2021 ML4EO Bootcamp

Lecture 1: Introduction to Earth Observations

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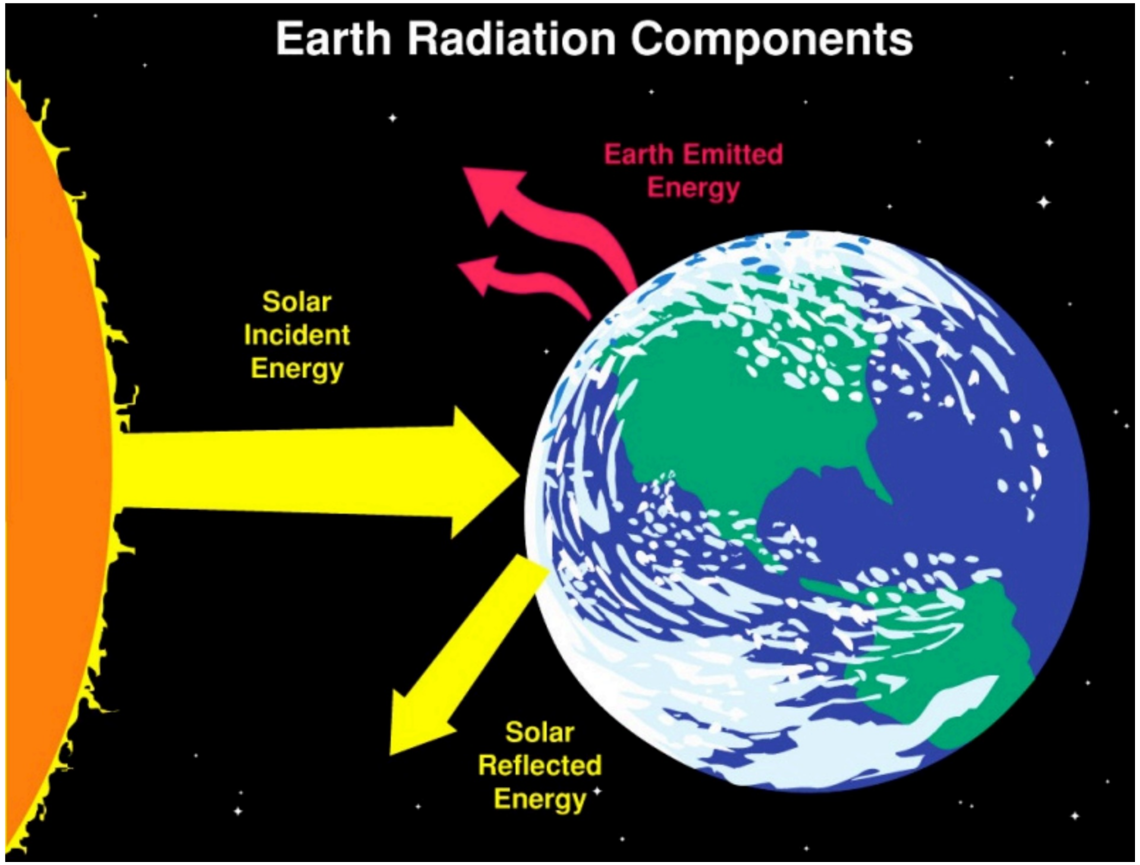
Remote Sensing

Measurement of a quantity associated with an object by a device not in direct contact with the object



Satellite Remote Sensing

Satellites carry instruments or sensors which measure electromagnetic radiation coming from the earth-atmosphere system.



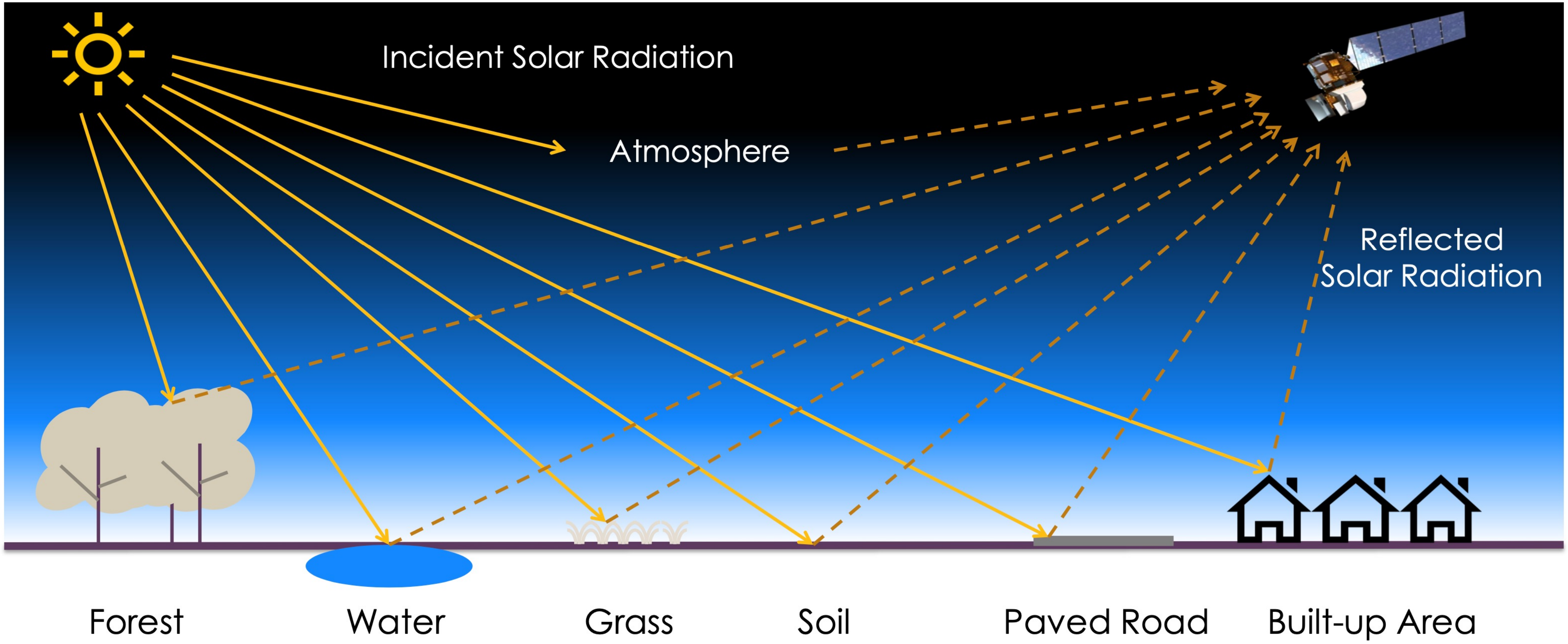
** We will talk about radar (active) sensors in the second half.*

Measuring Earth Surface and Atmospheric Properties

- The intensity of reflected and emitted radiation to space is influenced by the surface and atmospheric conditions.

- Thus, satellite measurements contain information about the surface and atmospheric conditions.

Measuring Earth Surface and Atmospheric Properties

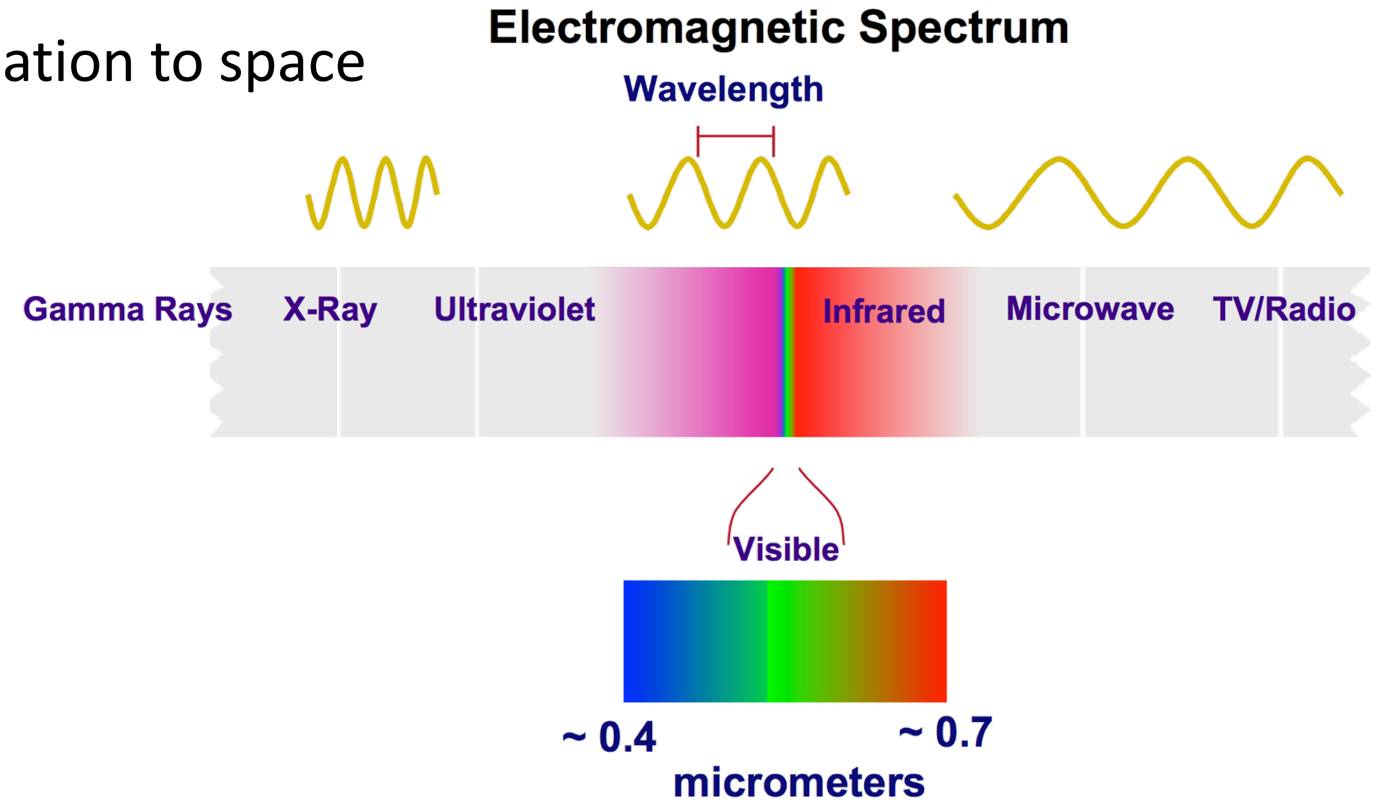


source: NASA's Applied Remote Sensing Training Program

Electromagnetic Radiation

Earth-Ocean-Land-Atmosphere System:

- Reflects solar radiation back to space
- Emits Infrared and Microwave radiation to space



