Operational 20-km global forecasts of atmospheric composition with SILAM

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Outline

Global operational forecasts

CAMS-GLOB-ANT v5.3 inventory

Fire forecasting model

Saharan dust in Finland

Impact of assimilation of MODIS AOD on surface PM

Road dust

Final remarks

SILAM global forecasts

Questions from users:

- What is the latency of your forecasts?
- Why is the analysis missing?
- We will do an evaluation. Can we have your $+0$, $+6 \ldots +120$ forecasts?

Implicit assumption:

Observations collection $\rightarrow$ Analysis $\rightarrow$ forecast with snapshots every X hours

Not the way SILAM forecasts work

Non-assimilating AQ forecasts

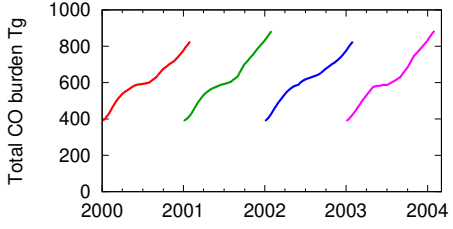
- Run with NWP forecast(s), that use DA for initial state
- Initial conditions: D-1 forecast

Mass comes from

- Emissions
- Chemistry
- ~~Boundaries~~

Mass leaves to

- Deposition
- Chemistry
- ~~Boundaries~~



Example of poorly-balanced model

- ”Best-timeseries” forecast is same as a free model run
- Closed system: Model acts as integrator of inconsistencies
- Outdated NRT emissions (fires)

Global 0.2-deg suite arrangement

Step 1: AQ

- Start D-2, 24h
- ”Best” meteo forecast
- NRT fire emissions
- **Strict** chemistry tolerances
- Model-state dumps

Step 2: AQint

- Start D-1, 24h
- ”Best” meteo forecast
- Replicated fire emissions
- **Fast** chemistry tolerances
- Model-state dumps

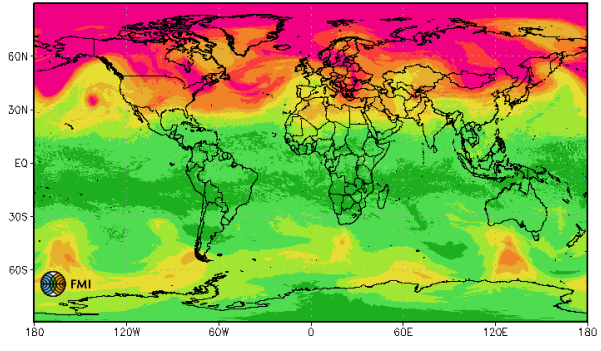
Step 3: AQfc

- Start D0, 120h
- Latest 00Z meteo forecast
- Replicated fire emissions
- **Fast** chemistry tolerances
- No dumps

- Published (normally) soon after 00Z
- Hourly **averaged** output, starting from +1
- Apparent 48-h latency
- Observed fires and strict-tolerances inherited

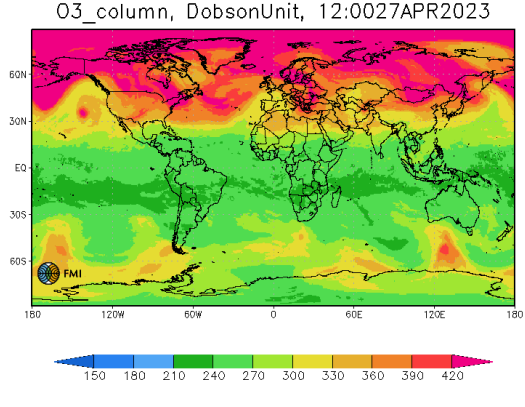
Global 0.2° suite

- 0.2 deg ECMWF meteo
- CAMS-GLOB-2.1 Emissions (update soon)
- 7 days of forecast from -2 days, hourly output
- 28 layers up to 10 Pa
- CBM5 + Strato + SOA chemistry
- ~ 150 tracers
- ~~3 hours @ 64 nodes of Cray XT40 (3.5k cores)~~
- 20min + 15min + 60min @ 16 nodes of Atos (2048 cores)
- 4TB output, 900G published, 100G archived

