Remote Sensing in Agriculture: *Leveraging Cloud Technologies for Earth System Data Management*

PSSC 2025
IPK Leibniz Institute

David Montero

UNIVERSITÄT LEIPZIG

iDiv

Experts

Meet the
Instructor

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Leipzig University, Germany

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GDE, Europe Region

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UNIVERSITÄT LEIPZIG iDiv Experts

UNIVERSITÄT
LEIPZIG

Institute of Earth System Science and Remote Sensing

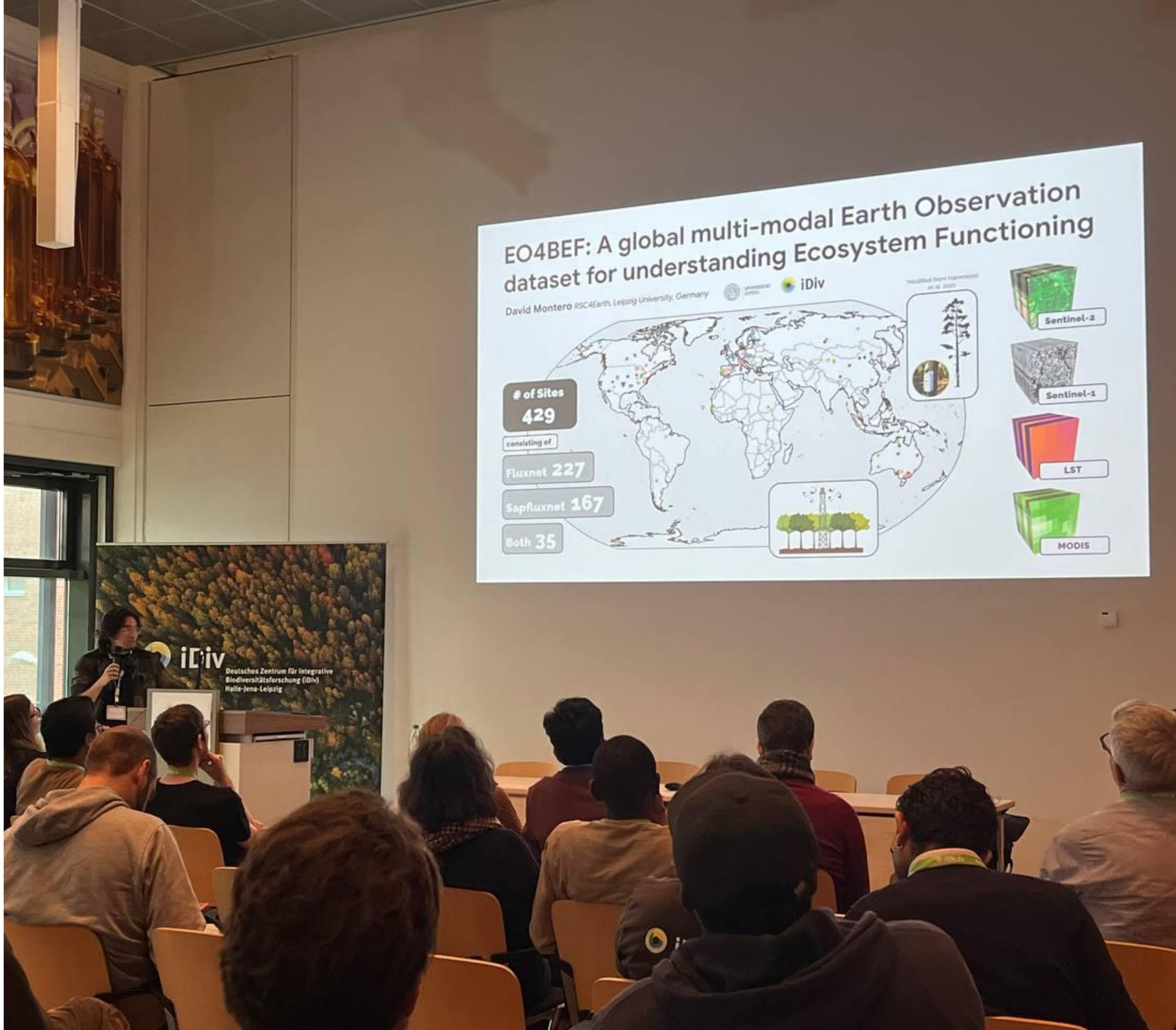
Environmental Data Science and Remote Sensing

iDiv

German Centre for Integrative Biodiversity Research

Biodiversity and Ecosystem Functioning

flexpool



Experts

Google Developers Experts

Google Earth Engine

@davemlz

awesome-spectral-indices/**awesome-spectral-indices** Public

A ready-to-use curated list of Spectral Indices for Remote Sensing applications.

Python 974 155

eemont Public

A python package that extends Google Earth Engine.

Python 426 69

awesome-spectral-indices/**spyndex** Public

Awesome Spectral Indices in Python.

Python 216 23

awesome-spectral-indices/**spectral** Public

Awesome Spectral Indices for the Google Earth Engine JavaScript API (Code Editor).

JavaScript 187 40

ESDS-Leipzig/**cubo** Public

On-Demand Earth System Data Cubes (ESDCs) in Python

Python 192 14

ESDS-Leipzig/**sen2nbar** Public

Nadir BRDF Adjusted Reflectance (NBAR) for Sentinel-2 in Python

Python 56 5

Workshop **Structure**

Part 1 **(25 min)**
Earth System Data and Remote Sensing

Part 2 **(15 min)**
Rasters and Data Cubes

Part 3 **(5 min)**
Where do we find the data?

Part 4 **(60 min)**
Hands-on Session

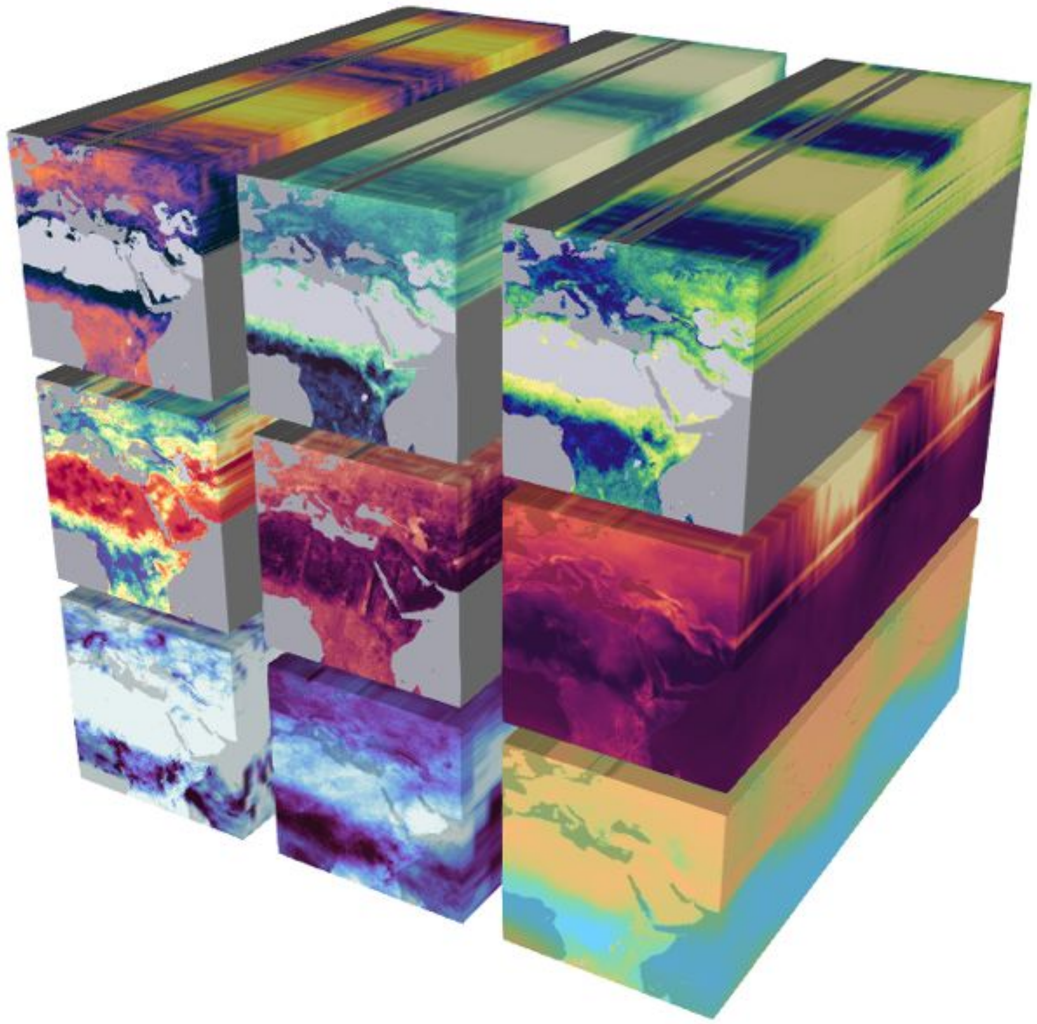
Part 1

Earth System Data and Remote Sensing

1

EARTH SYSTEM DATA

Measured or estimated variables that describe Earth system processes across space and time



Mahecha et al., 2020
Earth System Dynamics

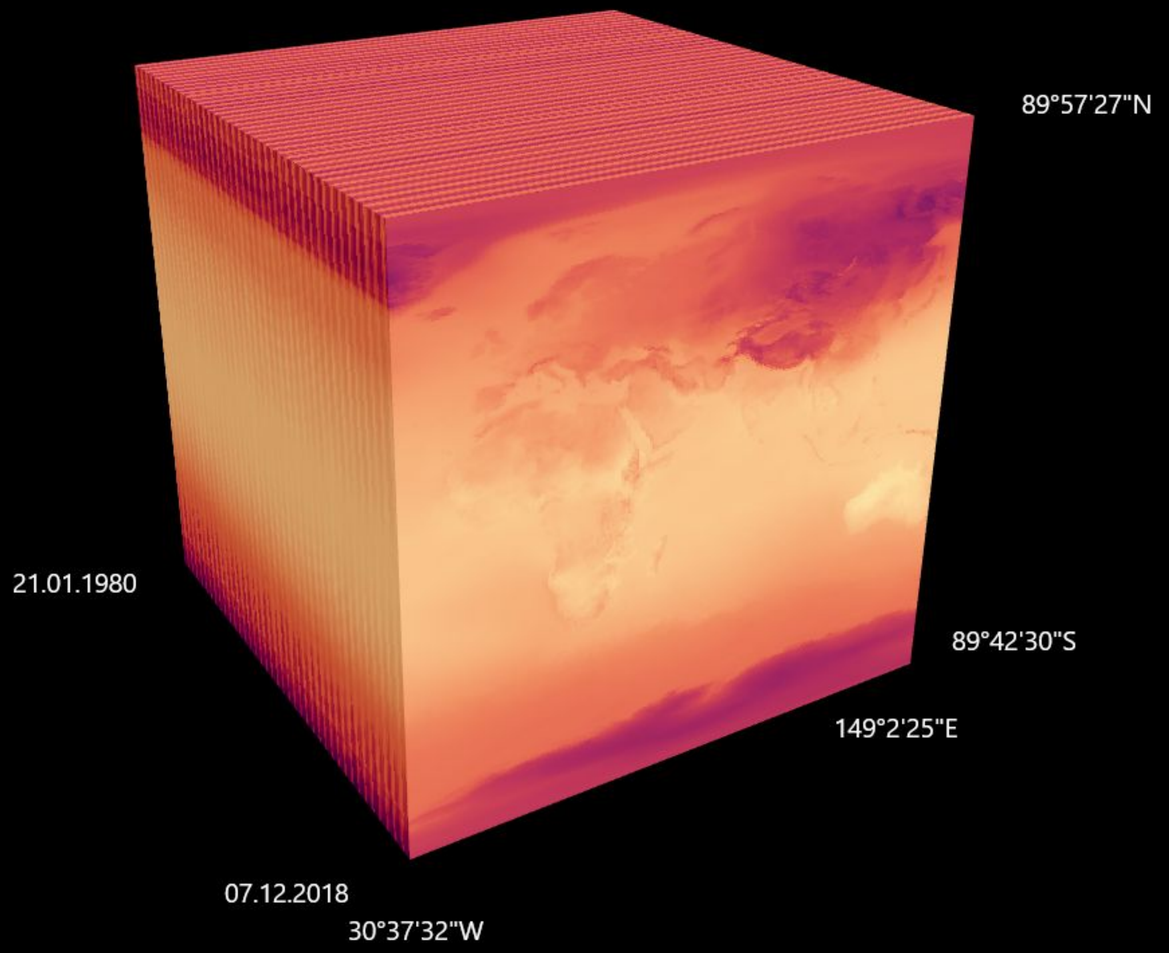
Source: https://msoechting.de/en/

Maximilian Söchting

PhD candidate at the Remote Sensing Centre for Earth System Research and the Image and Signal Processing Group at Leipzig University.

Developing LexCube, an interactive visualization for large-scale earth data sets.

