Online Young Scientist School (YSS) – MEGAPOLIS-2021

"Multi–Scales and –Processes Integrated Modelling, Observations and Assessments for Environmental Applications"

Hosts: University of Helsinki (UHEL, Helsinki, Finland) & Moscow State University (MSU, Moscow, Russia)

Satellite remote sensing: basics, approaches, applicability

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18th November, 2021

This visualization is a result of combining NASA satellite data with sophisticated mathematical models that describe the underlying physical processes.

https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=12772&button=recent&fbclid=IwAR0MmkxOwLxeVwWb16uAyL-TroNTkJInXvm_6Qax8Wa7XSOuTXiUos8hipM

What is Remote Sensing?

- **Remote sensing** is the science of obtaining the properties of an area or objects located at considerable distances from instruments. In contrast to in situ or on-site observations, remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object.

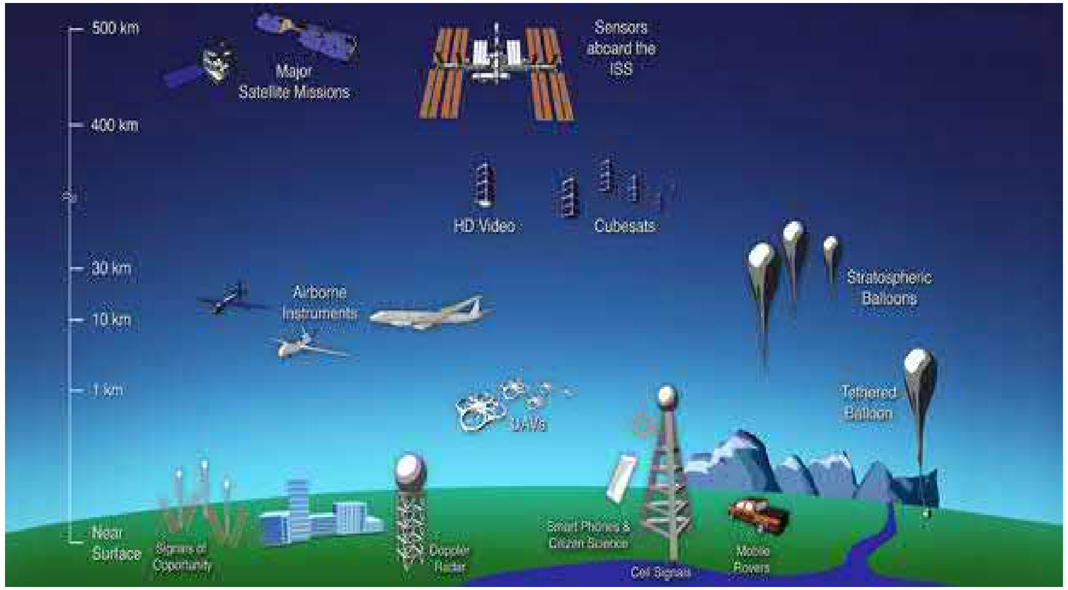
- **Remote sensing** technique allows users to capture, visualize, and analyse objects and features on the Earth's surface.

- **Remote sensing** uses a sensor to capture a signal , or an image. It involves interaction between incident radiation and target of interest.

- **Remote sensing** instruments are installed on different platforms: ground-based, airplanes, satellites, space shuttles

- For issues like climate change, natural resources, disaster management, and the environment, **remote sensing** provides a wealth of information on a global scale.

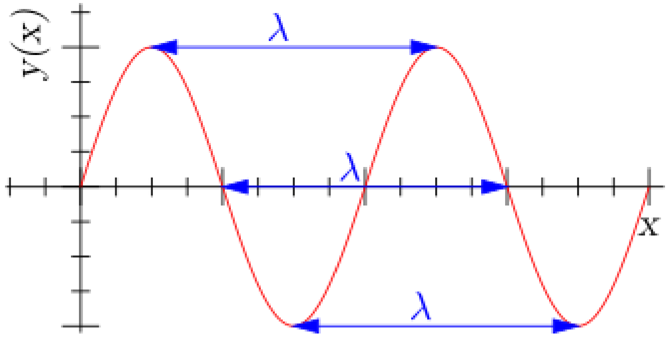
- **Remote sensing** deals with data collected by electromagnetic energy. Orbital platforms collect and transmit data from different parts of the electromagnetic spectrum



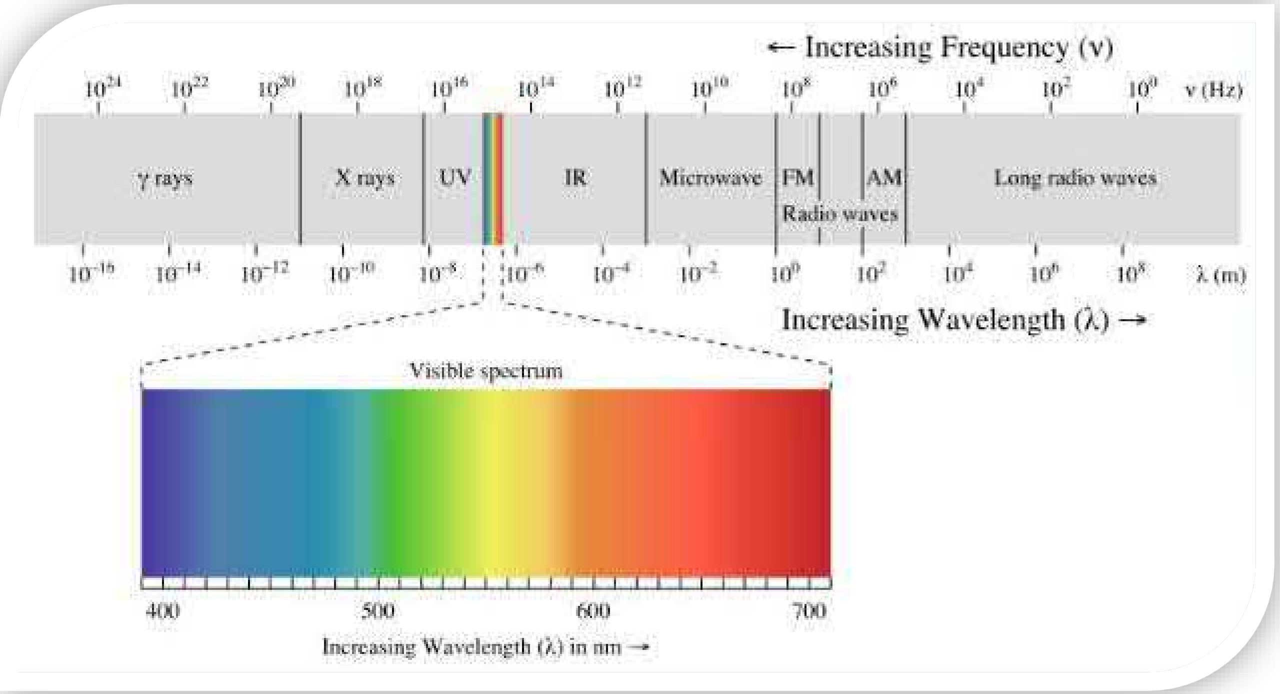
major **remote sensing technologies** and their typical altitudes

Electromagnetic spectrum

- The **electromagnetic spectrum** is the full range of frequencies (the spectrum) of electromagnetic radiation and their respective wavelengths and photon energies
- the **wavelength** is the **spatial period** of a periodic wave—the distance over which the wave's shape repeats



- spans energies from radio waves to gamma-rays

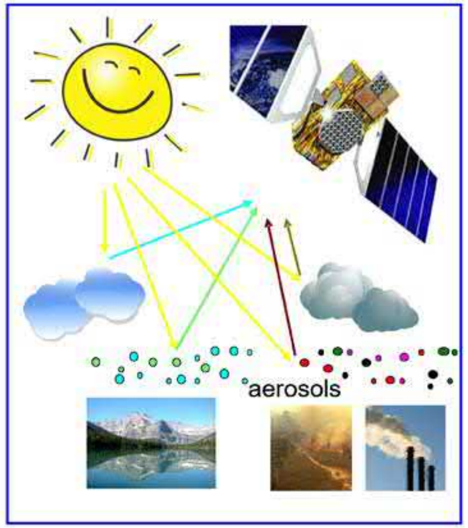


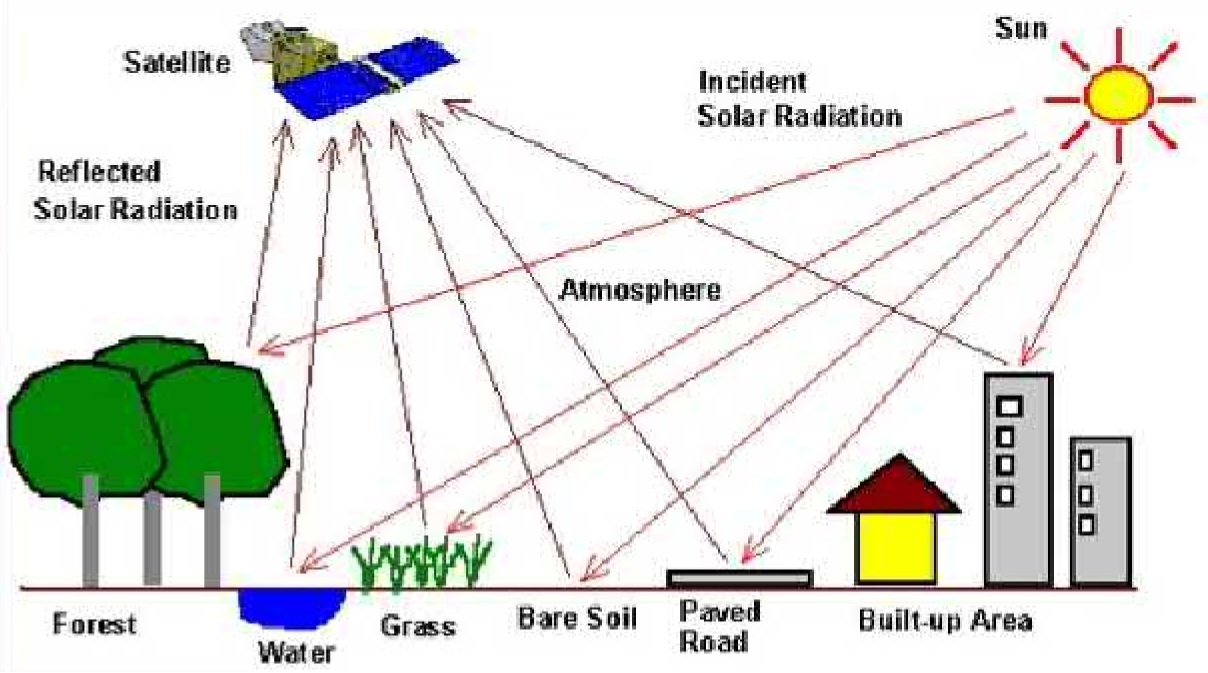
In remote sensing, typical applications include the visible light (380–780 nm), infrared (780 nm–0.1 mm), and microwave (0.1 mm–1 m) ranges.

Components of remote sensing

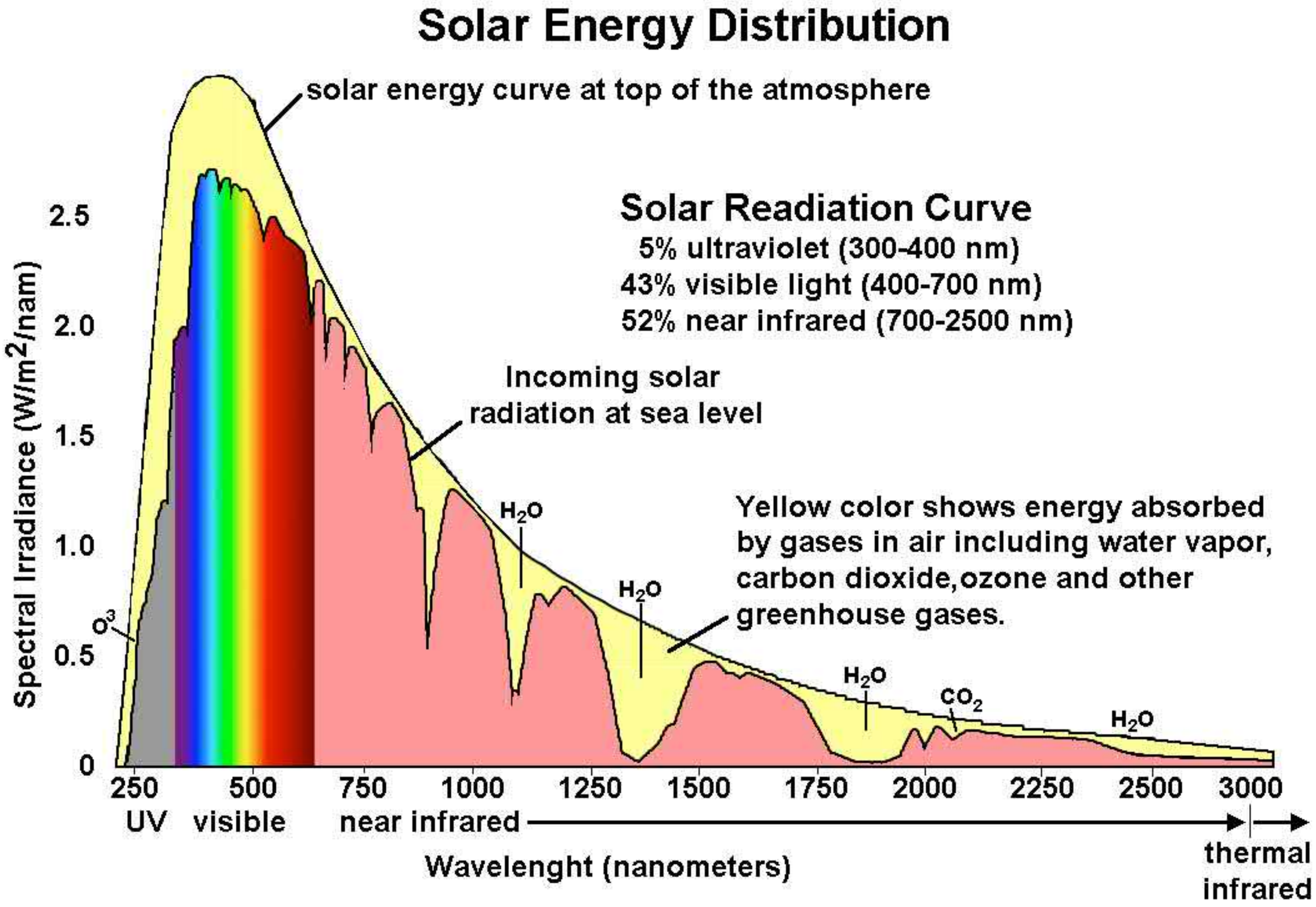
The satellite instrument receives the reflected solar radiation from the surface, from gases, from aerosols and from clouds; hence the radiation measured at the the top of the atmosphere radiation (TOA) is determined by:

- Surface characteristics
- Aerosol optical properties
  - scattering
  - absorption
- Molecular optical properties
  - scattering
  - absorption
- Clouds





Absorption bands



http://geologycafe.com/oceans/images/insolation_curve.jpg

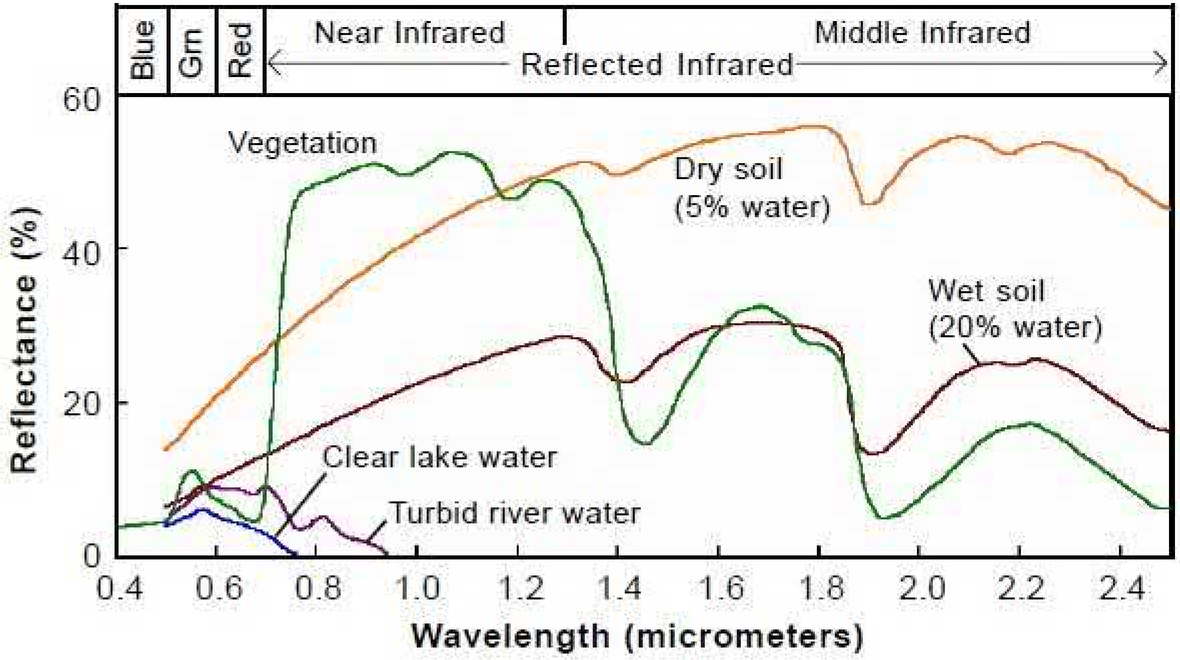
It is estimated that only 67% of sunlight directly heats the Earth. The remainder of the light is absorbed and refLected by the atmosphere. The Earth's atmosphere strongly absorbs infrared and UV radiation.