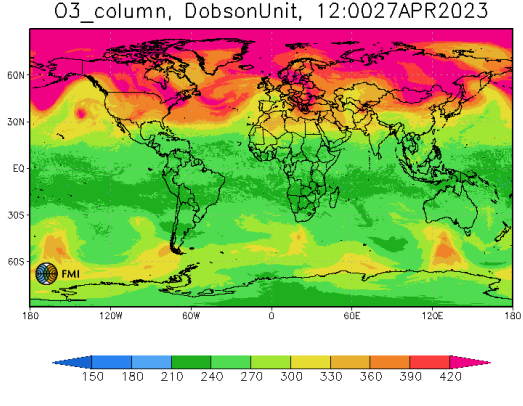


Global 0.6° suite

0.6-degree global suite

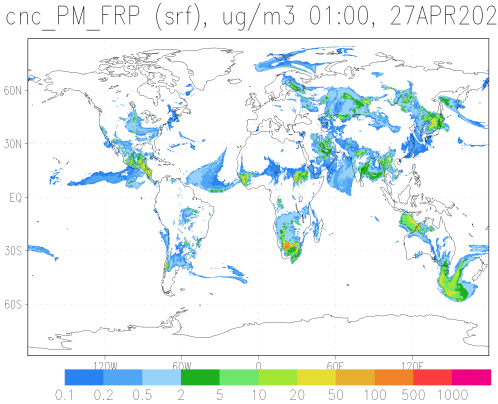


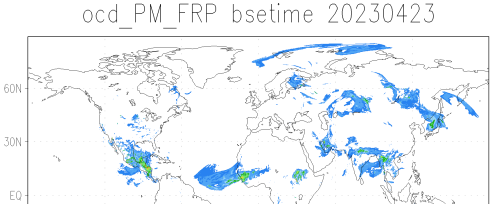
0.2-degree global suite

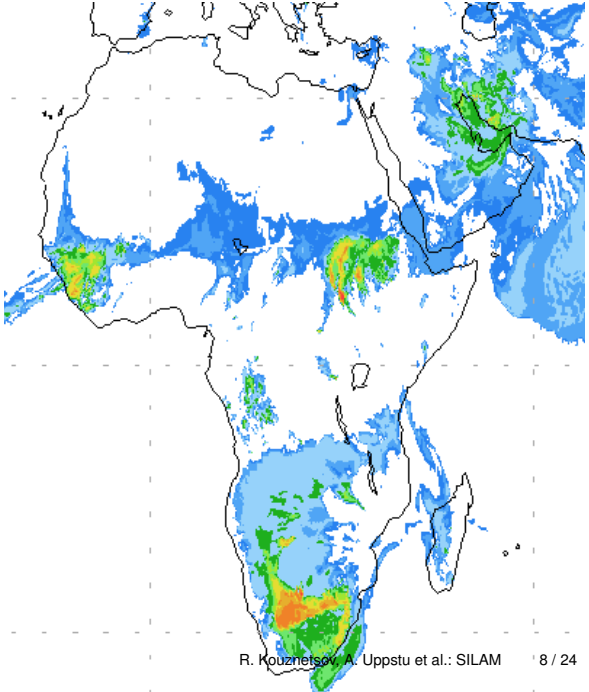


0.6-deg: 30 times lighter, 10 times smaller data

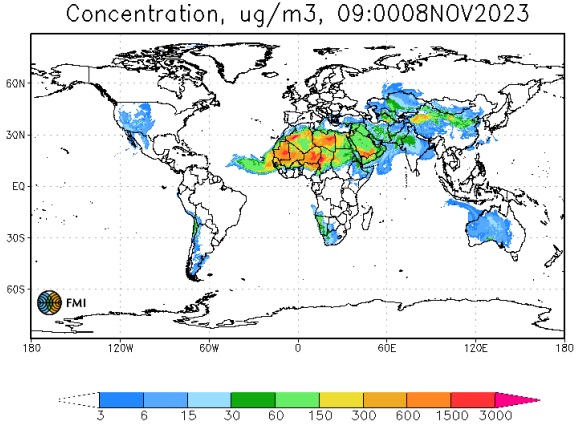
0.1° Fire suite -48h to +120h

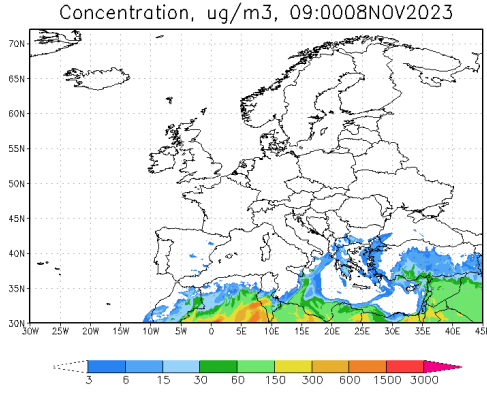






0.1° Dust suite 0h to +120h



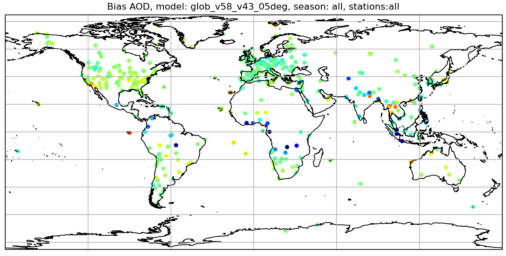


- No need for spin-up: emission depends only on meteo

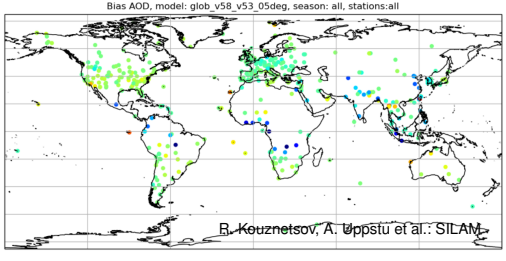
CAMS-GLOB-ANT v5.3 inventory

- Available from ECCAD since end 2022
- 0.1°x 0.1°
- 360GB total (21 years)
