



ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

SILAM global AQ forecast: model outlook, current status and challenges

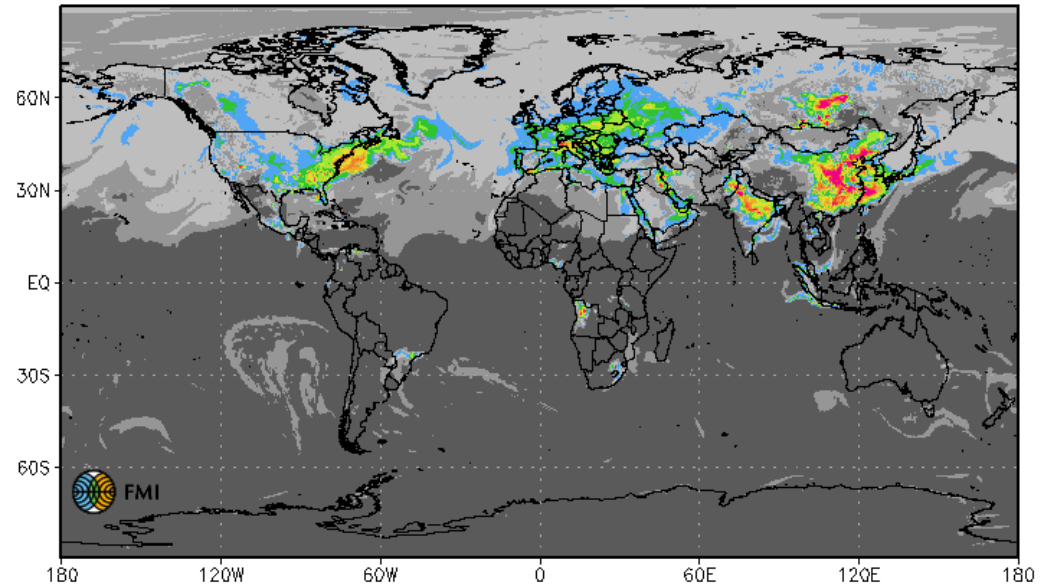
System for Integrated modeLling of Atmospheric coMposition

M.Sofiev, R.Kouznetsov, J.Vira, M.Prank,
J.Soares, V.Tarvainen

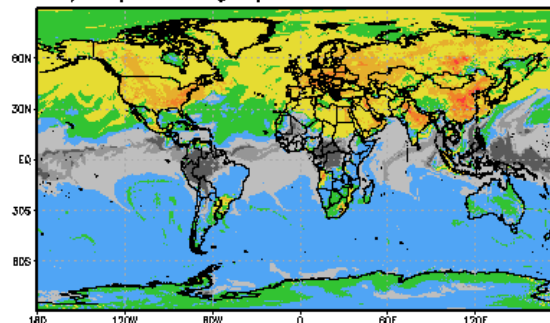
Outline

- Tools: SILAM, IS4FIRES, STEAM, dust
- AC Reanalysis 1980-2016
 - first evaluations
 - challenges
- Operational forecasts
Forecast arrangement
 - online evaluations
 - data
- Conclusions

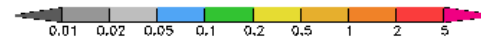
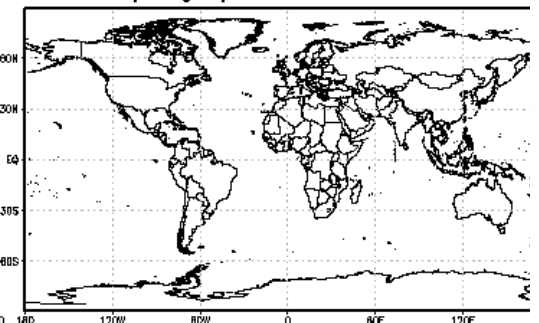
Concentration, $\mu\text{gO}_3/\text{m}^3$, 16:0026JUN2017



Dry dep. $0.1 \mu\text{gO}_3/\text{m}^2\text{sec}$, 16:0026JUN2017



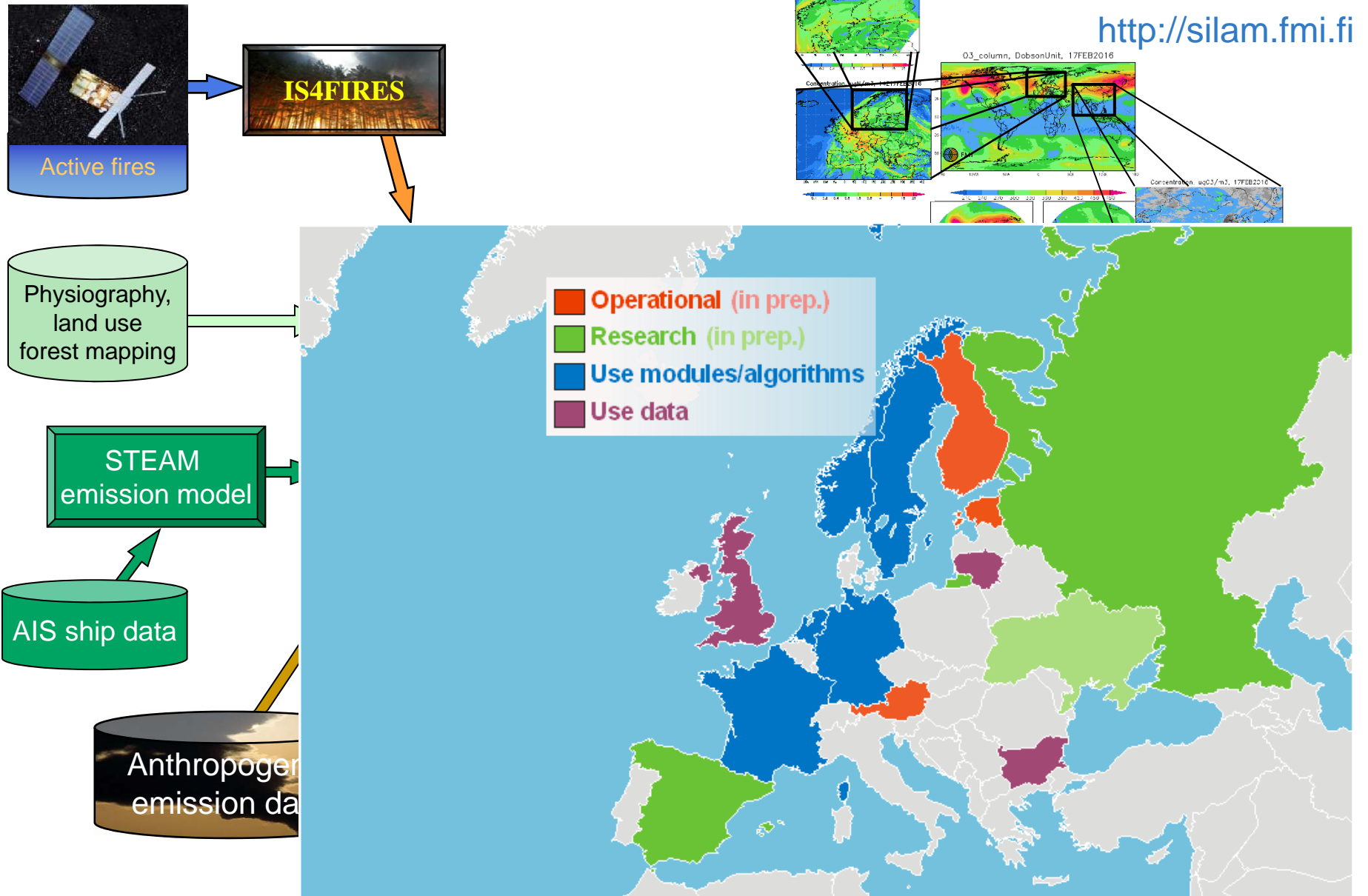
Wet dep. $\mu\text{gO}_3/\text{m}^2\text{sec}$, 16:0026JUN2017



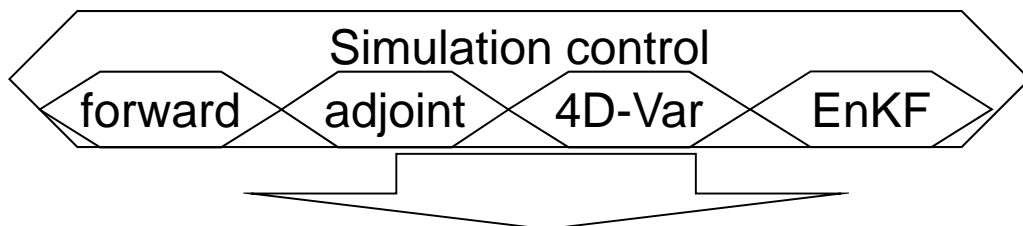
SILAM in general

- An offline chemistry-transport model
- Global-to-meso- γ 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 AQ assessment and forecasting platform



SILAM v.5.5



Modules

- 9 chemical transformations (7 open)
- 8 source types
- 4 aerosol dynamics
- 3D-, 4D-

New species: 22

- Terpenes
- VBS
 - Anthropogenic 1 NVOC, 4 SVOC (gas + aerosol), 3 IVOC
 - Biogenic 1 NVOC, 4 SVOC (gas + aerosol)

New reactions: 31

- Terpene oxydation: 4
- SOA formation: 20
 - XYL, TOL, ISOP, TERP; lo and hi NOx
- SOA aging: 11

Gas – aerosol partitioning: 8

CB4 - possibly not good enough

- 32 species, 81 reactions

Large uncertainties emissions

- IVOC - Primary OC emission * 2.5
- Composition of anthropogenic NMVOC
- Biogenic emissions of isoprene, monoterpenes ec

- Aerosol dynamics
- SOA VBS
- PSC
- Simple
- Basic
- Transformation

Source types

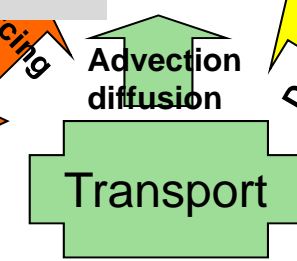
- Area
- Point
- Nuclear bomb
- Bio-VOC
- Pollen
- Sea salt
- Desert dust
- Wild fires

