FMI update

Rostislav Kouznetsov, Silam team

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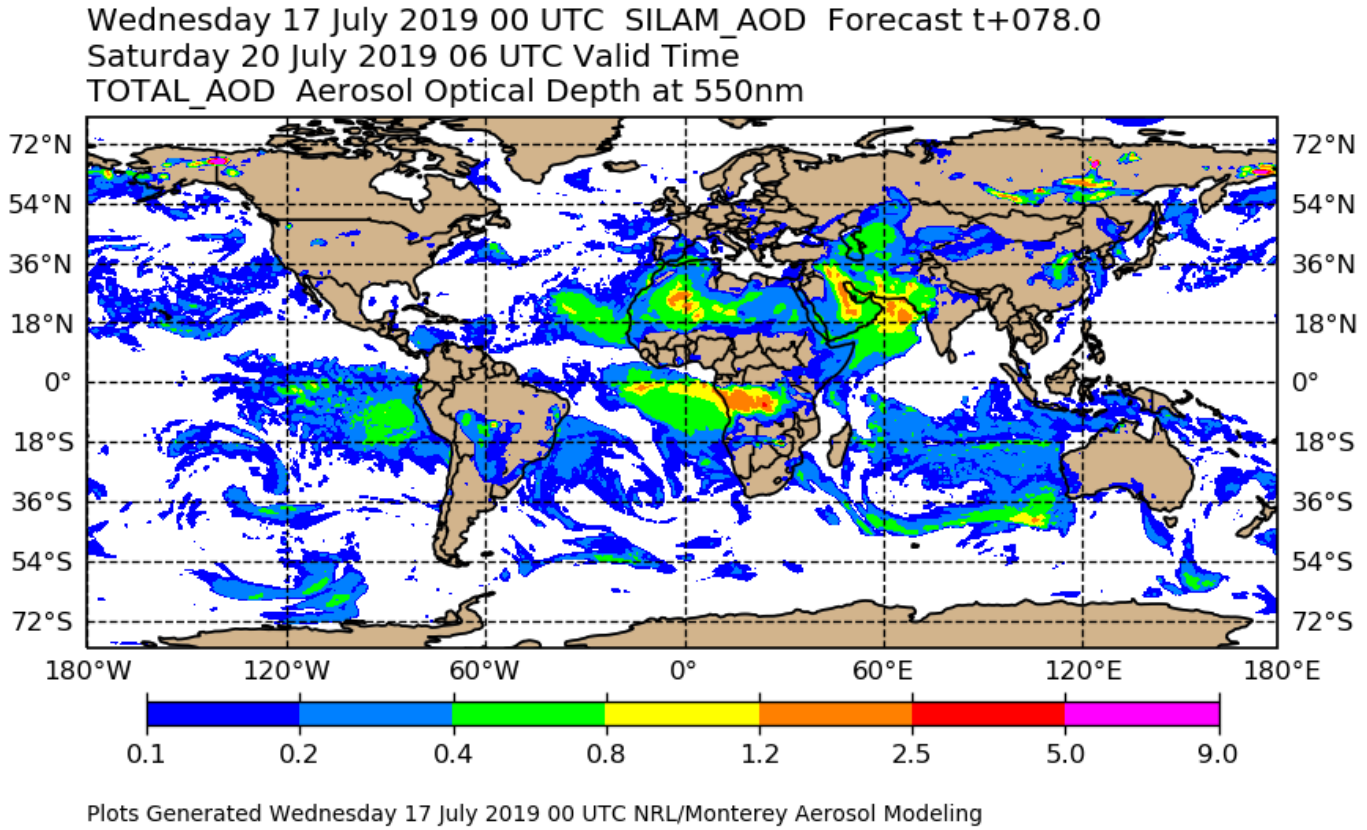
Contents

- Silam outlook
  - Operational suites
  - 10-km global fire-smoke suite
  - 20-km global full-chemistry suite
  - Validation
  - Data availability
- Some research highlights
  - Steam updates
  - Fire-source calibration
  - Source assimilation for African dust
- Conclusions

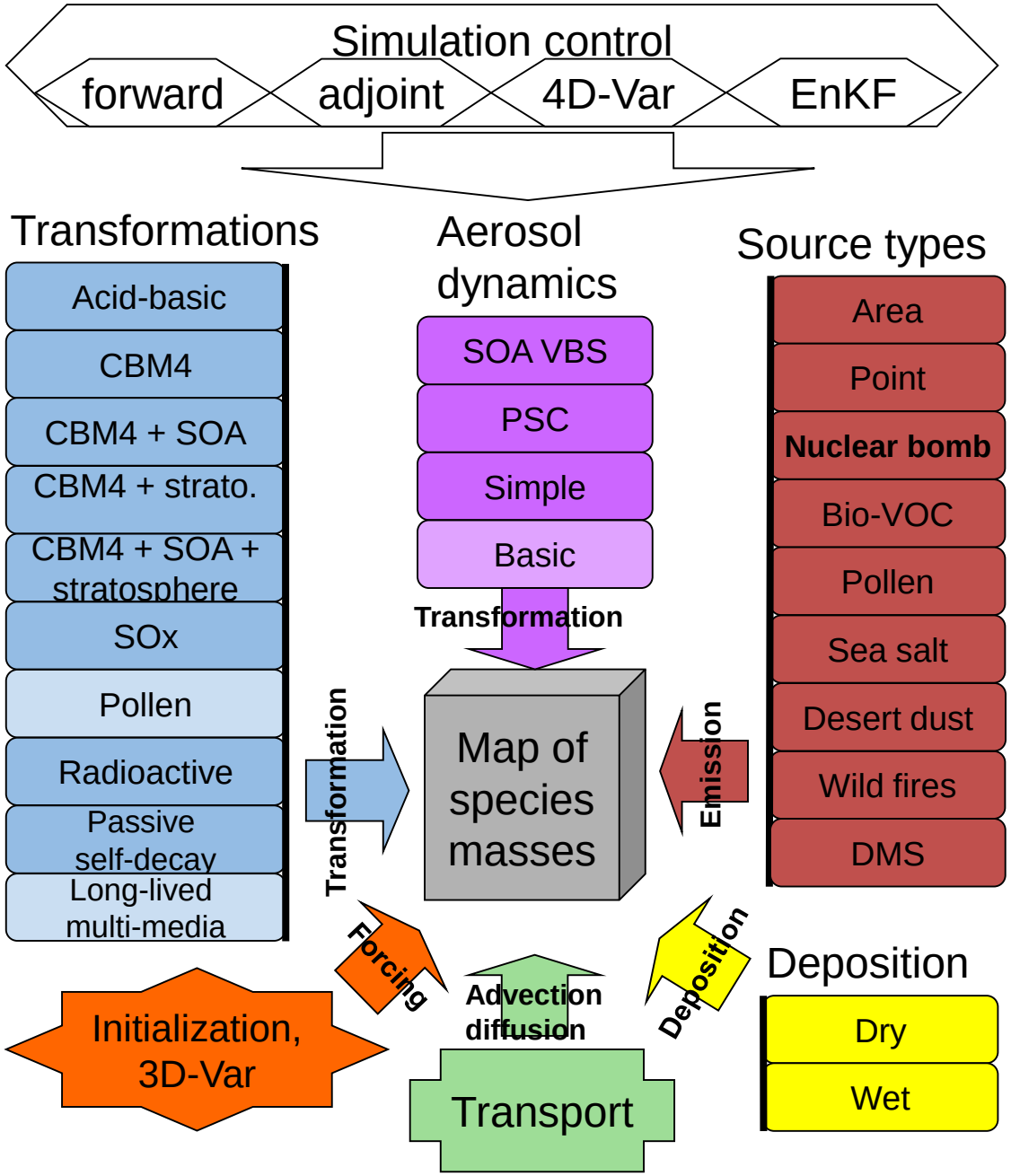


Silam in general

- An offline chemistry-transport model
- Global-to-meso-gamma scales (up to 1km resolution)
- Spans over the troposphere and the stratosphere with the corresponding physical and chemical mechanisms
- Eulerian and Lagrangian transport schemes
- Incorporates adjoint dispersion formalism, 3D- and 4D- variational and ensemble Kalman filter data assimilation
- Developed for a wide variety of problems, from emergency decision support to air quality and atmospheric composition studies and operational activities
- Open-code system, installed in 7 countries, modules used in >10 other models

SILAM v.5.6

- Modules
  - 10 chemical and physical transformation modules (8 open for operational use)
  - 9 source terms (all open)
  - 4 aerosol dynamics (3 open)
  - 3D-,4D- Var, EnKF, EnKS
- Domains: from global to beta-meso scale (~1km resolution)
- Meteo input:
  - ECMWF
  - HIRLAM, HARMONIE, AROME
  - WRF
  - ECHAM, NorESM, other GCM / RCM



SILAM AQ modelling

IS4FIRES

Physiography, land use forest mapping

STEAM emission model

AIS ship data

Anthropogenic emission data

Global boundary cond. + own simulations

Fire emission model

Desert dust emission model

Phenological model

BioVOC emission model

Sea salt emission model

SILAM CTM

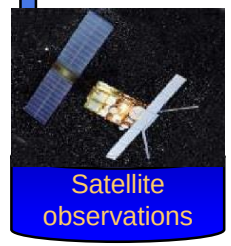
Meteorological data

Global: ECMWF
Regional: HIRLAM, WRF
Meso-scale: HARMONIE, AROME,WRF
Climate scenarios: ECHAM, RCA, G/RCM

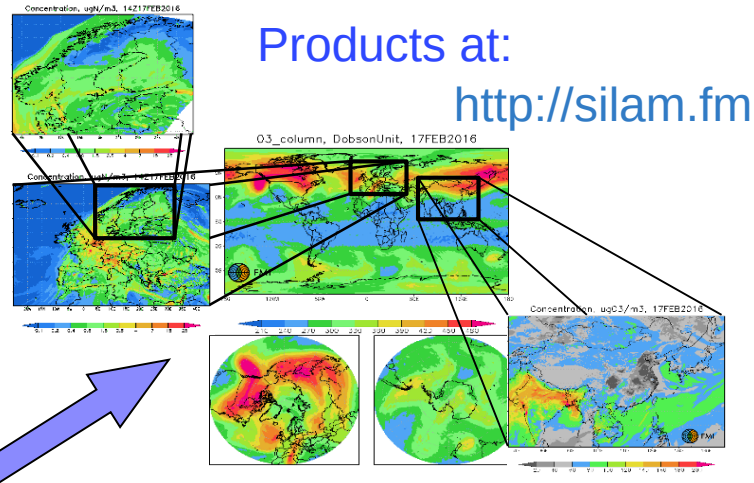
EVALUATION and DATA ASSIMILATION 3D-, 4D-VAR

Online AQ monitoring

Aerobiological observations



Products at:
http://silam.fmi.fi



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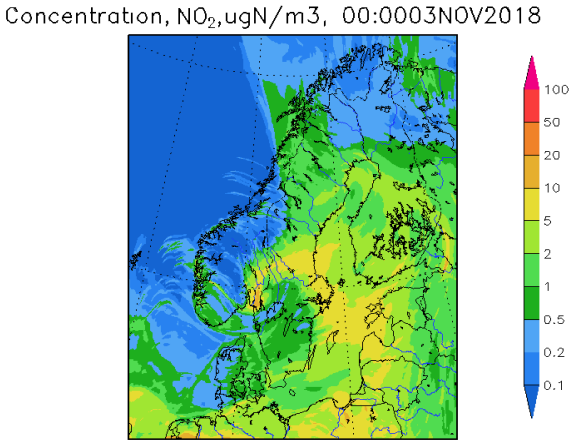
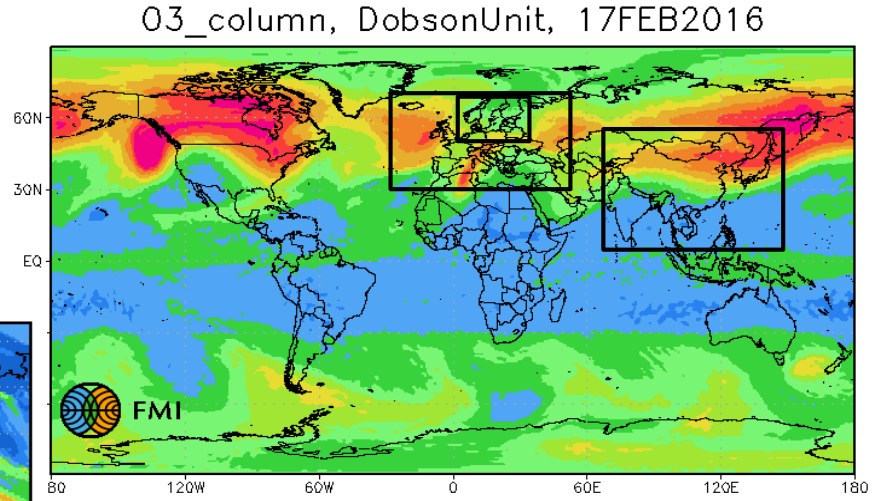
Operational AC/AQ-chain

