10TH ADVANCED TRAINING COURSE ON
LAND REMOTE SENSING

esa

Introduction to Optical Remote Sensing for Forestry

Krištof Oštir, University of Ljubljana, Faculty of Civil and Geodetic Engineering

Outline

Optical remote sensing

Interaction with the atmosphere and surface

Spectral response

What do we measure

Removing the atmosphere

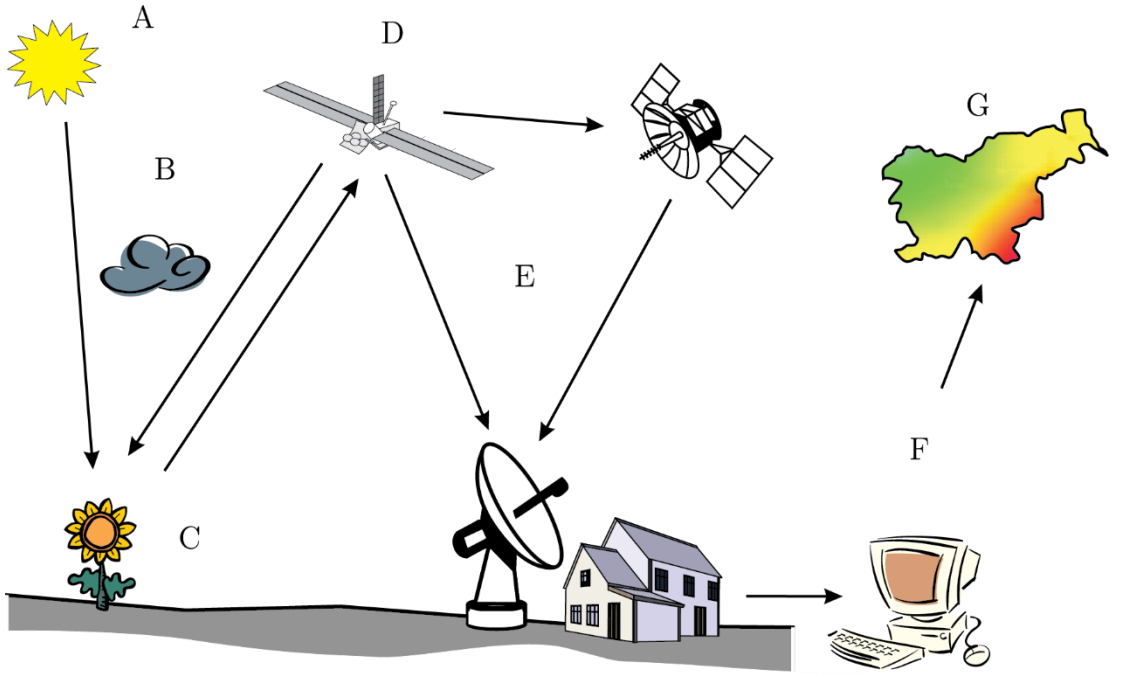
Analysis Ready Data

Time series

Vegetation development

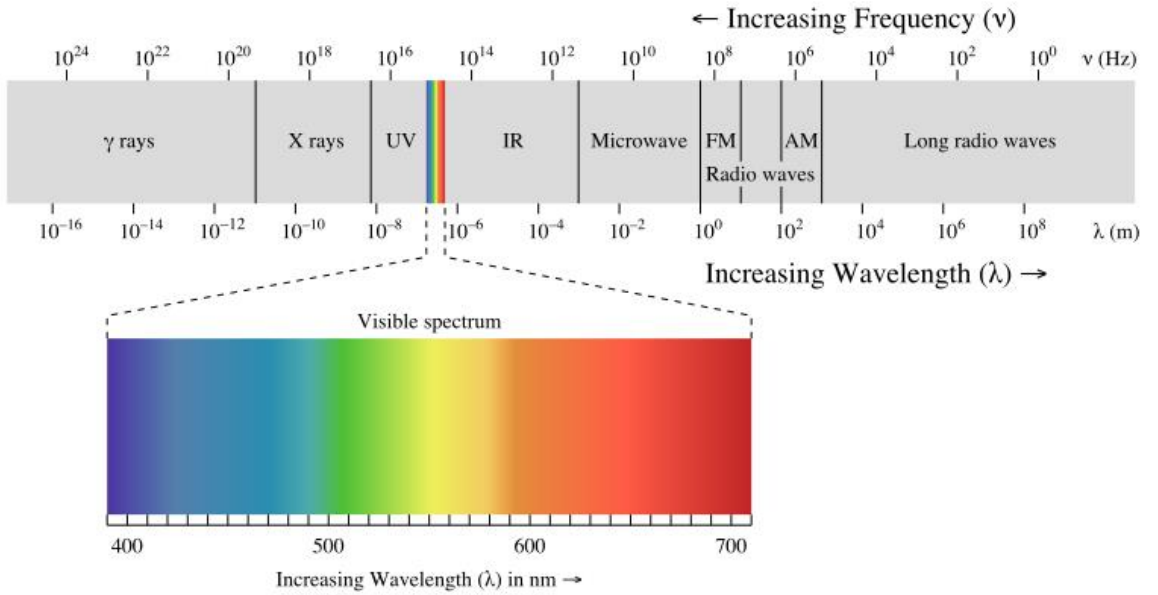
What is remote sensing?

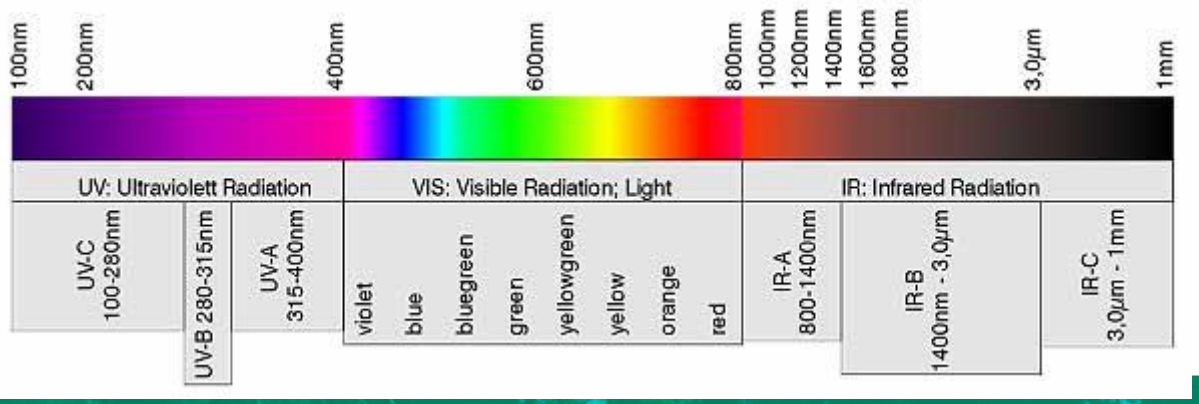
Remote sensing is the science of **obtaining information on Earth's surface without coming into direct contact with it.** In doing so, we detect and record a reflected or radiated electromagnetic waves, process them, analyse them and use this information in different applications.



Energy Source or Illumination (A)
Radiation and the Atmosphere (B)
Interaction with the Target (C)
Recording of Energy by the Sensor (D)
Transmission, Reception, and Processing (E)
Interpretation and Analysis (F)
Application (G)

Spectrum EMR





Optical 100 nm – 1 mm

Visible (VIS) 400 nm – 800 nm – perceived by the human eye

Ultraviolet (UV) < 400 nm

Infrared (IR) > 800 nm

[The Wavelength Range Of Optical Radiation (light-measurement.com)]

Interaction with the atmosphere

Before radiation used for remote sensing reaches the surface it has to travel through some distance of the atmosphere.

Particles and gases in the atmosphere can affect the incoming light and radiation.

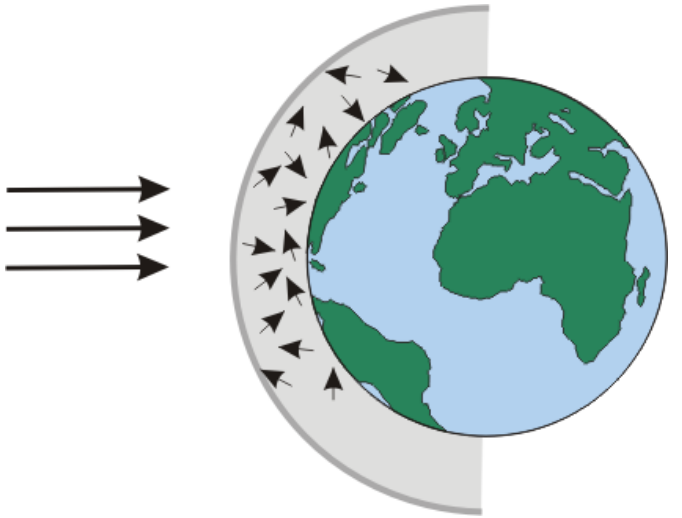
Three types of interaction:

- Scattering
- Absorption
- Refraction

Interaction with the atmosphere

Scattering occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected.

- Rayleigh
- Mie



Interaction with the atmosphere

Rayleigh

- Small-size particles in the atmosphere compared to the wavelength
- Intensity is proportional to the $1/\lambda^4$
- At the wavelength 400 nm is almost 10 x stronger than in 700 nm
- Blue sky

Interaction with the atmosphere

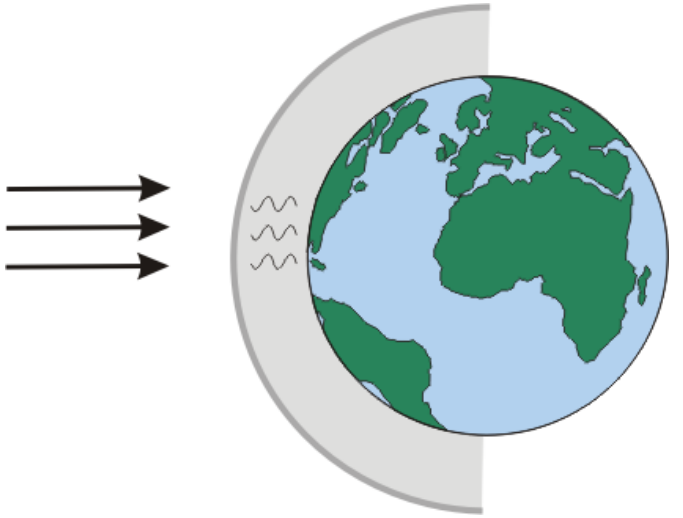
Mie

- Particles about the same size as the wavelength
- Dust, pollen, smoke and water vapour
- More strongly affects longer wavelengths

Interaction with the atmosphere

Absorption causes molecules in the atmosphere to absorb energy at various wavelengths.

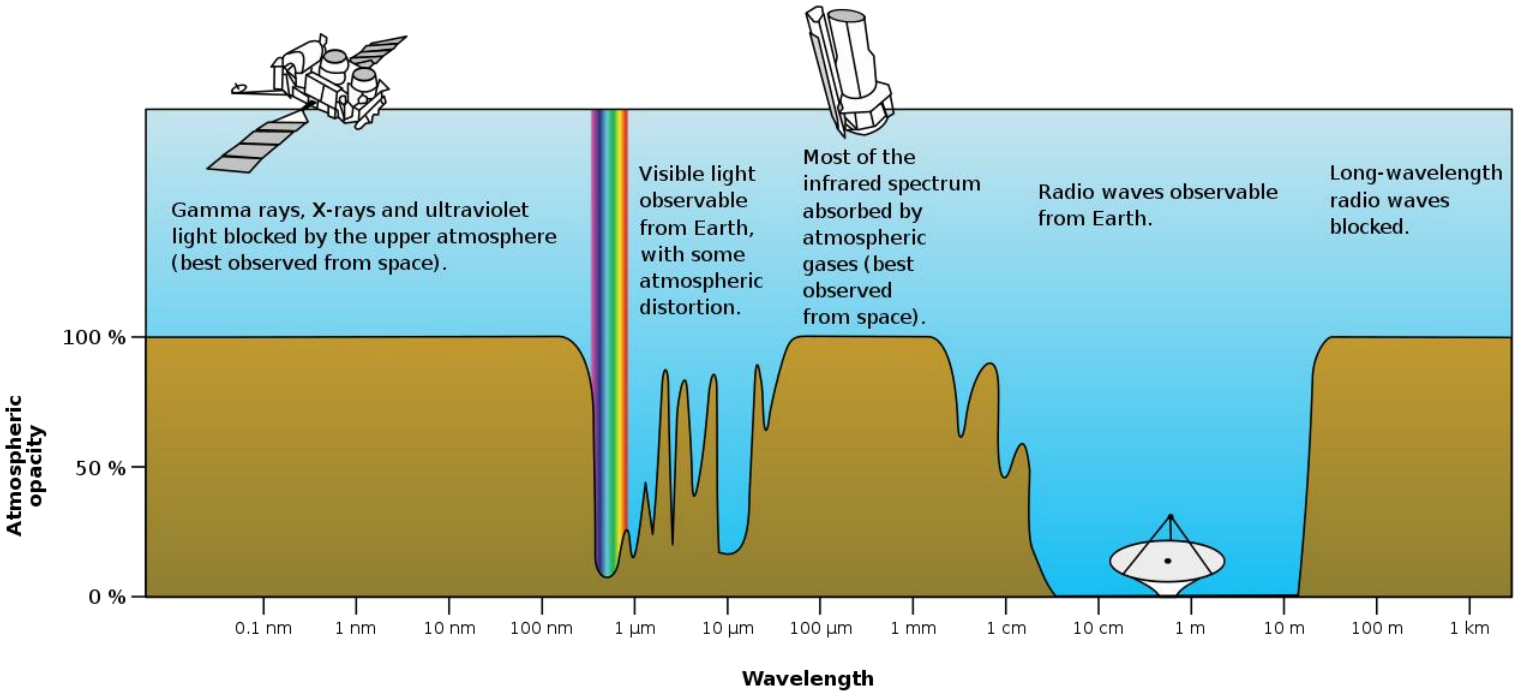
- Ozon, UV
- Carbon dioxide, Thermal IR
- Water vapor, long wave IR, microwaves



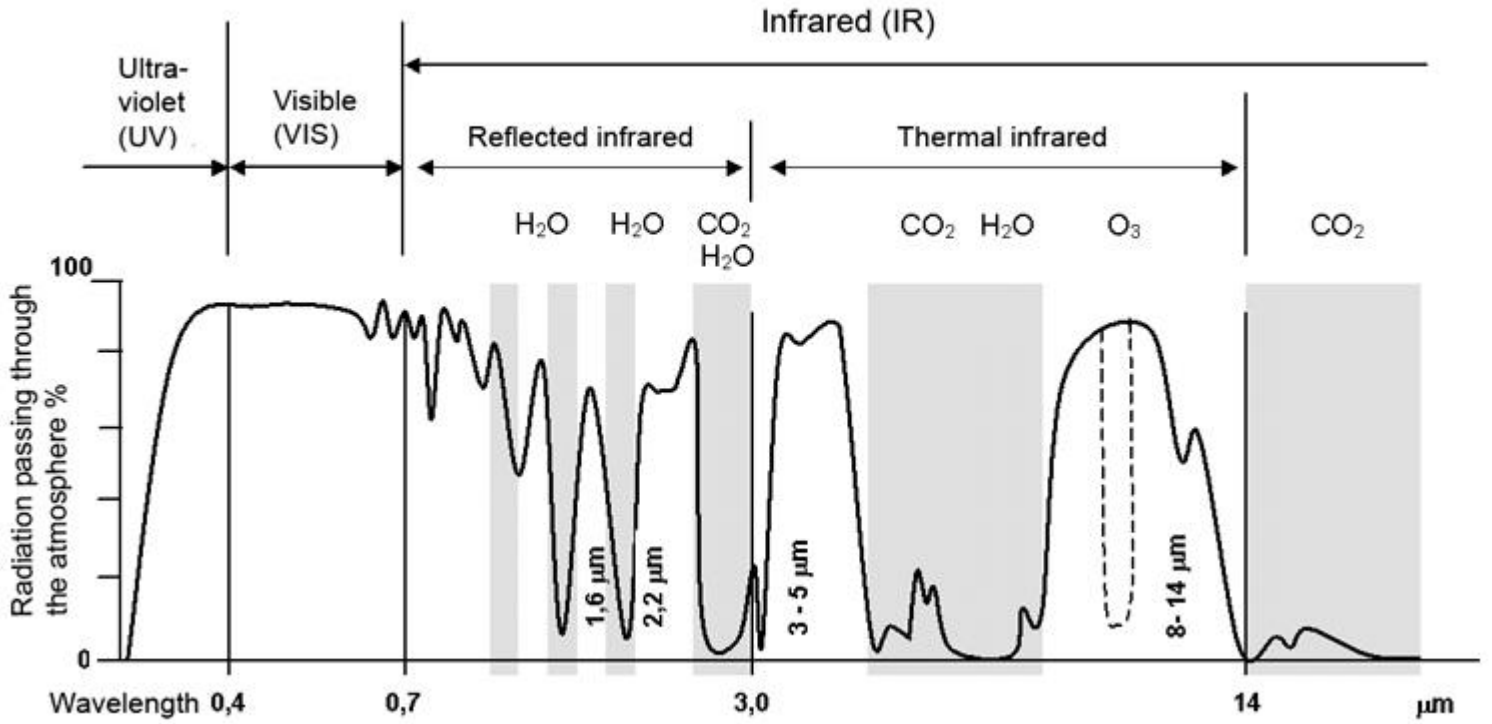
Earth's atmosphere opacity

Some wavelengths are more effected by the atmosphere than others

Those with little effect on signal are ‘windows’ for remote sensing.