- Improves SILAM scores
- Coming soon to operations

AOD bias v. 4.2



AOD bias v. 5.3



IS4FIRES at a glance

- The system was born in 2006 in GEMS, a CAMS precursor
- After GEMS, independent development with Academy of Finland IS4FIRES project
- Key input data: MODIS Fire Radiative Power
- Steps towards VIIRS, SLSTR, geostationary products
- Strong link to SILAM: IS4FIRES emission factors are calibrated via SILAM towards MODIS AOD and in-situ

Problems

- Satellites provide **past**-fire observations
- Satellites miss many fires (clouds, rare sampling, smoke obscuration, detection limit)

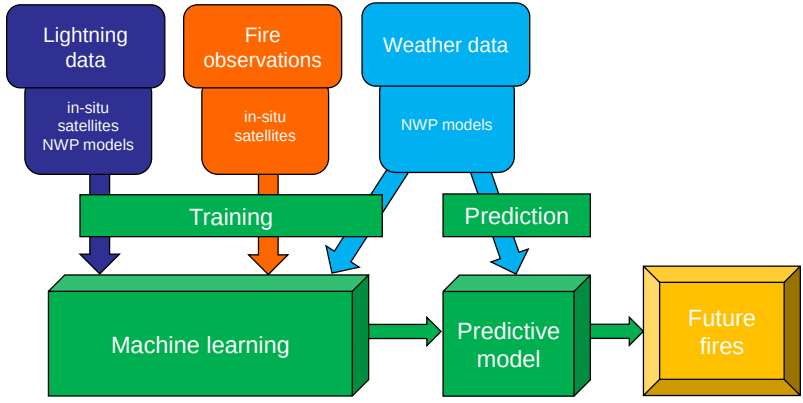
Can be addressed with **Fire forecasting**