Each part of the spectrum has different characteristics and gives rather different information about earth's surface. In addition, different surface covers (vegetation, water, soil, etc) absorb and reflect differently in different parts of the spectrum. Different wavebands in the electromagnetic spectrum therefore tend to be useful for different purposes.

Spectral signatures

The absorbance, reflectance, transmittance coefficients for different surfaces are highly dependent on the wavelength.
The specific combination of these coefficients for an object can uniquely define the characteristics of that object and determine what exactly that object is.

Spectral signature is reflective behavior of an object along the EM spectrum



Radiative transfer

Radiative transfer is the physical phenomenon of energy transfer in the form of electromagnetic radiation.

The propagation of radiation through a medium is affected by absorption, emission, and scattering processes.

The **equation of radiative transfer** describes these interactions mathematically.

$$\frac{1}{c}\frac{\partial}{\partial t}I_\nu + \hat{\Omega}\cdot\nabla I_\nu + (k_{\nu,s} + k_{\nu,a})I_\nu = j_\nu + \frac{1}{4\pi}k_{\nu,s}\int_\Omega I_\nu d\Omega$$

where c is the speed of light, j_ν is the emission coefficient, $k_{\nu,s}$ is the scattering opacity, $k_{\nu,a}$ is the absorption opacity, the $\frac{1}{4\pi}k_{\nu,s}\int_\Omega I_\nu d\Omega$ term represents radiation scattered from other directions onto a surface.

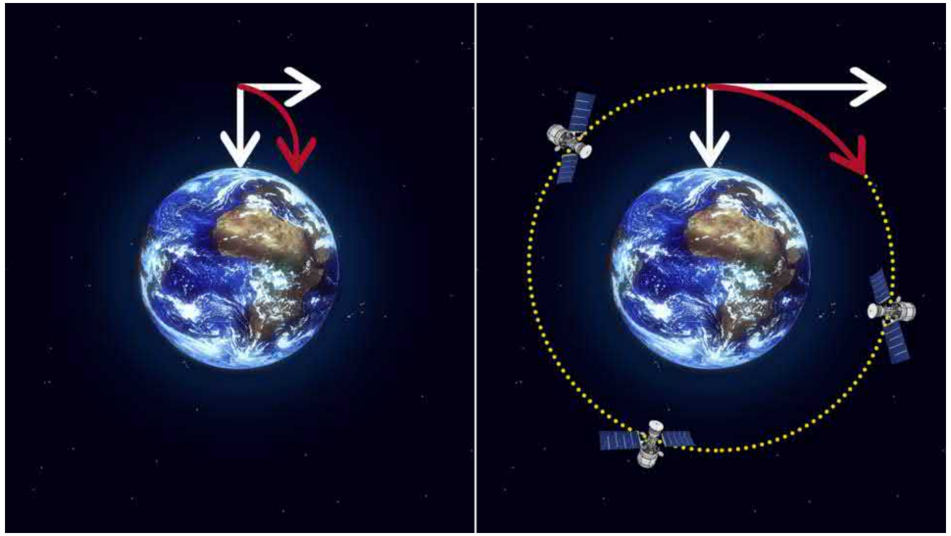
Analytic solutions to the radiative transfer equation (RTE) exist for simple cases but for more realistic media, with complex multiple scattering effects, numerical methods are required.

https://en.wikipedia.org/wiki/Radiative_transfer

TYPES OF ORBITS

When rockets launch our satellites, they put them into orbit in space. There, gravity keeps the satellite on its required orbit – in the same way that gravity keeps the Moon in orbit around Earth.

- Geostationary orbit (GEO)
- Low Earth orbit (LEO)
- Medium Earth orbit (MEO)
- Polar orbit and Sun-synchronous orbit (SSO)
- Transfer orbits and geostationary transfer orbit (GTO)
- Lagrange points (L-points)

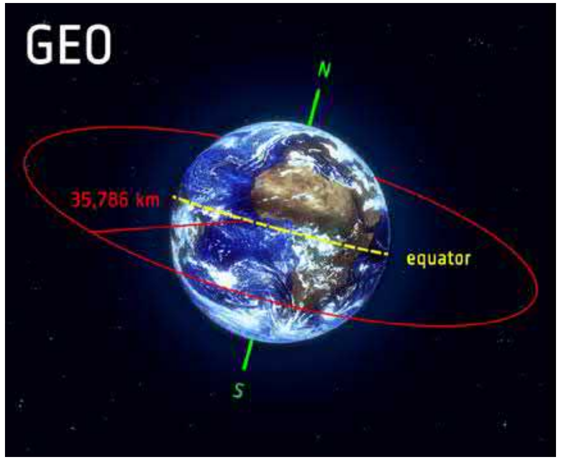


https://www.esa.int/Enabling_Support/Space_Transportation/Types_of_orbits

TYPES OF ORBITS (cont)

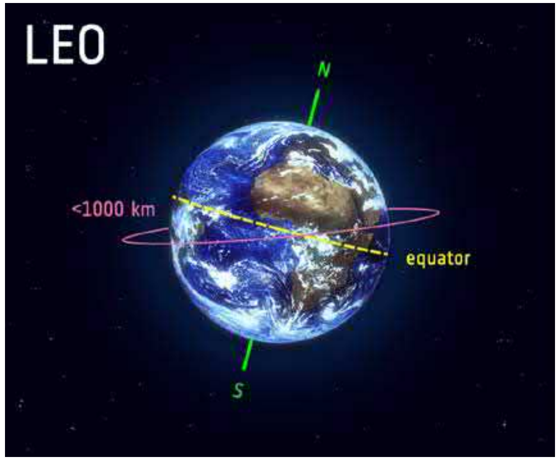
Geostationary orbit (GEO)

- Satellites in geostationary orbit (GEO) circle Earth above the equator from west to east following Earth's rotation – taking 23 hours 56 minutes and 4 seconds – by ***travelling at exactly the same rate as Earth.***
- This makes satellites in GEO appear to be 'stationary' over a fixed position. In order to perfectly match Earth's rotation, the speed of GEO satellites should be about 3 km per second at an altitude of 35 786 km. This is much farther from Earth's surface compared to many satellites.



Low Earth orbit (LEO)

- It is normally at an altitude of less than 1000 km but could be as low as 160 km above Earth – which is low compared to other orbits, but still very far above Earth's surface.
- LEO satellites do not always have to follow a particular path around Earth in the same way
- It is the orbit most commonly used for **satellite imaging**, as being near the surface allows it to take images of higher resolution.



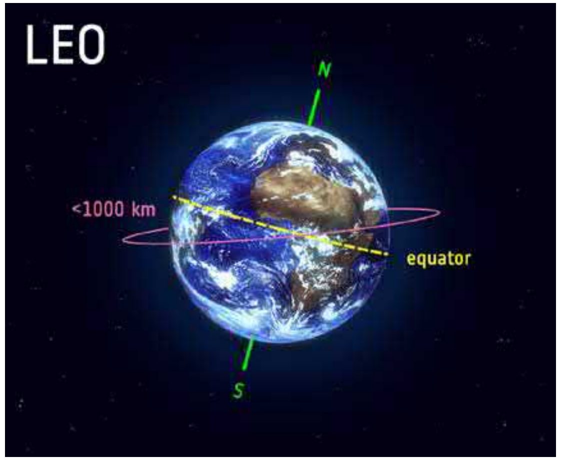
TYPES OF ORBITS (cont)

Medium Earth orbit (MEO)

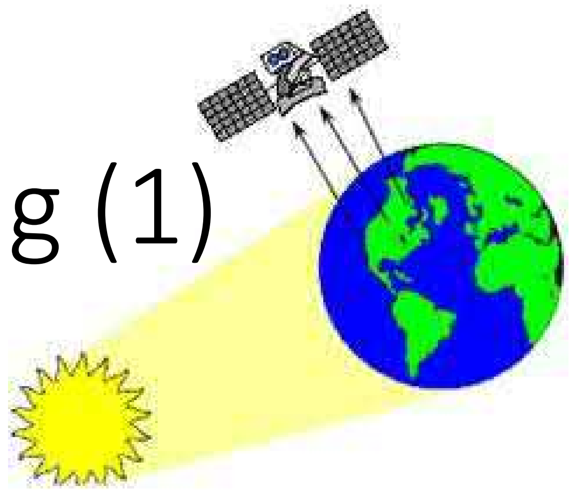
- Medium Earth orbit comprises a wide range of orbits anywhere between LEO and GEO. It is similar to LEO in that it also does not need to take specific paths around Earth, and it is used by a variety of satellites with many different applications.
- It is very commonly used by **navigation satellites**, like the European Galileo system. Galileo powers navigation communications across Europe, and is used for many types of navigation. Galileo uses a constellation of multiple satellites to provide coverage across large parts of the world all at once.

Polar orbit and Sun-synchronous orbit (SSO)

- Satellites in polar orbits usually travel past Earth from north to south rather than from west to east, passing roughly over Earth's poles.
- Polar orbits are a type of low Earth orbit, as they are at low altitudes between 200 to 1000 km.
- Sun-synchronous orbit (SSO) is a particular type of polar orbit. This means they are synchronized to always be in the same ‘fixed’ position relative to the Sun, visiting the same spot at the same local time. That serves a number of applications; for example, it means that scientists and those who use the satellite images can compare how somewhere changes over time.



Passive vs active remote sensing (1)

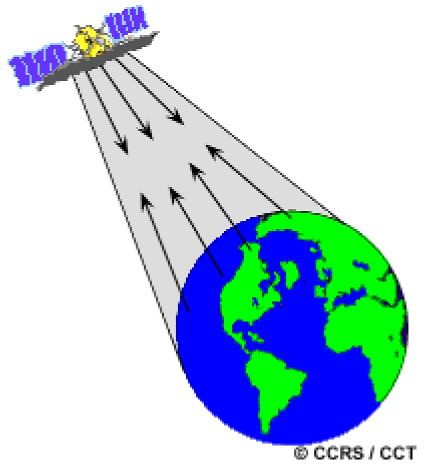


Remote sensing systems which measure energy that is naturally available are called passive sensors.

- Passive sensors can only be used to detect energy when the naturally occurring energy is available (when the sun is illuminating the Earth)
- Energy that is naturally emitted (such as thermal infrared) can be detected day or night, as long as the amount of energy is large enough to be recorded

http://www.nrcan.gc.ca/earth-sciences/geography-boundary/remote-sensing/fundamentals/1212

Passive vs active remote sensing (2)

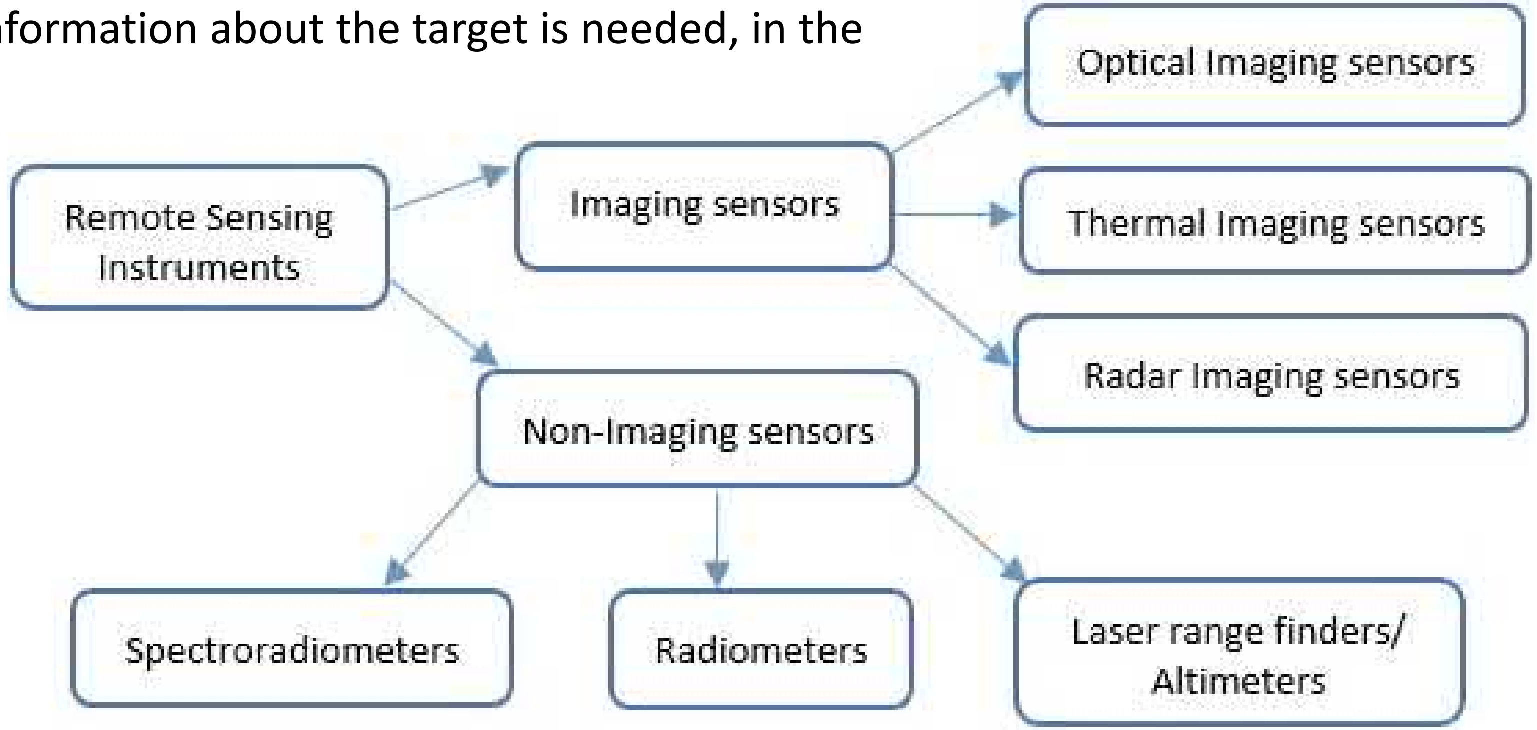


- Active sensors, on the other hand, provide their own energy source for illumination.
    - The sensor emits radiation which is directed toward the target to be investigated
    - Advantages for active sensors include the ability to obtain measurements anytime, regardless of the time of day or season
    - Active sensors can be used for examining wavelengths that are not sufficiently provided by the sun, such as microwaves

http://www.nrcan.gc.ca/earth-sciences/geography-boundary/remote-sensing/fundamentals/1212

Remote sensing instruments

Imaging sensors measure radiation at different points on the target and this information can be processed in order to obtain an image. This is necessary when spatial information about the target is needed, in the form of a map.



