Remote Sensing Data showing Climate Change Consequences

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Presentation supported by Miroslav Havranek and Natalia Kobliuk

Aims of the workshop

- to motivate teachers and students to use remote sensing data and applications in GLOBE research and studying

-to show opportunities to observe and evaluate climate change using open remote sensing data

- to present hands-on applications implemented into GLOBE

https:// www.natur.cuni.cz/

Charles University, Faculty of Science, Prague

The Department of Applied Geoinformatics and Cartography

Research and Education in the fields of:

- GIS a geodatabases
- Remote sensing and photogrammetry
- Cartography
- Computational geometry, algorithm development & programming
- Geodetic and surveying methods of data collection

EO4Landscape research team

eo4landscape.natur.cuni.cz

EO4Landscape

•**Earth Observation (EO)**
Advanced classification methods using remote sensing data, Time Series, Normalization methods of remote sensing data, Big Data, Cloud computing and satellite data - Google Earth Engine, Sentinel Hub

•**Land Use/Land Cover (LUCC)**
Long-term Land Use/Land Cover Change, Driving forces of LUCC,

•**3D**
Vizualization of the dynamic landscape changes in 3D,

•**Web GIS technologies and maps services**
vizualization of landscape changes, in-situ data colection

•**Capacity building and education in GIS and EO**

https://www.linkedin.com/company/eo4landscape-research-group

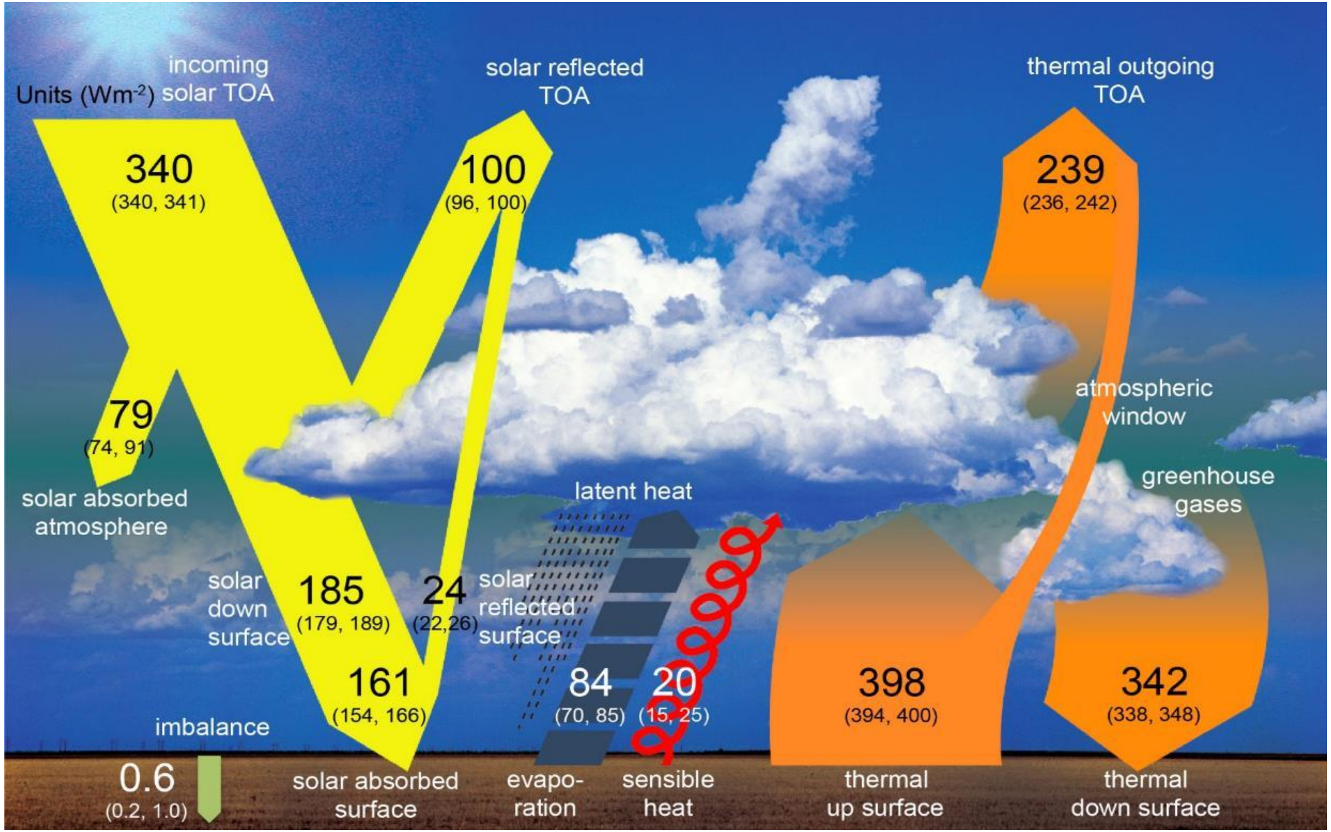
What is Remote Sensing?

Remote Sensing is studying the objects without touching them.

Source: https://earthdata.nasa.gov/learn/backgrounders/remote-sensing

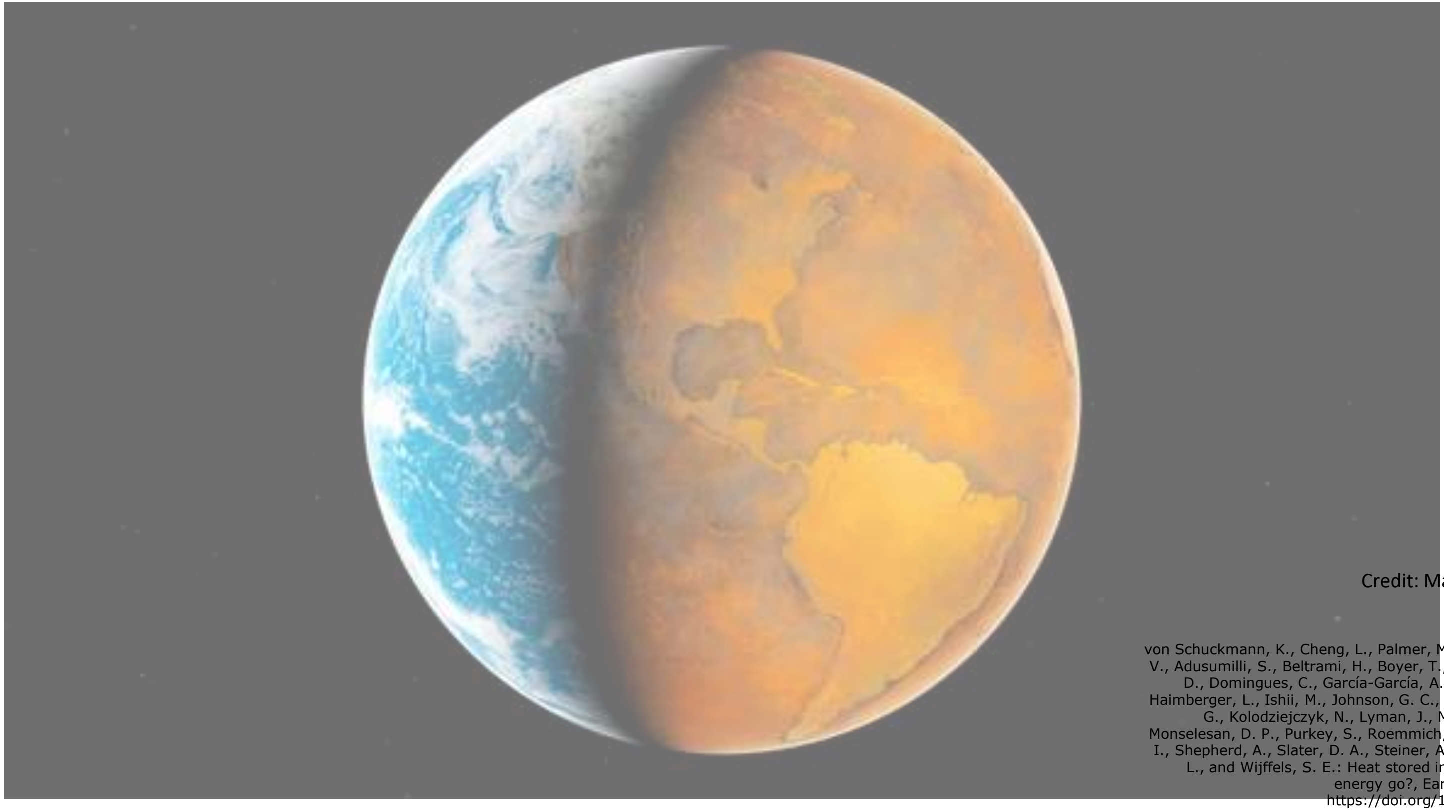
Why remote sensing and climate change?

Energy balance of the planet



(source: IPCC, 2013)

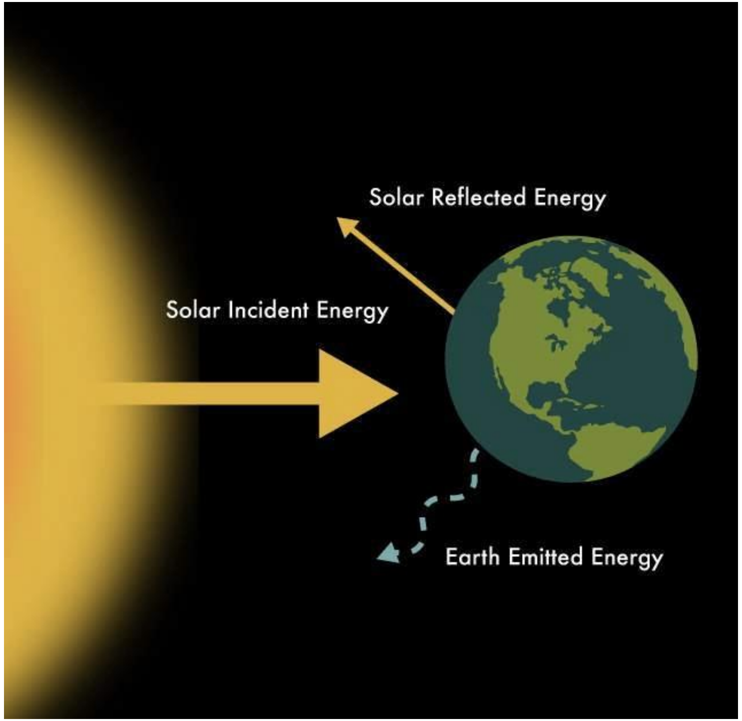
Climate change is a consequence of the disturbed energy balance of the planet

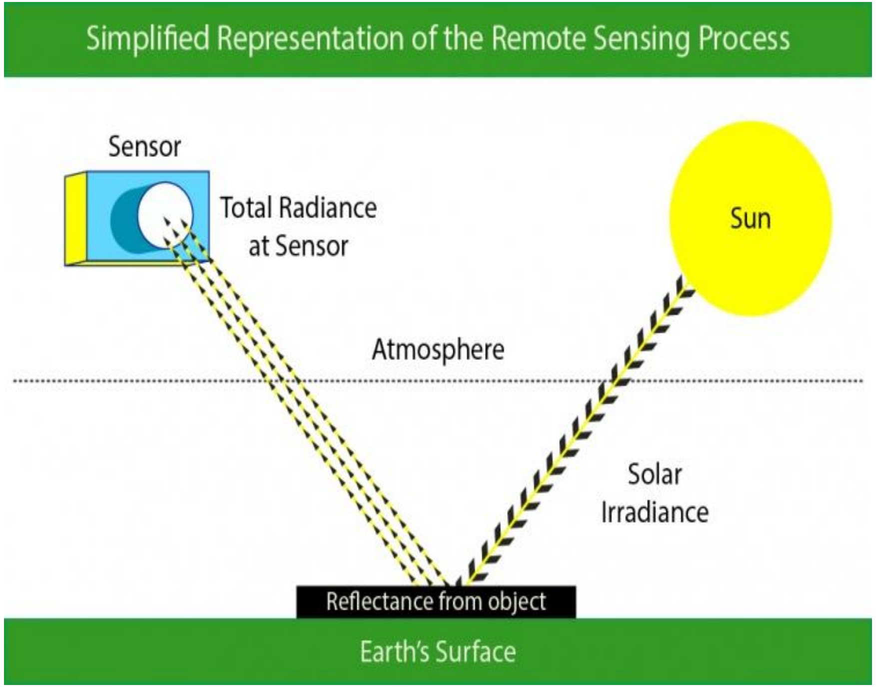


Credit: Mark Garlick Getty Images

von Schuckmann, K., Cheng, L., Palmer, M. D., Hansen, J., Tassone, C., Aich, V., Adusumilli, S., Beltrami, H., Boyer, T., Cuesta-Valero, F. J., Desbruyères, D., Domingues, C., García-García, A., Gentine, P., Gilson, J., Gorfer, M., Haimberger, L., Ishii, M., Johnson, G. C., Killick, R., King, B. A., Kirchengast, G., Kolodziejczyk, N., Lyman, J., Marzeion, B., Mayer, M., Monier, M., Monselesan, D. P., Purkey, S., Roemmich, D., Schweiger, A., Seneviratne, S. I., Shepherd, A., Slater, D. A., Steiner, A. K., Straneo, F., Timmermans, M.-L., and Wijffels, S. E.: Heat stored in the Earth system: where does the energy go?, Earth Syst. Sci. Data, 12, 2013–2041, https://doi.org/10.5194/essd-12-2013-2020, 2020.

