CAMS

COPERNICUS ATMOSPHERE MONITORING SERVICE

PROGRESS AND CHALLENGES WITH AIR QUALITY FORECASTING IN EUROPE

Vincent-Henri Peuch (ECMWF)

…and many European colleagues

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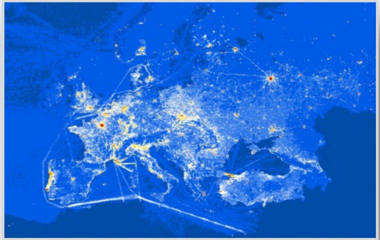
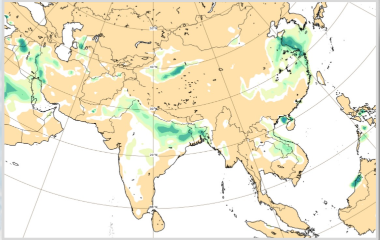
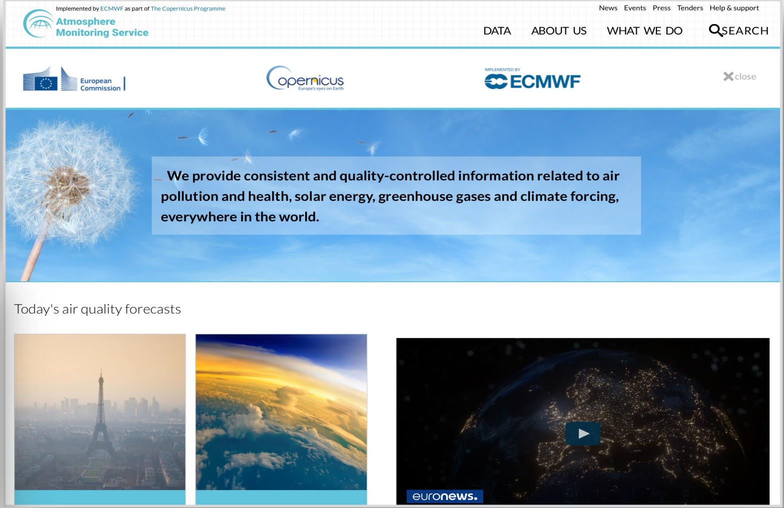
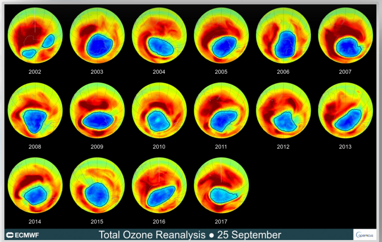
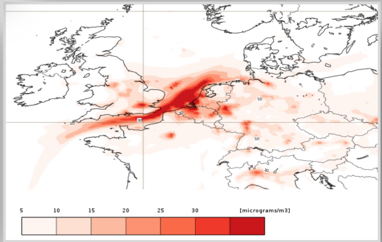
http://atmosphere.copernicus.eu

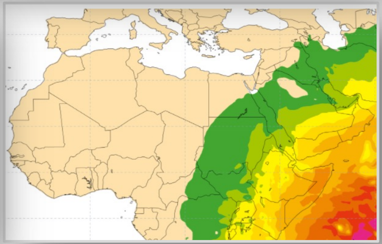












CAMS provides **open & free** information products based on Earth Observation about:

- past, current and near-future (forecasts) global atmospheric composition;
- the ozone layer;
- European air quality;
- emissions and surface fluxes of key pollutants and greenhouse gases;
- solar radiation;
- climate radiative forcing.

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CAMS DISTRIBUTED IMPLEMENTATION

CAMS 4th General Assembly, Budapest, September 2019

196 different entities from 31 European countries, IOs and 3rd countries.

CAMS INFORMATION FLOW

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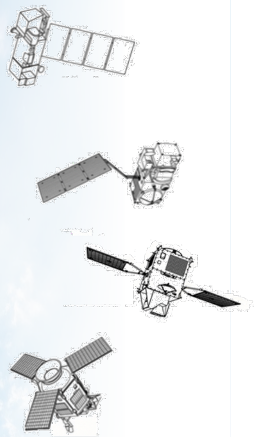
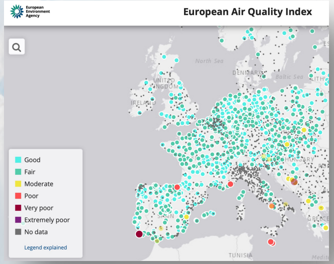
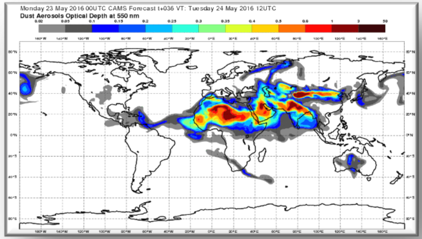


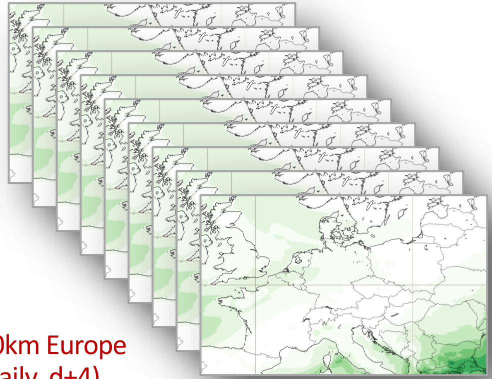
Earth Observation from satellite (>80 instruments) and in-situ (regulatory and research)





