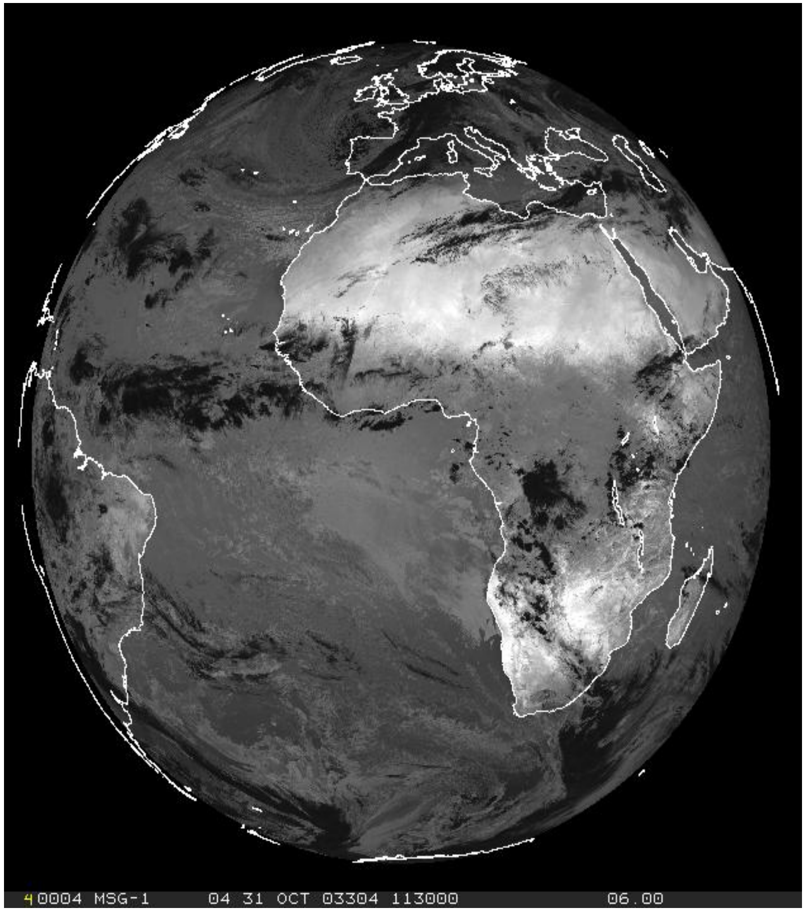
Environment Remote Sensing

Instructor:

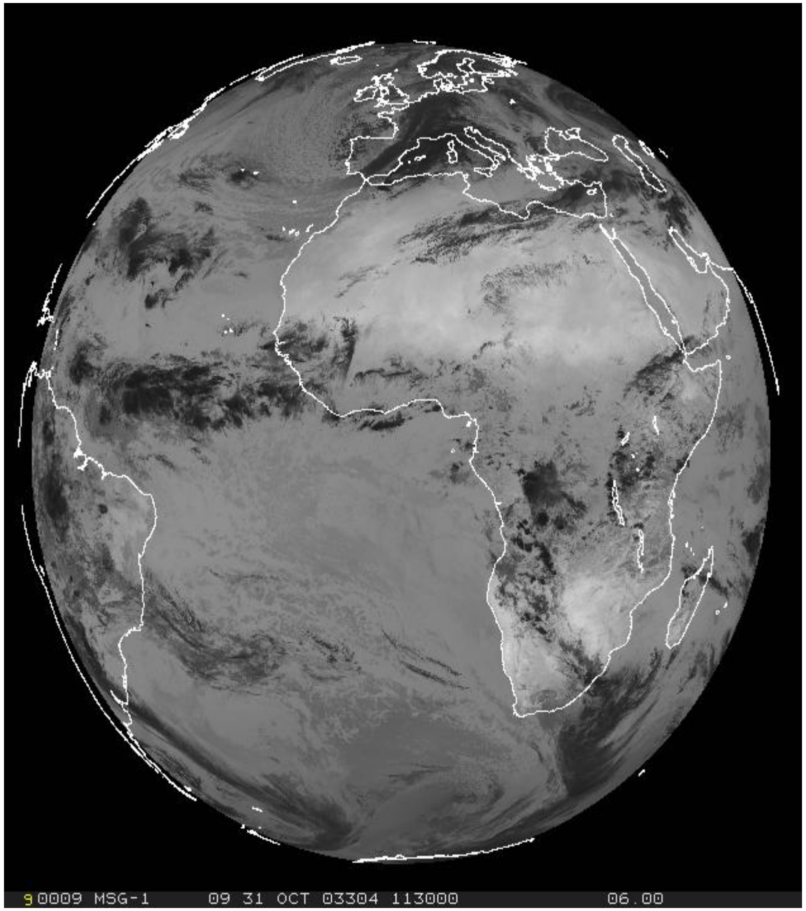
Prof. Prashanth Reddy Marpu

SAMPLE METEOSAT SEVIRI CHANNELS

96 acquisitions per day (12 channels in each acquisition)

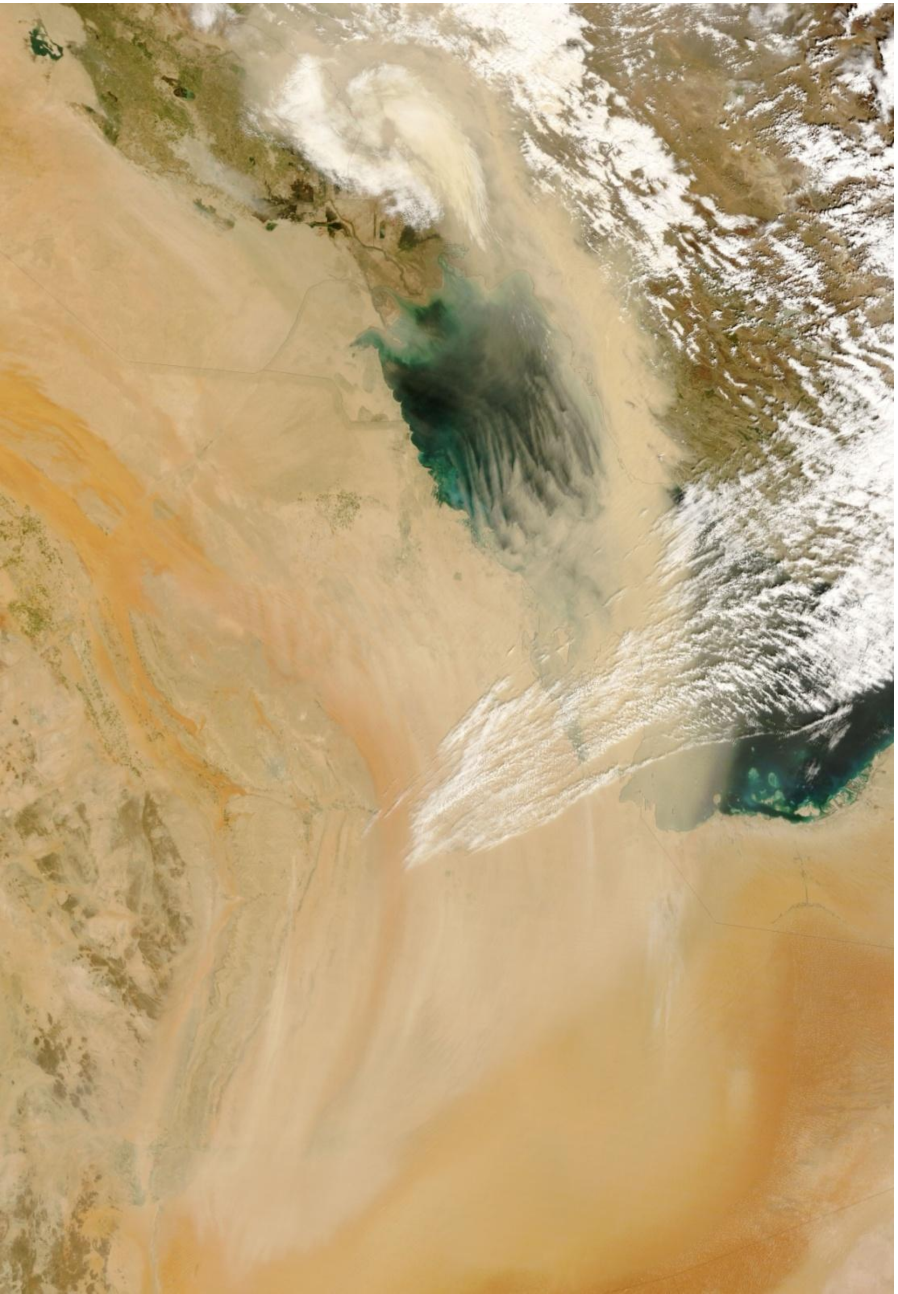


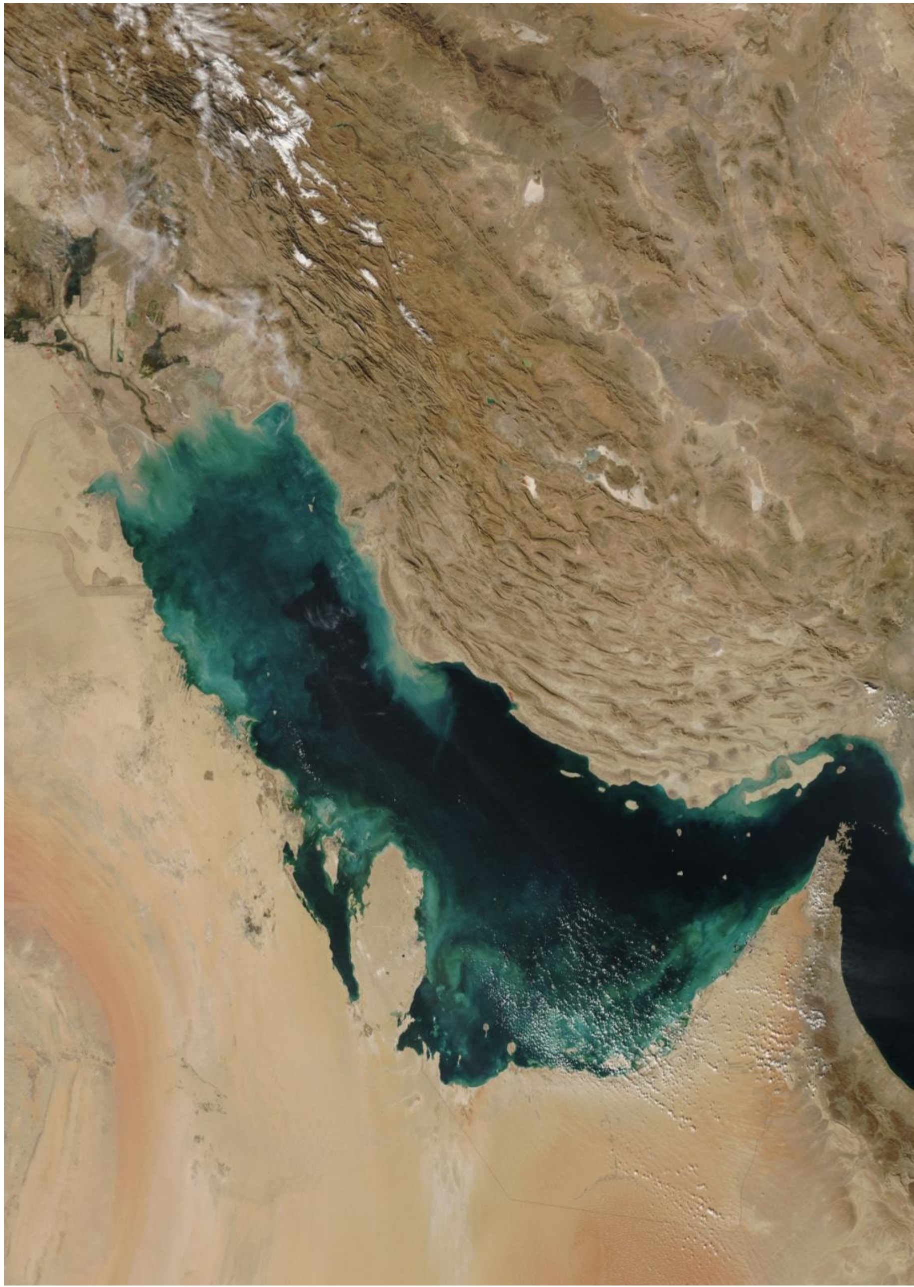
Channel 04 (IR3.9)



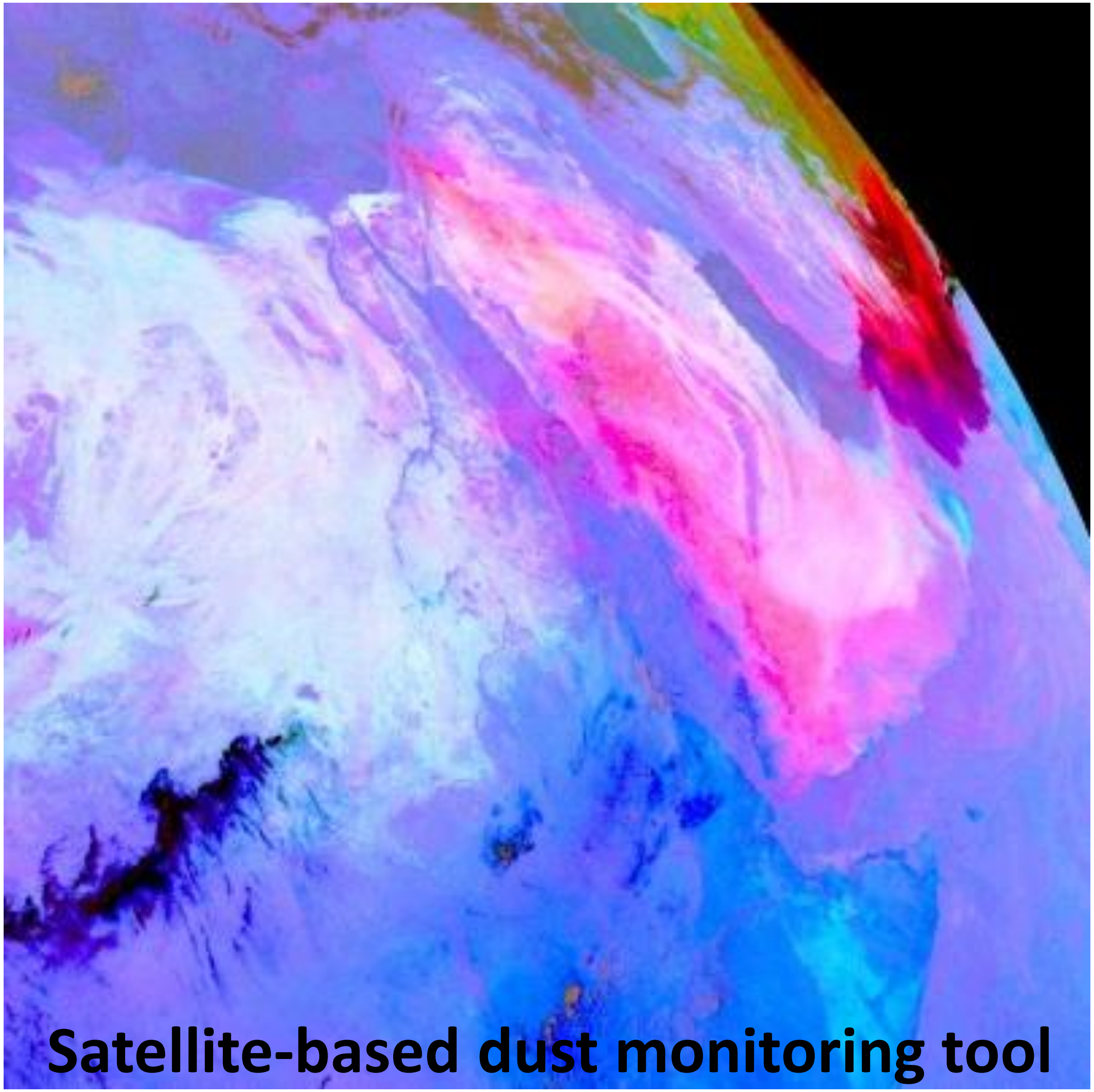
Channel 09 (IR10.8)

MODIS Data



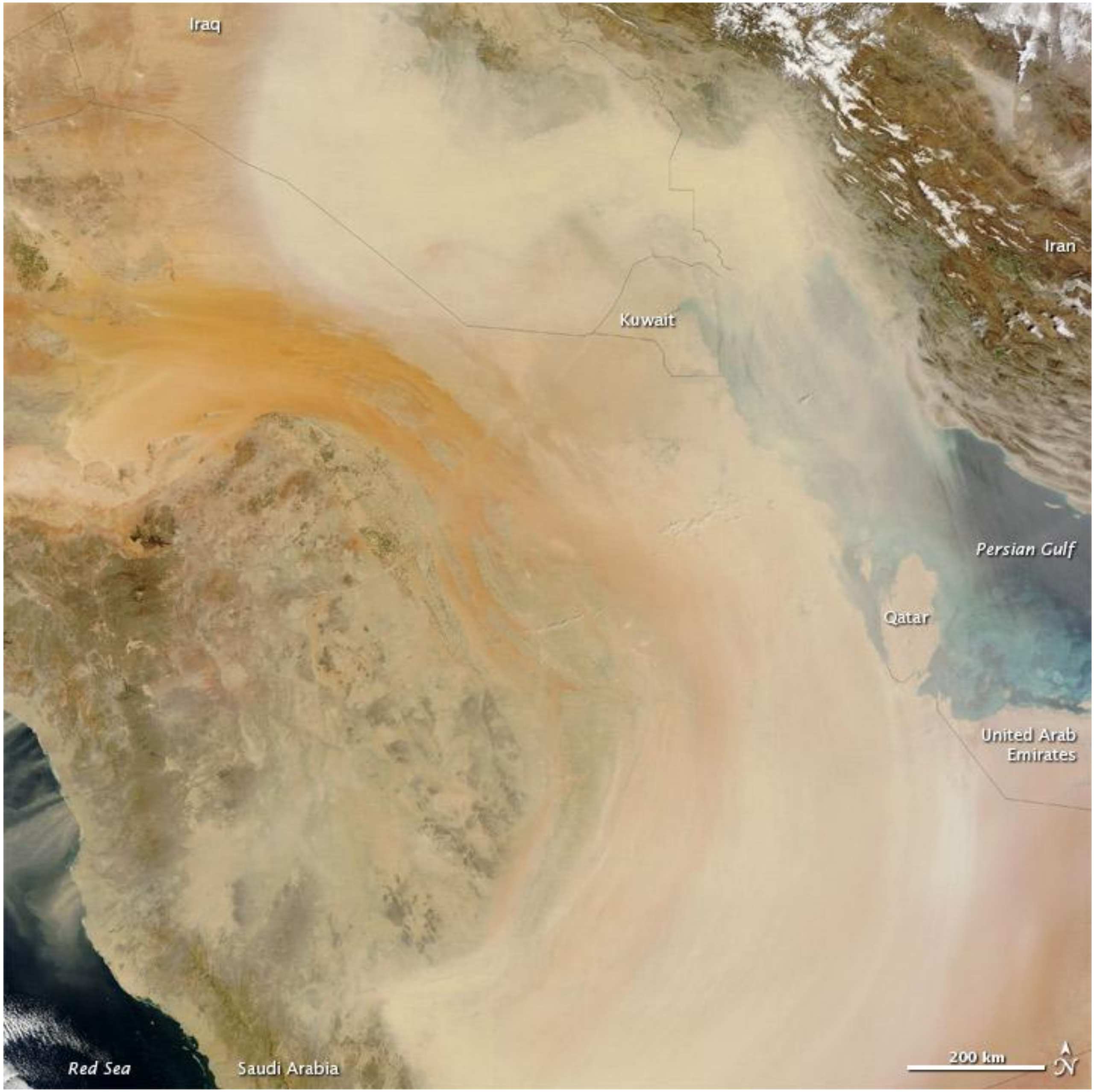


Real-Time Monitoring of Dust Sources in the Region



RGB composite image captured on March 19, 2012 (Masdar Institute receiving station)