Lexcube.org



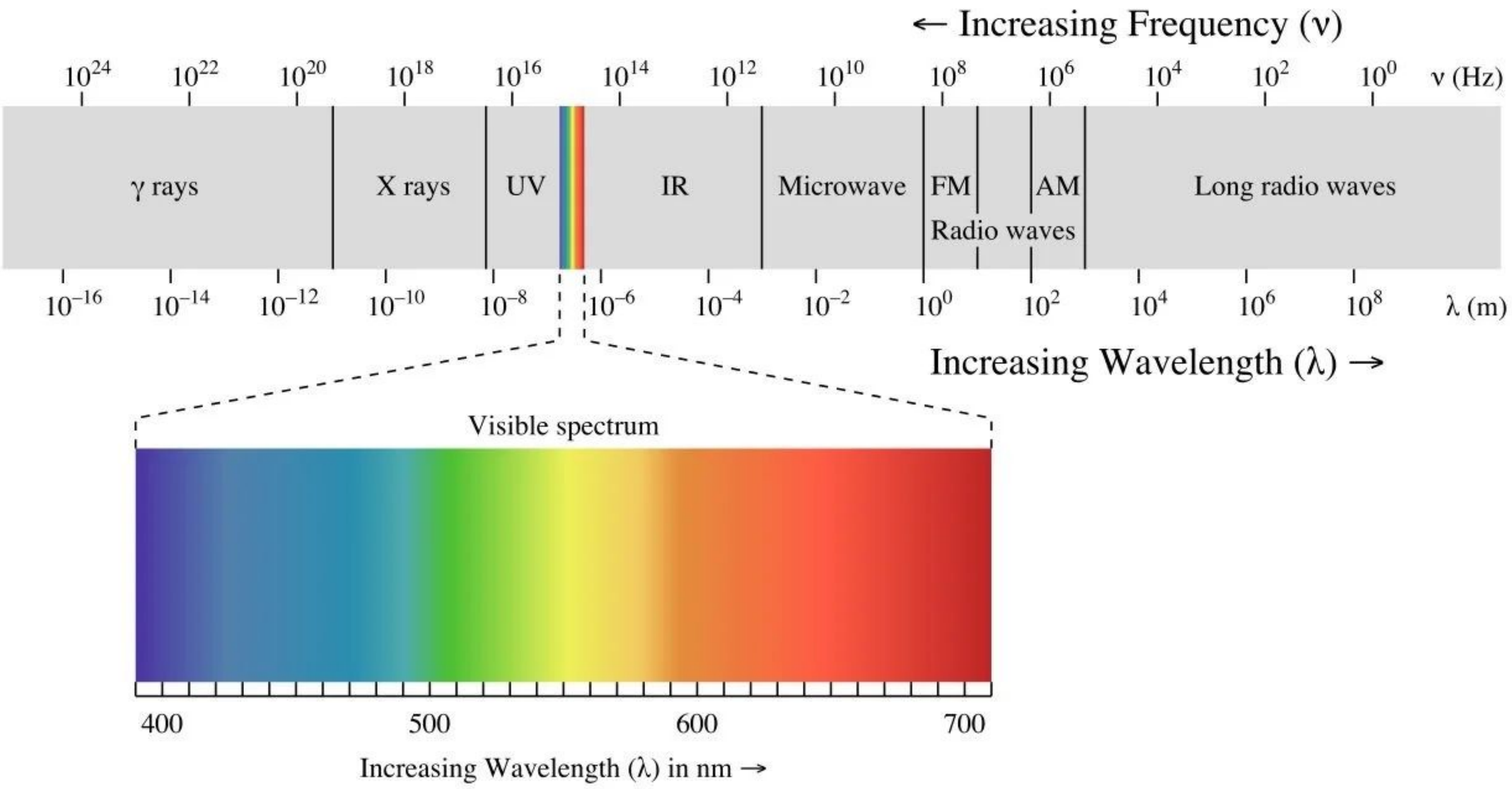
2 metre air temperature

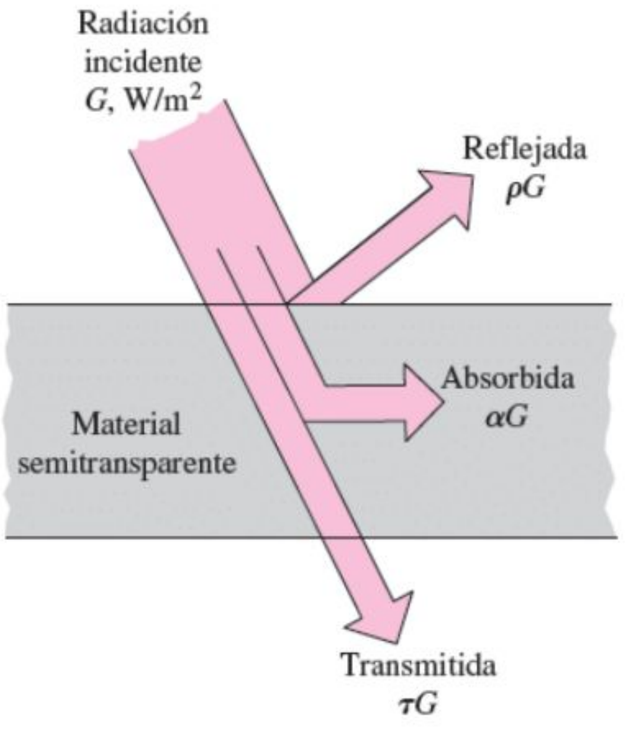
Data Source: ERA5

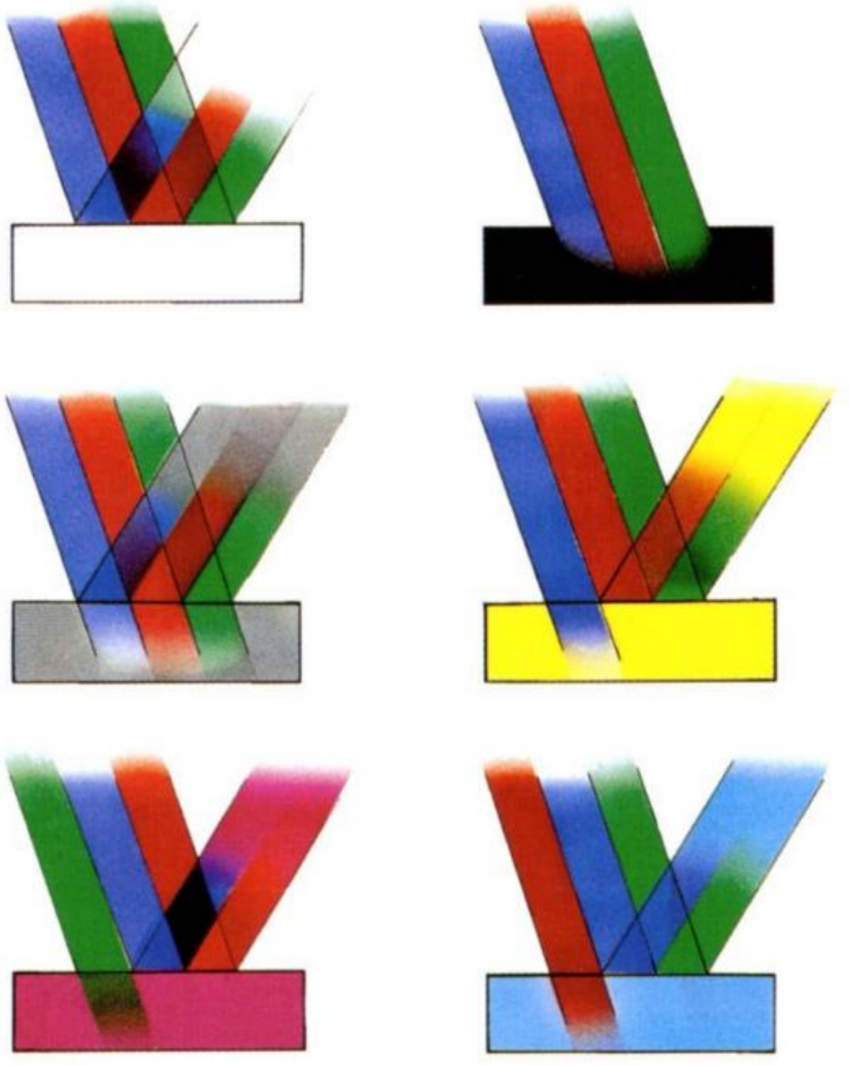
Data attribution and license

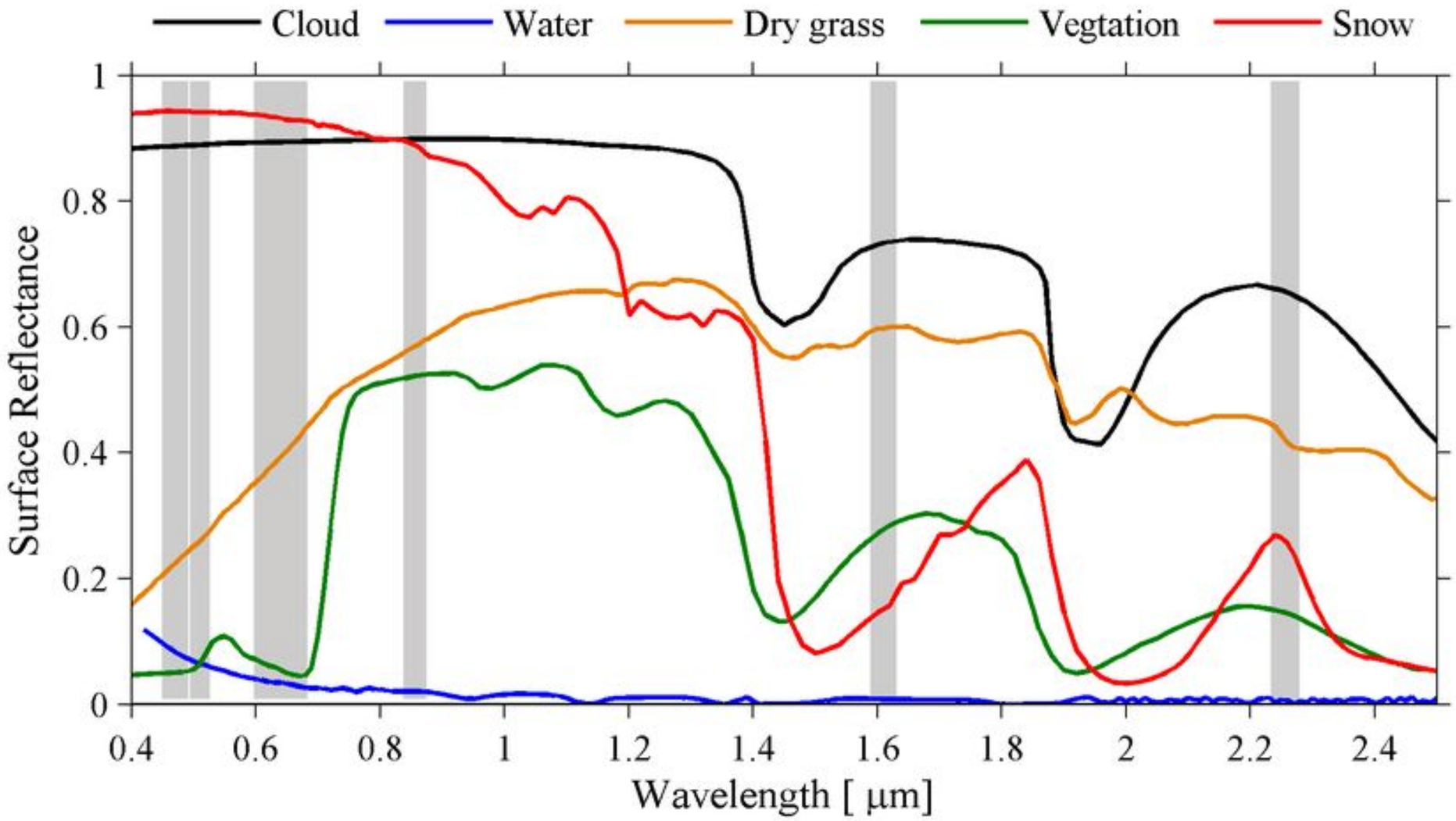
Images generated by LexCube - Leipzig Explorer of Earth Data Cubes by Maximilian Söchting are licensed under CC BY 4.0

REMOTE SENSING

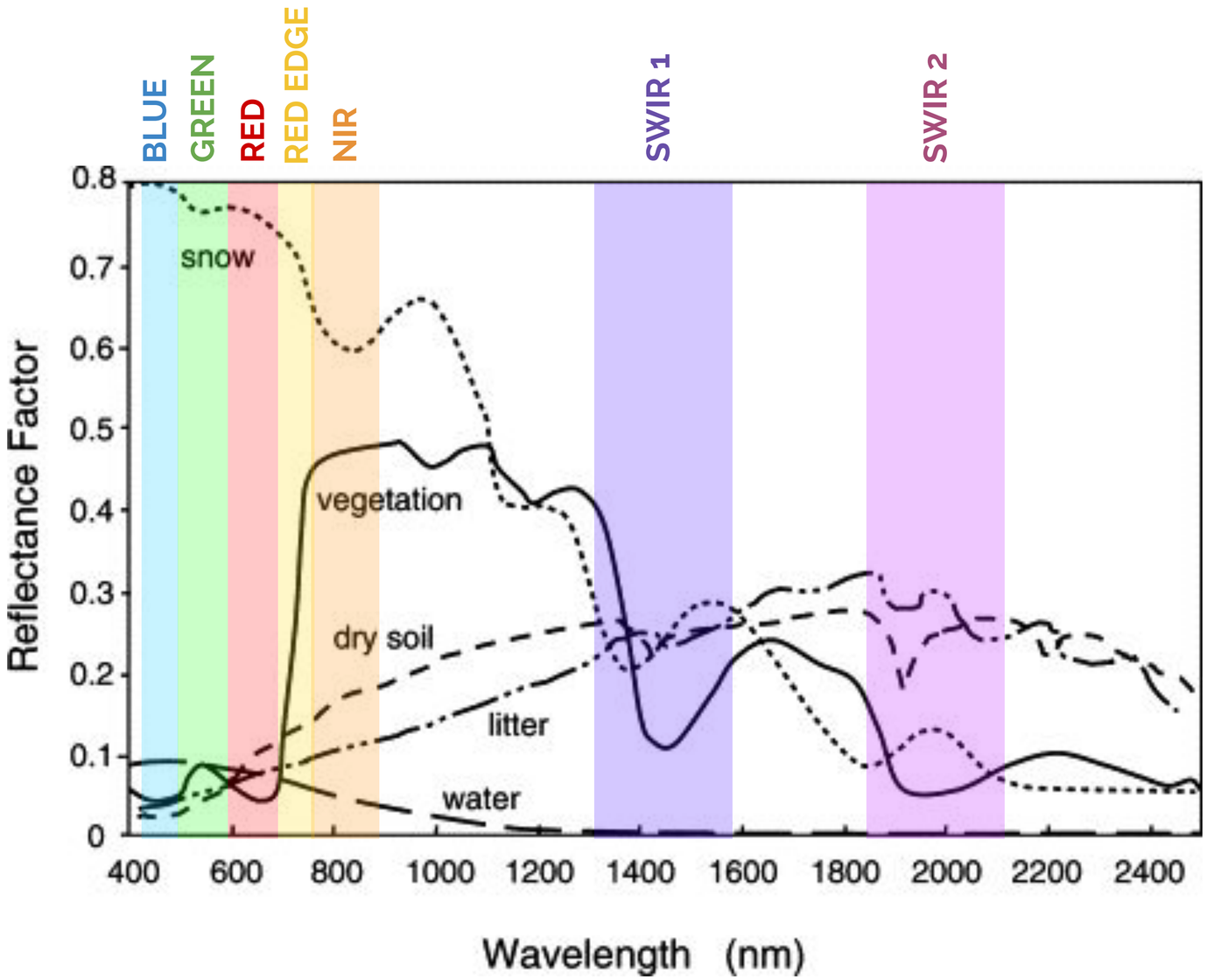

← Increasing Frequency (ν)
10^24 10^22 10^20 10^18 10^16 10^14 10^12 10^10 10^8 10^6 10^4 10^2 10^0 ν (Hz)
γ rays
X rays
UV
IR
Microwave
FM
AM
Radio waves
Long radio waves
10^−16 10^−14 10^−12 10^−10 10^−8 10^−6 10^−4 10^−2 10^0 10^2 10^4 10^6 10^8 λ (m)
Increasing Wavelength (λ) →
Visible spectrum
400
500
600
700
Increasing Wavelength (λ) in nm →


Radiación
incidente
G, W/m^2
Reflejada
ρG
Absorbida
αG
Material
semitransparente
Transmitida
τG

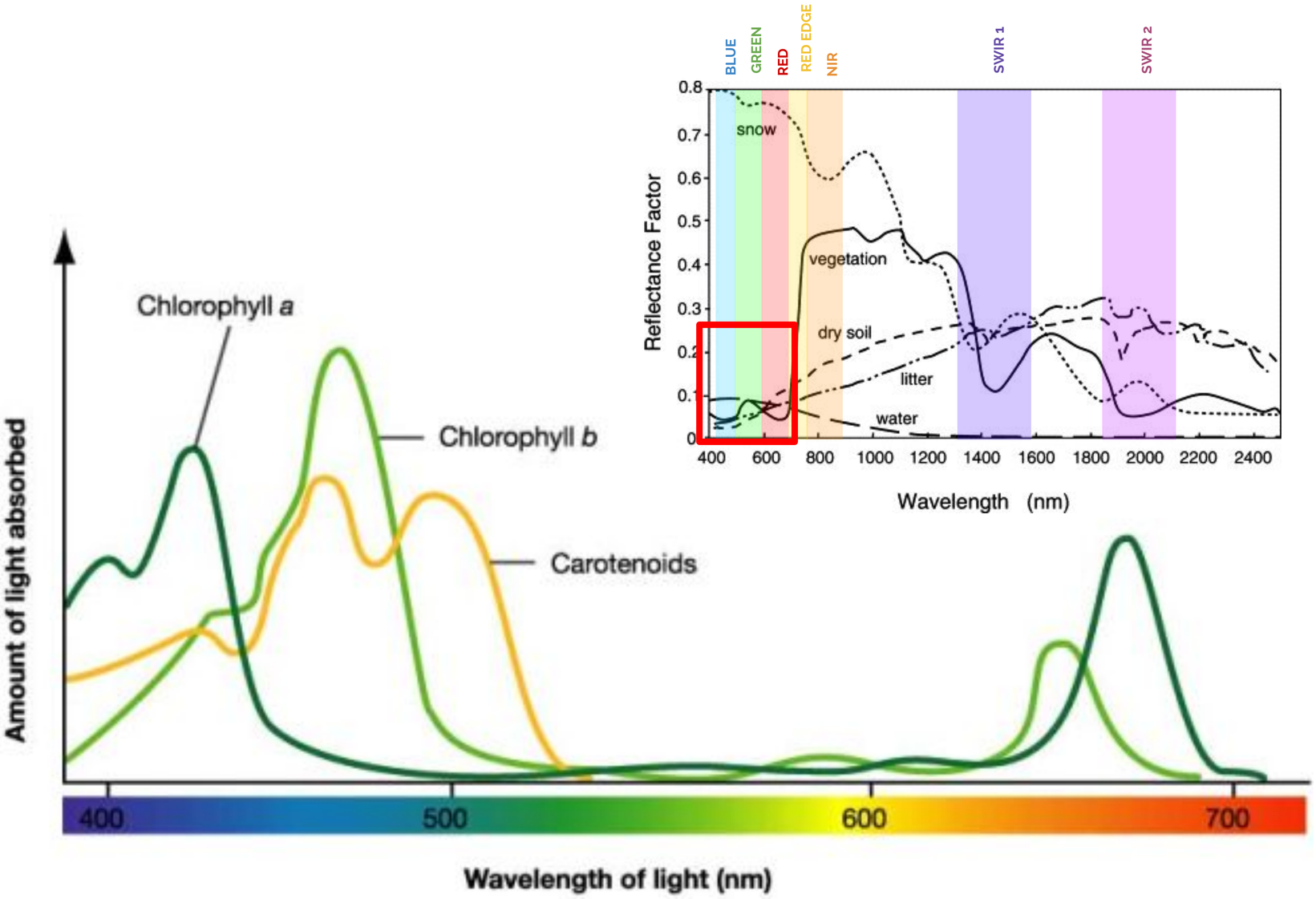




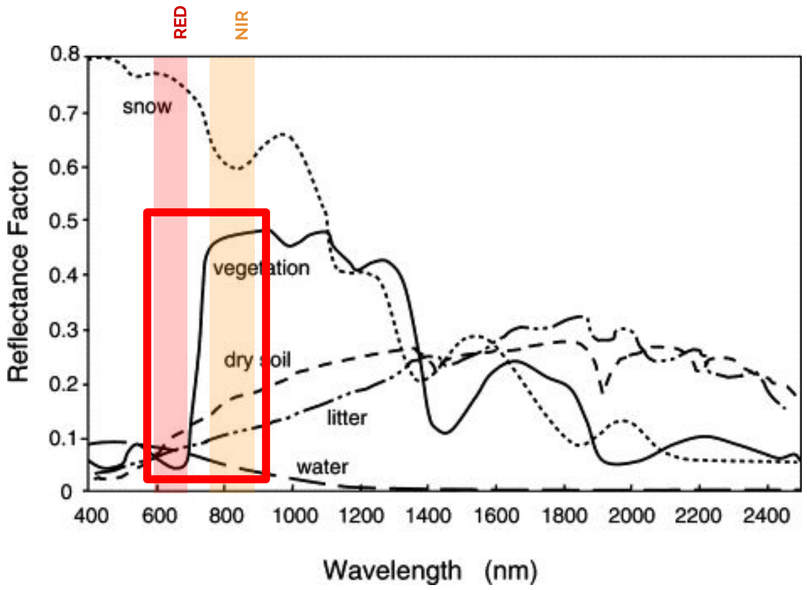
Zhuge et al., 2017
IEEE TGARS

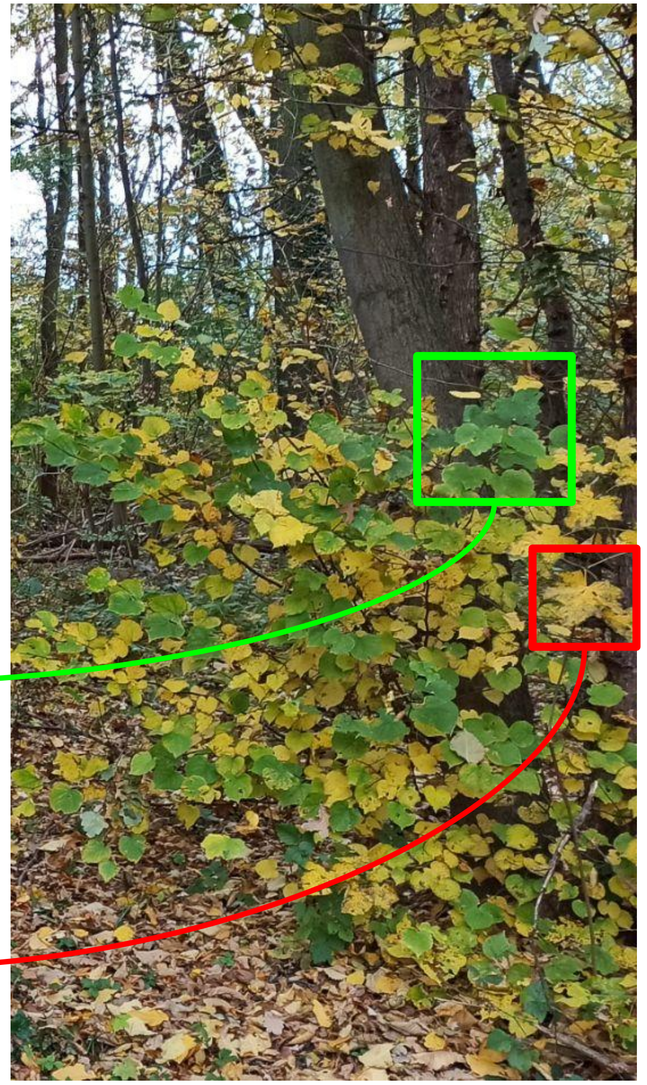


Huete et al., 2004
Environmental Monitoring and Characterization


BLUE
GREEN
RED
RED EDGE
NIR
SWIR 1
SWIR 2
Reflectance Factor
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
snow
vegetation
dry soil
litter
water
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Wavelength (nm)
Chlorophyll a
Chlorophyll b
Carotenoids
Amount of light absorbed
400
500
600
700
Wavelength of light (nm)

NDVI = (NIR - RED)/(NIR + RED)