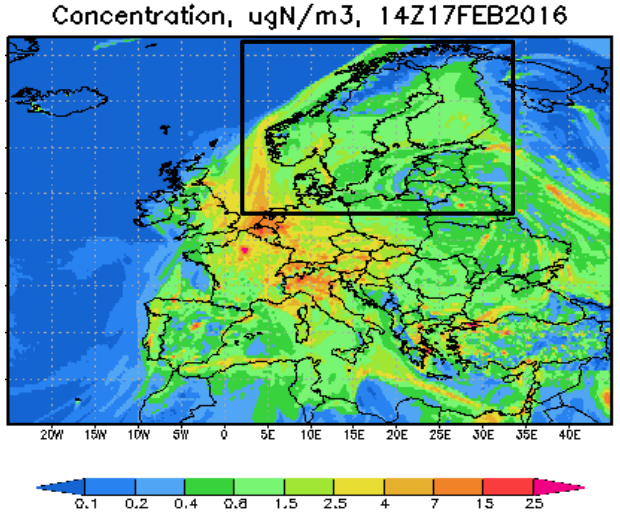


Northern Europe:
2.5km, troposphere

Global: 20km (NEW),
troposphere+ stratosphere

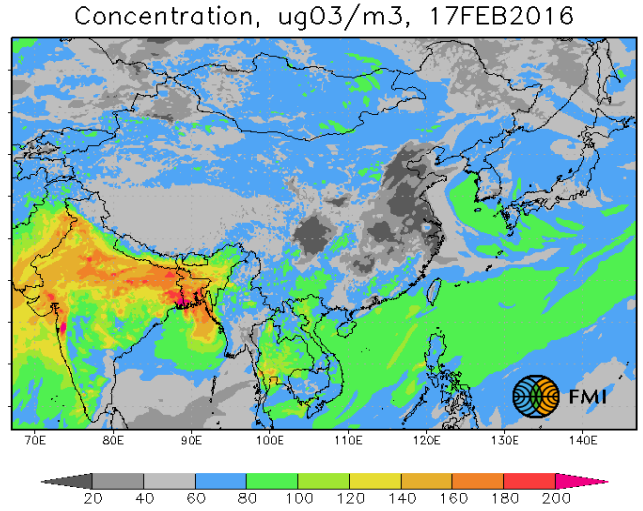


All forecasts:
4 days with 1hr step,
SILAM v.5.5/5.6
http://silam.fmi.fi

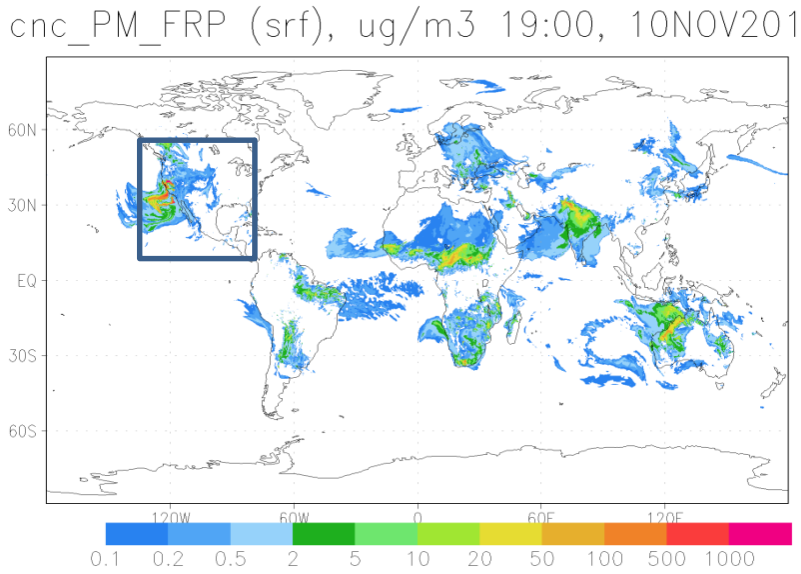


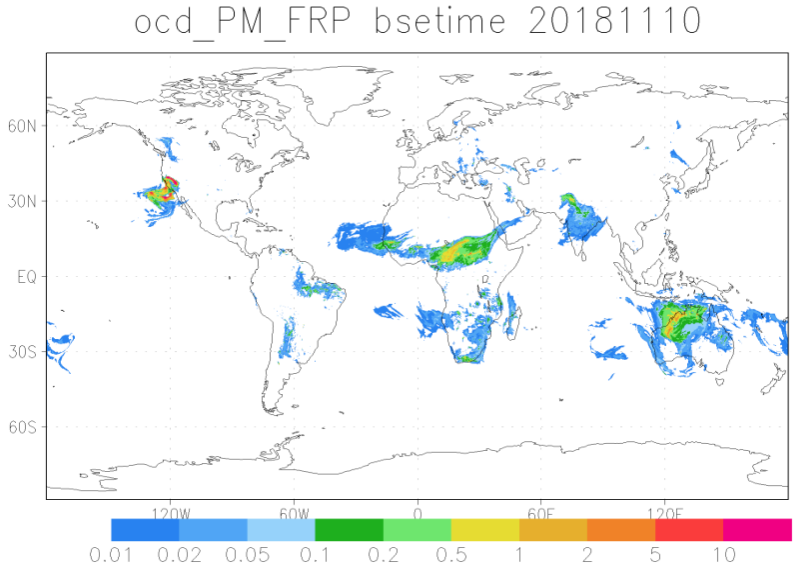
Europe:
10km, troposphere
boundaries: C-IFS
hindcast: 3D-Var

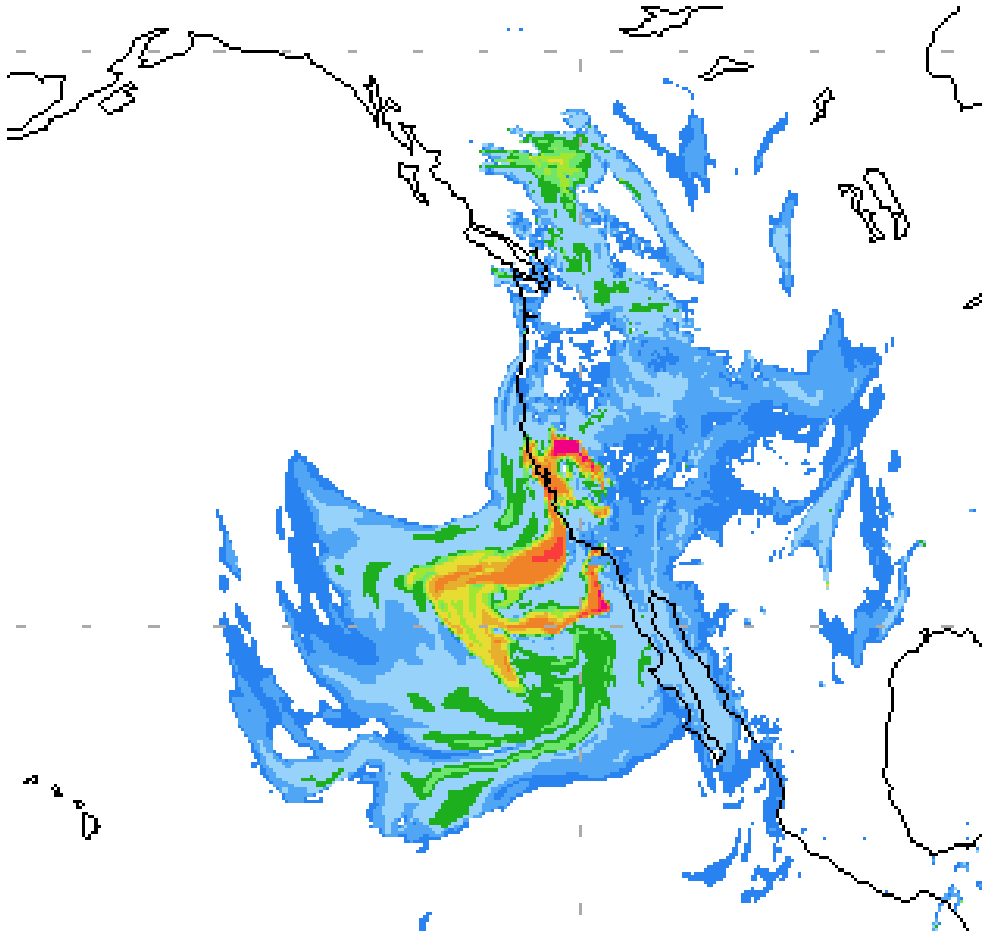
Asia: 14km,
troposphere



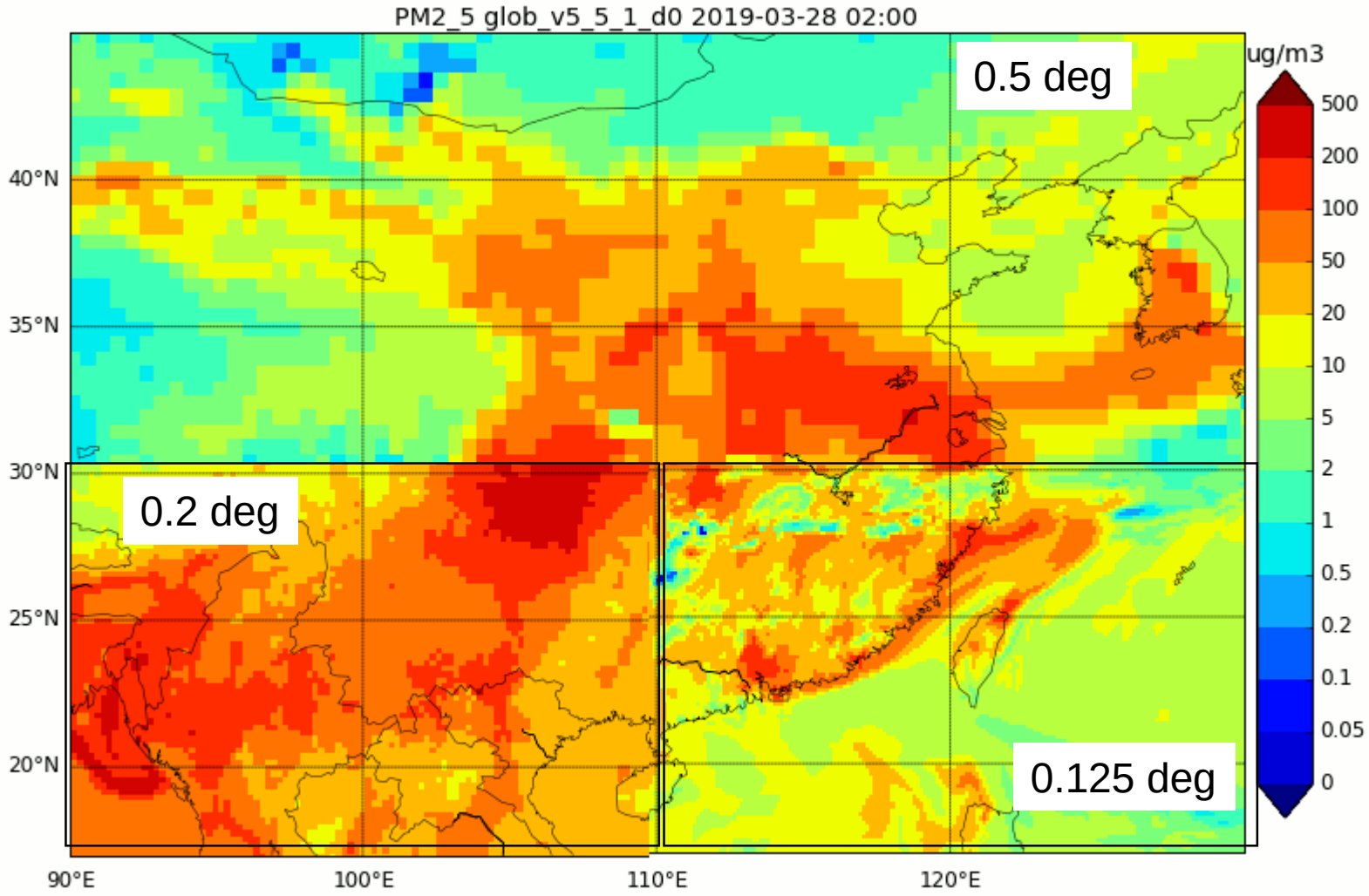
Hi-Res Fire suite 0.1 deg. glob







Hi-Res Globe

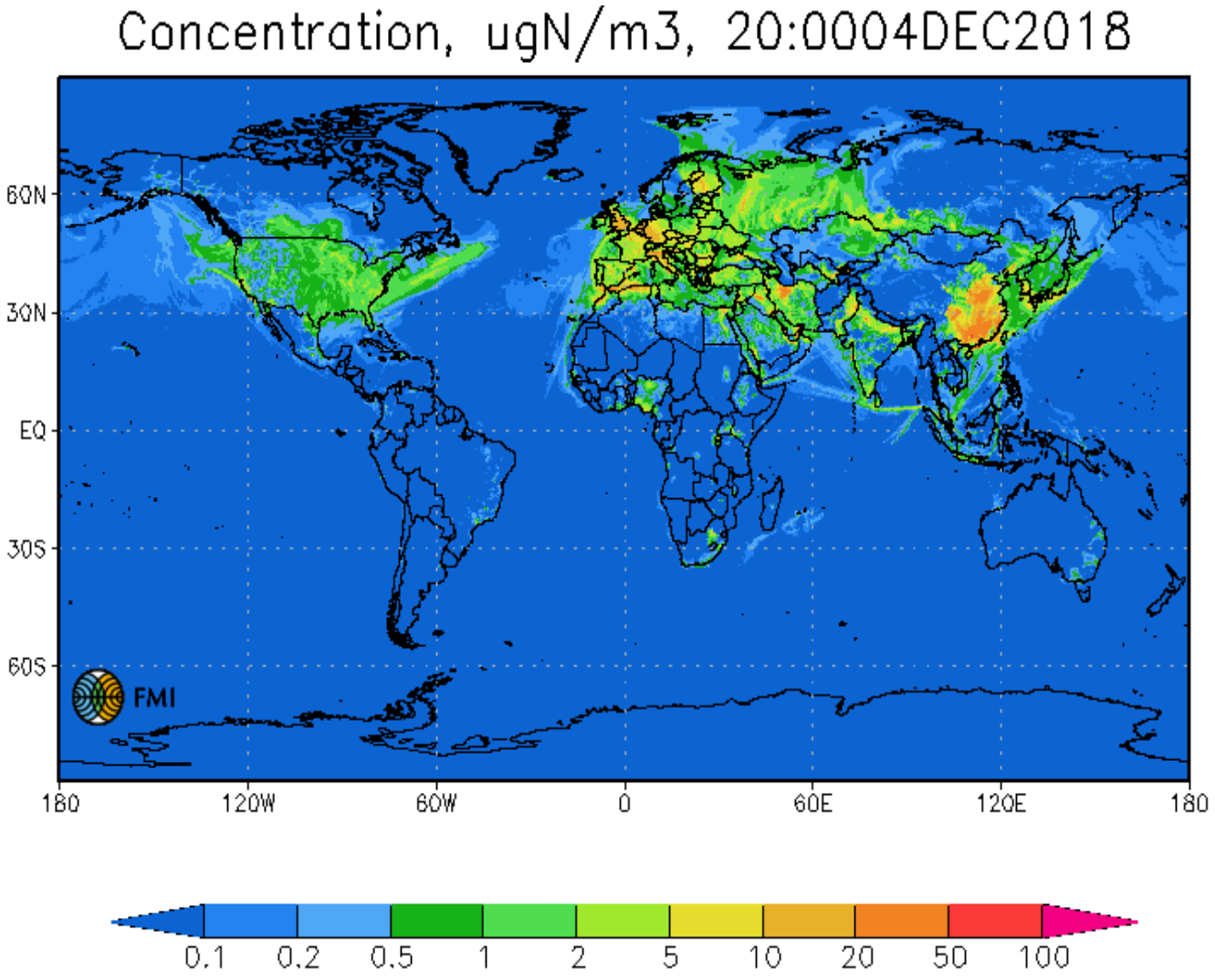


- AQ/AC forecast
  - High-resolution
  - Global
  - Free-running

Applications:

- Global exposure effects
- Boundaries for regional AQ anywhere
- Many more…

0.2deg Global AQ suite

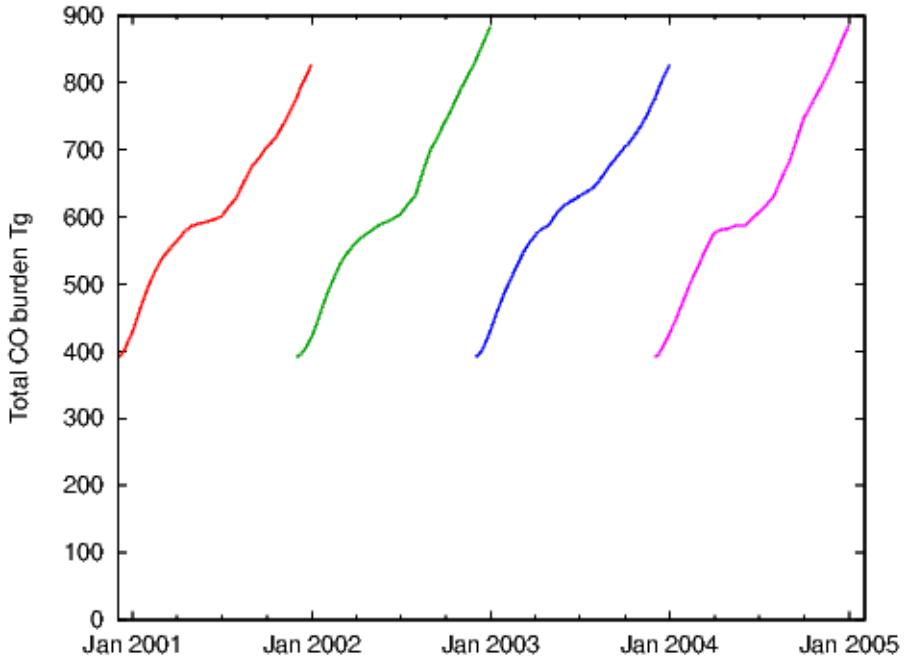


- 0.2 deg ECMWF meteo
- MACCity inventory
- 7 days of forecast from -2 days, hourly output
- 29 layers up to 10 Pa
- Full CBM4 + Strato +SOA: 113 tracers
- 3 hours @ 64 nodes of Cray XT40 (3.5k CPU, hyper-threaded)
-

Challenges

- Very heavy runs
  - Compute power
  - Scalability
- Very large output
  - Post-processing
  - Distribution
  - Archiving
- Stratospheric chemistry
- Closed system
  - Integrates errors
  - Long relaxation times

Example:
CO burden in global simulations
(one of first trials few years ago)

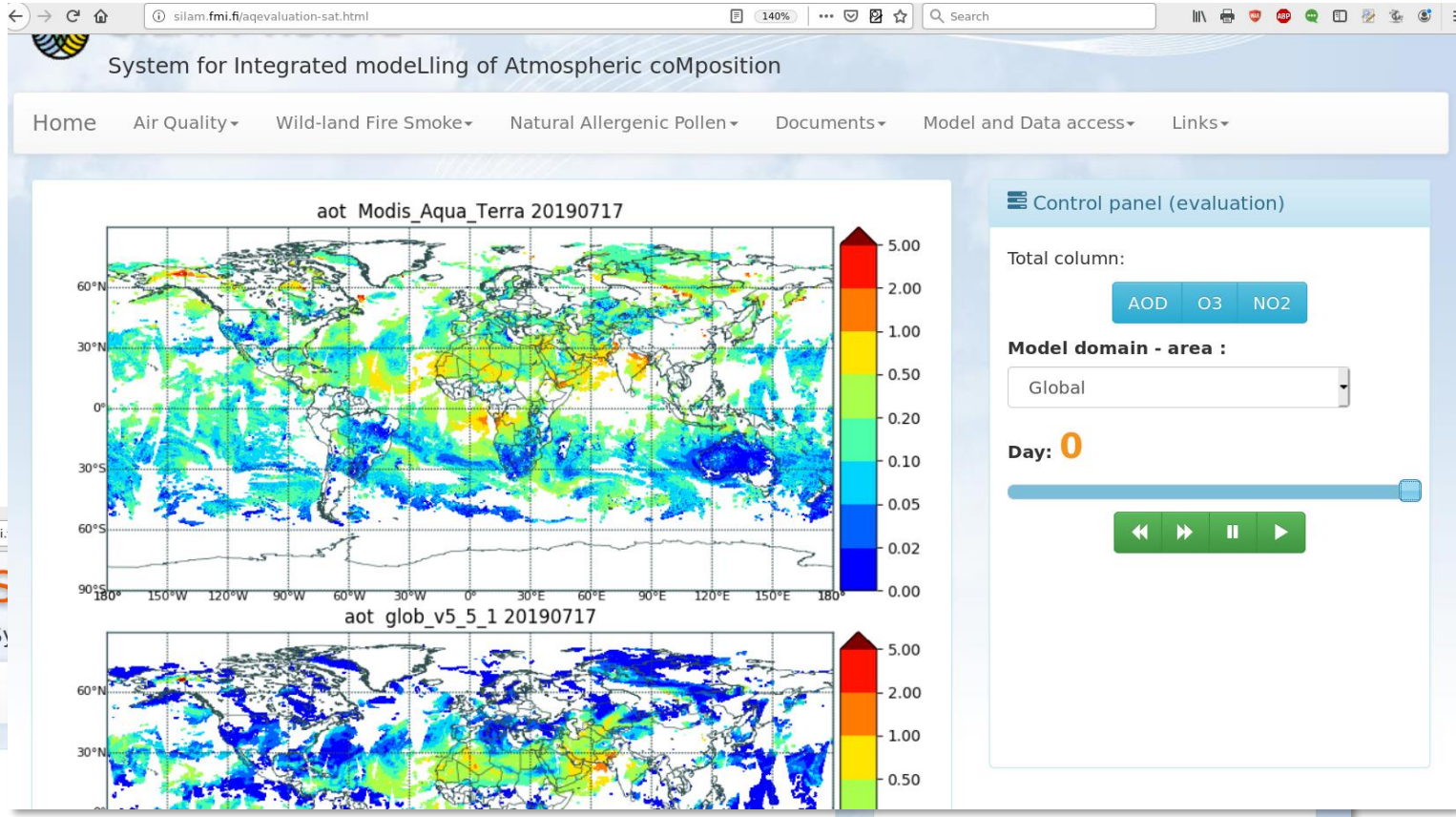


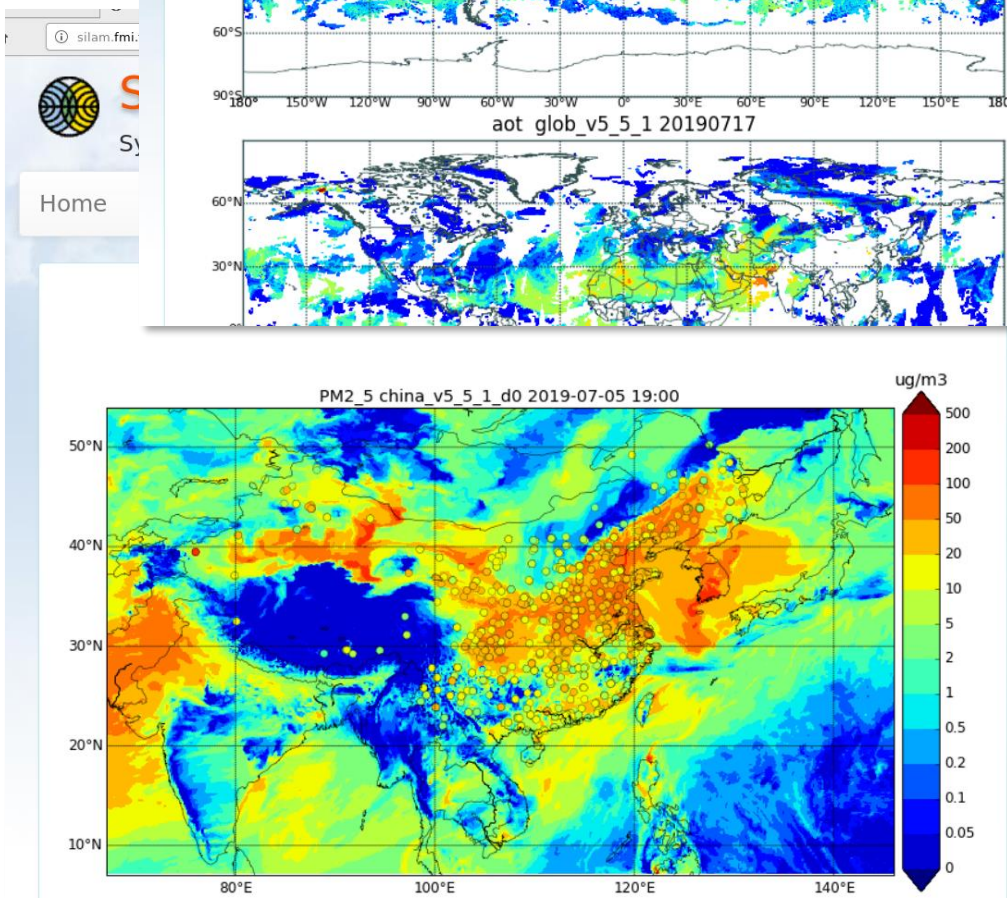
Currently, CO performs much better

Validation

- Satellite collocated columns
- NO2 -- DOMINO
- O3 -- OMI
- AOD – MODIS
- In-situ
- Chinese AQ network
- O3 NO2 CO SO2 PM2.5 PM10

- http://silam.fmi.fi
  -> AirQuality
  ->evaluation





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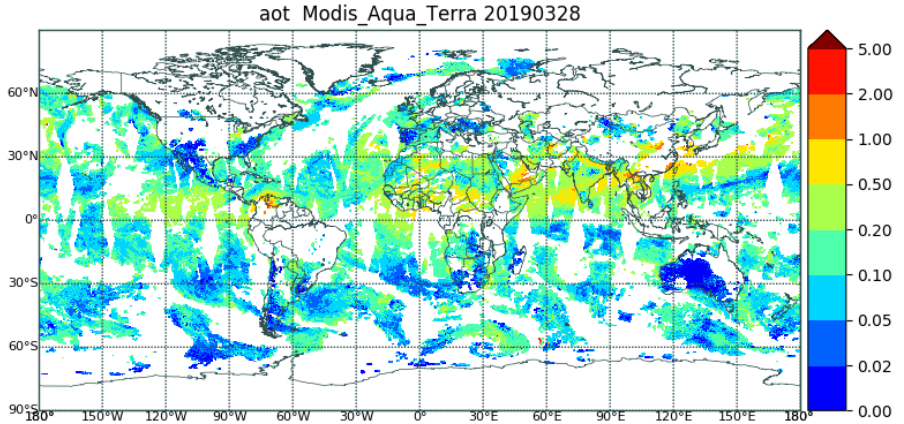
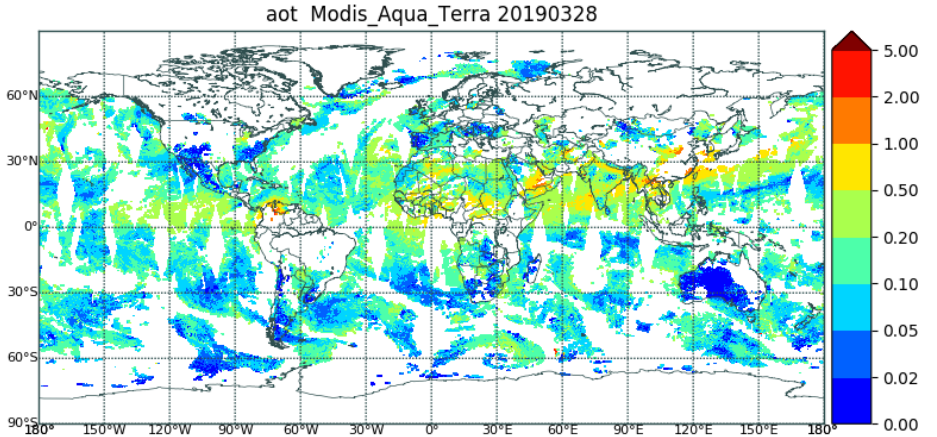
MODIS vs Silam AOD evaluation

