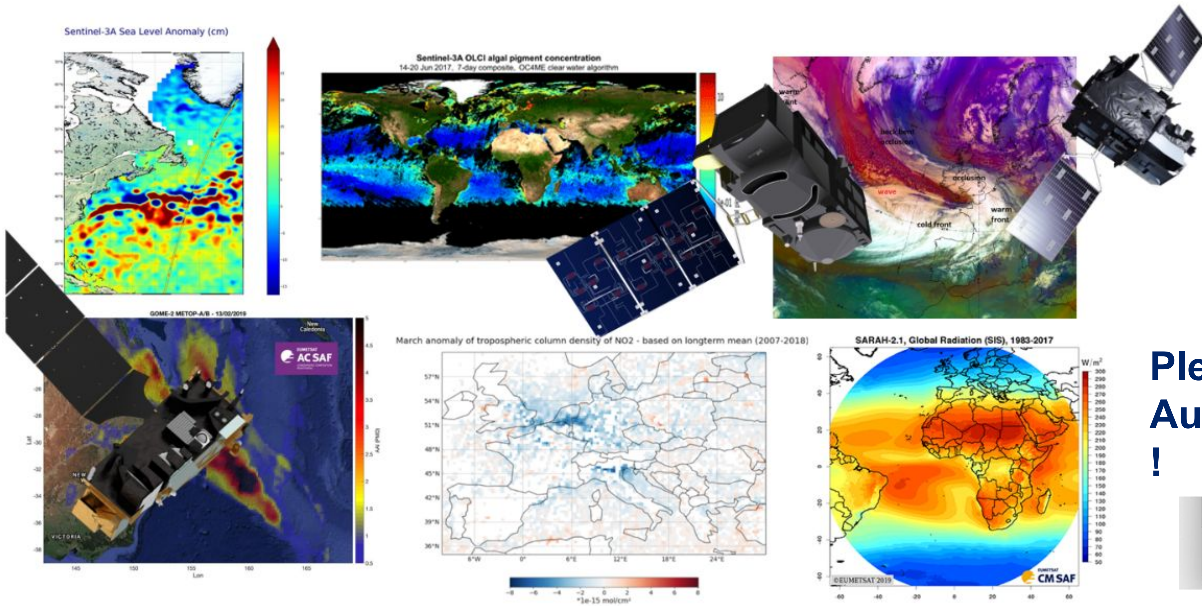
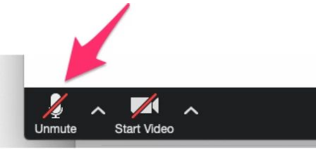
Welcome - The session will begin at 12 UTC - 13 CET



Please keep your Audio and Video off !



Copernicus Europe's eyes on Earth | EUMETSAT | EUMETSAT AC SAF Atmospheric Composition Monitoring | EUMETSAT CM SAF Climate Monitoring

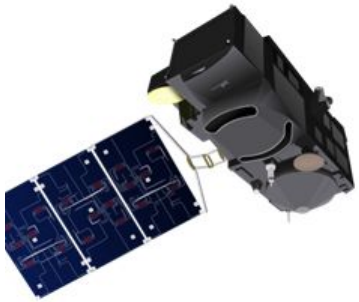
If you have technical issues, please send a message in the chat box to **Support**.

For **Q&A**: go to Slido.com – event code: **#EUMSC25**

What is EUMETSAT ? Satellite Monitoring of Climate & Weather for Europe …

EUMETSAT

Copernicus
Europe's eyes on Earth



EUMETSAT programs

- METOP (1-3)
- Meteosat
- Meteosat III Gen
- Polar II Gen
- Monitor CO_2

SENTINEL-1: 4-40m resolution, 3 day revisit at equator	S1A and 1B in orbit
SENTINEL-2: 10-60m resolution, 5 days revisit time	S2A and 2B in orbit
SENTINEL-3: 300-1200m resolution, <2 days revisit	S3A and S3B in orbit
SENTINEL-4: 8km resolution, 60 min revisit time	1st Launch 2022
SENTINEL-5p: 7-68km resolution, 1 day revisit	S5P in orbit
SENTINEL-5: 7.5-50km resolution, 1 day revisit	1st Launch 2023
SENTINEL-6: 10 day revisit time	1st Launch 2020

Make data available at best

- Gather (and satisfy) needs
- Grant data access
- Help and support Users
- Training (also on-line)
- Explore applications
- Communicate - outreach

AI for atmospheric composition - how to enhance resolution using satellite data

M. Houet – MEEO @EUMETSAT
F. Fierli - EUMETSAT

Course Program

(1) Webinar & Data discovery

12:00 - 12:25: Intro

12:25 - 12:50: AI approach

12:50 - 13:30: Practical + Q&A

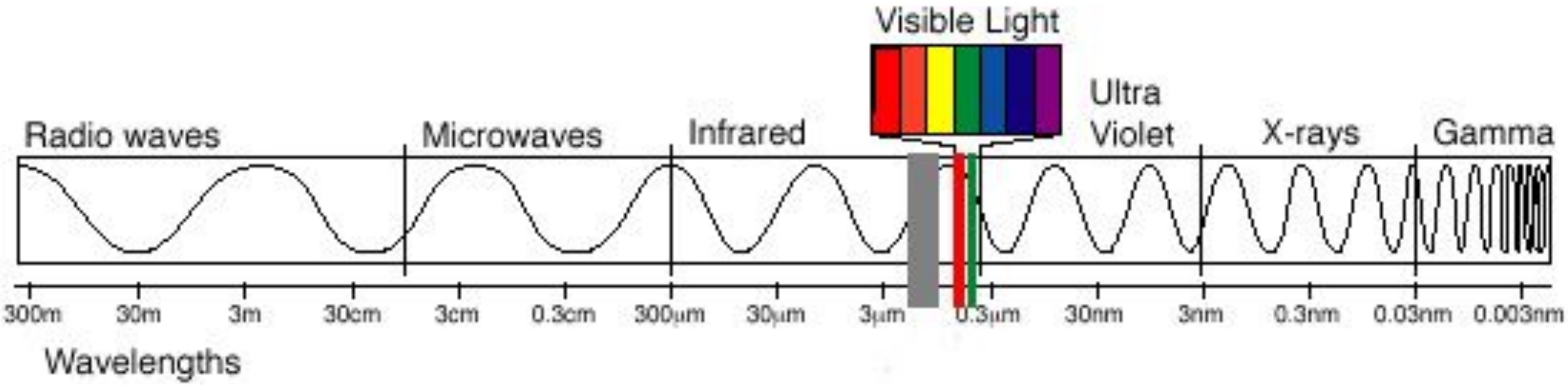
Discussion Q&A on:

slido.com #EUMSC25

Access the data / handling tools

https://training.eumetsat.int/course/view.php?id=438

The Electromagnetic Spectrum



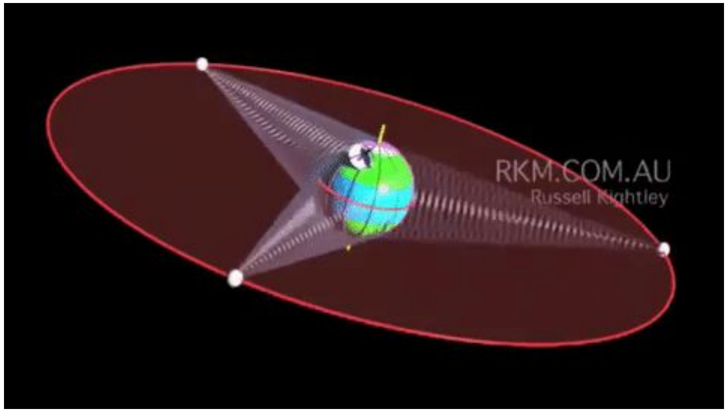
- Remote sensing uses the radiant energy that is reflected and emitted from Earth at various “wavelengths” of the electromagnetic spectrum
- Our eyes are only sensitive to the “visible light” portion of the EM spectrum

Satellite orbits

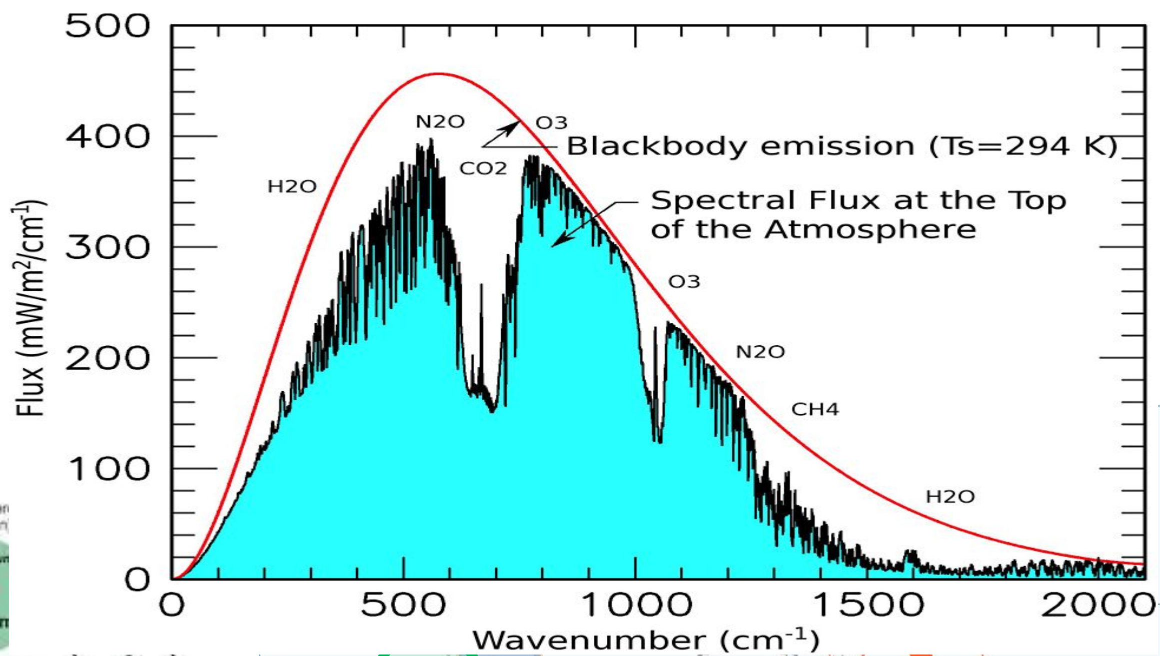
<u>Advantages:</u>
More near to Earth -> Higher spatial resolution
Used also for Active Obs.(Radar/Lidar) and PMW
<u>Disadvantages:</u>
Poorer time resolution -> needs of constellation

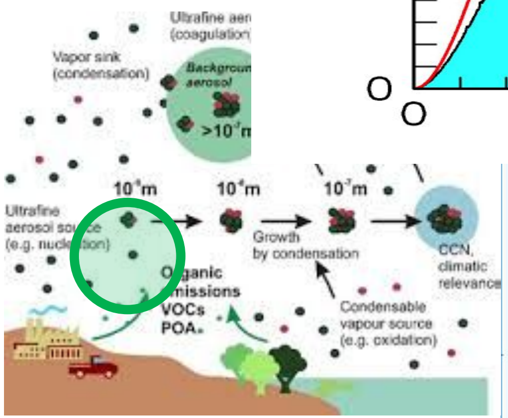
<u>Advantages:</u>
Better time resolution