New development: Fire prediction

Majority of fires are started by humans (up to 90%)

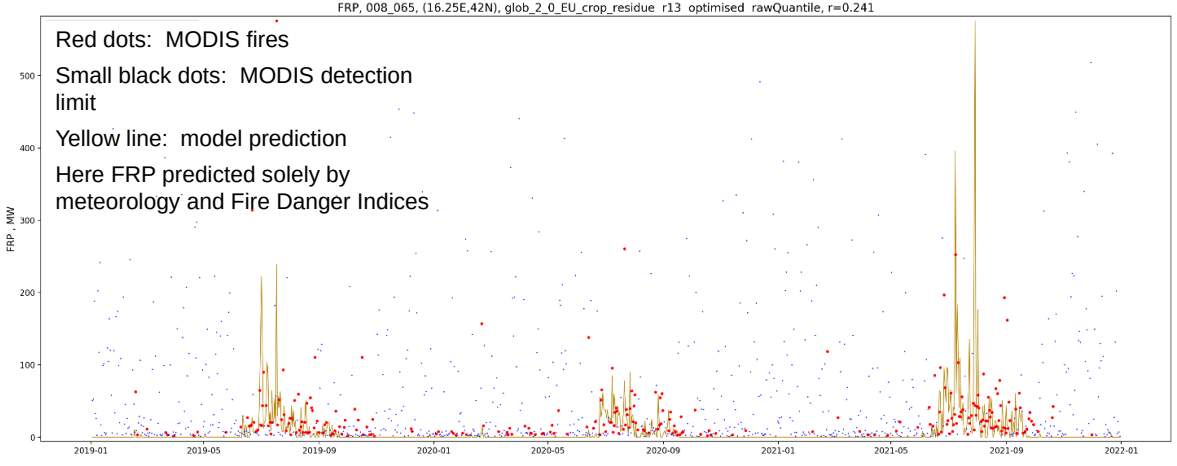
- depends on the area accessibility for people
- varies between the regions

