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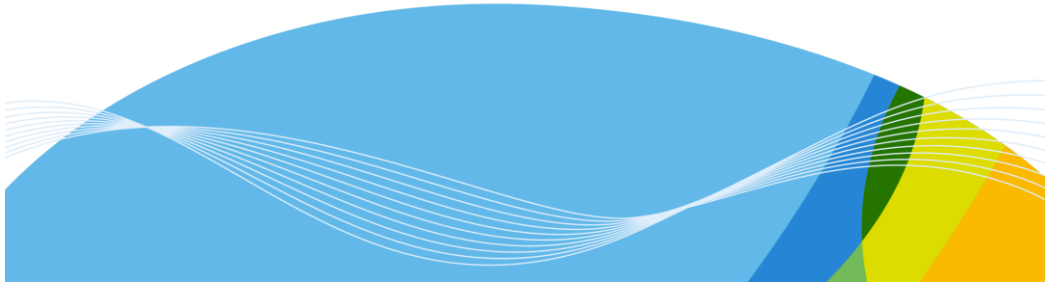
# Air quality forecasting and assessment
## Ankara, 21.10.2015

Res.Manager, Adj Prof. Ari Karppinen +
J. Soares, M. Sofiev, M. Prank, J. Vira, R. Kouztenov, V. Tarvainen, P. Siljamo, J-P. Jalkanen



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## Air pollution

- Sources:
  - Anthropogenic
  - Biogenic from vegetation
  - Natural (e.g. sea salt and dust)
  - Wildland fires
- Important facts:
  - Marine traffic: 40% of NOx and 50% of SOx of total-European anthropogenic emission
  - Wild-land fires: on average contribute 10-50% of European anthropogenic emission of PM and some gases (e.g. CO)
  - AQ problems can have a regional/local or transboundary origin
  - Transport-related air pollution is increasingly contributing to environmental health risks in many countries.

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# Air quality forecast & assessment

- Goals:
  - information to public and authorities
  - AQ forecast: decision support for short-term abatement
  - AQ assessment: analysis for long-term decision-making

- Main regulated species: $O_3$, $NO_2$, $SO_2$, $PM_{2.5}$, $PM_{10}$
- AQ forecasting/assessment: numerical models applied from global to national level

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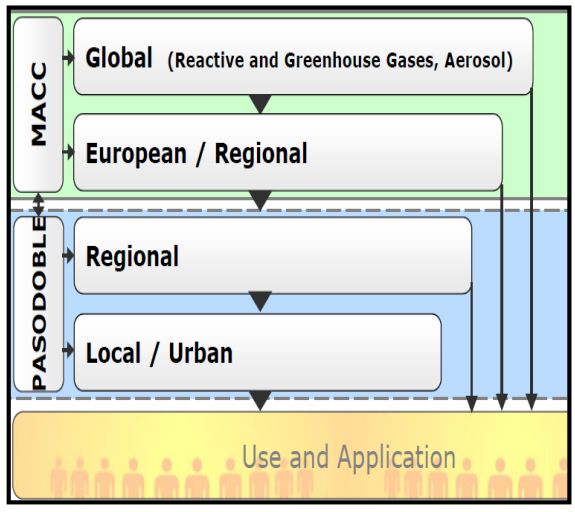
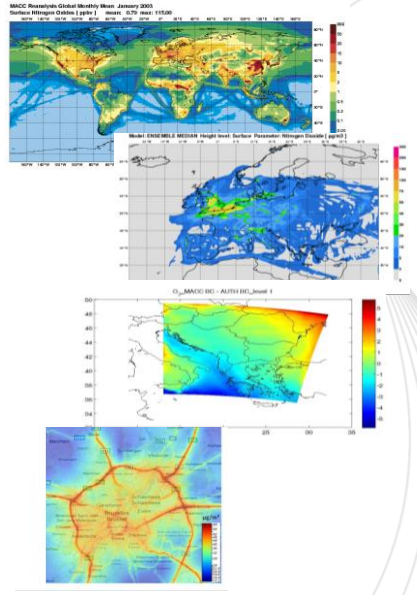
# European AQ service chain