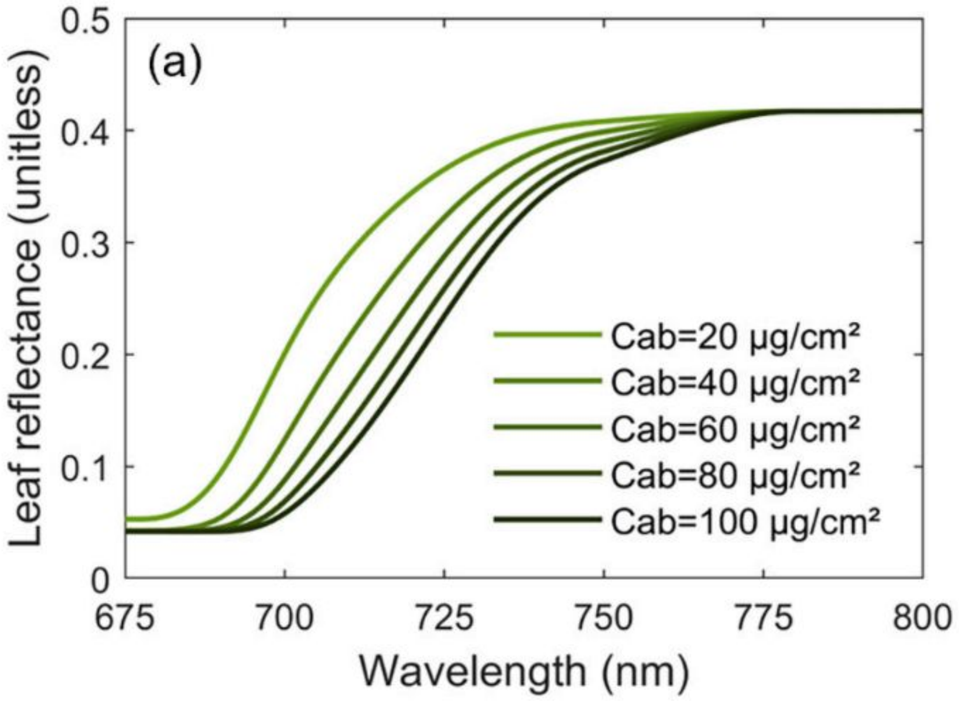


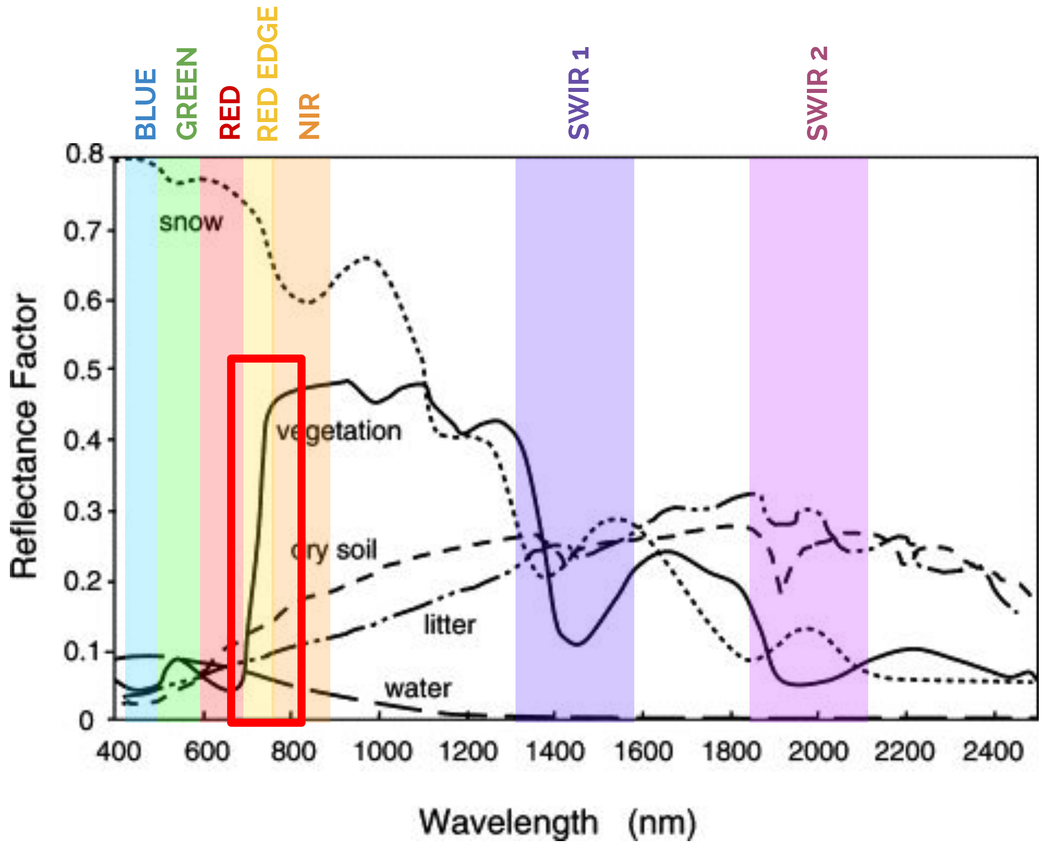
NDVI = 0.75

NIR = 0.50
RED = 0.07

NDVI = 0.31

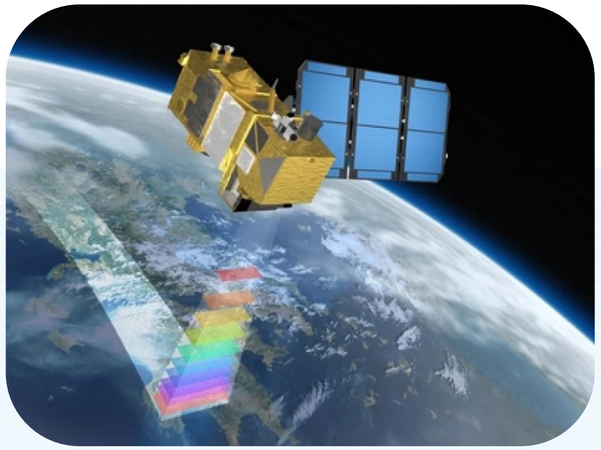
NIR = 0.48
RED = 0.25

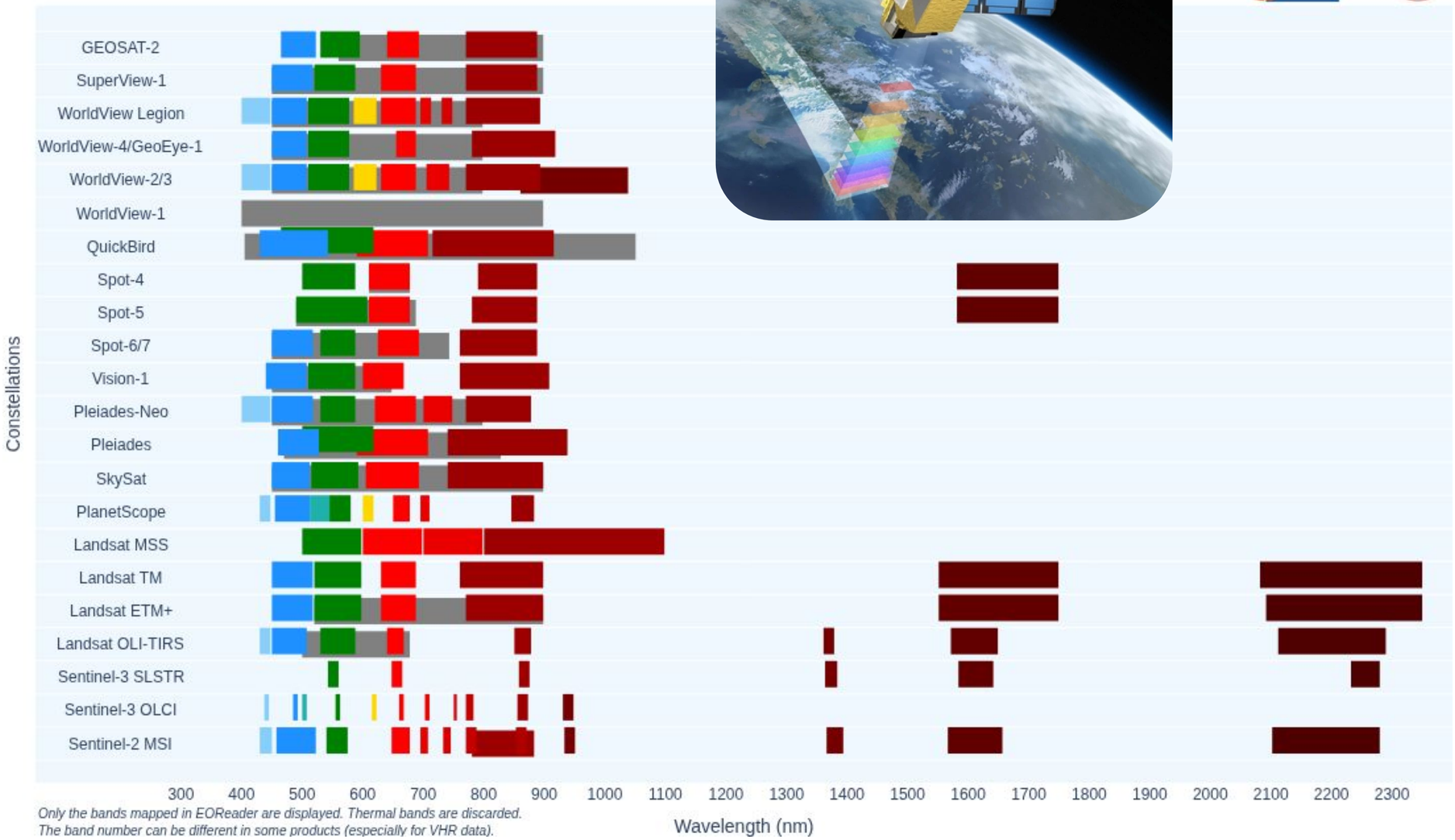




Zeng et al., 2021
Remote Sensing of Environment

EOReader Spectral Band Mapping



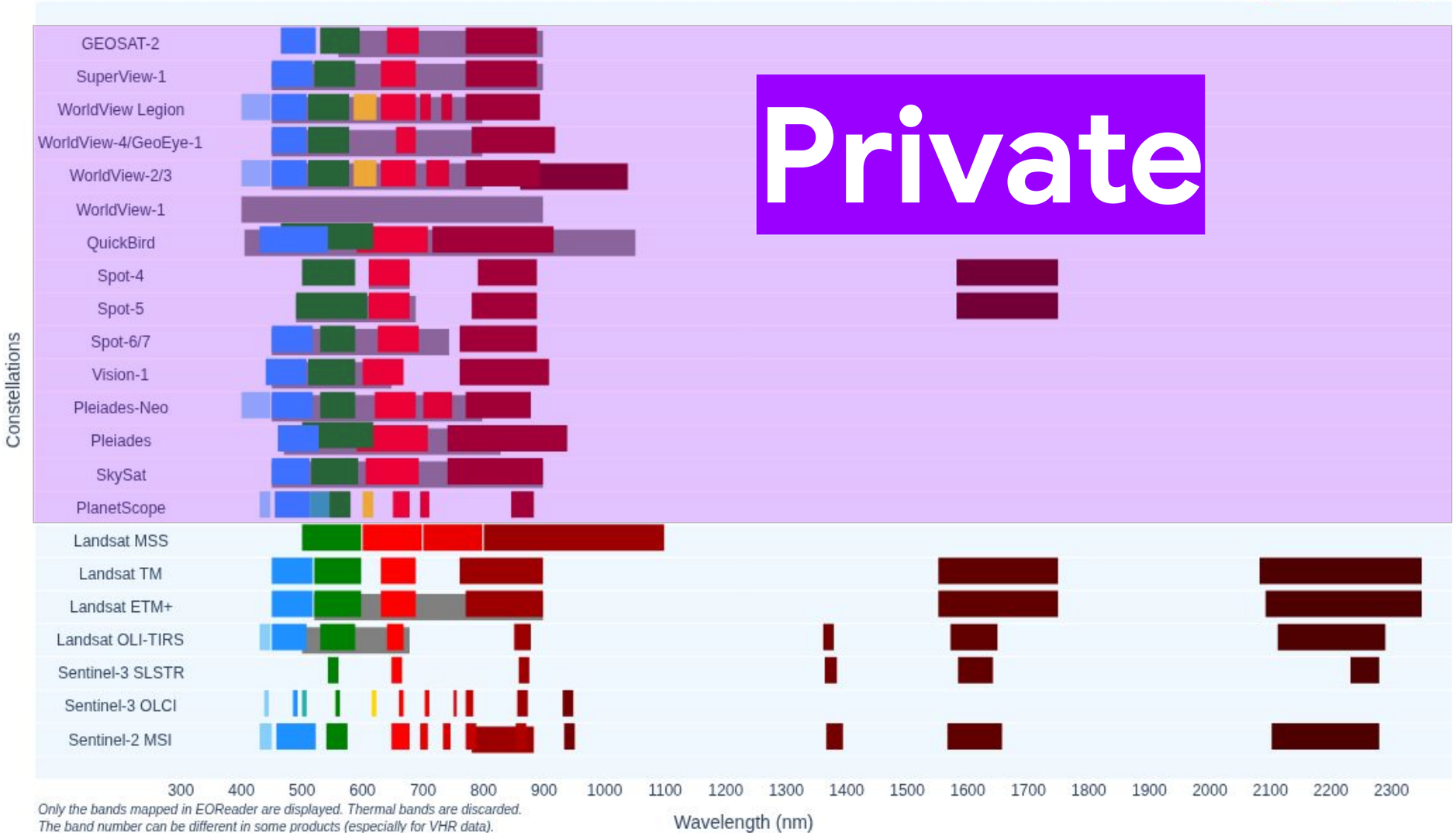


Only the bands mapped in EOReader are displayed. Thermal bands are discarded.
The band number can be different in some products (especially for VHR data).

EARTH OBSERVATION

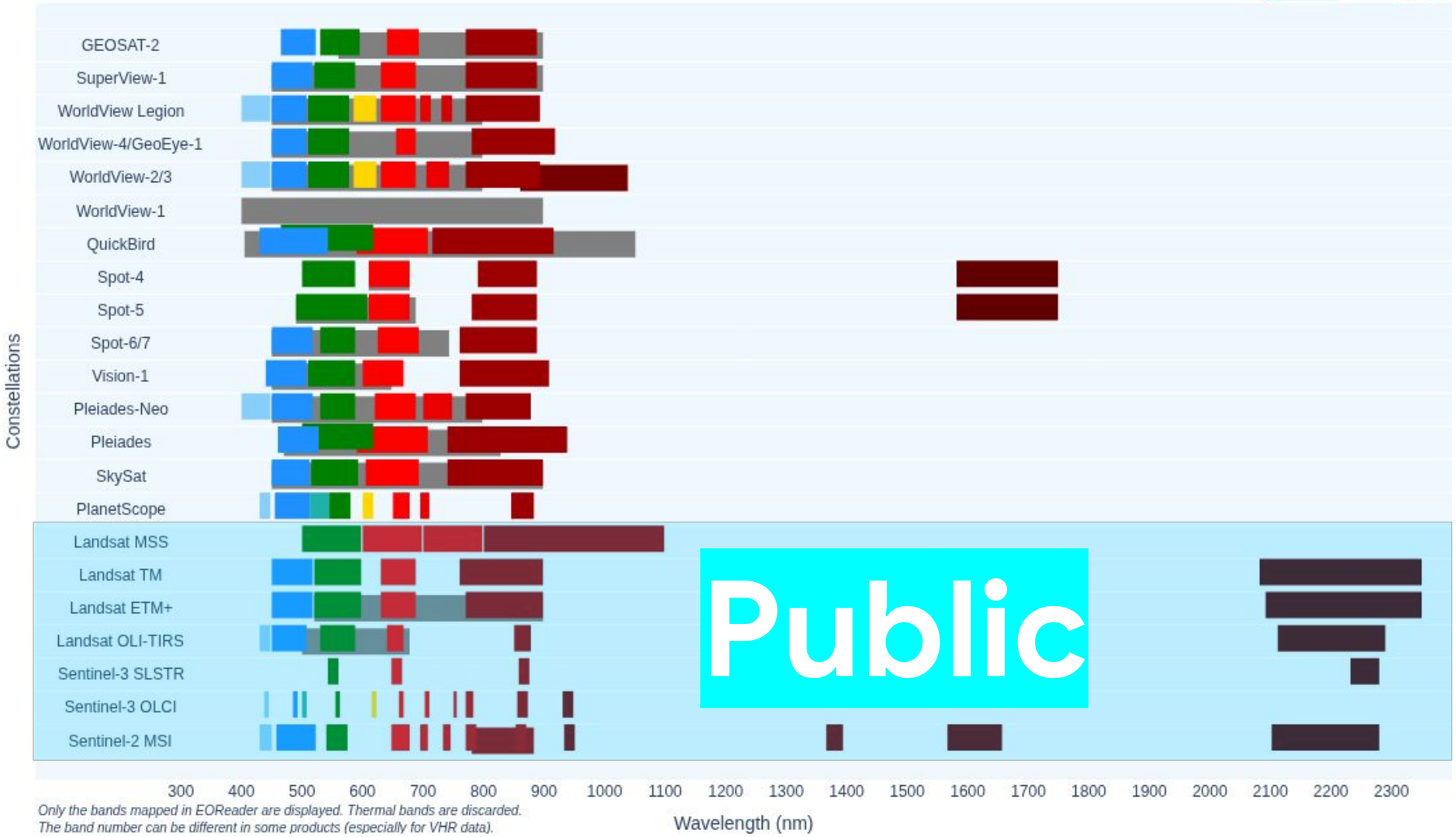
OR EO

EOReader Spectral Band Mapping



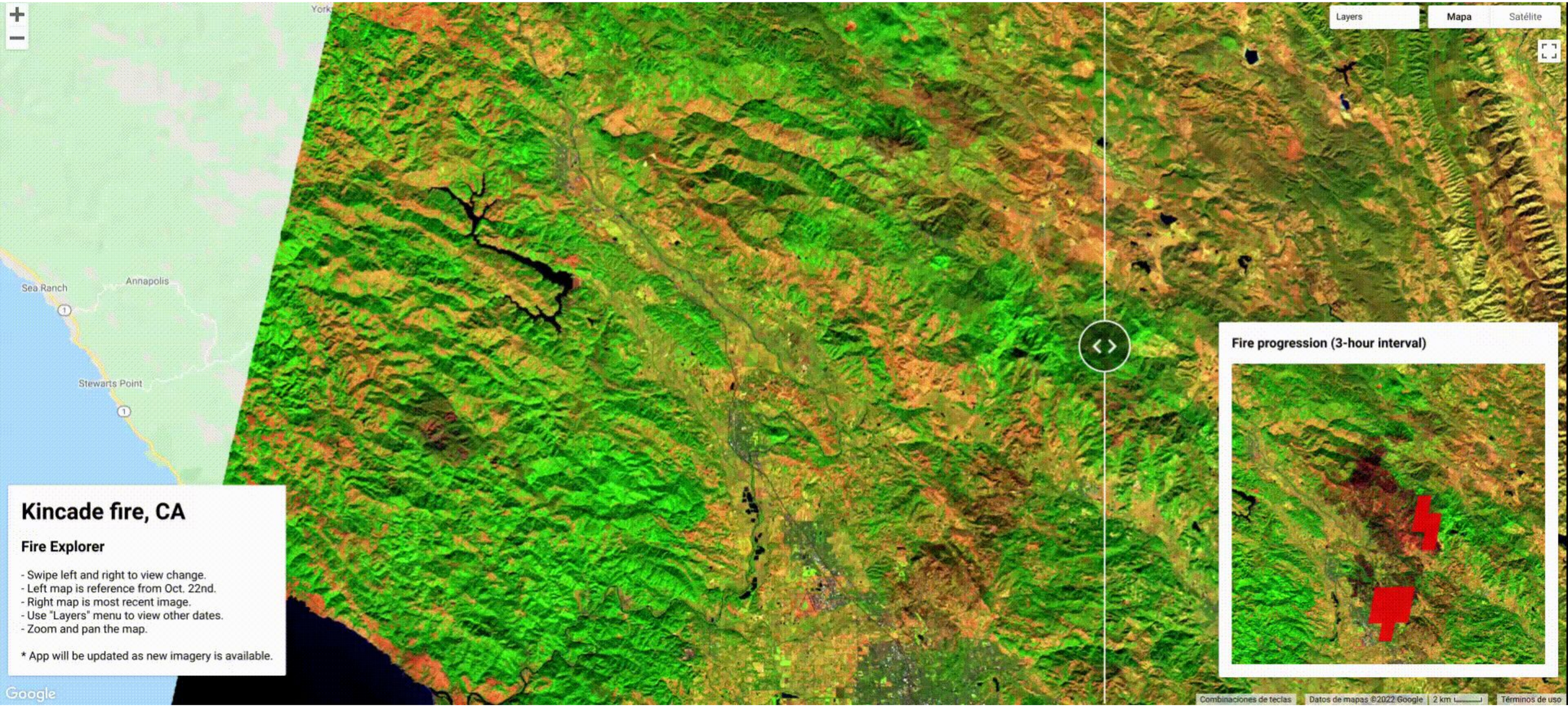
Only the bands mapped in EOReader are displayed. Thermal bands are discarded.
The band number can be different in some products (especially for VHR data).