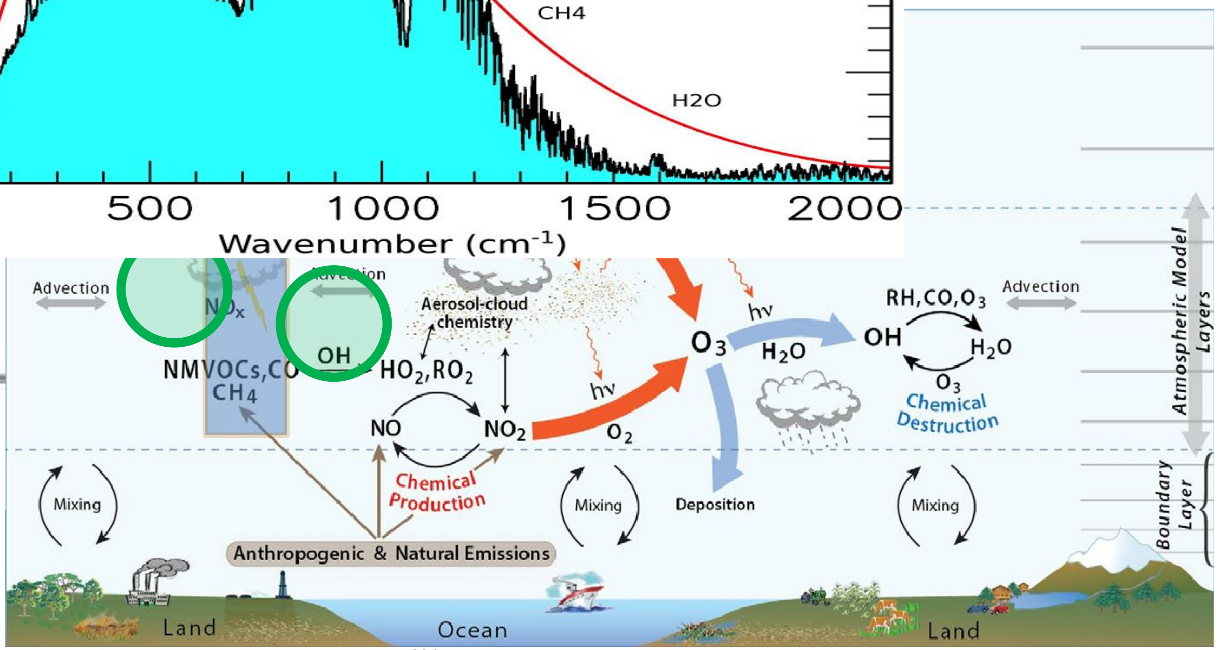
<u>Disadvantages:</u>
One side of the Earth -> needs of constellations
large viewing angles at the borders -> geometrical distorsions
Only VIS/IR and passive Obs.

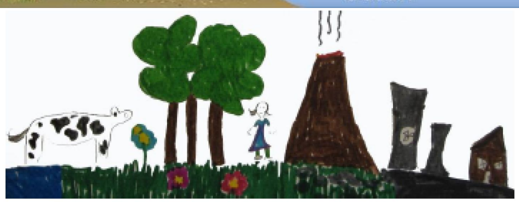


What we see and what Satellites see

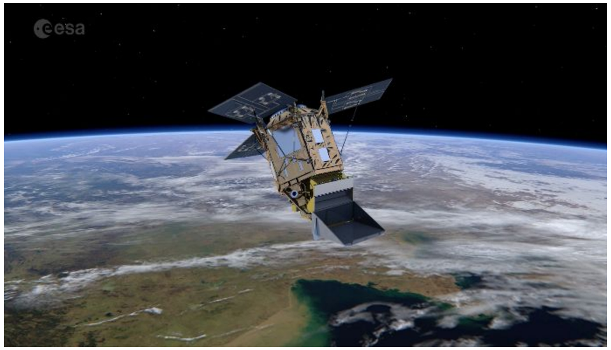








Aggregate data of polar satellite: example of Sentinel5P



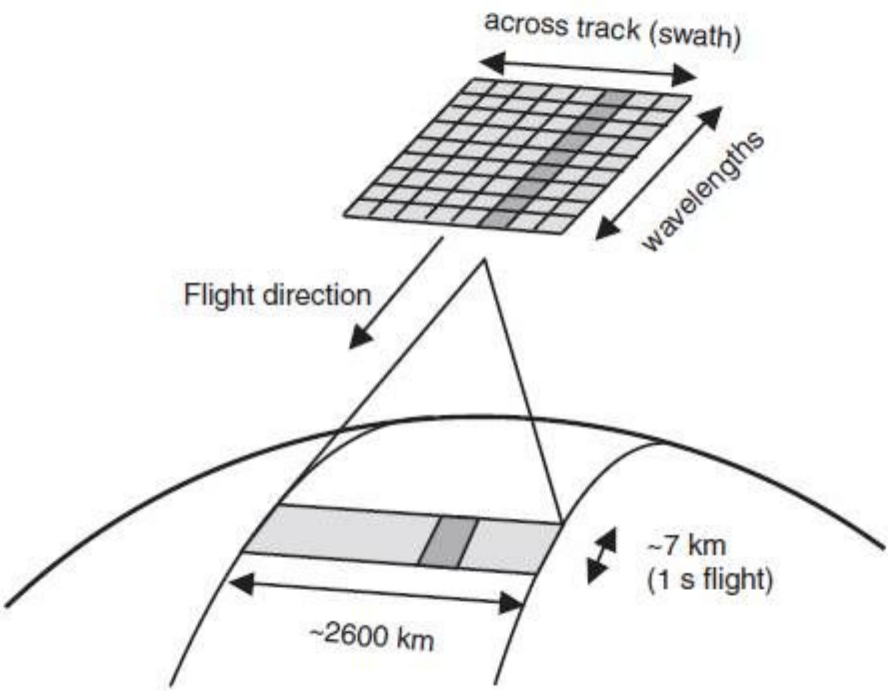
Main parameters:

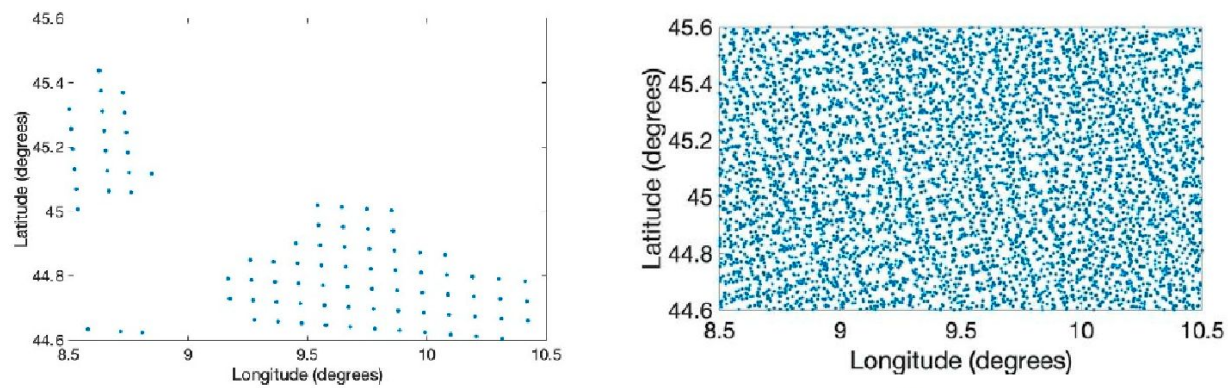
- S5p is the first **atmospheric Sentinel** mission focusing on global observations of the atmospheric composition for **air quality** and **climate monitoring**;
- Launched on **Oct. 13 2017**; **7 years** design lifetime;
- **Daily overpass** ~13:30 hrs; **Swath** ~2600 km;
- **Spatial resolution** at nadir ~5.5x3.5 km2 in UVVIS, ~7x7 km2 in SWIR;
- **Use case**: Investigate signatures of the human **emission reductions** due to COVID19 lockdown measures;
- Target datasets: tropospheric columns of **NO2** and **CO**;
- Match-up with **ground-based** data and **models**.

Related publications:

- http://www.esa.int/Applications/Observing_the_Earth/Copernicus/SentinelP/Air_pollution_remains_low_as_Europeans_stay_at_home
- https://physicstoday.scitation.org/do/10.1063/PT.6.2.20200501a/full/
- https://news.agu.org/press-release/covid-19-lockdowns-significantly-impacting-global-air-quality/
- https://news.agu.org/files/2020/05/2020GL087978-Stavrakou.pdf

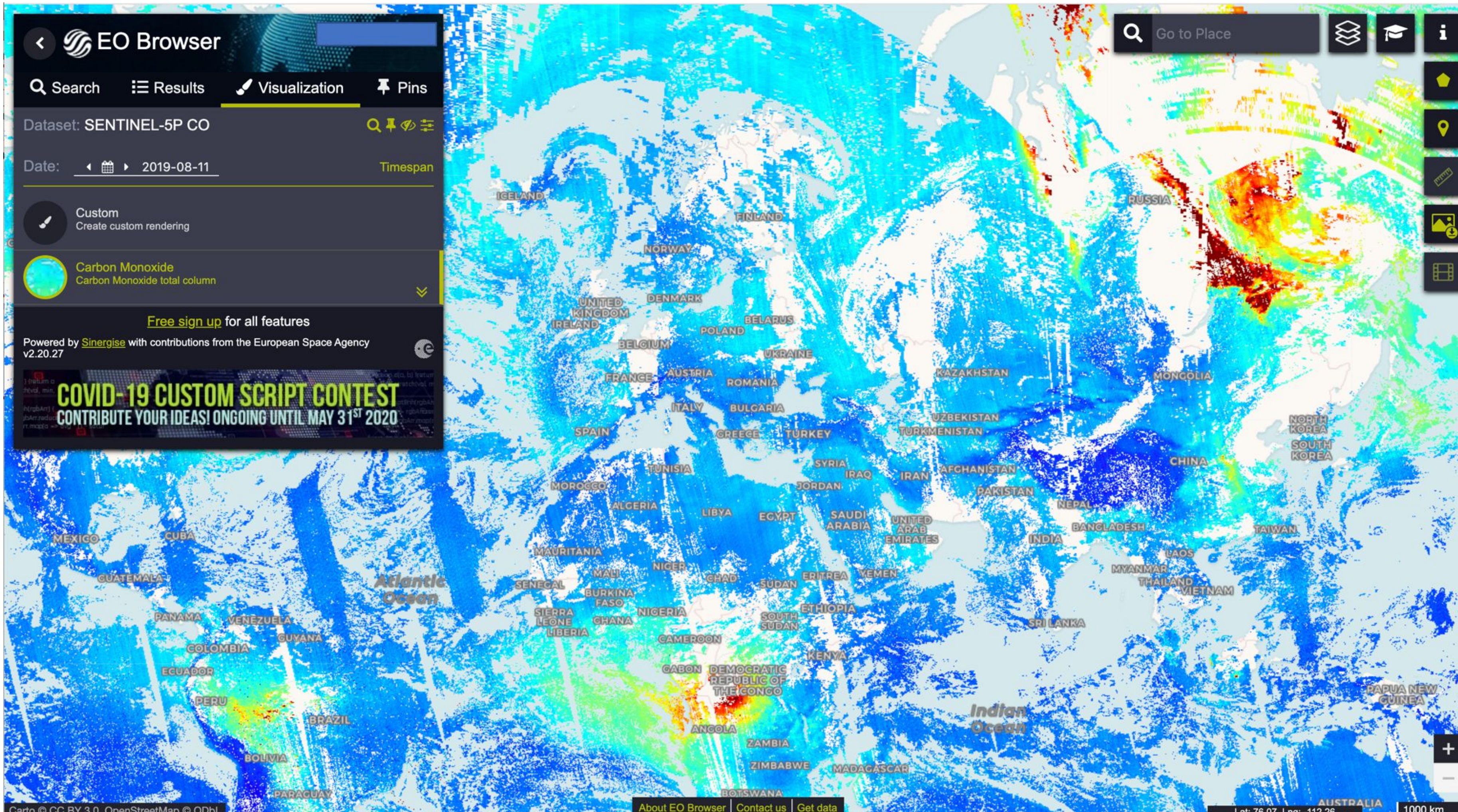
Aggregate data of polar satellite: example of Sentinel5P





(a) (b)

Figure 3. Clear sky Tropospheric Monitoring Instrument (TROPOMI) satellite footprints (whose centers are shown with a dot) for one single overpass (**a**) and after one month of overpasses (**b**).


