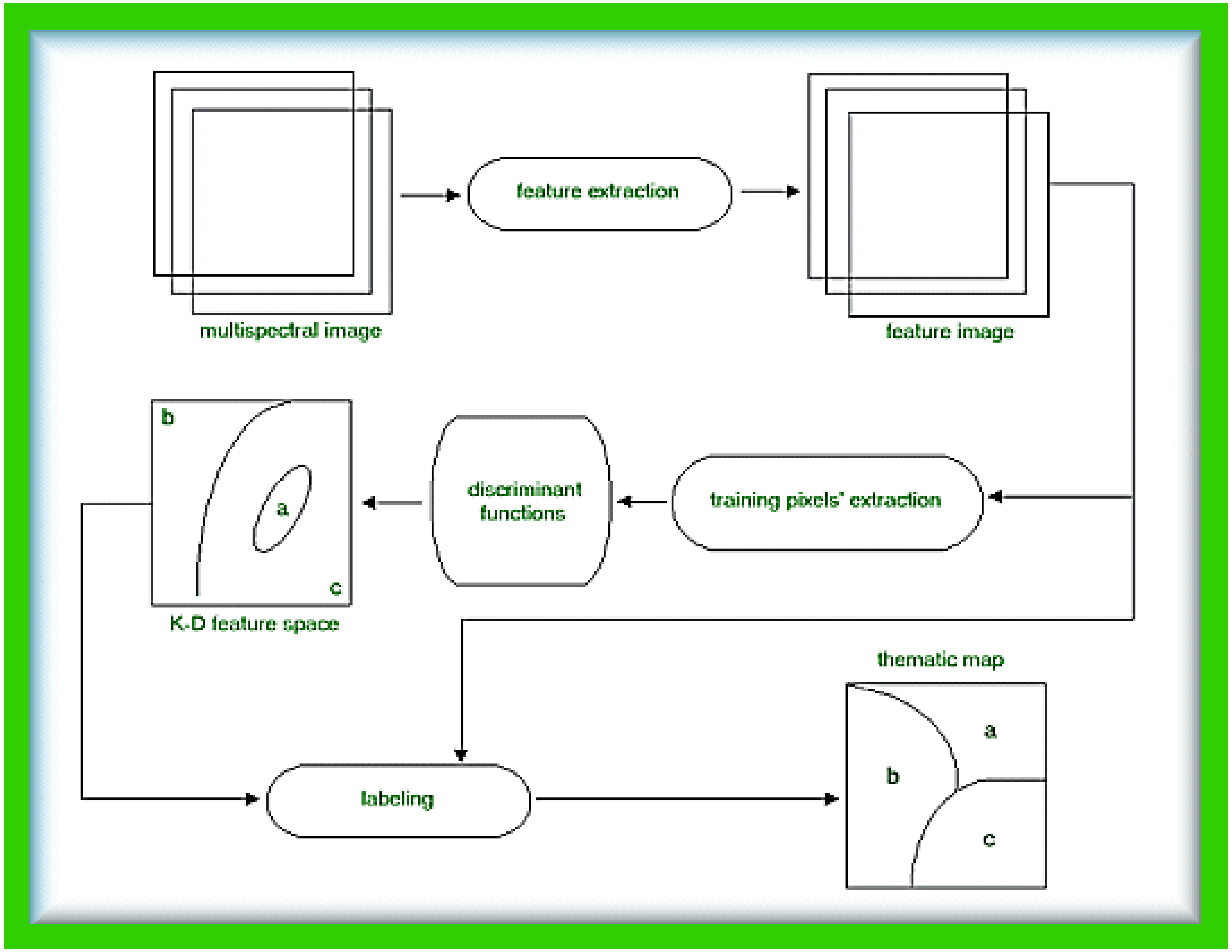
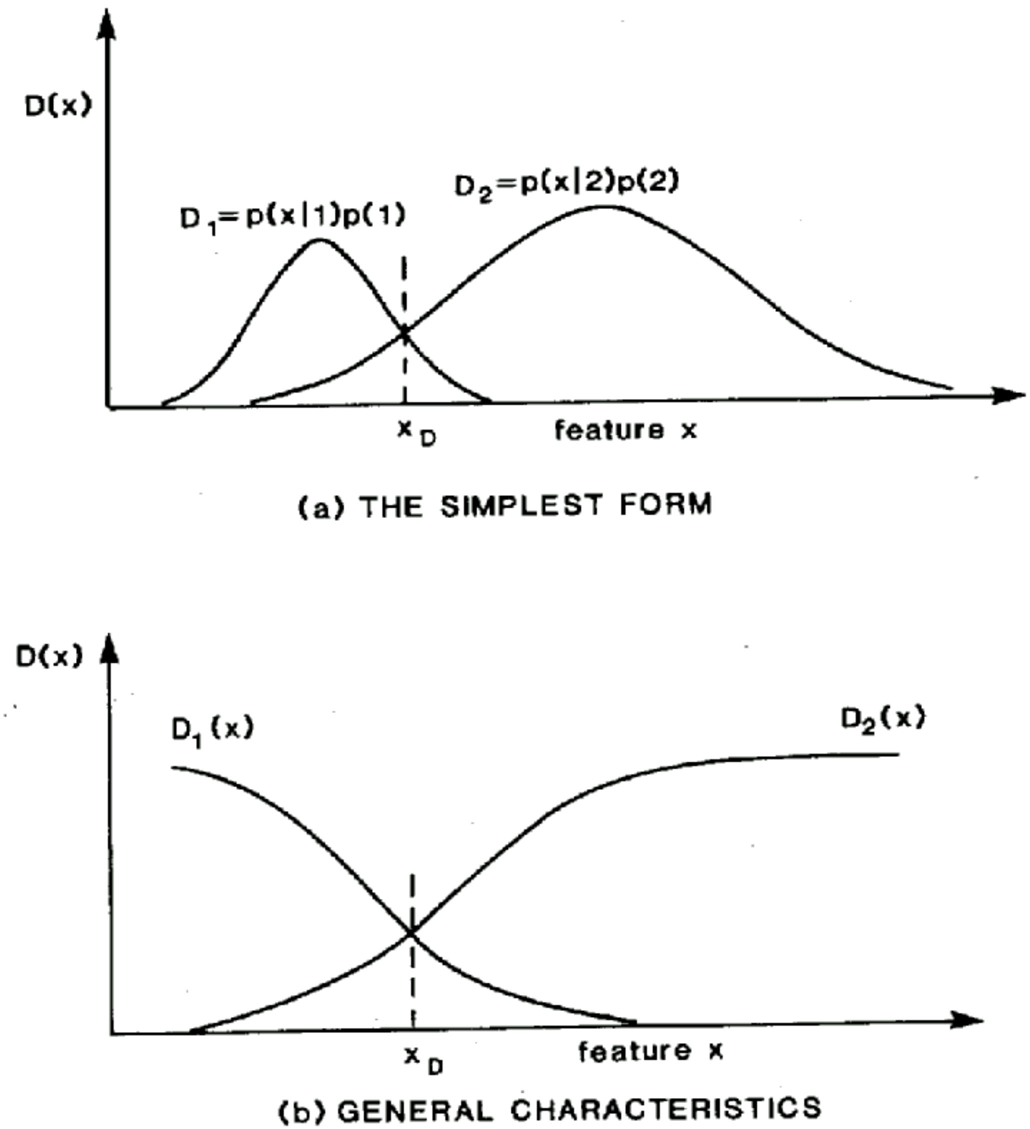
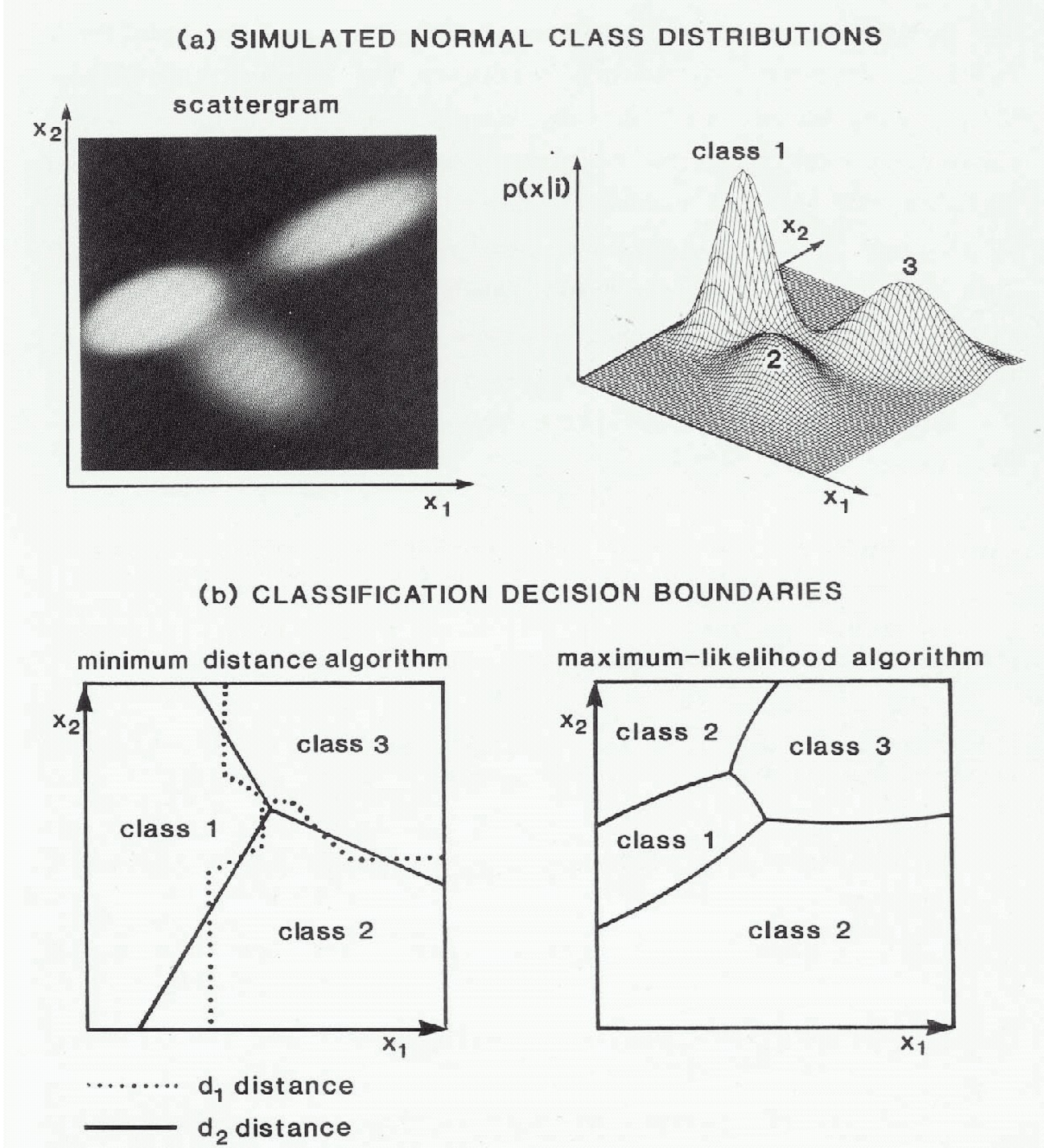