40km Globe (twice daily, d+5)

CAMS main operational data assimilation and modelling systems



10km Europe (daily, d+4)

CAMS users

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THE CAMS ATMOSPHERE DATA STORE (ADS)

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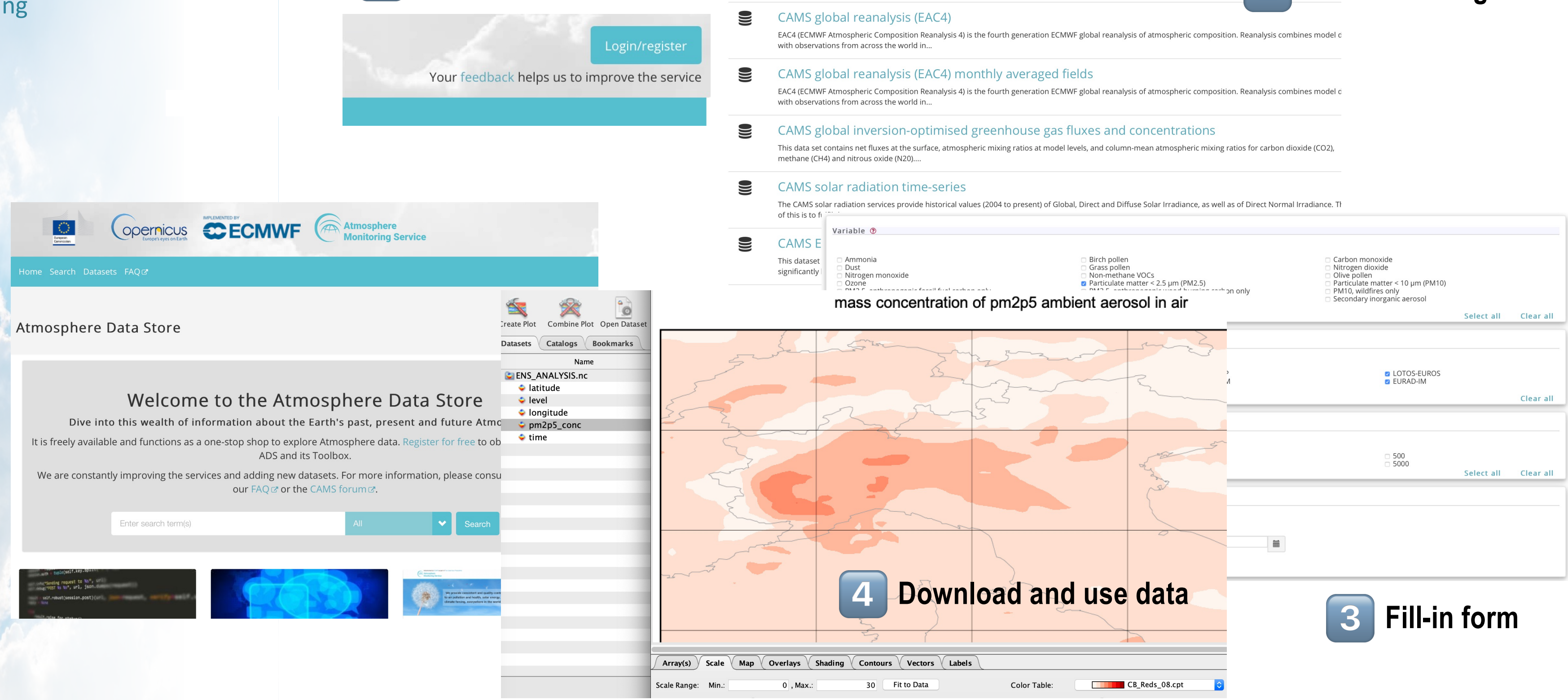
1 Register (once)

2 Search catalogue

3 Fill-in form

4 Download and use data



http://ads.atmosphere.copernicus.eu

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WHAT'S GOING ON NOW?

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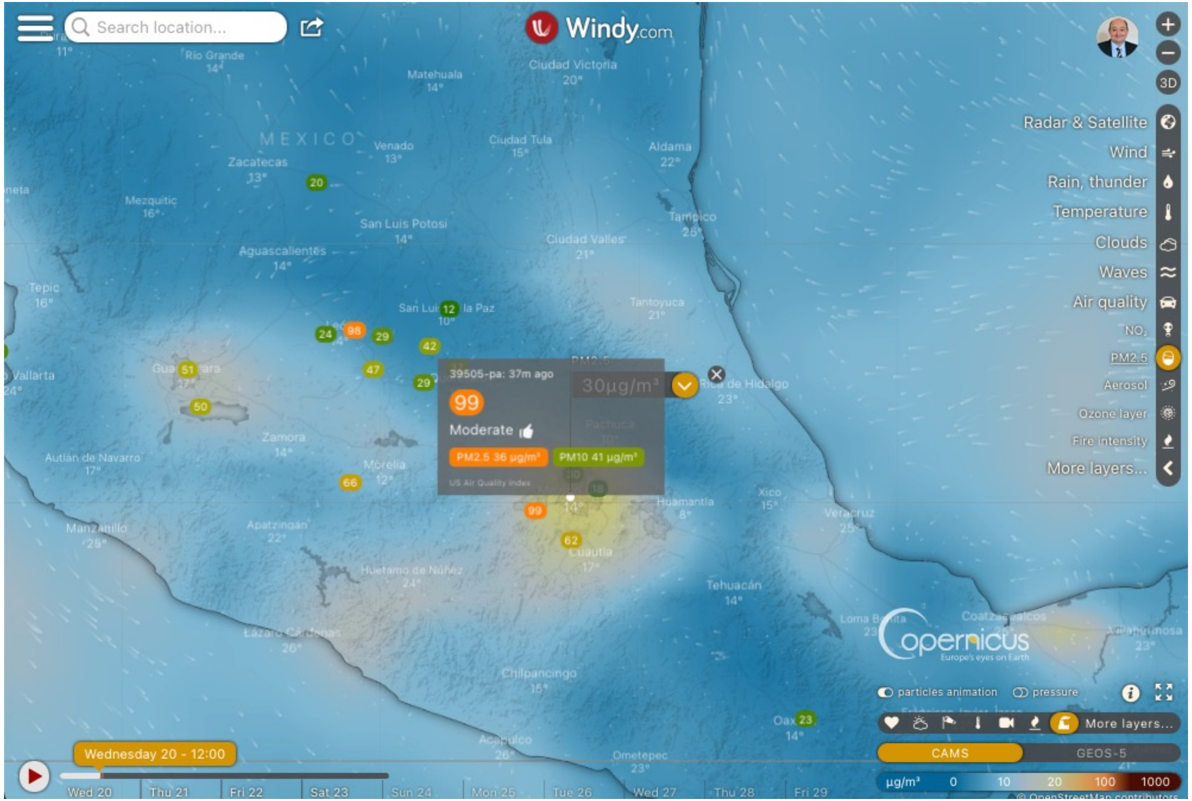