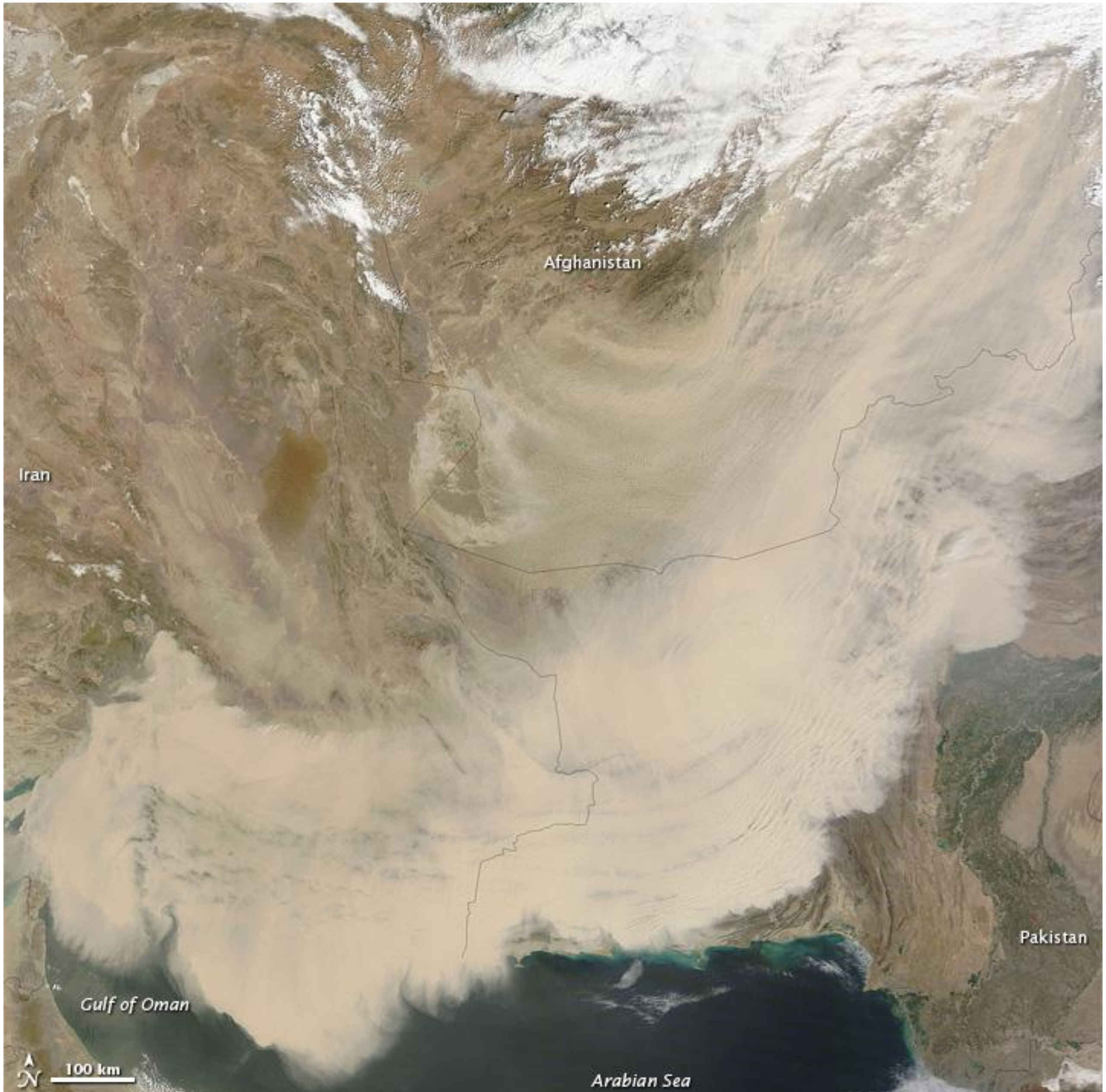
Real-Time Monitoring of Dust Sources in the Region



Recent Dust Storm
MODIS Aqua Image
March 18, 2012
(NASA)

UAE Research Center for Renewable Energy Mapping and Assessment

Real-Time Monitoring of Dust Sources in the Region



Recent Dust Storm

MODIS Aqua Image

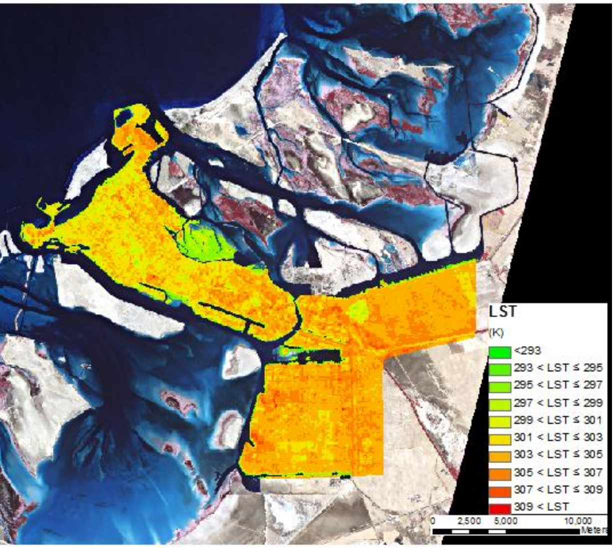
March 19, 2012

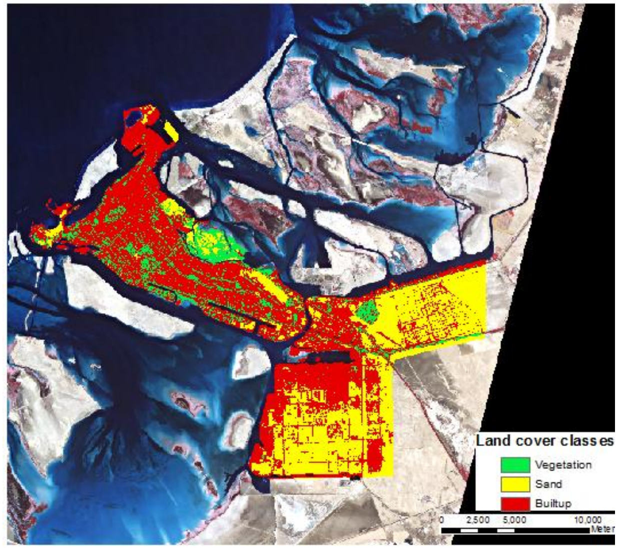
(NASA)

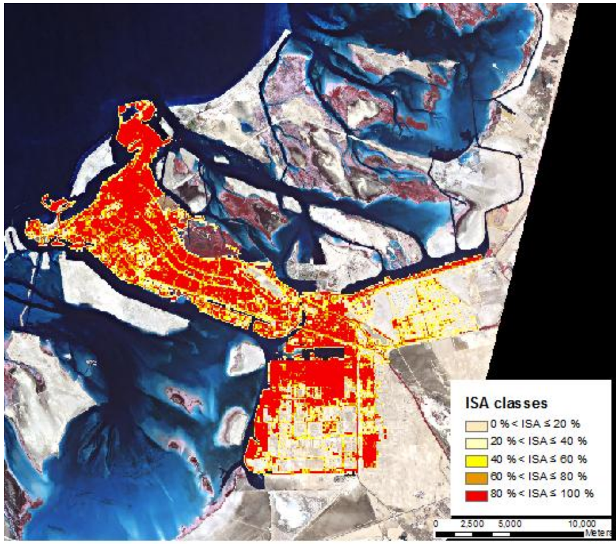
Research Center for Renewable Energy Mapping and Assessment
A Masdar Institute research center

Thermal Mapping (Abu Dhabi)

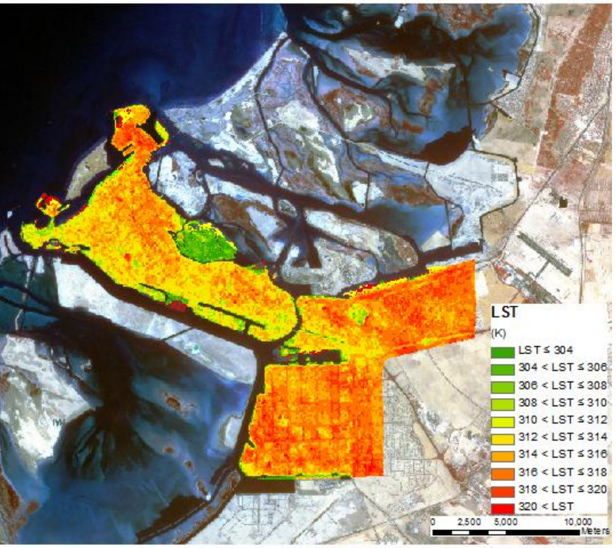
Masdar INSTITUTE معهد مصدر

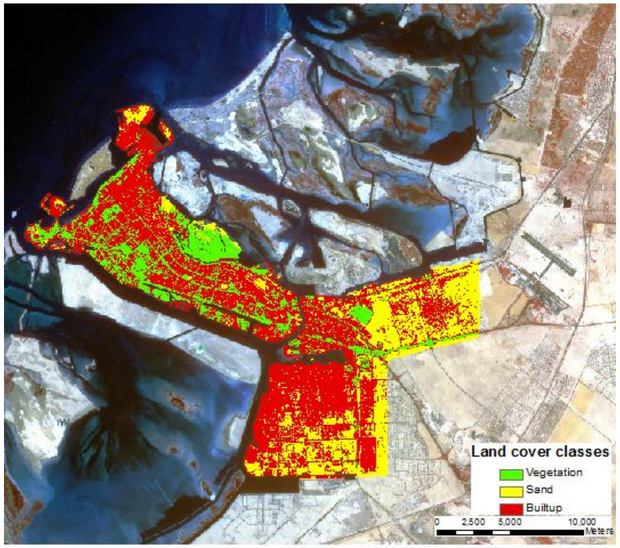


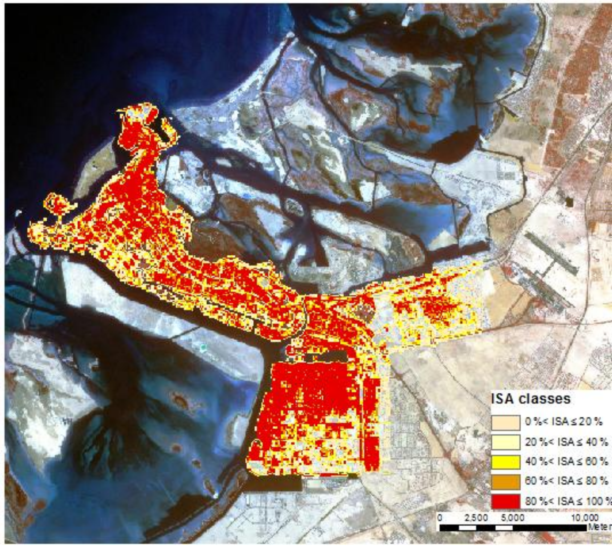




ASTER maps of LST, land cover and ISA percentage (Winter)







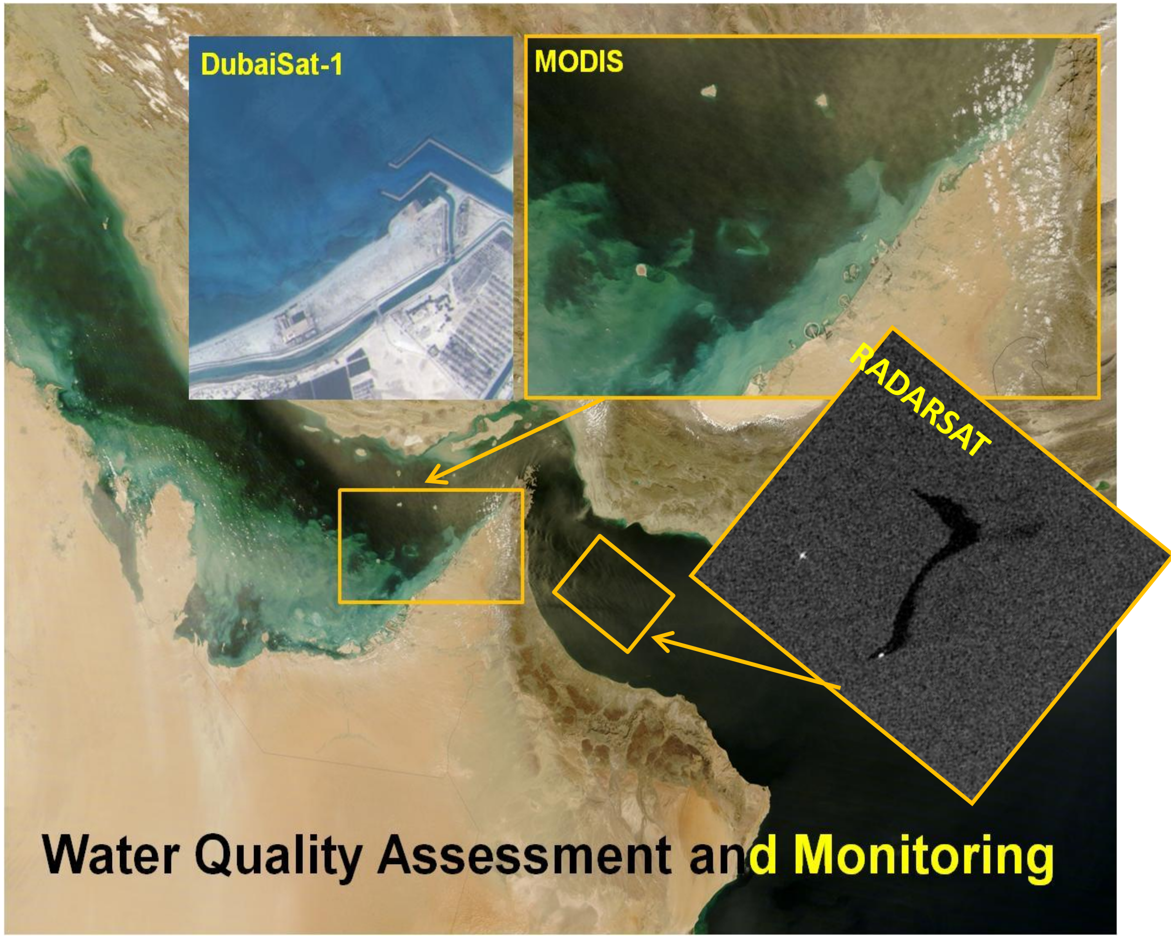
ASTER maps of LST, land cover and ISA percentage (Summer)

Water Quality Assessment and Monitoring

• Protecting seawater intakes for major desalination plants in the United Arab Emirates: Developing an automated tool for **oil spills** detection and monitoring using active microwave satellite data.

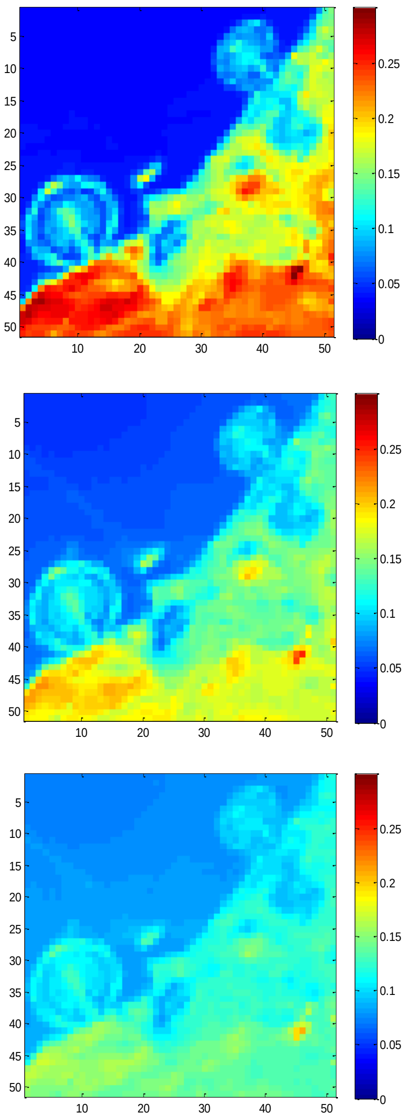
• Developing a fluorescence-based model for MODIS Satellite to detect and monitor **red tide** outbreaks in the Arabian Gulf.

•Using medium and high resolution satellite images in monitoring water quality surrounding the discharges of **desalination plants** in the UAE

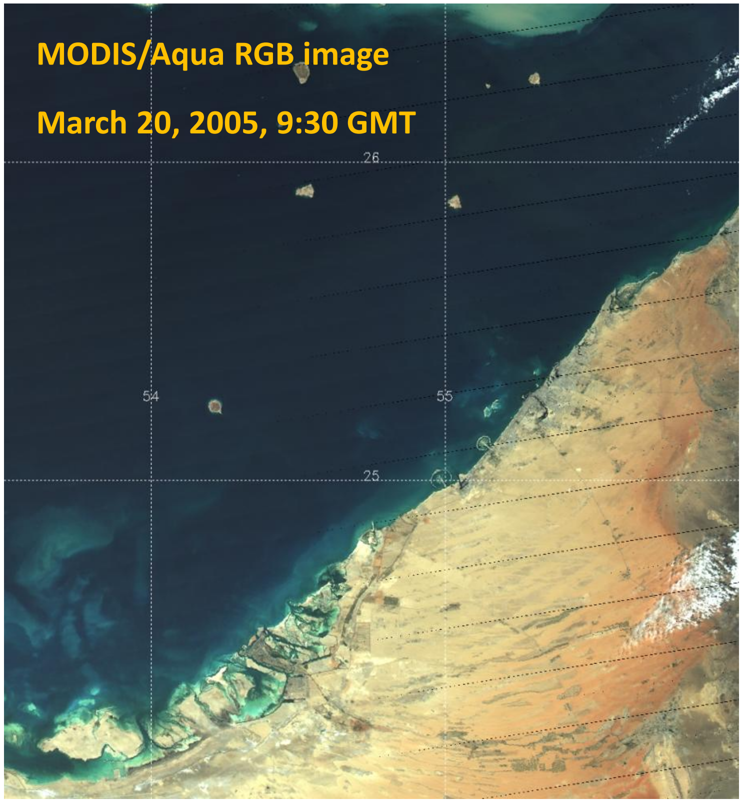


Water Quality Assessment and Monitoring

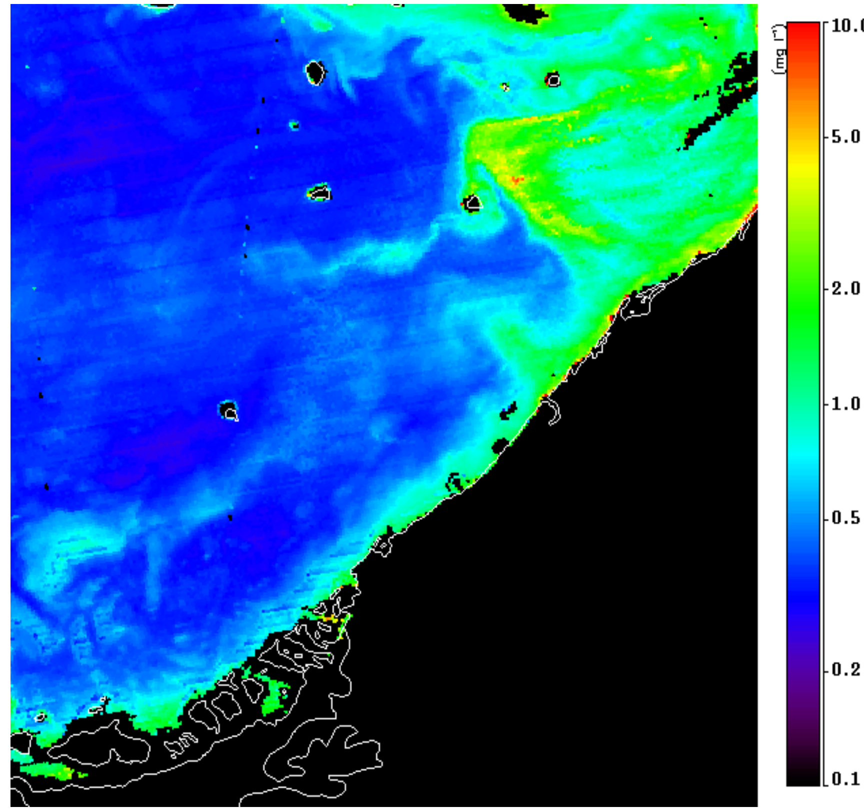
Monitoring water quality surrounding the discharges of desalination plants in the UAE using medium and high resolution satellite images.



