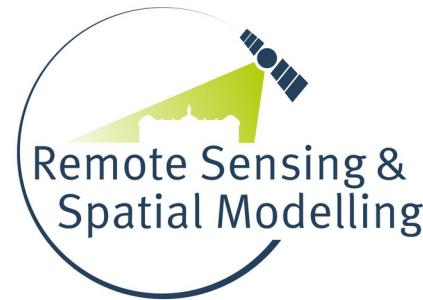


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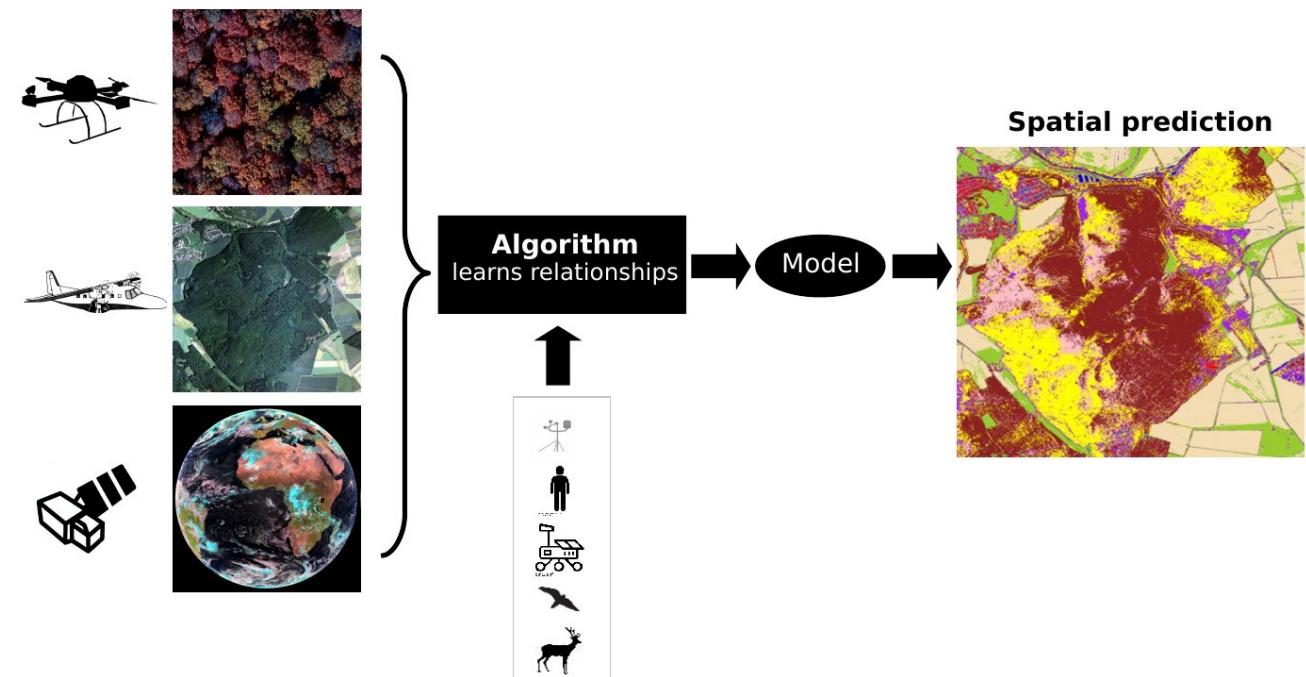


Remote sensing and machine learning: Towards a spatio-temporal continuous monitoring of the environment

Hanna Meyer

Remote Sensing & Spatial Modelling,
Institute of Landscape Ecology, WWU Münster

Part 1: Introduction to remote sensing data



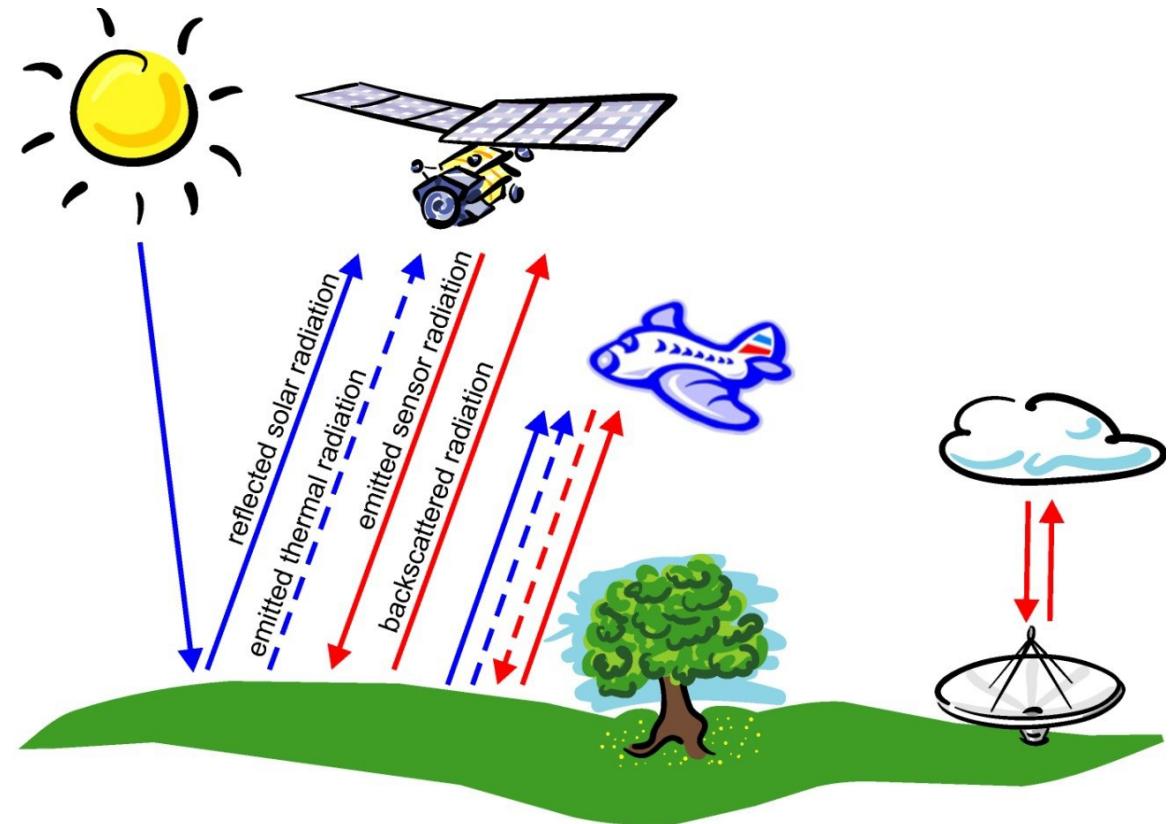
What are remote sensing data?

Passive Sensors

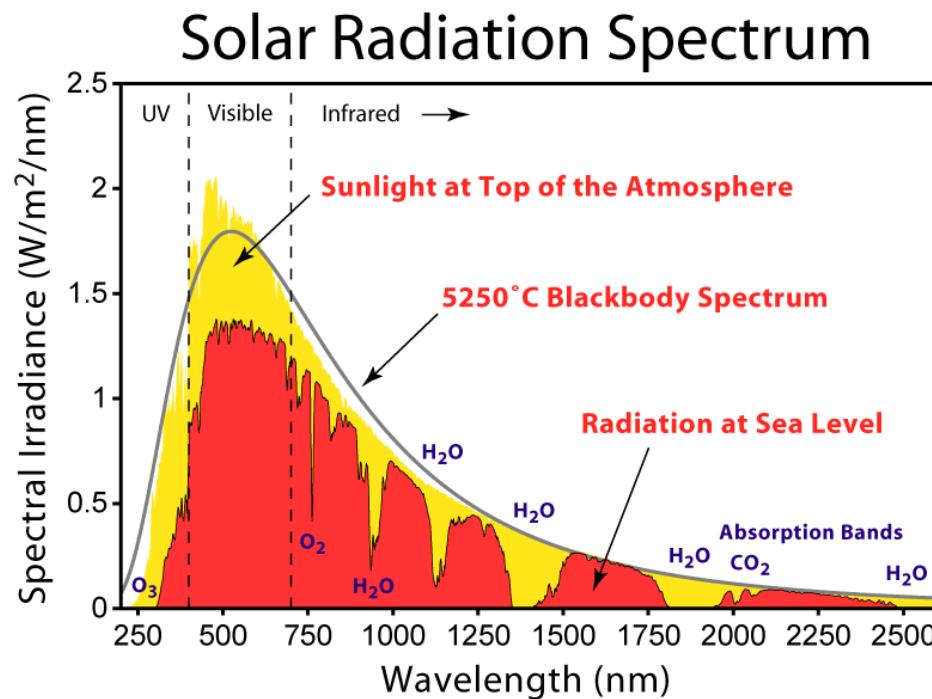
- Natural source of radiation
 - Solar radiation
 - Terrestrial radiation
- Broad spectrum
 - UV/VIS/NIR
 - TIR

Active Sensors

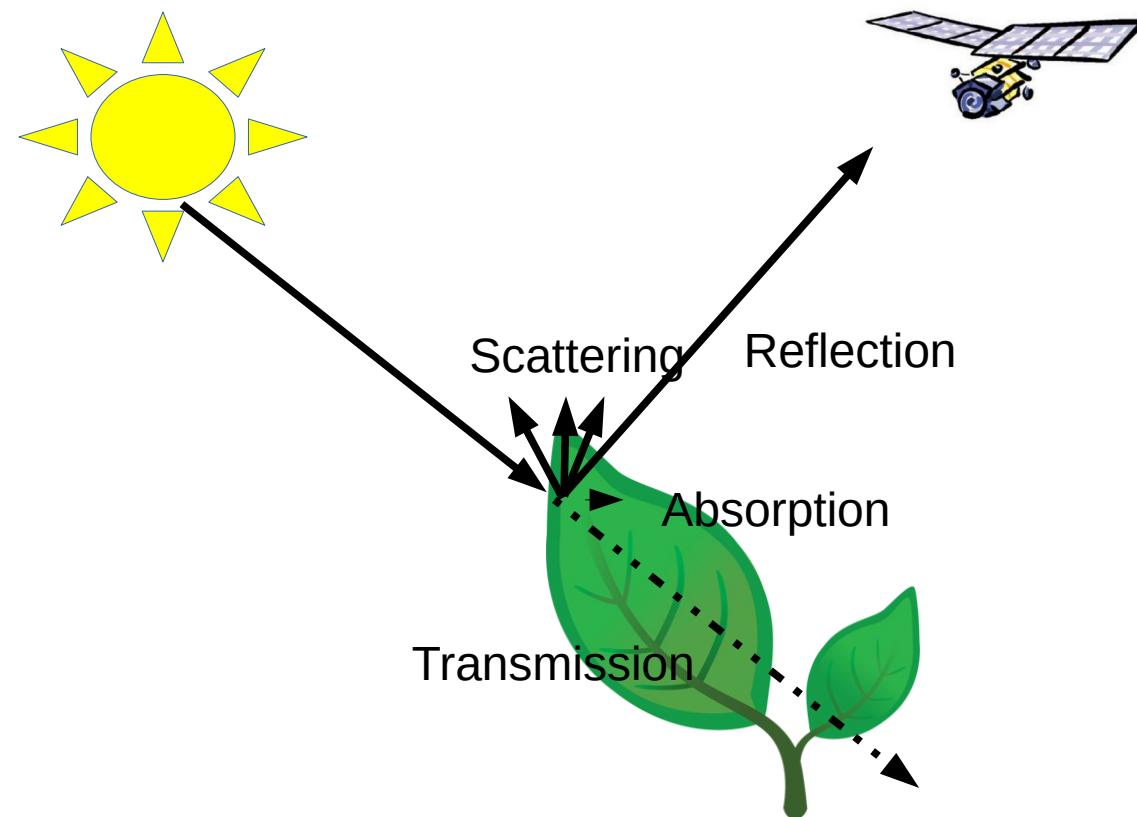
- Artificial source of radiation
 - LiDAR
 - Radar