Image classification

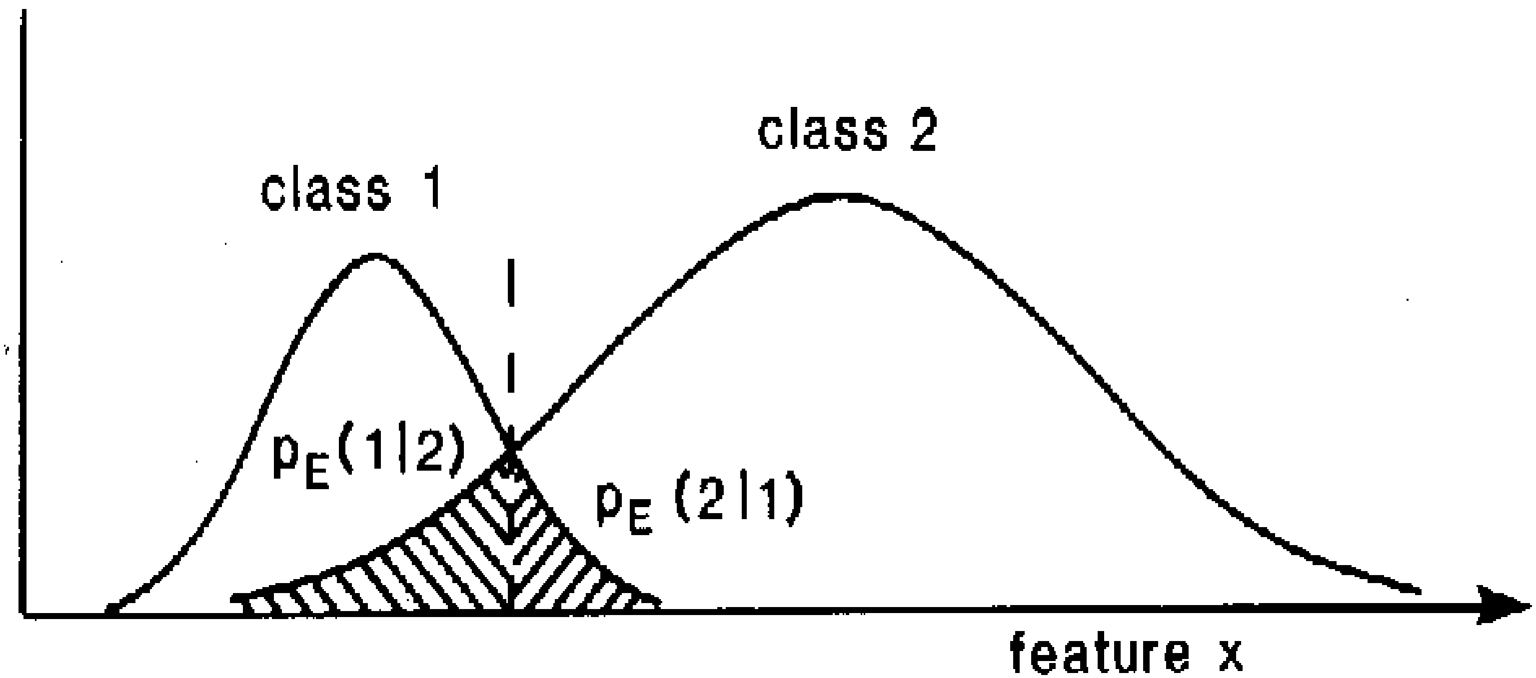




Discriminant functions for the Bayes optimal partition between two classes



Decision Boundaries for a three-class, two dimensional set of normal distributions.



Probability of Error, p_E' for a maximum likelihood classification.

Estimation of Model Parameters: it determines the '*a posteriori*' probability that a given pixel belong to class '*i*', given that the pixel has the feature '*f*'. This probability is calculated using *Bayes' Rule* of conditional probability:

$$\boxed{p(i|f) = \frac{p(f|i)p(i)}{\sum_{j} p(f|i)p(i)}}$$

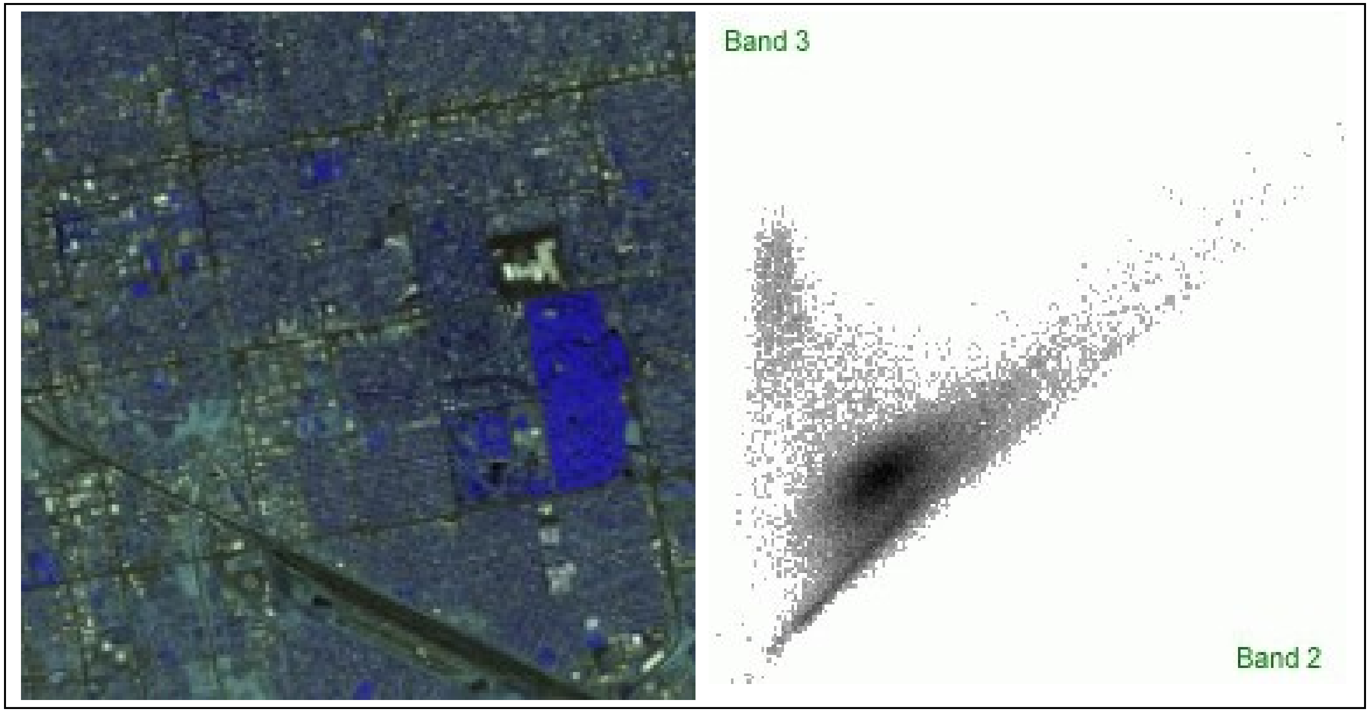
Discriminant function: it establishes the decision rule to classify a pixel. It is usually set to be equal the '*a posteriori*' probability for optimal results. It is stated as follows:

if

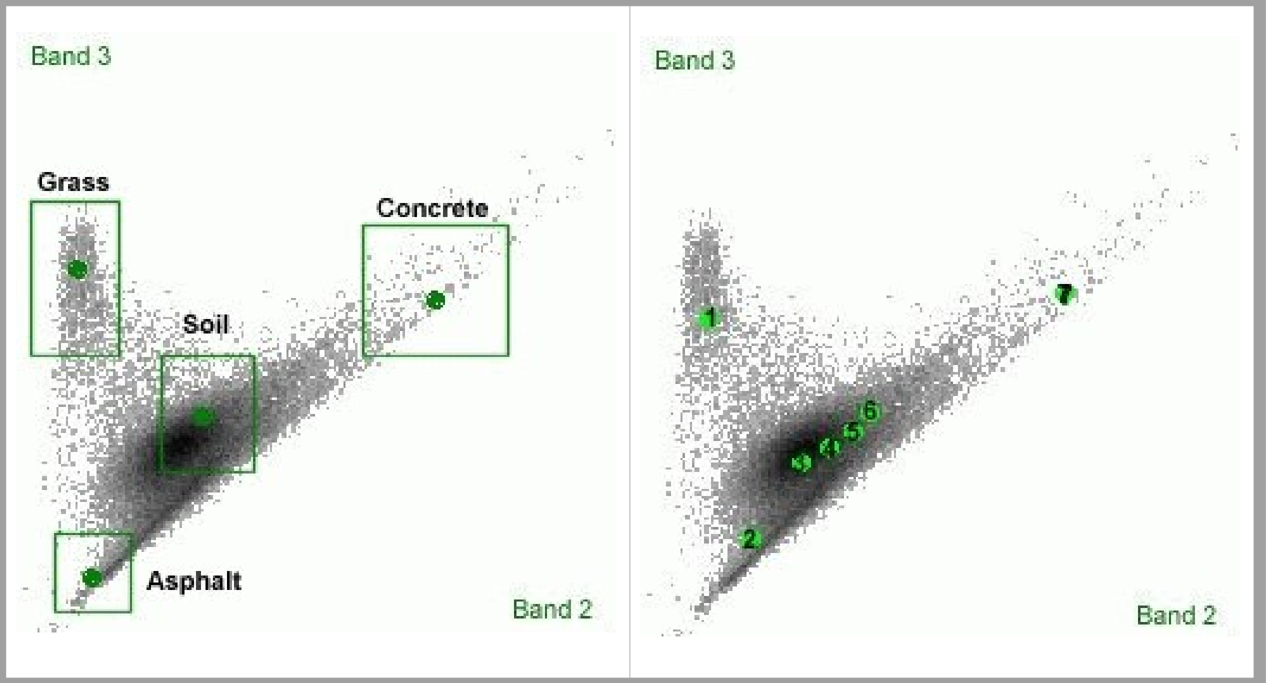
$$\boxed{D_i(f) \geq D_k(f)}$$

Then this pixel goes to class i

DECISION BOUNDARIES IN SCATTER PLOTS



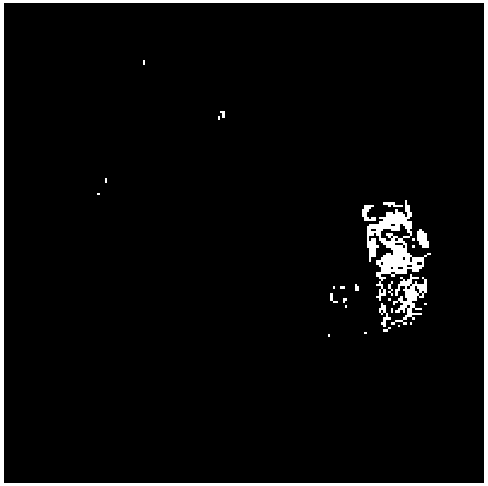
3 band multispectral image



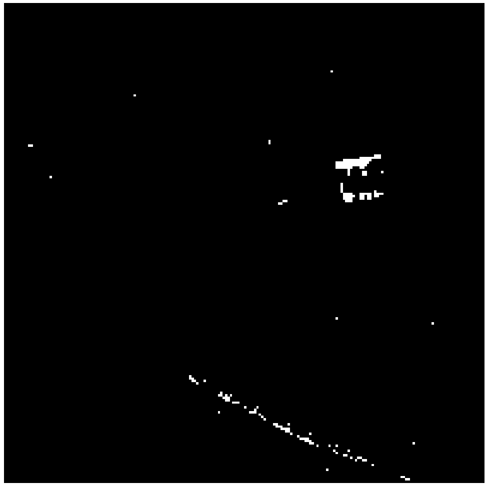
Supervised site training

Class	Cover type	Band2 Min Max	Band3 Min Max
1	Grass	7 31	92 148
2	Concrete	115 166	92 143
3	Asphalt	12 39	9 36
4	Soil	45 82	54 91