Example: MODIS products derived from a scene acquired over Abu Dhabi coastline



RGB true-color composite shows the clear atmosphere



SeaDAS-derived total suspended sediment (TSS) concentrations (mg/L).

REMOTE SENSING

Slides adopted from **Jensen, 2007** and lecture notes of **Dr. Mathias Disney, UCL Geography, University College London**

What is remote sensing?

The Experts say "Remote Sensing (RS) is..."

- **“The science technology and art of obtaining information about objects or phenomena from a distance (i.e. without being in physical contact with them”**

http://ccrs.nrcan.gc.ca/glossary/index_e.php?id=486

The not so experts say "Remote Sensing is..."

- Advanced colouring-in.
- Seeing what can't be seen, then convincing someone that you're right.
- Being as far away from your object of study as possible and getting the computer to handle the numbers.

One of the first RS images using 7 Kites carrying a 23 Kg camera

Remote Sensing: scales and platforms

•Both taken via kite aerial photography

•http://arch.ced.berkeley.edu/kap/kaptoc.html

•http://activetectonics.la.asu.edu/Fires_and_Floods/

Remote Sensing: scales and platforms

upscale

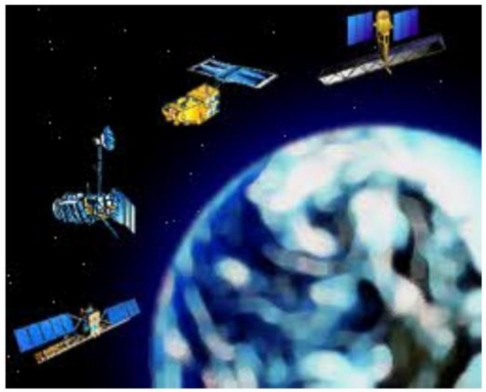
upscale

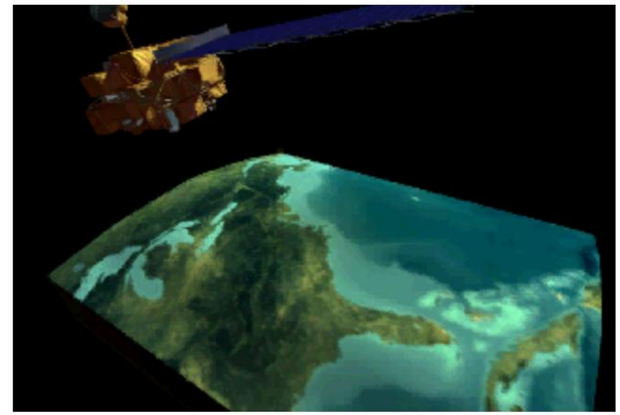
upscale

http://www-imk.fzk.de:8080/imk2/mipas-b/mipas-b.htm

- Platform depends on application
  - What information do we want?
  - How much detail?
  - What type of detail?

upscale





- Many types of satellite
    - Different orbits, instruments, applications

Why do we study/use remote sensing?

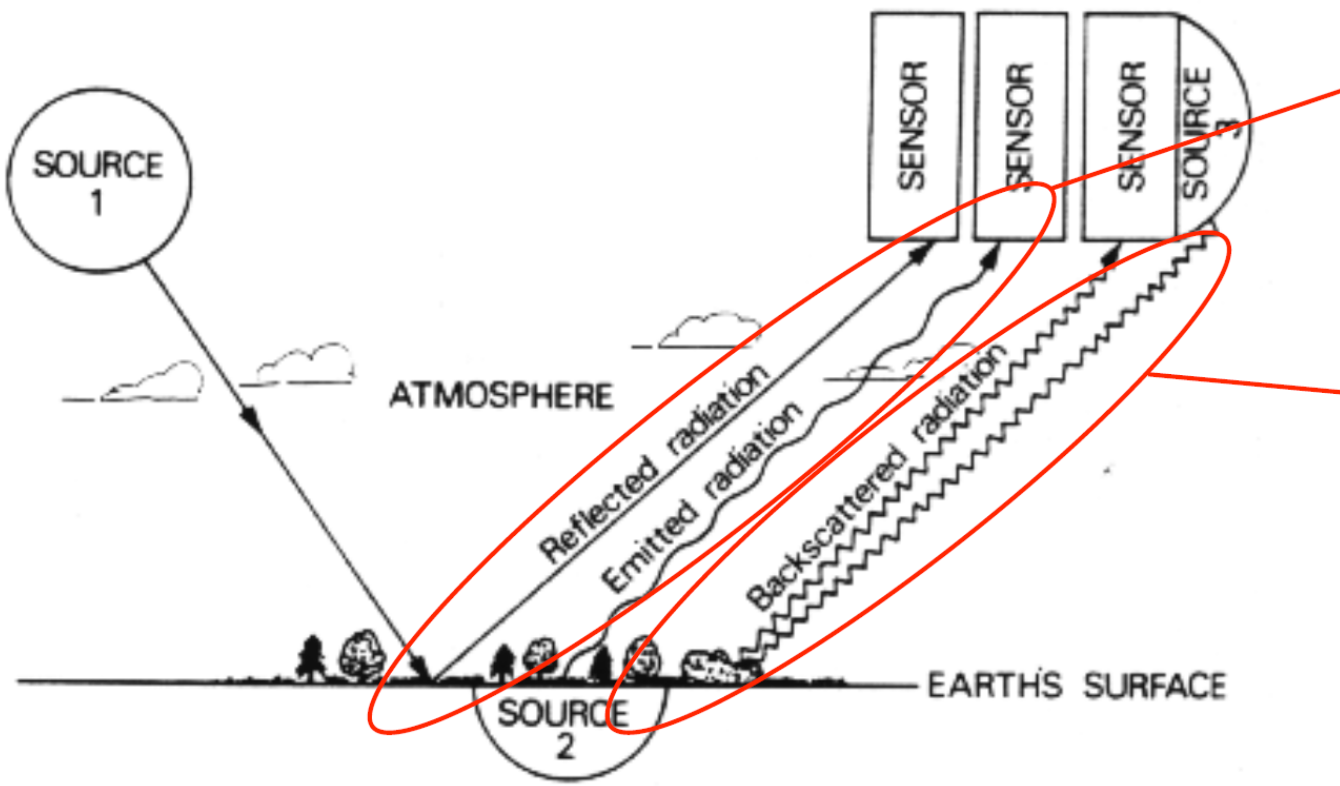
- source of spatial and temporal information (land surface, oceans, atmosphere, ice)
- monitor and develop understanding of environment (measurement and modelling)
- information can be accurate, timely, consistent
- remote access
- some historical data (1960s/70s+)
- move to quantitative RS e.g. data for climate
  - some commercial applications (growing?) e.g. weather
  - typically (geo)'physical' information but information widely used (surrogate - tsetse fly mapping)
  - derive data (raster) for input to GIS (land cover, temperature etc.)

EO process in summary.....

- Collection of data
  - **Some type of remotely measured signal**
  - **Electromagnetic radiation of some form**
- Transformation of signal into something useful
  - **Information extraction**
  - **Use of information to answer a question or confirm/ contradict a hypothesis**

The Remote Sensing Process

- Collection of information about an object without coming into physical contact with that object



Passive: solar reflected/emitted

Active:RADAR (backscattered); LiDAR (reflected)

The Remote Sensing Process

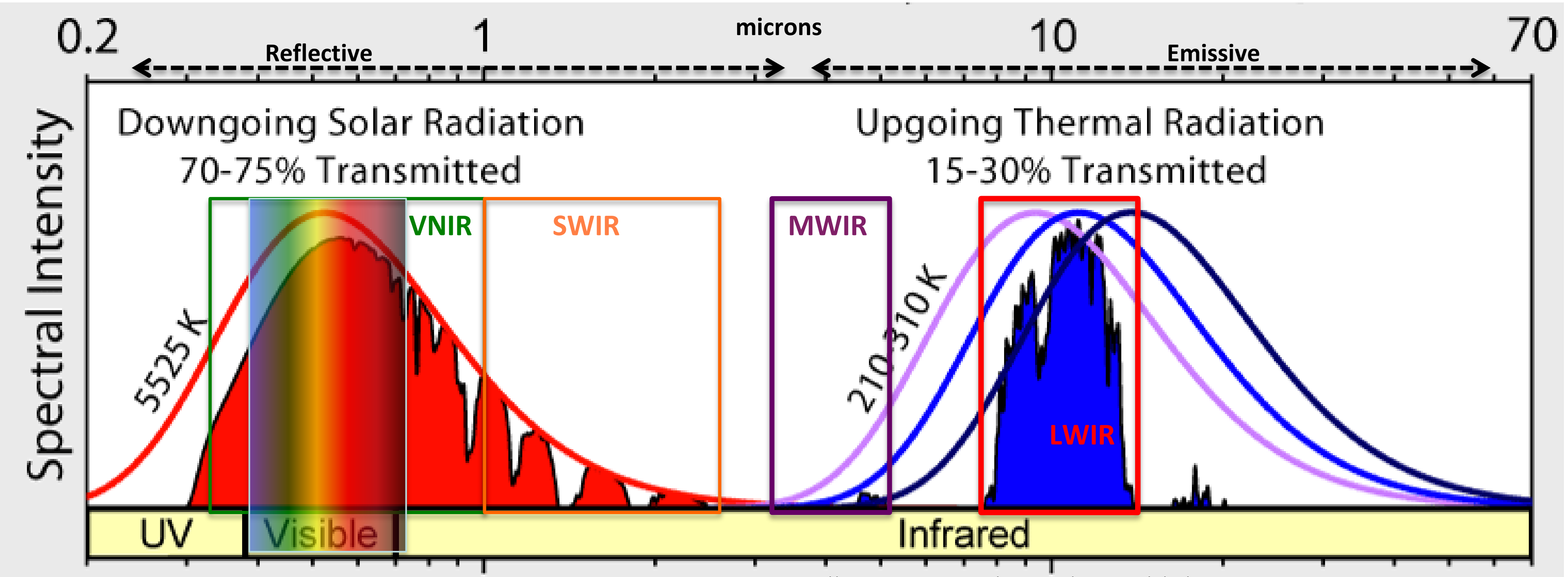
- What are we collecting?
  - Electromagnetic radiation (EMR)
- What is the source?
  - Solar radiation
    - passive – reflected (vis/NIR), emitted (thermal)
  - OR artificial source
    - active - RADAR, LiDAR even sonar
- Note various paths
  - Source to sensor direct?
  - Source to surface to sensor
  - Sensor can also be source

EM Spectrum

- EM Spectrum
  - Continuous range of EM radiation
  - From very short wavelengths (<$300x10^{-9}$m)
    - high energy
  - To very long wavelengths (cm, m, km)
    - low energy
  - Energy is related to wavelength (and hence frequency)

EM Spectrum

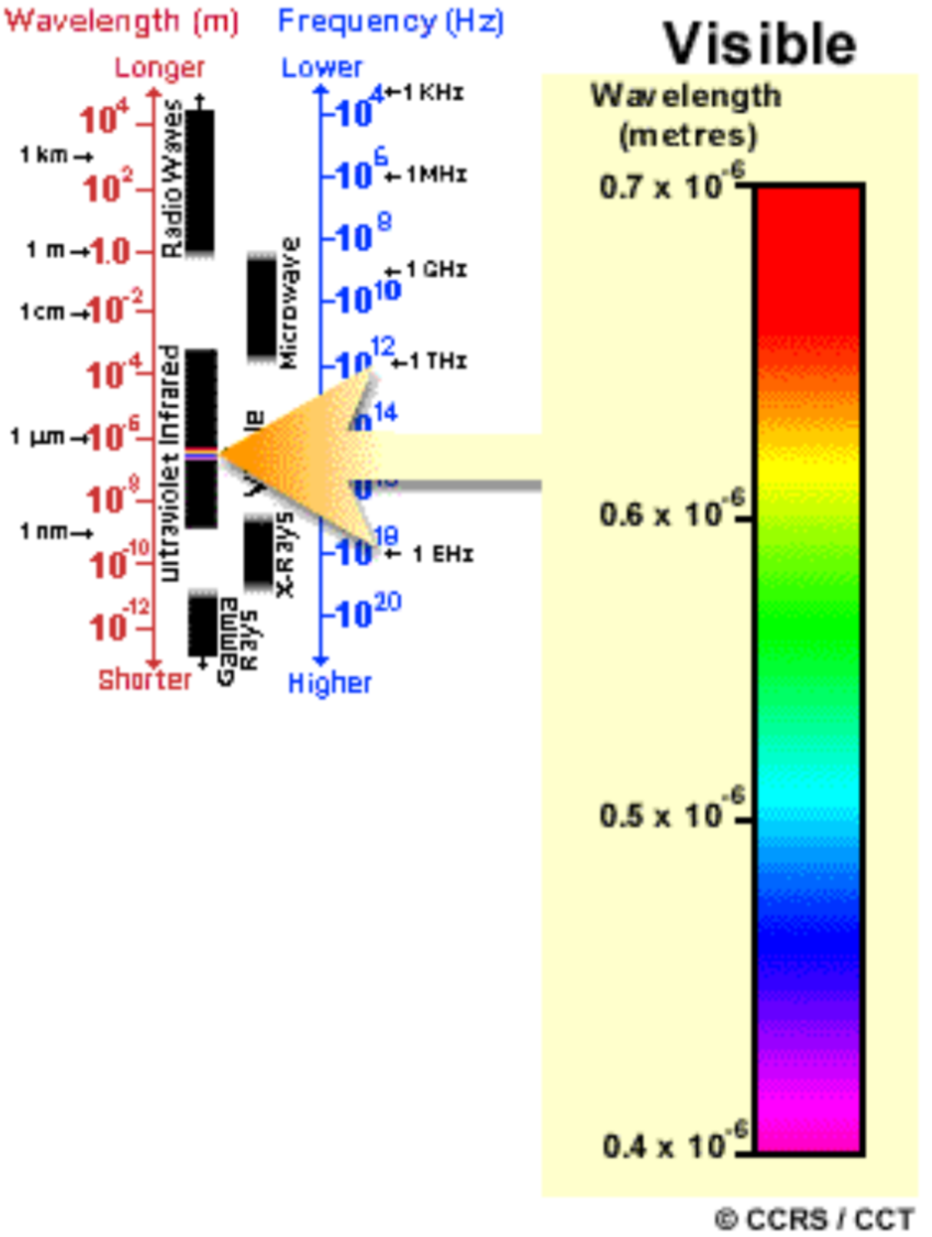
Spectrum: For the purpose of this workshop – Reflective / Emissive



Base image - http://upload.wikimedia.org/wikipedia/commons/7/7c/Atmospheric_Transmission.png

- Note that peak of sun's energy around 0.5 μm
  - negligible after 4-6μm
- Peak of Earth's radiant energy around 10 μm
  - negligible before ~ 4μm
- Total energy emitted in each case is **area under curve**

Electromagnetic Spectrum- Visible



- Visible part - very small part
  - from visible blue (shorter λ)
  - to visible red (longer λ)
  - ~0.4 to ~0.7µm

Violet: 0.4 - 0.446 µm

Blue: 0.446 - 0.500 µm

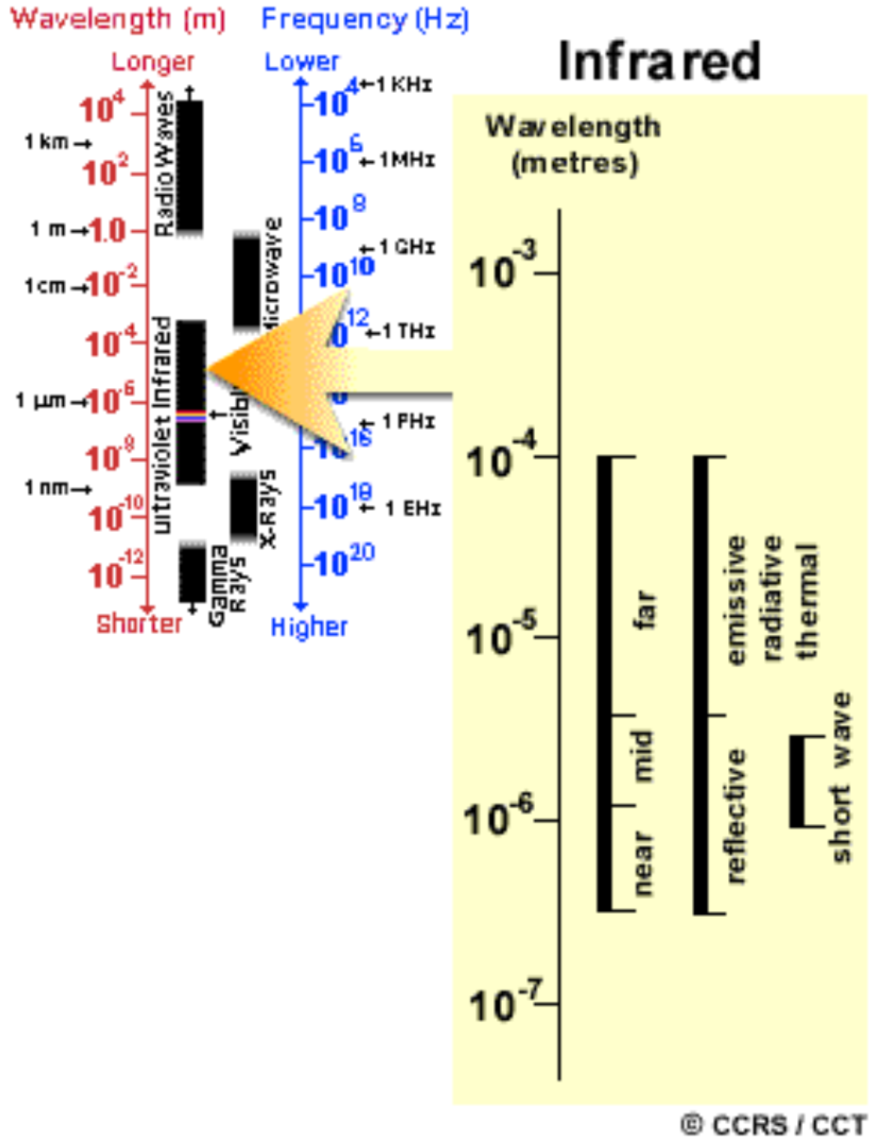
Green: 0.500 - 0.578 µm

Yellow: 0.578 - 0.592 µm

Orange: 0.592 - 0.620 µm

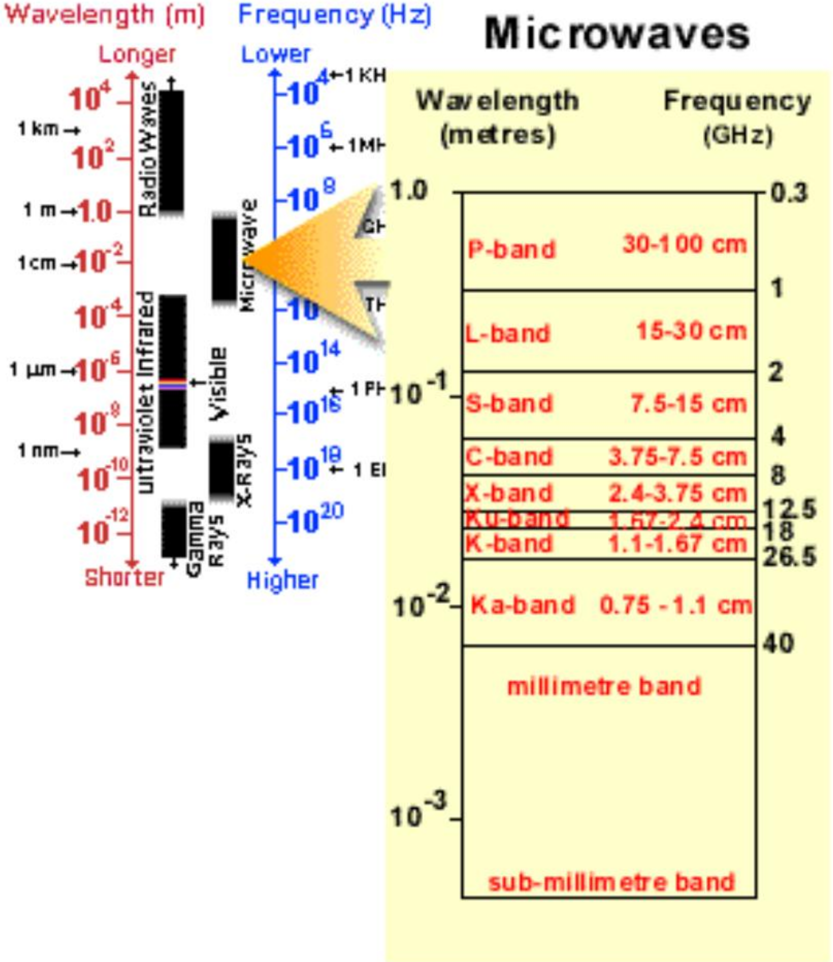
Red: 0.620 - 0.7 µm

Electromagnetic spectrum: IR



- Longer wavelengths (sub-mm)
- Lower energy than visible
- Arbitrary cutoff
- IR regions covers
  - reflective (shortwave IR, **SWIR**)
  - region just longer than visible known as near-IR, **NIR**
  - and emissive (longwave or thermal IR, **TIR**)

