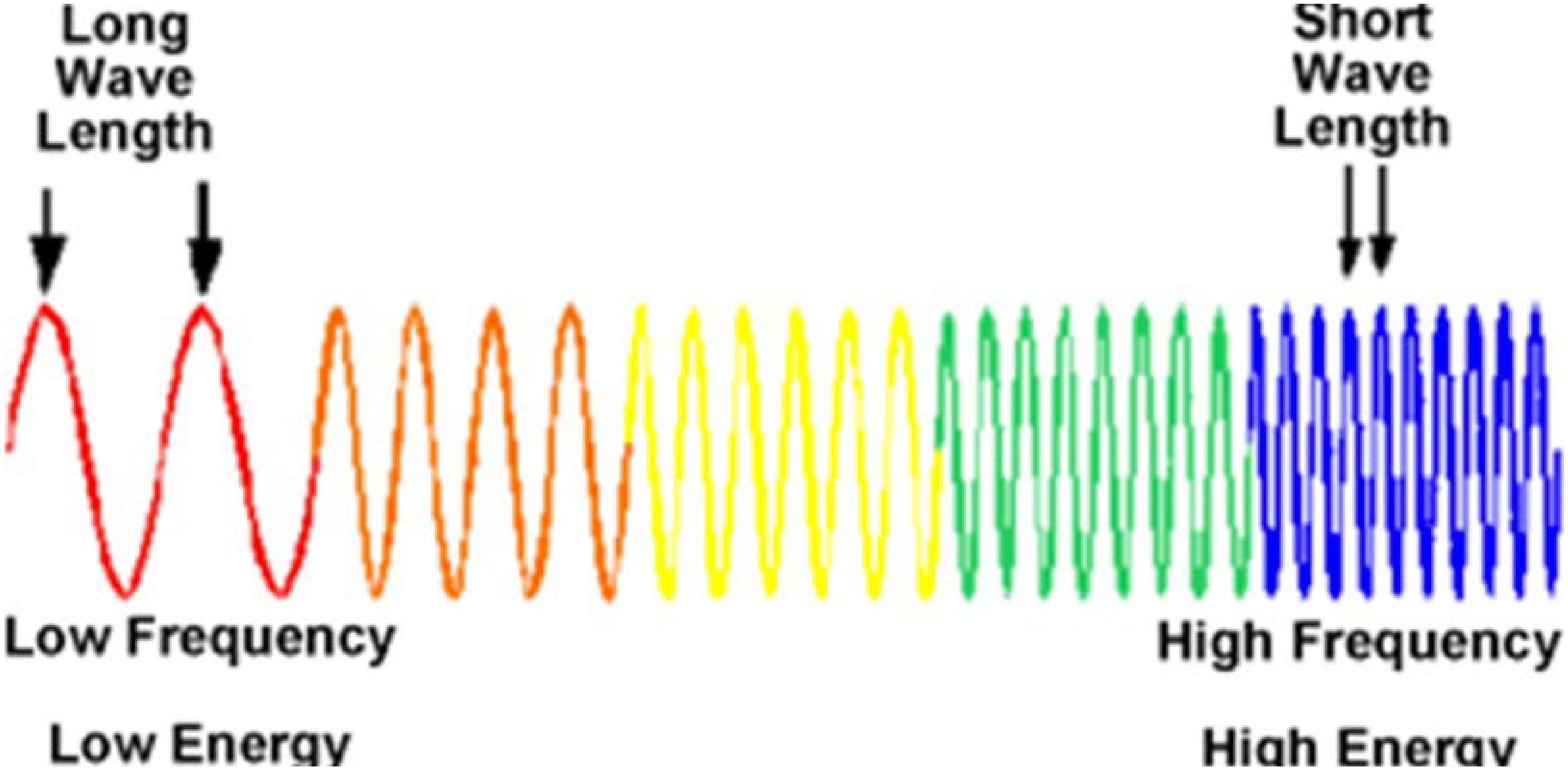
ESS 474 Remote Sensing Lab

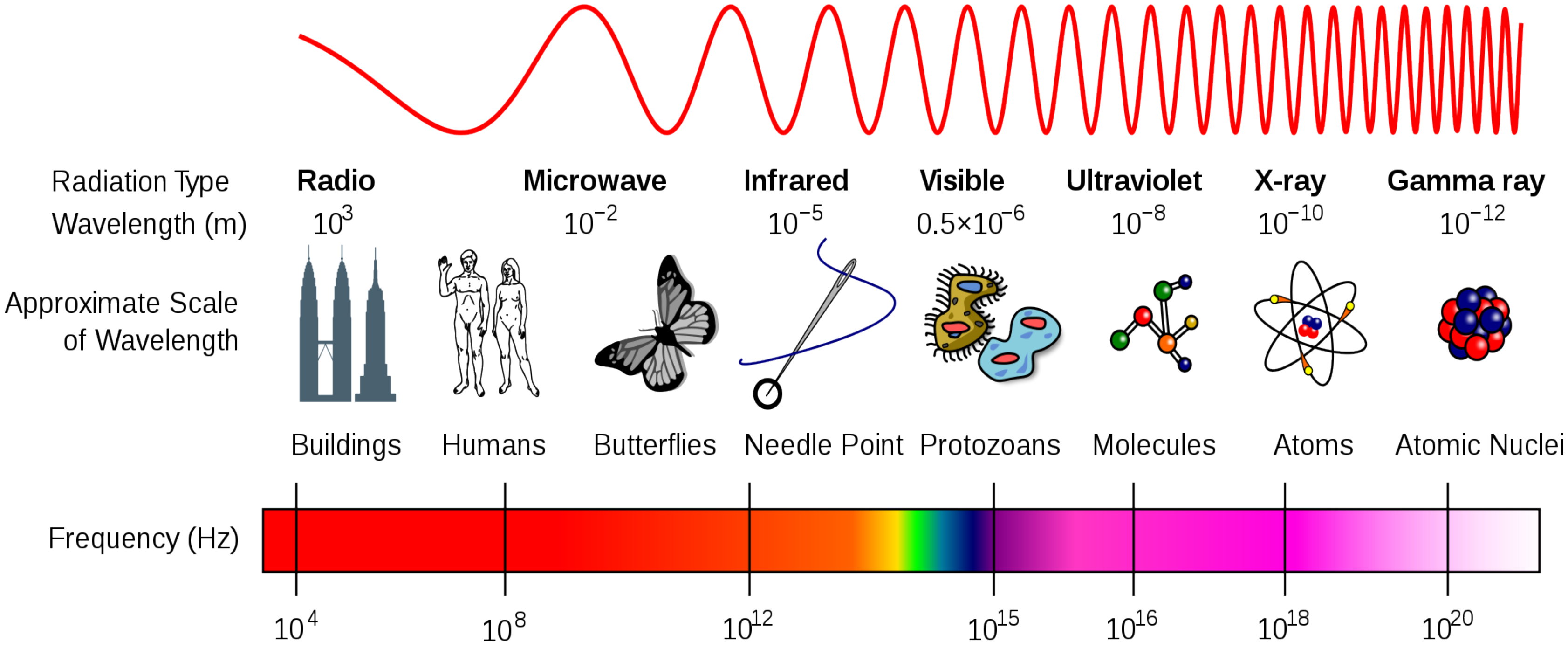
October 11, 2024

Plan for today

- Questions about recent lab assignments?
- Remote sensing lecture
- Google Earth Engine Lab

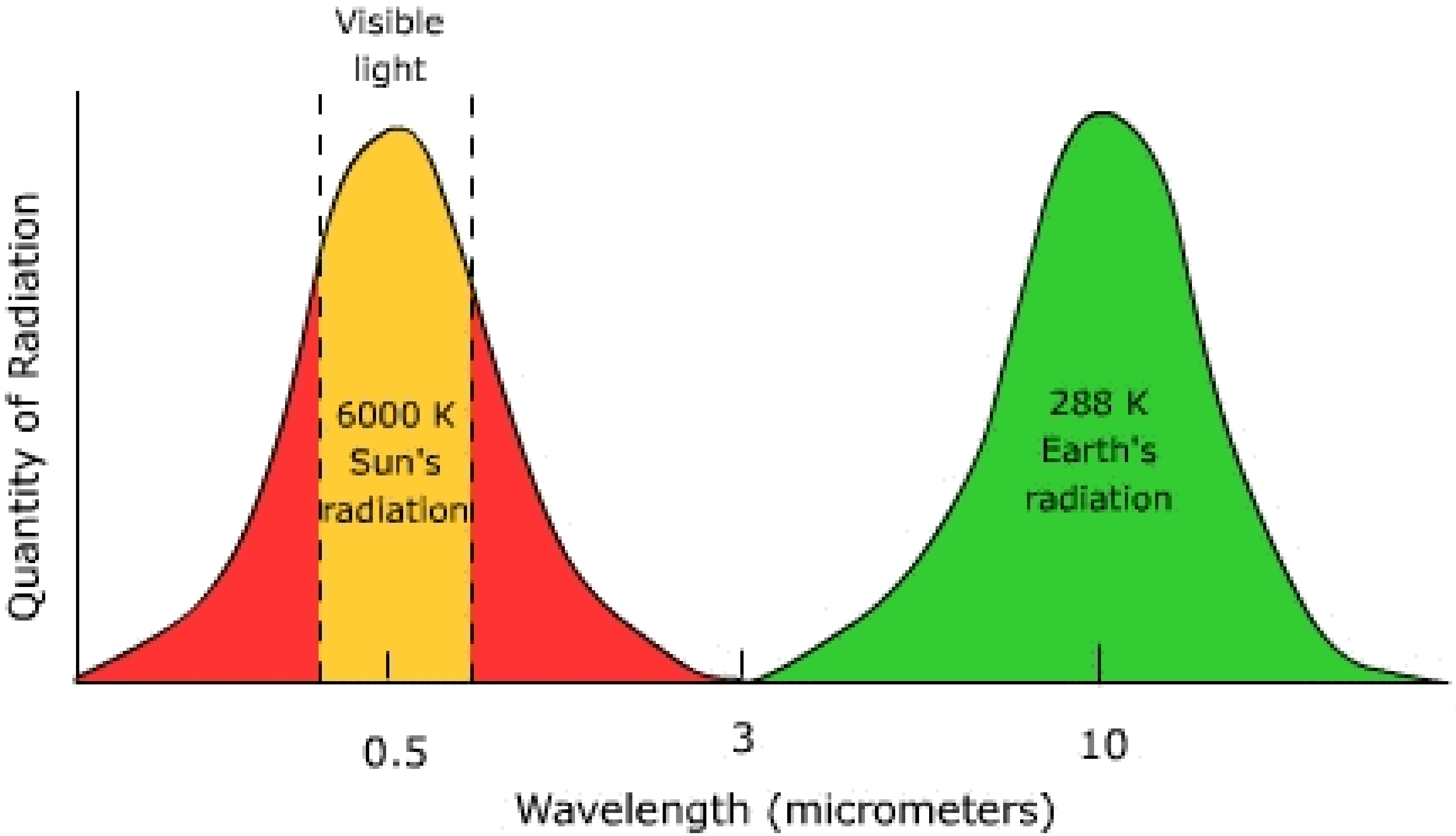

Long
Wave
Length
Short
Wave
Length
Low Frequency
High Frequency
Low Energy
High Energy

