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Eyes in the Sky: An Introduction to Remote Sensing

Ashley York
Rowan University, yorka@rowan.edu

Eyes in The Sky: An Introduction to Remote Sensing

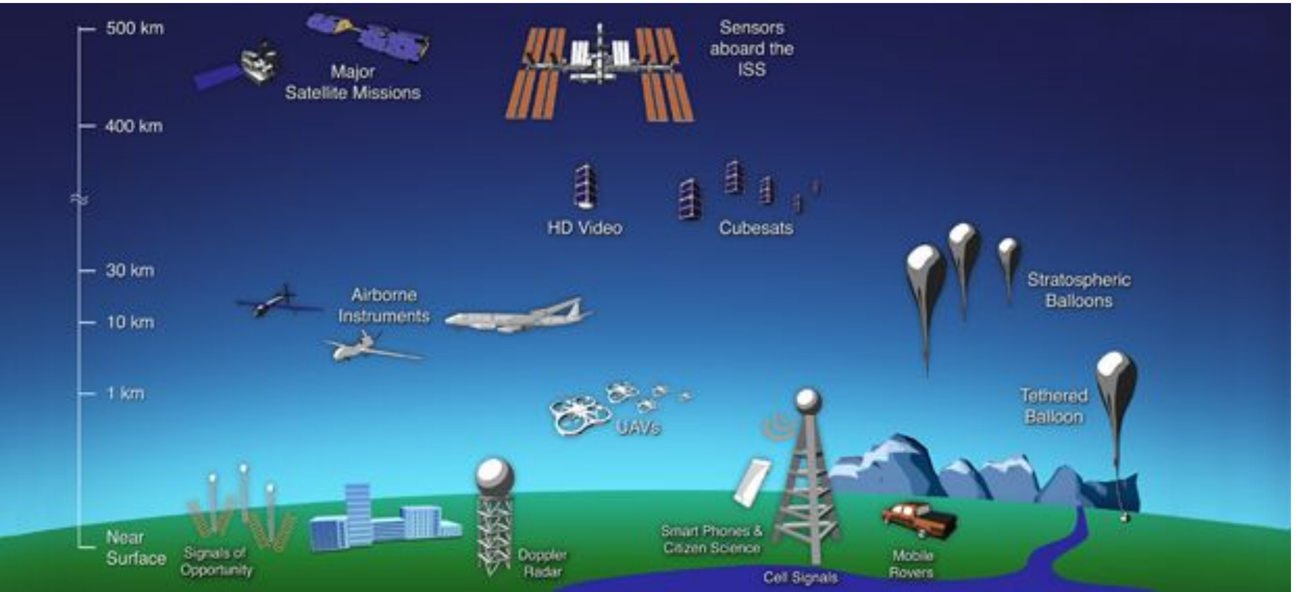
Dr. Ashley York (yorka@rowan.edu)
Department of Geography, Planning and Sustainability

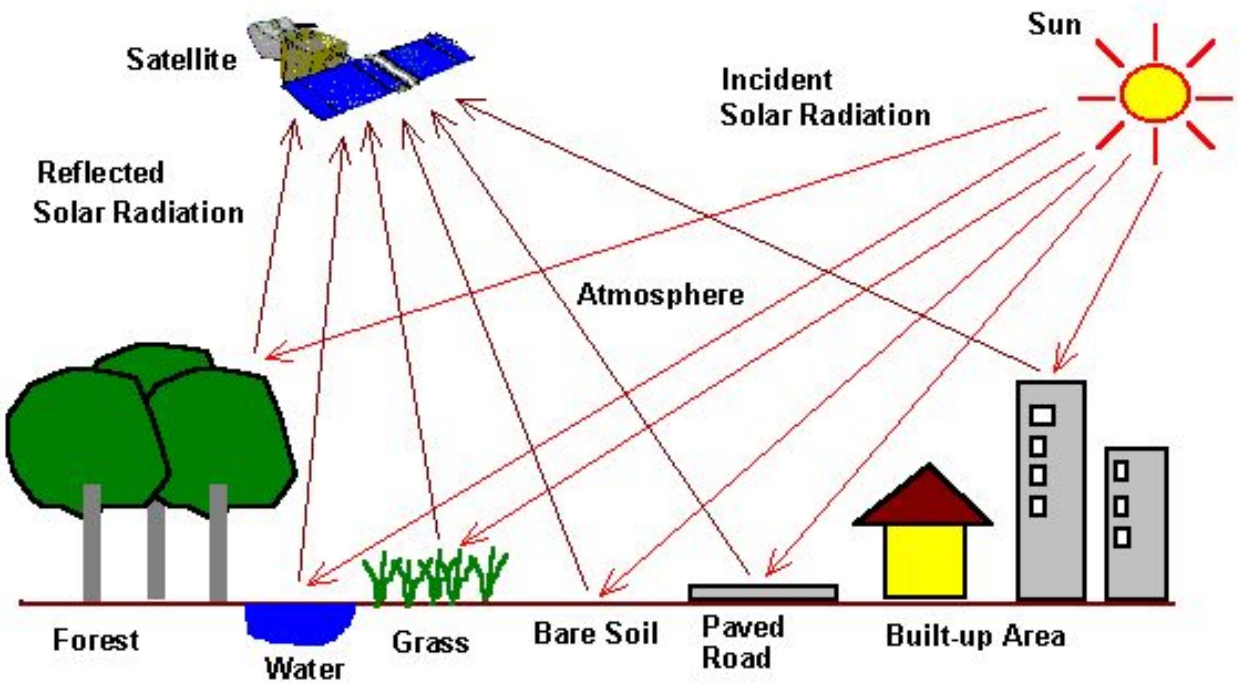
Remote Sensing – Definition

- The acquisition of information about an object or area from a distance/without making contact with that object

- The process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted electromagnetic radiation from a distance

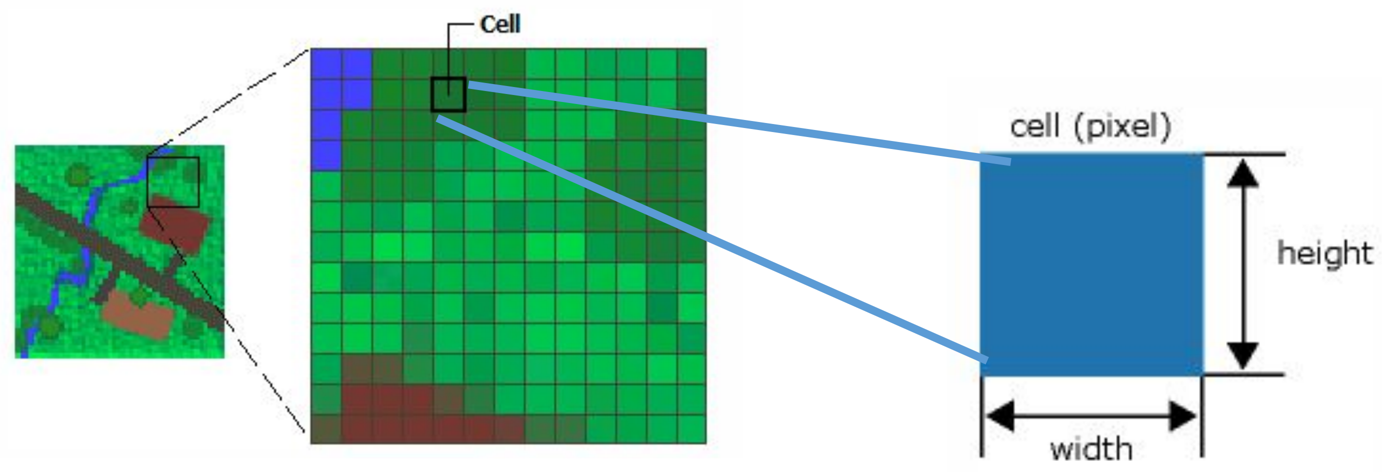
- Your eyes are the best remote sensors!

