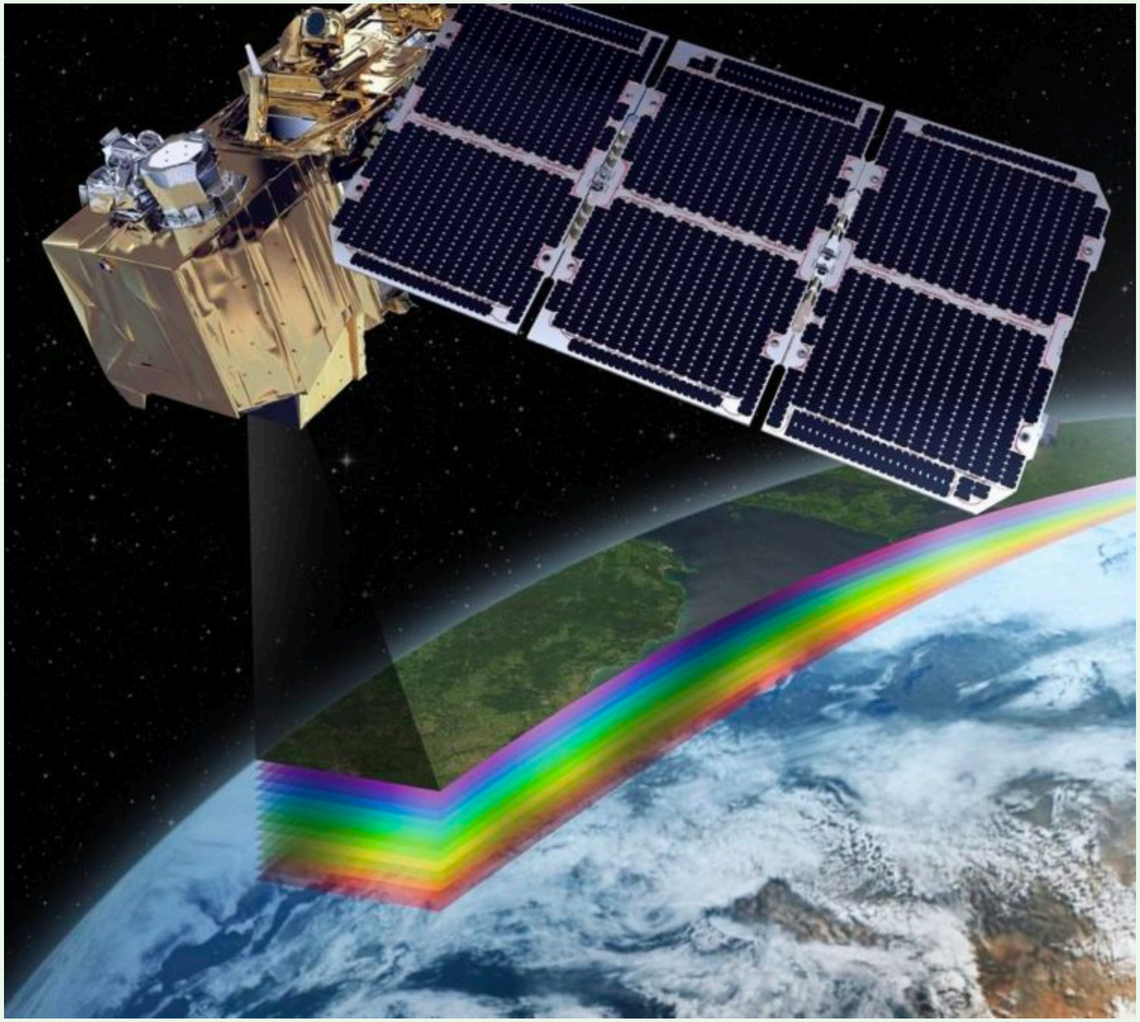
GEOG 358: Introduction to Geographic Information Systems

Remote Sensing



Remote Sensing

Topics

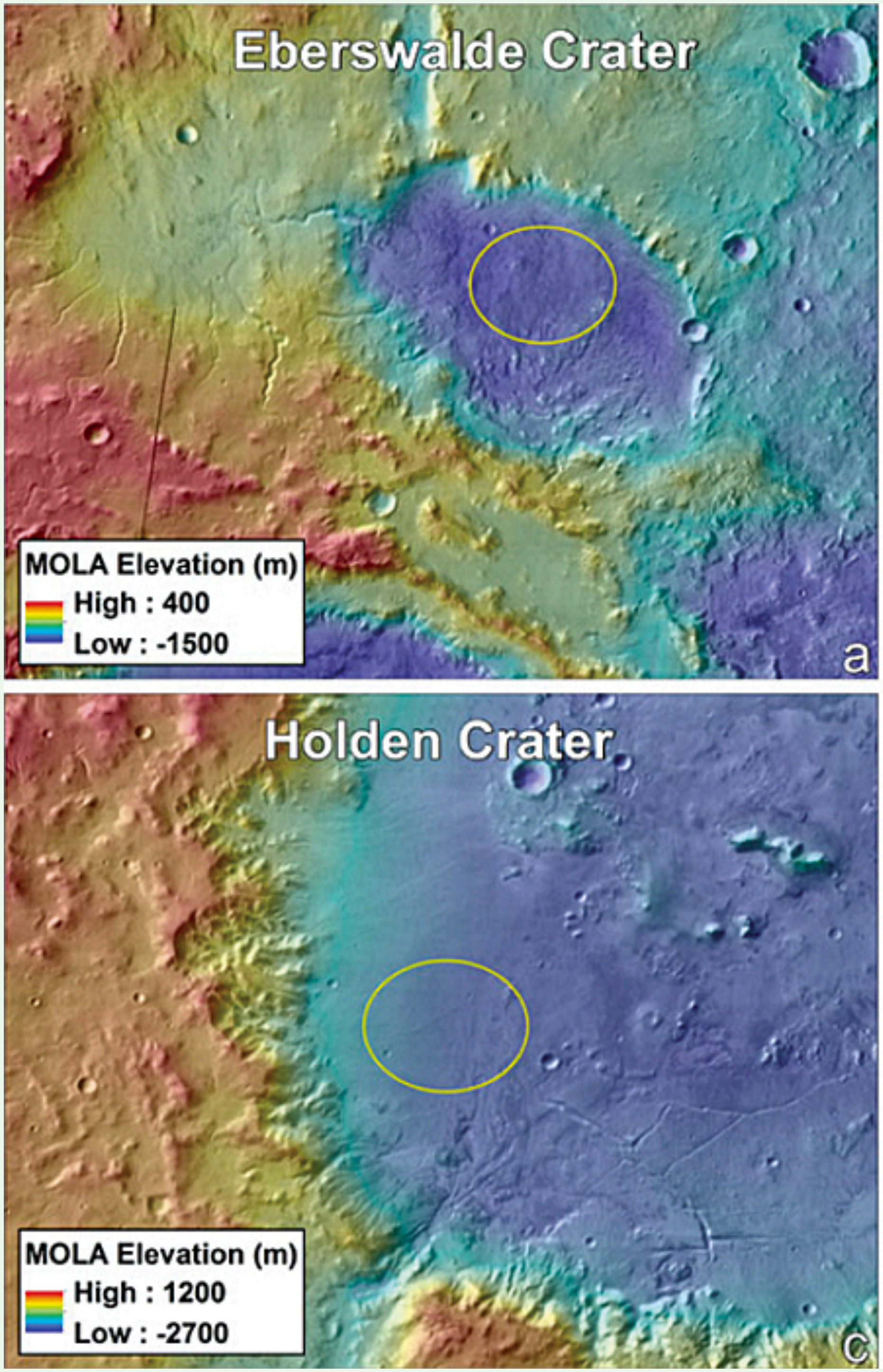
- Principles of remote sensing
- Aerial remote sensing
- Satellite remote sensing
- Active remote sensing
- Image processing

What is remote sensing?

- Acquire information from a distance
- Measurement & mapping technology
    - location, geometry (shape & size), attributes
- Definition from the Manual of Remote Sensing (1983)
    - "The measurement or acquisition of information of some property of an object or phenomenon, by a recording device that is not in physical or intimate contact with the object or phenomenon under study"

Geospatial remote sensing

- "… not in physical or intimate contact .."
- How far is remote?
    - 1 m, 100 m, or 1 million meters?
    - Virtually all astronomy studies are based on remote sensing
    - An X-ray device is also a "remote sensing" instrument

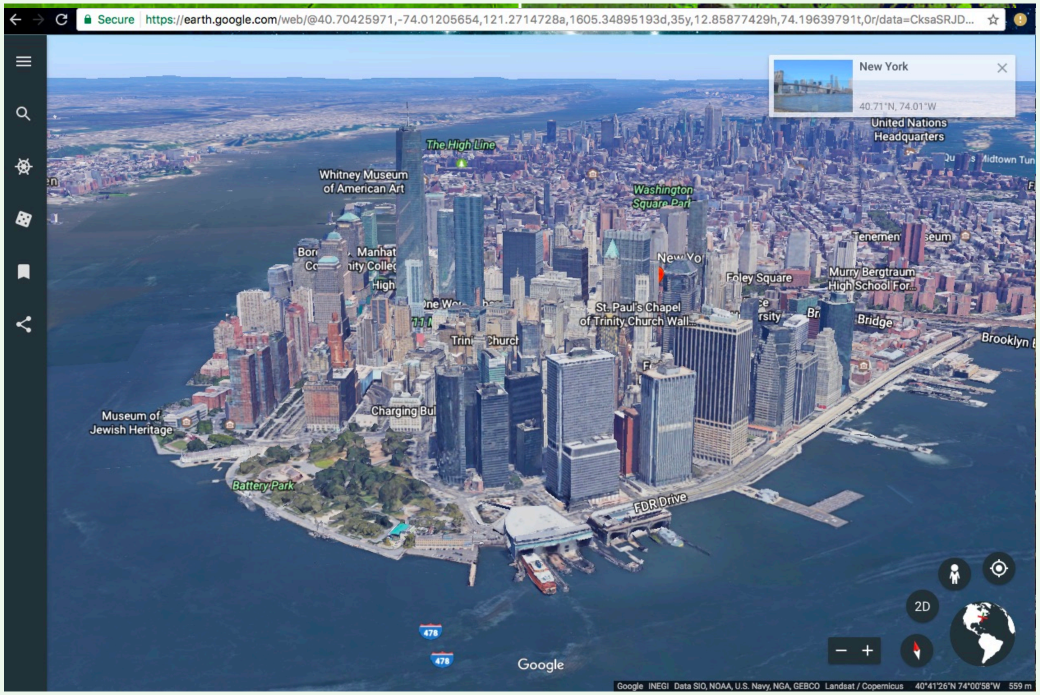


Geospatial remote sensing

- Geospatial (environment or earth resources) remote sensing
  - On or close to Earth surface
  - Location and attributes

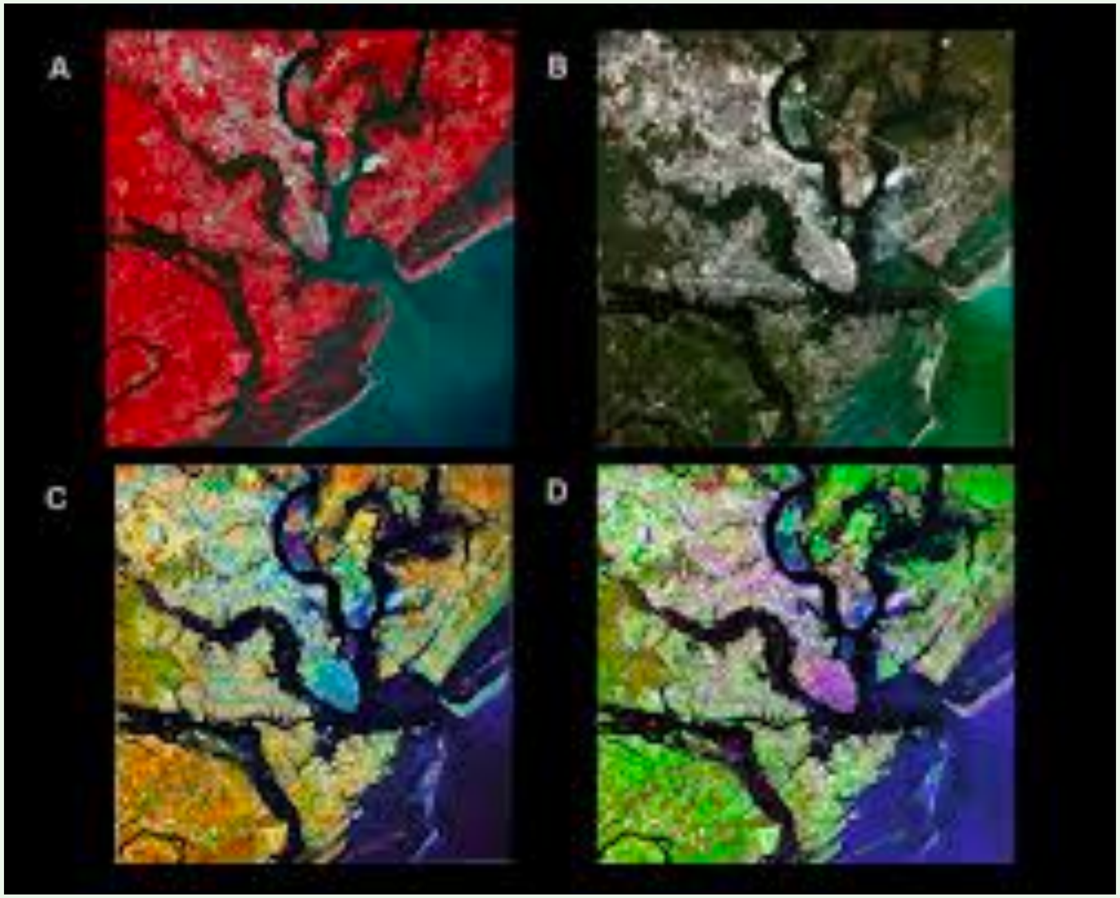
What can remote sensing do?

- Mapping
    - collecting geospatial data
    - location & attributes
- Monitoring environmental change
    - repeated observations
- Virtual geographic
    - terrain visualization

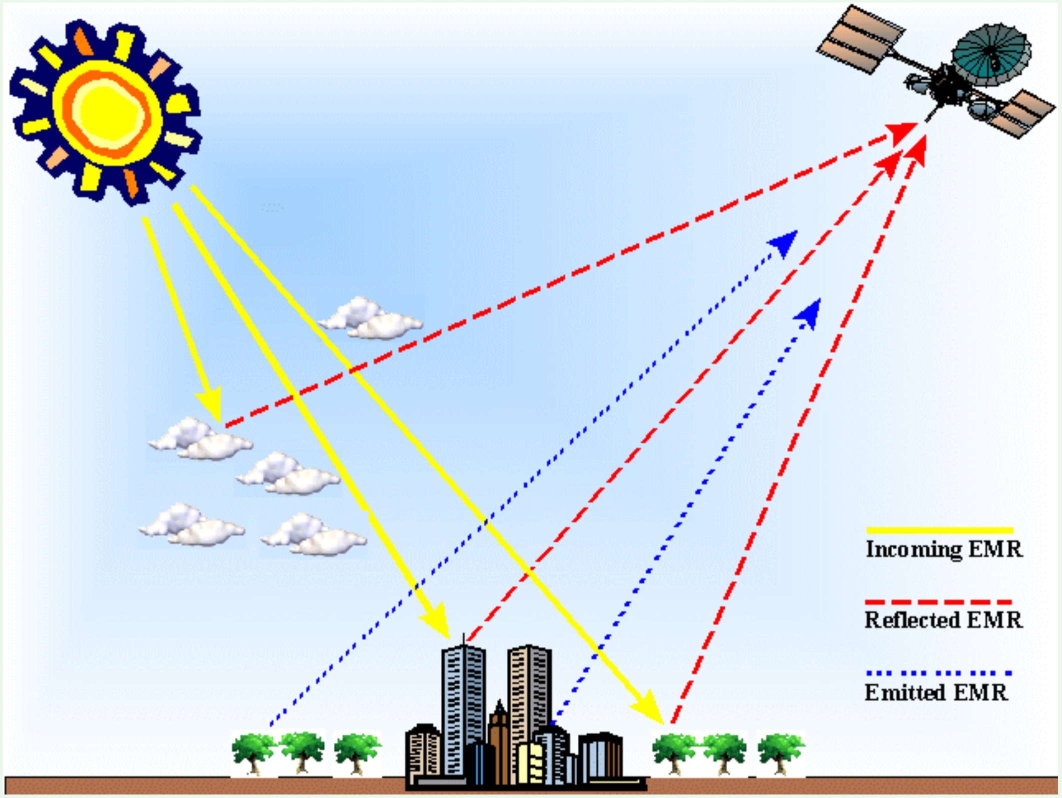


Why remote sensing?

