

# History of Remote Sensing

[http://observe.arc.nasa.gov/nasa/  
exhibits/history/history\\_0.html](http://observe.arc.nasa.gov/nasa/exhibits/history/history_0.html)

- remote sensing is simply obtaining information about an object without coming into direct physical contact with it



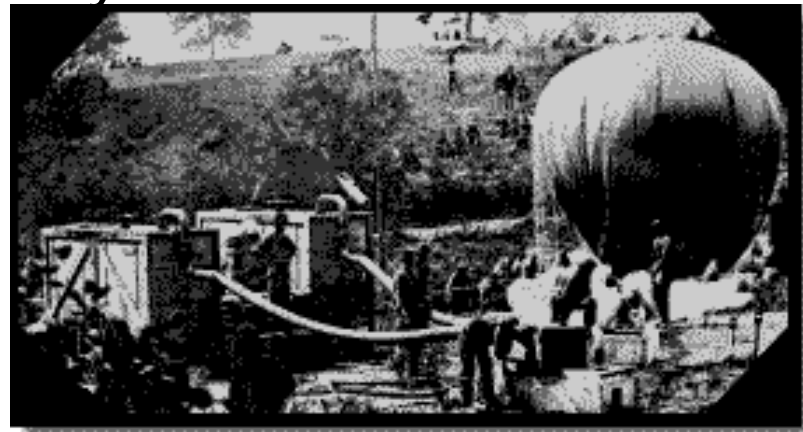
- **Galileo -- telescope : 1609**
  - spots on the Sun
  - imperfections on the Moon
  - the Milky Way was composed of a myriad of faint stars.
  - satellites orbiting Jupiter



- **The First Aerial Photographer: 1859**
  - Gaspard Felix Tournachon (Nadar), was a famous French photographer and balloonist who carried his bulky cameras aloft.
  - His goal was to make land surveys from aerial photographs.



- **The US Army Balloon Corps:1862**
  - Professor Thaddeus Lowe believed that balloons could be useful for reconnaissance.
  - President Lincoln authorized the US Army Balloon Corps
  - Despite its advantage to the North during the American Civil War, the unit was deactivated in 1863. Balloons had a not-surprising tendency to draw enemy fire.



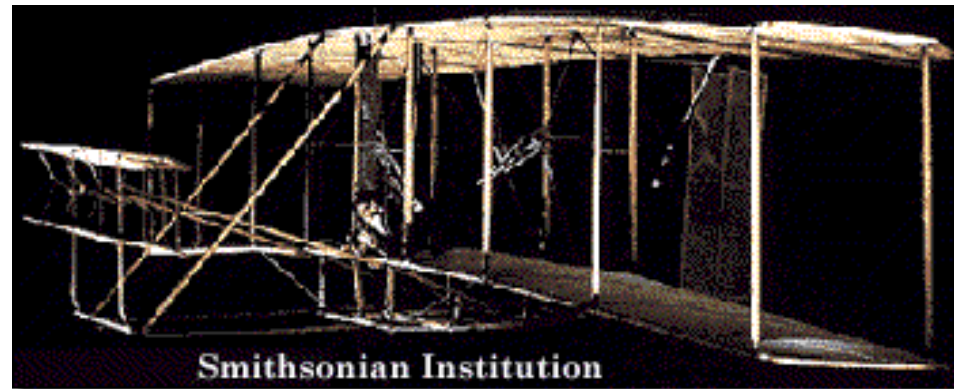
- **The Bavarian Pigeon Corps: 1903**

- attach a very light camera to a carrier pigeon.
- cameras took a picture every thirty seconds as the pigeon winged its way home.



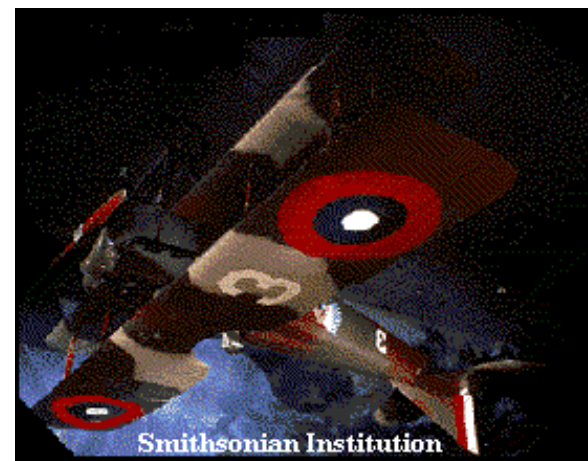
- **Photos from an Aeroplane: 1909**

- Wilbur Wright was the pilot for two notable events in remote sensing history.
- The first photographs from an aircraft were taken by Wilbur's passenger, L. P. Bonvillain, on a demonstration flight in France in 1908.
- the first aerial motion pictures were taken in Italy when another photographer accompanied Wright.



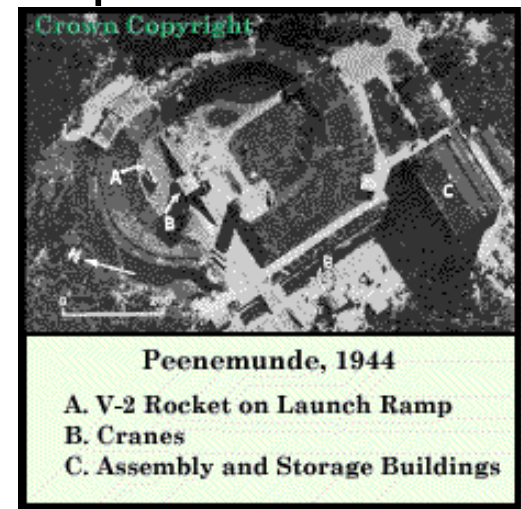
- **The Great War: 1914-1918**

- The biplane replaced the balloon for observing enemy positions in the World War I.
- the Germans acquired 4,000 photos a day as part of the planning for their last great offensive of 1918
- the US Army made over one million prints in the last four months of the war.



- **The Buzz Bomb: 1944**

- As Royal Air Force photo interpreter was studying stereo air photos of the German experimental station
- She had discovered the infamous V-1 "buzz bomb," a jet-powered missile
- the newer V-2 was a liquid-fueled rocket.
- Post-war experiments and tests with captured V-2s led, in the late 1950s, to the development of satellite launch vehicles and the exploration of space.



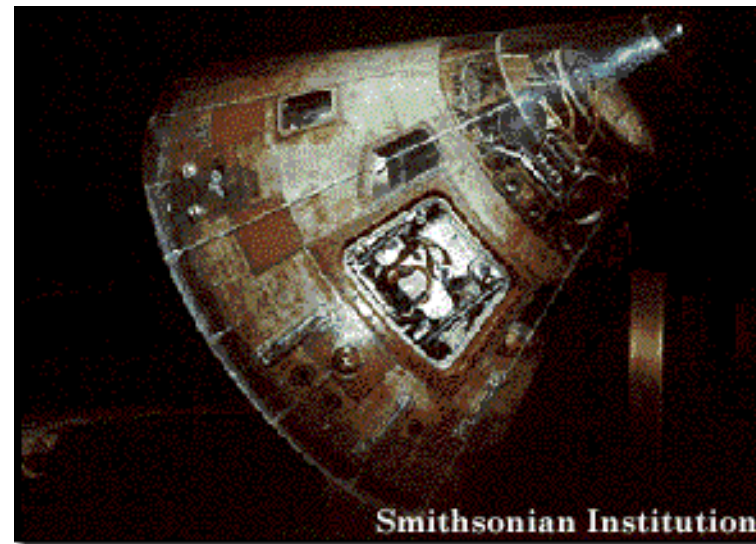
## • The Cuban Missile Crisis: 1962

- In the fall of 1962, there were unconfirmed reports that the Soviets were installing intermediate-range nuclear missiles in Cuba.
- Remotely sensed imagery from satellites, and especially from high flying U-2 airplanes, provided incontrovertible proof that the rumors were true.
- Soviet Premier Khrushchev and US President John F. Kennedy in October 1962 brought the world to the brink of war. Both superpowers relied heavily on interpretations of remotely sensed images to make their assessments and decisions.



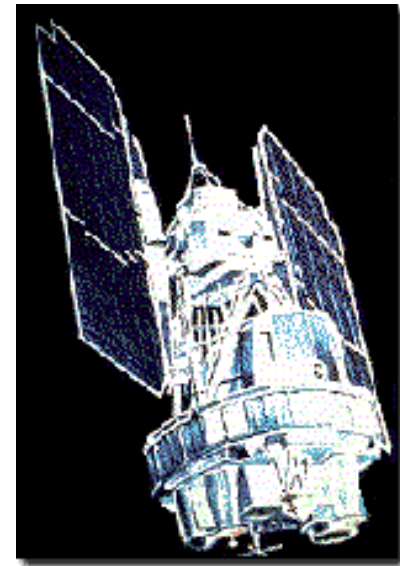
- **Apollo Program**

- The mission to the Moon needed maps of the lunar surface, especially of the proposed landing sites.
- Apollo 8 returned the first pictures of the Earth from deep space (1968).
- Images from the Apollo 9 multispectral four-lens camera were digitized and used to develop techniques for processing Landsat data



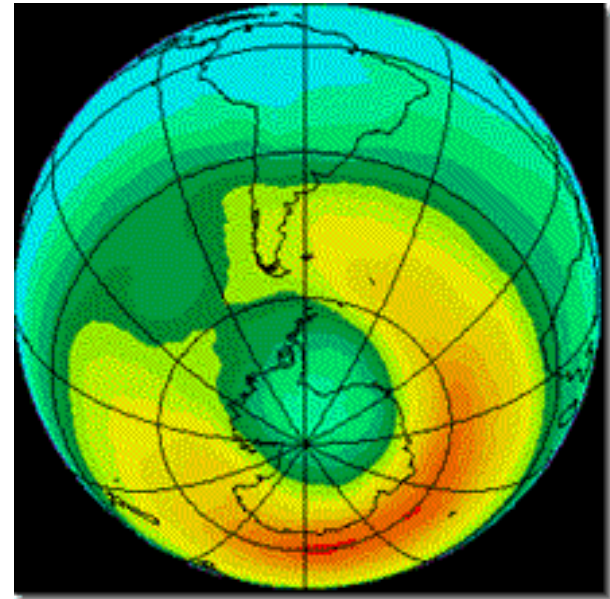
- **Civilian Satellite Remote Sensing: 1972**

- In late July 1972 NASA launched the first Earth Resources Technology Satellite (ERTS-1).
- The multispectral data provided by the on-board sensors led to an improved understanding of crops, minerals, soils, urban growth, and many other Earth features and processes.
- The name of the satellite, and those that followed, was soon changed to a more pleasant-sounding Landsat. Landsats 2 through 5 have provided more data about the Earth than can ever be analyzed.



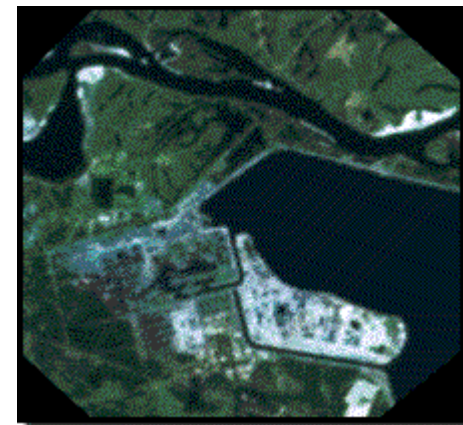
- **The Ozone Hole: 1985**

- Ozone depletion over Antarctica, first noted by British scientists, was confirmed by measurements from the Nimbus-7 Total Ozone Mapping Spectrometer (TOMS), launched in 1978.
- Since then, TOMS has made daily polar ozone maps of an ozone hole as large as the United States. Satellite data were invaluable in supporting the first Montreal Protocol, wherein forty nations agreed to a fifty percent reduction in the use of chlorofluorocarbons by 1999.



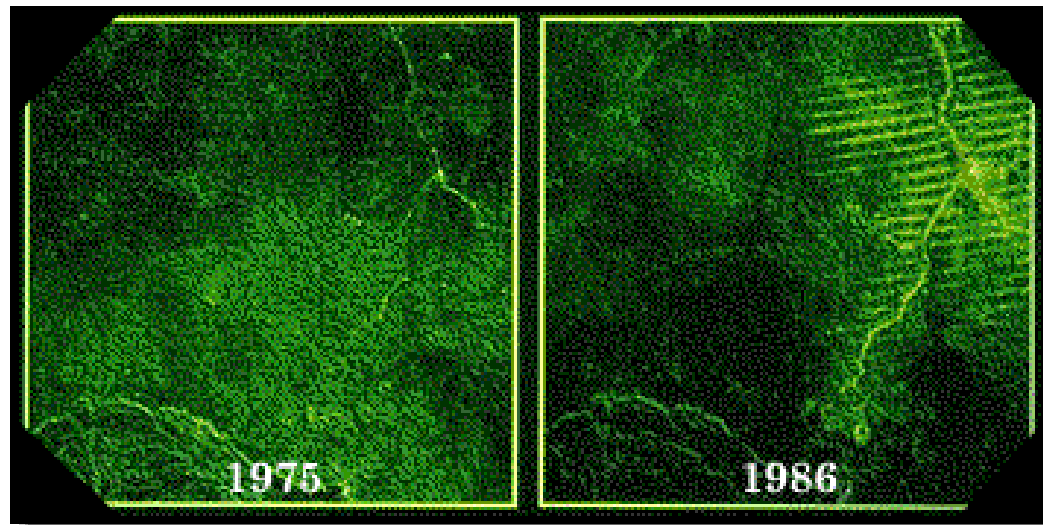
- **Chernobyl: 1986**

- On April 26, 1986, one of the nuclear reactors in Chernobyl, Ukraine, exploded, spewing large amounts of radioactive materials into the atmosphere.
- Images from US and French remote sensing satellites monitored the activity at the site. Even after the fire was out, the heat from the reactor was detected by infrared sensors in orbit. The reactor complex is the green rectangular area located just to the left of the black cooling pond. The use of remote sensing imagery to monitor emergency situations is becoming a well-established part of the field of emergency management.



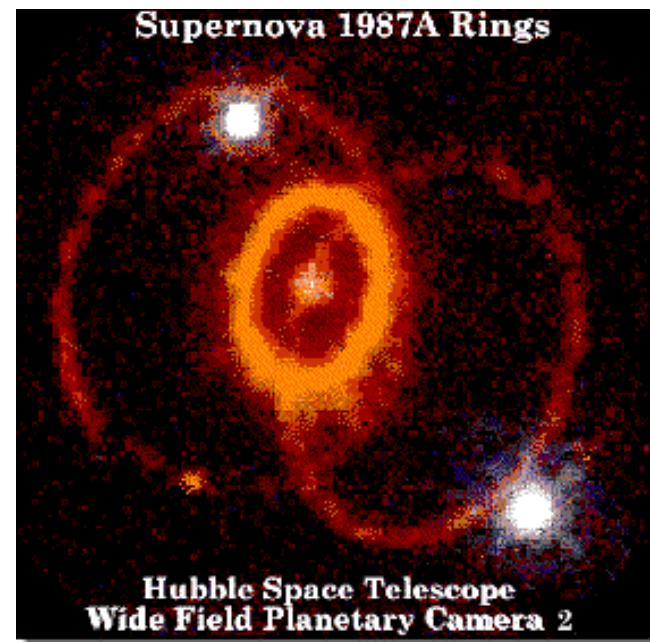
- **Deforestation: 1986**

- Detecting changes through time is one of the most powerful uses of remote sensing.
- These Landsat images, taken in 1975 (left) and 1986(right), disclose how many acres of forest lands were converted to agricultural use in the Brazilian state of Rondonia.
- The fishbone pattern of roads radiating from the major highway indicates the changes. NASA researchers have estimated that 9,000 square miles have been converted from forest to agriculture in this area of Brazil.



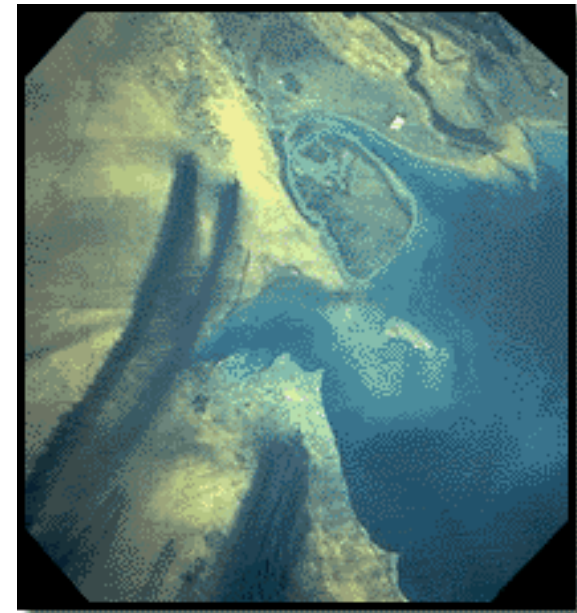
- **Supernova: 1987**

- Oscar Duhalde was outside taking a break from his telescope at the Las Campanas Observatory in northern Chile. In the southern sky he noticed a bright object he had never seen before near the Tarantula nebula.
- The star that exploded was a blue super giant; the light from it had been traveling for 160,000 years through space before reaching the Earth



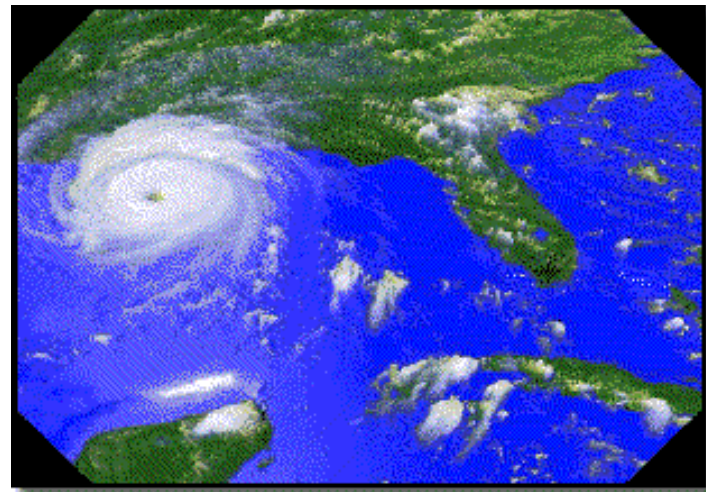
- **Oil Field Fires, Kuwait: 1991**

- The Kuwaiti oil field fires were easily visible from space. Astronauts aboard the space shuttle in the spring of 1991 captured this image of Kuwait.
- It shows a few of the smoke plumes from the 700 oil wells blown up by the defeated Iraqi army as they fled Kuwait. The smoke plume reached about 16,000 feet, and black rain fell in parts of Iran and Saudi Arabia.



- **Hurricane Andrew: 1992**

- Hurricane Andrew was the most costly natural disaster in US history, sweeping into heavily populated south Florida with winds of up to 160 mph.
- human casualties were low because of advance warning from satellites. High-resolution satellite images also allowed a three-dimensional reconstruction of the hurricane, which aided forecasters in predicting hurricane movements. More accurate storm position forecasts enable emergency managers to conduct evacuations in threatened areas.



- **Mississippi River Flooding: 1993**

- The Midwestern US floods of 1993 are best seen and understood from a satellite's viewpoint. These views of St. Louis before and during the flood illustrate how remote sensing can be used to assess changes and aid in emergency planning and remediation efforts .



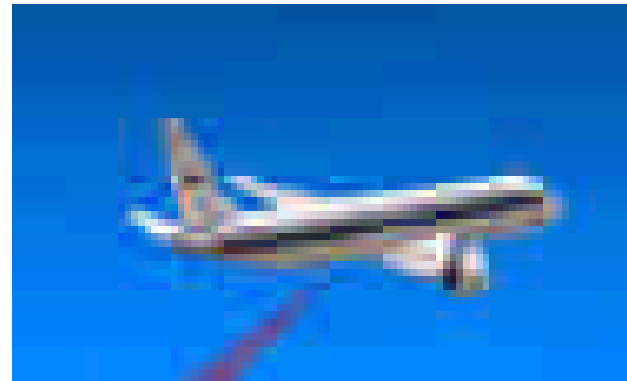
# Other information

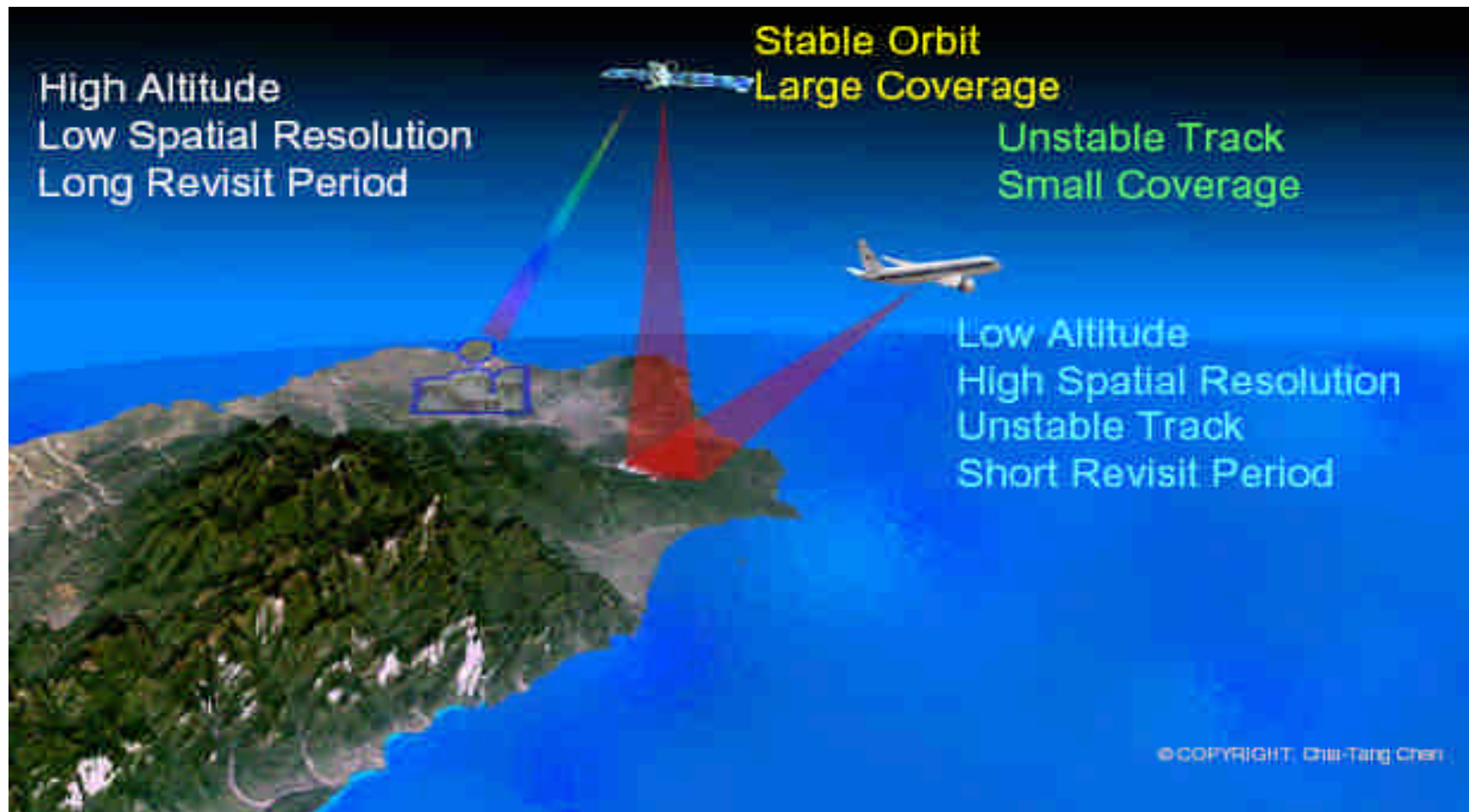
- <http://www.geog.ucsb.edu/~jeff/115a/remotesensinghistory.html>
- [http://ccrs.nrcan.gc.ca/org/history/index\\_e.php](http://ccrs.nrcan.gc.ca/org/history/index_e.php)
- <http://employees.oneonta.edu/baumanpr/geosat2/RSHistory/HistoryRSPart1.htm>
- [http://www.yc.ycc.u-tokai.ac.jp/ns/cholab/RS-fun/english/RS\\_QA/RS\\_QA01.swf](http://www.yc.ycc.u-tokai.ac.jp/ns/cholab/RS-fun/english/RS_QA/RS_QA01.swf)