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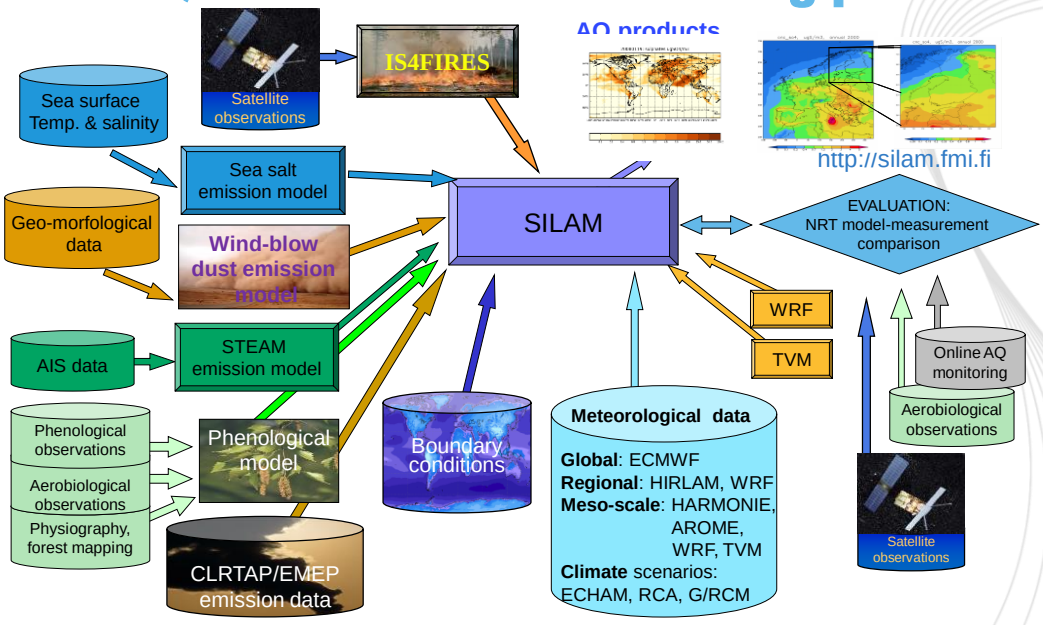
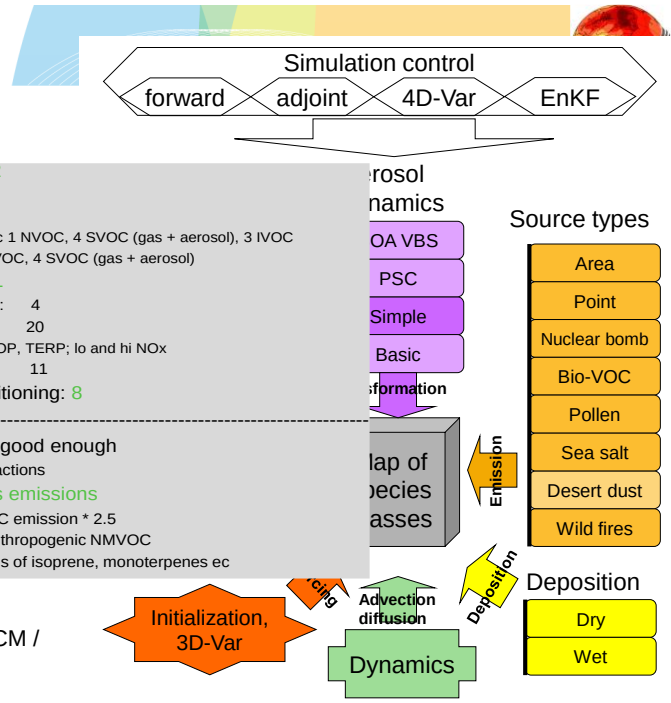
# FMI AQ assessment & forecasting platform




# SILAM v.5.5




- Modules
  - 9 chem… transfo… (7 oper…
  - 8 sourc…
  - 4 aeros…
  - 3D-,4D…
- Domains: … scale (~1k…
- Meteo inp…
  - ECMW…
  - HIRLAM … ECHAM … write G…
  - WRF
  - ECHAM, NorESM, other GCM / RCM

- 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

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- 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