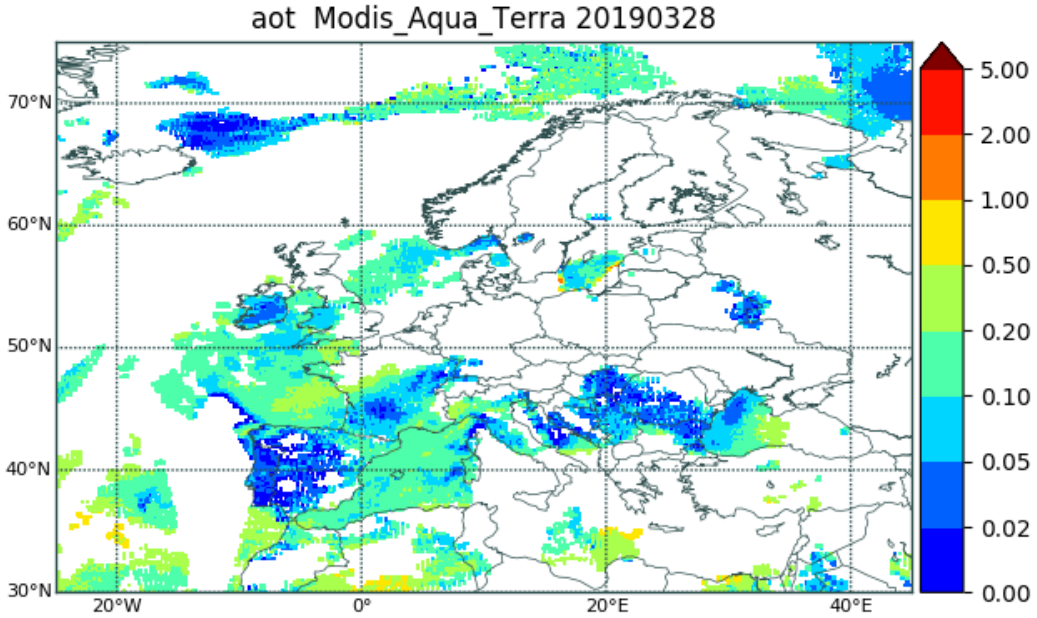
0.2 deg glob

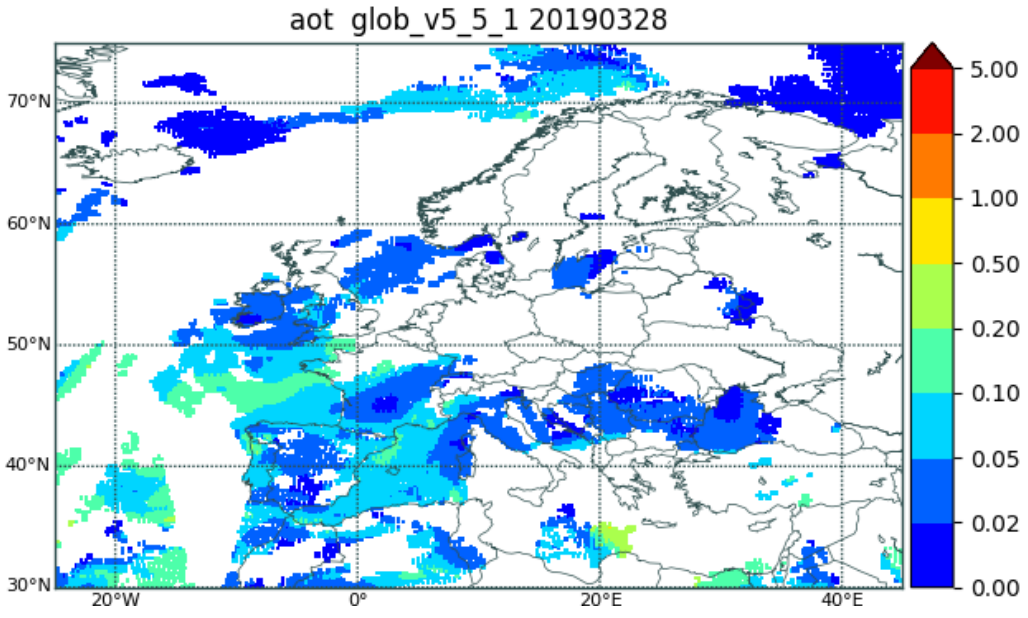


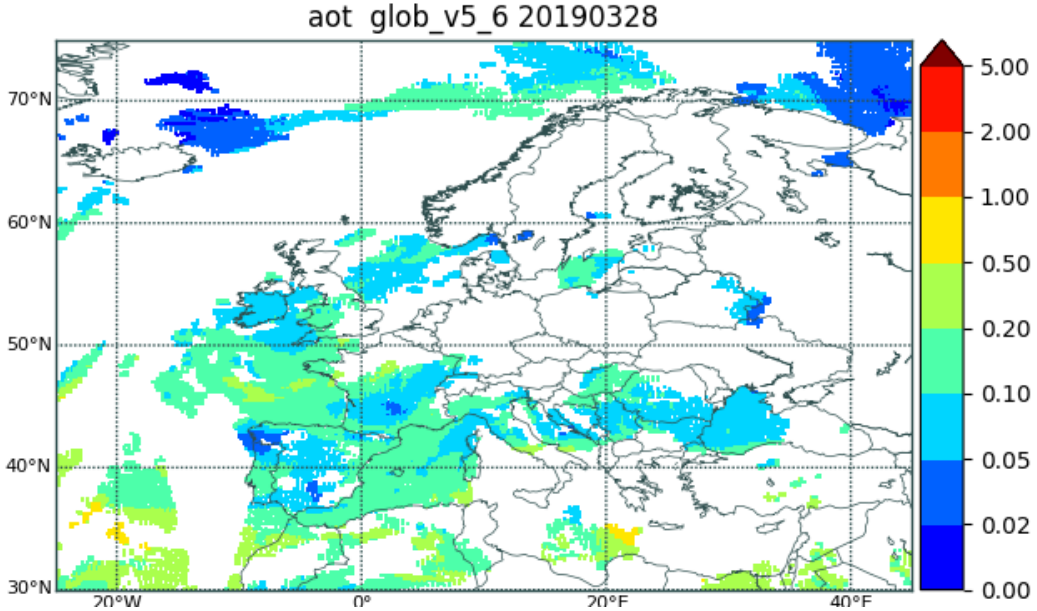
0.5 deg glob

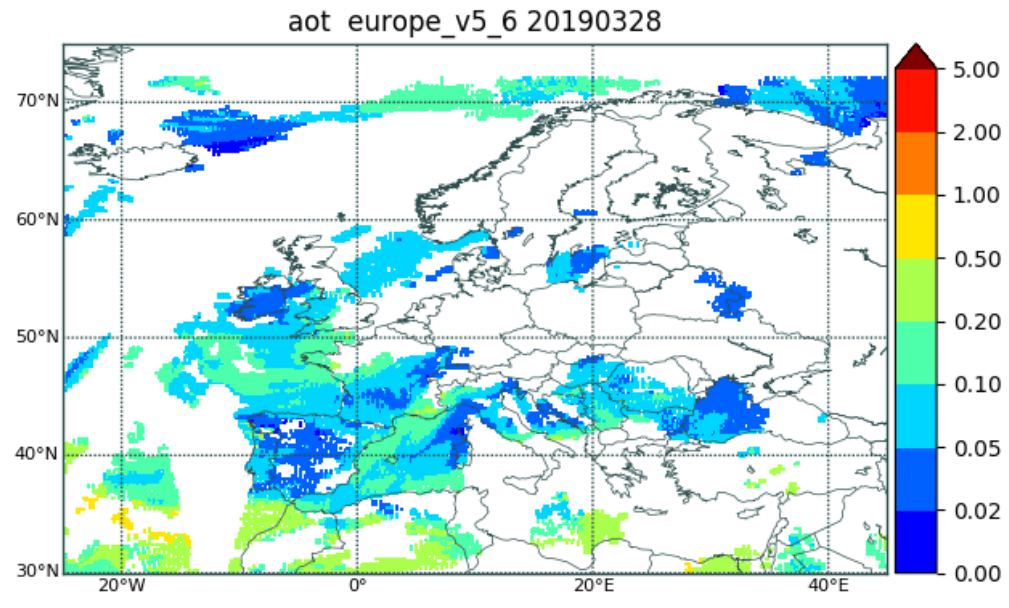


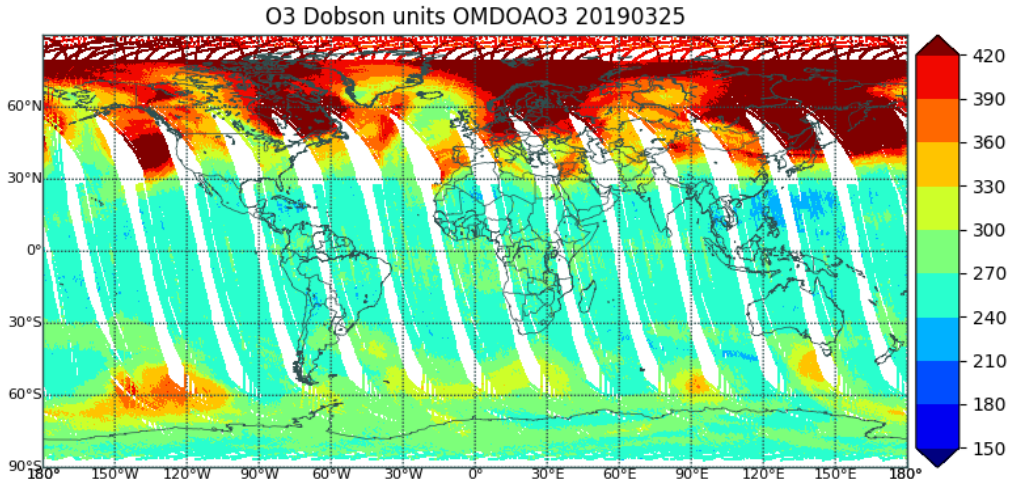
MODIS vs Silam AOD evaluation

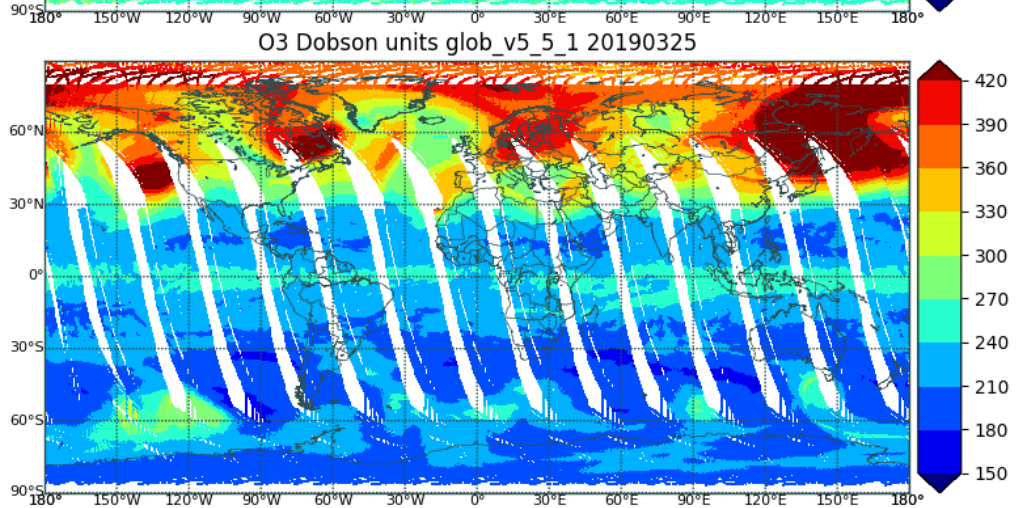


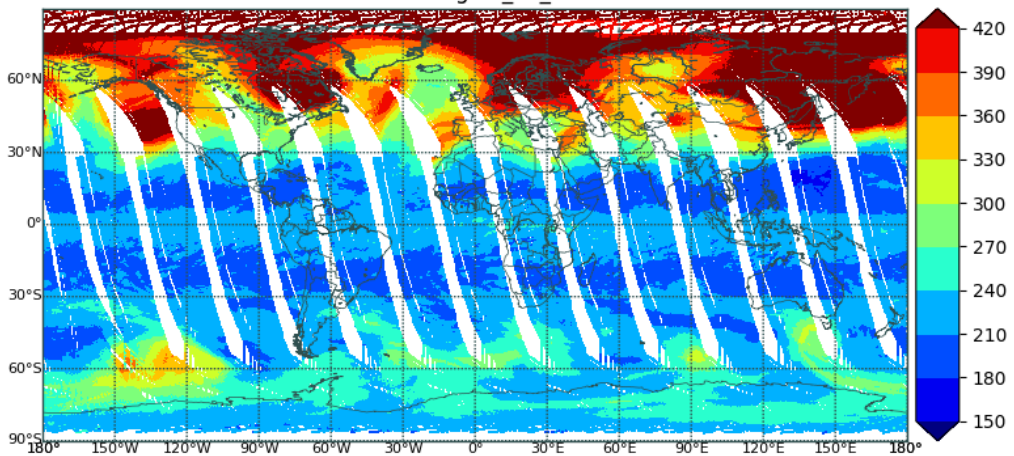


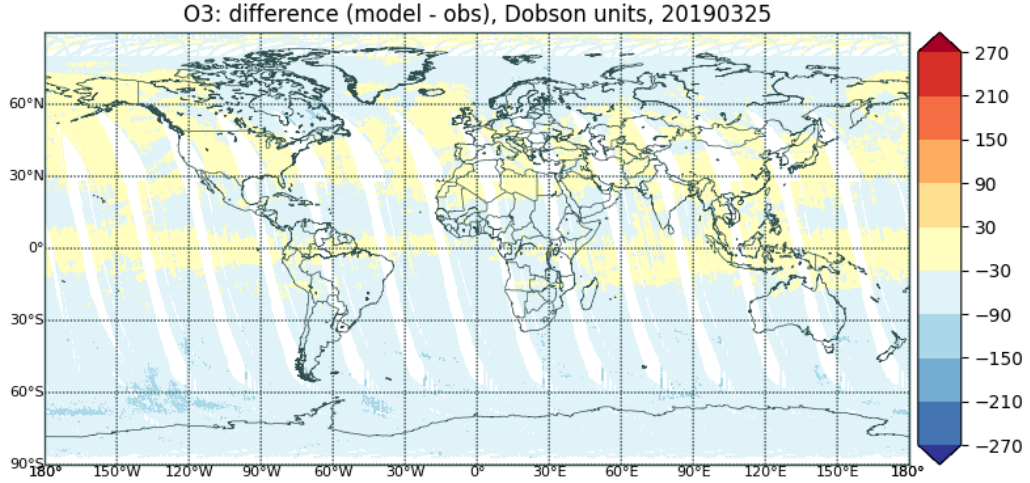


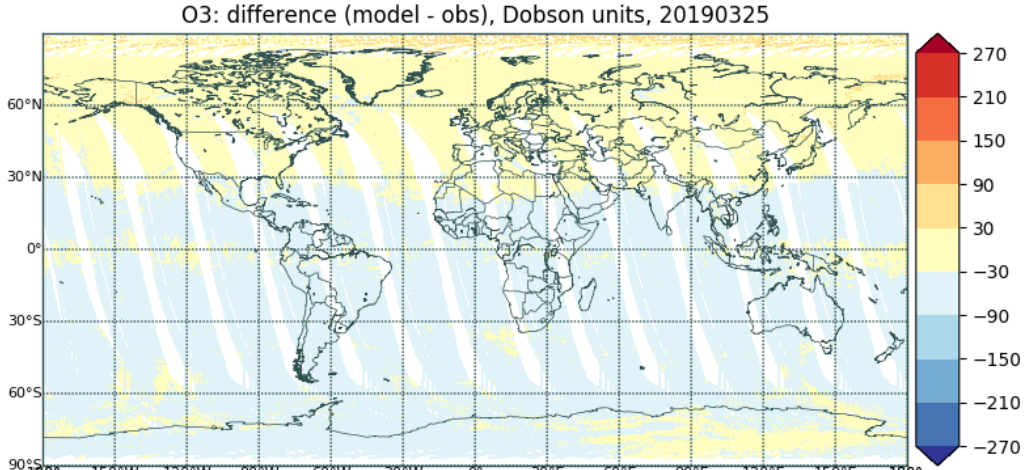






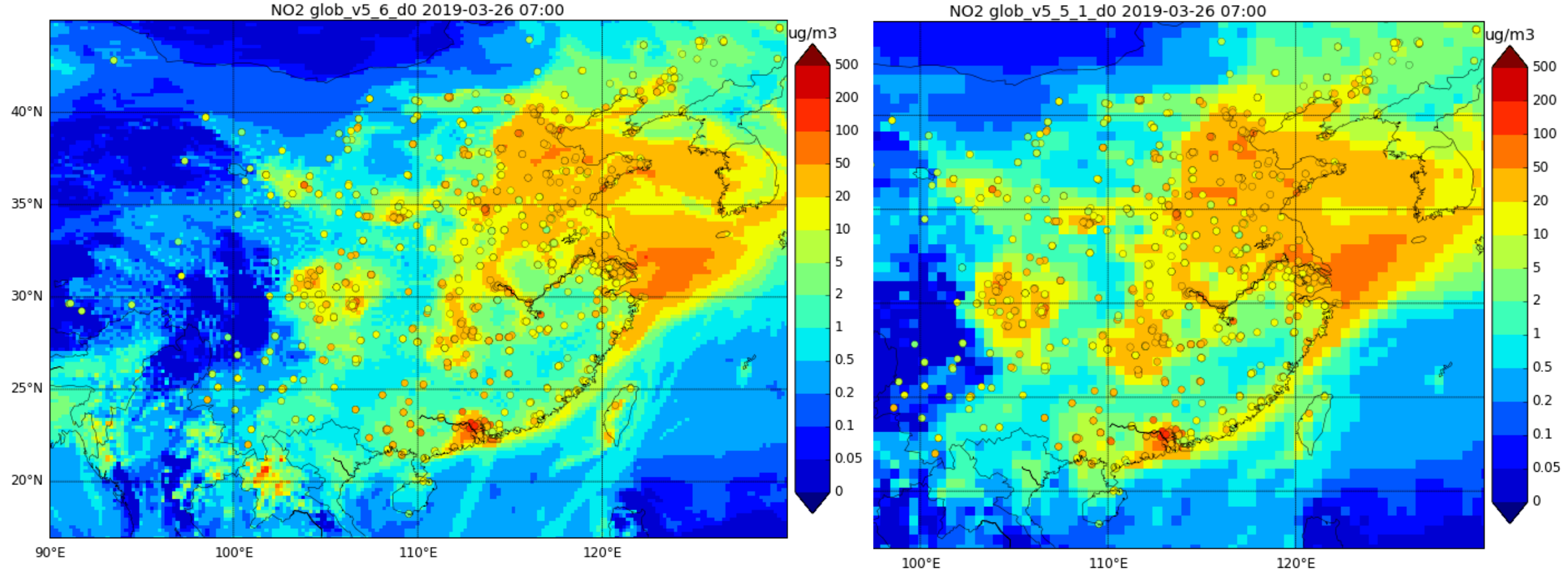






- Better spatial patterns of O3 layer
- Low stratospheric O3 in tropics

Evaluation with Chinese stations



- ~1500 stations reporting hourly
- Unknown source/area type
- Unknown representativeness