Natural fire ignition is predominantly due to lightning



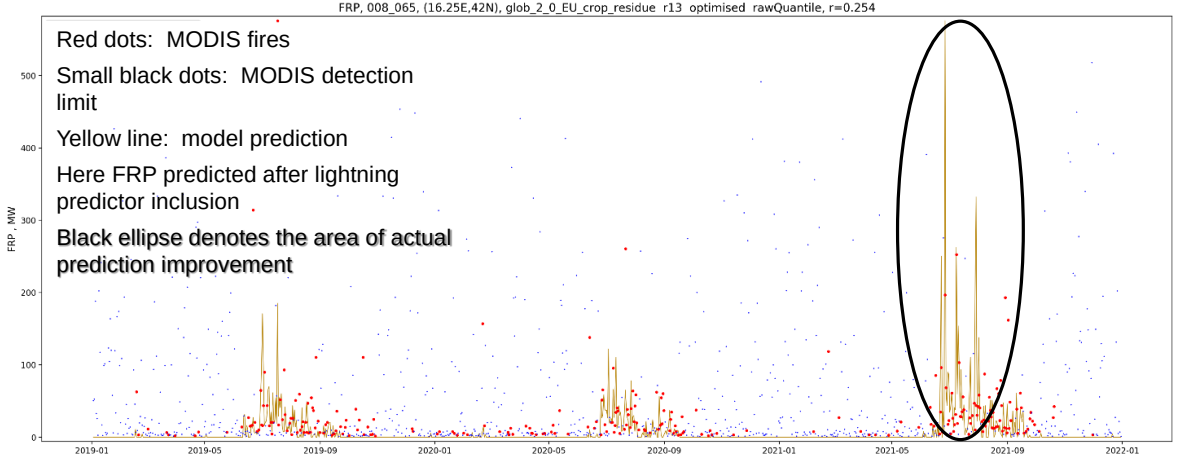
Example of model prediction

Europe, crop residue, 2°×2°, (16.25E, 42N), daily-FRP corr.coeff = 0.24



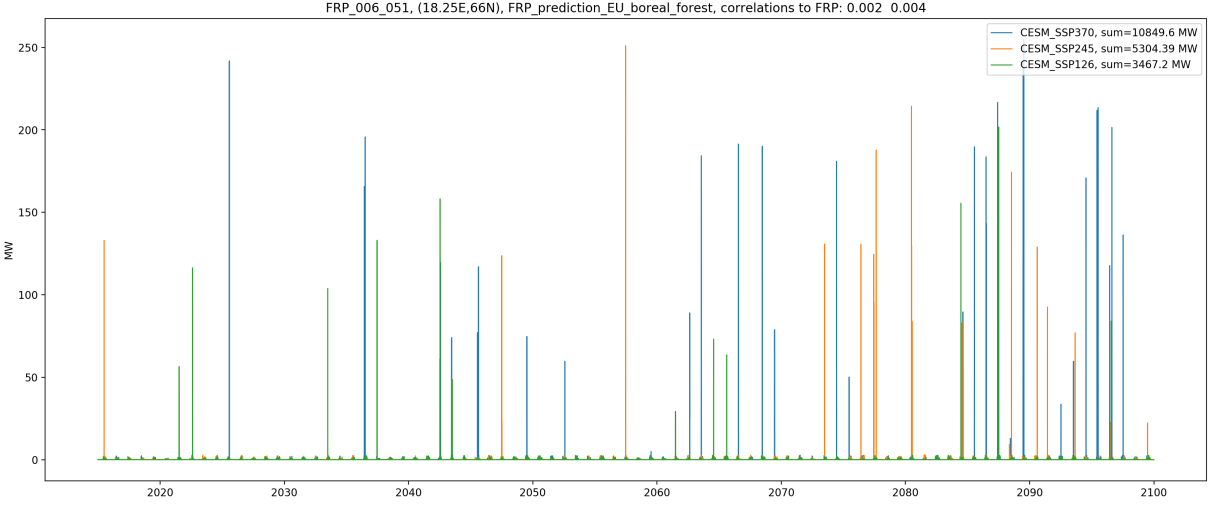
Example of model prediction (incl. lightnings)

Europe, crop residue, 2°×2°, (16.25E, 42N), daily-FRP corr.coeff = **0.254**



Example of model prediction

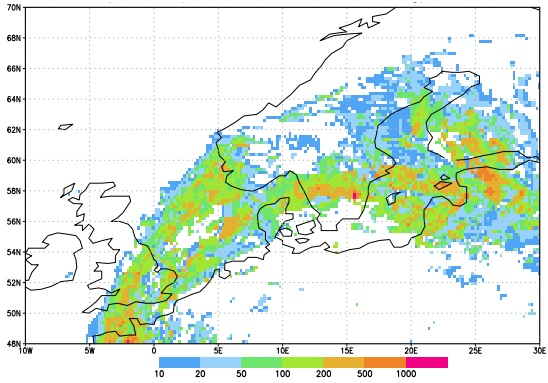
IS4FIRES FFM has been run until 2100 with CESM meteo: SSP 126, 245, 370