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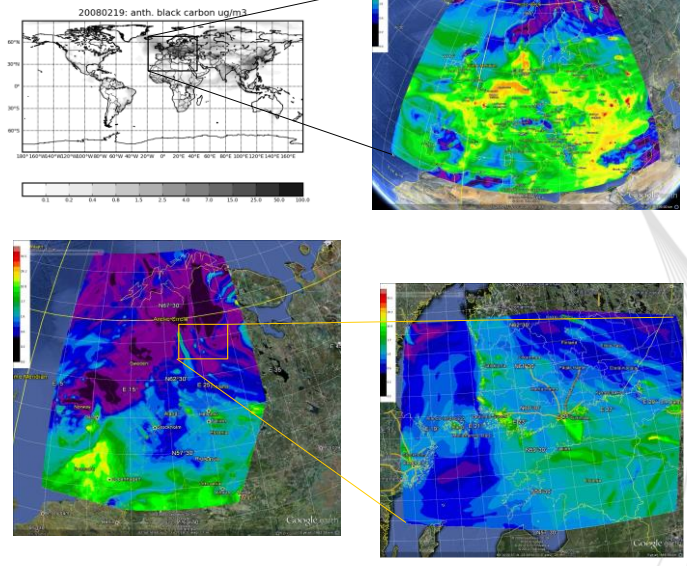
# SILAM scales

SILAM is suitable from global to smaller scales (1-2 km) simulations

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# SILAM network

- SILAM system is a joint effort of
  - Finland: FMI, University of Helsinki, University of Turku, VTT Energy
  - Russia: Main Geophysical Observatory, Hydrometeorological University
  - Estonia: University of Tartu
  - Austria: Medical University of Vienna
  - Israel: Ben Gurion University
- SILAM algorithms in:
  - sea salt emission: EURAD (Germany), WRF-Chem (US), CAMx (Greece)
  - pollen emission: GMES MACC modelling ensemble (CHIMERE, EMEP, EURAD, LOTOS-EUROS, MATCH, MOCAGE)
- SILAM users (open-code system)
  - Available from Web: ~40 downloads, over 15 countries
  - Known working installations: Estonia, Russia, Lithuania, Spain (2), FYR Macedonia
  - Finland: Helsinki Metropolitan Area Council, University of Turku (forecasts)
  - Estonia: University of Tartu (boundary conditions)
  - Lithuania: EPA (forecasts), Vilnius city (boundary conditions)
  - European Aeroallergen Network (forecasts)
  - FYR Macedonia: Macedonian Environmental Information Center (forecast/assessment)

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# SILAM application types

- **Short-term forecasting and re-analysis**
  - atmospheric chemical composition
  - allergenic air pollution
  - plumes of wild-land fires
- **Emergency preparedness**
  - nuclear
  - volcanic
- **Observational campaign analysis**
- **Source apportionment studies**
  - anthropogenic sources
  - natural sources: allergenic pollen, volcanoes, fires
- **Risk assessment**
  - chemical
  - nuclear
- **Climate change forcing and impact**

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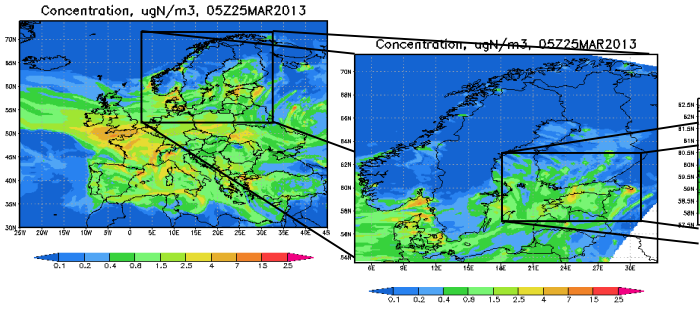
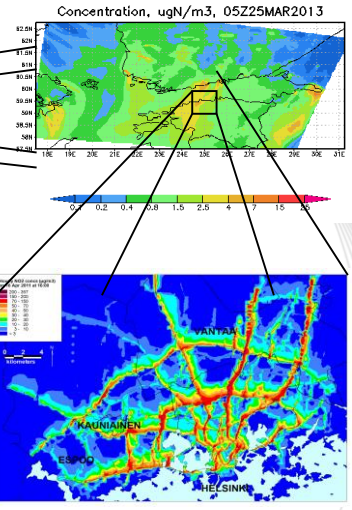
# Air Quality forecasting