You can also see CAMS outputs through several of our own users (here: windy.com). Overlay of current air pollution (PM2.5) and local observations.

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IFS: COMPOSITION CONFIGURATIONS

A. Inness et al., The CAMS reanalysis of atmospheric composition, ACP, https://doi.org/10.5194/acp-19-3515-2019, 2019.

A. Agusti-Panareda et al., Modelling CO_2 weather – why horizontal resolution matters?, ACP, https://doi.org/10.5194/acp-2019-177, 2019.

S. Rémy et al., Description and evaluation of the tropospheric aerosol scheme in the Integrated Forecasting System (IFS-AER, cycle 45R1) of ECMWF, GMD, 12, 4627–4659, 2019, https://doi.org/10.5194/gmd-12-4627-2019.

V. Huijnen et al., Quantifying uncertainties due to chemistry modelling – evaluation of tropospheric composition simulations in the CAMS model (cycle 43R1), GMD, https://doi.org/10.5194/gmd-12-1725-2019.

Current oper version

- Based on IFS Cy47r3 (12/10/21)
- T511 (~40km)
- L137

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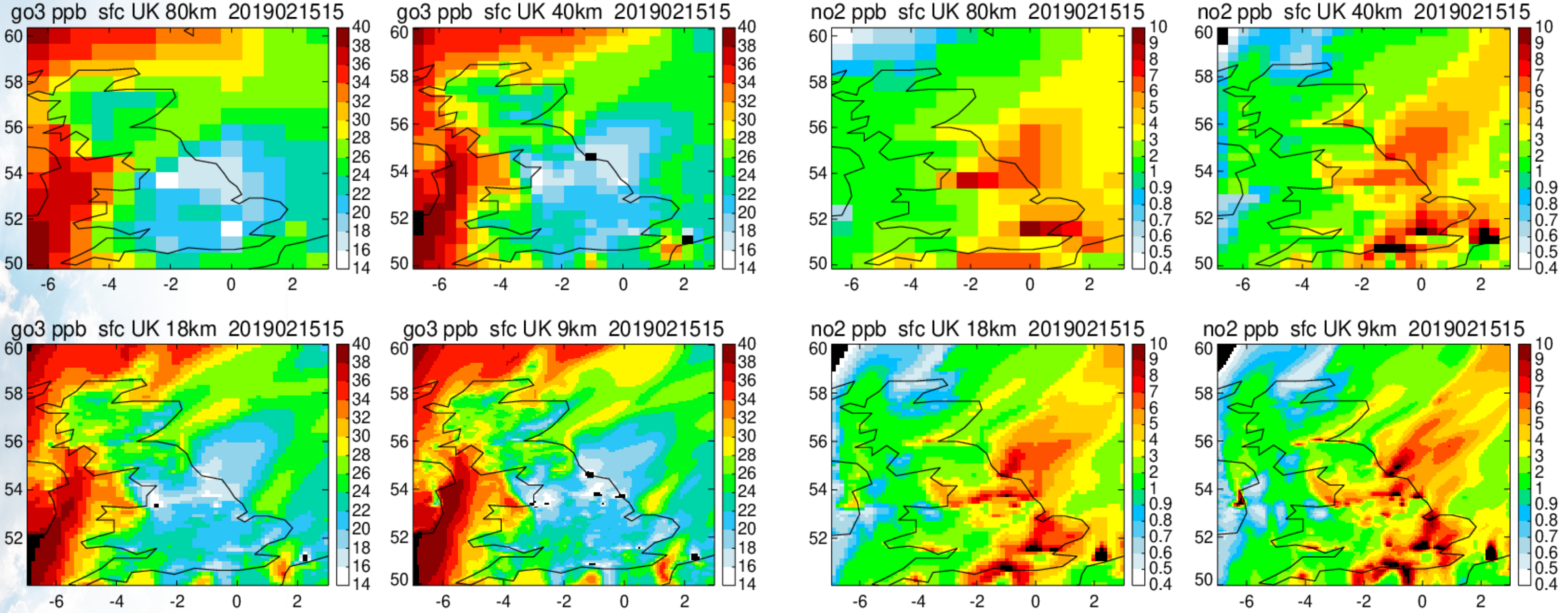
IMPACT OF HOR. RESOLUTION CHANGES