Optical Atmospheric Windows

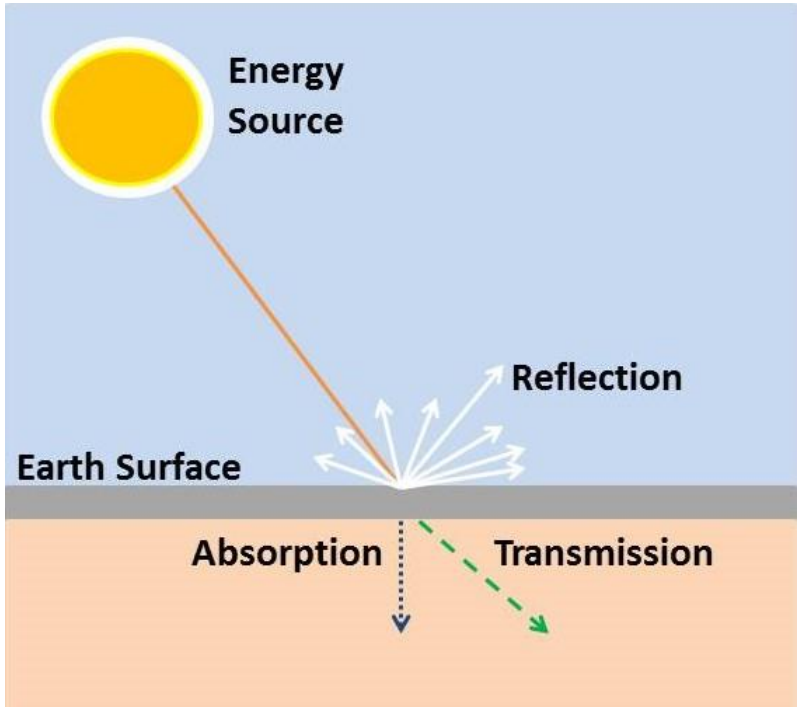


Wavelength (λ)	Band
0.30 – 0.75 µm 0.77 – 0.91 µm	Visible light
1.55 – 1.75 µm 2.05 – 2.40 µm	Near infrared
8.0 – 9.2 µm 10.2 – 12.4 µm	Thermal infrared

Interaction with the surface

The interaction of electro-magnetic radiation with the surface is driven by three physical processes: reflection, absorption, and transmission of radiation.

Reflection involves the returning or throwback of the radiation incident on an object on the surface.



[Electro-Magnetic Radiation (EMR) Interaction with Earth Surface Features (gisoutlook.com)]

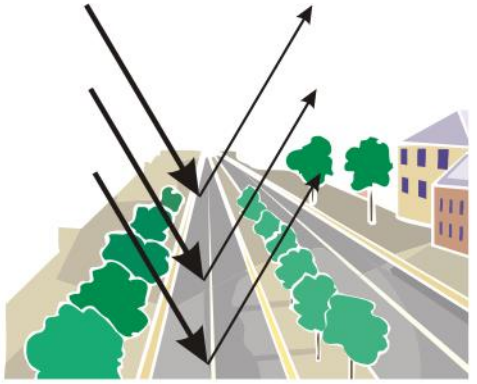
Interaction with the surface

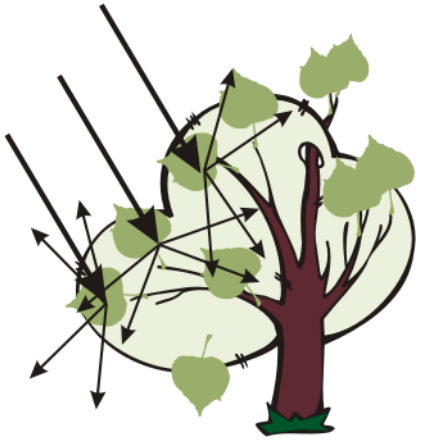
Spectral reflectance refers to the amount of reflectance in a specified wavelength range.

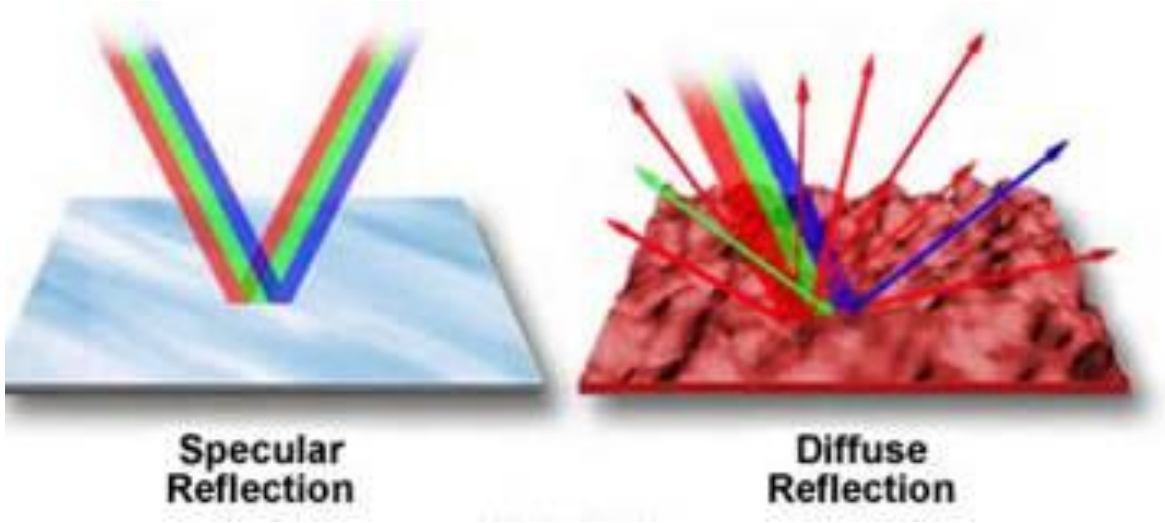
It depends on:

- the type of material
- the nature of the surface, particularly whether it is a rough surface or a smooth surface, diffuse and specular
- the wavelength of the incident radiation
- other factors, such as the slope of the surface, its condition …