Maps of $NO_2$ forecast




Operational AQ forecasting
- from European to Helsinki city-scale
- open for public
- AQ Index for Helsinki, predictions for monitoring sites
- anthropogenic and natural emission
- smoke from forest fires

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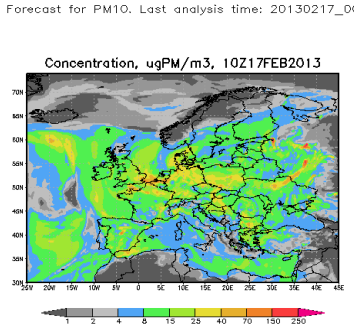
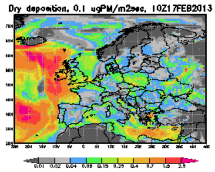
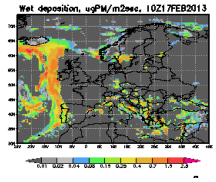
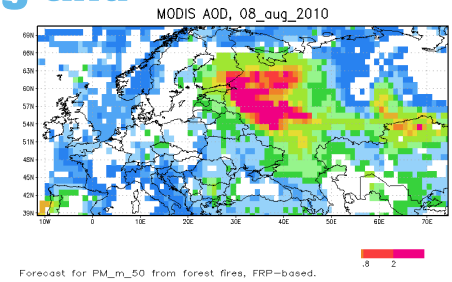
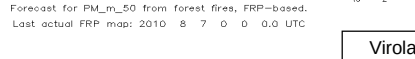
# Short-term forecasting and re-analysis

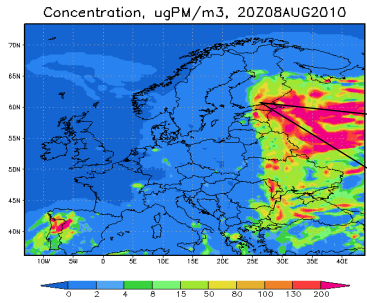


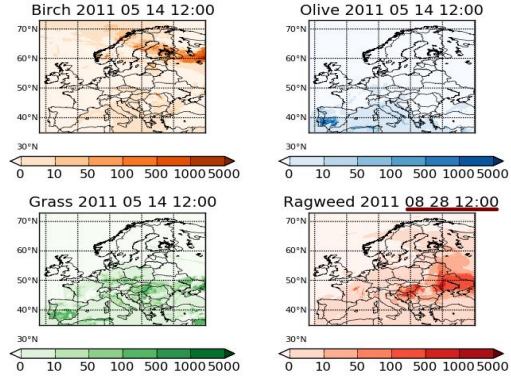

Virolahti, 8.8.2010
Predicted (+24hrs): 120 µg PM2.5 / m3
Observed: 140 µg PM2.5 / m3

## Natural allergens: pollen

- Allergy prevalence: ~30% of European population
- Hyper-sensitivity to tree and grass pollen is among the most-common causes
- Pollen forecasts
  - daily
  - whole Europe
  - public
  - basis for allergy alert servic and pollen bulletins
  - generated by FMI in co-operation with European Aeroallergen Network

Example of forecast for:

- birch, grass, olive: 14.05.2011 12:00 UTC
- ragweed for 28.08.2011 12:00UTC



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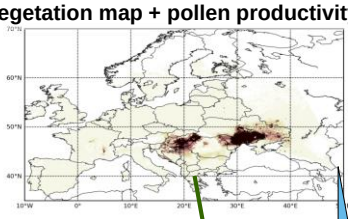
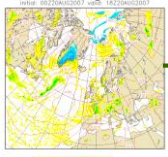
# Ground-breaking forecast: Pollen