All simulations are global

Ozone

NO_2



Higher spatial resolution allows to make use of high-res information of emission data

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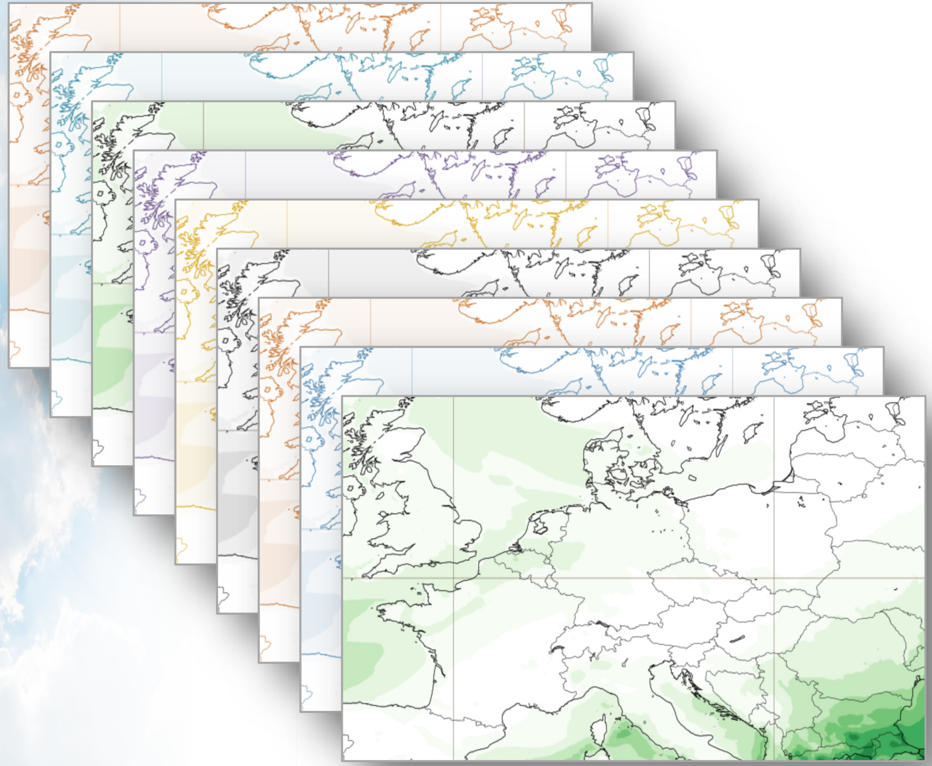
CAMS REGIONAL AIR QUALITY ENSEMBLE



- Over Europe, a multi-model ensemble is used to deliver forecasts (with uncertainty).
- It has now 9 operational members (CHIMERE, DEHM, EMEP, EURAD, GEM-AQ, LOTOS-EUROS, MATCH, MOCAGE, SILAM) and 2 more are ramping up (MONARCH, MINNI).
- Effectively, a “premier league” for original air quality models in Europe, leveraging on national efforts and expertise.

ROUTINE PERFORMANCE EVALUATION

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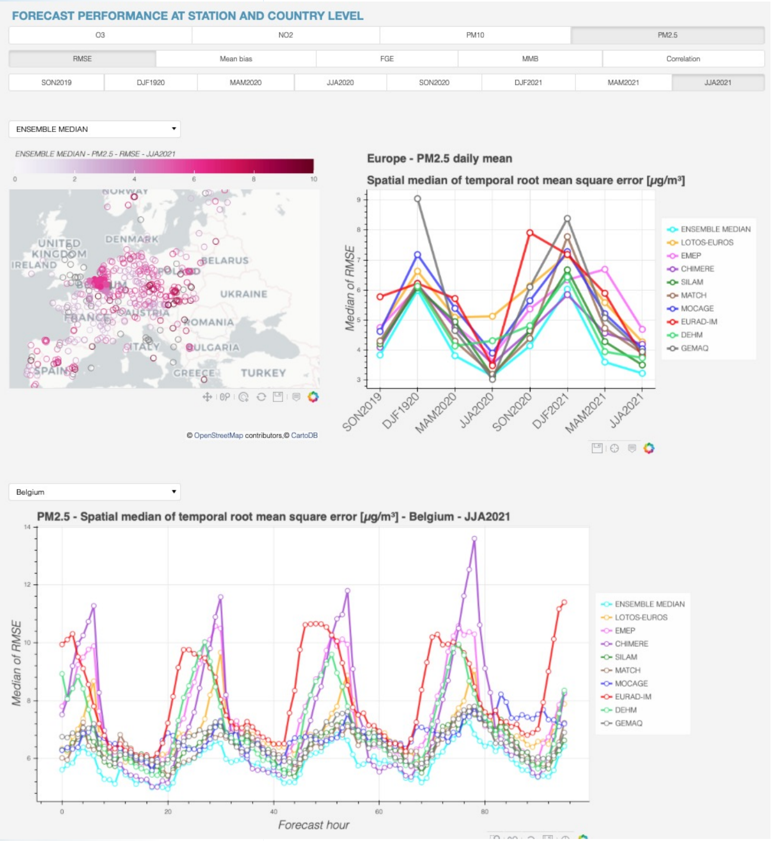
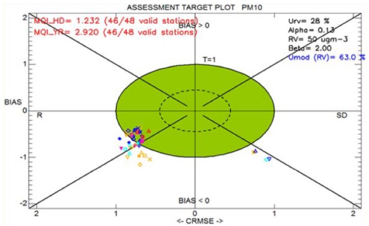
https://regional.atmosphere.copernicus.eu/evaluation.php?interactive=cdf