Major divisions of the EM spectrum



Source: [*http://en.wikipedia.org/wiki/Electromagnetic_spectrum*](http://en.wikipedia.org/wiki/Electromagnetic_spectrum)

Comparison of Solar and Earth Radiation Spectra

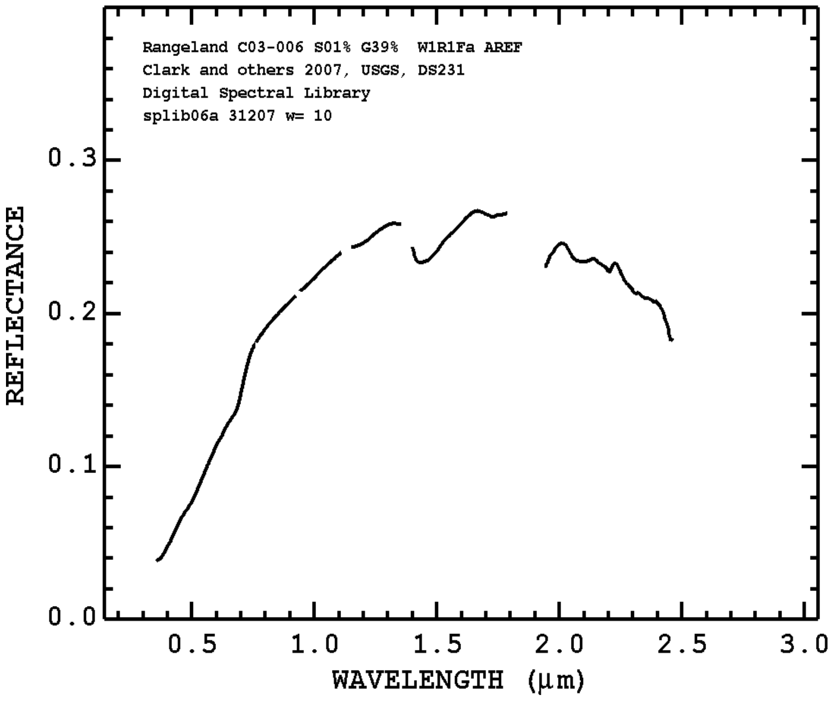


Spectral Signatures

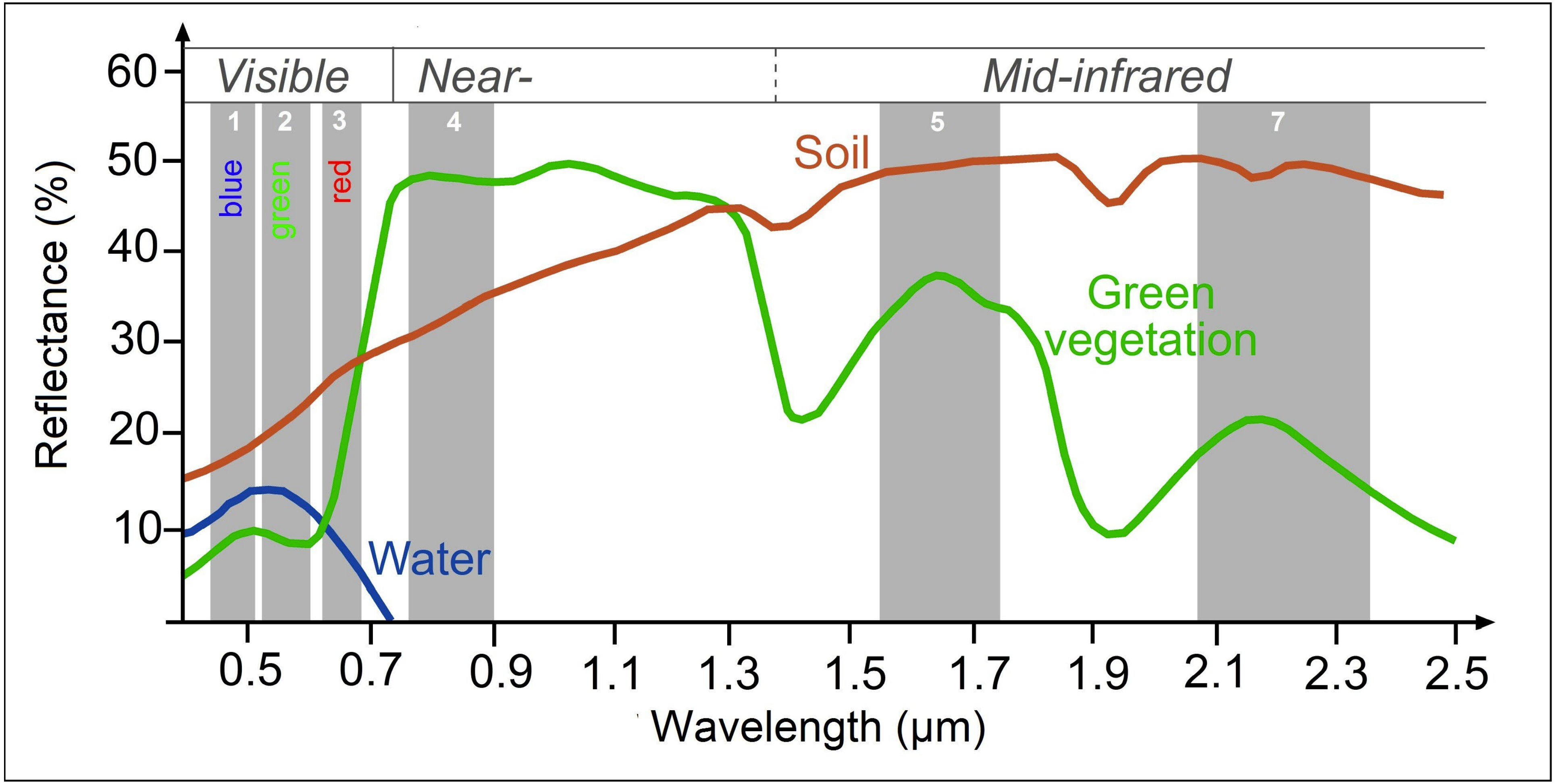
$\boldsymbol{p(\lambda) =}$

$\boldsymbol{R_R(\lambda) / R_I(\lambda)}$

A **spectral signature** of a surface is the relationship between the reflectance ***p(λ)*** and the wavelength ***λ***.