- Not intrusive
- Large geographical coverage
  - Beyond human reach
  - Beyond country boundary
- Extended spectral range
  - Beyond human eyesight
- Higher sampling resolution and accuracy compared to traditional field survey
- Relatively cheap



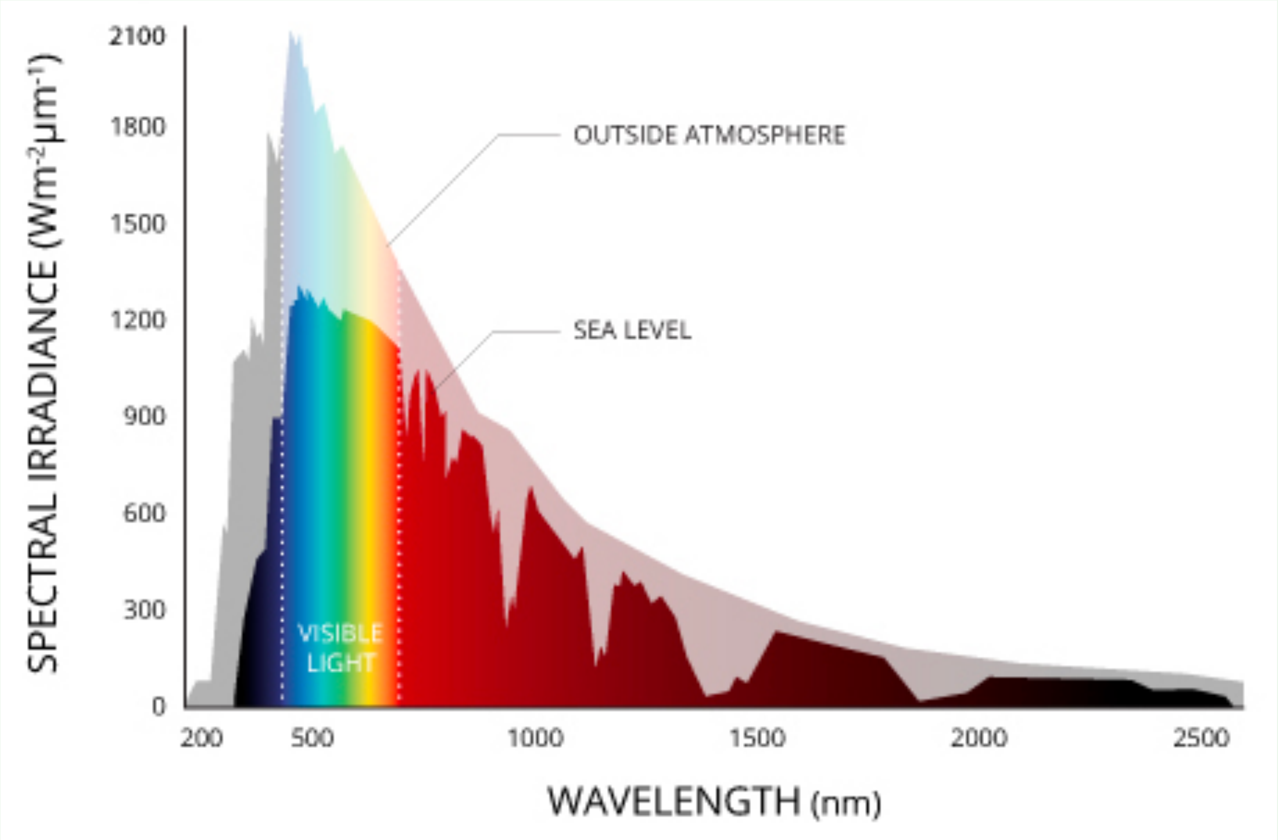
How does remote sensing work?

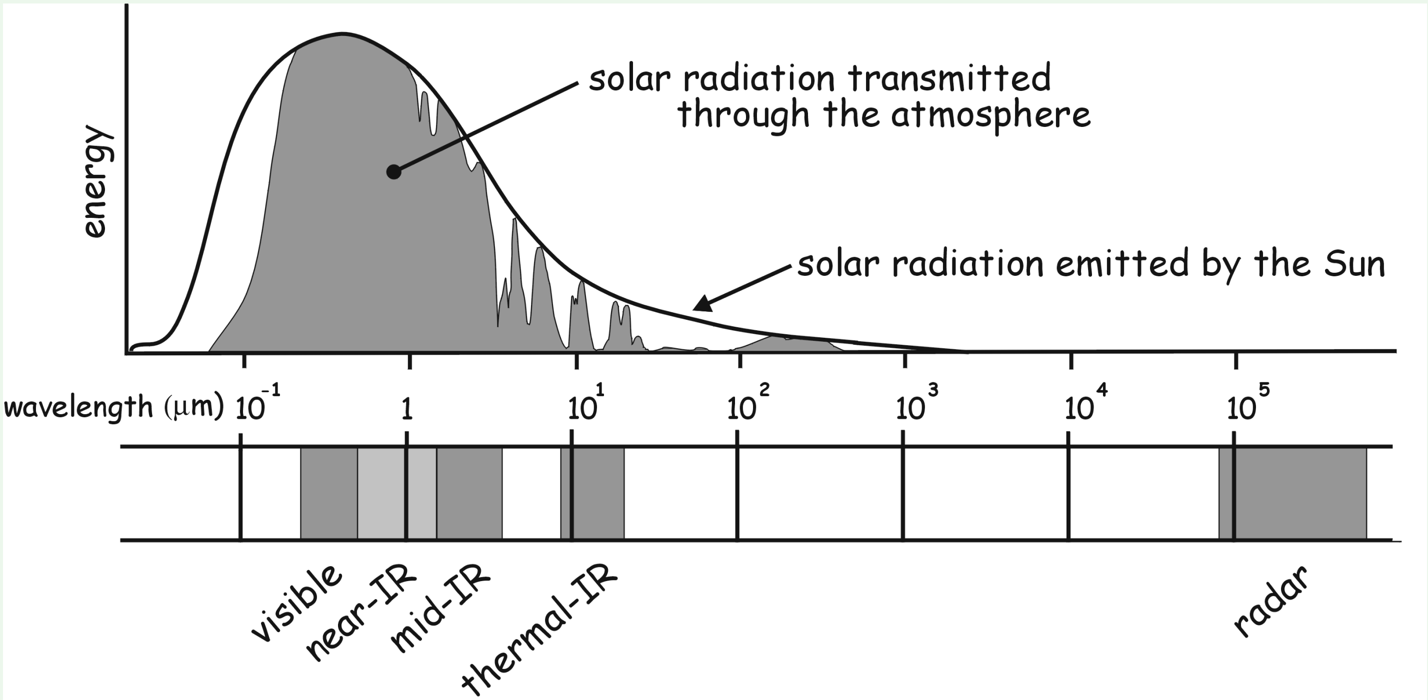


- Incoming solar radiation is reflected, absorbed, or transmitted by Earth’s surface
- Outgoing electromagnetic radiation (EMR) is recorded by the satellite
  - averaged over a geographic area

How does remote sensing work?

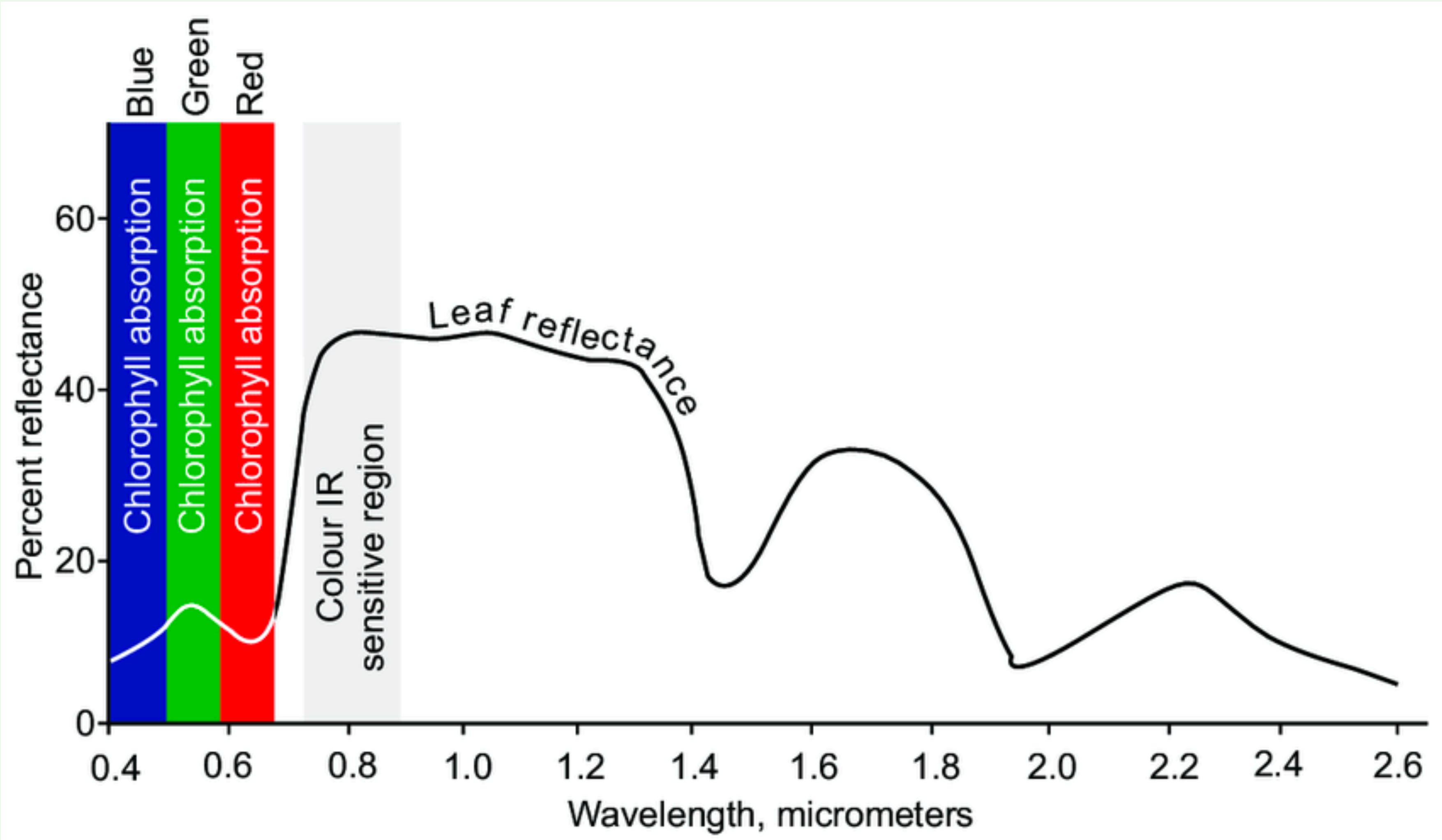
- EMR carries information about the objects it interacts with


SPECTRAL IRRADIANCE (Wm-2µm-1)
2100
1800
1500
1200
900
600
300
0
OUTSIDE ATMOSPHERE
SEA LEVEL
VISIBLE
LIGHT
200
500
1000
1500
2000
2500
WAVELENGTH (nm)

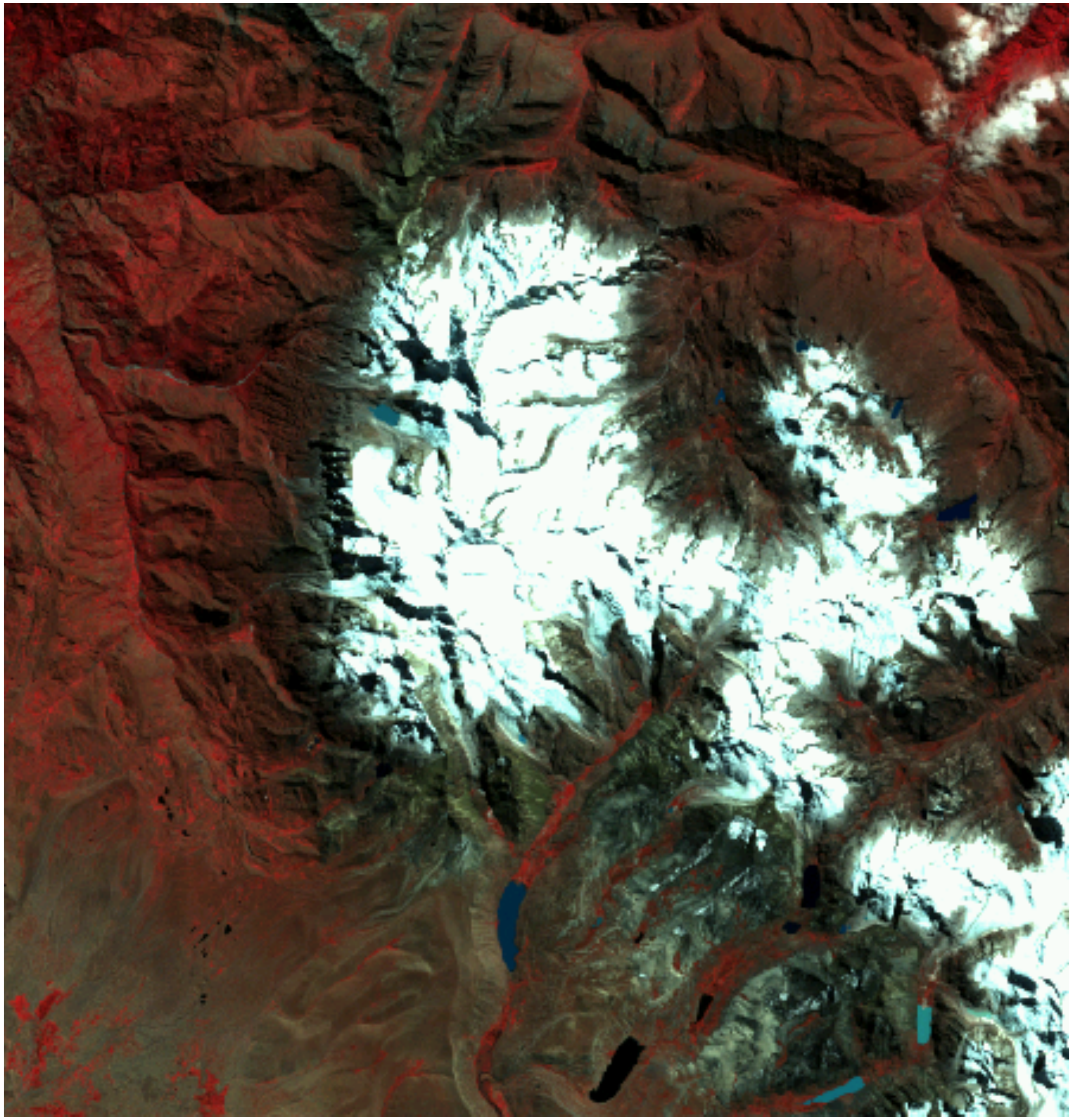

energy
solar radiation transmitted
through the atmosphere
solar radiation emitted by the Sun
wavelength (µm)
10-1
1
101
102
103
104
105
visible
near-IR
mid-IR
thermal-IR
radar

Spectral response curve

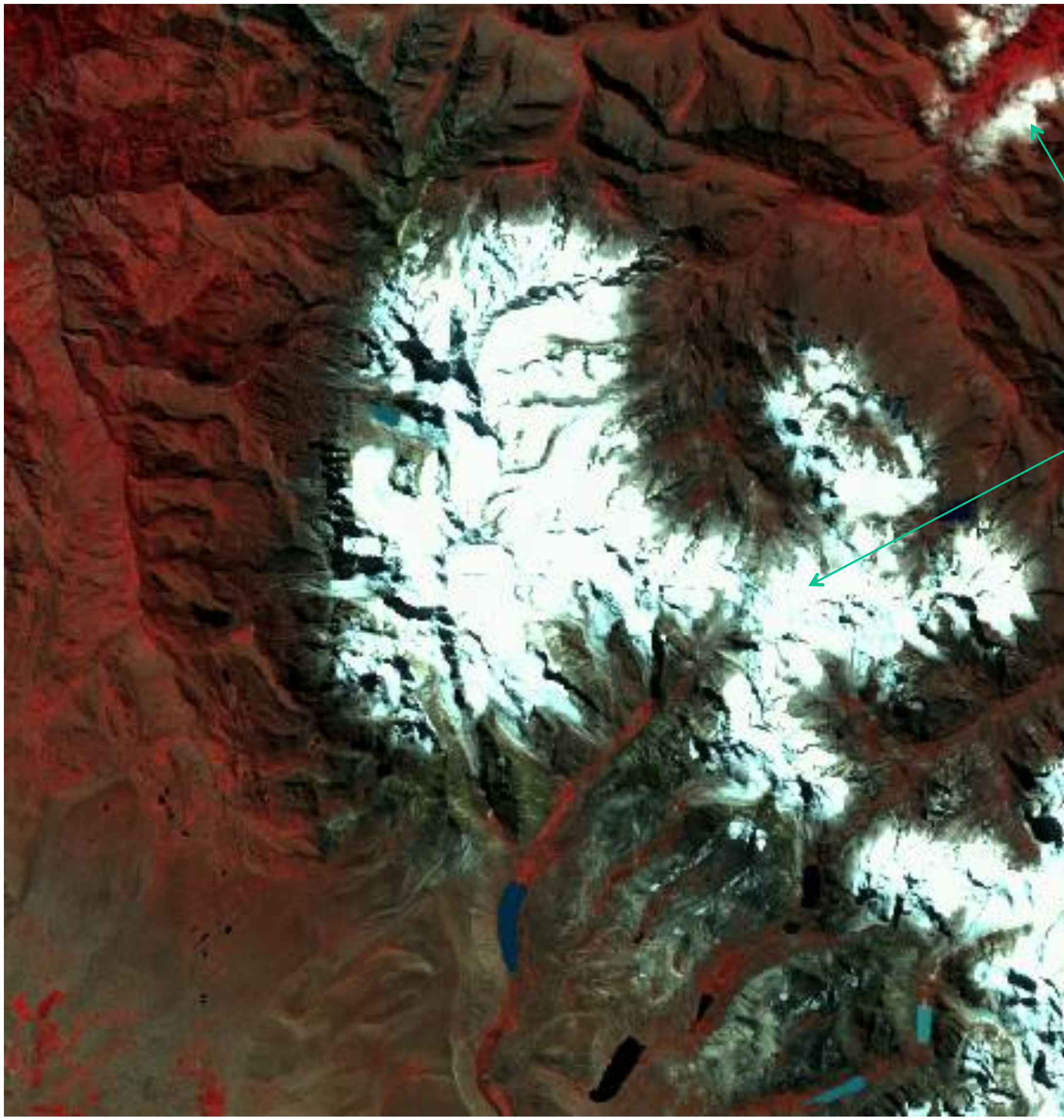
Spectral Reflectance Curve--the proportion of incoming radiation that is reflected varies across wavelengths