Solar radiation and reflection properties

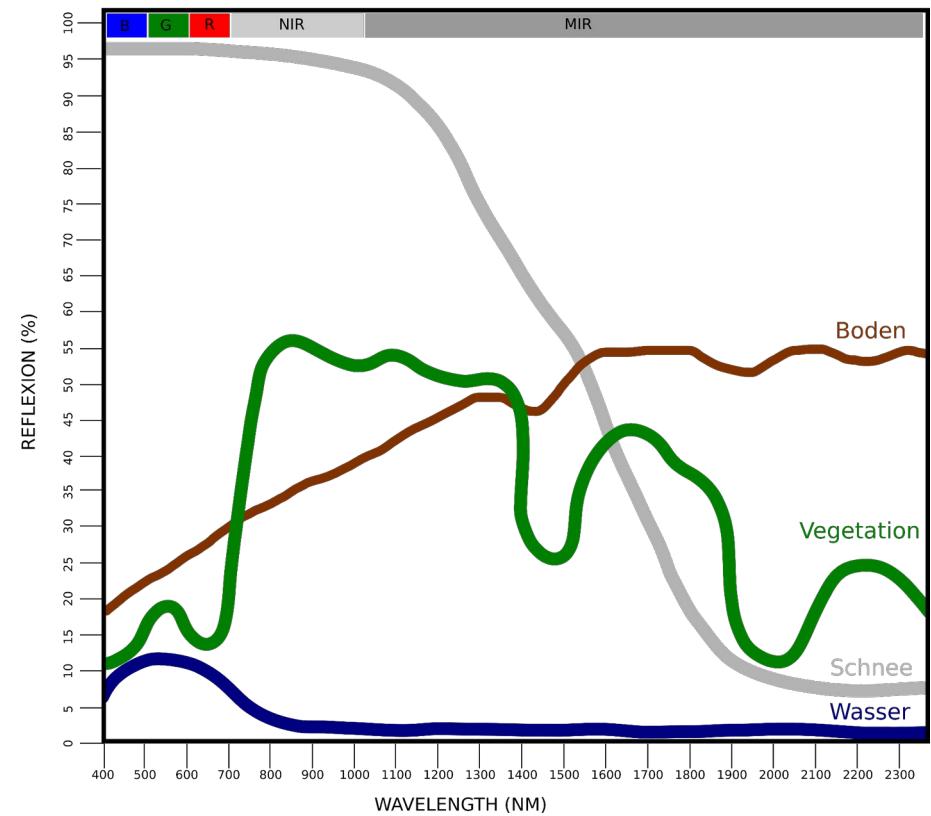


https://commons.wikimedia.org/wiki/File:Solar_Spectrum.png

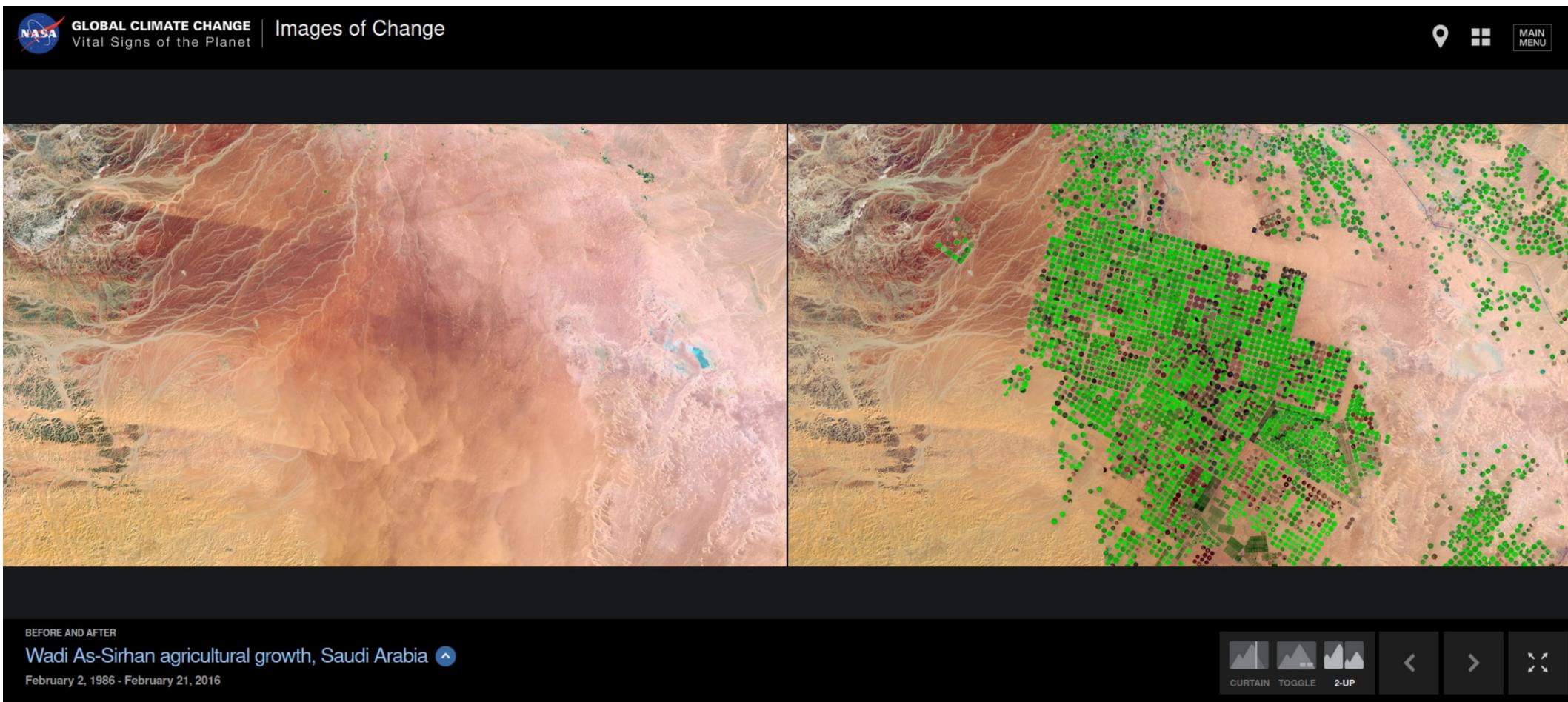


Solar radiation and reflection properties

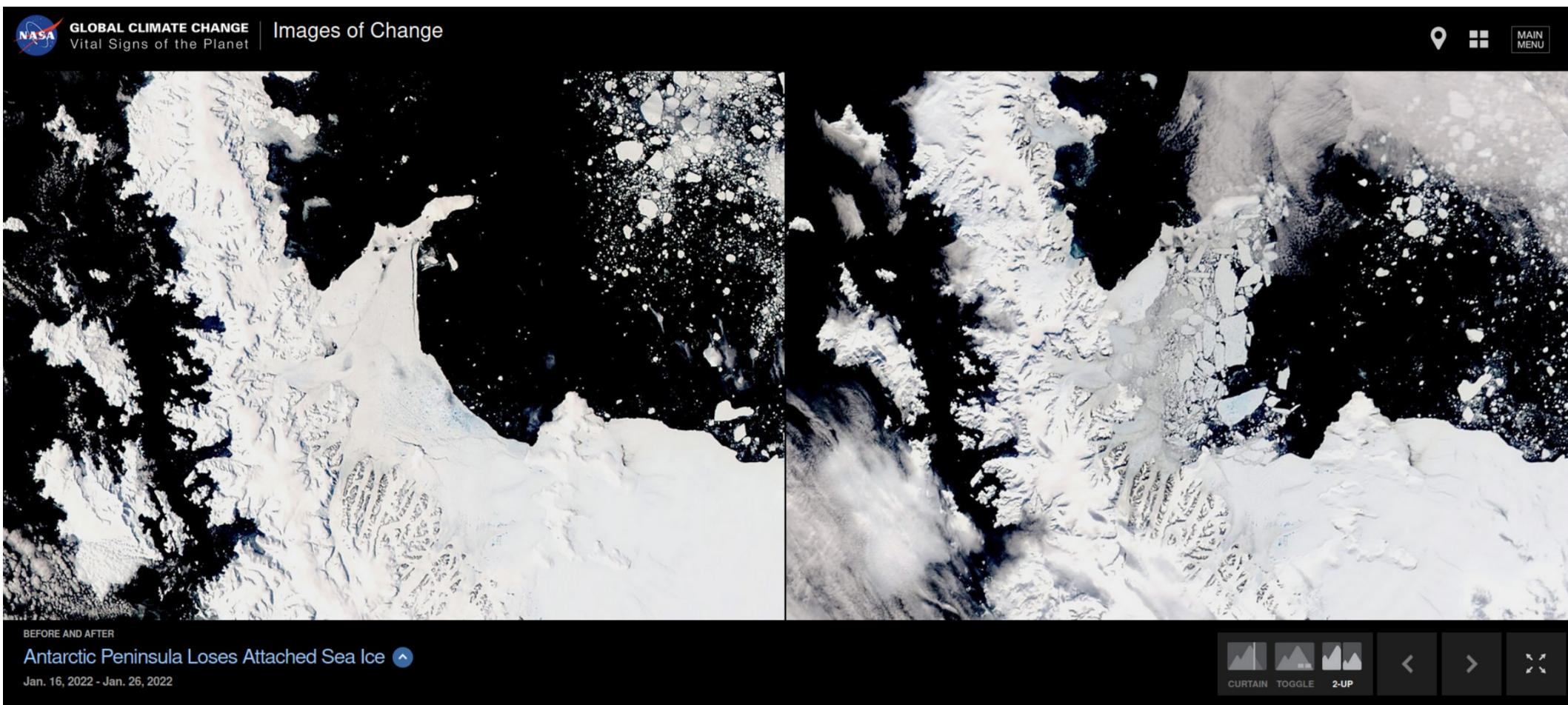
- Different objects reflect differently in different wavelengths
 - Characteristic reflection curves
- Basis for land cover classifications
- Also differences depending on e.g. vegetation health