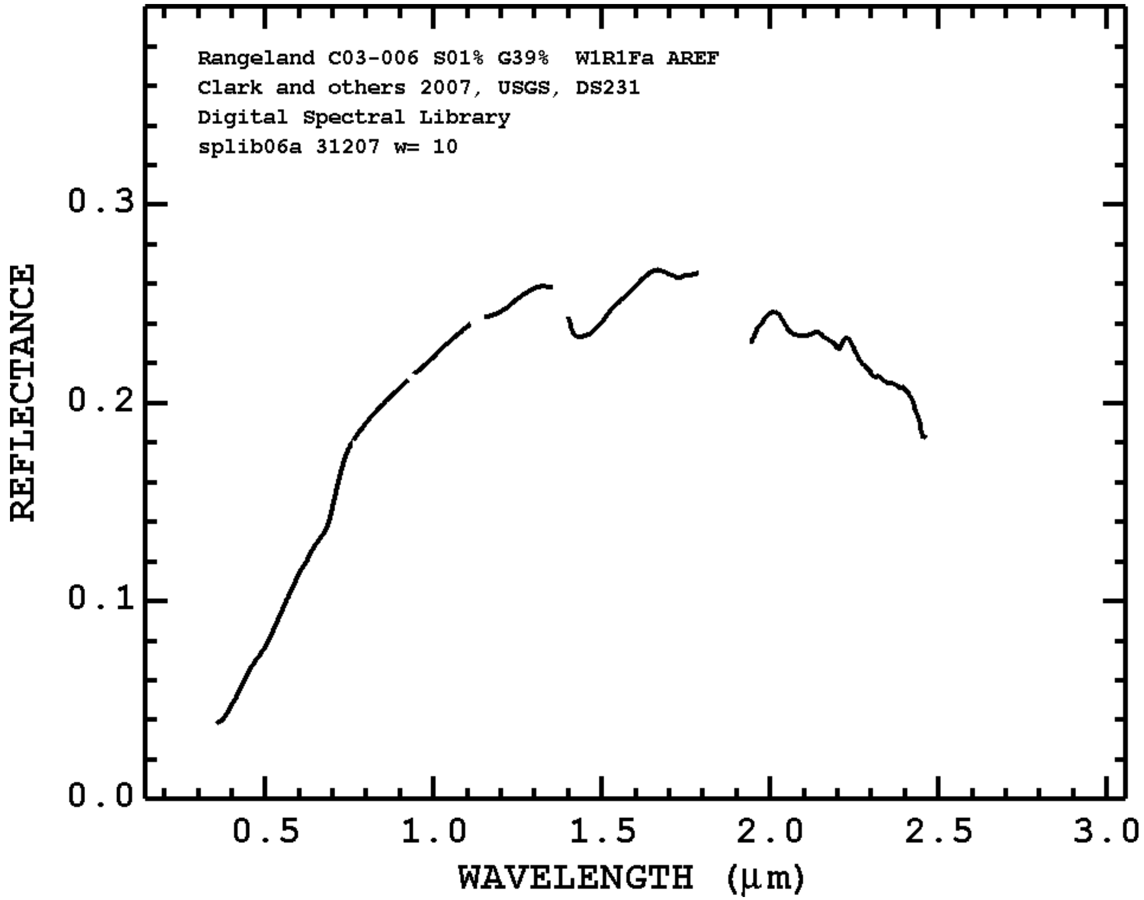


Spectral bands



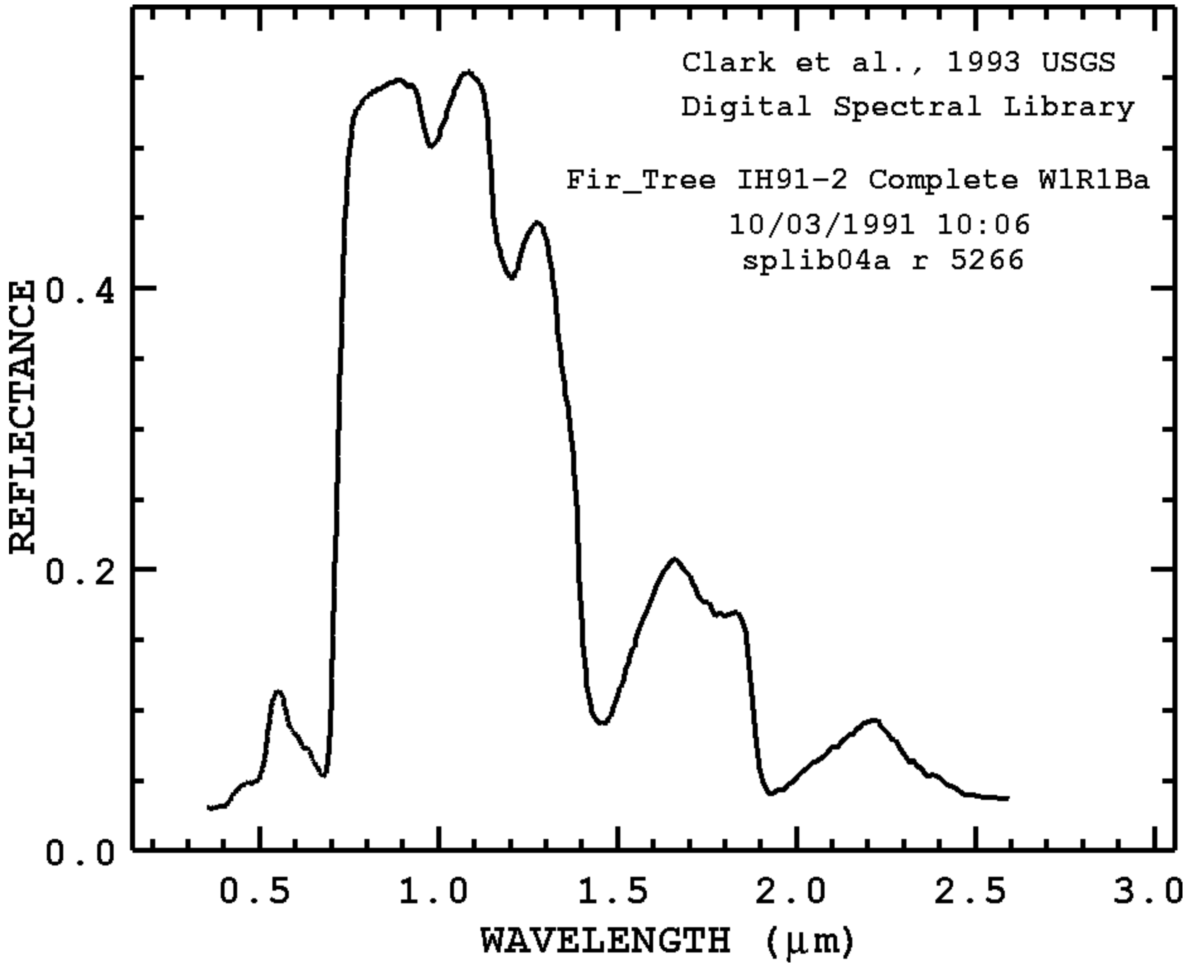
http://www.seos-project.eu/

Reflectance Spectrum



Source: http://speclab.cr.usgs.gov/spectral.lib04/spectral-lib.desc+plots.html

Reflectance Spectrum



Source: http://speclab.cr.usgs.gov/spectral.lib04/spectral-lib.desc+plots.html

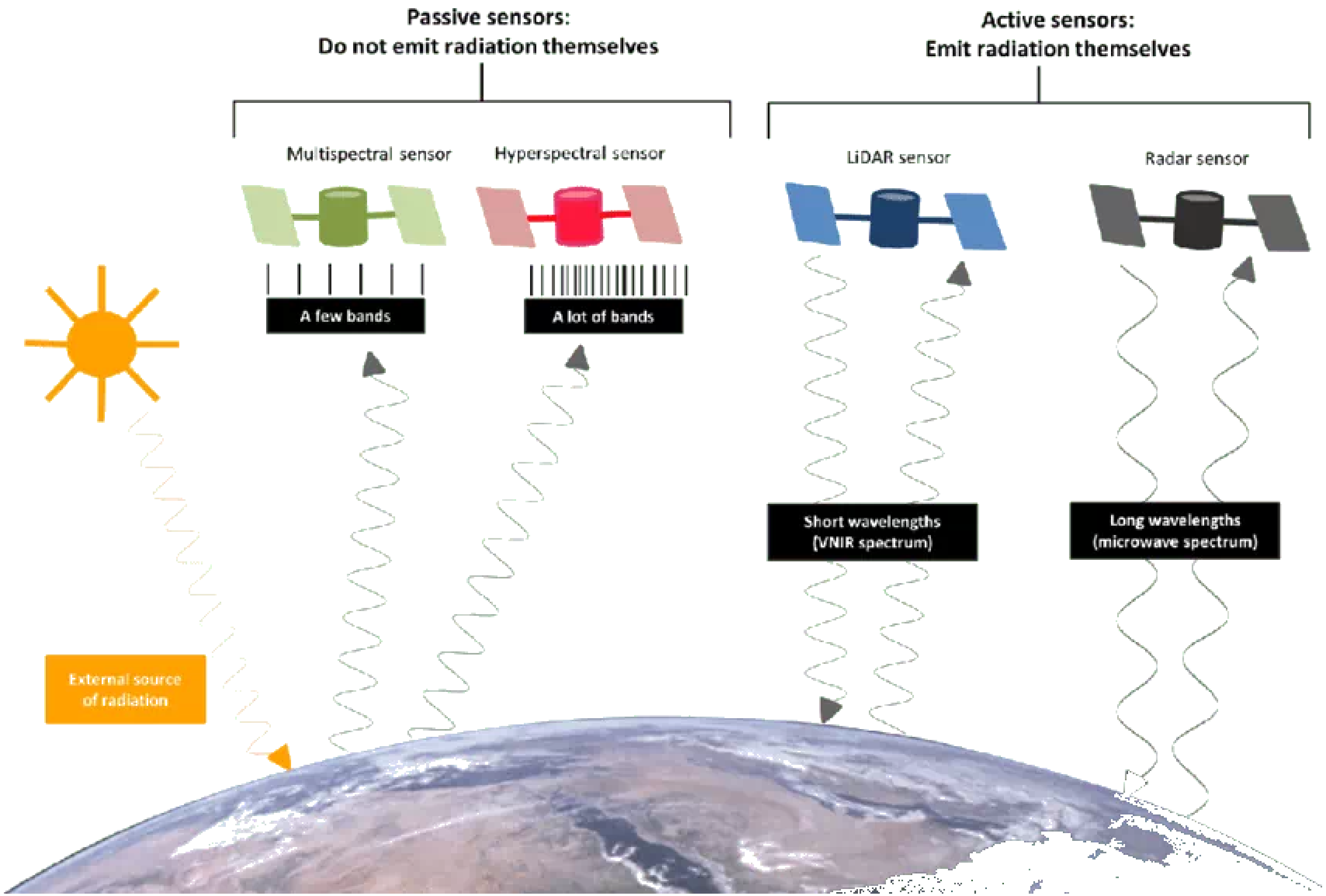
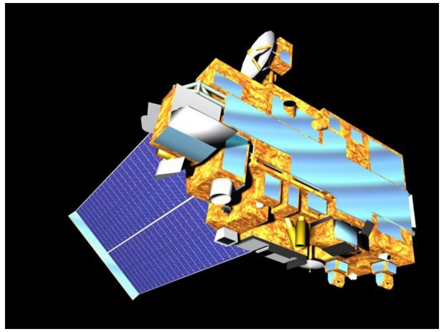
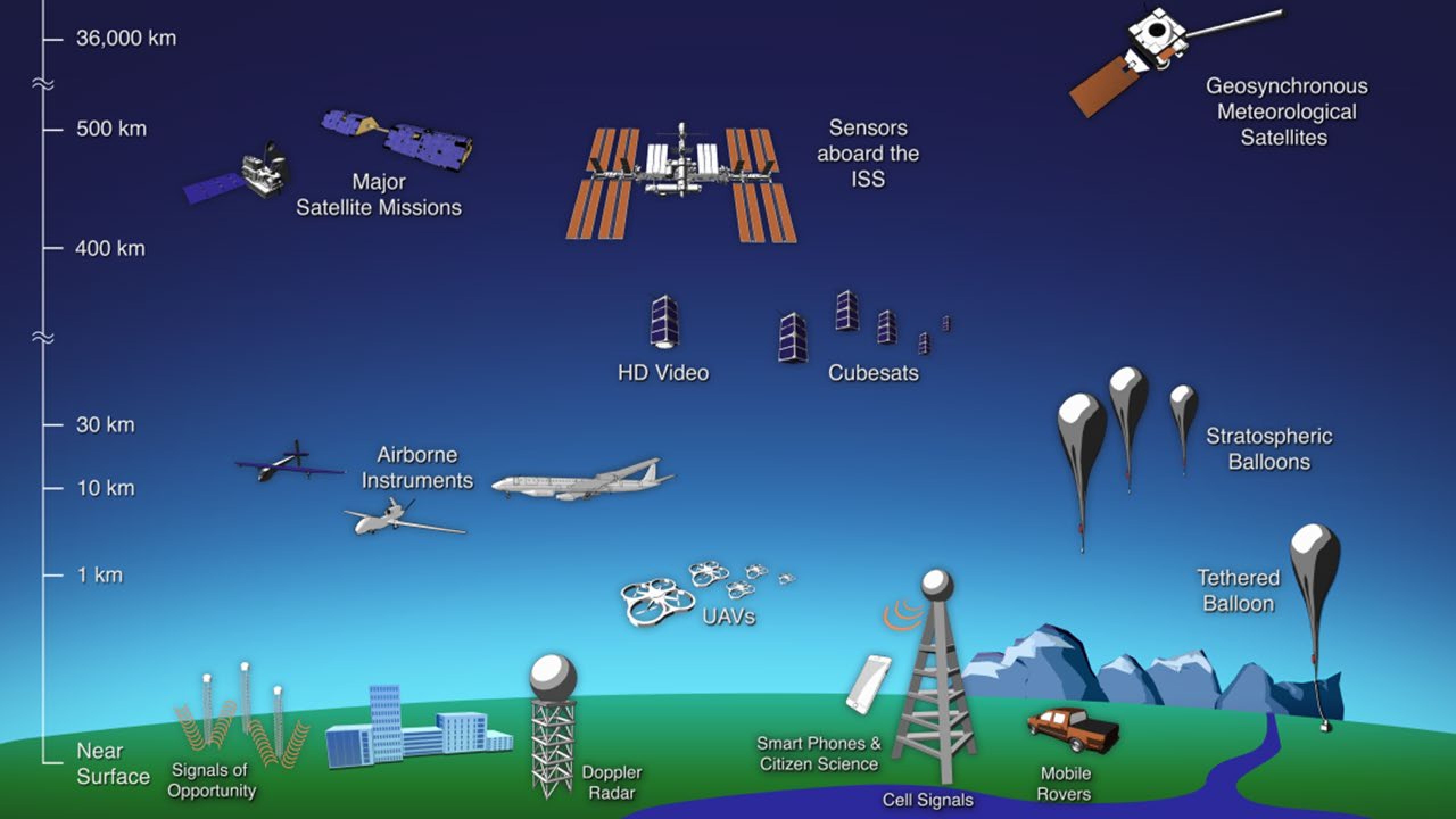