Landsat Thematic Mapper (TM) Image of Andes Mountains

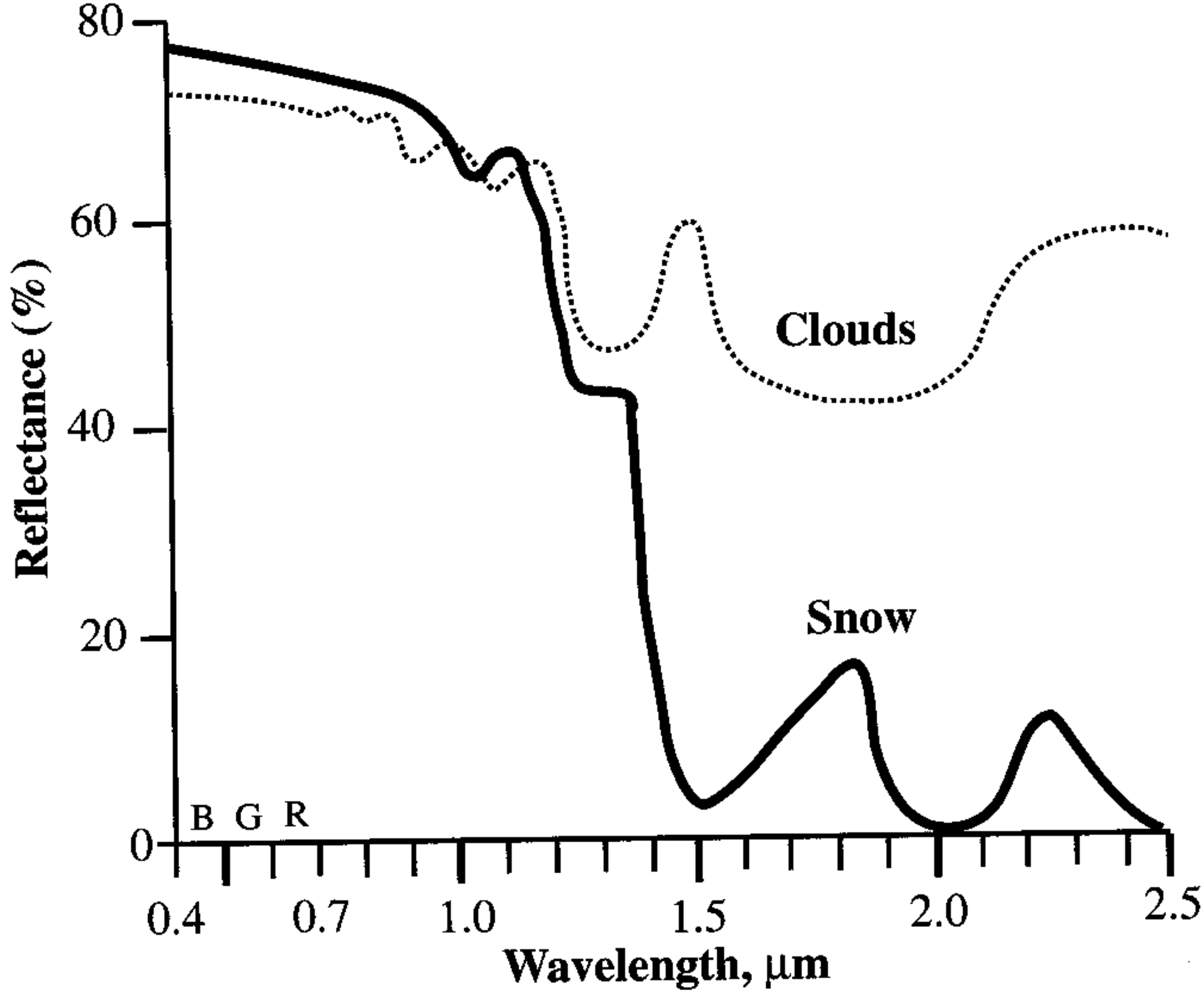


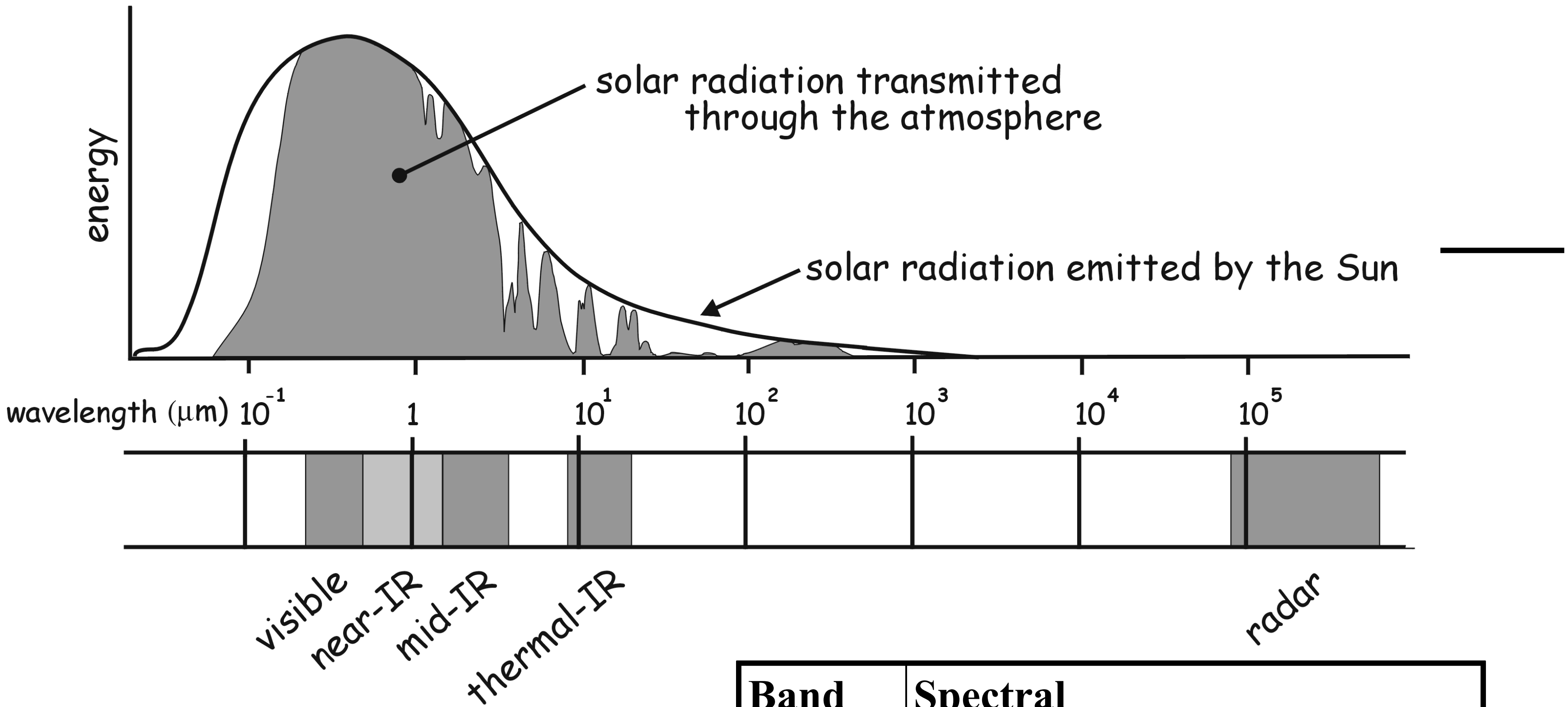
How to Make Sense of "Sensing"?



Which is snow or cloud?

Reflectance Curves of Snow and Cloud

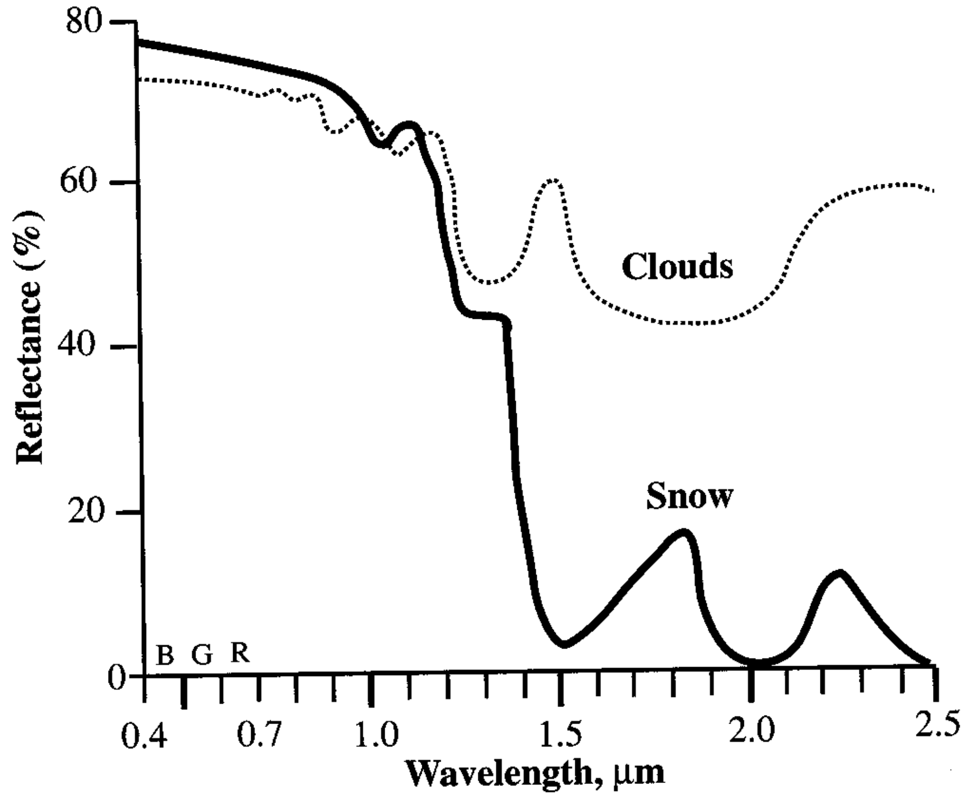




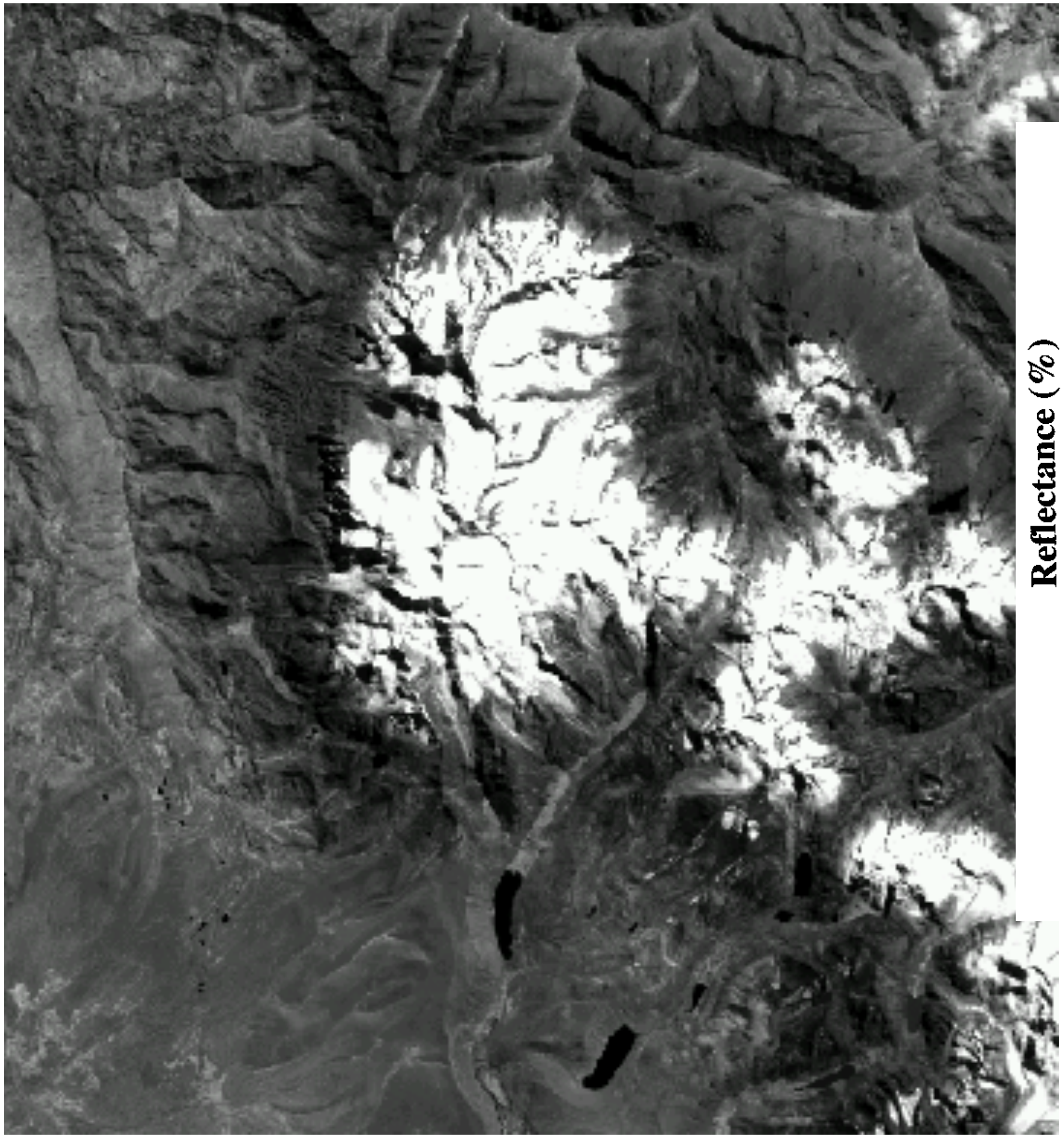
Landsat Thematic Mapper (TM) Bands

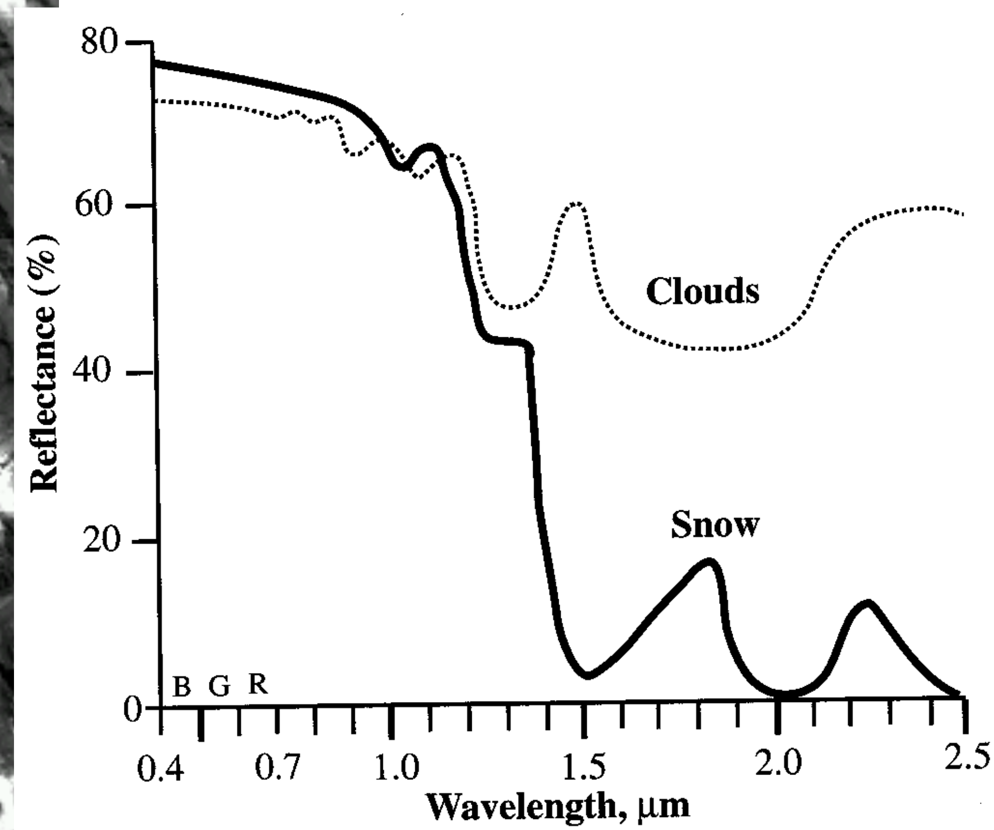
Band	Spectral Resolution (um)
1	0.45 – 0.52 (blue)
2	0.52 – 0.60 (green)
3	0.63 – 0.69 (red)
4	0.76 – 0.90 (NIR)
5	1.55 – 1.75 (Mid-IR)
6	10.40 – 12.5(Thermal-IR)
7	2.08 – 2.35 (mid-infrared)