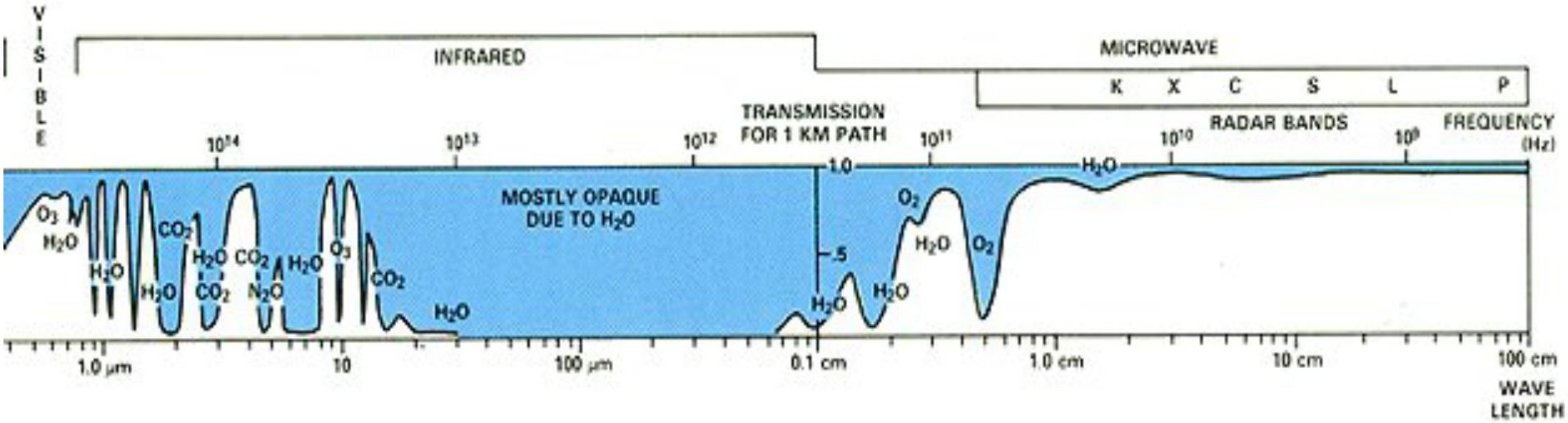
Electromagnetic spectrum: microwave



© CCRS / CCT

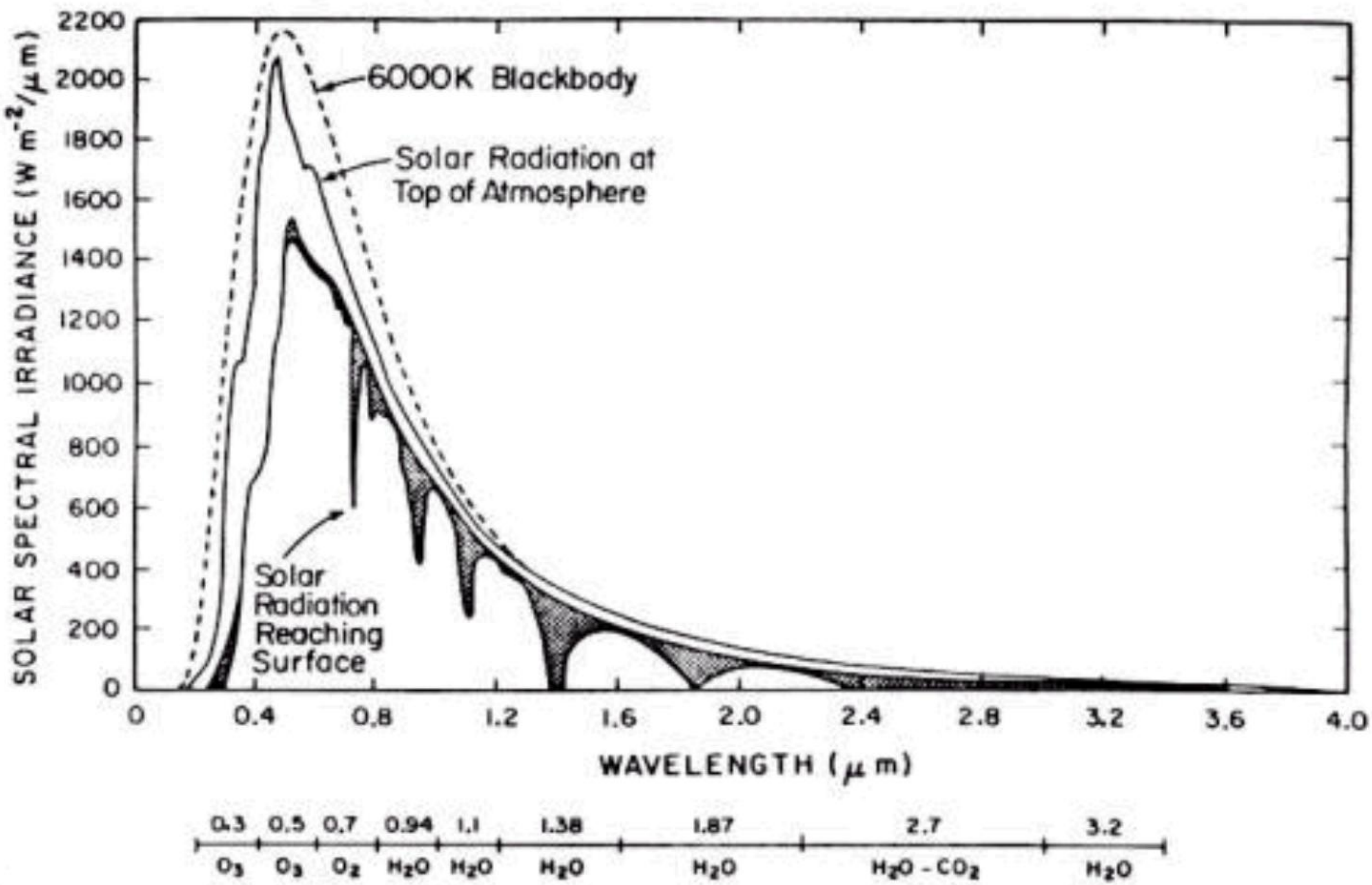
- Longer wavelength again
  - RADAR
  - mm to cm
  - various bands used by RADAR instruments
  - long λ so low energy, hence need to use own energy source (active μwave)

Electromagnetic spectrum



- Interaction with the atmosphere
  - transmission NOT even across the spectrum
  - need to choose bands carefully!

Departure from blackbody radiation



Remote Sensor Resolutions

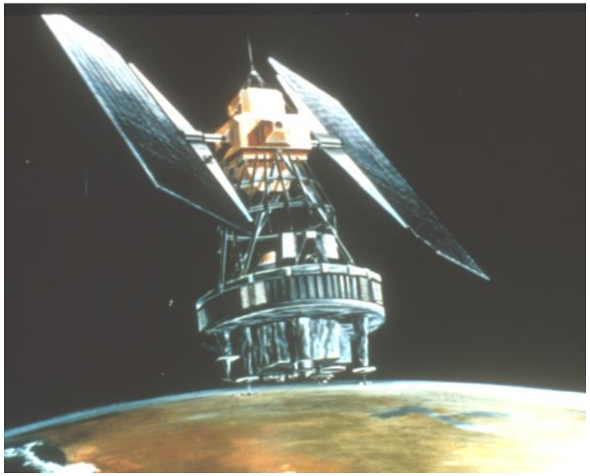
• Spatial: the size of the field-of-view, e.g. 10 x 10 m.

• Spectral: the number and size of spectral regions the sensor records data in, e.g. blue, green, red, near-infrared thermal infrared, microwave (radar).

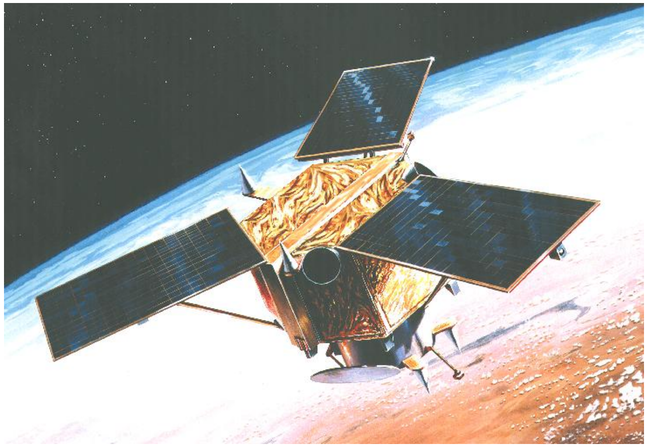
• Temporal: how often the sensor acquires data over the same location, e.g. every 15 min, 30 min, 12 hrs, 5 days…etc.

• Radiometric: the sensitivity of detectors to small differences in electromagnetic energy.

Today, we are on the verge of...



1972 - 80m resolution

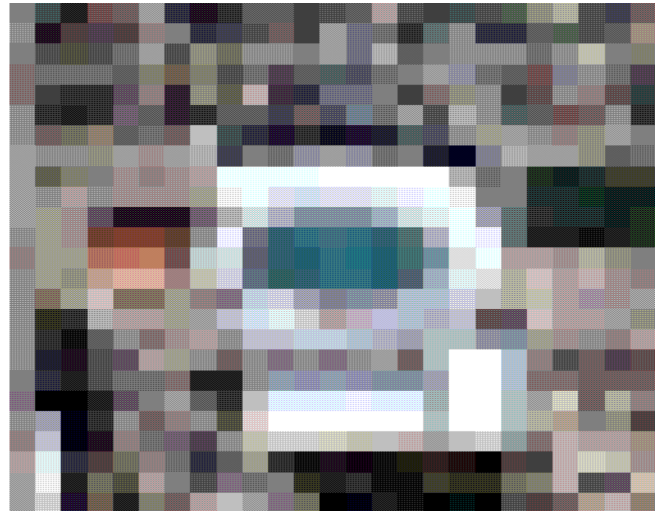


Today - 0.6m resolution

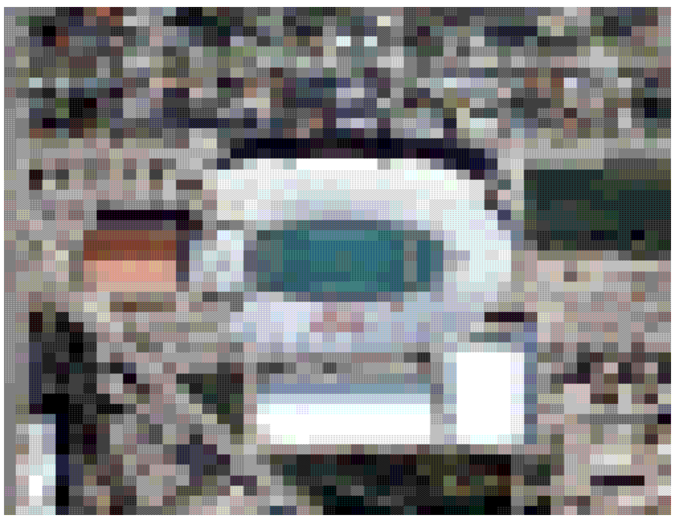
The Next Era of Satellite Remote Sensing Systems

Spatial Resolution

30 meter resolution
1982 Landsat Technology



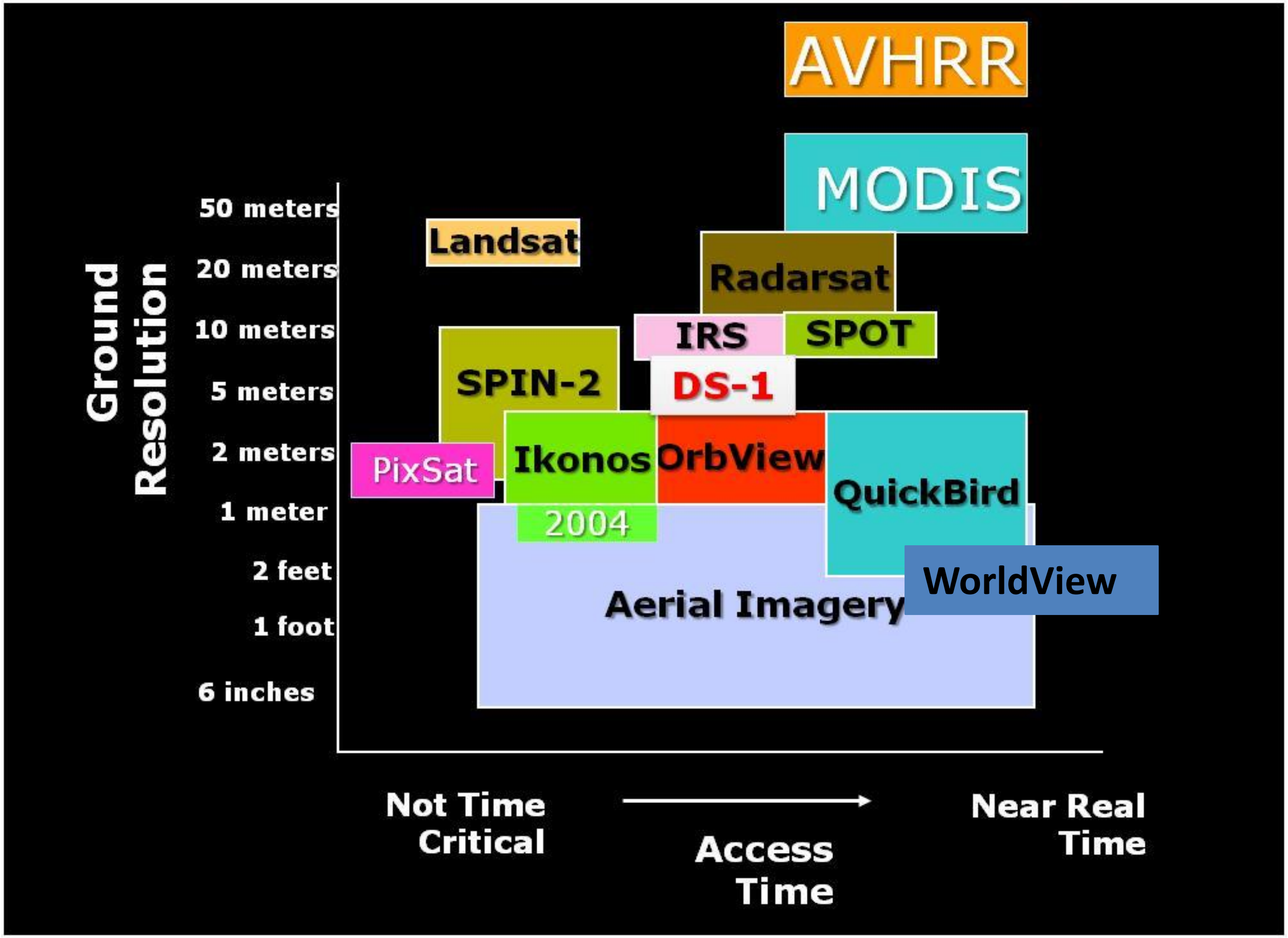
20 meter resolution
1986 SPOT Technology



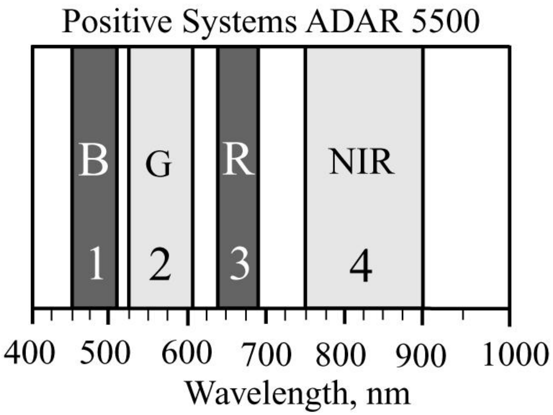
10 meter resolution
1986 SPOT Technology