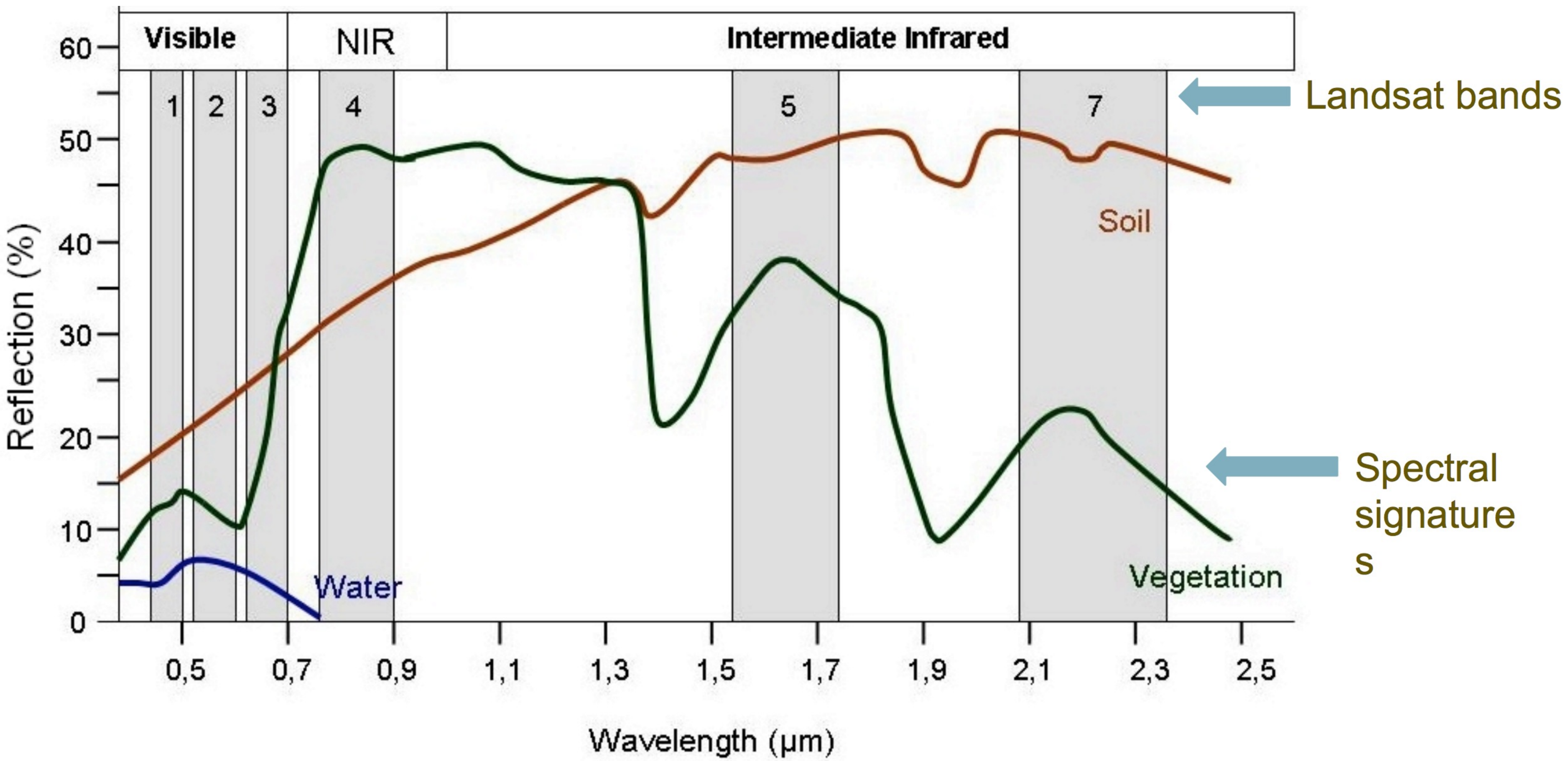
Interaction with Vegetation

Example: Healthy, green vegetation absorbs Blue and Red wavelengths and reflects Green and (near) Infrared (NIR).

Since we cannot see NIR radiation,
we see healthy vegetation as green.

Spectral Signatures in Imagery

Remotely sensed imagery acquires information in different wavelengths, representing different parts of the Electromagnetic Spectrum.



Spectral Indices

Normalized Indices ([-1, 1])

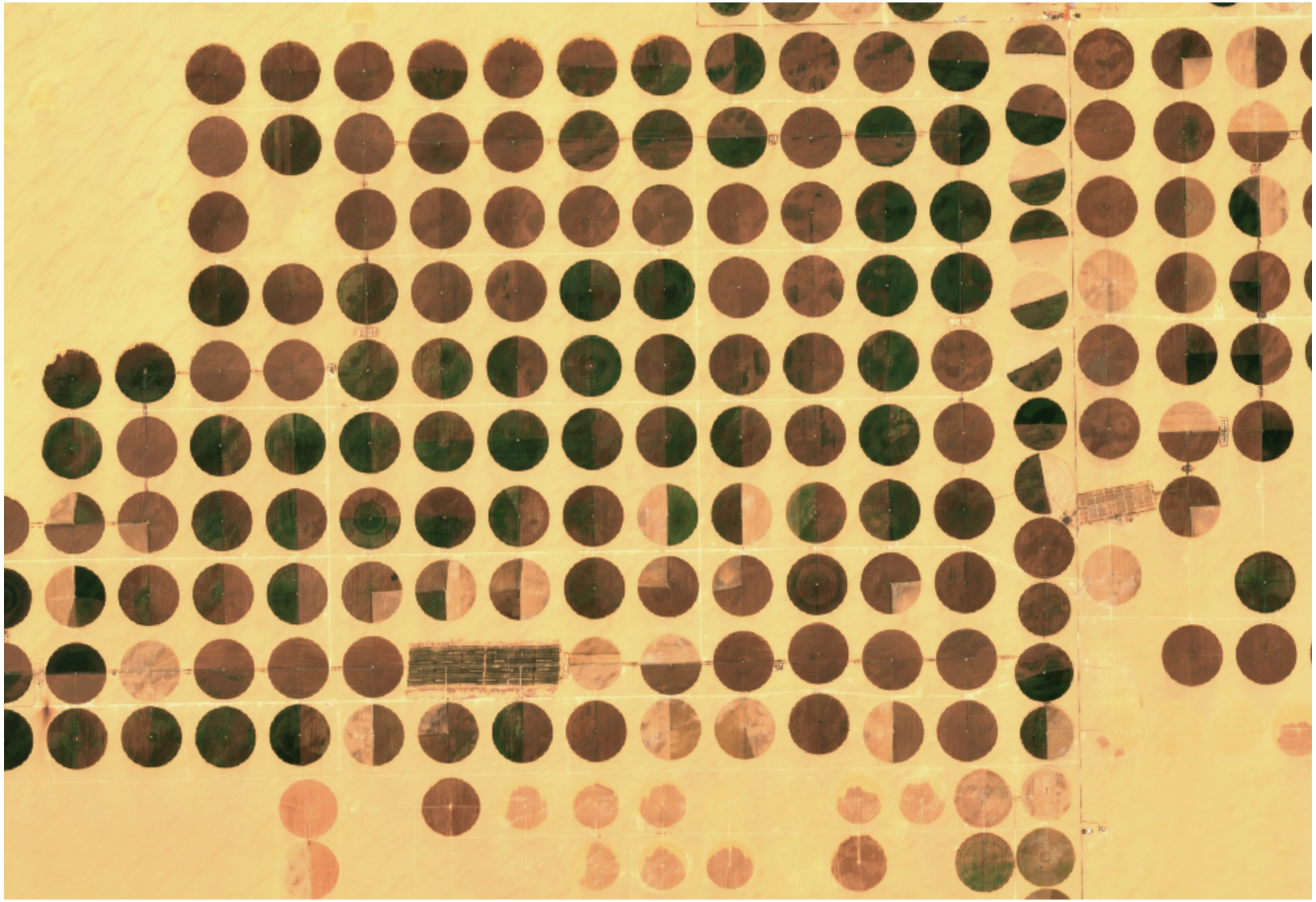
- Normalized Difference Vegetation Index (NDVI

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{Red}}{\mathrm{NIR} + \mathrm{Red}}$$

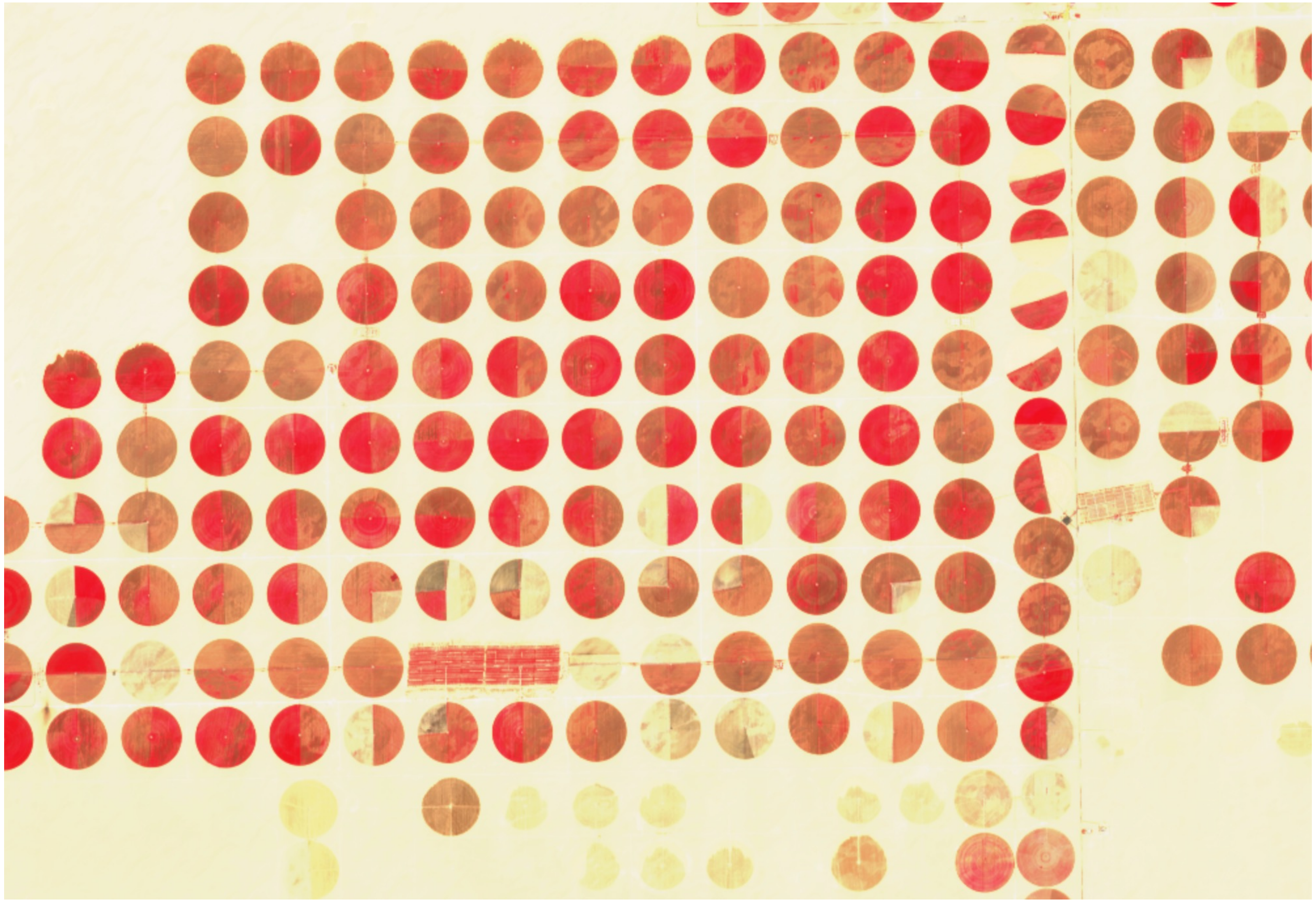
- Normalized Difference Water Index (NDWI)

$$\mathrm{NDWI} = \frac{\mathrm{Green} - \mathrm{NIR}}{\mathrm{Green} + \mathrm{NIR}}$$