TM Band 3 (Red 0.63-0.69)

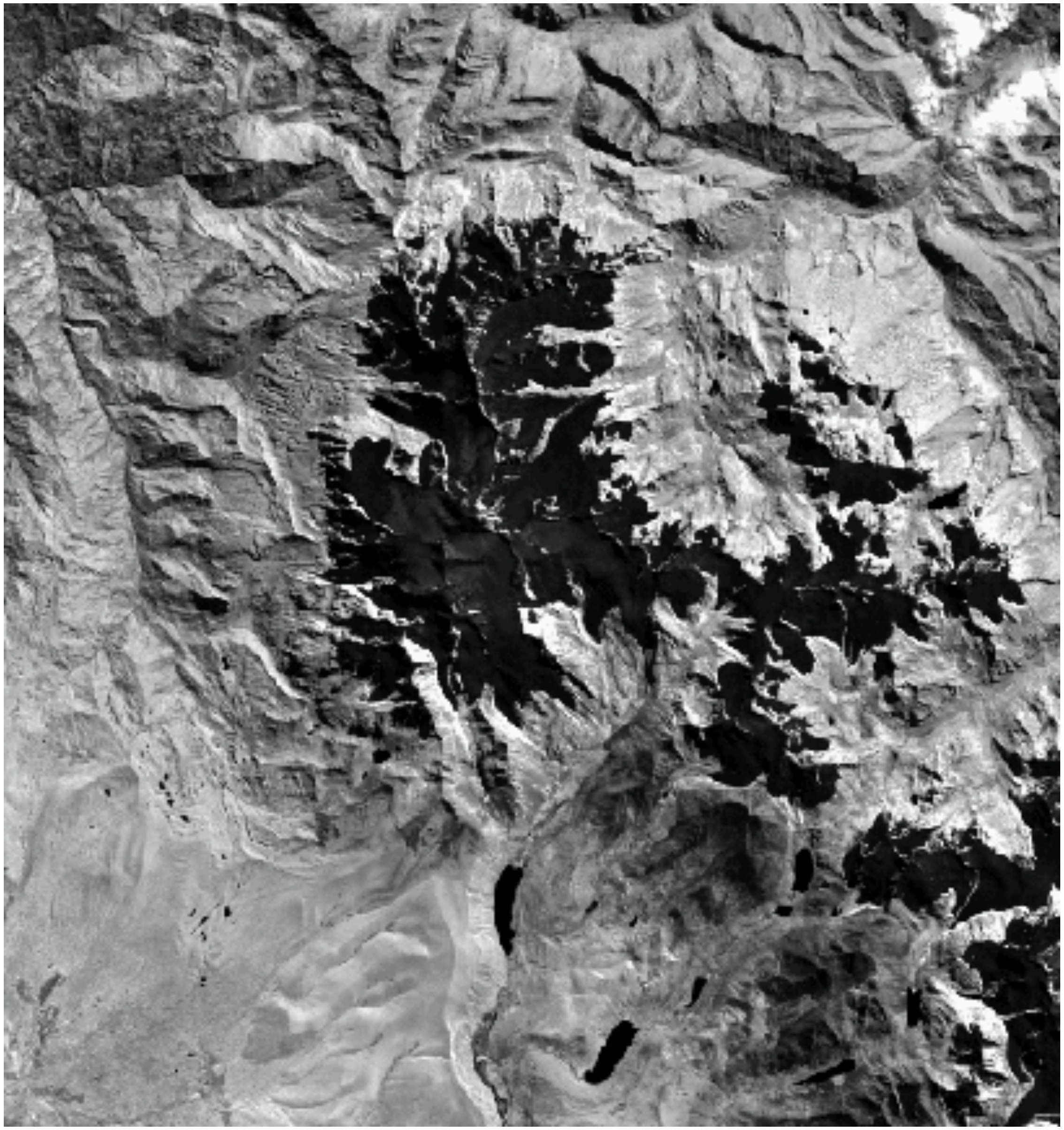


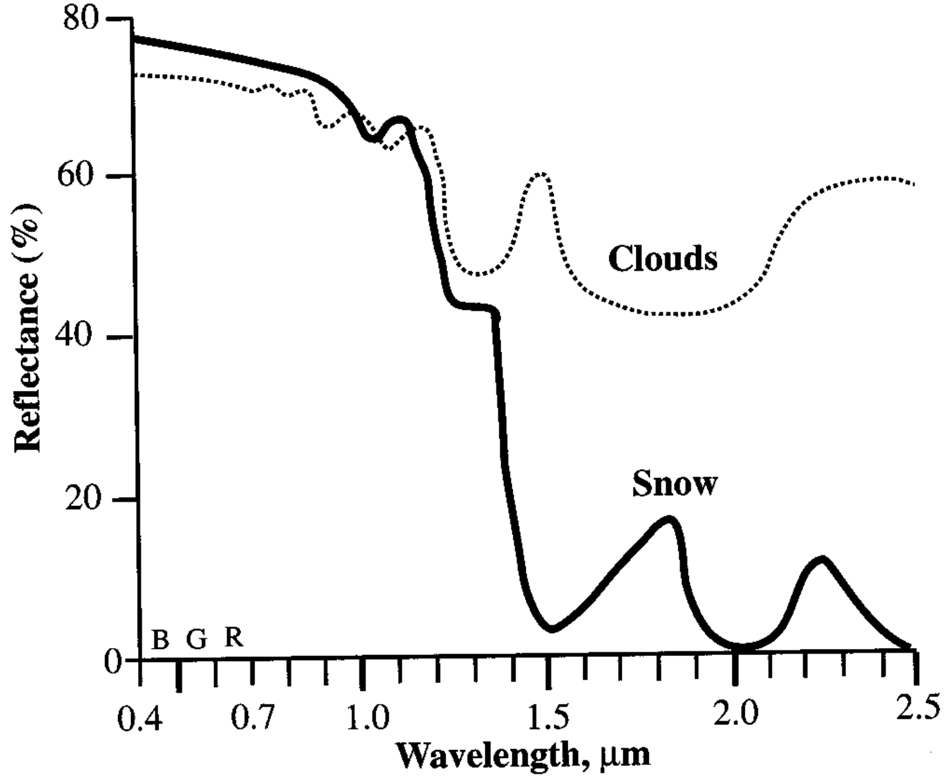
TM Band 4 (NIR 0.76-0.90)



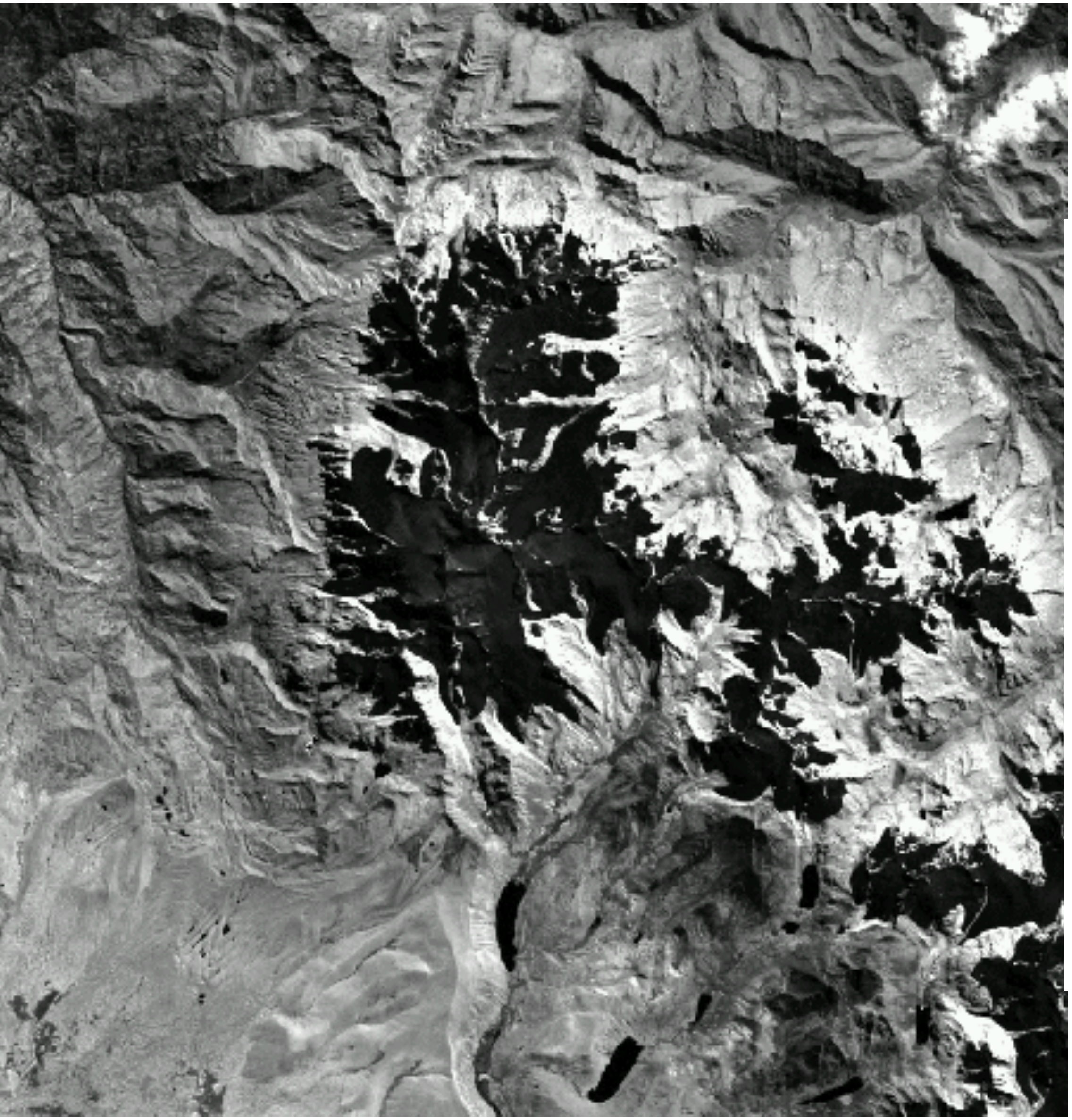


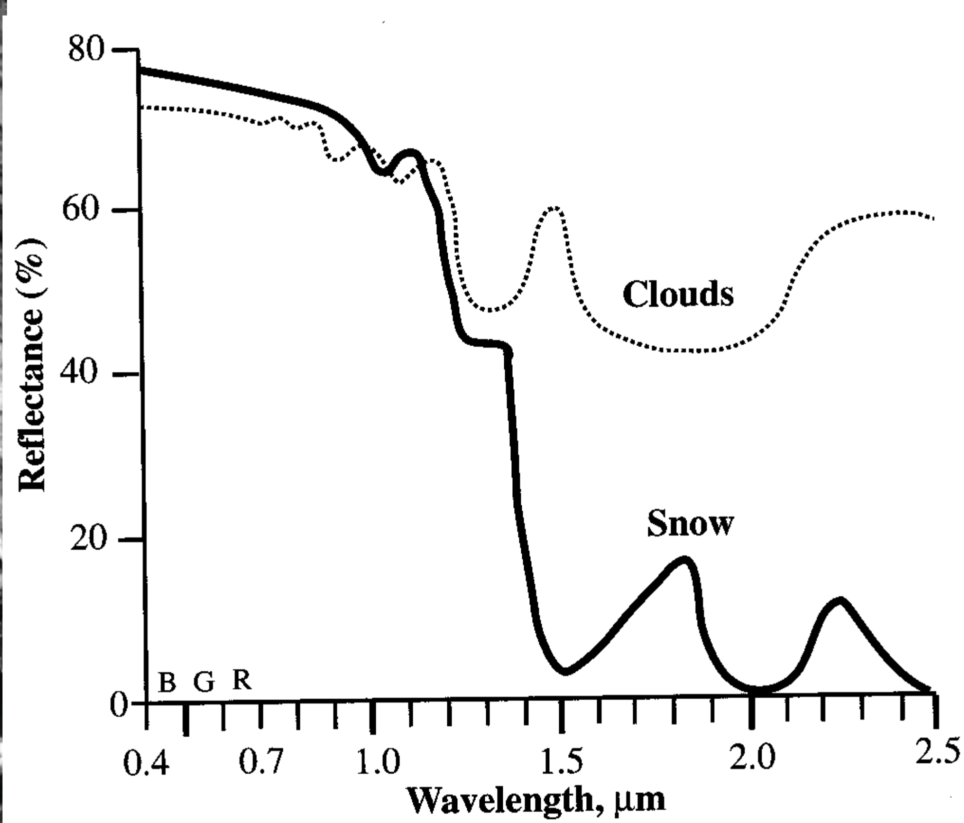
TM Band 5 (MIR 1.55-1.75)





TM Band 7 (MIR 2.08-2.35)