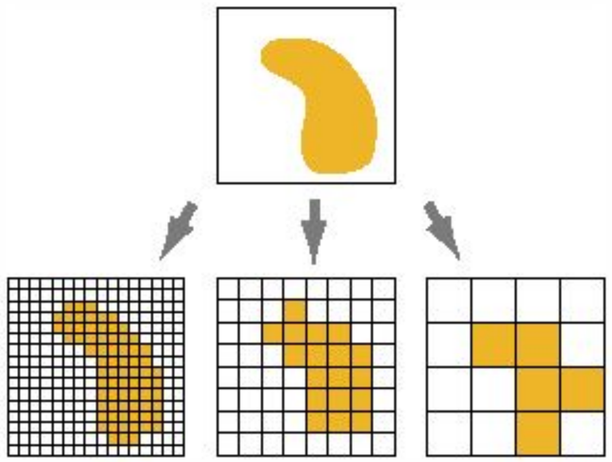




Raster Imagery

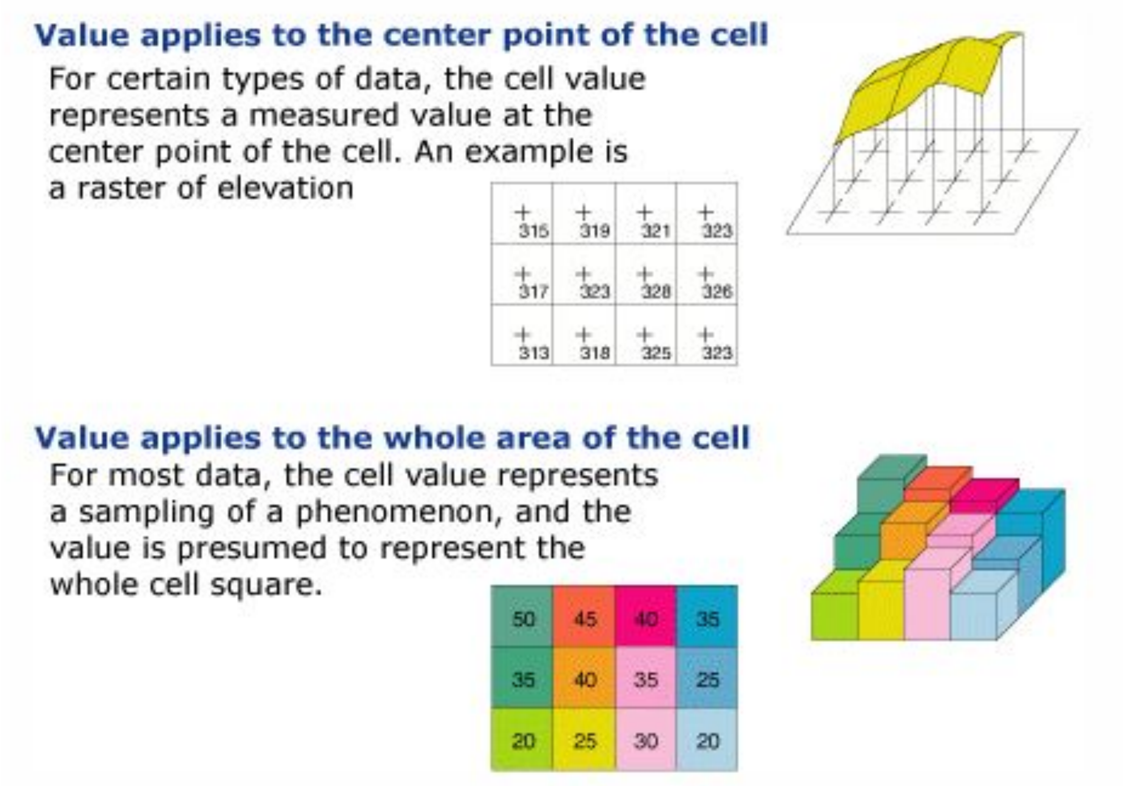
- "Raster" is a data model used to store information about *continuous* phenomena on Earth (things that happen everywhere)
  - elevation, temperature, air quality, color, energy...
- For our sake, a raster is just an image, like any picture you may take
- Just like if you zoom into any picture, you start to see individual pixels
- So if you imagine a satellite taking a picture (raster) looking down at Earth, then each pixel (cell) covers a certain area on Earth's surface (e.g. 30mx30m, 1mx1m, 250kmx250km)
- Different sources of satellite imagery have different resolutions/cell dimensions
- Each of these cells then gets only one value of the phenomena it is trying to represent
- There can be spatial inaccuracies due to the limits imposed by the cell size (mixed pixel)





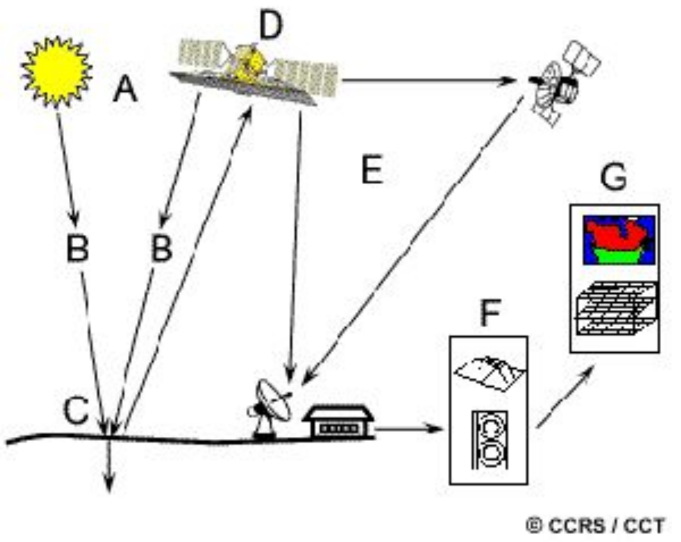
Raster

- Each cell (pixel) has a value where the values represent the phenomenon portrayed by the raster dataset such as a category, magnitude, height, or *electromagnetic radiation/spectral value*
    - In satellite imagery and aerial photography, spectral values are used to represent light reflectance and color, which are unique to different Earth surface phenomena

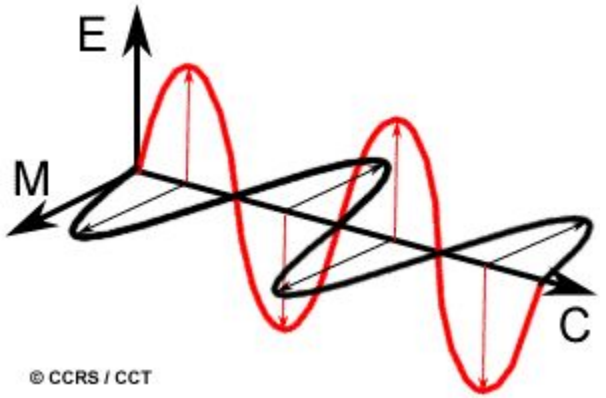


80	74	62	45	45	34	39	56
80	74	74	62	45	34	39	56
74	74	62	62	45	34	39	39
62	62	45	45	34	34	34	39
45	45	45	34	34	30	34	39

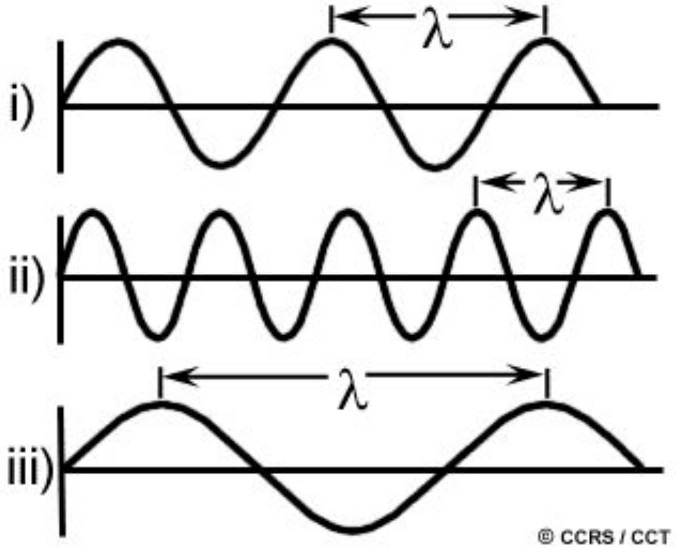
Remote Sensing – Theory – Electromagnetic Radiation



- **Electromagnetic radiation** consists of an electrical field (E) which varies in magnitude in a direction perpendicular to the direction in which the radiation is traveling, and a magnetic field (M) oriented at right angles to the electrical field. Both fields travel at the speed of light (C).



- Two characteristics of electromagnetic radiation are particularly important for understanding remote sensing – the **wavelength and frequency**
  - The shorter the wavelength, the higher the frequency
  - The longer the wavelength, the lower the frequency



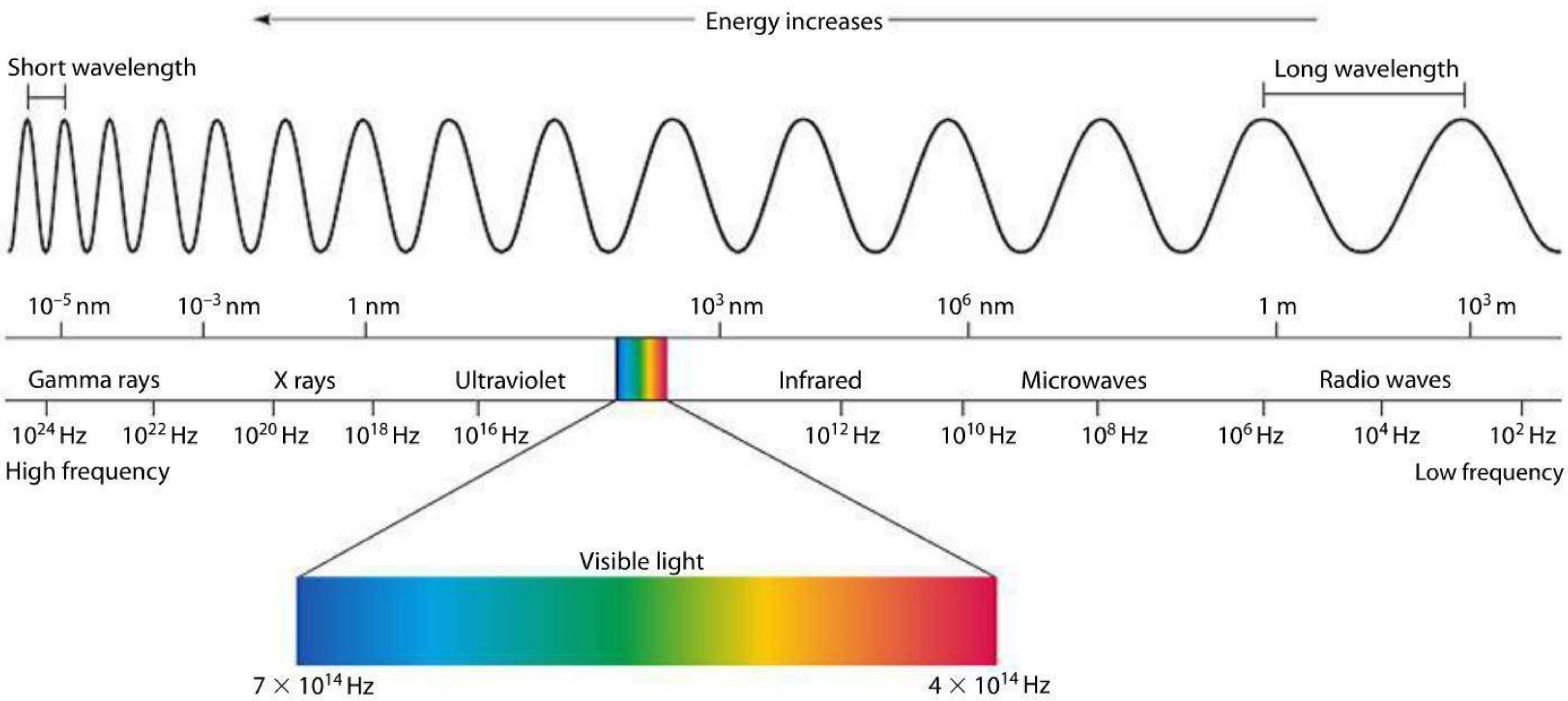
$c = \lambda \nu$

where:

λ = wavelength (m)
ν = frequency (cycles per second, Hz)
c = speed of light (3×10^8 m/s)

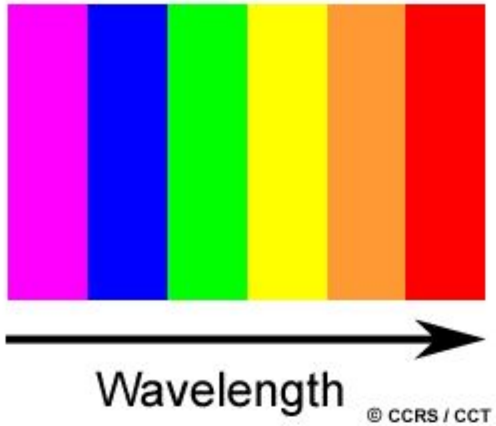
Remote Sensing – Theory – Electromagnetic Spectrum