Domains: meso scale

Meteo inp

- ECMV
- HIRLA
- ECHA
- can w
- WRF
- ECHAM, NorESM, other GCM / RCM

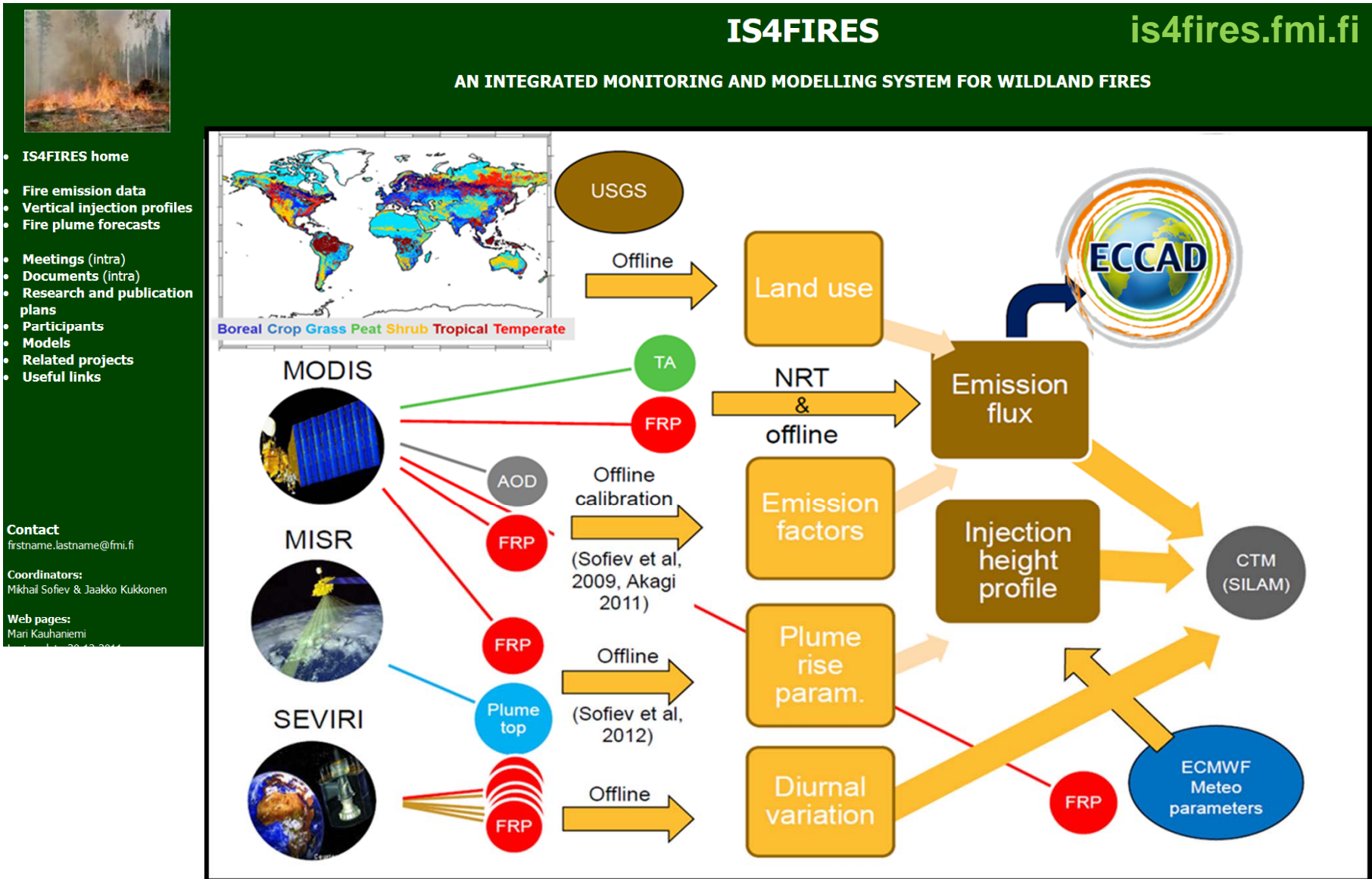
Map of species masses



Deposition

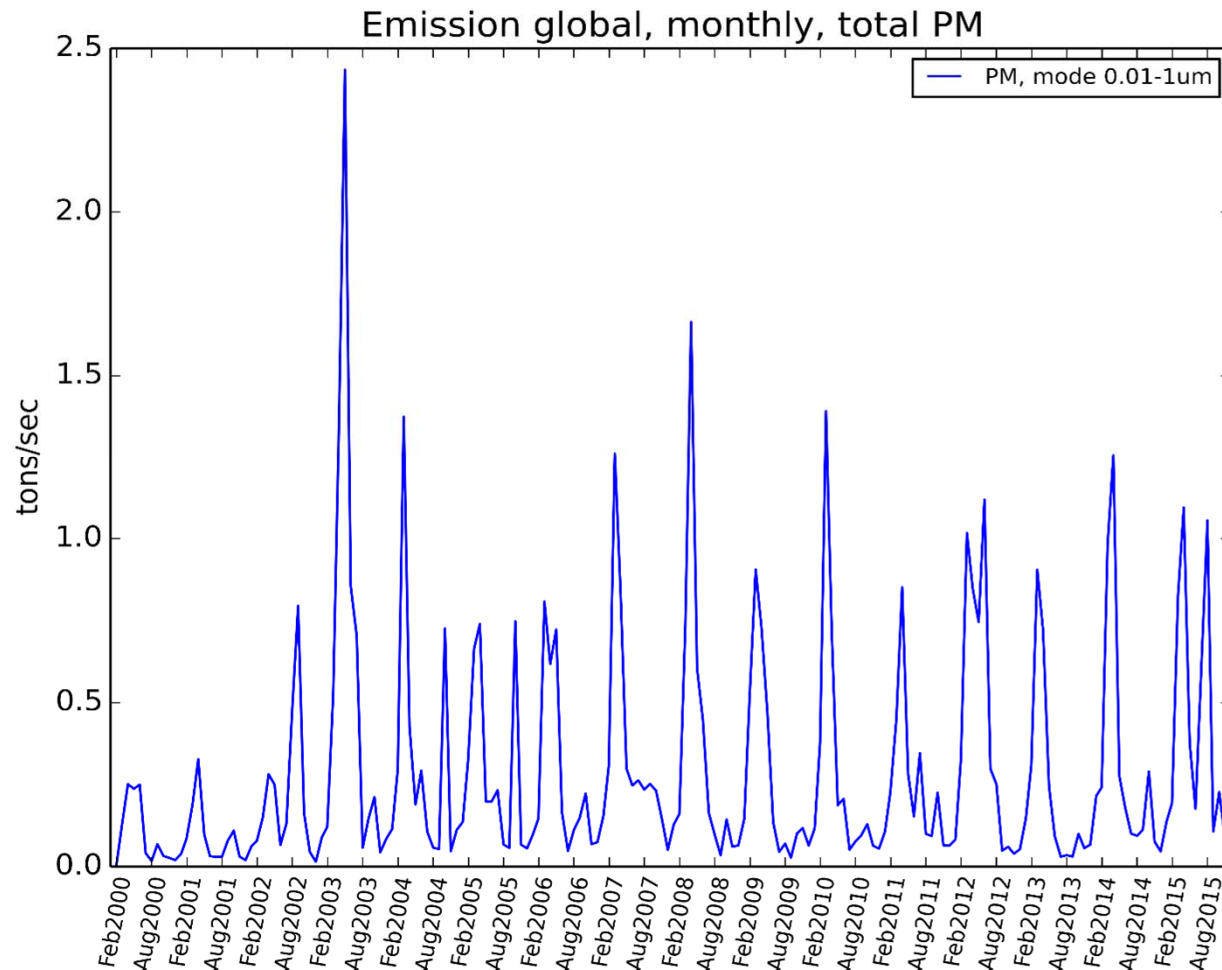
- Dry
- Wet

Fire data for emission: IS4FIRES



Features of IS4FIRES v.2

- Top
 - a
 - re
- Bott
 - b
- High
- Aero
- from
- Sep
- fires



ns

ght

g

High-energy non-fire s



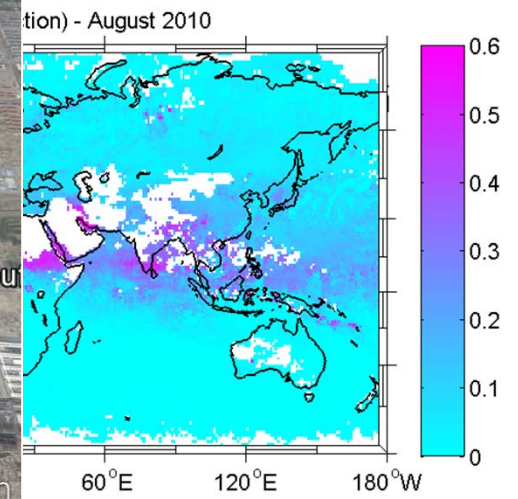
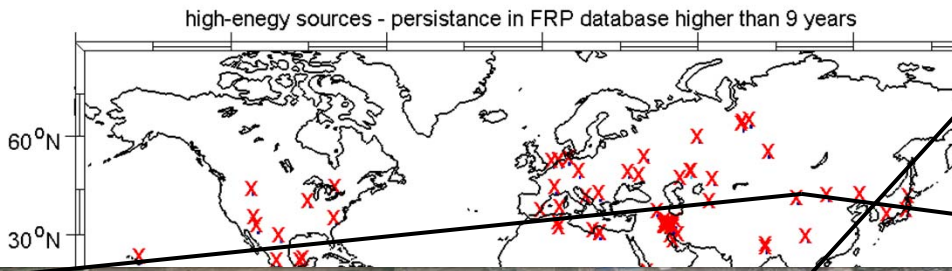
pixel over the globe: MODIS-FRP

✓ Suspicious: > 50 fire days in a

- 2013, 402 cells
ed more than 4 times.

straint: 9 years

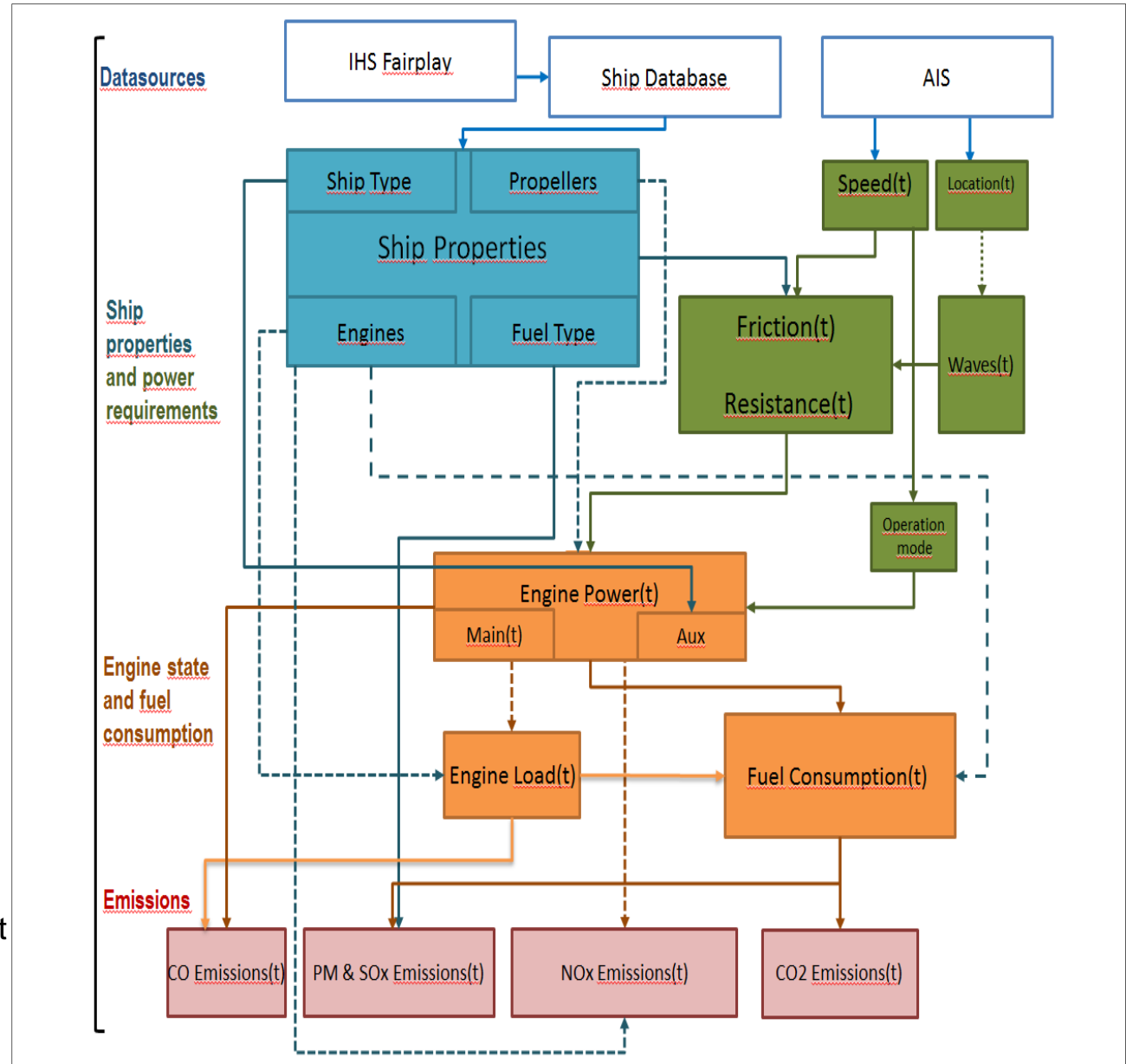
e.