A **non-imaging sensor** measures the radiation received from all points in the sensed target, integrates this and registers a single response value, hence no image can be made from the data.

https://acris.aalto.fi/ws/portalfiles/portal/28684794/57384.pdf

Imaging sensors

Optical imaging sensors

- Optical imaging sensors operate in the visible and reflective IR ranges.
- Typical optical imaging systems on space platform include panchromatic systems, multispectral systems, and hyperspectral systems.
- The resulting images can be utilized to recognize objects, identify materials, and detect elemental components.

Thermal IR imaging sensors

- A thermal sensor typically operates in the electromagnetic spectrum between the mid-to far-infrared and microwave ranges, roughly between 9 and 14 μm.
- Commonly used thermal imaging sensors include IR imaging radiometers, imaging spectroradiometers, and IR imaging cameras. Currently, the satellite IR sensors in use include ASTER, MODIS, ASAA, and IRIS.

Radar imaging sensors

- A radar (microwave) imaging sensor is usually an active sensor, operating in an electromagnetic spectrum range of 1 mm–1 m (between 400 MHz to 36 GHz). The sensor transmits light to the ground, and the energy is reflected from the target to the radar antenna to produce an image at microwave wavelengths.
- Each pixel in the radar image represents the radar backscatter for that area on the ground.
- A microwave instrument can operate in cloudy or foggy weather and can also penetrate sand, water, and walls.

Non-imaging sensors

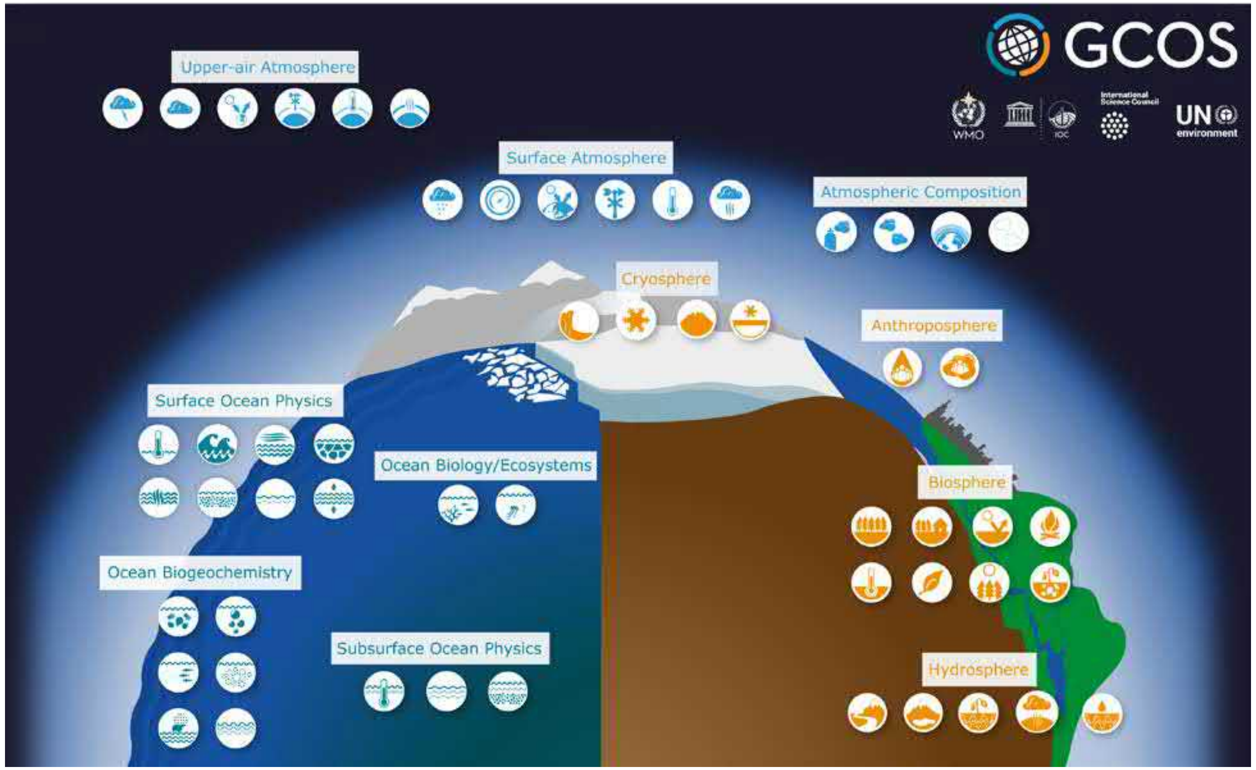
Sensor	Operational wave band	Definition To measure …	Application
Radiometer	UV, IR, mw	…the amount of electromagnetic energy present within a specific wavelength range	Calculating various surface and atmospheric parameters
Altimeter	IR, mv/rw, sonic	…the altitude of an object above a fixed level	Mapping ocean-surface topography
Spectrometer	Visible, IR, microwave	…the spectral content of the incident electromagnetic radiation	Multispectral and hyperspectral imaging
Spectro-radiometer	Visible, IR, microwave	…the intensity of radiation in multiple spectrums	Monitoring sea surface temperature, cloud characteristics, ocean color, vegetation, trace chemical species in the atmosphere
LIDAR	Ultraviolet, visible, NIR	…distance and intensity	Meteorology, cloud measurements, wind profiling and air quality monitoring
Sonar	Acoustic	…the distance to an object; determine the depth of water	Navigation, communication and security (e.g., vessels) and underwater object detection.
Sodar	Acoustic	…wind speeds and the TD structure of the lower layer of the atmosphere	Meteorology: atmospheric research, wind monitoring (typically in a range from 50 to 200m above ground level)
A radio acoustic sounding system (RASS)	Radio wave and acoustic wave	…the atmospheric lapse rate	Is added to a radar wind profiler or to a sodar system

Types (resolution) of satellite products

- Level 0: Satellites detect radiation, using a detector that provides an electrical signal (current, voltage)
- Level 1: Calibration, geolocation
- Level 2: Conversion to physical units
- Level 3: Processed geo-physical data, e.g. maps
- Level 4: Interpretated user products

Global Climate Observing System (GCOS)

GCOS was established in 1992 to ensure that the observations and information needed to address climate-related issues are obtained and made available to all potential users.



ECV are identified based on the following criteria:

•**Relevance**: The variable is critical for characterizing the climate system and its changes.
•**Feasibility:** Observing or deriving the variable on a global scale is technically feasible using proven, scientifically understood methods.
•**Cost effectiveness:** Generating and archiving data on the variable is affordable, mainly relying on coordinated observing systems using proven technology, taking advantage where possible of historical datasets.

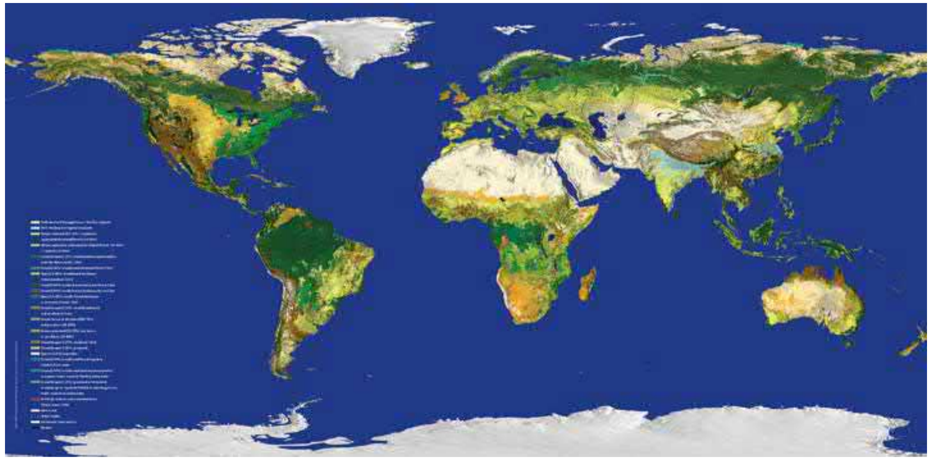
ESA Climate Change Initiative (CCI)

Climate Change Initiative (CCI) is European Space Agency (ESA) program, where a suite of satellite data records of key components of the climate system, known as Essential Climate Variables (ECVs) are developed.
Scientists use ECVs to study climate drivers, interactions and feedbacks, as well as reservoirs, tipping points and fluxes of energy, water, and carbon.
These climate-quality datasets are a major contribution to the evidence base used to understand climate change and to predict the future, which drives international action.

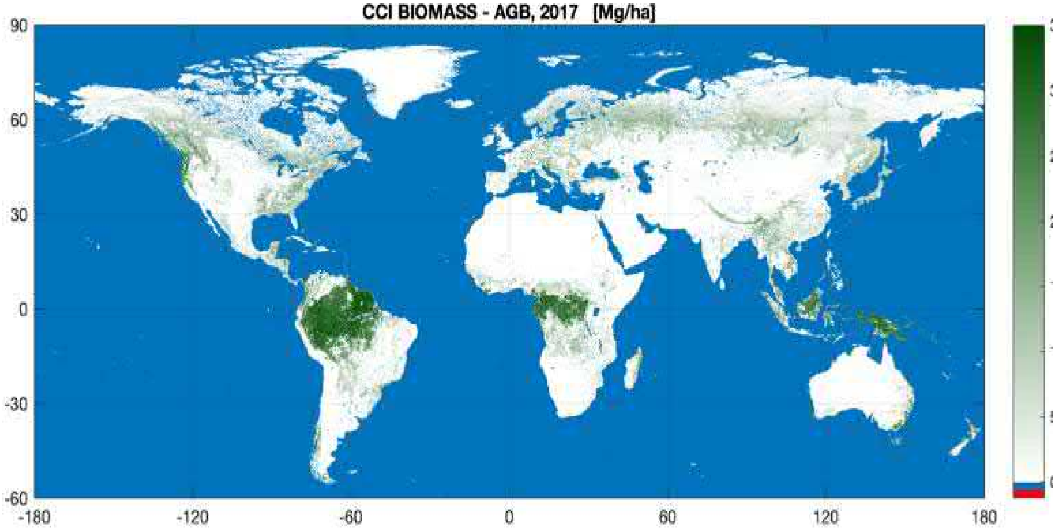
https://climate.esa.int/en/projects/

ESA CCI products

Land cover

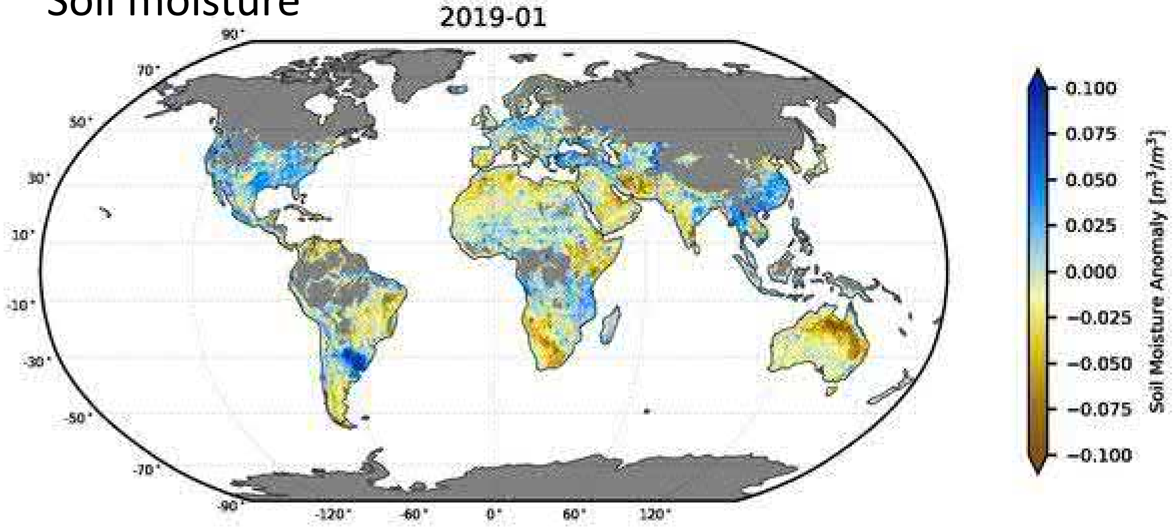


Biomass

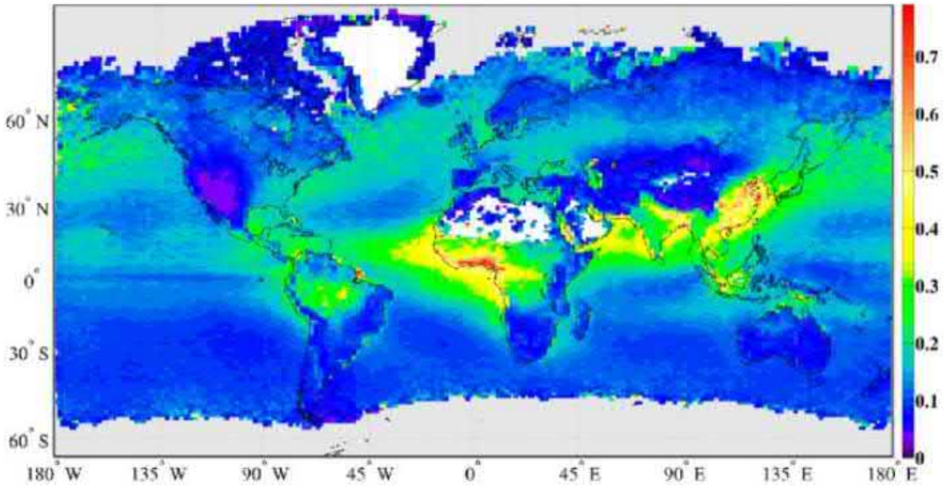


Snow extent

Soil moisture



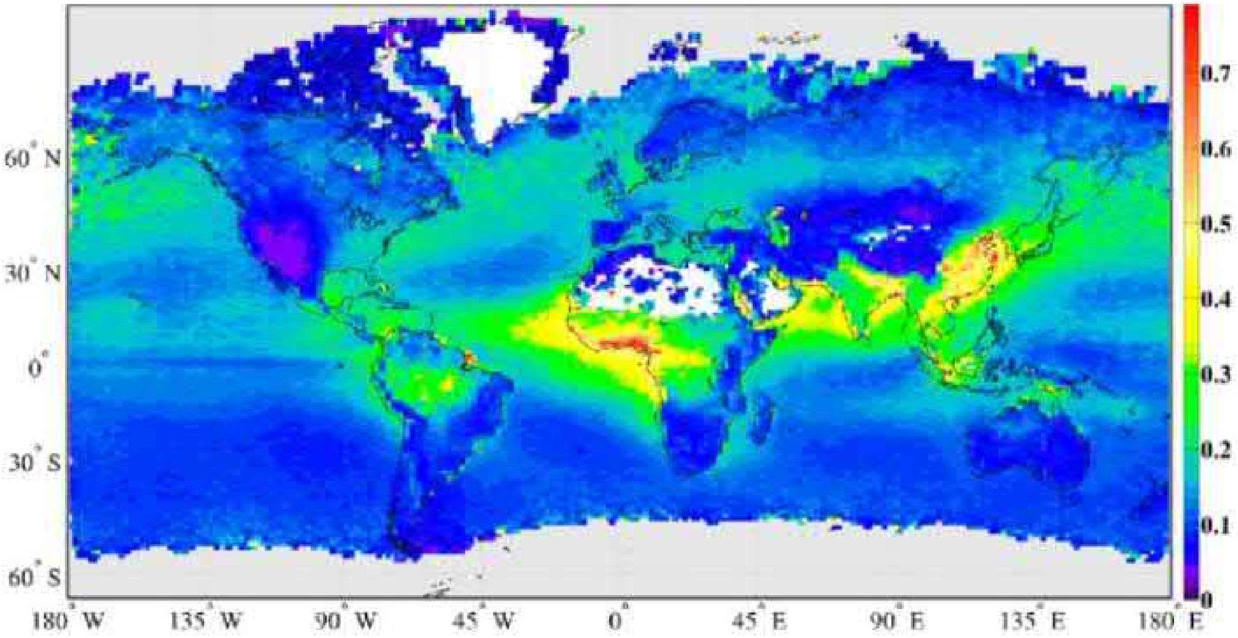
Aerosol Optical Depth (AOD)