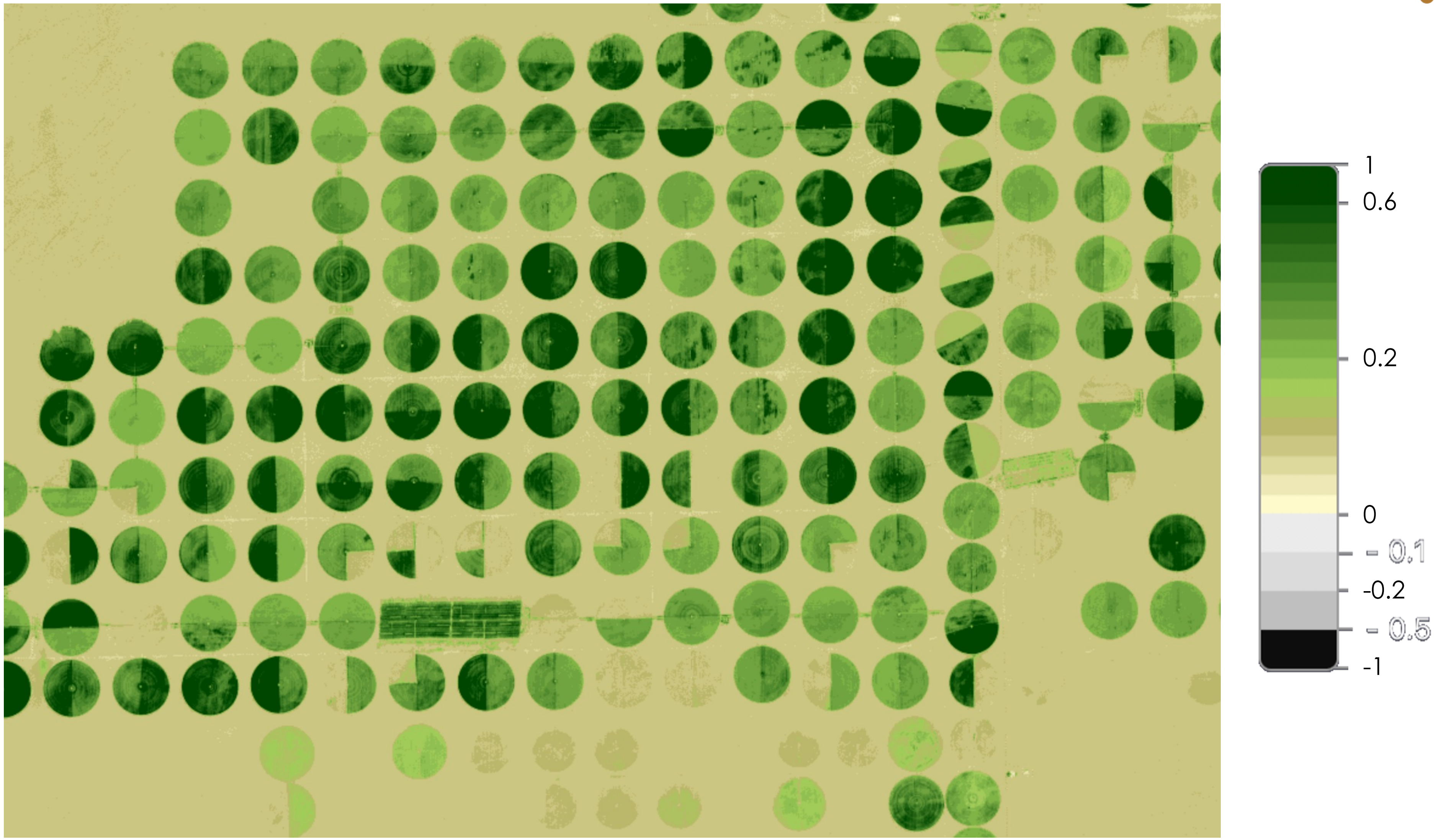
True Color (R,G,B)



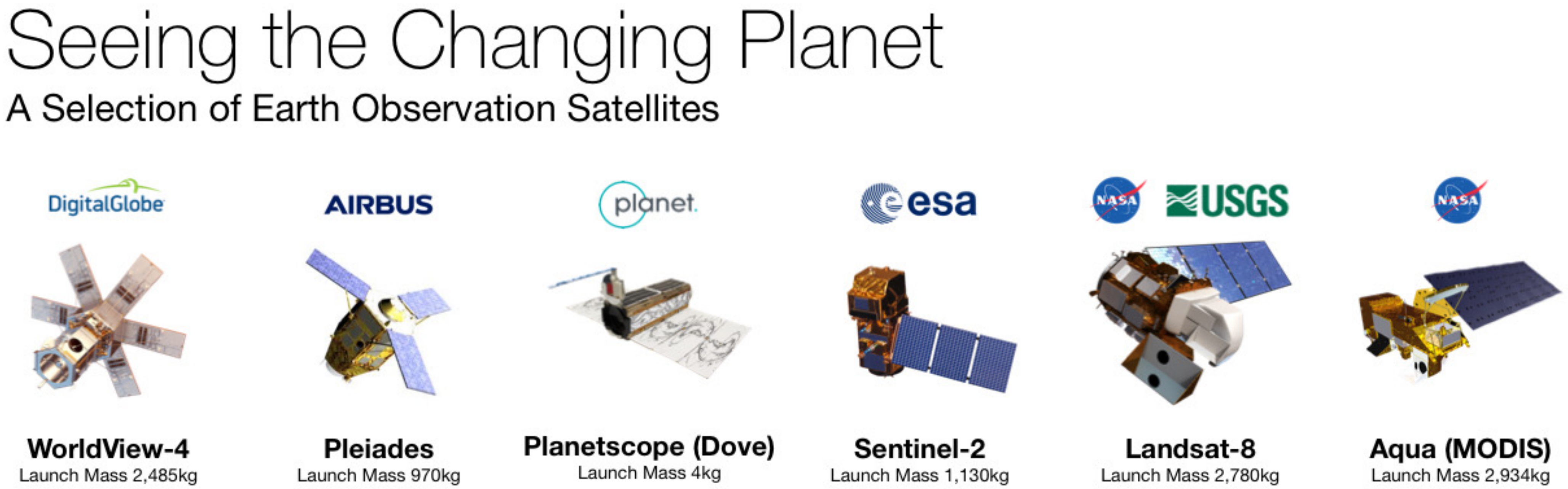
False Color (NIR,R,G)



NDVI



Satellite Platforms

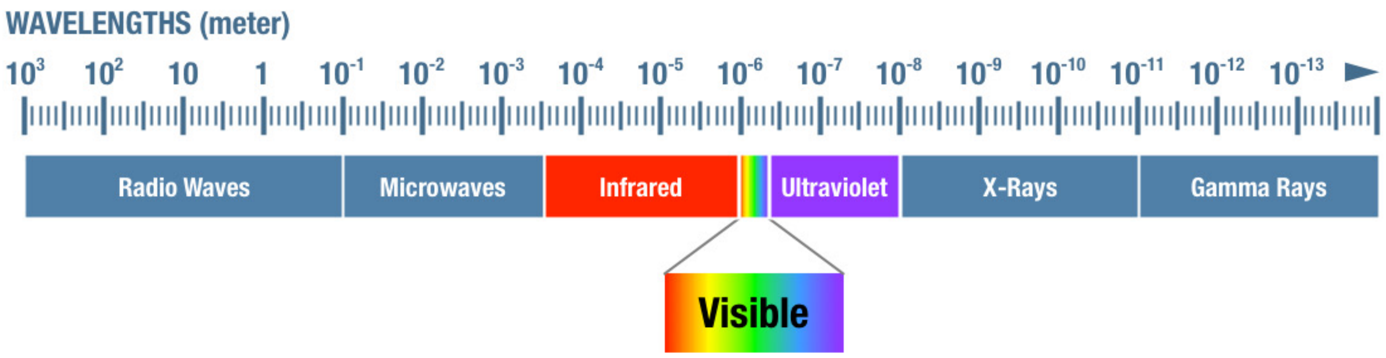


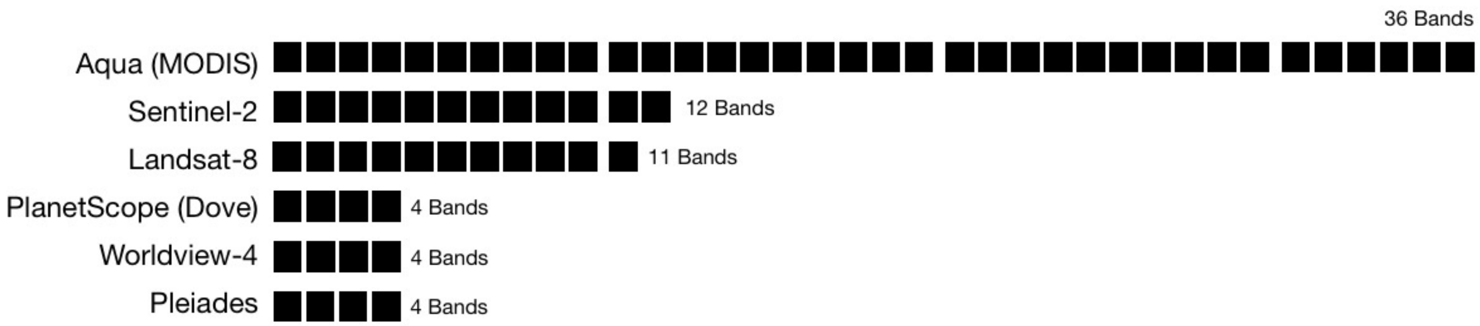
Spectral Resolution

Spectral Resolution

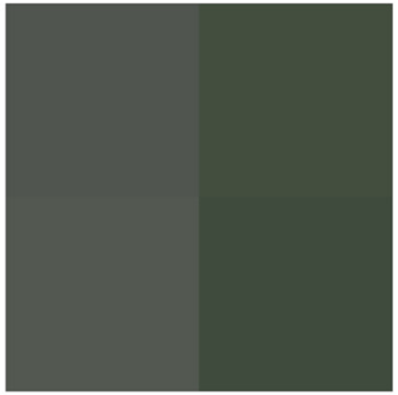
The number of bands of radiation in the electromagnetic spectrum that a satellite can sample (visible, infrared, ultraviolet, microwave, x-ray, etc.)