STEAM

Ship Traffic Emission Assessment Model

J.-P. Jalkanen, L. Johansson, J. Kukkonen, A. Brink, J. Kalli, and T. Stipa, Extension of an assessment model of ship traffic exhaust emissions for particulate matter and carbon monoxide, *ACP*, **12** (2012) 2641-2659.



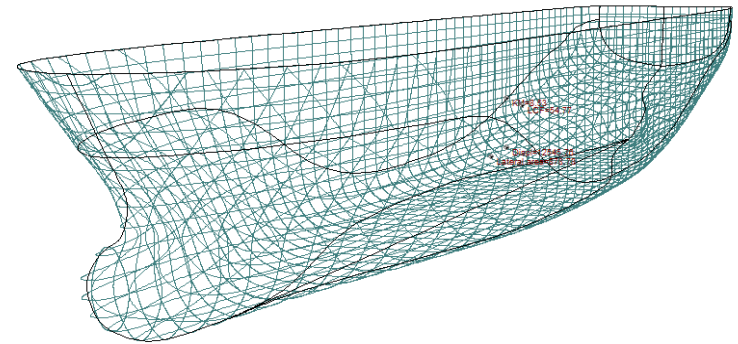
Source of ship activity

- Automatic transponder (Automatic Identification System, AIS)
 - VHF radio transmissions, anyone can receive
 - Time stamp, vessel identification, position, speed
 - Vessel traffic control system, built for collision avoidance
- Position update every 2 sec at maximum
- **Mandatory for all ships**
- Wealth of data: EU sea areas -> Over 1000 million position updates each year
 - **Data received each year for the Baltic Sea alone is more than ten times than what was received globally during the last 250 years**

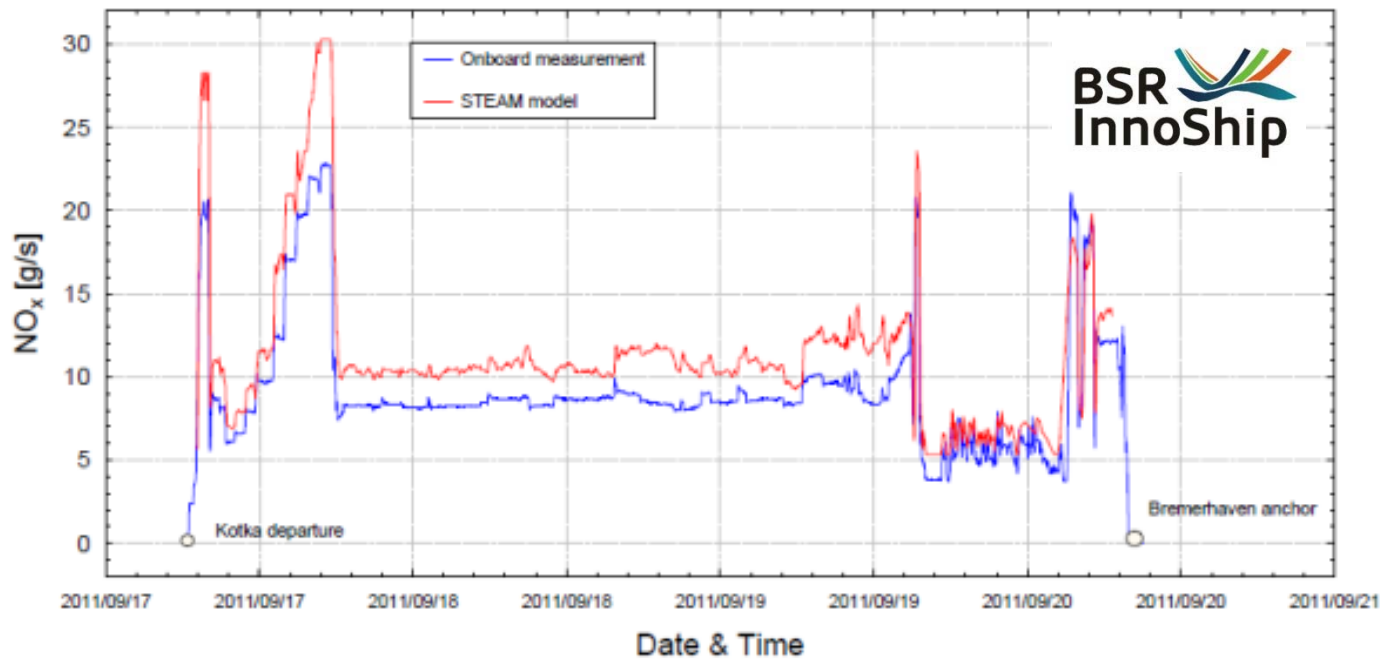
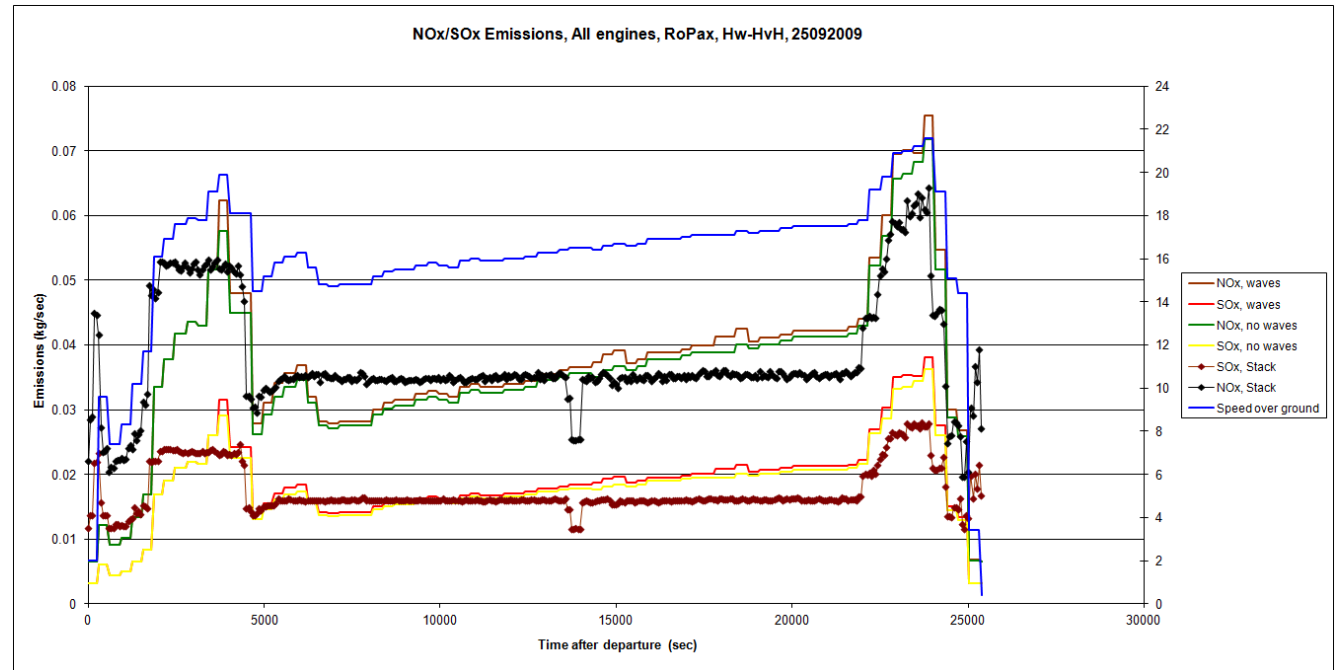
Ship technical data

- Physical dimensions; Hull form
- Powering; all installed engines, generators
- Emission abatement, emission certificates
- Fuel type; sulphur content; specific consumption
- Current legislation; ECAs, directives, IMO Tiers
- Engine load vs fuel consumption/emissions; power transmission
- Propellers
- Capacity; reefer containers, cabins
- Each vessel handled as unique case
 - **No averages, compromises, shortcuts**

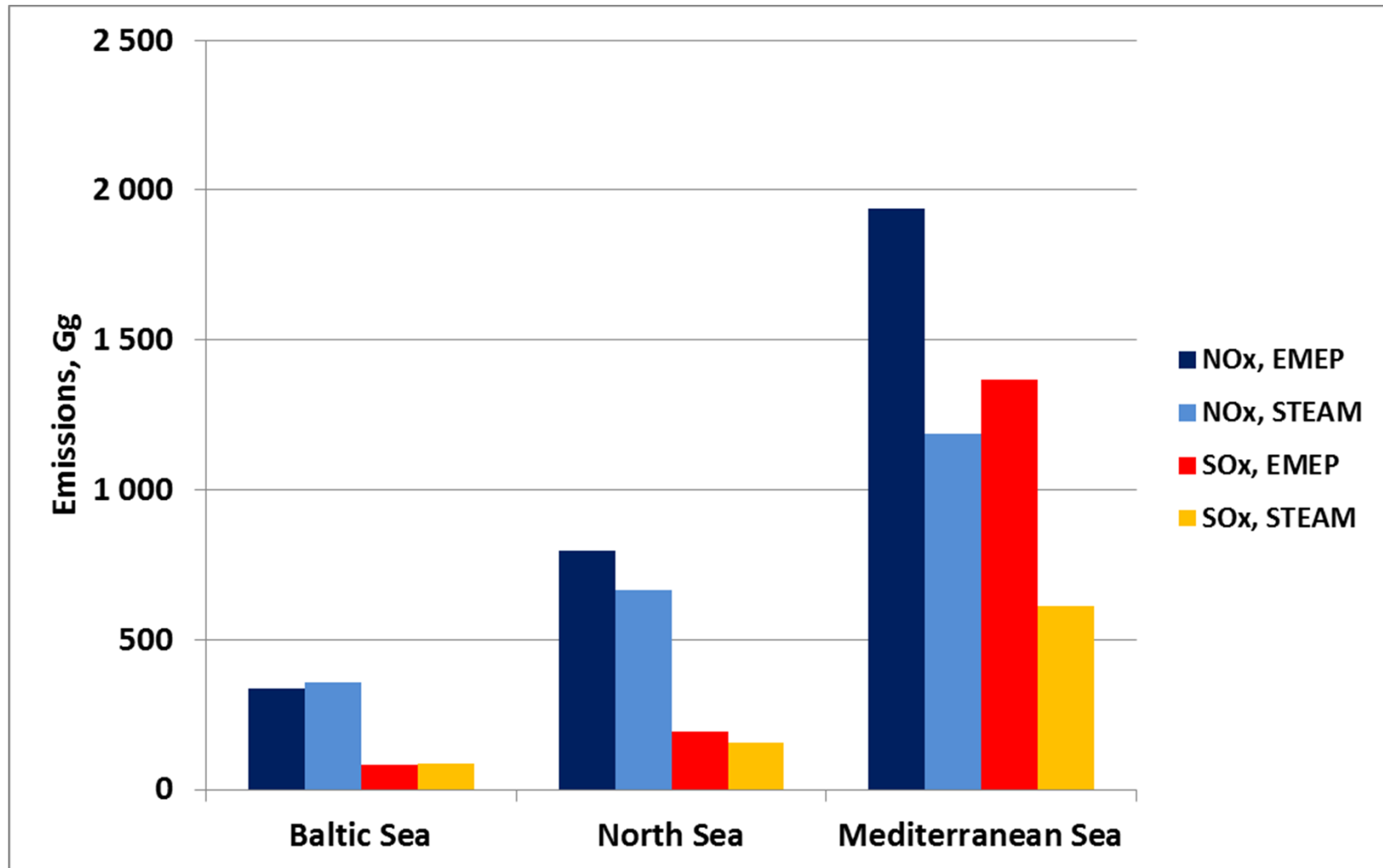
- All information may not be available!
- Combination of different data sources
 - IHS Fairplay
 - Other classification societies
 - Ship owners
 - Engine manufacturers
 - ...