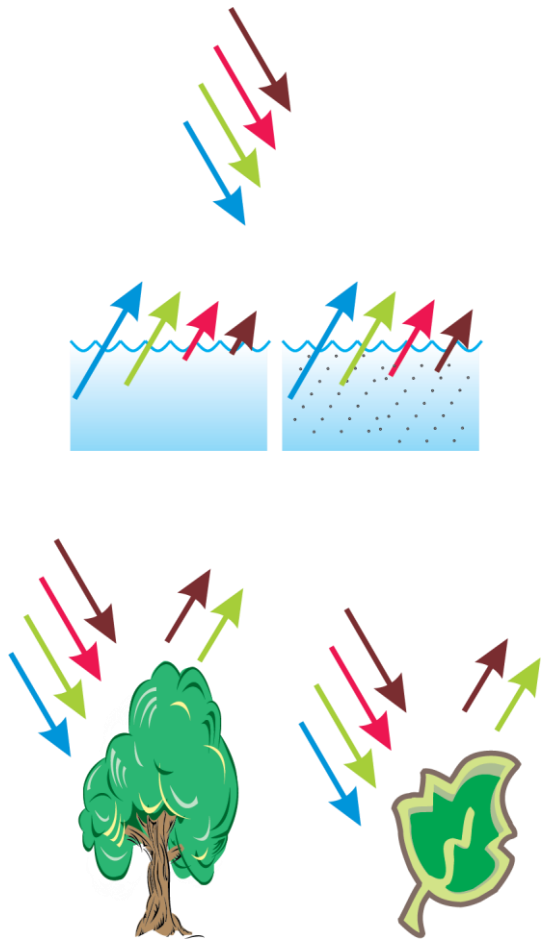
Specular and diffuse reflection

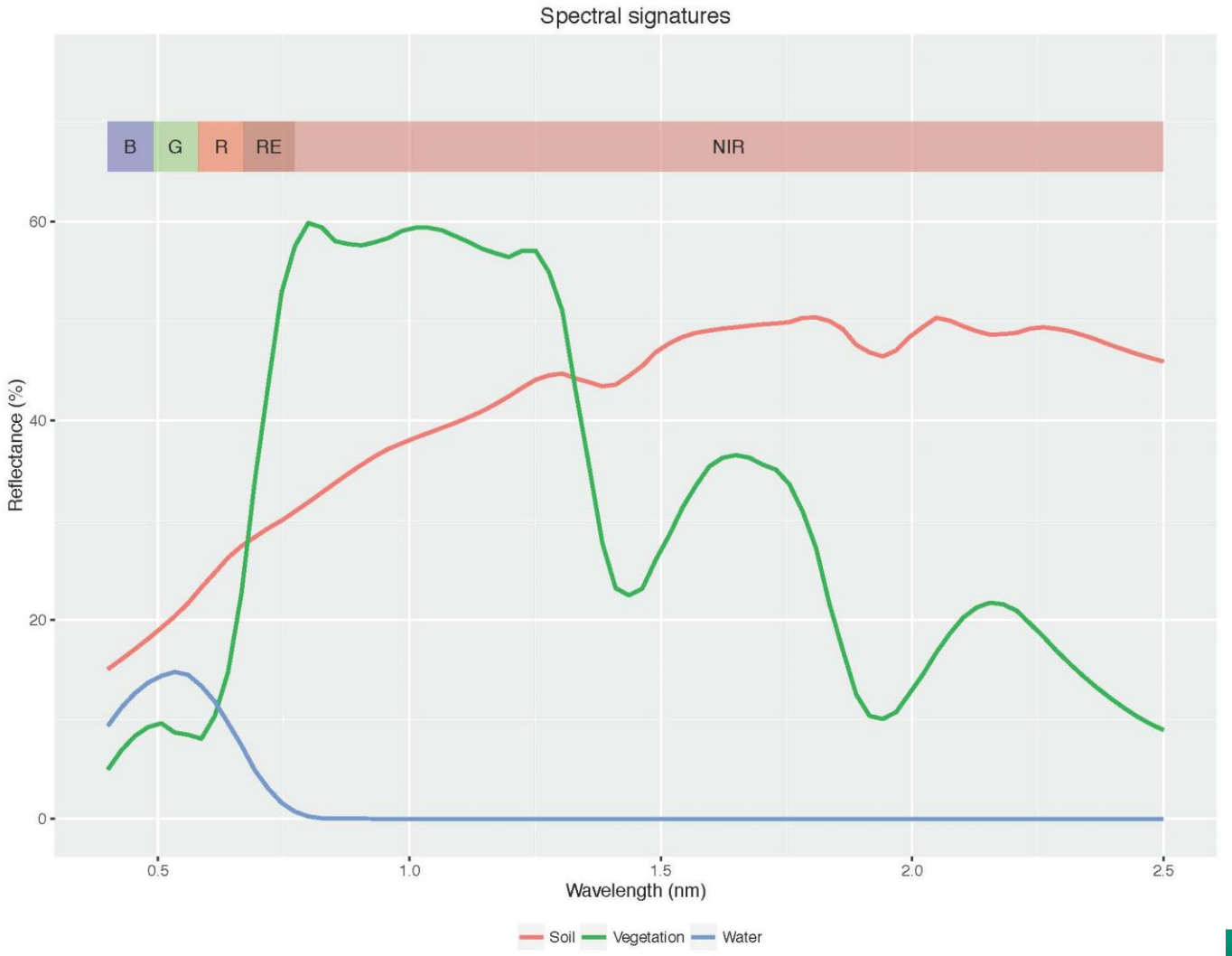




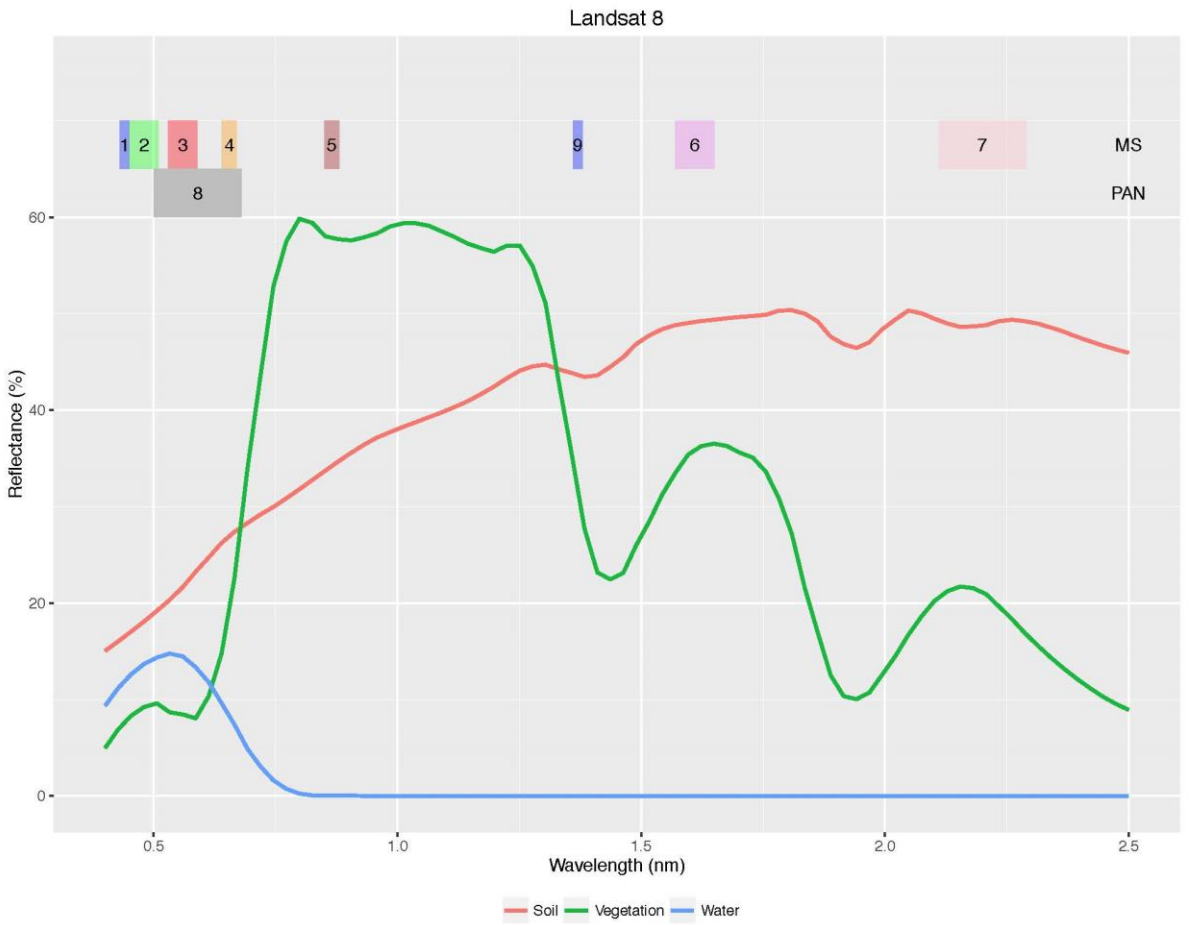


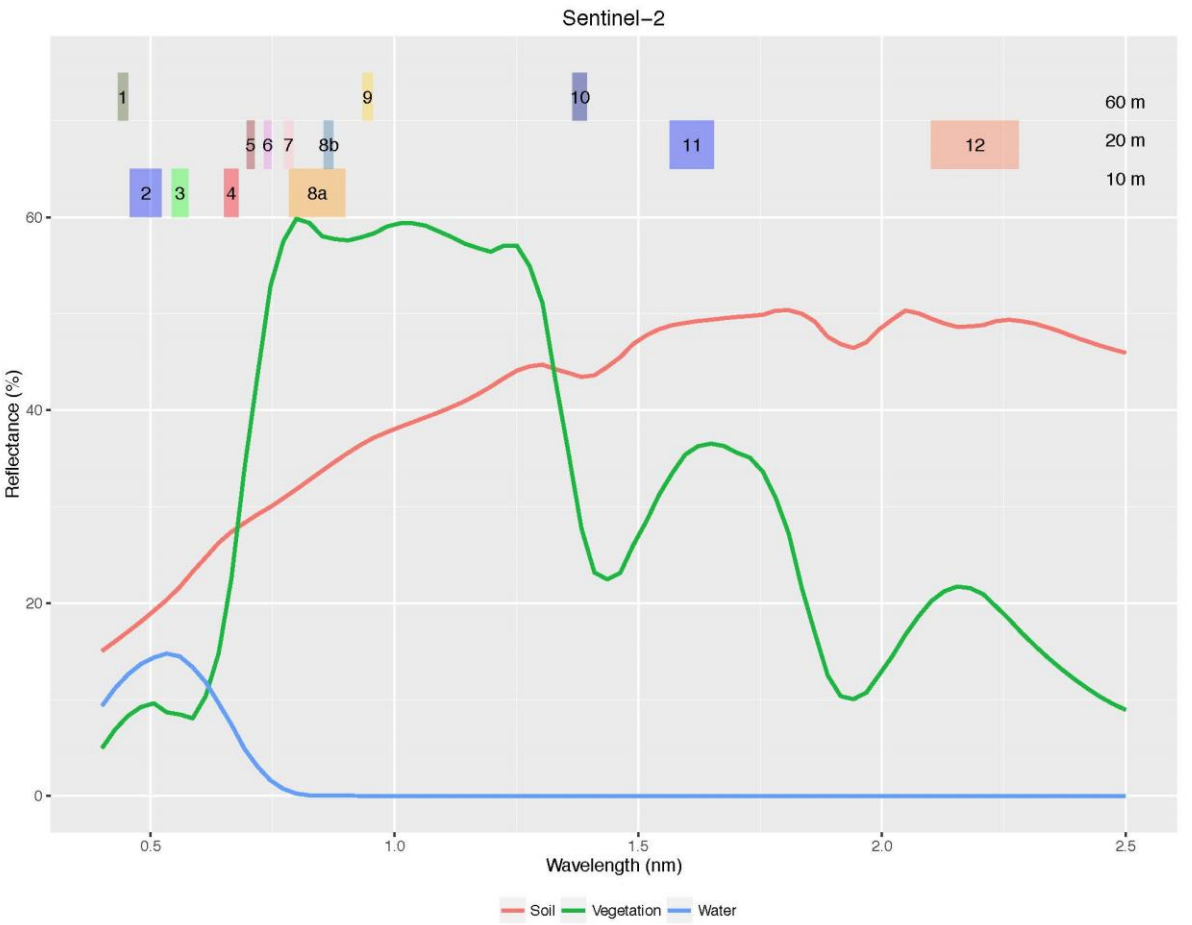
Interaction with vegetation and water





Landsat 8 and Sentinel-2 bands





Optical satellites

Optical satellites are passive

They use devices that are simples – lens and detectors

They observe the surface of the Earth across a varied spectrum of wavelengths

The number of spectral channels/bands and bandwidth is different

Optical imagery is more accessible and easier to interpret

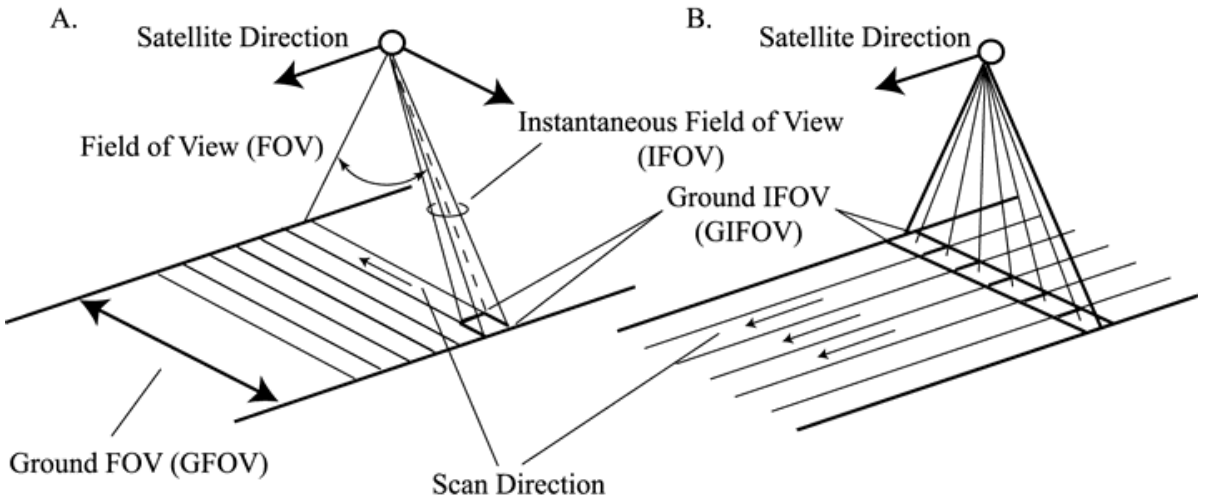
Optical scanners

Across track

- Landsat – up to 7

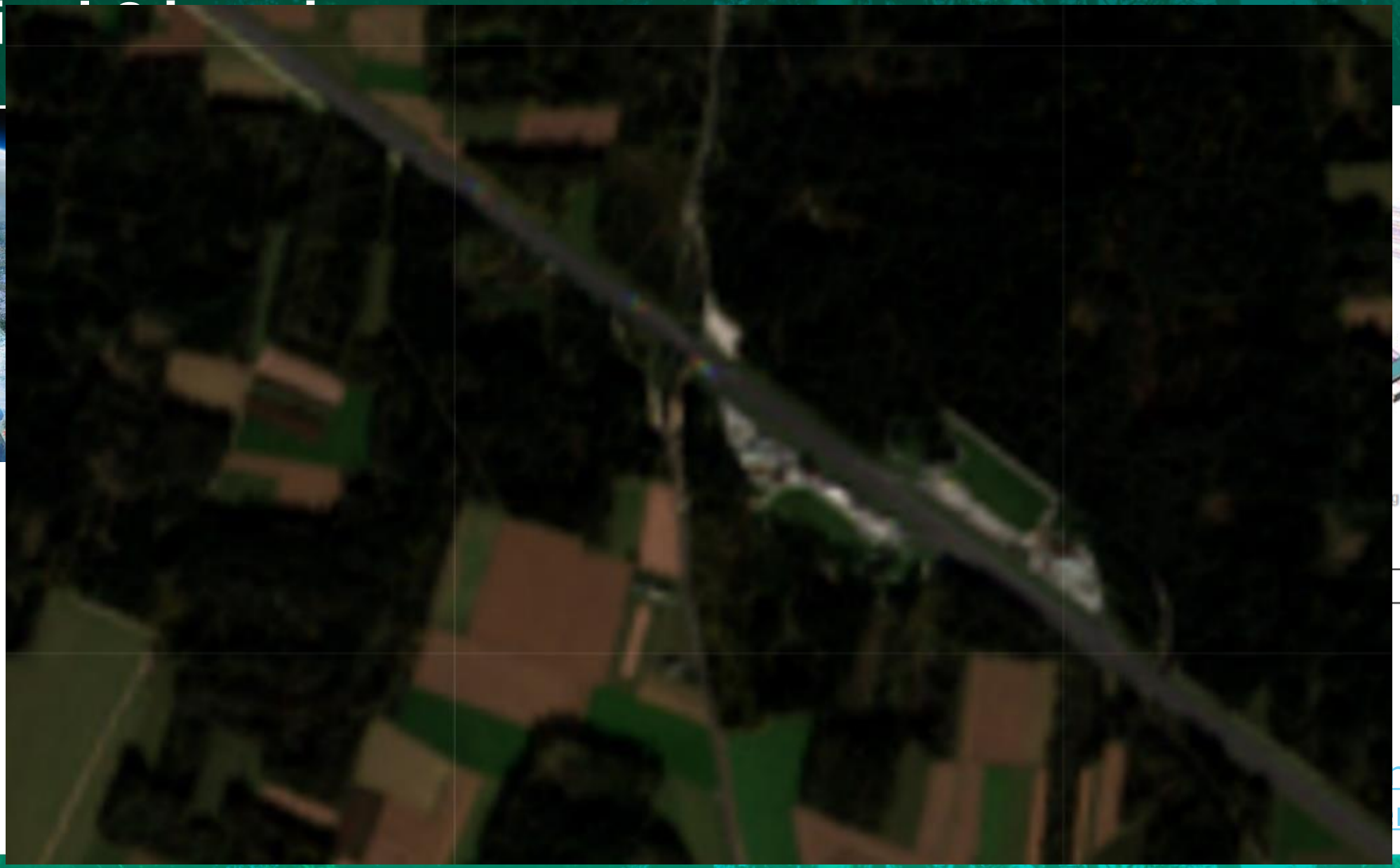
Along track

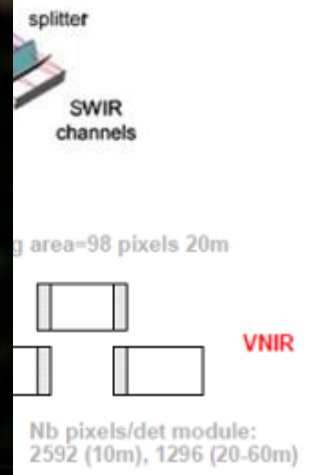
- All HR and VHR
- Sentinel-2
- Landsat 8



(18) (PDF) An introduction to satellite sensors, observations and techniques (researchgate.net)

Senti

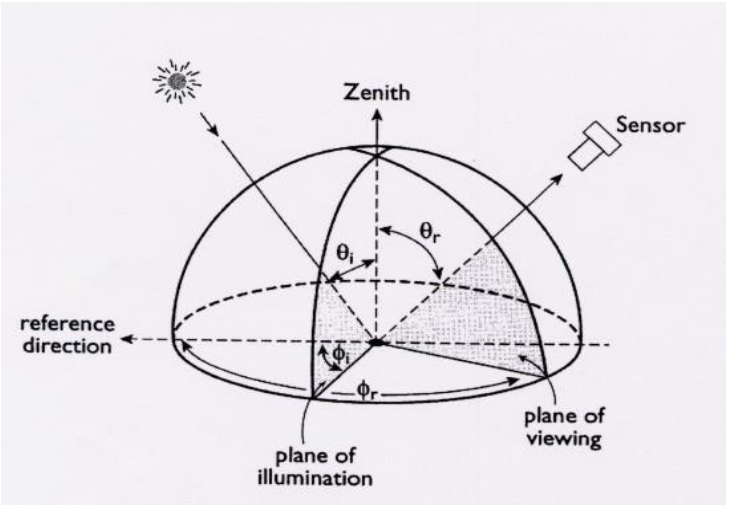


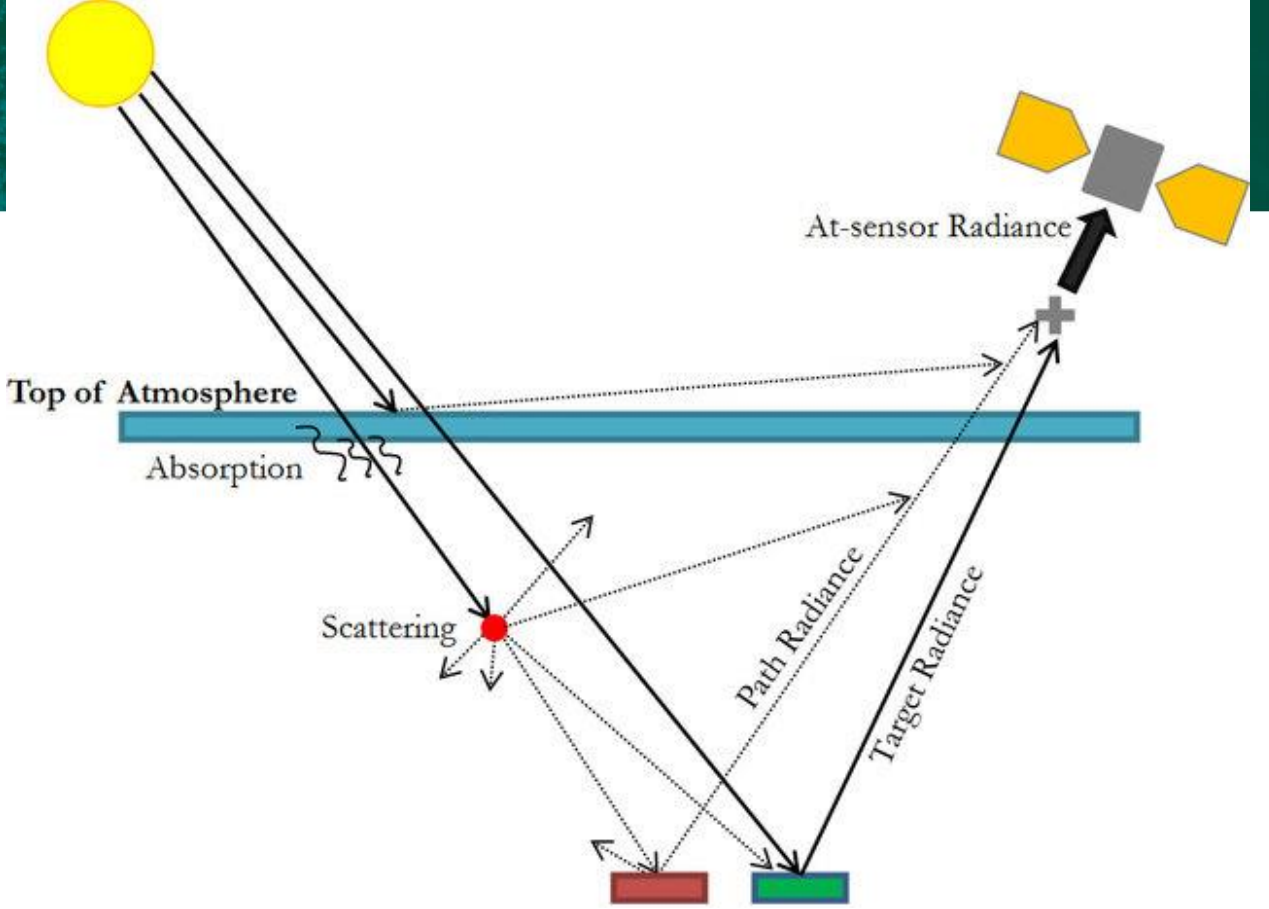


nical Guide –
rnicus.eu)

What is being measured?