- The **electromagnetic spectrum** ranges from the shorter wavelengths (including gamma and x-rays) to the longer wavelengths (including microwaves and broadcast radio waves)

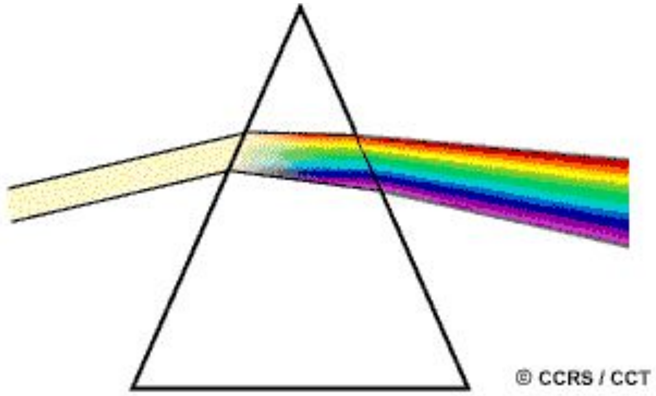


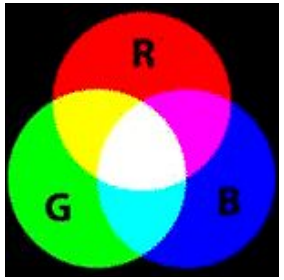
Remote Sensing – Theory – Visible Spectrum

- The light which our eyes - our "remote sensors" - can detect is part of the **visible spectrum**
- It is important to recognize how small the visible portion is relative to the rest of the spectrum
    - The visible wavelengths cover a range from approximately 0.4 to 0.7 µm
    - The longest visible wavelength is red and the shortest is violet
- There is a lot of electromagnetic radiation around us which is invisible to our eyes, but can be detected by other remote sensing instruments and used to our advantage to highlight certain phenomena on Earth's surface



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

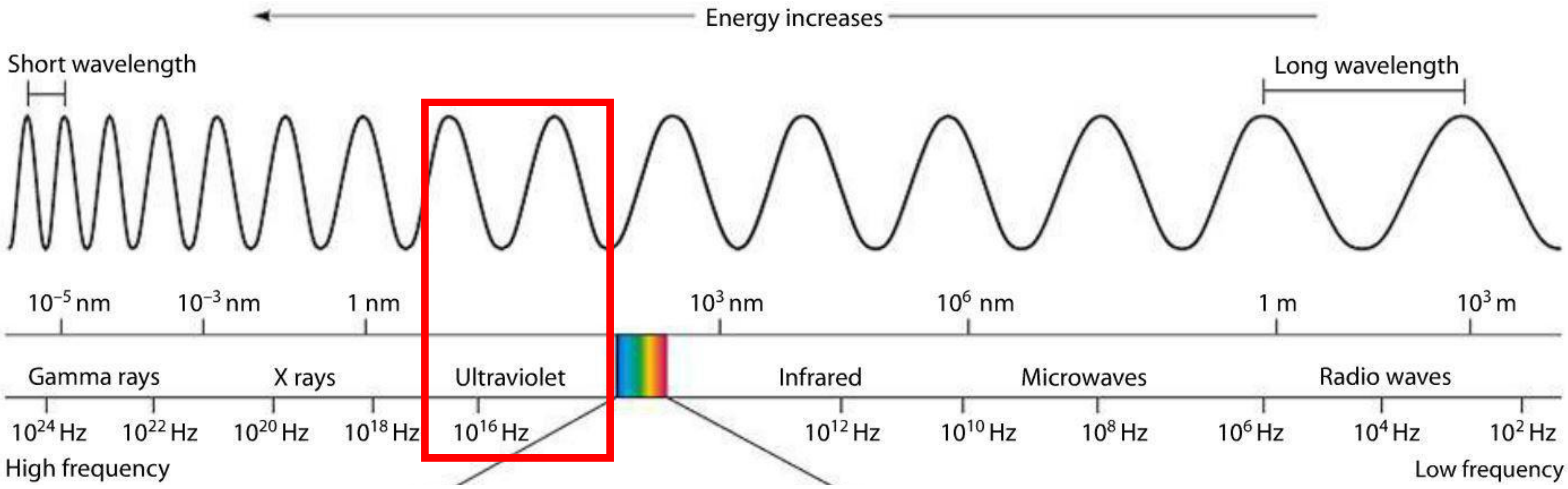




Blue, **green**, and **red** are the **primary colours** or wavelengths of the visible spectrum. They are defined as such because no single primary colour can be created from the other two, but all other colours can be formed by combining blue, green, and red in various proportions. Although we see sunlight as a uniform or homogeneous colour, it is actually composed of various wavelengths of radiation in primarily the ultraviolet, visible and infrared portions of the spectrum. The visible portion of this radiation can be shown in its component colours when sunlight is passed through a **prism**, which bends the light in differing amounts according to wavelength.

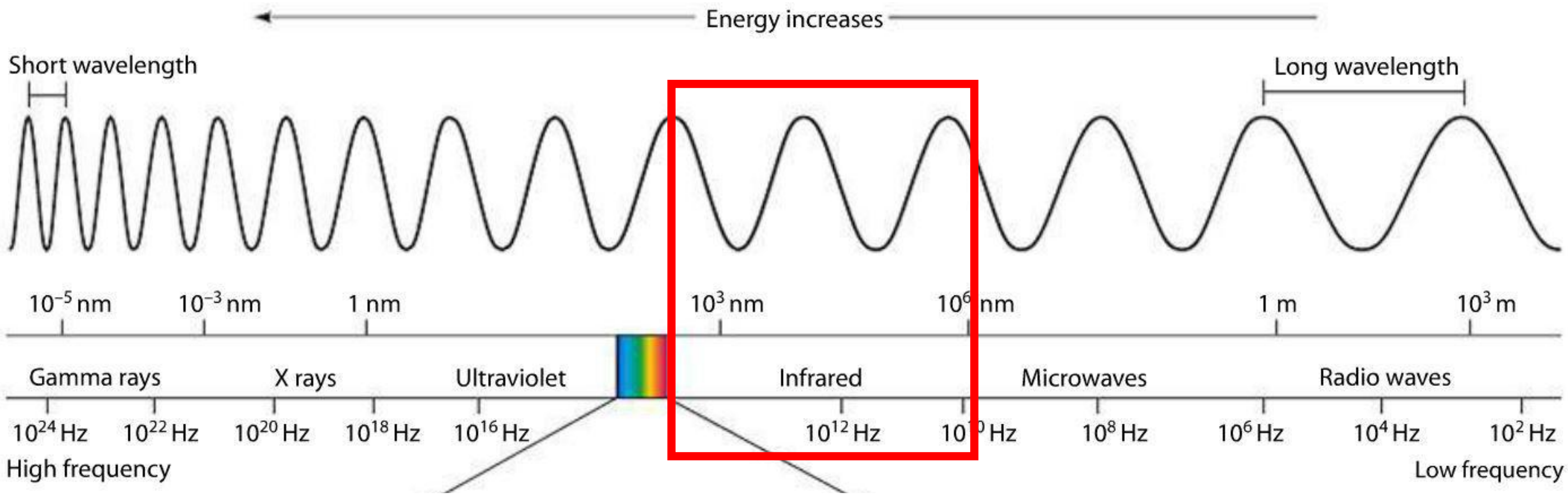
Remote Sensing – Theory – Other Spectral Regions Useful for RS

- The **ultraviolet/UV** portion of the spectrum has the shortest wavelengths practical for remote sensing. This radiation is just beyond the violet portion of the visible wavelengths, hence its name. Earth surface materials, primarily rocks and minerals, fluoresce or emit visible light when illuminated by UV radiation. Also scorpions!



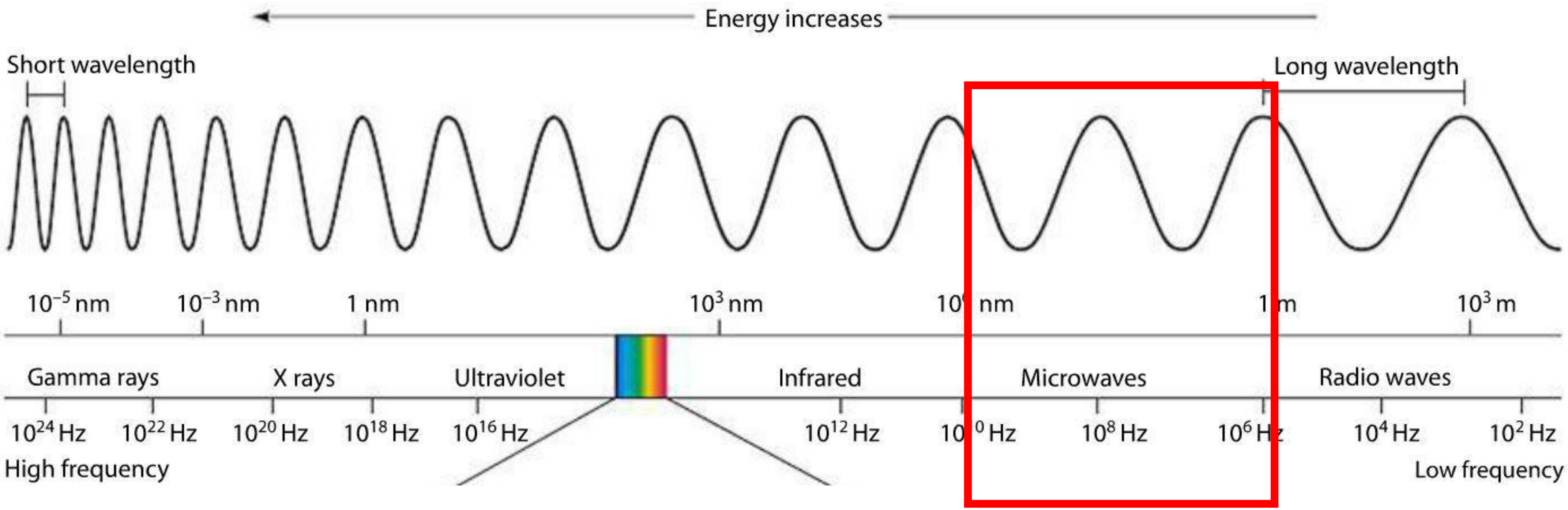
Remote Sensing – Theory – Other Spectral Regions Useful for RS

- The next portion of the spectrum of interest is the infrared (IR) region which covers the wavelength range from approximately 0.7 µm to 100 µm - more than 100 times as wide as the visible portion!
- The infrared region can be divided into two categories based on radiation properties - the **reflected IR (near IR and shortwave IR)**, and the emitted or **thermal IR**.
    - Radiation in the reflected IR region is used for remote sensing purposes in ways very similar to radiation in the visible portion (e.g. NIR and vegetation, SWIR and water content)
    - The thermal IR region is quite different than the visible and reflected IR portions - this energy is essentially the radiation that is emitted from the Earth's surface in the form of heat.