Measurements by:
Joint Research Centre,
Maritime University of Szczecin



Comparison, EMEP/STEAM, 2011

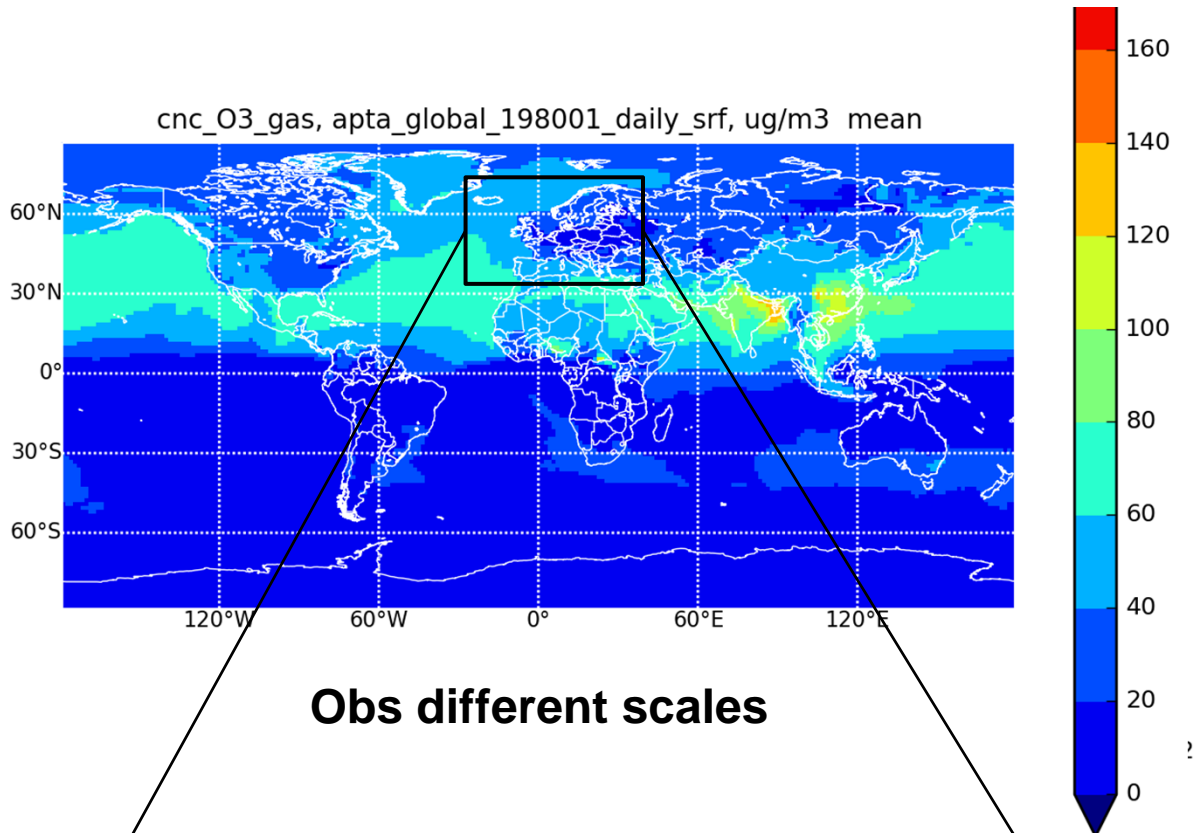


Wind-blown dust emission

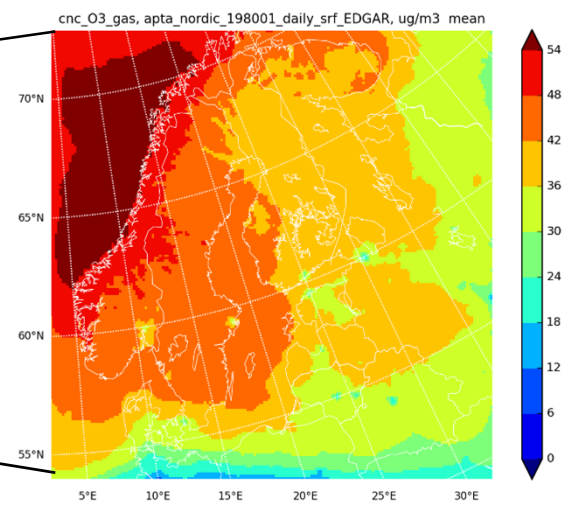
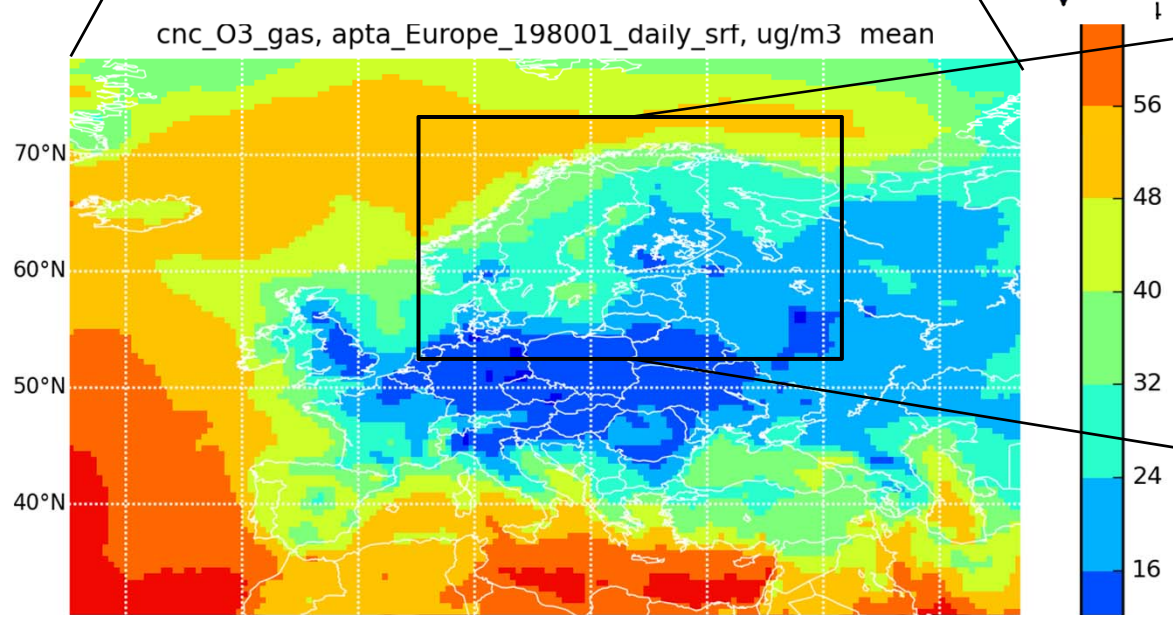
- Saltation-based algorithm, modified from Marticorena and Bergametti (1995) & Zender (2003)
 - threshold friction velocity (“pure” friction velocity, convective addition, gustiness)
 - sand properties (refitted)
 - soil humidity
 - Owen effect (positive feedback)
 - saltation saturation (negative feedback)
 - technological improvements (analytical and approx. solutions)
- Parameterized for Sahara
 - problems with soil humidity in ERA-Interim for other regions
 - is being evaluated and refitted for Asia and America
 - prognostic model for soil humidity

Re-analysis 1980-2016

- global
 - $1.44^\circ \times 1.44^\circ \times 18$ yrs (10 Pa)
 - MACCity anthropogenic, ACCMIP fire, MEGAN-MACC biogenic, GEIA lightning and aircraft, and EDGAR anthropogenic PM emissions
 - ERA-Interim
 - wind-blown dust, volcanoes, and SOA turned off, reserved for separate runs
- European
 - $0.5^\circ \times 0.5^\circ \times 13$ yrs (400 hPa)
 - MACCity anthropogenic, ACCMIP fire, MEGAN biogenic, GEIA lightning and aircraft, and EDGAR anthropogenic PM emissions
 - ERA-Interim
 - wind-blown dust and SOA turned off, reserved for separate runs
- Northern Europe (up to 2014)
 - $0.1^\circ \times 0.1^\circ \times 13$ yrs (~5km)
 - EDGAR anthropogenic, ACCMIP fire, MEGAN biogenic, GEIA lightning and aircraft
 - HIRLAM BaltAn (1980-2005) + ECMWF IFS (2006-2014)
 - wind-blown dust and SOA turned off, reserved for separate runs

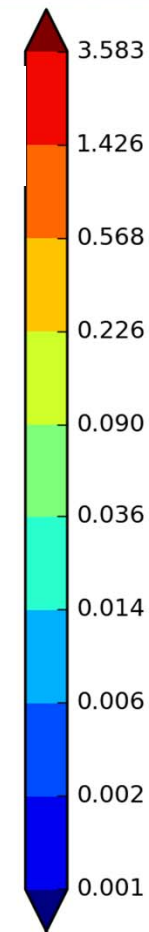
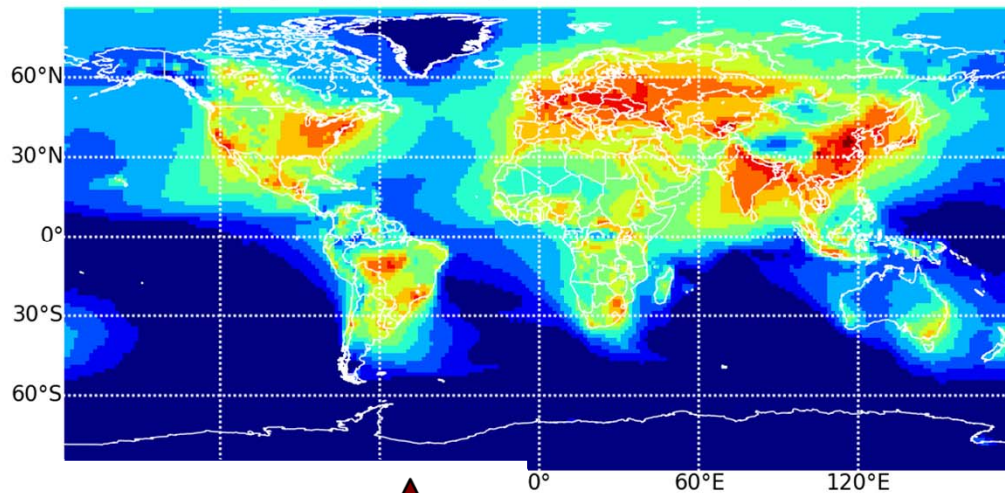


Obs different scales

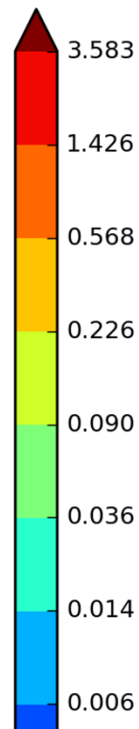
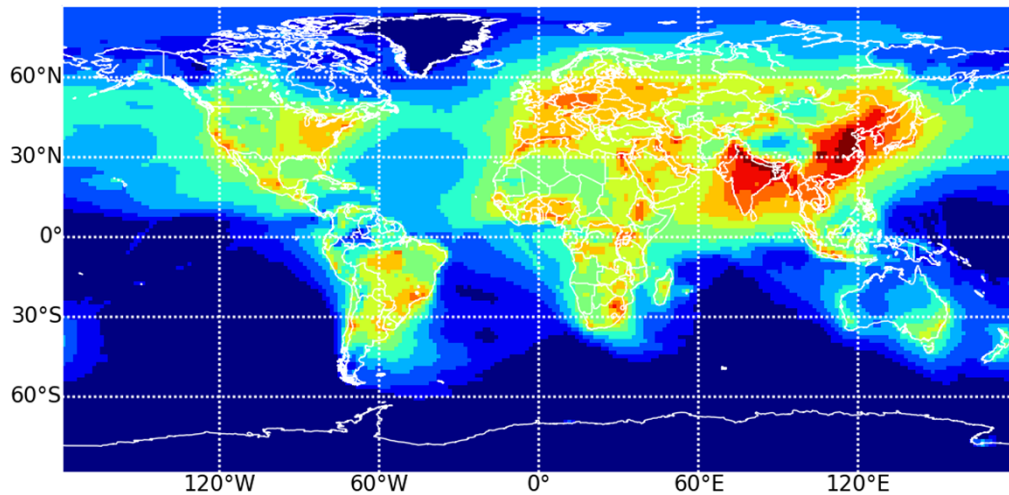