**Vegetation map + pollen productivity**

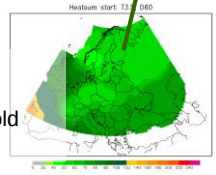


**Meteorological forecast**

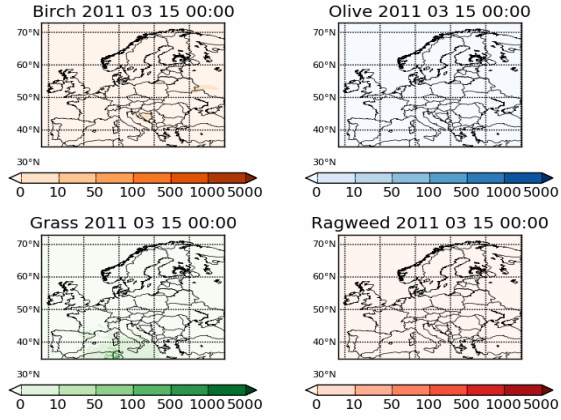


SILAM
release
transport
sinks

**Flowering intensity**
Multi-threshold model



**Pollen concentration** [#/m3]

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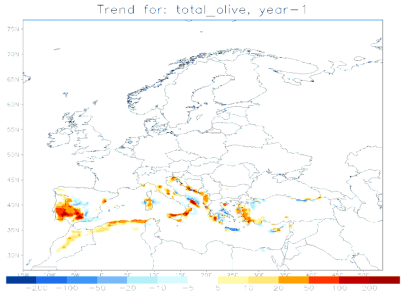
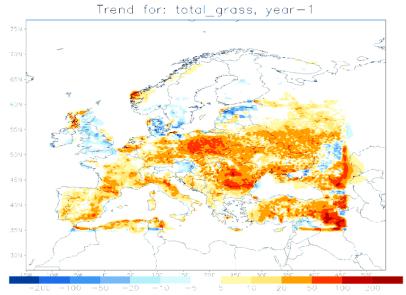
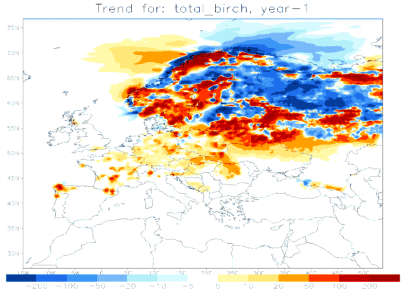
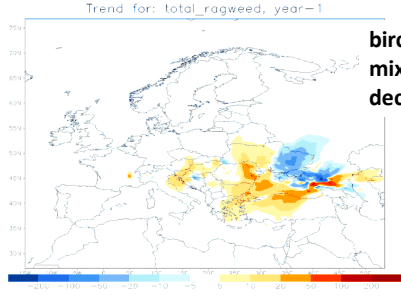
# 30-years modelled trends




**grass, olive: mainly increase**



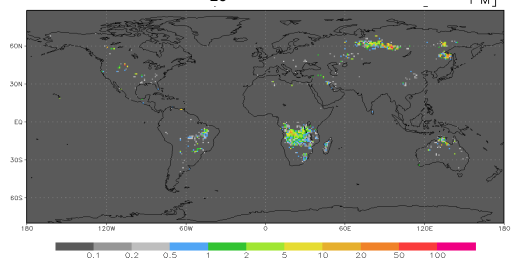




**birch, ragweed: mixed, mainly decrease**

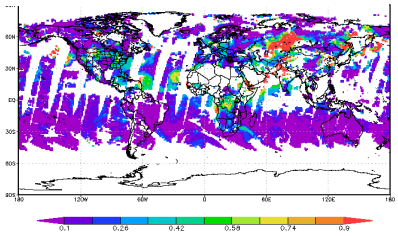
# Wild-land fires

- Regular phenomenon, among the most-powerful sources of air pollutants
- Affected by anthropogenic activities
- Strong air quality and climate forcing

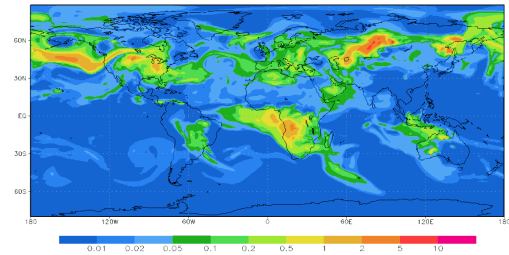
Fire-induced $PM_{10}$ emission, 5.07.2012