The **quantity of radiation** passing through or emitted from a surface and falls **within a given solid angle** in a specified direction.

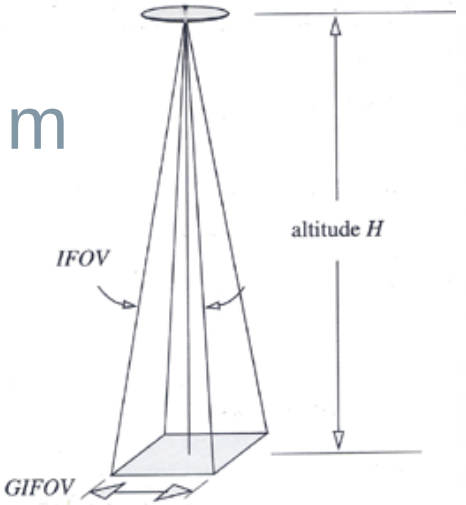


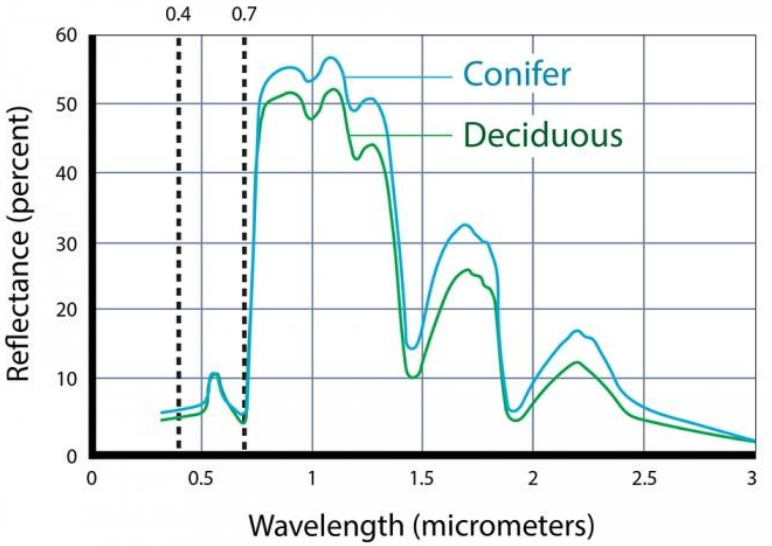


[PowerPoint Presentation (ucdavis.edu)]
[(18) (PDF) Estimation of PM10 Distribution Using Landsat5 and Landsat8 Remote Sensing (researchgate.net)]

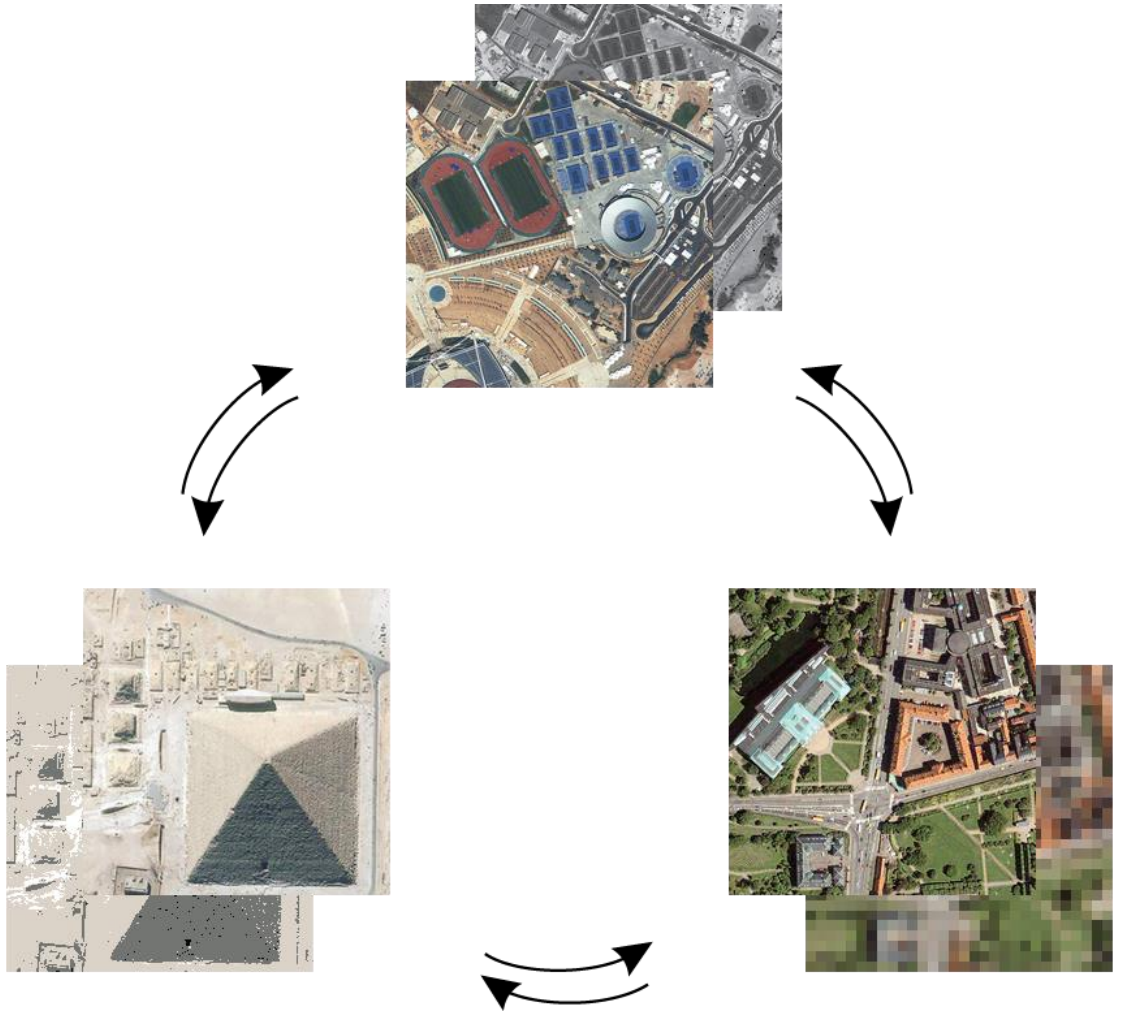
Resolution

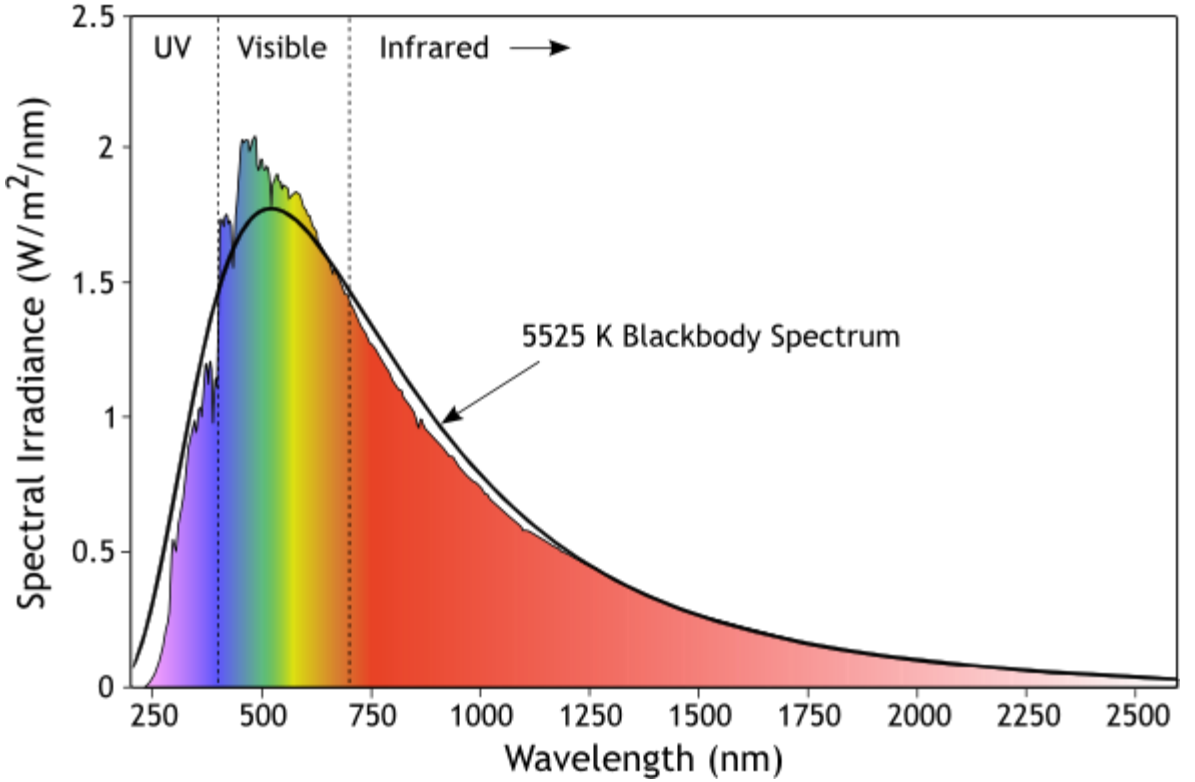
	Sentinel-2
Spatial resolution	10, 20, 60 m
Spectral resolution	13 bands
Radiometric resolution	12-bit
Temporal resolution	5 days





Selecting optimum resolution





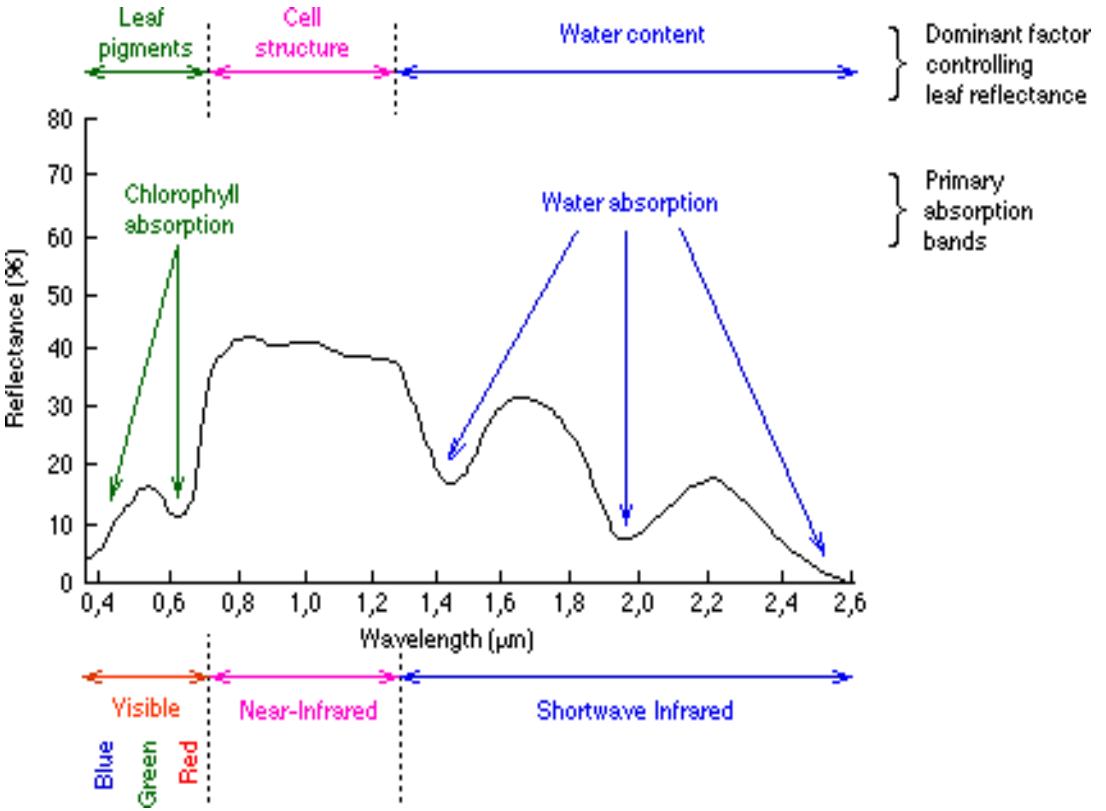
Vegetation Spectra

Particular wavelengths are sensitive to particular chemicals and compounds.

Result in absorption features.

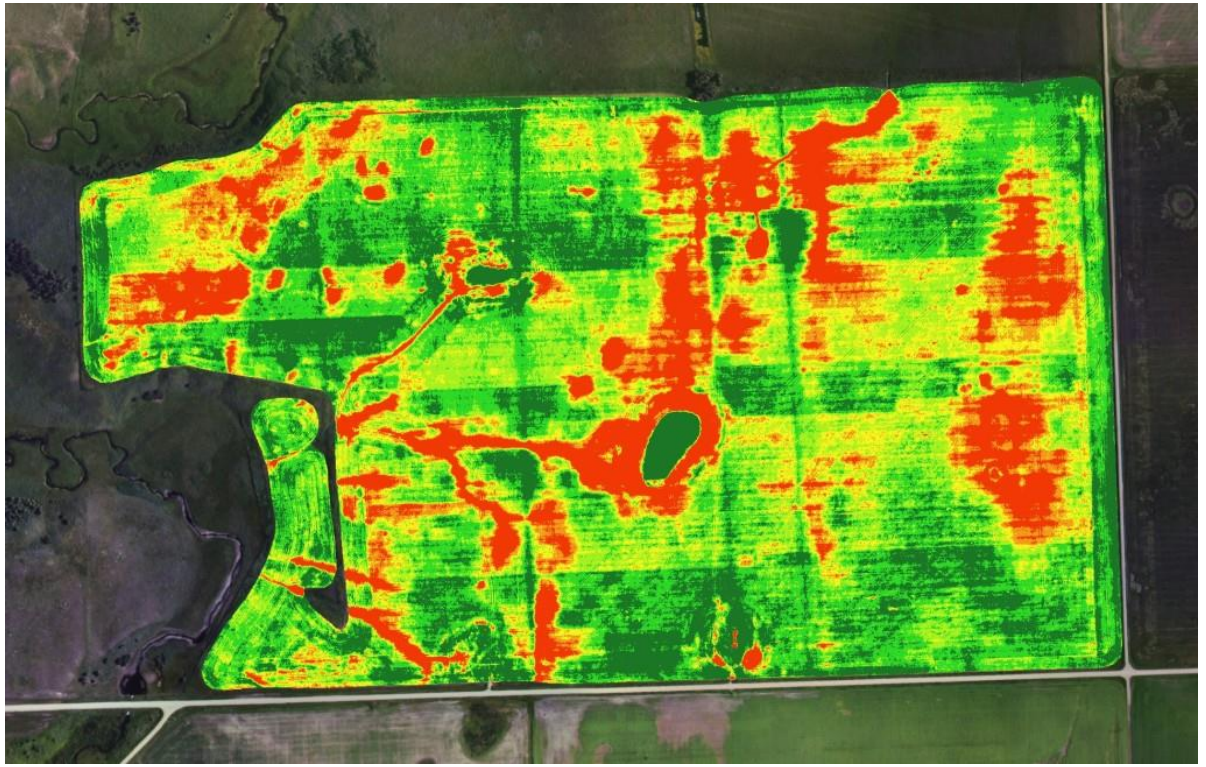
Make measurements related to those compounds.