The Remote Sensing





Global Temperature

↑ 1.2 °C above pre-industrial level
More

European Temperature

↑ 2.2 °C above pre-industrial level
More

Arctic Temperature

↑ 3 °C above pre-industrial level
More

Carbon Dioxide (CO_2)

↑ 417 **ppm**, annual average level
More

Carbon Dioxide (CO_2) Increase

↑ 2.4 **ppm per year**, since 2010
More

Methane (CH_4)

↑ 1894 **ppb**, annual average level
More

Global Glaciers

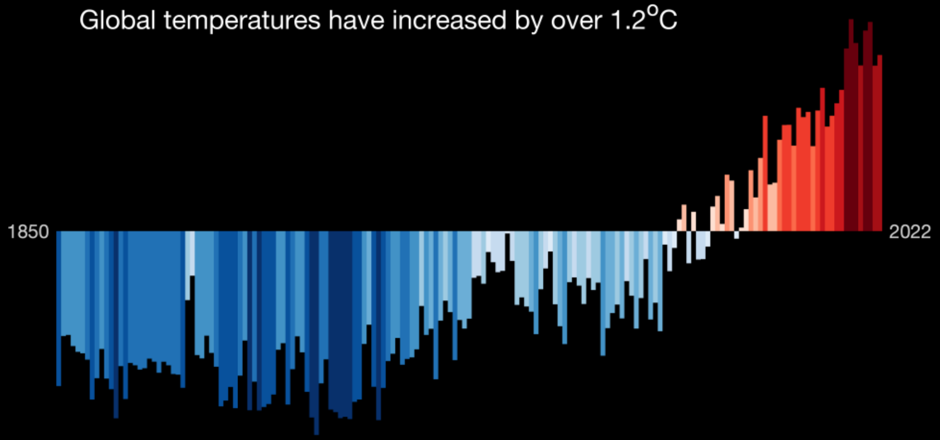
↓ 8600 **km^3**, ice loss since 1997
More

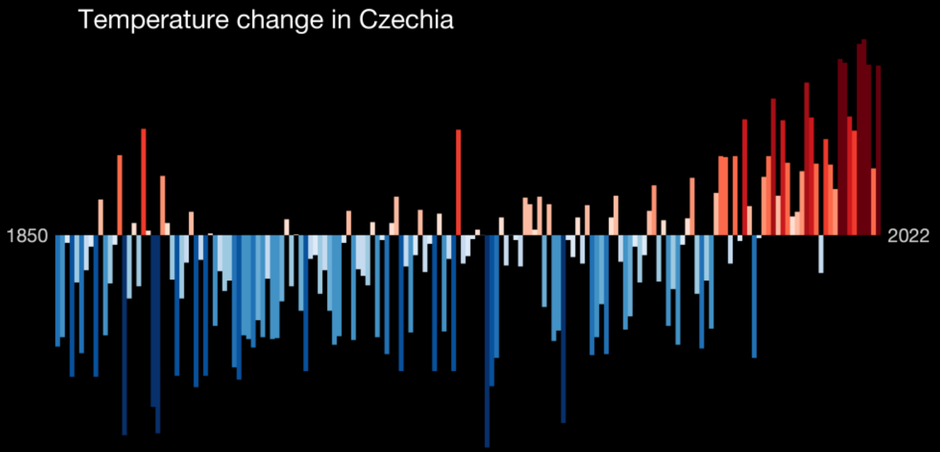
European Glaciers

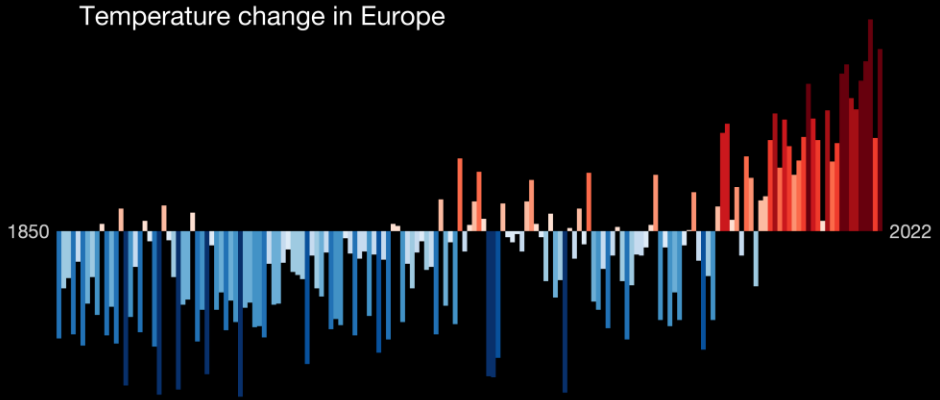
↓ 960 **km^3**, ice loss since 1997
More

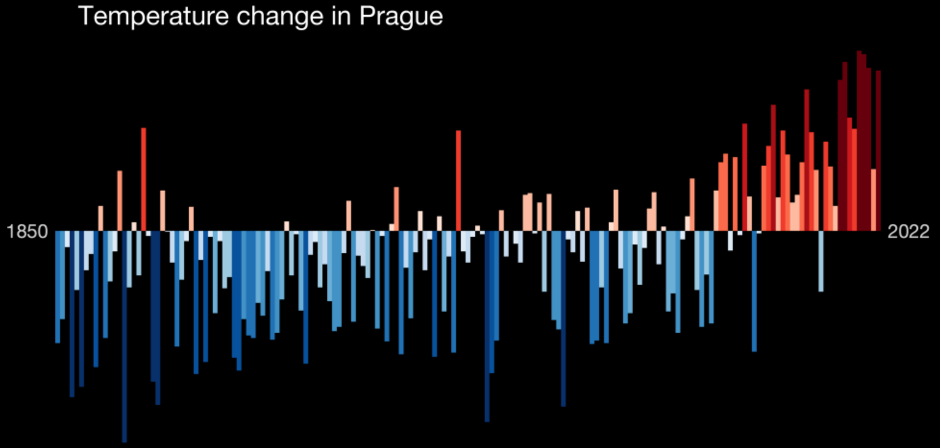
Greenland Ice Sheet

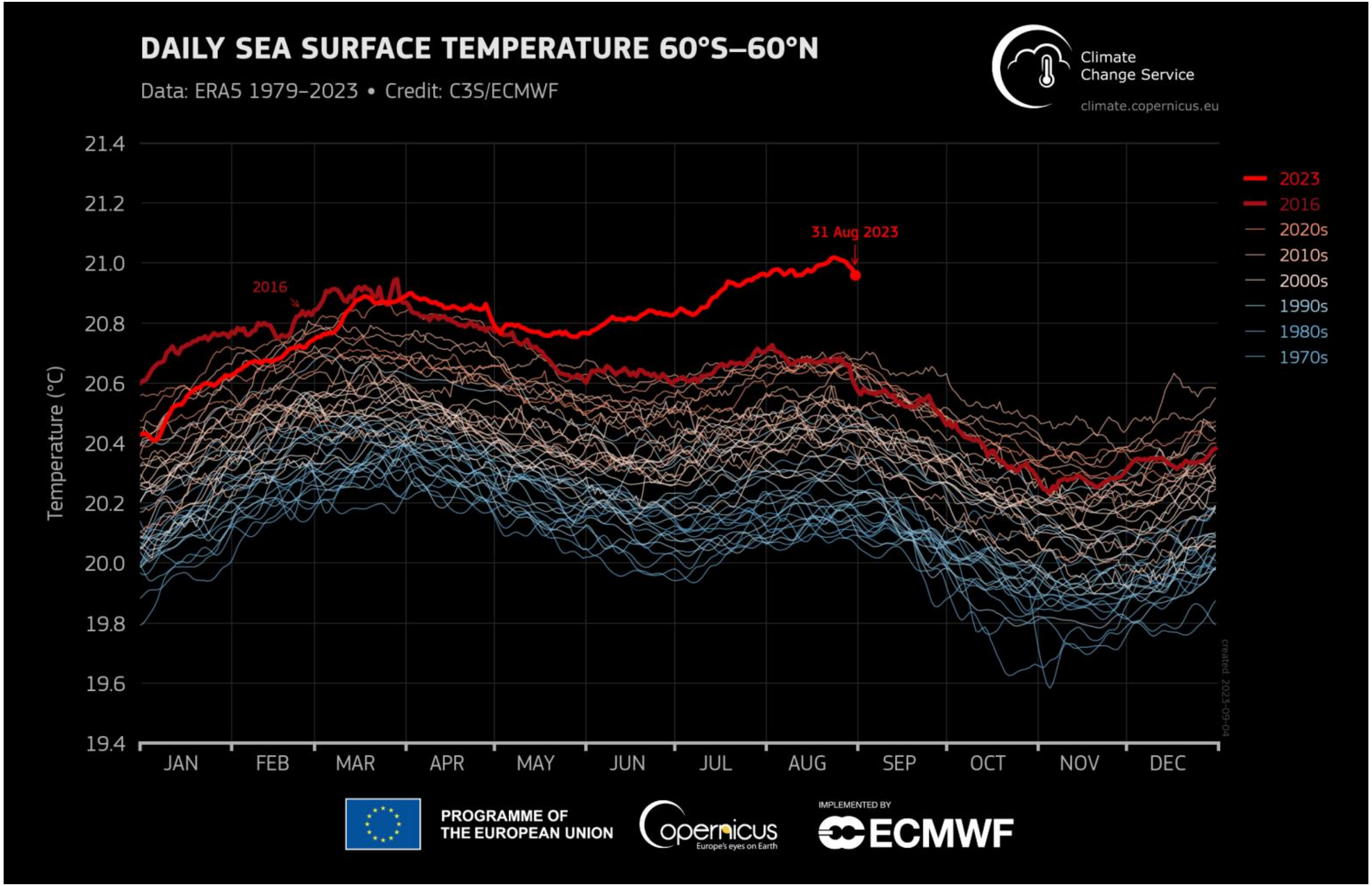
↓ 5850 **km^3**, ice loss 1992-2020
More