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  - Spatial
  - Spectral

# Platform





# Satellite Sensor

SPOT



ERS



LandSat



RadarSat

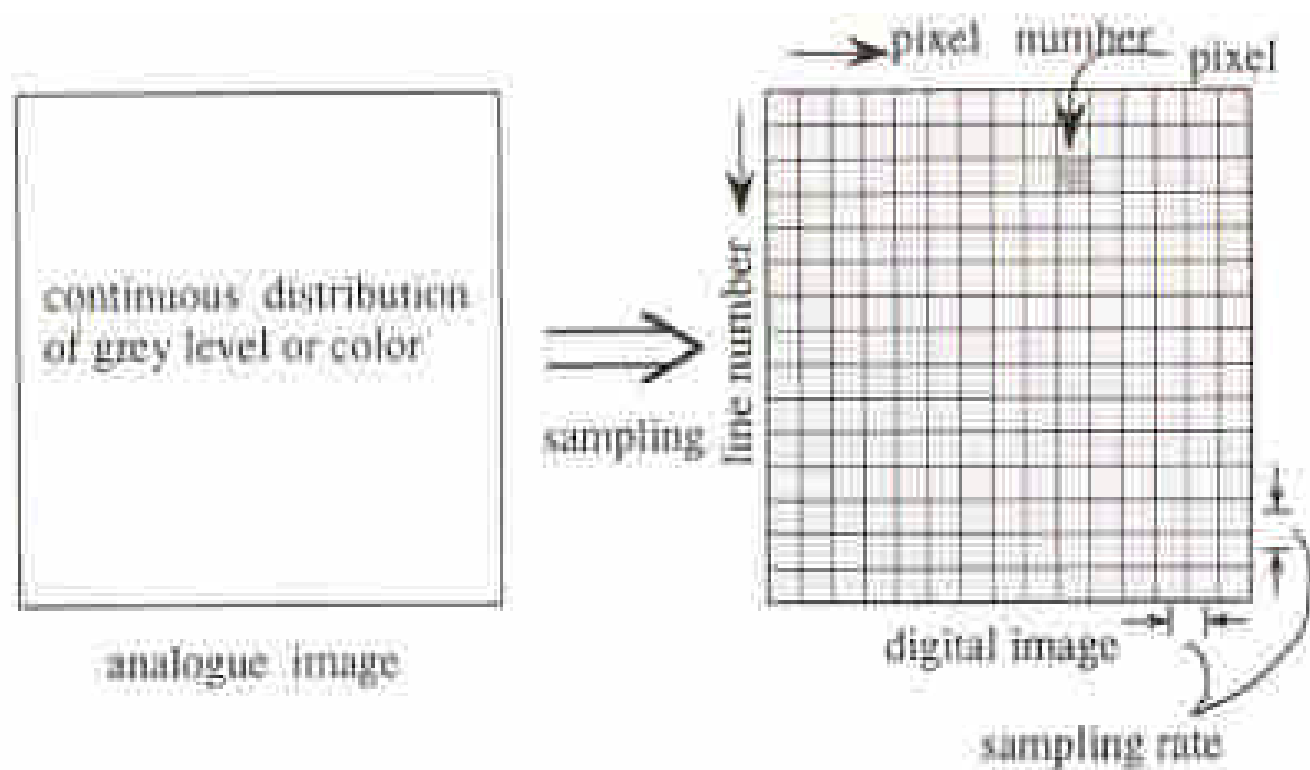


## Digital remote sensing image

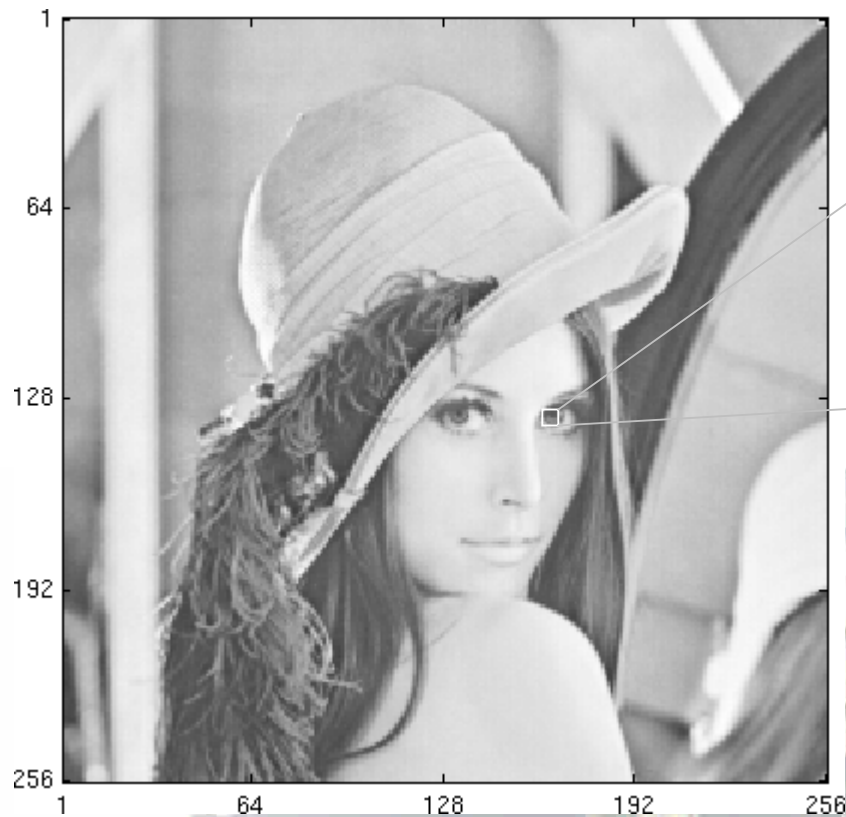
- Radiometric resolution
- Spatial resolution
- Spectral resolution
- Temporal resolution



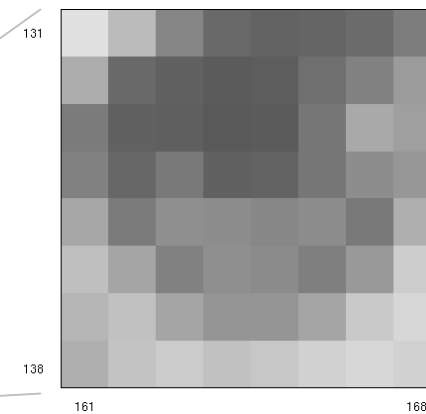
# Digital Image



```
>> load lena.dat
>> image(lena)
>> colormap(gray(256))
```



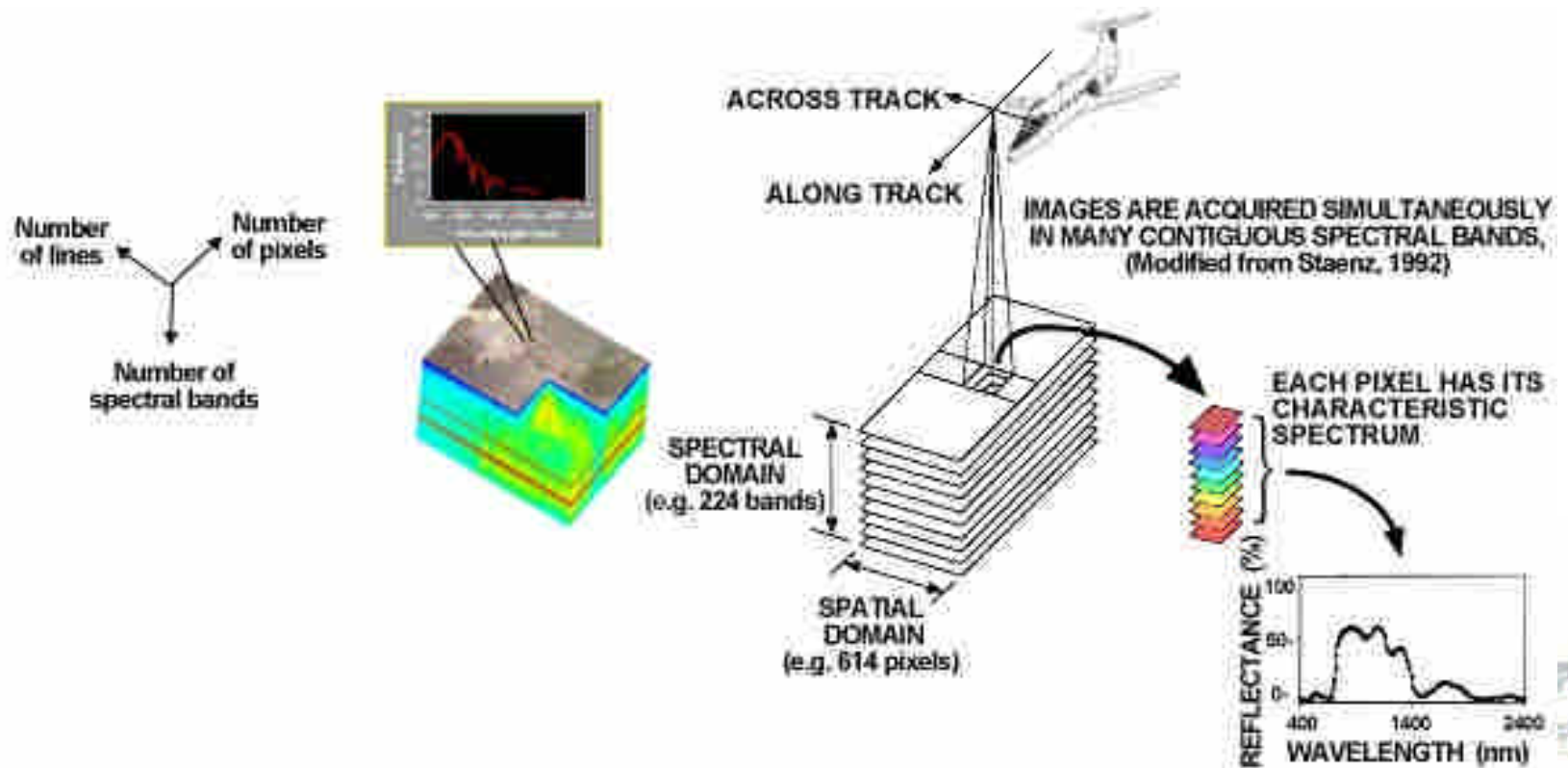
```
>> image(lena(131:138,161:168))
```



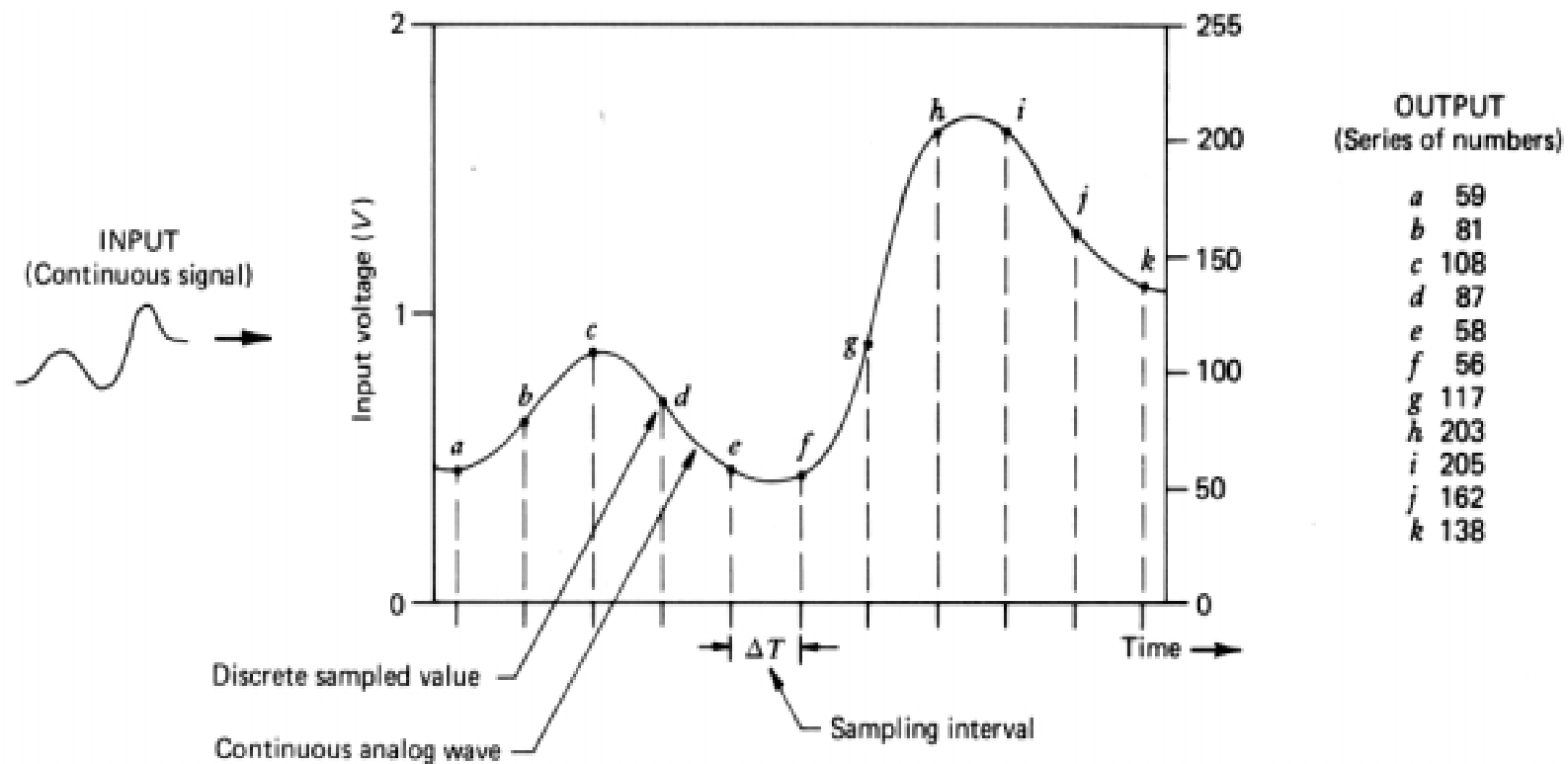
```
>> lena(131:138,161:168)
```

225	187	134	105	100	101	107	126
174	105	97	92	94	112	129	156
124	97	96	89	92	119	170	159
129	103	122	98	100	120	142	152
167	124	143	142	136	142	122	175
191	166	130	143	139	128	154	205
181	194	166	149	149	166	202	215
176	196	203	194	200	209	215	209

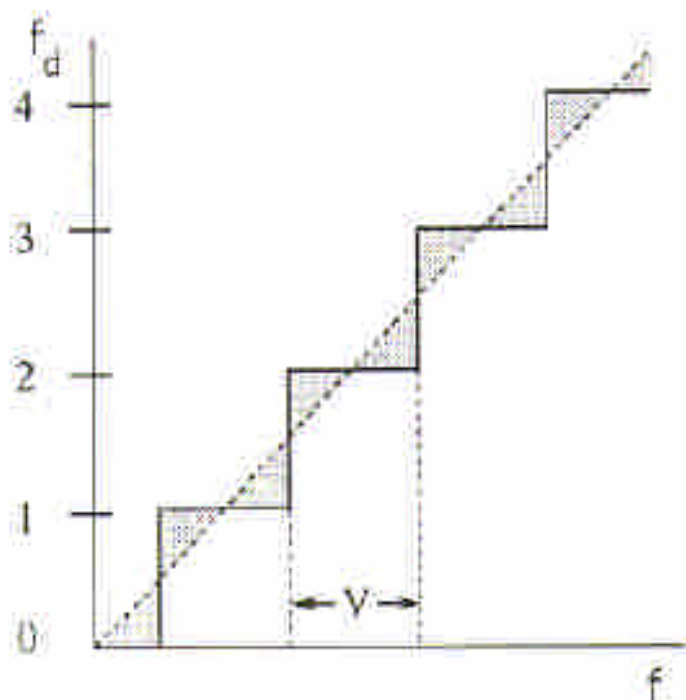
# Digital Remote Sensing Image



# Radiometric Resolution



# Quantization



$f$  : analogue intensity

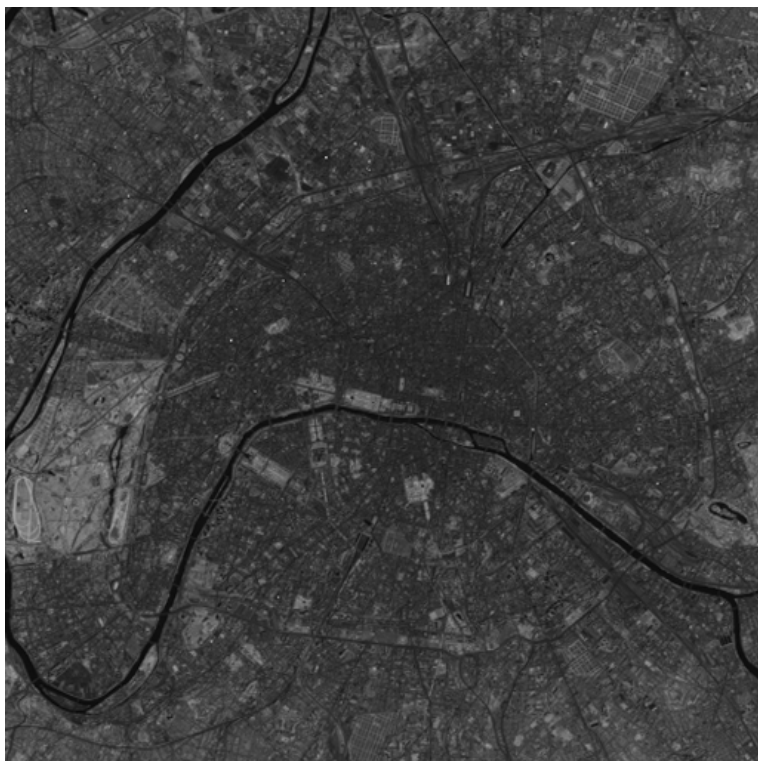
$f_d$  : quantized intensity

$V$  : unit intensity

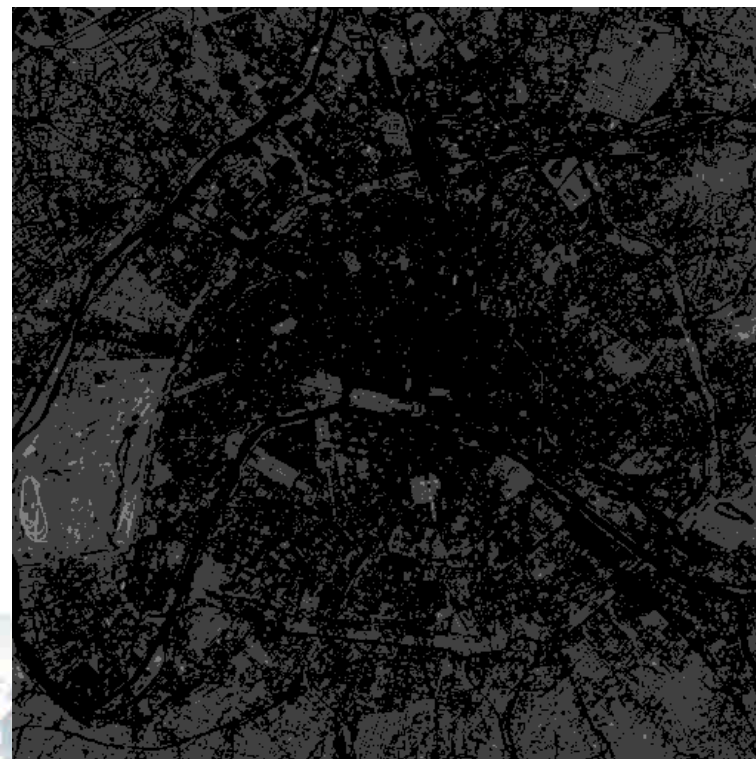
$n$  : integer

$(n-0.5)V \leq f < (n+0.5)V \rightarrow f_d = n$

quatization error =  $f - f_d$  (shaded part)