Electromagnetic Radiation Spectrum





Spatial Resolution



Aqua (MODIS)
250m Resolution

Landsat-8
30m Resolution

Sentinel-2
10m Resolution

PlanetScope (Dove)
3m Resolution

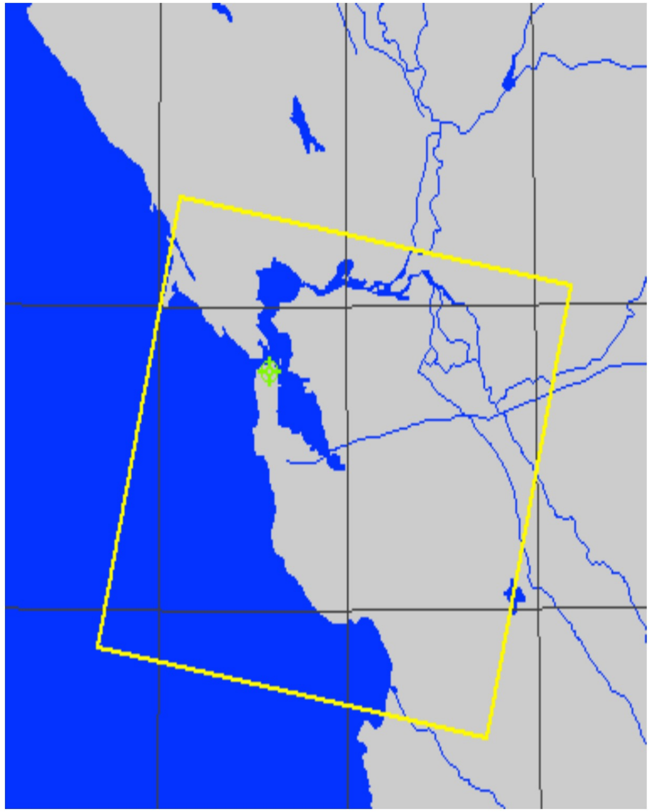
Pleiades
0.5m Resolution

Worldview-4
0.3m Resolution

Spatial Resolution vs Footprint

Generally, the higher the spatial resolution the less area is covered by a single image.

MODIS (250m -1 km)

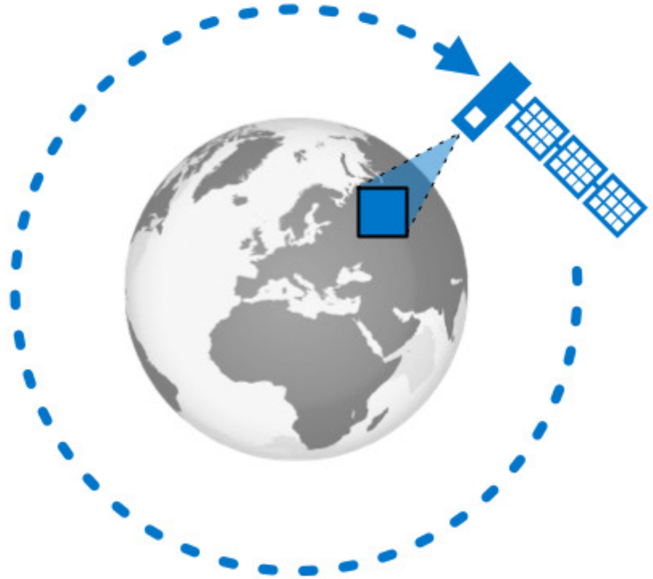


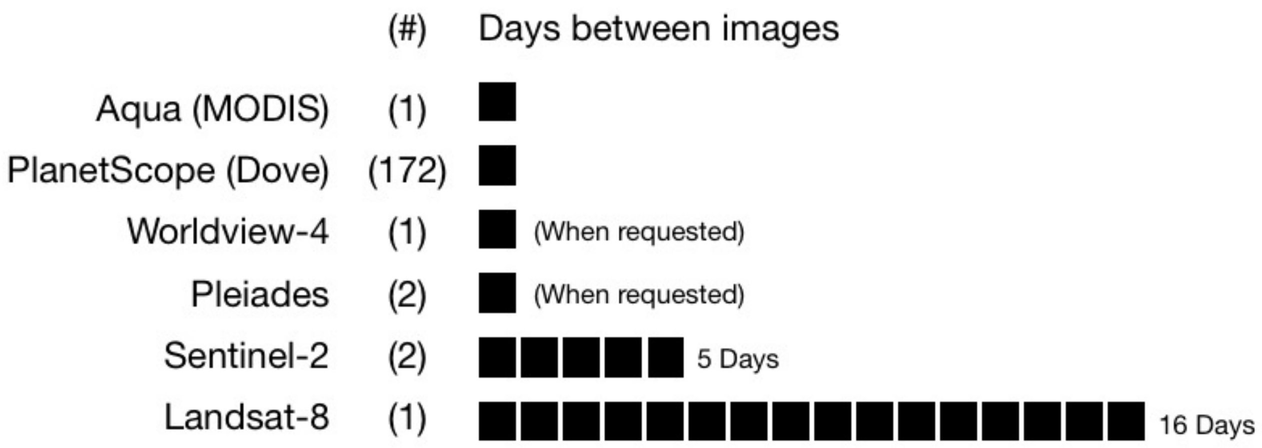
Landsat (30 m)

Temporal Resolution

Temporal Resolution

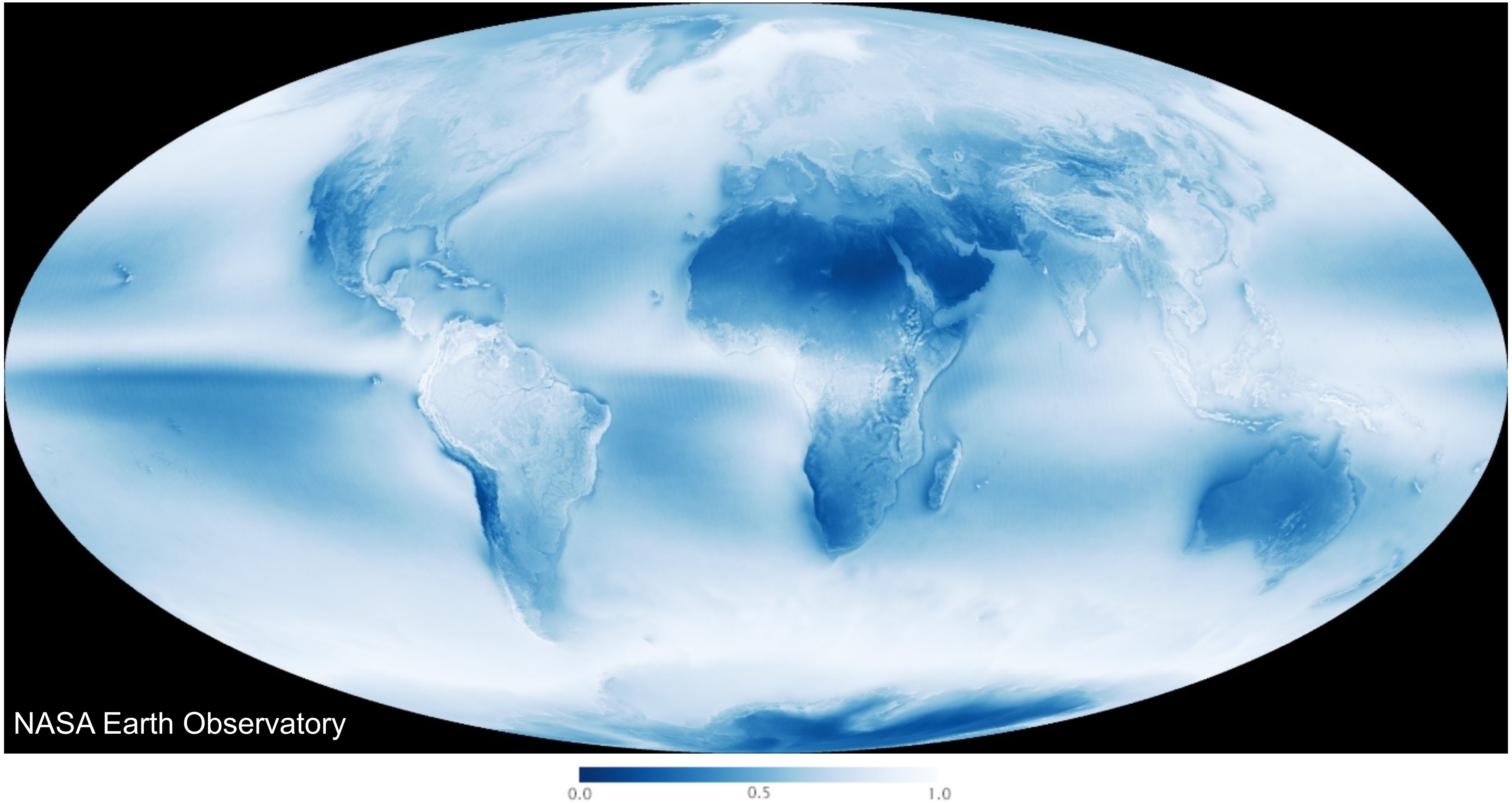
Temporal resolution varies by satellite and describes the time it takes for an individual satellite to orbit and revisit a specific area. Some satellites operate as a constellation with multiple satellites working together to increase their global coverage daily.