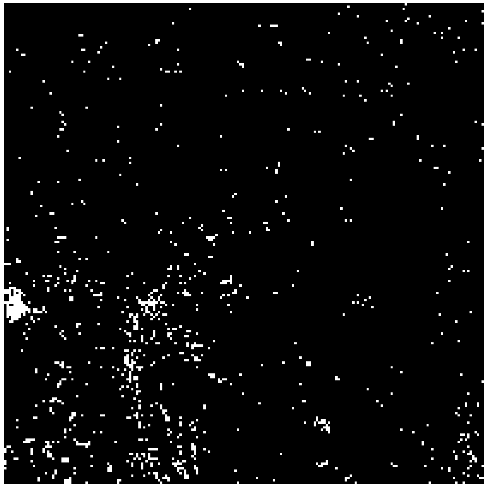
Level slice algorithm



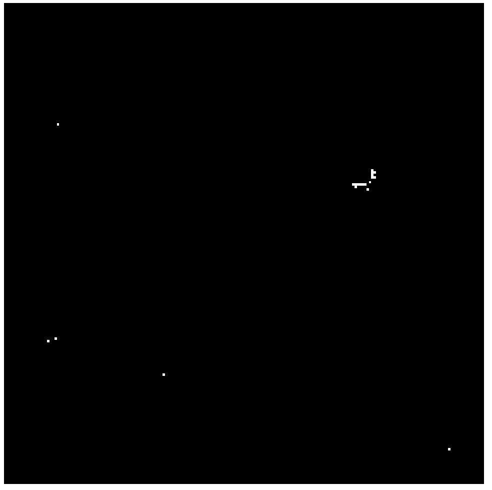
Vegetation -grass



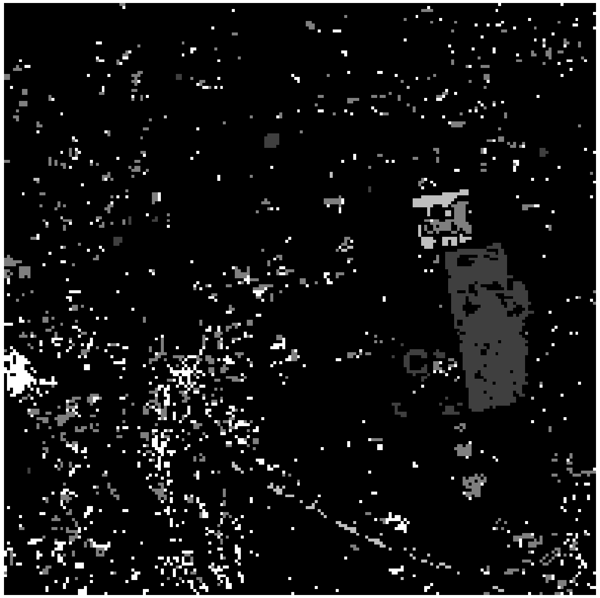
asphalt



Bare soil

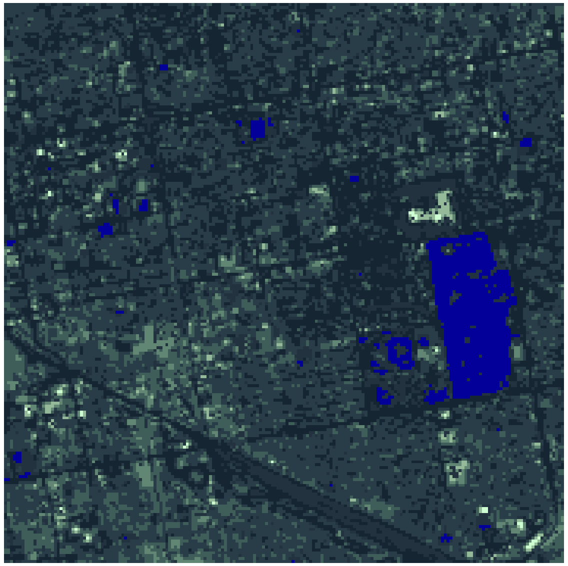


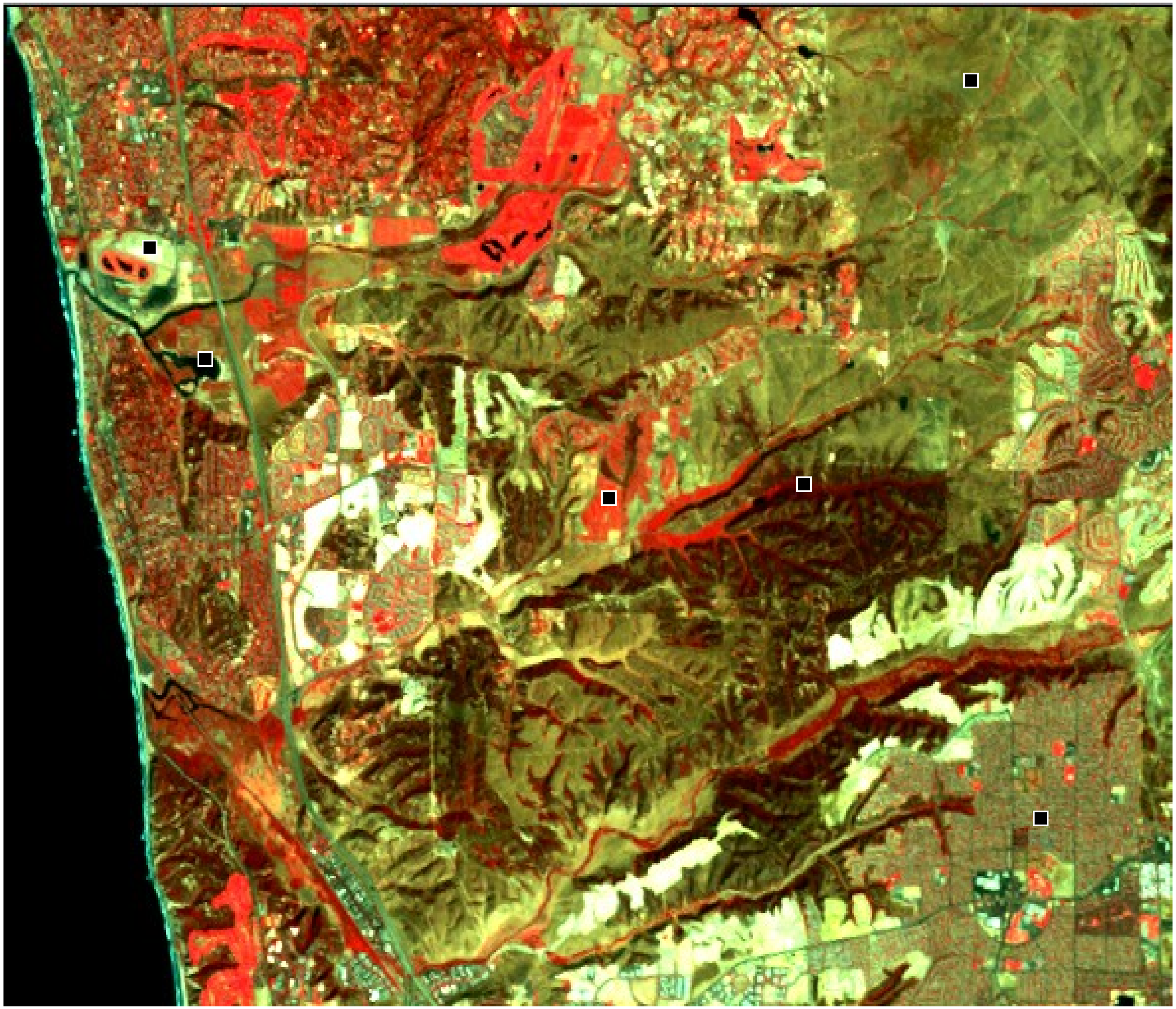
Bright roof



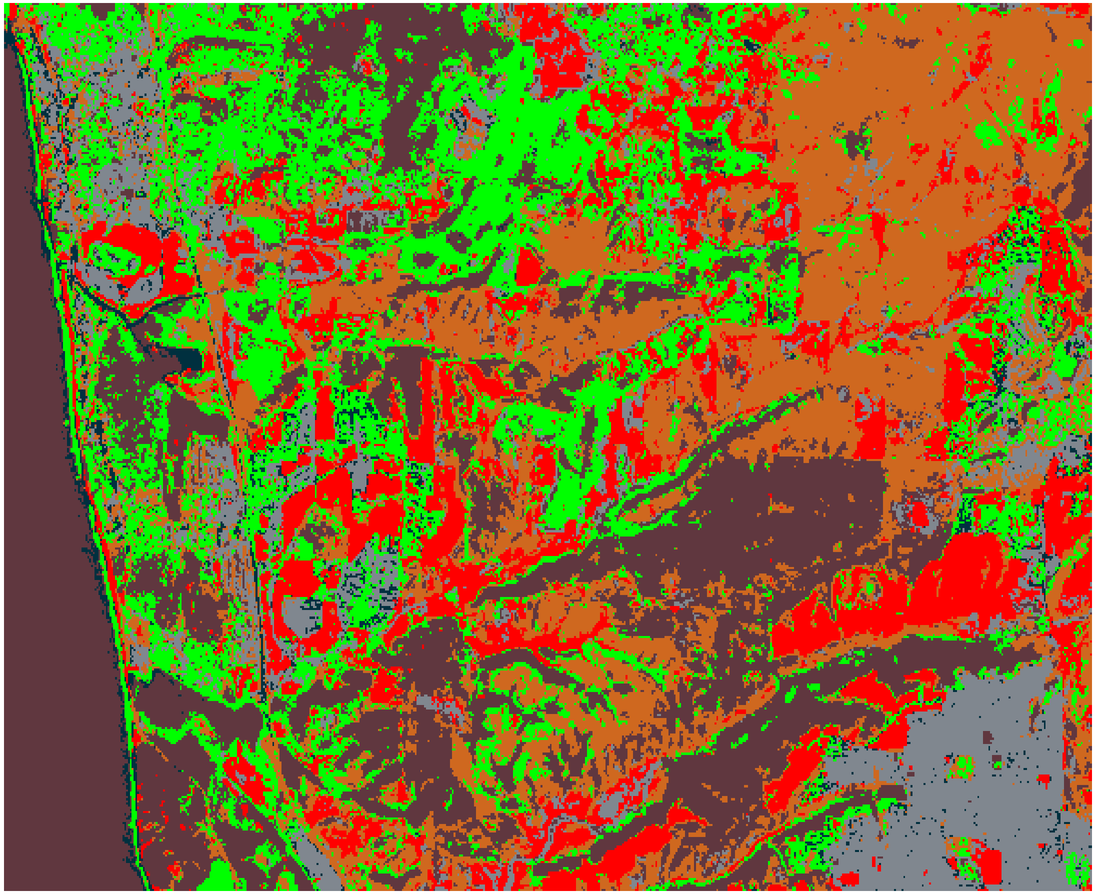
Classified image

Original image





Training Areas for different classes

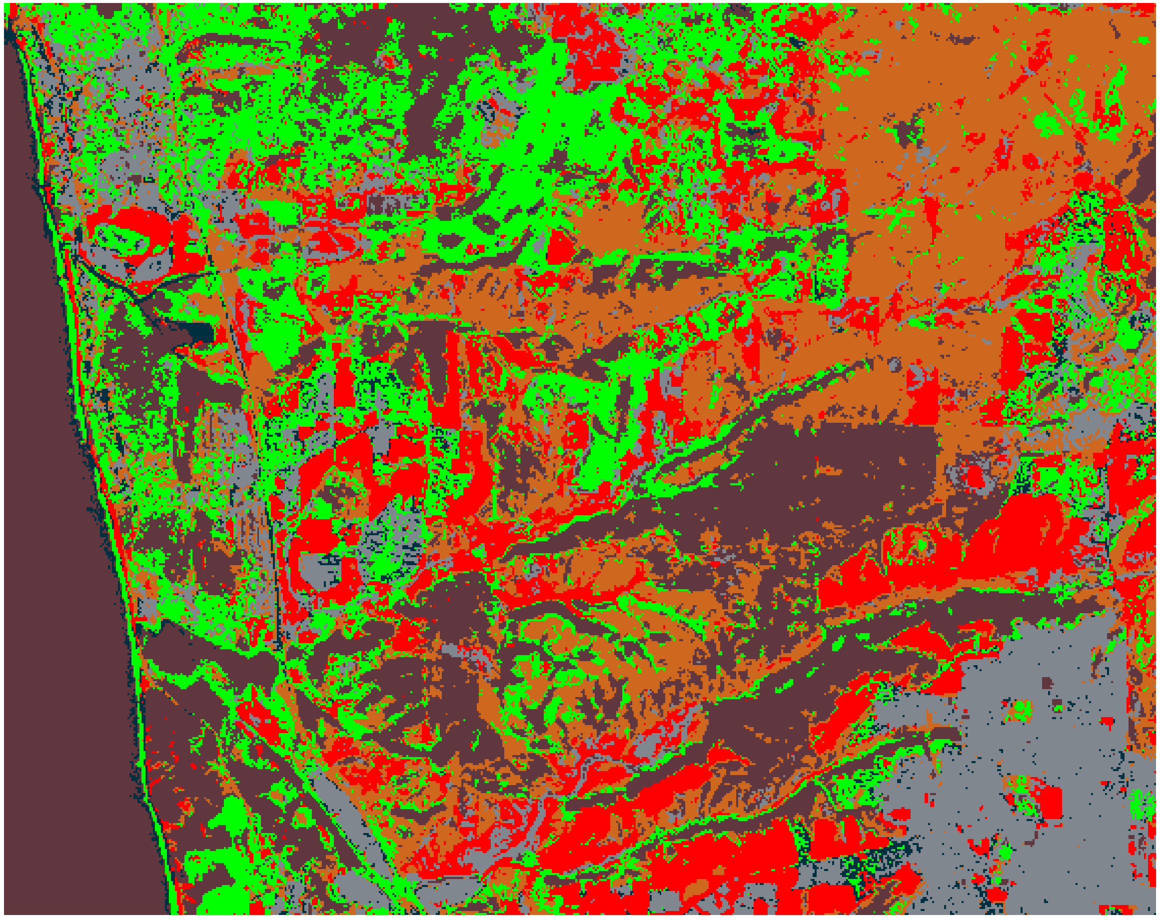


Maximum Likelihood Classifier

Color	Class Names
	Unclassified
	Class 1
	vegetation
	barren land
	settlements
	water bodies
	thick vegetation

Data	Unclassifi	Class 1	vegetation	barren lan	settlement	water bodi	thick vege	Row Total
Unclassifi	0	0	0	0	0	0	0	0