EO Browser
Search
Results
Visualization
Pins
Dataset: SENTINEL-5P CO
Date: 2019-08-11
Timespan
Custom
Create custom rendering
Carbon Monoxide
Carbon Monoxide total column
Free sign up for all features
Powered by Sinergise with contributions from the European Space Agency
v2.20.27
COVID-19 CUSTOM SCRIPT CONTEST
CONTRIBUTE YOUR IDEAS! ONGOING UNTIL MAY 31ST 2020
Go to Place
ICELAND
FINLAND
NORWAY
RUSSIA
UNITED KINGDOM
IRELAND
DENMARK
BELARUS
POLAND
BELGIUM
UKRAINE
FRANCE
AUSTRIA
ROMANIA
KAZAKHSTAN
MONGOLIA
ITALY
BULGARIA
UZBEKISTAN
TURKMENISTAN
SPAIN
GREECE
TURKEY
NORTH KOREA
SOUTH KOREA
TUNISIA
SYRIA
IRAQ
IRAN
AFGHANISTAN
CHINA
MOROCCO
JORDAN
PAKISTAN
ALGERIA
LIBYA
EGYPT
SAUDI ARABIA
UNITED ARAB EMIRATES
NEPAL
BANGLADESH
INDIA
TAIWAN
MEXICO
CUBA
MAURITANIA
LAOS
GUATEMALA
NIGER
MALI
CHAD
SUDAN
ERITREA
YEMEN
MYANMAR
THAILAND
VIETNAM
Atlantic Ocean
SENEGAL
BURKINA FASO
SIERRA LEONE
LIBERIA
GHANA
NIGERIA
ETHIOPIA
SOUTH SUDAN
SRI LANKA
PANAMA
VENEZUELA
GUYANA
COLOMBIA
CAMEROON
ECUADOR
GABON
DEMOCRATIC REPUBLIC OF THE CONGO
KENYA
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PARAGUAY
BOTSWANA
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About EO Browser
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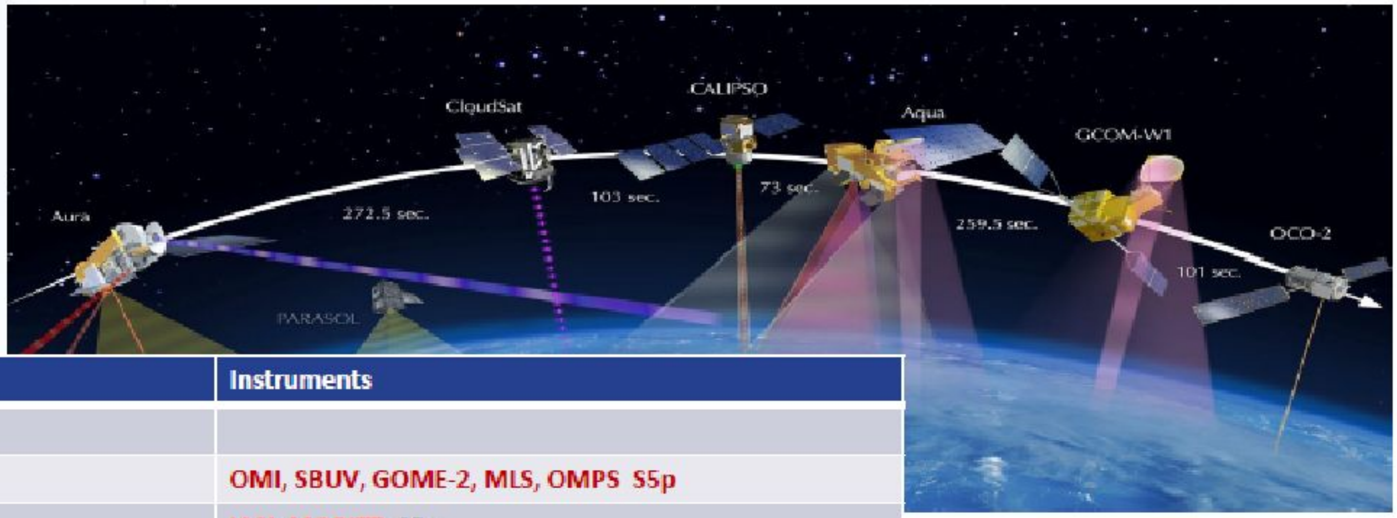
Lat: 76.07, Lng: -112.26
1000 km

CAMS Service (2)

Atmosphere Monitoring

Earth Observation satellites



Species	Instruments
Global system	
O_3	OMI, SBUV, GOME-2, MLS, OMPS S5p
CO	IASI, MOPITT, S5p
NO_2	OMI, GOME-2, S5p
SO_2	OMI, GOME-2, S5p
Aerosol	MODIS, PMAp, VIIRS, S3
CO_2	GOSAT, OCO-2
CH_4	GOSAT, IASI, S5p
GFAS fire emissions	MODIS, SEVIRI*, VIIRS, Sentinel-3, GOES-E/W*, HIMAWARI-8*