Remote Sensing – Theory – Other Spectral Regions Useful for RS

- The longest wavelength portion of the spectrum of particular interest to remote sensing is the **microwave region** from ~1 mm to 1 m
- Can penetrate clouds, and ice emits more microwave radiation than water, so ice-covered waters appear much brighter than the open ocean

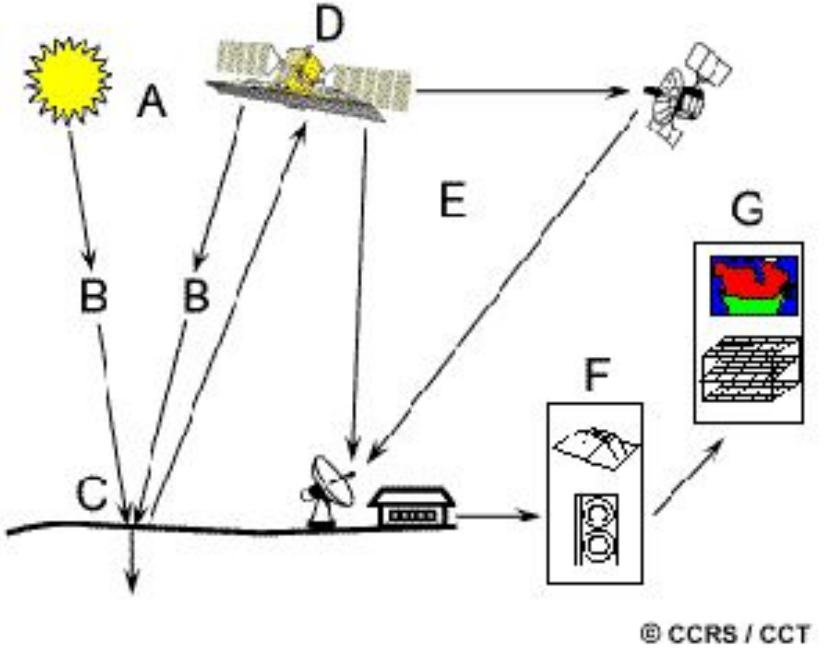


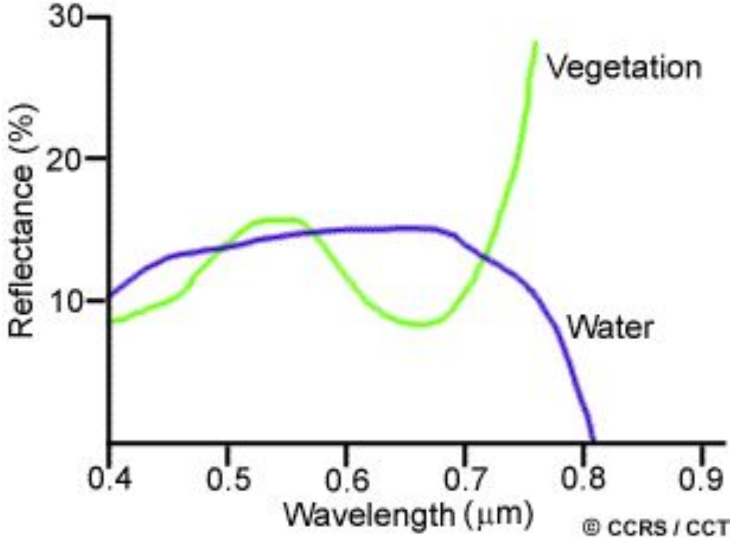
Remote Sensing – Theory – Target Interactions

- Biggest takeaway idea: different targets/surfaces/ objects/phenomena on Earth absorb, transmit, and reflect different wavelengths of energy in different quantities

- Each phenomena on Earth's surface has a (more-or-less) unique electromagnetic response, or <u>*spectral signature,*</u> based on these proportions of energy that are absorbed, transmitted, and reflected

- This is why things/colors look different to your eyes!
  - Black absorbs all wavelengths of light and reflects none
  - The sum/reflection of all colors add up to white
  - The color of something is the color it is reflecting, it absorbs all others



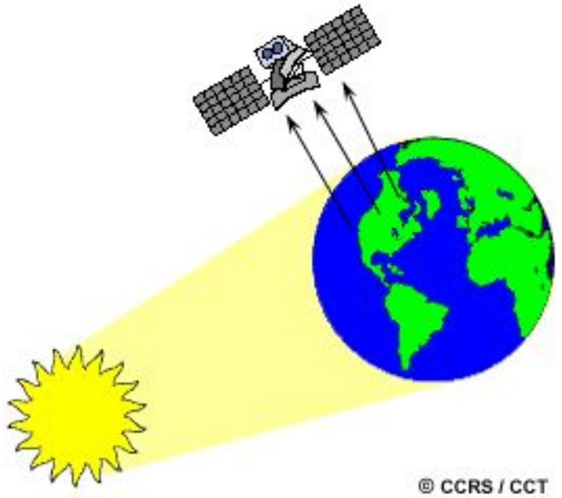


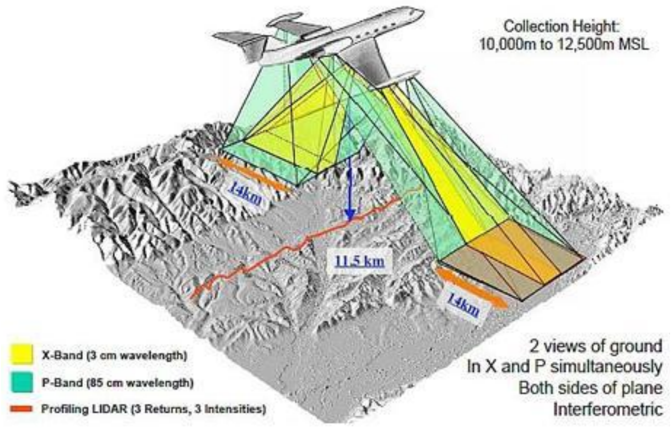
Remote Sensing – Sensors

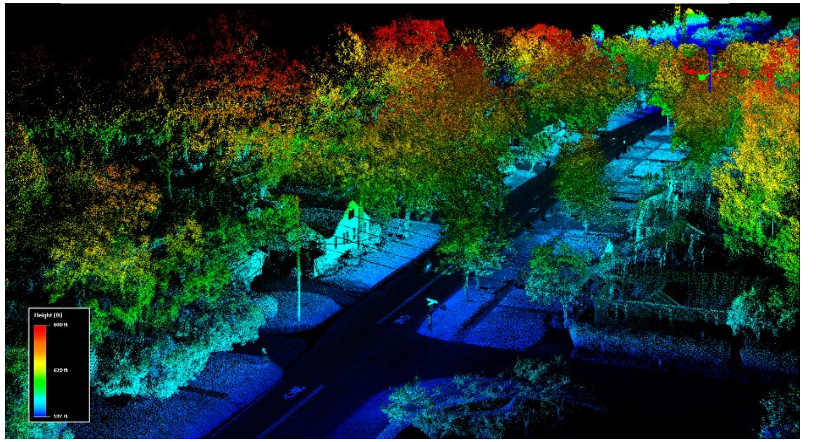
- Where does the electromagnetic energy come from?

- Remote sensing systems which measure energy that is naturally available are called **passive sensors**
  - The sun's energy is either reflected, as it is for visible wavelengths, or absorbed and then re-emitted, as it is for thermal infrared wavelengths (taking a picture)

- **Active sensors**, on the other hand, provide their own energy source for illumination
  - The sensor emits/sends a signal of radiation which is directed toward the target, then the radiation reflected from that target is detected and measured by the sensor (or the time it takes)







[Passive Remote Sensing](#) [Active Remote Sensing](#)