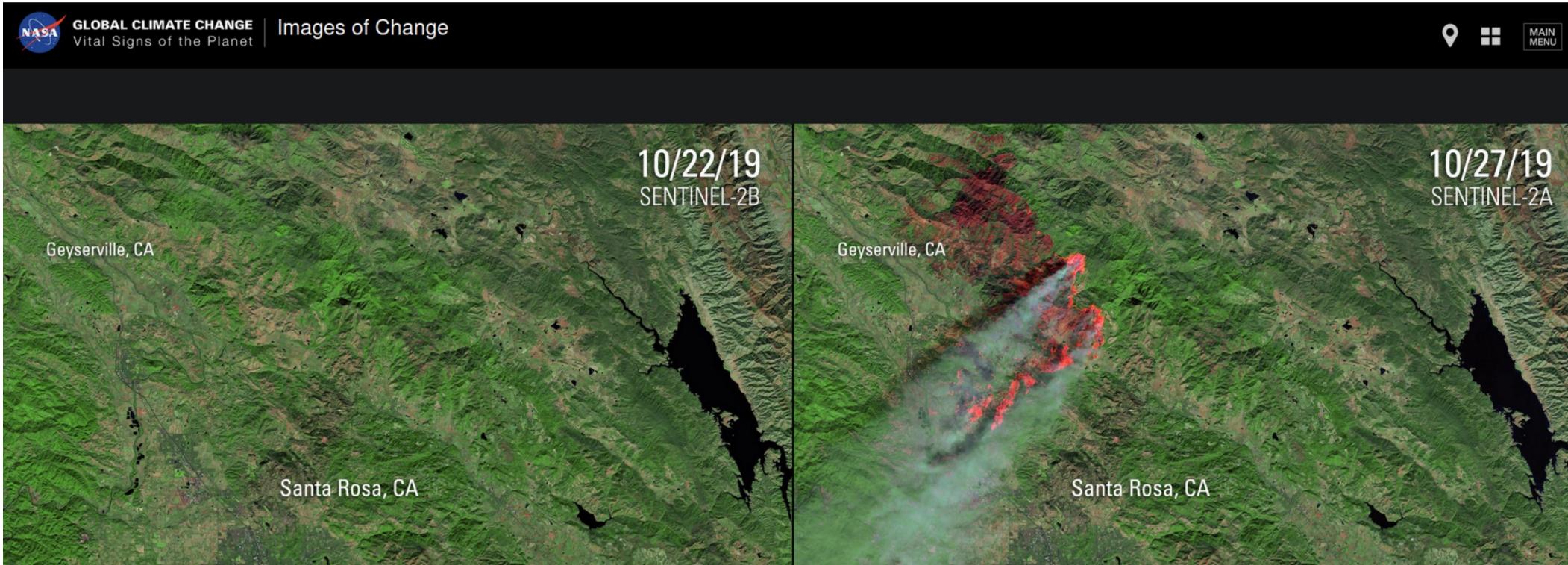
Detecting land cover and land cover change



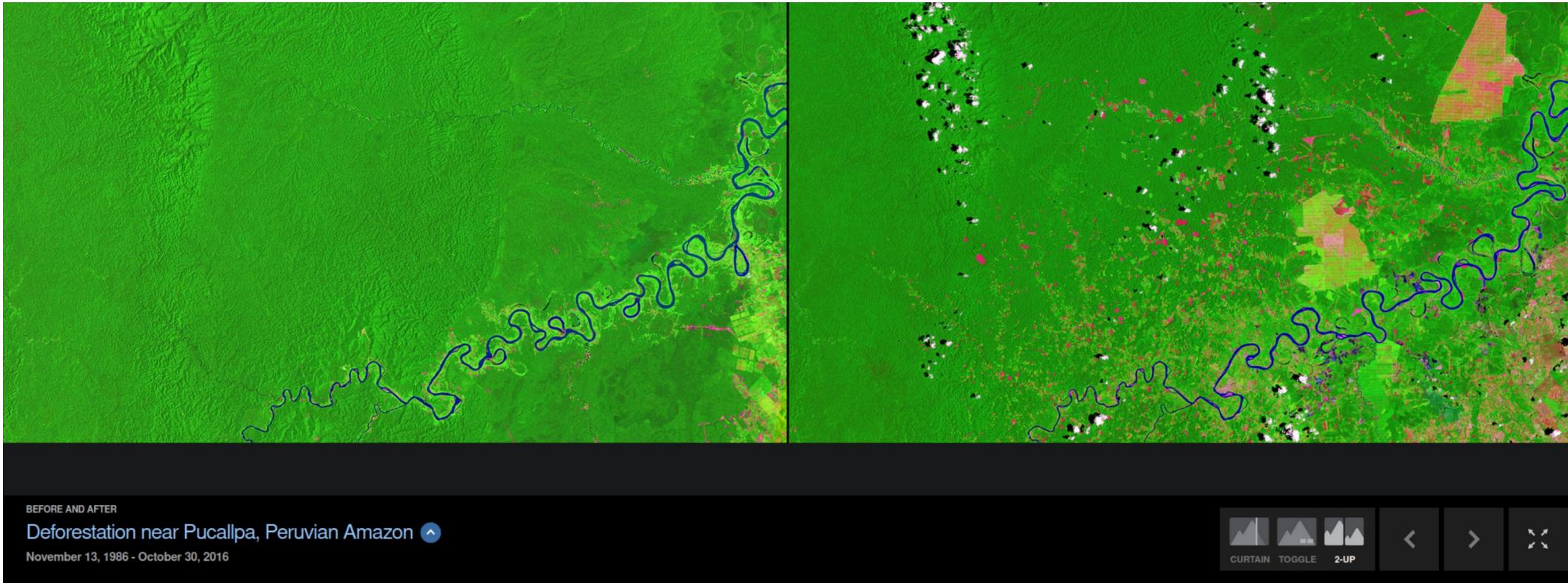
Detecting land cover and land cover change



Detecting land cover and land cover change



Detecting land cover and land cover change



So let's get some satellite data... but from which satellite?

| Platform/Sensor | Spatial resolution (m) | Temporal resolution | Availability |
|----------------------------|------------------------|---------------------|--------------|
| Landsat MSS | 79 | 16 days | since 1972 |
| Landsat TM | 30 | 16 days | since 1982 |
| Landsat ETM+ | 30 | 16 days | since 1999 |
| Landsat 8 (OLI) | 30 | 16 days | since 2013 |
| Sentinel-2 | 10 | 5/10 days | since 2014 |
| MODIS Terra/Aqua | 250-1000 | 4 per day | since 2000 |
| Meteosat Second Generation | 3000 | 15 minutes | since 2002 |