Panchromatic band

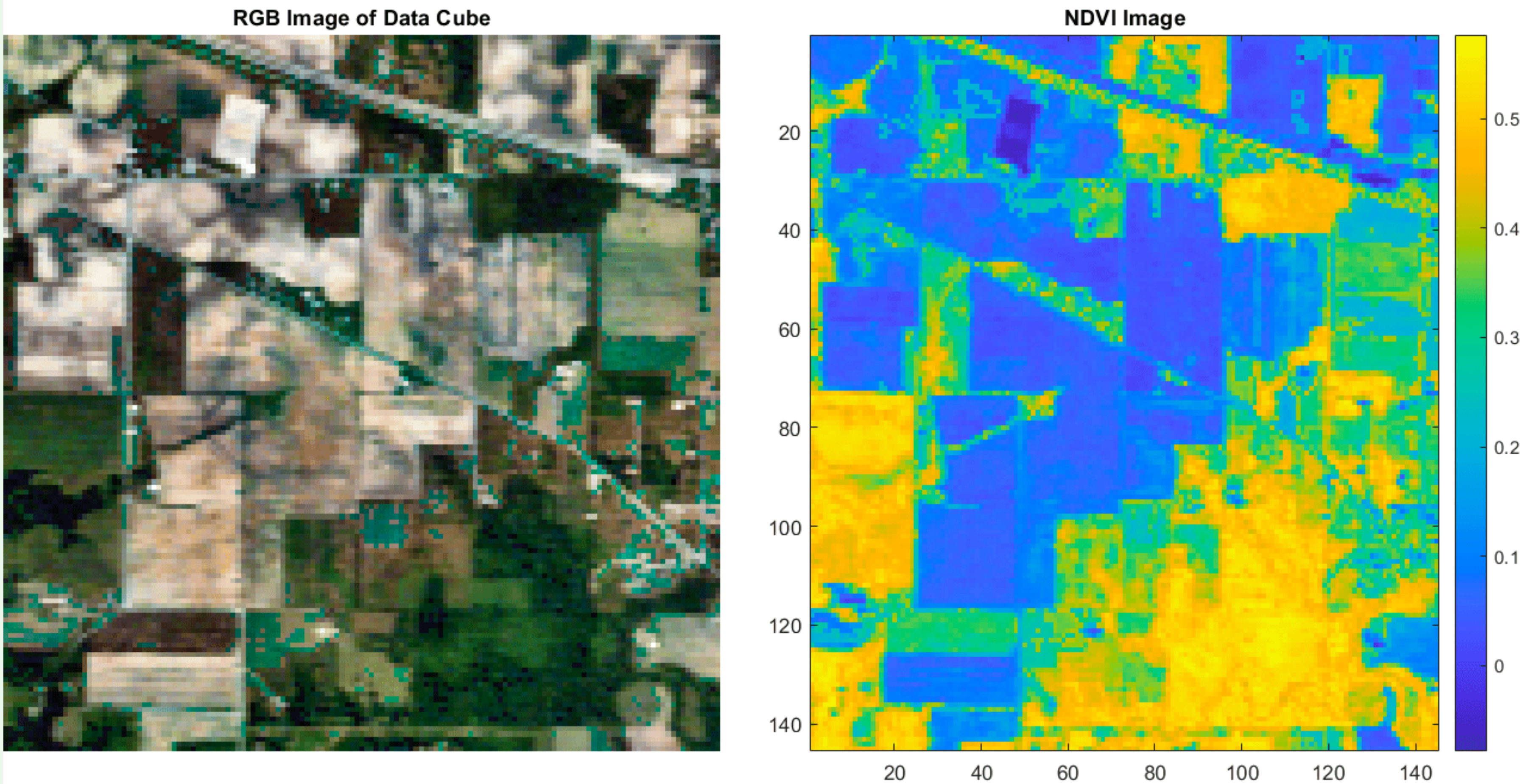
Green band

Red band

NIR band

False color composite—green, red, NIR

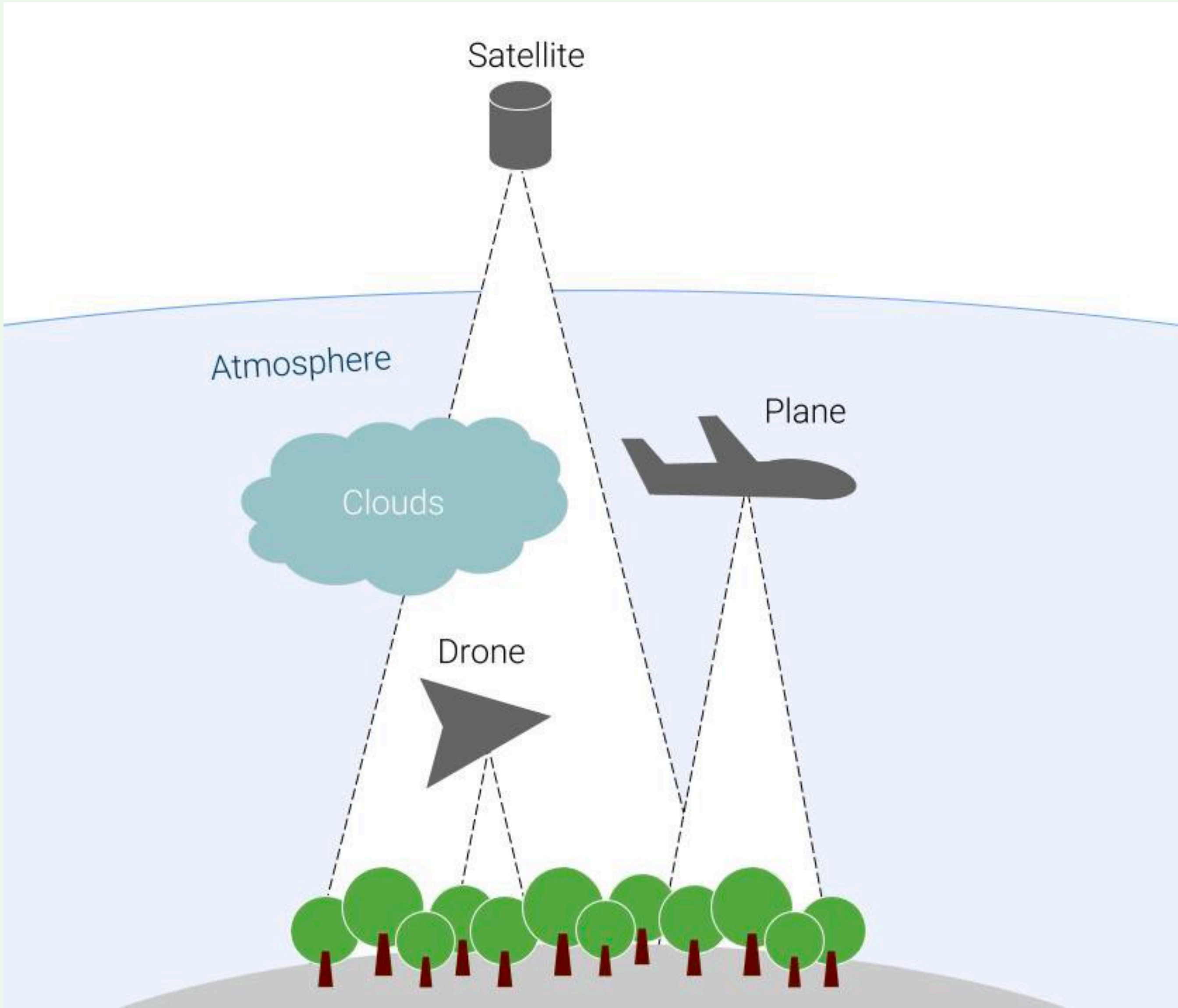
NDVI


RGB Image of Data Cube
NDVI Image
20
40
60
80
100
120
140
20
40
60
80
100
120
140
0.5
0.4
0.3
0.2
0.1
0

False color composite

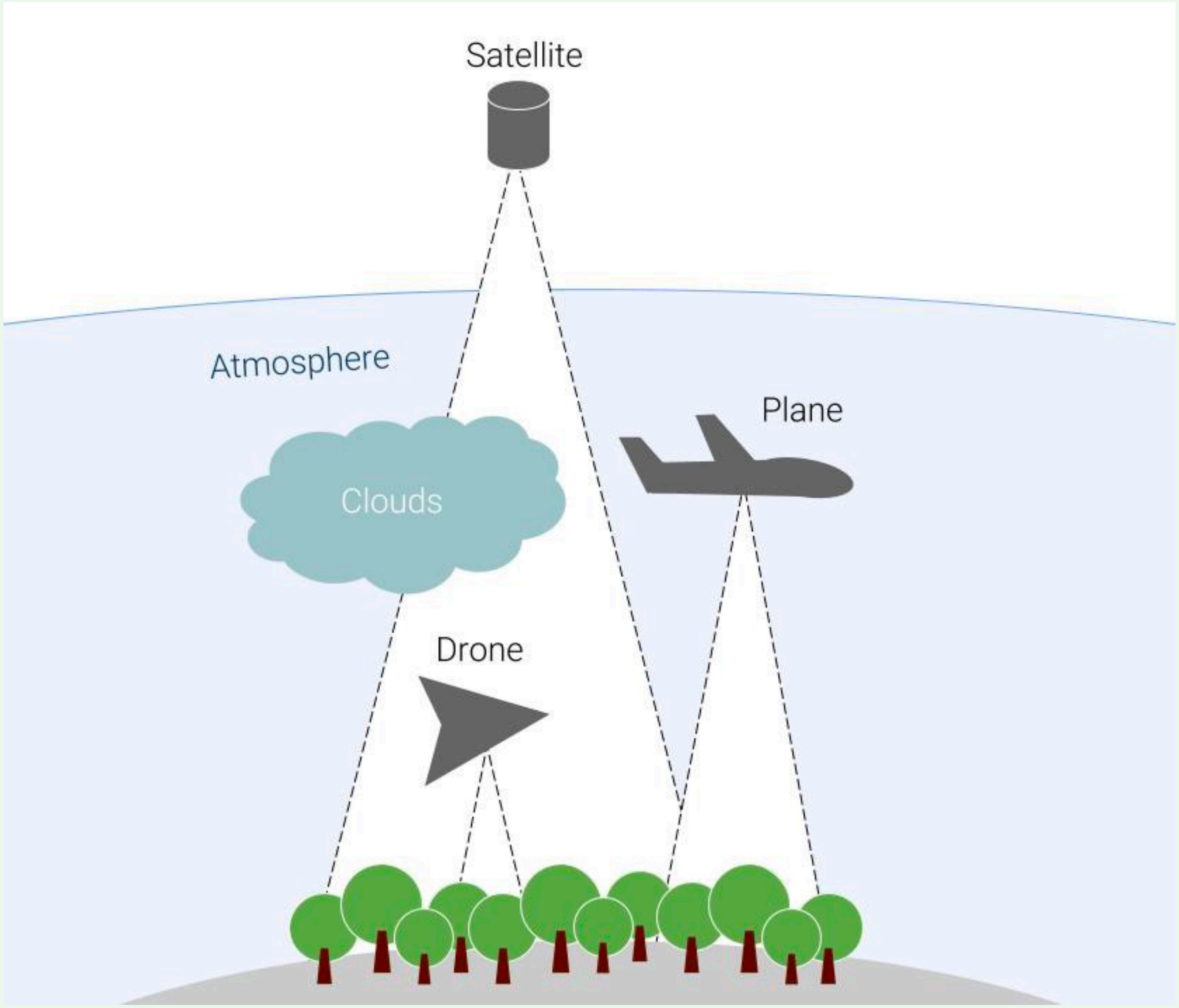
Remote sensing platforms

- Classified by height above ground
  - Airborne remote sensing
    - 100s of meters to ~ 20 km
  - Satellite (orbital) remote sensing
    - higher than 20 km
- Classified based on energy source
  - Passive vs. active systems



Aerial system

- small area coverage
- high distortion
- high spatial resolution
- flexible image acquisition

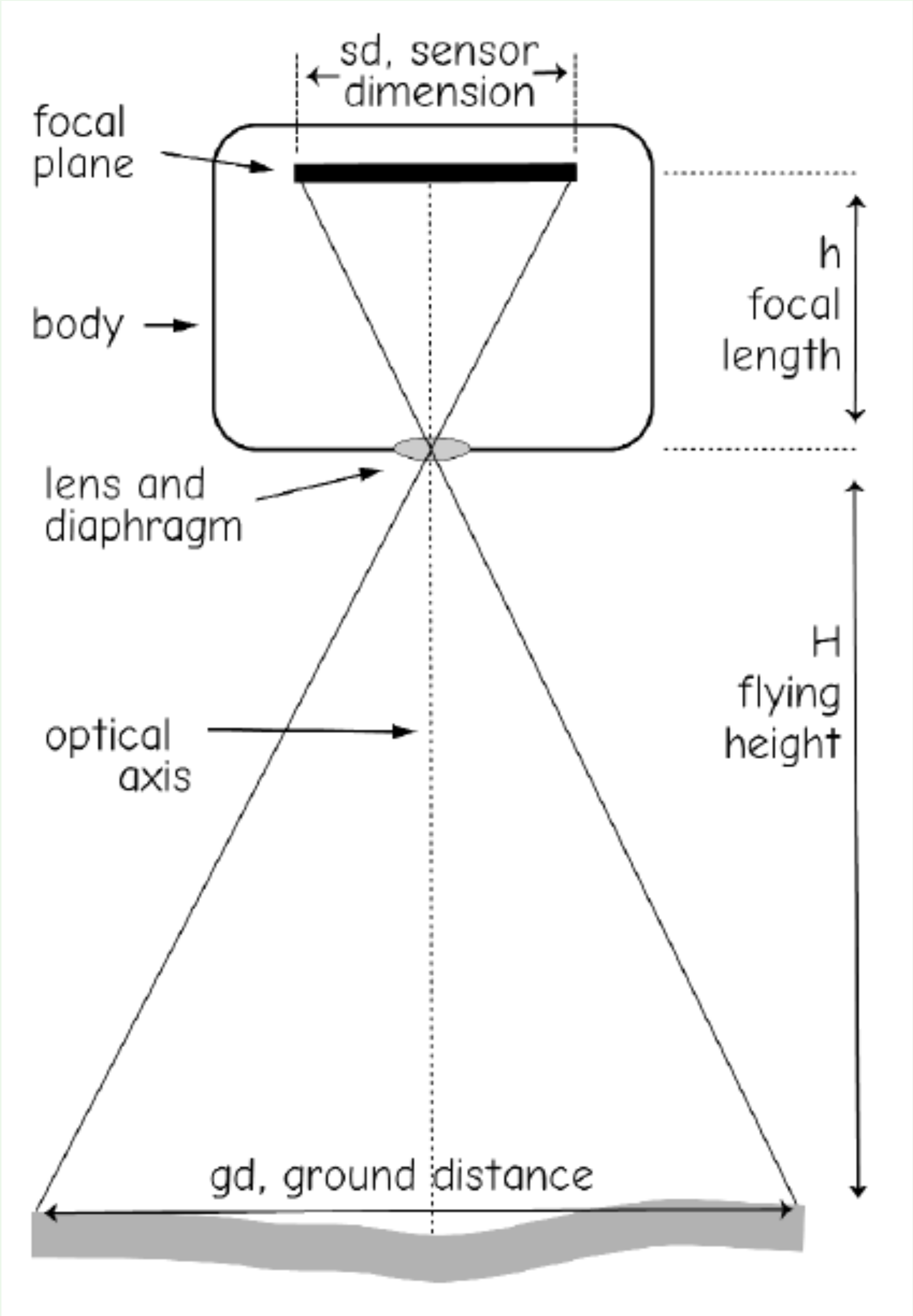


Satellite system

- large area coverage
- low distortion
- low spatial resolution
- Limited flexibility on image acquisition

Aerial Image Scale and Resolution

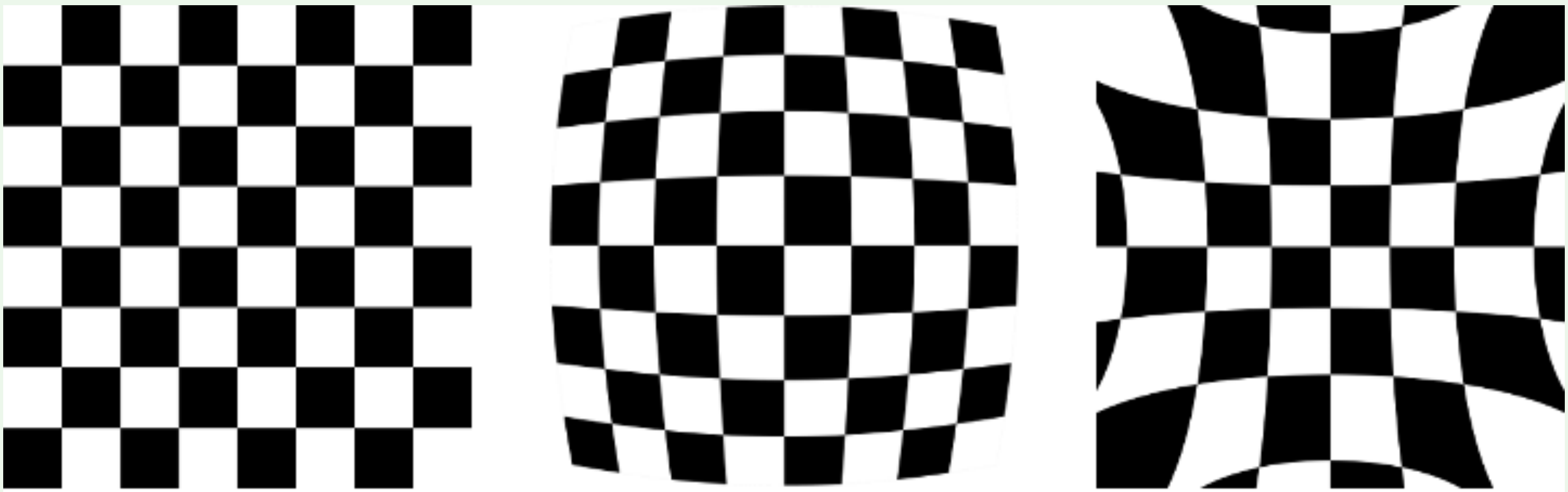
- Map (image) scale is approximately equal to $\frac{h}{H}$
  - h—focal length
  - H—flying height
- Scale can be adjusted by changing the flying height
  - $\frac{sd}{gd} = \frac{h}{H}$



Distortions of aerial images

- Lens distortion
- Tilt distortion due to unstable camera
- Terrain (relief) distortion due to variation in elevation