RS limitations in AOD retrievals

- Cloudiness
- Bright surface
- High solar zenith angle

- Assumptions depend on the type of the instrument
  - Vertical profile
  - Aerosol components
  - …



FMI ADV/SDV AOD product

ESA-DEVELOPED EARTH OBSERVATION MISSIONS
esa
2010
2015
2020
2025
2030
ERS-1
ERS-2
Envisat
MetOp-A
Meteosat 10 (MSG)
MetOp-B
Meteosat 11 (MSG)
Proba-1
SMOS
GOCE
CryoSat
Swarm
Proba-V
Sentinel-1A
Sentinel-1B
Sentinel-2A
Sentinel-2B
Sentinel-3A
Sentinel-3B
Sentinel-5P
Sentinel-6 Michael Freilich
MetOp-C
Sentinel-1C
Sentinel-2C
Sentinel-3C
Sentinel-1D
Sentinel-2D
Sentinel-3D
Sentinel-6B
MTG-I1
Sentinel-5A MetOp-SG-A1
Arctic Weather Satellite
MetOp-SG-B1
Sentinel-4A MTG-S1
MTG-I2
CO2M-A
CO2M-B
CO2M-C
Aeolus
ALTIUS
EarthCARE
Biomass
FLEX
ESP-MACCS
HydroGNSS
TRUTHS
FORUM
Harmony
Earth Explorer-11
CRISTAL-A
CIMR-A
ROSE-L-A
LSTM-A
CHIME-A
CRISTAL-B
CIMR-B
ROSE-L-B
LSTM-B
CHIME-B
MTG-I3
Sentinel-4B MTG-S2
Sentinel-5B MetOp-SG-A2
MetOp-SG-B2
Sentinel-1
Sentinel-2
Sentinel-3
Sentinel-6
Continuation of Sentinel Next Generation Missions
Science
esa
Copernicus
European Union
Meteorology
EUMETSAT

Monitoring the environment with Copernicus Program

Copernicus is the world's largest and most ambitious Earth observation program in existence today.

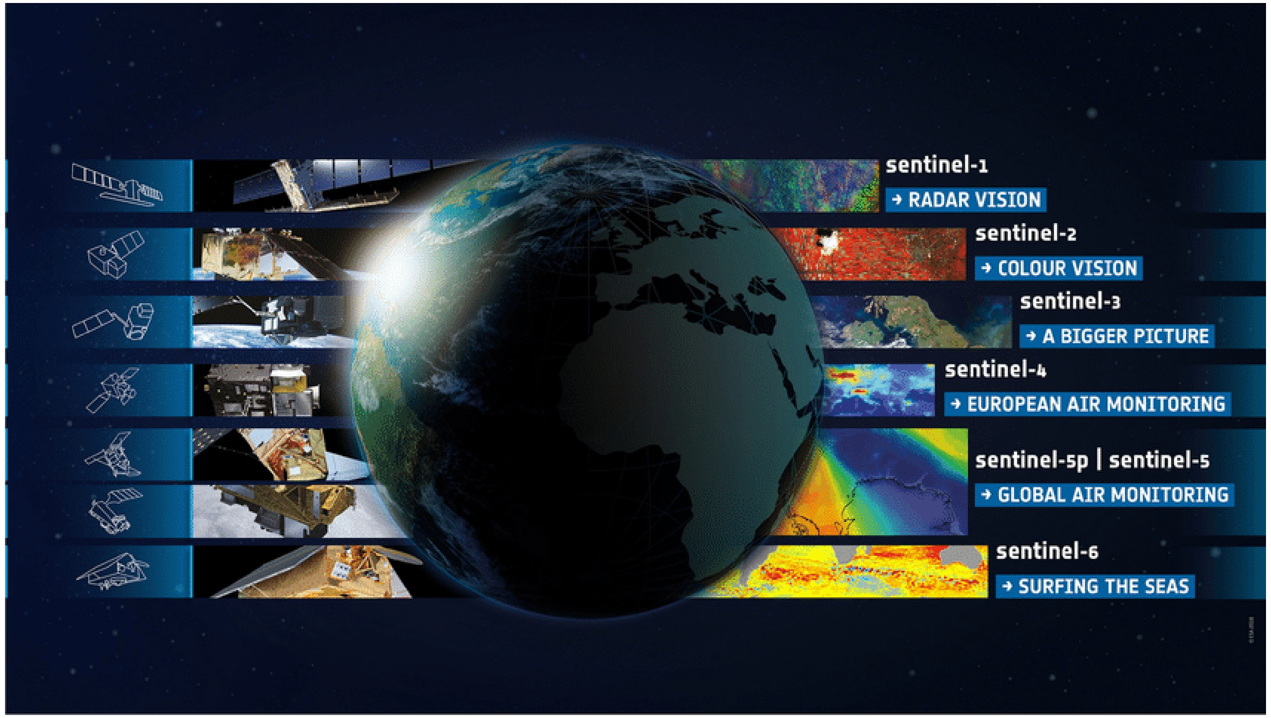
It is the European Union's Earth observation programme, looking at our planet and its environment to benefit all European citizens.

It is coordinated by the European Commission in partnership with the European Space Agency (ESA), EU Member States and other EU Agencies. Established in 2014, it builds on ESA's Global Monitoring for Environment and Security (GMES) programme.

Copernicus encompasses a system of satellites, airborne data, and ground stations supplying global monitoring data and operational services on a free-of-charge basis across six themes: atmosphere, marine, land, climate, emergency response and security.

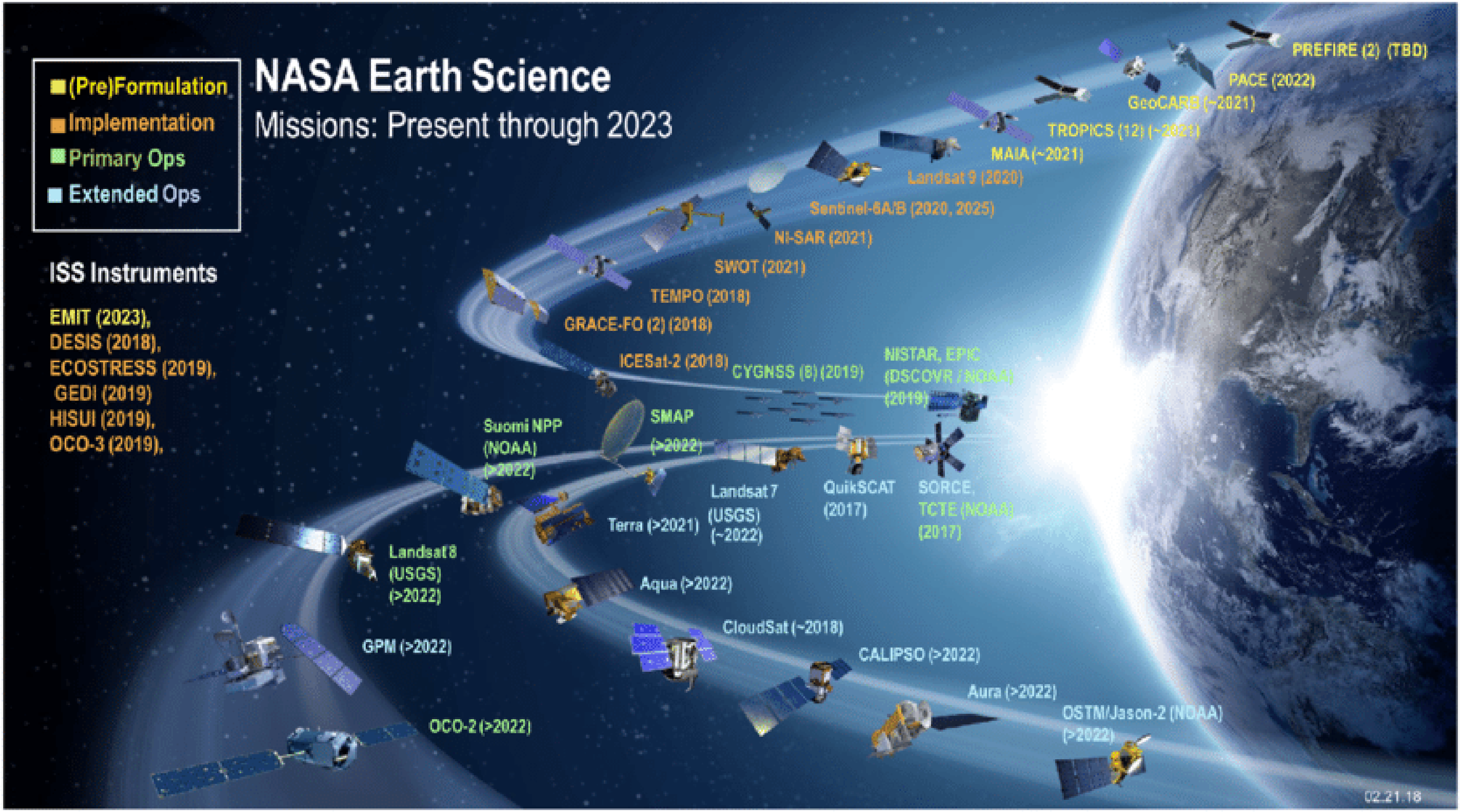
Copernicus Sentinels

- The Sentinels carry a range of technologies, such as radar and multi-spectral imaging instruments for land, ocean and atmospheric monitoring



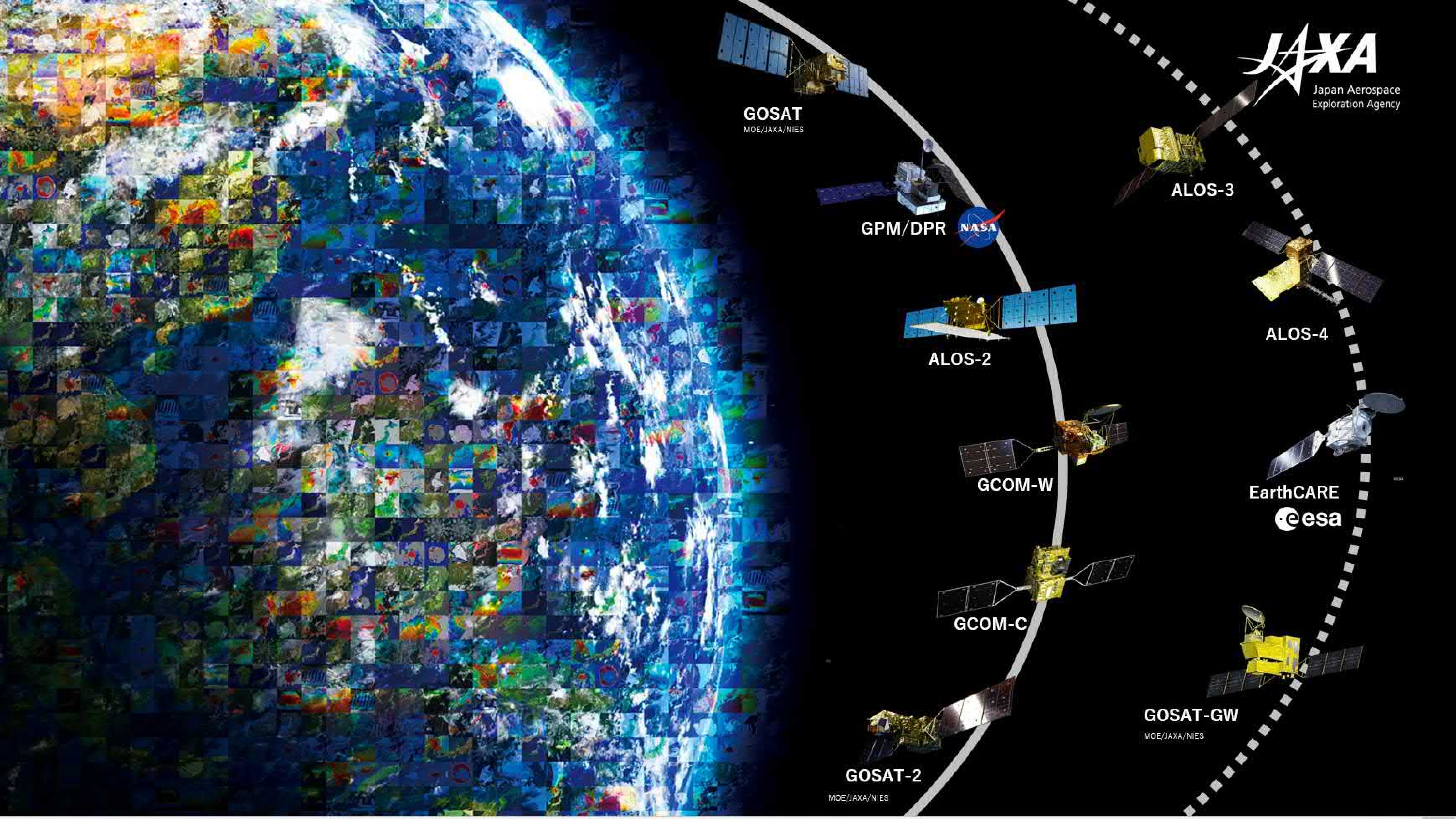
Copernicus' six Sentinel satellites collect comprehensive pictures of the following themes: land, ocean, emergency response, atmosphere, security, and climate change.

•Sentinel-1 provides all-weather, day and night radar imagery for land and ocean services
•Sentinel-2 provides high-resolution optical imagery for land services
•Sentinel-3 provides high-accuracy optical, radar and altimetry data for marine and land services
•Sentinel-4 and Sentinel-5 will provide data for atmospheric composition monitoring from geostationary orbit and polar orbit, respectively
•Sentinel-5P monitors air pollution in the atmosphere from a sun-synchronous orbit. For example, it will capture ozone, NO2, SO2, CO, aerosol and trace gases. Precursor is meant to bridge the gap between Envisat (Sciamachy data in particular) and Sentinel-5
•Sentinel-6 provides radar altimetry data to measure global sea-surface height, primarily for operational oceanography and for climate studies
Sentinel-4 and -5 will be instruments carried on also the next generation of meteorological satellites: Meteosat Third Generation (MTG) and MetOp Second Generation.