1 meter resolution
Technology Available Since 1999

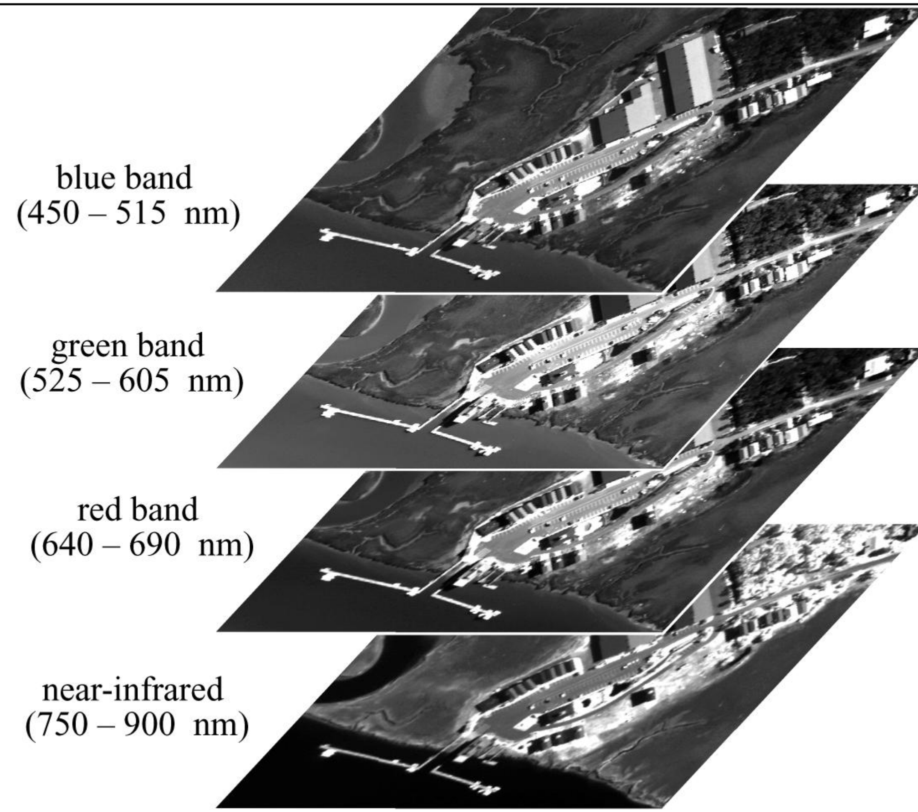
Remote Sensing Today



Spectral Resolution

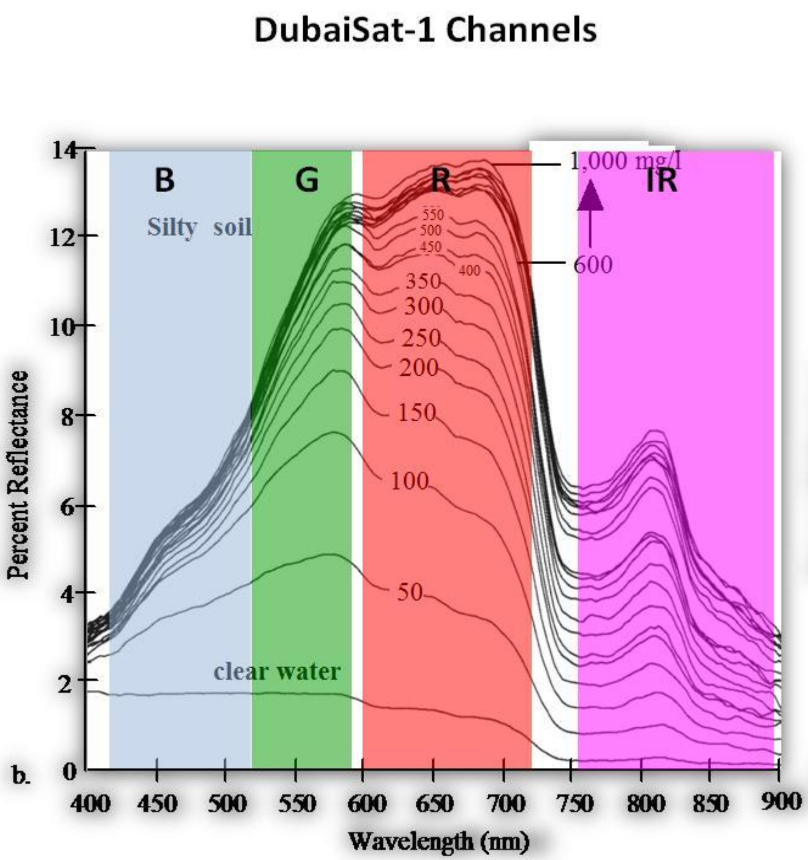


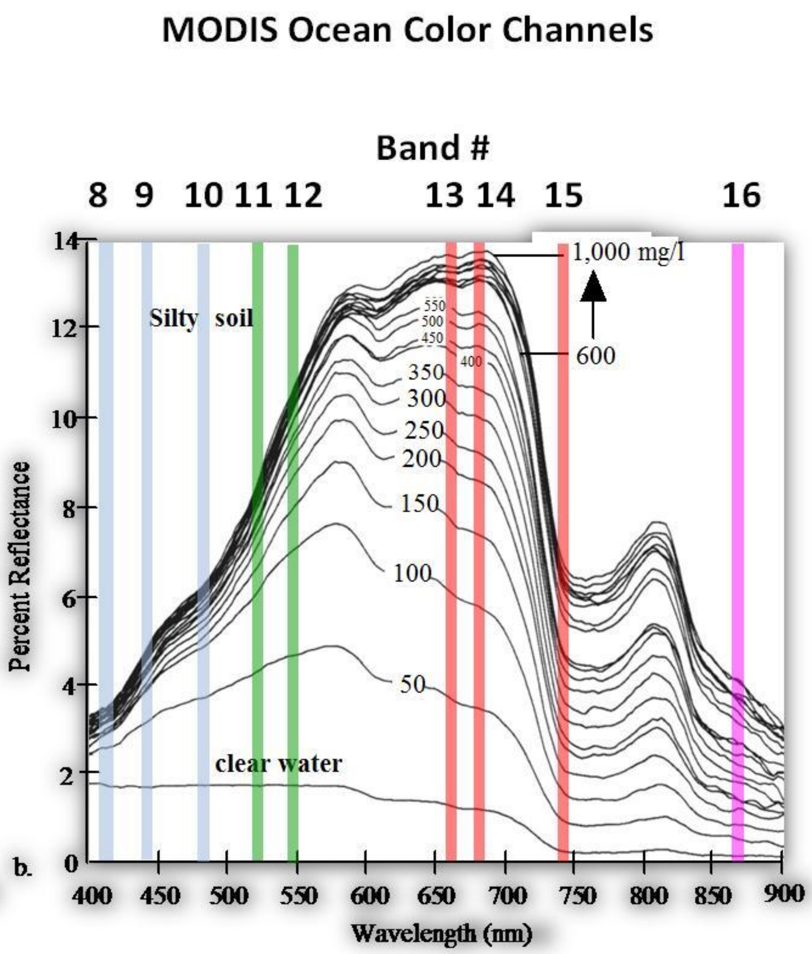
a. Nominal spectral resolution of the Positive Systems ADAR 5500 digital frame camera.

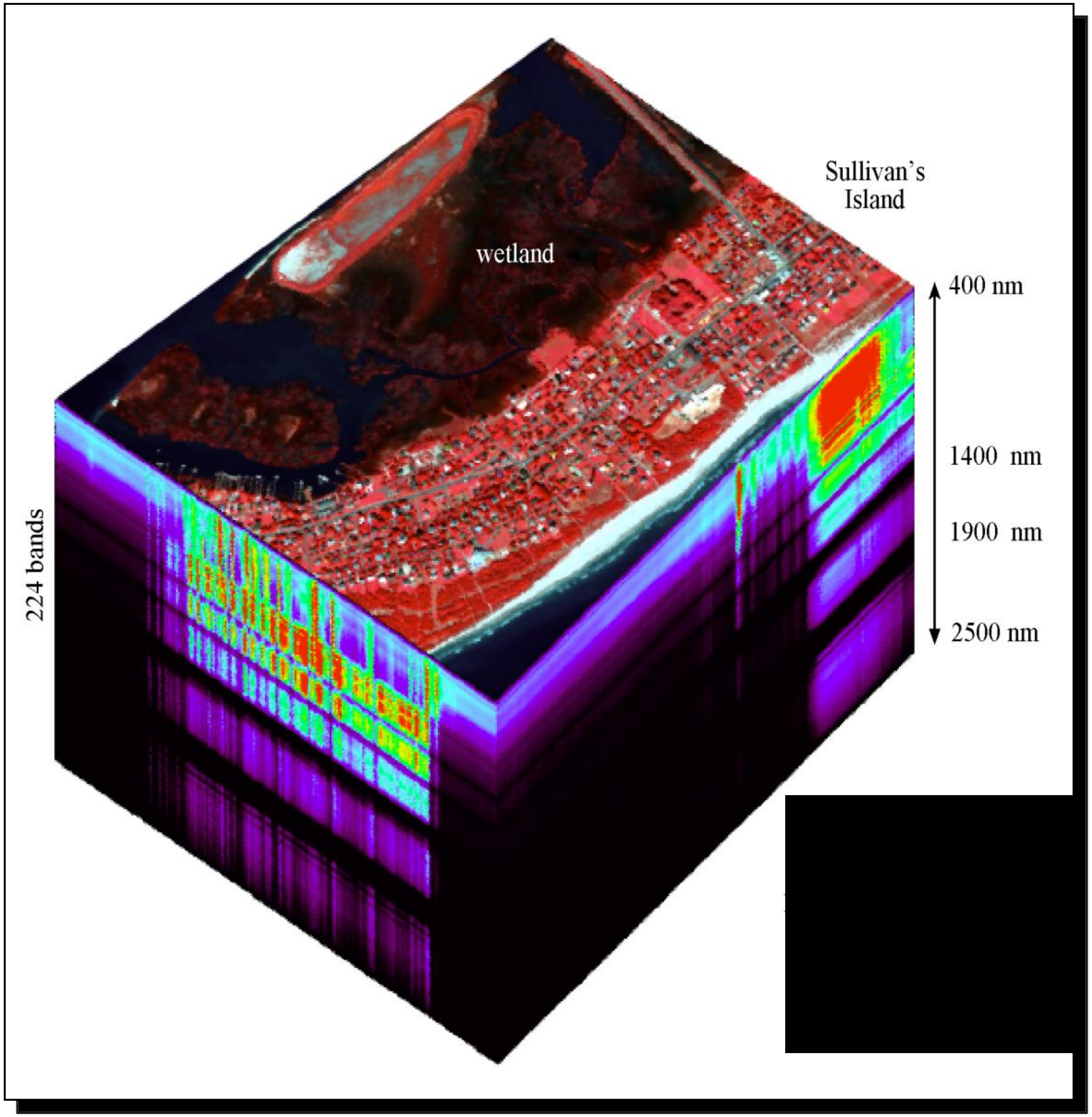


b. Multispectral remote sensing

Spectral Resolution

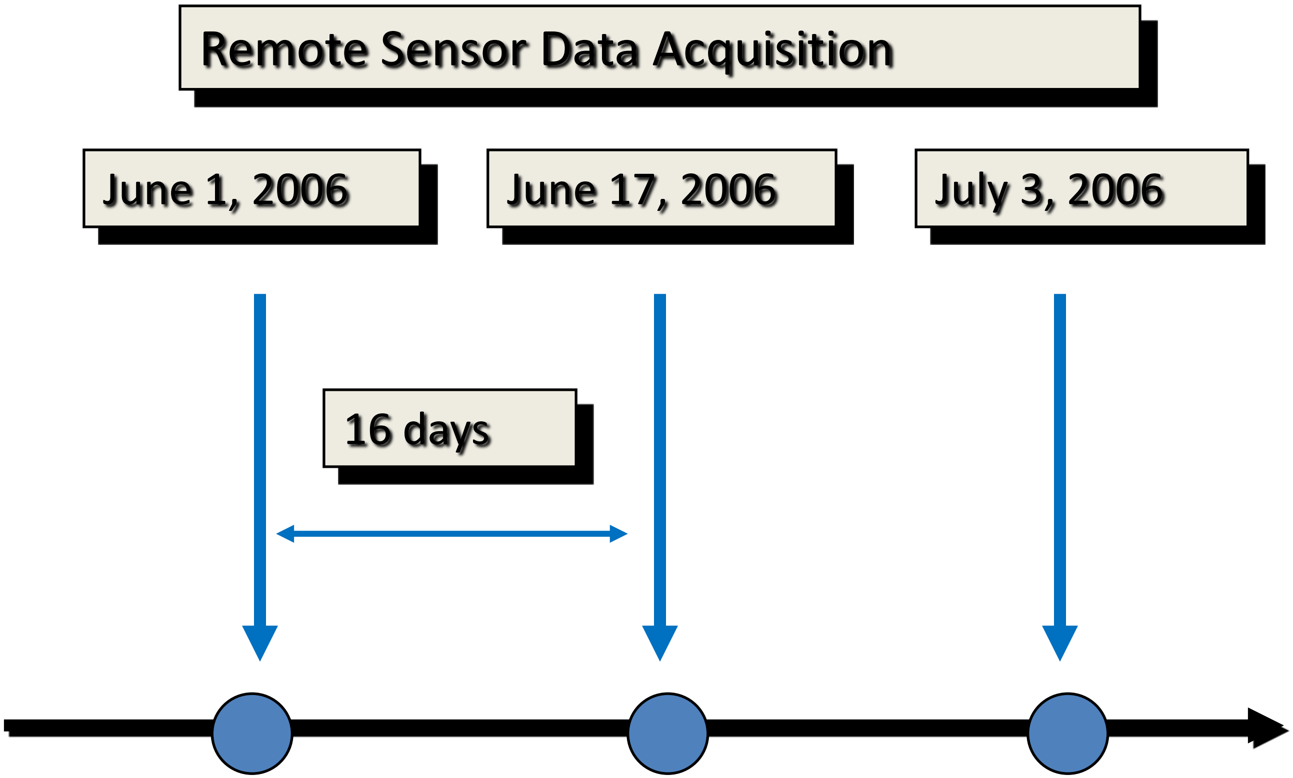






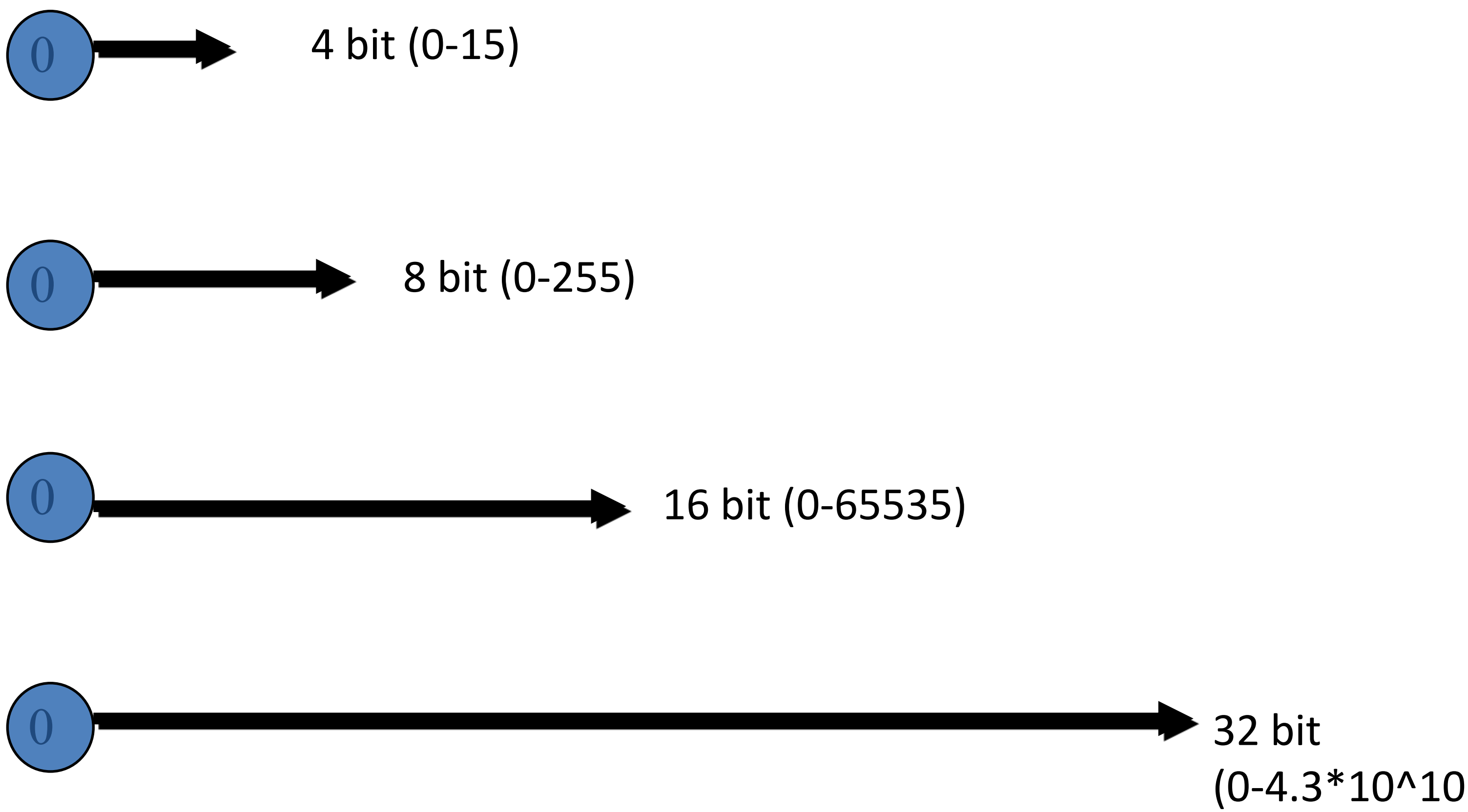
Airborne Visible Infrared Imaging Spectrometer (AVIRIS) Data cube of Sullivan's Island Obtained on October 26, 1998

Temporal Resolution



Jensen, 2007

Radiometric Resolution



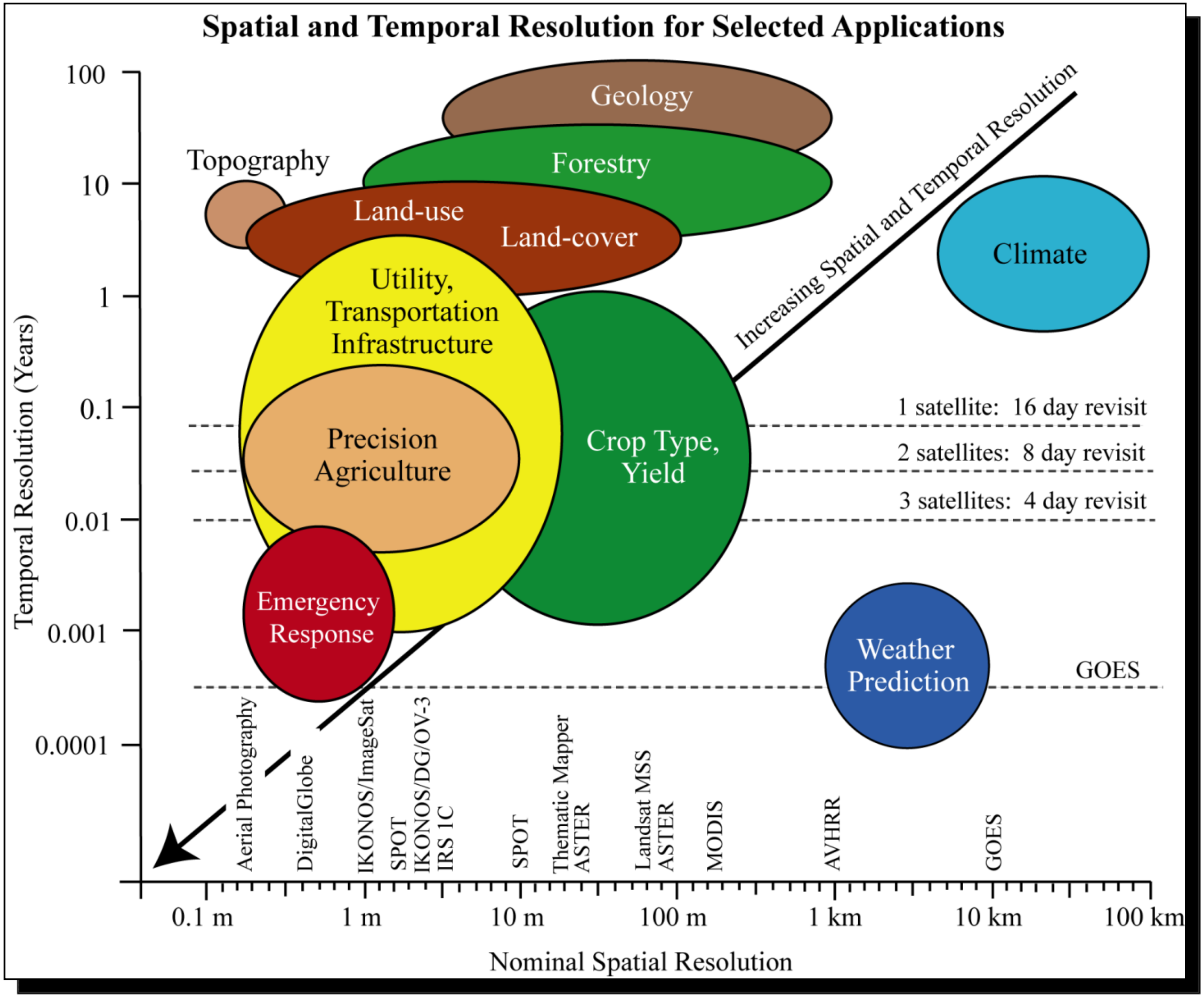

Spatial and Temporal Resolution for Selected Applications
Temporal Resolution (Years)
100
10
1
0.1
0.01
0.001
0.0001
Geology
Forestry
Topography
Land-use
Land-cover
Utility, Transportation Infrastructure
Precision Agriculture
Crop Type, Yield
Emergency Response
Climate
Weather Prediction
Increasing Spatial and Temporal Resolution
1 satellite: 16 day revisit
2 satellites: 8 day revisit
3 satellites: 4 day revisit
GOES
Aerial Photography
DigitalGlobe
IKONOS/ImageSat
SPOT
IKONOS/DG/OV-3
IRS 1C
SPOT
Thematic Mapper
ASTER
Landsat MSS
ASTER
MODIS
AVHRR
GOES
0.1 m
1 m
10 m
100 m
1 km
10 km
100 km
Nominal Spatial Resolution

Table 1-2. Biophysical and Hybrid Variables and Potentially Useful Remote Sensing Systems (proposed sensor systems are in italics)

Biophysical Variables	Potential Remote Sensing System
x, y Geographic location	Aerial photography, Landsat TM, SPOT HRV, Russian KVR-1000, IRS-1CD, ATLAS, Radarsat, ERS-1,2 microwave, Landsat 7 ETM+, Space Imaging IKONOS, Terra *MODIS, ASTER, EarthWatch Quickbird, ORBIMAGE OrbView 3,4*
z Topographic/bathymetric	Aerial photography, TM, SPOT, IRS-1CD, Radarsat, LIDAR systems, ETM, IKONOS, *ASTER, Quickbird, OrbView 3,4*
Vegetation	
chlorophyll concentration	Air photos, TM, SPOT, IRS-1CD, ETM, IKONOS, *ASTER, MODIS, OrbView 3,4*
biomass (green & dead)	Air photos, AVHRR, TM, SPOT, IRS-1CD, ETM, IKONOS, *MODIS, OrbView 3,4*
foliar water content	Radarsat, ERS-1,2; TM Mid-IR, ETM, IKONOS, *MODIS, ASTER, OrbView 3,4*
Absorbed photosynthetically active radiation	ETM, IKONOS, *MODIS, OrbView 3,4*
phytoplankton	SeaWiFS, TM, AVHRR, ETM, IKONOS, *MODIS, OrbView 3,4*
Surface temperature	GOES, SeaWiFS, AVHRR, TM, Daedalus, ATLAS, ETM, *ASTER, MODIS*
Soil moisture	ALMAZ, TM, ERS-1,2; Radarsat, Intermap Star 3i, IKONOS, *ASTER, OrbView 3,4*
Surface roughness	Air photos, ALMAZ, ERS-1,2; Radarsat, Star 3i, IKONOS, *ASTER, OrbView 3,4*
Evapotranspiration	AVHRR, TM, SPOT, CASI, ETM, *MODIS, ASTER*
Atmosphere tropospheric chemistry, temperature, water vapor, wind speed/direction, energy inputs, precipitation, cloud and aerosol properties	GOES, UARS, ATREM, *MODIS, MISR, CERES, MOPITT*