Lens distortion

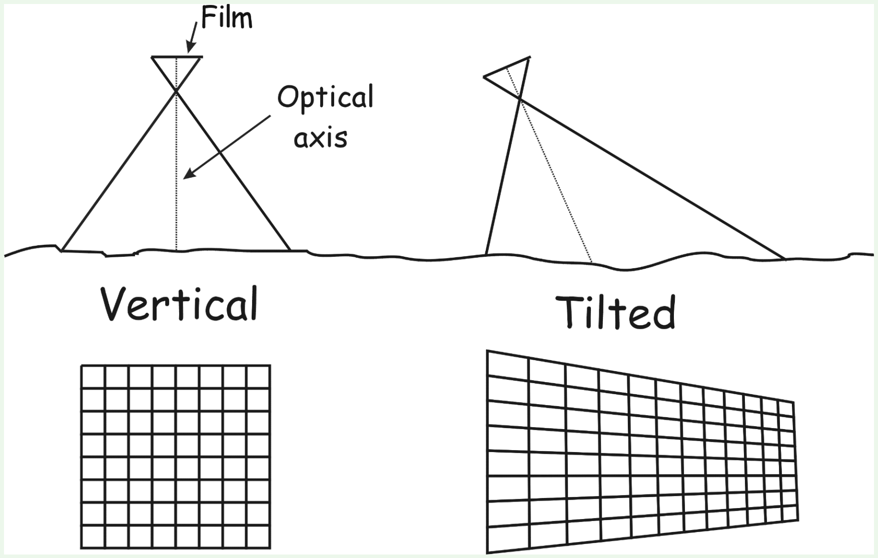


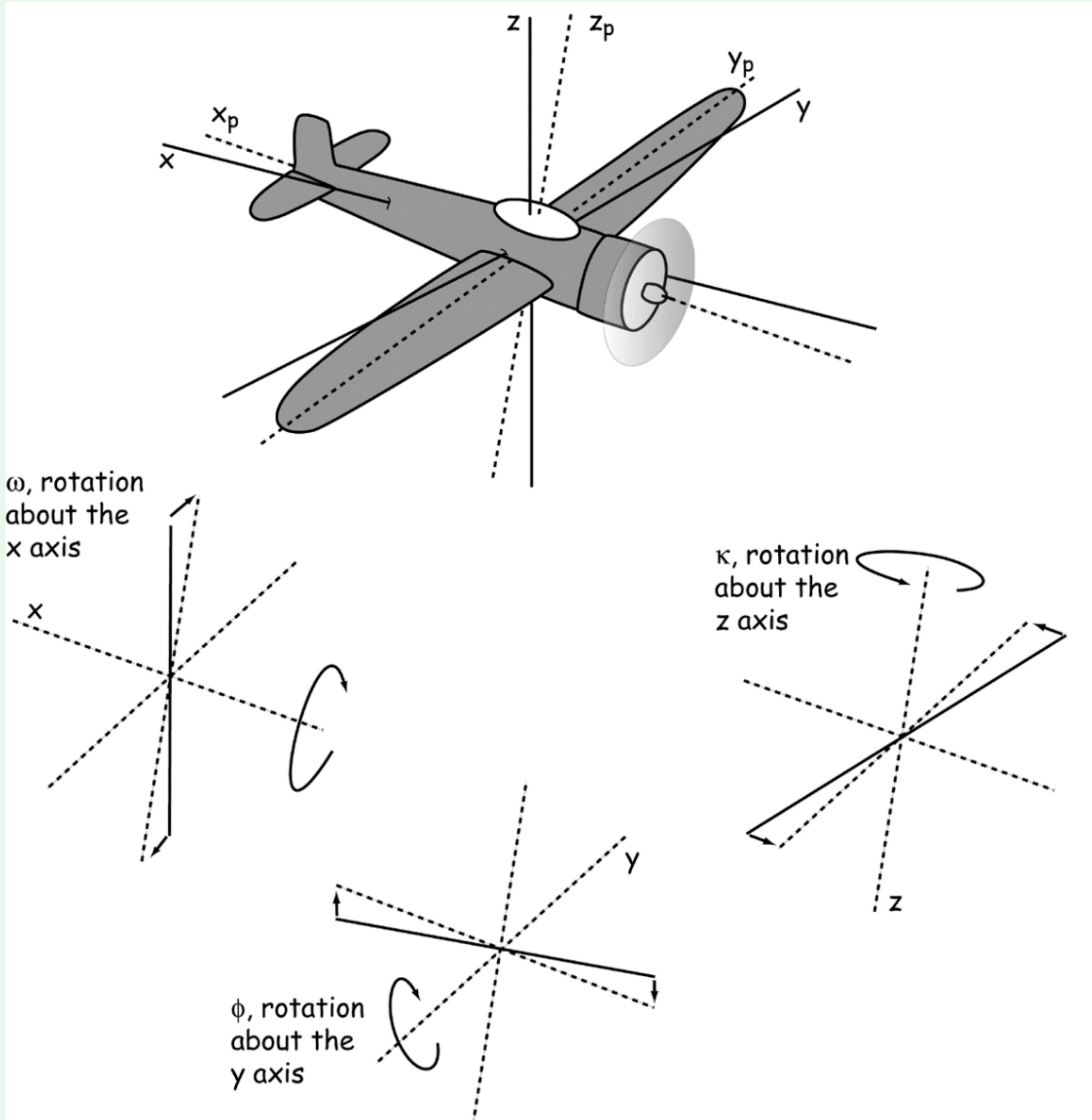
No distortion

Positive radial distortion
(Barrel distortion)

Negative radial distortion
(Pincushion distortion)

Tilt distortion





Terrain distortion

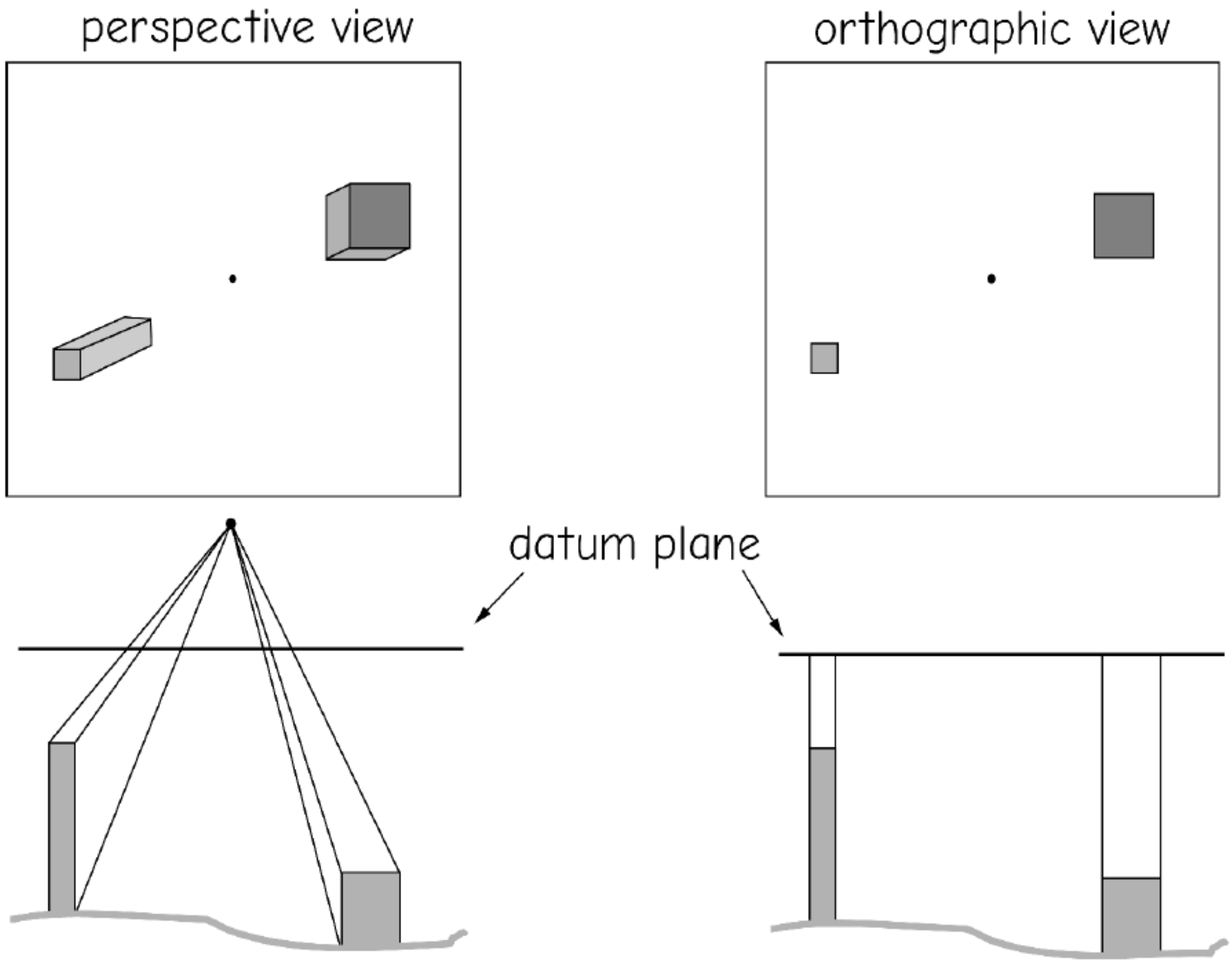


Figure 6-19: Orthographic (left) and perspective (right) views. Orthographic views project at right angles to the datum plane, as if viewing from an infinite height. Perspective views project from the surface onto a datum plane from a fixed viewing location.

Terrain distortion

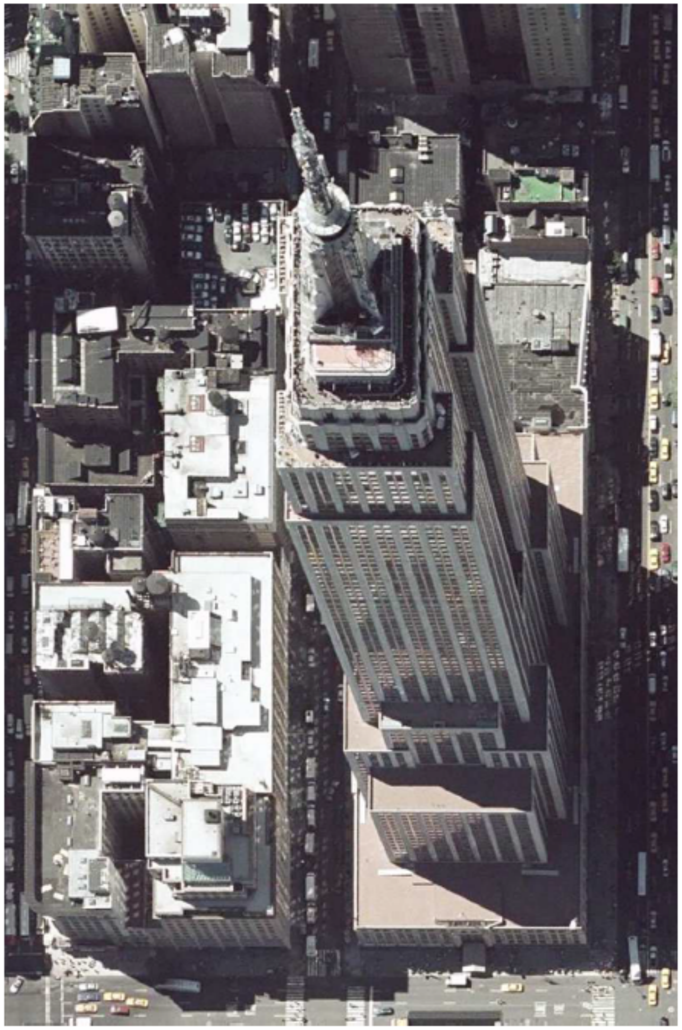
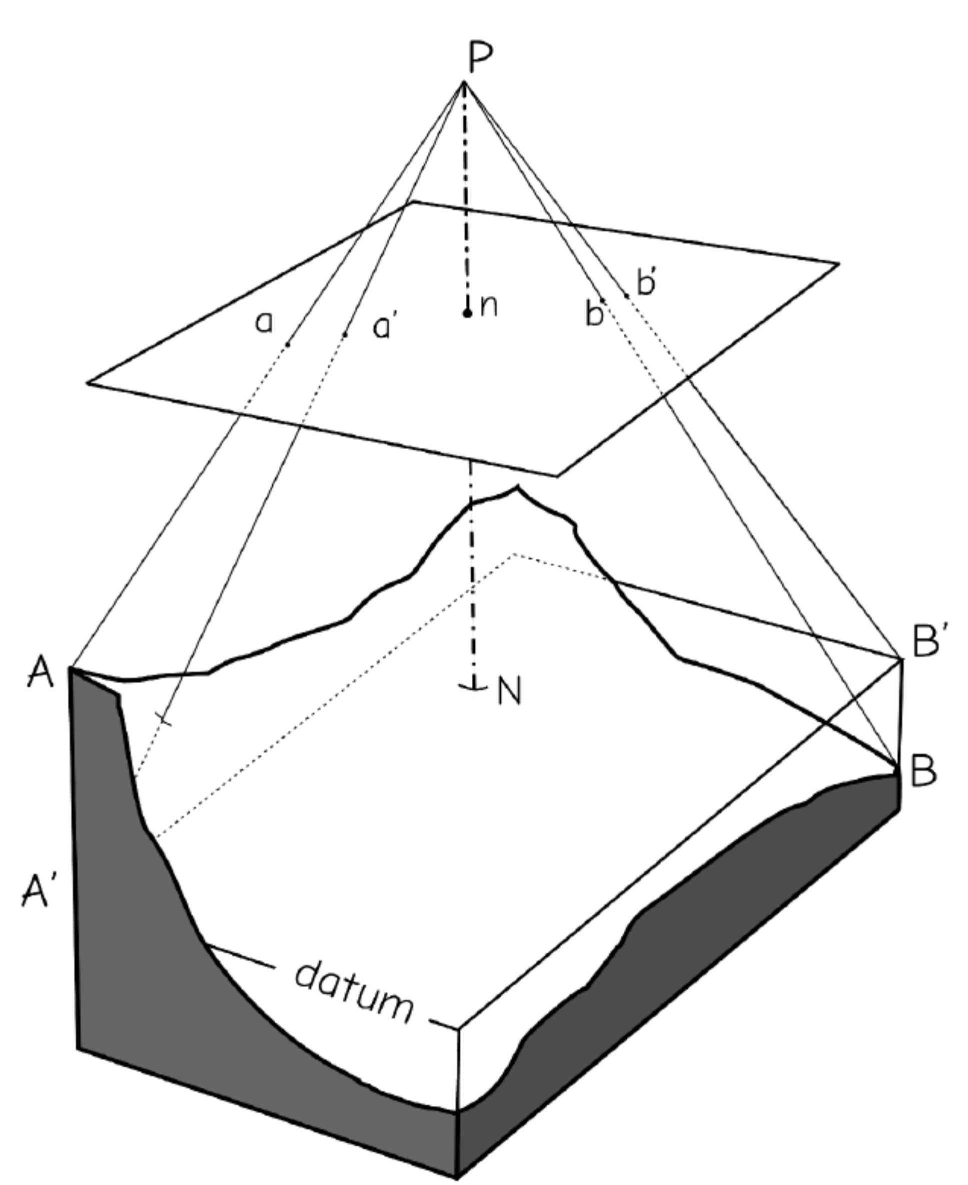


Figure 6-18: Tilt distortion is common on aerial and some satellite images, the result of perspective distortion when imaging the top and bottom of buildings, or any objects at different elevations.