0 days 00 hours 00 minutes
Sentinel-2 constellation:
summer solstice

Atmospheric Transparency

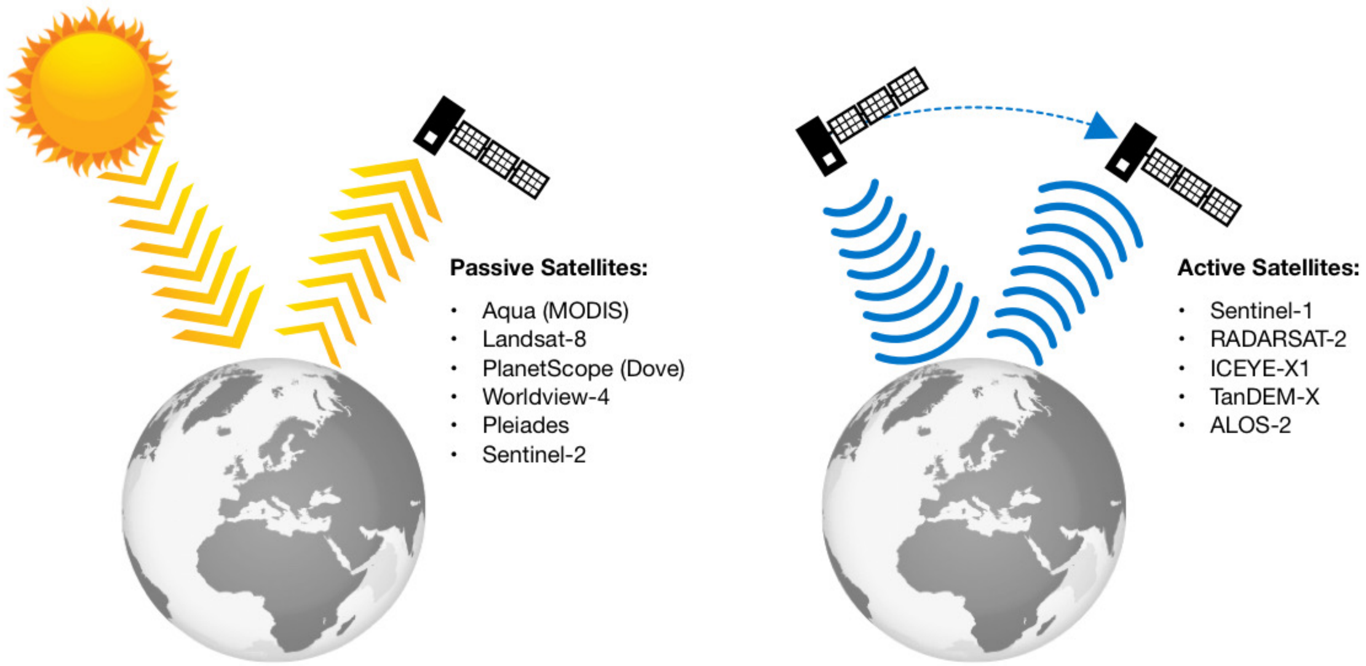


Average cloudiness (2002 - 2015)

Different Sensors

Passive vs. Active Sensors

Most Earth observation satellites are passive, only receiving image data from reflected sunlight, but a few utilize active image capture by transmitting their own signal.



PASSIVE Earth Observation Satellites

Passive satellites detect radiation reflected off the Earth's surface, such as visible light and infrared. In general, passive satellites are not able to work through clouds.

ACTIVE Earth Observation Satellites

Active satellites transmit energy towards the Earth and measure the returned signal which provides information about the Earth's surface. In general, active satellites can see through clouds.

Advantages and Disadvantages of Radar Remote Sensing

Advantages

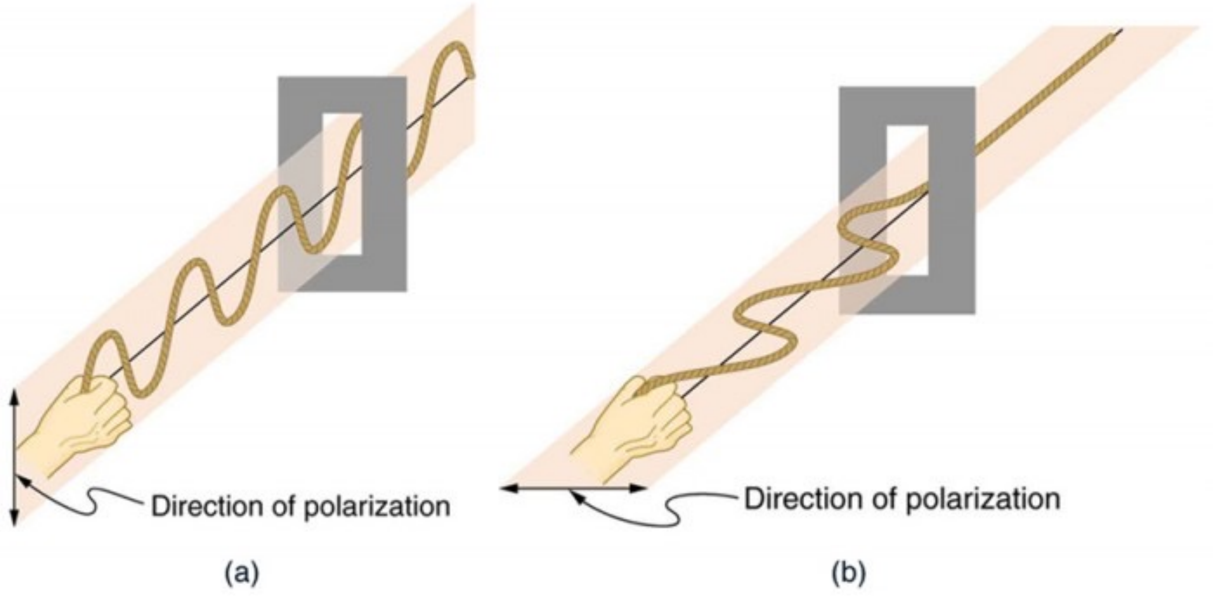
- All weather capability
- Day or night capability
- Minimal atmospheric effects
- Penetration through the vegetation canopy (depending on the frequency)
- Penetration through the soil (depending on the frequency)

Disadvantages

- Information content is different than optical and sometimes difficult to interpret
- Speckle effects (graininess in the image)
- Effects of topography

Radar Parameters: Polarization

- The radar signal is polarized
- The polarizations are usually controlled between Horizontal and Vertical:
  - **HH**: Horizontal Transmit, Horizontal Receive
  - **HV**: Horizontal Transmit, Vertical Receive
  - **VH**: Vertical Transmit, Horizontal Receive
  - **VV**: Vertical Transmit, Vertical Receive



Not every satellite measures all four parameters.

Multispectral vs Radar

- In Multispectral observations, the information is contained in reflectance values of different ***frequencies***

  Blue, Green, Red, NIR, SWIR, etc

- In Radar observations, the information is contained in backscatter values of different ***polarizations***

  VV, HH, VH, HV

Radar Indices

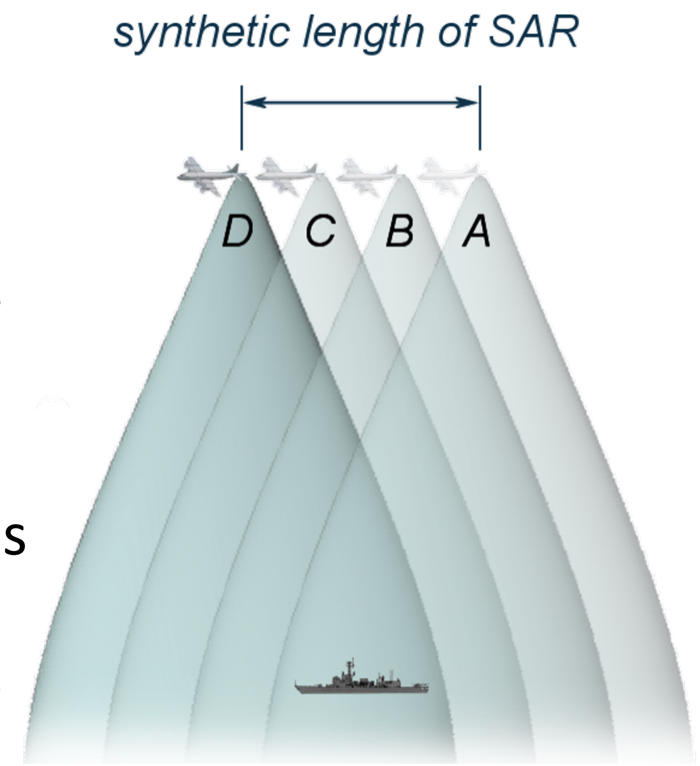
- Radar Vegetation Index (RVI)

$$RVI = \frac{8 \times HV}{HH + VV + 2 \times HV}$$

** HH, HV, and VV represent the radiometrically and geometrically corrected SAR backscattering coefficient (gamma-nought) for each polarization combination in linear units (m2 /m2)*

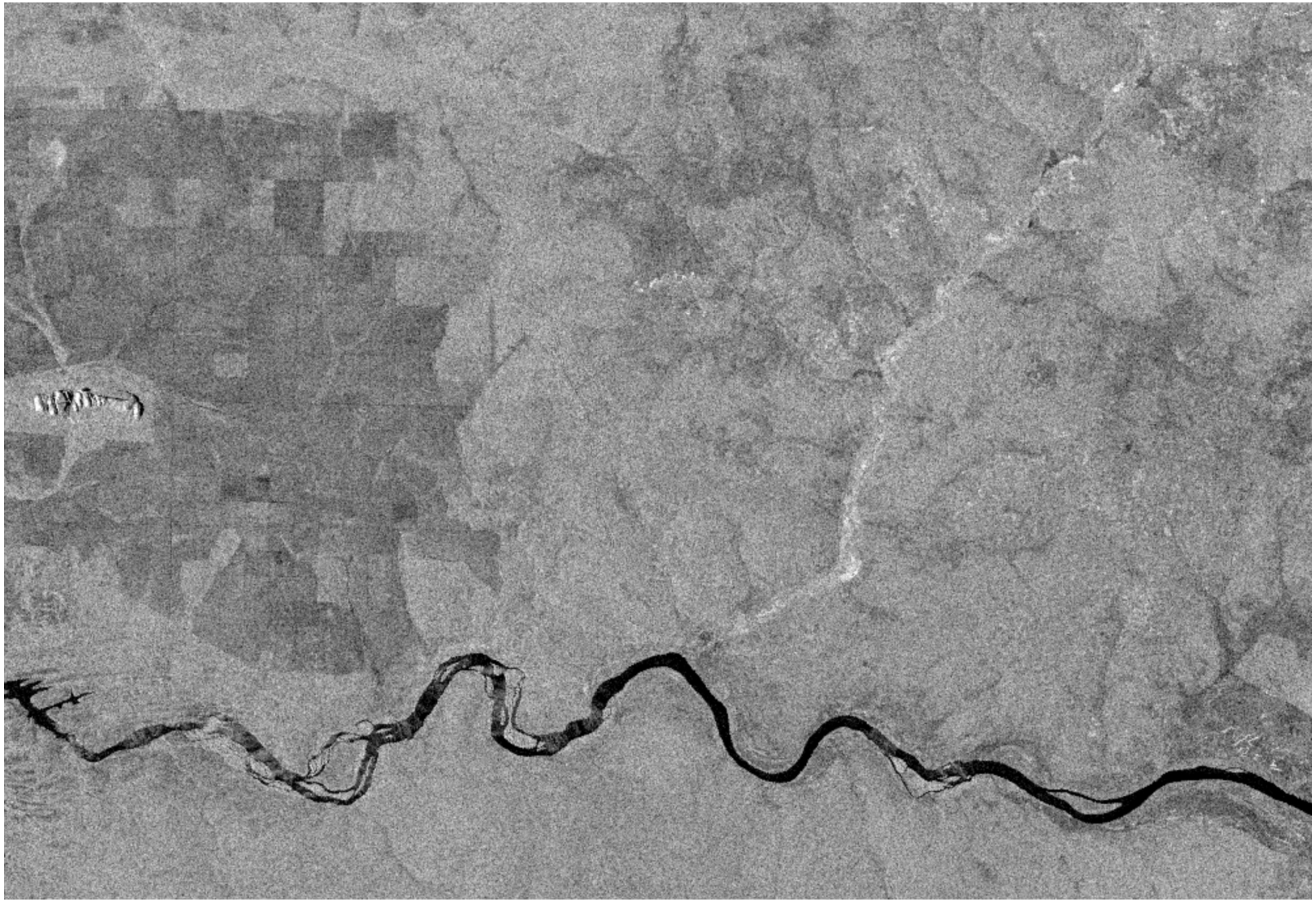
Synthetic Aperture Radar (SAR)

- The spatial resolution of radar data is related to the sensor wavelength and the length of its antenna.
- For a given wavelength, the longer the antenna, the higher the spatial resolution.
  - Example: At wavelength of about 5 cm (Sentinel-1 satellite), in order to get a spatial resolution of 10 m, a radar antenna about 4,250 m long is needed.
- In Synthetic Aperture Radar (SAR), a sequence of acquisitions from a shorter antenna are combined to simulate a much larger antenna, thus providing higher resolution data (hence called ***Synthetic***).