Class 1	0	3	0	1	0	0	0	4
vegetation	0	0	4	1	1	0	0	6
barren lan	0	0	0	6	0	0	0	6
settlement	0	0	0	0	4	0	0	4
water bodi	0	0	0	0	1	0	0	1
thick vege	0	0	0	0	0	1	2	3
Column Total	0	3	4	8	6	1	2	24

Error Matrix for Maximum Likelihood Classifier

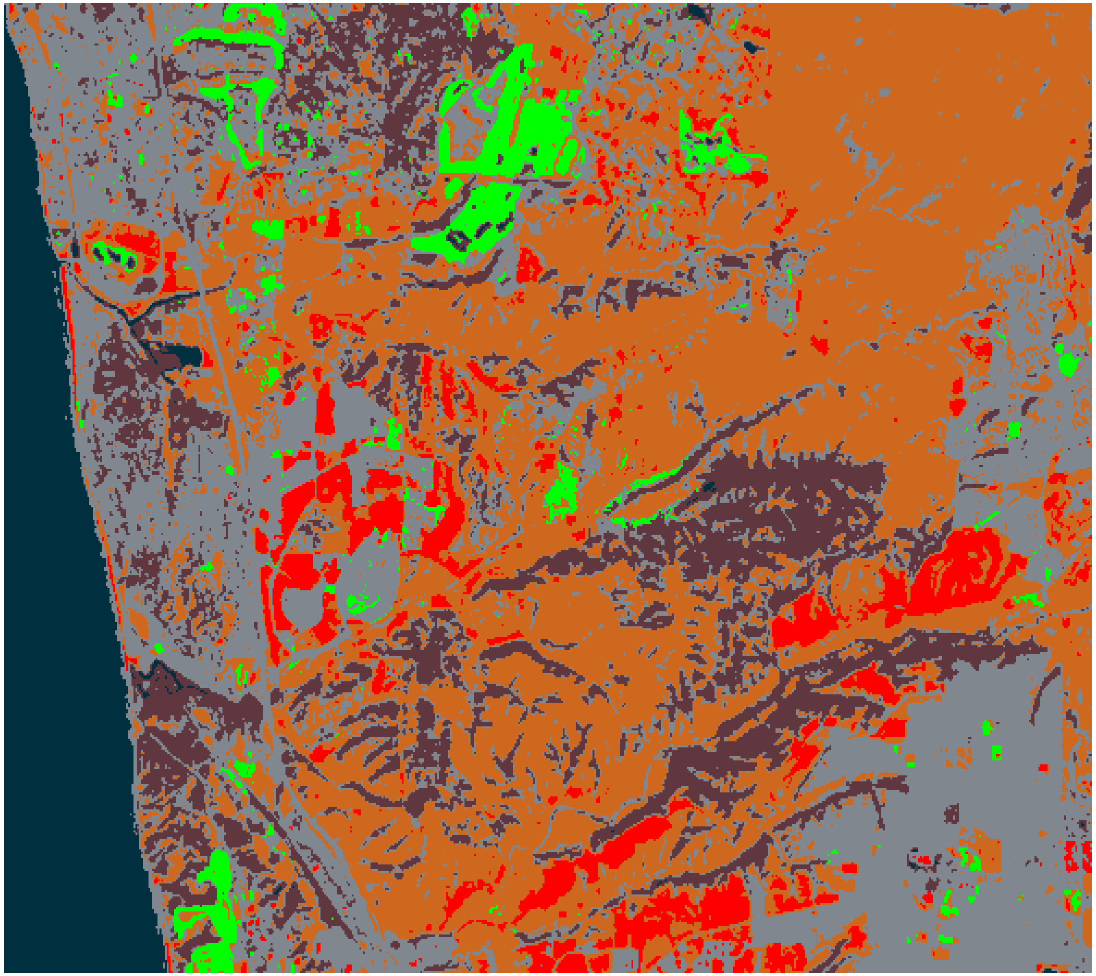


Mahalanobis Distance Classifier

Color	Class Names
	Unclassified
	Class 1
	vegetation
	barren land
	settlements
	water bodies
	thick vegetation

Data	Unclassifi	Class 1	vegetation	barren lan	settlement	water bodi	thick vege	Row Total
Unclassifi	0	0	0	0	0	0	1	1
Class 1	0	2	0	2	0	0	0	4
vegetation	0	0	3	1	0	0	0	4
barren lan	0	0	0	4	0	0	0	4
settlement	0	0	0	2	2	0	0	4
water bodi	0	0	0	1	0	2	0	3
thick vege	0	0	0	2	0	0	2	4
Column Total	0	2	3	12	2	2	3	24