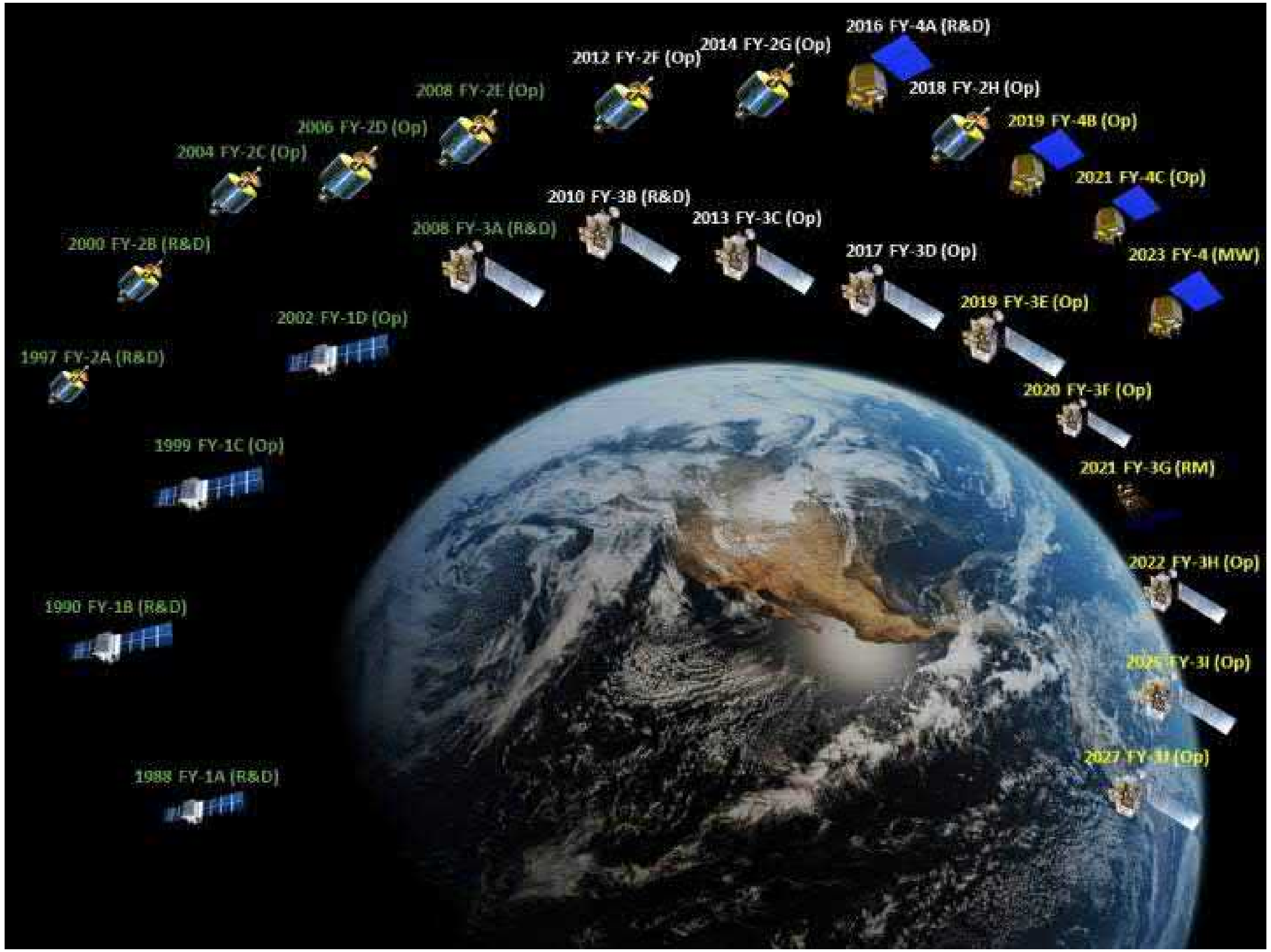


NASA Earth Science
Missions: Present through 2023
(Pre)Formulation
Implementation
Primary Ops
Extended Ops
ISS Instruments
EMIT (2023),
DESIS (2018),
ECOSTRESS (2019),
GEDI (2019)
HISUI (2019),
OCO-3 (2019),
PREFIRE (2) (TBD)
PACE (2022)
GeoCARB (~2021)
TROPICS (12) (~2021)
MAIA (~2021)
Landsat 9 (2020)
Sentinel-6A/B (2020, 2025)
NI-SAR (2021)
SWOT (2021)
TEMPO (2018)
GRACE-FO (2) (2018)
ICESat-2 (2018)
CYGNSS (8) (2019)
NISTAR, EPIC (DSCOVR / NOAA) (2019)
SMAP (>2022)
Suomi NPP (NOAA) (>2022)
Landsat 7 (USGS) (~2022)
QuikSCAT (2017)
SORCE, TCTE (NOAA) (2017)
Terra (>2021)
Landsat 8 (USGS) (>2022)
Aqua (>2022)
CloudSat (~2018)
GPM (>2022)
CALIPSO (>2022)
Aura (>2022)
OCO-2 (>2022)
OSTM/Jason-2 (NOAA) (>2022)
02.21.18


NASA Earth Science Missions with International Partners
PACE
SWOT
NISAR
SENTINEL-6 Michael Freilich/B
GRACE-FO
CALIPSO
CLOUDSAT
GPM
TERRA
AURA
AQUA
SUOMI NPP
(PRE) FORMULATION
IMPLEMENTATON
PRIMARY OPS
EXTENDED OPS
06.05.20


GOSAT
MOE/JAXA/NIES
GPM/DPR
NASA
ALOS-2
GCOM-W
GCOM-C
GOSAT-2
MOE/JAXA/NIES
JAXA
Japan Aerospace
Exploration Agency
ALOS-3
ALOS-4
EarthCARE
esa
GOSAT-GW
MOE/JAXA/NIES

China satellites



Data access

In the case of the Sentinel EO satellites, developed by ESA for the European Commission’s Copernicus programme, access to data is provided through multiple channels:

1.The Copernicus Open Access Hub provides free and open access to a rolling repository of Sentinel user products. A simple and fast registration is required to create an account, before getting free access to the Sentinel data. The data access is configured to avoid saturation resulting from massive downloads by a limited number of users (e.g. maximum number of parallel downloads, maximum volume per retrieval).

2.A collaborative ground segment is also in development in several member states (e.g. http://sentinels.space.noa.gr/ (Greece) or http://sedas.satapps.org/ (UK)). It is intended to allow complementary access to Sentinel data and/or to specific data products by establishing additional pick-up points (e.g. mirror sites). It is composed of elements funded by third parties (i.e. from outside the ESA/EU Copernicus programme).

3.Copernicus Space Component Data Access (CSCDA) is restricted to users eligible to Copernicus Services, as defined by the European Commission (e.g. institutions and bodies of the EU, participants to a research project financed under the EU research programmes, international organisations and NGOs...). Access is provided with committed performances, together with possibilities to order specific tasking of the satellites participating in Copernicus.

EO data access (1)

Earth Observation data can be acquired through different channels. Free of cost data is generally provided by public agencies, under potential conditions linked to the application envisaged and the nationality of the entity requiring access.

PUBLIC EO DATA PROVIDERS	
ESA	https://earth.esa.int/web/guest/home
ESA-Sentinel	https://sentinel.esa.int/web/sentinel/
Sentinel Hub	https://www.sentinel-hub.com/
Eumetsat	http://www.eumetsat.int/website/home/index.html
USGS (Landsat)	http://earthexplorer.usgs.gov/
NOAA	http://www.ospo.noaa.gov/
NASA	https://earthdata.nasa.gov/earth-observation-data
Japan	http://www.eorc.jaxa.jp/en/about/distribution/index.html
China	http://www.cma.gov.cn/en
India	http://bhuvan.nrsc.gov.in/bhuvan_links.php

EO data access (2)

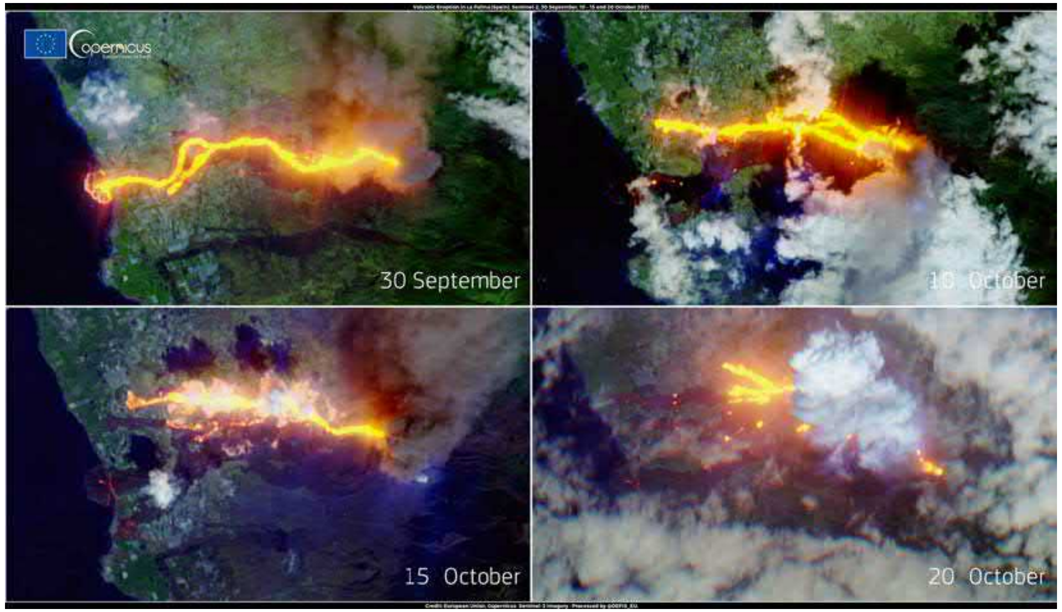
Worldview, NASA https://worldview.earthdata.nasa.gov/?v=8.212028631284909,-46.54687500000001,192.3192213687151,53.01562500000001&t=2021-10-28-T05%3A01%3A35Z

Giovanni, NASA, https://giovanni.gsfc.nasa.gov/giovanni/

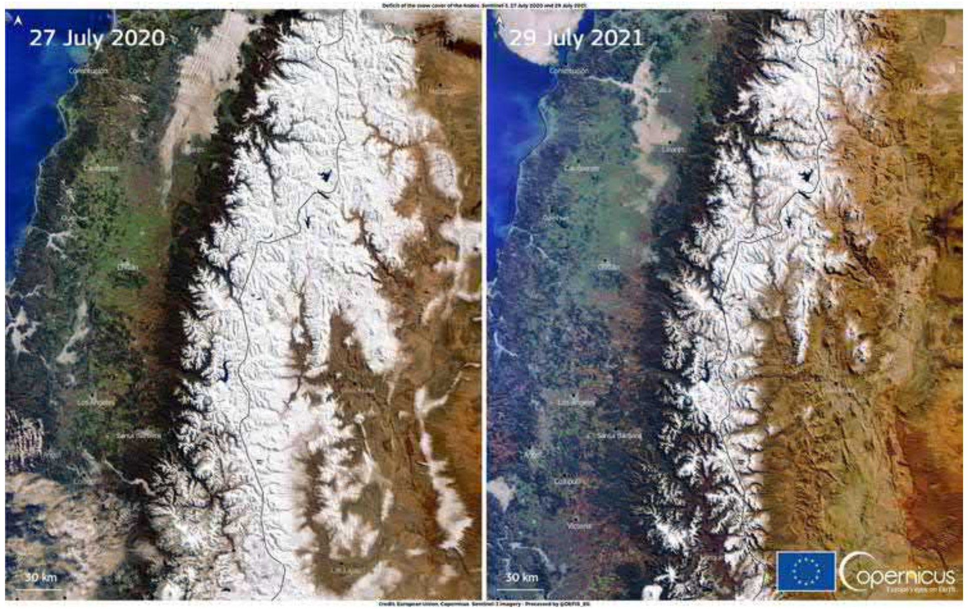
Copernicus Climate data store https://cds.climate.copernicus.eu/#!/home

Application of remote Sensing

- **Climate**
- **Weather**
  - T, p, wind speed, albedo, solar radiation, …ets
- **Disasters**
  - Monitoring of active volcanoes
  - Tracking hazards
- **Forestry**
  - Wildfires
  - Illegal cutting
  - **spread of forest diseases**
- **Ecology**
- **Agriculture**
- **Estimation of surface elevation**
- **Transportation, telecommunication**
  - Creating an automated road network
- **Society**
  - Population growth
  - Spread of cities
  - Improving efficiency and safety of air traffic control
- **Business/politics**
  - Planning an optimal telecom network capacity
  - Navigation
  - Navigating ships safely with the most optimal route
  - Spinning the globe with mapping services
  - Detecting land cover/use types for decision making
  - Monitoring oil reserves

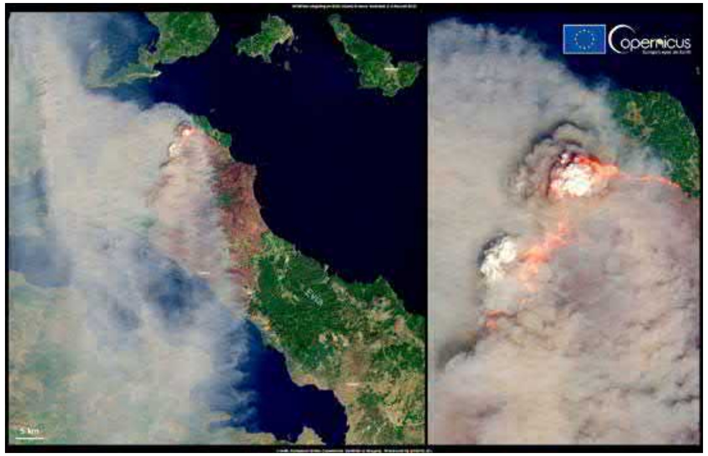


La Palma eruption



snow cover deficit in the Andes

false-colour image, combining several bands of the multispectral imager to highlight the different rock types in the Anti-Atlas Mountains



agricultural land fragmentation in southern Romania

Suspended particulate matter in coastal waters

Mediterranean wildfires crisis of the summer of 2021

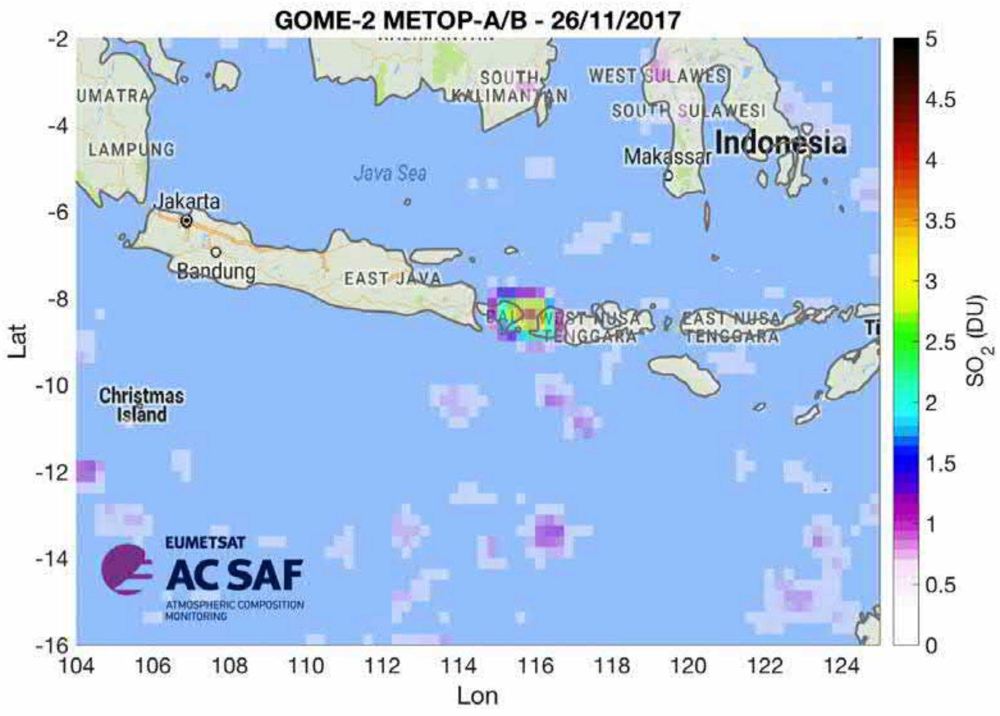
EUMETSAT Satellite Application Facility (SAF)