EOReader Spectral Band Mapping

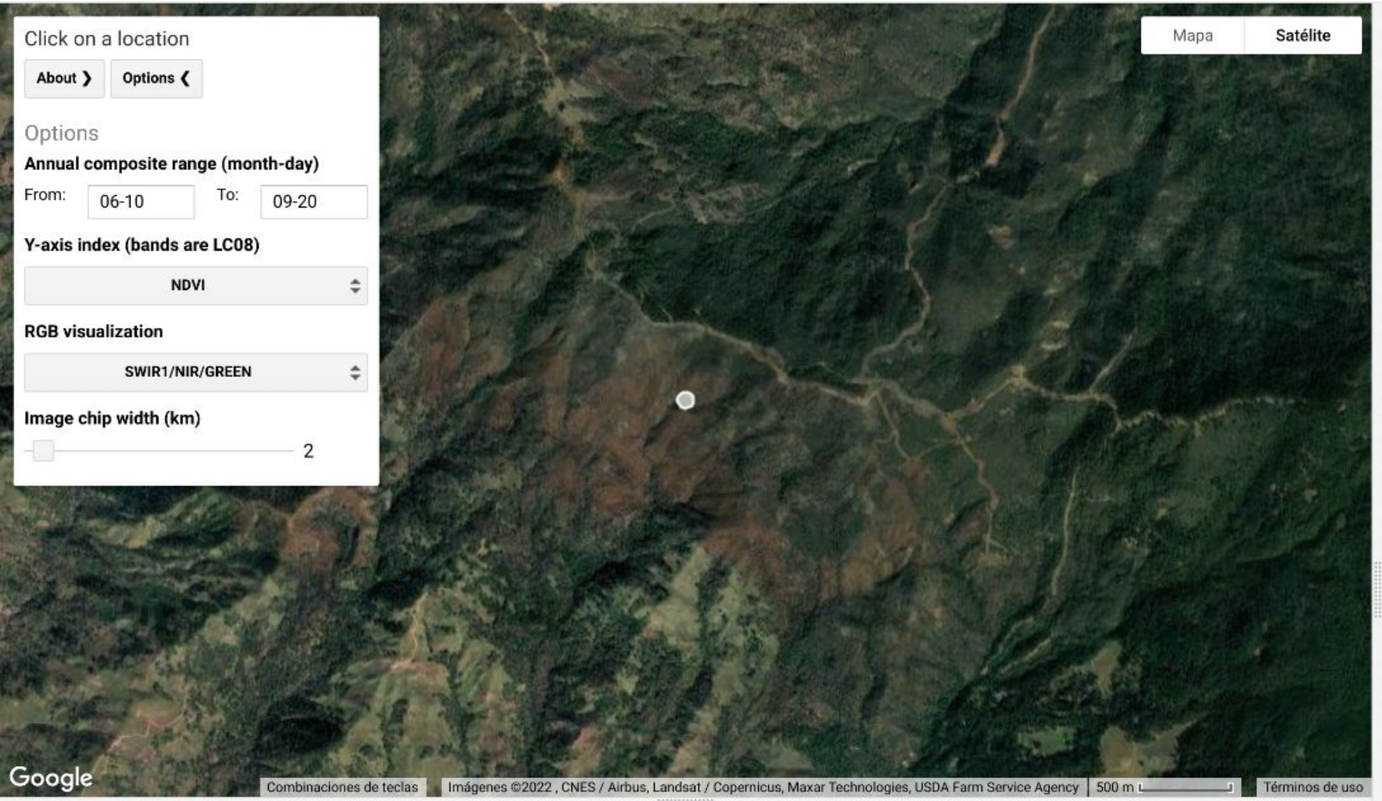


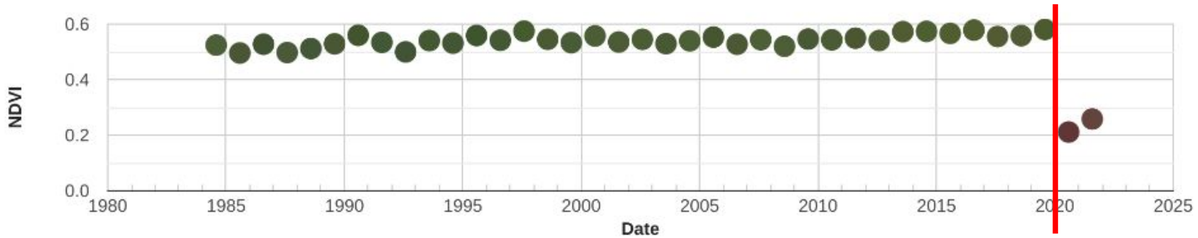
Only the bands mapped in EOReader are displayed. Thermal bands are discarded.
The band number can be different in some products (especially for VHR data).

Public

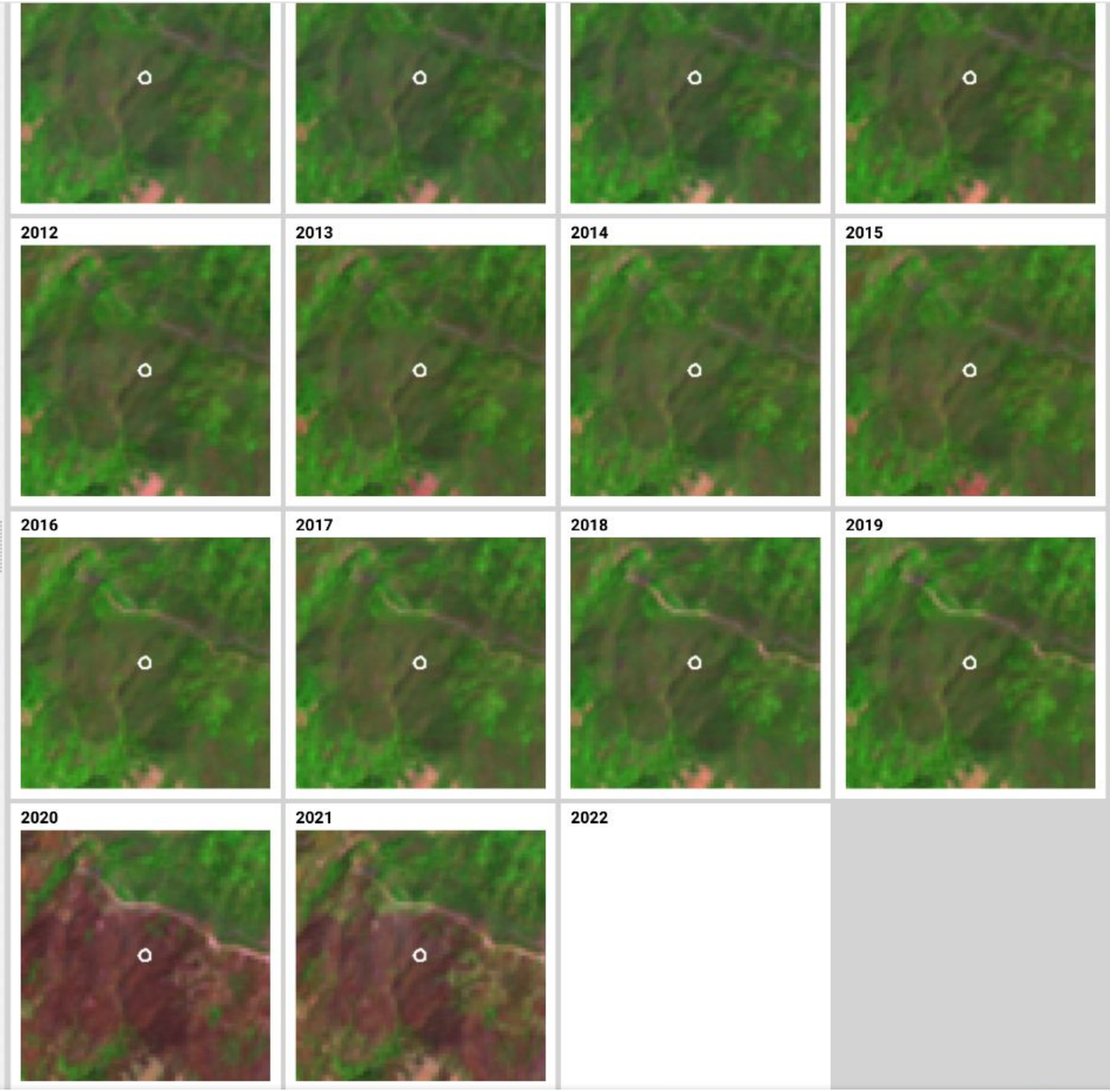


Source image: ([Braaten, 2022](#))



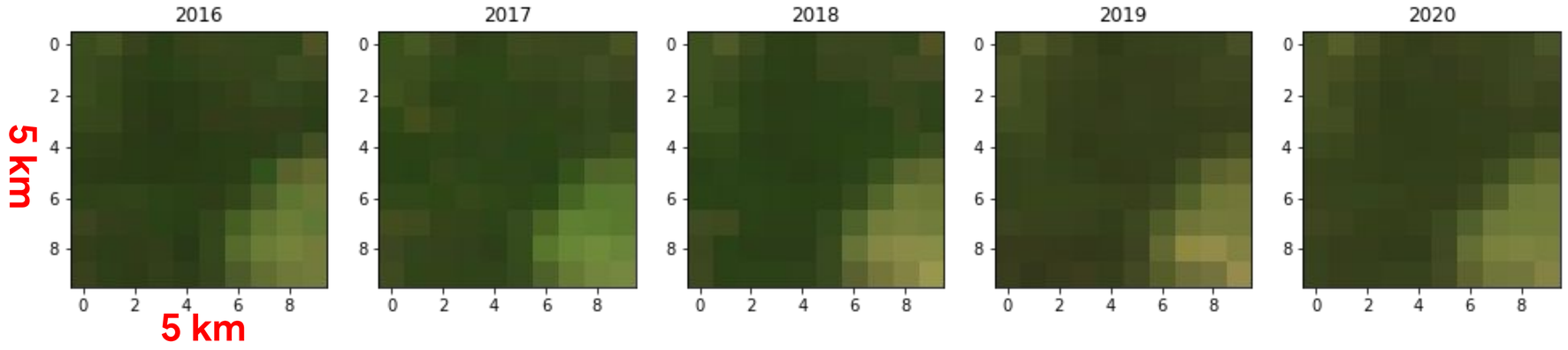


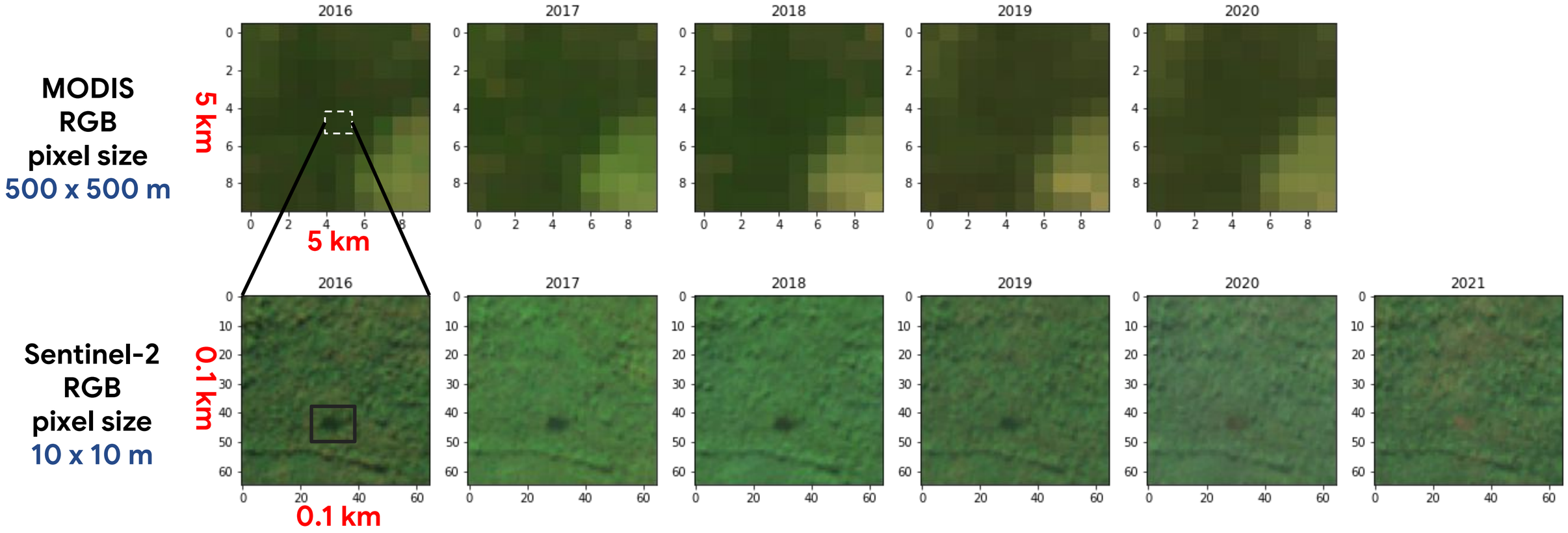
2020 Fire

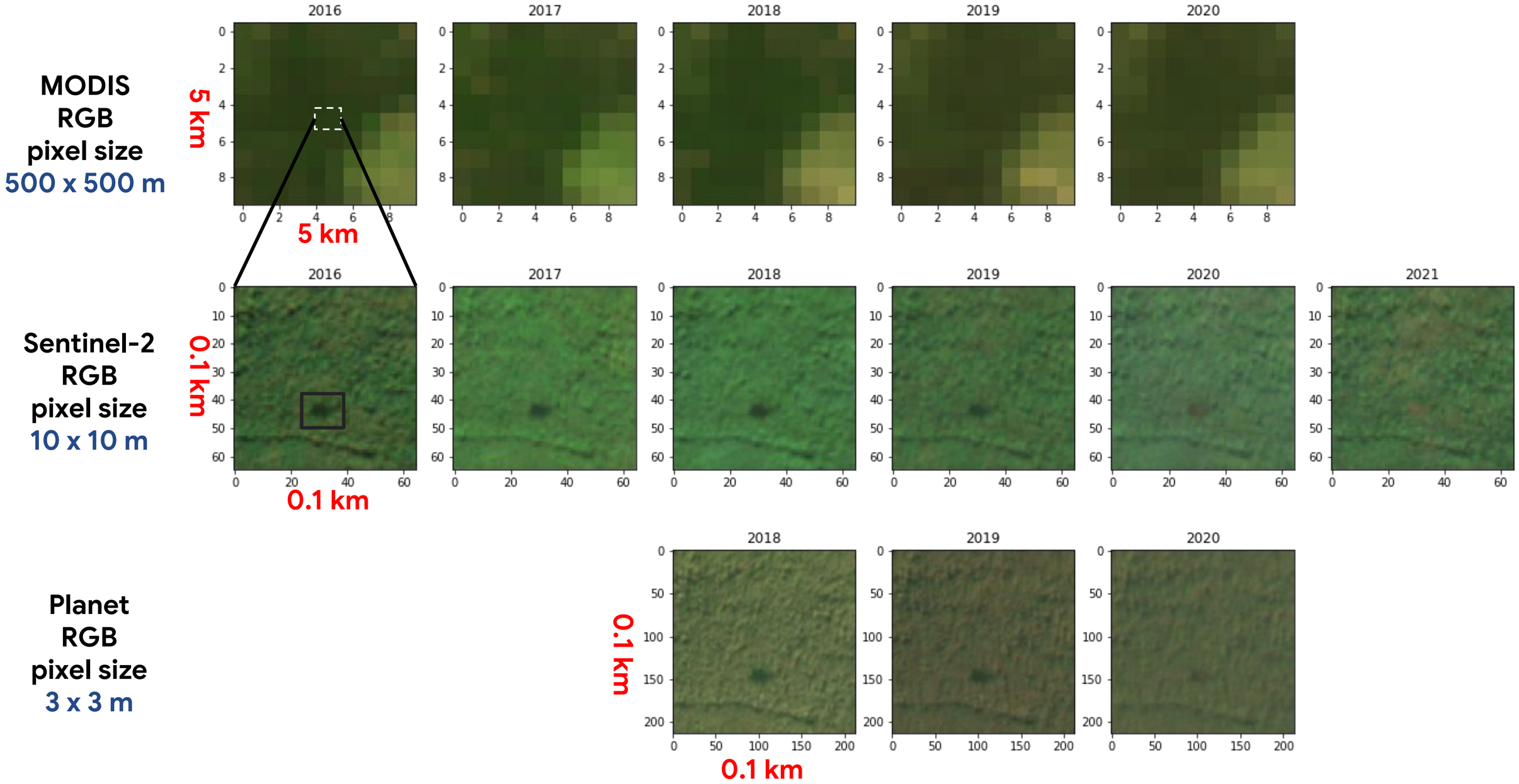


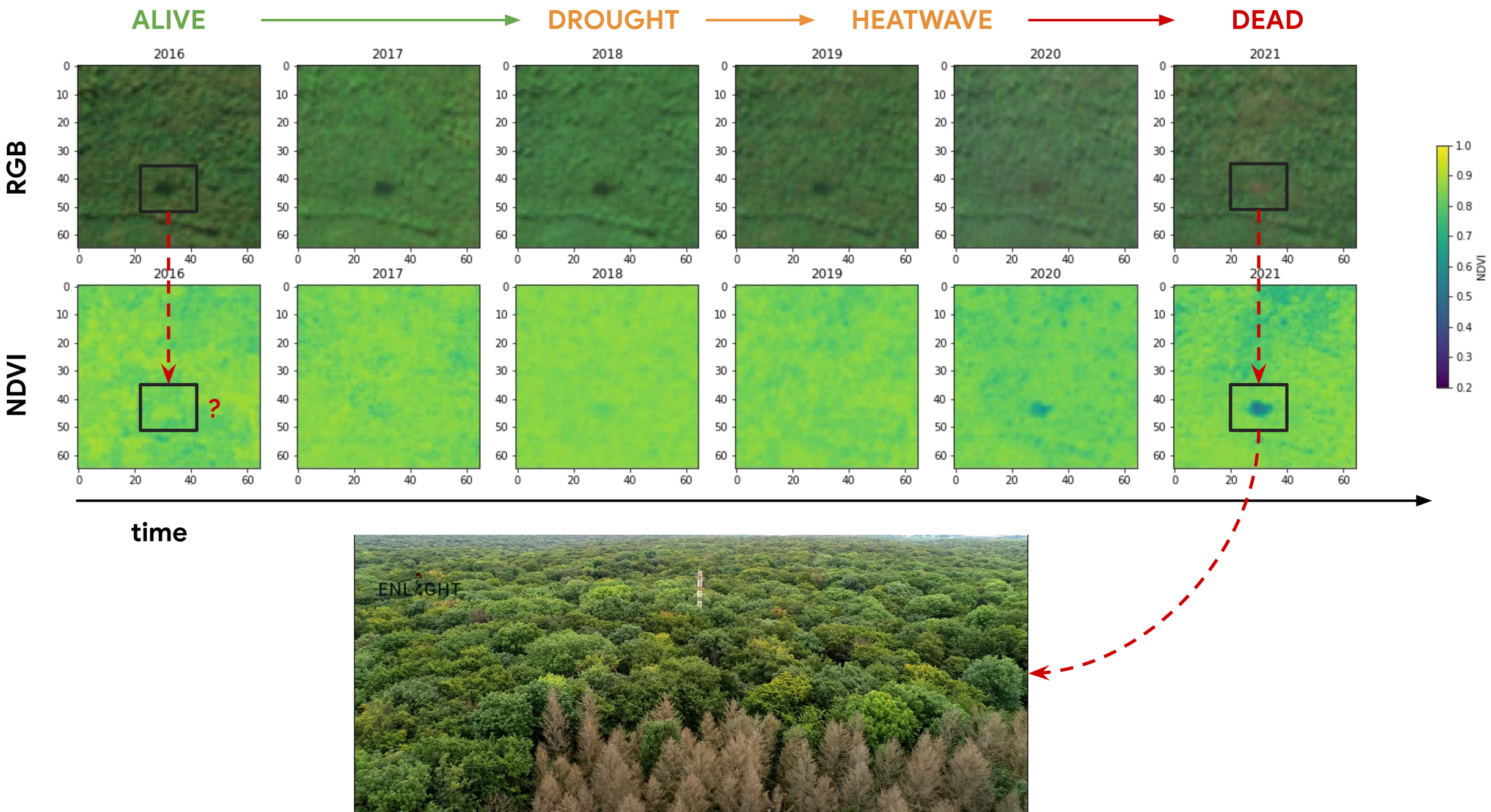
Source image: ([Braaten, 2022](#))