Indices take advantage of these wavelength features.



Vegetation Indices

- VI - Vegetation Index
- NDVI - Normalized Difference Vegetation Index
- EVI - Enhanced Vegetation Index
- SAVI - Soil Adjusted NDVI
- AVI - Advanced Vegetation Index
- NDMI - Normalized Difference Moisture Index ...



IDB - Index DataBase

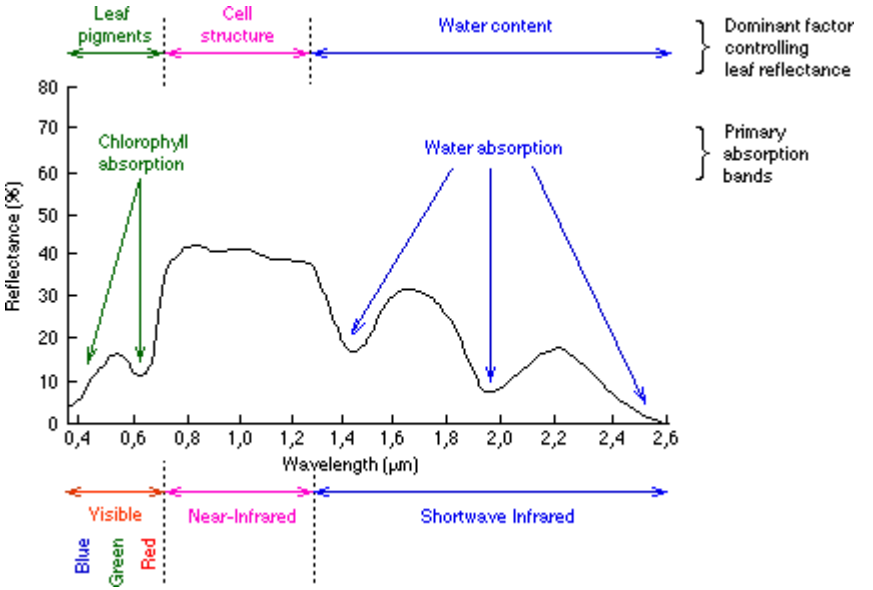
Normalised Difference Vegetation Index (NDVI)

Vegetation has high NIR and low Red reflectance.

Other land cover have NIR and Red which are much close together

$$NDVI = \frac{IR - R}{IR + R}$$

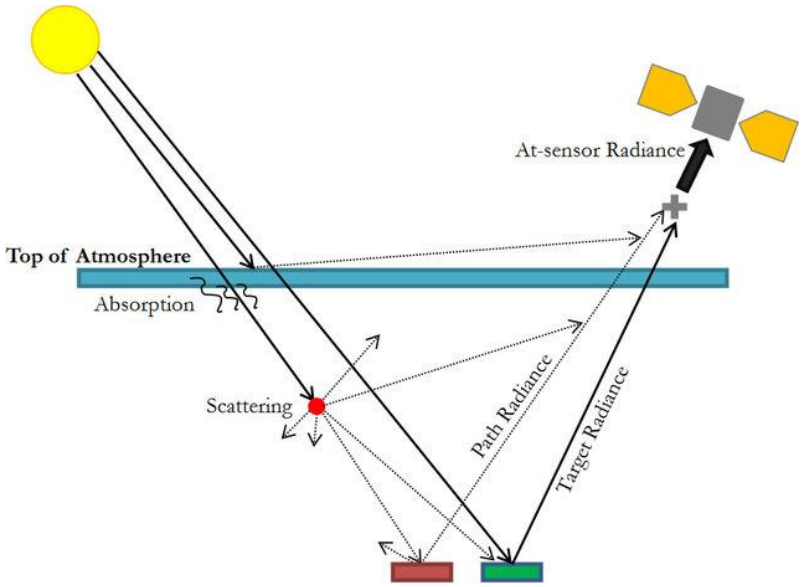
- -1.0 to +1.0
- vegetation from 0.3 to 0.8, depending on health/intensity
- water (sea, lakes, rivers) low positive or even negative
- bare floor low positive values from 0,1 to 0,2



Retrieval of Surface Reflectance

We want to use a surface reflectance

- Allows comparison between images
- Allows repeatable measurements
- Represents a physical unit



To retrieve surface reflectance we need to 'add back' the component 'lost' in the atmosphere.

At Sensor Refl = Surface Refl + Atmospheric Refl

What is in the atmosphere?

Aerosols

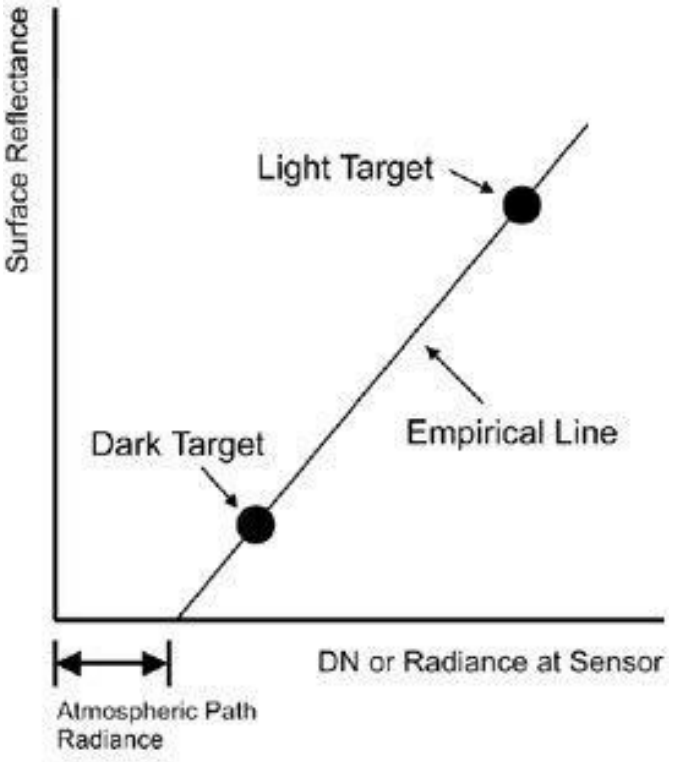
- E.g., fine dust, sea salt, water droplets, smoke, pollen, spores, bacteria
- Has a significant effect on the visible wavelengths (Blue, Green and Red)
- Aerosol Optical Depth (AOD)
- Aerosol Optical Thickness (AOT)

Water Vapour

- Particularly effects the SWIR bands

Options for Atmospheric Correction

- Empirical Line Calibration
- Dark Object Subtraction
- Modelled Atmosphere



Modelled Atmosphere

Aerosol Optical Depth

Amount and proportion of aerosols within the atmosphere

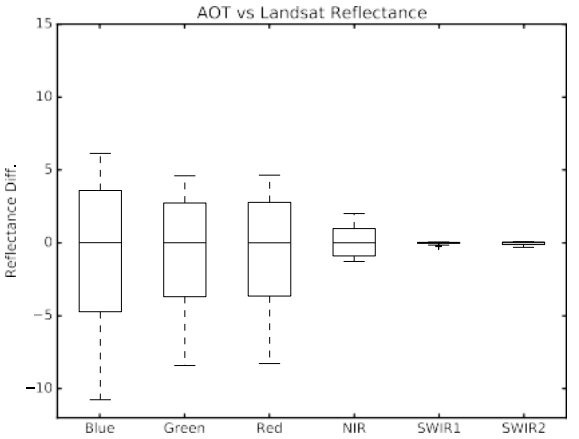
Varies over small spatial distances and temporal baselines.

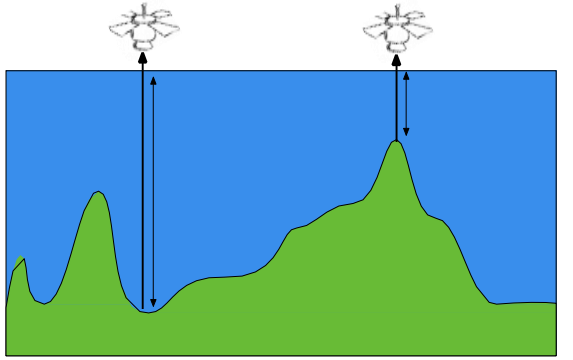
Water Vapour

Amount within the vertical column

Surface Elevation

Thickness of the atmosphere



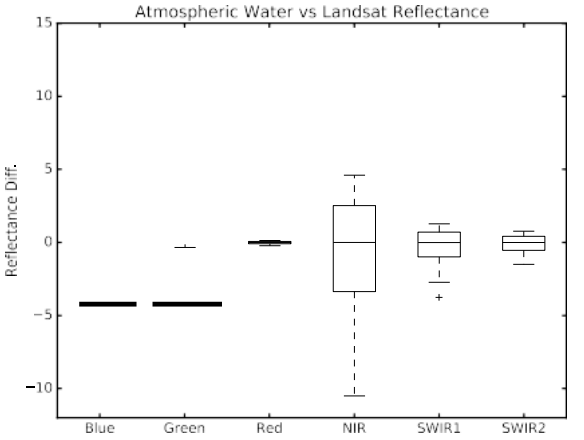


Relative contributions:

AOT = 80 %

Water Vapour = 15 %

Altitude = 4 %



Modelled Atmosphere

Use an atmospheric radiative transfer model to calculate the amount of atmospheric reflectance to be removed from the TOA to get surface reflectance.

Number of models are available but the main two are:

- MODTRAN (Commercial)
  - http://modtran.spectral.com/
- 6S (Open Source)
  - https://salsa.umd.edu/6spage.html

Available Software Tools

Software	RT Model	Sensors	License	URL
ATCOR-4 (Airborne)	MODTRAN	Many – see website	Commercial	https://www.rese-apps.com/software/atcor-4-airborne
ATCOR-3 (Satellite)	MODTRAN	Many – see website	Commercial	https://www.rese-apps.com/software/atcor-3-satellites
FLAASH	MODTRAN	Many – see website	Commercial	http://www.harrisgeospatial.com/docs/FLAASH.html
LEDAPS	6S	Landsat (TM, ETM+)	Partly Open Source	http://ledaps.nascom.nasa.gov
Sen2Cor	MODTRAN	Sentinel-2	Partly Open Source	http://step.esa.int/main/third-party- plugins-2/sen2cor/
ARCSI	6S	Landsat (MSS, TM, ETM+,OLI), Rapideye, SPOT5, SPOT6, SPOT7, WorldView-2, Sentinel-2	Open Source	http://arcsi.remotesensing.info

Sen2Cor

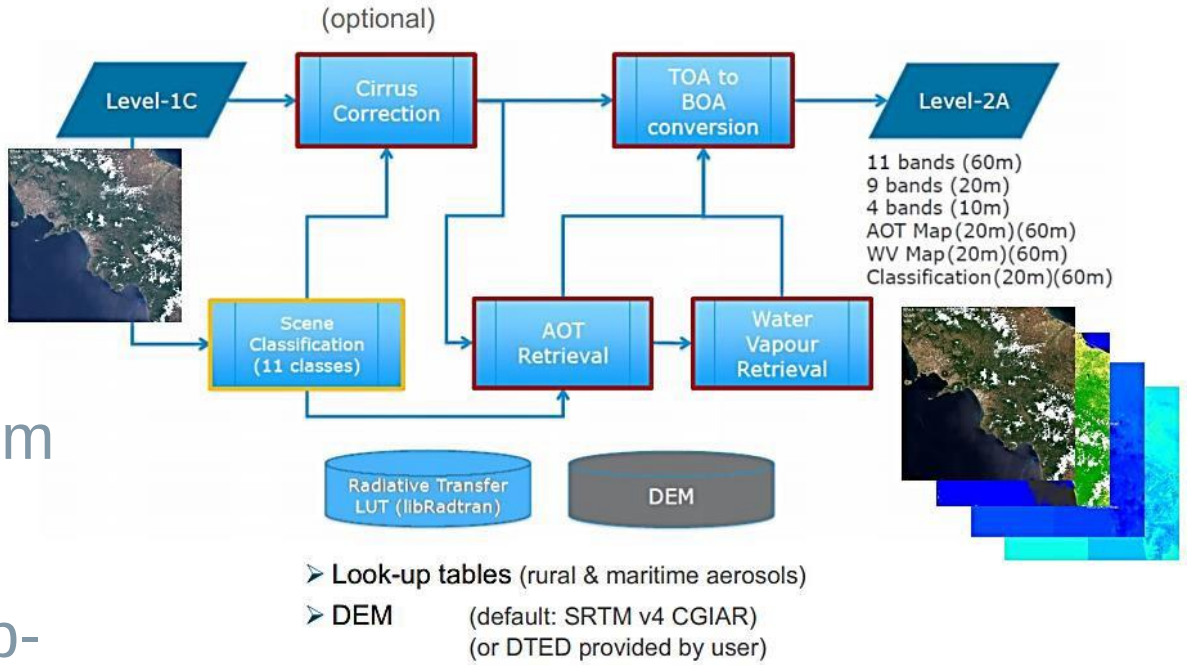
Single image processing algorithm with orthorectified L1C granule in input

Cloud Screening and Classification

Atmospheric Correction over land surface (from ATCOR DLR)

Radiative Transfer code: LibRadtran (Look-Up-Tables)

Python application, as command line tool, plug-in of S2 toolbox, and integrated in S2 Ground Segment



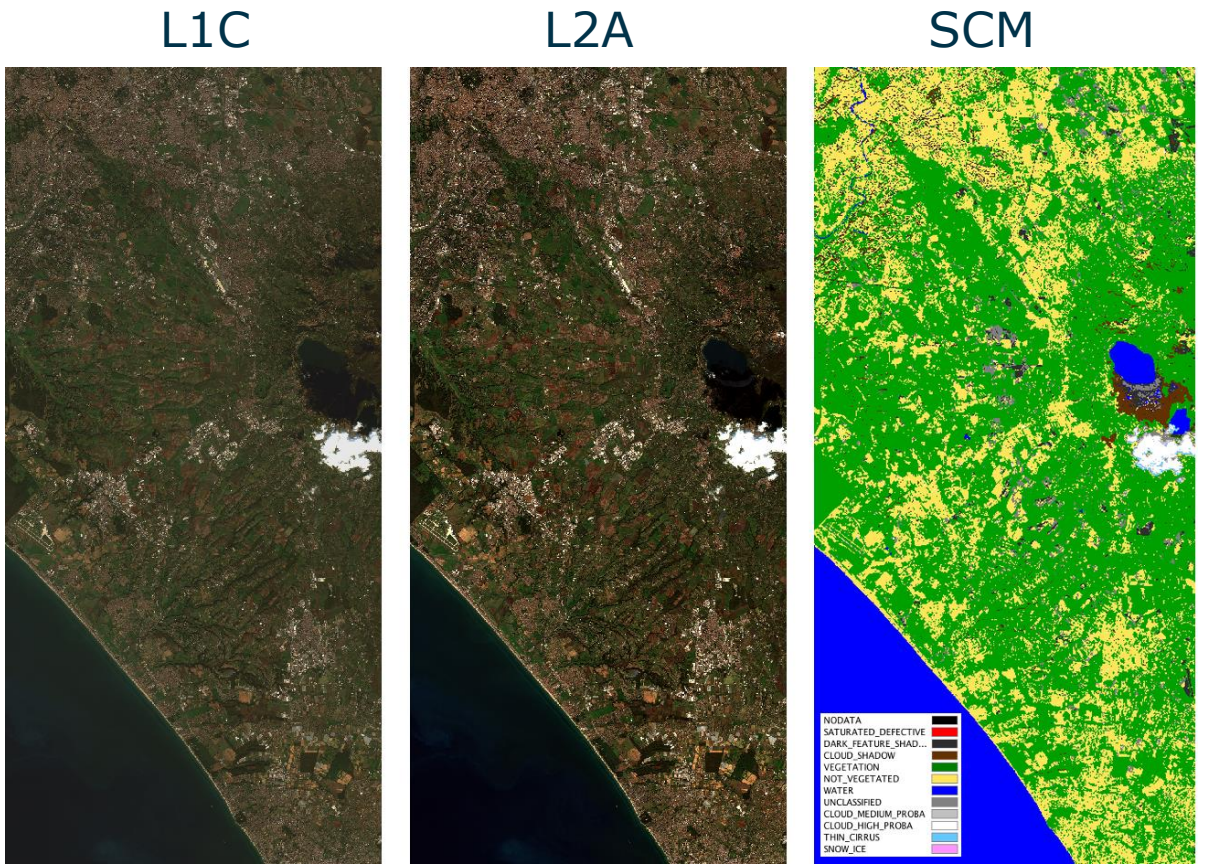
Sentine-2 Level 2 Data

Level-2A main output is an orthoimage Bottom-Of-Atmosphere (BOA) corrected reflectance product.