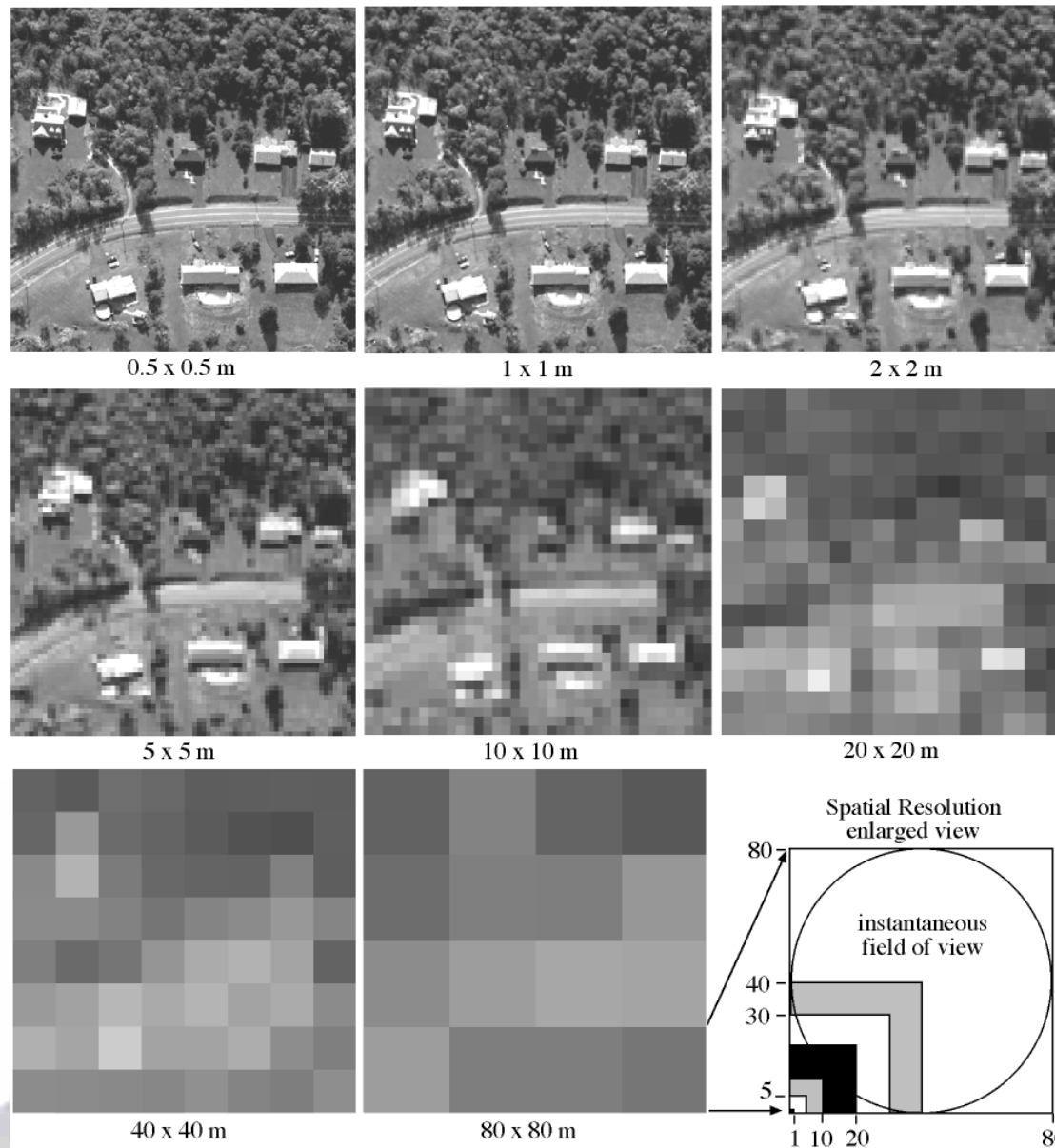


8 bits

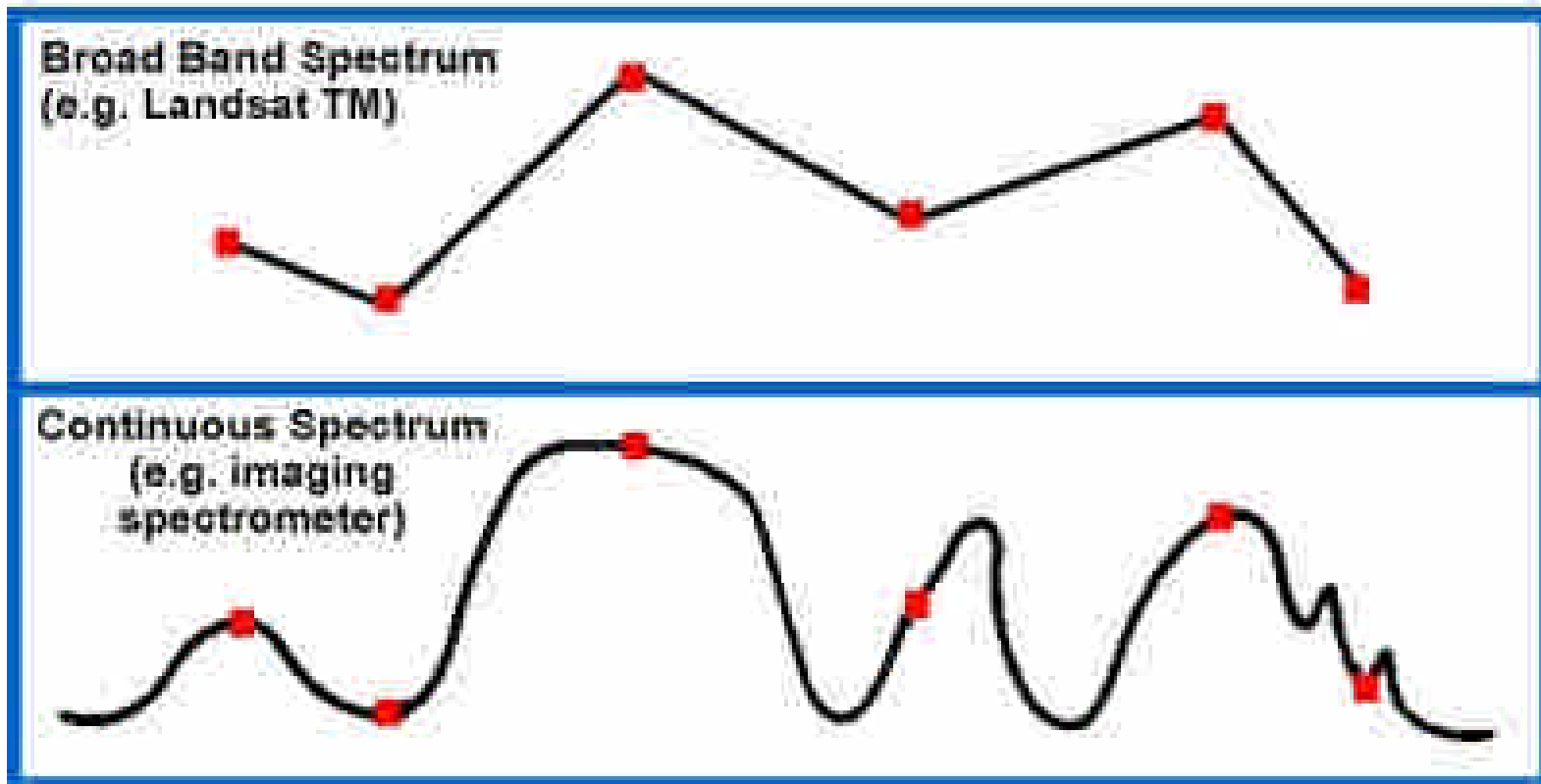


2 bits

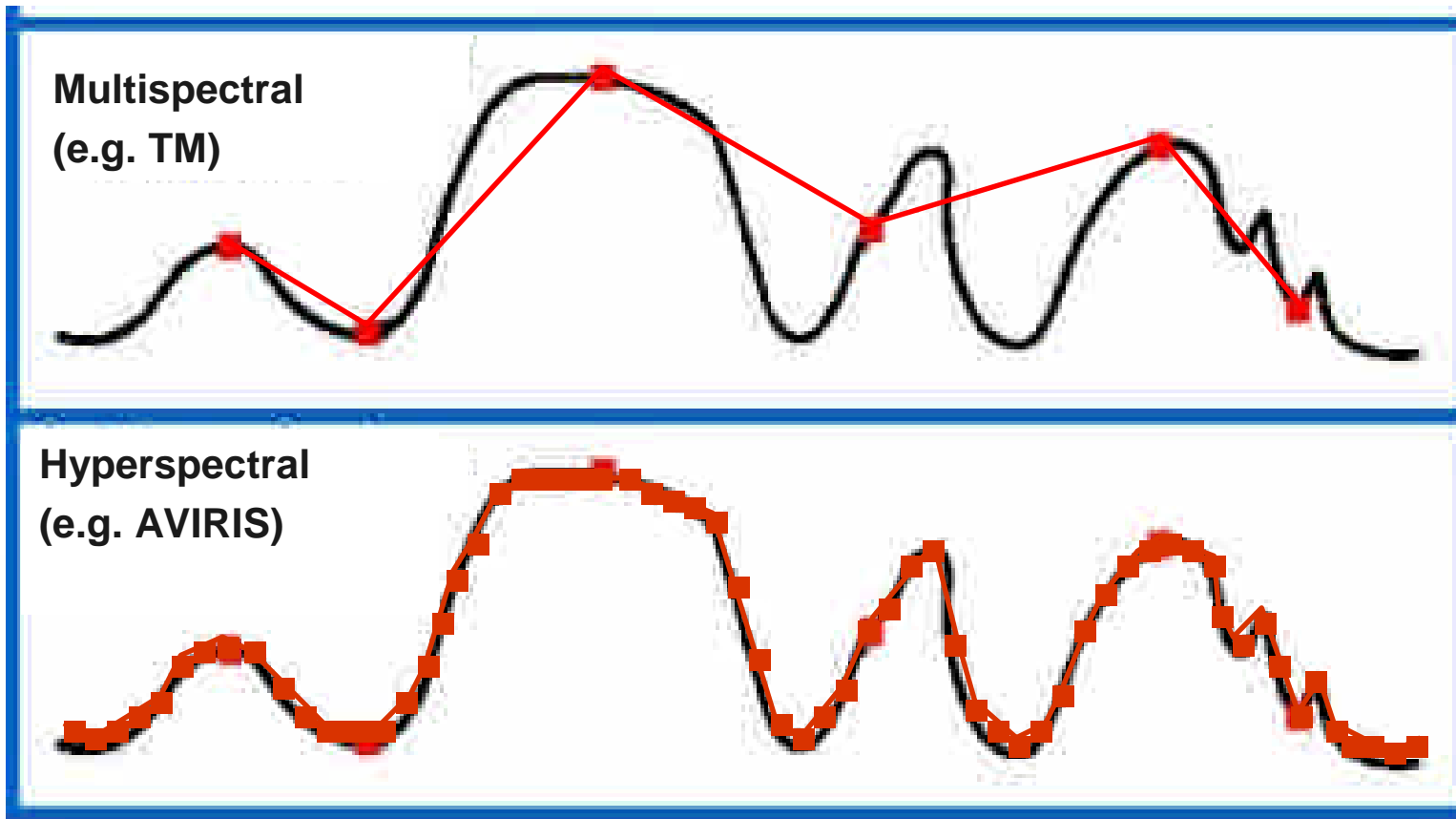
# Spatial Resolution

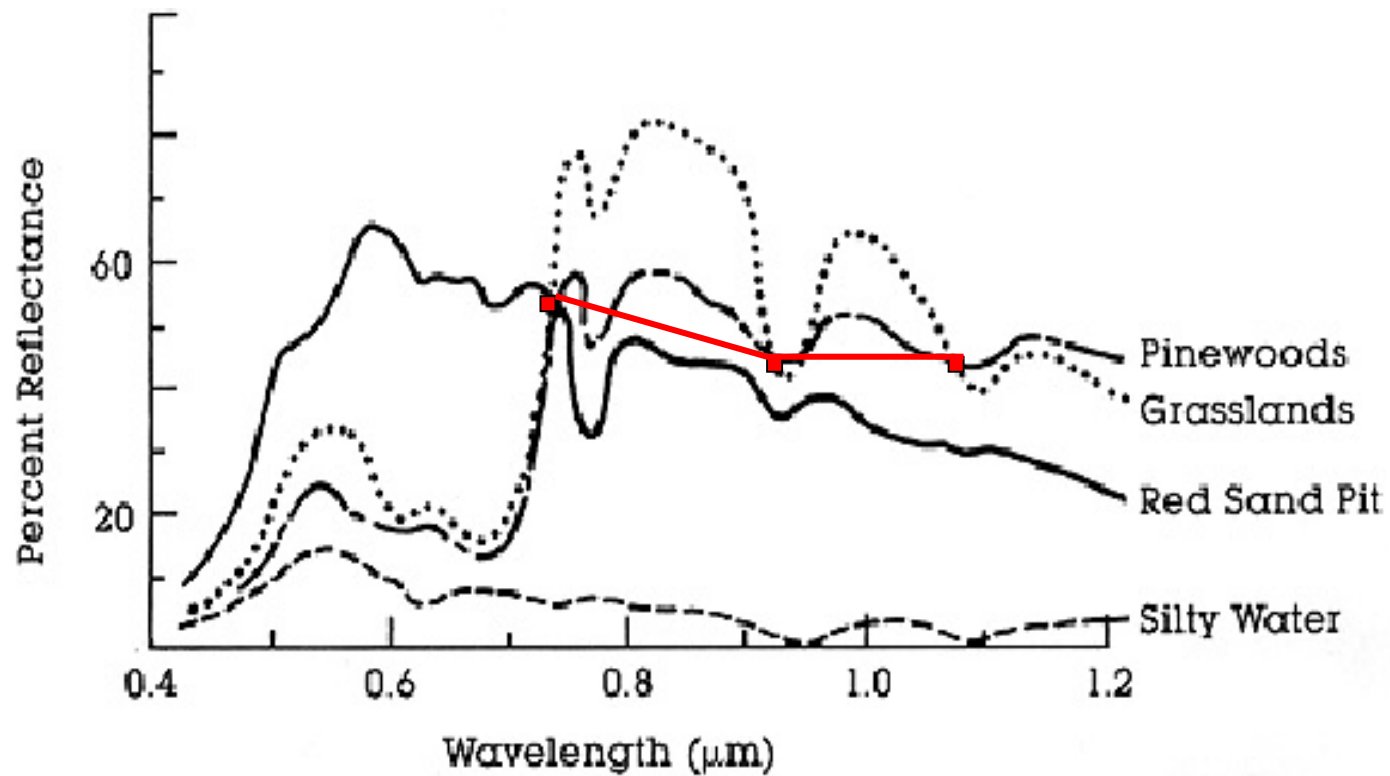


# Spectral Resolution

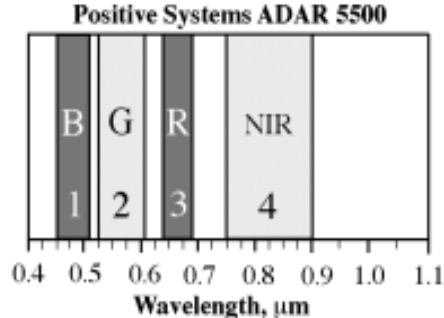
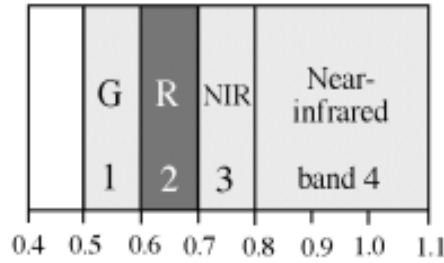


# Multispectral vs Hyperspectral





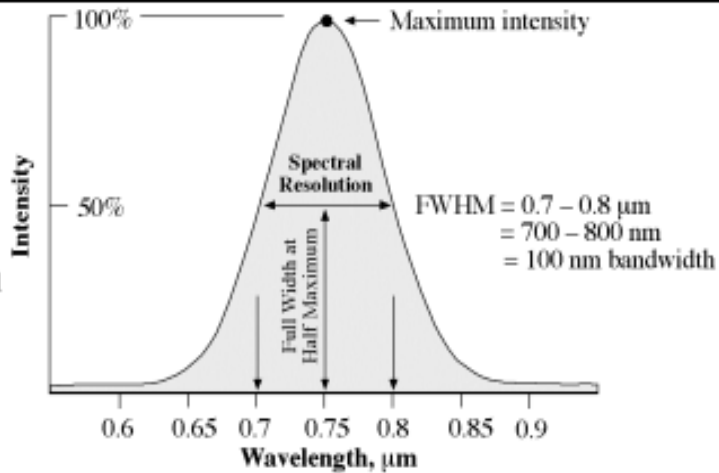
**Landsat Multispectral Scanner (MSS)**



a. Nominal spectral resolution of the Landsat Multispectral Scanner and Positive Systems ADAR 5500 digital frame camera.



c. Single band of ADAR 5500 data



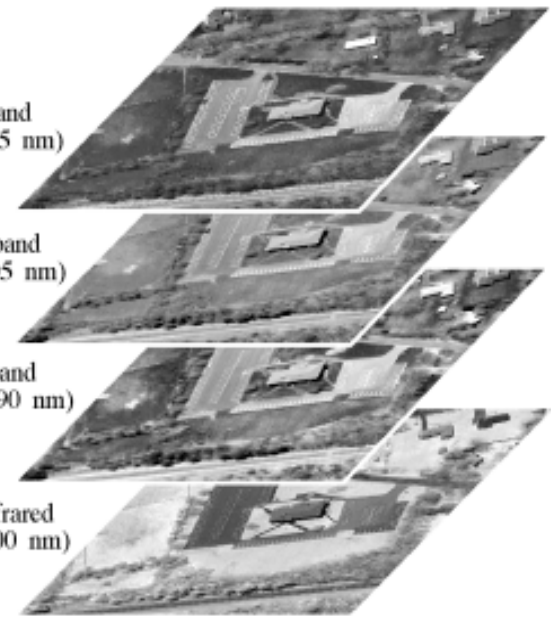
b. Precise bandpass measurement of a detector based on Full Width at Half Maximum (FWHM) criteria

blue band (450 - 515 nm)

green band (525 - 605 nm)

red band (640 - 690 nm)

near-infrared (750 - 900 nm)



d. Multispectral remote sensing



## Temporal Resolution

System	Resolution (day)
Landsat 1, 2, 3	18
Landsat 4, 5	16
AVHRR	1
SPOT	26
MODIS	2

# Data Compression

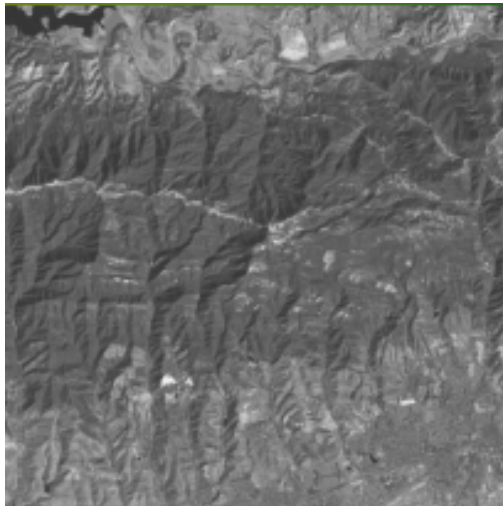
## ■ SPOT5

- XI: XS1, XS2, XS3: 10m
- SWIR: 20m
- PAN: 5m
- 60km x 60km:
  - XI:  $(60000(\text{m})/10(\text{m}))^2 \times 3(\text{band}) = 108 \text{ MB}$
  - SWIR:  $(60000(\text{m})/20(\text{m}))^2 = 9 \text{ MB}$
  - PAN:  $(60000(\text{m})/5(\text{m}))^2 = 144 \text{ MB}$
  - Total: 261 MB

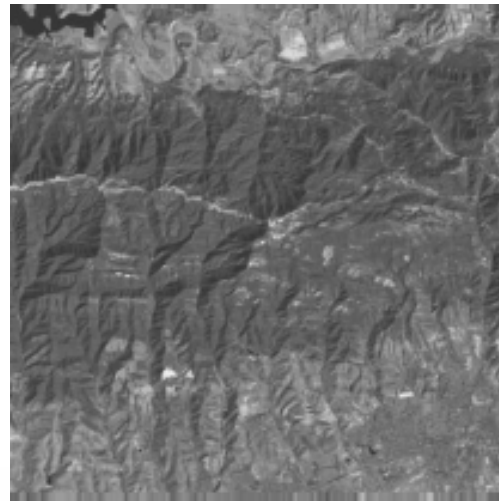
<b>COMPRESSION TYPE</b>
<i>Lossless</i>
<b>Run Length Coding</b>
<b>Huffman Coding</b>
<i>Lossy</i>
<b>Joint Photographic Experts Commission (JPEG) - DCT</b>
<b>Vector Quantization (VQ)</b>



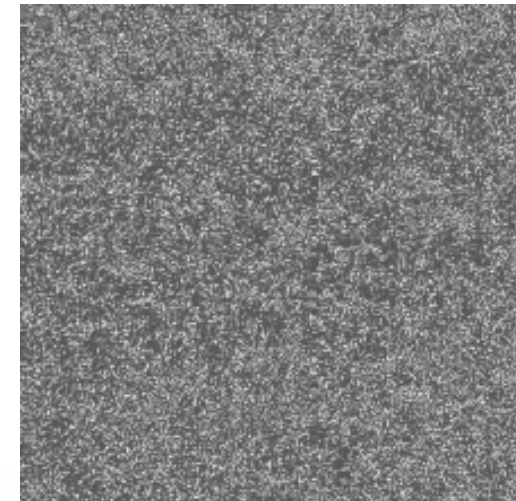
# Vector Quantization



Original



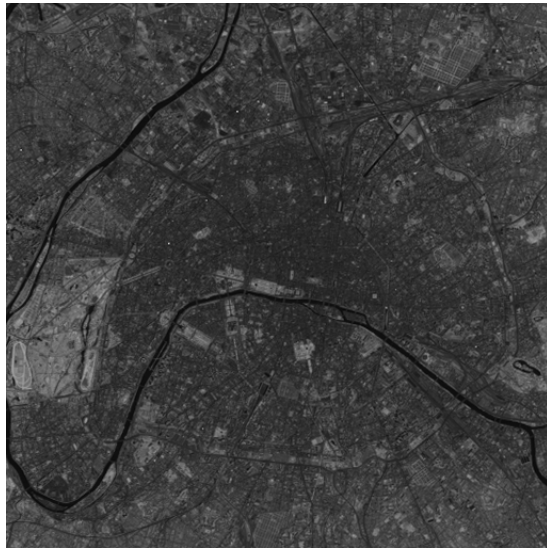
10:1 ratio



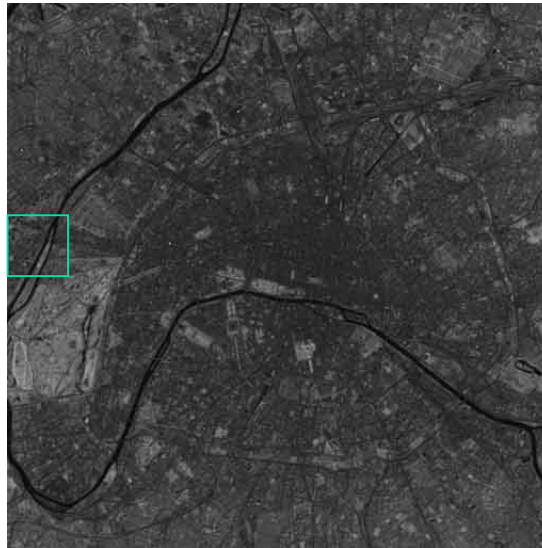
Error



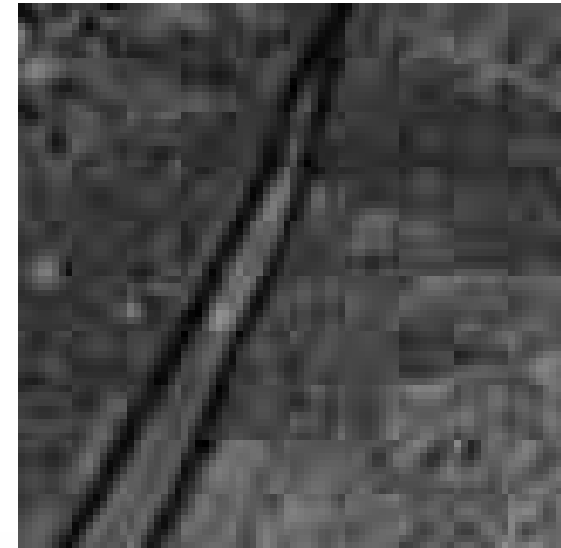
# JPEG



Original



8:1 ratio

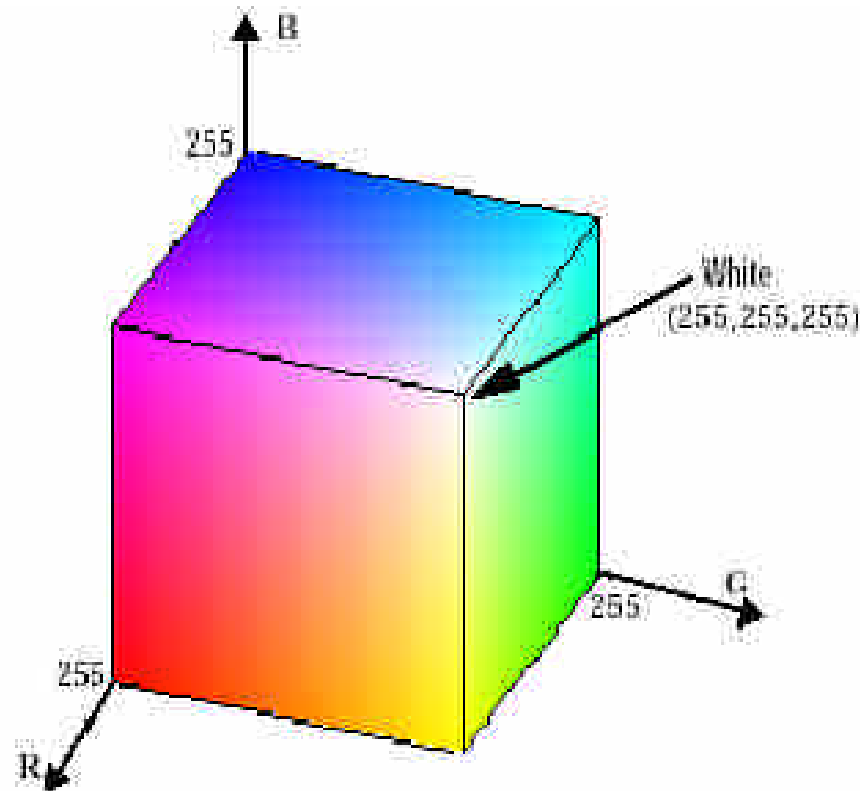


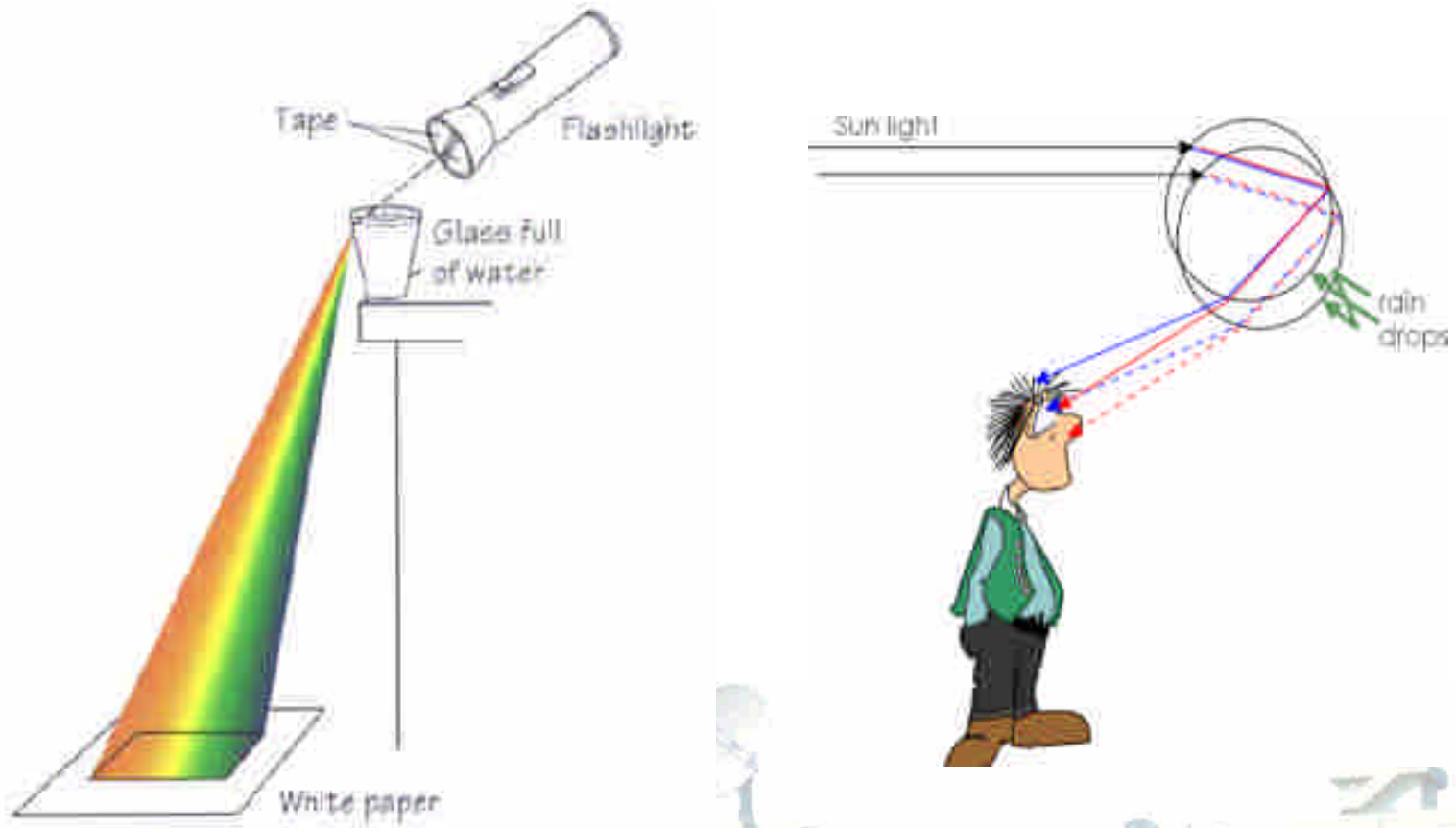
## Image Display

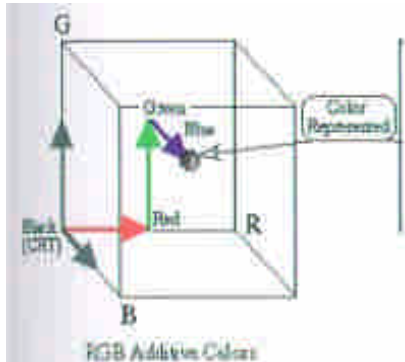
- False color
- Pseudo color
- Color system