Part of the EUMETSAT Ground Segment

Leading entity: FMI
Partners: AUTH, BIRA, DMI, DLR, DWD, KNMI, LATMOS, MKF, RMI, S&T, ULB

Current target: Development, processing and dissemination of GOME-2 and IASI atmospheric products. Future: S4, S5 and 3MI…

Constituents: Trace gases (O_3, NO_2, SO_2, BrO, HCHO, CO…..), Aerosols, radiation products (UV, LER, SIF)

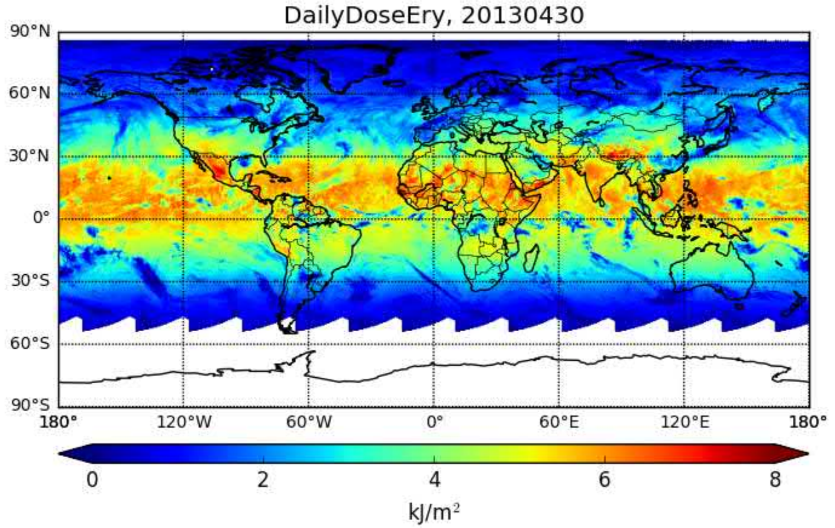


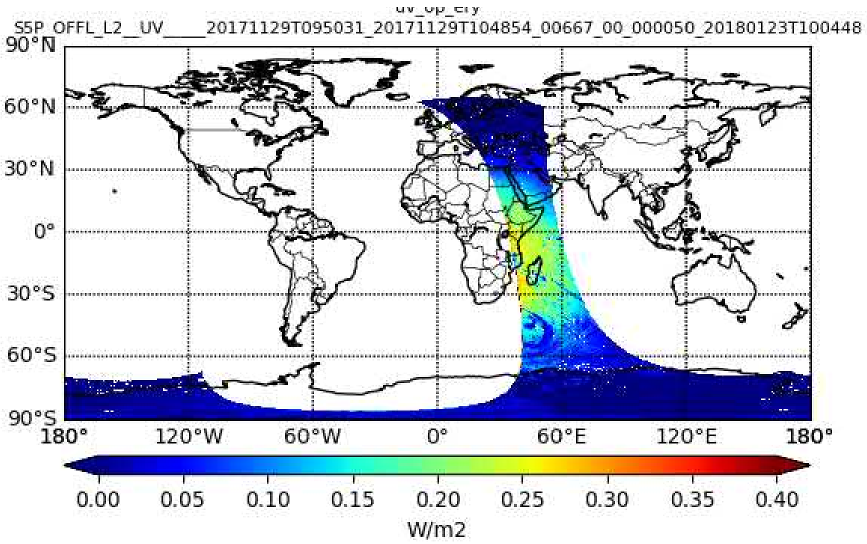
https://acsaf.org @Atmospheric_SAF

EUMETSAT
AC SAF
ATMOSPHERIC COMPOSITION MONITORING

Satellite UV products

- AC SAF UV product
  - daily product: daily integrated dose, maximum dose rates and photolysis rates
  - combines total ozone (GOME-2) with imager cloud data (AVHRR, in future: VIIRS,MetImage,SEVIRI,FCI …)
  - uncertainty estimates are propagated from inputs
- TROPOMI / S5p L2 UV product
  - orbit-by-orbit product continuing TOMS/OMI heritage
  - processing in Sodankylä Copernicus Collaborative Ground Segment
- ESA S5L2PP project
  - L2 UV product prototype for Copernicus Sentinel 5

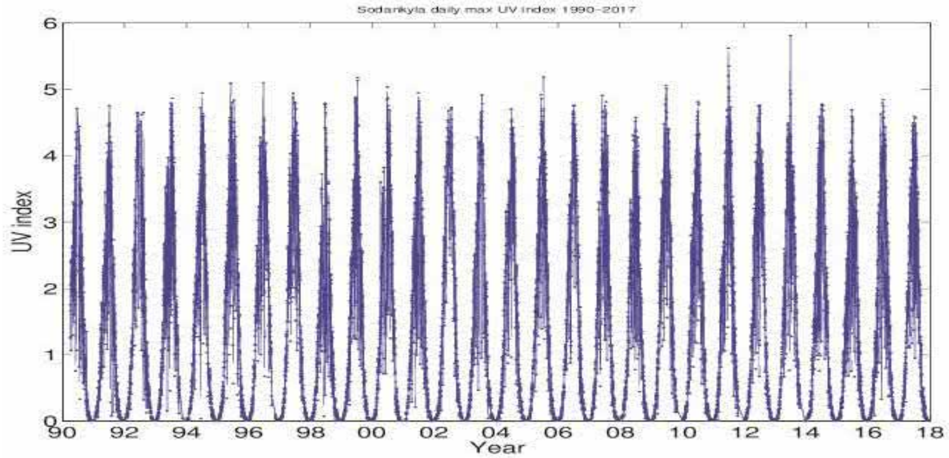




UV observations and research

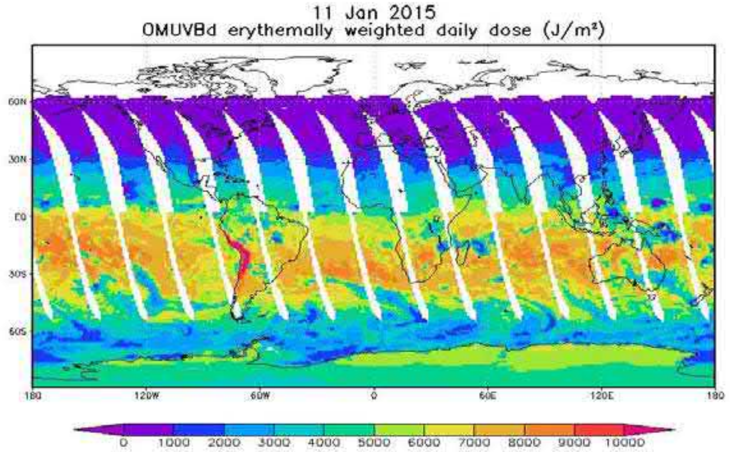
Spectral and broadband UV measurements in Sodankylä since 1990. Multifilter UV radiometers since 2002.

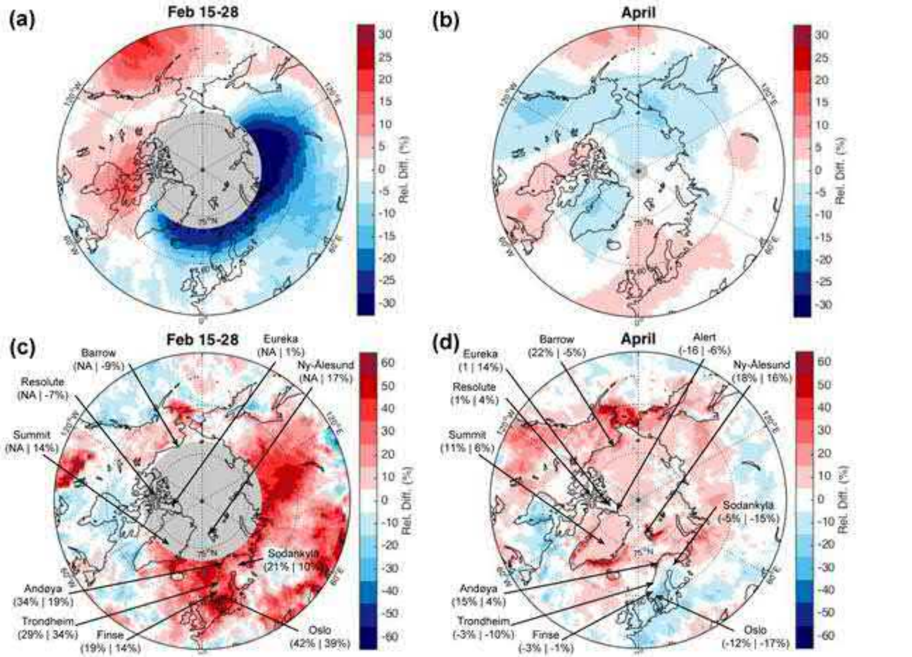
Two Brewer spectroradiometers, one of the longest spectral UV time series in the Arctic.



Dark room in Sodankylä, calibration and characterization facilities

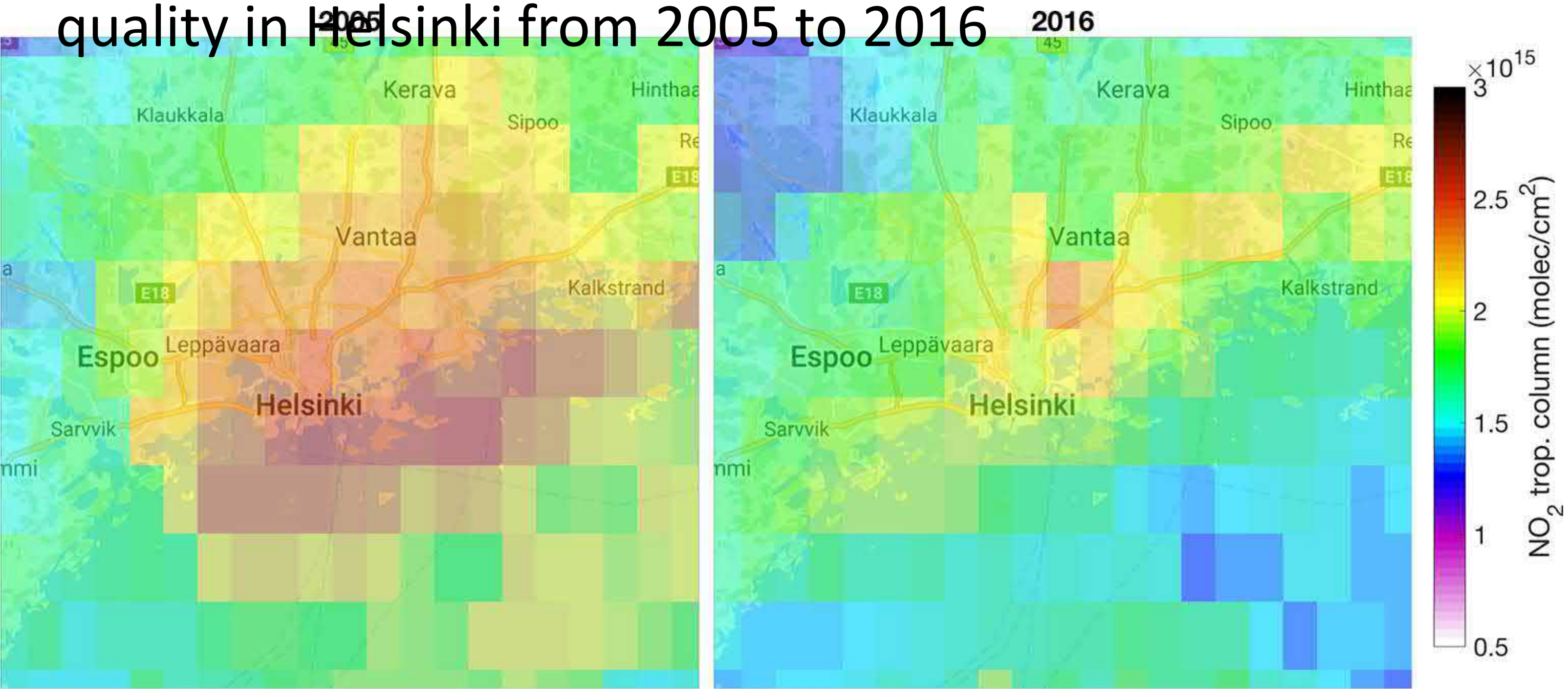
Brewer data + OMI UV and O_3 data yearly contribution to assessment of climate, BAMS, Bernhard et al.



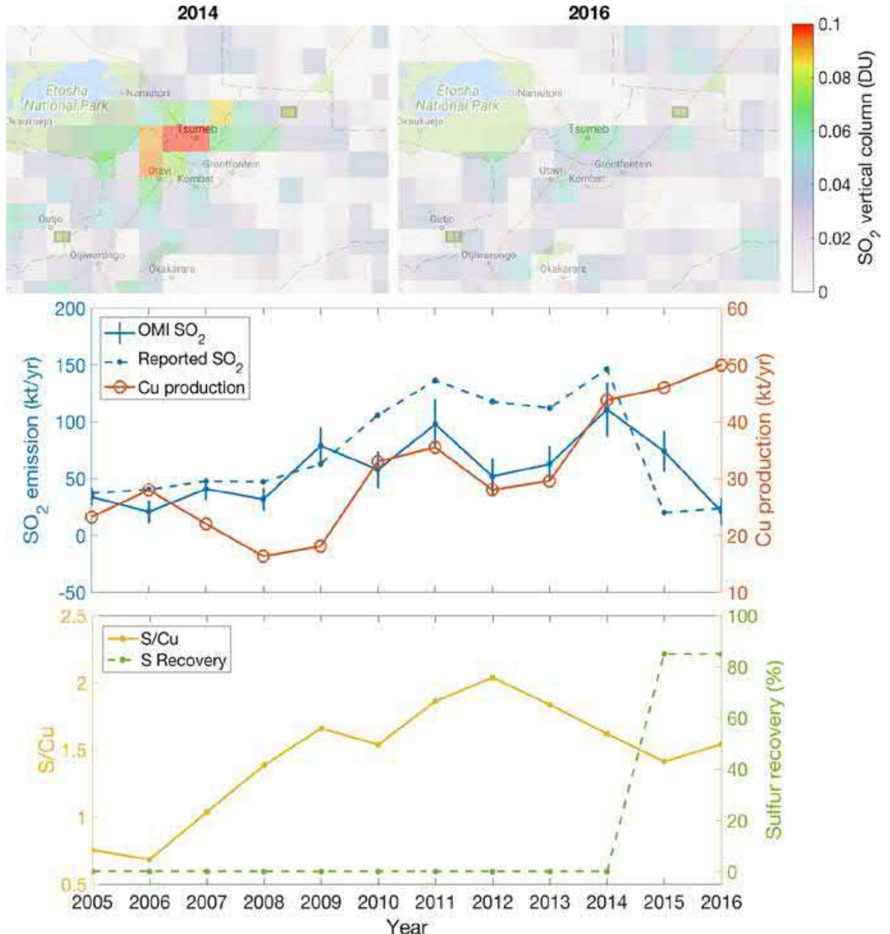


Air quality from satellite-based observations

Satellite data for urban environmental authorities: OMI NO_2 observations detects an improvement in air quality in Helsinki from 2005 to 2016



Satellite data support Cleantech sector: OMI SO_2 observations detects reduction in polluting emission from copper smelter as result of Outotec sulfur-removing technology

