Monitoring of ground-level pollutant concentrations from space

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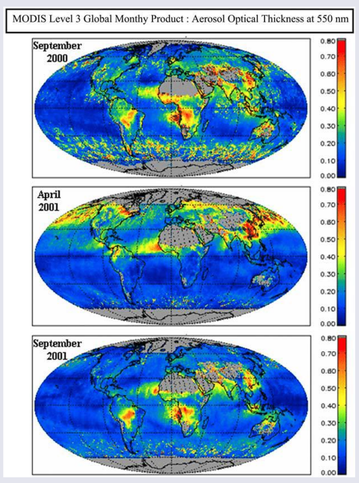
1 Air pollution monitoring from space

- **Comprehensive monitoring** and mapping of ground-level air pollutants is **essential for evaluating population's exposure** and **assessing** the resulting **health effects**
- Information provided by heterogeneously distributed monitoring sites is not sufficient for area-wide monitoring of the pollutant's spatio-temporal distribution
- **Satellites** provide a cost-effective for **area-wide pollution monitoring**. However, despite steady progress in remote sensing techniques, advanced techniques such as **machine-learning** are required to **infer** the **ground-level concentration from the column-integrated quantity**.
- A proof-of-concept for ground-level **PM10 using CAMS** simulations is presented

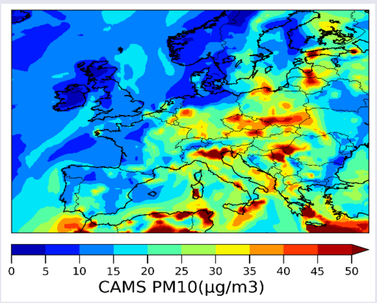
2 From AOT to ground-level PM10

Aerosol column loading retrieved by satellite (AOT)



From AOT to PM10 with ML

Ground level PM10 concentrations at spatio-temporal resolution of satellite



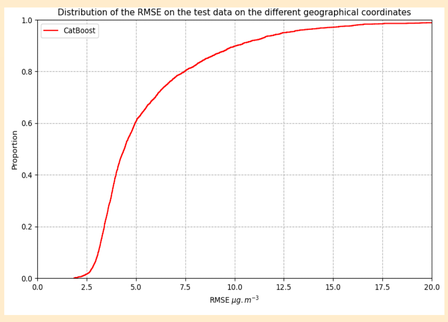
- **Surrogate Model calculates PM10 from satellite AOT**
- **Surrogate Model is trained entirely with CTM simulations**
- Surrogate Models are **faster and lighter** than CTMs with comparable **performance**
- **Due to the independence of in-situ data, the surrogate model is applicable to any region**

OBJECTIVE
Associate a ground-level PM10 concentration to each cloud-free satellite AOT

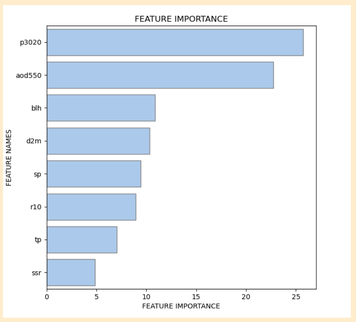
3 Building a surrogate model and Proof-of-Concept

Train and validate surrogate model with 3-months (JJA 2018) of **CAMS Global Composition Forecast** data over Europe.

(a)

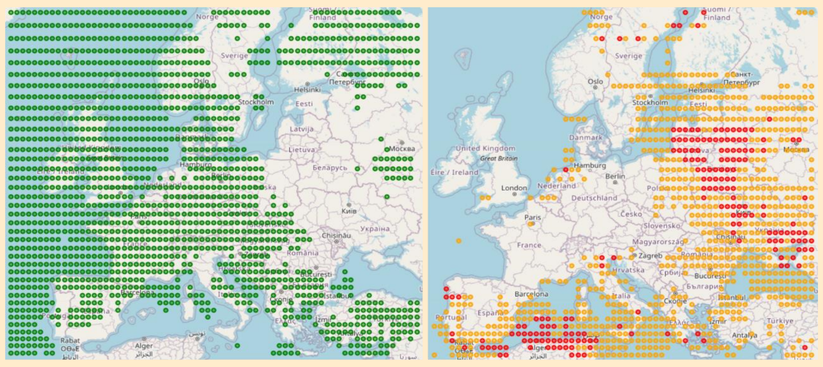


(b)



(a) Cumulative distribution of Root-Mean Square Error in PM10 between CatBoost Algorithm and unused CAMS data averaged over all grid points in JJA 2018**. CatBoost yields similar performance to CTMs, which have accuracy of around 10 µg/m³** over Europe (Bessagnet et al., 2016, ACP). (**b**) **Feature importance** values averaged over each grid point. It indicates which variables are considered the most important by the CatBoost algorithm in the prediction of ground-level PM10.