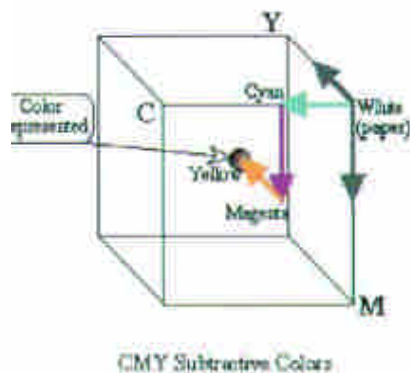
# Color



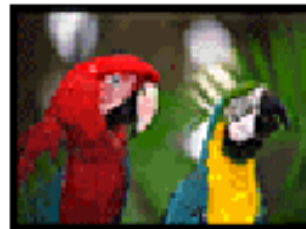
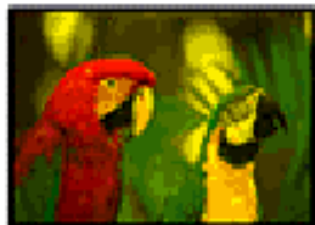




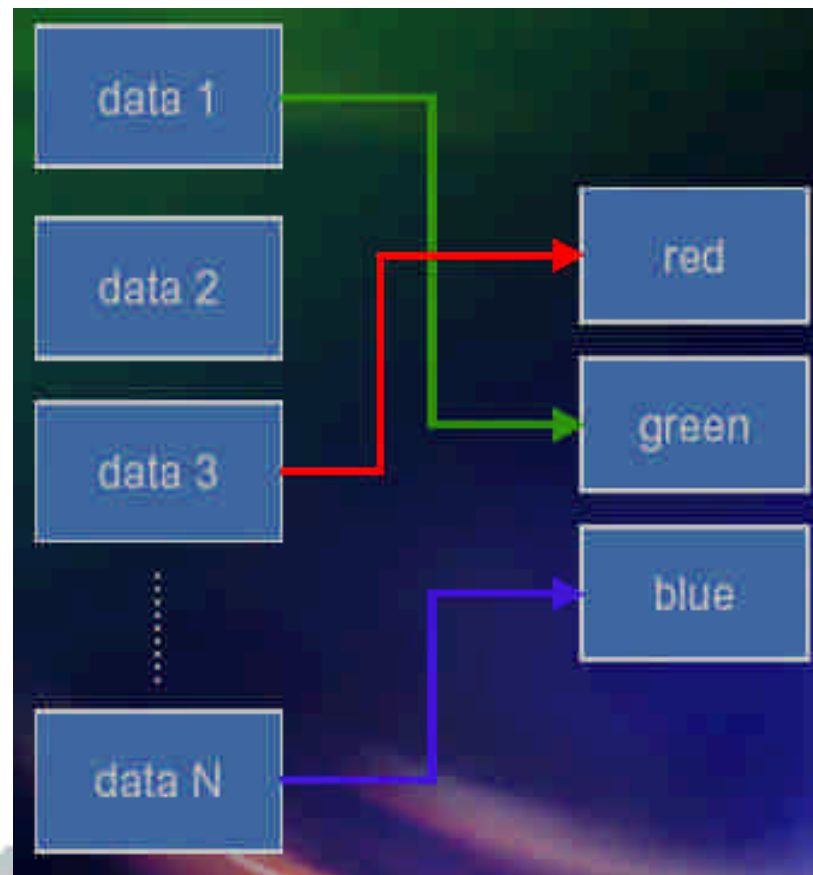
- additive color property.
- primary colors of Red, Green and, Blue (RGB).
- it works for the mixing of primary colors that are emitting light.



- The subtractive colors,
- called secondary colors, are Cyan, Magenta, and Yellow (CMY).
- This procedure is mainly used in the printing industry.



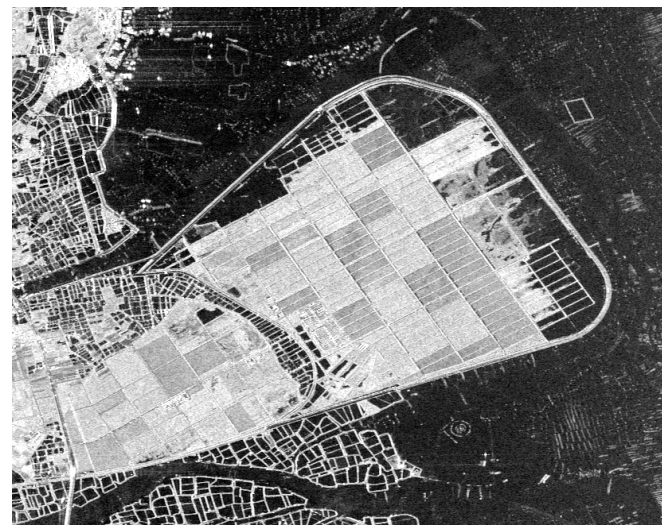
## 假色 (false color)



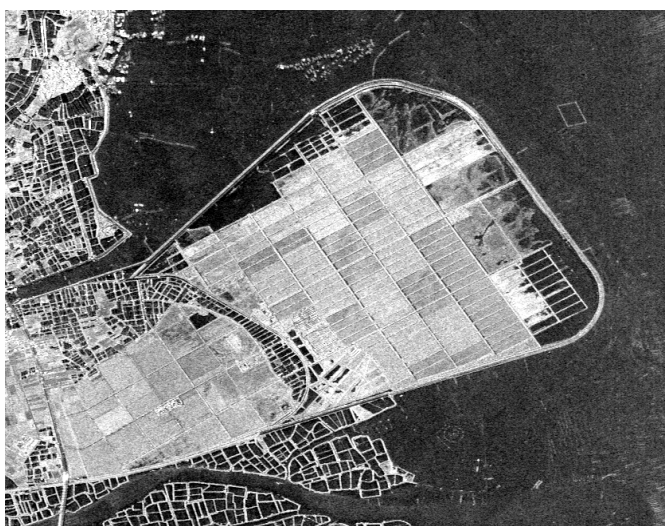
# SAR Image



(a) C-band |HV|



(b) C-band |HH|

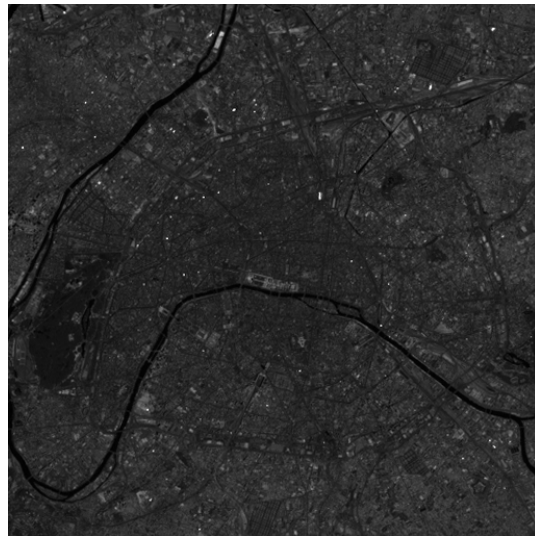


(c) C-band |VV|

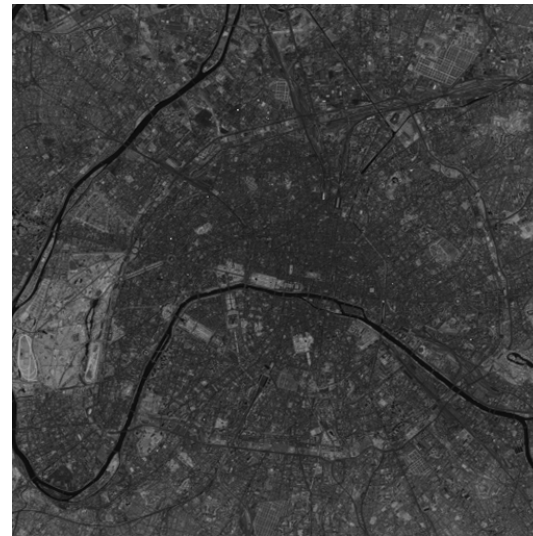


(d) 假色影像 (R: |HV| G: |HH| B: |VV|)

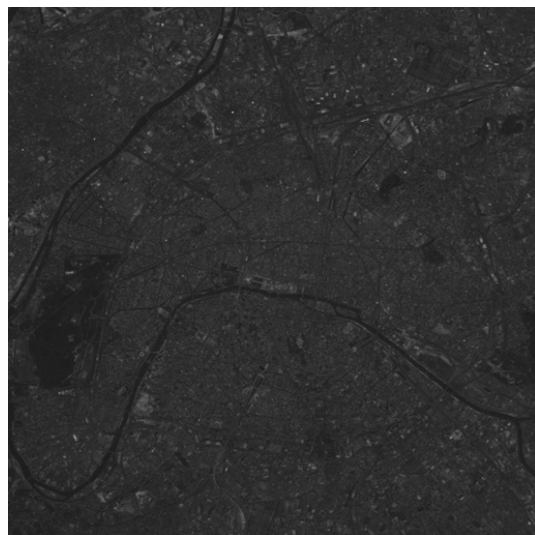
# Landsat Image



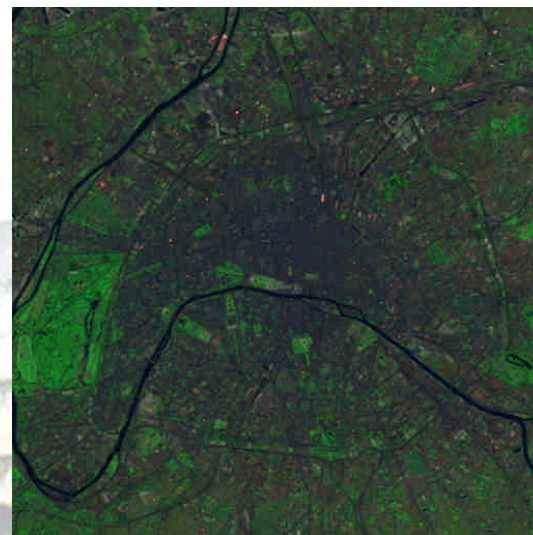
(a) band 7



(b) band 4

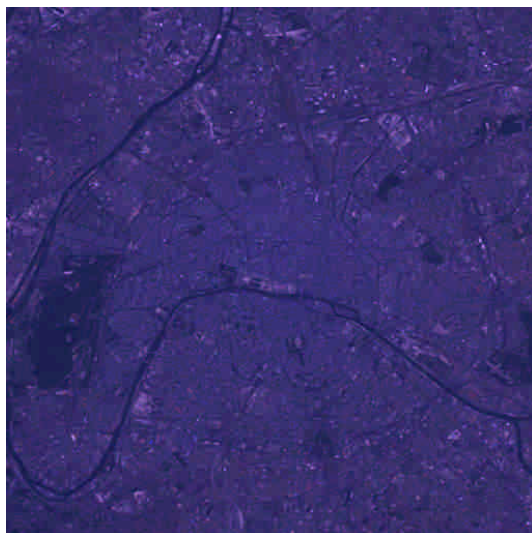


(c) band 2

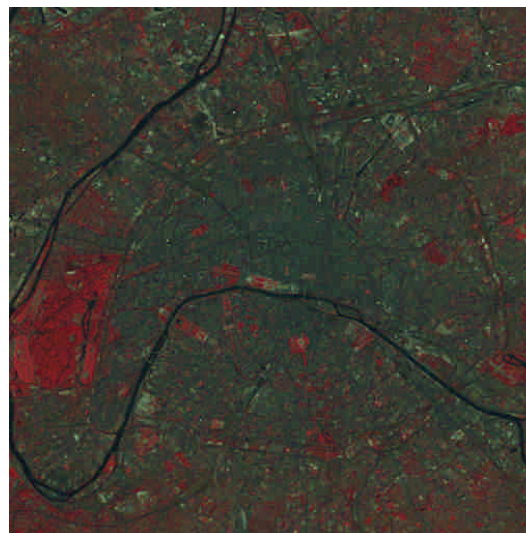


(d) 假色影像 (R: 7 G: 4 B: 2)

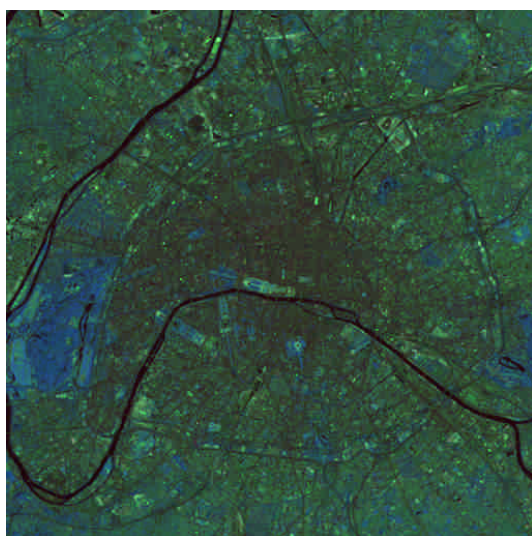
# Landsat (false color)



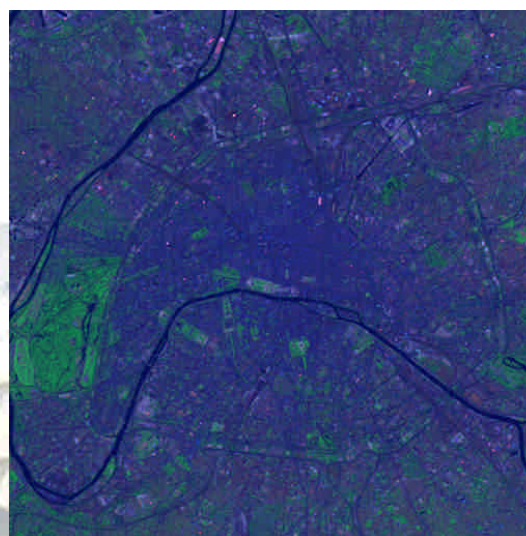
(c) 假色影像 (R: 3 G: 2 B: 1)



(d) 假色影像 (R: 4 G: 3 B: 2)

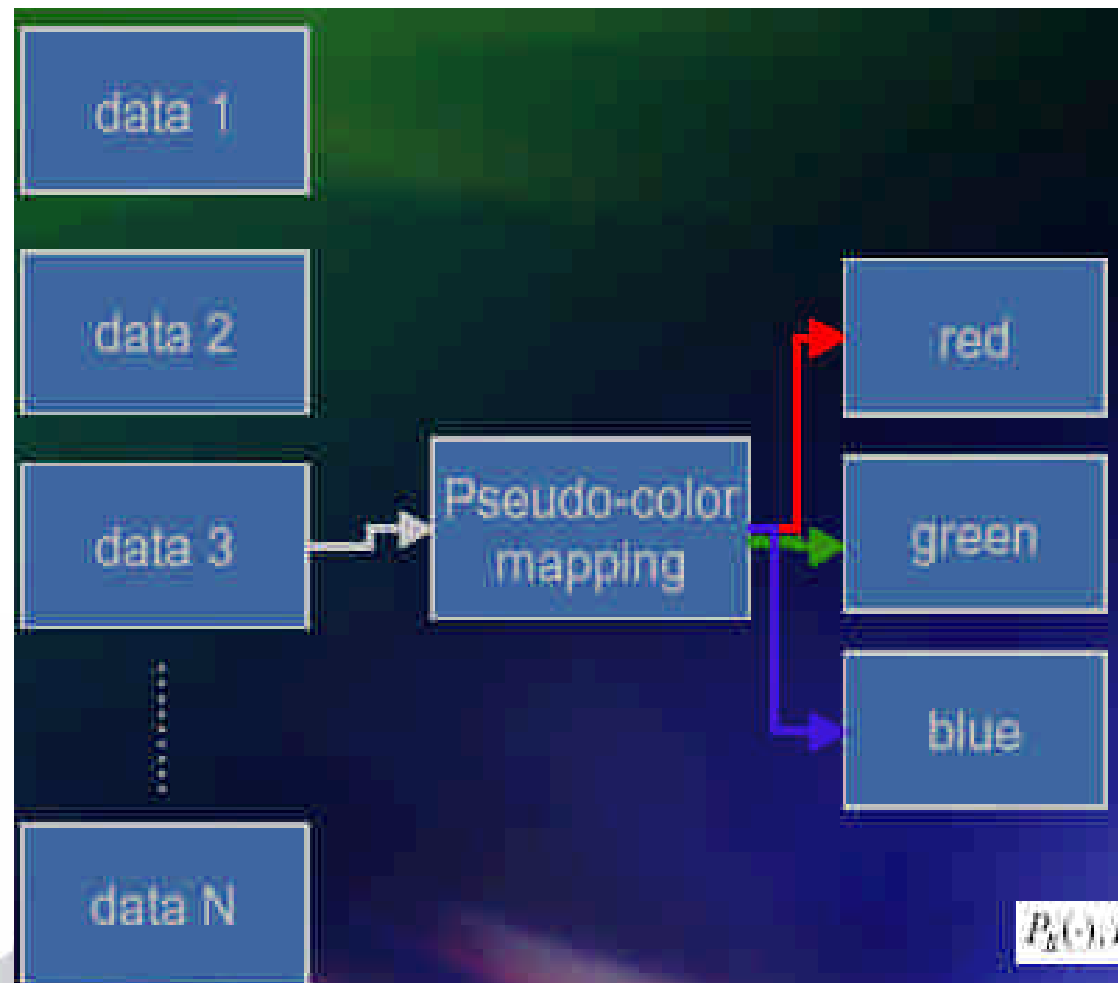


(c) 假色影像 (R: 2 G: 5 B: 4)

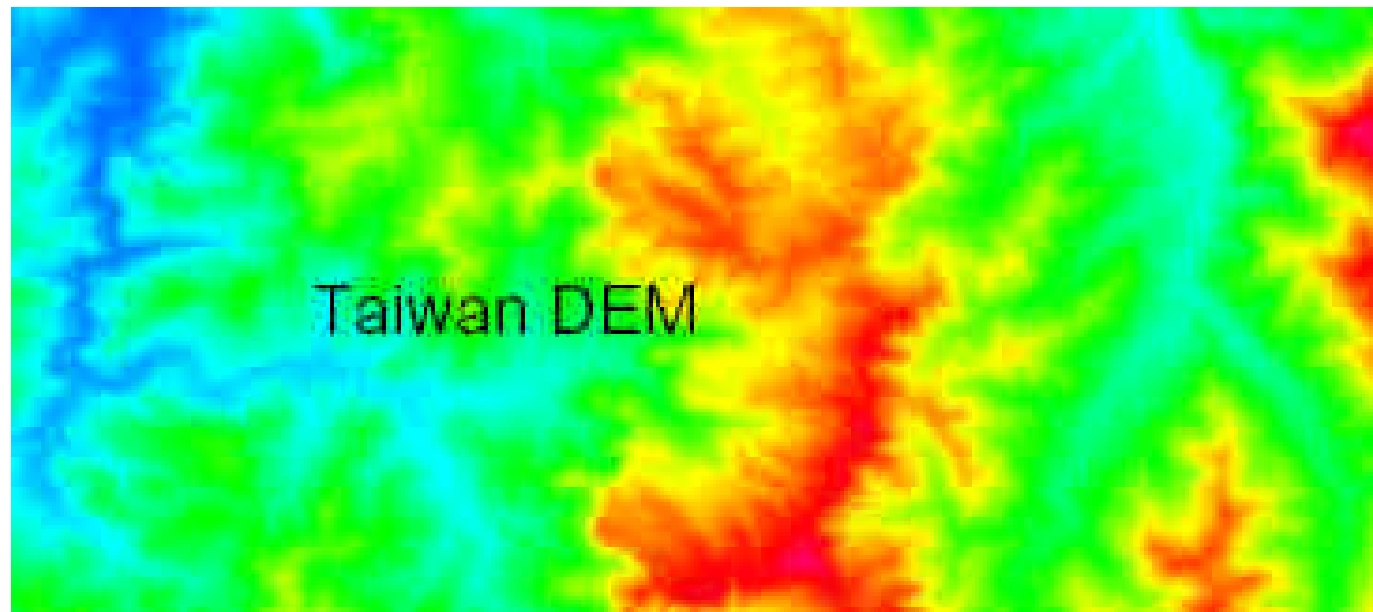


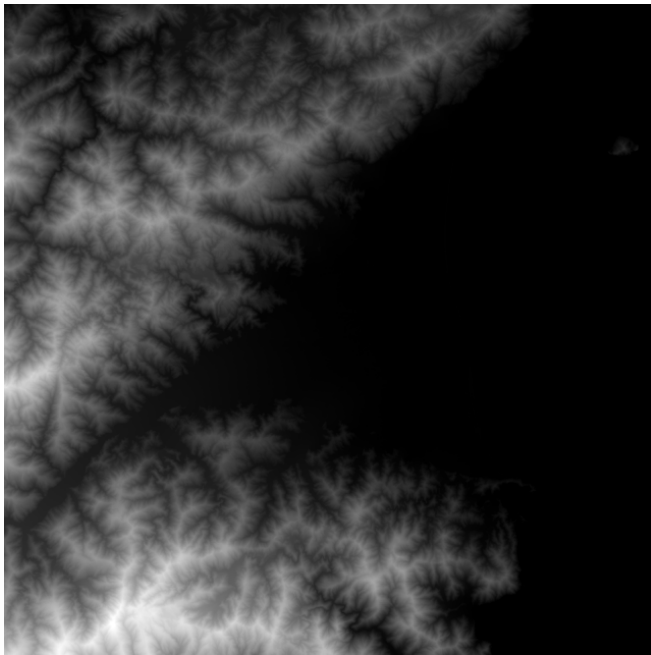
(d) 假色影像 (R: 7 G: 4 B: 1)