MODIS
RGB
pixel size
500 x 500 m




MODIS
RGB
pixel size
500 x 500 m
5 km
5 km
2016
2017
2018
2019
2020
Sentinel-2
RGB
pixel size
10 x 10 m
0.1 km
0.1 km
2016
2017
2018
2019
2020
2021


MODIS
RGB
pixel size
500 x 500 m
5 km
5 km
2016
2017
2018
2019
2020
Sentinel-2
RGB
pixel size
10 x 10 m
0.1 km
0.1 km
2016
2017
2018
2019
2020
2021
Planet
RGB
pixel size
3 x 3 m
0.1 km
0.1 km
2018
2019
2020

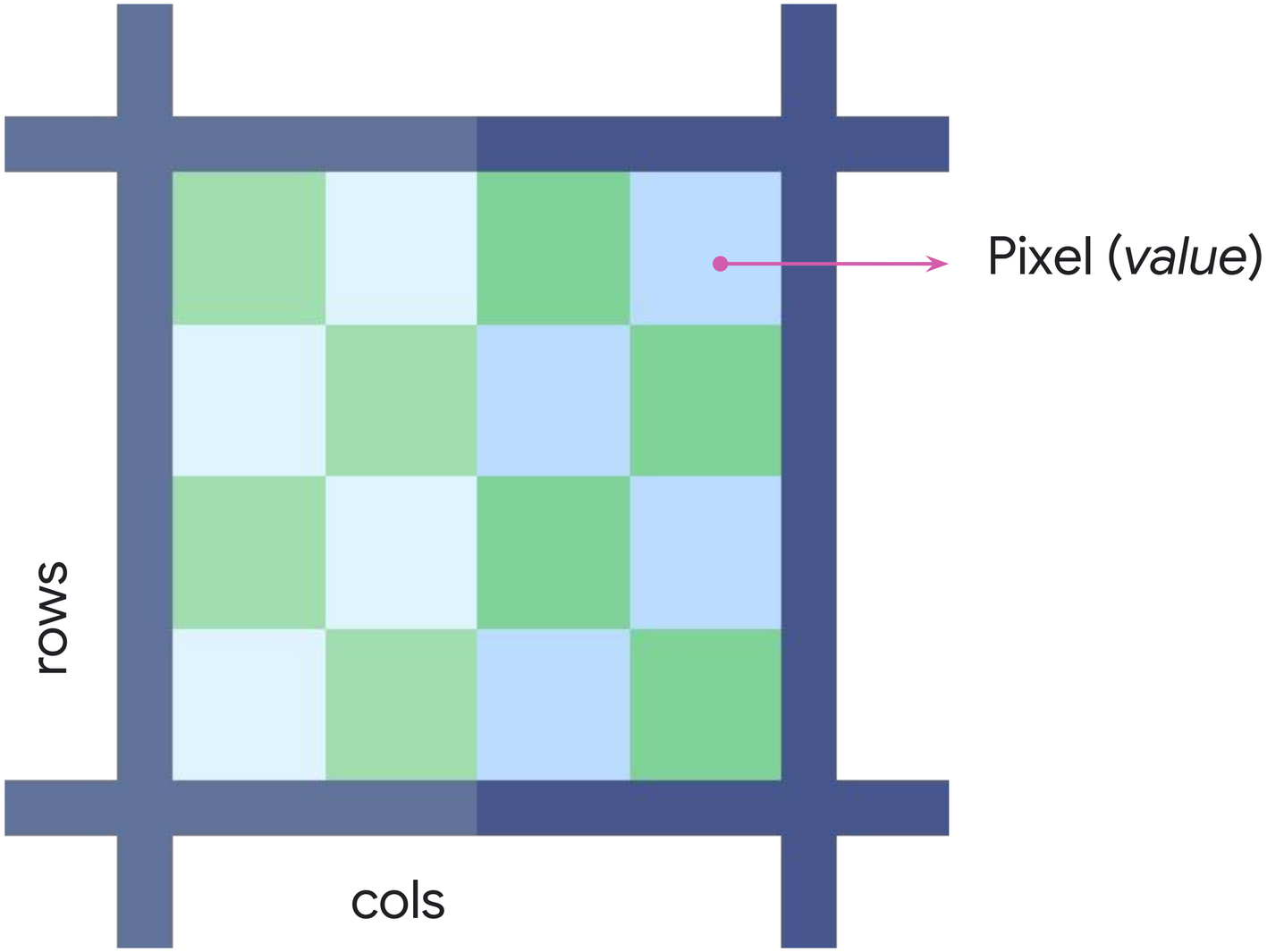

ALIVE
DROUGHT
HEATWAVE
DEAD
RGB
NDVI
2016
2017
2018
2019
2020
2021
?
NDVI
time
ENLIGHT

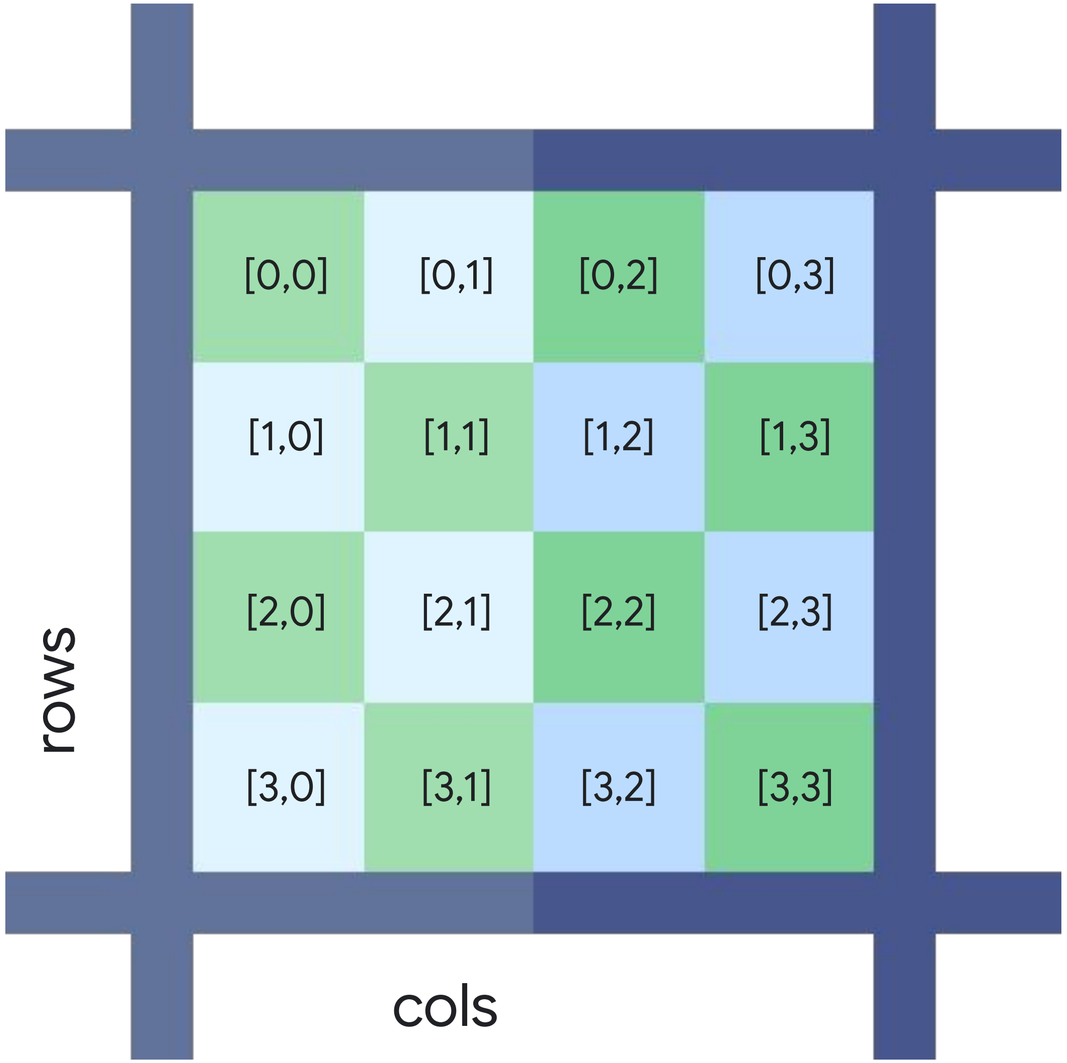
Part 2

Rasters and Data Cubes

2

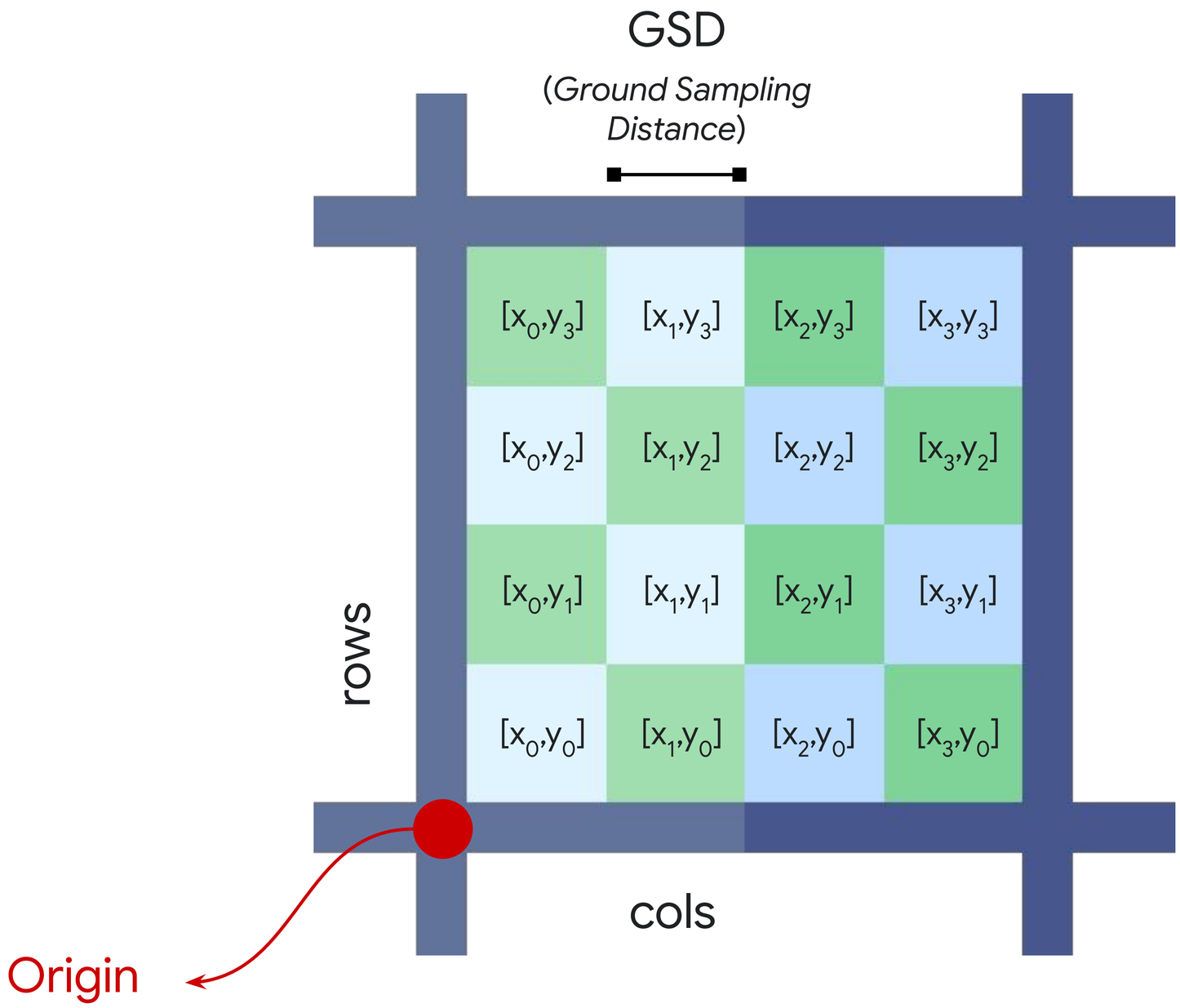
RASTERS


Pixel (*value*)
rows
cols



Dimensions=(*rows x cols*)

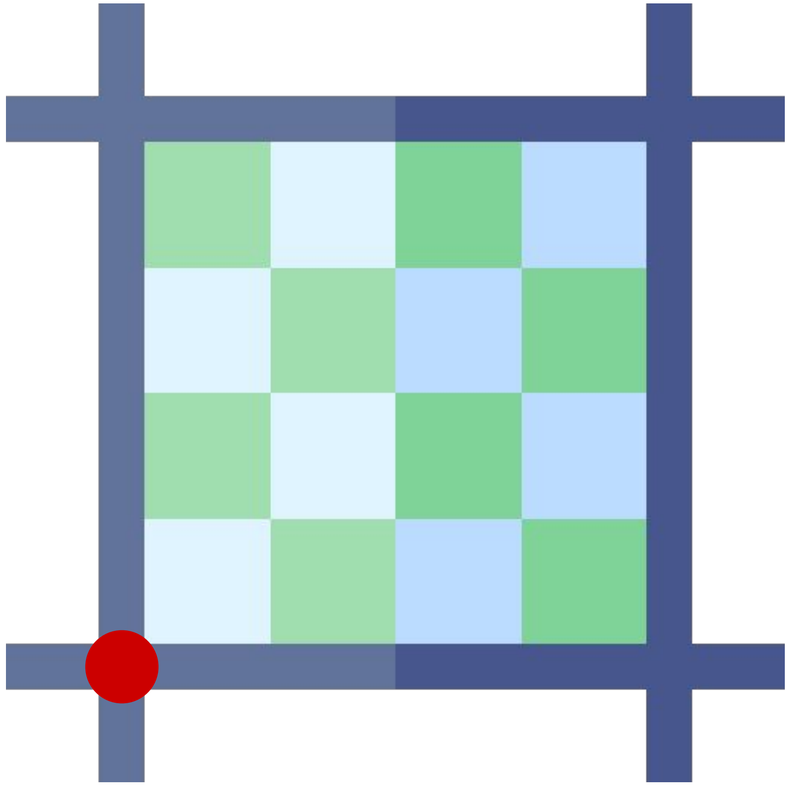
Dimensions=(4x4)



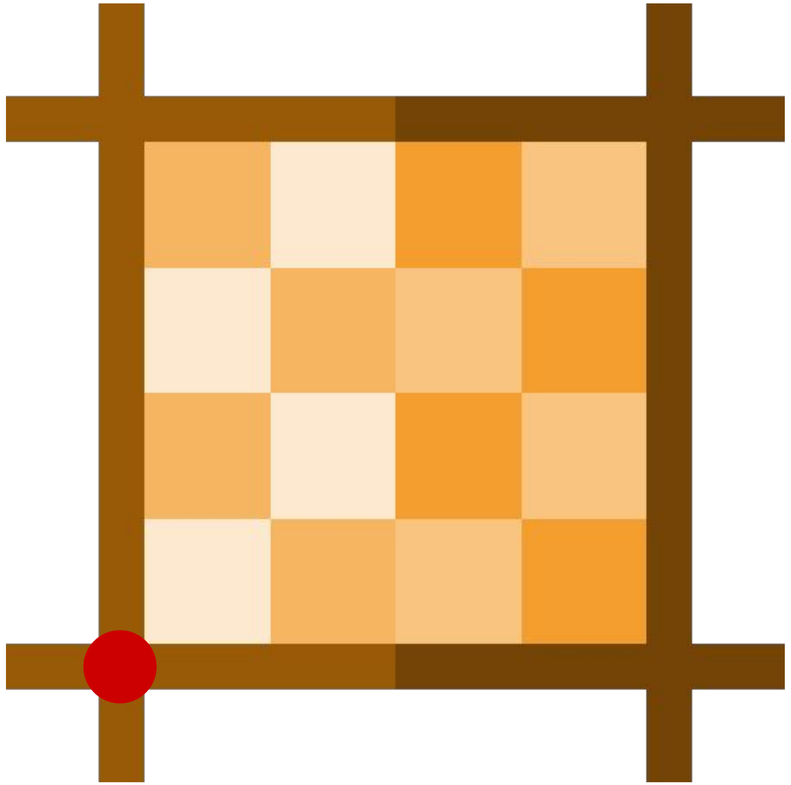
+ CRS

(Coordinate Reference System)