MODIS-Terra observed total optical thickness, 5.07.2012



Modelled optical thickness of fire plumes 5.07.2012



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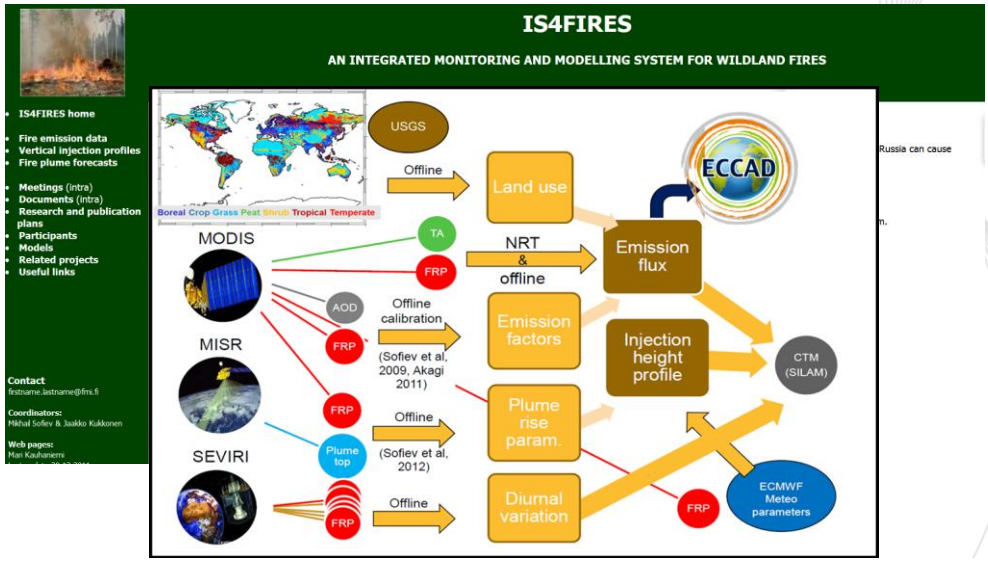
# Fire information to emission: IS4FIRES

**is4fires.fmi.fi**



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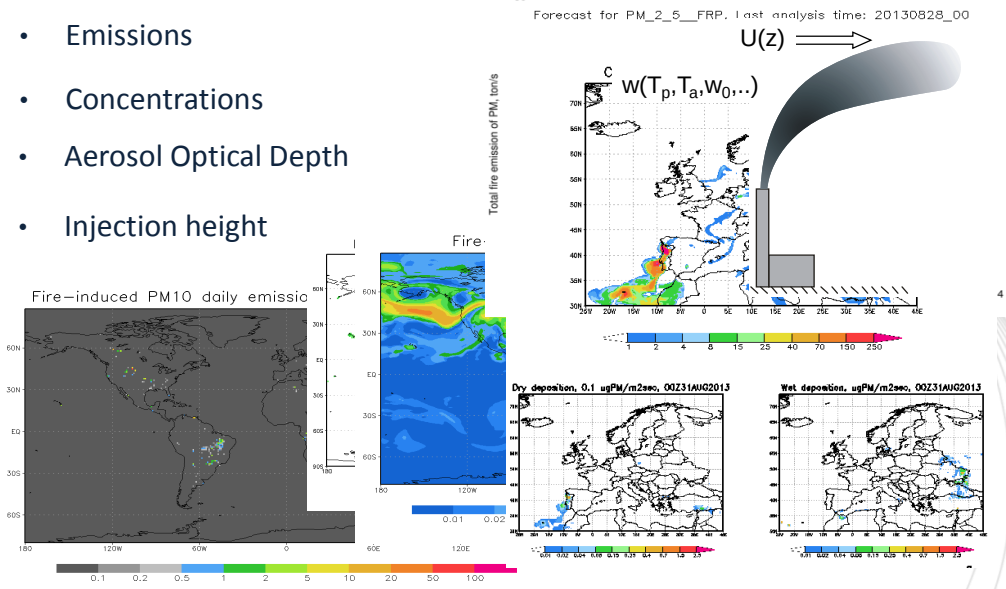
# Fire Assimilation System: products