# 虛擬色 (Pseudo color)

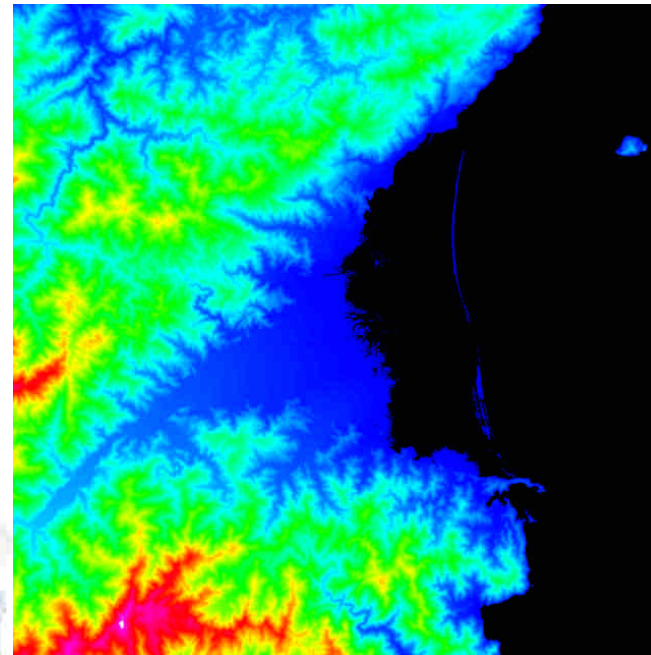


# Digital Elevation Model



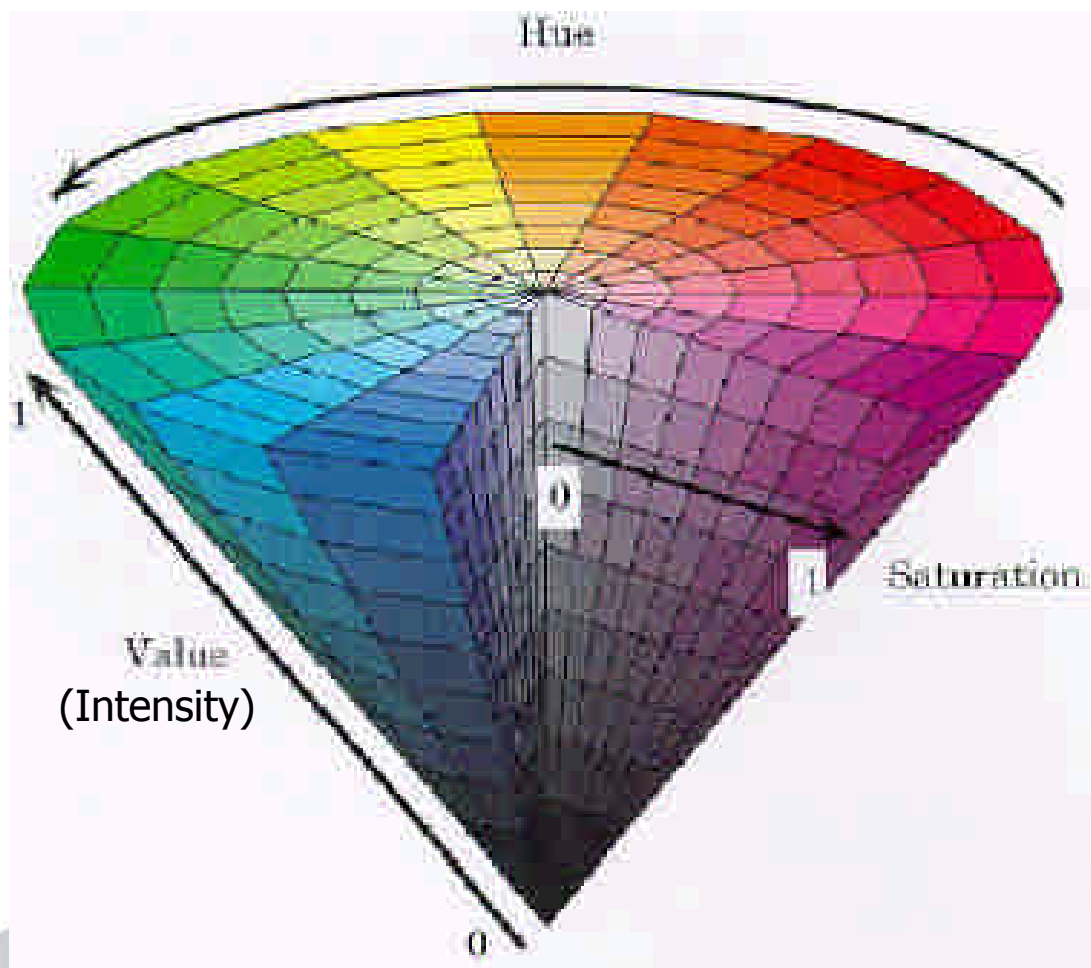


(a) Gray level



(b) Pseudo color

# Hue, Saturation, Value (HSV) (色調, 飽和度, 亮度)





Change in Saturation



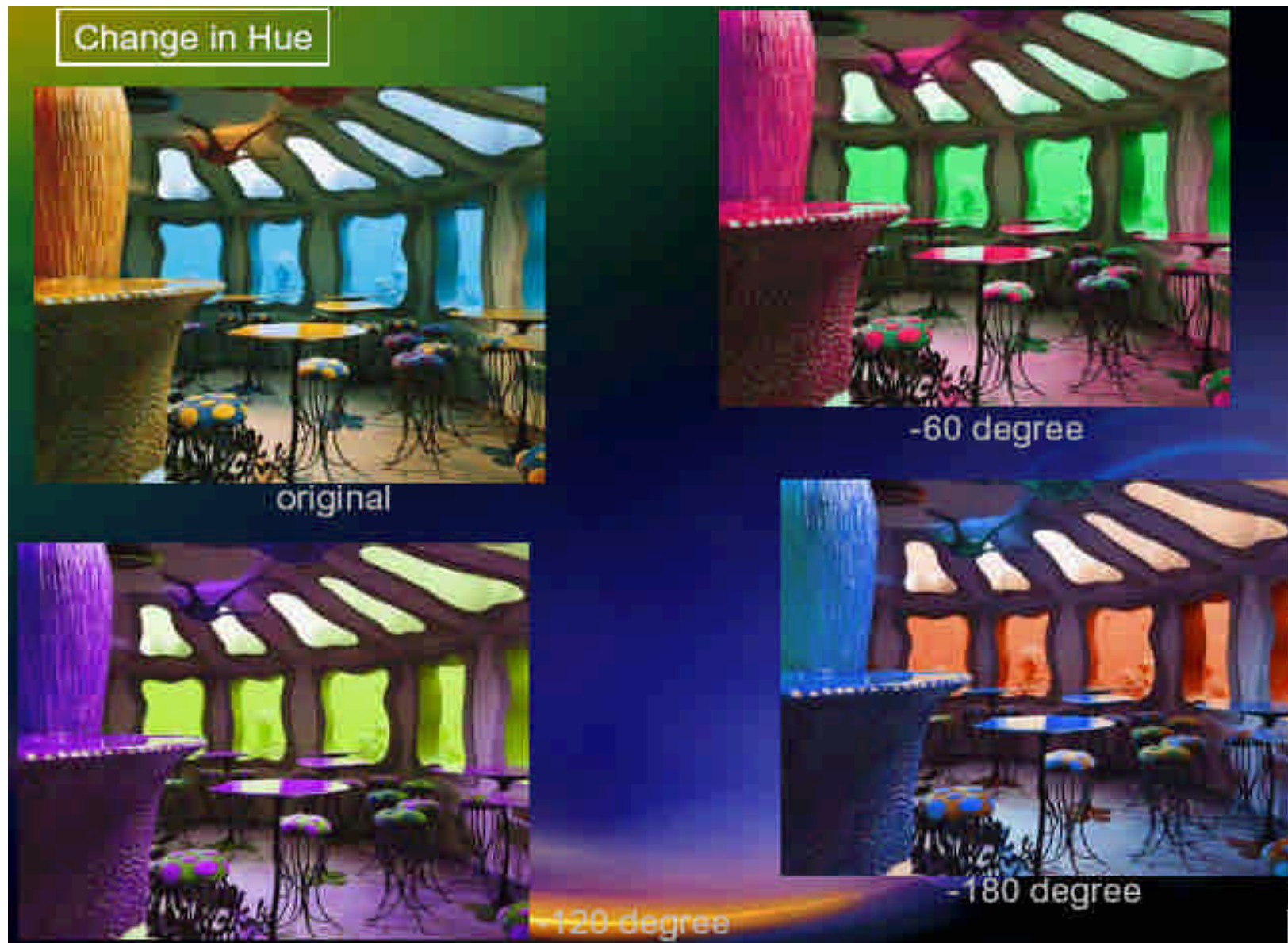
original



40% saturation



160% saturation



## Other Color System

- YIQ:
  - TV
- YUV:
  - PAL and Digital Video
- CMY:
  - Printer



# Color System Conversion

## ■ RGB to CMY

- $C = W - R$
- $M = W - G$
- $Y = W - B$

## ■ RGB to YIQ

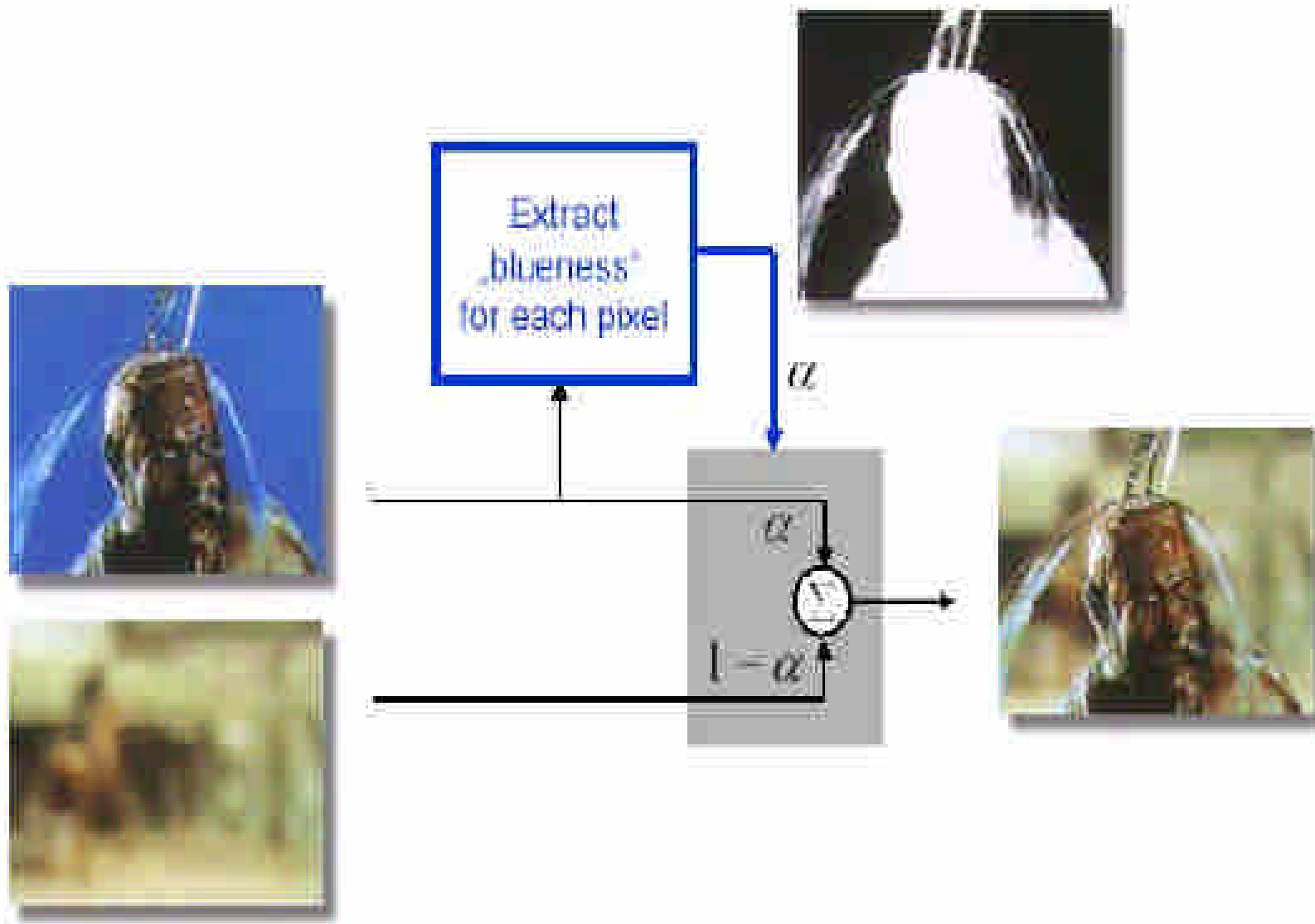
- $Y = 0.299R + 0.587G + 0.114B$
- $I = 0.596R - 0.274G - 0.322B$
- $Q = 0.211R - 0.523G + 0.312B$

## ■ RGB to HSI

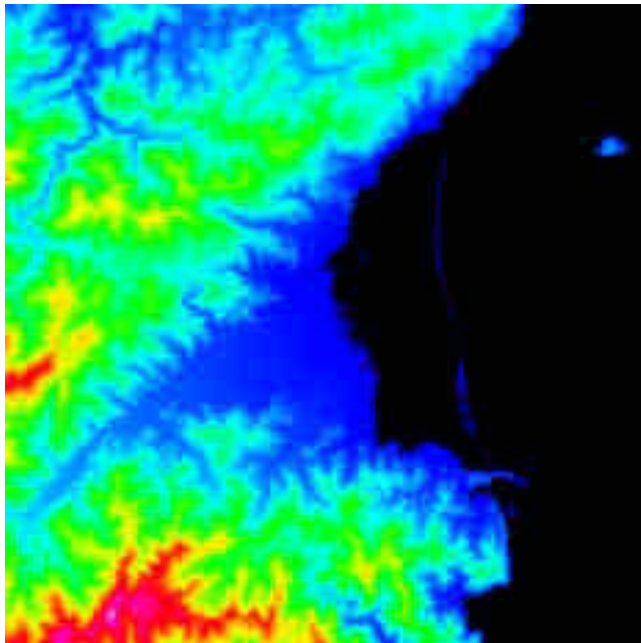
- $H = (90 - \arctan(F/1.71) + C) / 360$ , with  $F = (2R - G - B)/(G - B)$   
and  $C = 0$  if  $G > B$ , or  $C = 180$ , if  $G < B$
- $S = 1 - \min(R, G, B) / V$ ,
- $I = (R + G + B) / 3$ .

## ■ RGB to YUV

- $Y = 0.299R + 0.587G + 0.114B$ , Intensity, Luminance
- $U = 0.493 ( B - Y )$ ,
- $V = 0.877 ( R - Y )$ , Color Differences, Chrominance



# 3-D Model

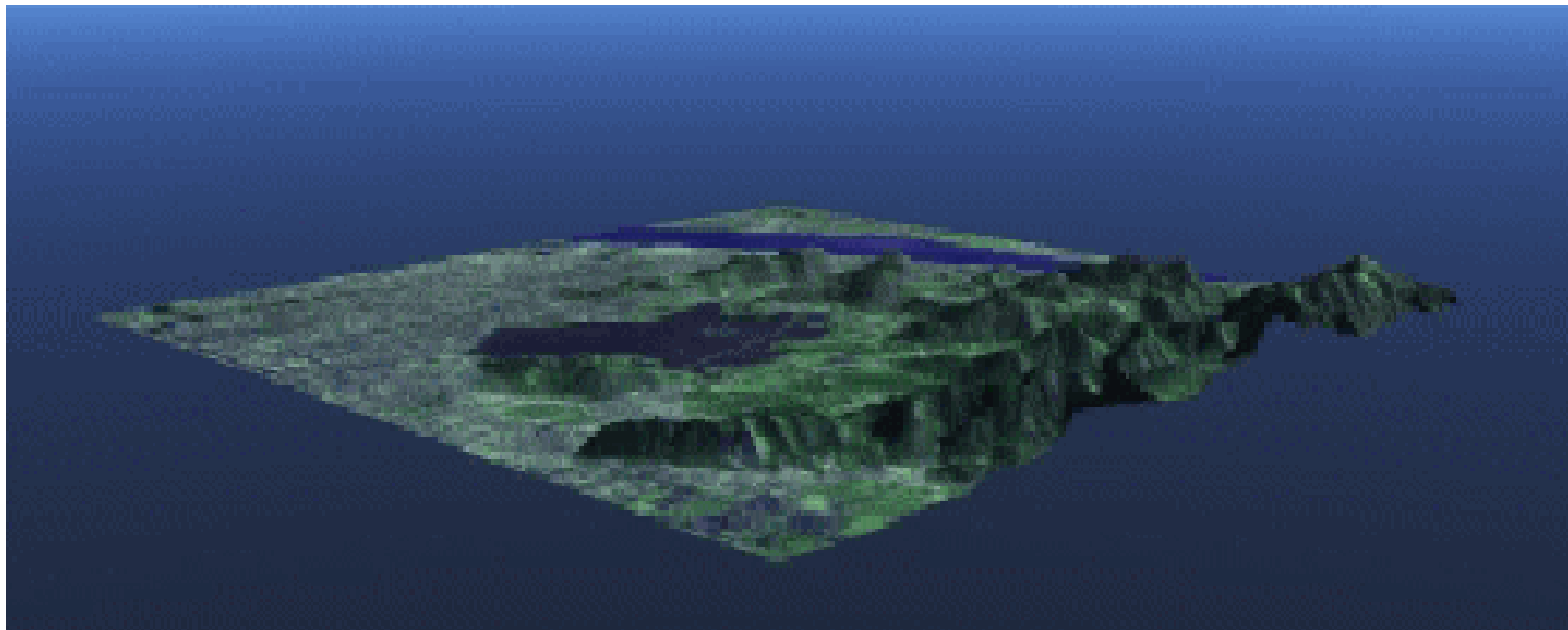


DEM



False color

## 3-D立體模型



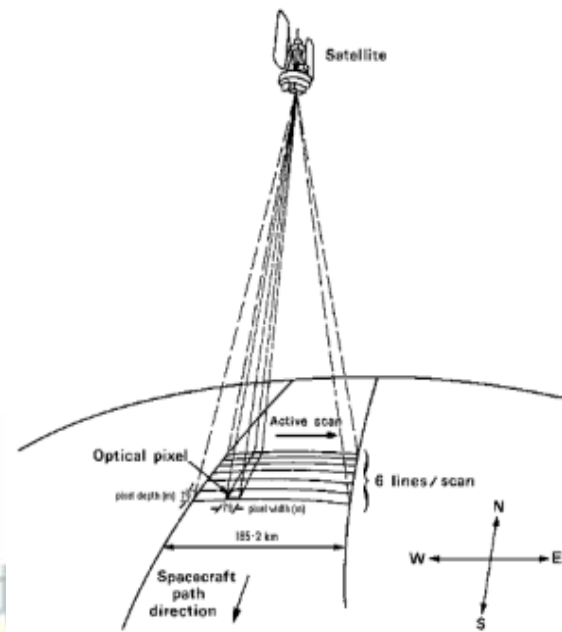
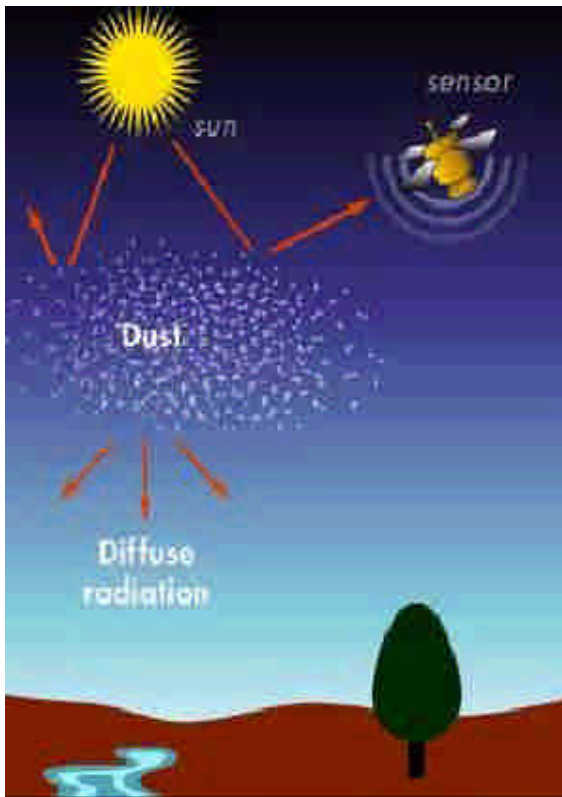
Pattern Computing Laboratory, Center for Space and Remote Sensing Research, NCU.

# Atmosphere and Geographic Effect

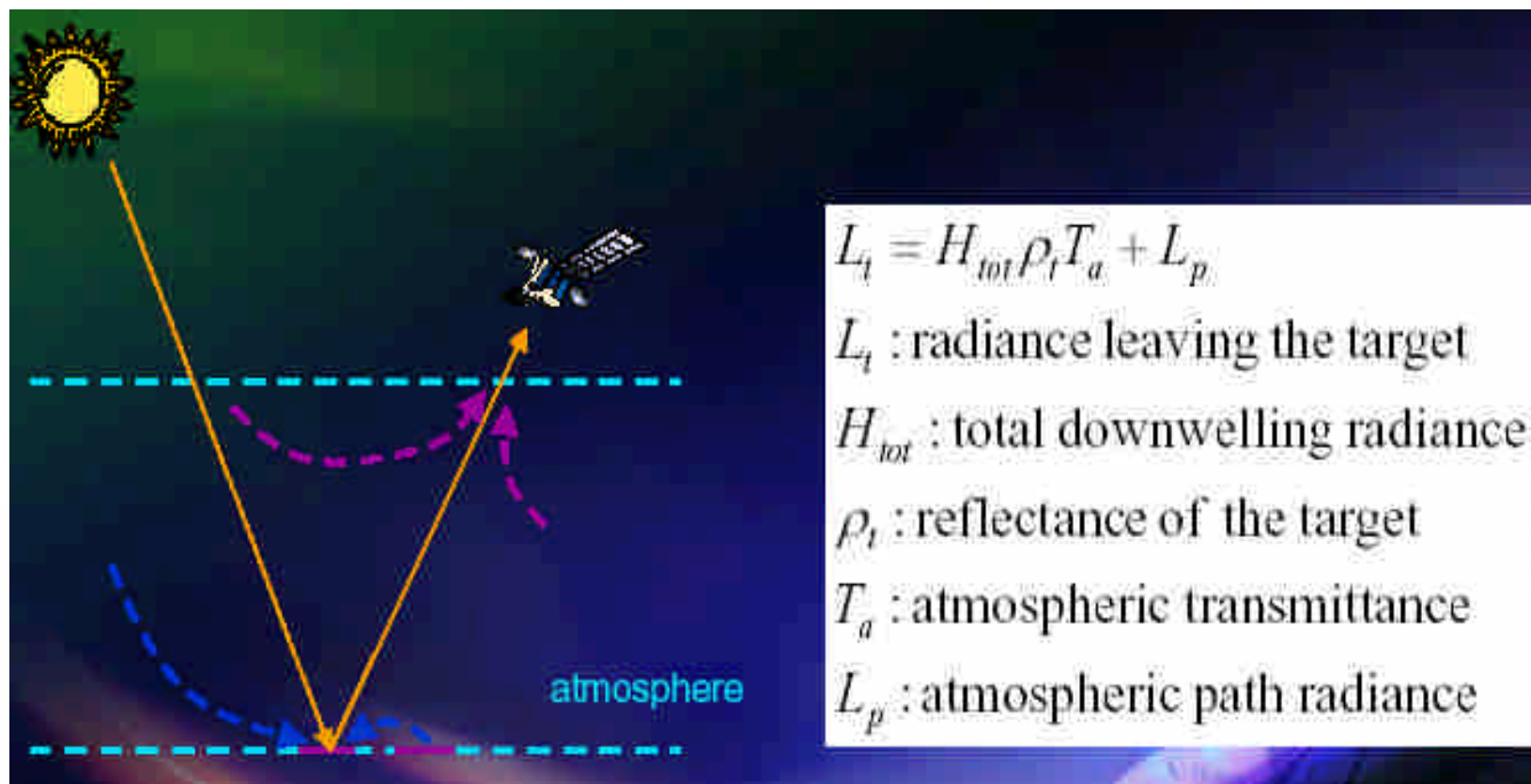


Pattern Computing Laboratory, Center for Space and Remote Sensing Research, NCU.