Dust on snow in Finland

- Dust on snow 21-23.02.2021
- Citizen-collected samples
- Silam simulations

Deposition observed 100 – 1000 ug/m^2



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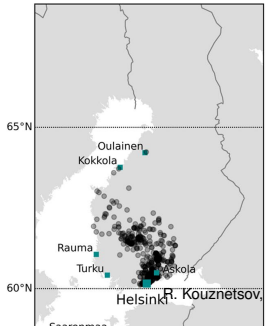
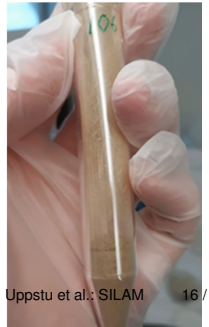
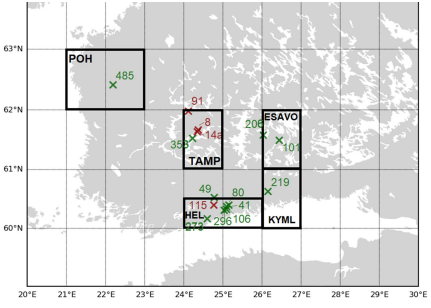
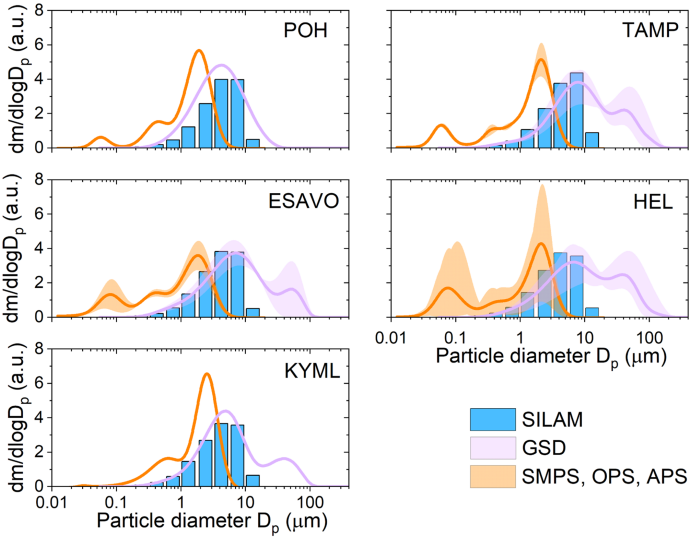




Dust size distribution

- Aerosolize samples and use aerosol sizers (SMPS, OPS, APS)
- Pre-treat and measure size distribution (GSD)





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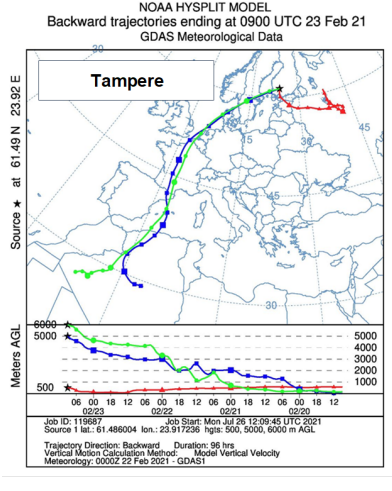
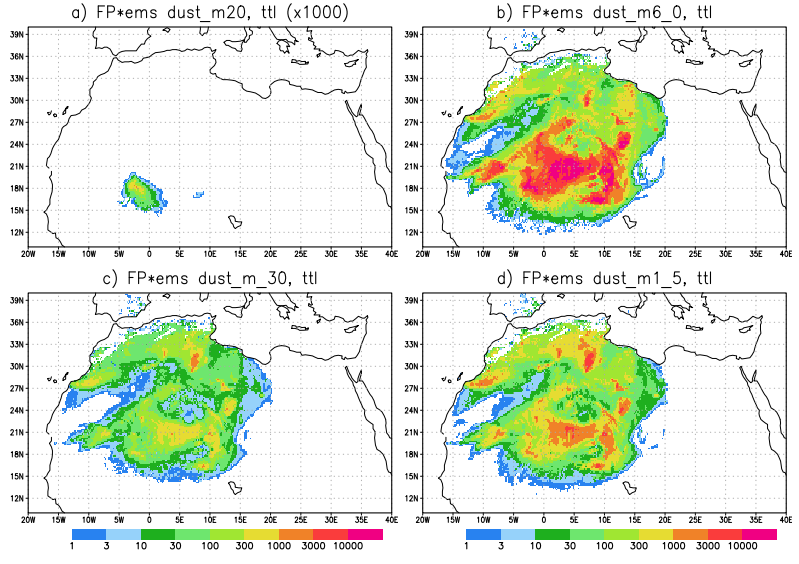
Origin of the dust over Tampere