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Data access

- Pictures and animations online
- http://silam.fmi.fi/

- Hourly forecasts: last few days – full model output online
- http://silam.fmi.fi/thredds (Model & data access -> All AQ forecasts)
- Needed subset can be requested

- Archives (on request):
- Surface hourly pollutants + daily mean, max
- Forecasts (first day fields)
- Retrospective simulations for past years

Fire smoke emission: IS4FIRES

IS4FIRES is4fires.fmi.fi

AN INTEGRATED MONITORING AND MODELLING SYSTEM FOR WILDLAND FIRES

- **IS4FIRES home**
- **Fire emission data**
- **Vertical injection profiles**
- **Fire plume forecasts**
- **Meetings** (intra)
- **Documents** (intra)
- **Research and publication plans**
- **Participants**
- **Models**
- **Related projects**
- **Useful links**

Contact
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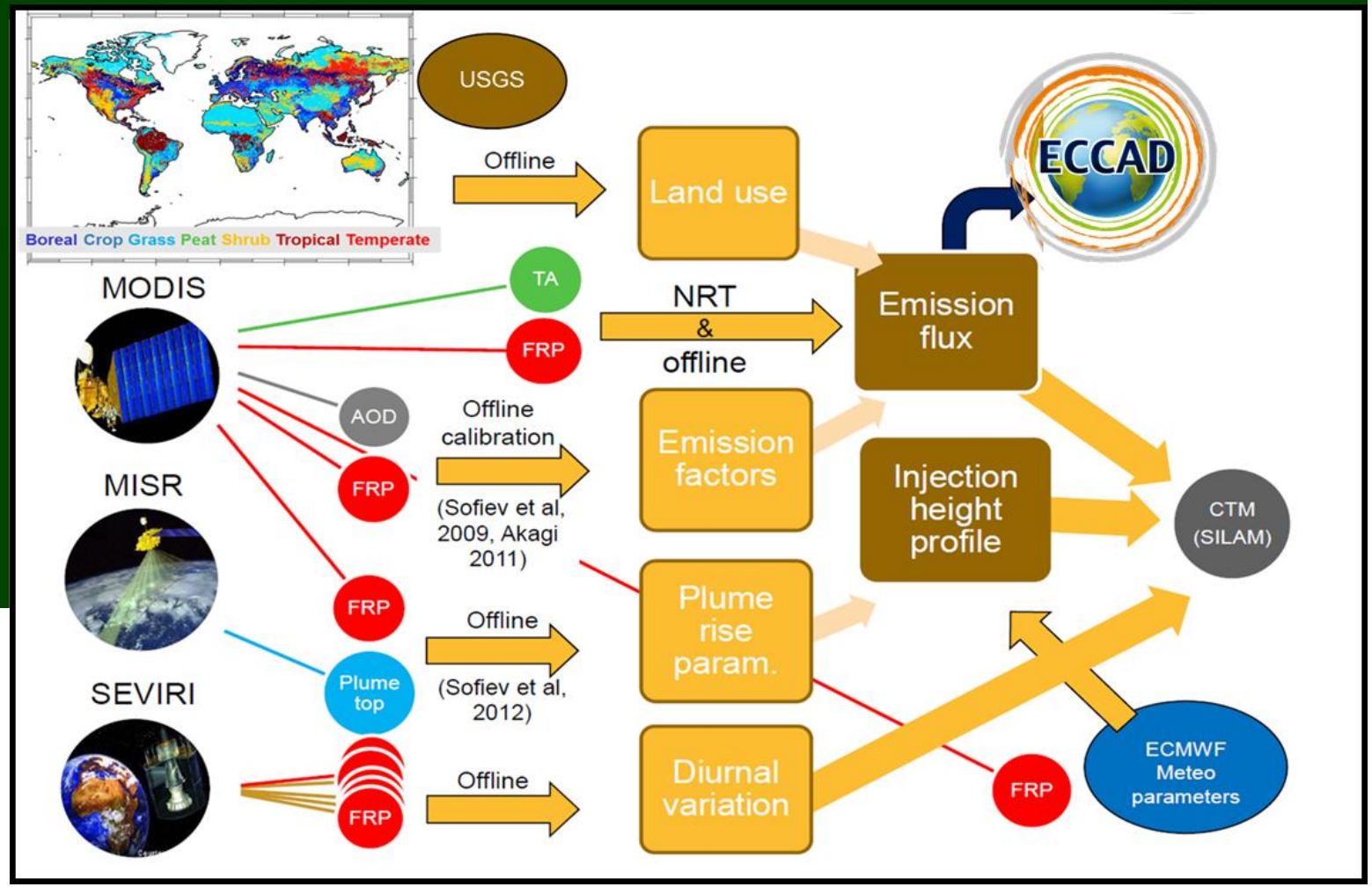
Coordinators:
Mikhail Sofiev & Jaakko Kukkonen

Web pages:
Mari Kauhaniemi



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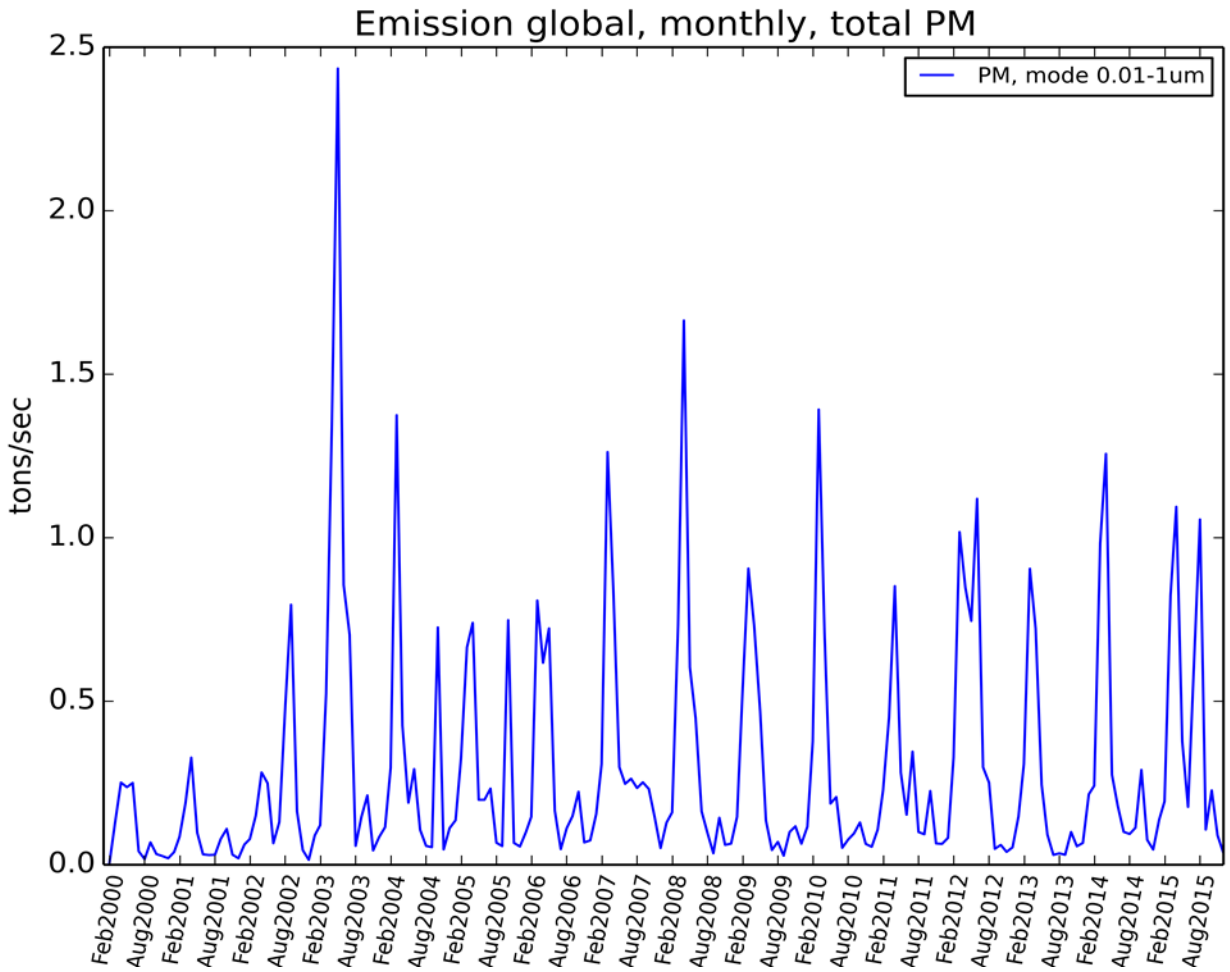
Features of IS4FIRES v.2

- Top-down emission calibration for 7 land-use types
  - additional segregation of forests with regard to continents seems reasonable
- Bottom-up plume calculation with dynamic injection height
  - both fire features and meteorology drive the uplift
- High-energy permanent sources are masked out
- Aerosol size spectrum is reviewed and parameterized from direct observations (under evaluation)
- Separate consideration given to flaming and smoldering fires (in progress)

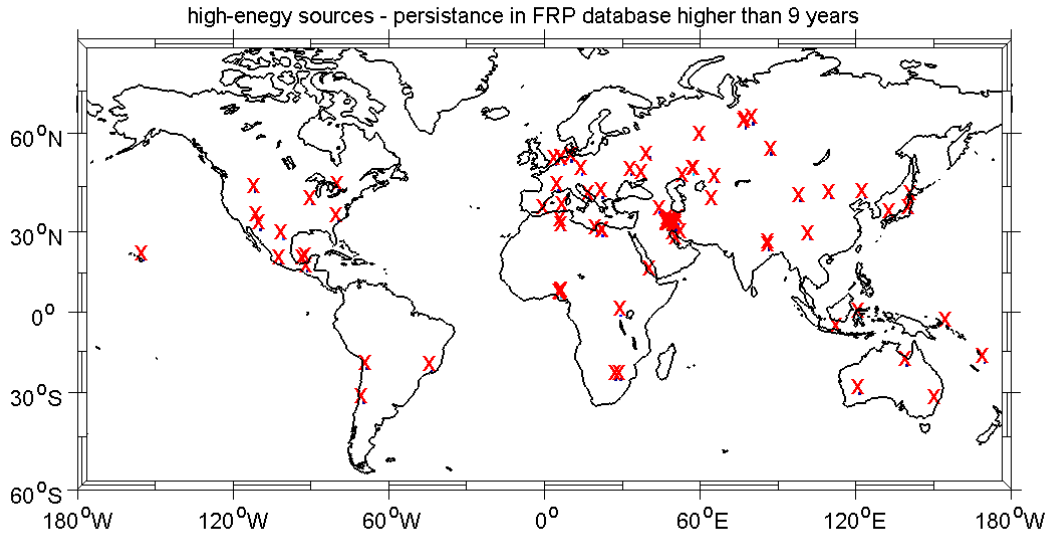
Challenge: Emissions depend on coverage

- Top-down calibration
- Incomplete information
- Observed fires
- Observed plumes
- Plumes from observed fires are biased due to non-observed ones
- New observations will require recalibration
- Regional for geostationary satellites