Remote Sensing – Common Platforms – Landsat

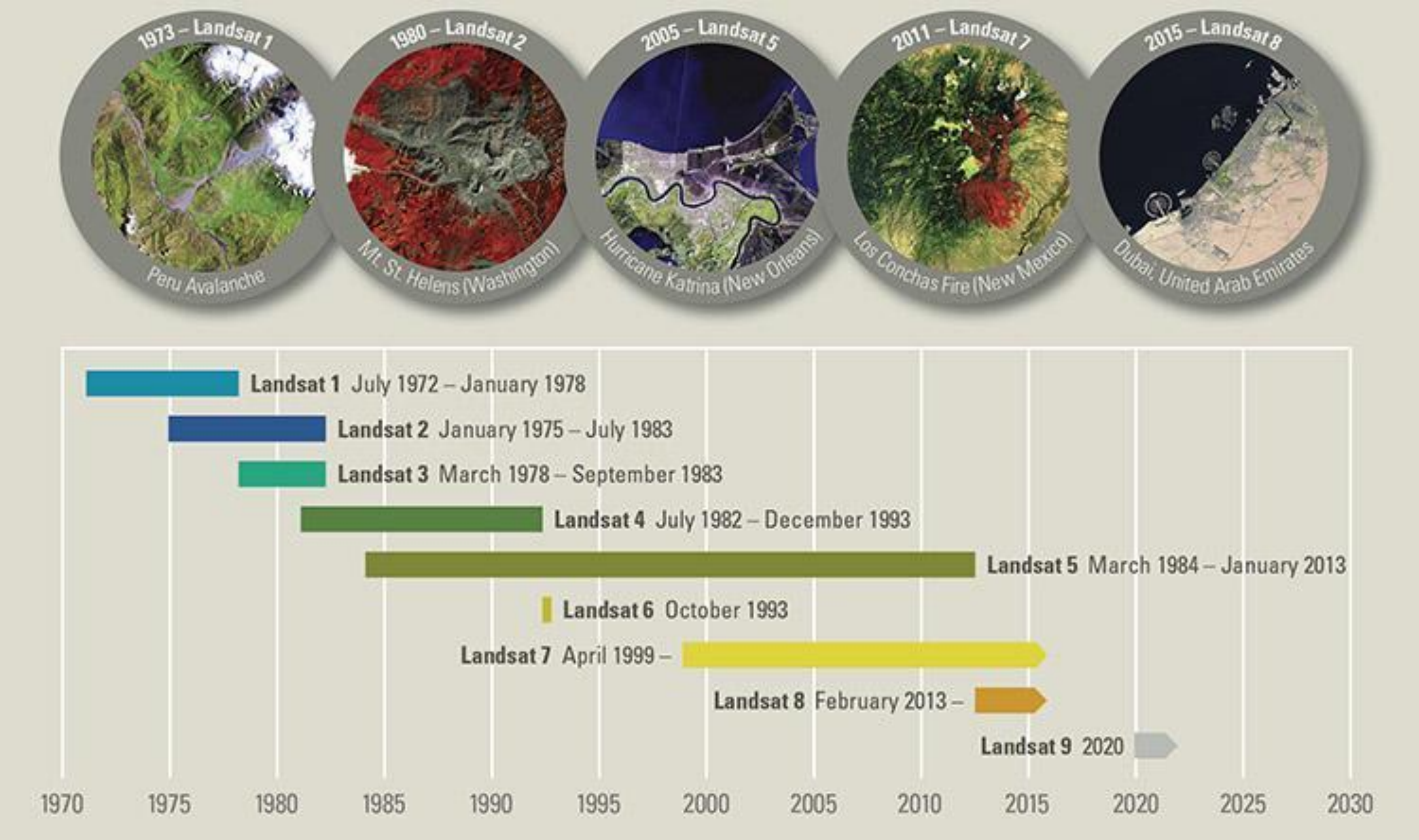
- Landsat-8

- Near polar, sun-synchronous orbit, passive

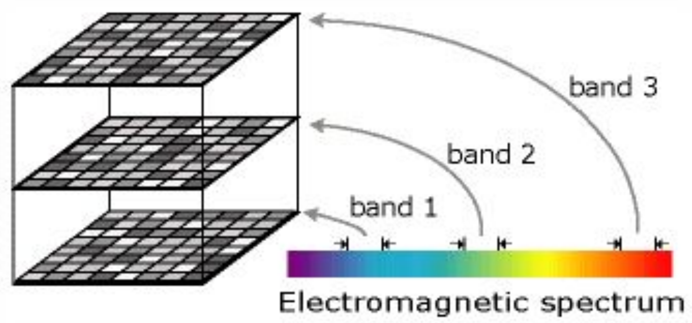
- 16-day repeat cycle

- 30m x 30m cell size
(how much area a single pixel covers)

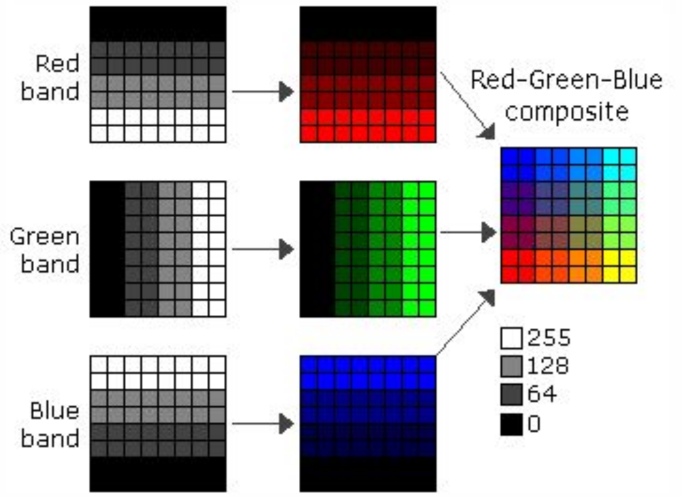
- 185 km x 185 km swath
(how much area the entire image covers)



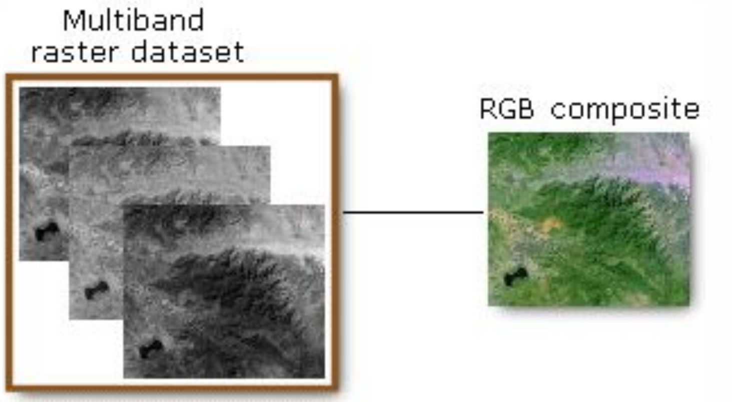
Remote Sensing – Bands



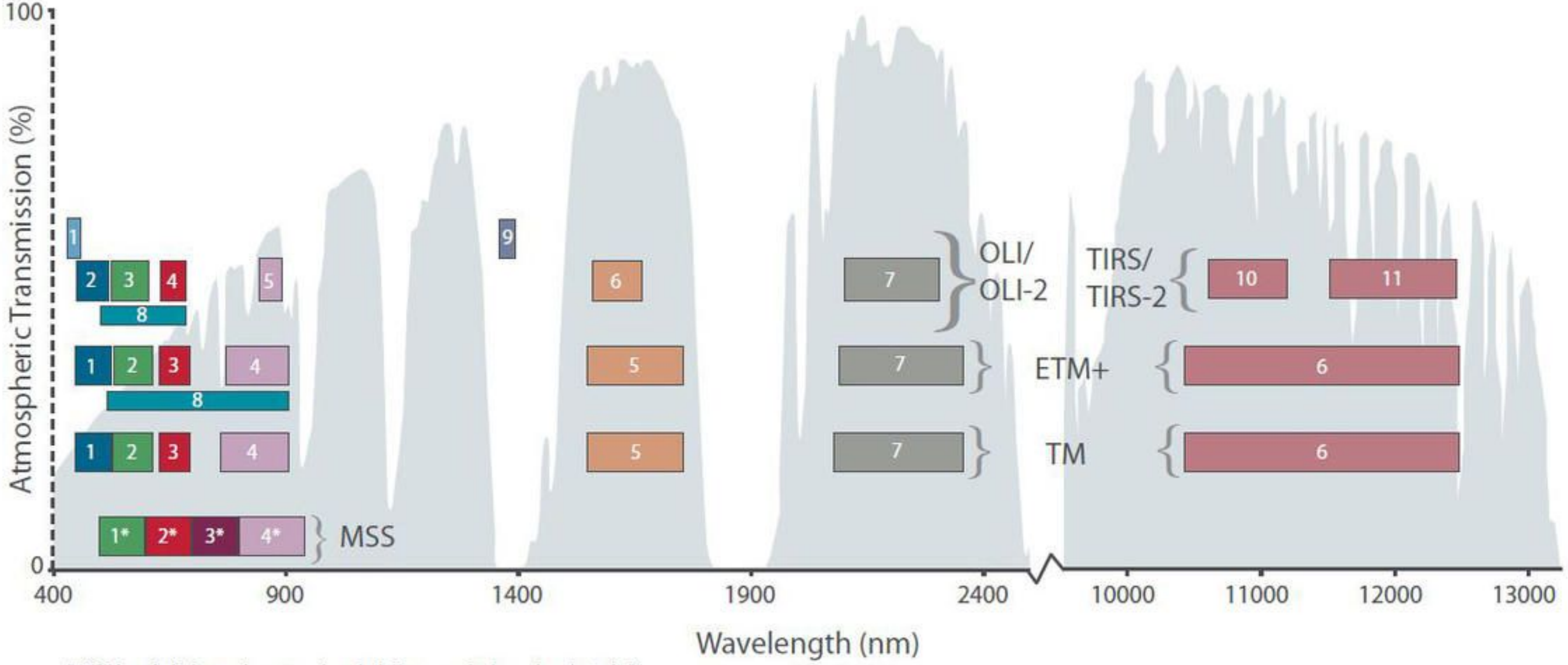
- For our sake, satellites take individual pictures (called bands) for different colors (portions of the electromagnetic spectrum)
  - e.g. one picture of all the red reflected on Earth, one picture for all of the blue reflected on Earth
- Every cell then has more than one spectral value associated with it



- Bands can represent any portion of the electromagnetic spectrum, including ranges not visible to the eye, such as the infrared or ultraviolet or microwave
  - Total number of bands, ranges of the spectrum covered by each vary by satellite
  - [Many Different Satellite Sensors]



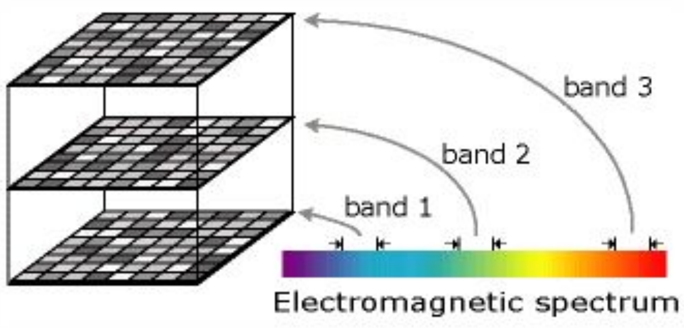
Remote Sensing – Common Platforms – Landsat Bands

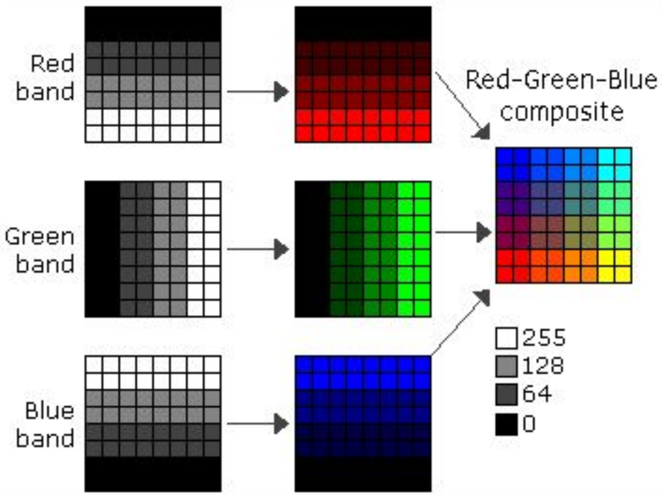


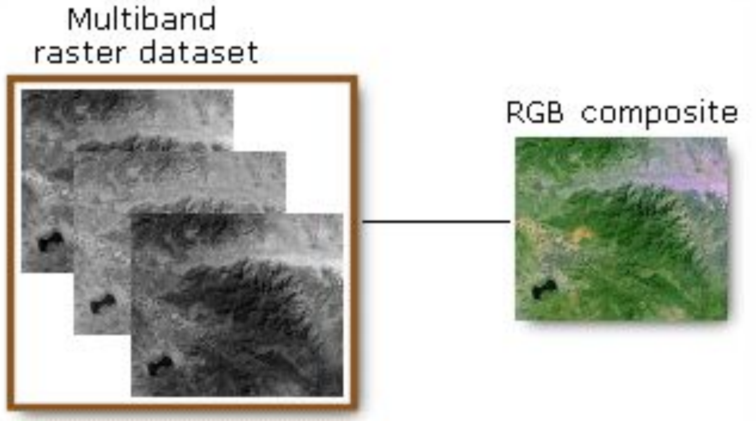
* MSS bands 1–4 were known as bands 4–7, respectively, on Landsats 1–3

Remote Sensing – Multiple Bands – Band Composites

- When you create a map layer from a raster image, you can choose to display a single band of data or form a composite of multiple bands
    - Think of this as stacking your different color images
- Our computers display images based on RGB channels
- A combination of any three of the available bands in a multiband raster dataset can be used to create RGB composites
- By displaying bands together as RGB composites, often more information is gleaned from the dataset than if you were to work with just a single band
- We can assign corresponding bands to the RGB channels on our computer display, or we can choose other bands...