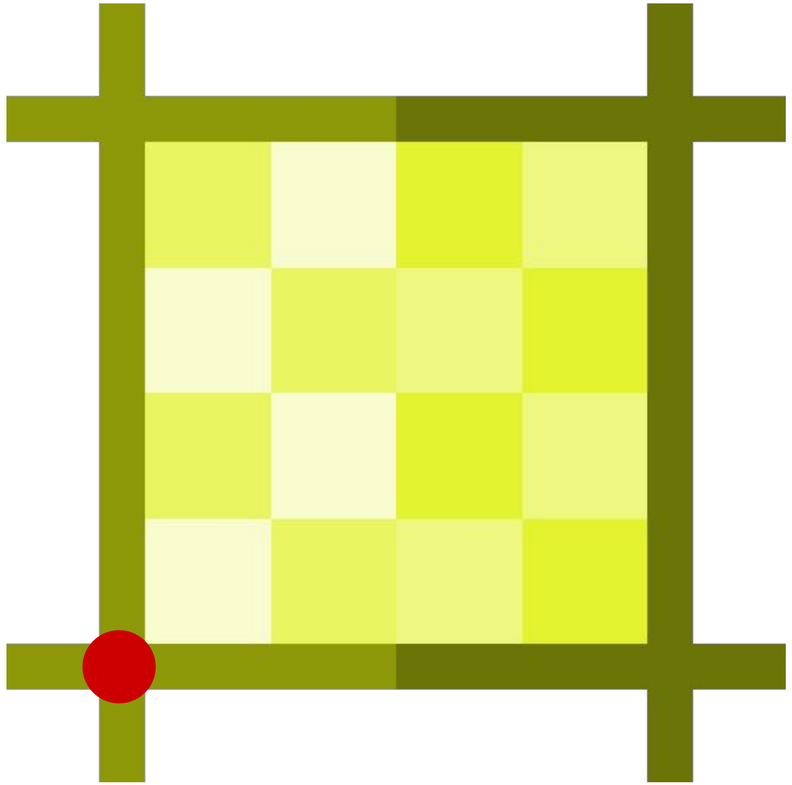
Variable 1



Variable 2



Variable 3



GEO TIFF

COG

CLOUD OPTIMIZED

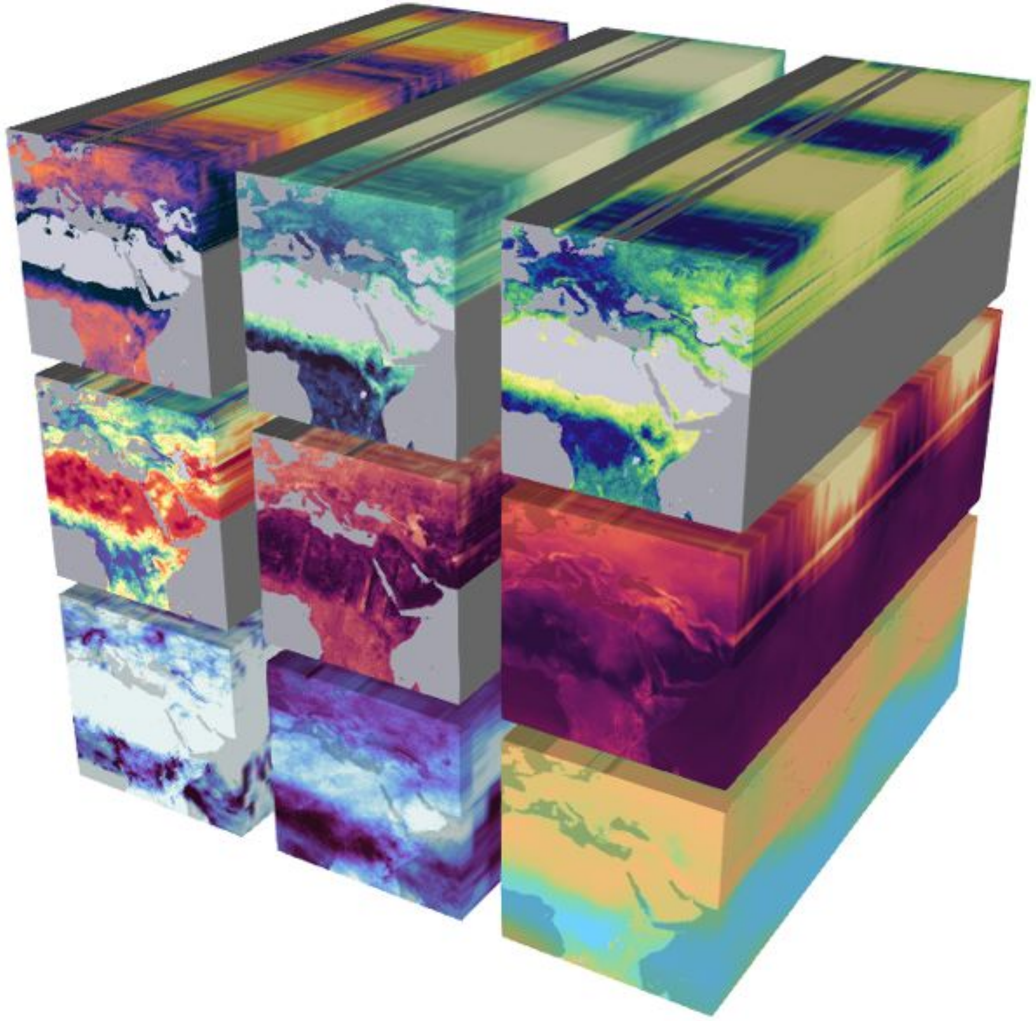
GEOTIFF

Chunk

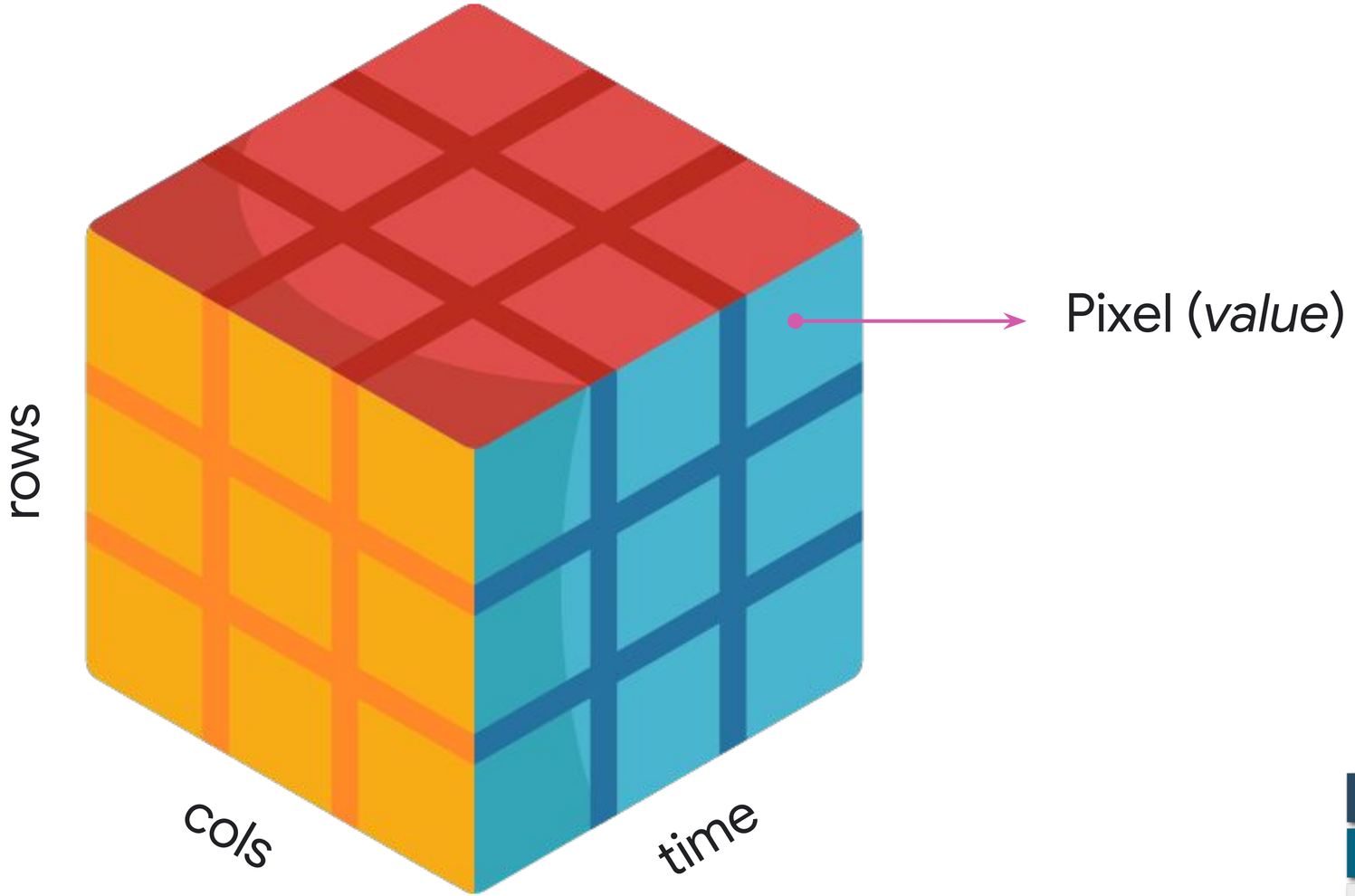
COG
CLOUD OPTIMIZED
GEOTIFF

DATA CUBES

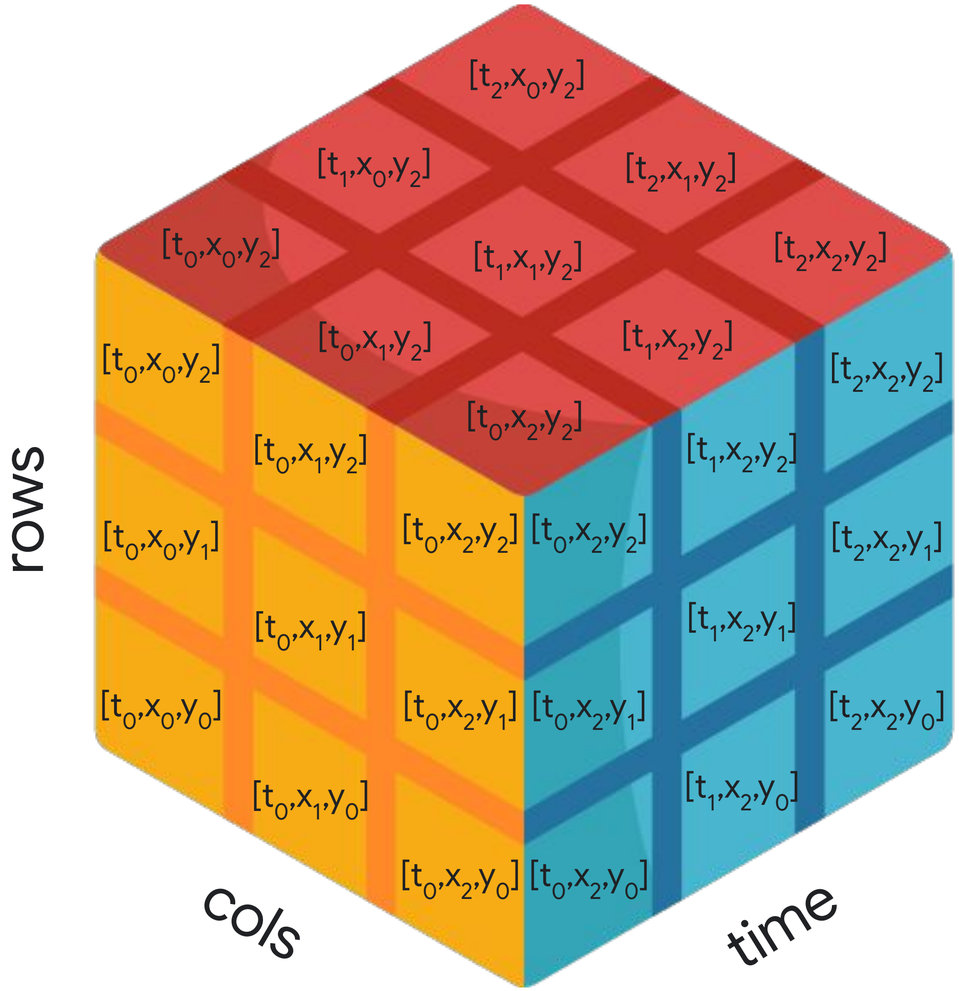
Multidimensional arrays of Earth system data with: *dimensions*, *grids*, *data*, and *attributes*



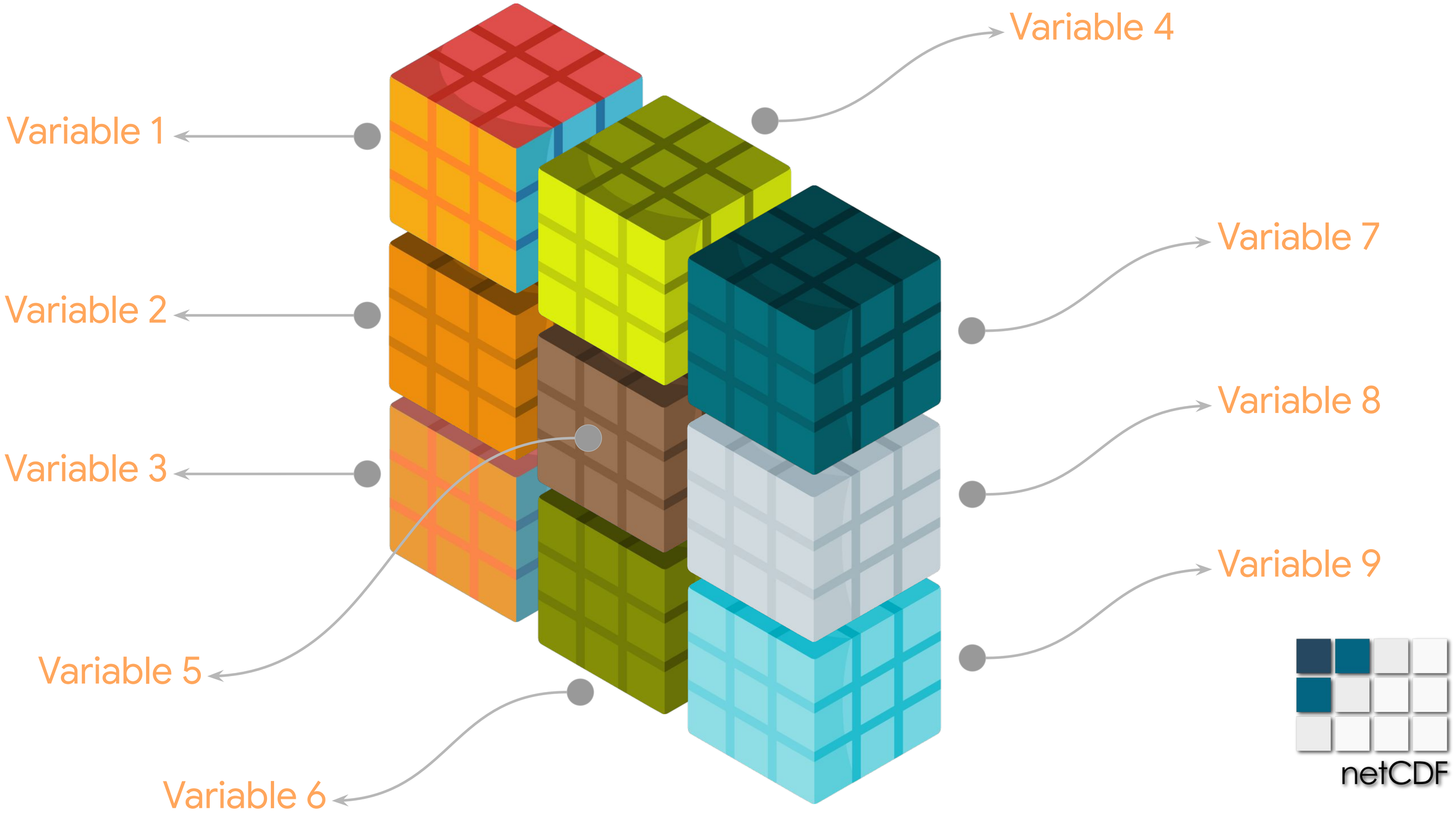
Mahecha et al., 2020
Earth System Dynamics