Global temperatures have increased by over 1.2°C
1850
2022

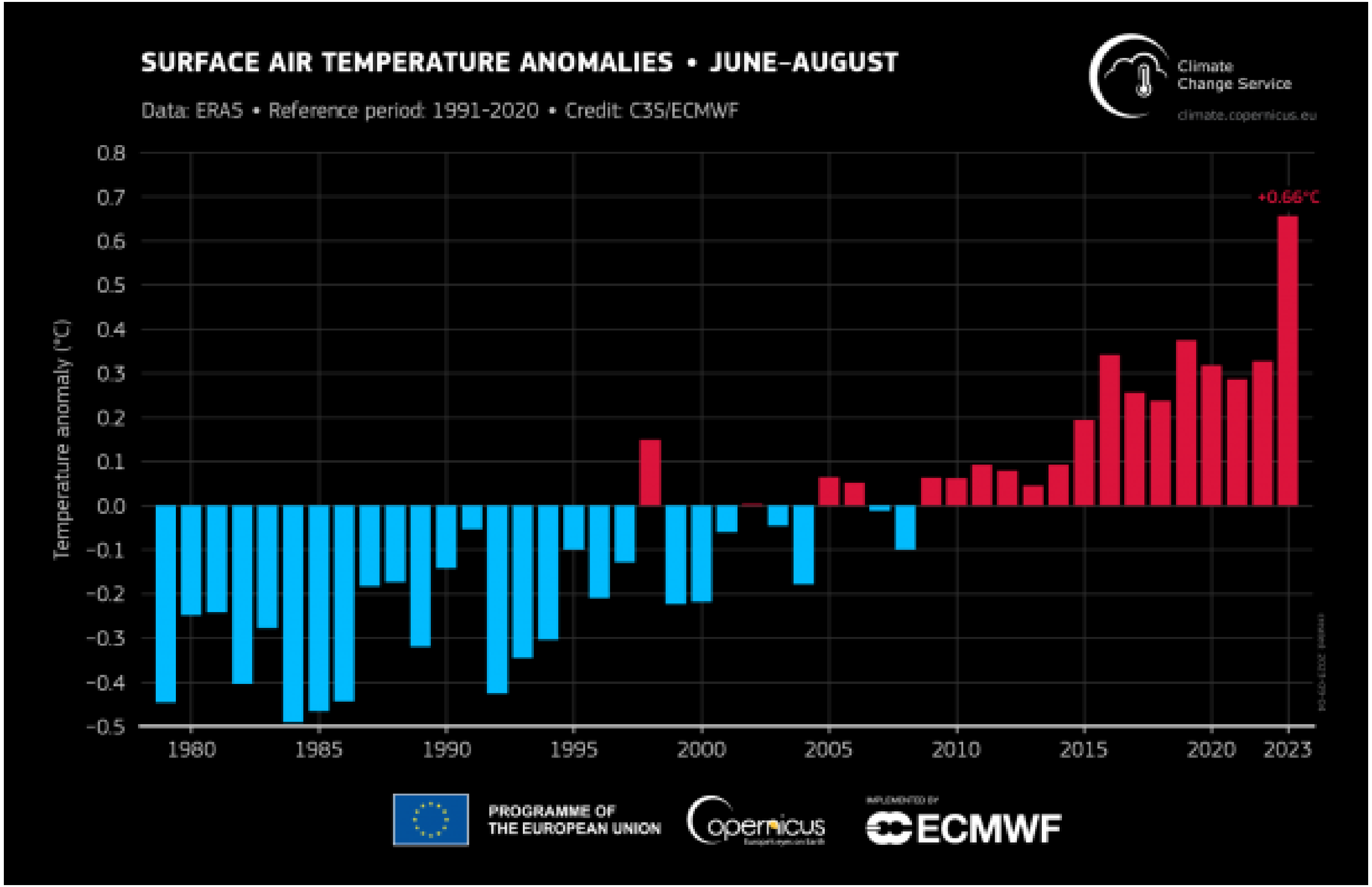

Temperature change in Czechia
1850
2022


Temperature change in Europe
1850
2022

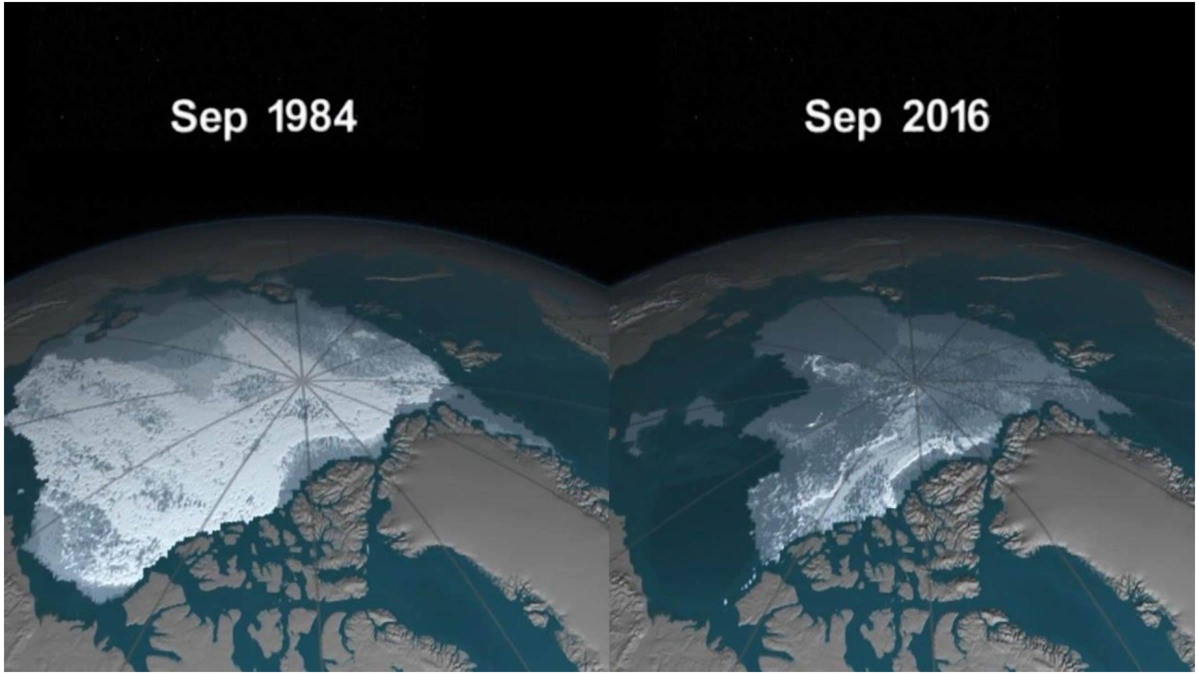

Temperature change in Prague
1850
2022

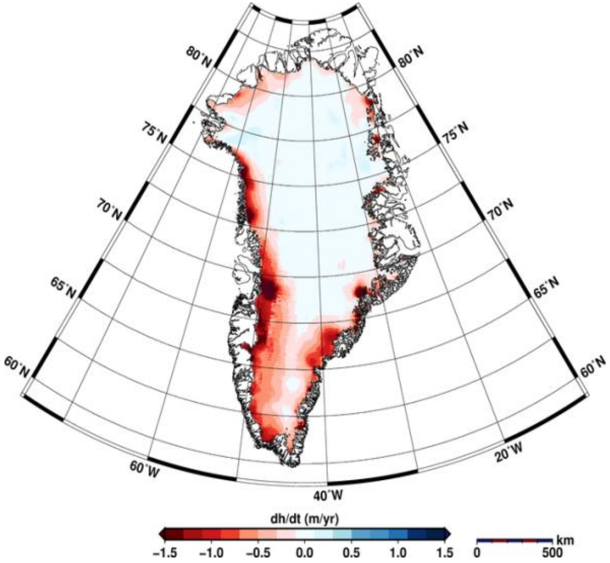


DAILY SEA SURFACE TEMPERATURE 60°S–60°N
Data: ERA5 1979–2023 • Credit: C3S/ECMWF
Climate Change Service
climate.copernicus.eu
Temperature (°C)
21.4
21.2
21.0
20.8
20.6
20.4
20.2
20.0
19.8
19.6
19.4
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
2016
31 Aug 2023
2023
2016
2020s
2010s
2000s
1990s
1980s
1970s
created 2023-09-04
PROGRAMME OF THE EUROPEAN UNION
Copernicus
Europe's eyes on Earth
IMPLEMENTED BY
ECMWF

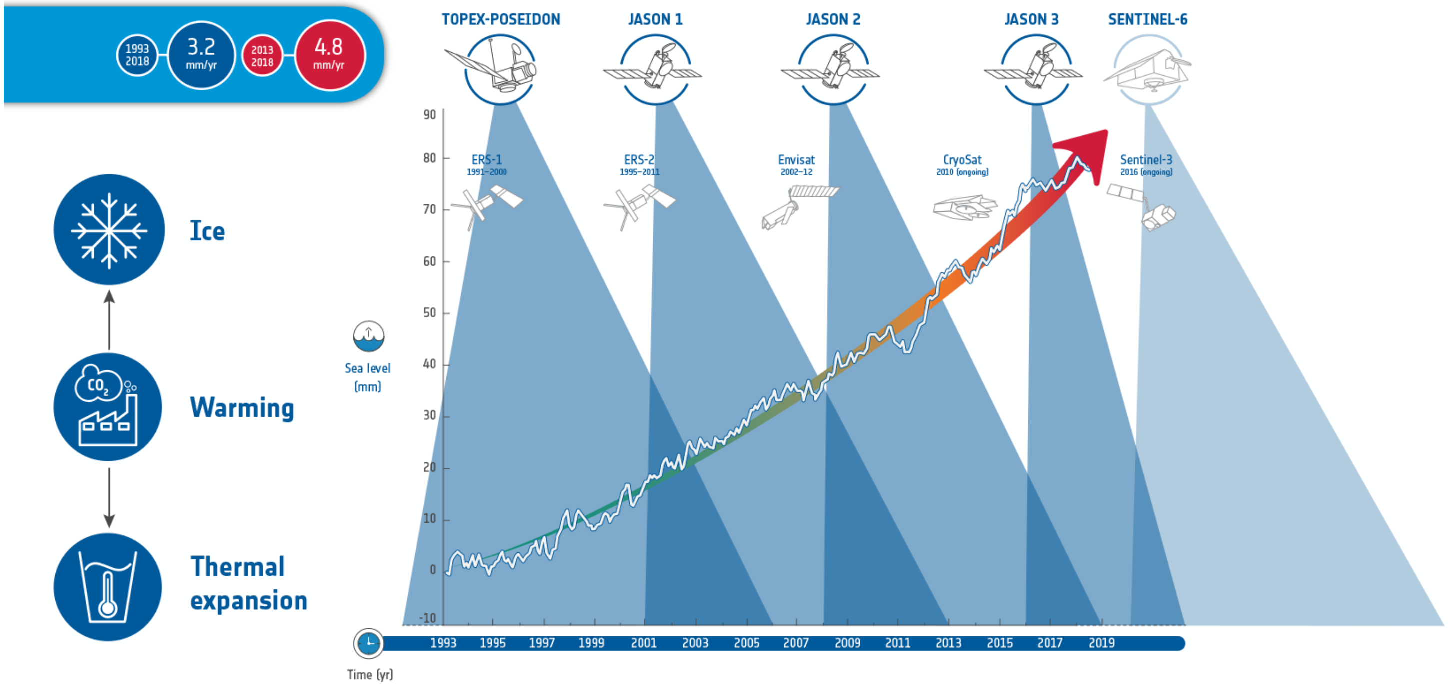

SURFACE AIR TEMPERATURE ANOMALIES • JUNE–AUGUST
Data: ERA5 • Reference period: 1991-2020 • Credit: C3S/ECMWF
Climate
Change Service
climate.copernicus.eu
Temperature anomaly (°C)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
+0.66°C
1980
1985
1990
1995
2000
2005
2010
2015
2020
2023
PROGRAMME OF
THE EUROPEAN UNION
opernicus
ECMWF

The Cryosphere





© Helm et al.
(Alfred Wegener Institut)
The Cryosphere,
2014



1993 2018
3.2 mm/yr
2013 2018
4.8 mm/yr
Ice
Warming
Thermal expansion
TOPEX-POSEIDON
JASON 1
JASON 2
JASON 3
SENTINEL-6
ERS-1 1991–2000
ERS-2 1995–2011
Envisat 2002–12
CryoSat 2010 (ongoing)
Sentinel-3 2016 (ongoing)
Sea level (mm)
Time (yr)