# Atmosphere and Geographic Effect

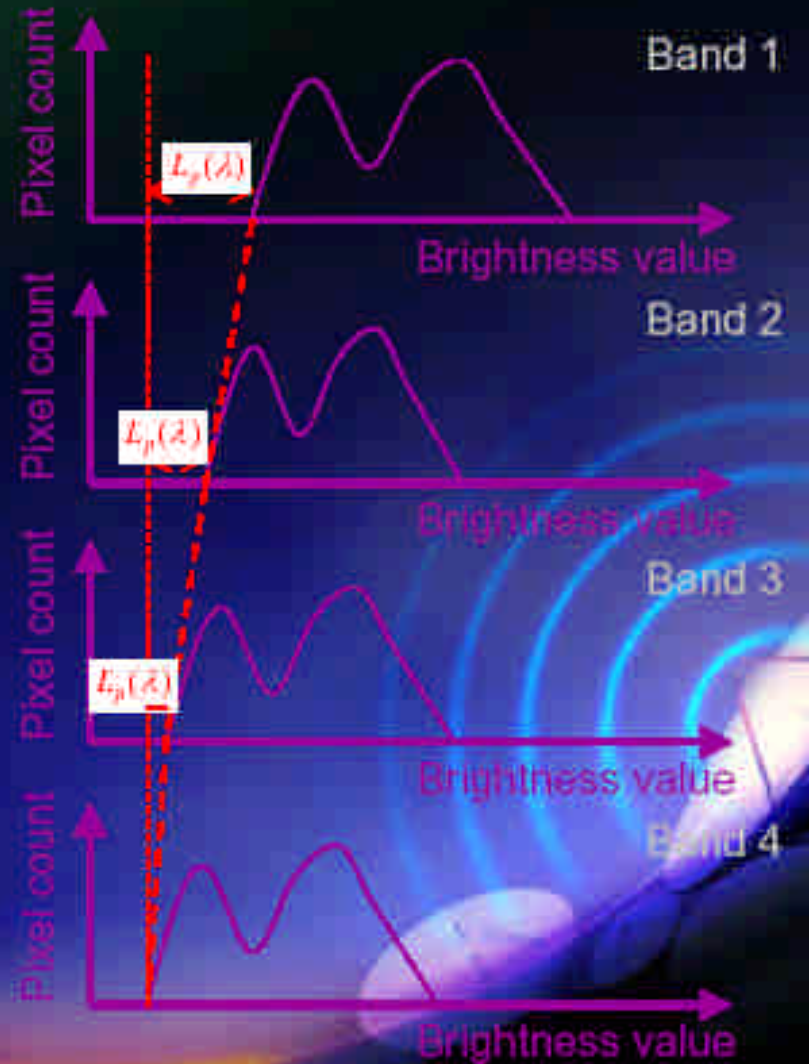


# Atmosphere Effect



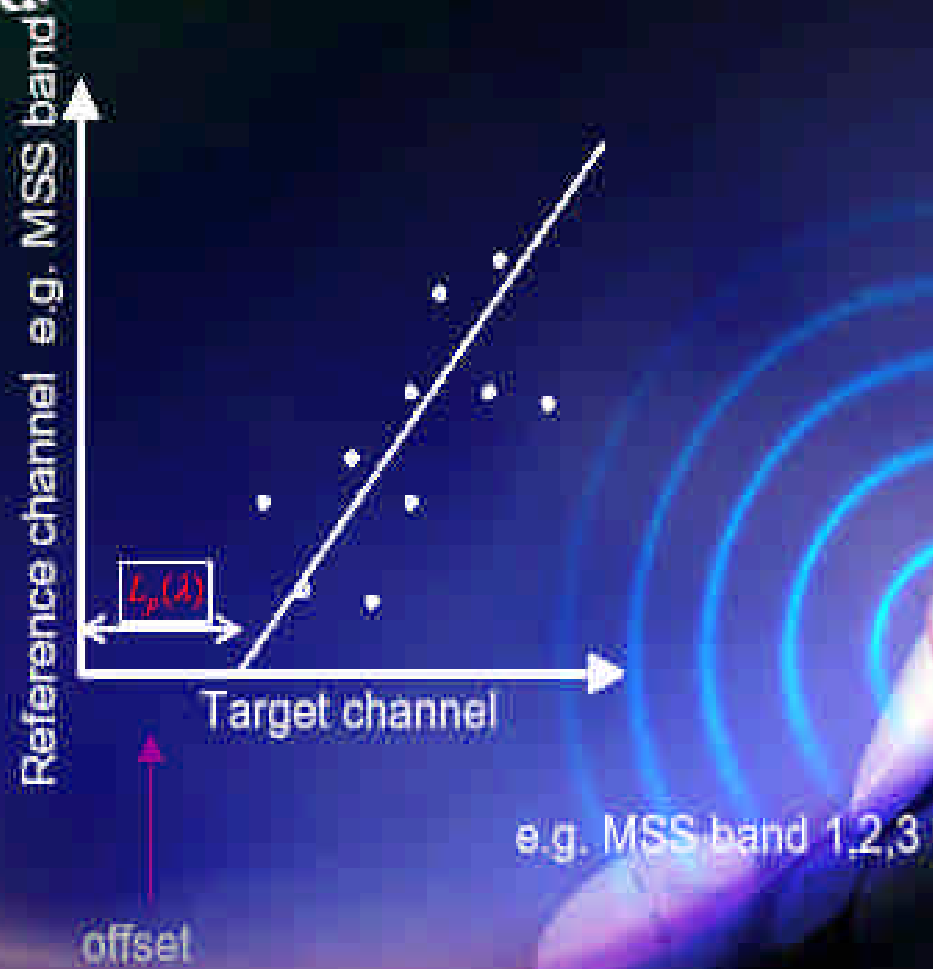
@ Bulk Correction  
(Histogram minimum method)

$$L_t = H_{tot} \rho_t T_a + L_p$$



## Regression method

$$L_v = H_{101} \rho_v T_a + L_p$$

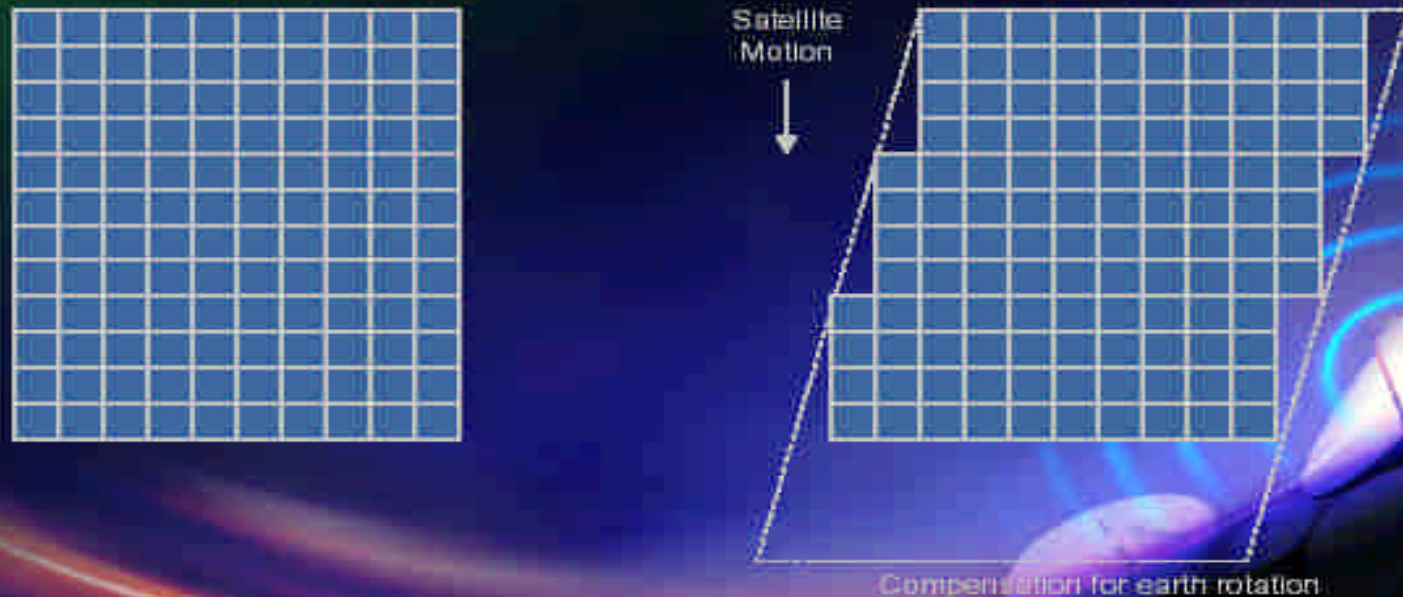


## Sources of Geometric Error

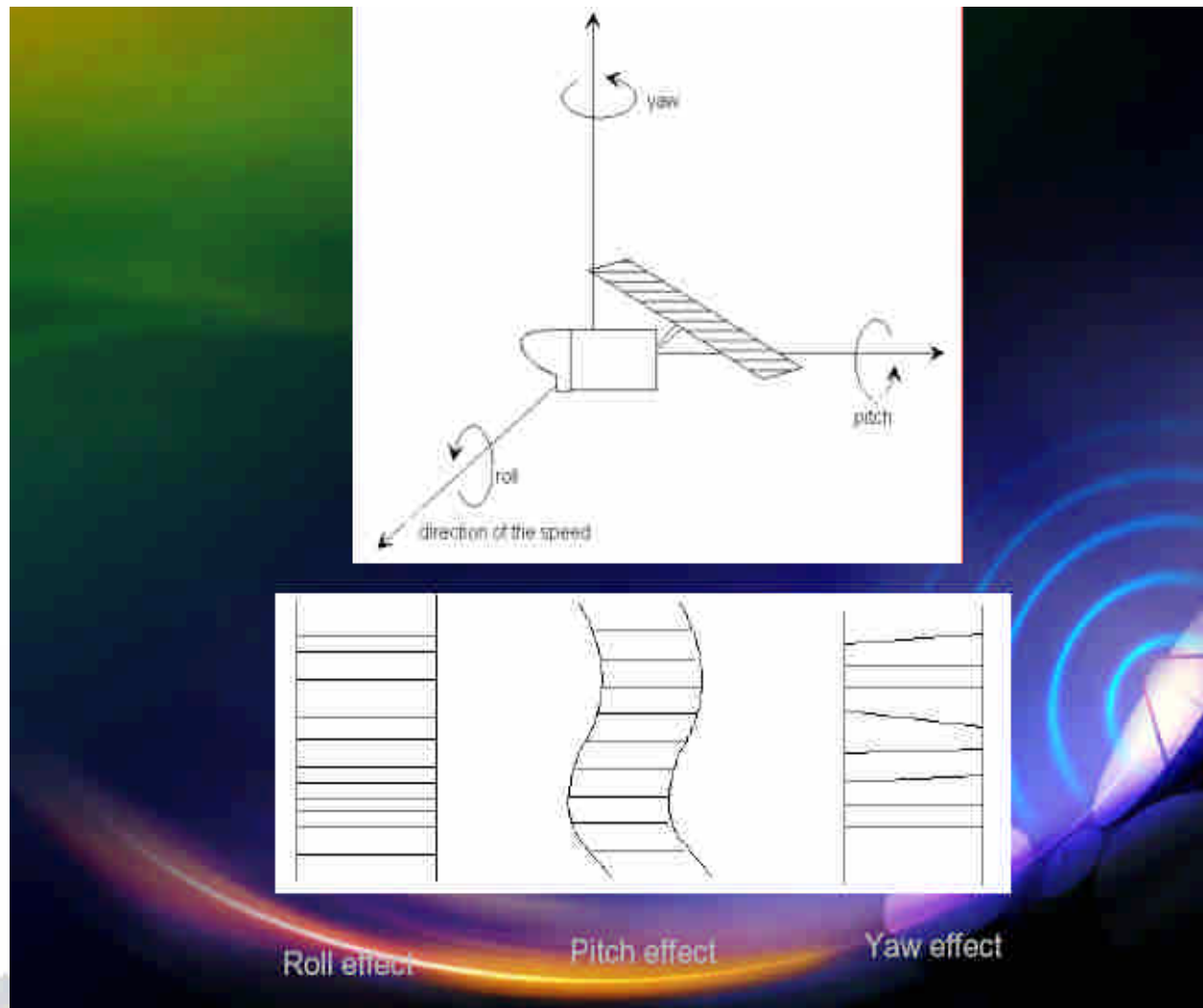
- Instrument error
  - Distortion of optical system
  - Non-linearity of the scanning mechanism
  - Non-uniform sampling rates
- Panoramic distortion
  - Difference of angular FOV among sensors
- Earth rotation
- Earth curvature
- Platform instability

# Sources of Geometric Error

## @ Earth Rotation Effect



# Platform Instability



# Geometric Corrections

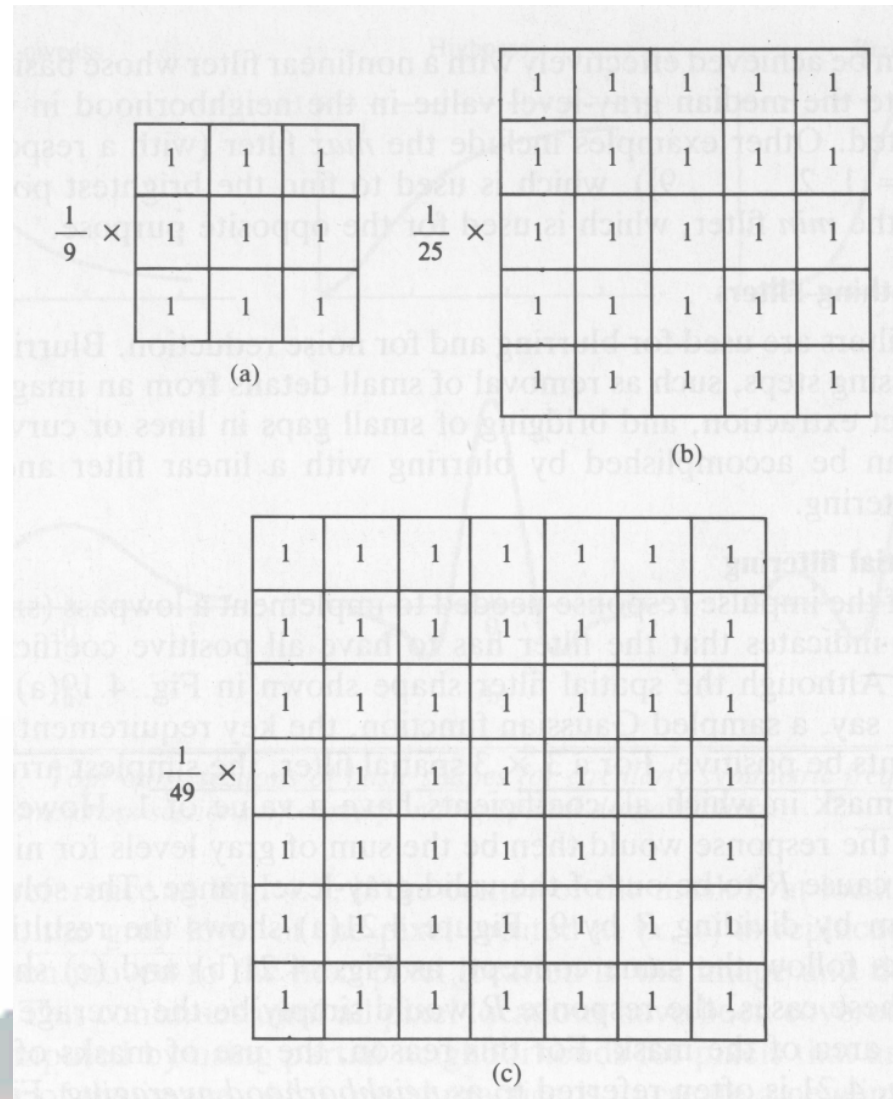
- Transform an Image to match a Map projection
- Locate points of interest on Map and Image
- Bring adjacent Images into registration
- Overlay temporal sequences of image of the same area, perhaps acquired by different sensors
- Overlay Images and Maps within a GIS

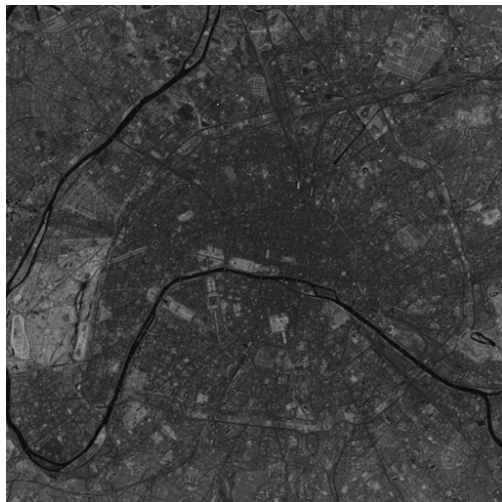
# Noise Suppression

- Spatial filters
  - Lowpass spatial filtering
  - Median filtering
- Frequency domain filters
  - Lowpass filtering
  - Band-rejection filtering

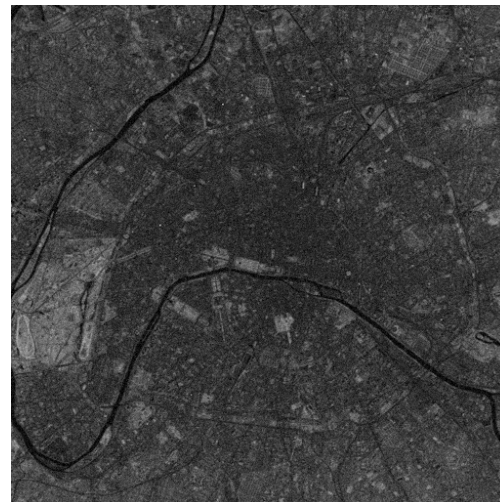
# Lowpass Filter

- Blurring and noise reduction (Gaussian noise)

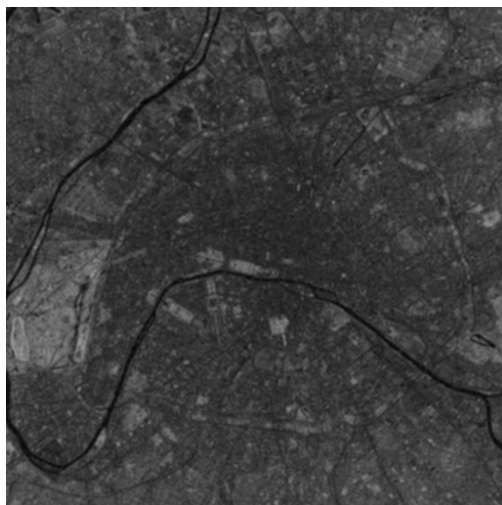




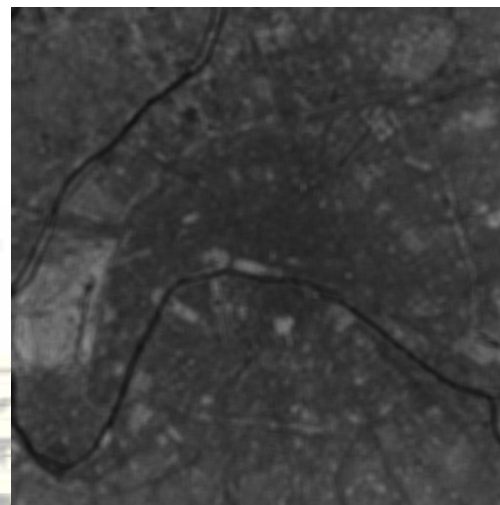
Original



Add Gaussian Noise



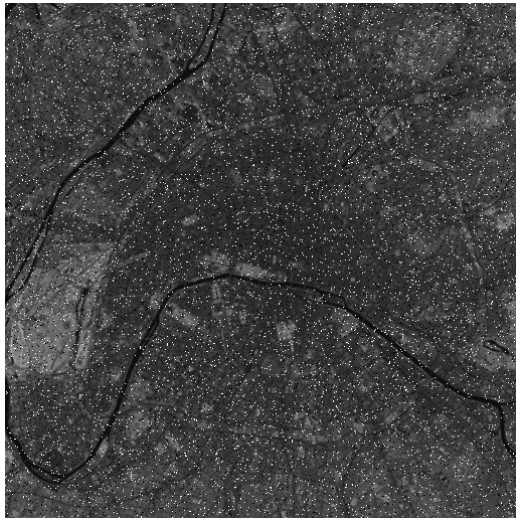
$N = 3$



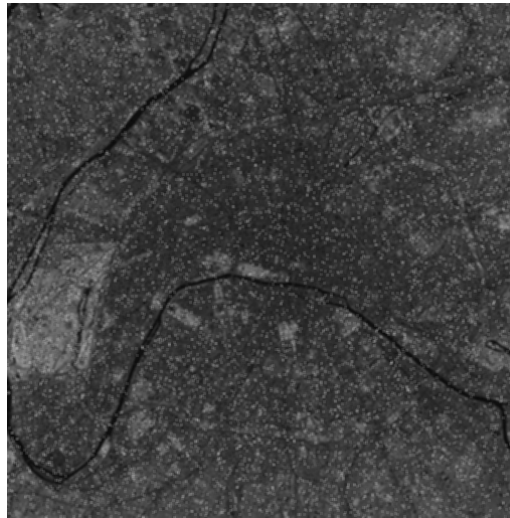
$N = 7$

# Median Filter

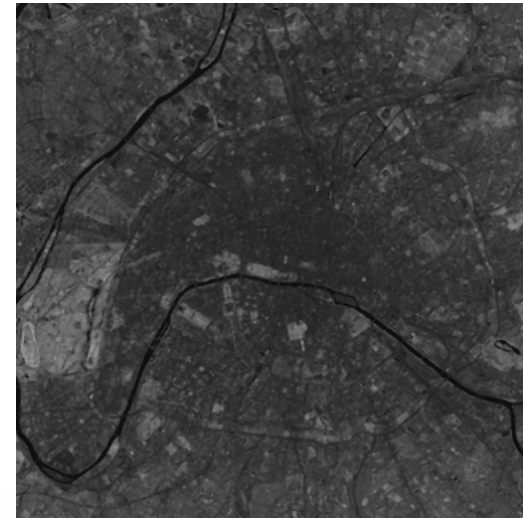
- Salt and Pepper noise
- Median in the mask area