- Careful selection of sites for verification (representativeness)
- 9 models + ensemble median
- 8 last quarters
- O_3, NO_2, PM_{10}, $PM_{2.5}$
- RMSE, Mean bias, FGE, MMB
- Expanding to incorporate JRC-led FAIRMODE Modelling Quality Objectives and Benchmarking



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IN-DEPTH MODEL EVALUATION

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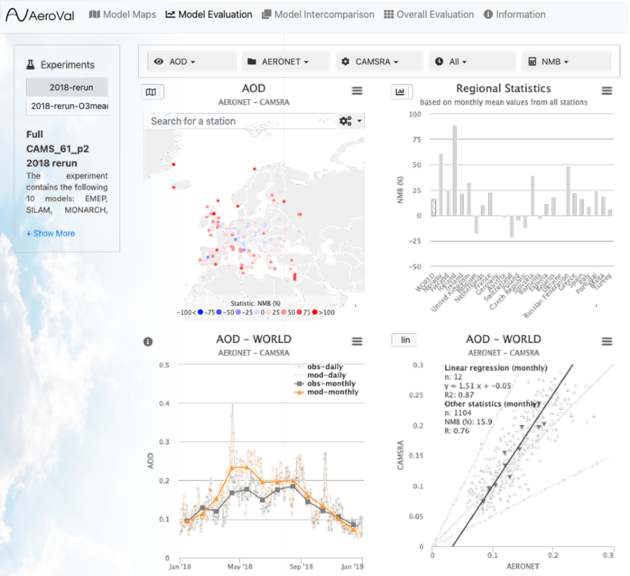
3 phases, including re-runs with additional outputs in order to get deeper understanding on the strengths and weaknesses of each modelling system. Focus on 2018.



https://aerocom-evaluation.met.no/main.php?project=cams61_p2&exp=2018-rerun

Work led by TNO (R. Timmermans, M. Schaap et al.)

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SELECTED FINDINGS

Ozone

- positive bias in the Mediterranean area, worse where where mesoscale phenomena could control the ozone dynamics
- generally, the models do a poorer job at capturing the ozone diurnal cycle than the seasonal cycle, and across the percentiles

PM

- there is a large spread in the results for sea salt, with approximately a factor 5 between the model with the lowest and highest sea salt concentrations, both in PM10 and PM2.5.
- most models underestimate OC in summer. Recommend to perform a sensitivity analysis with much increased BVOC emissions in summer.
- most models underestimate SO4 by 35% and more. Sulphur wet deposition is substantially underestimated.
- comparison to observations of ammonia plus ammonium and ammonia indicates that the temporal emission profiles for NH3 overestimates NH3 emissions in late winter.
- ammonium aerosol concentrations and nitrate varies from being substantially overestimated to substantially underestimated.
- most model significantly underestimate wet deposition of oxidized nitrogen.

MODEL OUTPUT STATISTICS (PM10, 2019)

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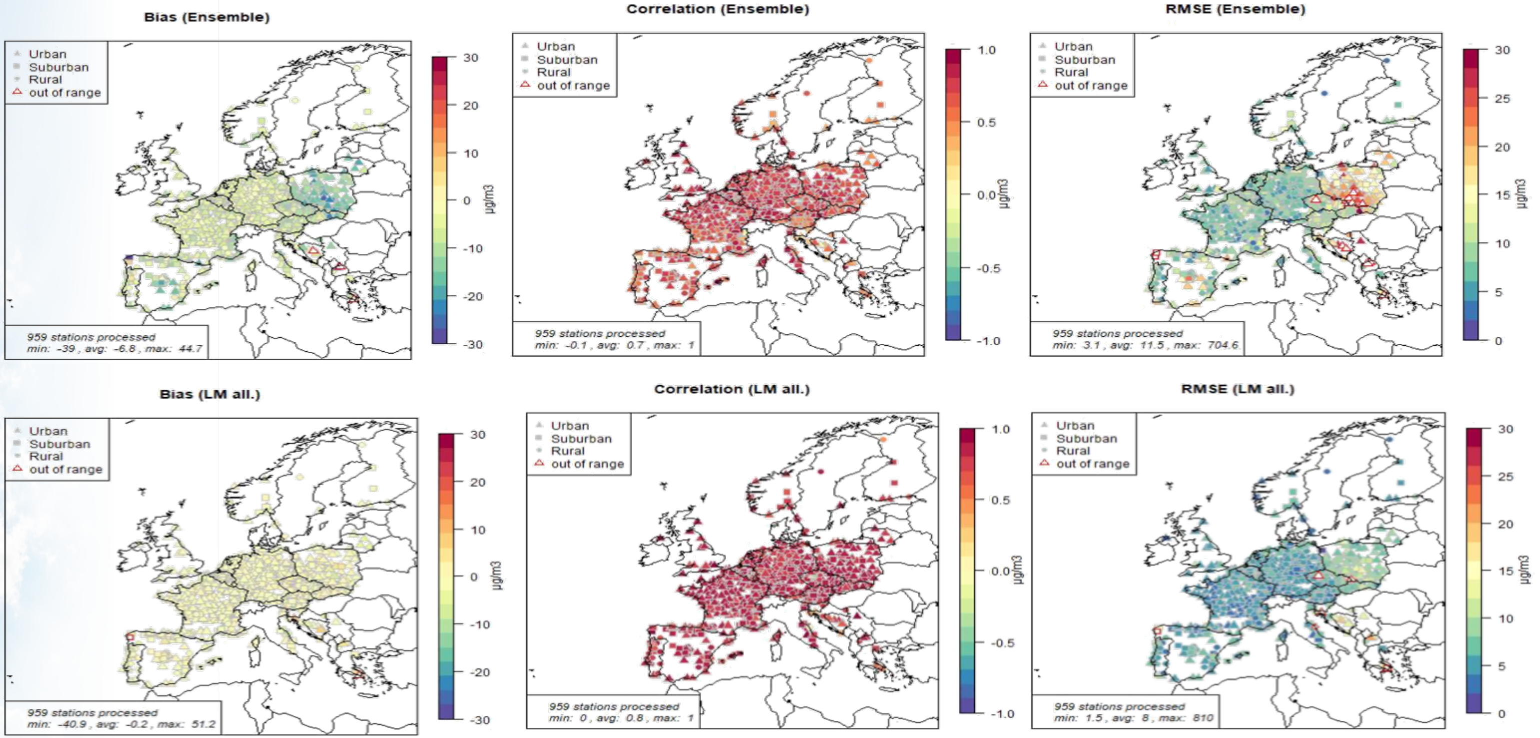