Image credit: One-StopGIS

Platforms

The **platform** is what a sensor is mounted on:



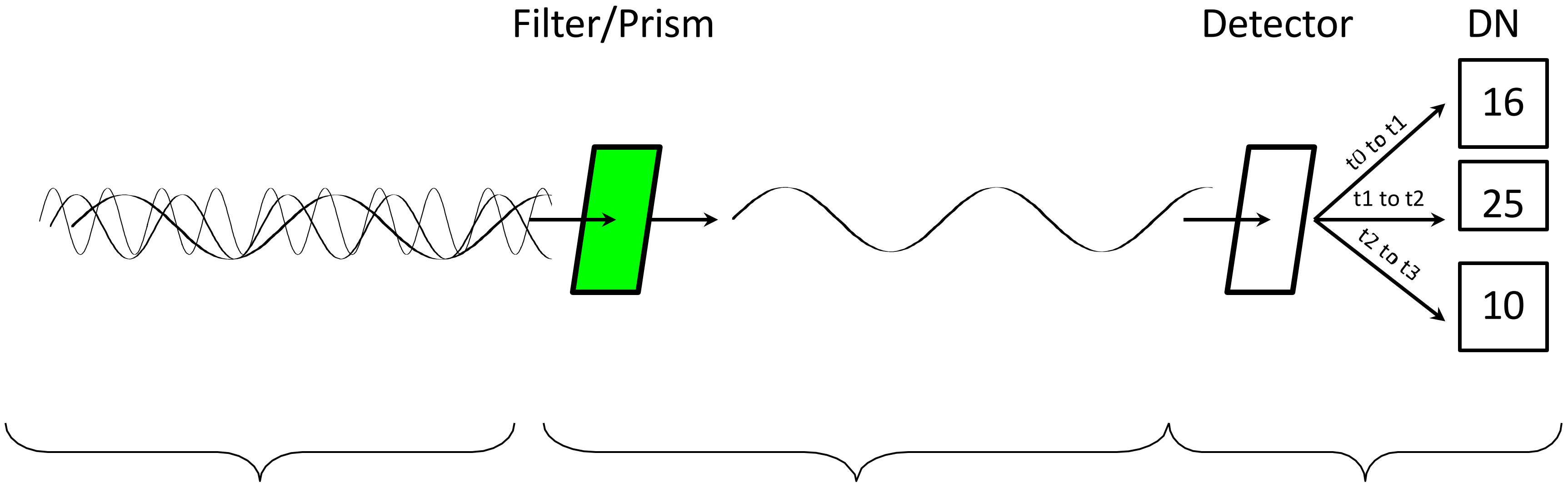

36,000 km
500 km
400 km
30 km
10 km
1 km
Near Surface
Geosynchronous Meteorological Satellites
Major Satellite Missions
Sensors aboard the ISS
HD Video
Cubesats
Stratospheric Balloons
Airborne Instruments
UAVs
Tethered Balloon
Signals of Opportunity
Doppler Radar
Smart Phones & Citizen Science
Cell Signals
Mobile Rovers

Passive vs. Active Sensors

Passive sensors detect and record EMR reflected or emitted from an **external source** (the sun or the Earth).

Active sensors detect and record EMR **emitted from the sensor itself**.

Building a Sensor: Detectors



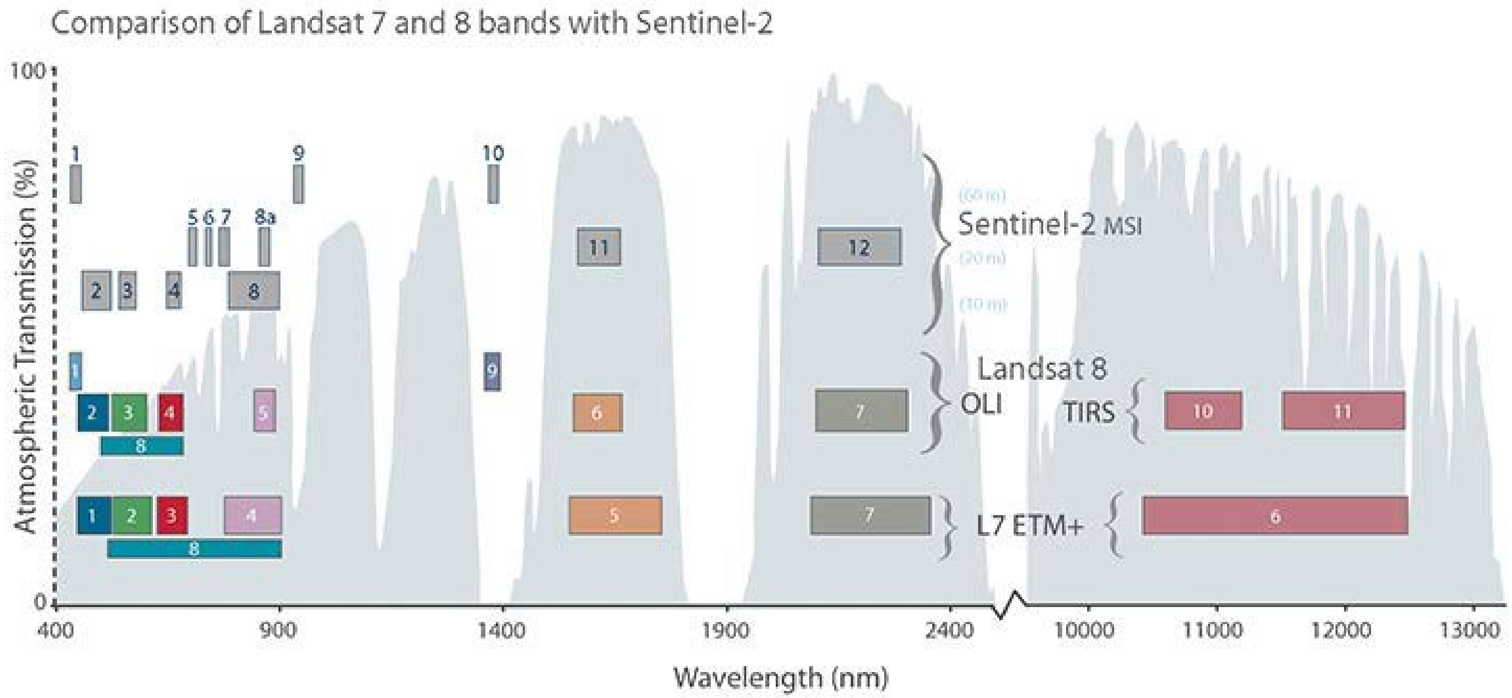
Light

A subset of wavelengths is allowed to pass to the detector. This subset is referred to as a **spectral band**.

Light generates a voltage when it hits the sensor plate. The voltage is sampled for a discrete amount of time (Mt), and is "quantized" and recorded as a **digital number** (DN).

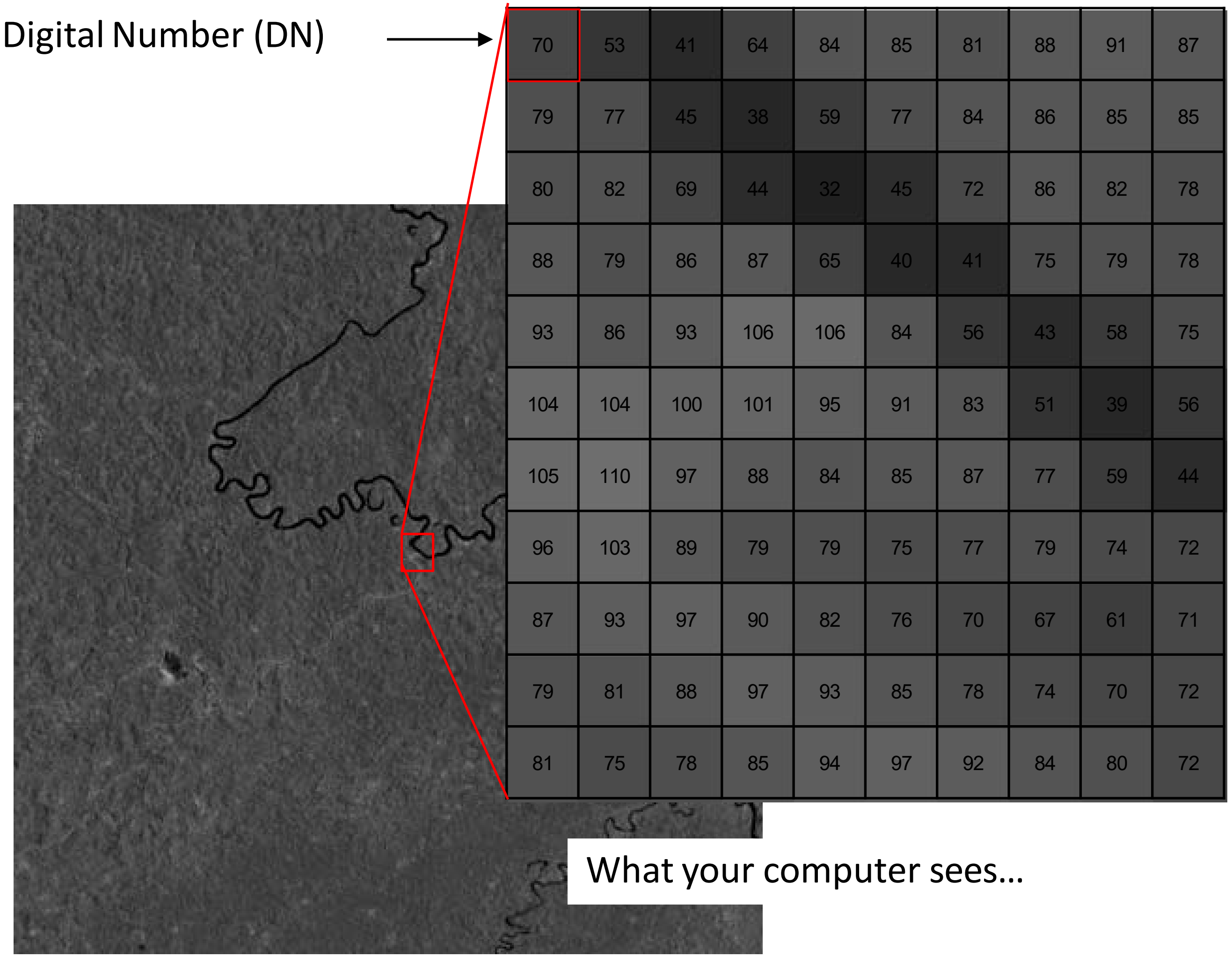
Important: the detector has a set field of view, and therefore measures **RADIANCE**.