Aerosol Optical Thickness (AOT)

Water Vapour (WV)

Scene Classification Map (SCM)



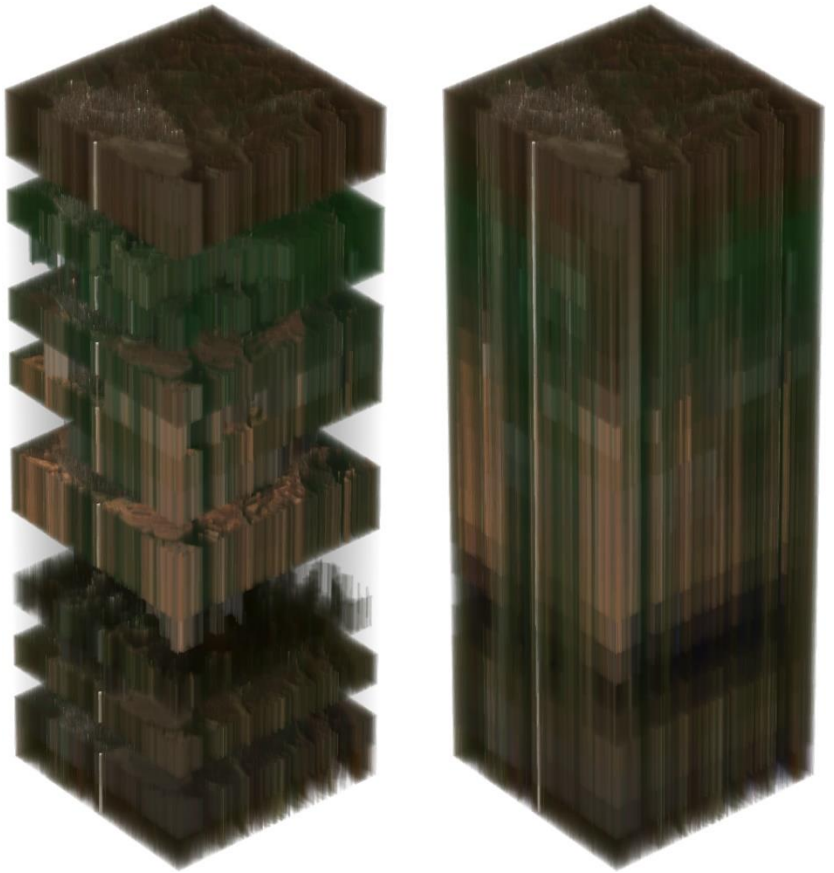
Time series

Set of satellite images taken over the same area of interest at different times

Same or multiple sensors

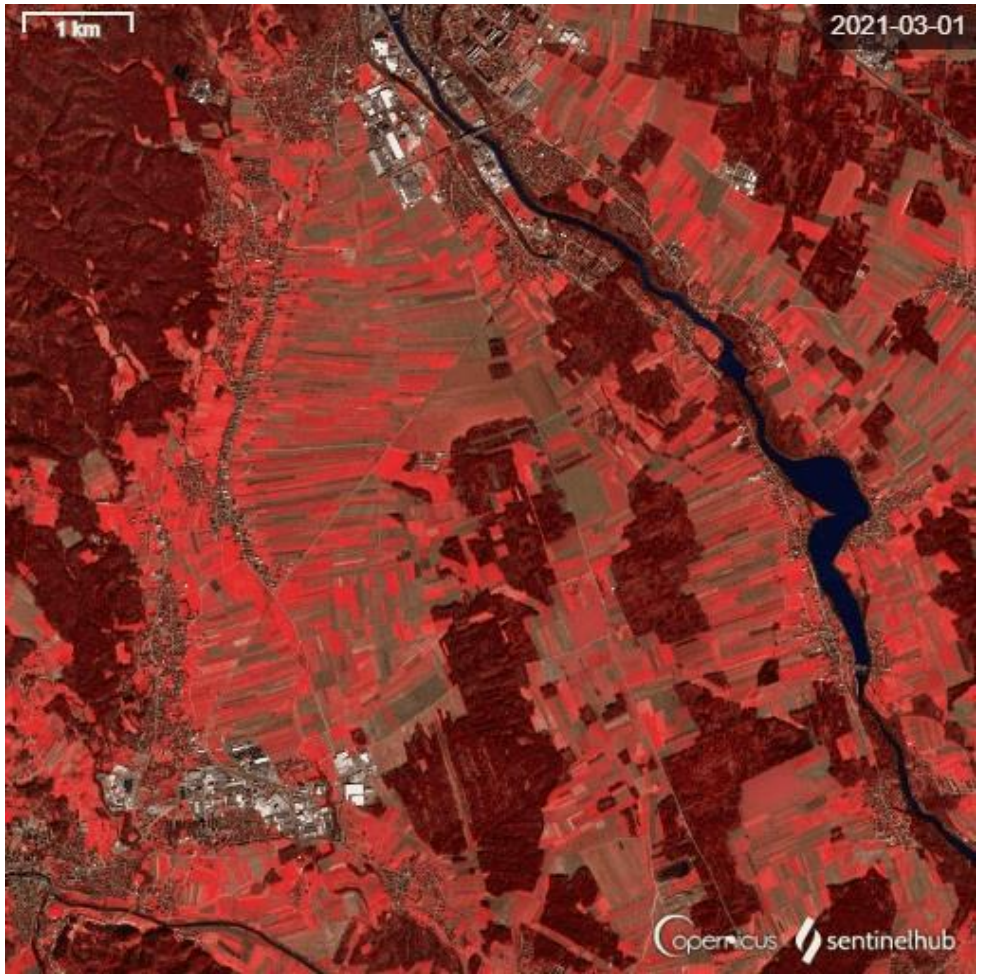
Time Series of Satellite observations offer opportunities:

- for understanding how Earth is changing
- for determining the causes of these changes
- for predicting future changes
- for discriminating features



[Land Cover Classification with eo-learn: Part 2 | by Matic Lubej | Sentinel Hub Blog | Medium]

Time series


1 km
2021-03-01
Copernicus
sentinelhub

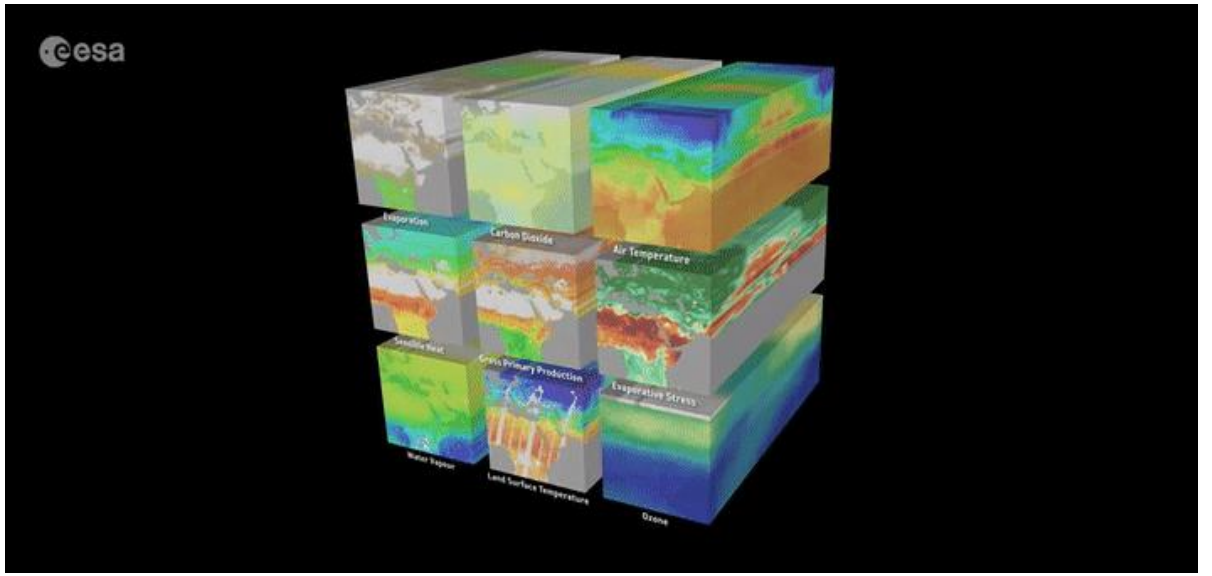

1 km
2021-03-01
Copernicus
sentinelhub

Analysis Ready Data (ARD)

CEOS – Committee on Earth Observation Satellites:

Analysis Ready Data are satellite data that have been processed to a minimum set of requirements and organized into a form that allows immediate analysis with a minimum of additional user effort and interoperability both through time and with other datasets.

Data which is ready to use.

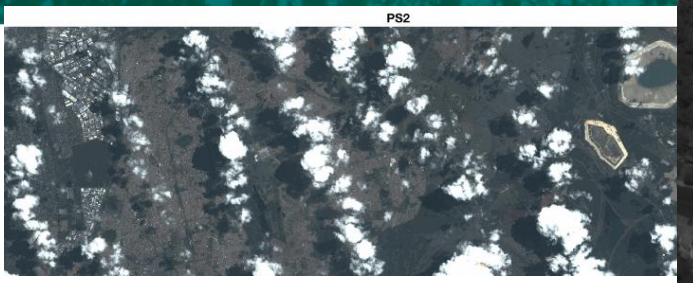


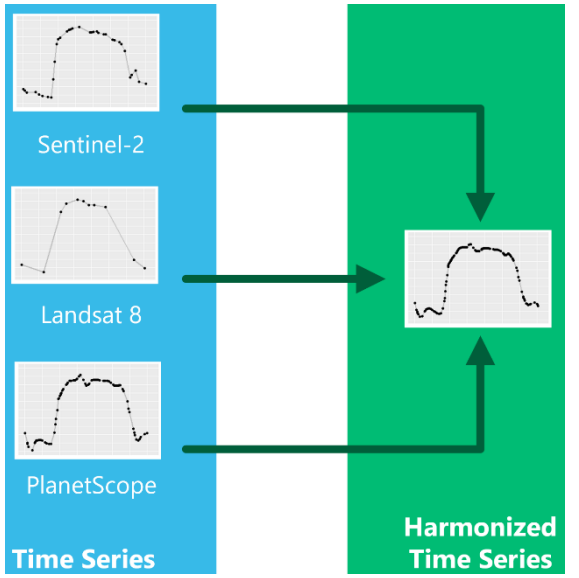
[CEOS Analysis Ready Data]
[Analysis Ready Data Defined. Cloud Native Geoprocessing Part 2 | by Chris Holmes | Planet Stories | Medium]
[Harness the power of Sentinel Hub, xcube, EOxHub, GeoDB and more in Euro Data Cube | by Dorothy Rono | Euro Data Cube | Medium]

Analysis Ready Data (ARD)

ARD processing may differ between applications

- Image clipping
- Masking – Usable/Unusable Data Masks
- Atmospheric Correction
- Pixel Alignment
- Sensor Alignment





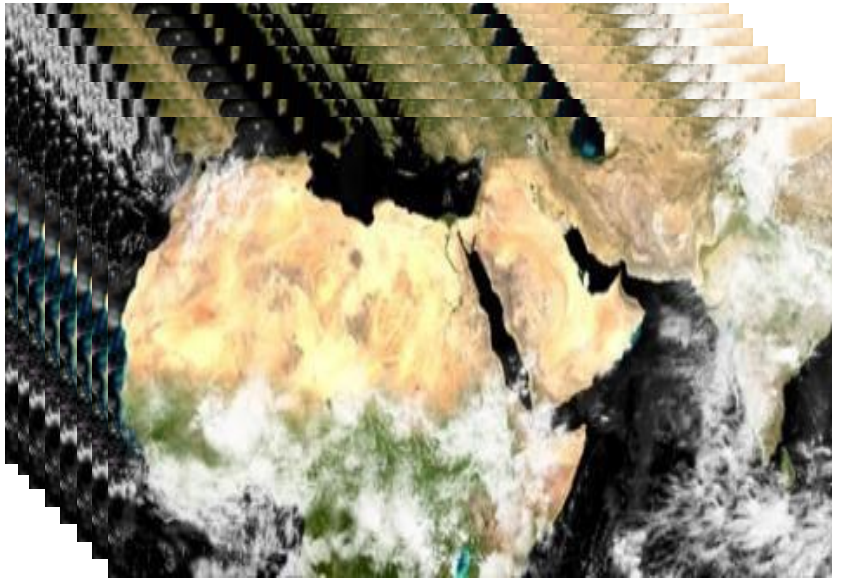
[Analysis Ready Data Defined. Cloud Native Geoprocessing Part 2 | by Chris Holmes | Planet Stories | Medium]

Compositing

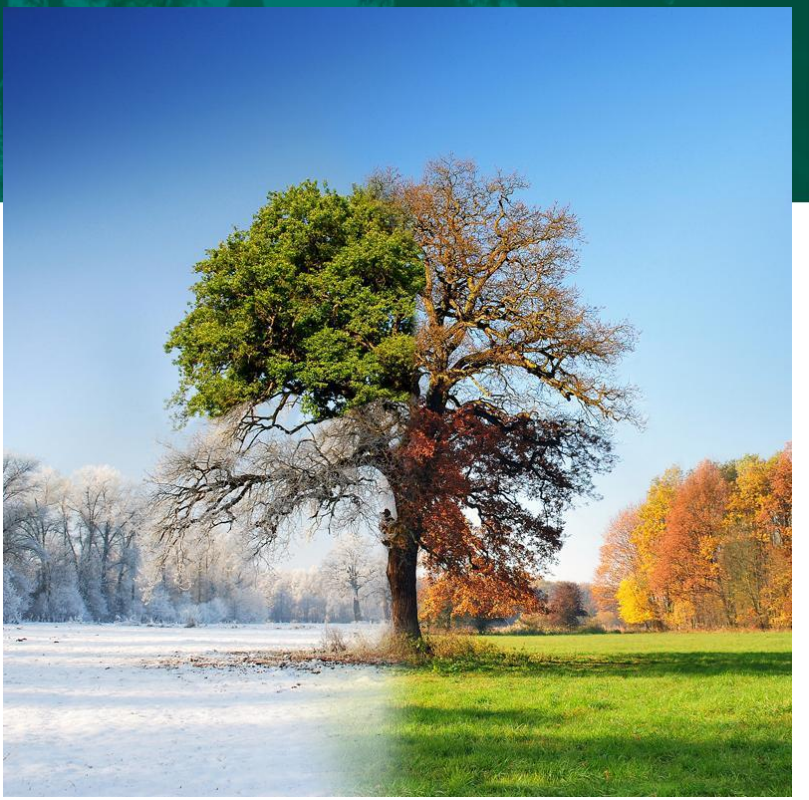
An image where the holes associated with cloud and other invalid pixels are filled with data from another images.