IS4FIRES (MODIS) global totals

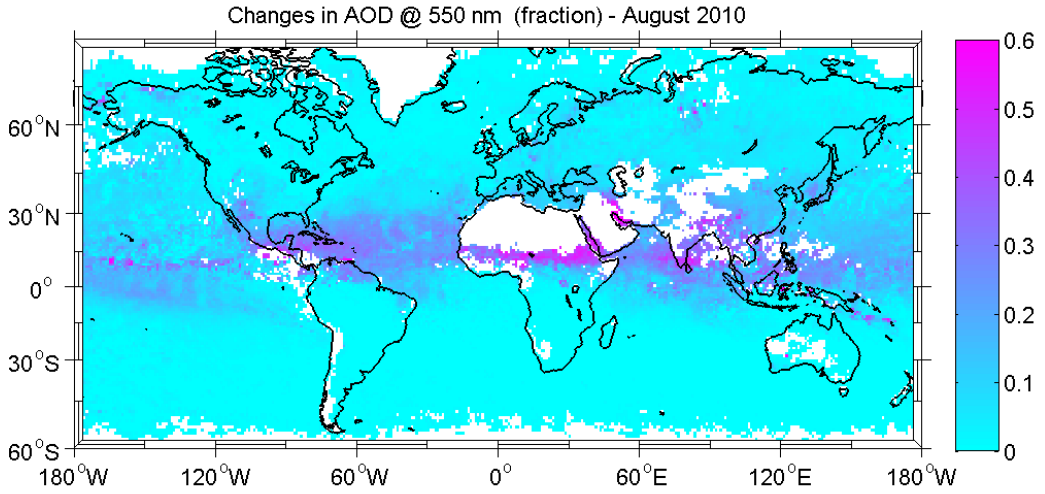


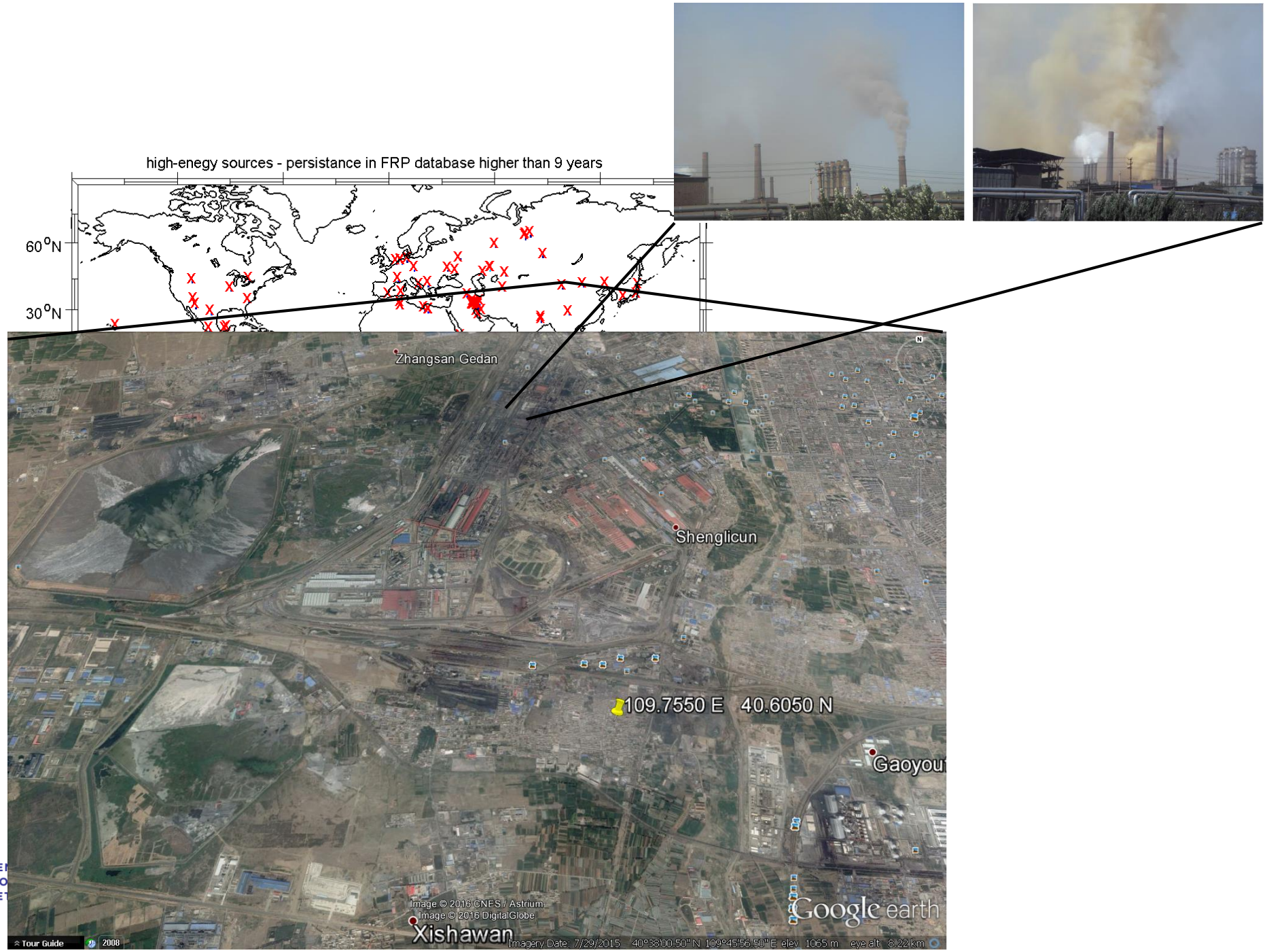
High-energy non-fire sources



- ✓ fires occurring in each 3 × 3 km pixel over the globe: MODIS-FRP
- ✓ Suspicious: > 50 fire days in a year
- ✓ Over 2002 - 2013, 402 cells were flagged more than 4 times.
- ✓ Final constraint: 9 years persistence.

- ✓ Clear impact of oil extraction/production plants
- ✓ AOD can be reduced by ~60% in the immediate vicinity of the sources but effect quickly falls out with distance from the oil flares.





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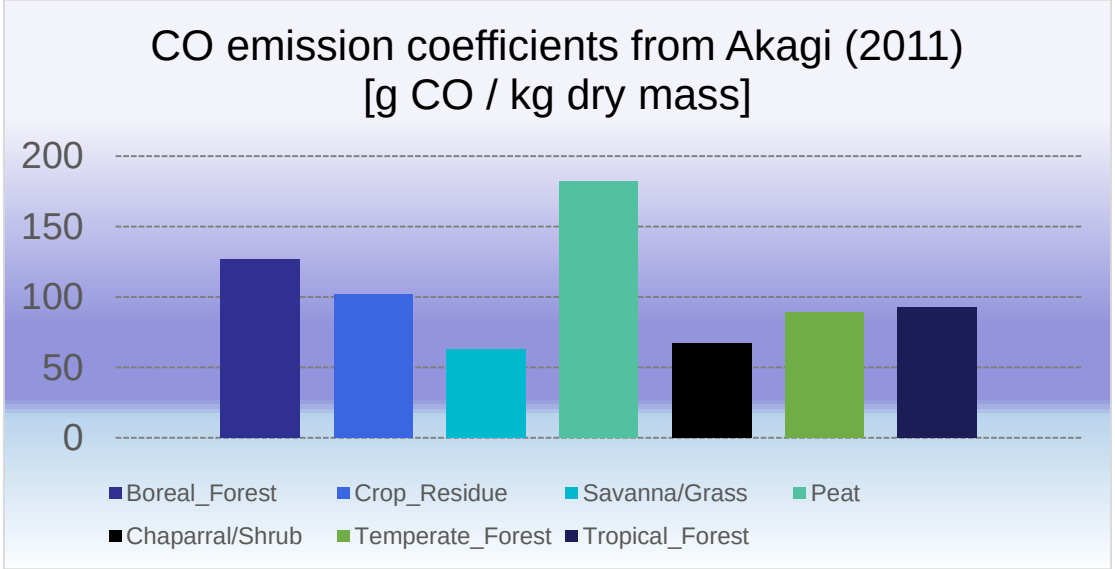
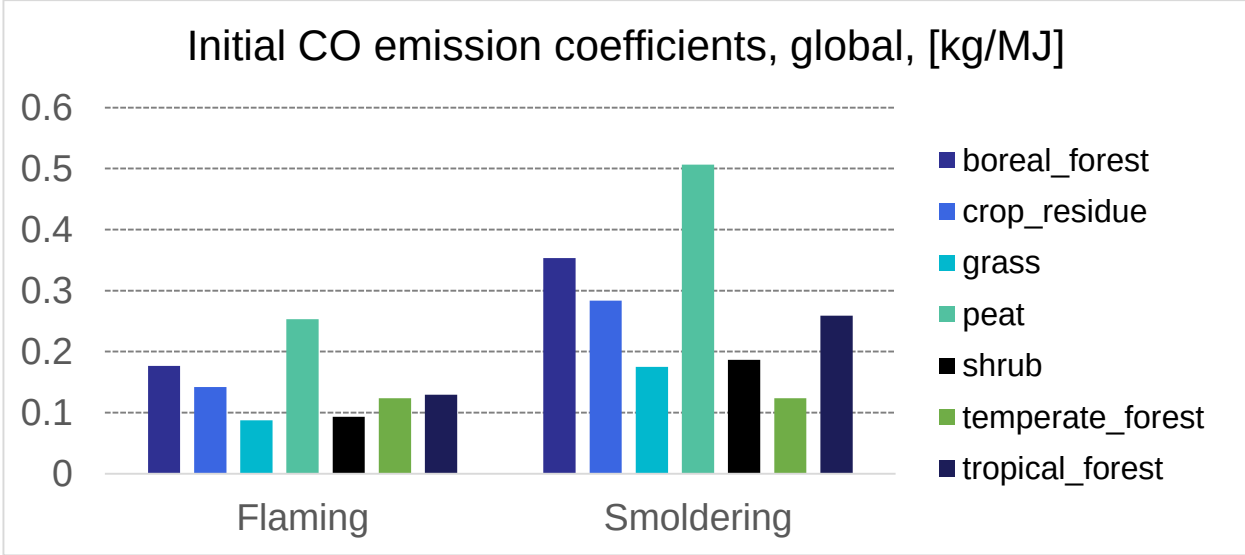
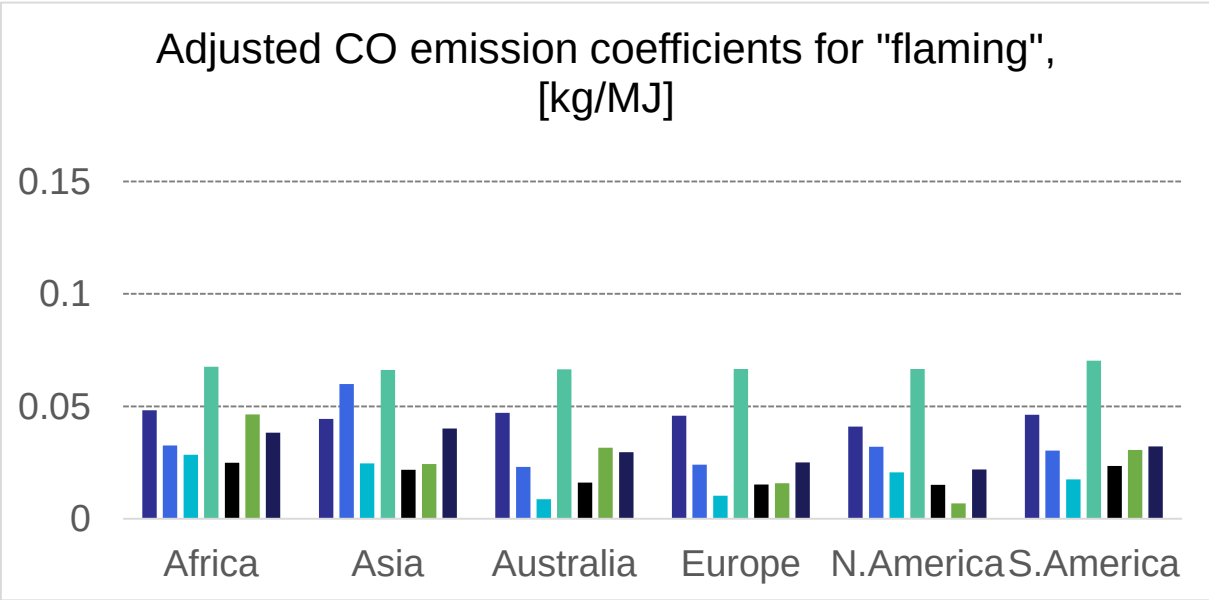
Extension to non-PM (in progress)

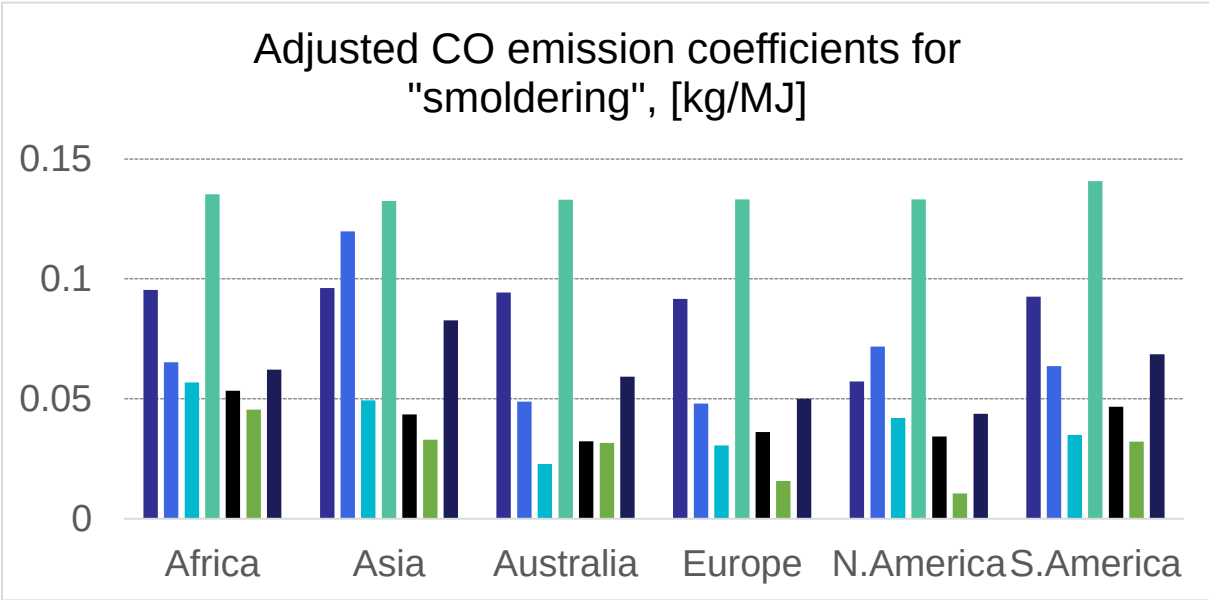
- CO good indicator of incomplete combustion
- MOPITT CO columns
- SILAM plumes with Land-Use-Type and flaming/smoldering segregation
- Emission coefficients [kg/MJ]
- TODO: Scaling to other species, incl. PM precursors and recalibration of PM emissions

Emission Coefficients: FRP -> Rate





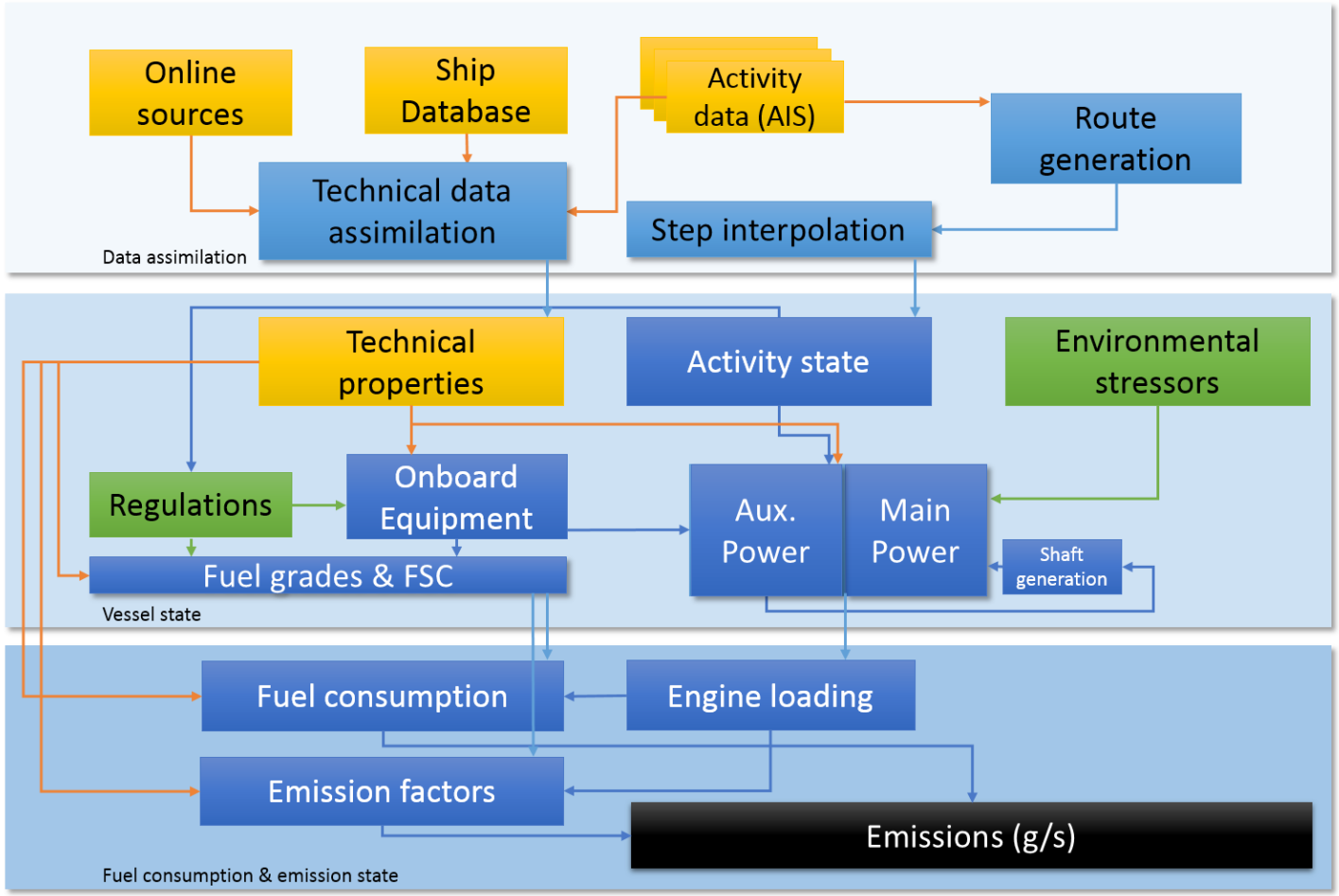




Ship Traffic Emission AssessmentModel STEAM

J.-P. Jalkanen, L. Johansson, J. Kukkonen Global assessment of shipping emissions in 2015 on a high spatial and temporal resolution. Atmospheric Environment, **167** (2017)403-415