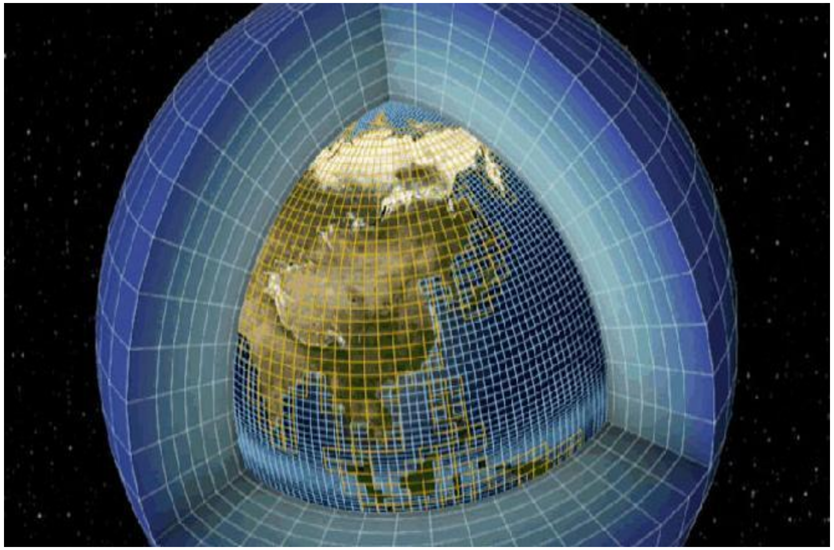
Assimilated **Monitored** Under development *Geostationary platform

CAMS uses Earth Observation data from many satellites for atmospheric composition and weather.

What is a model ?

(crucial for large-scale, complex atmospheric models)

- Global models have 3D domain with finite number of gridboxes. Typical global models: horizontal resolution of ~100km, vertical of ~1km -> total of ~10^6 gridboxes. Equation then solved for *all* gridboxes.



Conservation of mass (mass balance equation) for a gas/aerosol constituent

$$\frac{\partial n}{\partial t} = -\nabla \bullet (n\mathbf{U}) + D\nabla^2 n + P - L$$

Small in trop/strat

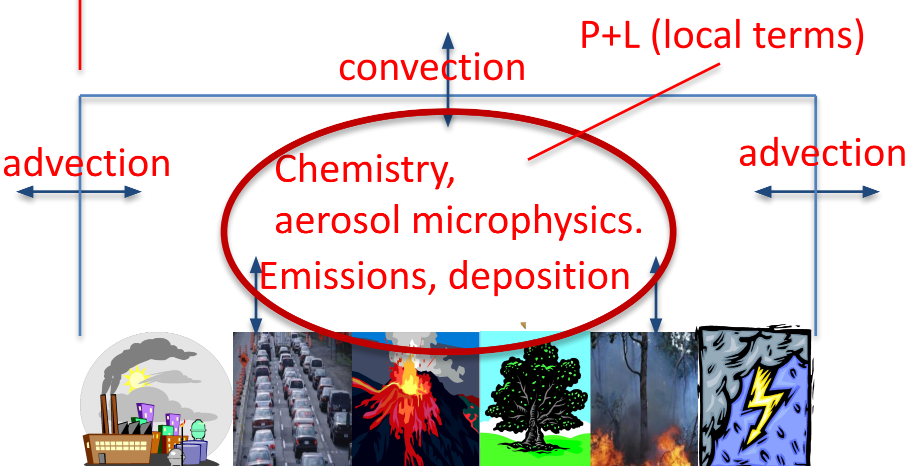
Change of concentration of constituent with time (in molec. m^{-3} s^{-1}).

Flux divergence due to transport (advection/convection). **U** is the wind velocity vector (m s^{-1}).

Flux divergence due to molecular diffusion. *D* is the molecular diffusion coefficient (m^2 s^{-1}).

Local production term: Emission, chemical production, microphysics (in kg m^{-3} s^{-1}).

Local loss term: Chemical loss, wet and dry deposition, microphysics (in kg m^{-3} s^{-1}).



- This equation is for number concentration, but equivalent equations can be written for mass, mass concentration etc.

Recent advances that revolutionized atmospheric science

Models have advanced a lot in the last 2-3 decades, with higher and higher resolution and more and more processes included (increasing computational power has been crucial).

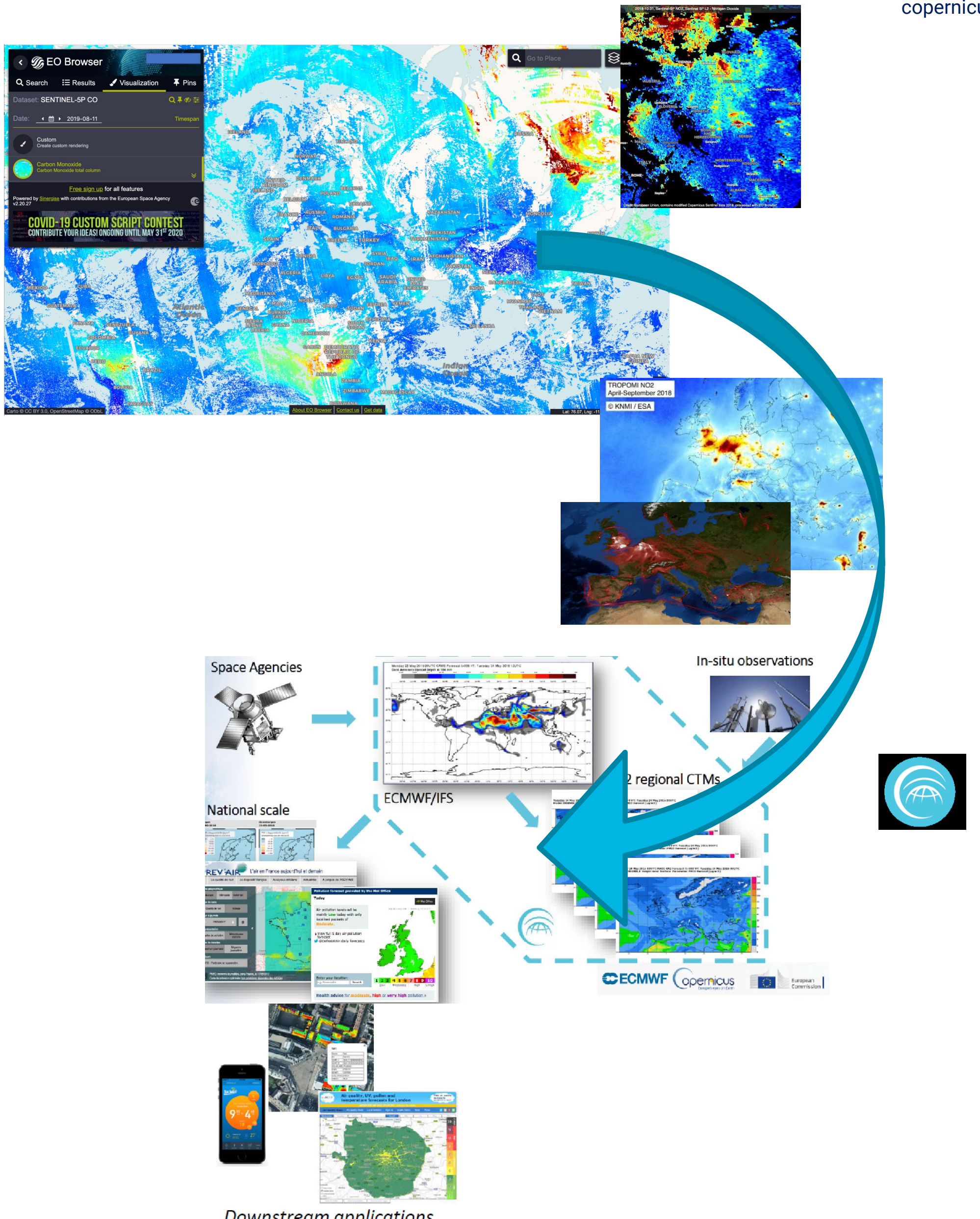
Satellite observations of atmospheric constituents have produced a wealth of data that helps us constrain our models in a way that we could not have done before!