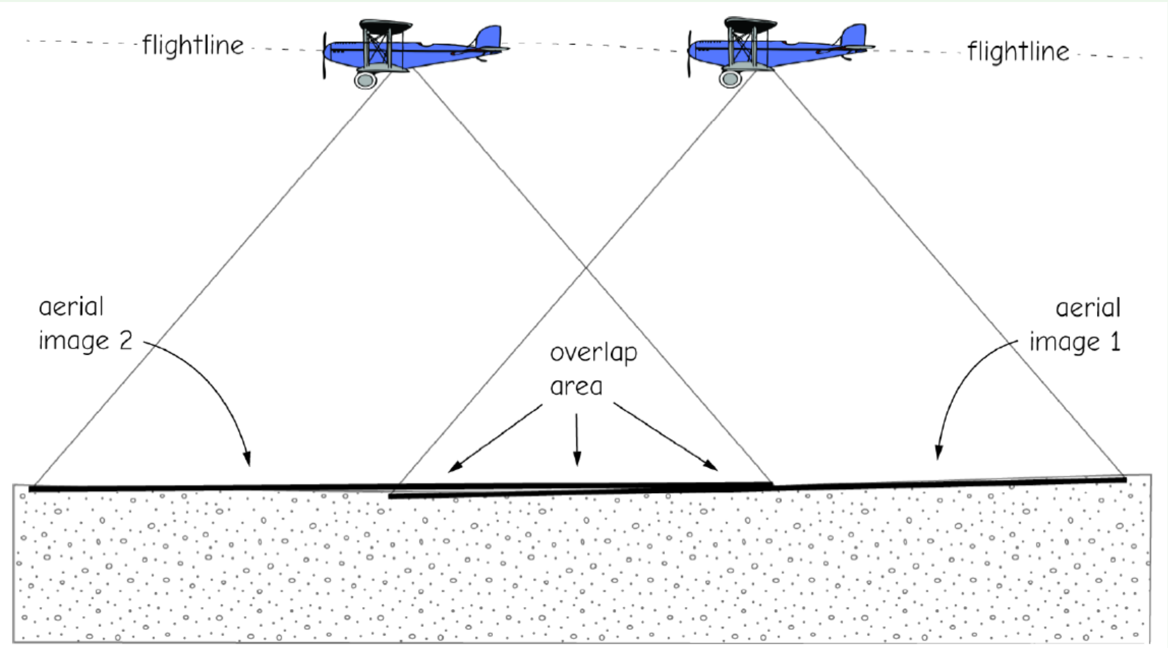


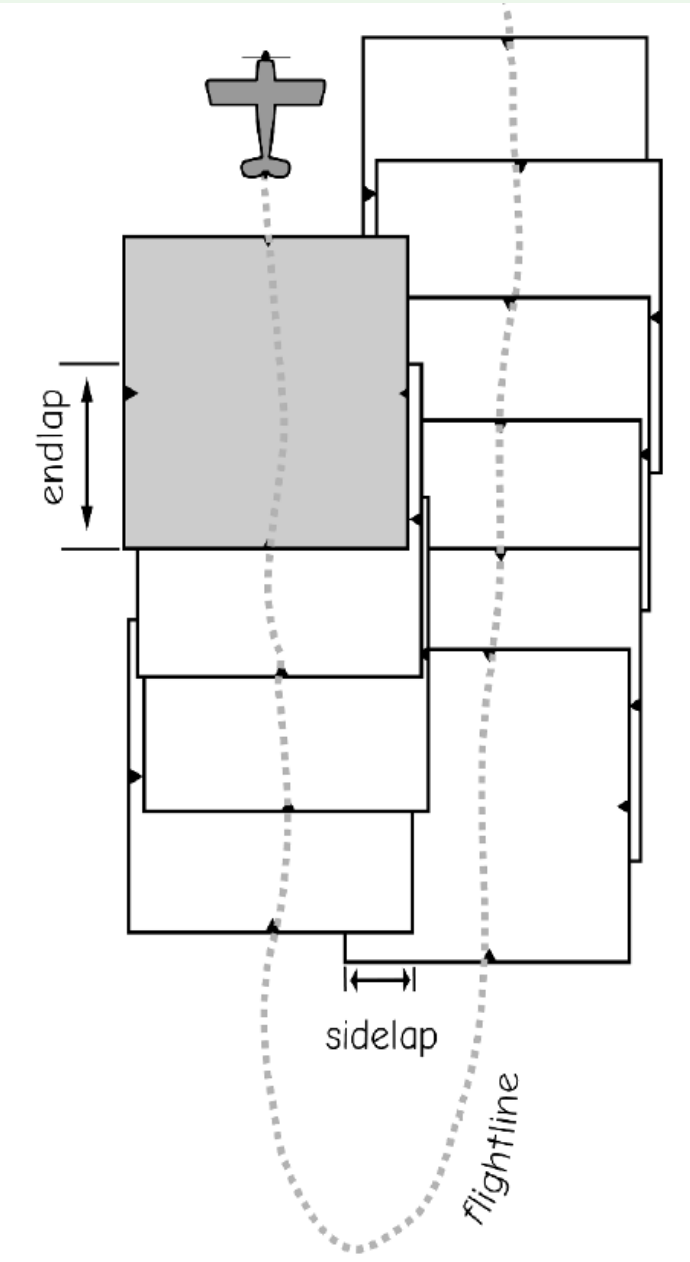
Geometric correction of aerial images

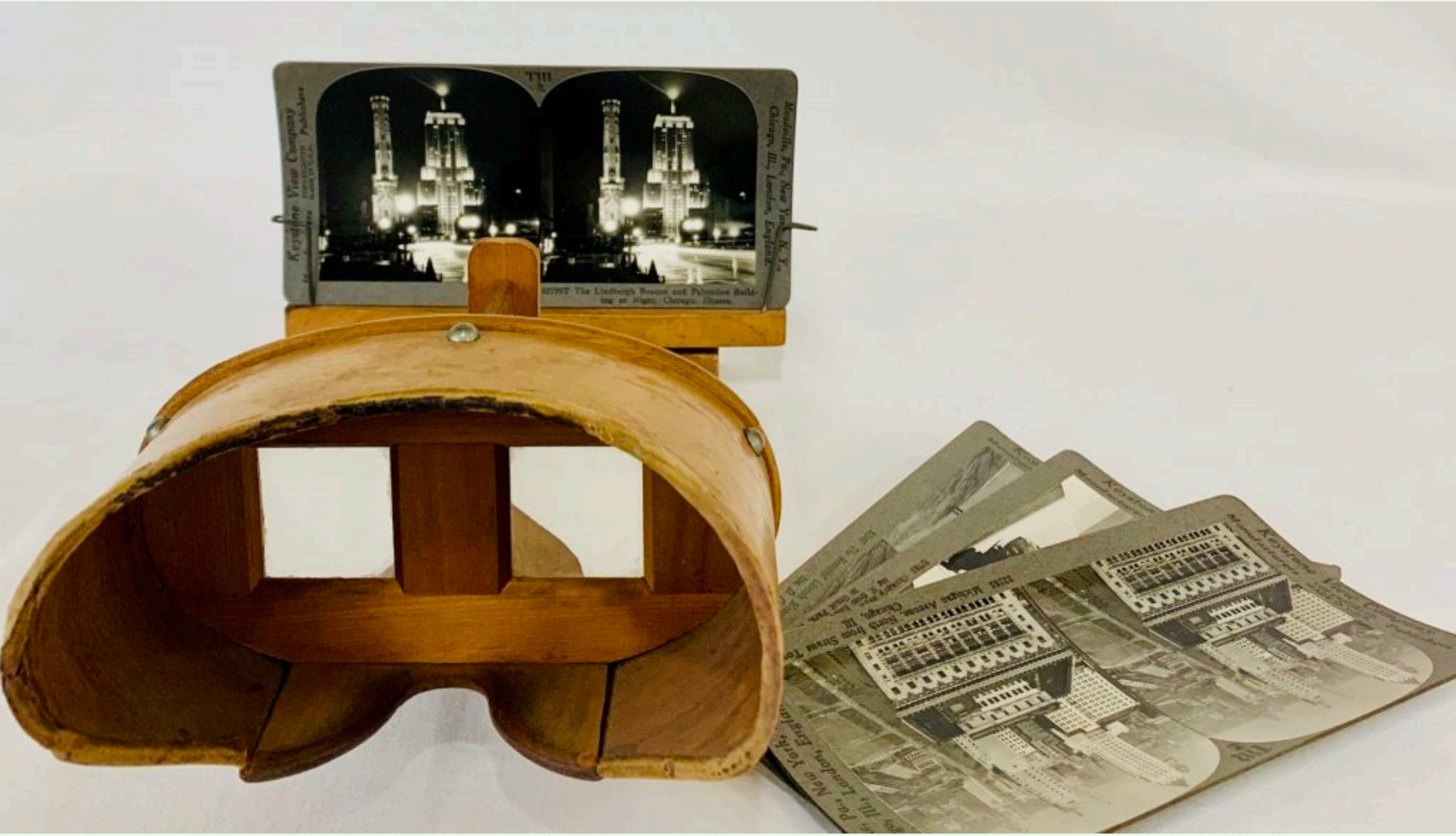
- Photogrammetry engineering
  - Complex techniques using math and projection geometry to remove relief displacement and various distortions
- Depends on two measurements
  - Camera location and orientation when image is taken
  - Terrain height
- Stereo photograph for estimating height
  - How topography was mapped

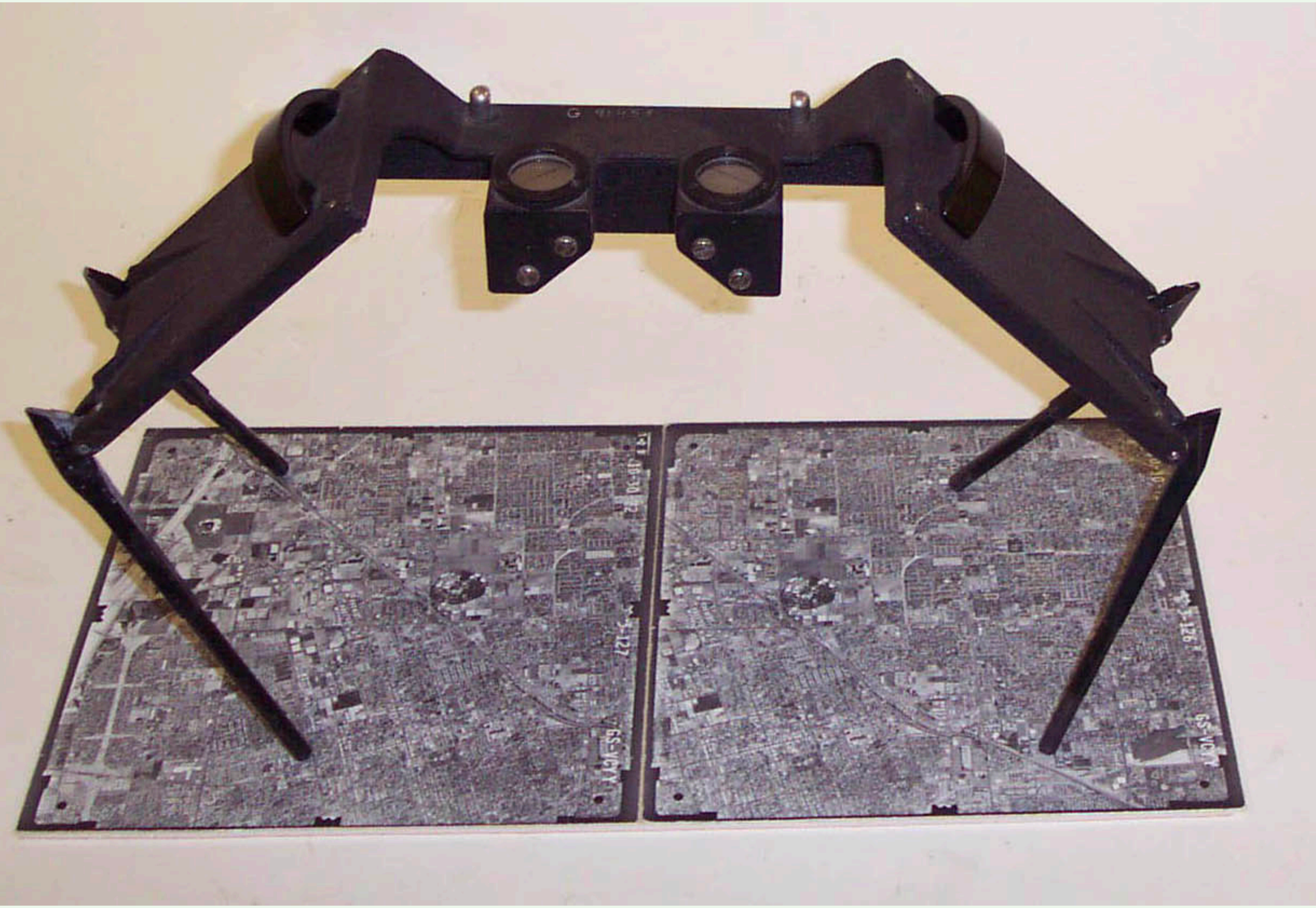
Geometric correction of aerial images

- Stereo photograph
- Sidelap ~ 25% and endlap ~ 65%






Keystone View Company
Meadville, Pa., New York, N. Y.
Chicago, Ill., London, England.
The Lindbergh Beacon and Palmolive Build-
ing at Night, Chicago, Illinois.
Keystone



Screen stereoscope on mounted on PC

Screen stereoscope mounted on laptop

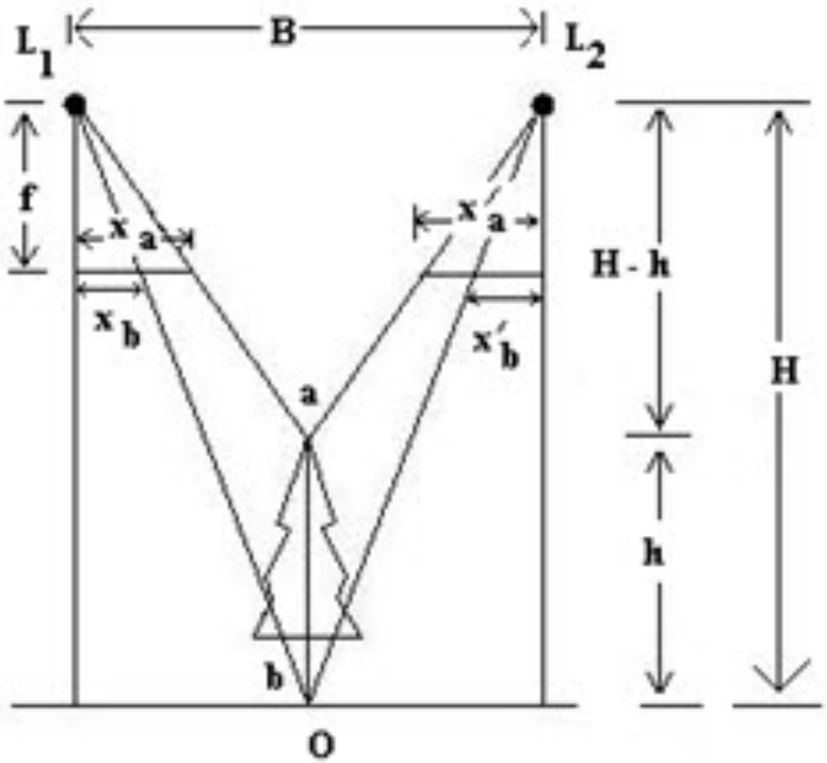


Fig. 8.5

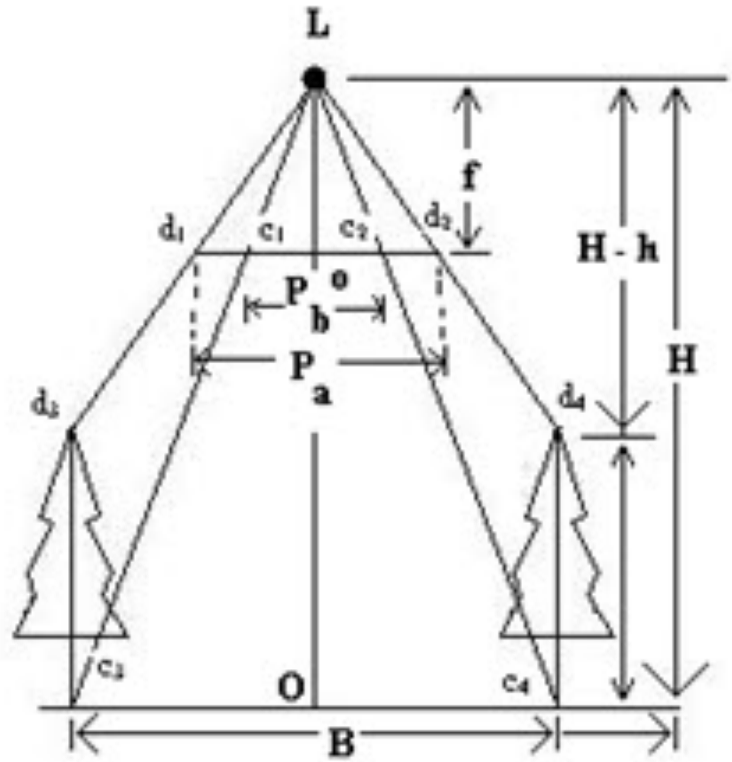


Fig. 8.6

Geometric correction of aerial images

- Orthophotos
  - images without terrain and tilt distortions

Drones

- Personal remote sensing
- Limited range and height

Obtaining NDVI from UAV-based aerial photography

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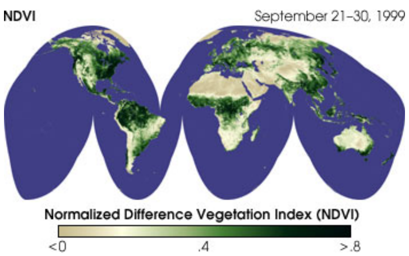
Introduction

Healthy vegetation has a unique spectral signature. The chlorophyll in plants strongly absorbs red wavelengths of light for use in photosynthesis, while the cellular structure of the leaves strongly reflects near-infrared wavelengths. The Normalized Difference Vegetation Index, or NDVI, takes advantage of this difference in reflection to characterize the health of vegetation, or "greenness". NDVI is calculated with red and near-infrared bands as $\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{RED})}{(\mathrm{NIR} + \mathrm{RED})}$. NDVI produces a range of values from -1 to 1 with healthy green vegetation having values from approximately 0.8 to 1.



Low values show a lack of, or unhealthy, vegetation, and high values indicate high raters of photosynthesis.

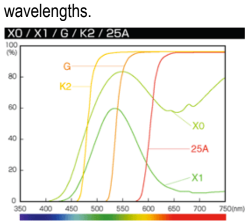
Image source: NASA Earth Observatory

Purpose

The purpose of this project was to establish a method for obtaining NDVI imagery from a single digital sensor affixed to an unmanned aerial vehicle (UAV). The UAV used was a DJI Phantom 2 Vision +, a remotely controlled quadcopter. A private property southwest of Lawrence, Kansas was the study area, chosen for ease of access and the presence of several different land-cover types within the property boundaries.

Methods

In order to obtain multispectral imagery with a single digital camera, a converted Canon EOS M was purchased. The internal no-pass filters had been removed, making the camera a full spectrum digital sensor. In order to obtain the bands necessary to calculate NDVI, a low-pass yellow filter was added in order to block light in the UV and blue wavelengths.



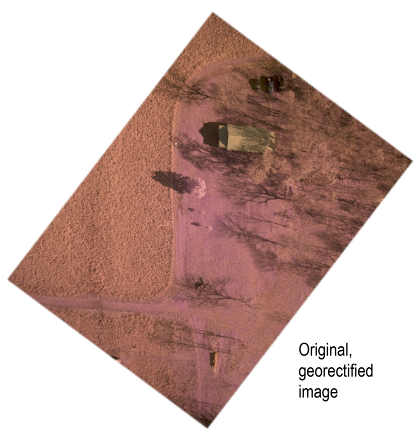
The yellow filter (K2 in the image) blocks light with wavelengths shorter than approximately 500 nm.

Image source: Hoya Filters

Methods

The modified camera was mounted to the UAV using cardboard and duct tape with the shutter depressed in order to collect continuous imagery. The imagery used in this analysis was obtained from an above ground altitude of approximately 114 meters on 20 April 2015.

Due to technical issues it was not possible to follow the programed flight plan and the UAV was flown manually. Consequently many of the images did not contain the established ground control points. A single image was selected based on recognizable features, and georectified to NAIP imagery using Erdas Imagine.