- With SILAM ⇒
- With backward trajectory ⇓





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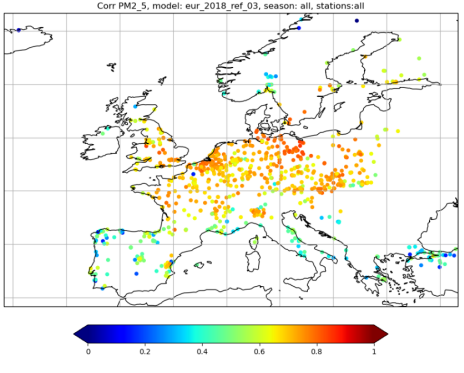
Impact of assimilation of MODIS AOD on surface PM

- Test of whether AOD assimilation improves model surface PM
- CAMS European domain, full year 2018, ECMWF IFS operational meteorological data and boundary condition
- 0.3 x 0.3 deg
- Ensemble Kalman Filter with 40 members
- Perturbation of time of the meteodata, emissions, and boundary conditions
- Model domain extends up to about 100 hPa
- Evaluation against in situ surface AQ stations used for CAMS operational evaluation and level 1.5 AERONET AOD (hourly values for everything)

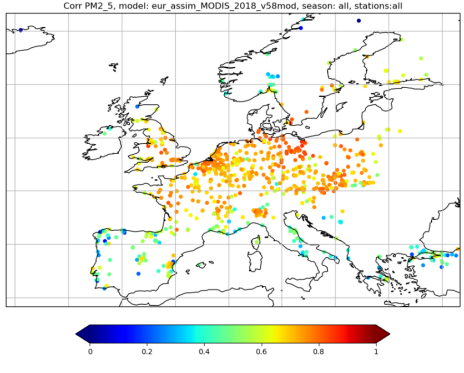
Results

species	corr ref	corr assim	RMSE ref	RMSE assim
PM2.5 ($\mu g/m^3$)	0.70	0.71	9.33	9.15
PM10 ($\mu g/m^3$)	0.54	0.55	14.9	14.7
O3 ($\mu g/m^3$)	0.79	0.80	19.4	19.2
AOD	0.72	0.77	0.86	0.79

Corr, PM2_5 all



Corr, PM2_5 all



Road dust

- Major source of air pollution in the Nordic countries in early spring, but likely also in some less developed parts of the world
- Not included (?) in any CAMS air quality model
- Goal: to develop a basic global model for road dust

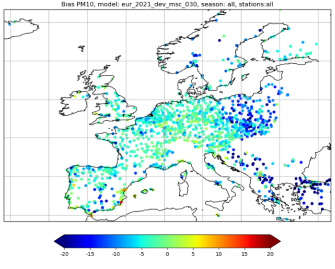
Version 1.0

- Emission is proportional to the traffic NOX emission raised to some power
- Emission is negatively proportional to ”road wetness” (between 0 and 1)
- Roads dry with a rate negatively proportional to the 2 m relative humidity
- Snow present during the past 10 days: 5x emissions