Mean Biais: -6.8 to -0.2 µg/m3
Correlation: 0.7 to 0.8
RMSE: 11.5 to 8 µg/m3

Recommended solutions compatible with model upgrades use ML (ridge and LASSO)

Work led by INERIS (A. Colette et al.)

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MEDIAN APPROACH ON THE WAY OUT…

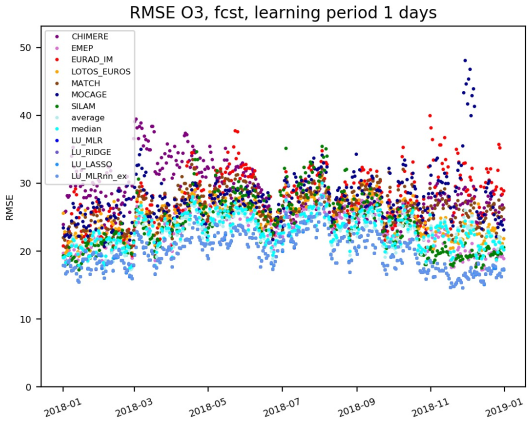
Five fusion methods tested:

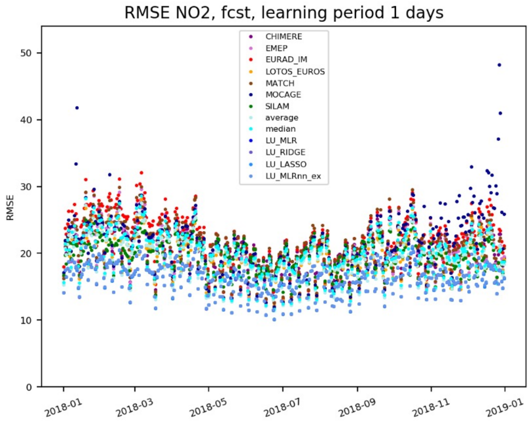
- multi-linear regression (MLR);
- regularized MLR with the LASSO regularization term (Least Absolute Shrinkage and Selection Operator); regularized MLR with Ridge regularization term (RIDGE);
- conditional MLR with non-negative model weights MLRnn;
- Krishnamuti et al. version of classical multilinear regression (KRISH).

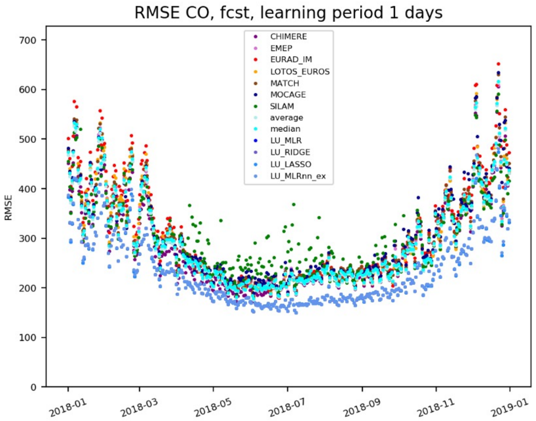
The tests covered analysis and forecast for NO_2, O_3, CO, SO_2, $PM_{2.5}$, PM_{10}. Considered learning periods ranged from 1 to 350 days. The hourly weighting coefficients were handled with a Gaussian smoother with width ranging from 0.01 h up to 5 h. **The simulations confirmed the added value of the fusion post-processing of the ensemble.**

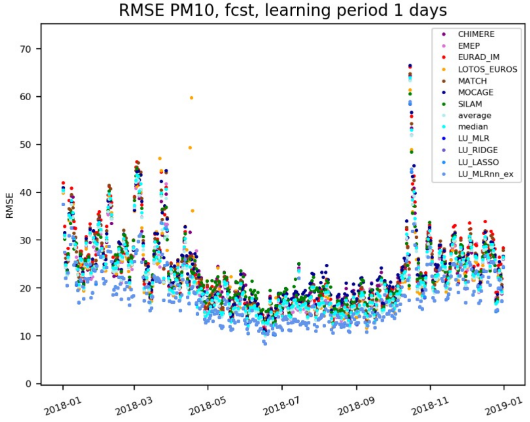
Work led by FMI (M. Sofiev et al.)