Weekly, Monthly, Yearly …

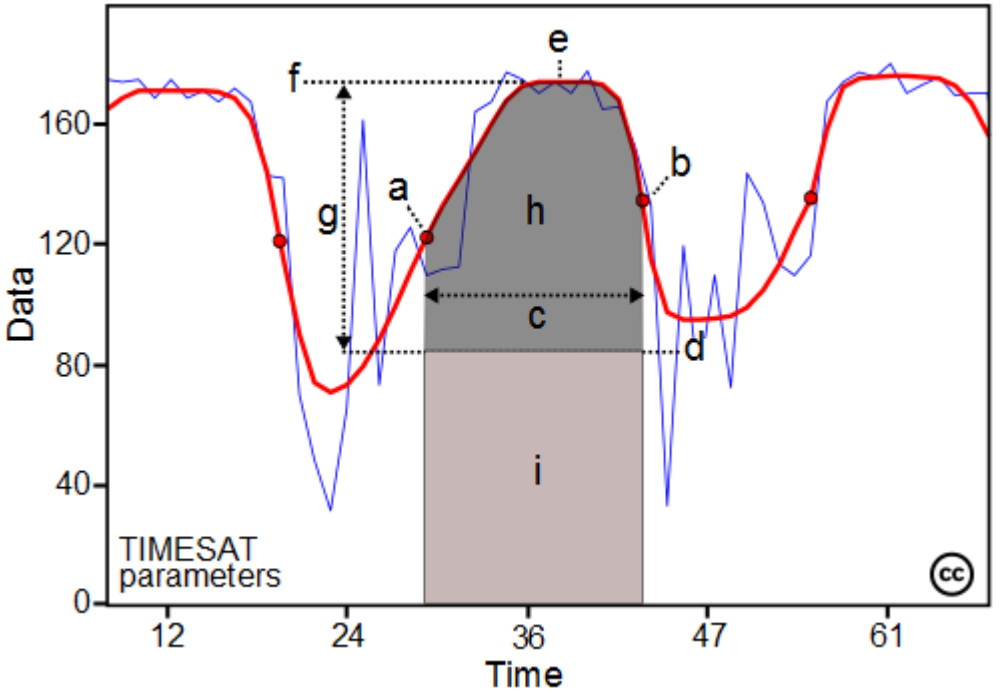
Compositing produces images with added value, but can mask important information.



Temporal development of vegetation

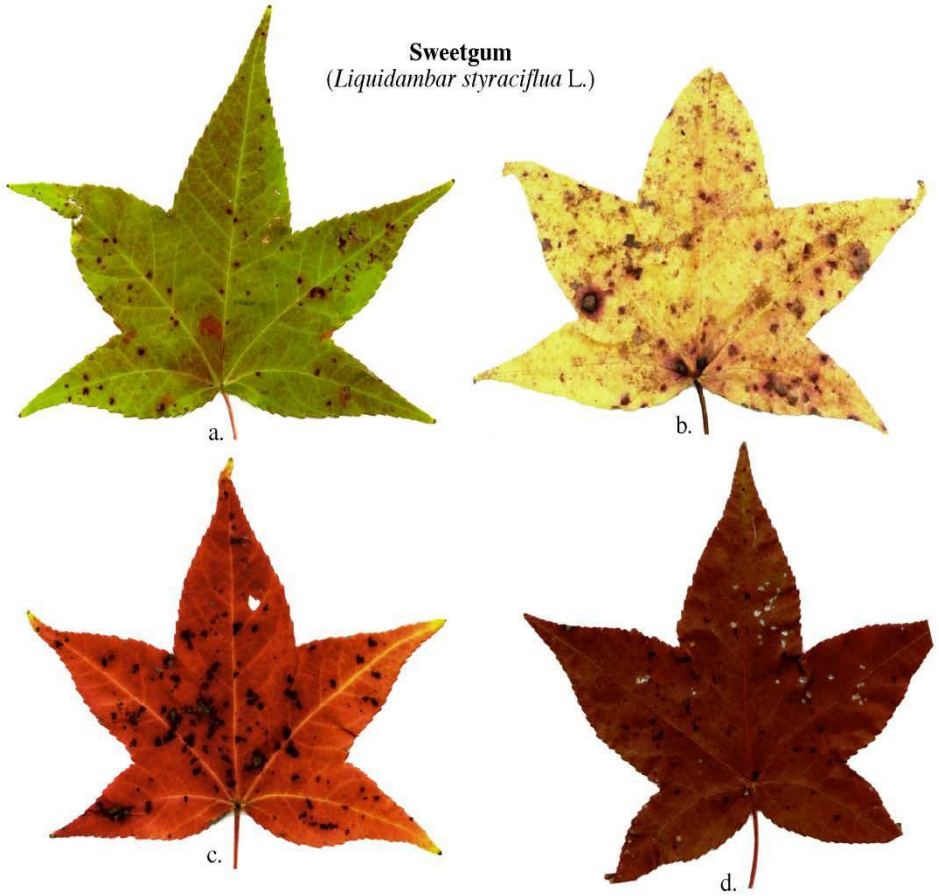


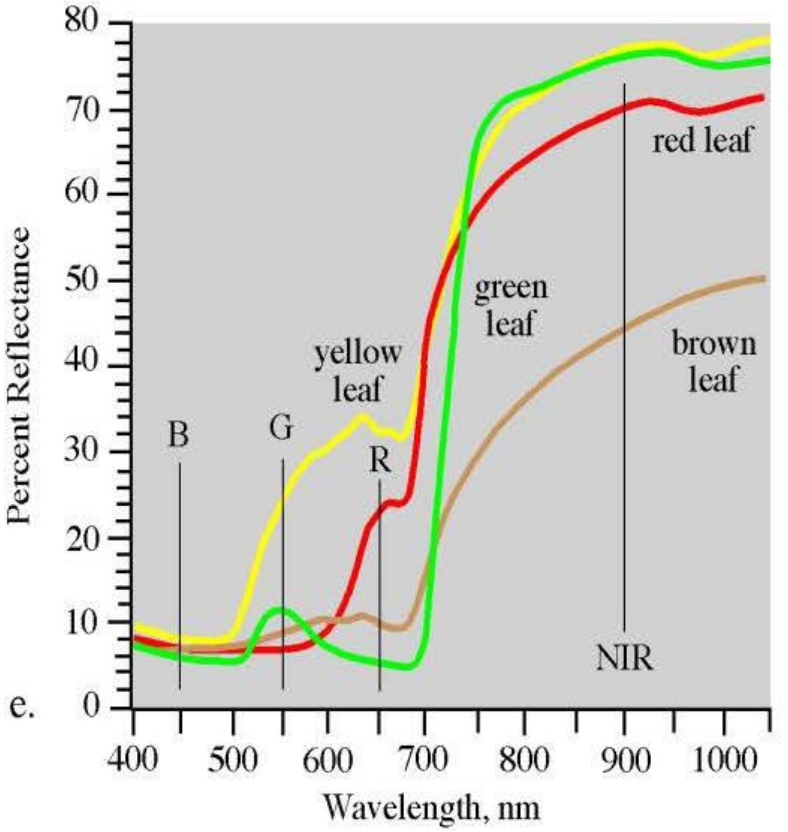
(a) beginning of season
(b) end of season
(c) length of season
(d) base value
(e) middle of season
(f) maximum value
(g) amplitude



[Welcome to the TIMESAT pages! (lu.se)]

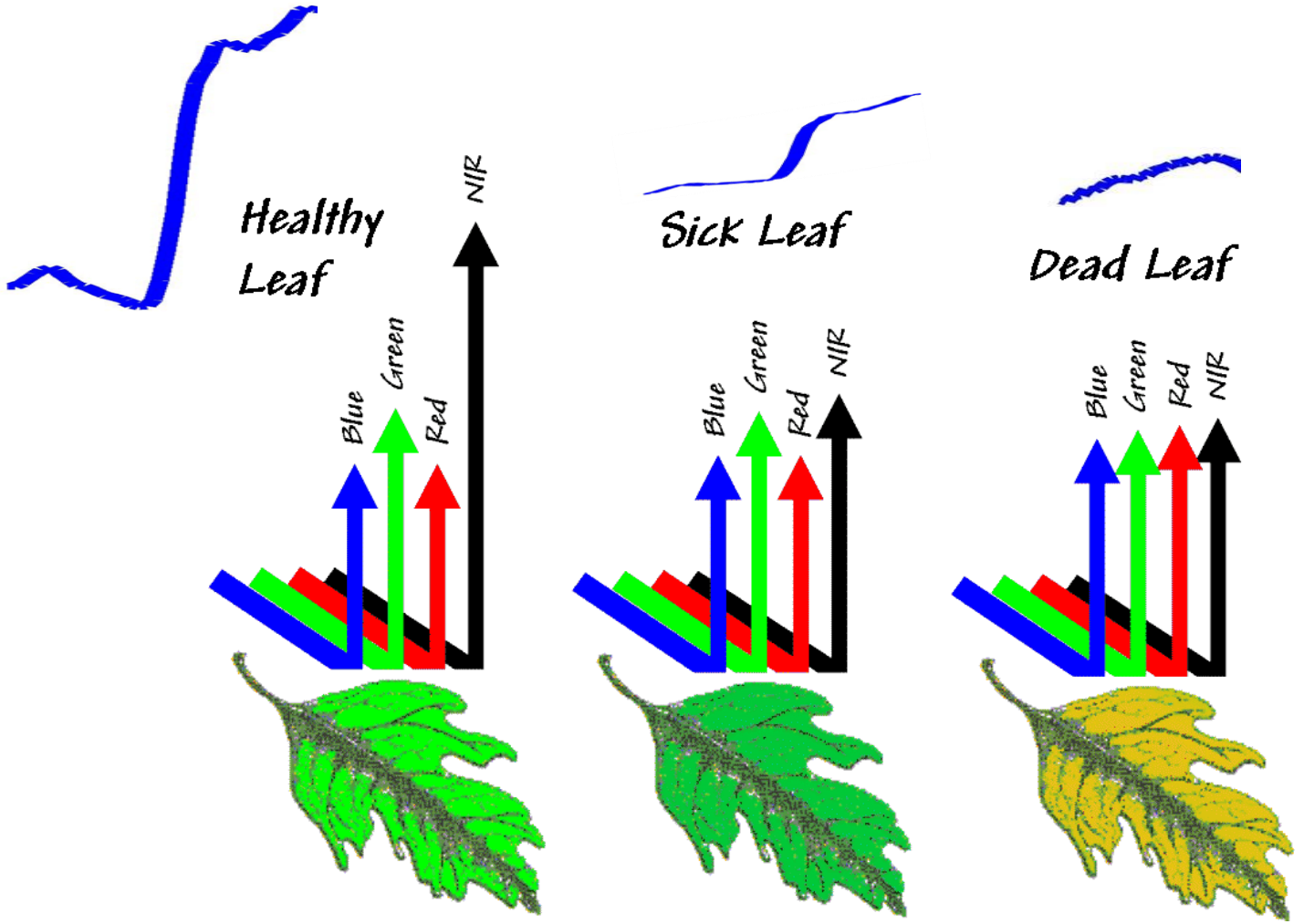
Sweetgum Leaves (Liquidambar styraciflua L.)



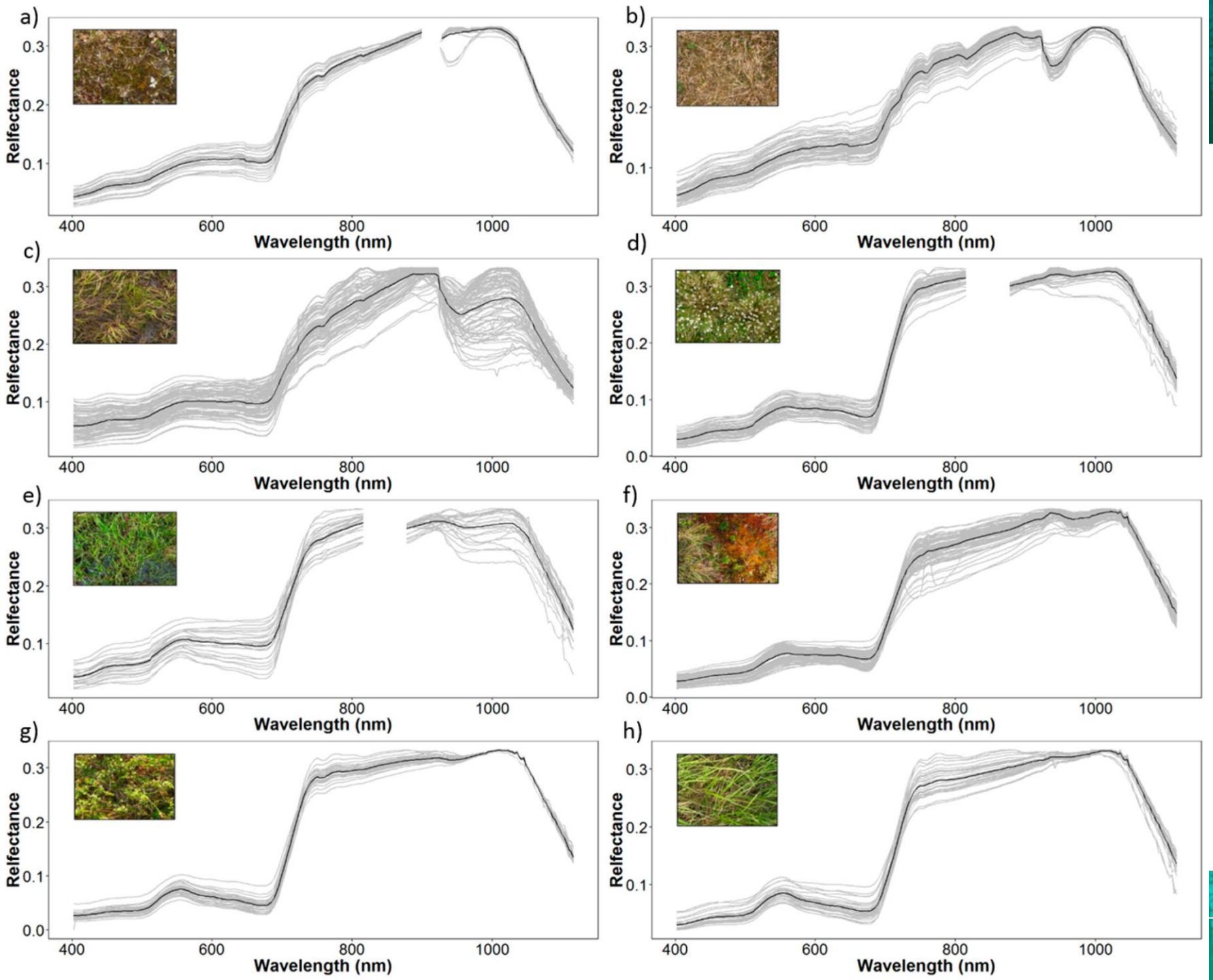


[PowerPoint Presentation (ucdavis.edu)]