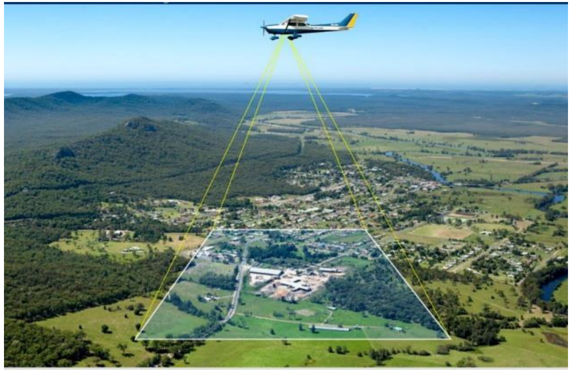
Introduction to Remote Sensing

Modern Remote Sensing Platforms

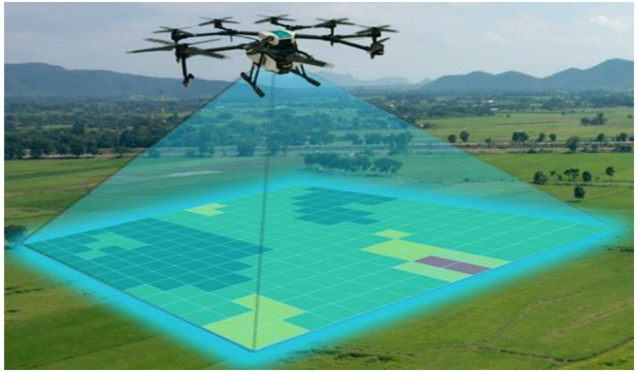
Airplanes

UAVs

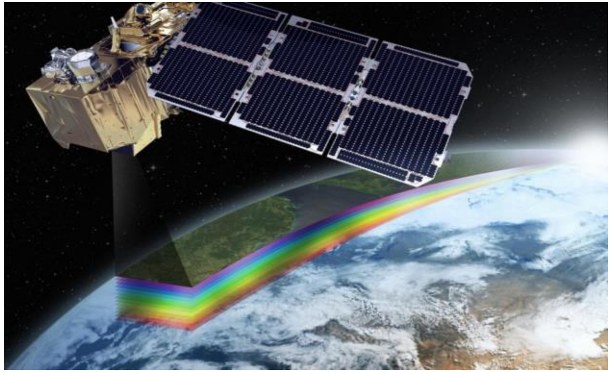
Satellites



Source: https://www.slideshare.net/saislideshere/remote-sensing-sainath-aher

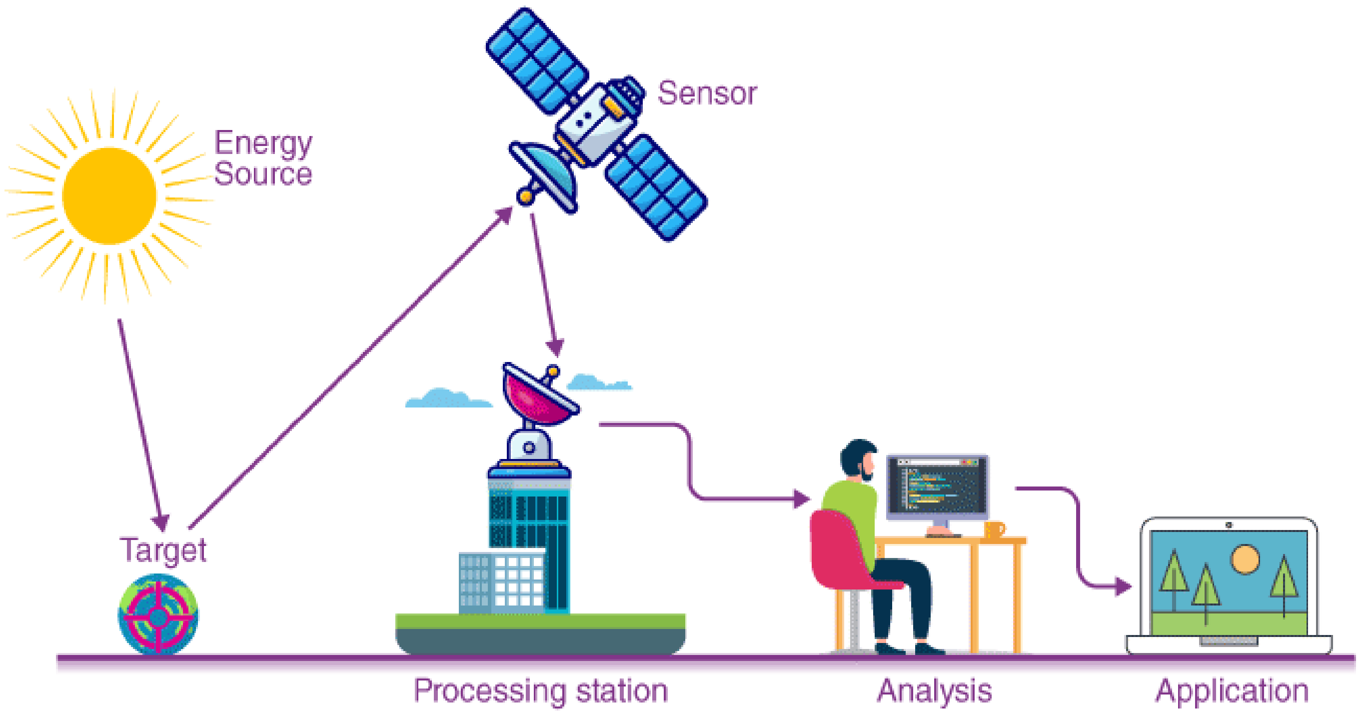


Source: https://www.inrae.fr/en/news/remote-sensing-dossier

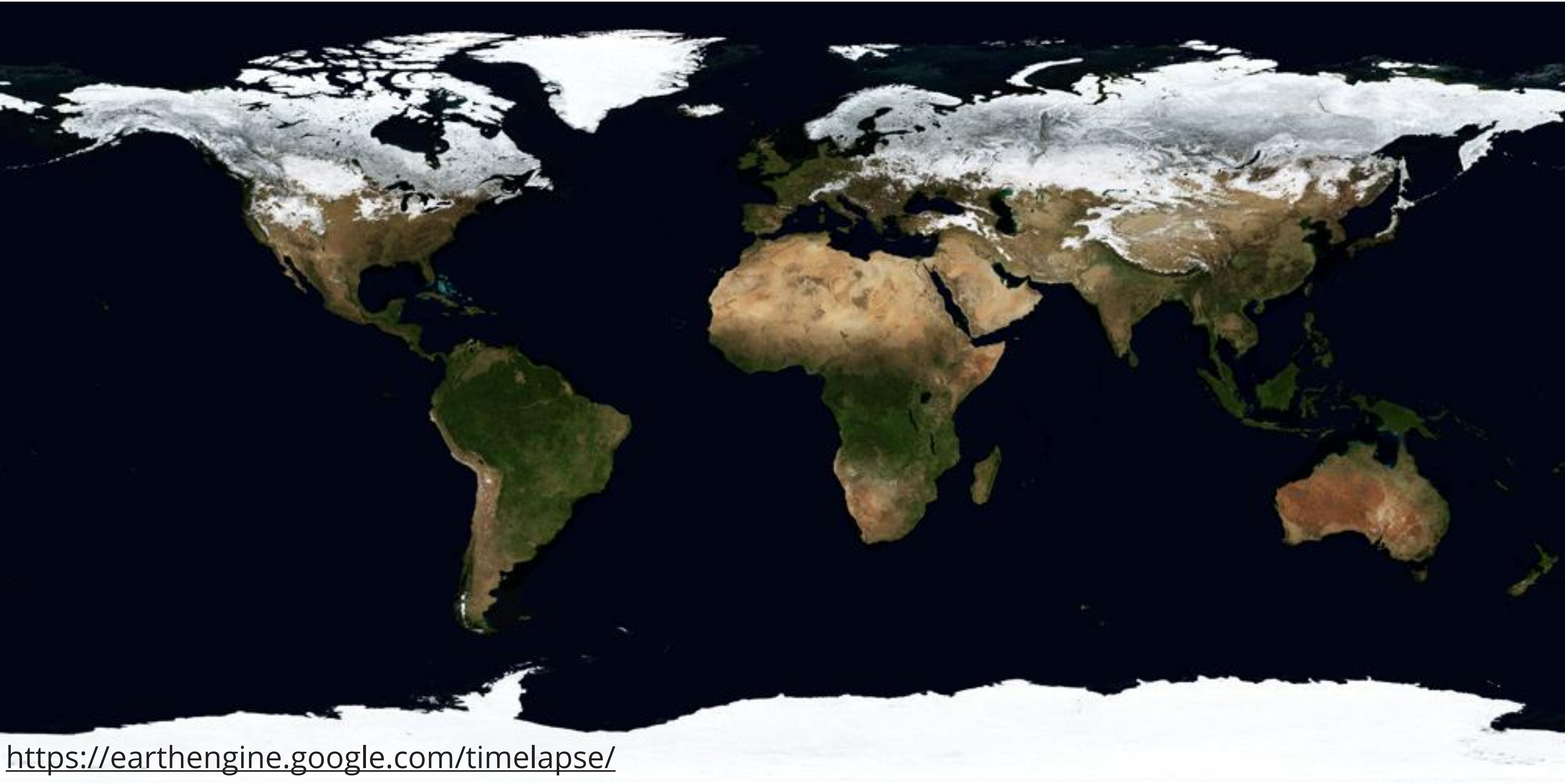


Source: https://cervest.earth/remote-sensing-of-planet-earth-part-1-introduction-to-satellite-imagery/