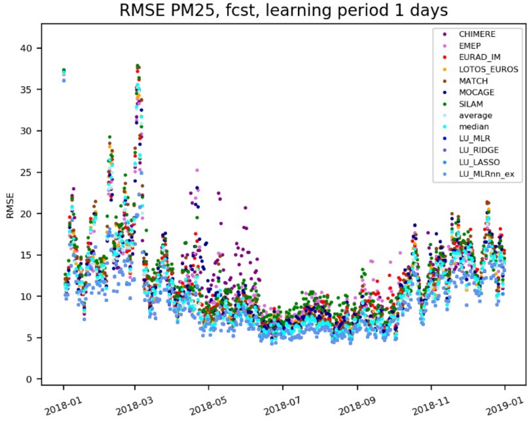
WORKING ON ENSEMBLE METHODS

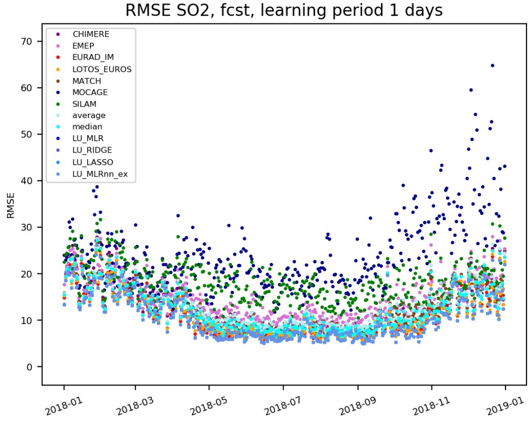












MEDIAN APPROACH ON THE WAY OUT…

The following setups were identified for operational usage of the system:

- For analysis / reanalysis, a 1-day learning with hourly coefficients with σ = 0.01 hr. For such setup, space-resolving RIDGE showed sufficiently stable results but non-negative MLR can also be considered for its reasonable performance.
- For forecasting, the situation is completely different. A reasonable compromise between the strongest skill of the day 0 of the forecast and day 4 is achieved for: 10 days of learning, hourly resolution of weights and σ = 2 hours. In this case, space-resolving RIDGE demonstrates the best skills followed by non-negative space-resolving MLR.

All fusion models show lower RMSE and higher correlation coefficient than individual and ensemble-mean models. Behaviour of the standard deviation ratio is essentially not constrained by the current fusion approaches.

Work led by FMI (M. Sofiev et al.)

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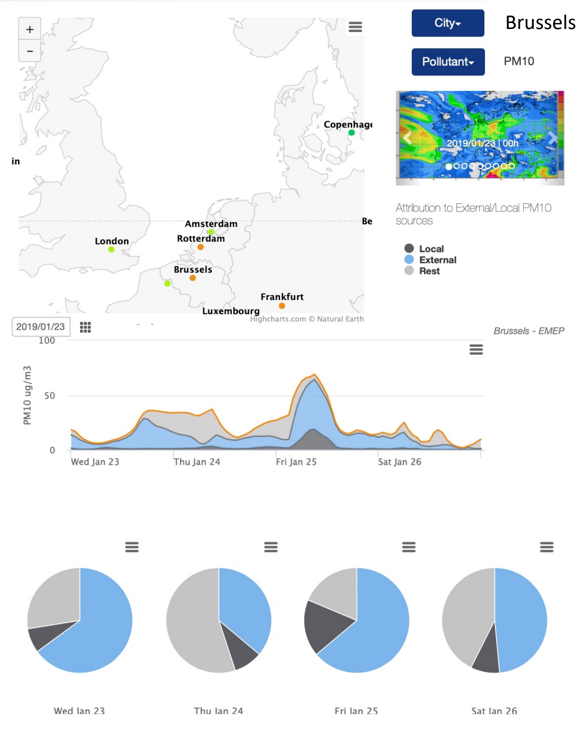
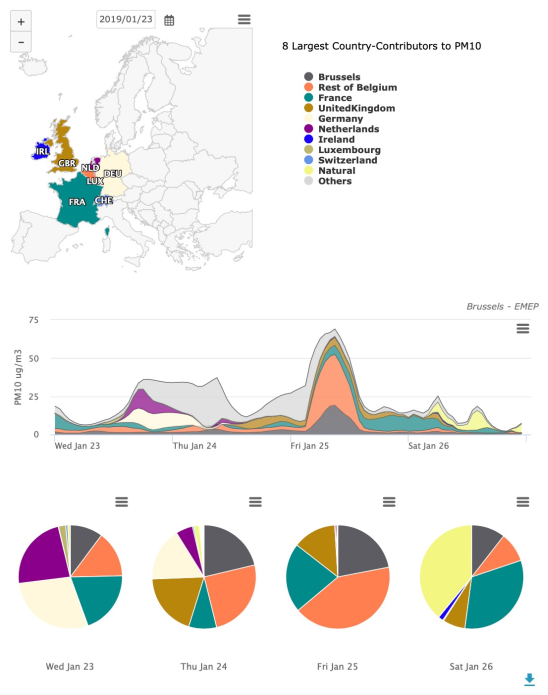
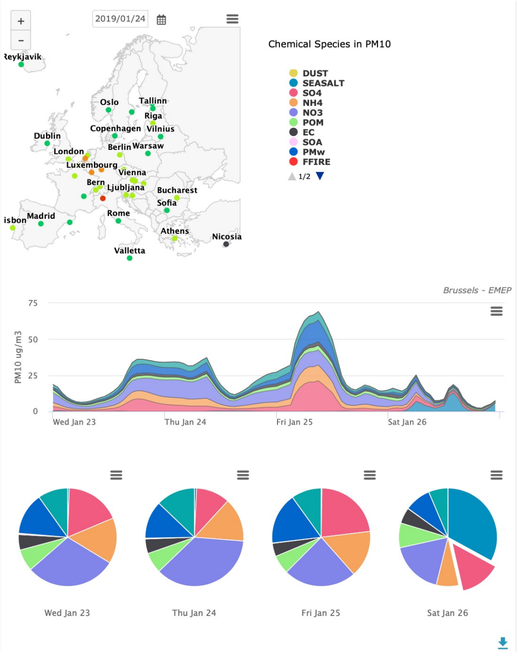
PRODUCTS FOR AIR QUALITY MANAGERS