After Jensen, p. 9

BRDF (bidirectional reflectance distribution function)	*MODIS*, *MISR*, *CERES*
Ocean color, phytoplankton, biochemistry, sea height	TOPEX/POSEIDON, SeaWiFS, ETM, IKONOS, *MODIS*, *MISR*, *ASTER*, *CERES*, *OrbView 3,4*
Snow and sea ice extent and characteristics	Aerial photography, AVHRR, TM, SPOT, Radarsat, SeaWiFS, IKONOS, ETM, *MODIS*, *ASTER*, *OrbView 3,4; Quickbird*
Volcanic effects temperature, gases	ATLAS, *MODIS*, *MISR*, *ASTER*
Selected Hybrid Variables	**Potential Remote Sensing System**
Land use urban infrastructure and land use	Aerial photography, AVHRR, TM, SPOT, Russian KVR-1000, IRS-1CD, Radarsat, Star 3i, ETM, IKONOS, *MODIS*, *ASTER*, *OrbView 3,4; Quickbird*
Vegetation stress	Aerial photography, Daedalus, ATLAS, AVHRR, TM, SPOT, IRS-1CD, IKONOS, SeaWiFS, ETM, *MODIS*, *ASTER*, *OrbView 3,4; Quickbird*

Remote Sensing Image Interpretation

- *1) Visual interpretation*
- *2) Digital image processing for information extraction from sensor data sets*

Digital image processing (computer-based)

Computer-based analysis and reprocessing of raw data into new visual or numerical products, which then are interpreted either by approach 1 or are subjected to appropriate decision-making algorithms that identify and classify the scene objects into sets of information

The techniques fall into three broad categories:

Image Restoration and Rectification
Image Enhancement
Image Classification

Image representation

65	63	68	76	82	81	79	82	91	99	100	97	94	94	96	98	98	95	84	60	29	14	15	18	27	40	47	50	57	59	55	54	57	59	58	56	57	57	56	52	51	53	55	56	56	55	53	51	50	50	49	45	44	47	49	45	46	51	54	54	54	54	52	52	55	58	64	62	55	49	41	29	20	16	15	18	23	33	32	30
72	75	78	82	86	87	89	93	99	107	107	100	96	96	100	100	95	89	78	55	28	16	21	24	34	47	52	53	61	59	56	55	57	61	56	54	56	57	56	54	53	54	56	57	60	57	53	52	52	48	51	52	51	50	48	47	52	54	53	54	52	49	52	58	62	63	68	63	49	36	27	17	14	15	15	15	20	32	35	35
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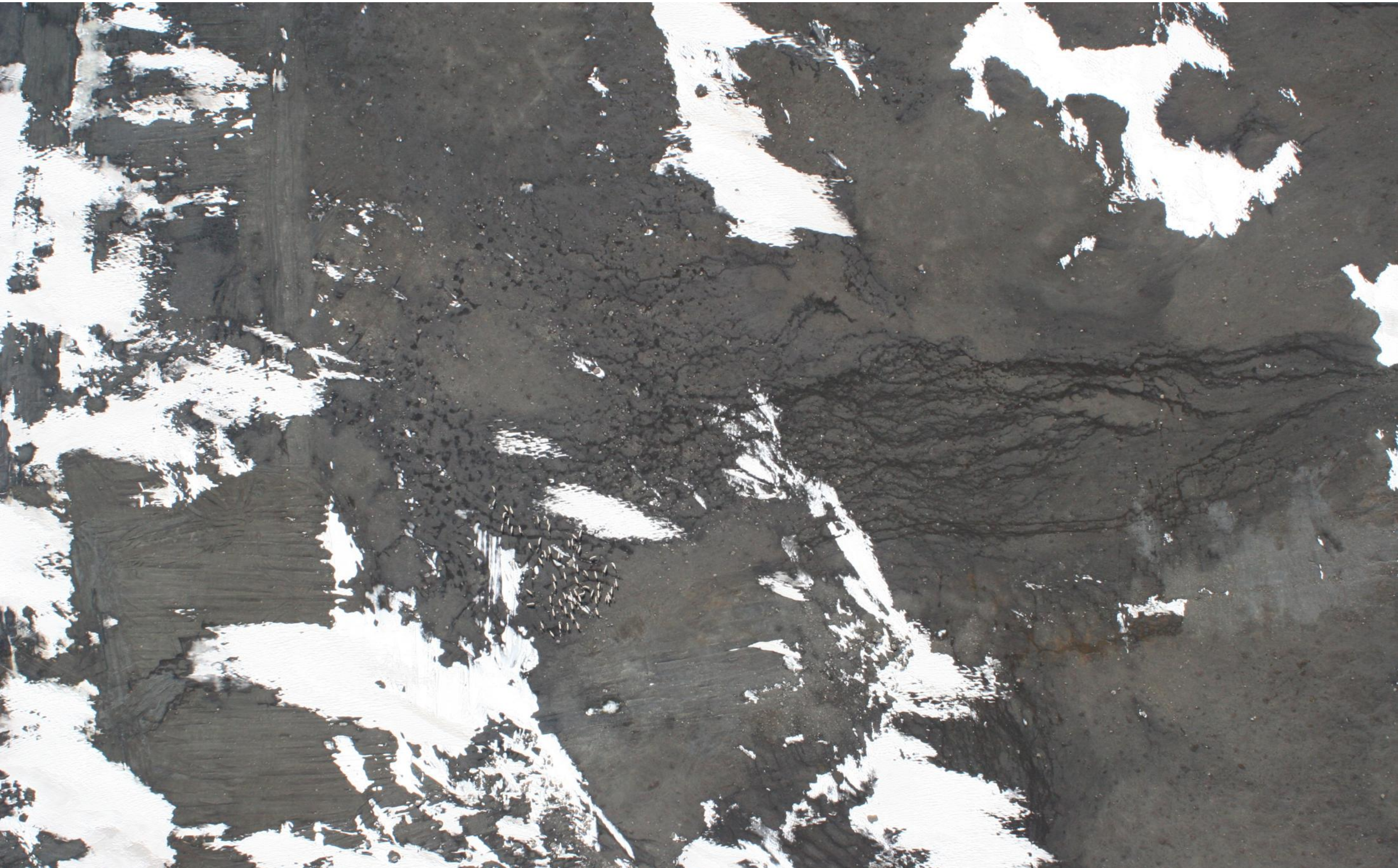
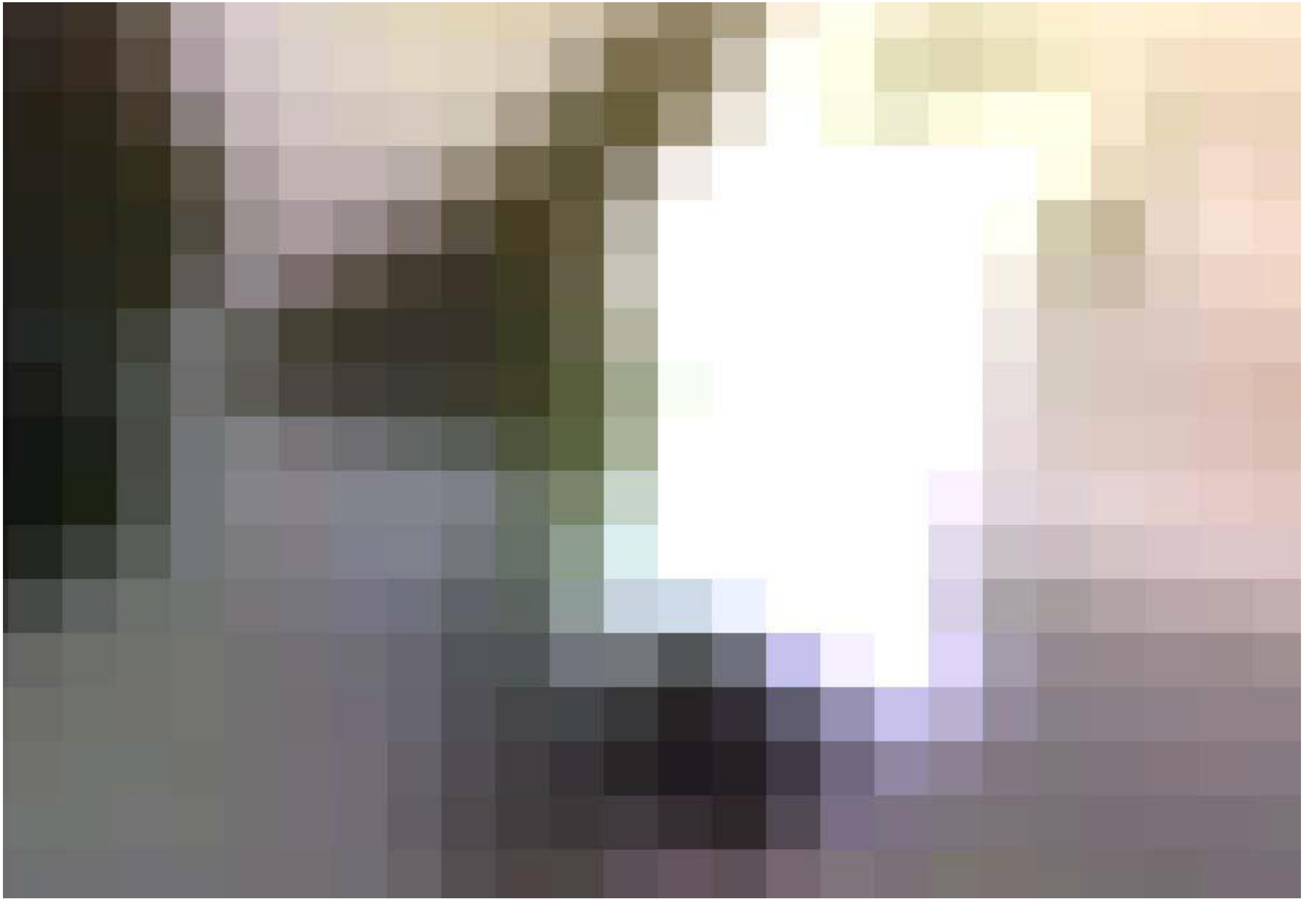
Keys for image interpretation



What do you see?



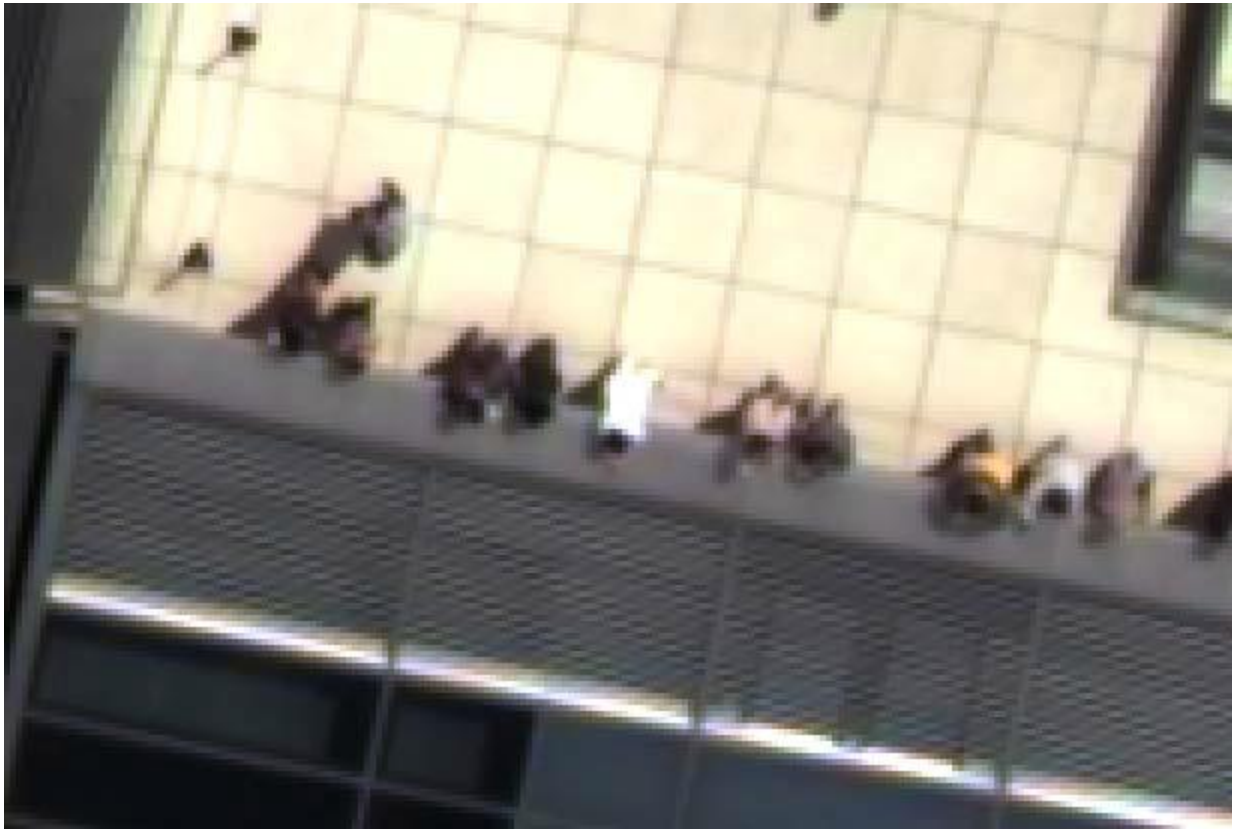


Image interpretation is a combination of experience and adaptability.

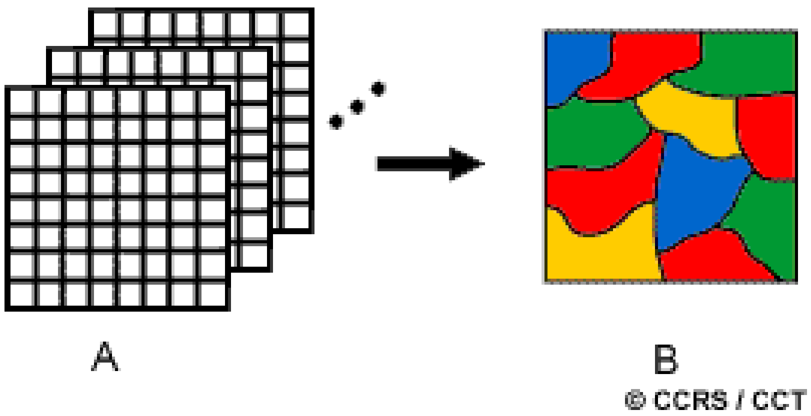
The following are all important while interpreting satellite images.

Spectral information,
Shape,
Size,
Texture and
Context

Classification of RS data

What is classification?

Classification is the task of relating pixel information in a digital image to ground truth based on spectral, spatial and contextual information.



Classification

- Supervised

➢ Requires examples based on ground truth to train the classifiers.

➢ The ground truth classes may not contain pixels with similar spectra.

- Unsupervised

➢ Clusters the data and assigns the corresponding clusters to the classes based on user input.

➢ The maximally-separable clusters in spectral space may not match our perception of the important classes on the landscape.

Supervised classification

1. Selecting training regions
2. Training the classifier
3. Validating the results based on a test set

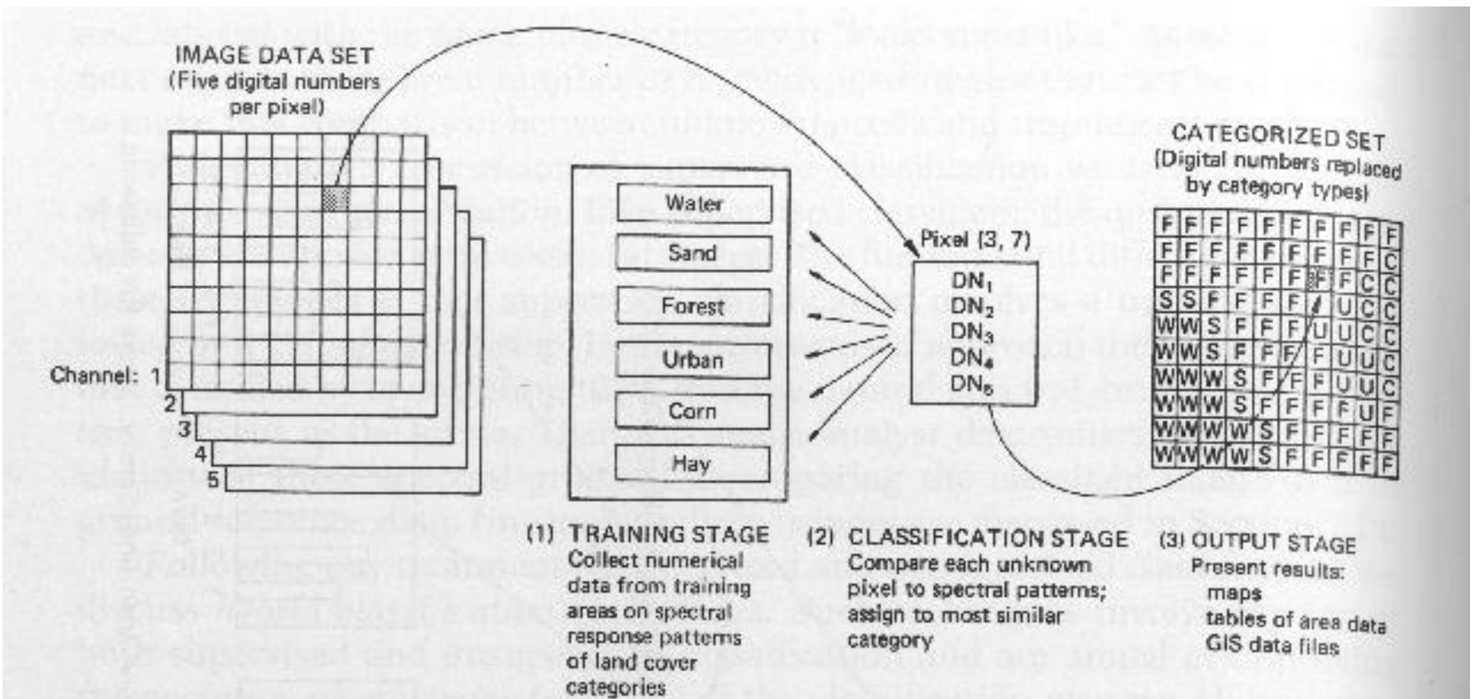
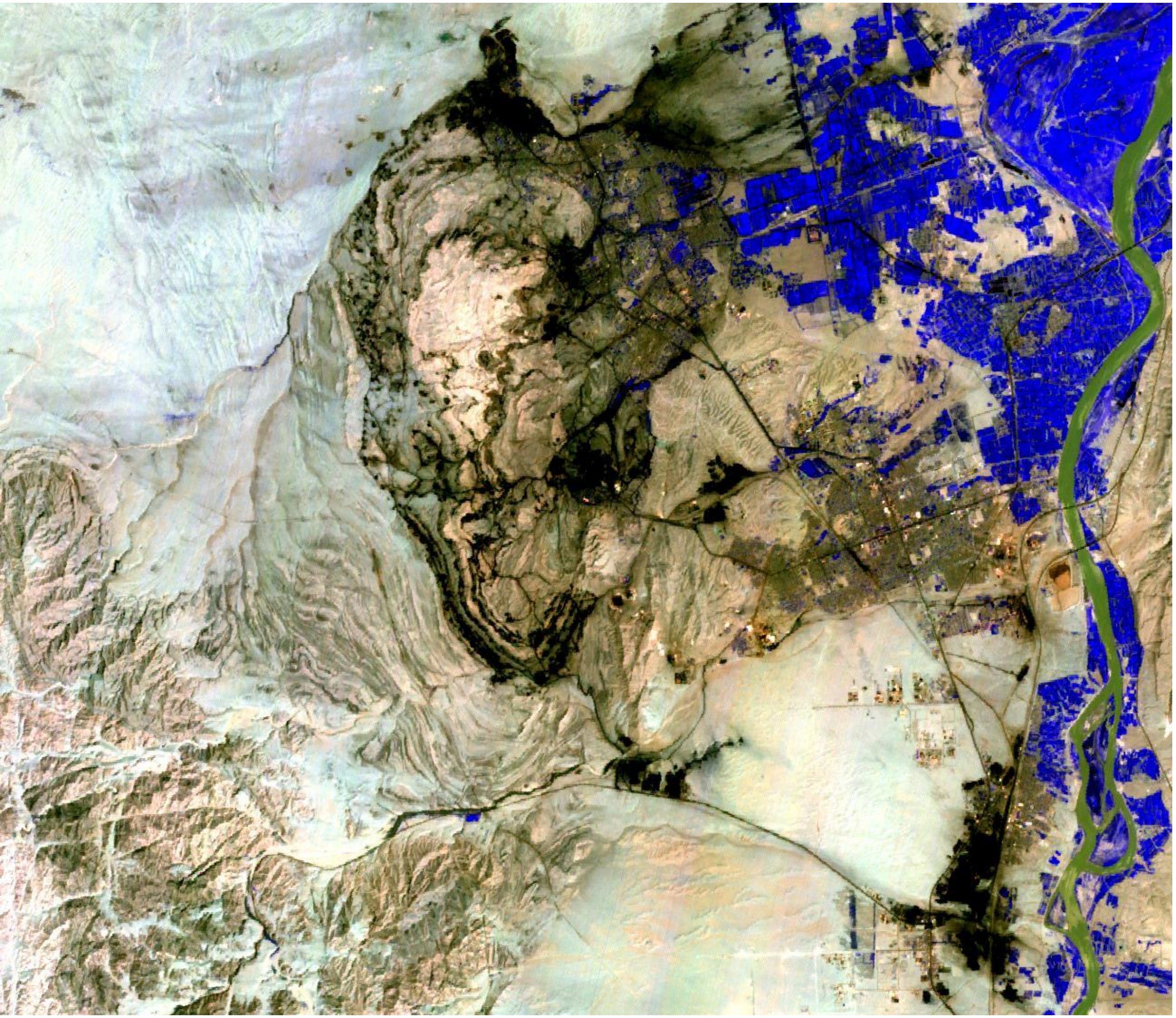