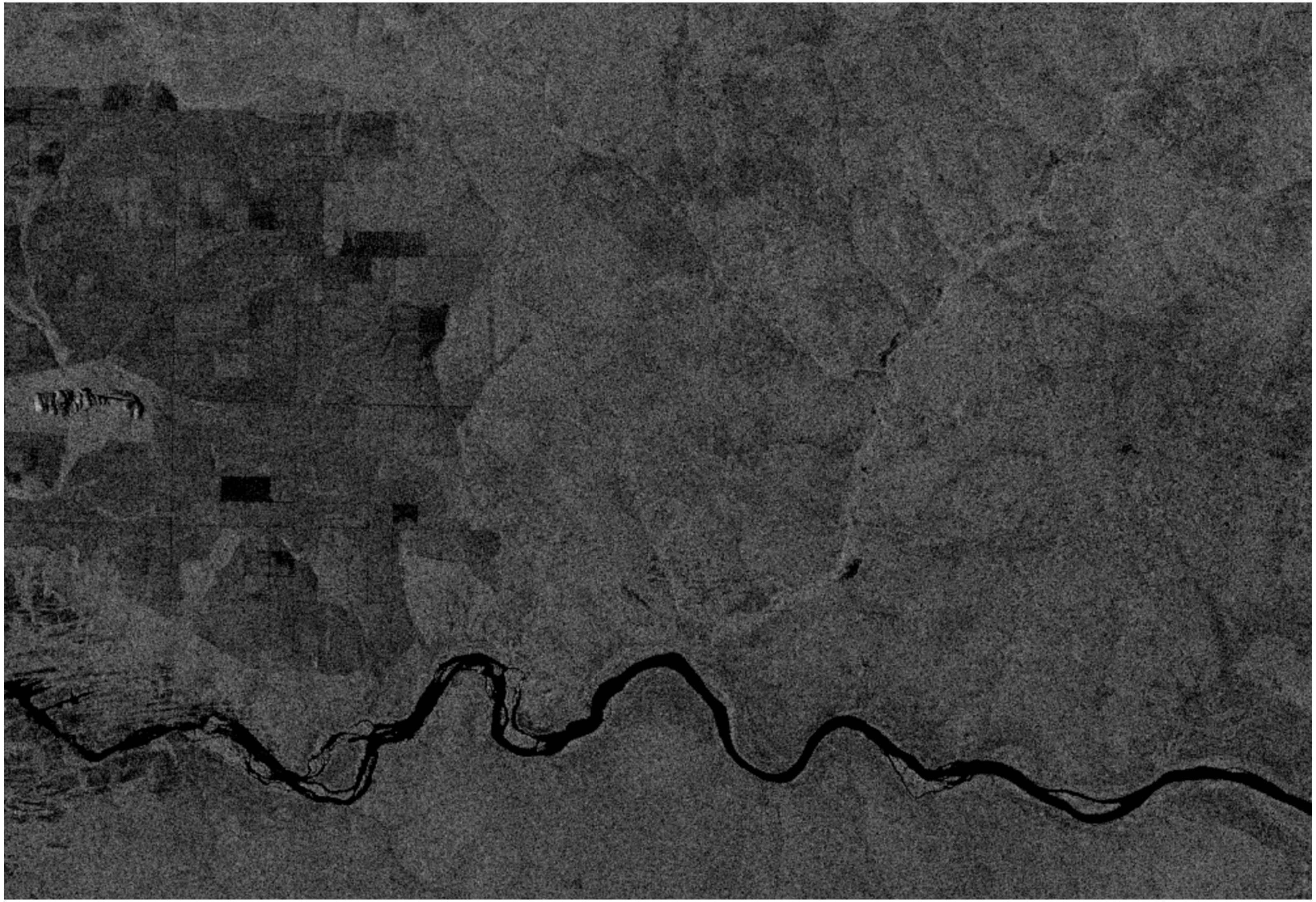


Credit: Christian Wolff

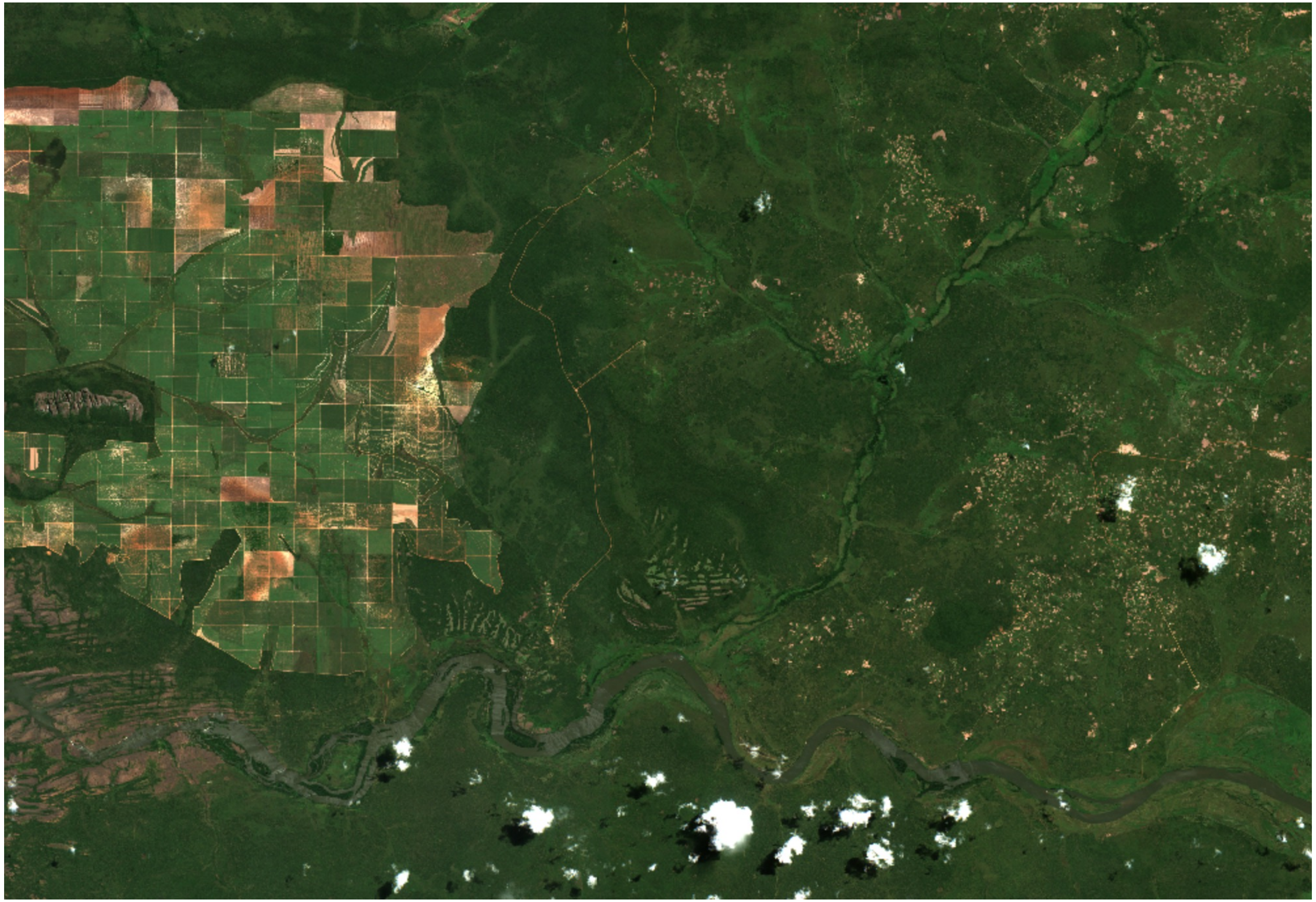
SAR - VV



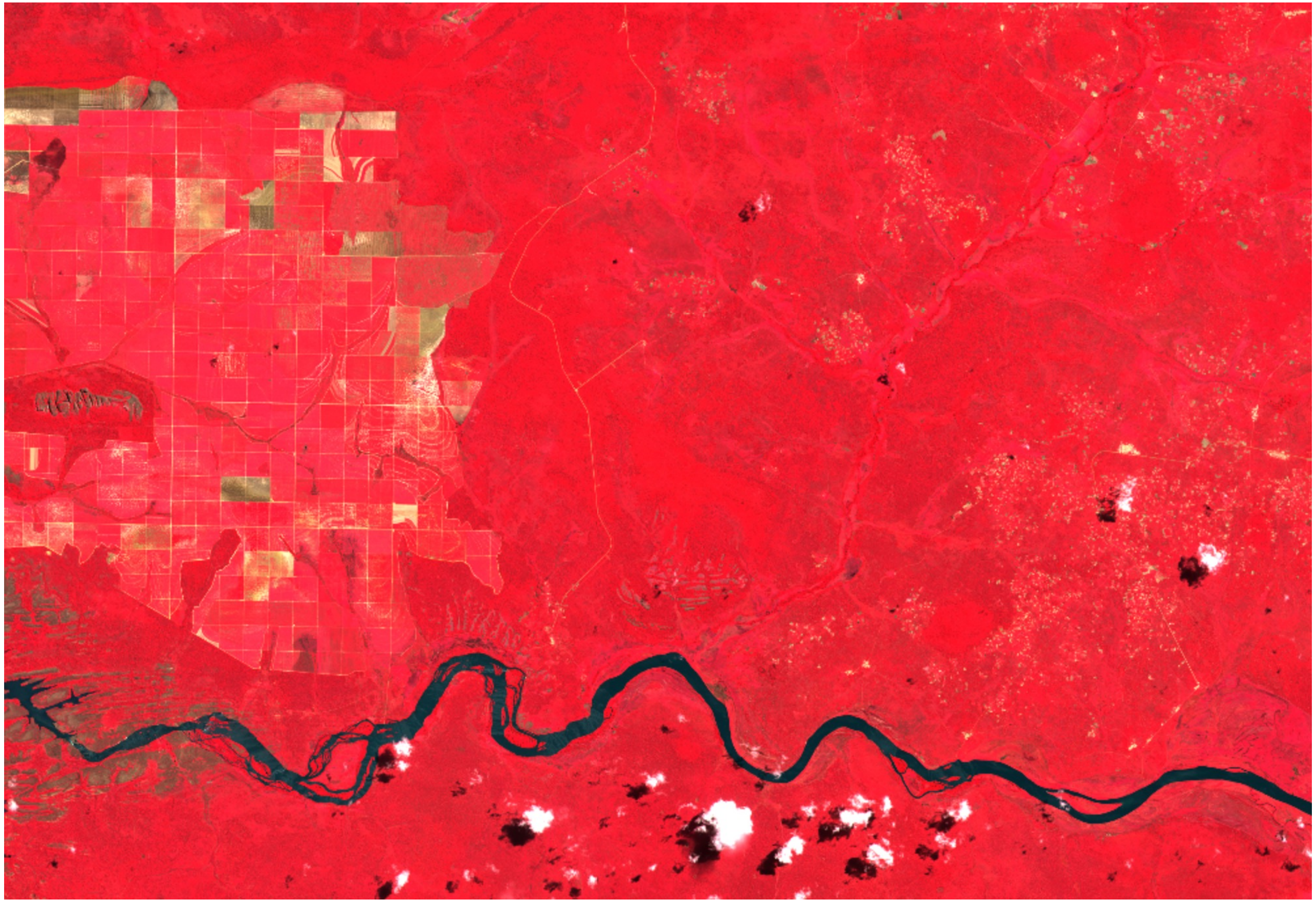
SAR - VH



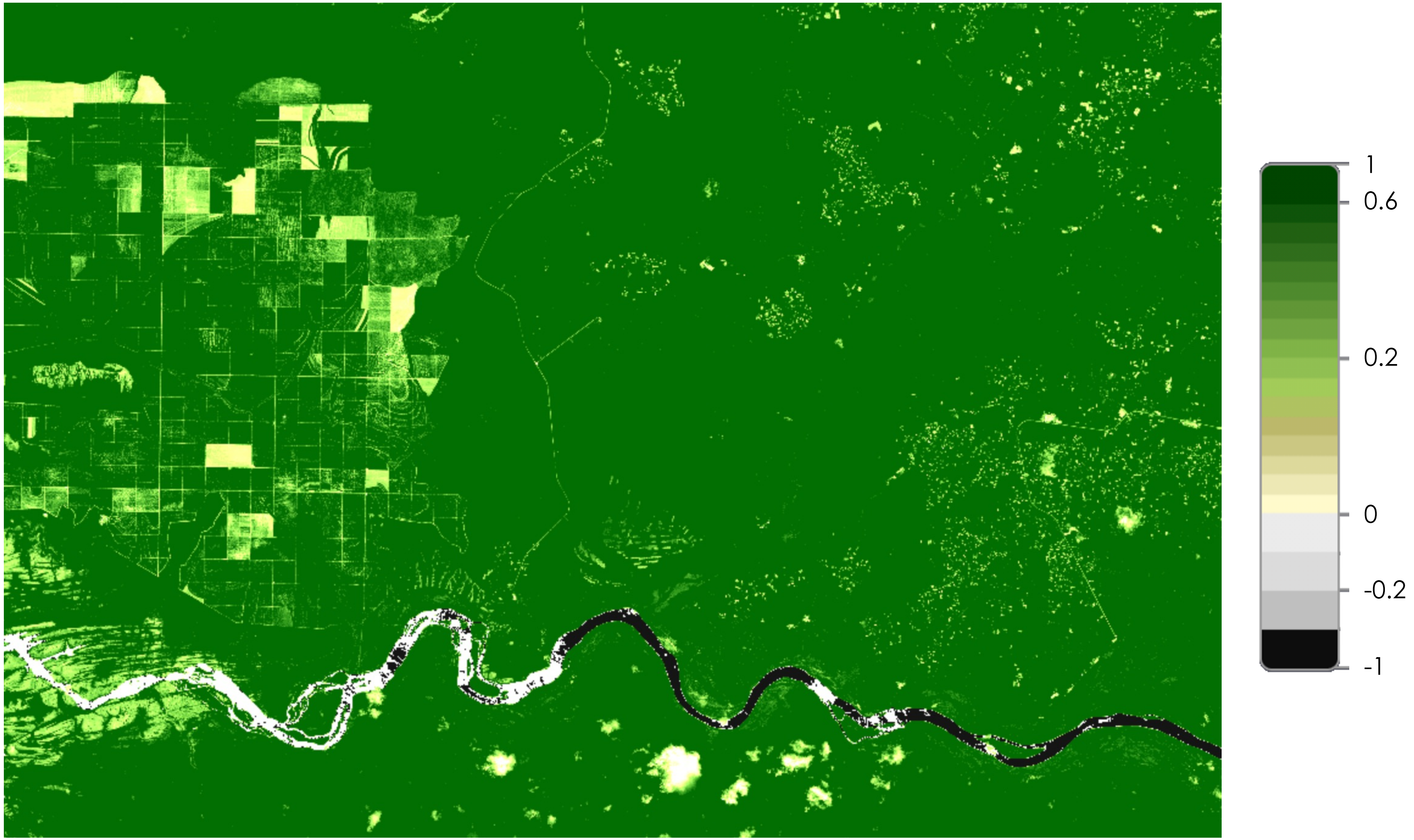
Multispectral (R,G,B)



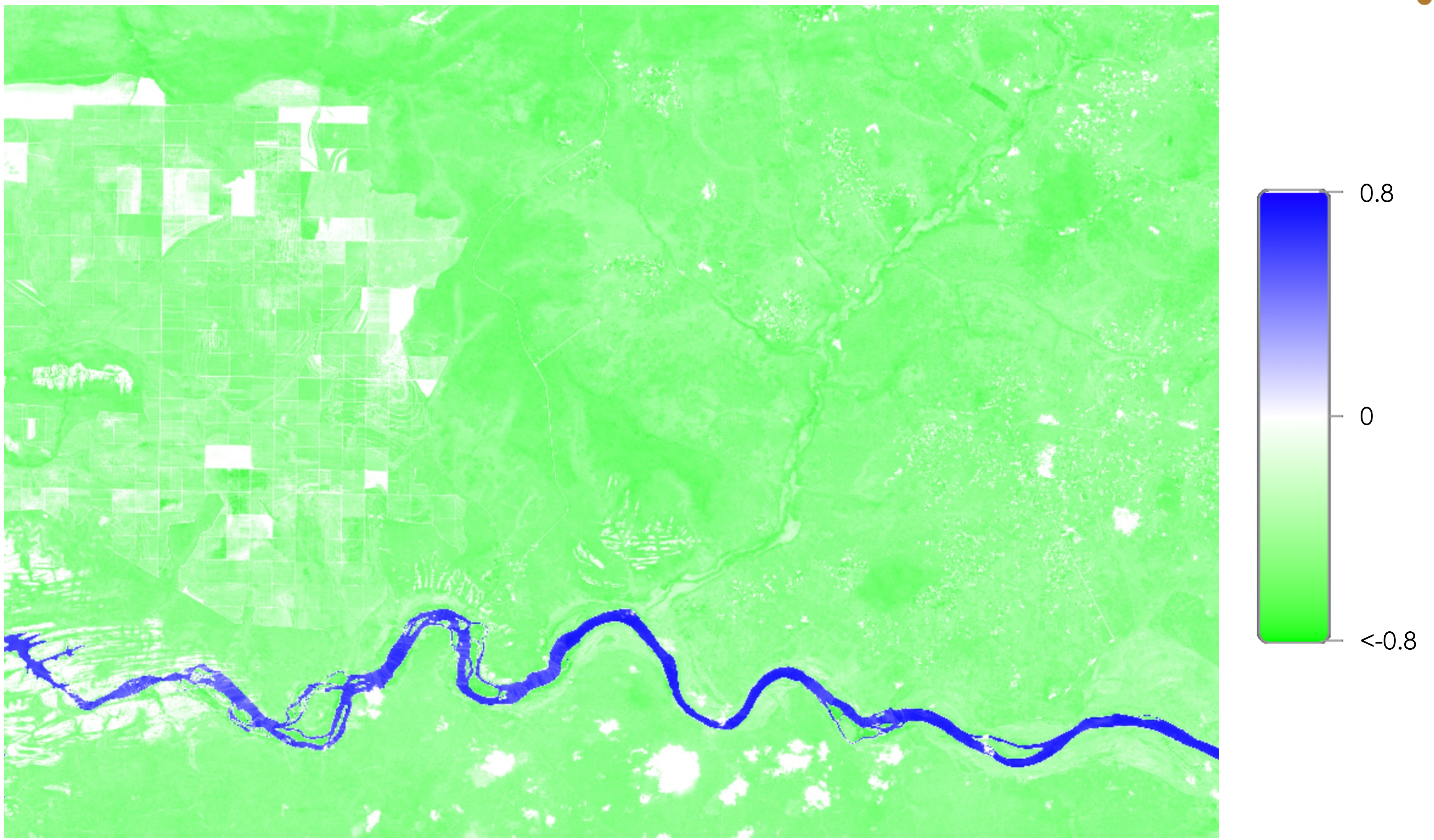
Multispectral (NIR,R,G)



Multispectral (NDVI)



Multispectral (NDWI)



References

The following resources were used to develop this content:

https://appliedsciences.nasa.gov/join-mission/training/english/arset-fundamentals-remote-sensing

https://appliedsciences.nasa.gov/join-mission/training/english/arset-introduction-synthetic-aperture-radar

Sentinel-1 and -2 Images are captured from EO-Browser (https://www.sentinel-hub.com/explore/eobrowser/)

Radiant Earth Foundation
EARTH IMAGERY FOR IMPACT

Radiant MLHub:
An Ecosystem to Advance Machine Learning Applications in Earth Science

Mission

Empowering organizations and individuals globally with open Earth observation training data, standards and tools to cultivate a global community focused on machine learning and Earth observations to meet the world's most critical challenges.