Which data to use? Spatial resolution

Aerial image (Google Earth): <1m



Landsat-scale: 30m

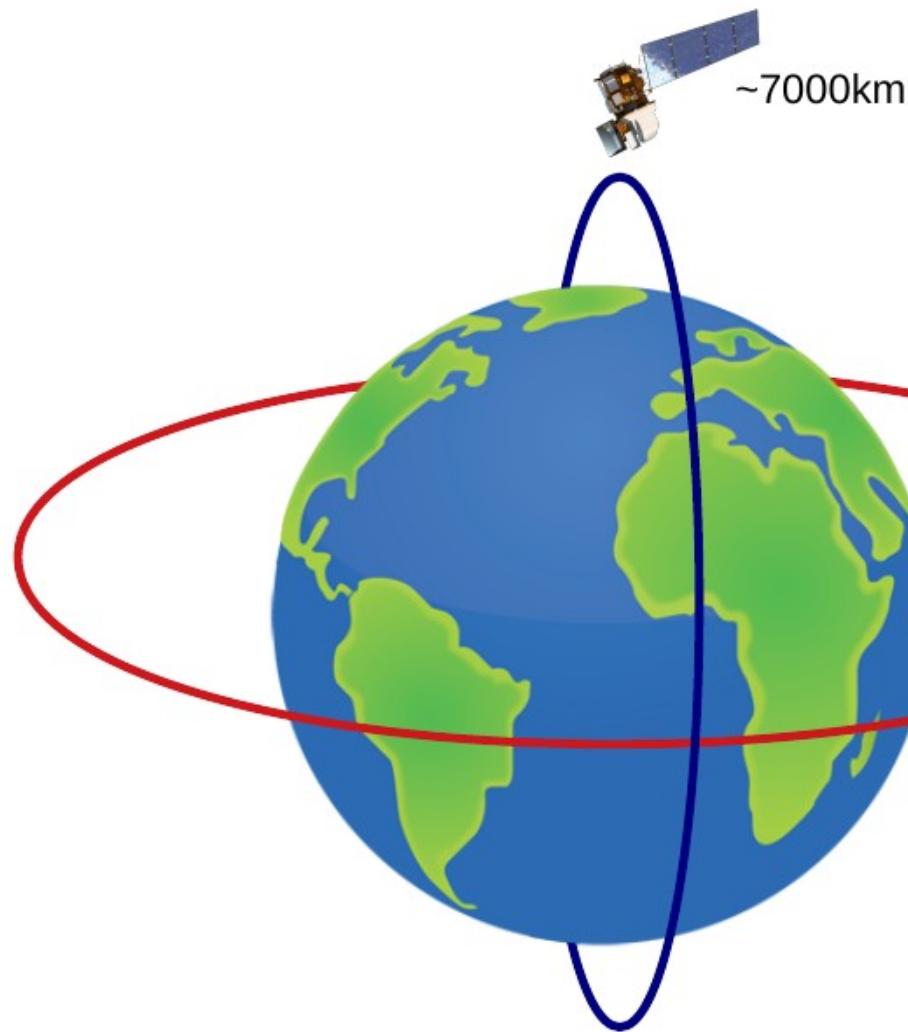


MODIS-scale: 500m



Which data to use? Temporal resolution

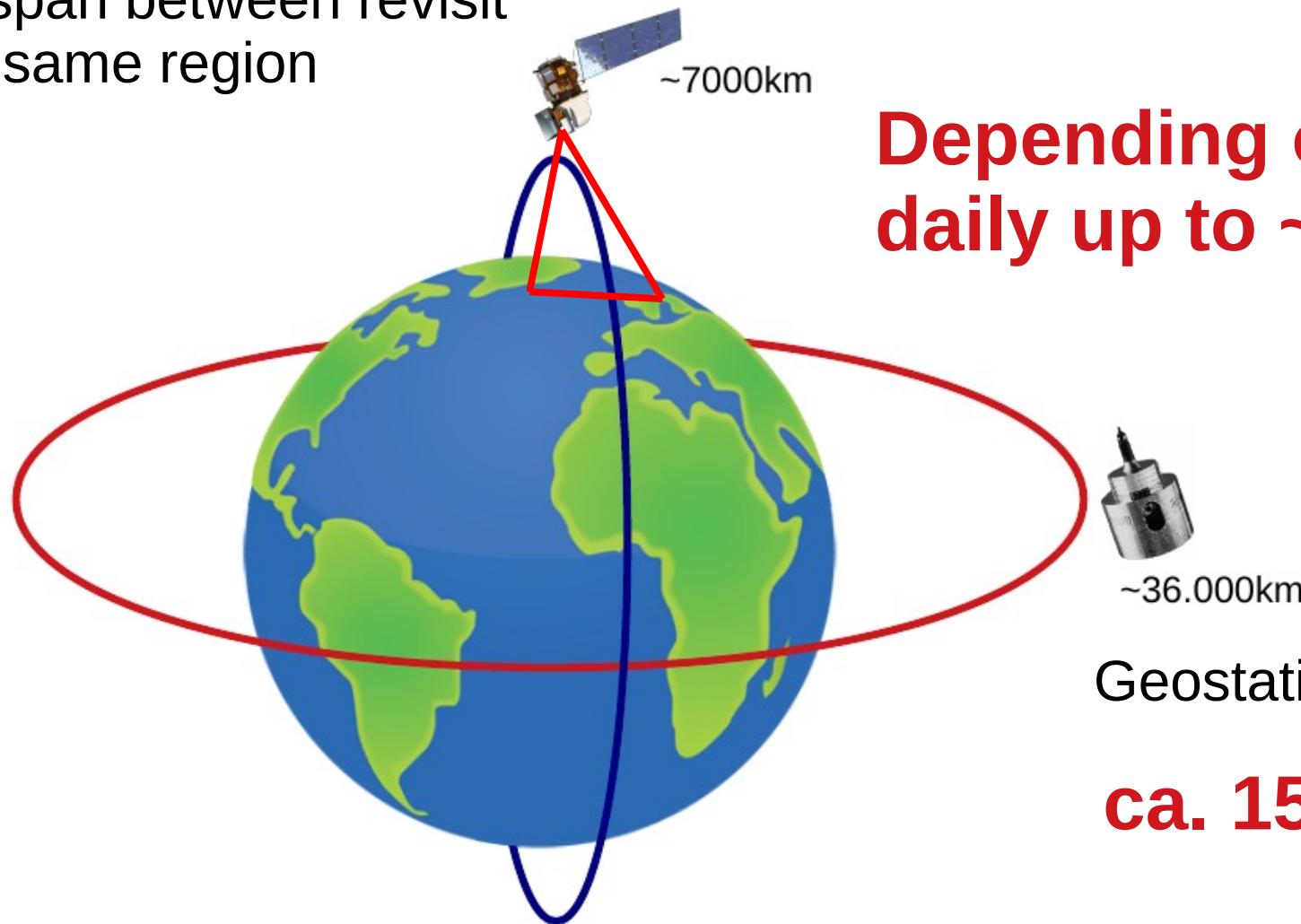
Polar orbit



Geostationary orbit

Which data to use? Temporal resolution

Time span between revisit
of the same region



Polar orbit

**Depending on Swath.
daily up to ~14 days**



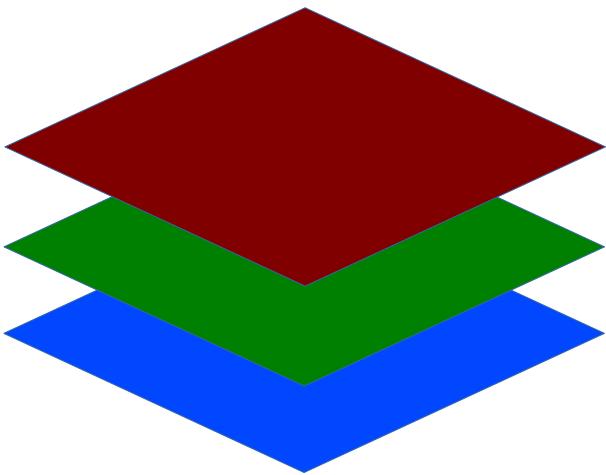
~36.000km

Geostationary orbit

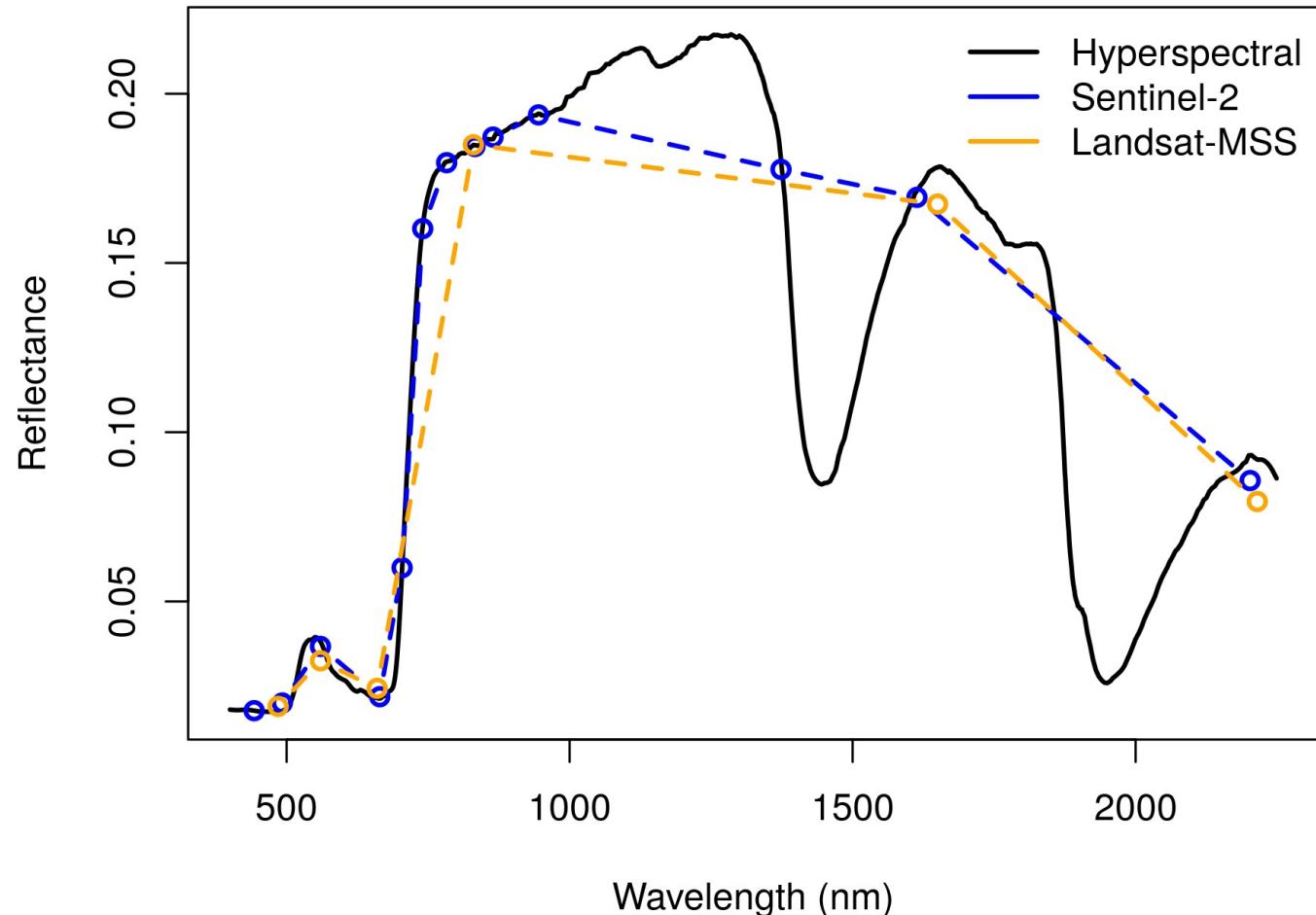
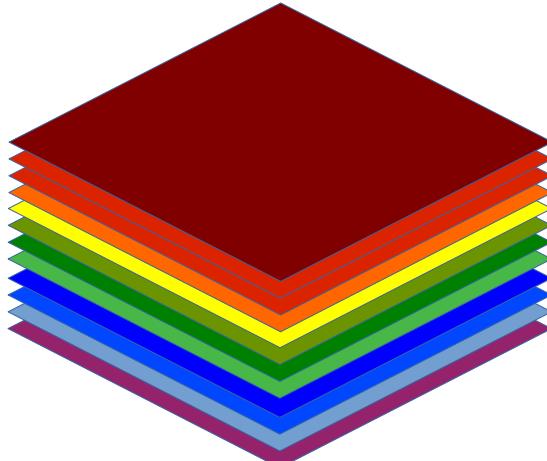
ca. 15 min

Which data to use? Spectral resolution

Multispectral



Hyperspectral



Spectral resolution of Sentinel-2 data

| Platform/Sensor | Spatial resolution (m) | Temporal resolution | Availability |
|----------------------------|------------------------|---------------------|--------------|
| Landsat MSS | 79 | 16 days | since 1972 |
| Landsat TM | 30 | 16 days | since 1982 |
| Landsat ETM+ | 30 | 16 days | since 1999 |
| Landsat 8 (OLI) | 30 | 16 days | since 2013 |
| Sentinel-2 | 10 | 5/10 days | since 2014 |
| MODIS Terra/Aqua | 250-1000 | 4 per day | since 2000 |
| Meteosat Second Generation | 3000 | 15 minutes | since 2002 |

Spectral bands for the Sentinel-2 sensors^[9]

| Sentinel-2 bands | Sentinel-2A | | Sentinel-2B | | Spatial resolution (m) |
|------------------------------|-------------------------|----------------|-------------------------|----------------|------------------------|
| | Central wavelength (nm) | Bandwidth (nm) | Central wavelength (nm) | Bandwidth (nm) | |
| Band 1 - Coastal aerosol | 442.7 | 21 | 442.2 | 21 | 60 |
| Band 2 - Blue | 492.4 | 66 | 492.1 | 66 | 10 |
| Band 3 - Green | 559.8 | 36 | 559.0 | 36 | 10 |
| Band 4 - Red | 664.6 | 31 | 664.9 | 31 | 10 |
| Band 5 - Vegetation red edge | 704.1 | 15 | 703.8 | 16 | 20 |
| Band 6 - Vegetation red edge | 740.5 | 15 | 739.1 | 15 | 20 |
| Band 7 - Vegetation red edge | 782.8 | 20 | 779.7 | 20 | 20 |
| Band 8 - NIR | 832.8 | 106 | 832.9 | 106 | 10 |
| Band 8A - Narrow NIR | 864.7 | 21 | 864.0 | 22 | 20 |
| Band 9 - Water vapour | 945.1 | 20 | 943.2 | 21 | 60 |
| Band 10 - SWIR - Cirrus | 1373.5 | 31 | 1376.9 | 30 | 60 |
| Band 11 - SWIR | 1613.7 | 91 | 1610.4 | 94 | 20 |
| Band 12 - SWIR | 2202.4 | 175 | 2185.7 | 185 | 20 |

<https://en.wikipedia.org/wiki/Sentinel-2>

Which data for which purpose?