Example: Landsat 8 vs Sentinel-2



What Is A Digital Image?

Digital Number (DN)



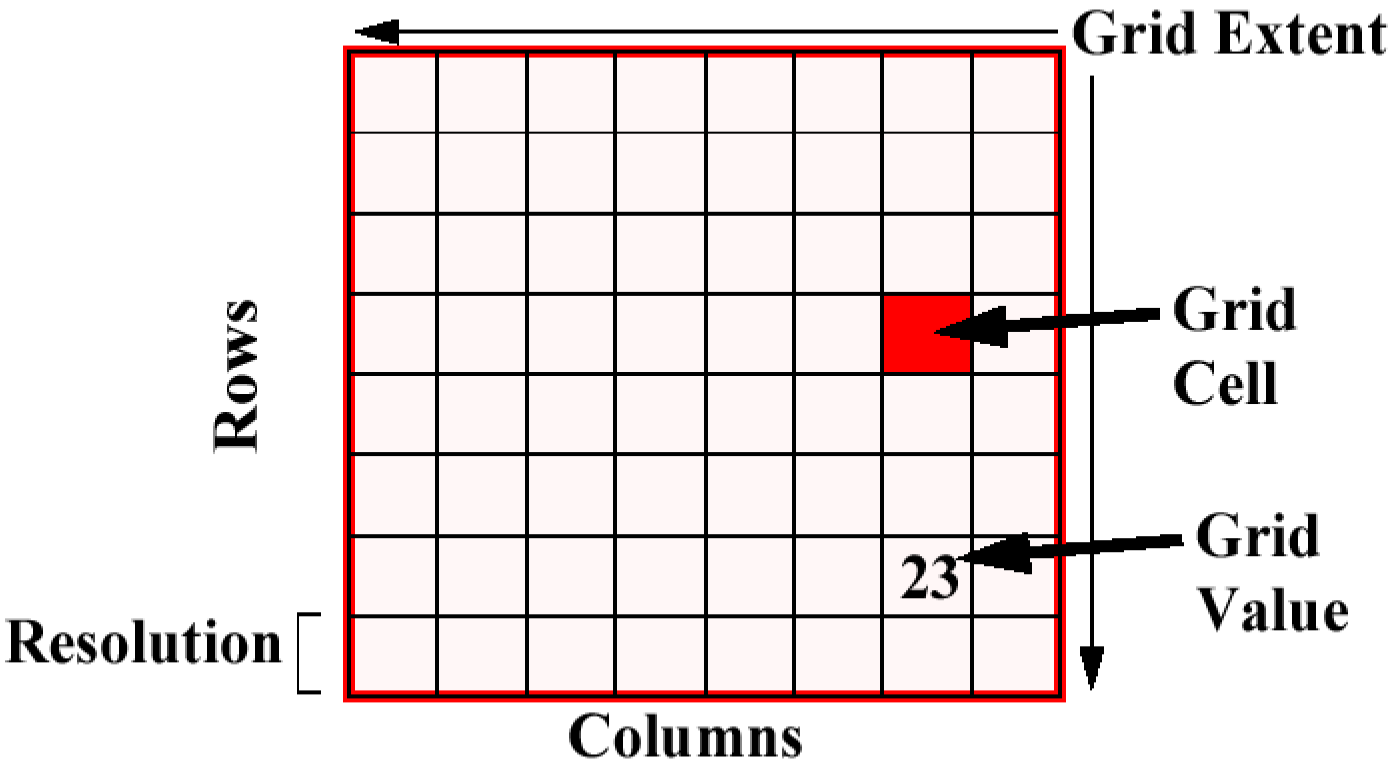
What your computer sees…

Digital numbers (DNs) typically range from 0 to 255; 0 to 511; 0 to 1023, etc. These ranges are binary scales: $2^8=256$; $2^9=512$; $2^{10}=1024$.

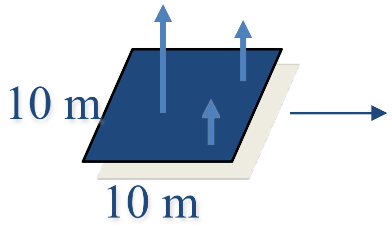
Images

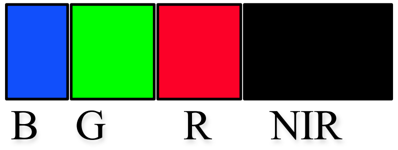
- **Rectangular**
  - fixed number of columns and rows
- Can have multiple **bands** to add a third dimension
  - Sometimes called “layers”
- **Pixel** – building block of an image
  - aka “cell”
- Each pixel represents an **area** on the Earth’s surface
- Each pixel holds **one** numerical attribute per band
  - Typically **brightness** of that pixel as measured by the sensor
- Every pixel in the image has a value, even if the value is “missing”

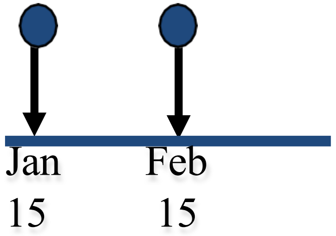
Structure of a 2-D Image (Grid)



Properties of measurement **Remote Sensor Resolution**







2^n

$n = 2, 4, 8, 16, 32, 64, 128, 256$, etc.

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

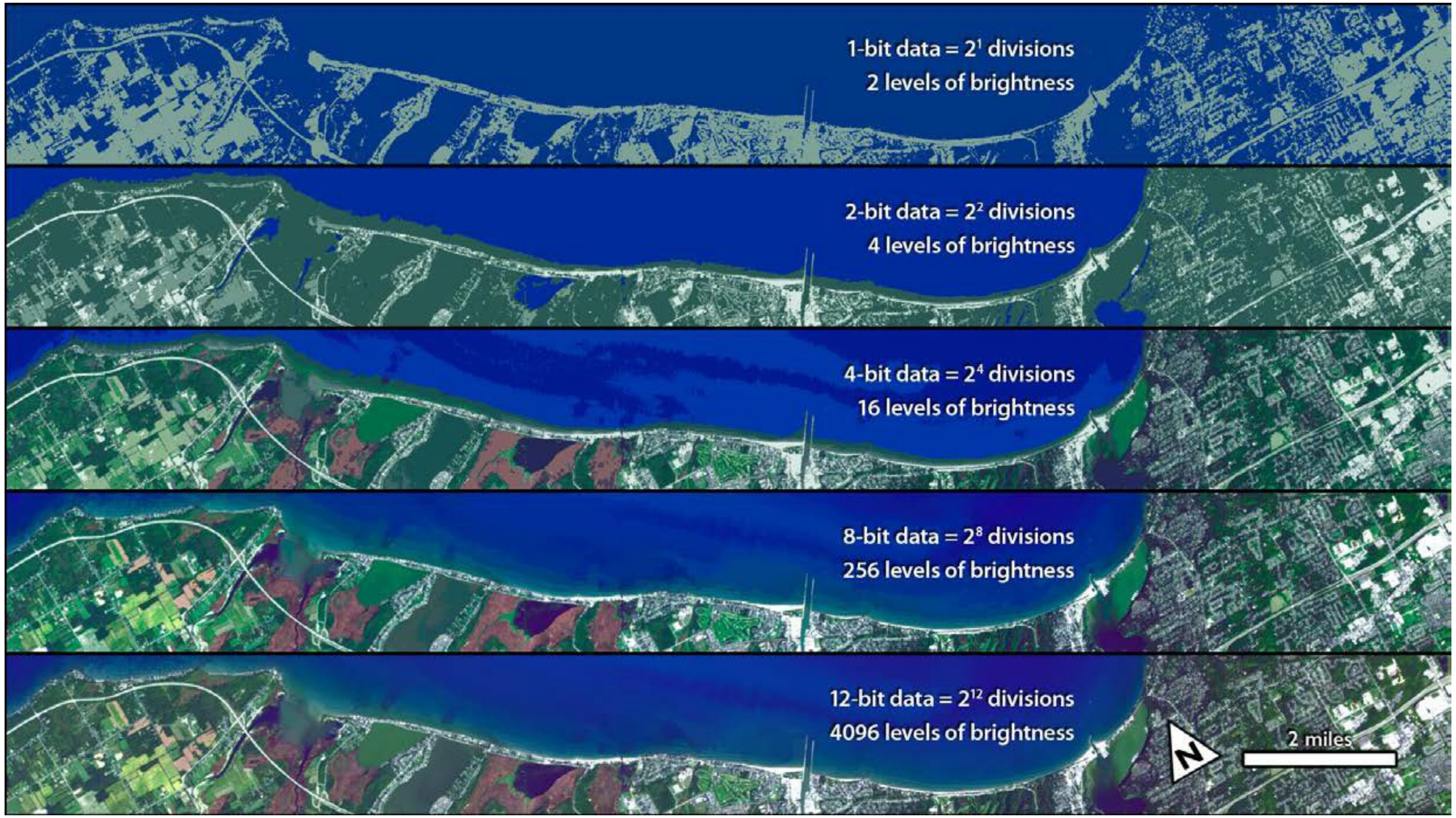
- **Spectral** - the number and size of spectral regions the sensor records data in, e.g. blue, green, red, near-infrared, thermal infrared, and microwave (radar).