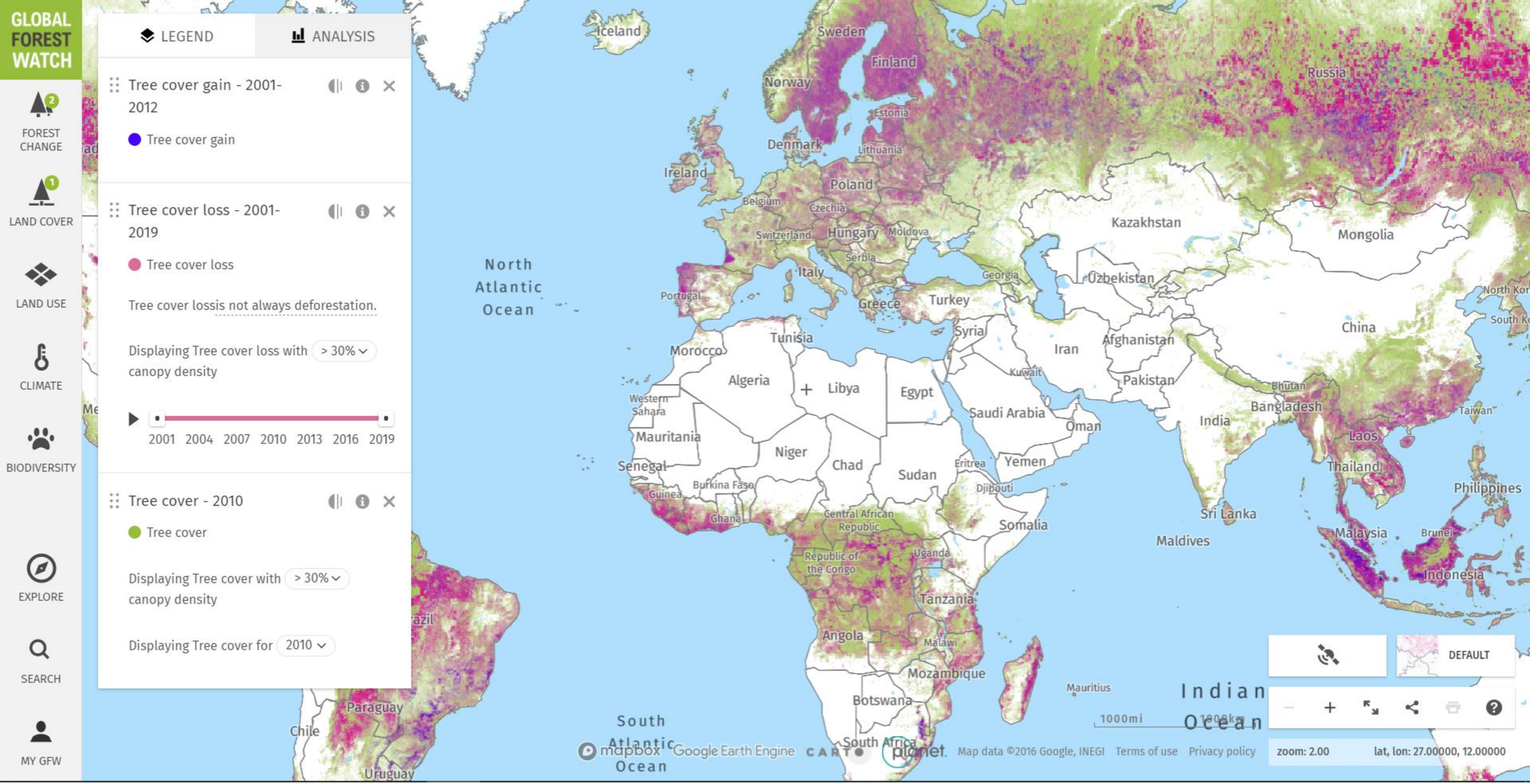
The Remote Sensing Process



Google Earth Timelapse

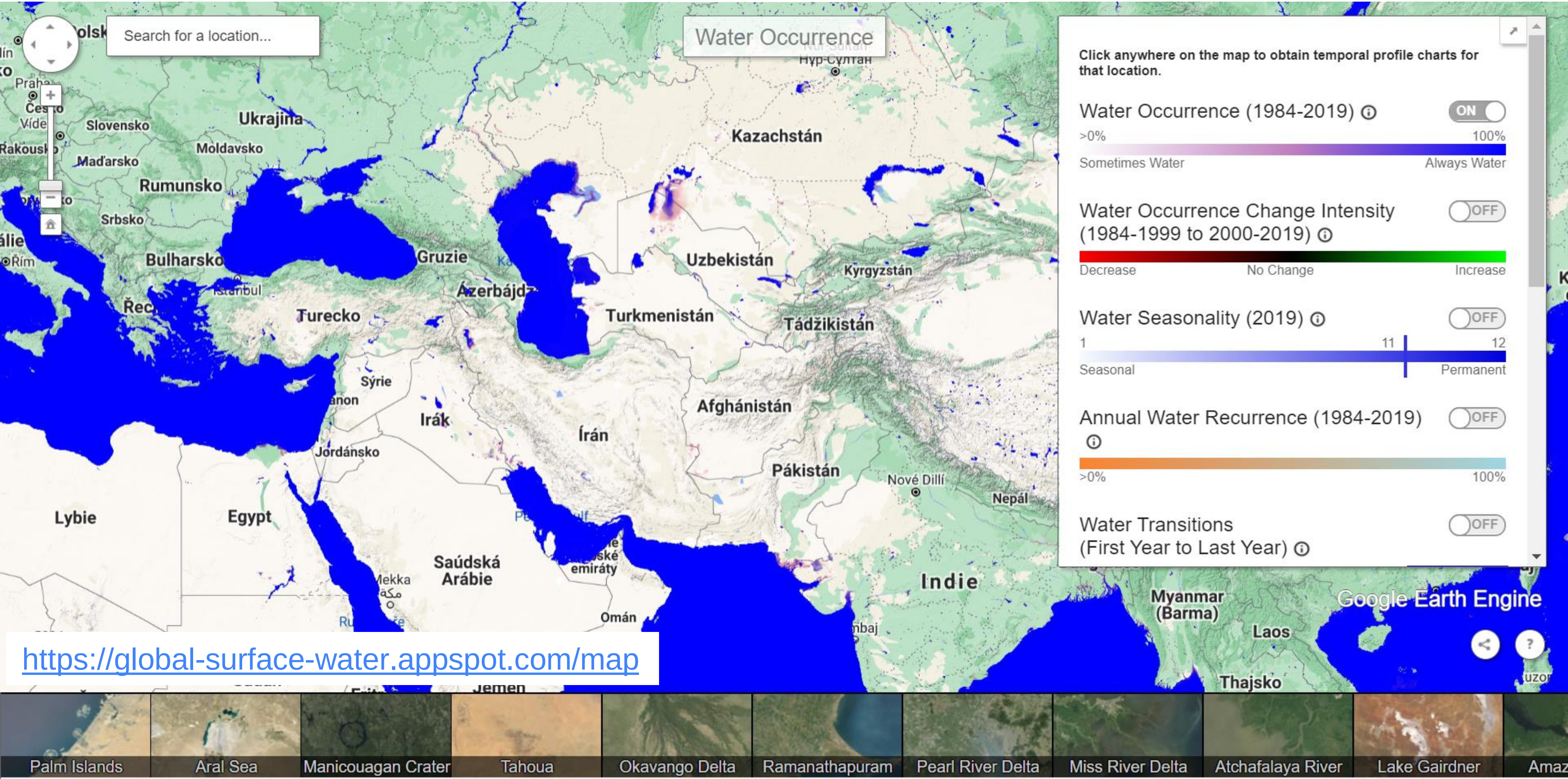


https://earthengine.google.com/timelapse/



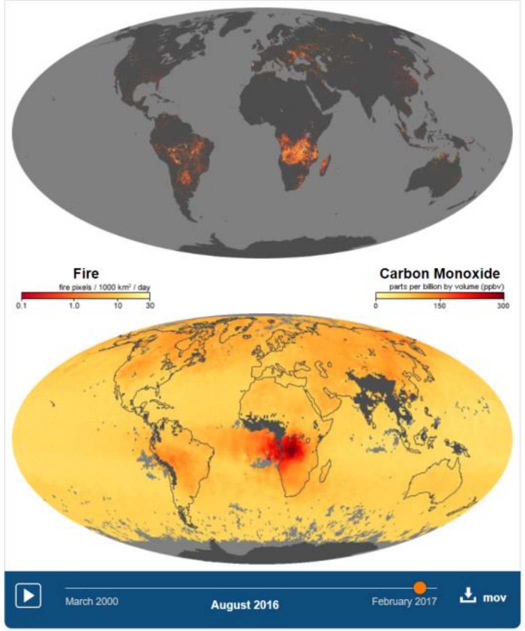
https://www.globalforestwatch.org/map/

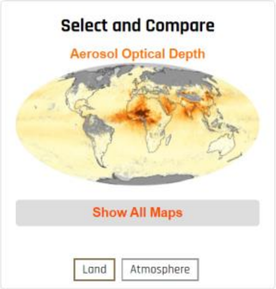
Global Surface Water Explorer

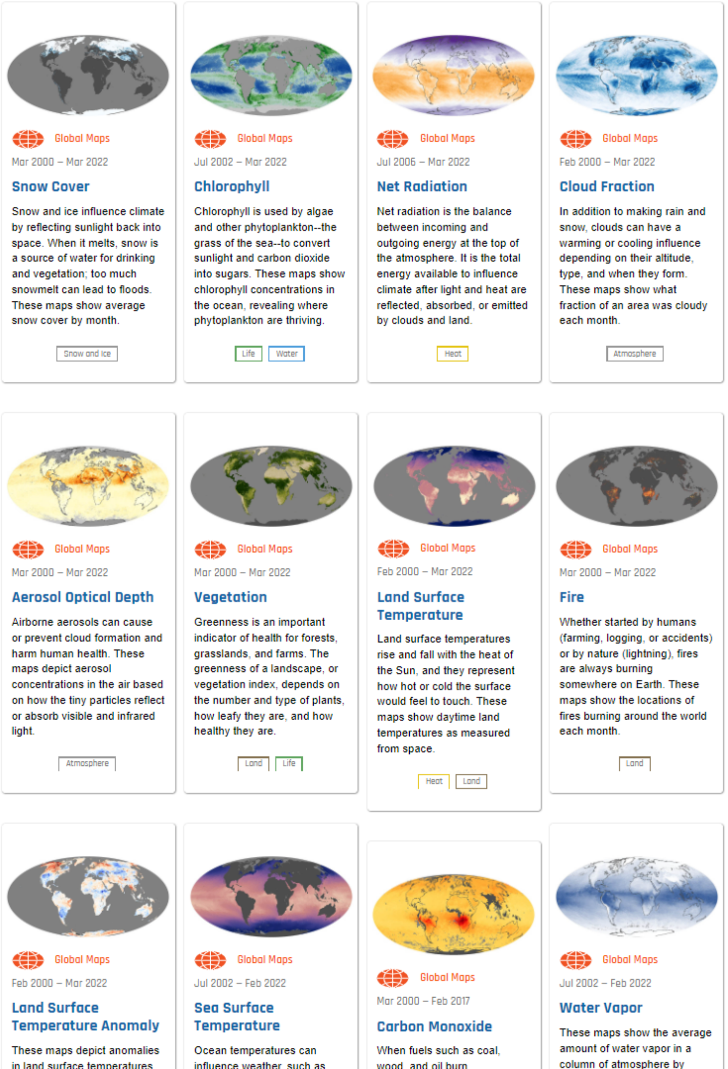


https://global-surface-water.appspot.com/map https://earthobservatory.nasa.gov/global-maps

Fire & Carbon Monoxide







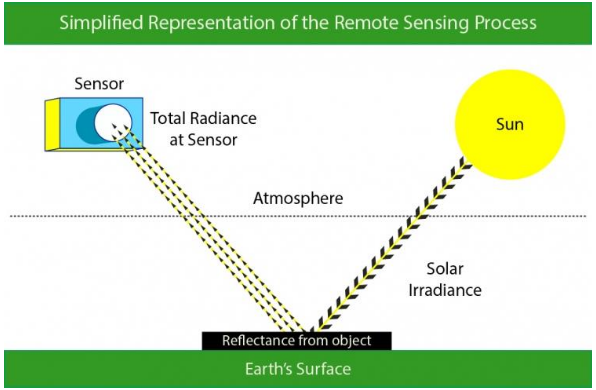
ESA Climate from Space

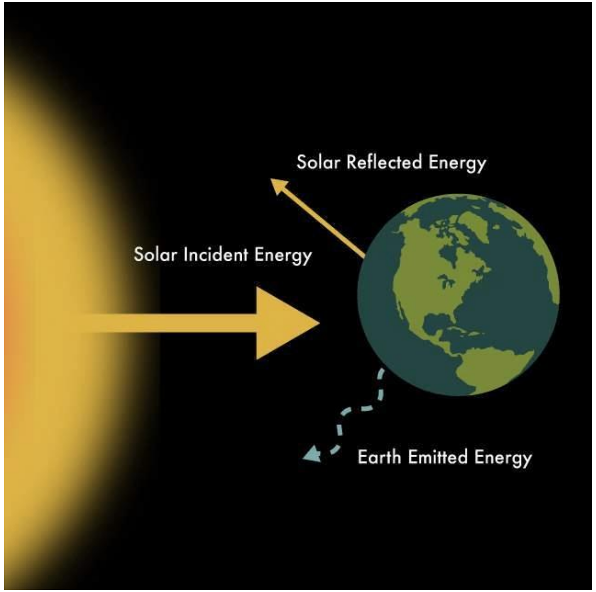
https://cfs.climate.esa.int

https://earthmap.org/

Basic principles of Remote Sensing

Solar radiation



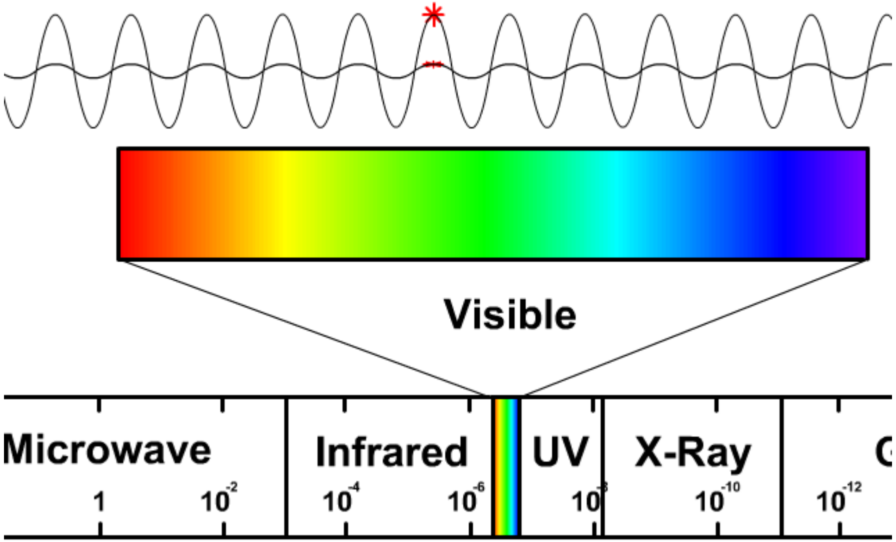


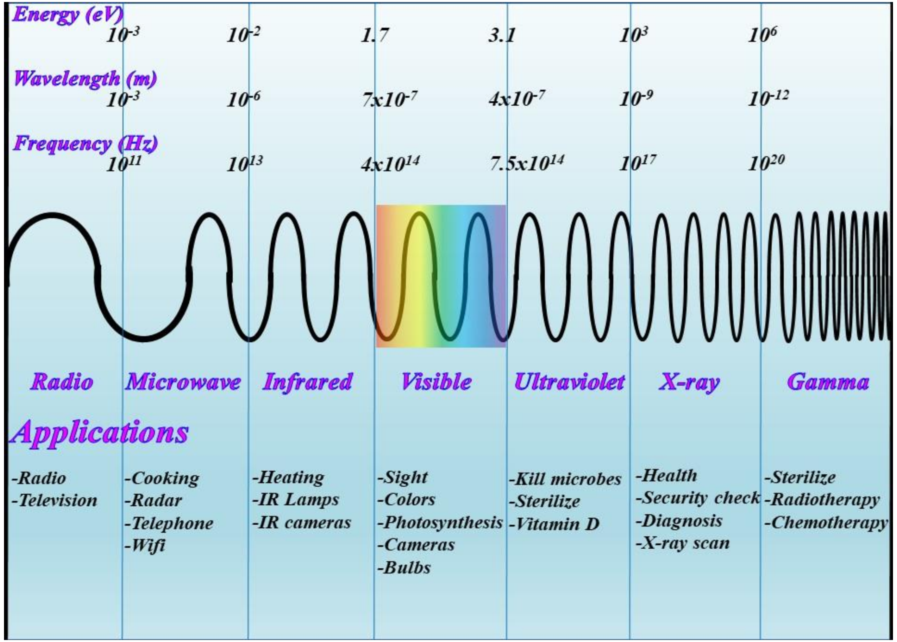
Incident Solar Energy is the radiant **solar energy** that hits the earth's surface and is referred as "global radiation" on a surface.

Reflected Solar Energy describes sunlight that has been **reflected** off of non-atmospheric things such as the earth's surface.

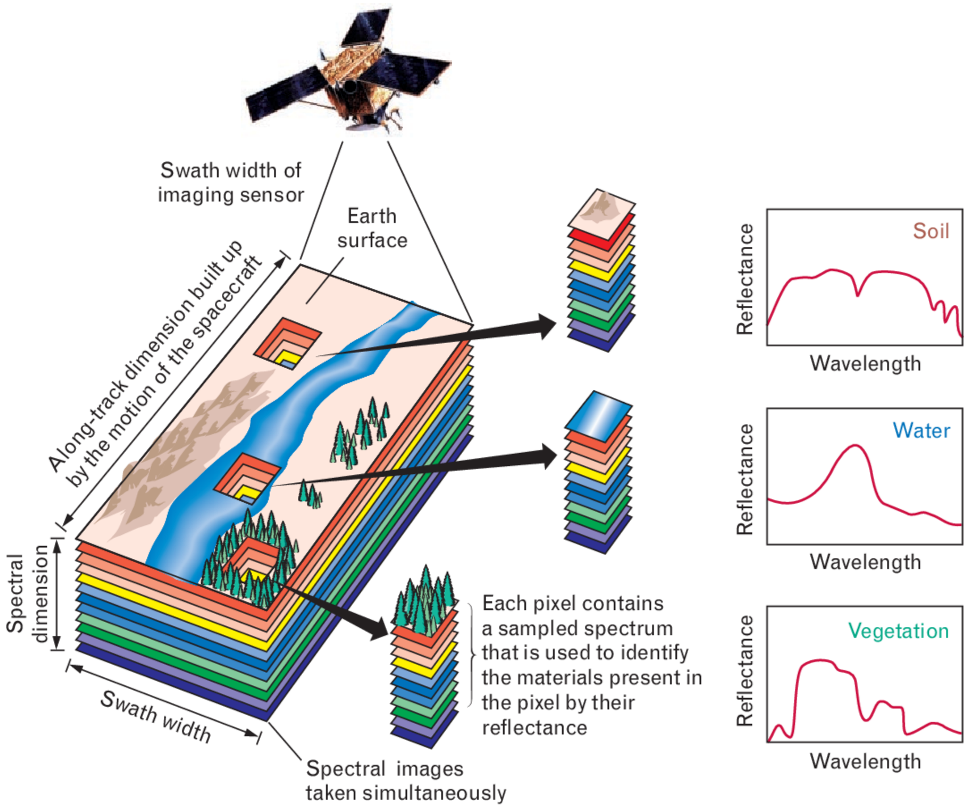
Earth Emitted Energy is the earth's own radiation emitted into atmosphere.