ECMWF supercomputers

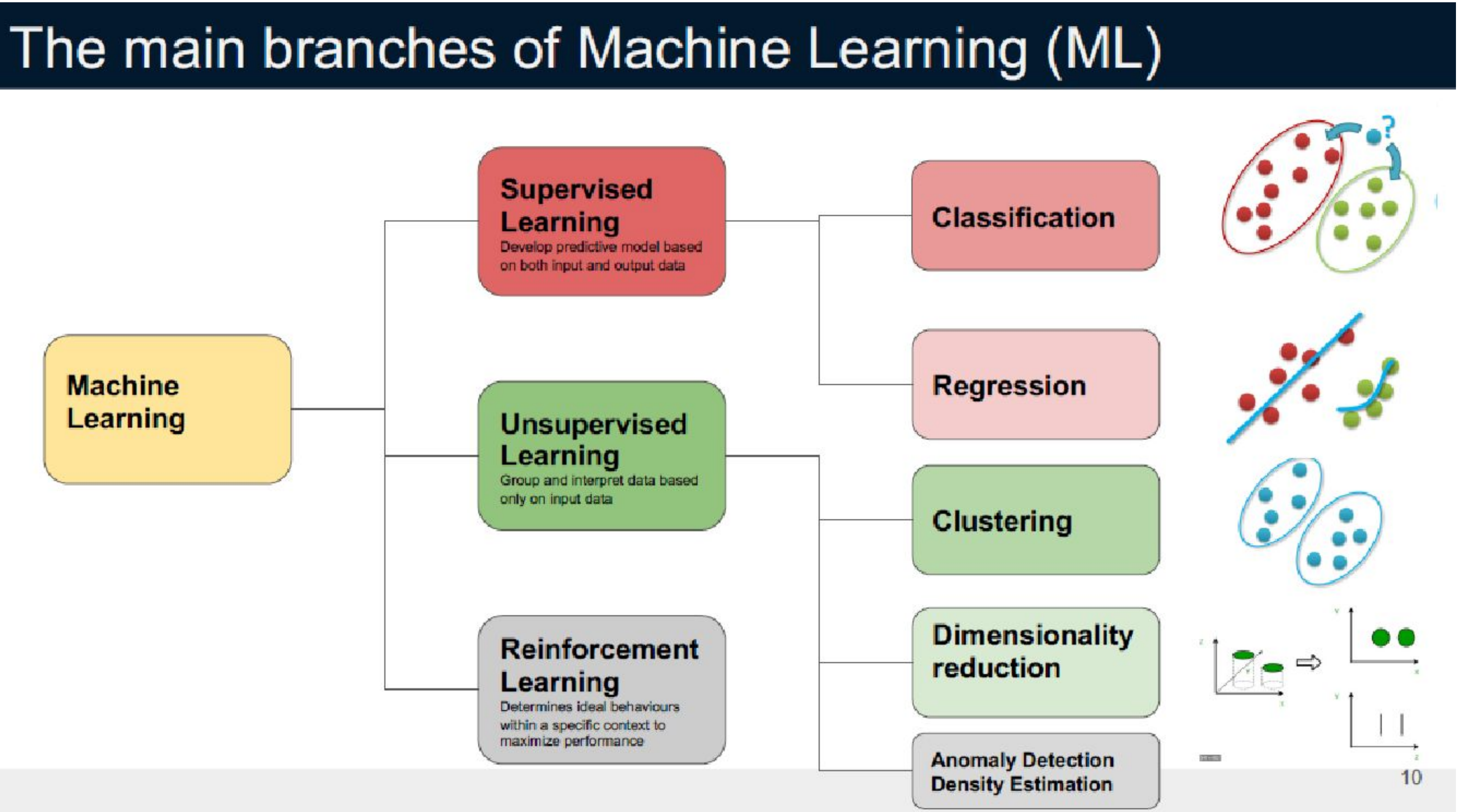
Sentinel-5P satellite

Merge Model and Observations - downscaling

copernicus.eumetsat.int

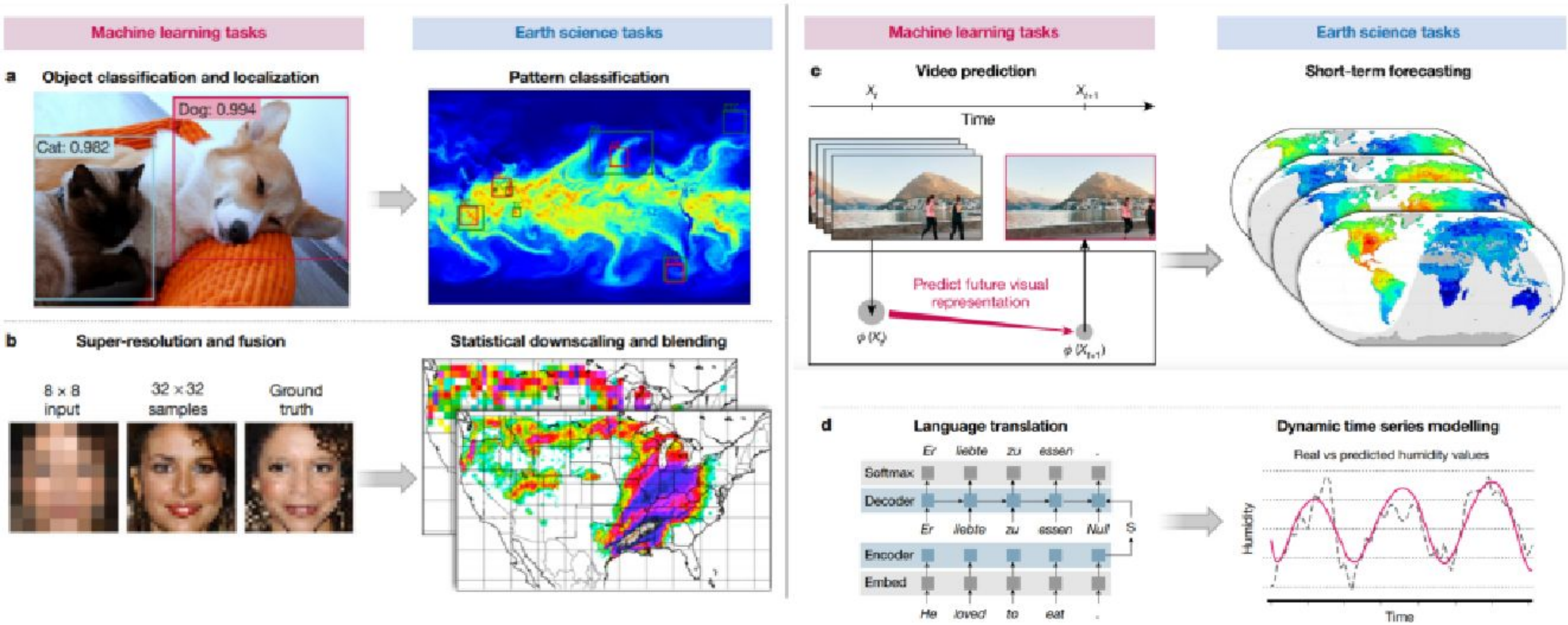


Principles ML - EO



Principles ML - EO

ML applied to Earth sciences… quick examples (I)



Markus et al 2019: Source: https://www.nature.com/articles/s41586-019-0912-1

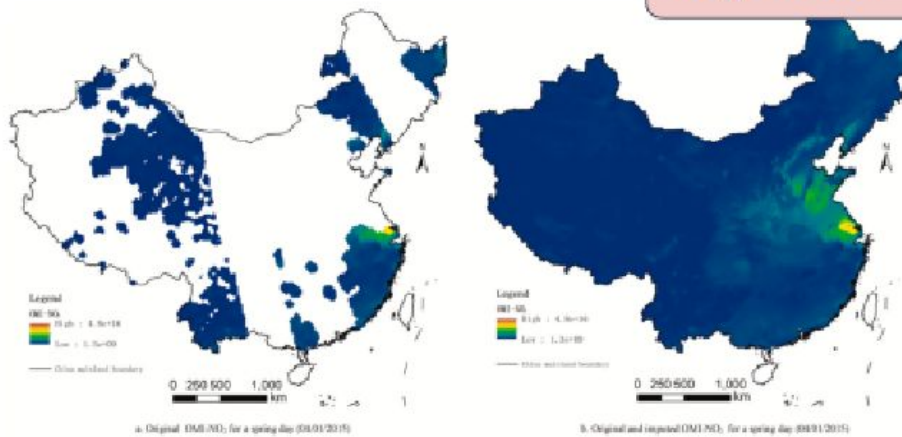
Example of Downscaling

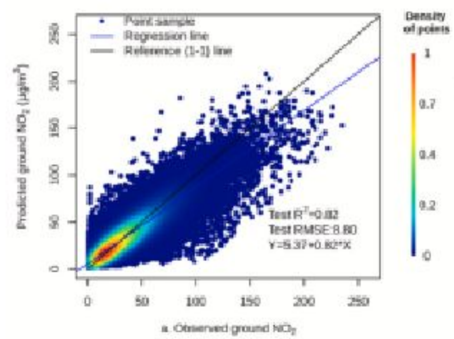
Spatio temporal estimation of satellite-borne and ground-level NO2

ML for Earth systems observation

Regression

- **Goal:** impute missing satellite-borne NO2 data (OMI-NO2) and estimate ground-level NO2 with uncertainty at a high spatial (1 × 1 km2) and daily resolution
- **Method**: full residual deep network
- **Input data:** OMI NO2 Columns and hourly ground measurements
- **Output: daily** NO2 column and ground estimations
- **Finding:** the final 1 × 1 km2 grids show natural and smooth spatial transitions between the observed and imputed OMI-NO2. Good results achieved between predicted and ground-level NO2 concentrations
- **Added value:** infer missing observations





Lianfa Li, Jiajie Wu, 2021, Remote Sensing of Environment 254 (2021) 112257