- **Temporal** - how often the sensor acquires data, e.g. every 30 days.

- **Radiometric** - the sensitivity of detectors to small differences in electromagnetic energy.

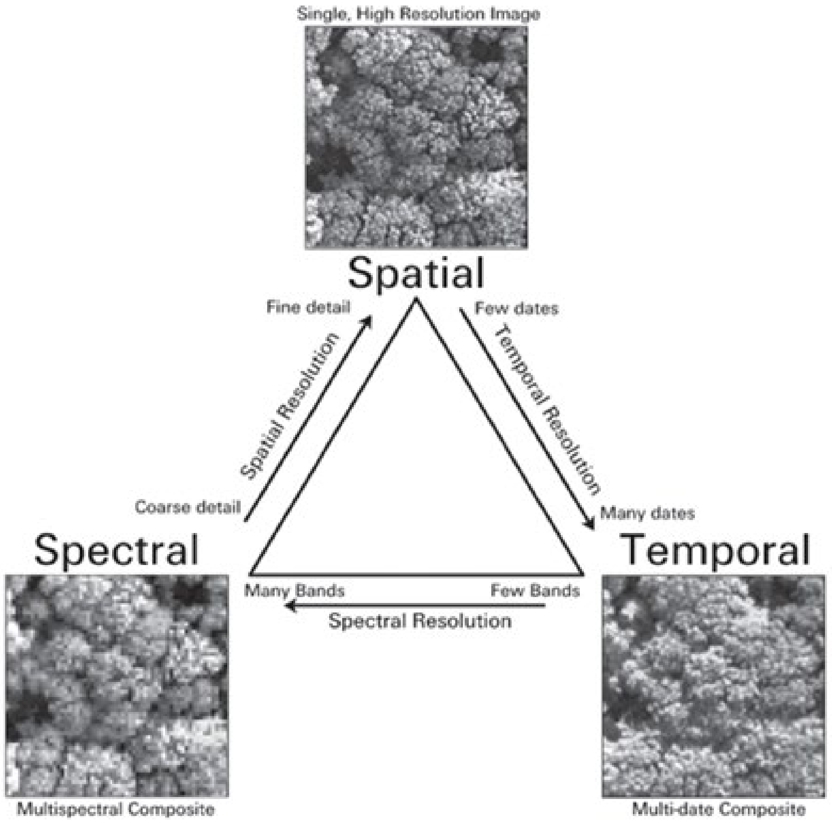
Jensen, 2007

Landsat 8 Bit Depth



Landsat 8 12-bit depth improves how we view coastal waters

Trade-offs in remote sensing resolution



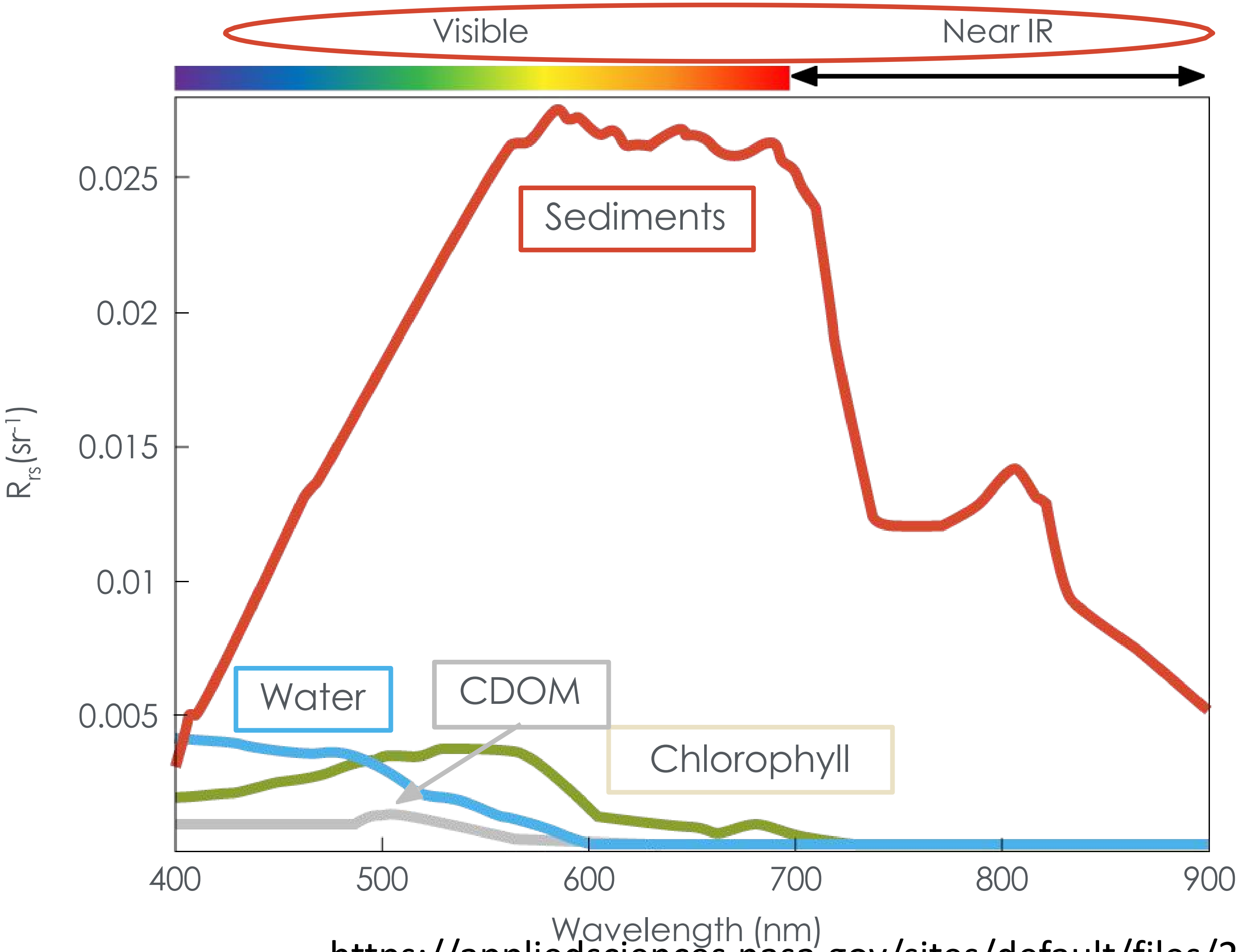
Remote Sensing and Limnology

True-Color image,
September 24, 2017 (MODIS)

Inherent Optical Properties (IOPs) and the ‘Color’ of Water

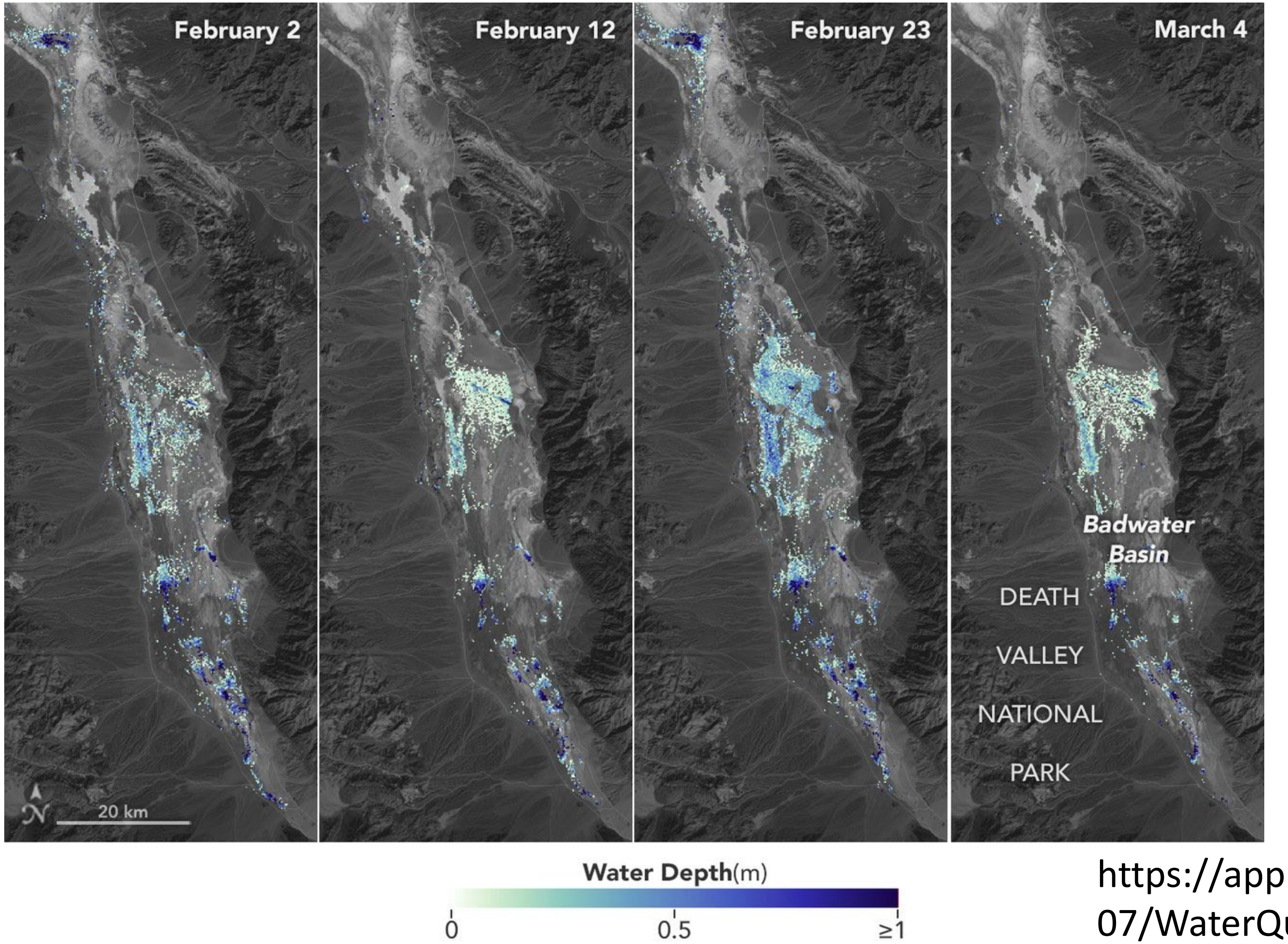
Inherent Optical Properties:

- Absorption by…
  - Phytoplankton (ph)
  - Non-Algal Particles (nap)
  - Colored Dissolved Organic Matter (CDOM)
  - Water (w)
- Scattering in forward (f) and backward (b) directions



https://appliedsciences.nasa.gov/sites/default/files/2023-07/WaterQuality_Part1_Final_0.pdf

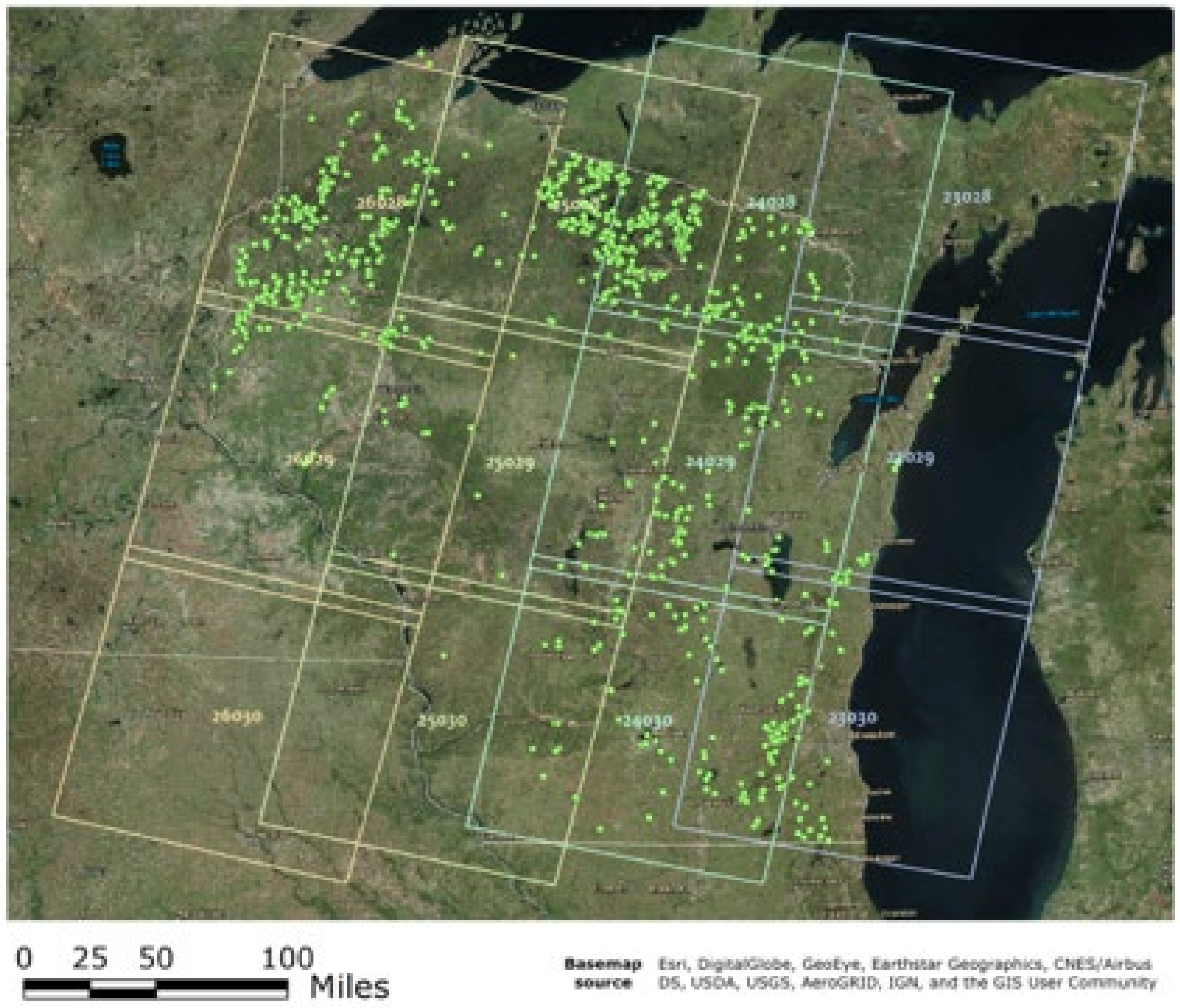
Remote Sensing and Limnology



SWOT Satellite measures depth and extent of surface water in a temporary lake in Death Valley, California

https://appliedsciences.nasa.gov/sites/default/files/2023-07/WaterQuality_Part1_Final_0.pdf

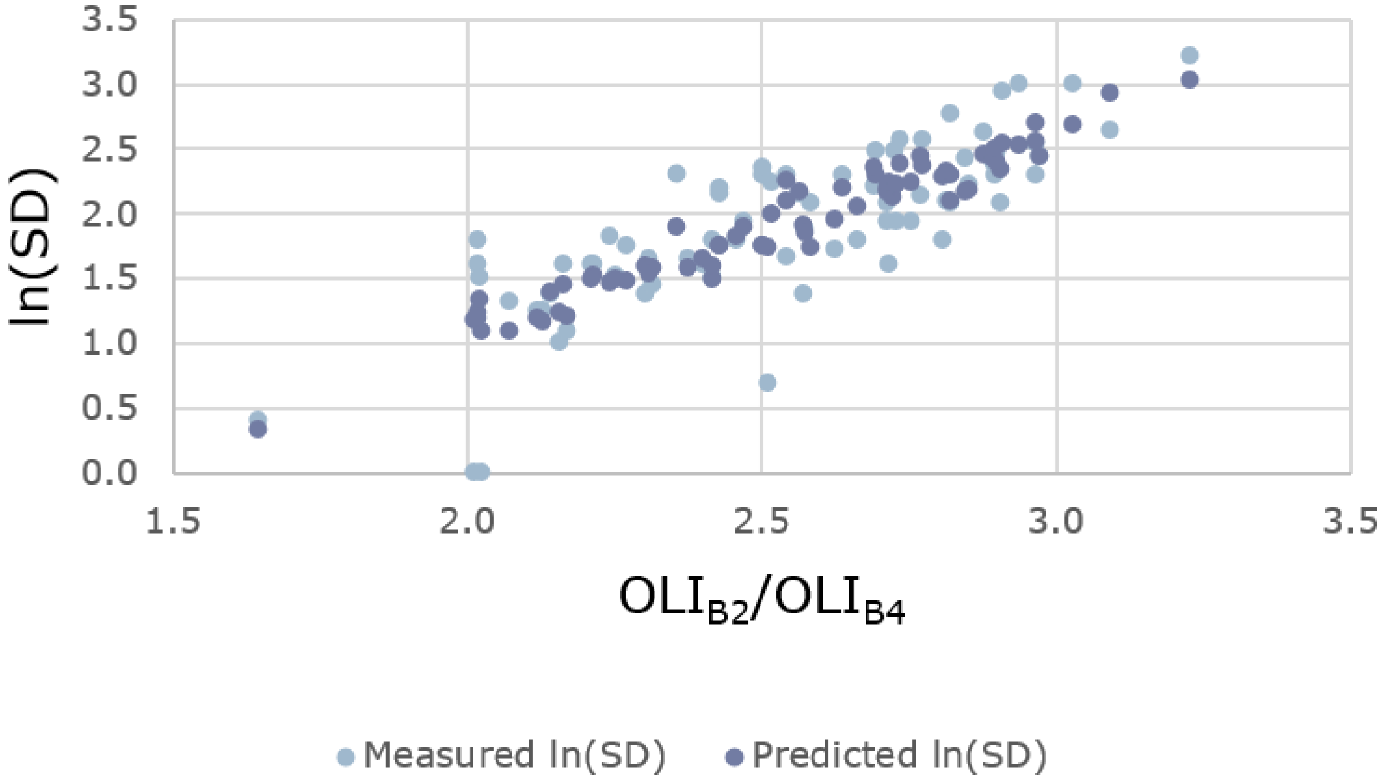
Model Calibration and Ground-truthing



Distribution of stations with on-the-ground Secchi depth data collected in 2016 shown for the paths and rows of the Landsat Worldwide Reference System 2 in Wisconsin.