Electromagnetic spectrum





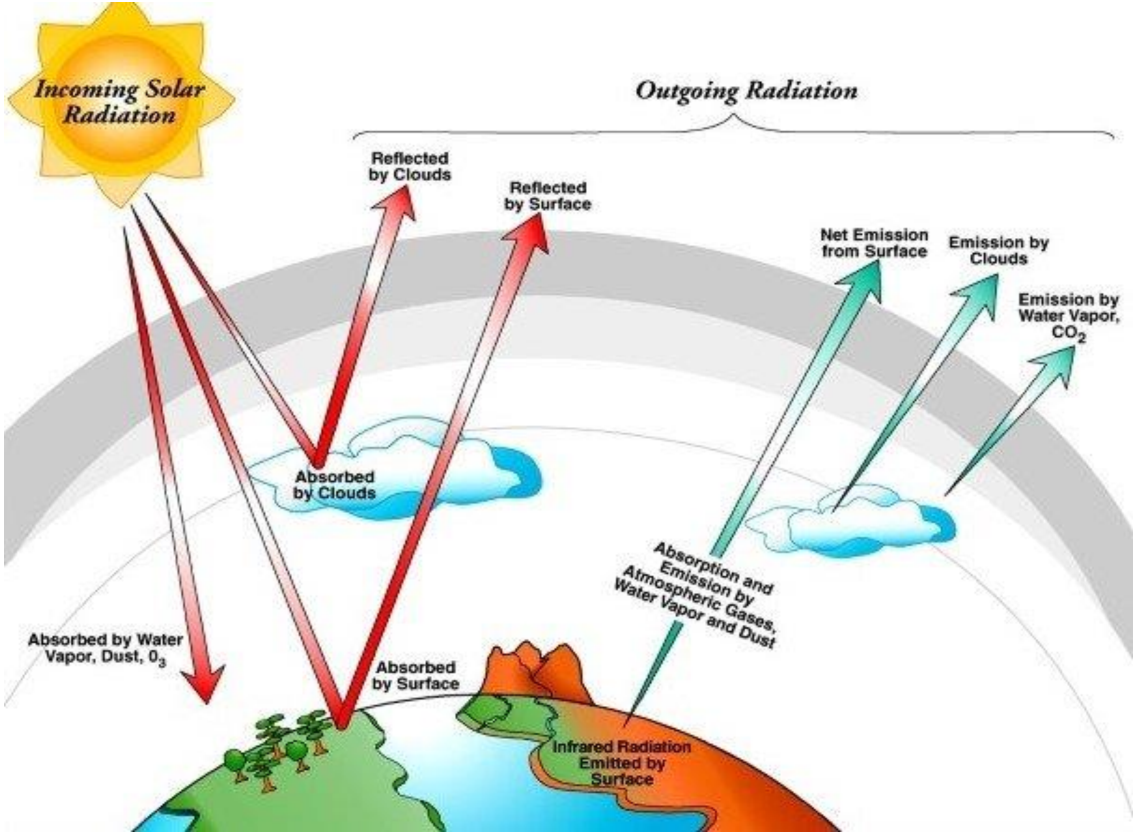
Spectrums of RS data



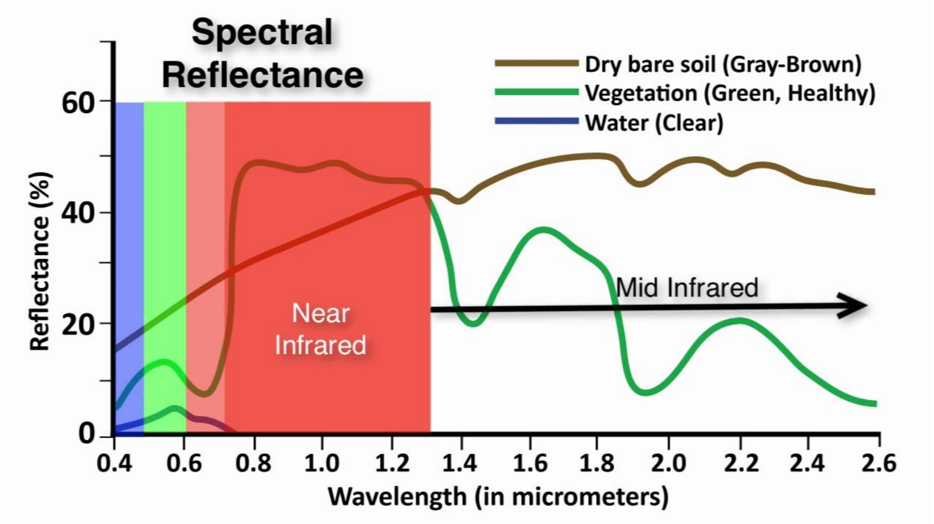
Satellite images often consist of several bands because they capture different portions of the electromagnetic spectrum.

The reason for having multiple bands is that different wavelengths of light interact differently with the Earth's surface and atmosphere. By capturing information across various bands, satellite images provide valuable insights into different aspects of the Earth's features and phenomena.

Interaction with the Earth Surface



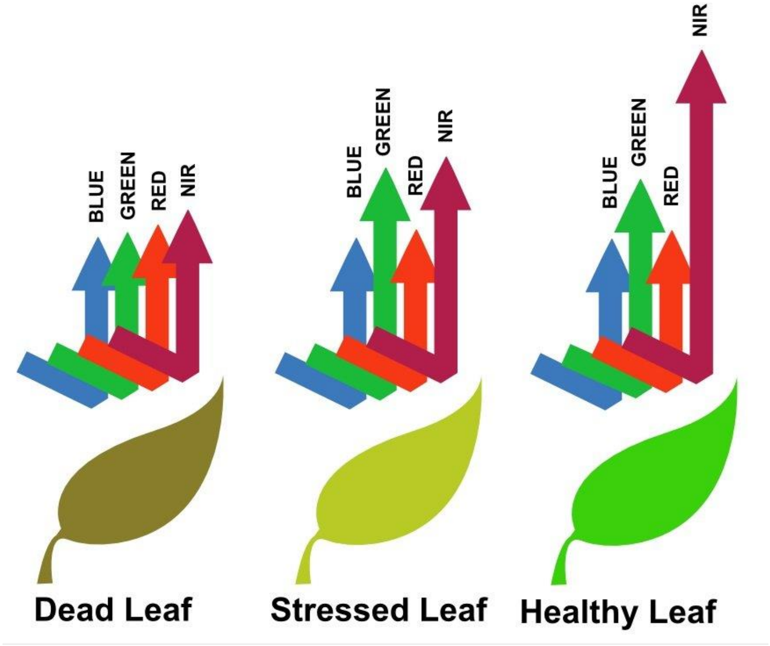
What is spectral signatures?

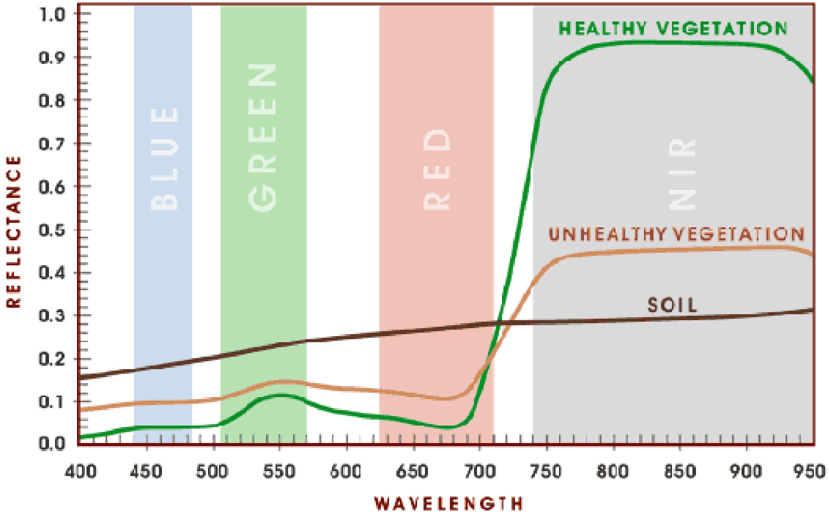


The **spectral signature** refers to the unique pattern of light or electromagnetic radiation that is reflected, emitted, or transmitted by an object or substance at different wavelengths. It is essentially a graph or plot that shows how an object interacts with light across a range of wavelengths.

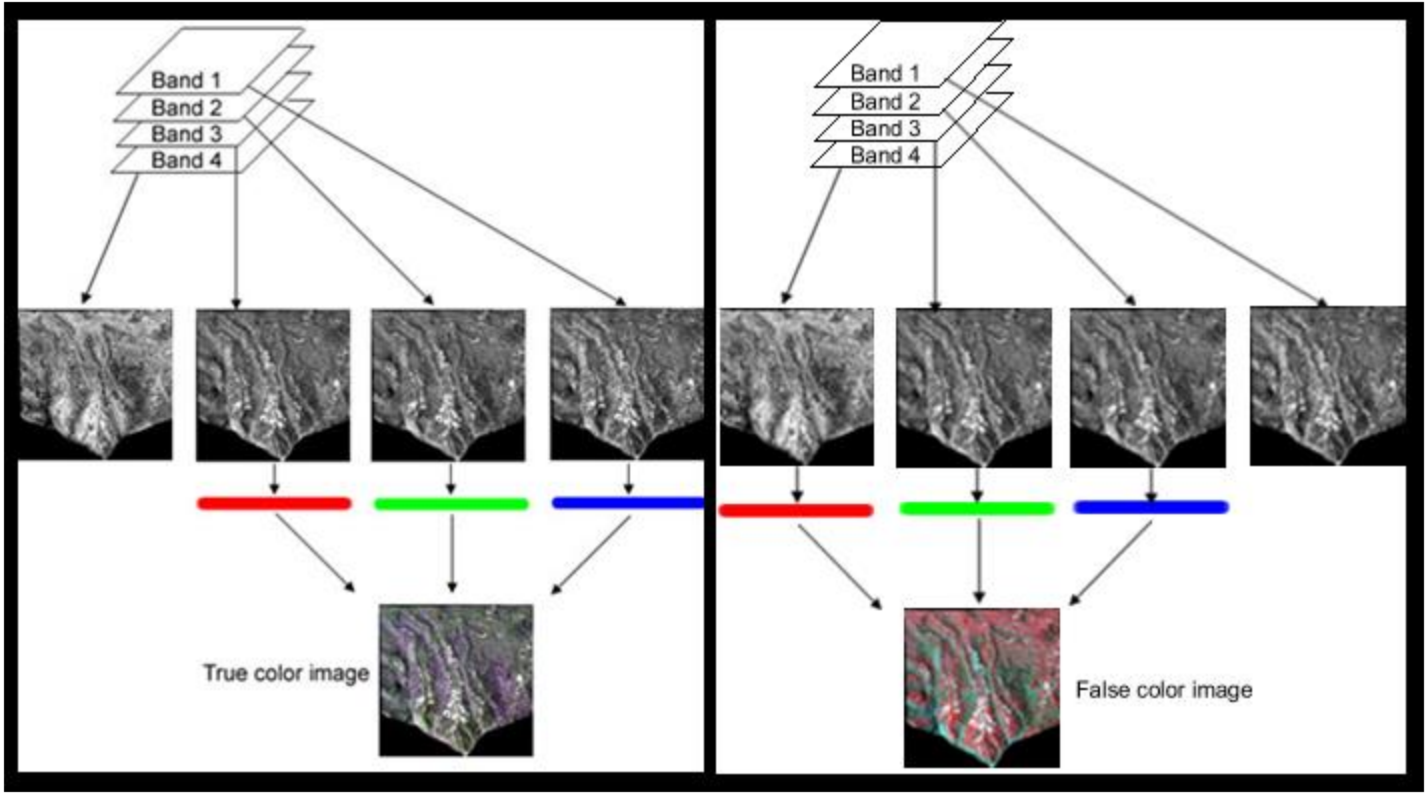
Every material or object has its own distinctive spectral signature, similar to a fingerprint. This signature is determined by the way the material absorbs, reflects, or emits light at different wavelengths within the electromagnetic spectrum, which includes visible light as well as other forms of radiation like infrared and ultraviolet.