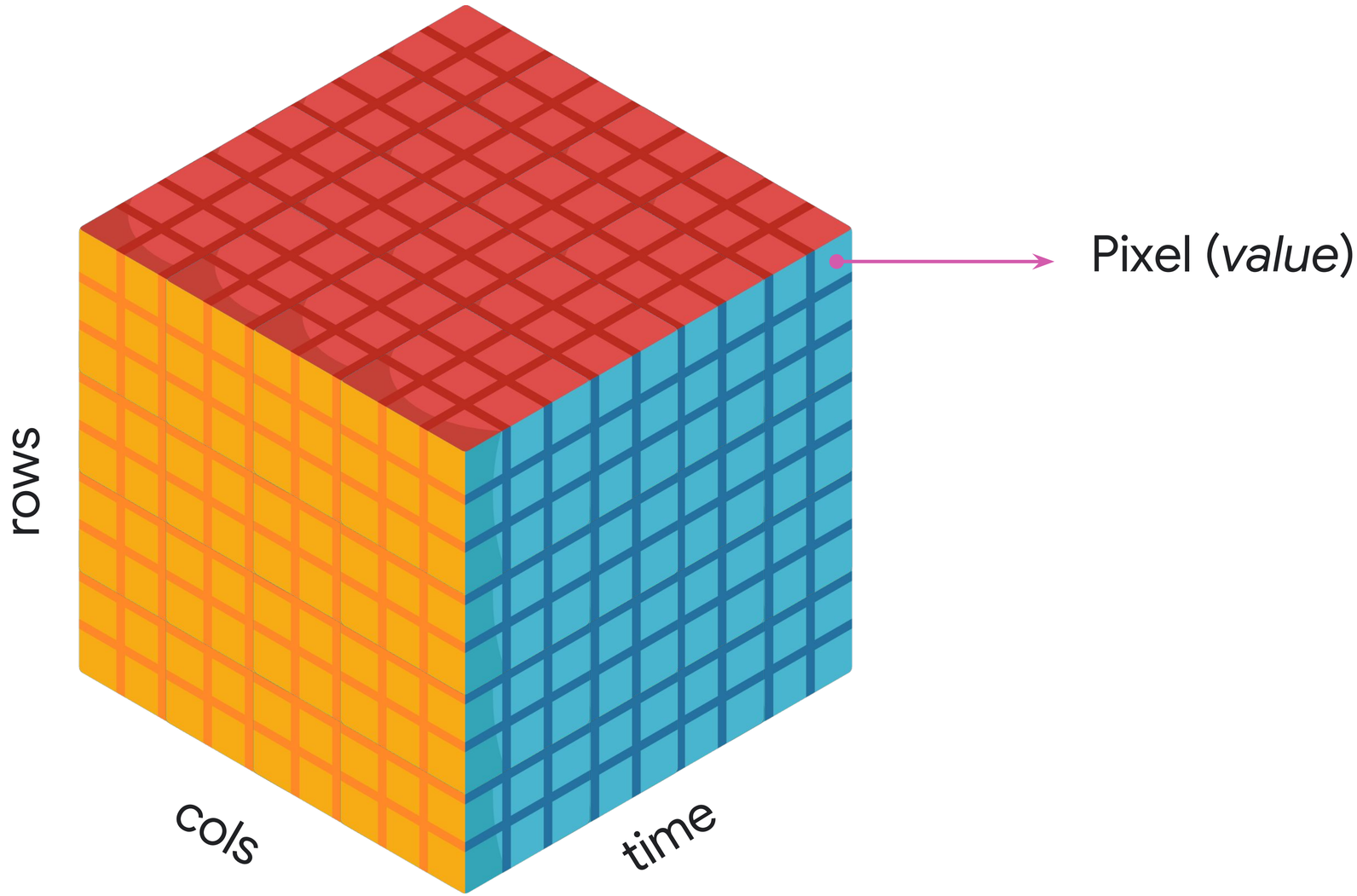


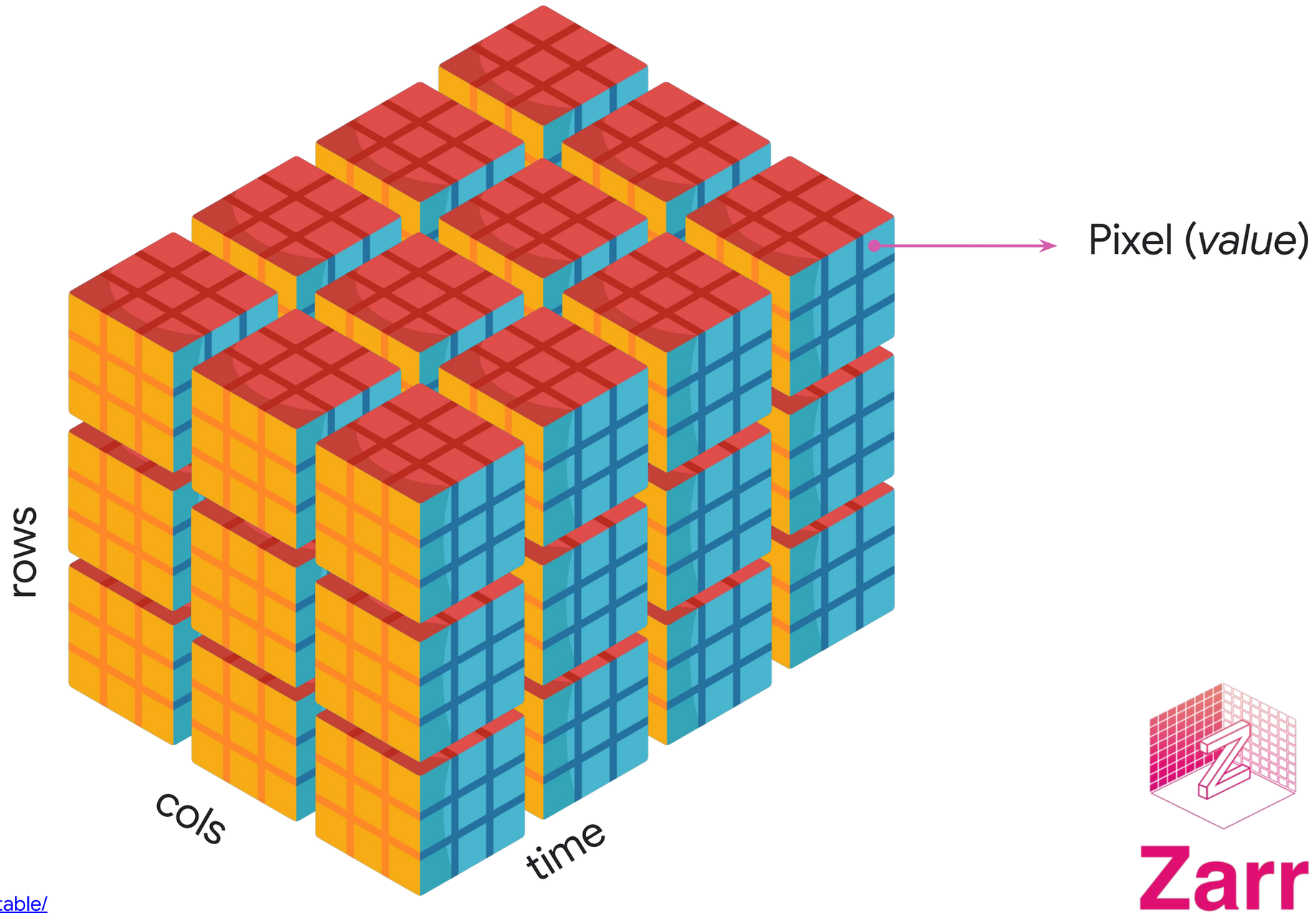
netCDF


[t2,x0,y2]
[t1,x0,y2]
[t2,x1,y2]
[t0,x0,y2]
[t1,x1,y2]
[t2,x2,y2]
[t0,x1,y2]
[t1,x2,y2]
[t0,x2,y2]
[t0,x0,y2]
[t0,x1,y2]
[t0,x2,y2]
[t0,x2,y2]
[t1,x2,y2]
[t2,x2,y2]
[t0,x0,y1]
[t2,x2,y1]
[t0,x1,y1]
[t1,x2,y1]
[t0,x0,y0]
[t0,x2,y1]
[t0,x2,y1]
[t2,x2,y0]
[t0,x1,y0]
[t1,x2,y0]
[t0,x2,y0]
[t0,x2,y0]
rows
cols
time

netCDF

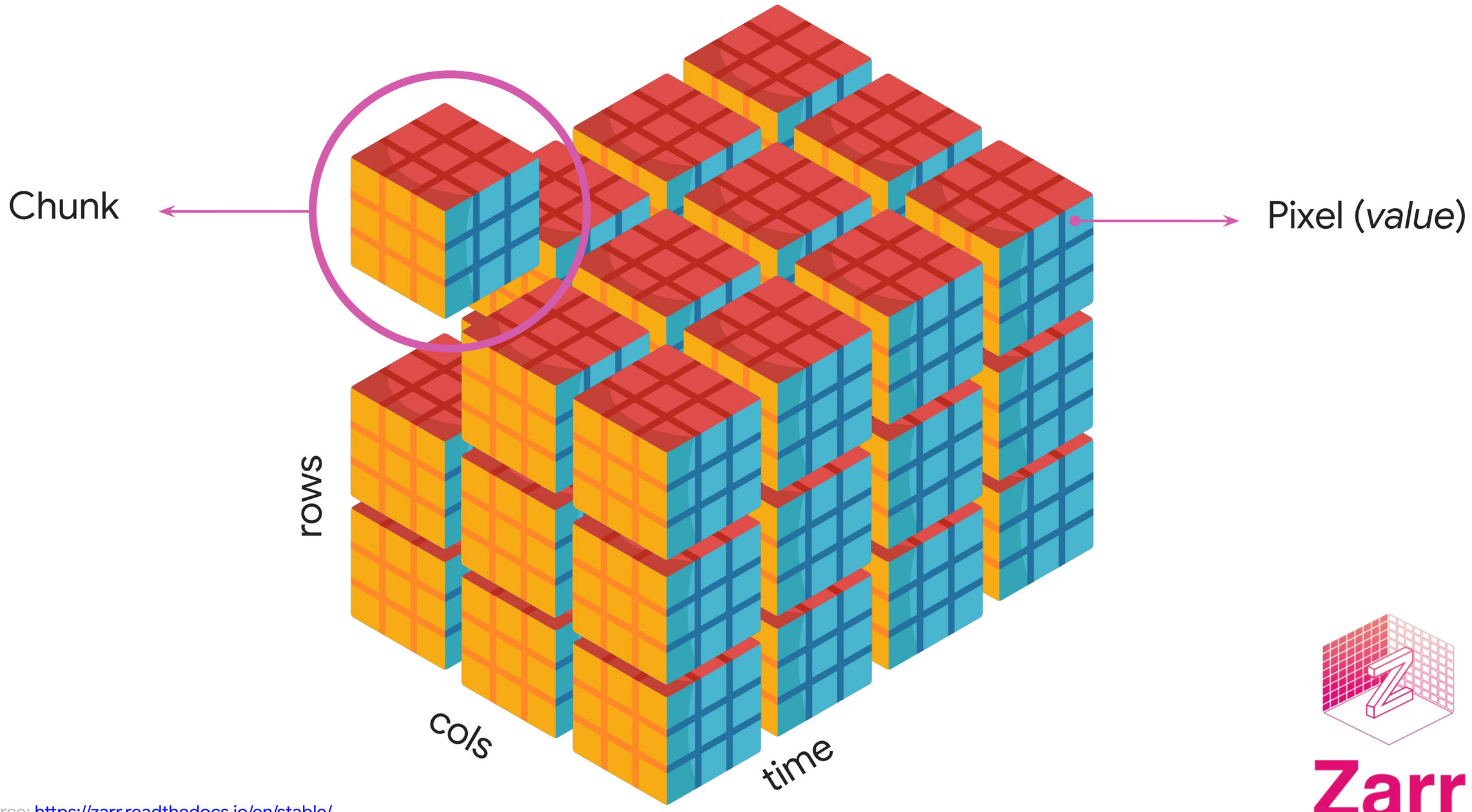

Variable 1
Variable 2
Variable 3
Variable 5
Variable 6
Variable 4
Variable 7
Variable 8
Variable 9
netCDF


rows
cols
time
Pixel (*value*)



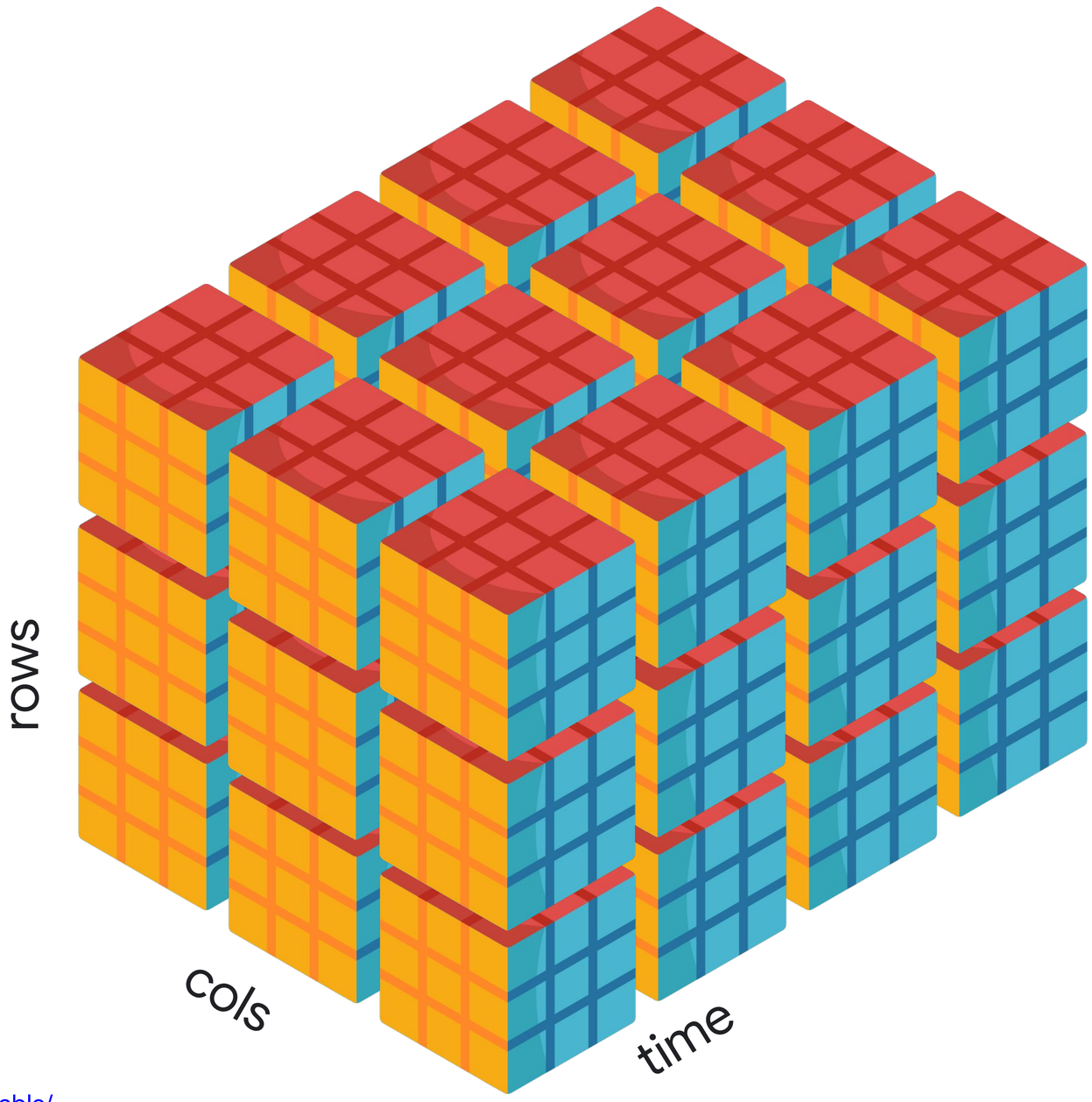
Source: https://zarr.readthedocs.io/en/stable/

Zarr



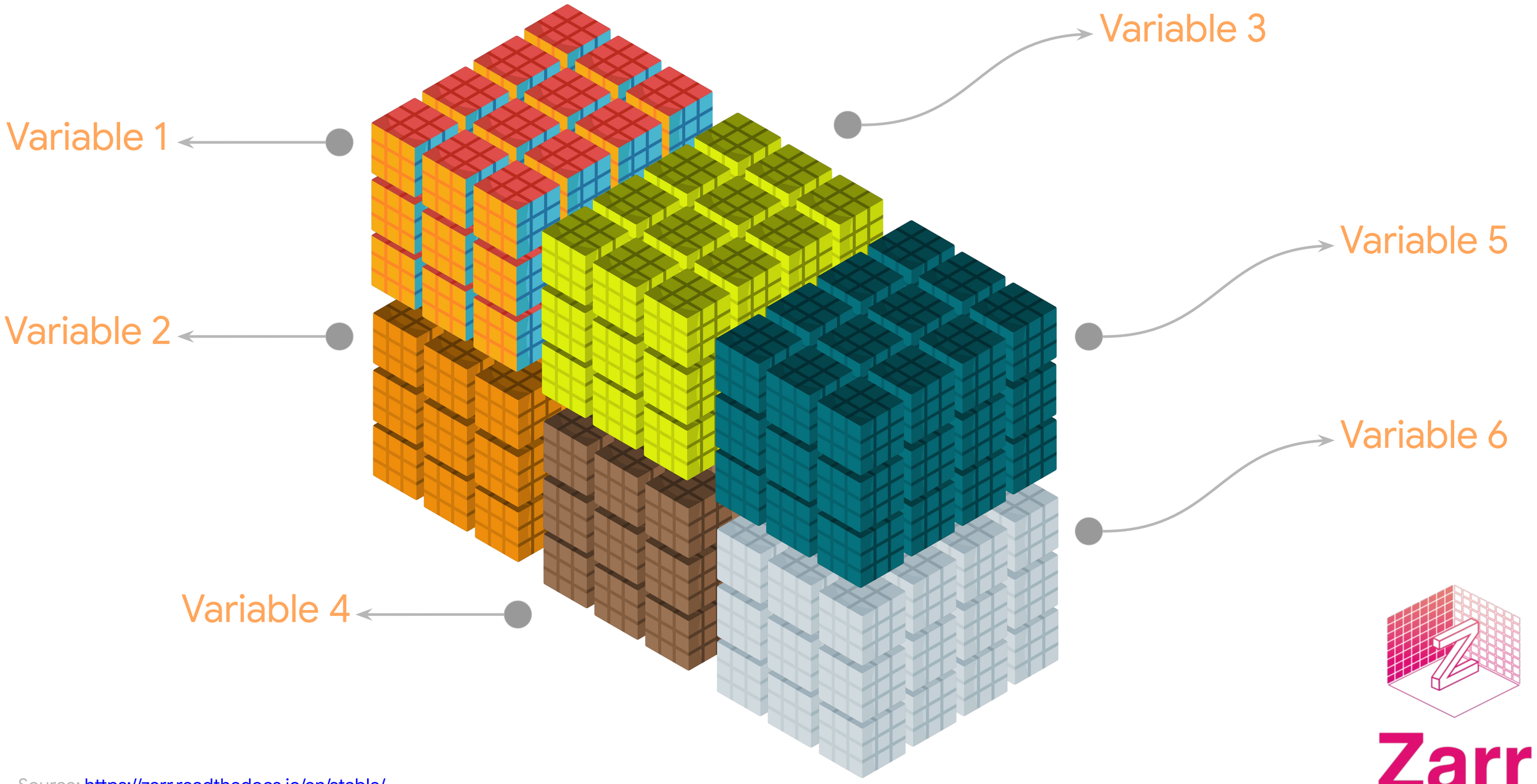
Source: https://zarr.readthedocs.io/en/stable/

Zarr

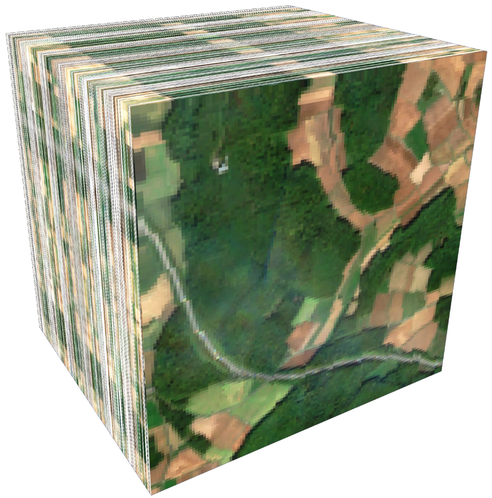


Source: https://zarr.readthedocs.io/en/stable/

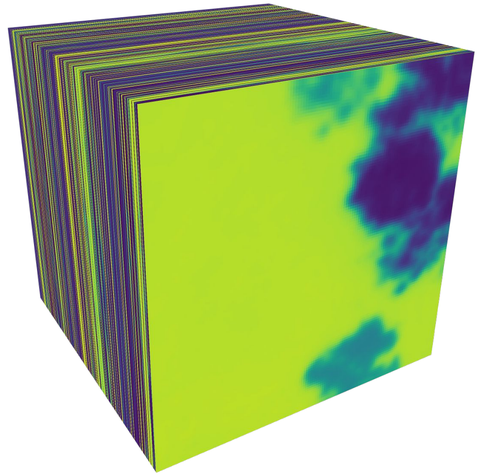
Zarr



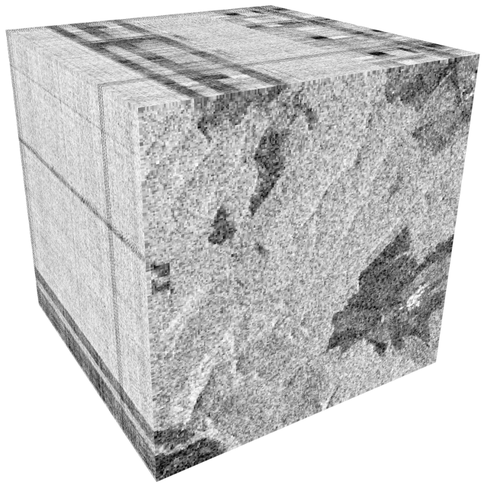
Source: https://zarr.readthedocs.io/en/stable/



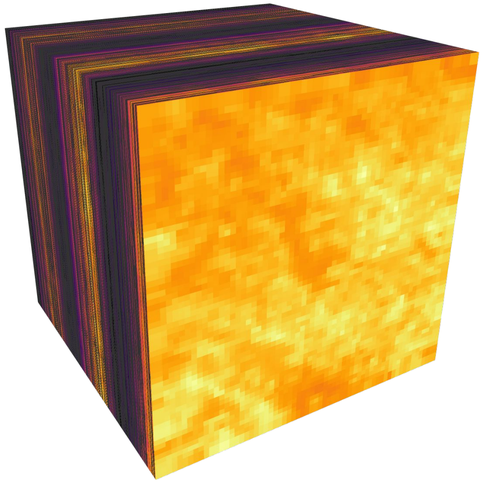
Sentinel-2



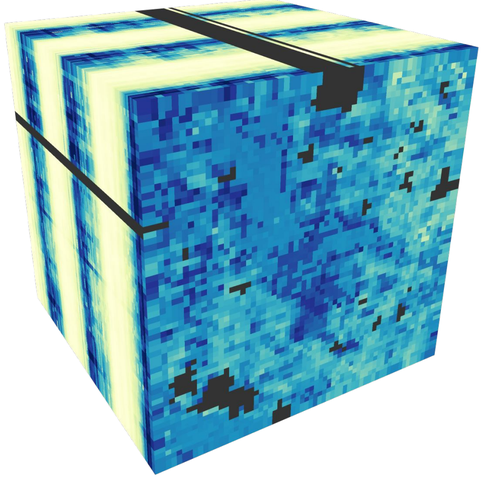
CloudScore+



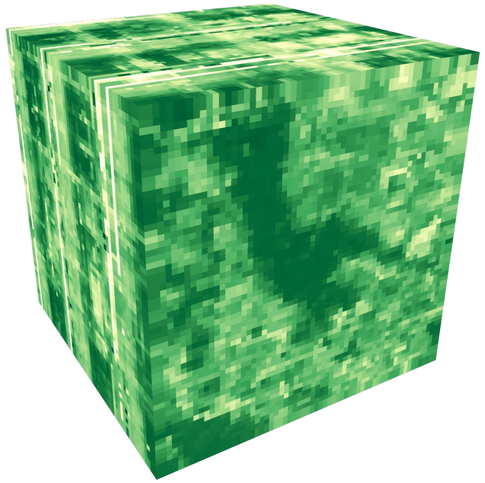
Sentinel-1



Land Surface Temperature



VI



Gross Primary Production

Part 3

Where do we find the data?