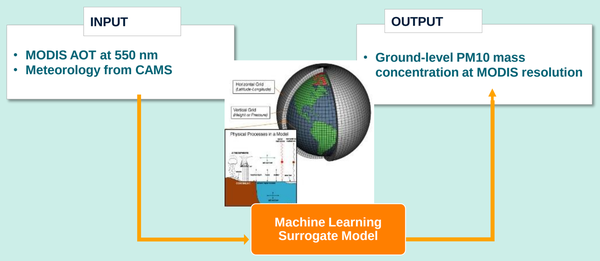
Spatial distribution of RMSE scores evaluated on test dataset (unused CAMS) during JJA 2018



RMSE $\leq 5\ \mu g\ m^{-3}$ for 60% of grid points

RMSE $\leq 12.5\ \mu g\ m^{-3}$ for 95% of grid points

4 Detection & forecast of pollution at local & regional scale – a test case with MODIS



- Use **MODIS** combined deep blue and target **AOT at 550 nm at 1° spatial resolution** as input to surrogate model in conjunction with meteorological parameters from CAMS
- **Application** of MODIS AOT and surrogate model **to wildfires in South western France on 19 July 2022**

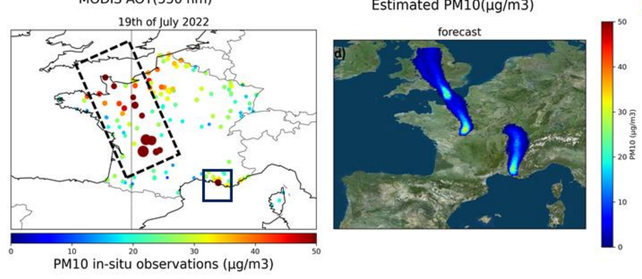
AOT observed by MODIS **satellite** on 19/07/2022

Elevated PM10 due to wildfires

Estimated PM10 from **surrogate model**

Local pollution event not seen by satellite

PM10 concentrations from French ***in situ*** network AASQA



Use PM10 maps as input to FLEXPART for simulating **plume dispersion** for 20/07/2022 at high spatial resolution

5 Development of a sustainable, scalable platform

	Orbit	Revisit	Spatial resolution	Mission status	Products
POLDER-3 on PARASOL	Polar	Daily	6 km x 6 km	Terminated	AOT
SEVIRI on MSG	Geostationary	15 minutes	15 km x 15 km	ongoing	AOT
OLCI-SLSTR on SENTINEL-3	Polar	2 days	5 km x 5 km	ongoing	AOT
TROPOMI on SENTINEL-5P	Polar	Daily	7 km x 3 km	ongoing	**O3, NO_2, SO_2, CH_4**
GAPMAP GRASP	Polar	5 x day	500 – 3 km	ongoing	**Aerosols**
UVN/SENTINEL-4 on MTG-S	Geostationary	Hourly	8 km x 8 km	**To come**	AOT, **O_3, NO_2, SO_2**
UVNS/SENTINEL-5 on METOP-SG	Polar	Daily	7 km x 7 km	**To come**	AOT, **O_3, NO_2, SO_2, CH_4**
3MI on METOP-SG	Polar	Daily	4 km x 4 km	**To come**	AOT
MAP-CO2i on SENTINEL-7	Polar	Daily	4 km x 4 km	**To come**	AOT, **CO_2, NO_2, CH_4**
ABSOLUT Sensing	Polar	GEN 1/2: daily GEN 3: > daily	50 m x 50 m	**To come**	GEN1 : **CH_4**; GEN2: **CO_2, CO, NO_2, NH_3, H_2O, NO_2**; GEN3: **+SO_2**

- **Applications** to **current & future satellite missions** with **different spatial resolution and revisit time.**
- **leverage new advanced air quality products** from up-coming missions: **ESA Sentinel-4 & 5**, **New Space technologies**

6 Current and future activities

- The monitoring tool has recently been **awarded the SCO label** (Space Climate Observatory project (SCO France: 2024 Edition | Space Climate Observatory) by CNES
- Development of much larger training data base 4 years of **high resolution simulations with CTM CHIMERE to cover seasonality and annual variability** and as many different meteorological and pollution events
- Validation of **PM10 concentrations** derived from **Sentinel-3 during Olympic Games 2024** in partnership with **INERIS**
- Computation of **ground-level SO_2 concentrations from Sentinel-5** has been conducted for the French electricity transmission system operator RTE
- Investigation of the potential impacts of **long-term time-series of PM2.5** for **health-related studies** in coordination with the **University Hospital CHU Toulouse**.

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