Spectral characteristics of vegetation

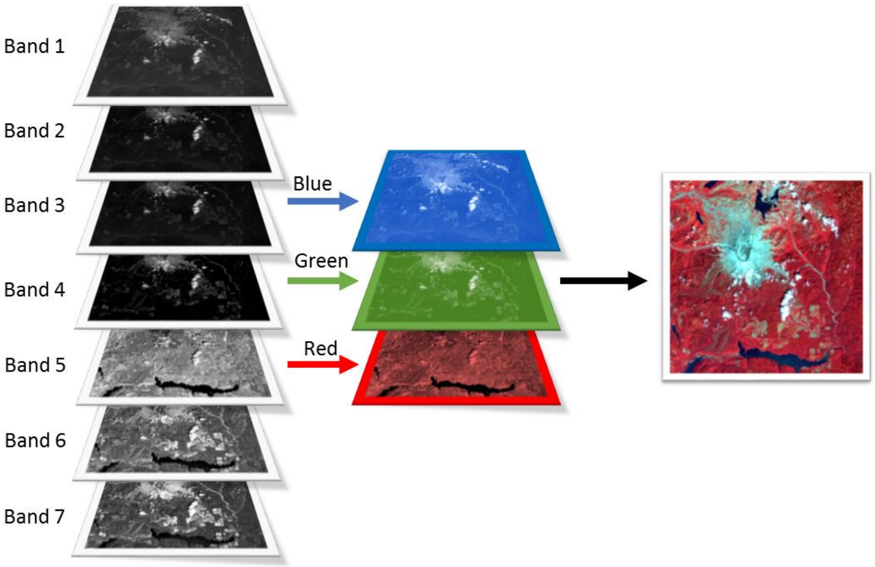




Combining bands of a satellite image



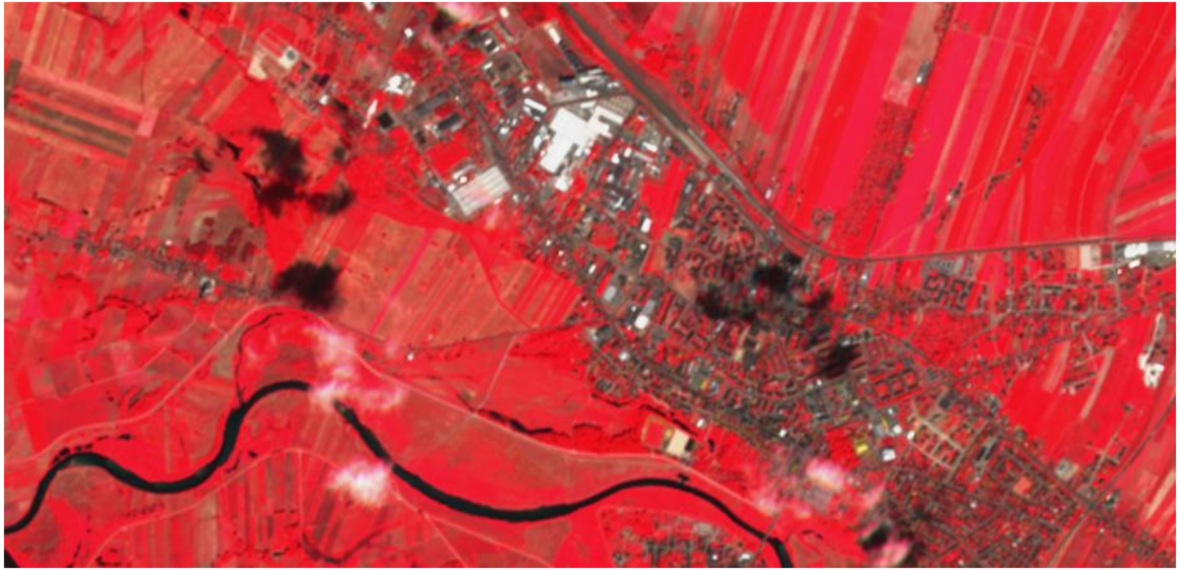
Band Combinations



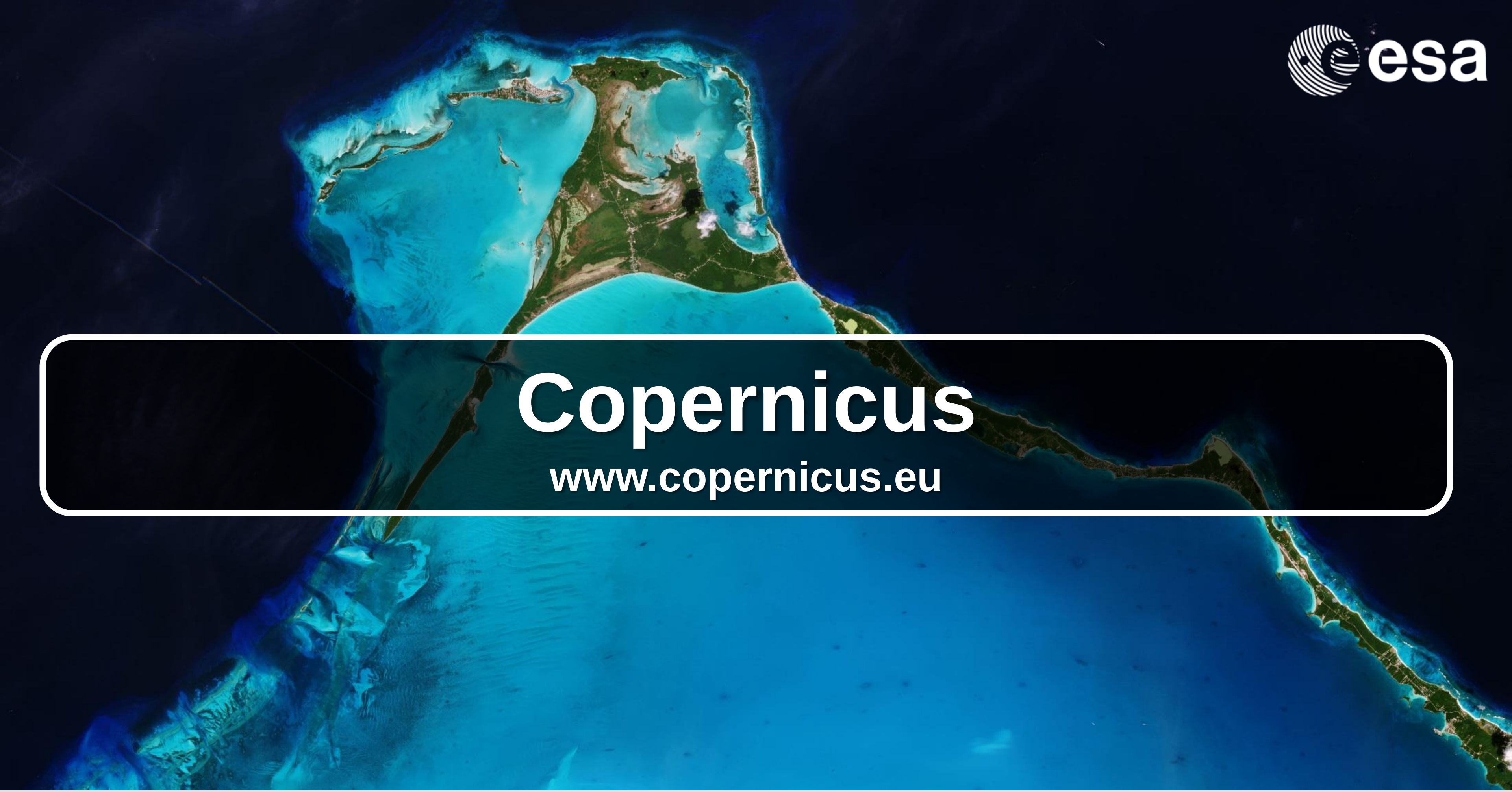
True Color

True color composite uses visible light bands red, green and blue in the corresponding red, green and blue color channels, resulting in a natural colored product, that is a good representation of the Earth as humans would see it naturally.

False Color



A false color composite uses at least one non-visible wavelength to image Earth. The false color composite using near infrared, red and green bands is very popular (a band is a region of the electromagnetic spectrum; a satellite sensor can image Earth in different bands). The false colour composite is most commonly used to assess plant density and health, since plants reflect near infrared and green light, while they absorb red. Cities and exposed ground are grey or tan, and water appears blue or black.


esa
Copernicus
www.copernicus.eu

Copernicus – a new Phase in EO

European Earth Observation System

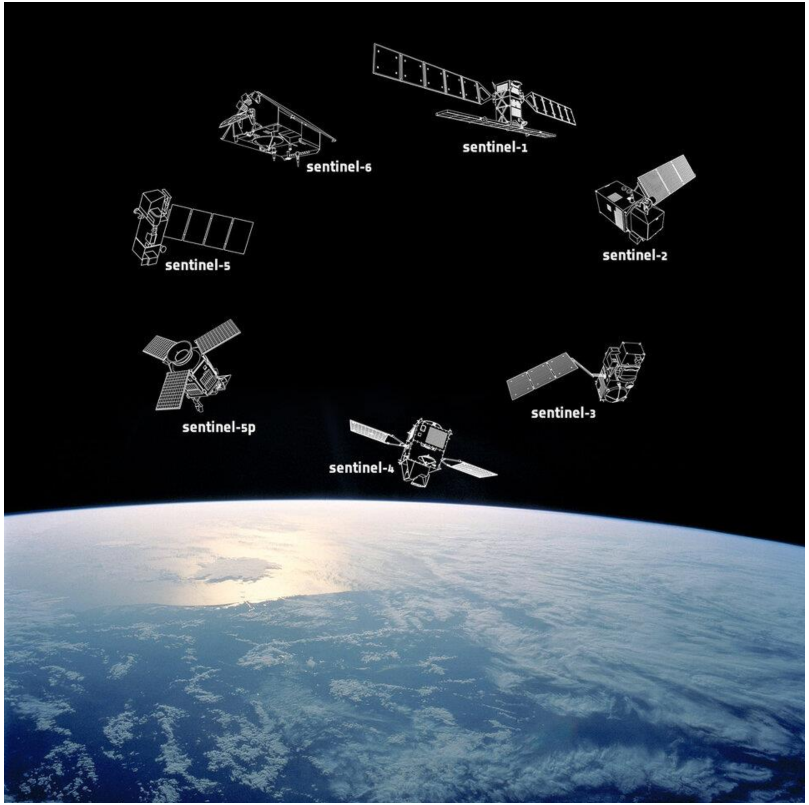
- Led by the EU
- EU-ESA Collaboration

European response to global needs:

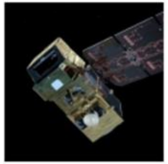
- to manage the environment
- to mitigate the effects of climate change
- to ensure civil security

European independence, contribution to global system (GEOSS)

Copernicus Program



With the objectives of Land and Ocean monitoring, Sentinel-1 will be composed of two polar-orbiting satellites operating day and night, and will perform Radar imaging, enabling them to acquire imagery regardless of the weather. The first Sentinel-1 satellite was launched in April 2014.

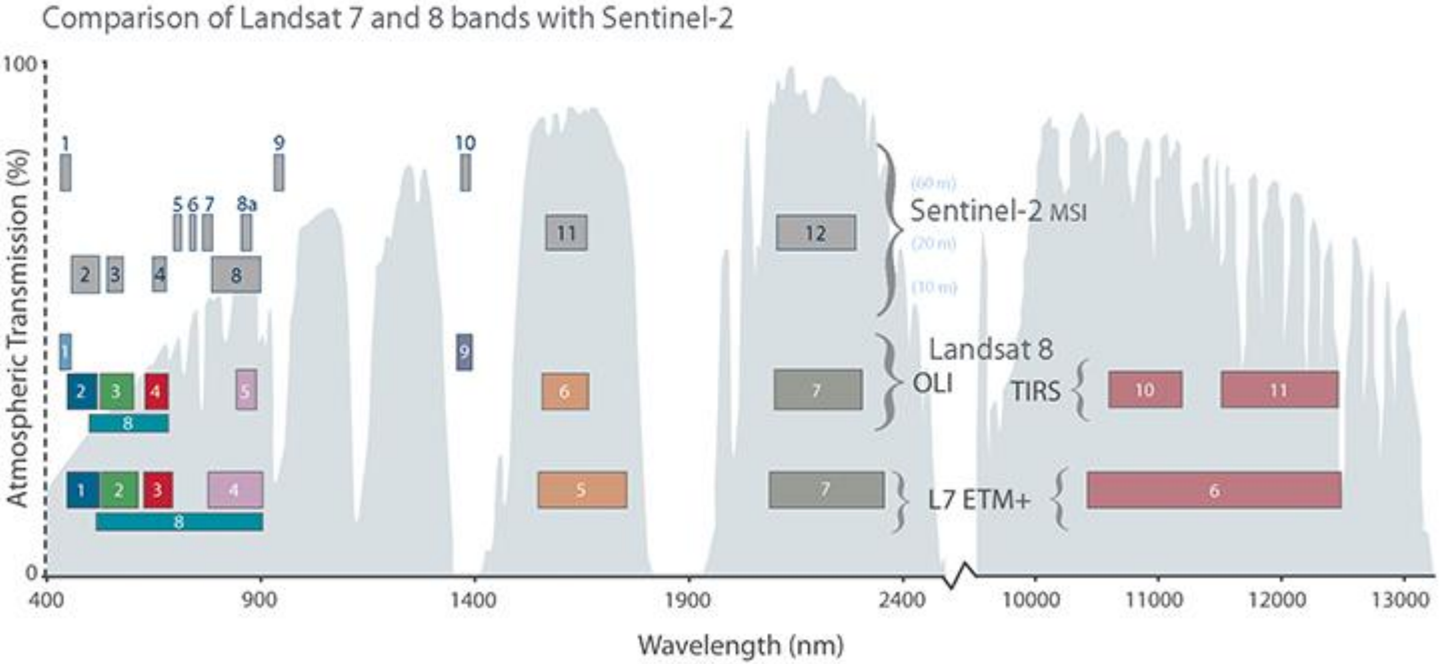


The objective of Sentinel-2 is land monitoring, and the mission will be composed of two polar-orbiting satellites providing high-resolution optical imagery. Vegetation, soil and coastal areas are among the monitoring objectives. The first Sentinel-2 satellite was launched in June 2015.