Temporal development: BC

cnc_BC_m_50, apta_global_1980_monthly_srf, ug/m3 mean

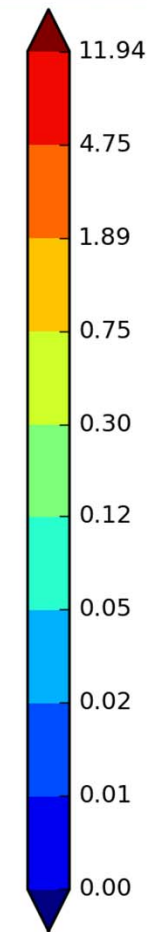
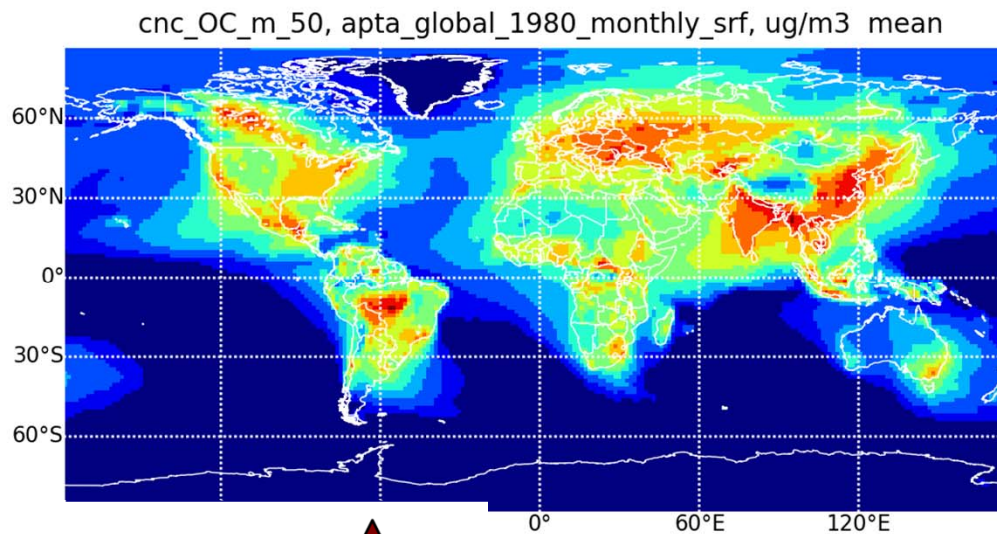


cnc_BC_m_50, apta_global_2014_monthly_srf, ug/m3 mean

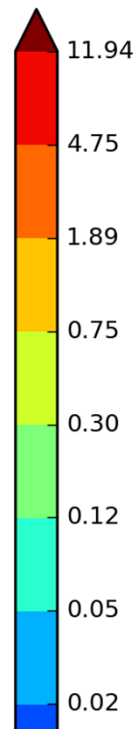
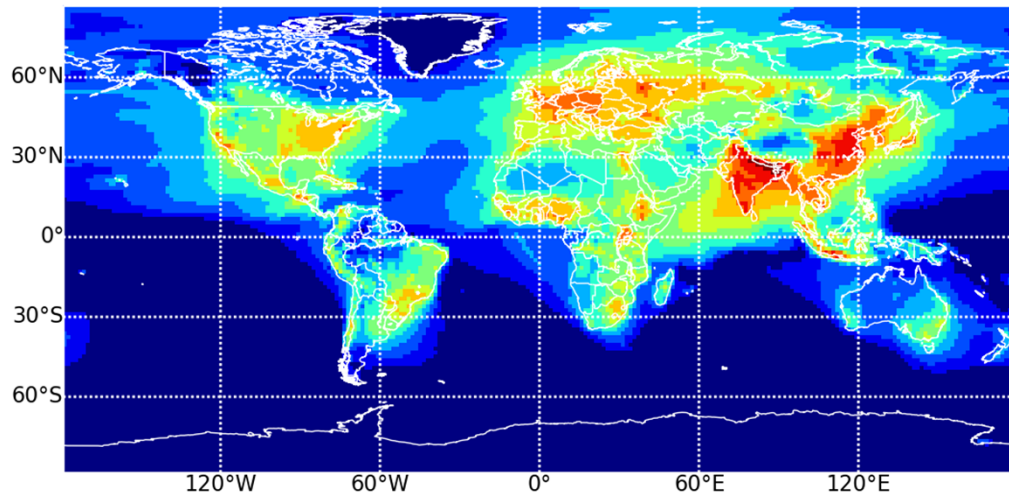


Difference between inventories

MACCITY, with fires



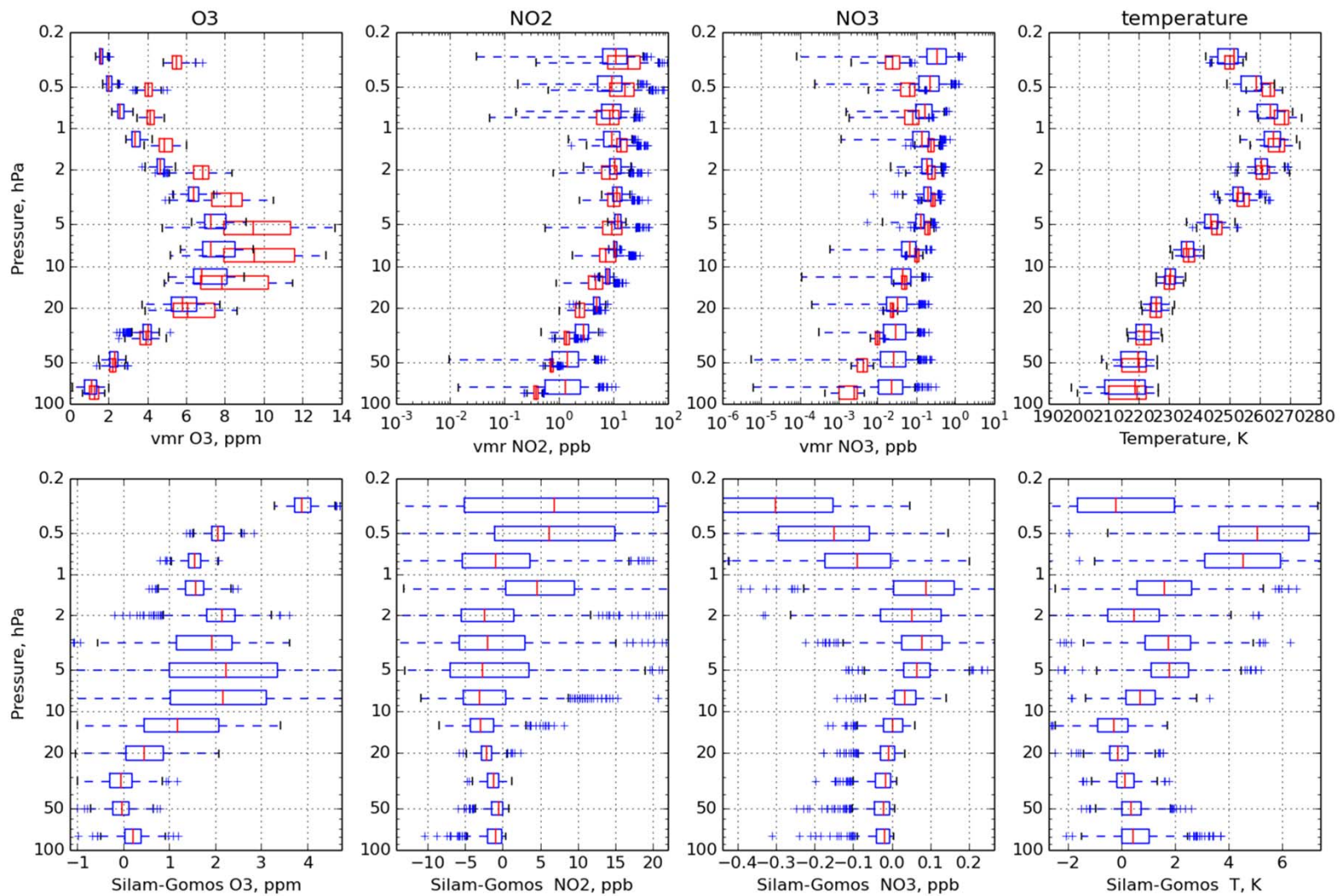
cnc_OC_m_50, apta_global_1980_monthly_srf_EDGAR_PM, ug/m3 mean