Reflectance with Leaf Health

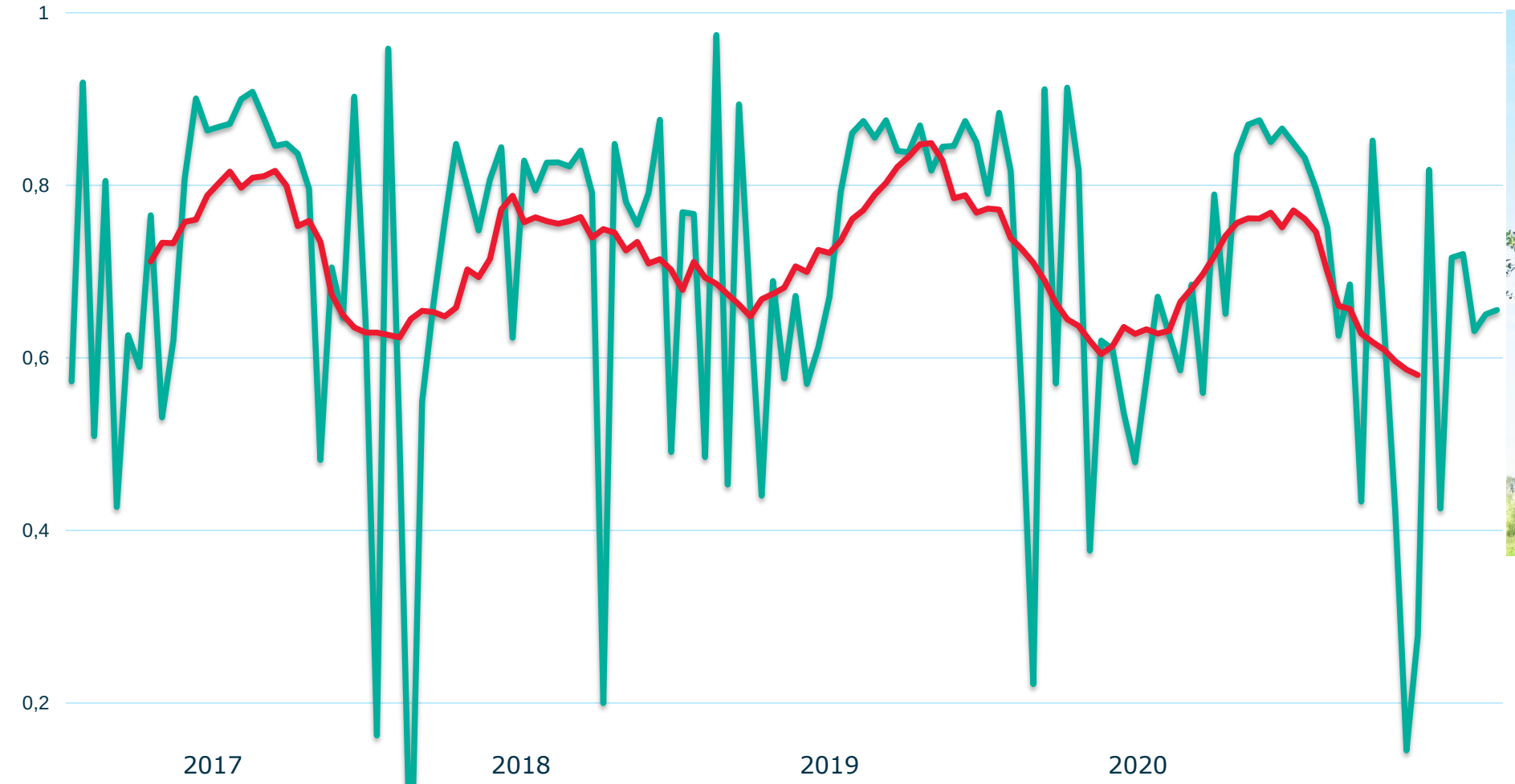


PowerPoint Presentation (ucdavis.edu)

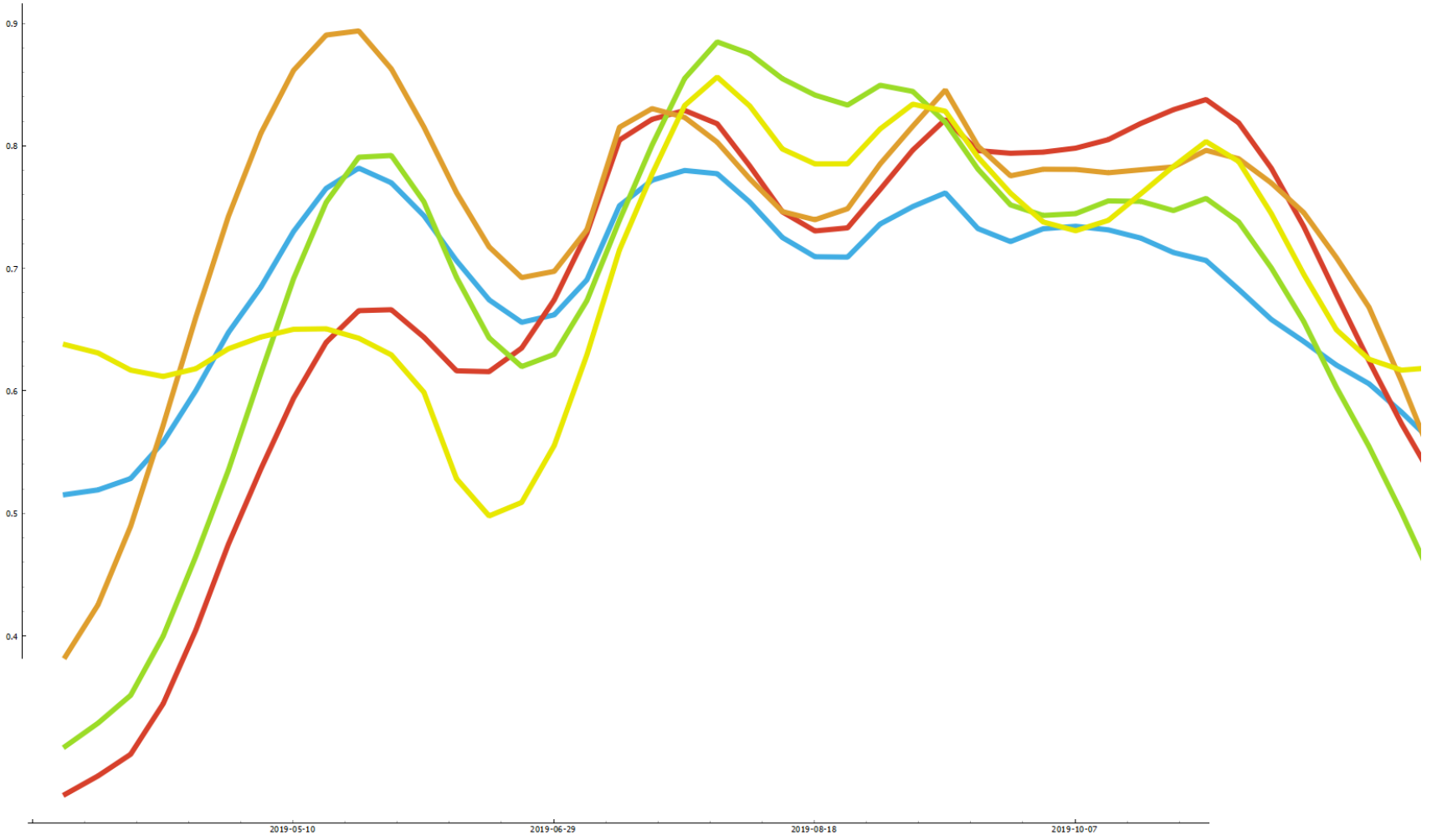


[Remote Sensing | Free Full-Text | Mapping Arctic Tundra Vegetation Communities Using Field Spectroscopy and Multispectral Satellite Data in North Alaska, USA | HTML (mdpi.com)]

Beech – Multiyear development



Different tree types



pine

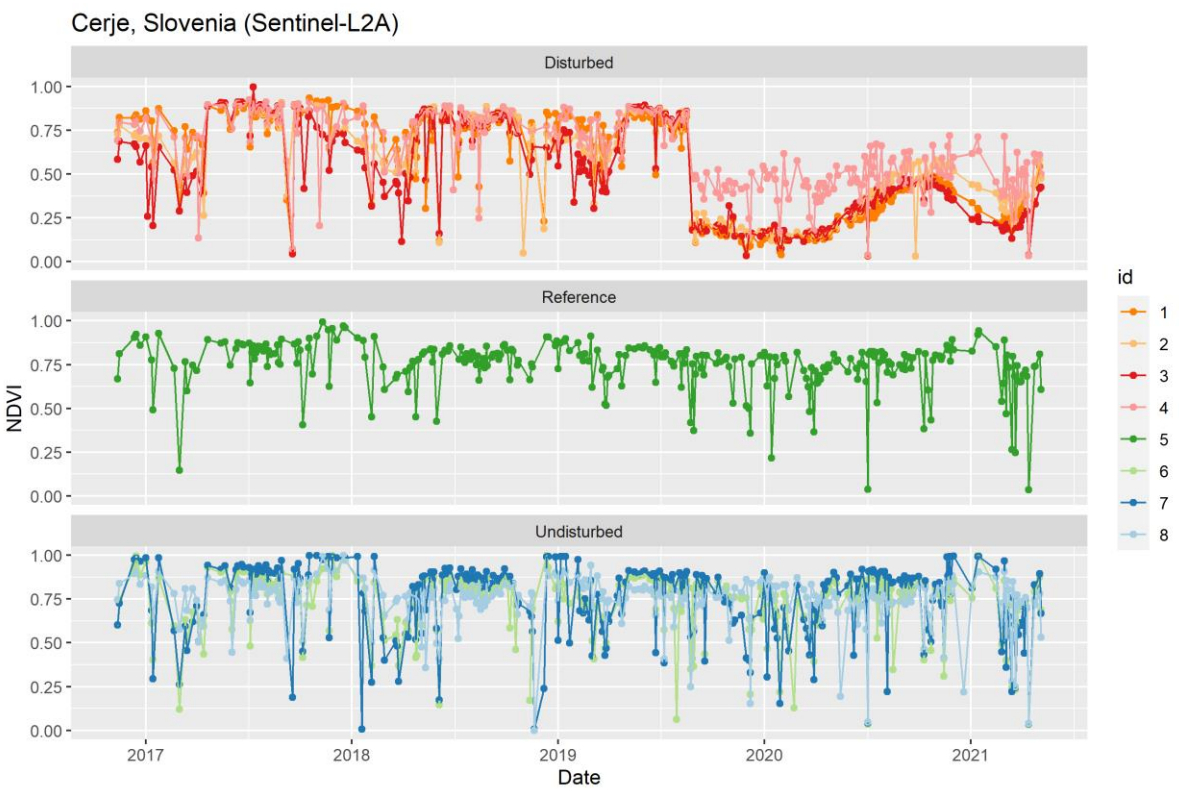
beech

oak

robinia

spruce

Disturbances



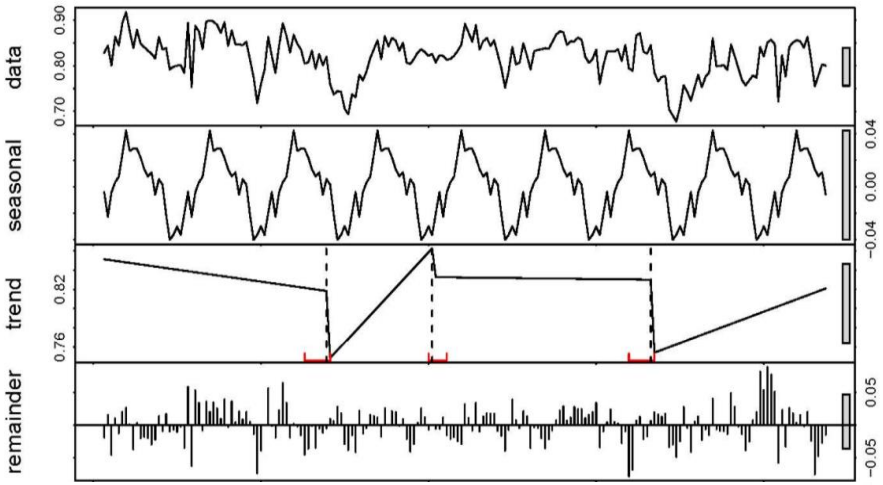
Long Term Satellite Image Time Series

Identify changes over time with long term satellite data sets

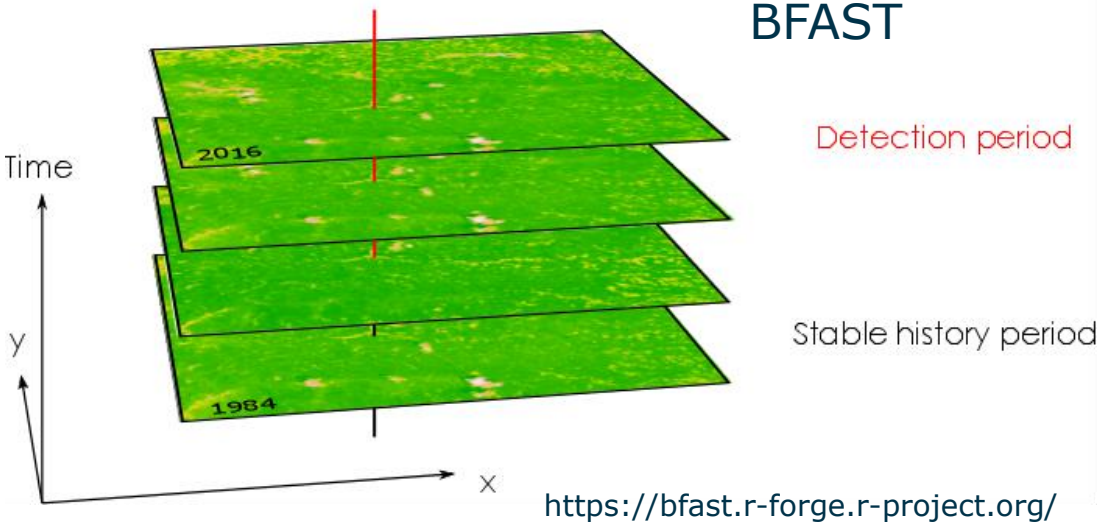
Normalised Difference Vegetation Index (NDVI) as an input variable

Time series processing methods and algorithms

Temporal changes in trend and seasonal components, breakpoint detection



BFAST



https://bfast.r-forge.r-project.org/

Conclusions

We have dense (weekly, multispectral) time series from multiple satellite systems

Freely and openly available

ARD is needed, but generating the ARD products is challenging

It is likely that in the future ARD data will be prepared by the data providers

Vegetation observation benefits with time series of optical (and SAR) data

Time series analysis is complex and requires knowledge from several disciplines

Artificial intelligence is providing answers to some of the problems

Applications are limited only by imagination

References

Concepts and methods for optical pre-processing and time series quality analysis, Pierre Defourny, Fabrizio Ramoino, Olivier Hagolle, LTC 2019

Intro: Optical Remote Sensing and Atmospheric Correction, Pete Bunting, LTC 2018

Remote Sensing for Earth Observation (soton.ac.uk)

Optics or Radars? What is Better for the Earth Observation Purposes? - Defence24.com

Earth Observation from Space: the Optical View - eo science for society (esa.int)