Error Matrix for Mahalonobis distance classifier

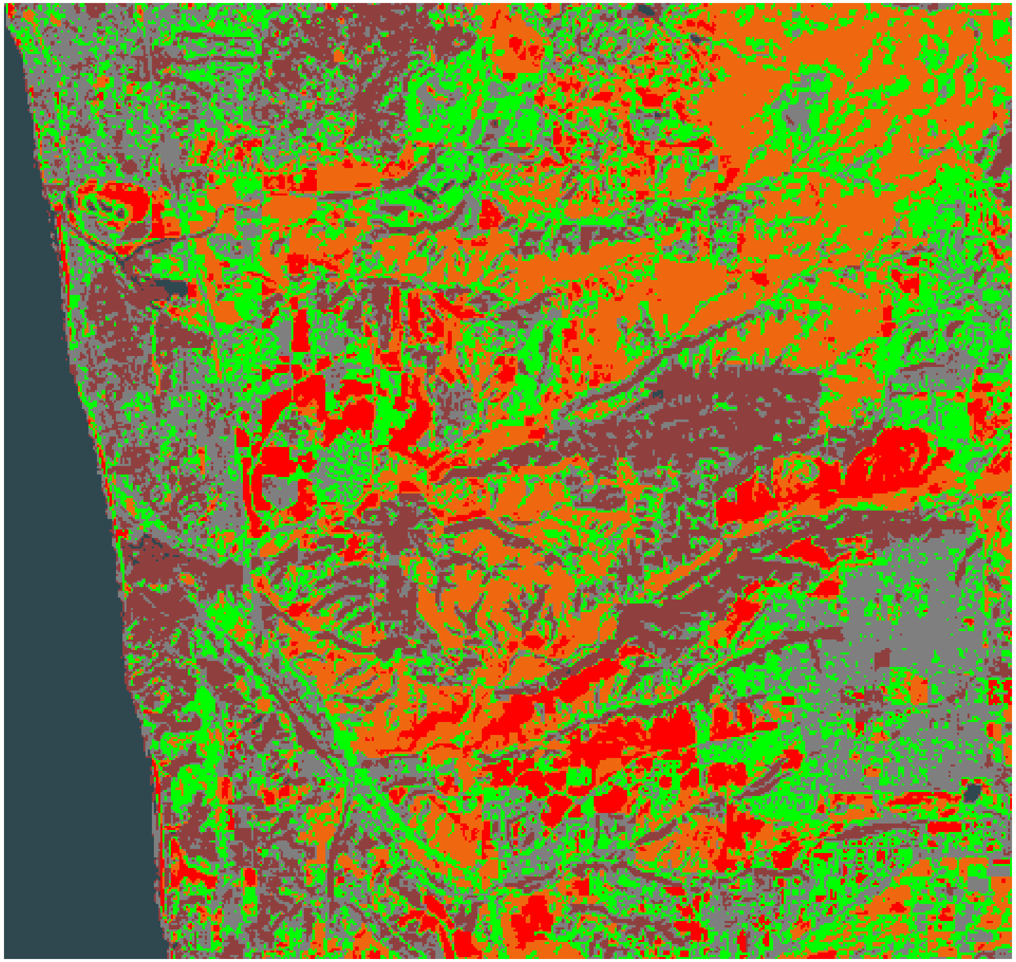


Color	Class Names
	Unclassified
	Class 1
	vegetation
	barren land
	settlements
	water bodies
	thick vegetation

Minimum Distance Classifier

Data	Unclassifi	Class 1	vegetation	barren lan	settlement	water bodi	thick vege	Row Total
Unclassifi	0	0	0	0	0	0	0	0
Class 1	0	1	0	0	0	0	0	1
vegetation	0	0	0	0	0	0	0	0
barren lan	0	0	0	13	0	0	0	13
settlement	0	0	0	1	4	0	1	6
water bodi	0	0	0	1	0	1	0	2
thick vege	0	0	0	0	0	0	2	2
Column Total	0	1	0	15	4	1	3	24

Error Matrix for Minimum Distance Classifier



Color	Class Names
	Unclassified
	Class 1
	Class 2
	Class 3
	Class 4
	Class 5
	Class 6

Unsupervised Classification

SUB-PIXEL CLASSIFICATION

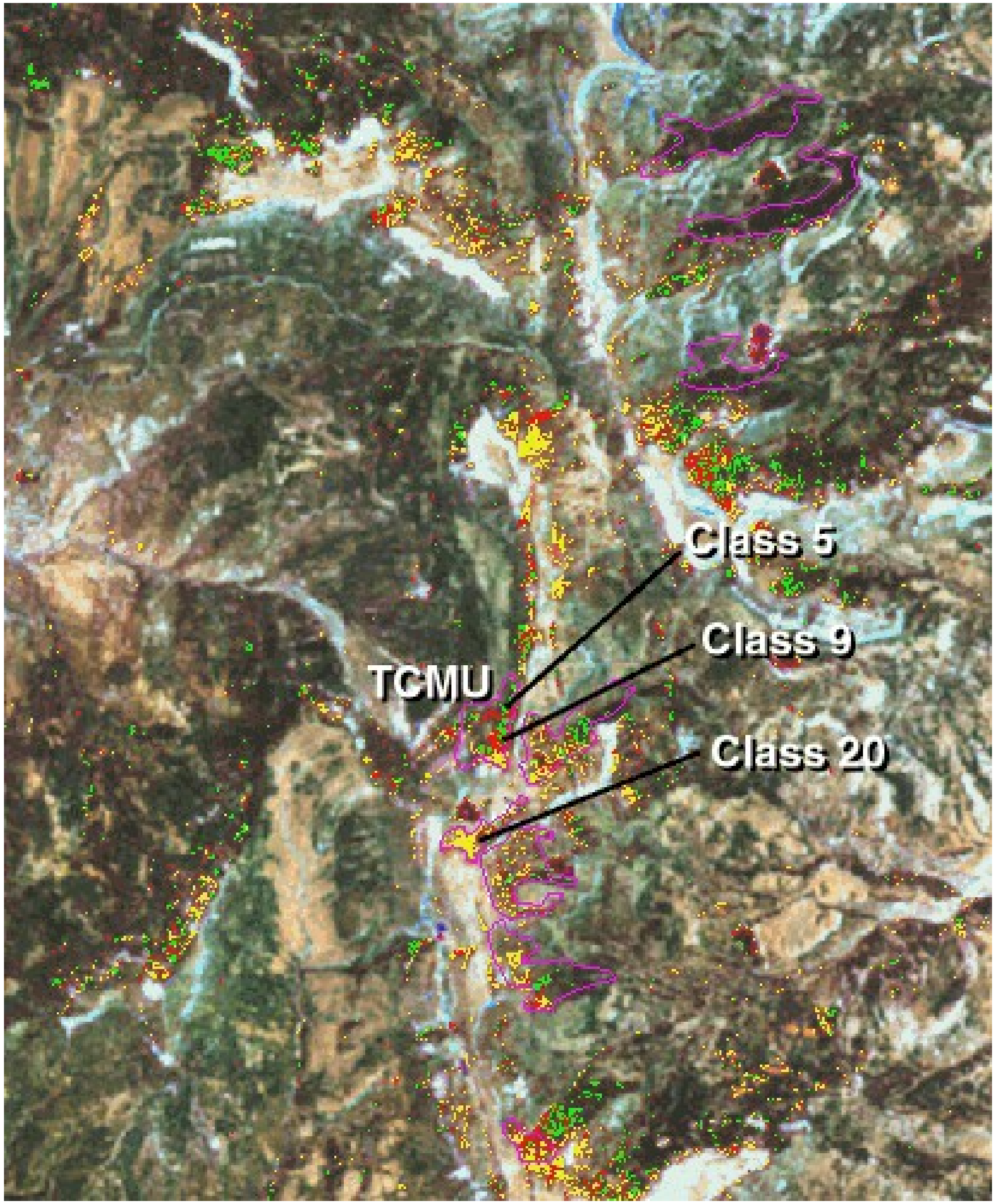
The basic concept behind subpixel analysis is that, with rare exceptions, the image pixels that contain the features of interest are mixed pixels, containing not only the feature of interest but other features as well.

The linear mixing model (LMM) approach reconstructs, or builds up the pixel spectra by mixing certain amounts of defined spectra from the image, called image end members using some form of decision rule

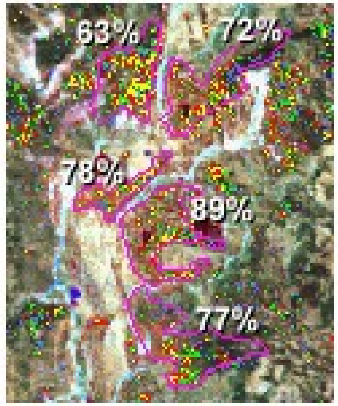
The other approach, used in this project, involves separating, or decomposing the pixel spectra into component parts, and evaluating the components to see if any match a known reference spectral signature within a given range of tolerances

Project area within the Wasatch Plateau

A masking operation was applied t
o the 1993 imagery to derive c
onifer-only areas. The masked
imagery was then used as input
to the subpixel analysis process.

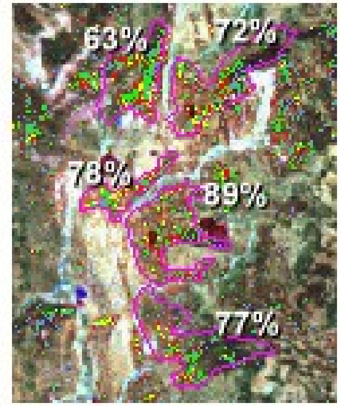


The second option was used in this project to locate candidate pixels for signature derivation. Three spectral clusters occurred in stands having known spruce beetle impact, and of these three clusters, two were used to create signatures for the subpixel classifier



Class 9 MMF = 1.0

Material Fraction	Pixels
Unclassified	634990
0.20-0.39	15120
0.40-0.59	12476
0.60-0.79	7705
0.80-1.00	4889



Class 9 MMF = 0.50

Material Fraction	Pixels
Unclassified	649886
0.20-0.39	10469
0.40-0.59	8782
0.60-0.79	4273
0.80-1.00	1770

Results of modifying the MMF (Mean Material Fraction)from whole pixel (1.0) to a subpixel level (0.50). Note the increase in number of unclassified pixels and changes in the distribution of the pixels between the material fraction classes.