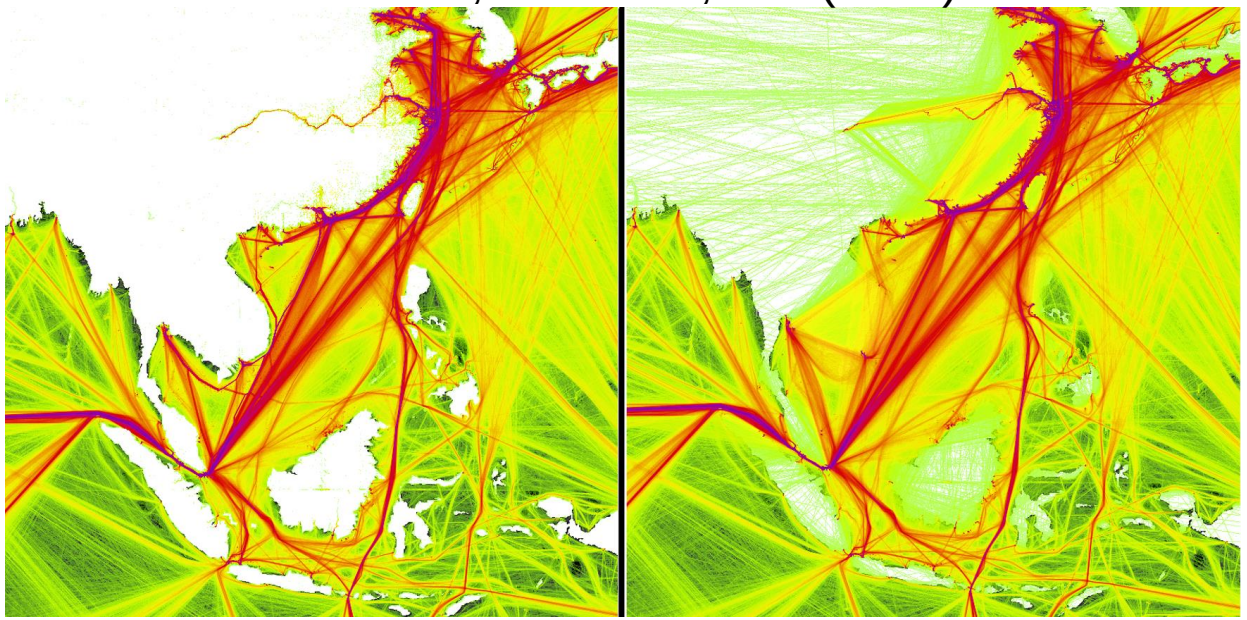
Wartsila RTA-96C



STEAM3, key algorithms

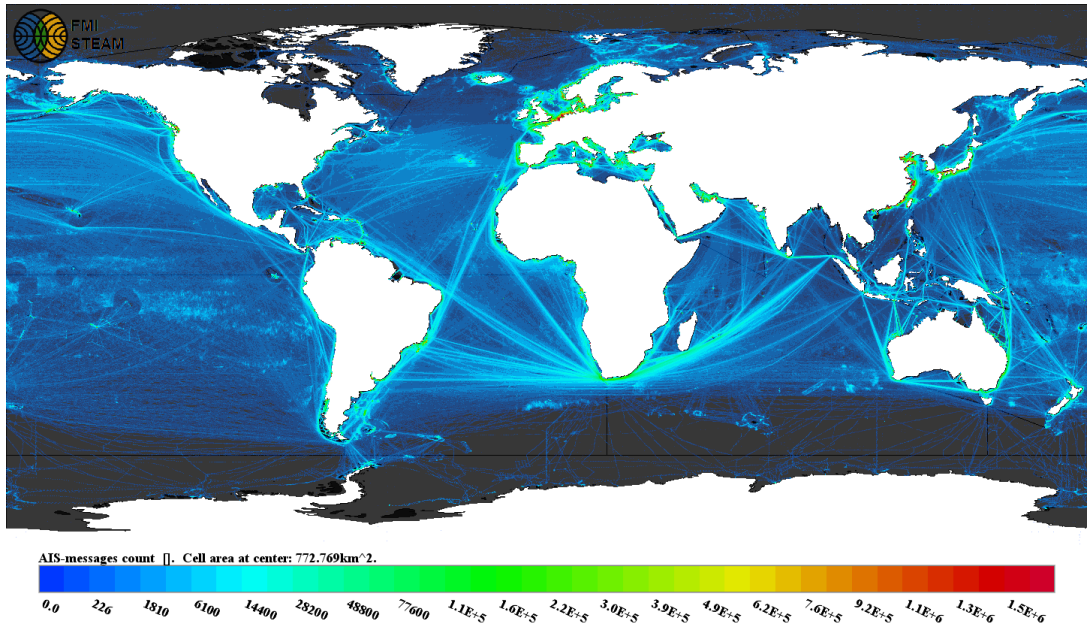
- Hollenbach resistance calculation
  - Squat currently ignored
- Smart routing; Dijkstra
- Impact of waves; Townsin & Kwon
- Impact of sea ice; Riska et al
- Noise: Wittekind
- Emissions to:
  - Air: NOx, SOx, CO2, CO, EC, OC, Ash, VOCs (4), Particle Number
  - Water: Bilge, Ballast, Grey/Black, Food waste, Antifouling, Scrubber (open/closed), stern tube oil
  - Noise: 63, 125, 2000 Hz

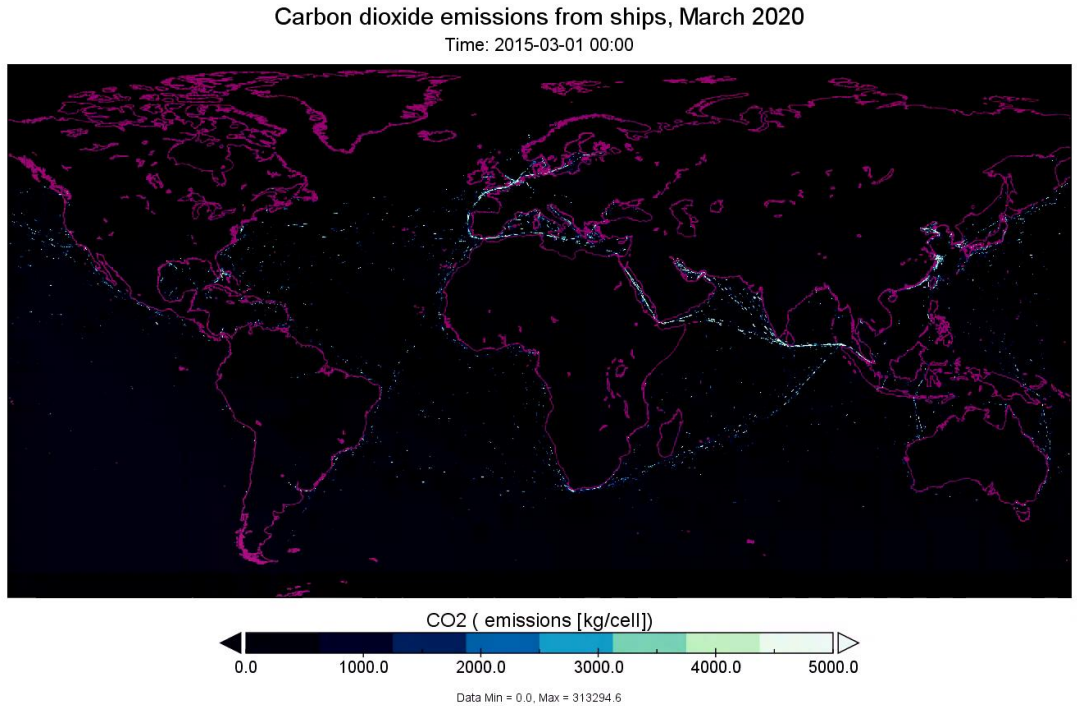
Johansson et al., Atm. Env., 167 (2017) 403-415



Activity

- AIS, both terrestrial and satellite datasets
  - Baltic Sea: 2005- (t)
  - North Sea: 2009, 2011 (t)
  - Europe: 2011 (t)
  - Global 2014- (t + s)
- LRIT, tested only as a benchmark for AIS in Third IMO GHG work
- VMS, no access
- ICOADS, AMVER, departure/arrival times; not tested yet





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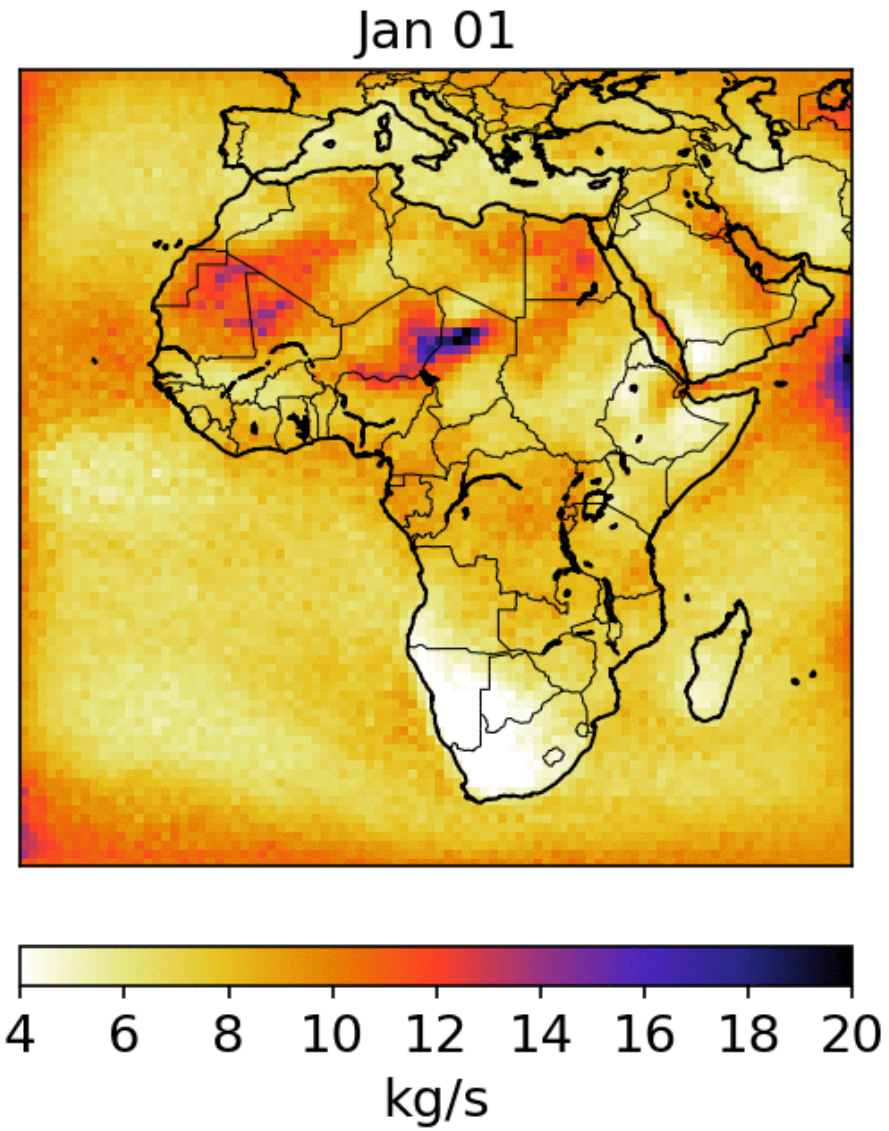
Desert dust emission assimilation

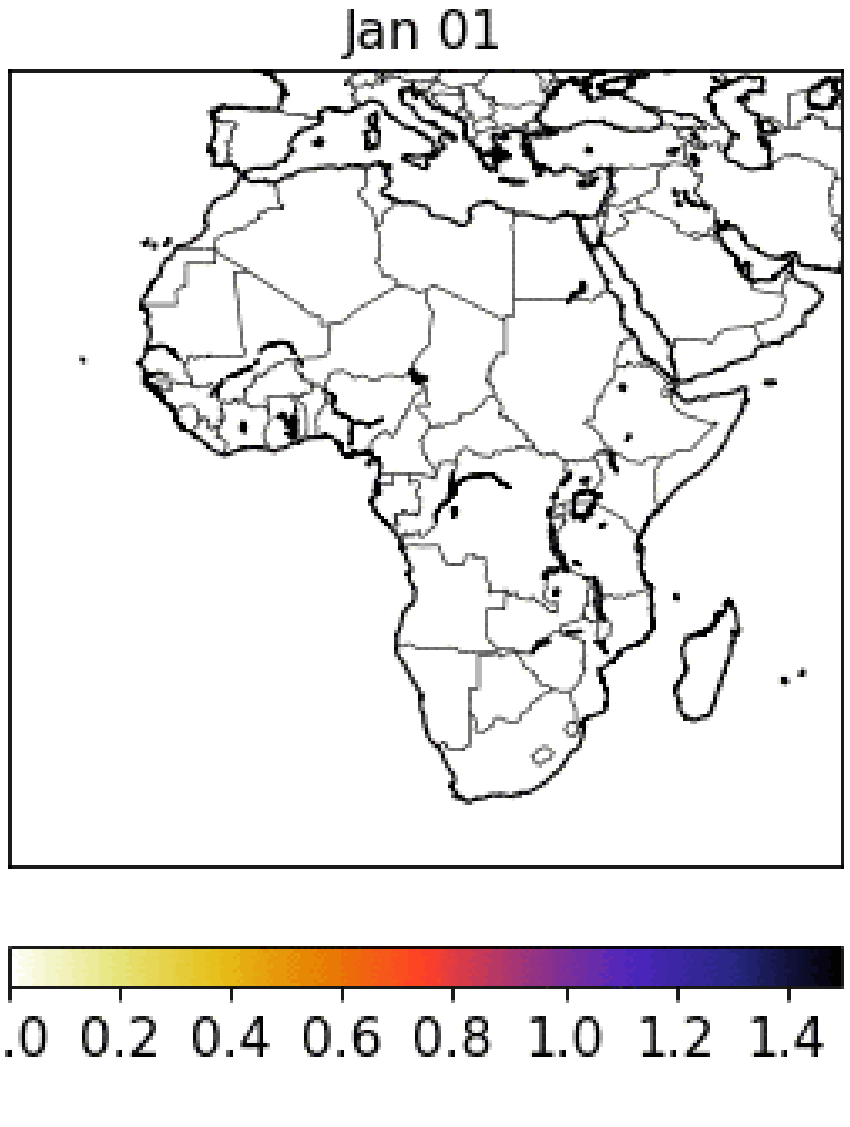
- 1-deg run over Africa
- 6-um PM emission in every cell
- 0-50m emission height
- EnKF 300 members
- Independent emission perturbation
- 2-week temporal smoothing after each iteration
- Same meteo for all members
- MODIS AoD assimilated for 2015