3

NOT SO FRIENDLY WAYS

ERA5-Land hourly data from 1950 to present

Overview | **Download** | Documentation

Complete all required fields before submitting the request.

Variable Select all

At least one selection must be made

Temperature

Select all

- [ ] 2m dewpoint temperature
- [ ] 2m temperature
- [ ] Skin temperature
- [ ] Soil temperature level 1
- [ ] Soil temperature level 2
- [ ] Soil temperature level 3
- [ ] Soil temperature level 4

Lakes

Select all

- [ ] Lake bottom temperature
- [ ] Lake ice depth
- [ ] Lake ice temperature
- [ ] Lake mix-layer depth
- [ ] Lake mix-layer temperature
- [ ] Lake shape factor
- [ ] Lake total layer temperature

An official website of the United States government Here's how you know

USGS
science for a changing world

EarthExplorer

Help Feedback Login

Search Criteria | Data Sets | Additional Criteria | Results

1. Enter Search Criteria

To narrow your search area: type in an address or place name, enter coordinates or click the map to define your search area (for advanced map tools, view the help documentation), and/or choose a date range.

Geocoder | KML/Shapefile Upload

Select a Geocoding Method

Feature (GNIS)

Search Limits: *The search result limit is 100 records; select a Country, Feature Class, and/or Feature Type to reduce your chances of exceeding this limit.*

US Features | World Features

Feature Name

(use % as wildcard)

State

All

Feature Type

All

Show | Clear

Polygon | Circle | Predefined Area

Degree/Minute/Second | Decimal

No coordinates selected.

Use Map | Add Coordinate | Clear Coordinates

Date Range | Cloud Cover | Result Options

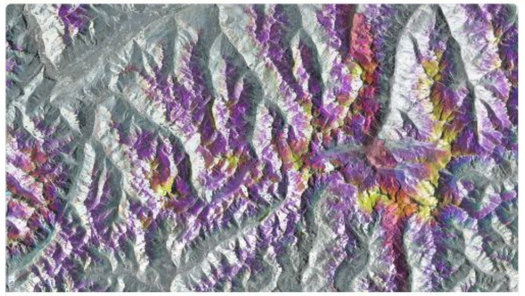
Search from: mm/dd/yyyy to: mm/dd/yyyy

Search Criteria Summary (Show)

Clear Search Criteria

A FRIENDLIER WAY

Google Earth Engine



Sentinel-1 SAR GRD: C-band Synthetic Aperture Radar

Data availability: 2014 – Present

The Sentinel-1 mission provides data from a dual-polarization C-band Synthetic Aperture Radar (SAR) instrument. SAR instruments are capable of acquiring meaningful data in all weather conditions (even clouds) during daytime and nighttime. Sentinel-1 data is used across many domains, including maritime activity, sea-ice mapping, humanitarian aid, crisis response, and forest management.

Sentinel-2 MSI: Multispectral Instrument

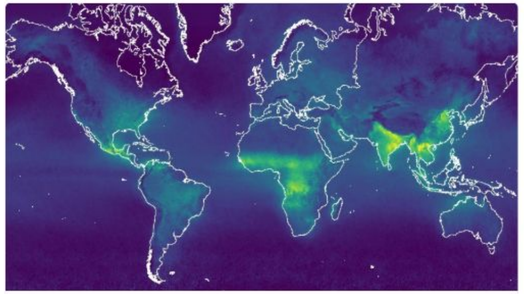
Data availability: 2015 – Present

The Sentinel-2 mission collects high-resolution multispectral imagery useful for a broad range of applications, including monitoring of vegetation, soil and water cover, land cover change, as well as humanitarian and disaster risk.

Sentinel-3 OLCI EFR: Ocean and Land Color Instrument

Data availability: 2016 – Present

The Sentinel-3 instrument provides systematic measurements of the planet's oceans, land, ice, and atmosphere, including the temperature, color and height of the sea surface as well as the thickness of sea ice.



Sentinel-5P TROPOMI: TROPOspheric Monitoring Instrument

Data availability: 2018 – Present

The Sentinel-5 Precursor mission collects data useful for assessing air quality, including concentrations of: ozone, methane, formaldehyde, aerosol, carbon monoxide, nitrogen oxide, and sulphur dioxide.

Landsat 8 Surface Reflectance

2013 - Present

Landsat 7 Surface Reflectance

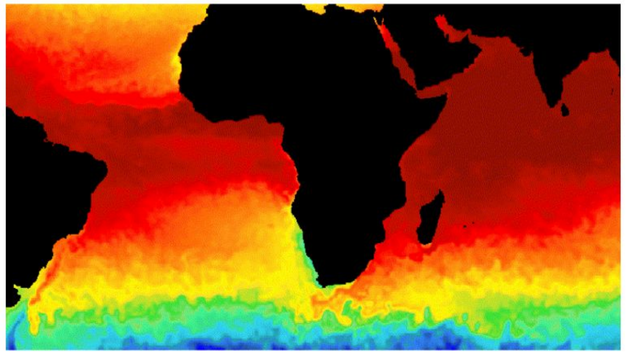
1999 - Present

Landsat 5 Surface Reflectance

1984 – 2012

Landsat 4 Surface Reflectance

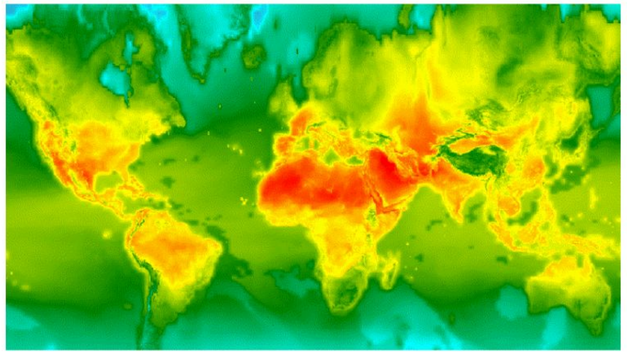
1982 - 1993



Surface Temperature

Thermal satellite sensors can provide surface temperature and emissivity information. The Earth Engine data catalog includes both land and sea surface temperature products derived from several spacecraft sensors, including MODIS, ASTER, and AVHRR, in addition to raw Landsat thermal data.

Explore temperature data



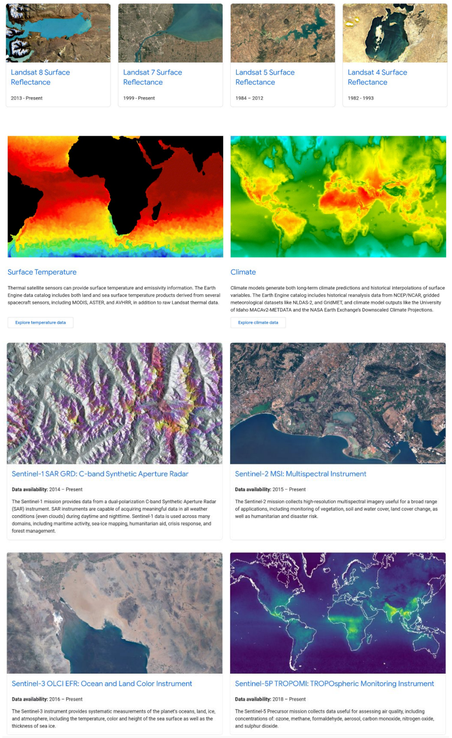
Climate

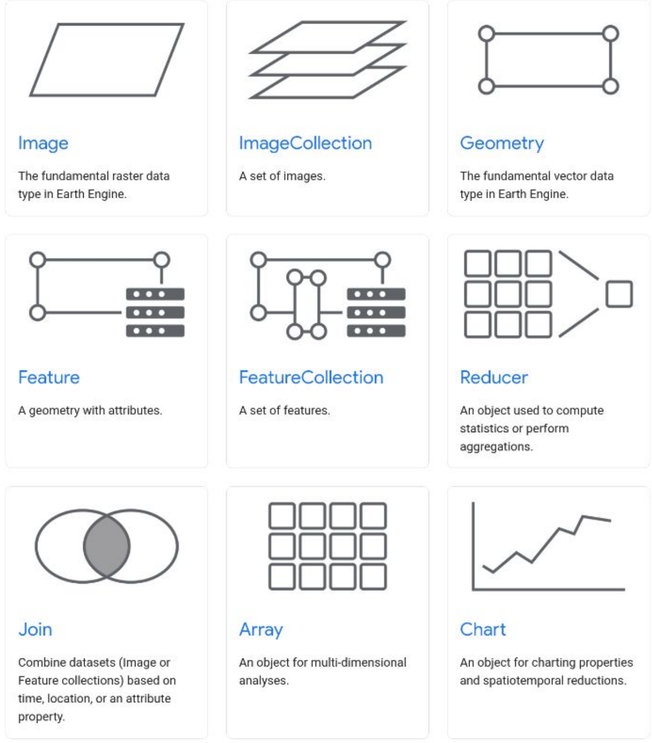
Climate models generate both long-term climate predictions and historical interpolations of surface variables. The Earth Engine catalog includes historical reanalysis data from NCEP/NCAR, gridded meteorological datasets like NLDAS-2, and GridMET, and climate model outputs like the University of Idaho MACAv2-METDATA and the NASA Earth Exchange's Downscaled Climate Projections.

Explore climate data

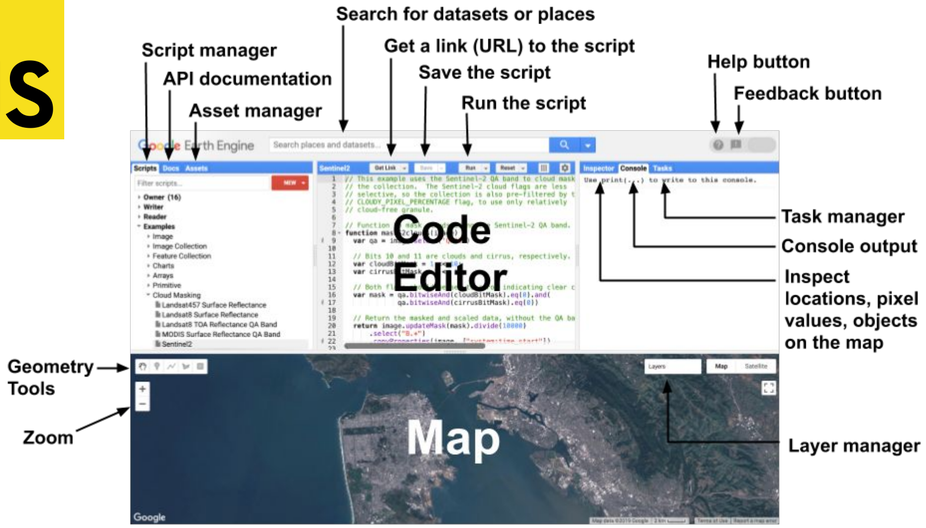
API: JavaScript and Python

Catalog





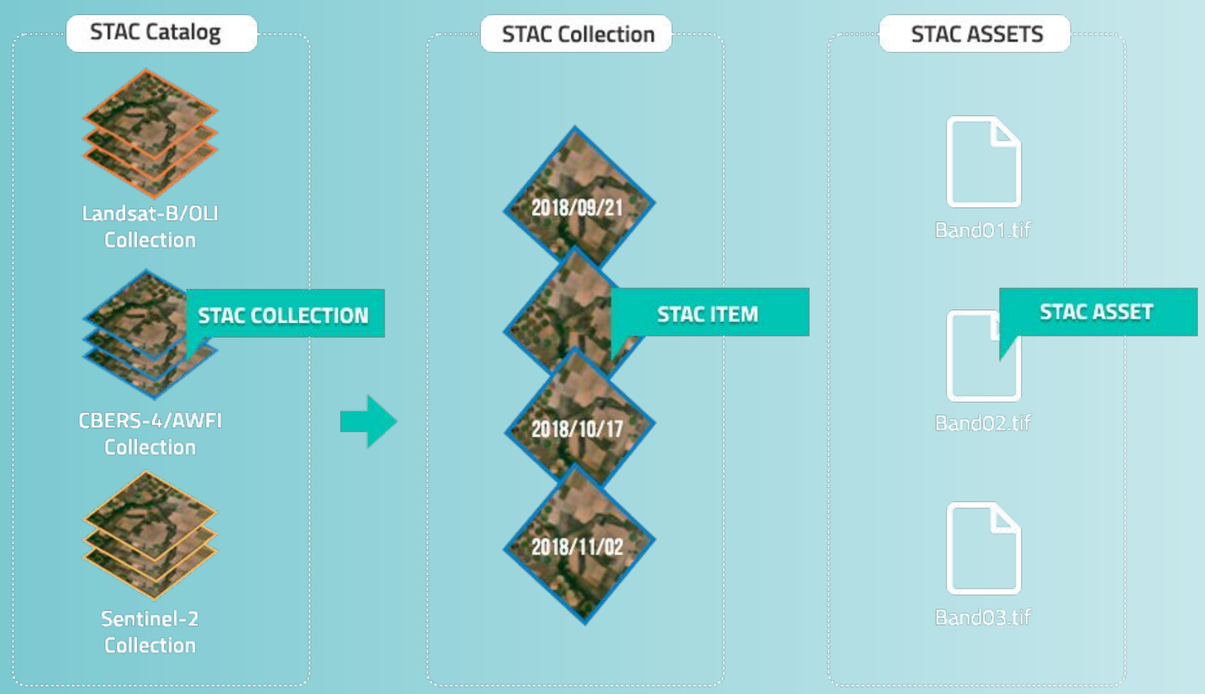
JS



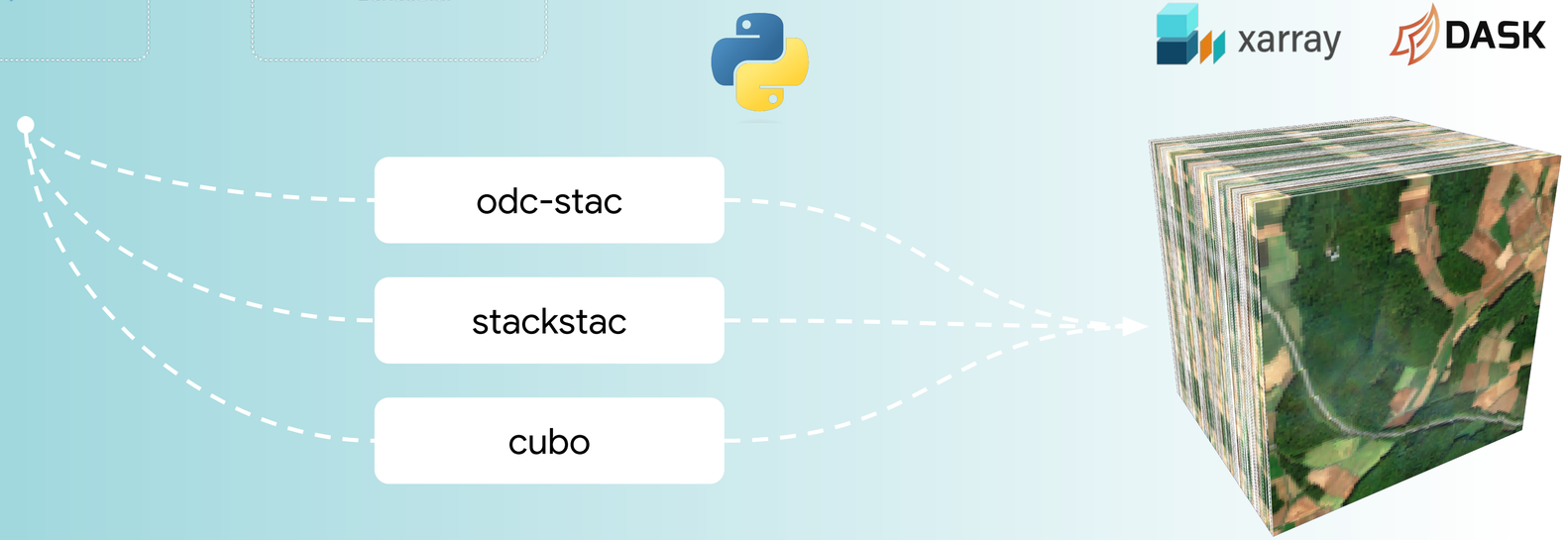
THE FRIENDLIEST WAY

STAC

SpatioTemporal
Asset Catalog



STAC
SpatioTemporal Asset Catalog



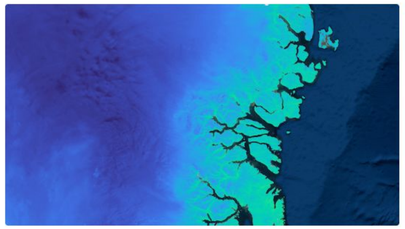
Modified from: https://data.inpe.br/bdc/web/en/stac-spatiotemporal-asset-catalog-2/

Microsoft | Planetary Computer

Landsat Collection

The Landsat program provides provides a comprehensive, continuous archive of multispectral imagery of the Earth's surface from 1972 to present.

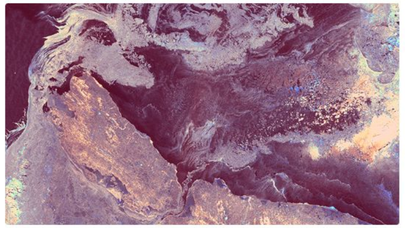
Landsat USGS NASA Satellite Global Imagery ···



MODIS Version 6.1 Products

The MODIS instrument operates on both the Terra and Aqua spacecraft, covering the entire surface of the Earth within one or two days. The derived data products describe atmosphere, cryosphere, land, and ocean features utilized in studies across various disciplines.

MODIS NASA USGS Satellite Global Imagery ···



Sentinel-1 Synthetic Aperture Radar (SAR)

Sentinel-1 comprises a constellation of two polar-orbiting satellites, operating day and night performing C-band synthetic aperture radar imaging.

ESA Copernicus Sentinel C-Band SAR

Sentinel-2 Level-2A

The Sentinel-2 program provides global imagery in thirteen spectral bands at 10m-60m resolution and a revisit time of approximately five days. This dataset contains the global Sentinel-2 archive, from 2016 to the present, processed to L2A (bottom-of-atmosphere).

Sentinel Copernicus ESA Satellite Global Imagery ···

Part 4
Hands-on

4

link to notebook

Thank you!

David Montero

UNIVERSITÄT LEIPZIG

iDiv

Experts

▶ TO BE CONTINUED