For the European capitals, daily analysis of local versus large scale contribution to air pollutant concentrations. Where does pollution come from? What is the chemical composition of PM?







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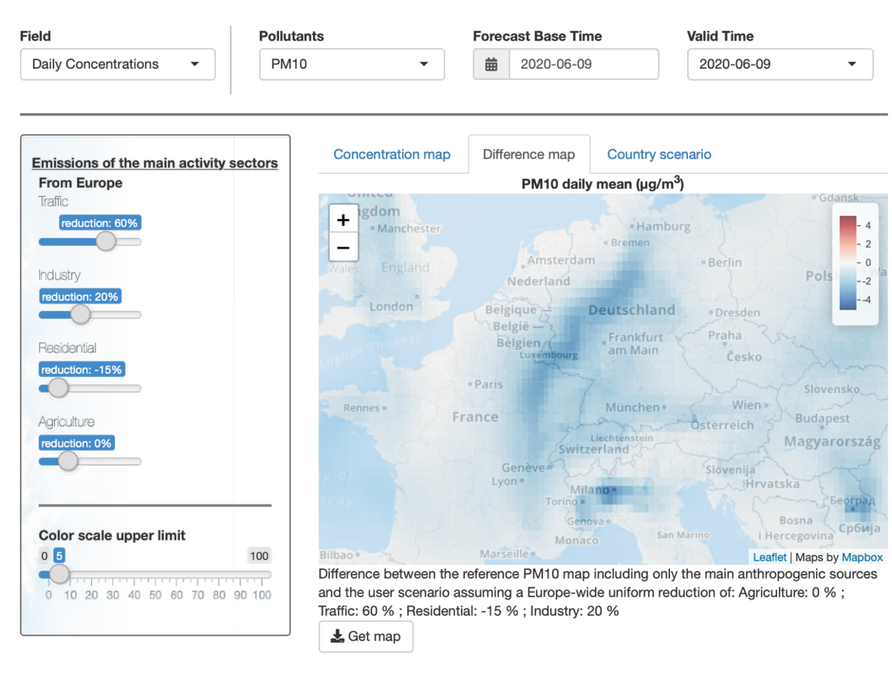
THE CAMS AIR CONTROL TOOLBOX (EUROPE)



The CAMS ACT has been recently adjusted to support European Member States with the management of air quality during the COVID-19 crisis.

Co-designed with EU Member States and operated using one of the ensemble members (CHIMERE, Ineris, FR).

https://policy.atmosphere.copernicus.eu

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TARGET: OBSERVATIONS-BASED EMISSIONS

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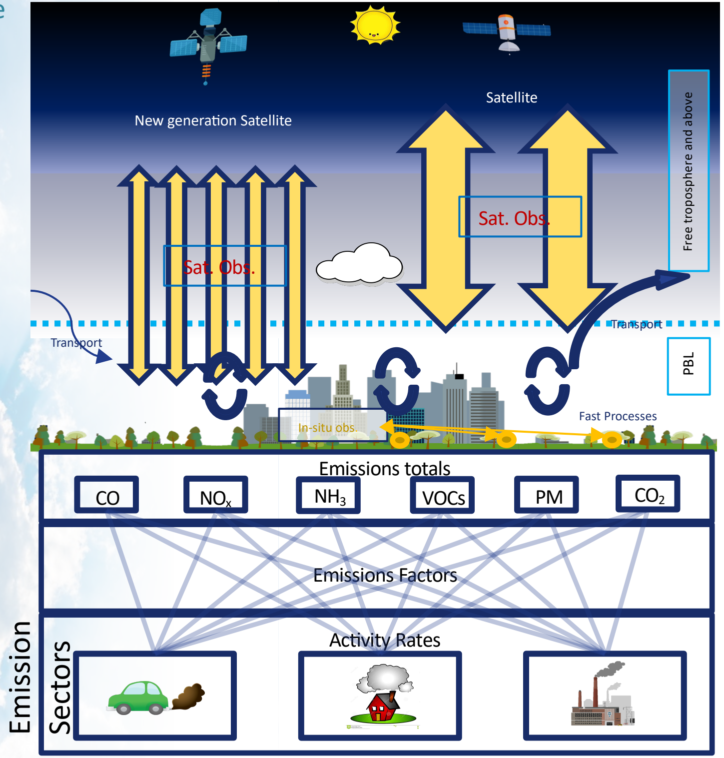

- Target species (direct): NO_2, CO, NH_3, CH_4, SO_2 (large sources only)
- Target species (indirect): $PM_{2.5}$/PM_{10} (AOD and aerosol size information) and NMVOCs (HCHO, glyoxal, vegetation parameters…).
- global, ~10km, hourly.
- Sectorial inversion.
- Requirements on emissions prior information (link to activities on uncertainty).
- Links and support to policies on AQ and GHG emissions, working with the Member States and national efforts.

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