https://dnr.wisconsin.gov/topic/lakes/clmn/remotesensing/research.html

Model Calibration and Ground-truthing



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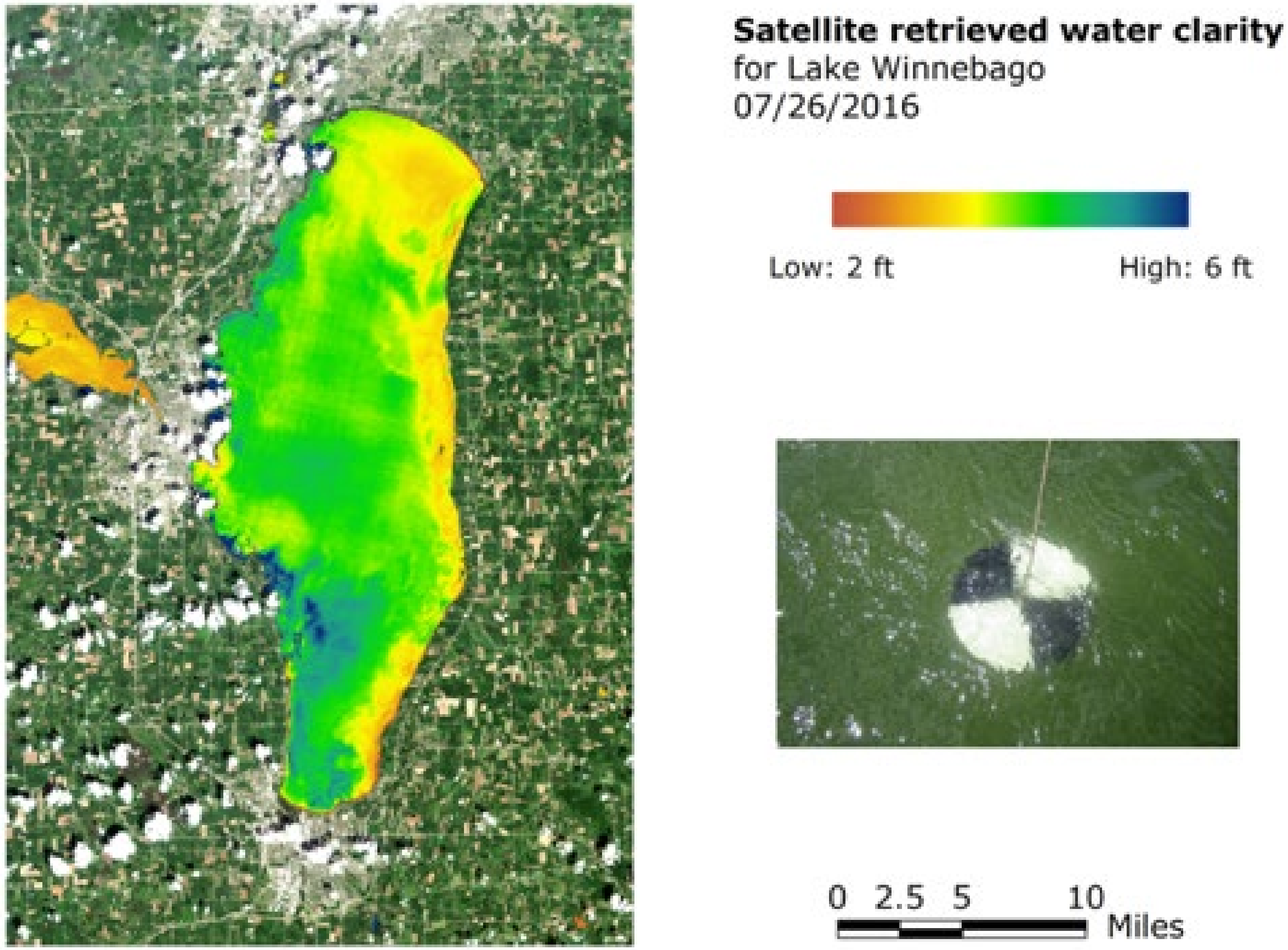
$$\ln(\mathrm{SD}) = a + b \times \frac{\mathrm{OLI}_{B2}}{\mathrm{OLI}_{B4}} + c \times \mathrm{OLI}_{B2}$$

Model Calibration and Ground-truthing



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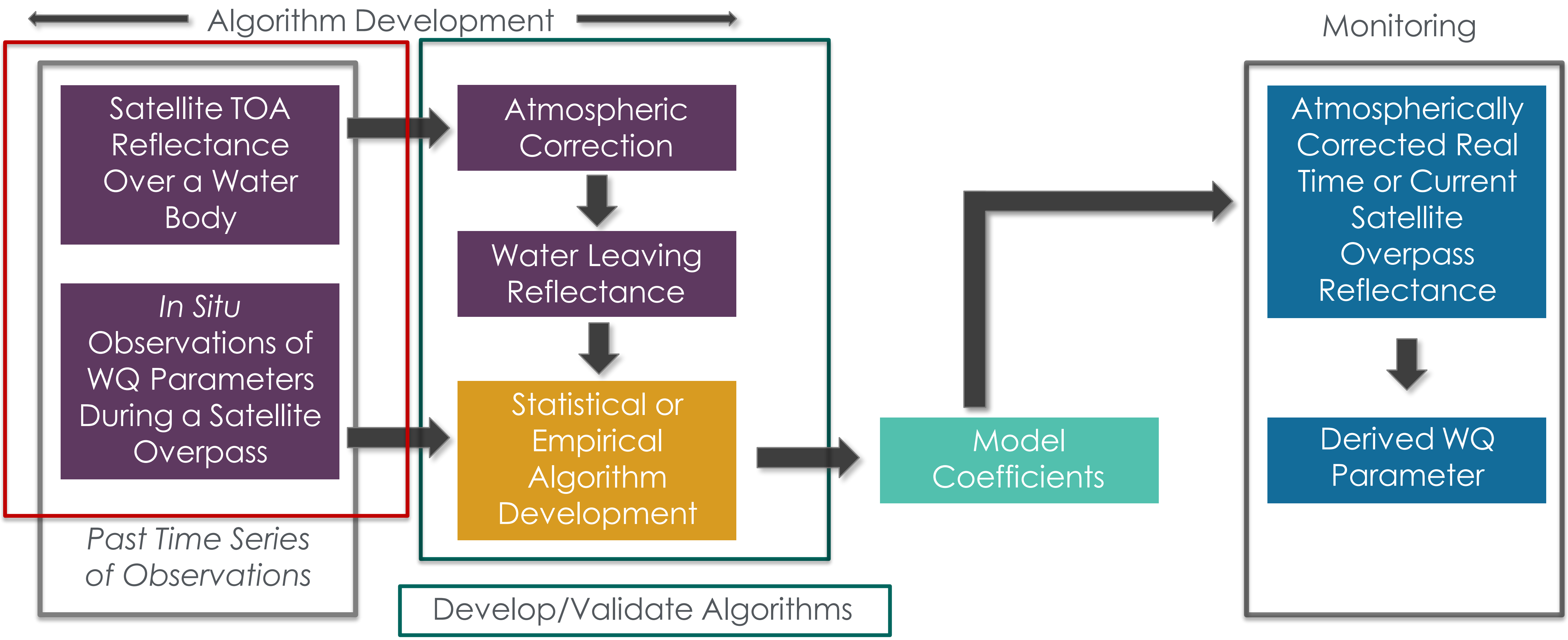
Quantitative Technique



https://appliedsciences.nasa.gov/sites/default/files/2023-07/WaterQuality_Part1_Final_0.pdf

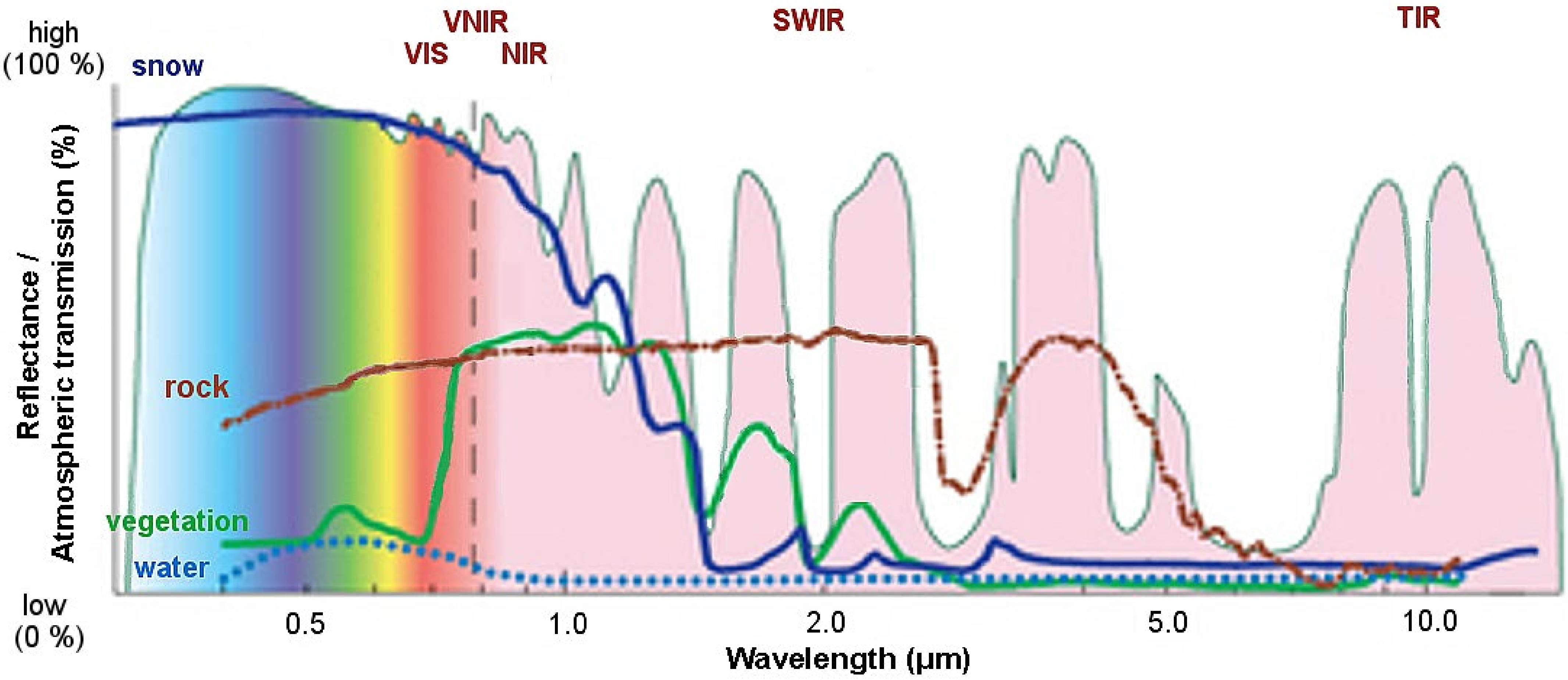
Spectral Indices

Two general forms, which are typically used when B1 and B2 have inversely related responses to the same biophysical phenomenon

Simple ratio = B1/B2

Normalized difference ratio = (B1-B2)/(B1+B2)

Spectral bands



Chlorophyll strongly absorbs light at wavelengths around 0.45 (blue) and 0.67 µm (red) and reflects strongly in green light, therefore our eyes perceive healthy vegetation as green. Healthy plants have a high reflectance in the near-infrared between 0.7 and 1.3 µm.

http://www.seos-project.eu/

Vegetation Indices

Vegetation indices typically leverage the (typically) inverse relationship between visible light and NIR light as vegetation chlorophyll varies, for instance:

Simple vegetation index = Red/NIR

Normalized difference vegetation index (NDVI) = (NIR-Red)/(NIR+Red)

NDVI

- Does not depend on absolute RED and NIR values
- Fixed, easy to understand bounds
  - -1.0 = *very low greenness*
  - +1.0=*very high greenness*
    - NDVI = 0.65-0.80 = vigorous vegetation
    - NDVI = 0.0-0.30 = stressed/senescent vegetation

http://tbrs.arizona.edu/project/MODIS/evi.php.

Google Earth Engine Tutorial

If this is super interesting to you and you want to dive in further…. Here is a tutorial.

https://ecology.colostate.edu/google-earth-engine/

We will just be scratching the surface today.

Step 1: Getting started with Google Earth Engine

1. Sign up or log in to GEE
   https://earthengine.google.com/

2. Create an empty code block

3. Explore Earth Engine Data Catalog
   https://developers.google.com/earth-engine/datasets/

4. Try some example code (*note: GEE is written in Java*)