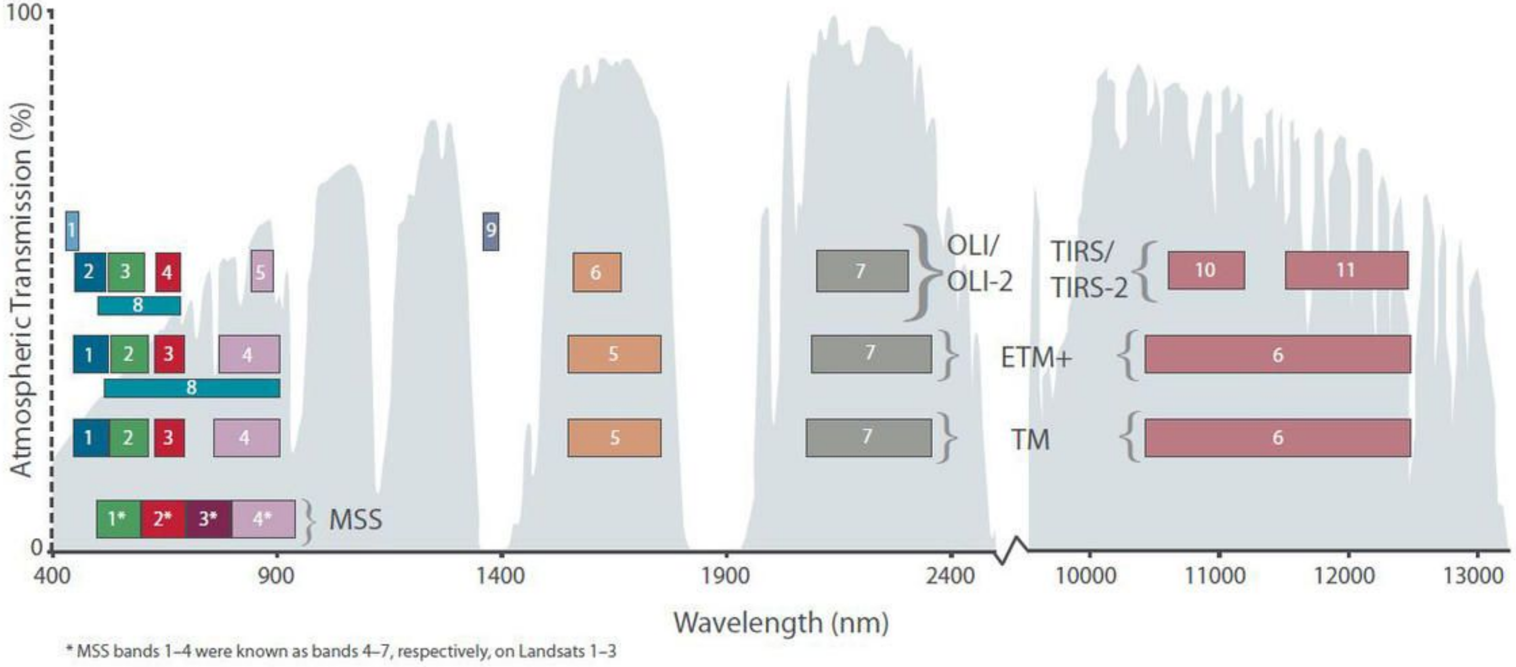




Remote Sensing – Band Composites– True Color

- A natural or **<u>true color composite</u>** is an image displaying a combination of the visible red, green and blue bands to the corresponding red, green and blue channels *on the computer display*
- For Landsat 8, a "True Color" combination
  - RGB, 432
  - R channel = red band 4, G channel = green band 3, B channel = blue band 2

These specific band <u>numbers</u> and which spectral ranges they cover vary by platform!

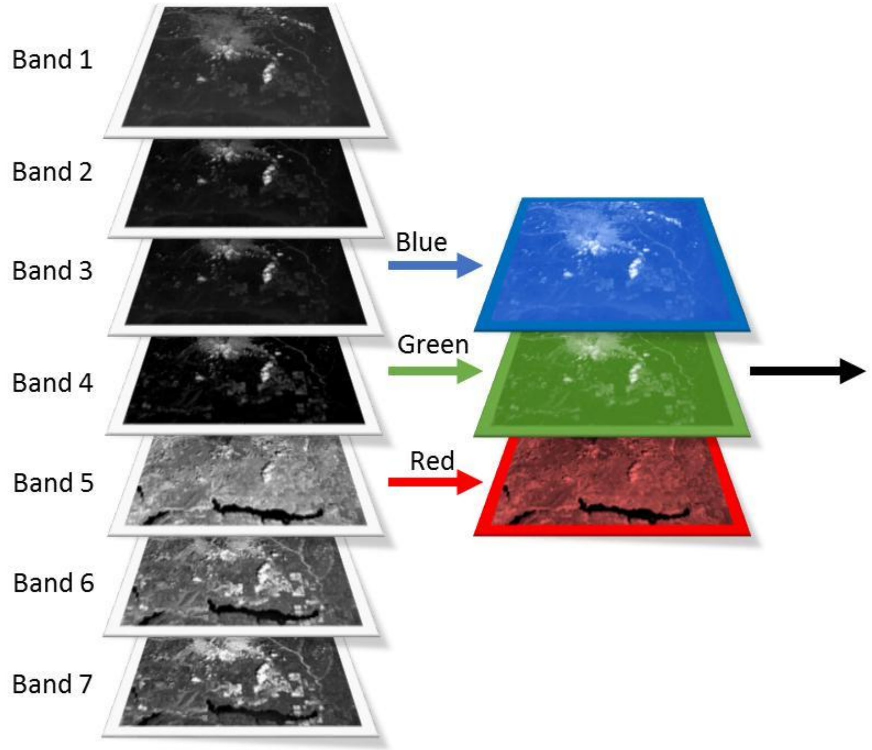


[Landsat Band Combinations]

Remote Sensing – Band Composites – False Color

- False color images are a representation of a multispectral image produced by NOT assigning the sensor's red, green and blue bands as the RGB channels of the display
- False color composites allow us to visualize wavelengths that the human eye can not see (e.g. near-infrared and beyond) and highlight different phenomena on Earth's surface

Composite Name	Bands
Natural Color	4 3 2
False Color (urban)	7 6 4
Color Infrared (vegetation)	5 4 3
Agriculture	6 5 2
Healthy Vegetation	5 6 2
Land/Water	5 6 4
Natural With Atmospheric Removal	7 5 3
Shortwave Infrared	7 5 4
Vegetation Analysis	6 5 4

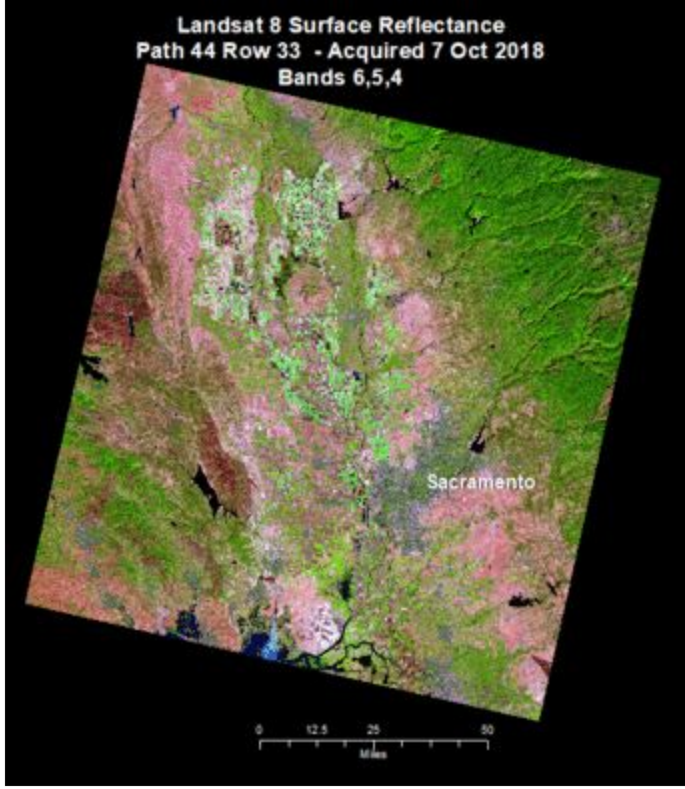


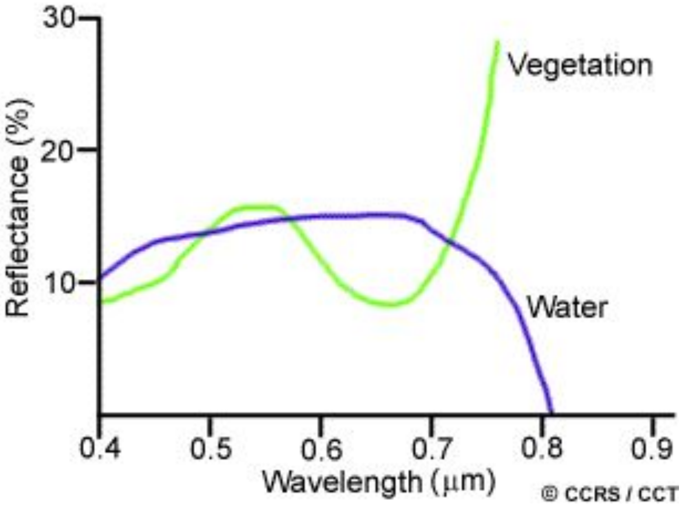
Remote Sensing – Spectral Indices

- Band composites are for photo interpretation/highlighting certain phenomena, while <u>spectral indices</u> are a *calculation* of the relationship between bands