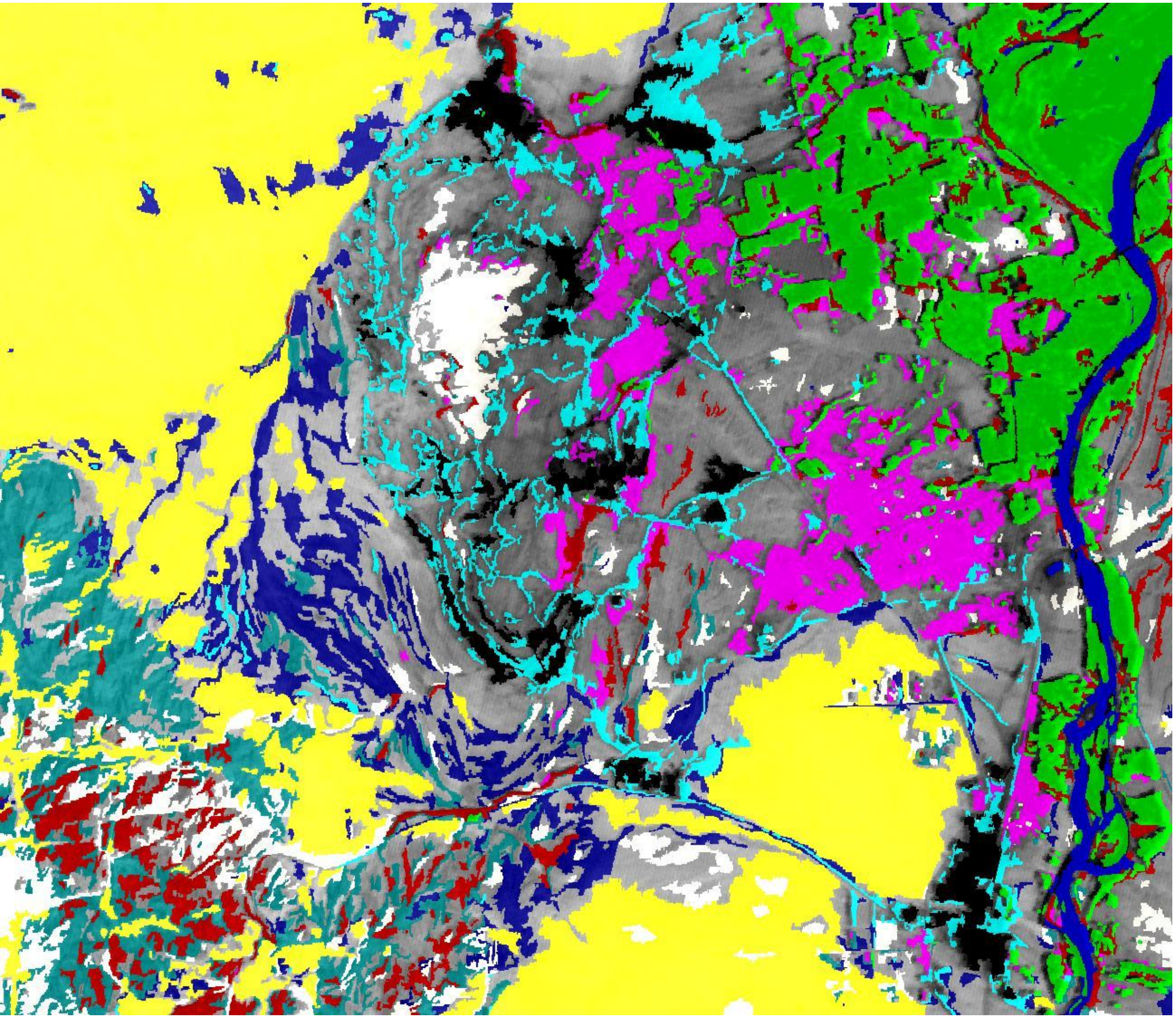
Figure 7.38 Basic steps in supervised classification.

From Lillesand, Kiefer and Chipman (2004)

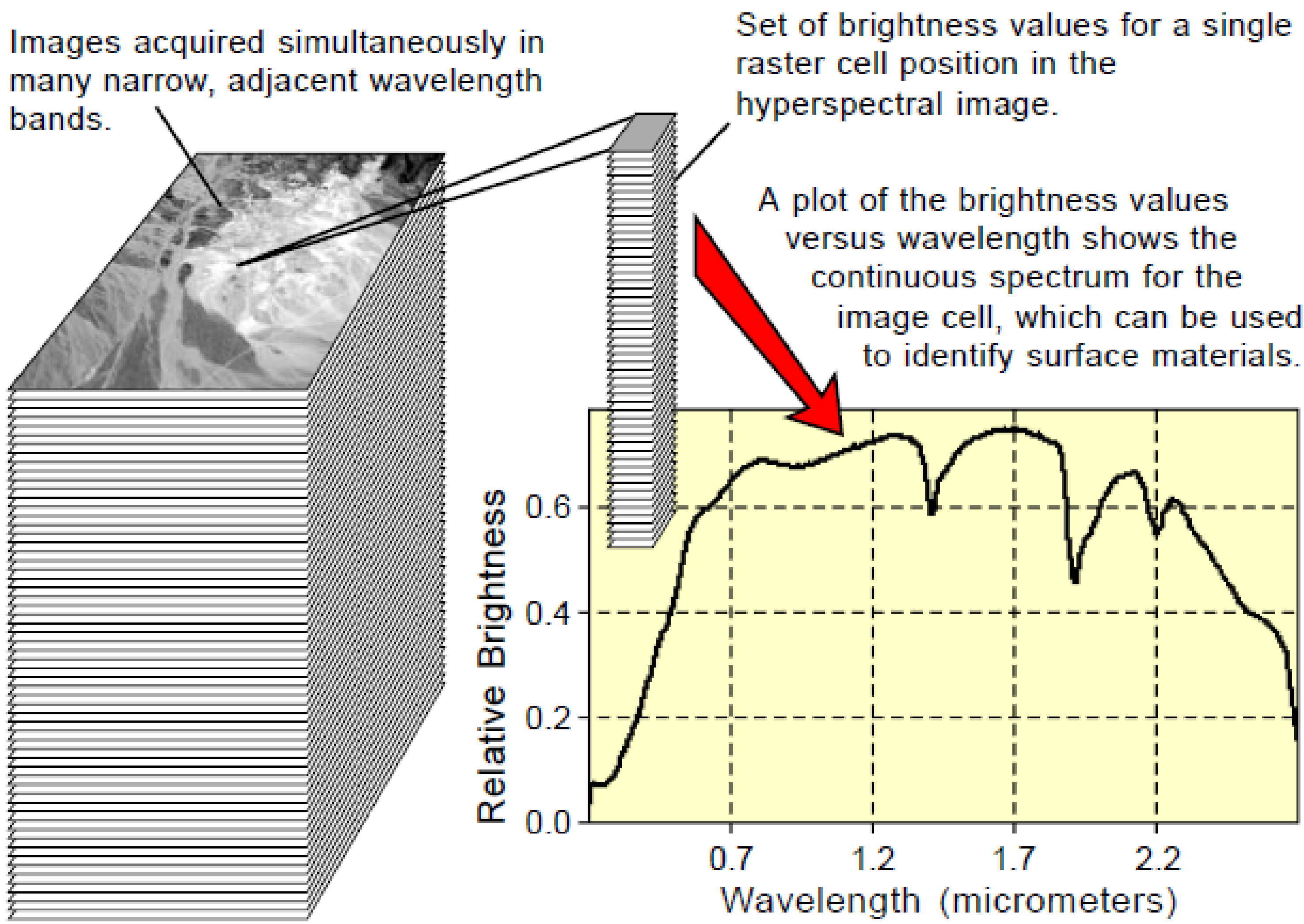
Coal fire prone areas mapping in China



Classification



Hyperspectral Imaging Applications



Hyperspectral Imaging Applications

Hyperspectral imaging using an airborne platforms can be used in surveillance applications such as:

1) Camouflage target detection.
2) Search and rescue.
3) Illegal disposal of waste.
4) Monitoring water quality in the gulf (e.g., algal blooms)

Change Detection

- Dynamic changes in Landscape (Human activities, natural disasters, changes in vegetation cover, shrinking of glaciers due to global warming, etc).
- Need for updating maps in short intervals.
- Earth observation (EO) data are increasingly being made available with better resolution.
- Need to develop efficient methods to map changes in a timely manner and maximize the automation to process huge amounts of data.

Multivariate Alteration Detection

2003

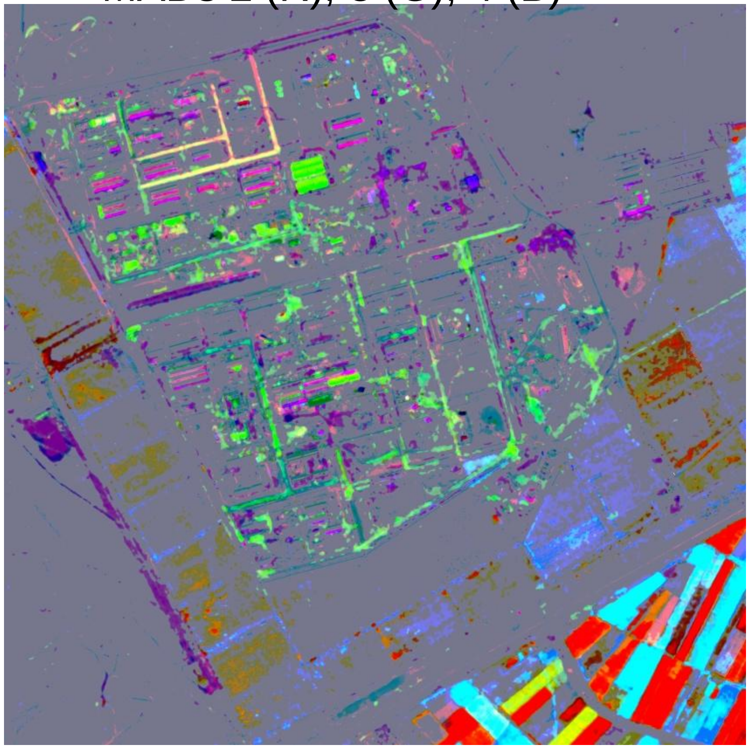
2002

$U = a^T F$

$$D = a^T F - b^T G$$

$V = b^T G$

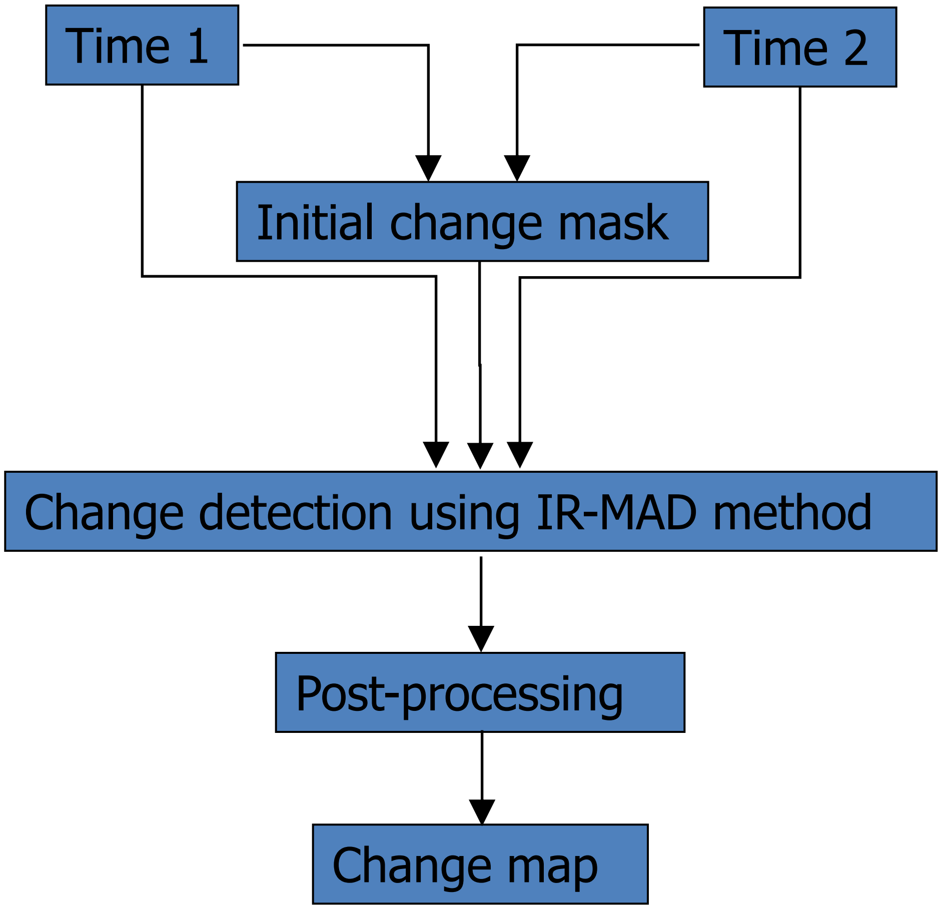
MADs 2 (R), 3 (G), 4 (B)



- Determination of **a** and **b**, so that the positive correlation between $U = a^T F$ and $V = b^T G$ is minimized.
- Canonical correlation analysis (Hotelling, 1936).
- Fully automatic scheme gives regularized iterated MAD variates, invariant to linear/affine transformations, orthogonal.

(Nielsen et al, 1998; Nielsen, 2007)

Our approach

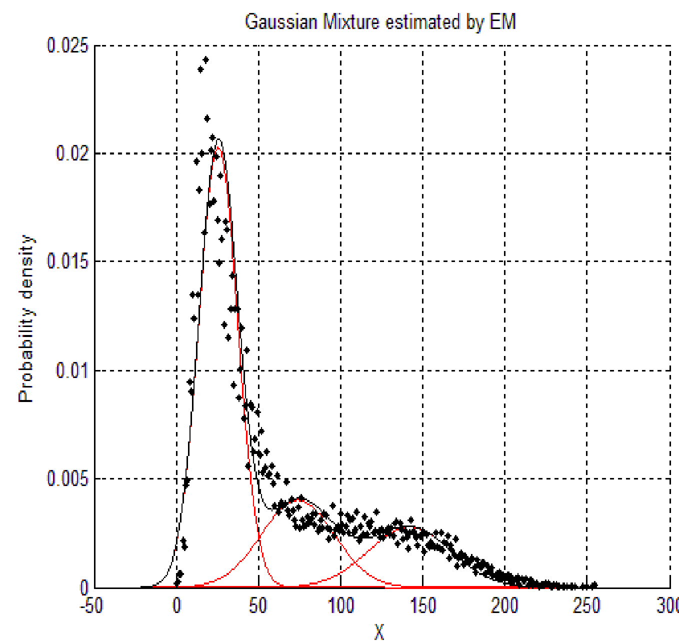


Strategies for generating the ICM

- Multispectral images

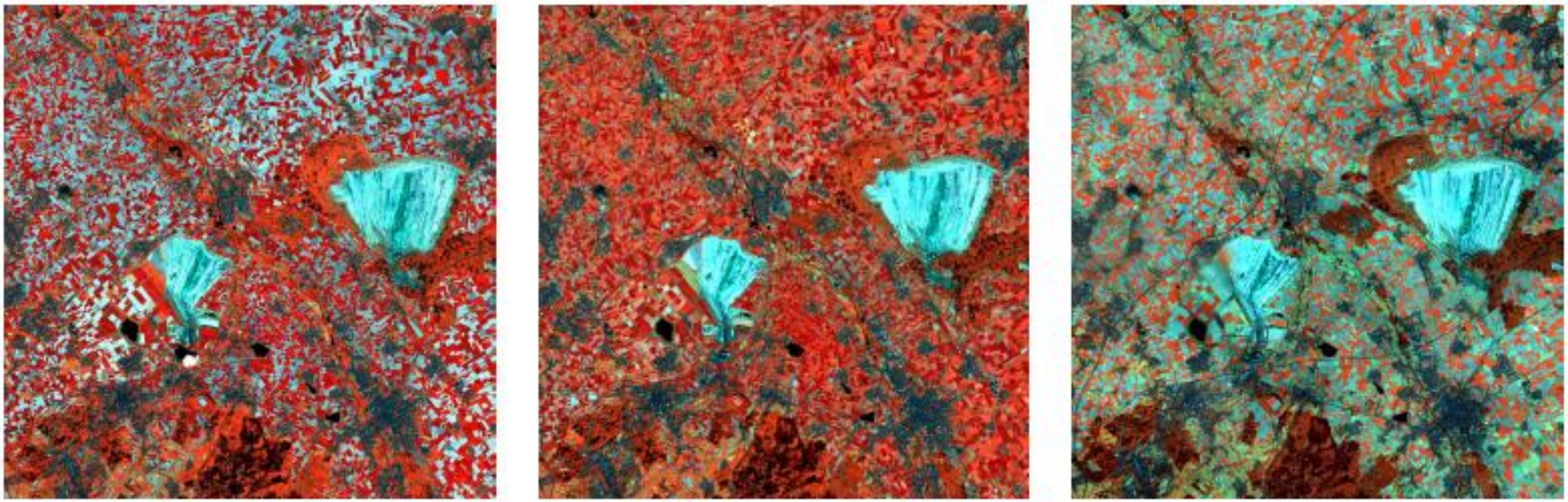
➢The data are stretched in the range of 0-255 and the maximum difference between two times, measured over all the bands, is calculated.

➢The resulting difference image is modelled as a mixture of 3 Gaussians and a threshold is identified to eliminate strong changes.



Multispectral change detection using IR-MAD and initial change mask.