The primary objective of Sentinel-3 is marine observation, and it will study sea-surface topography, sea and land surface temperature, ocean and land colour. Composed of three satellites, the mission's primary instrument is a radar altimeter, but the polar-orbiting satellites will carry multiple instruments, including optical imagers.

The main objective of the Sentinel-5P mission is to perform atmospheric measurements, with high spatio-temporal resolution, relating to air quality, climate forcing, ozone and UV radiation.

Sentinel-2 & Landsat 7,8 bands comparison



Landsat VS Sentinel 2

Landsat

Data availability: from 1972

Spatial resolution: 30, 100 m

Temporal resolution: 16 days

Has thermal bands!

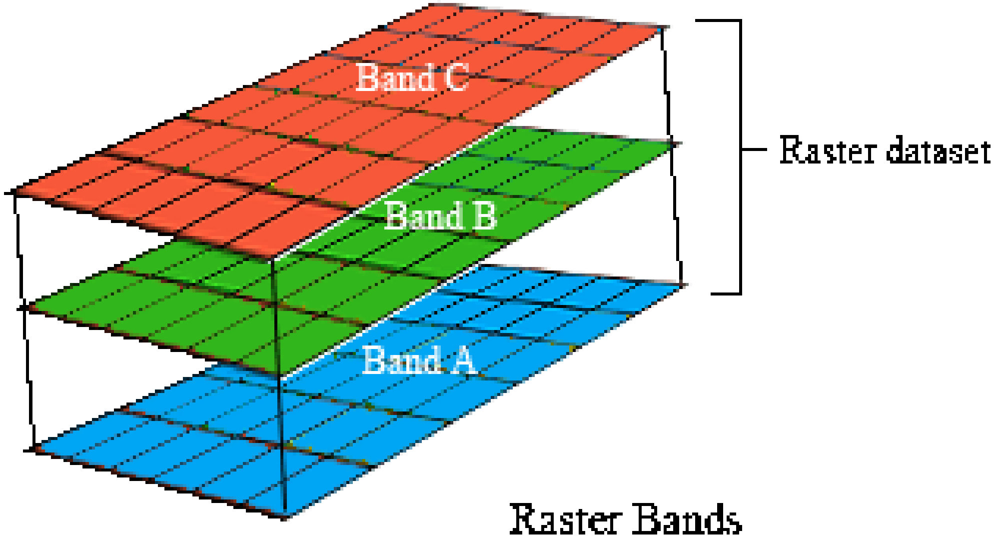
Sentinel 2

Data availability: from 2015

Spatial resolution: 10,20,60 m

Temporal resolution: 4-7 days

Spectral Indices

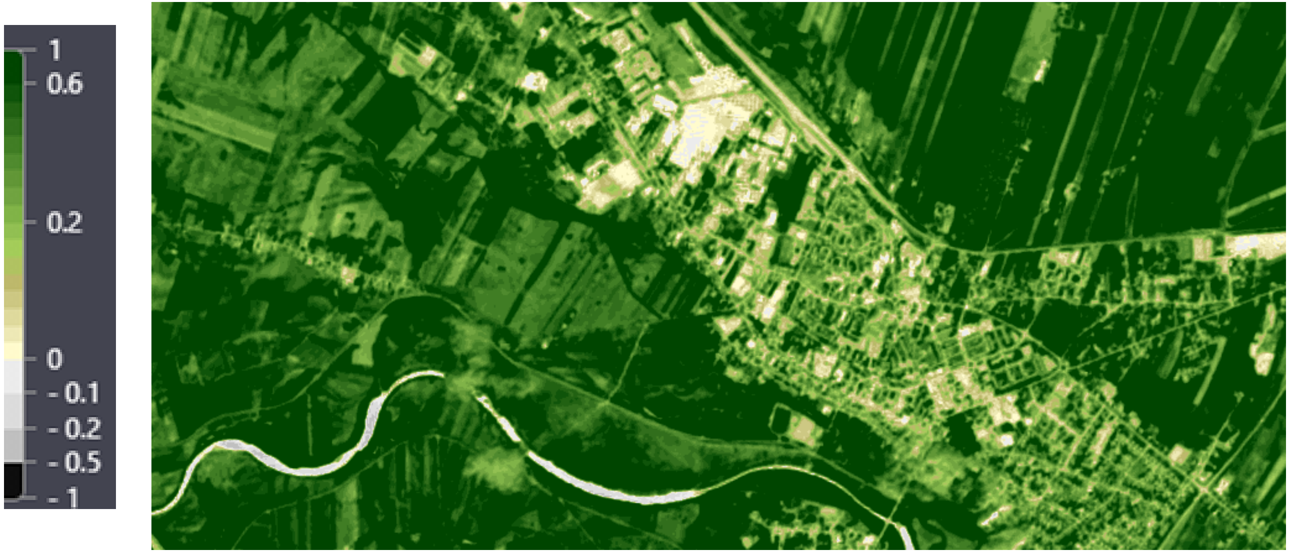


Spectral indices are combinations of **spectral** reflectance from two or more wavelengths that indicate the relative abundance of features of interest. Vegetation **indices** are the most popular type, but other **indices** are available for burned areas, man-made (built-up) features, water, and geologic features.

$$\frac{A-B}{B-A}=D$$

Normalized Difference Vegetation Index (NDVI)

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$



The normalized difference vegetation index is a simple, but effective index for quantifying green vegetation. It is a measure of the state of vegetation health based on how plants reflect light at certain wavelengths. The value range of the NDVI is -1 to 1. Negative values of NDVI (values approaching -1) correspond to water. Values close to zero (-0.1to 0.1) generally correspond to barren areas of rock, sand, or snow. Low, positive values represent shrub and grassland (approximately 0.2 to 0.4), while high values indicate temperate and tropical rainforests (values approaching 1).

Let's try to calculate NDVI

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

NIR

4	5	11	13	17	9
3	57	56	56	4	6
12	43	45	12	12	8
13	5	7	8	21	19
5	7	11	6	7	5
23	3	12	8	2	2

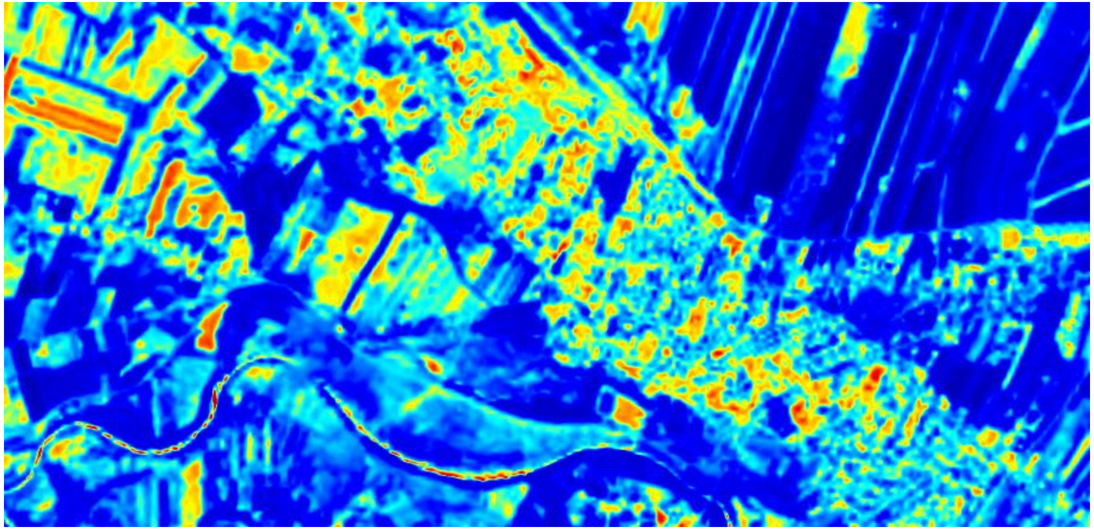
RED

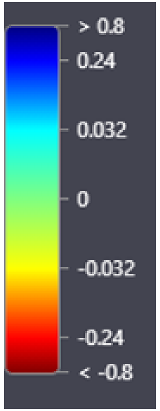
11	24	18	21	21	22
24	58	17	14	10	0
12	34	43	12	7	8
31	26	17	14	12	76
34	9	13	16	34	16
18	23	5	6	7	14

-0.46	*-0.65*	*-0.24*	*-0.24*	*-0.10*	*-0.42*
-0.77	*0*	*0.24*	*0.25*	*0.7*	*0.16*
…	…	…	…	…	…
…	…	…	…	…	…
…	…	…	…	…	…
…	…	…	…	…	…

Normalized Difference Moisture Index (NDMI)

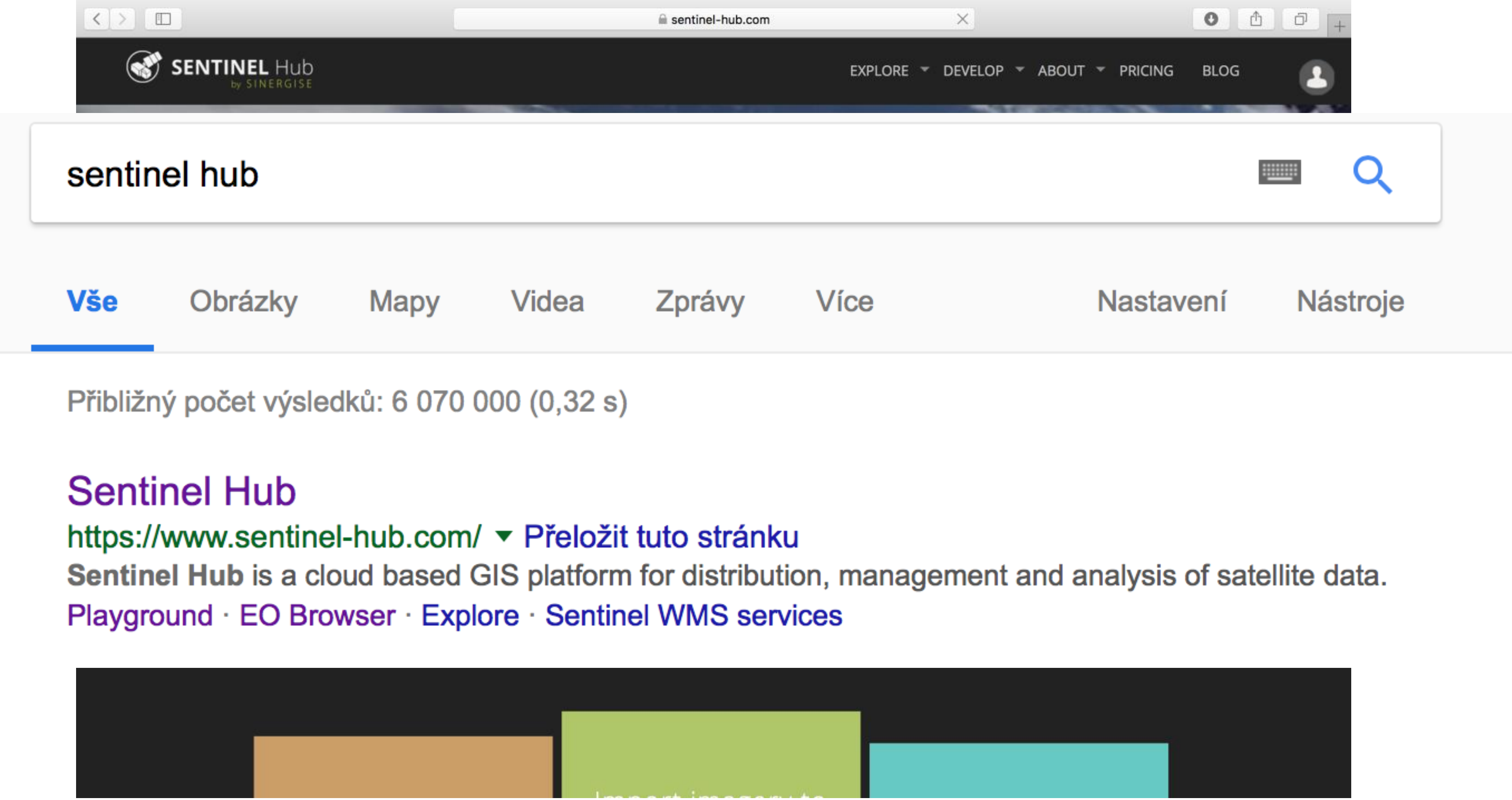
$$NDMI = \frac{NIR - SWIR}{NIR + SWIR}$$





The normalized difference moisture Index (NDMI) is used to determine vegetation water content and monitor droughts. The value range of the NDMI is -1 to 1. Negative values of NDMI (values approaching -1) correspond to barren soil. Values around zero (-0.2 to 0.4) generally correspond to water stress. High, positive values represent high canopy without water stress (approximately 0.4 to 1).

Sentinel Hub practice



Thank you for your attention

Acknowledgments: to thank for the support of the European Union's Caroline Herschel Framework Partnership Agreement on Copernicus User Uptake under grant agreement No. FPA 275/G/GRO/COPE/17/10042, project FPCUP (Framework Partnership Agreement on Copernicus User Uptake).