Salt & Pepper noise



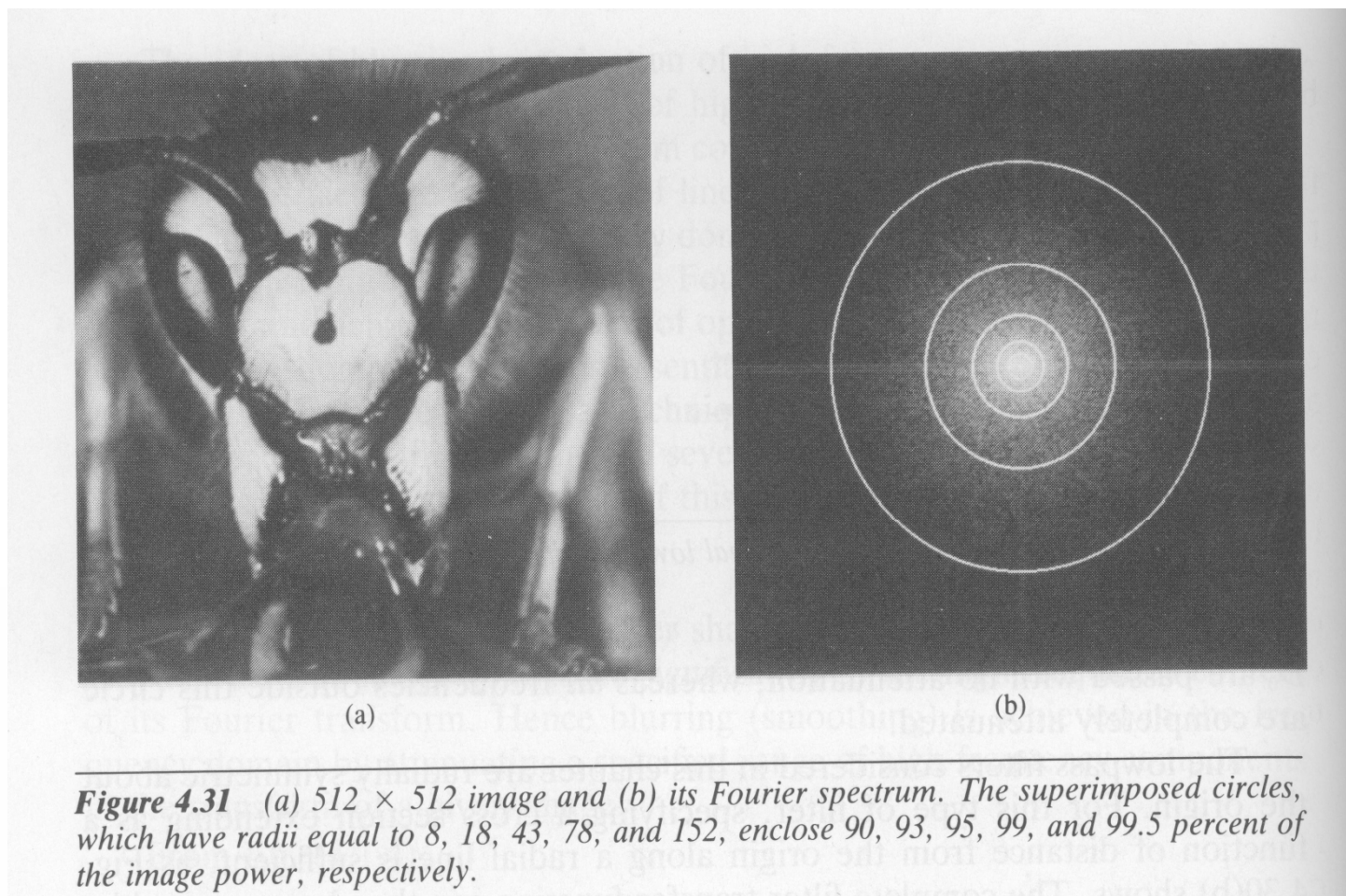
Gaussian filter



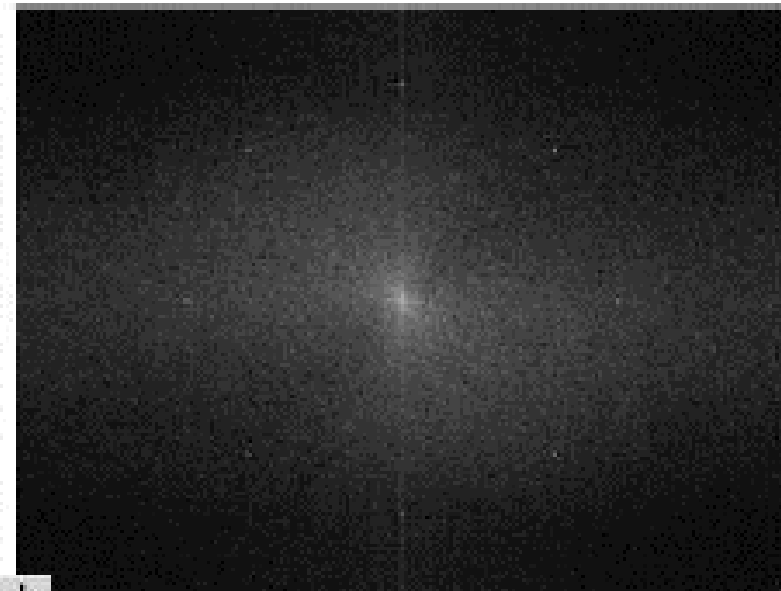
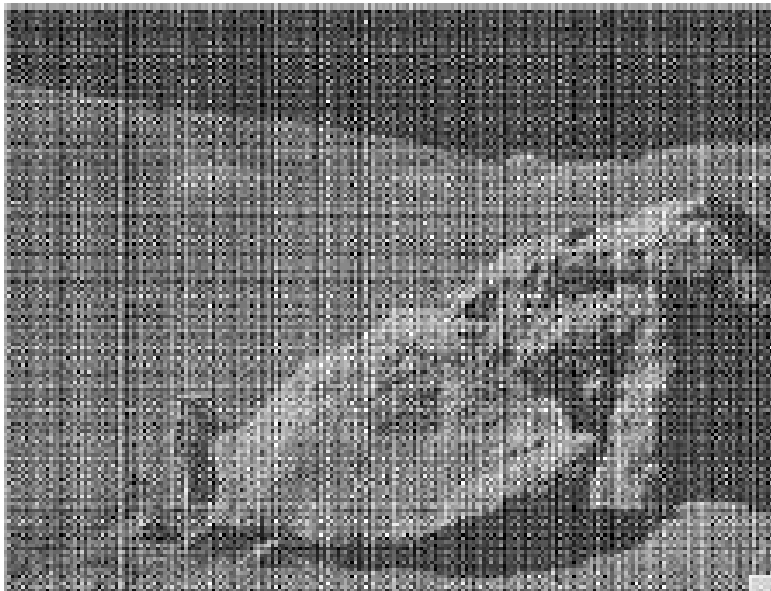
Medium filter



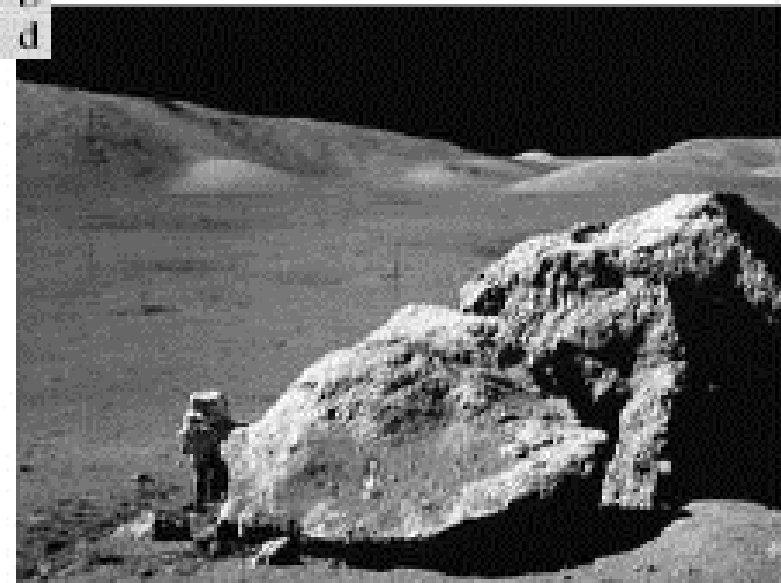
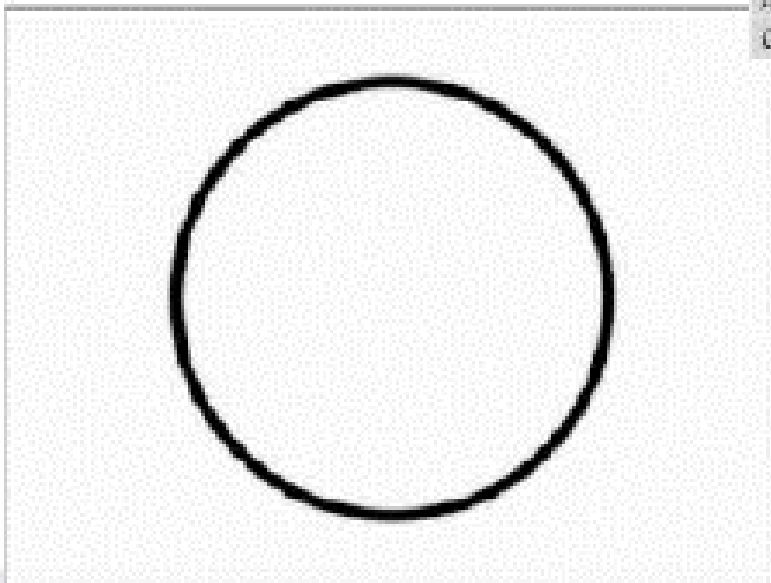
## 頻域低通濾波器



# Band Stop Filter



a b  
c d



# Detection and Classification

- Application
- Target Detection
  - Single Pixel:  
Radiance (reflectance) of the target
  - Neighbor Pixels:  
Size, Shape, Texture, Pattern of the target
  - Neighbor Targets:  
Target with its surroundings

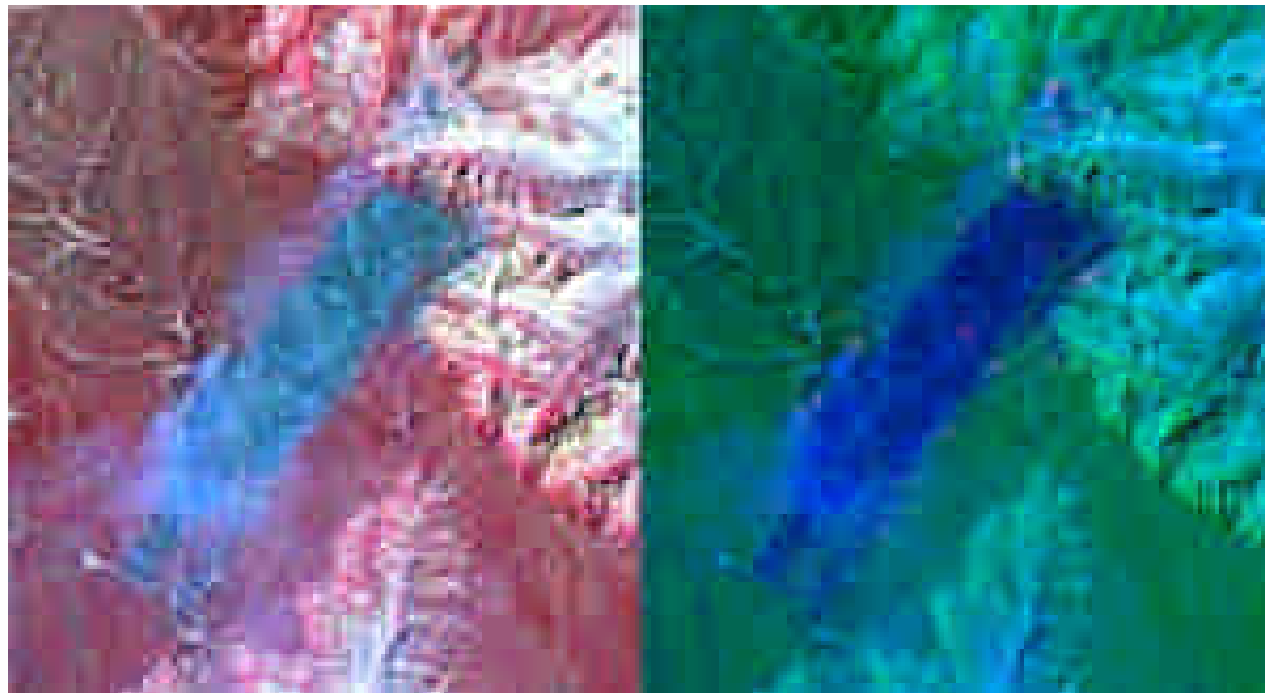
# Application

- Military
- Agriculture
- Forestry
- Mineral
- Environment
- Illegal development
- Urban



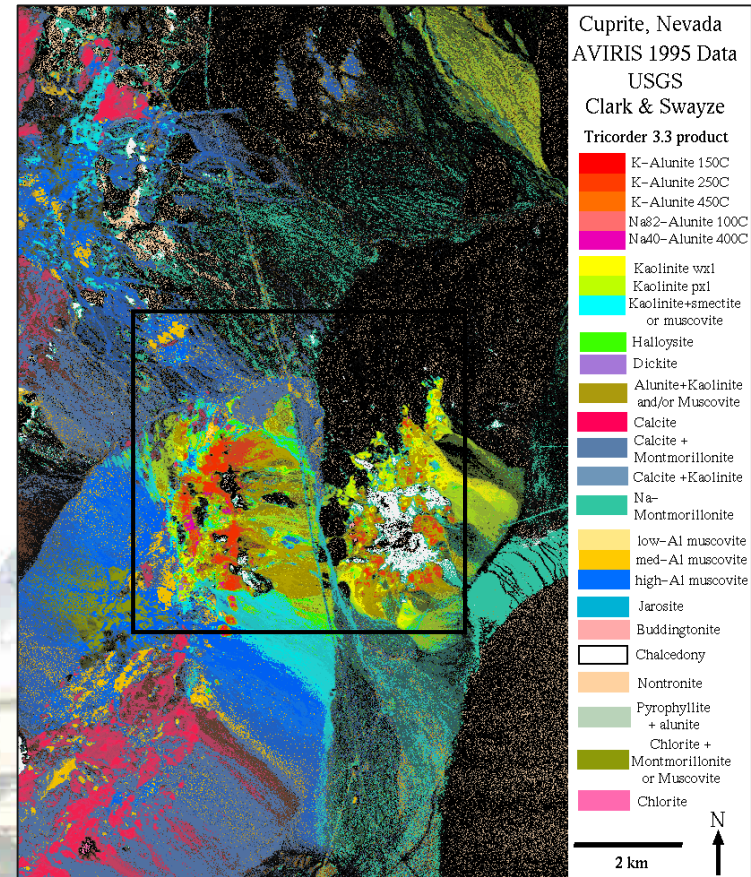
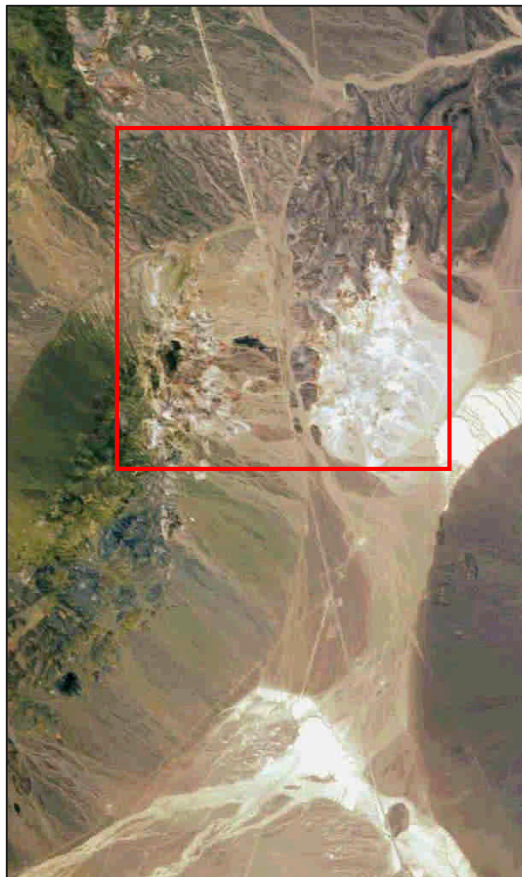
# 遙測應用

- Forest fire



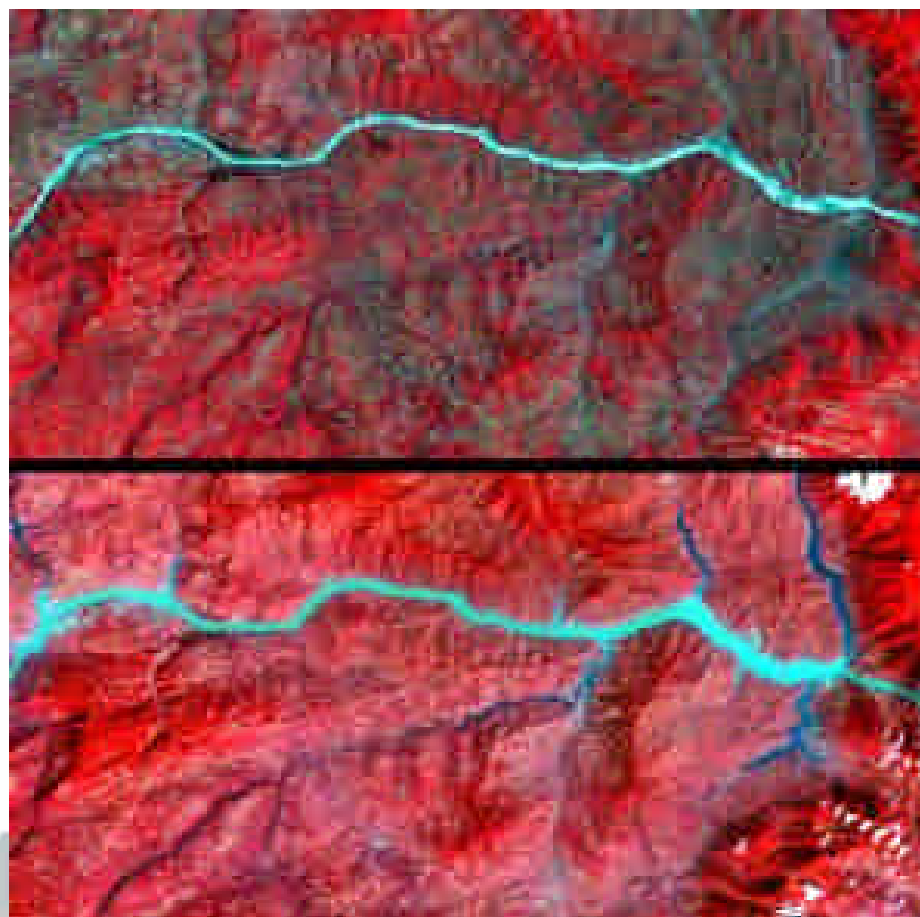
# 遙測應用

## ■ Mineral



## 遙測應用

- Yang-zhu River Dam



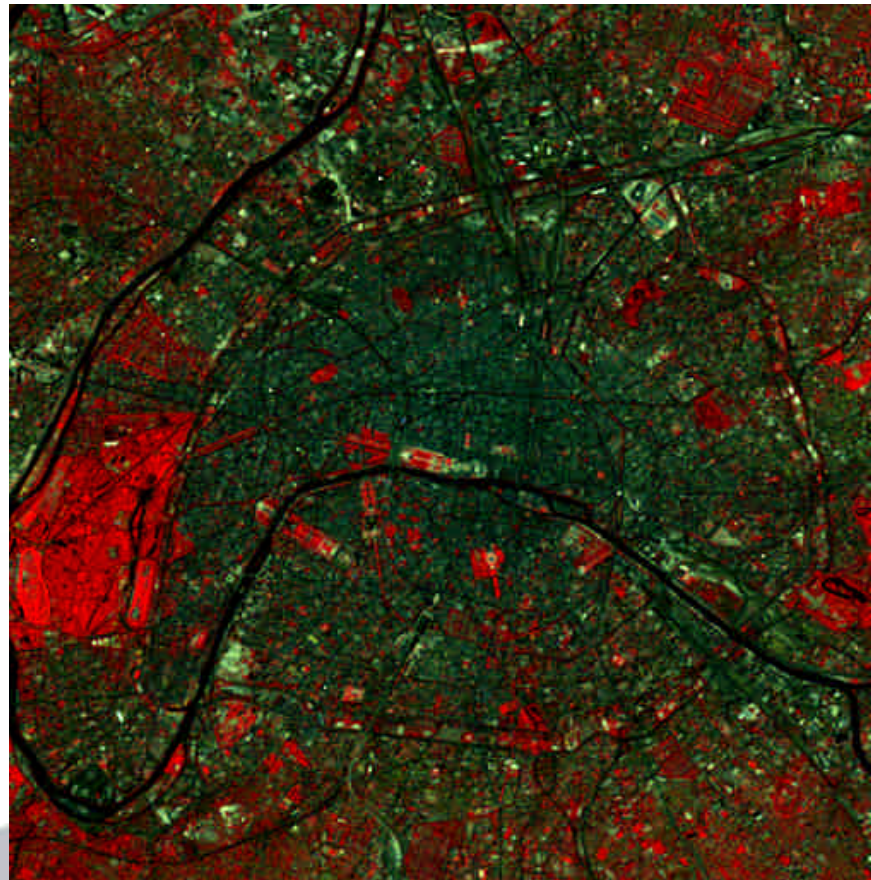
2001

2003

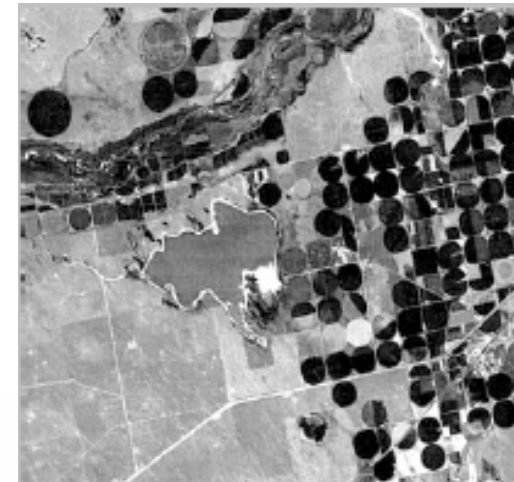
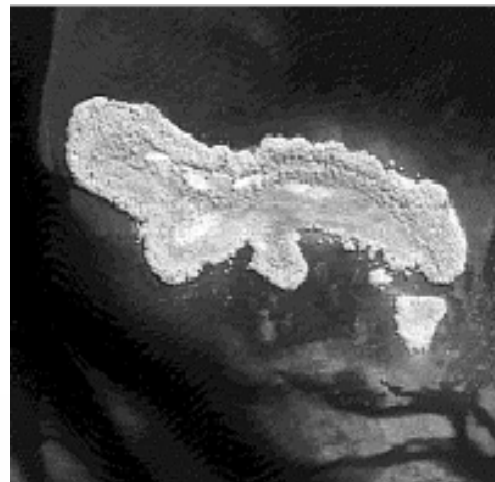