- What spectral resolution is required to detect the target objects?
- What spatial resolution is required (how large are the objects). High resolution is not always advantageous (amount of data, noise)
- Which time period and which temporal resolution is required (especially for change analyses)?

Getting satellite data

e.g. via Copernicus Open Access Hub: <https://scihub.copernicus.eu>

The screenshot shows the Copernicus Open Access Hub interface. At the top, there's a search bar with placeholder text "Insert search criteria...". Below it, a sidebar displays "Display 1 to 25 of 750 products" and "Order By: Ingestion Date". A list of five Sentinel-2 MSI products from October 2022 is shown, each with a thumbnail, download URL, mission, instrument, sensing date, and size. The main area features a map of Europe with a specific region highlighted in yellow and green, representing the area covered by the selected products. The map includes labels for many cities and towns.

| Product ID | Mission | Instrument | Sensing Date | Size |
|--|------------|------------|--------------------------|-----------|
| S2B_MSIL2A_20221009T103839_N0400_R008_T32ULC_20221009T132836 | Sentinel-2 | MSI | 2022-10-09T10:38:39.024Z | 1.13 GB |
| S2B_MSIL2A_20221009T103839_N0400_R008_T32UMC_20221009T132836 | Sentinel-2 | MSI | 2022-10-09T10:38:39.024Z | 1.08 GB |
| S2B_MSIL1C_20221009T103839_N0400_R008_T32UMC_20221009T124526 | Sentinel-2 | MSI | 2022-10-09T10:38:39.024Z | 783.21 MB |
| S2B_MSIL1C_20221009T103839_N0400_R008_T32ULC_20221009T124526 | Sentinel-2 | MSI | 2022-10-09T10:38:39.024Z | 813.53 MB |
| S2B_MSIL2A_20221006T102949_N0400_R108_T32ULC_20221006T161814 | Sentinel-2 | MSI | 2022-10-06T10:29:49.024Z | 446.07 MB |
| S2B_MSIL2A_20221006T102949_N0400_R108_T32UMC_20221006T161814 | Sentinel-2 | MSI | 2022-10-06T10:29:49.024Z | 446.07 MB |

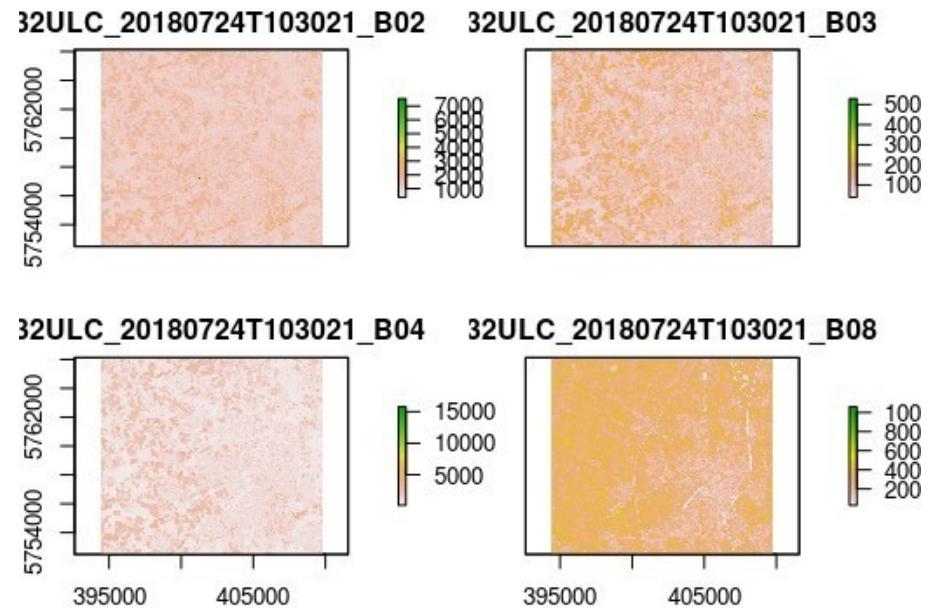
Load satellite data in R

- Load the channels red,green,blue,NIR into R
- Load the 20m resolution channels as well and resample to 10m



How to import satellite data into R

```
library(terra)
sen <- rast(c("blue.tif","green.tif",
             "red.tif","NIR.tif"))
plot(sen)
```

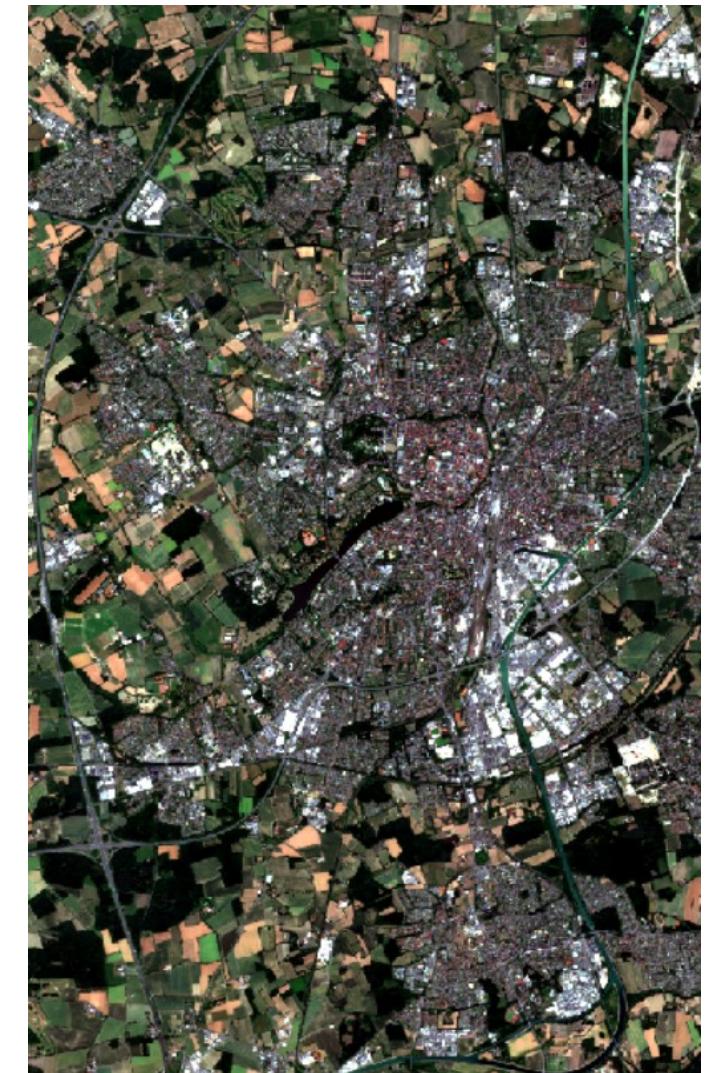


Crop the data



100 km

Crop the multi-band raster to the area of interest (?crop)



Crop the data

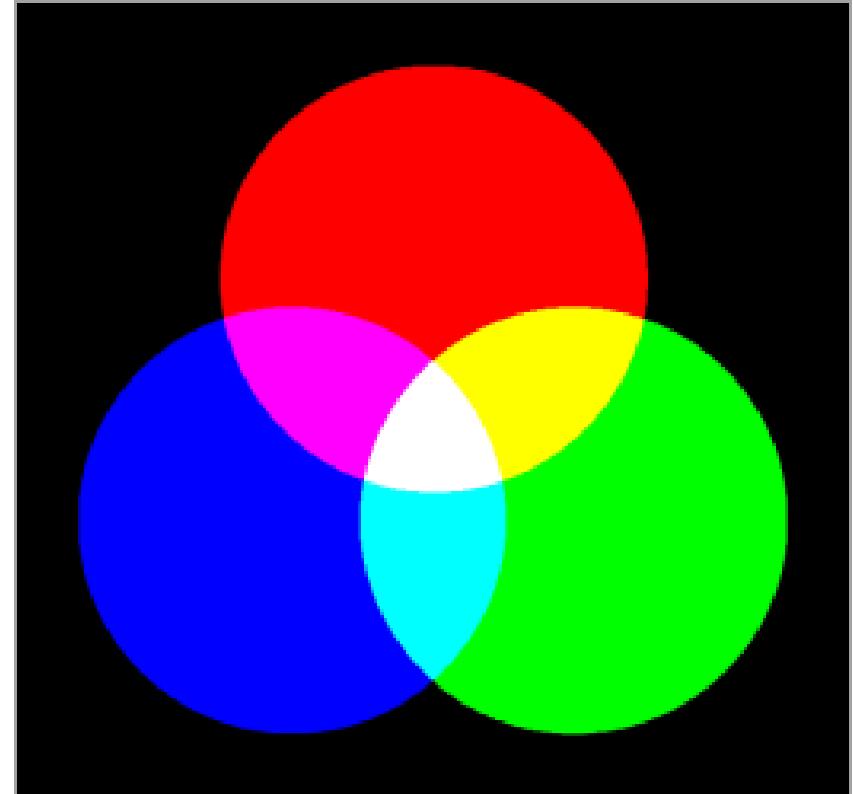
`crop(sen, c(xmin, xmax, ymin, ymax))`

Example Münster:

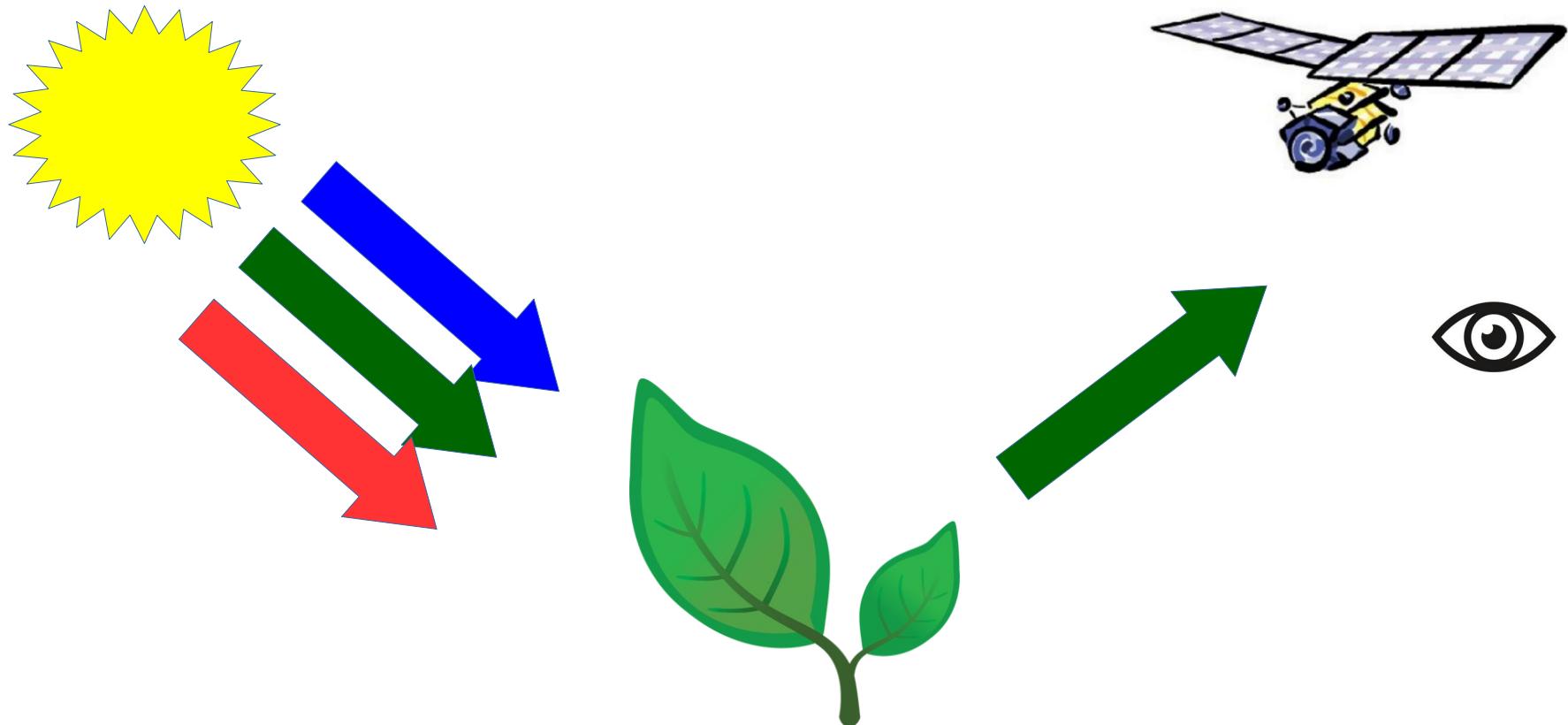
`crop(sen, c(396260, 409060, 5749550, 5763830))`

How do we get the “color” in the satellite data?

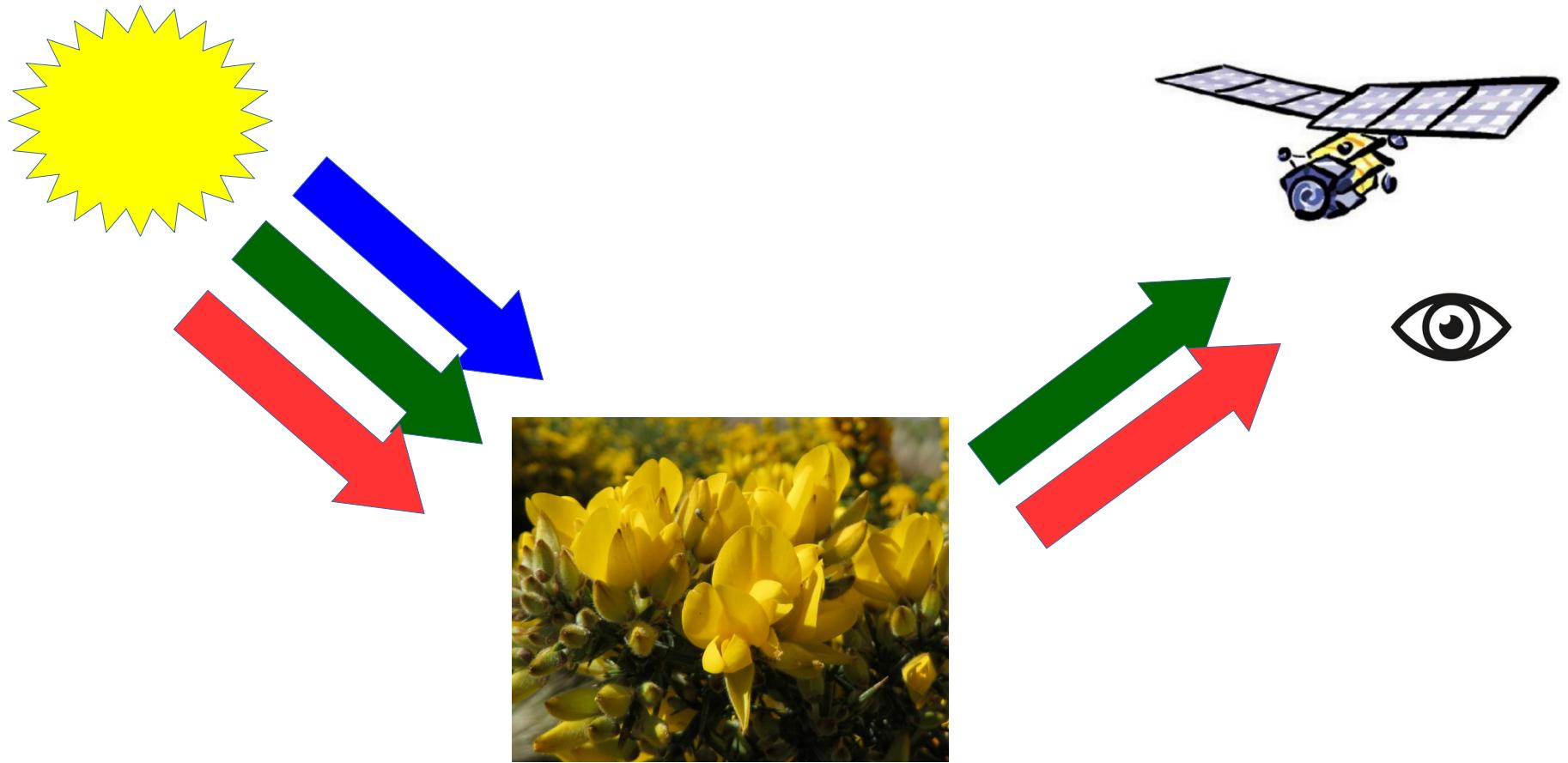
- Our eyes have three “sensors”: Blue, Green, Red
- Different colors through color mixing
- Idea: Combine visible channels to create a “true color composite”



How do we get the “color” in the satellite data?

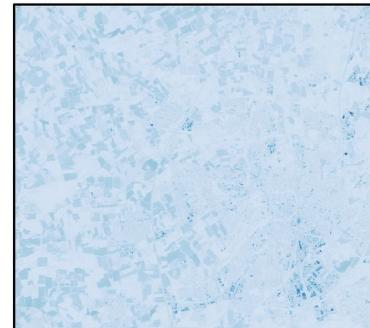
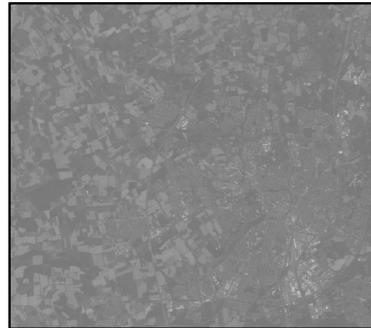


How do we get the “color” in the satellite data?

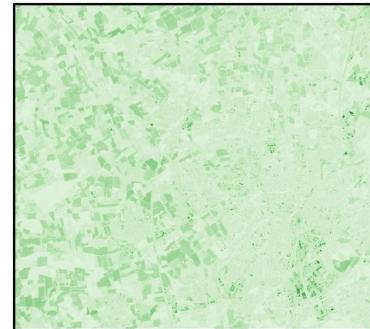
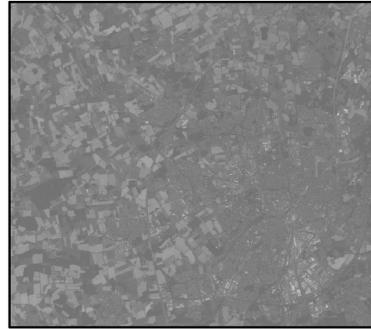


How do we get the “color” in the satellite data?

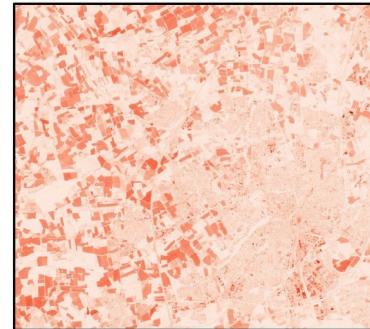
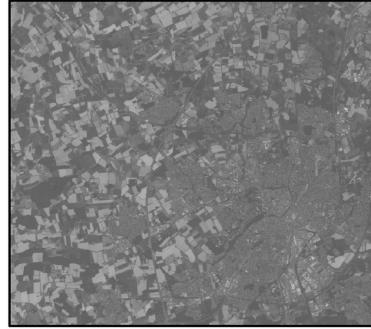
blue



green



red



How to do a color composite in R

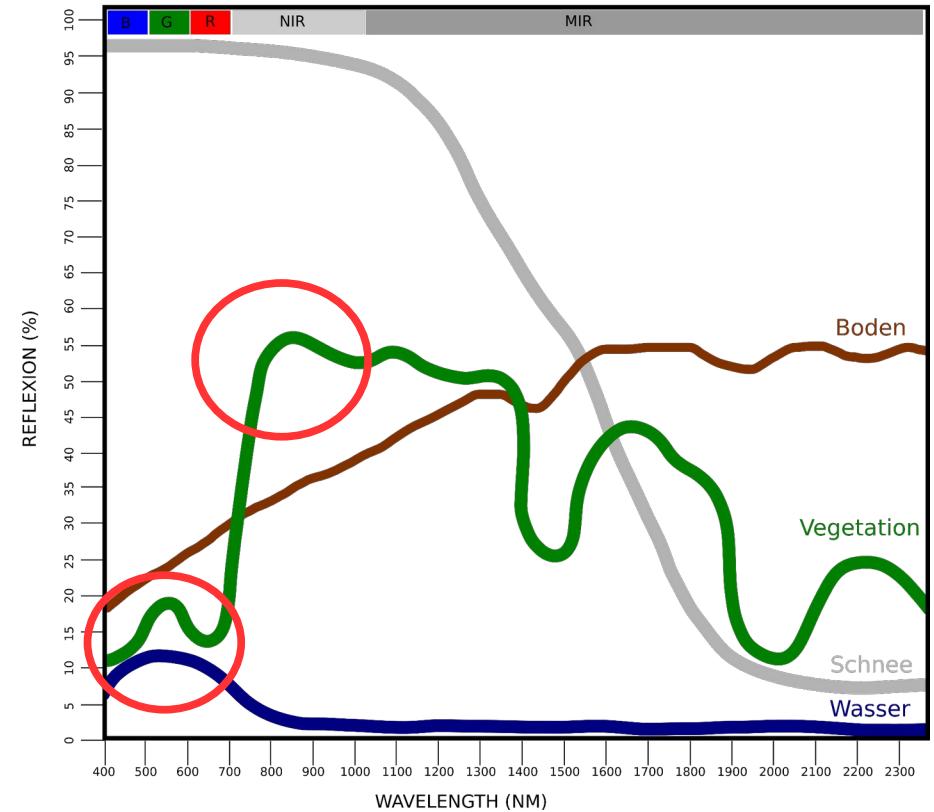
```
library(terra)
sen <- rast(c("blue.tif", "green.tif",
            "red.tif", "NIR.tif"))
plotRGB(sen,r=3,g=2,b=1,stretch="lin")
```

Artificial lawn or real grass?