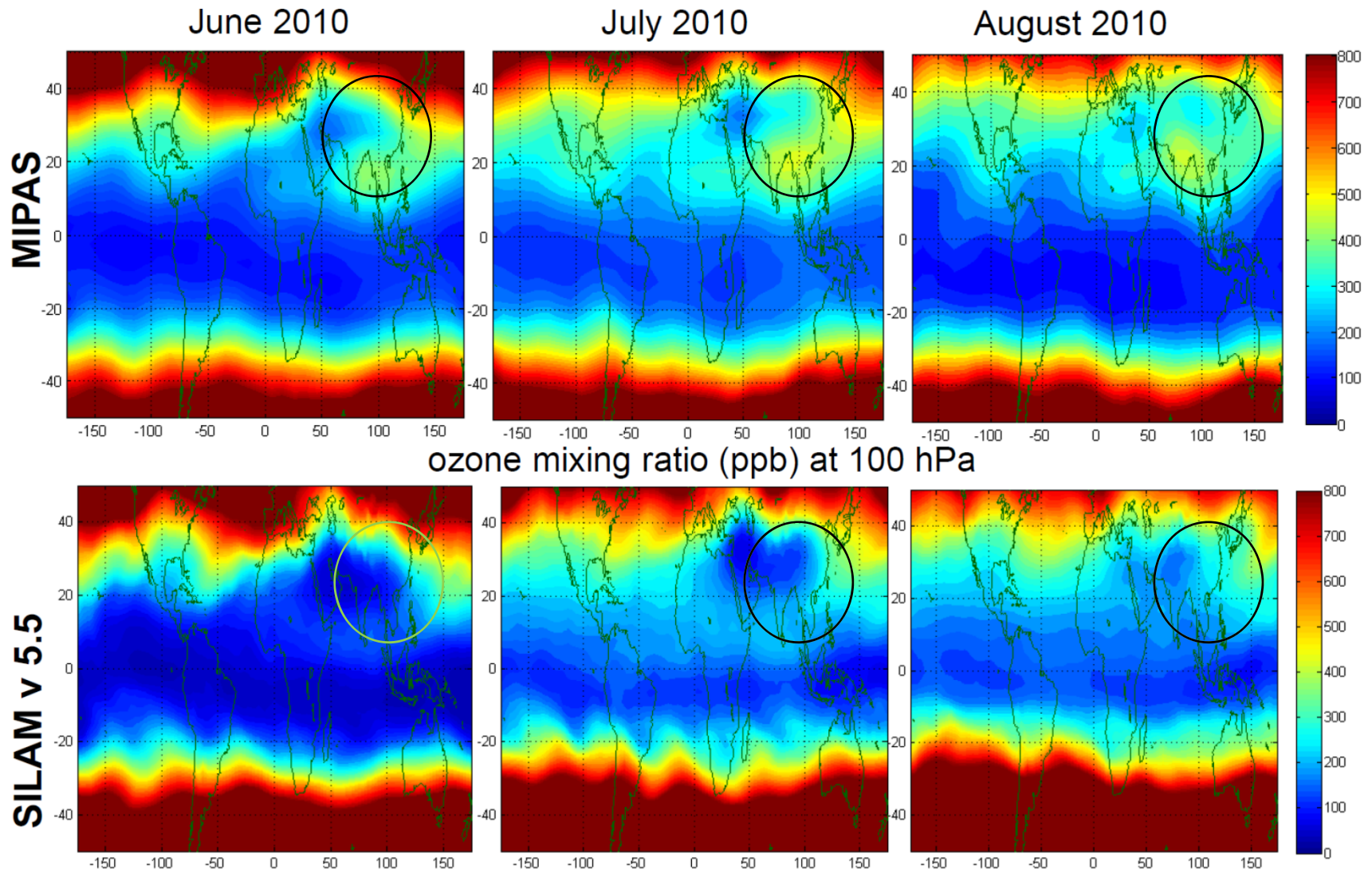
EDGAR OC, no fires

Stratospheric evaluation, 2010

SILAM-glob2010_cb4strat_dmatS_SAD_MAAD_tst MIDN 08-2010



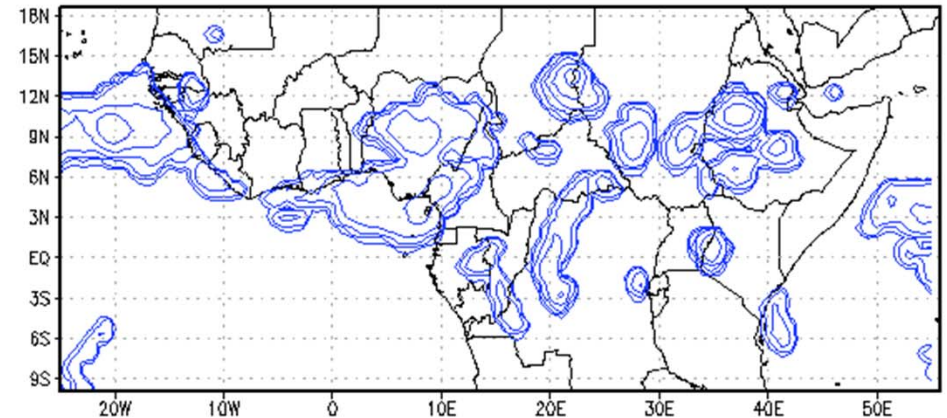
Evaluation of large-scale model features



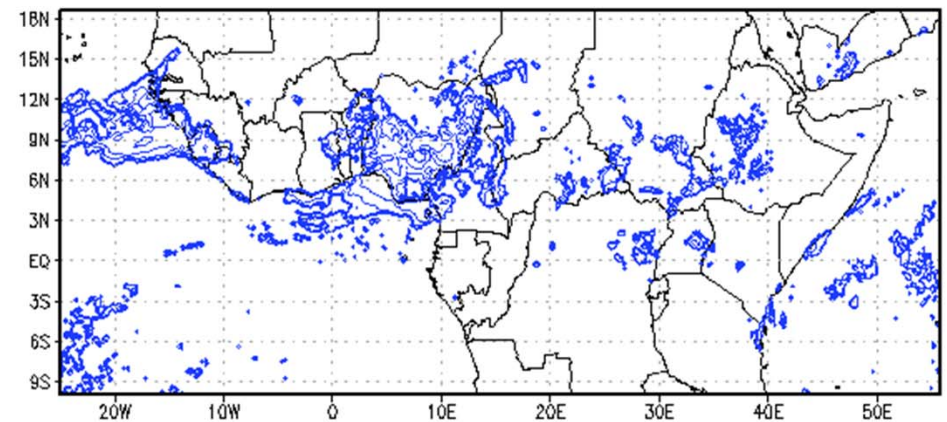
Effect of convective precipitation representation

- Easy-to-observe: smoke from African savannah fires
- African plumes are predicted shorter than MODIS suggests:
 - scavenging (?)
 - Consequently, emission is over-blown to reach unbiased mean AOD
- Reasons?
 - convective precipitation pattern of ERA-Interim

ERA-Interim T precip, ERA, 550nm, 15JUL2012 00:00

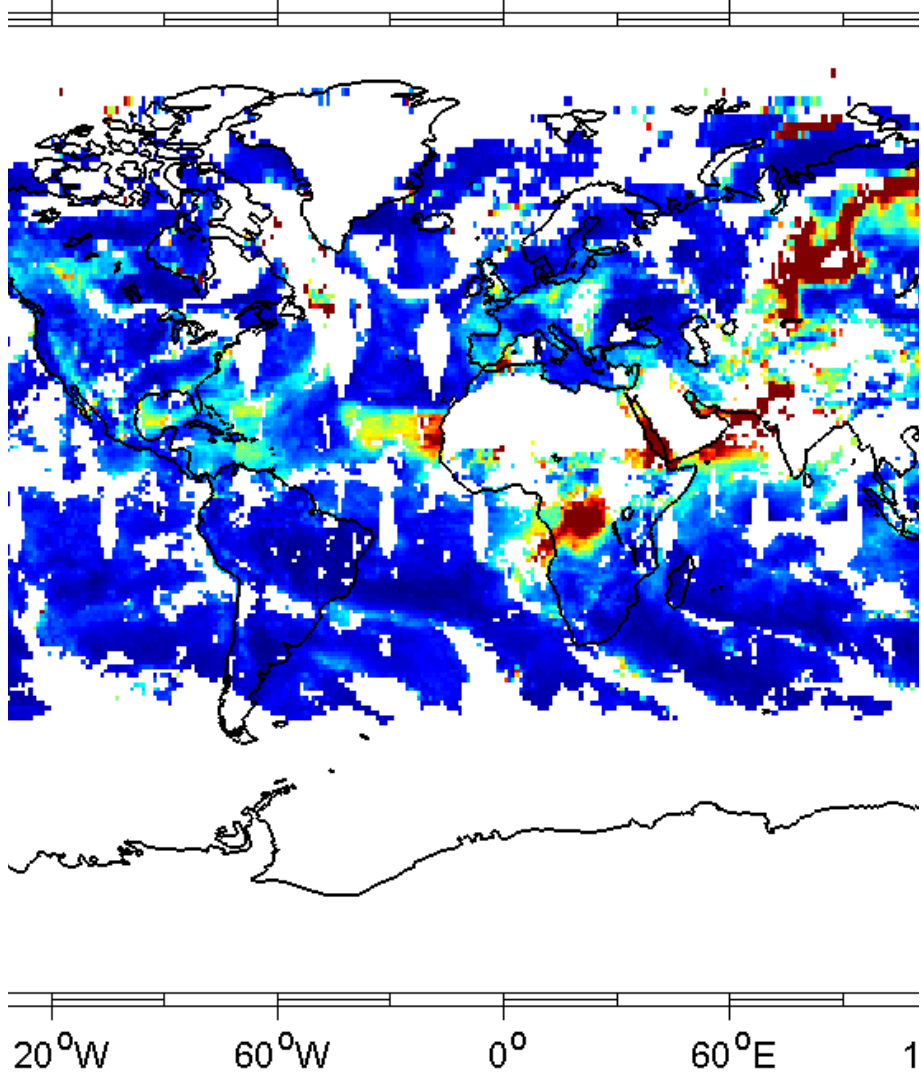


MODIS fires + precip, EC_OPER, 550nm, 15JUL2012 00:00

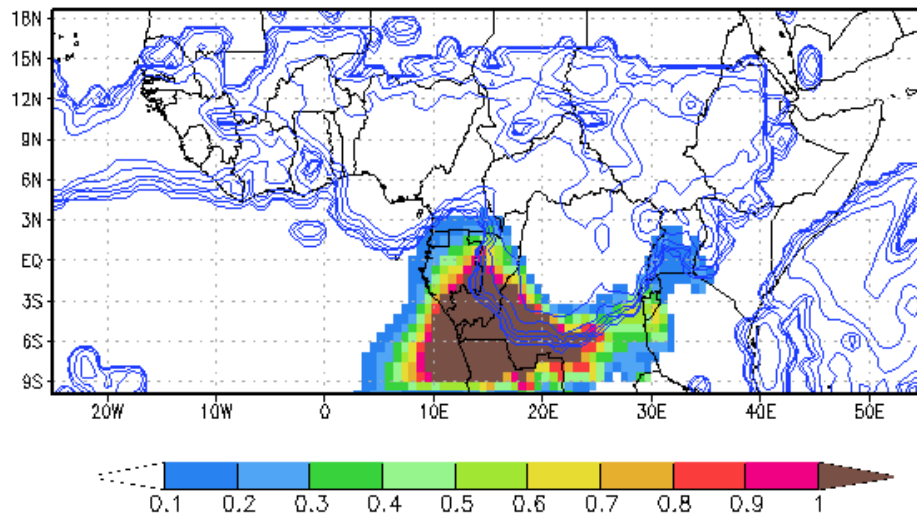




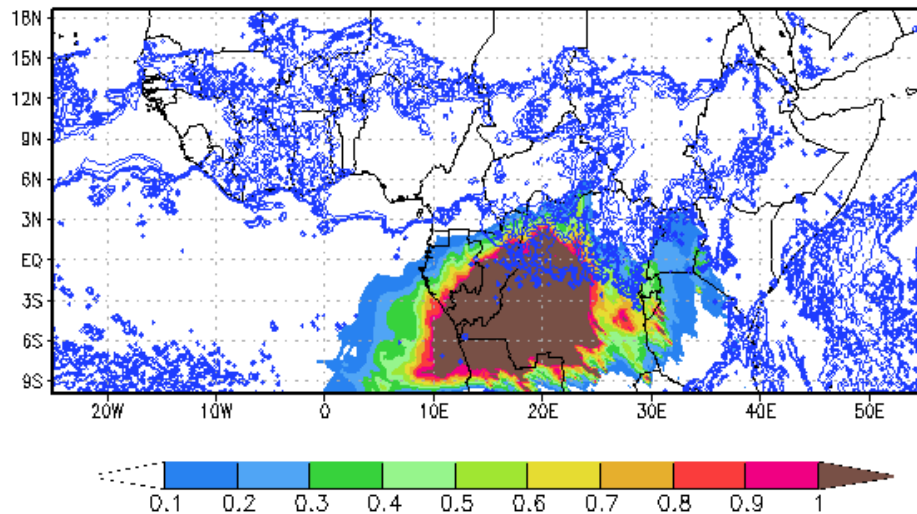
MODIS - AOD @ 550 nm - year:2012 julian day:208