Original, georectified image

The combination of the full-spectrum digital camera and the low-pass filter produced three bands of data:

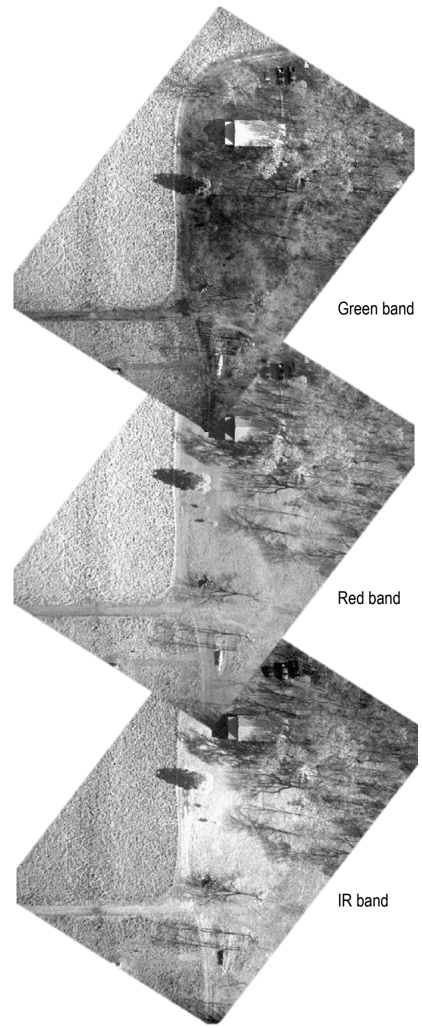
UV + Blue + IR – (UV + Blue) = **IR**

UV + Green + IR – (UV) = **Green + IR**

UV + Red + IR – (UV) = **Red + IR**

Utilizing raster calculator in ArcMap, the IR band was subtracted from the other two bands, resulting in an IR band, a green band, and a red band. These three bands were then stacked in Erdas Imagine to create a color-infrared composite image.

Methods



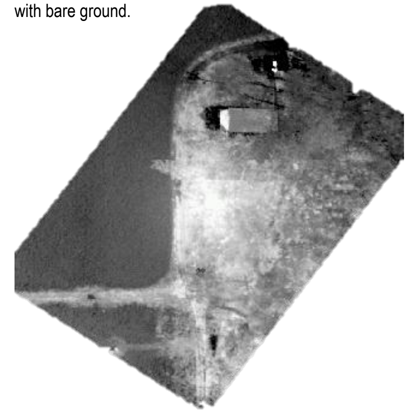
Green band

Red band

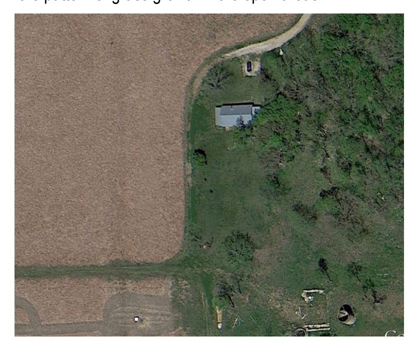
IR band

Results

NDVI was calculated in ERDAS Imagine with the color infrared composite using the red and infrared bands. Areas of high NDVI are shown with light shades and areas of low NDVI are shown with dark shades. The image shows a fallow field and a pattern of emerging grasses interspersed with bare ground.



The NDVI image was visually assessed against a Google Earth image from Digital Globe captured on 3 May 2014. The UAV imagery was obtained prior to tree greenup and so does not show the vegetated biomass in the tree crowns. The NDVI image does distinctly capture the pattern of grass growth in the open areas.



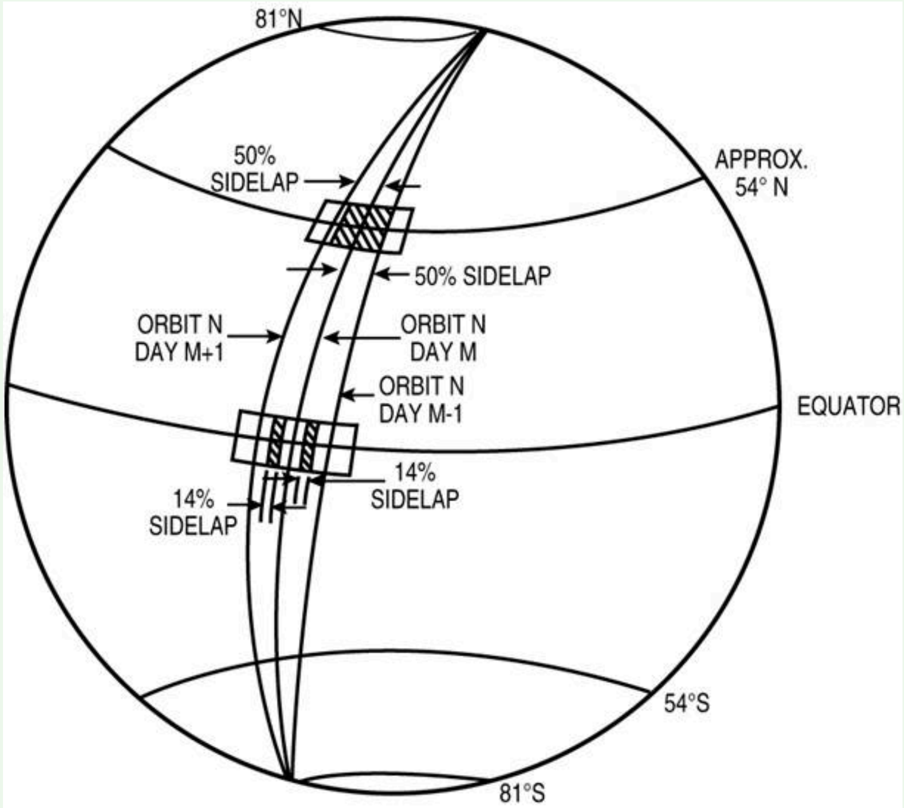
Further validation is necessary to assess the accuracy of the NDVI image. Due to a lack of precise spectral resolution there is inherent uncertainty in the process. Ground-based measurements should be taken using a spectroradiometer and NDVI calculated for a set of sample points. A confusion matrix could then be used to determine the accuracy of the aerial measurements. Based on a visual assessment of the NDVI image, the technique holds great promise for production of high spatial resolution NDVI imagery.

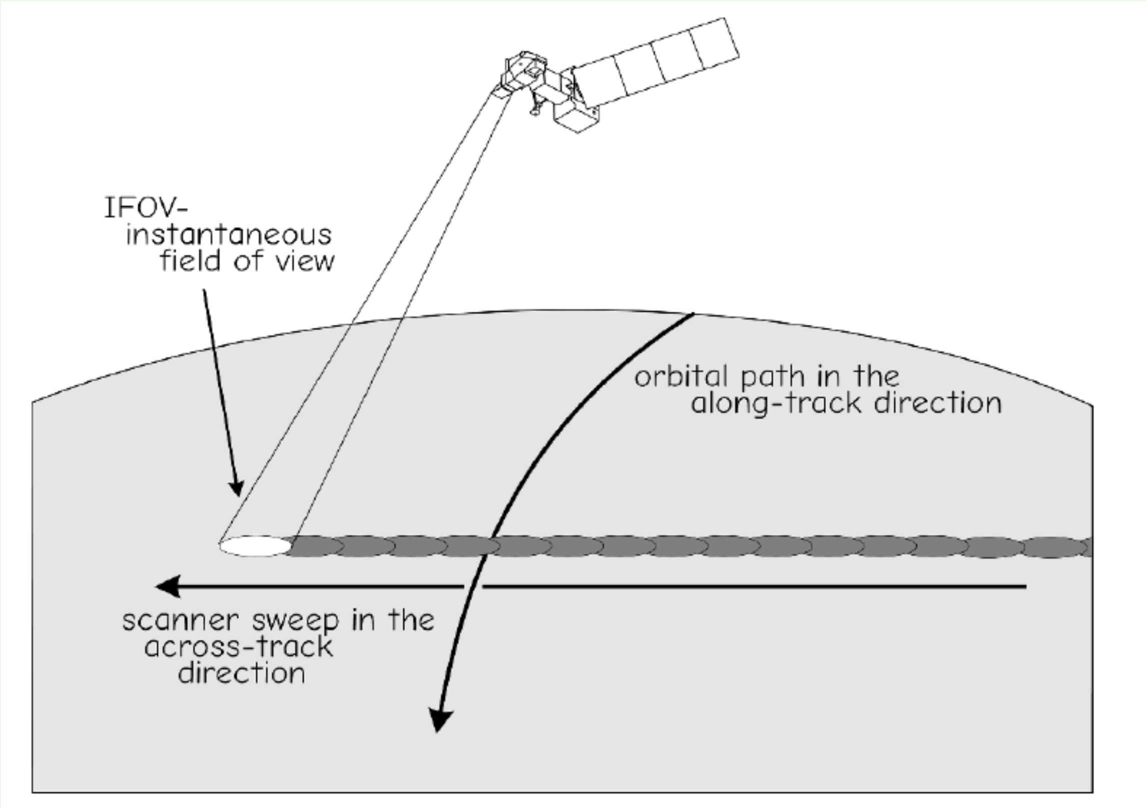
Reference: Rabatel, Gilles, Nathalie Gorretta, and Sylvain Labbé. "Getting NDVI spectral bands from a single standard RGB digital camera: a methodological approach." In *Advances in Artificial Intelligence*, pp. 333-342. Springer Berlin Heidelberg, 2011.

Satellite remote sensing

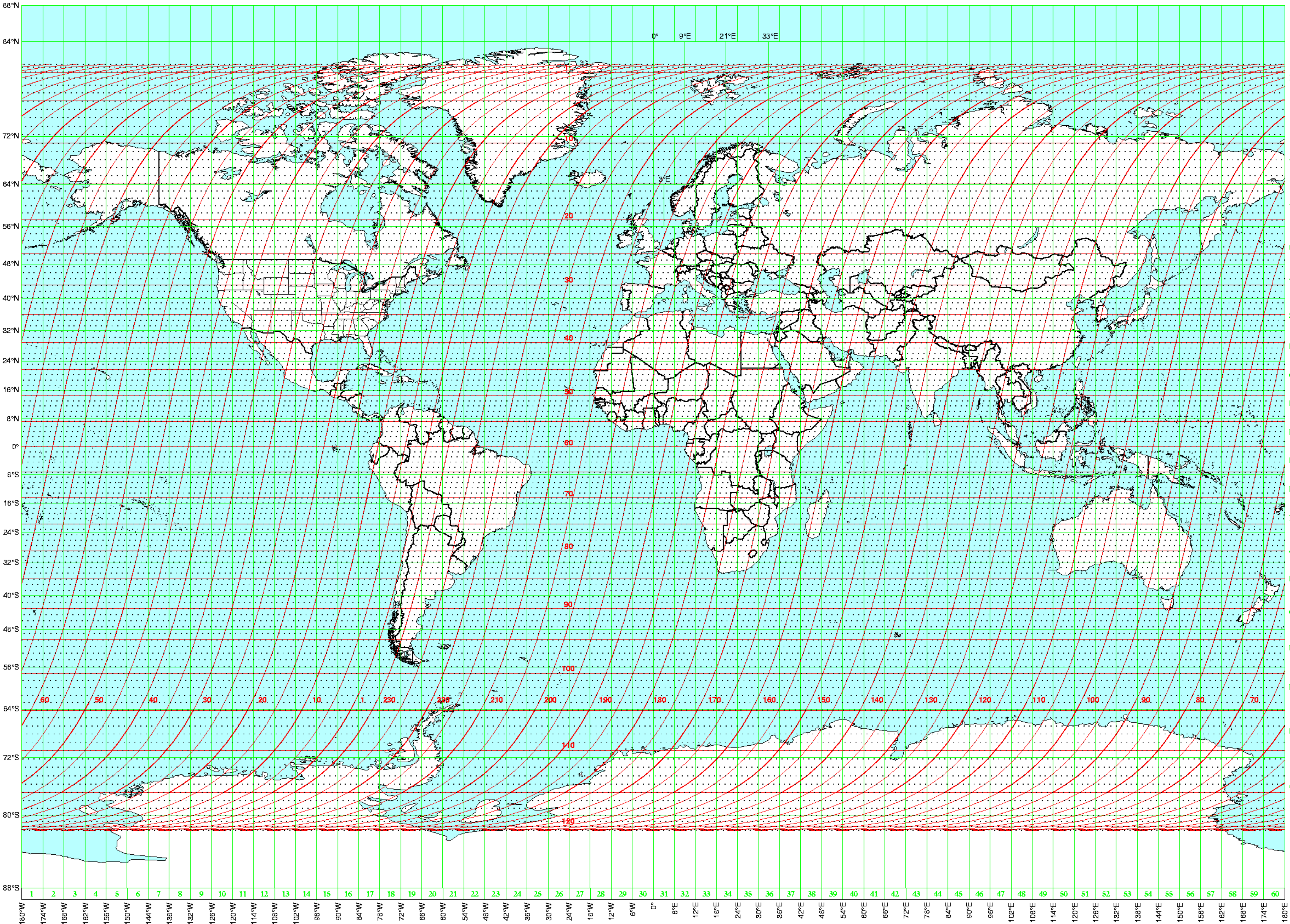
- One scene usually covers large area (generally at least 100s of square miles)
- Low cost per unit area
- High view, little relief displacement
- Stable satellites, little tilt distortion
- Wide spectral range, from visible to radar
- Extensive temporal range

Satellite remote sensing





WRS-2 Path / Row (Landsats 4, 5 and 7) and UTM Zones

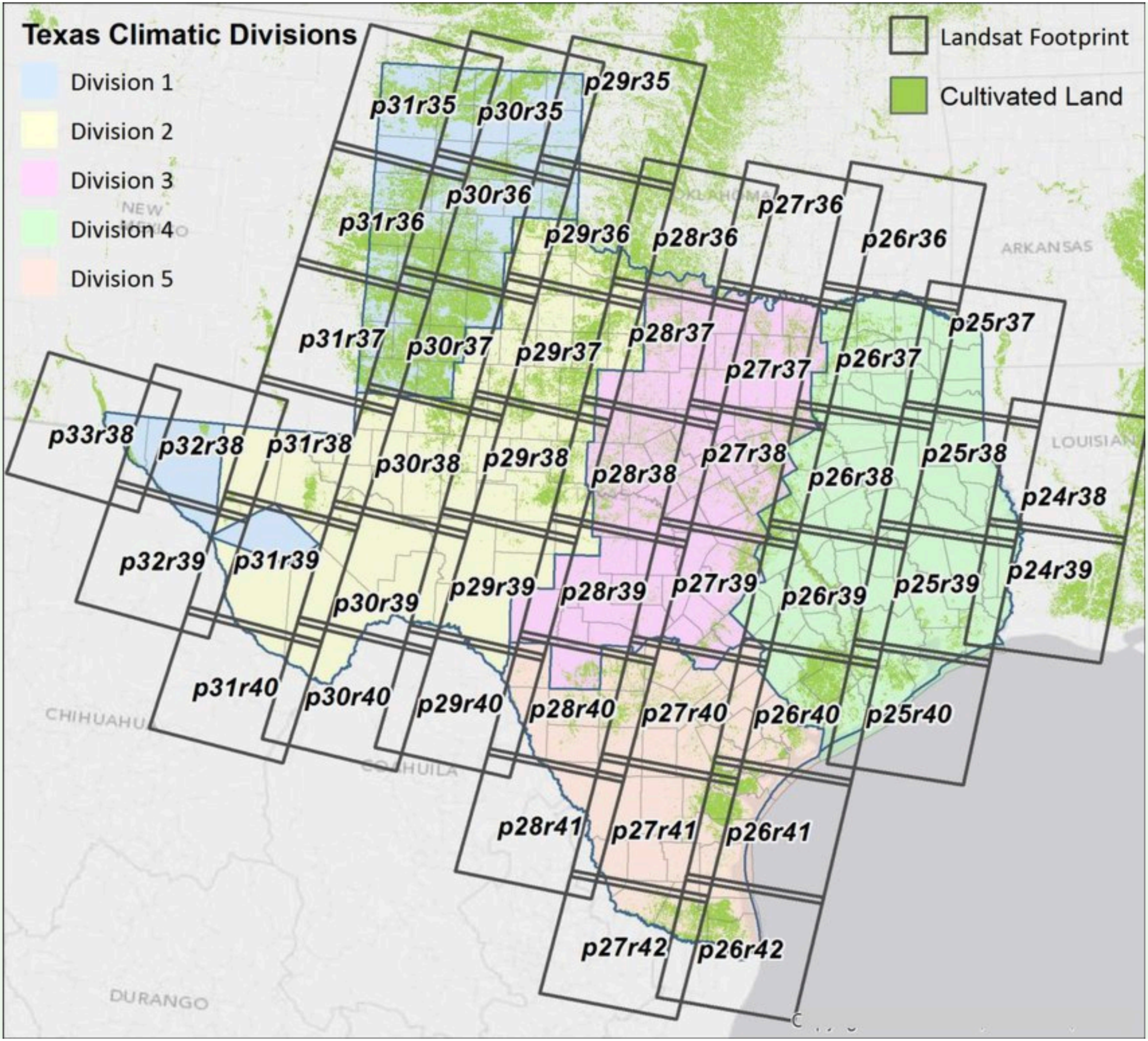


USGS
science for a changing world

WRS-2 Path / Row
UTM Zones

Black dots --- Intermediate Path / Row
Miller cylindrical projection

U.S. Geological Survey
National Mapping Division
EROS Data Center
Sioux Falls, SD



Texas Climatic Divisions
Division 1
Division 2
Division 3
Division 4
Division 5
Landsat Footprint
Cultivated Land
p31r35
p30r35
p29r35
p31r36
p30r36
p29r36
p28r36
p27r36
p26r36
p31r37
p30r37
p29r37
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NEW MEXICO
OKLAHOMA
ARKANSAS
LOUISIANA
CHIHUAHUA
COAHUILA
DURANGO