Hyperspectral Imaging

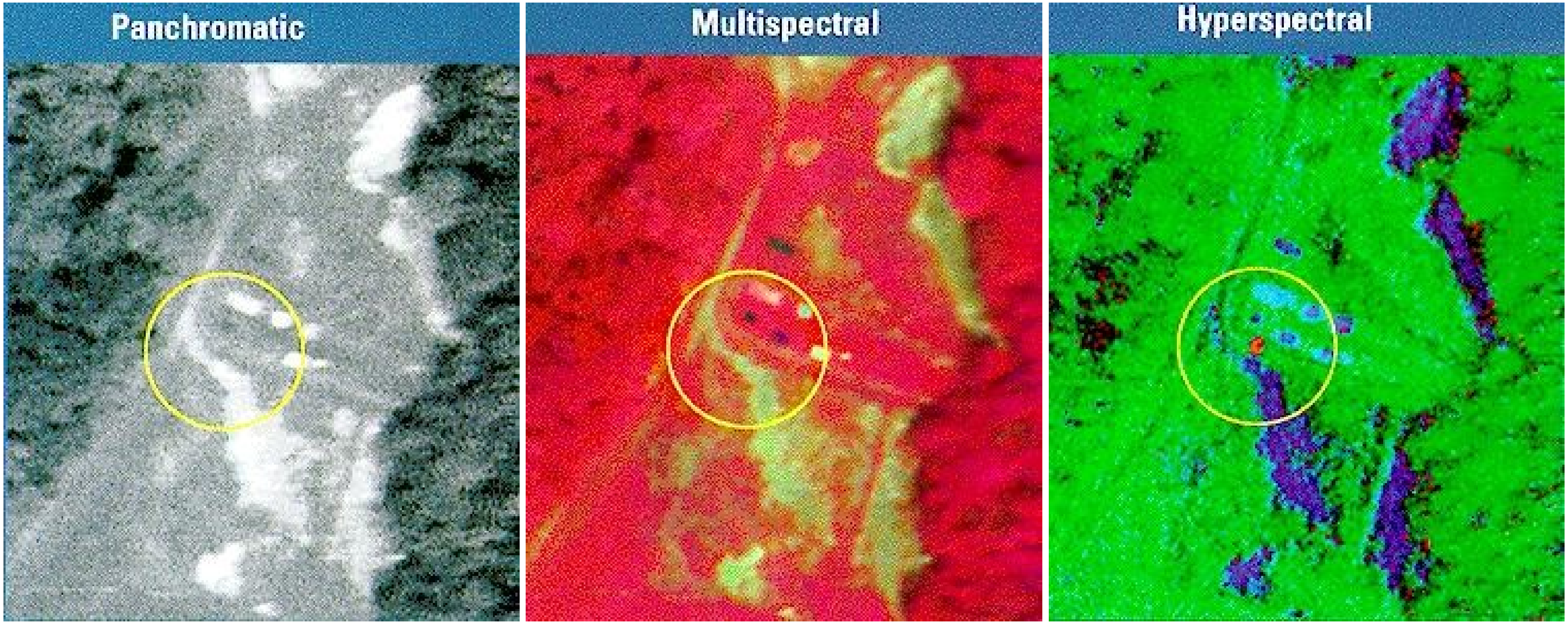
A primary goal of using multispectral/hyper spectral remote sensing image data is to discriminate, classify, identify as well as quantify materials present in the image. Another important applications are sub pixel target detection, which allows one to detect targets of interest with sizes smaller than the pixel resolution, and abundance estimation, which allows one to detect concentrations of different signature spectra present in pixels. In remote sensing image analysis, the difficulty arises in the fact that a scene pixel is mixed linearly or nonlinearly by different materials resident in the pixel where direct applications of commonly used image analysis techniques generally do not work well.

A primary goal of using multispectral/hyper spectral remote sensing image data is to discriminate, classify, identify as well as quantify materials present in the image.

The applications in the context of cities where remote sensing data are the most relevant are :

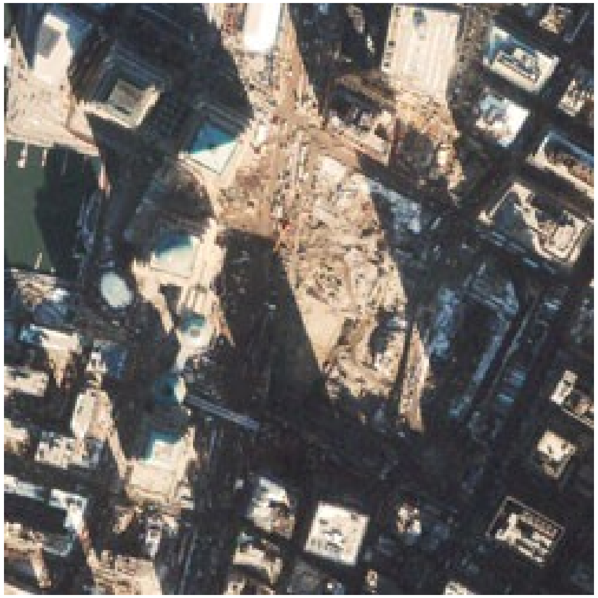
- land-cover mapping and change detection (urban growth modeling)
- environmental assessment
- traffic management (navigation information)
- air pollution modeling
- disaster management (prevention, crisis, post-crisis): flooding, earthquake subsidence
- indicators on citizen quality of life