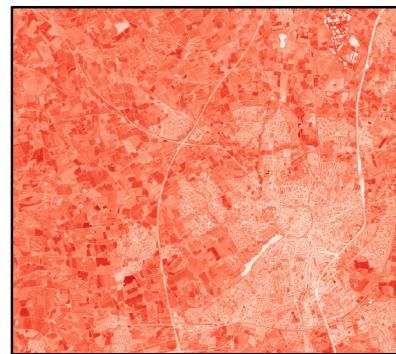
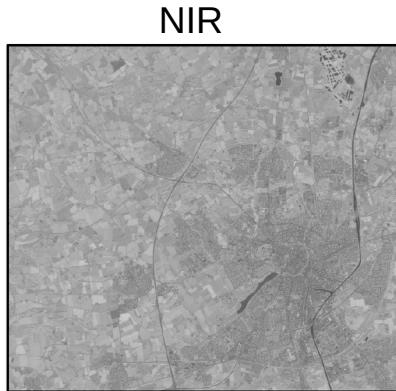
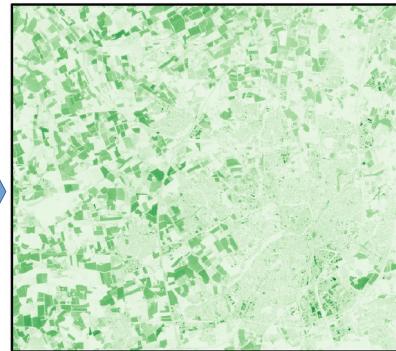
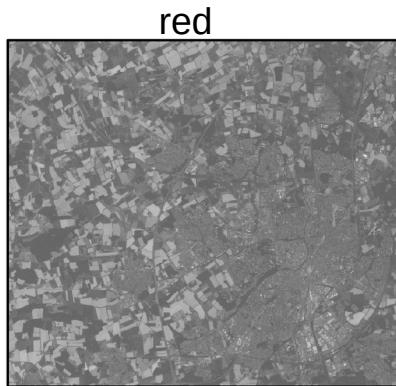
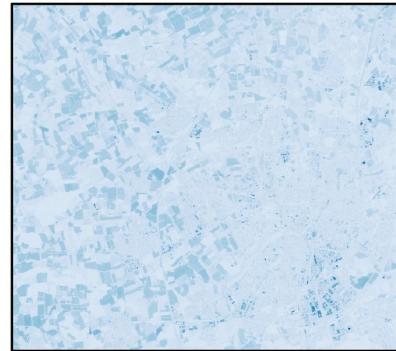
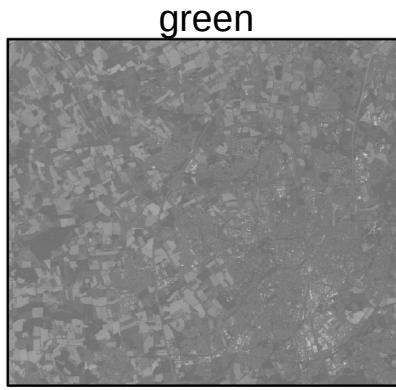


Marburg Uni-Stadion

Marburg Gaßmann-Stadion



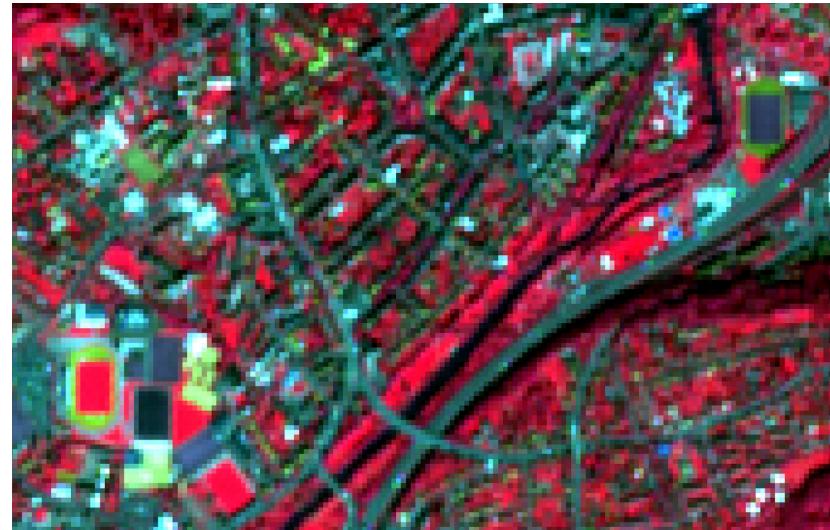
False color composite



Artificial lawn or real grass?