# 遙測應用

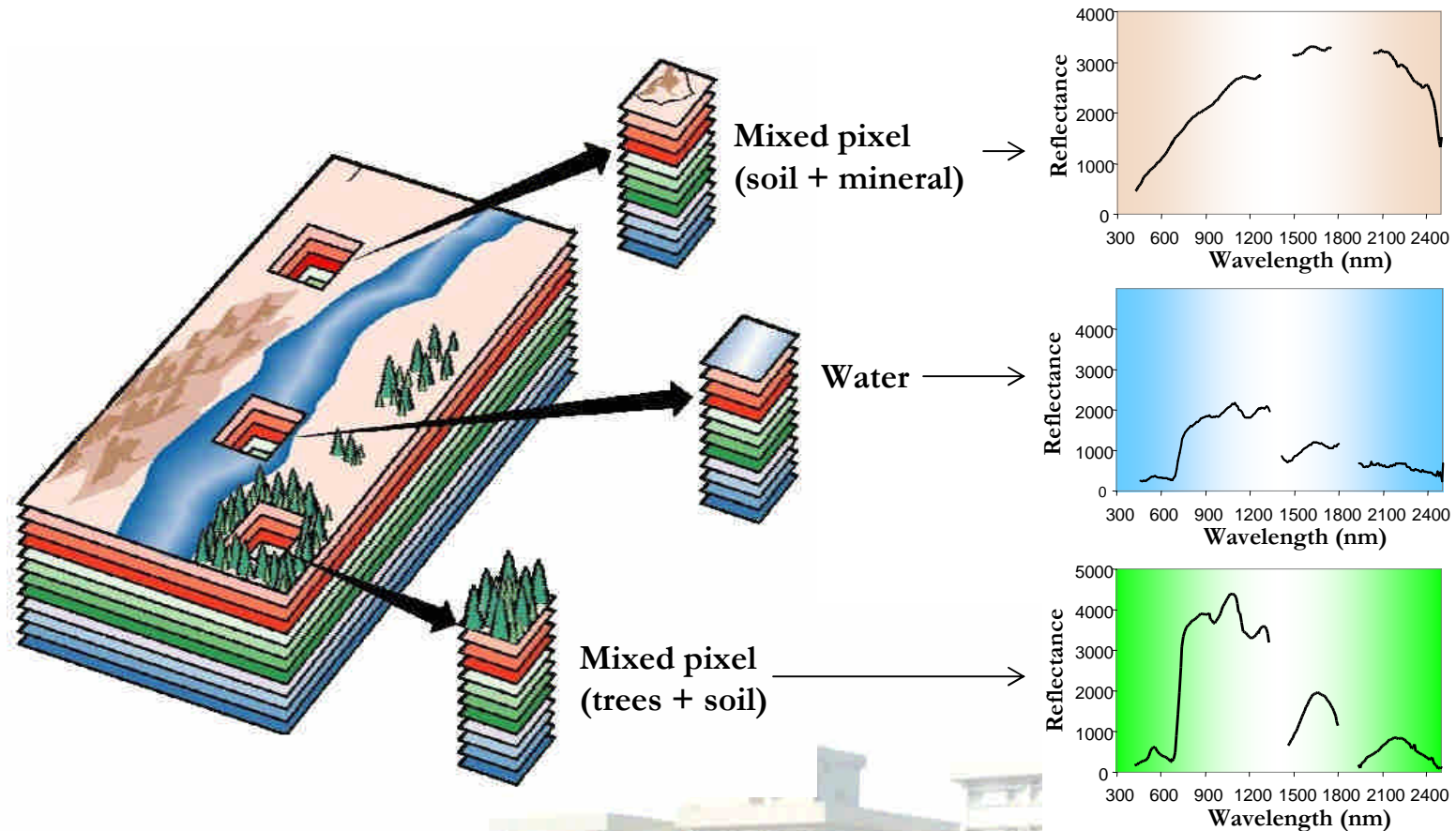
- Urban



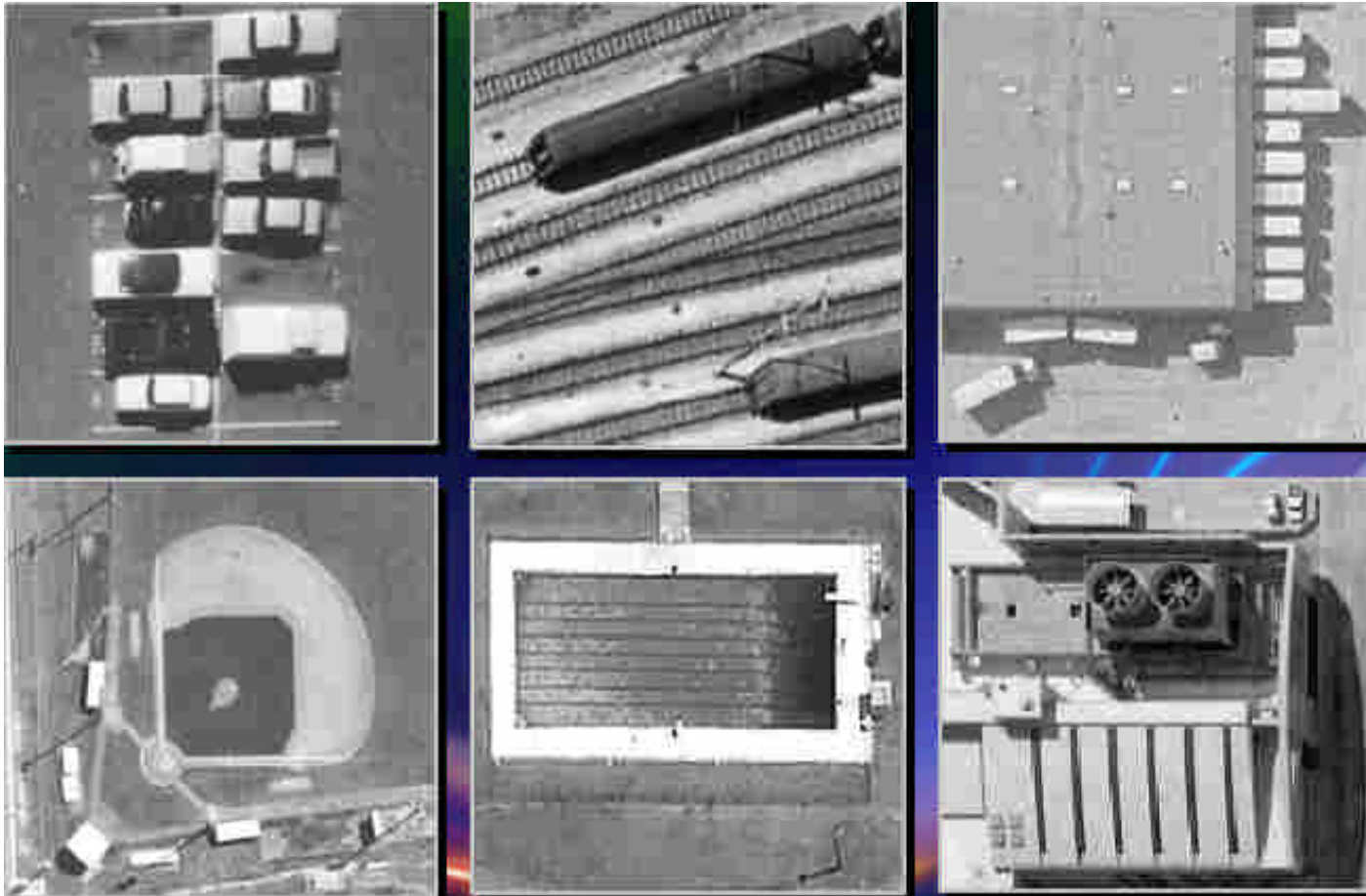
# Single Pixel: Tone



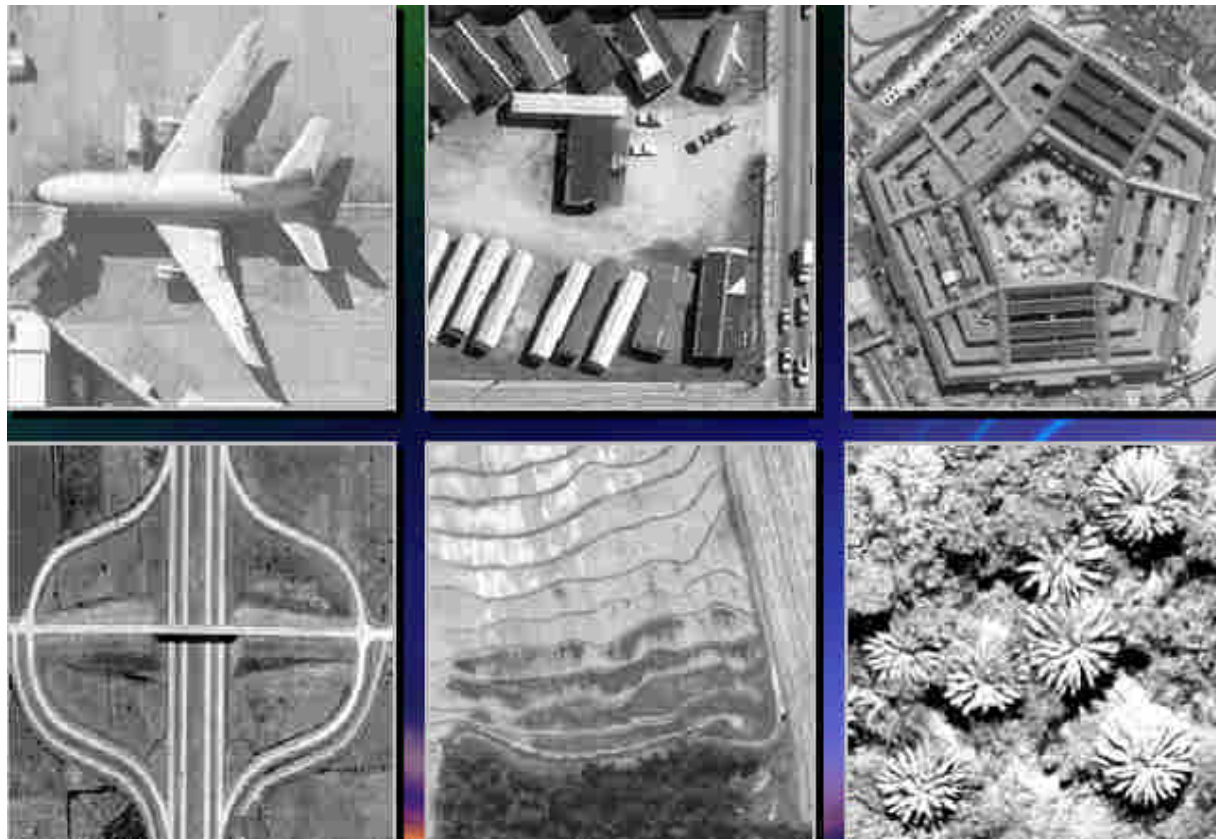
# Single Pixel: Spectrum



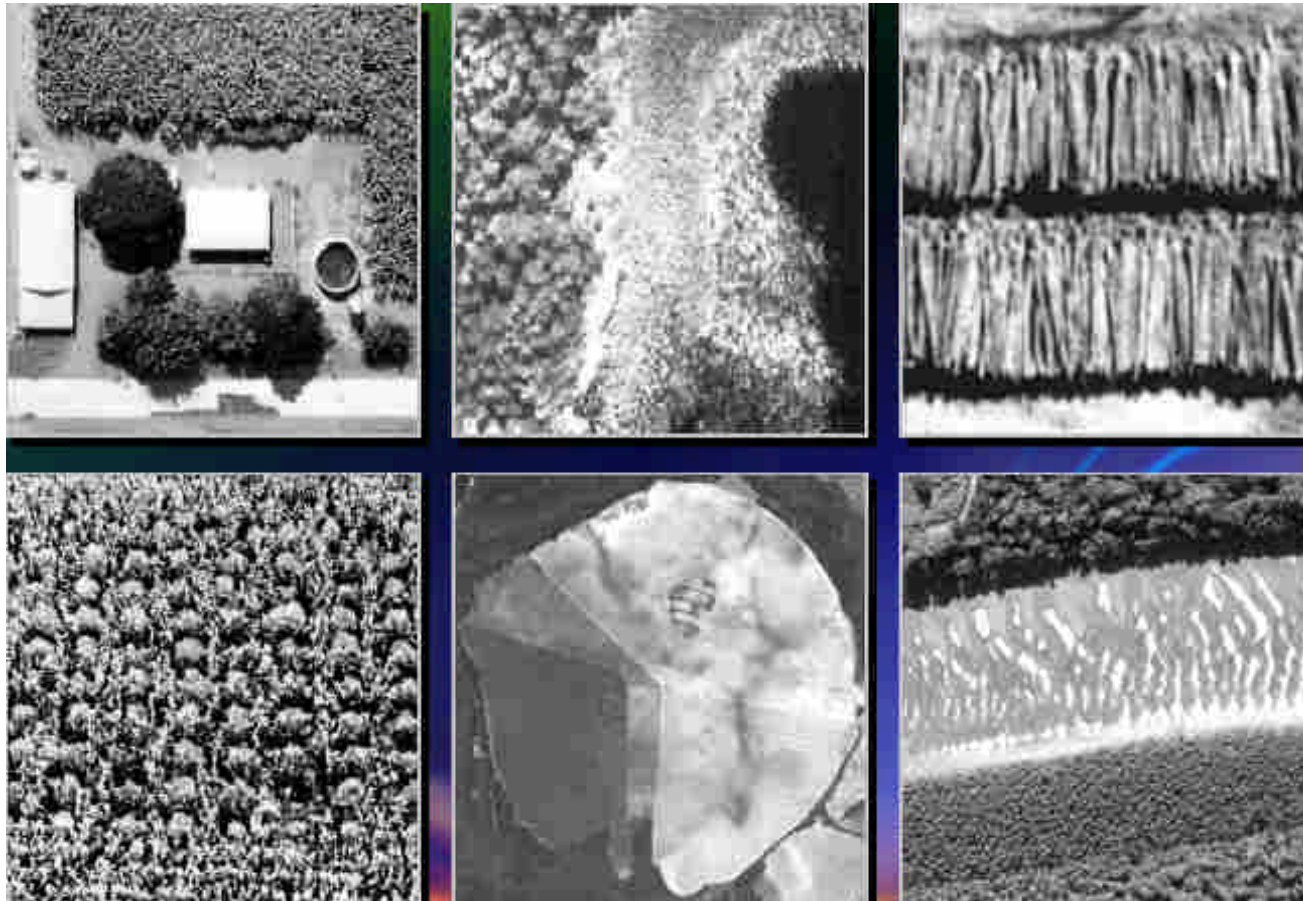
## Neighbor Pixels: Size



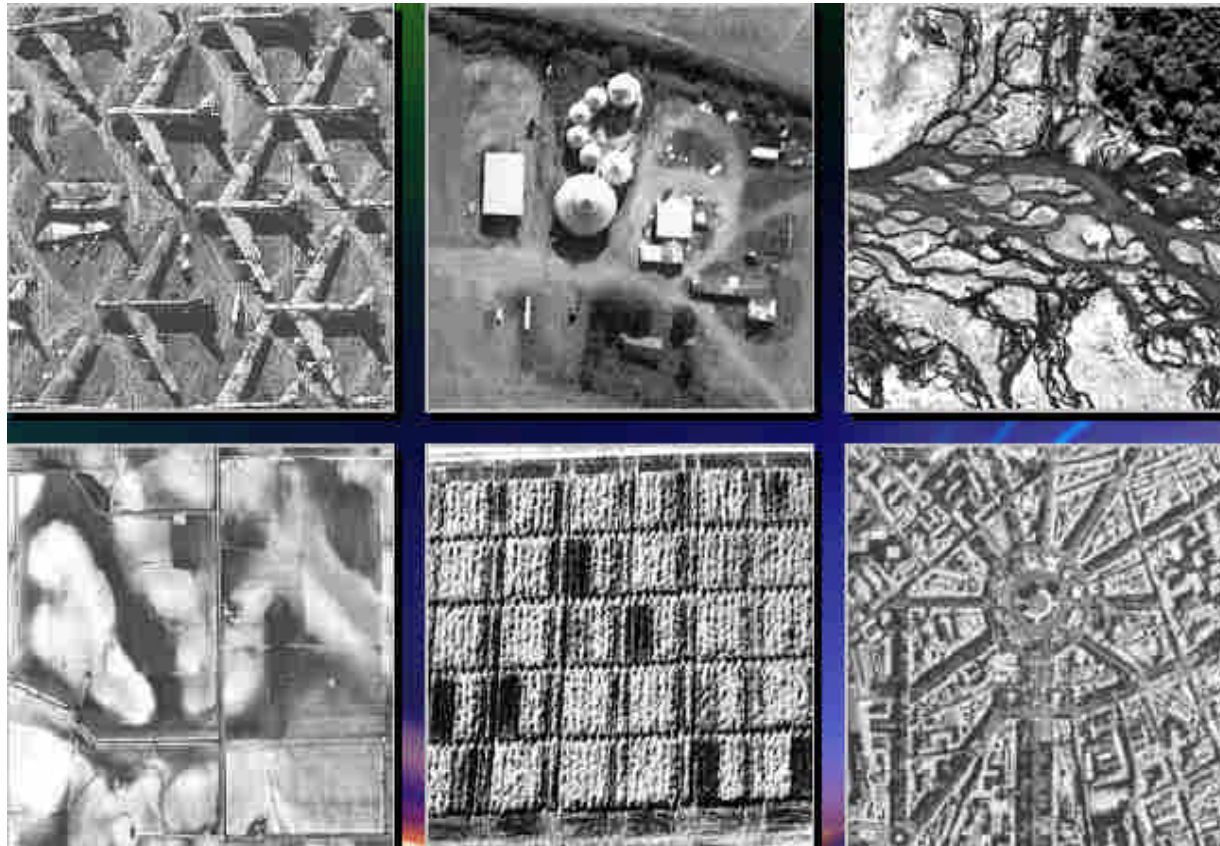
# Neighbor Pixels: Shape



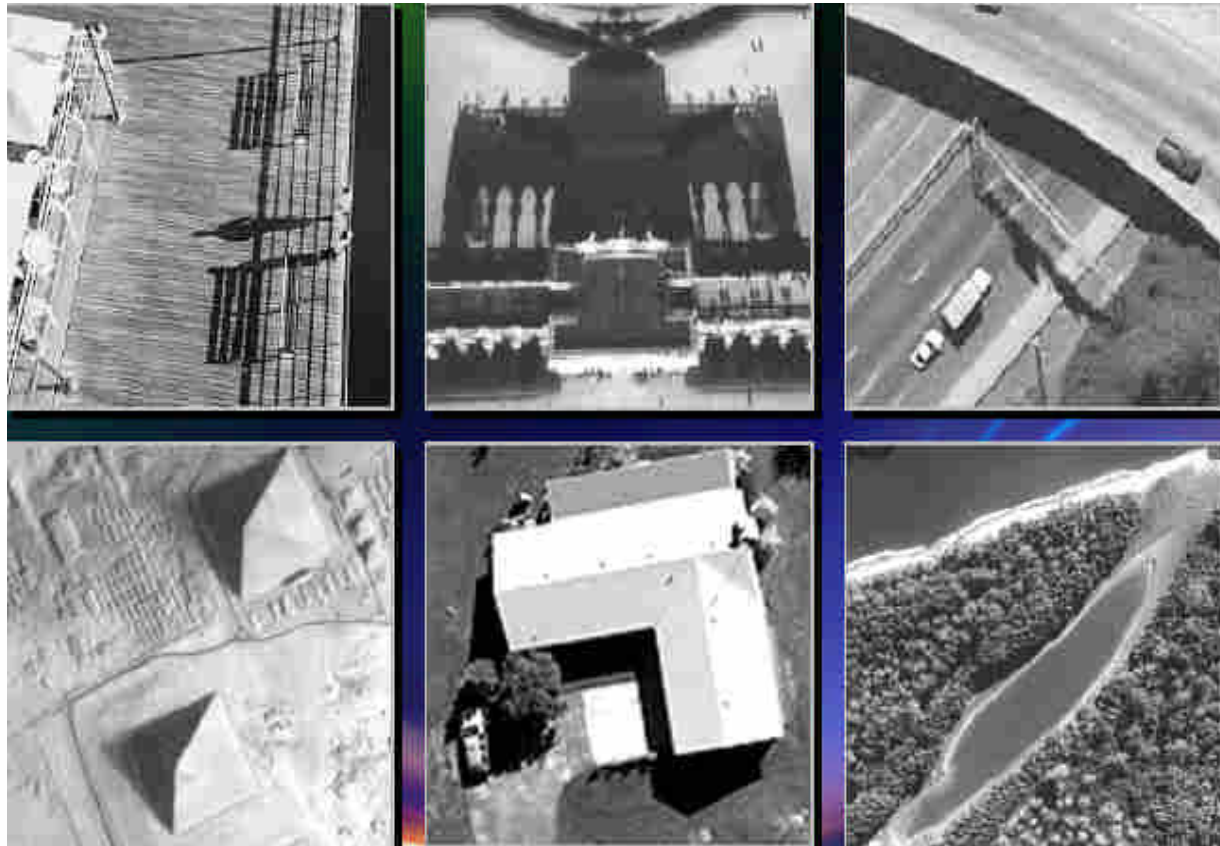
# Neighbor Pixels: Texture



# Neighbor Pixels: Pattern



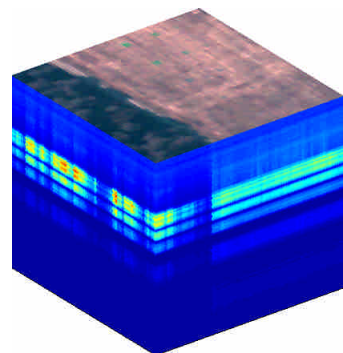
# Neighbor Pixels: Shadow



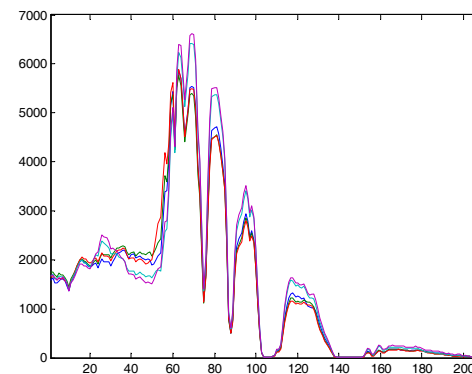
# Neighbor Targets: Area



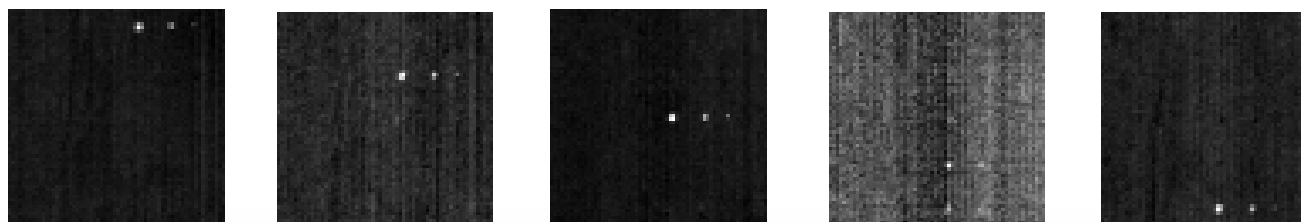
# Target Detection in Hyperspectral Image



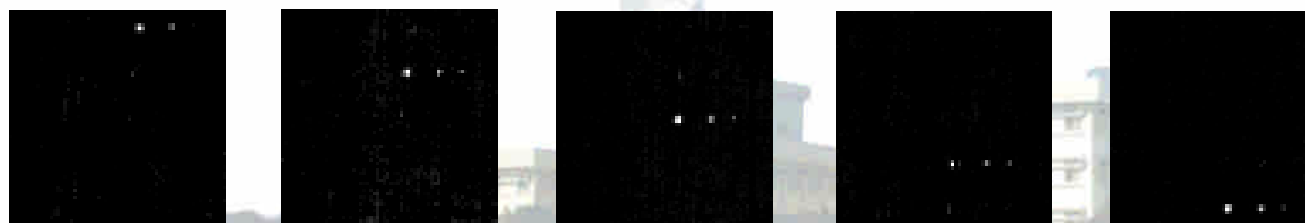
210 bands



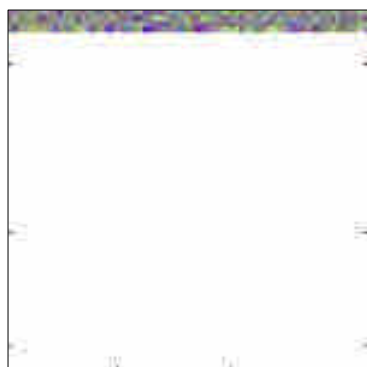
Target spectrum



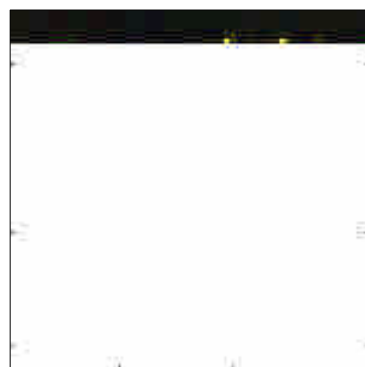
Unstrained



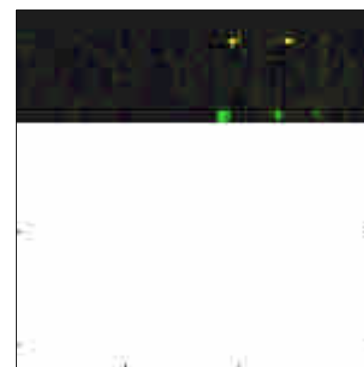
constrained



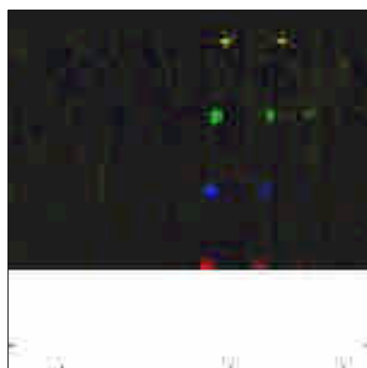
(a)



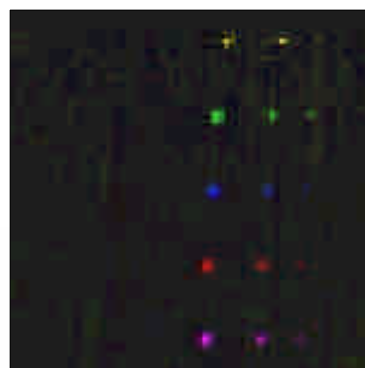
(b)



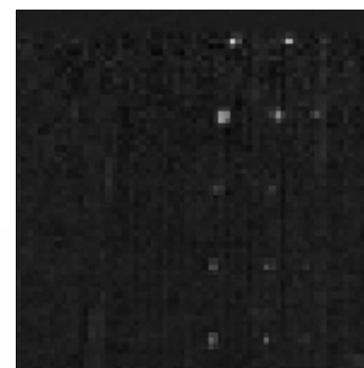
(c)



(d)



(e) 彩色視覺化



(f) 灰階視覺化