Hyperspectral Remote sensing

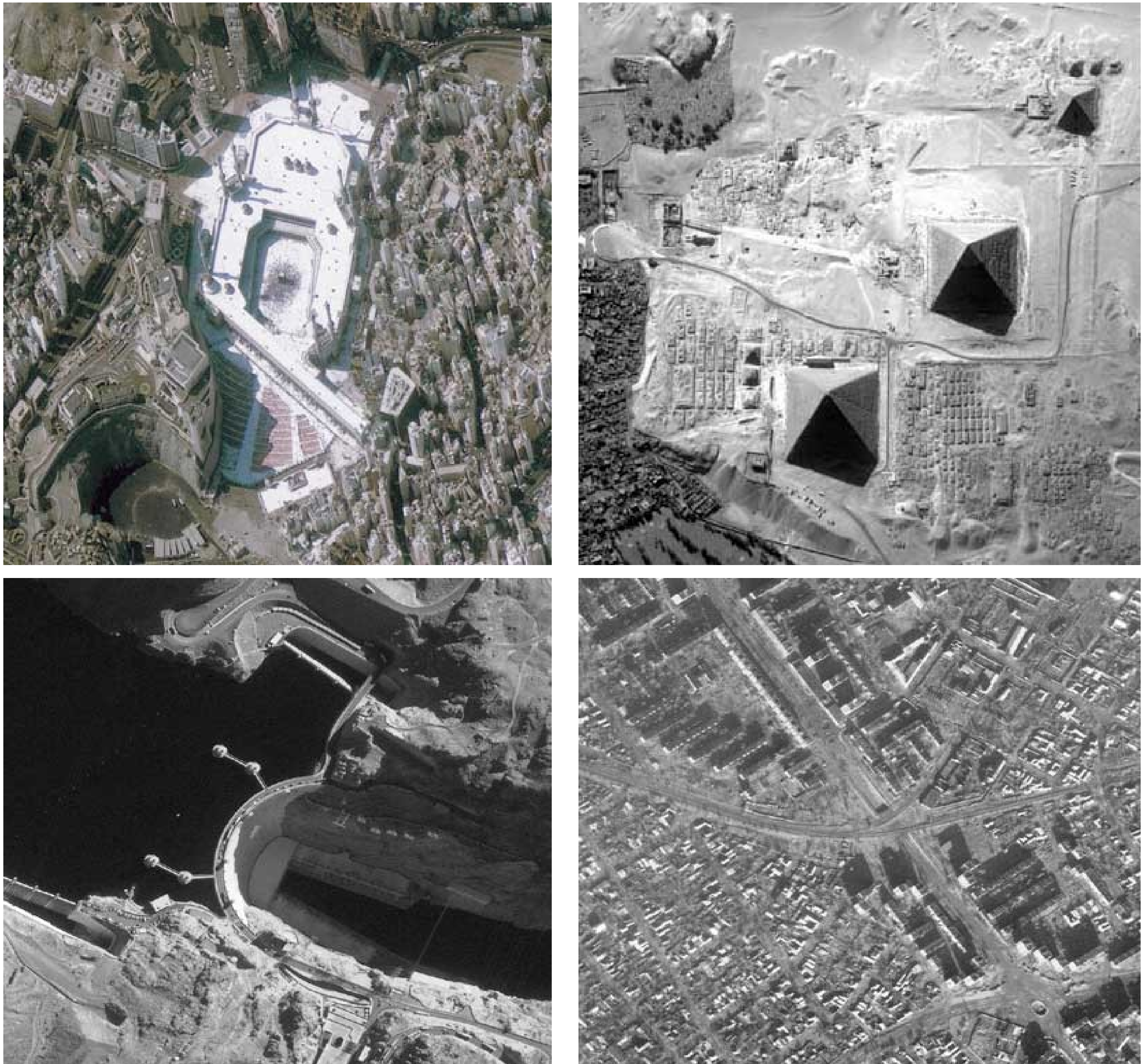


HIGH RESOLUTION REMOTE SENSING

WTC MISHAP



SAMPLE IKONOS DATA



SAMPLE QUICKBIRD DATA

Trapani, Sicily
Pan-sharpened multi-spectral infrared

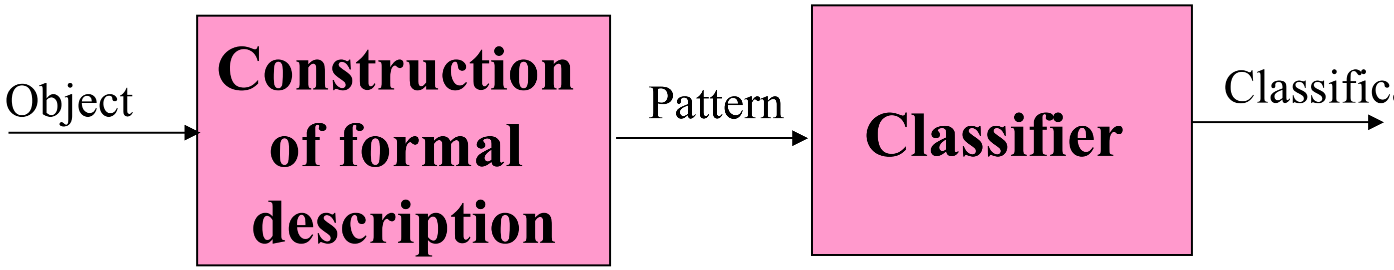
Resolution, 70 cm

Near Trapani, Sicily
Pan

Resolution, 70 cm

PATTERN RECOGNITION

Object recognition is based on assigning classes to objects, and the Device that does these assignments is called a **Classifier**.
The sensed object is called the **Pattern** and the classifier does not actually recognize the objects but recognize their pattern

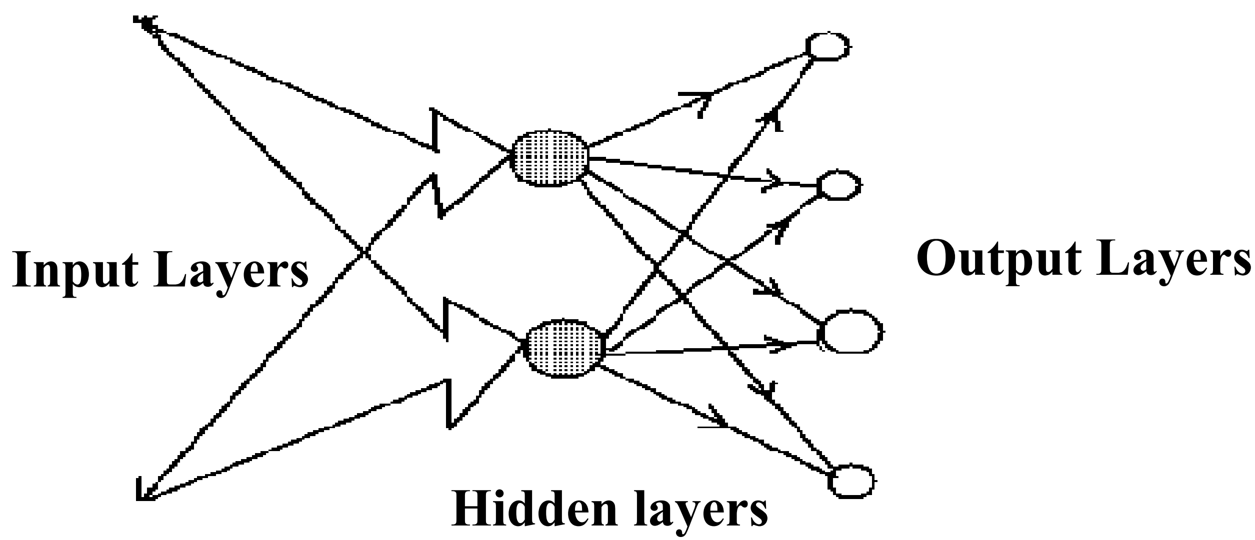


Main pattern recognition steps.

EXPERT SYSTEMS

Knowledge Representation

- The **syntax** of a representation specifies the symbols that may be used and the ways that may be arranged.
- The **Semantics** of a representation specifies how meaning is embodied in the symbols and the symbol arrangement allowed by the syntax.
- A **Representation** is a set of syntactic and semantic conventions that make it possible to describe things.



ARTIFICIAL NEURAL NETWORKS

Fuzzy Systems:
They represent complex knowledge and even knowledge from contradictory sources. They are based on fuzzy logic which represents a powerful approach to decision making.

ADVANTAGES OF THE FUZZY METHODOLOGY

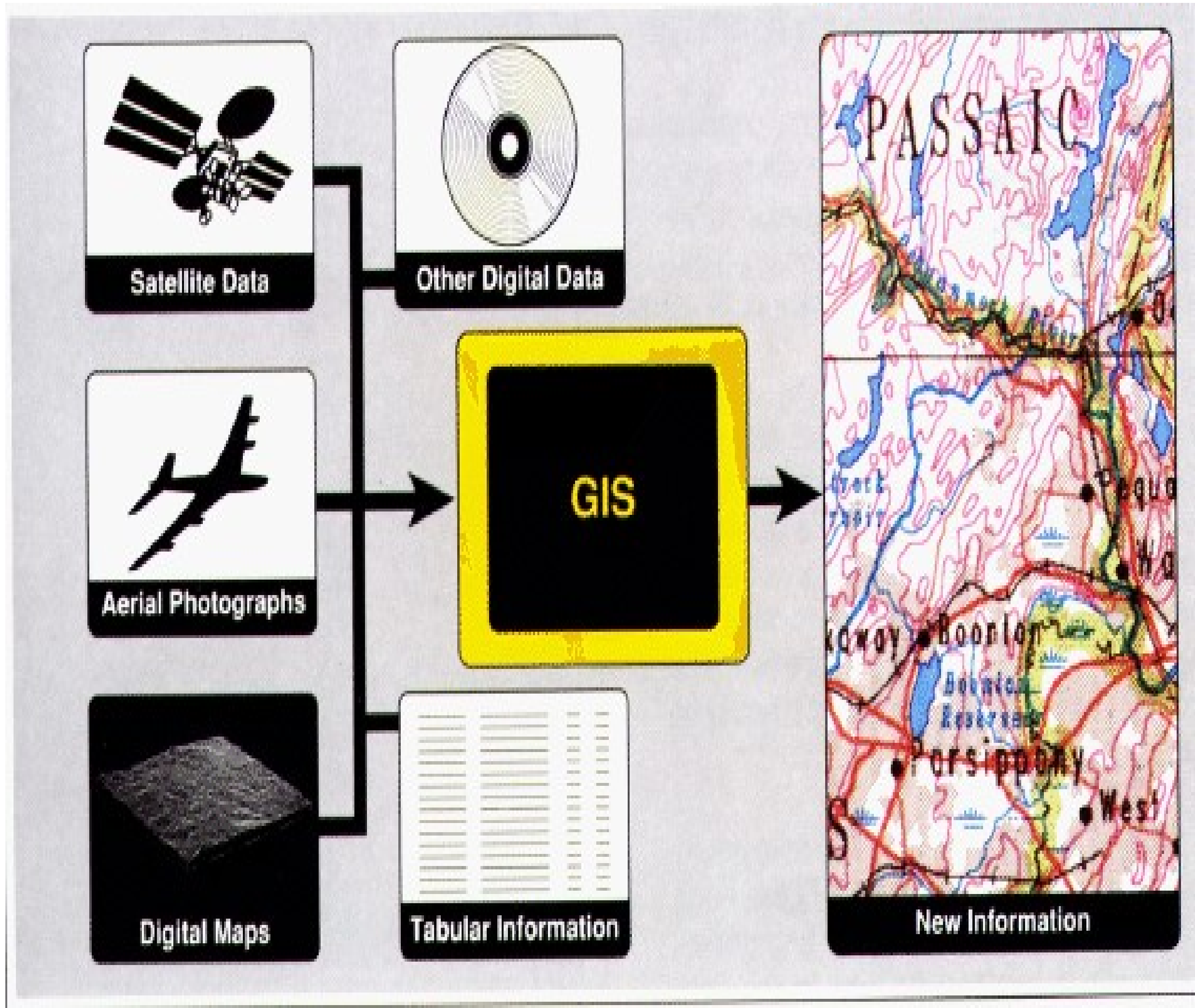
The methodology is based on physical parameters that are extracted from digital maps, satellite images or numeric land resources. As a consequence application is not restricted in time or space. Furthermore, data collection combined with satellite image data extraction at regional level ensures a high-resolution fragility calculation for large areas. It is a low cost and user friendly monitoring system based on physical parameters stored in a relational database.

INTEGRATION TO GIS

GIS accept large volumes of spatial data derived from a variety of sources. **GIS** efficiently store , retrieve , manipulate, analyze and display these data according to user-defined specifications.

GIS concepts

1. Data encoding
2. Data management
3. Data manipulation
4. Data output



THANK YOU