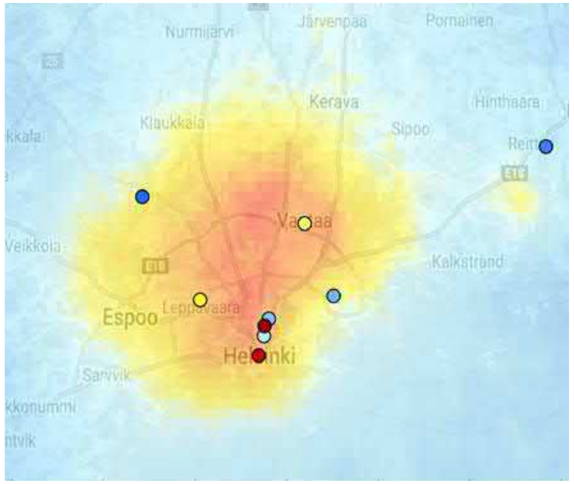


SA ILMApilot: Increasing the Societal Impact of Satellite-Based Observations for Air Quality Monitoring (http://blog.fmi.fi/ILMApilot/)

Satellite Remote Sensing Applications for Air Quality Monitoring

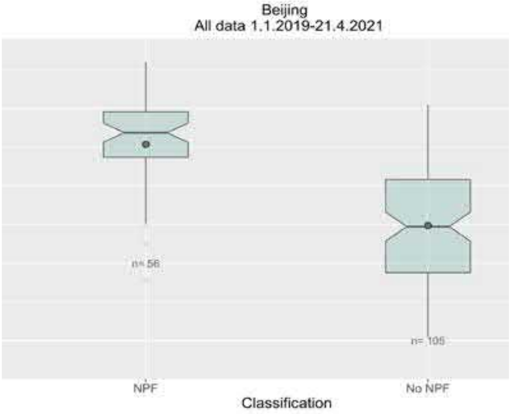
Examples of air quality applications from the Atmospheric remote sensing group:

Satellite observations to support Air Quality monitoring in Finland and national AQ reporting to EU



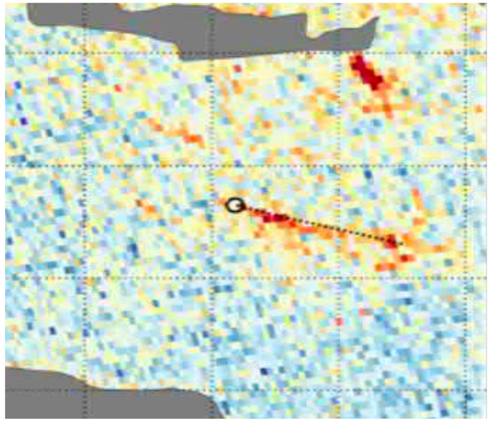
Project funding from Finnish Ministry of Environment

Developing satellite-based proxies for new particle formation



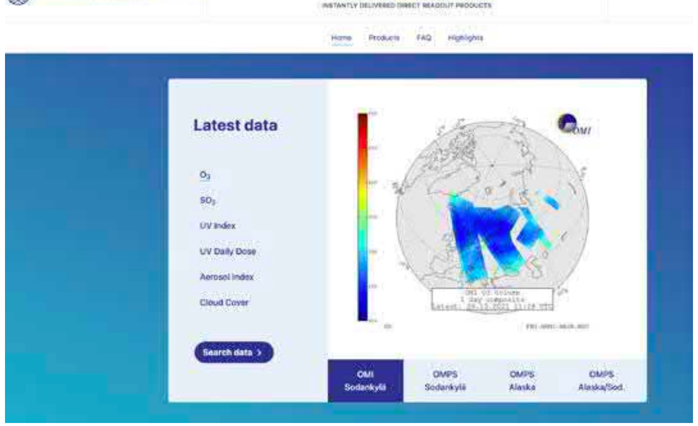
In collaboration with ACCC partners

Monitoring of NO_2 shipping emissions



H2020 projects SCIPPER and EMERGE

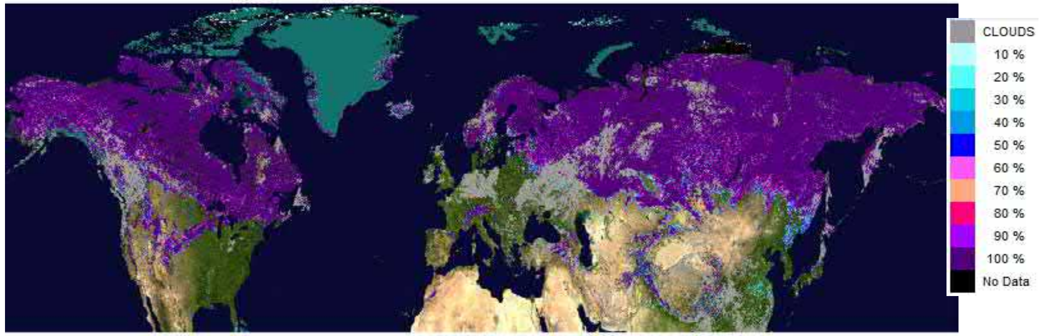
www.sampo.fmi.fi
Operating SAMPO Near Real Time satellite data service



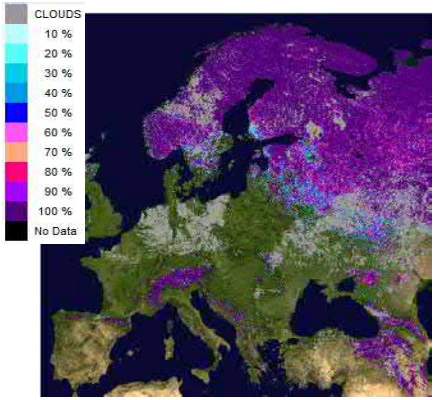
In collaboration with NASA, KNMI, NSO

Copernicus Global Land Service - Cryosphere theme

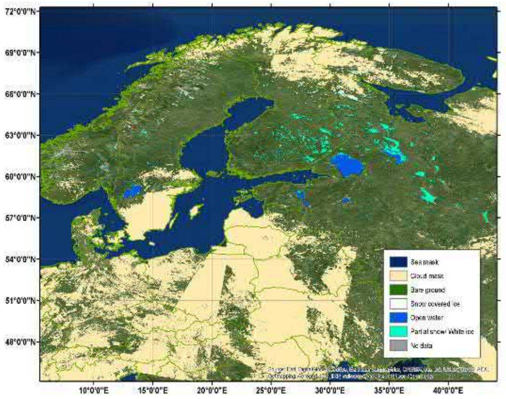
Daily Near Real-time production of Northern Hemisphere:
Snow Cover Extent, Snow Water Equivalent, Lake Ice Extent products



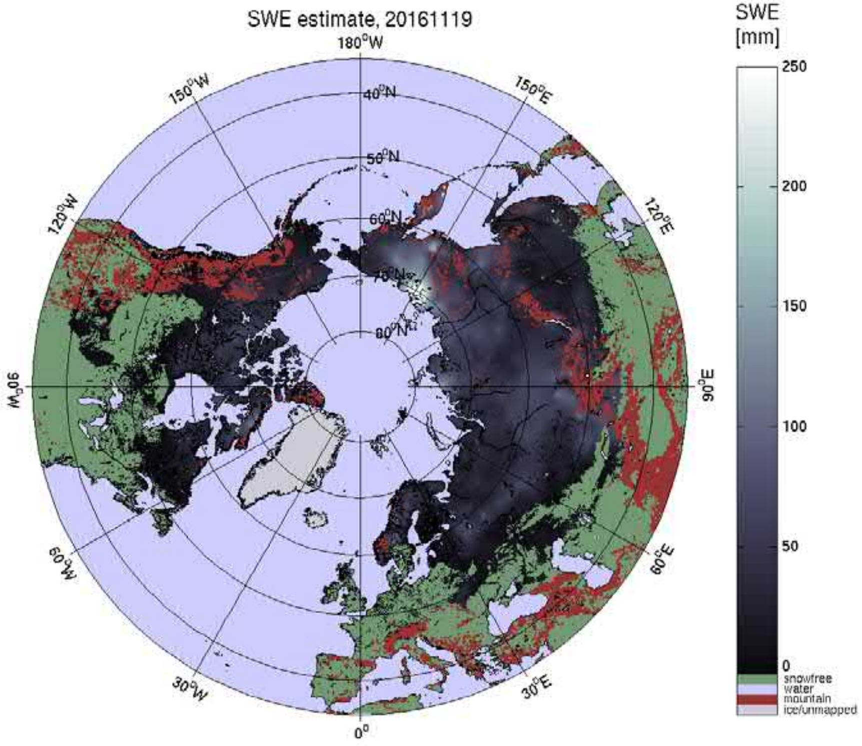
Northern-Hemisphere Snow Cover Extent (SCE)



Pan-European Snow Cover Extent (SCE)



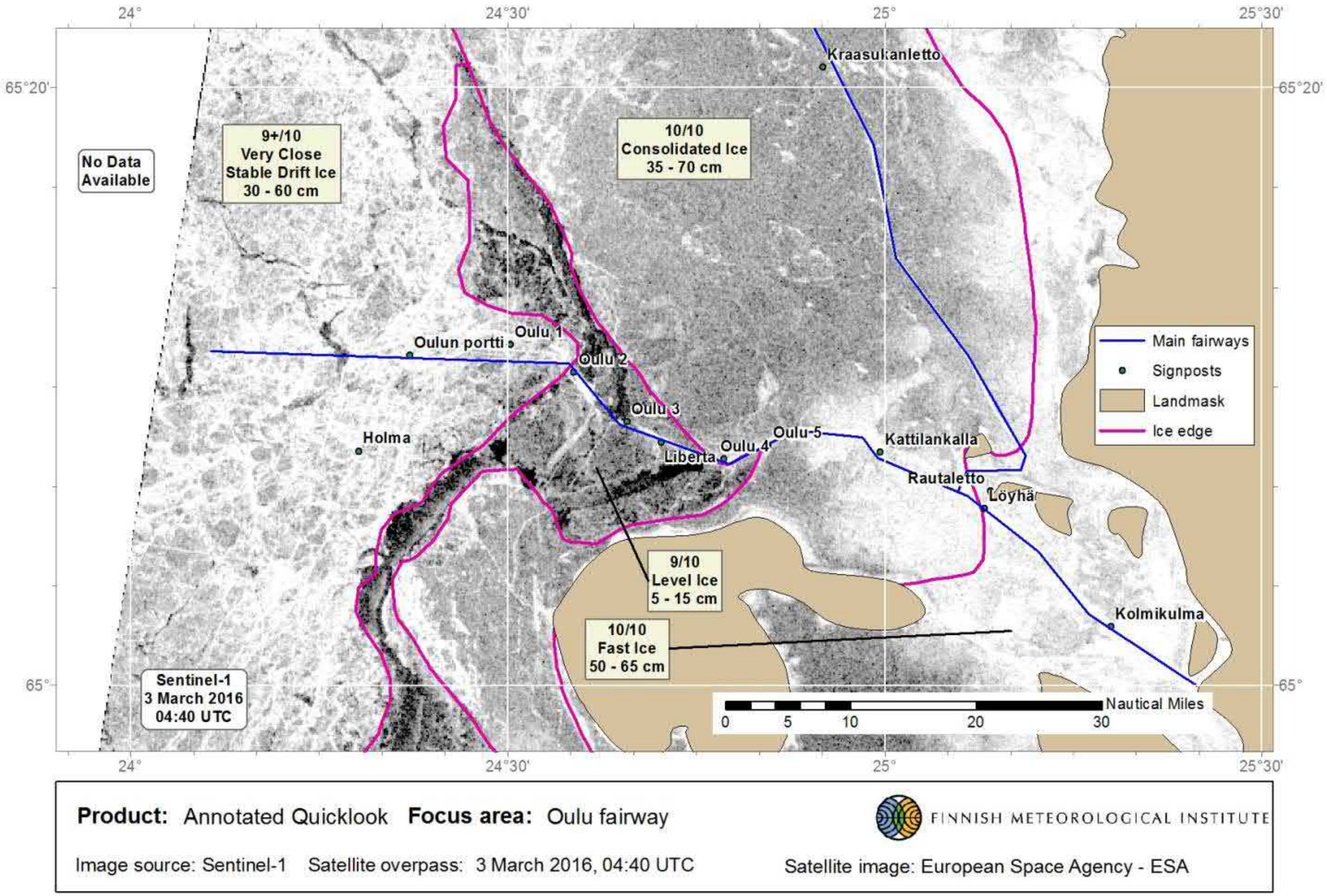
Lake Ice Extent (LIE) for Baltic Sea area



Service by: FMI, ENVEO, SYKE

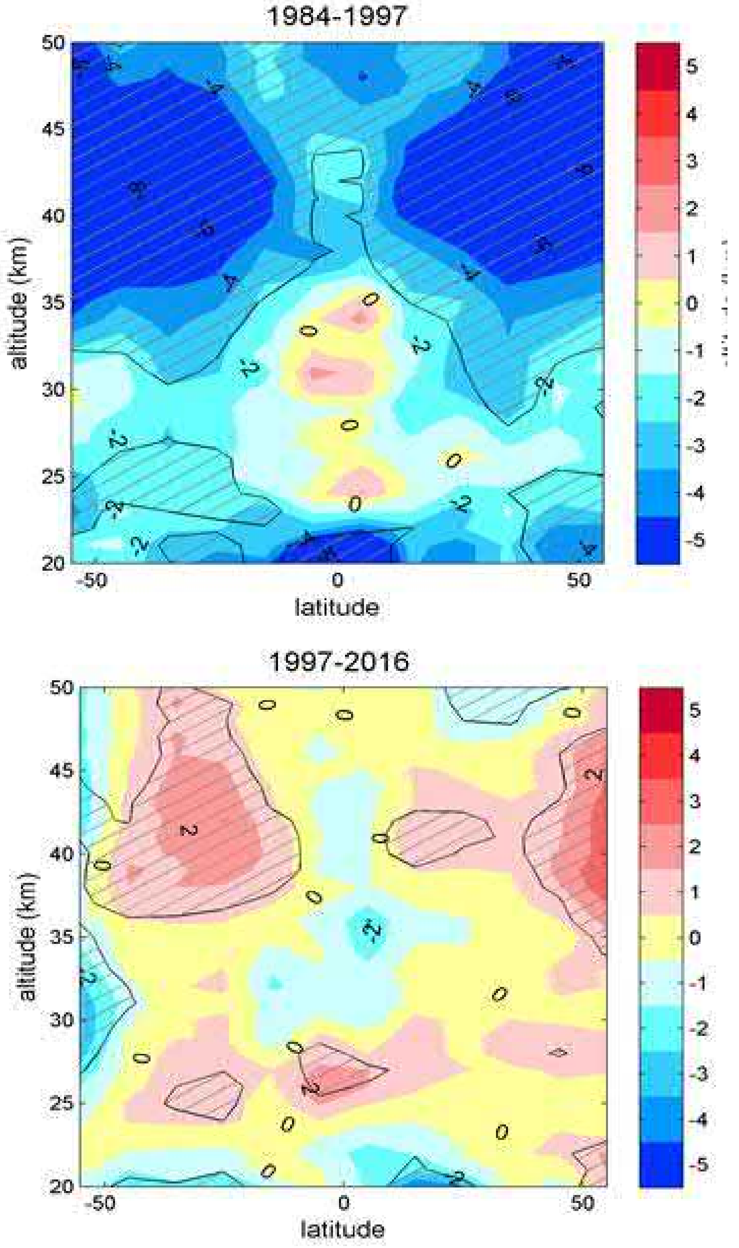
Sea ice charts from satellite data

FMI provides daily sea-ice information for marine navigation



Data for climate research

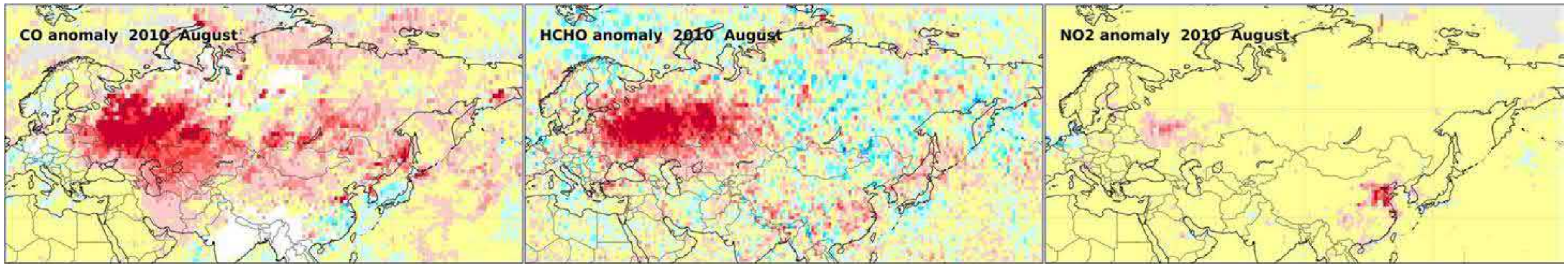
- ESA Climate Change Initiative (CCI)
    - CCI is a coordinated program to provide **stable, long-term**, satellite-based **essential climate variable** (ECV) data
    - successfully completed Phase I and II of Ozone_cci (2010-2017), 16 institutes from 10 countries
    - FMI responsible for creating **merged datasets from limb satellite instruments**
    - continuation in 2018 with CCI+ (optional proposals for water vapor ECV)
    - expected continuation of Ozone_cci in 2019
- Copernicus Climate Change Service (ongoing)
    - ECMWF-lead Copernicus service
    - **Ozone climate data records from limb instruments**