Experiments with ICM

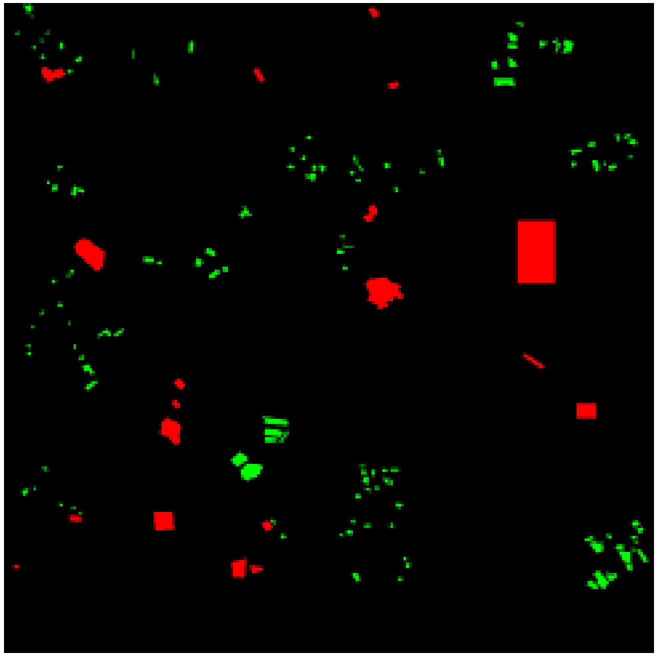


Landsat ETM+ images over Juelich, Germany taken in May, June and August, 2001.

Major changes due to agricultural regions. Only the human settlement areas and mining area remain unchanged.

Experiments

May- June



May- August

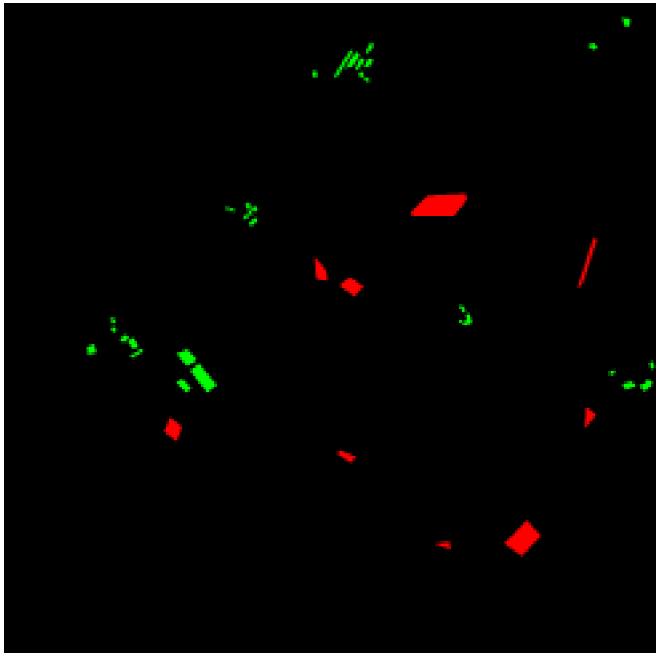
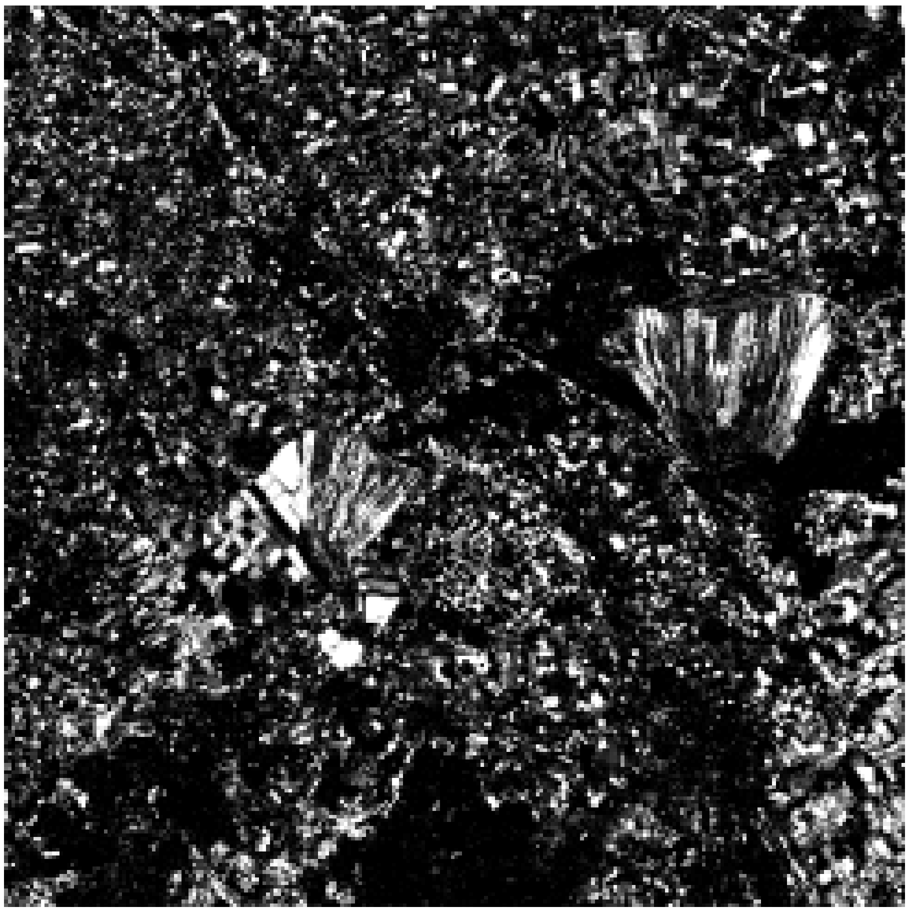


Image Pair	Change	No-change
May-June	9521	13911
May-August	4103	6317

Experiments

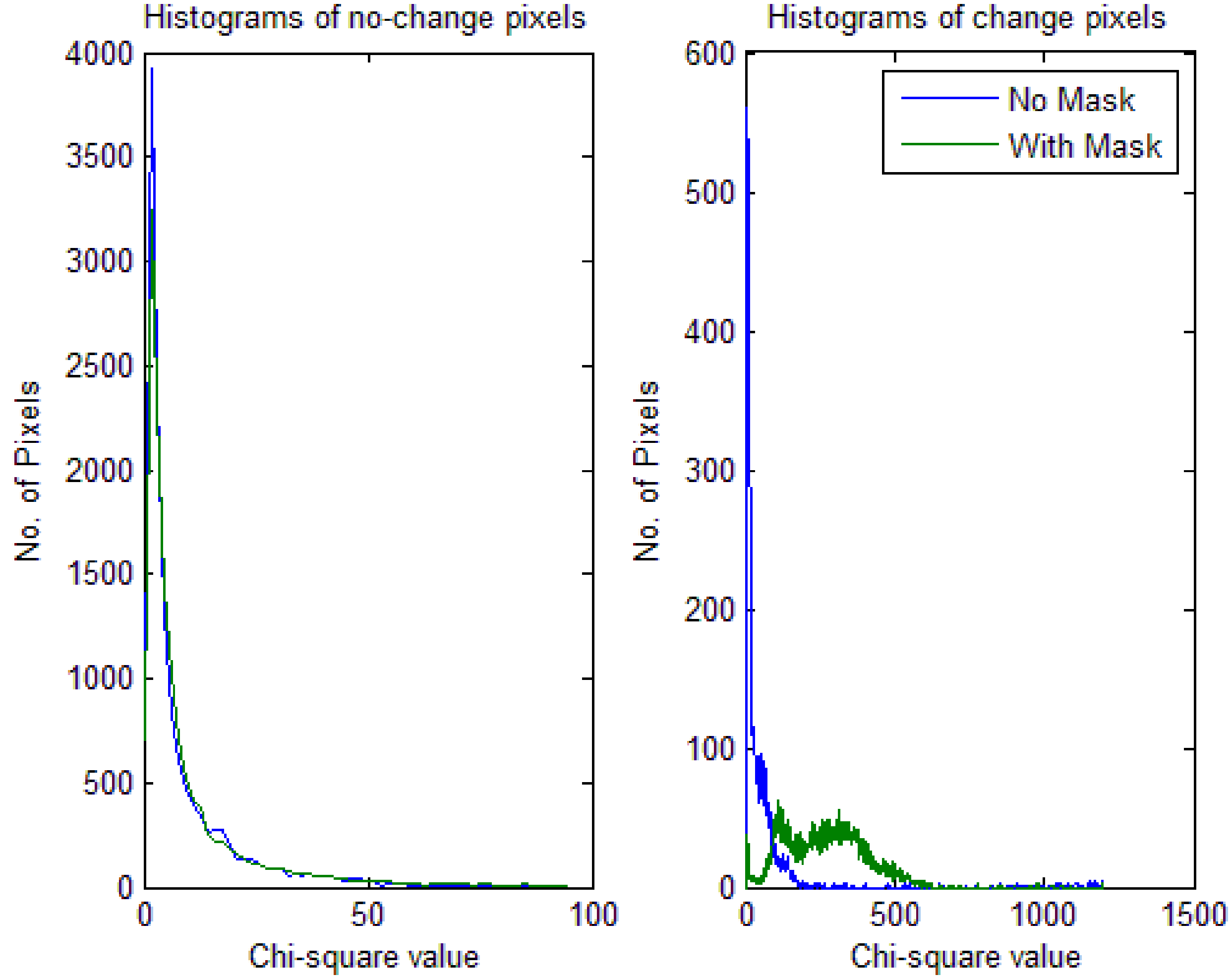
May -June



Without Mask

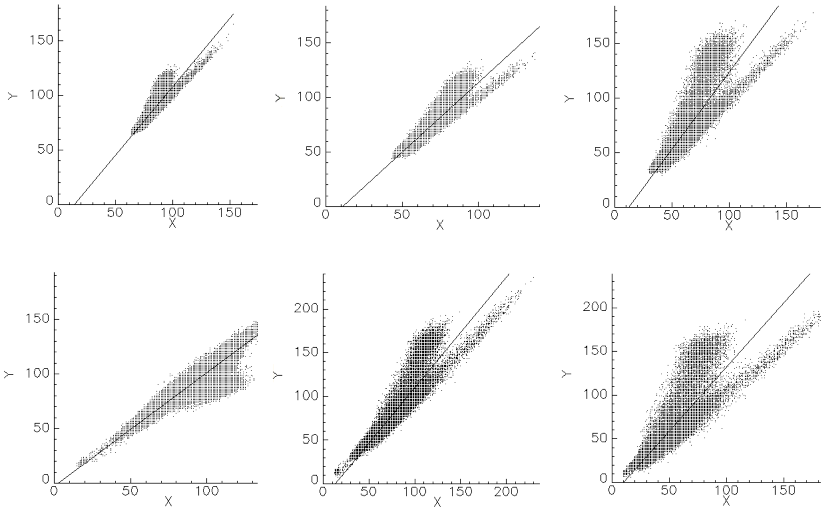
With Mask

Experiments

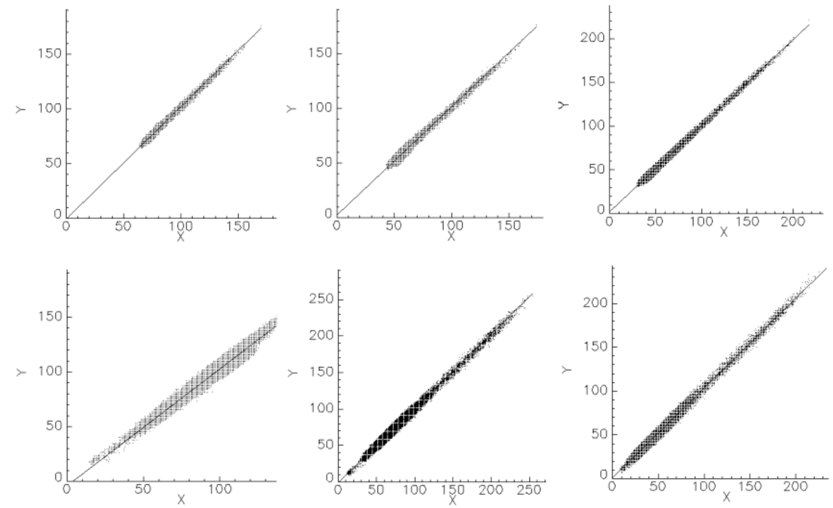


Experiments

Automatic radiometric normalization



Without Mask

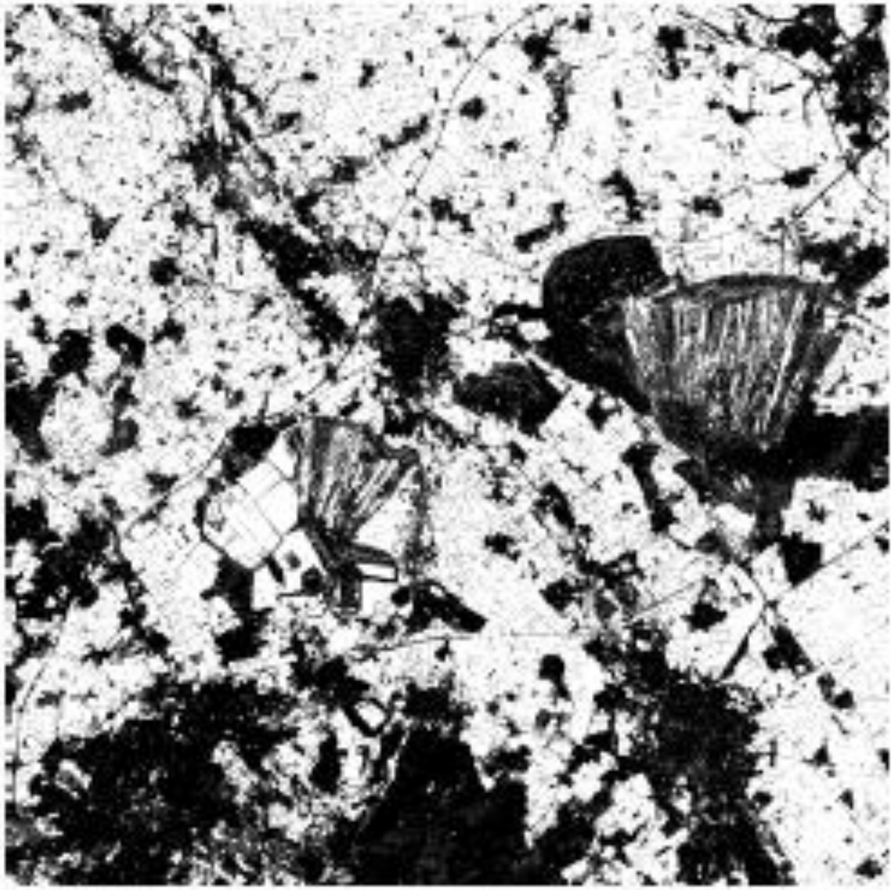


With Mask

Experiments

May- August

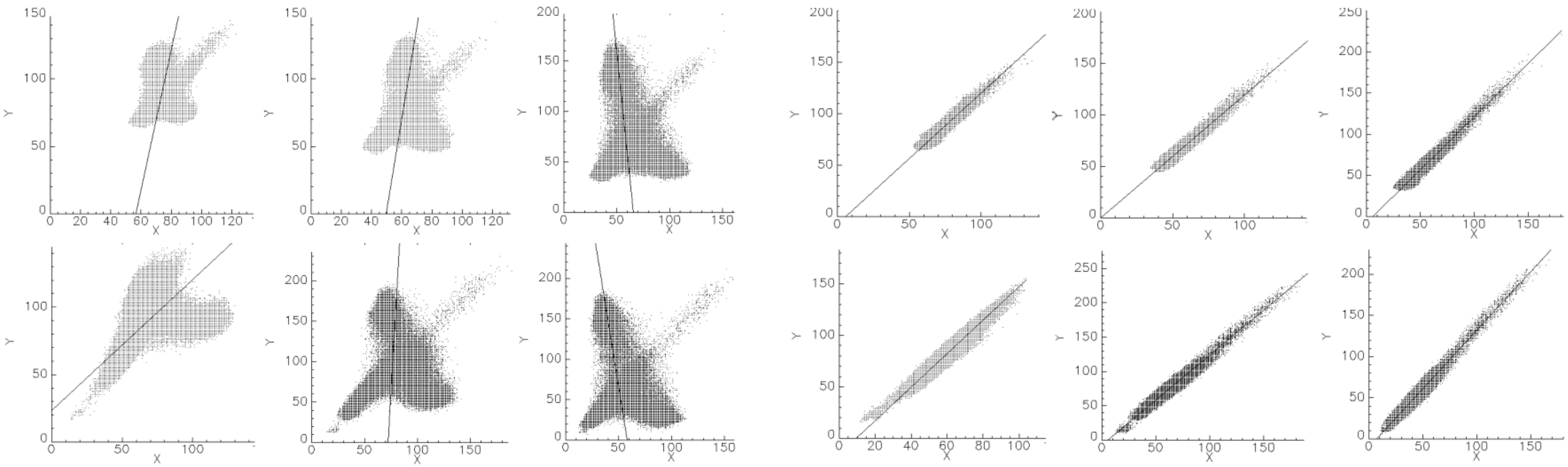
Without Mask



With Mask

Experiments

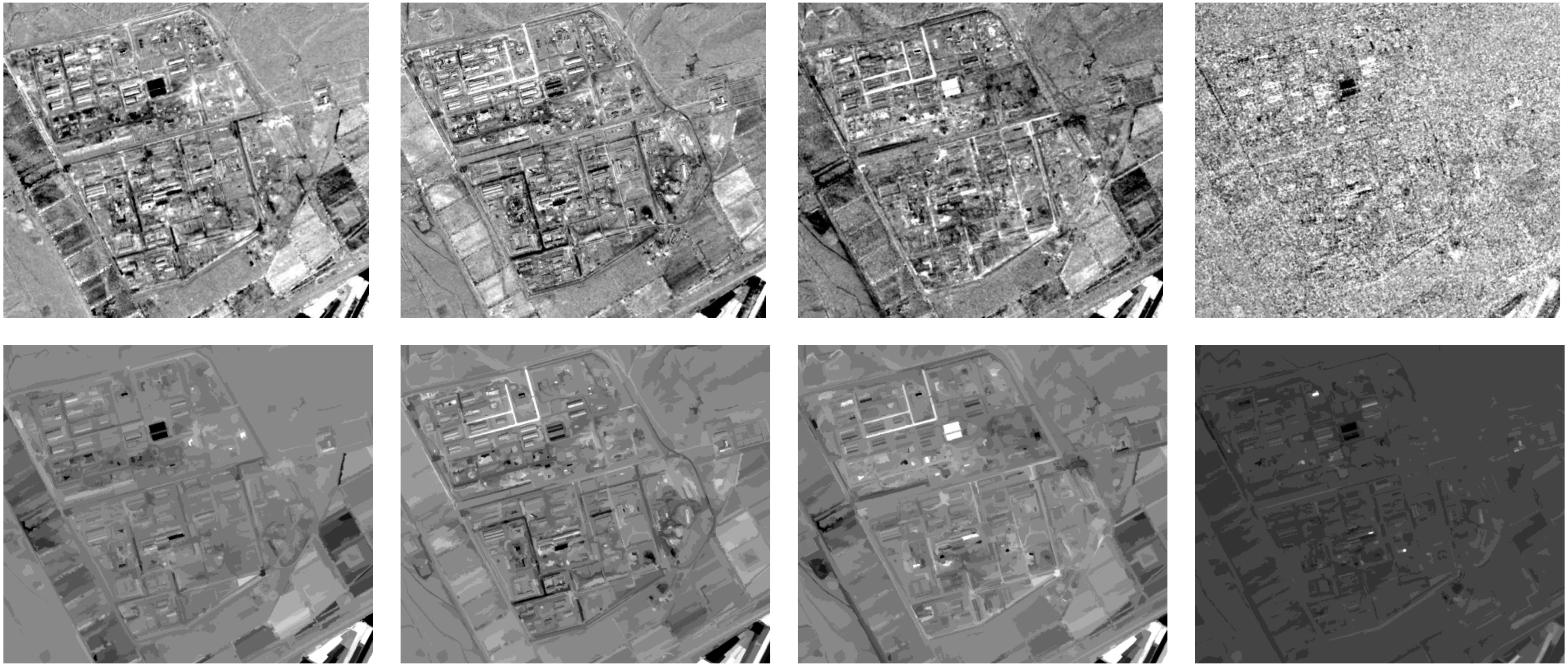
Automatic radiometric normalization



Without Mask

With Mask

CD with image segments



The effect of the noise is reduced and hence better projections are identified using MAD transformation.