OCD fires + precip, ERA, 550nm,26JUL2012

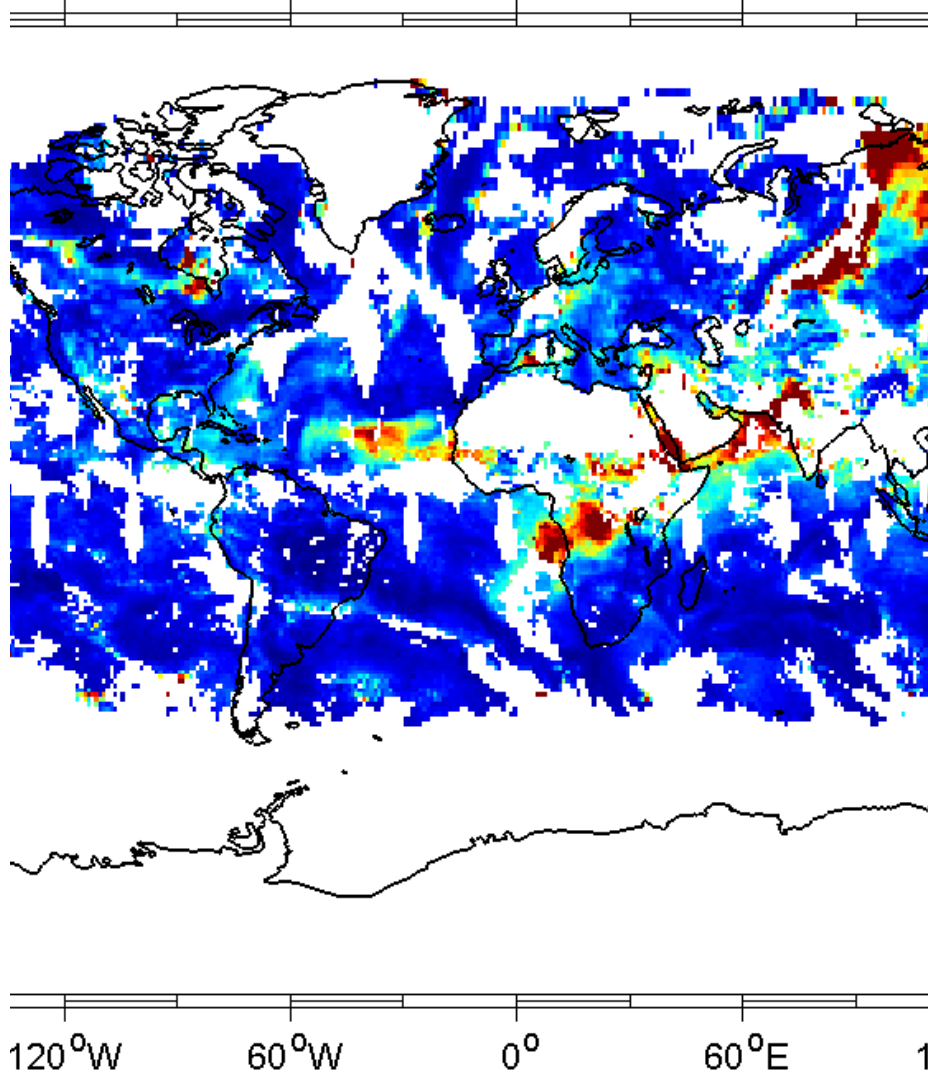


OCD fires + precip,EC_OPER,550nm,26JUL2012

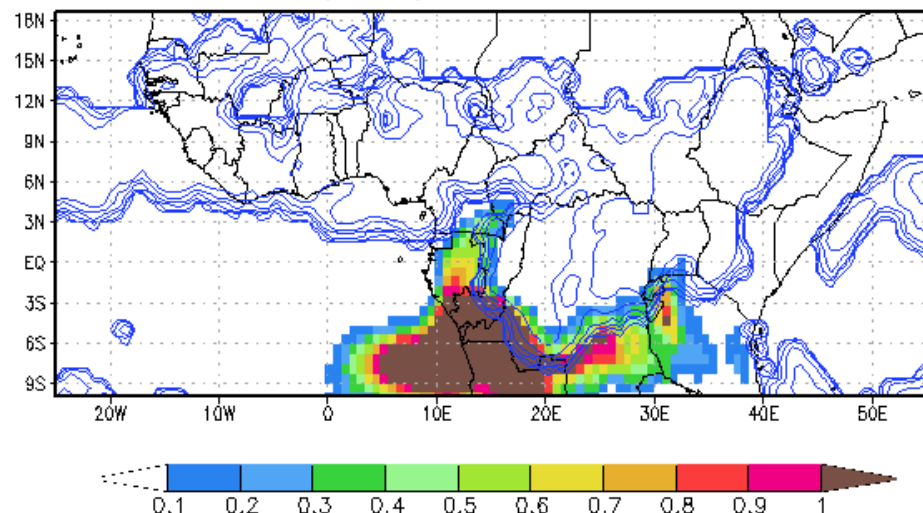




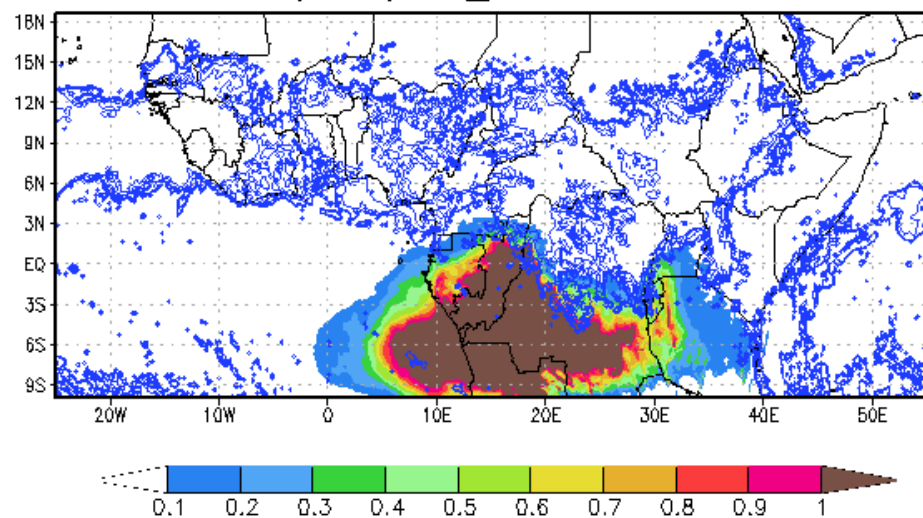
MODIS - AOD @ 550 nm - year:2012 julian day:210



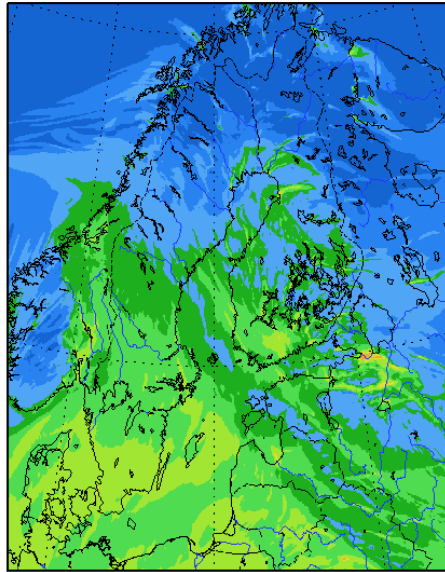
OCD fires + precip, ERA, 550nm,28JUL2012



OCD fires + precip,EC_OPER,550nm,28JUL2012



for NO2 gas. Last analysis time: 20170505 00
Concentration, ugN/m3, 13:00Z 27FE



Northern Europe:
2km, troposphere

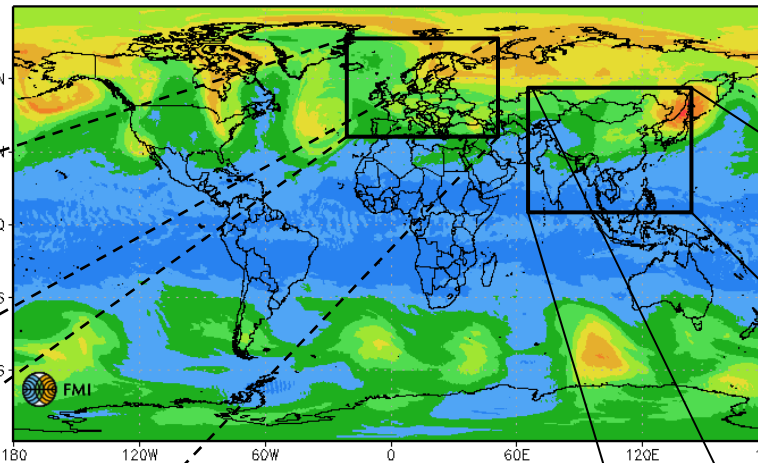
Operational AC/AQ-modelling at FMI

- Started: Feb 2016 -

Global: 50km,
troposphere+ stratosphere

Forecast for O3 column. Last analysis time: 20170505 00

O3_column, DobsonUnit, 19:00Z 07MAY2017

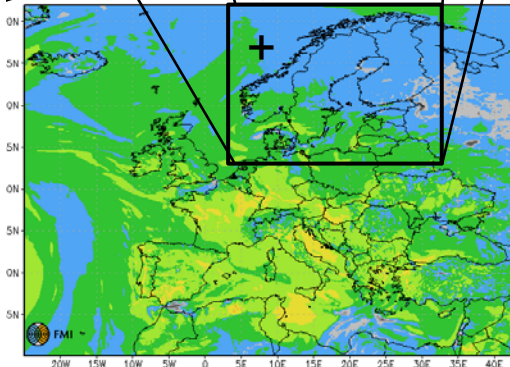


All forecasts:
4 days with 1hr step,
SILAM v.5.x

<http://silam.fmi.fi>

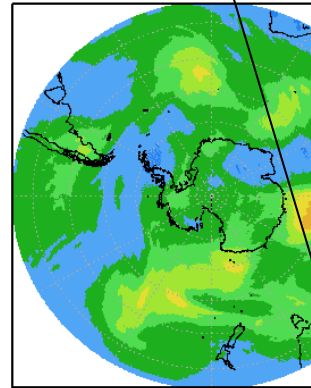
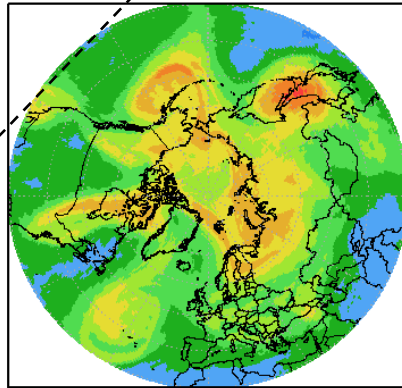
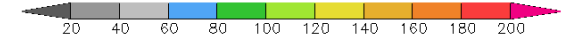
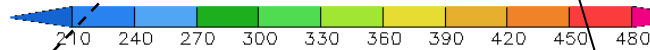
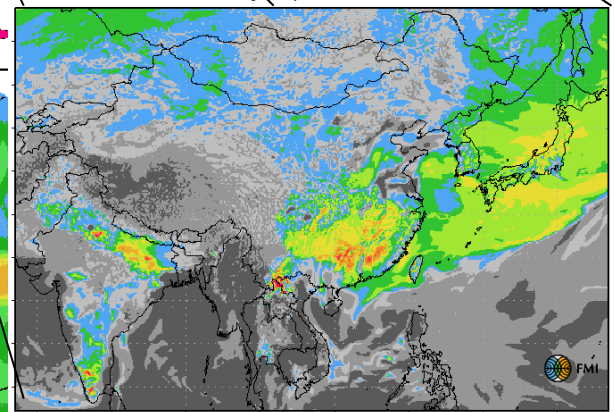
Asia: 14km,
troposphere

Concentration, ugO3/m3, 19:00Z 07MAY2017



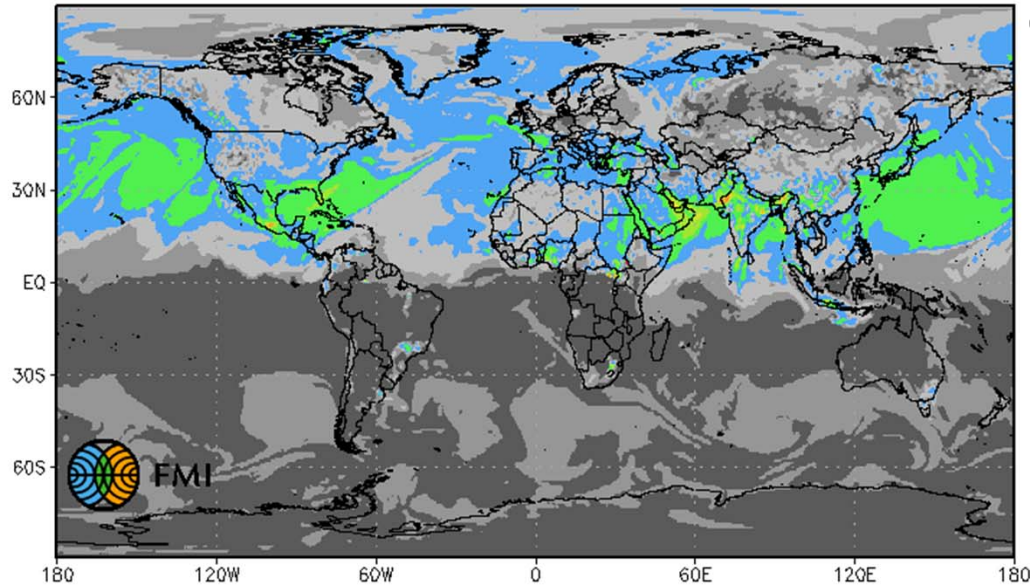
Europe:
10km, troposphere
boundaries: C-IFS
hindcast: 3D-Var