Vision

Leveraging machine learning and Earth observation for positive global impact

Training Data Challenges in Earth Science

Geospatial Training Data Catalogs:

- Lack of Geo-Diversity
- Scarce data sources
- Data Accessibility
- Inter-Operability
- Machine learning-readiness

Result of Gaps in Training Data Catalogs:

- Biased or incorrect results
- Inability to capture wide range of possible outcomes in space and time

ML Commons for Earth Observation

Hub

- EO Training Datasets
- ML Models
- Competitions
- Image annotation + ground-referencing

Community

- Convenings to develop standards for ML on EO
- Interoperability of datasets
- Technical Working Groups
- White Papers

Education

- EO market information
- Best practices on use of ML and EO
- Speaking engagements
- Media outreach

Radiant MLHub
Earth Imagery for Impact

Radiant MLHub Repository

- Each dataset has a DOI with version and citation

- FAIR data principles
  - Findable
  - Accessible
  - Interoperable
  - Reusable

Radiant MLHub Training Data Registry

Radiant MLHub
EARTH IMAGERY FOR IMPACT

CV4A Kenya Crop Type Competition

`https://doi.org/10.34911/rdnt.dw605x`

crop type | segmentation | sentinel-2

Description

This dataset was produced as part of the Crop Type Detection competition at the Computer Vision for Agriculture (CV4A) Workshop at the ICLR 2020 conference. The objective of the competition was to create a machine learning model to classify fields by crop type from images collected during the growing season by the Sentinel-2 satellites.

The ground reference data were collected by the PlantVillage team, and Radiant Earth Foundation curated the training dataset after

STAC Collections

Description
Crop Type Labels

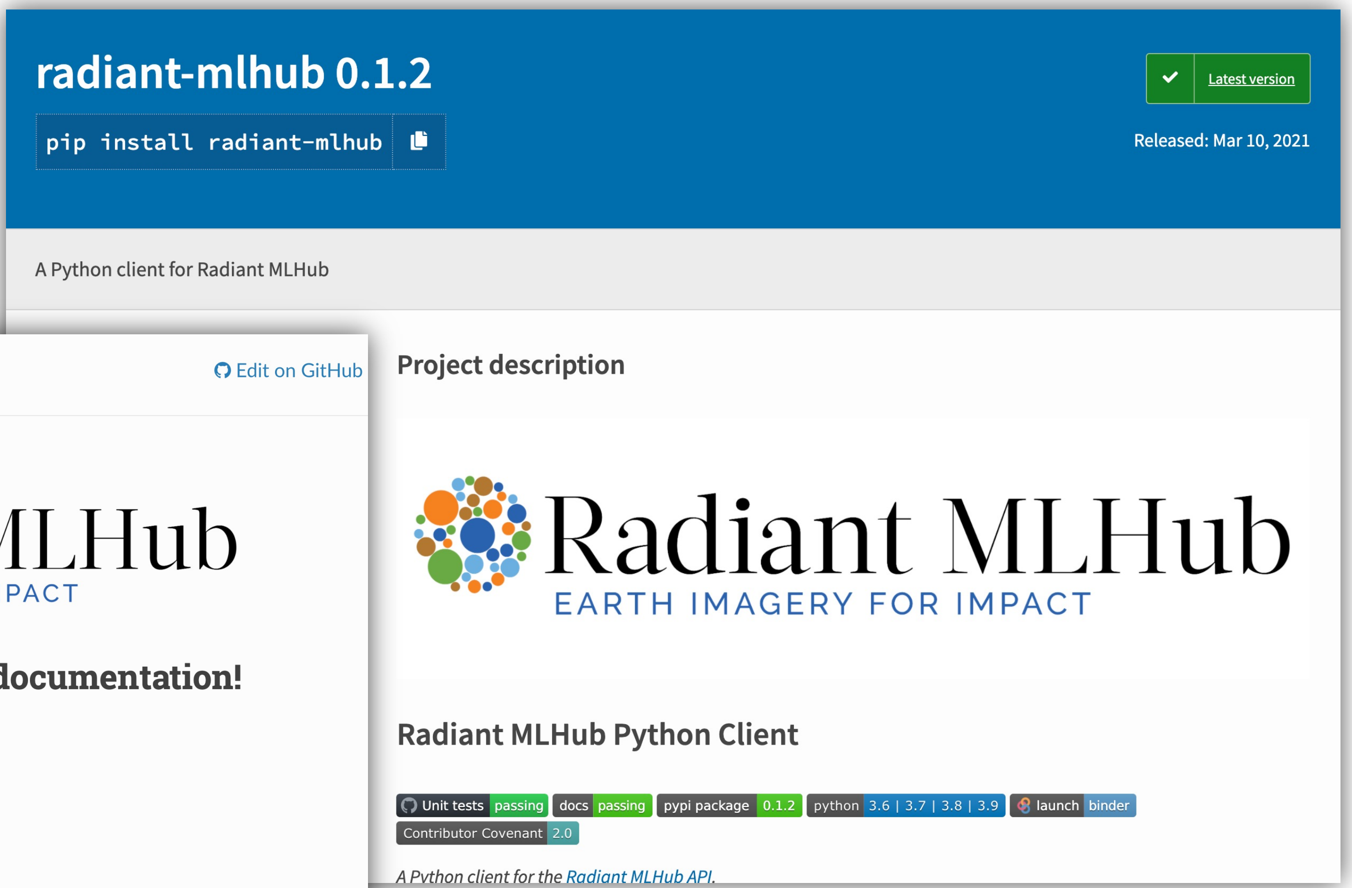
Resource type
Labels

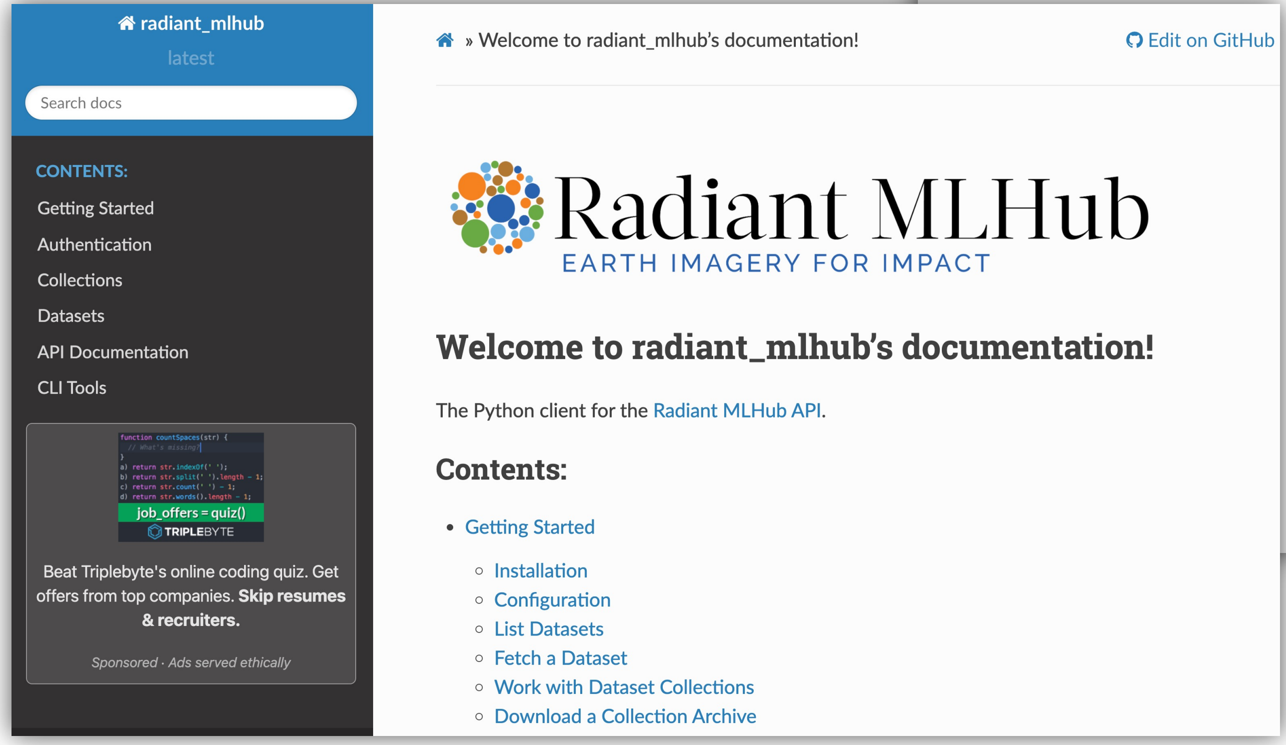
Collection ID
`ref_african_crops_kenya_02_labels`

License
CC-BY-SA-4.0

Radiant MLHub Python Client

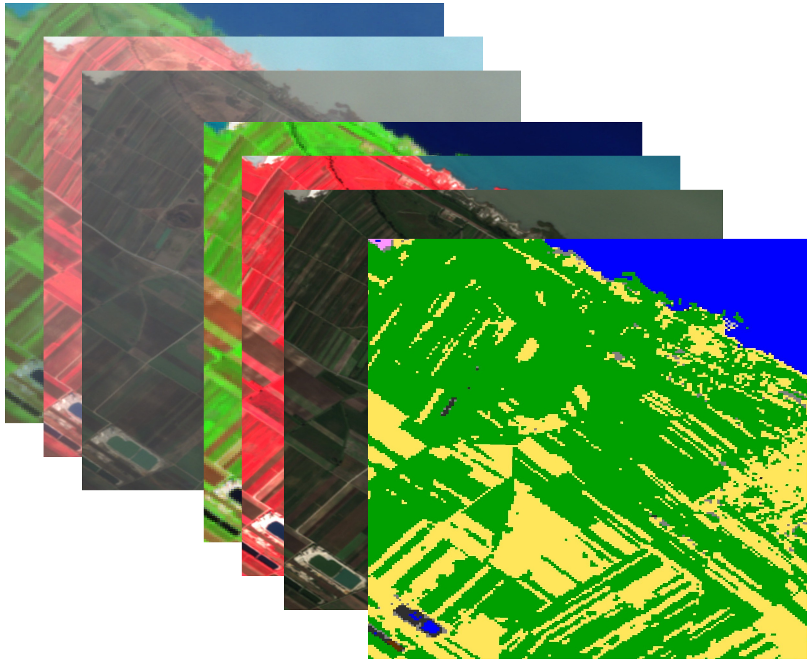
- Access the API
- Search for datasets
- Download datasets





Radiant MLHub Data Catalog

- **Crops**
  - Uganda
  - Kenya
  - Tanzania
  - South Sudan
  - Ghana
  - Central Asia
  - Benin
  - Rwanda
  - Mali
  - South Africa
- **Land Cover**
  - LandCoverNet
  - BigEarthNet (EU)
  - SpaceNet 1-7
  - Chesapeake Bay
- **Building Footprints**
  - Tanzania
- **Tropical Storms**
  - Pacific and Atlantic
- **Wildfire Fuel**
  - Western US
- **Flood**
  - SEN12Flood



Thanks!

www.radiant.earth

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github.com/radiantearth

github.com/radiantmlhub