- Spectral indices are combinations (math) of the spectral reflectance from two or more bands that indicate the relative abundance of features of interest

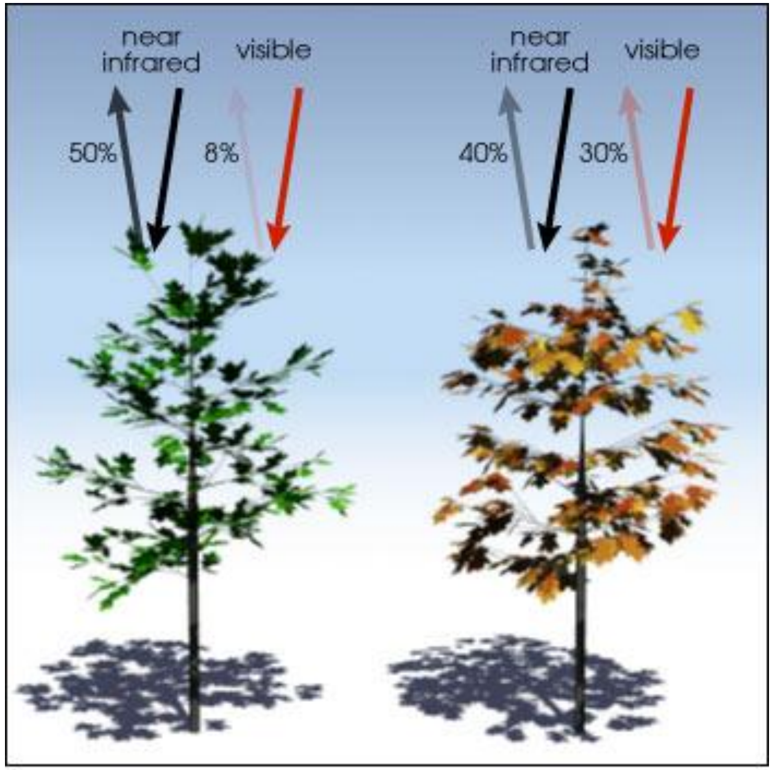
- Take advantage of unique *spectral signatures* of different phenomena – the idea that the proportions of energy absorbed/emitted in different wavelengths varies uniquely among phenomena (e.g. water vs. vegetation)
  - These signatures also vary within the same entities over time (e.g. seasonal changing of leaves on trees)
  - And among entities (e.g. deciduous vs. evergreen)





Remote Sensing – Spectral Indices – NDVI

- NDVI – Normalized Difference Vegetation Index – calculated from the visible and near-infrared light reflected by vegetation
  - "normalized" such that the minimum value is -1.0, and the maximum is +1.0
  - Healthy vegetation absorbs most of the visible light that hits it, and reflects a large portion of the near-infrared light
  - Unhealthy or sparse vegetation reflects more visible light and less near-infrared light



$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72 \qquad \frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$$

Ecosystem	Typical NDVI values	Location
Boreal forest	0.6-0.8	Alaska
Temperate forest	0.3-0.7	France
Coastal rainforest	0.88-0.92	Solomon Islands
Alpine pastures	0-0.35	Italy
Annual grassland	0.15-0.45	California
Desert	0.06-0.12	Sinai, Egypt

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

- Remote Sensing Indices
- NDVI in ArcMap

Remote Sensing – Spectral Indices – Others

- Normalized Difference….
- Snow Index
  - More specific ones for impurities, grain size

$$NDSI = \frac{Green - SWIR}{Green + SWIR}$$

- Water Index
  - Think about the variability in water color

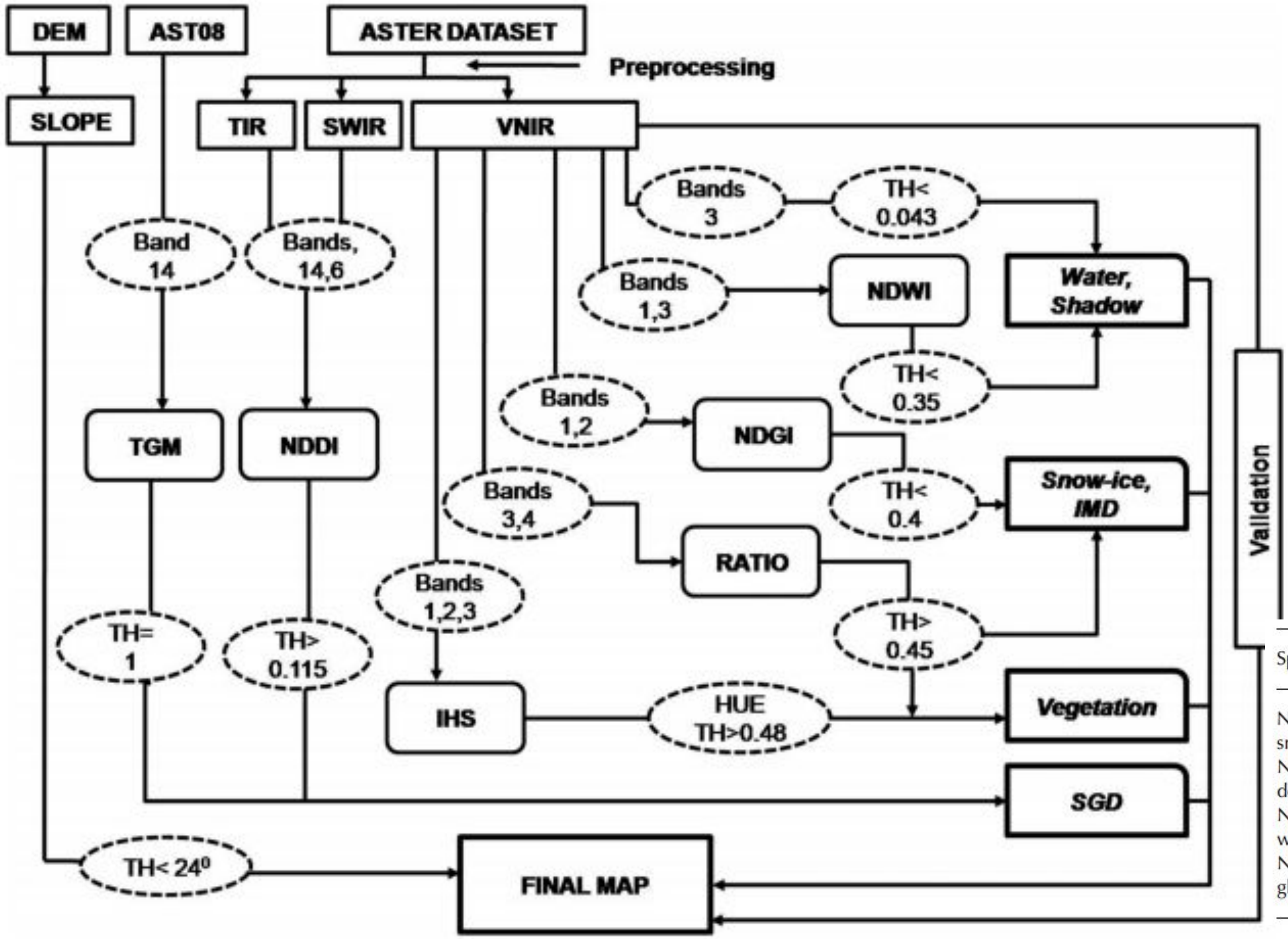
$$\mathrm{NDWI} = \frac{(Xnir - Xswir)}{(Xnir + Xswir)} \quad \mathrm{NDWI} = \frac{(Xgreen - Xnir)}{(Xgreen + Xnir)}$$

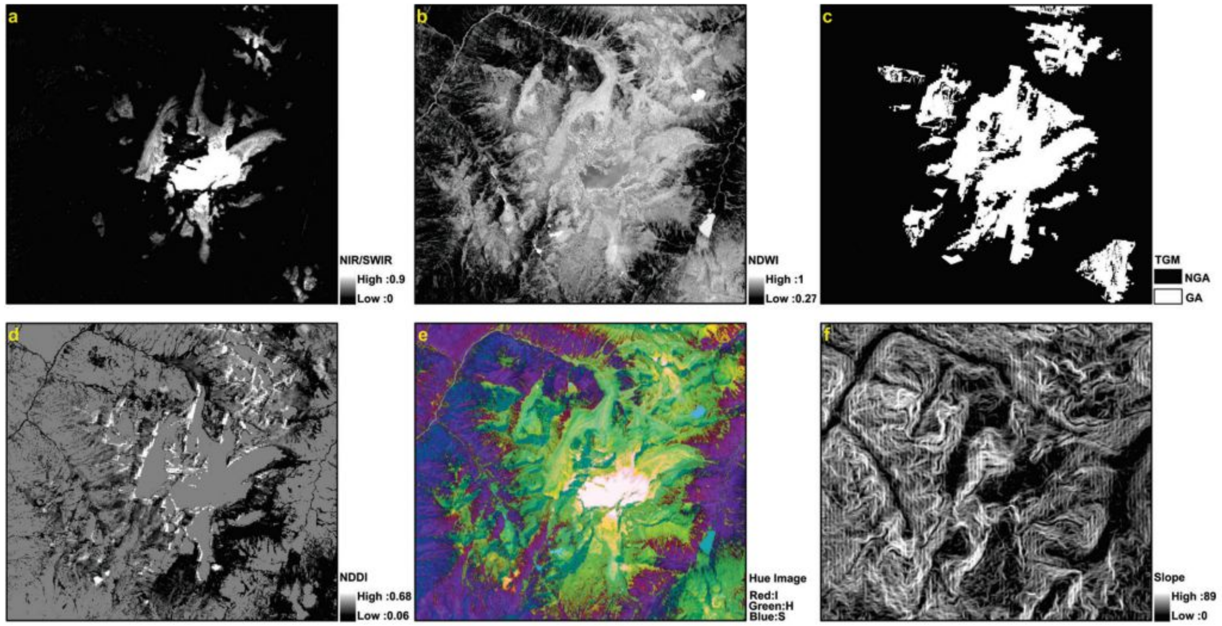
- So many!
  - [Spectral Indices]
  - [Spectral Indices in ArcGIS Pro]

- Some satellites automate these standard index calculations and create image "products"
- Specific band numbers (which equate to colors) will vary based on the sensor
- Multiple indices can be combined to create landcover maps….