Concentration, ugO3/m3, 19:00Z 07MAY2017



Forecast for O3_gas. Last analysis time: 20160213_00

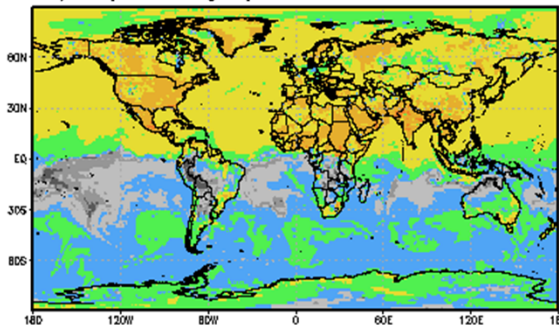
Concentration, ugO3/m3, 01:00 13FEB2016



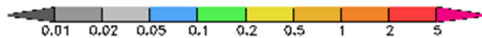
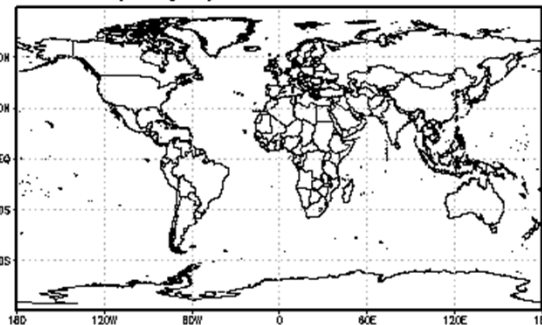
Global AQ Forecast

- Global, srf – 10Pa
- 720 x 360 cells
- 0.5x0.5 degree
- 28 hybrid levels
- Daily 0 +96 hours
- Available ~0400UTC
- Pre-operational
- presented at <http://silam.fmi.fi>

Dry dep. 0.1 ugO3/m2sec, 01:00 13FEB2016



Wet dep. ugO3/m2sec, 01:00 13FEB2016



Data availability

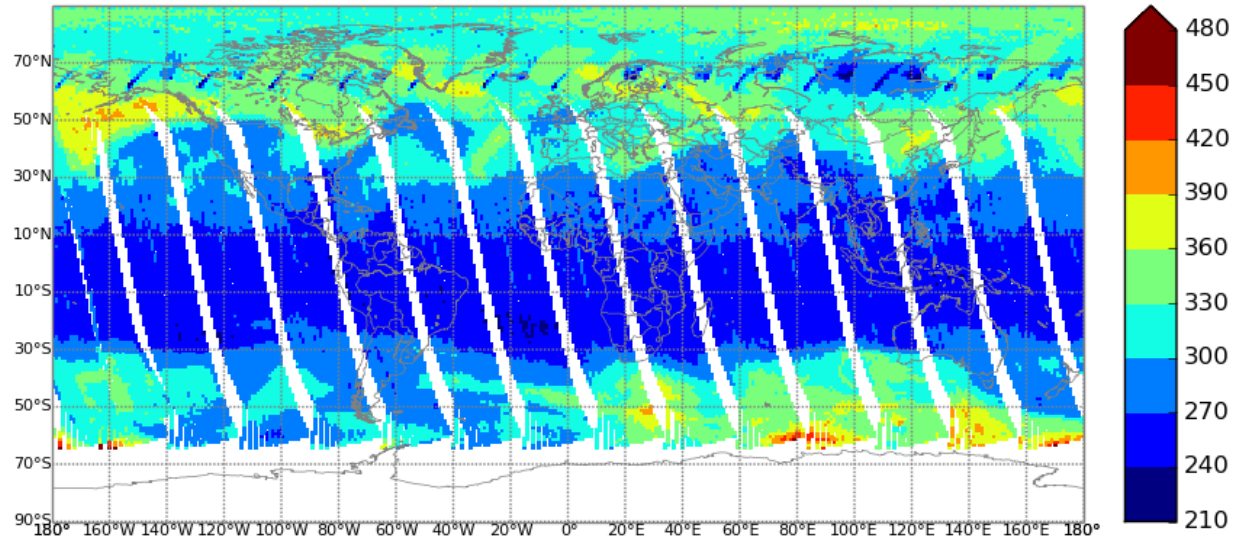
- hourly output of 2-3 latest forecasts
(e.g. boundaries, vertical profiles, station time series etc.)
- daily mean/max SO₂, NO, NO₂, CO, O₃, PM₁₀, PM_{2.5}

Formats:

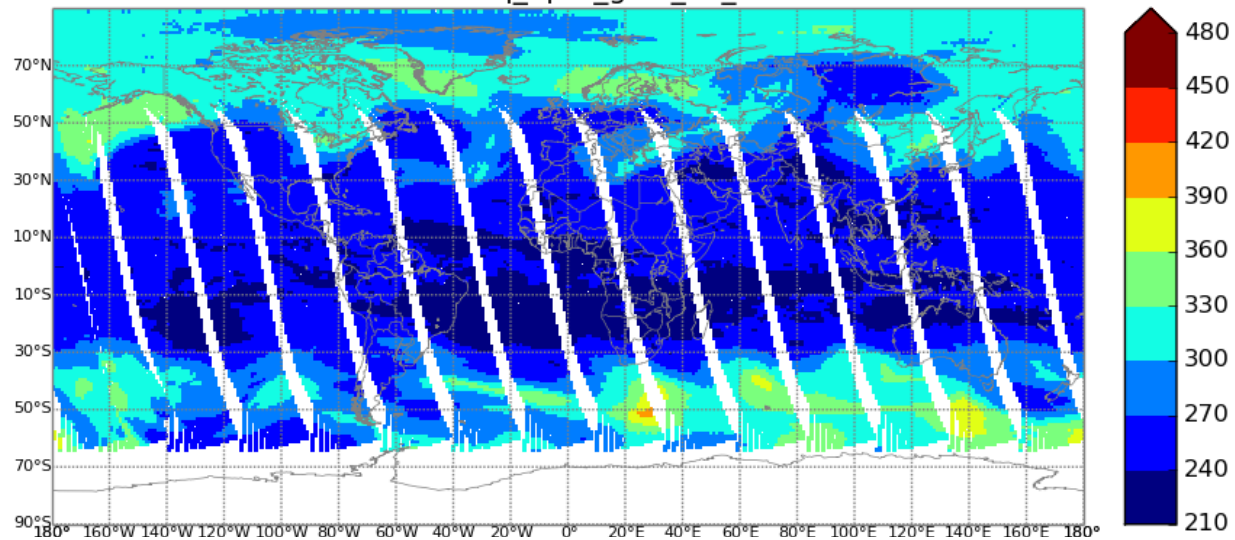
- Pictures/animations at <http://silam.fmi.fi>
- Pictures of daily mean/max (Silam colors, CAMS colors)
- OGC-kind data server THREDDS
<http://silam.fmi.fi/thredds>

Online evaluation (O3 column, OMI)

O3 Dobson units OMDOAO3 20170620

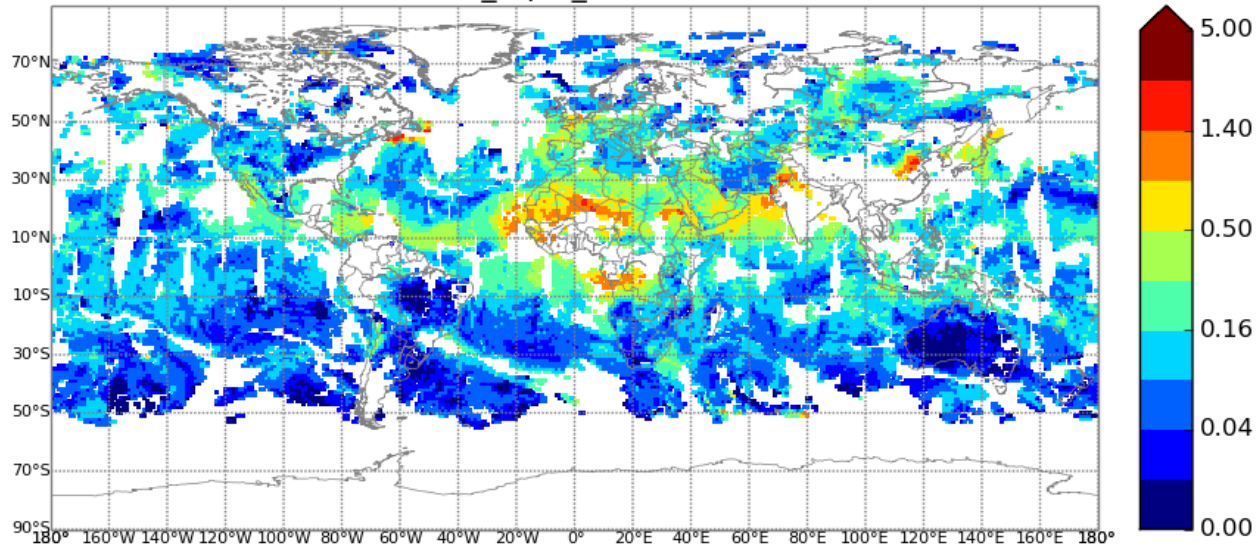


O3 Dobson units aq_apt_a_glob_v5_5 20170620

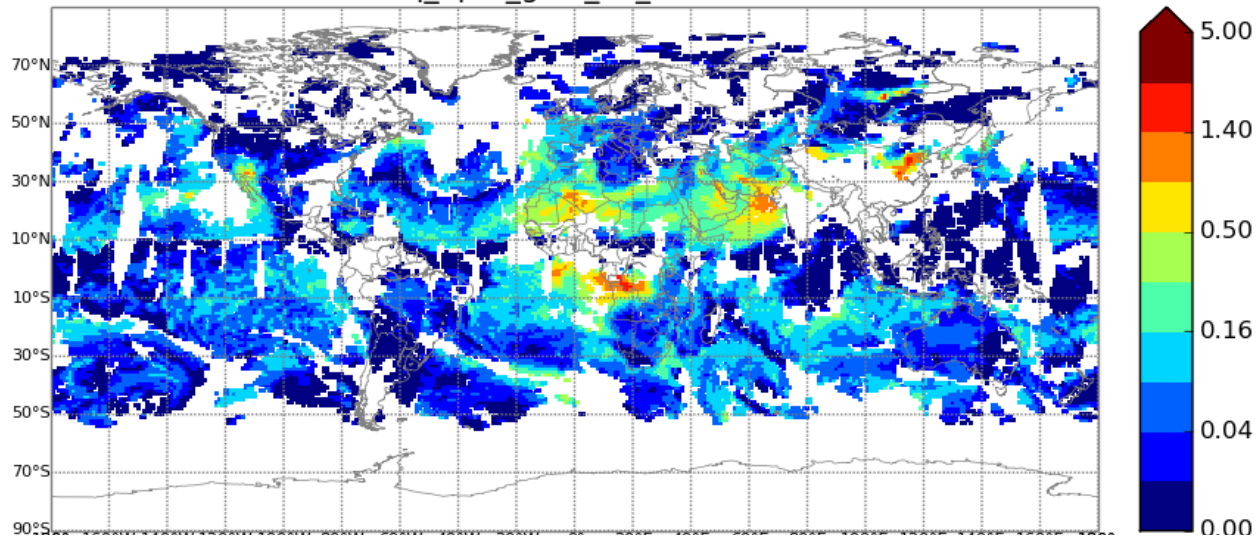


AOD column, MODIS

aot Modis_Aqua_Terra 20170620



aot aq_apt_glob_v5_5 20170620



Conclusions

- State-of-the-art emissions IS4FIRES, Steam, Desert dust
- Global AQ Reanalysis
 - 1980-last year, being evaluated, updated
 - Available on request
- Global operational forecasts
 - Online rolling archive
 - Online validation
 - TODO: PSCs, online BioVOC
- No assimilation (yet): free-running model