Ozone trends in % dec^{-1}, from Sofieva et al., 2017, ACP

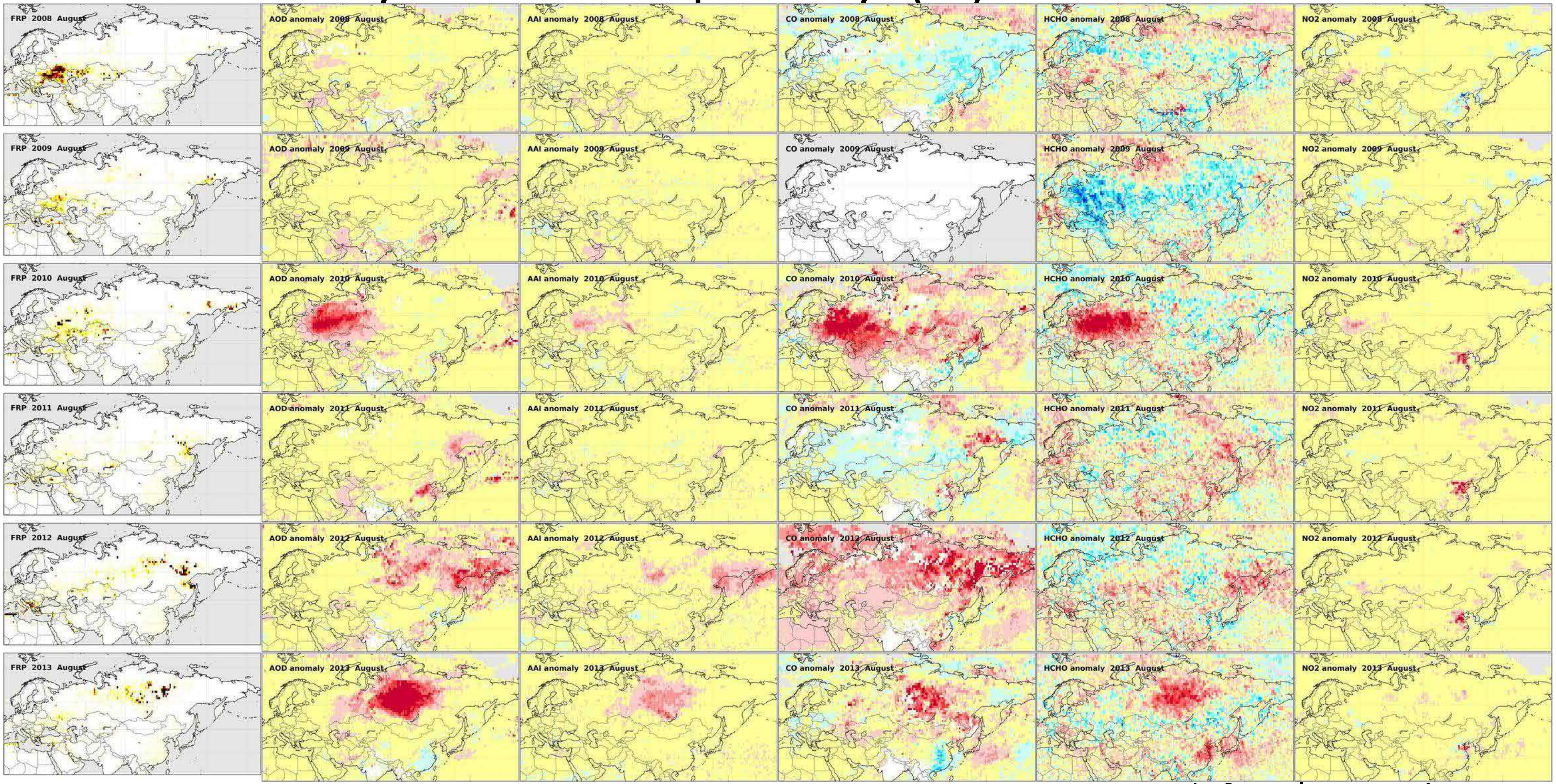
Fire activity and air quality (1)

- **AOD –** MODIS, Terra
- **AAI –** multi-satellite product
- **CO –** MOPPIT, Terra
- **FC –** MODIS
- **FRP -** MODIS
- **NO2** – OMI, TROPOMI
- **HCHO** – OMI, TROPOMI
- **SO2** – OMI, TROPOMI



L. Sogacheva, ms in preparation

Fire activity and air quality (2)



L. Sogacheva, ms in preparation

Aerosol Optical Depth (AOD), merged satellite product

SATELLITE MERGED AEROSOL OPTICAL DEPTH (AOD)

Global monthly record for 1995-2017

Product name: FMI_SAT_AOD-MERGED

Product specification:

Variables:	Period:
- AOD_{550}	1995-2017
- AOD_{550_unc}	**Temporal resolution:**
- Latitude	month
- Longitude	**Spatial resolution:**
- Time	1°x1°

Data access: aod.nsdc.fmi.fi

Username: aod_user

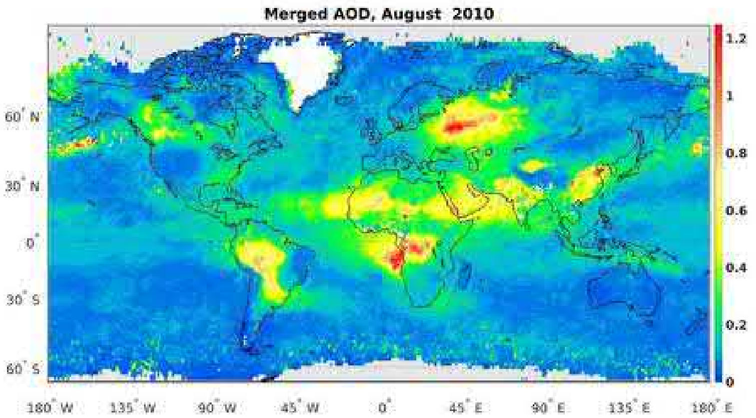
Get the password

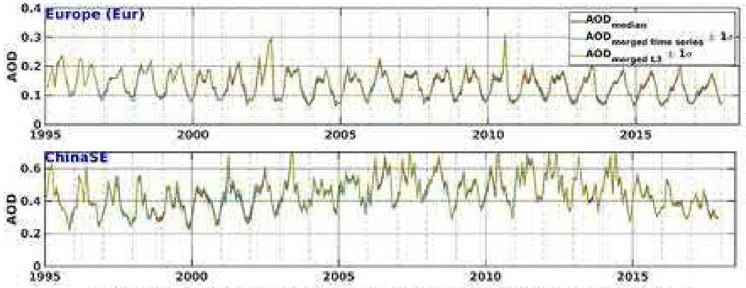
Login

Contact person:

Dr. Larisa Sogacheva (firstname.lastname(at)fmi.fi)

Overview:

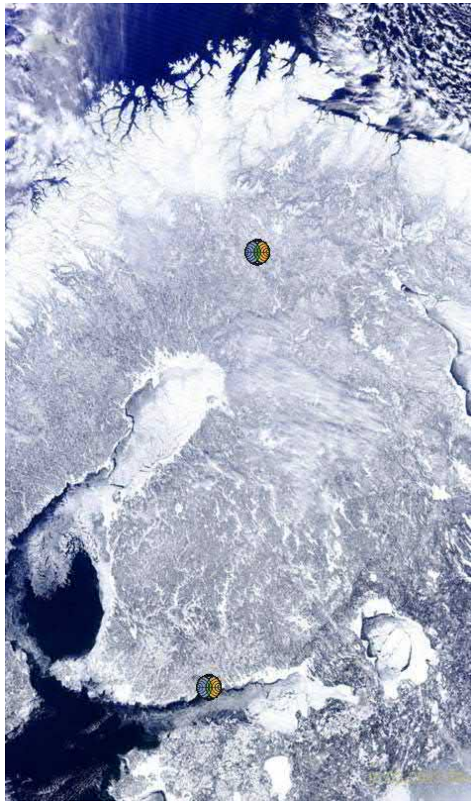




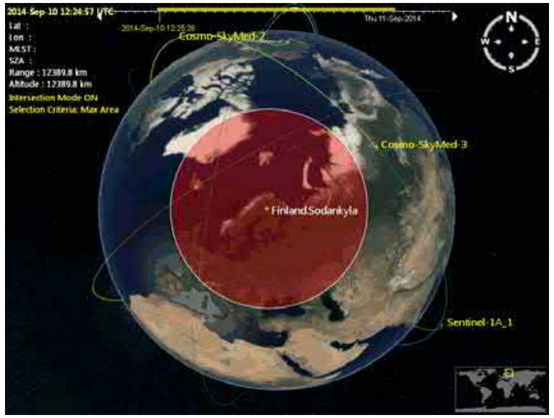
Merged AOD time series for Europe and south-eastern China for 1995-2017.

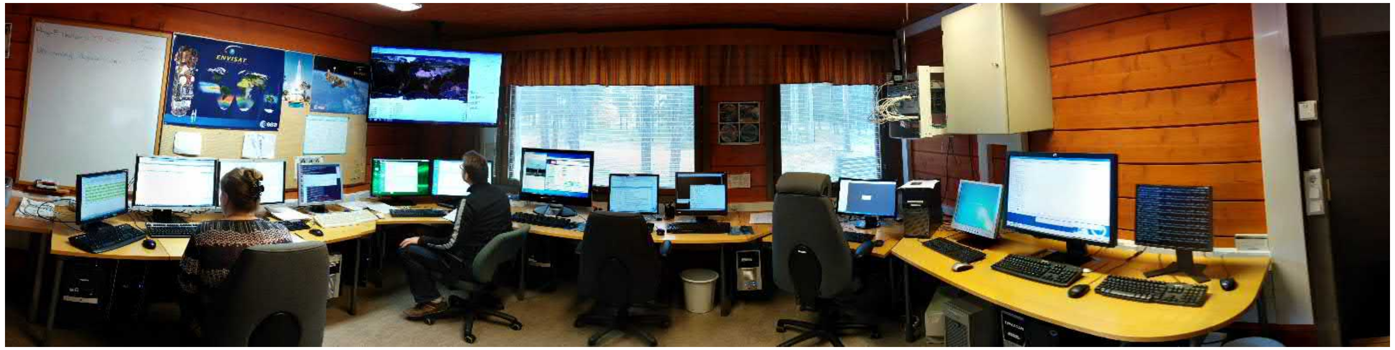
Link to the data: https://nsdc.fmi.fi/data/data_aod

FMI Arctic Space Centre (FMI-ARC)









National satellite data center providing satellite data reception and data processing services to Finnish and international partners

https://nsdc.fmi.fi

Advantages of the RS

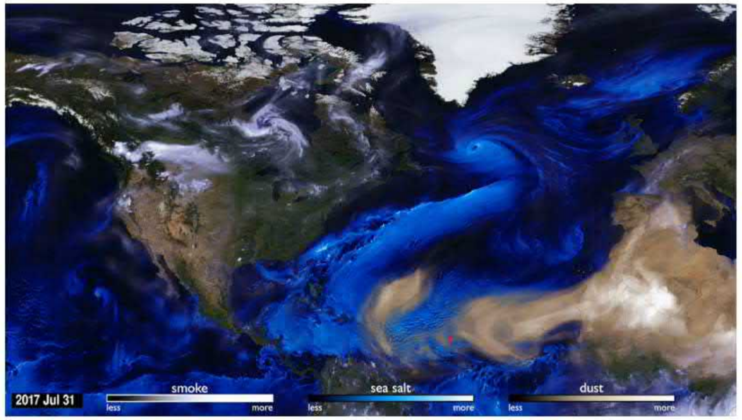
- **Large area coverage**: Remote sensing allows coverage of very large areas which enables regional surveys on a variety of themes and identification of extremely large features.
- Remote sensing allows **repetitive coverage** which comes in handy when collecting data on dynamic themes such as water, agricultural fields and so on.
- Remote sensing allows for easy collection of data over a **variety of scales and resolutions**.
- A single image captured through remote sensing can be analyzed and interpreted for use in **various applications** and purposes. There is no limitation on the extent of information that can be gathered from a single remotely sensed image.
- Remotely sensed data can easily be **processed and analyzed fast** using a computer and the data utilized for various purposes.

Disadvantages of the RS

- Remote sensing is a **fairly expensive** method of analysis
- Powerful active remote sensing systems such as radars that **emit their own electromagnetic radiation** can be intrusive and affect the phenomenon being investigated
- The instruments used in remote sensing may sometimes be un-calibrated which may lead to **un-calibrated** remote sensing data
- In the remote sensing we need to **solve an inverse problem**. We know the signature, or track, we need to resolve who left that signature
- The image being analyzed may sometimes be **interfered** by other phenomena that are not being measured and this should also be accounted for during analysis.

Great challenges in RS. Future plans

- **Increased Spatial and Temporal Coverage and Resolution of Satellite Observations**
- **Increased Information Content and Exploring Synergy of Observations**
- **Development of the State-of-Art Data Processing Approaches of the Next Generation**
- **Achieving Continuity in Consistent Satellite Observations and Long-Term Data Record**



Creation of new applications by the integration of satellite and ground-based sensors and assimilation of retrieved/measured data into the models

Some additional links to the lecture material

- https://navigator.eumetsat.int/start
- https://business.esa.int/newcomers-earth-observation-guide
- https://www.nrcan.gc.ca/maps-tools-and-publications/satellite-imagery-and-air-photos/tutorial-fundamentals-remote-sensing/9309
- https://www.ntia.doc.gov/legacy/osmhome/reports/ntia00-40/chapt3.htm
- https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=12772&button=recent&fbclid=IwAR0MmkxOwLxeVwWb16uAyL-TroNTkJInXvm_6Qax8Wa7XSOuTXiUos8hipM
- https://www.researchgate.net/publication/283355006_Remote_sensing_observations_for_monitoring_coastal_zones_Volturno_River_mouth_case_study?channel=doi&linkId=5637406e08ae88cf81bd51ef&showFulltext=true
- https://www.fondriest.com/environmental-measurements/parameters/weather/photosynthetically-active-radiation/