Remote Sensing – Spectral Indices – Applications

- Shukla and Ali, 2016

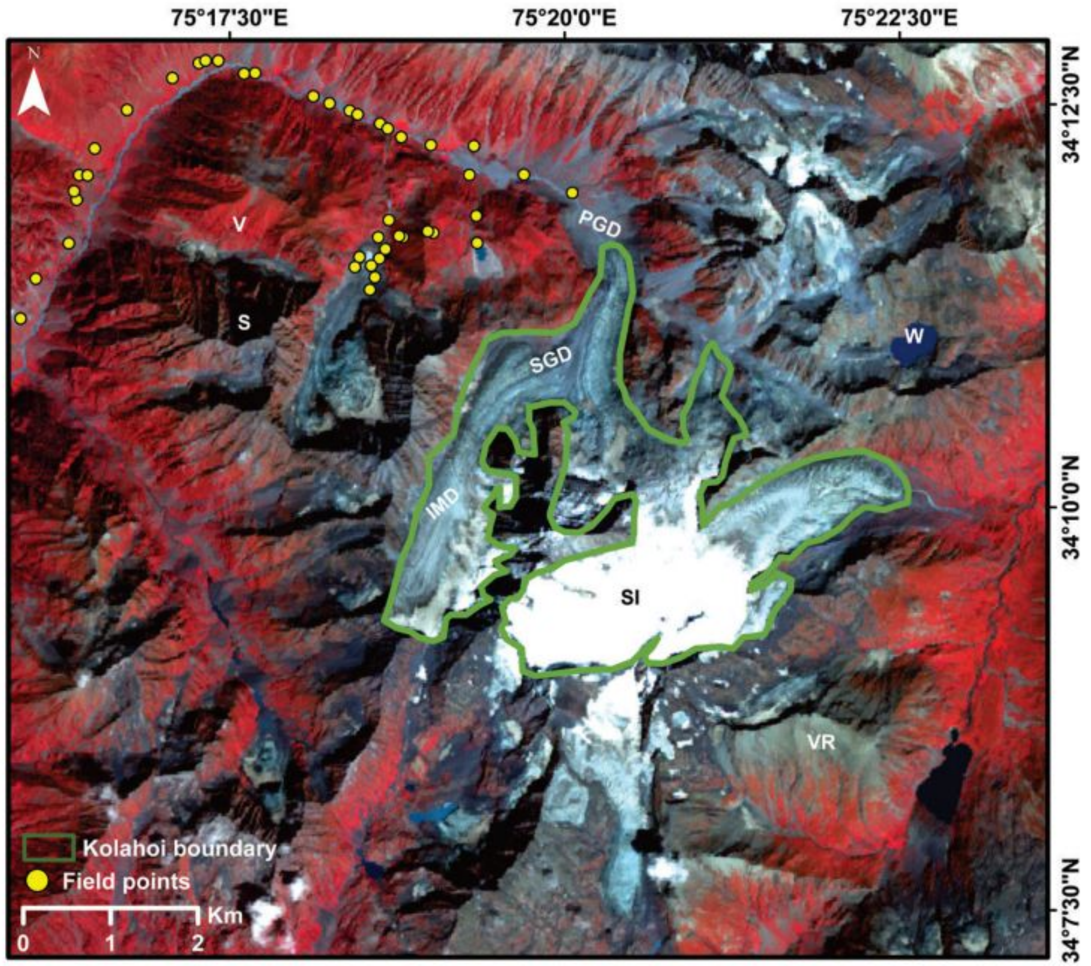




Spectral index	Source	Formulation	Utility
Normalized-difference snow index (NDSI)	Dozier (1989)	$NDSI = \frac{Green_{(ast\_b1)} - SWIR_{(ast\_b5)}}{Green_{(ast\_b1)} + SWIR_{(ast\_b5)}}$	Mapping and differentiating between snow-ice covered areas and non-snow-and-ice areas
Normalized-difference debris index (NDDI)	This study	$NDDI = \frac{SWIR_{(ast\_b6)} - -TIR_{(ast\_b14)}}{SWIR_{(ast\_b6)} + TIR_{(ast\_b14)}}$	Mapping and differentiating between supra-glacial debris and that of the terrain
Normalized-difference water index (NDWI)	McFeeters (1996)	$NDWI = \frac{Green_{(ast\_b1)} - -NIR_{(ast\_b3)}}{Green_{(ast\_b1)} + NIR_{(ast\_b3)}}$	Mapping surface water
Normalized-difference glacier index (NDGI)	Keshri and others (2009)	$NDGI = \frac{Green_{(ast\_b1)} - -Red_{(ast\_b2)}}{Green_{(ast\_b1)} + Red_{(ast\_b2)}}$	Mapping and differentiating between snow-ice and ice-mixed debris class

Remote Sensing – Spectral Indices – Applications

- Shukla and Ali, 2016



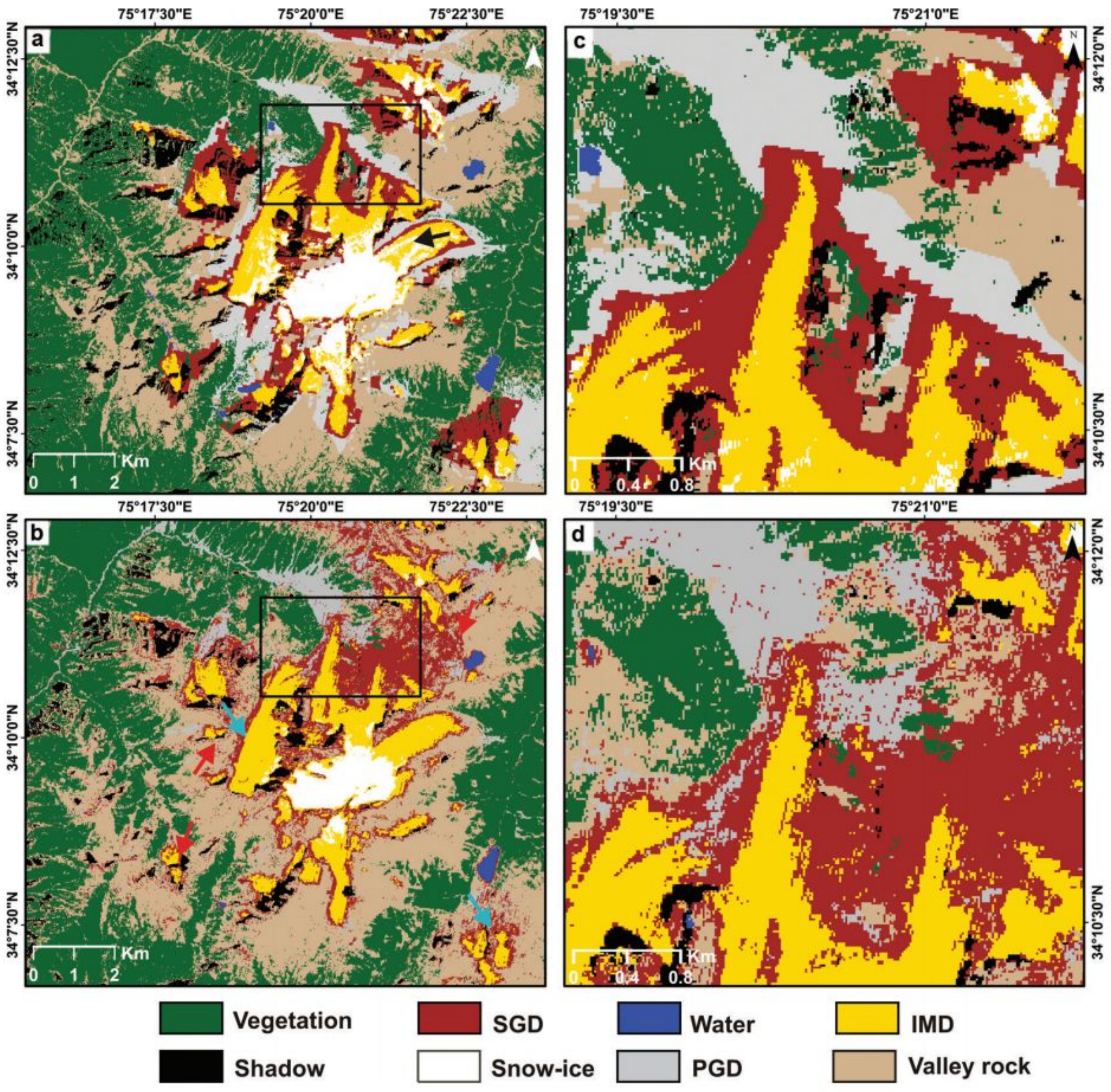


Fig. 6. Comparison of the glacier terrain mapping from the proposed HKBC and supervised classification (MLC). (a) Final map obtained from HKBC scheme; (b) map obtained from MLC. The rectangles in (a) and (b) are enlarged in (c) and (d) respectively. SGD: supraglacial debris; IMD: ice-mixed debris; PGD: periglacial debris.

Remote Sensing Applications

False color composites:
[Ice Could Crumble from Planpincieux Glacier]
[Flooding Along the Arkansas River]

NDVI:
[Tracking Deer Habitat by Satellite]
[Sap-sucking Bugs Threaten Hemlock Forests]

True/natural color image and NDVI:
[A Ring of Green Around Surgut]

Questions?

- Before we play with our own imagery...

Dr. Ashley York (yorka@rowan.edu)
Department of Geography, Planning and Sustainability

Notes for me

USGS Earth Explorer

yorka89

Glacier National Park

LC08_CU_008002_20210924_20211004_02_SR_

RGB = 4 3 2 true color

False Color Composites

RGB = 5 6 3 false color for ice

Greater Philadelphia Region

LC08_CU_028008_20210927_20211004_02_ST_B10

Rescaling Temperature Data

0.00341802 (band10) + 149.0

-273.15 K to C

Dixie Fire California

LC08_CU_003007_20210913_20210928_02_SR_

Normalized Difference Burn Index

Landsat 8, NBR = (Band 5 – Band 7) / (Band 5 + Band 7)

NDVI

Landsat 8, NDVI = (Band 5 – Band 4) / (Band 5 + Band 4)