- Validated with Aeronet 2017
- Compared to Annual scores at SDS-WAS (AE>0.6)

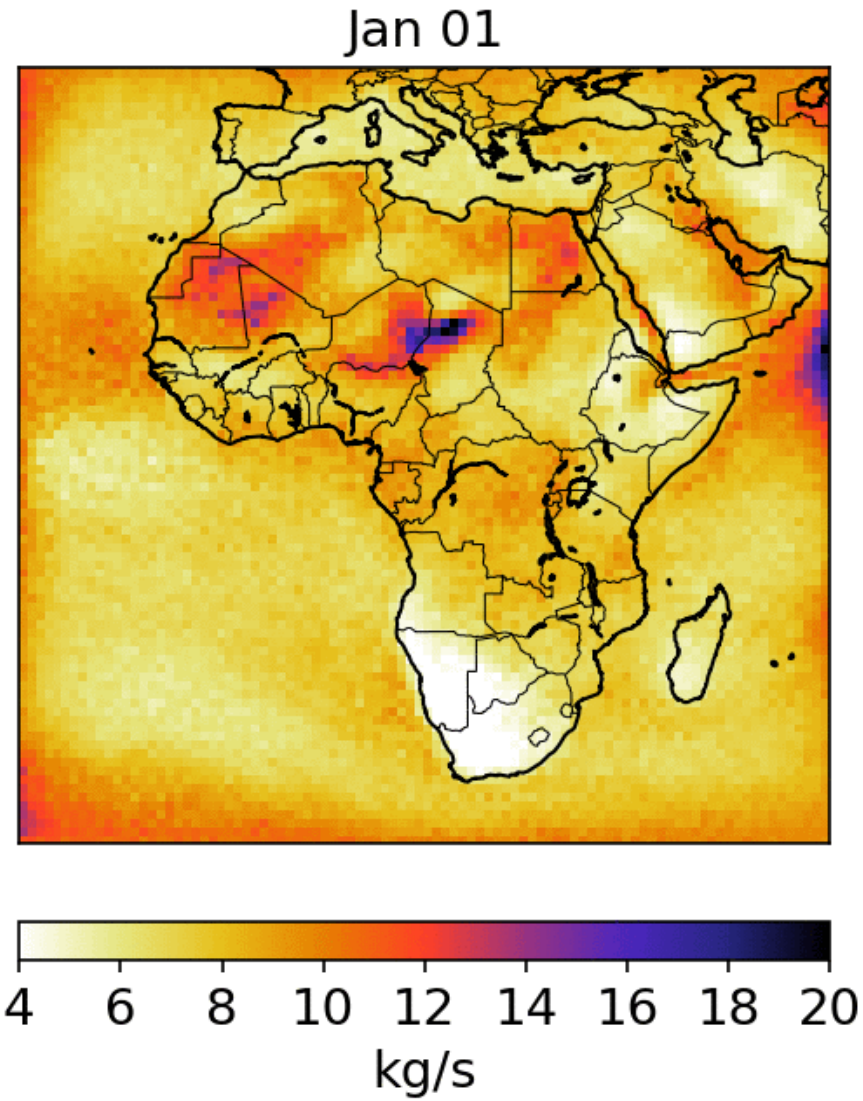
Emission



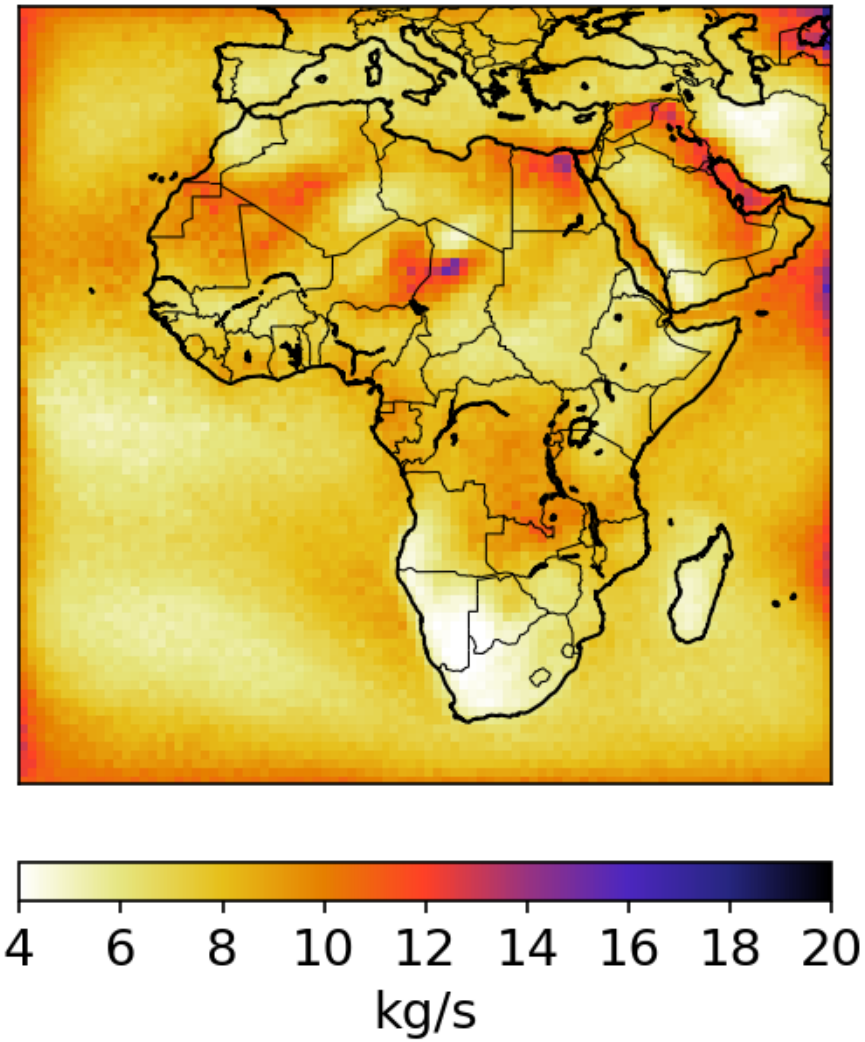
AOD



Faster emission animation



Annual average emission



Assimilated dust vs AERONET AOD

RMSE

	SILAM old	SILAM 2018	SDS-WAS median
Sahel/Sahara	0.39	0.30	0.31
Middle East	0.42	0.26	0.33
Mediterranean	0.20	0.18	0.15
All regions	0.35	0.26	0.28

Correlation coefficient

	SILAM old	SILAM 2018	SDS-WAS median
Sahel/Sahara	0.39	0.47	0.75
Middle East	0.13	0.56	0.52
Mediterranean	0.60	0.56	0.72
All regions	0.44	0.52	0.74

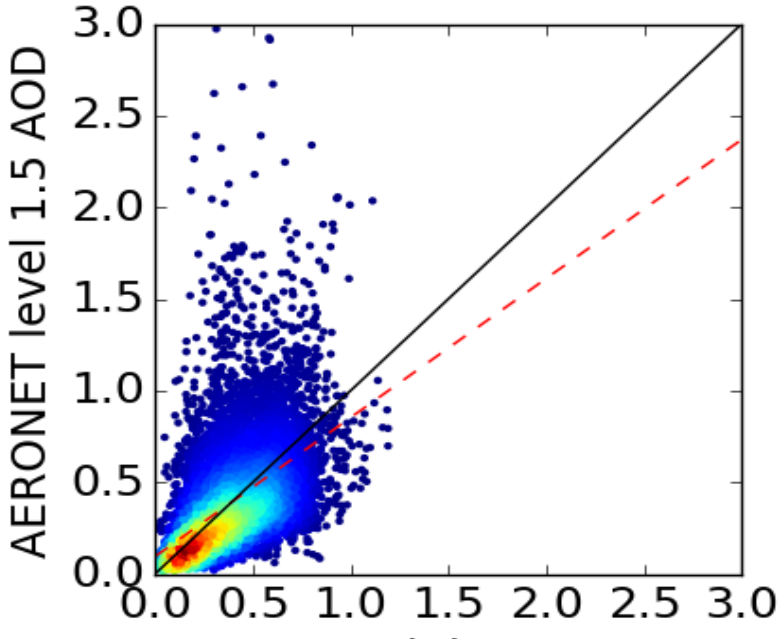
Bias

	SILAM old	SILAM 2018	SDS-WAS median
Sahel/Sahara	-0.22	-0.03	-0.18
Middle East	-0.21	-0.02	-0.18
Mediterranean	-0.14	0.06	-0.10
All regions	-0.20	0.00	-0.16

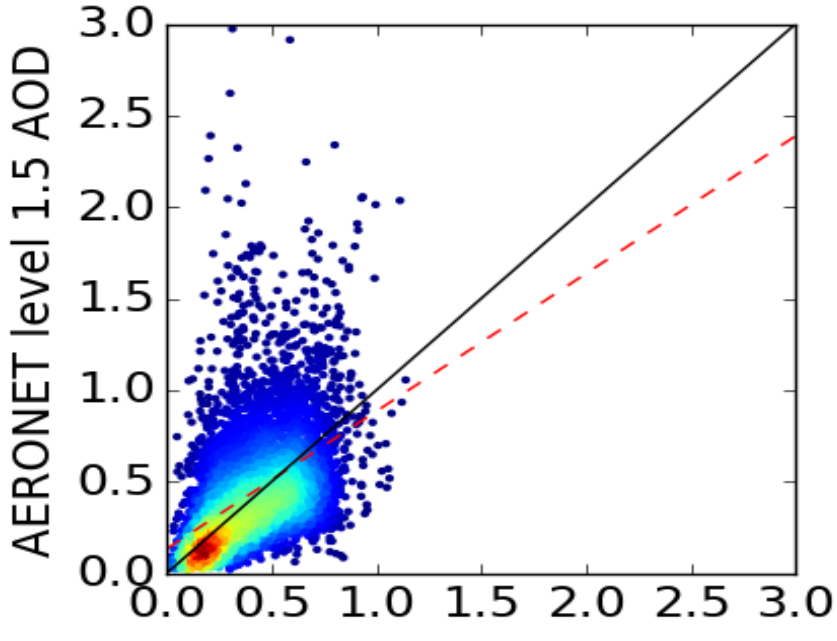
Fractional gross error

	SILAM old	SILAM 2018	SDS-WAS median
Sahel/Sahara	0.88	0.49	0.56
Middle East	0.88	0.37	0.56
Mediterranean	1.16	0.44	0.85
All regions	0.96	0.46	0.64

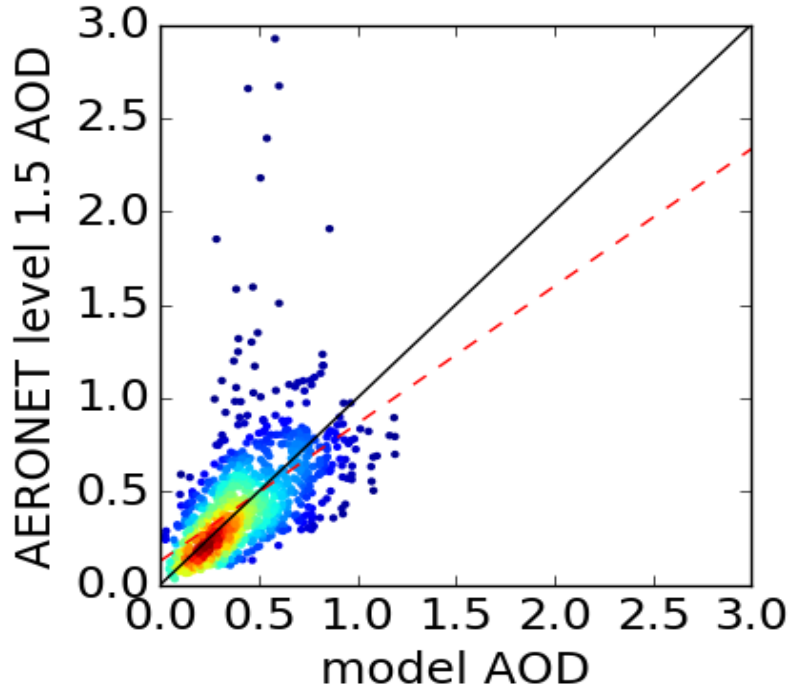
All points



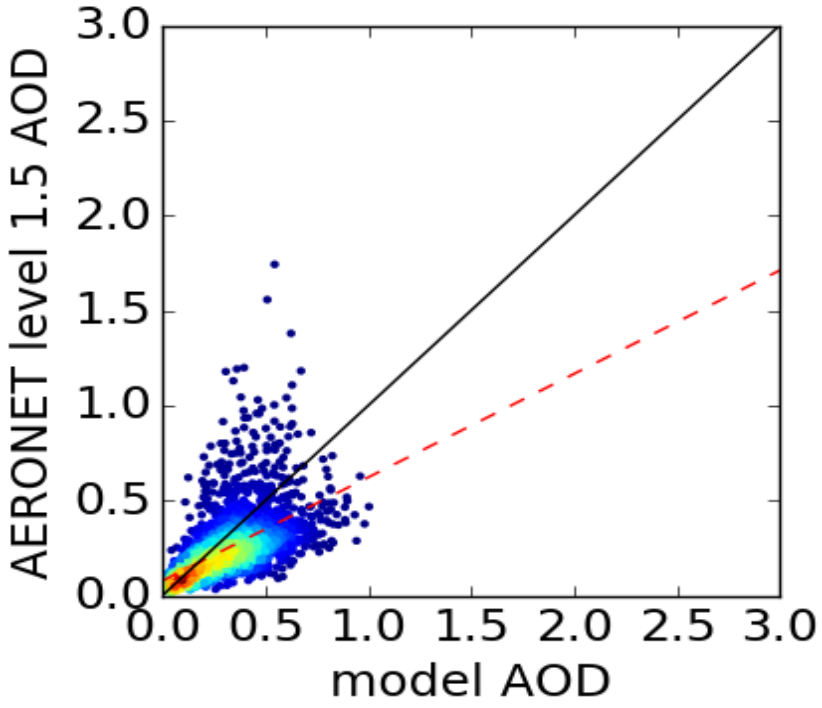
Sahara/Sahel



Middle East



Mediterranean



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Final remarks

- 0.2 degree full-chemistry and aerosols global forecasts
  - Technically feasible operational suite with NRT emissions
  - Compares ok with OMI, MODIS, DOMINO
  - Still many issues to address, aerosols OK
- IS4FIRES top-down fire PM, coefficients for CO, other gases coming
- STEAM – ultimate bottom-up shipping emissions
- Desert dust emission assimilation:
  - Outperforms mechanistic models by scores (RMS, FGE etc..)
  - No dust storms
- All operational results and online evaluations: http://silam.fmi.fi

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26.7.2019 **Nimi**