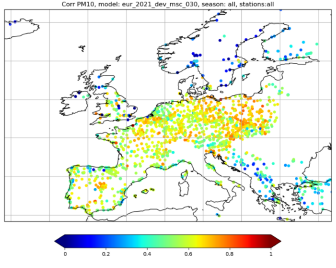
Model performance

No road dust

Bias, PM10 all

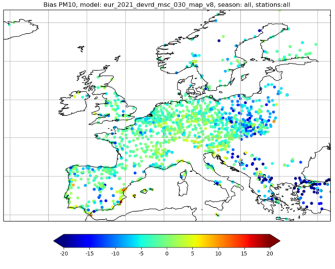


Corr, PM10 all

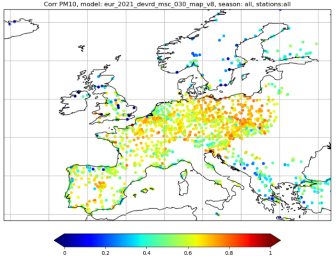


With road dust

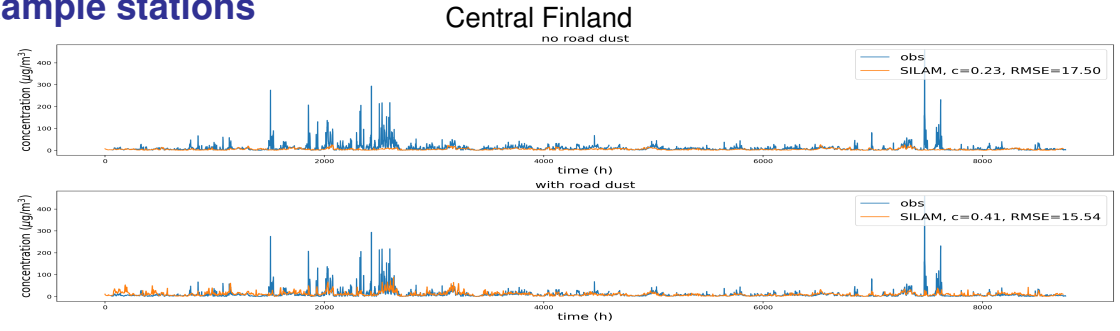
Bias, PM10 all

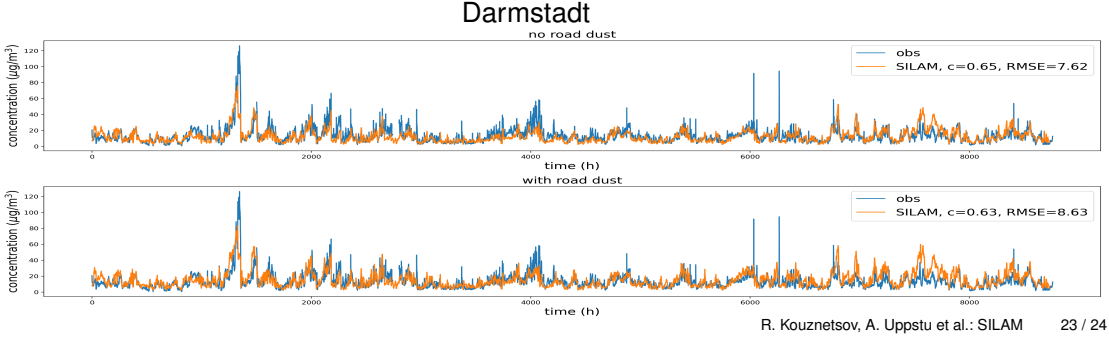


Corr, PM10 all



Example stations





Final remarks

- 0.2° and 0.6° global suites with gas-phase chemistry and aerosols
  - Move to new HPC complete
  - Emission updates soon
- Dedicated 0.1° global suites for fire smoke and for desert dust
- Fire-prediction model for IS4FIRES-SILAM
- Paper on Saharan dust in Finland
- The feasibility of assimilating AOD for the regional forecast has been studied
- New road-dust model
- Data and animations: `https://silam.fmi.fi`