Marburg Uni-Stadion



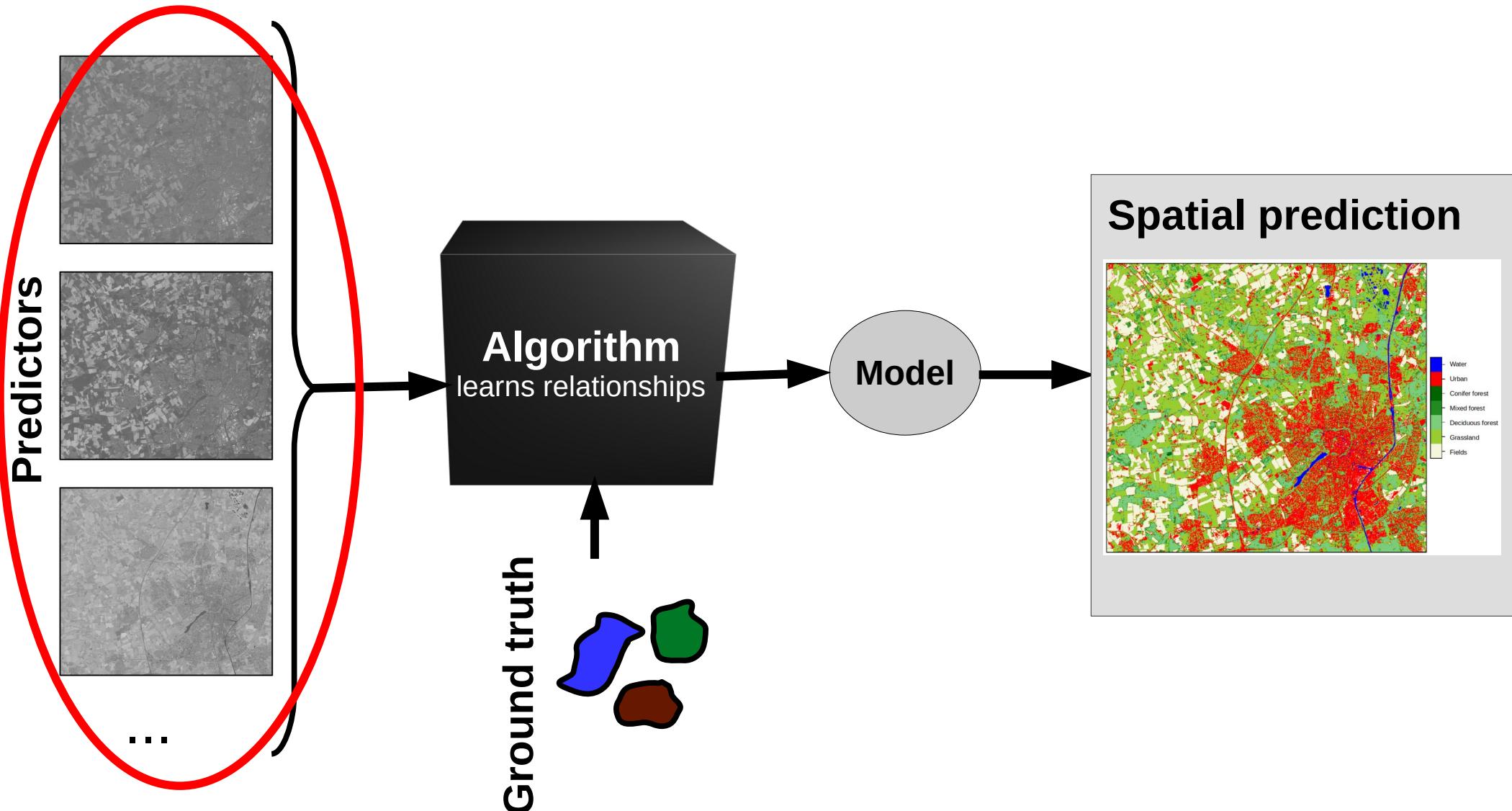
Marburg Gaßmann-Stadion

Task

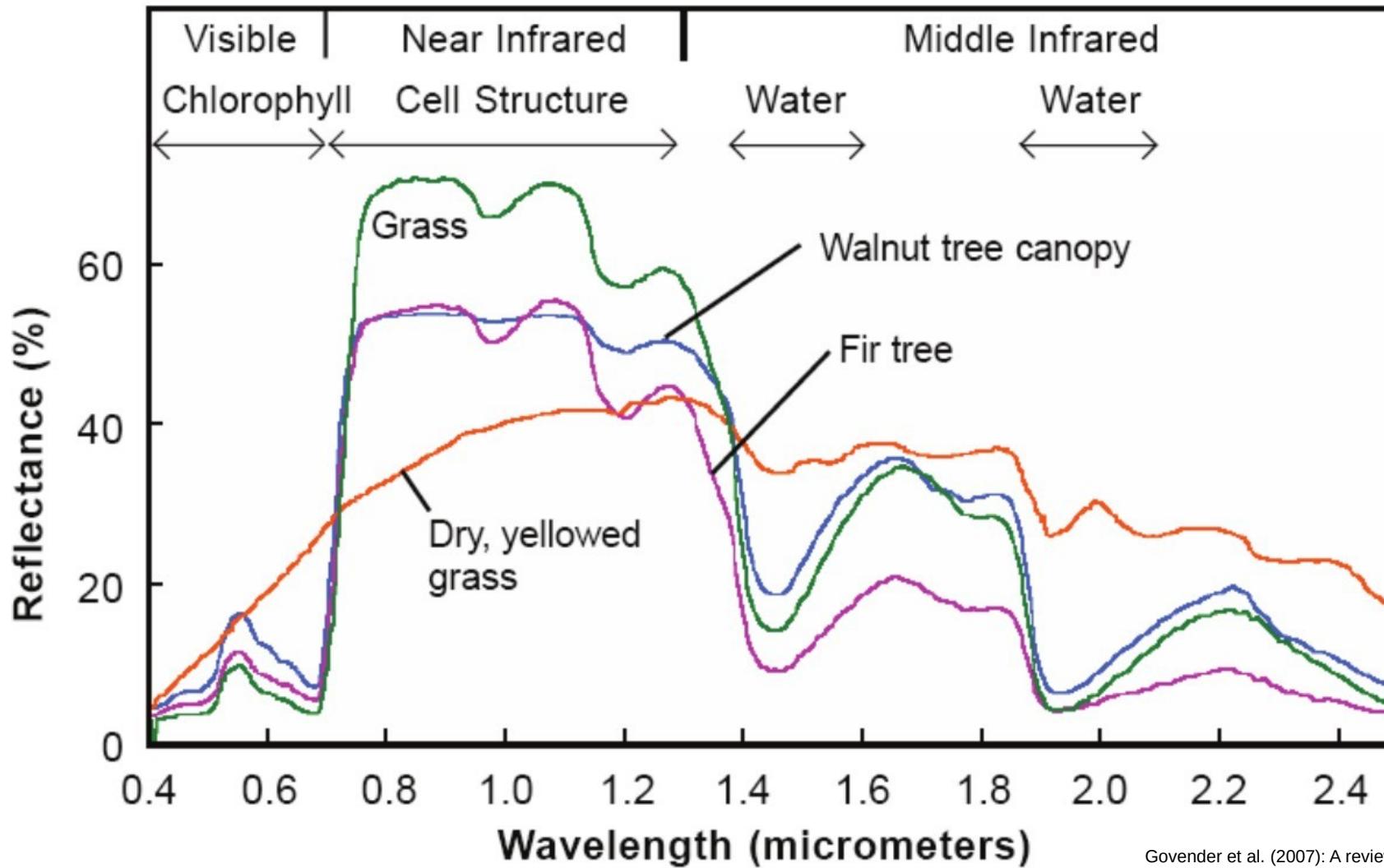
Visualize your image with a true color and a false color composite



Satellite-based predictors for land cover

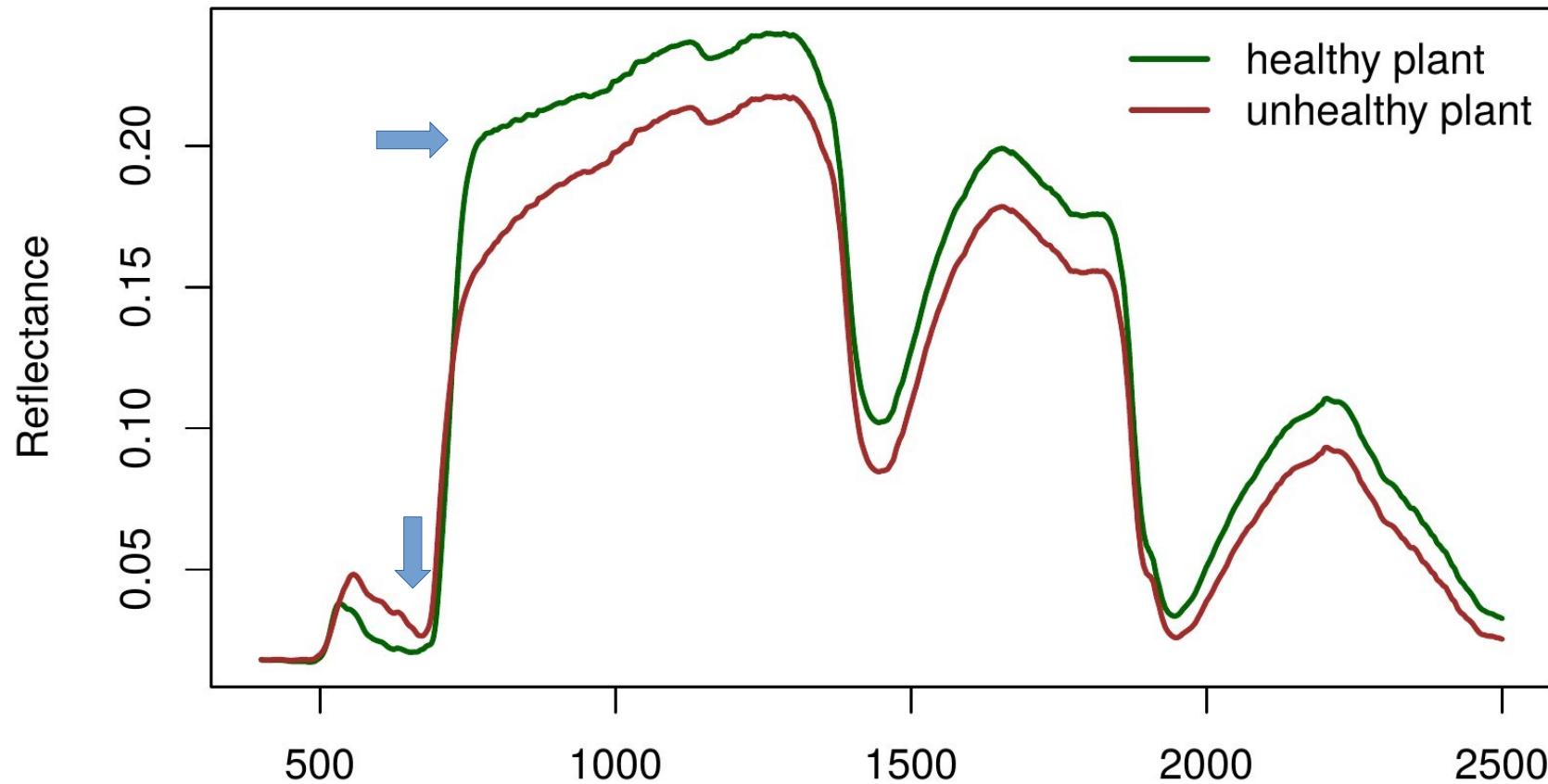


Further predictors: vegetation indices



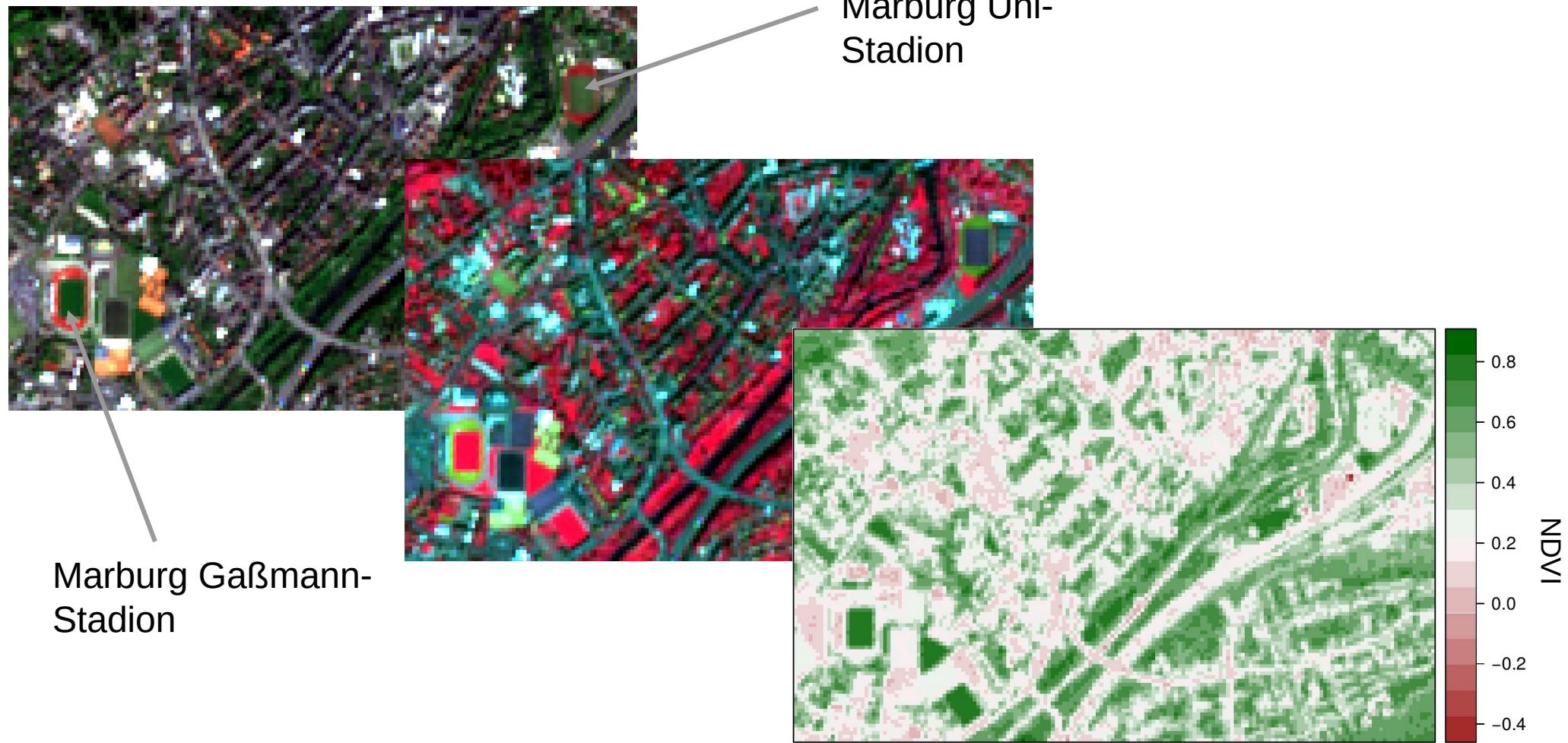
Govender et al. (2007): A review of hyperspectral remote sensing and its application in vegetation and water resource studies. Water S.A 33(2)

Further predictors: vegetation indices



$$NDVI = \frac{NIR - rot}{NIR + rot}$$

Further predictors: vegetation indices



Further predictors: vegetation indices

Calculate the NDVI of the satellite scene

$$NDVI = \frac{NIR - rot}{NIR + rot}$$



Compile predictors

Now make sure that you have the cropped raw channels
as well as the NDVI in one raster group.
Write it to disk with ?writeRaster