- Emissions
- Concentrations
- Aerosol Optical Depth
- Injection height



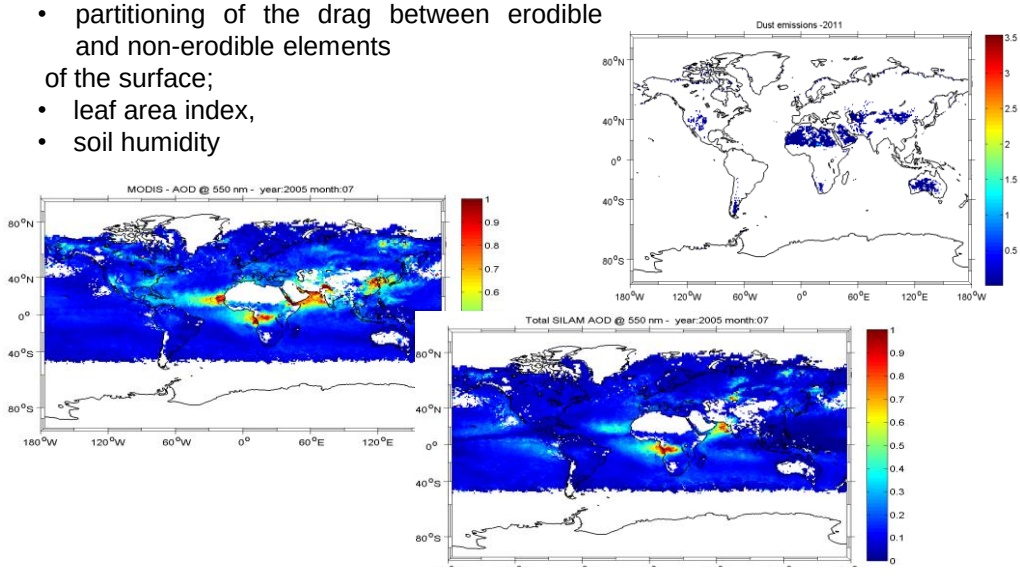

## Dust

Based on the saltation/sand blasting processes

- partitioning of the drag between erodible and non-erodible elements

of the surface;

- leaf area index,
- soil humidity



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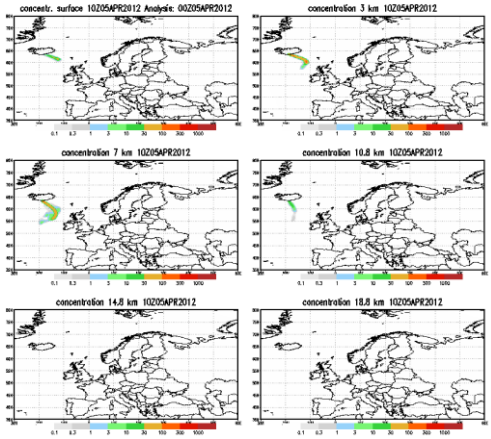
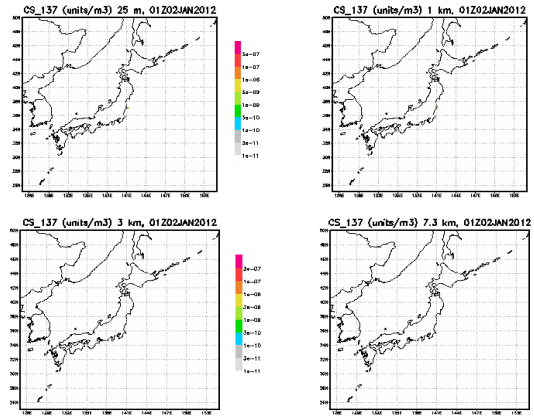
# Emergency preparedness

Nuclear




Volcanic

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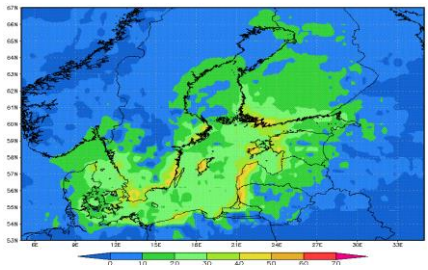
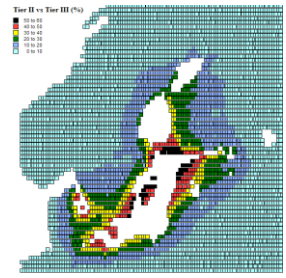
# Risk assessment

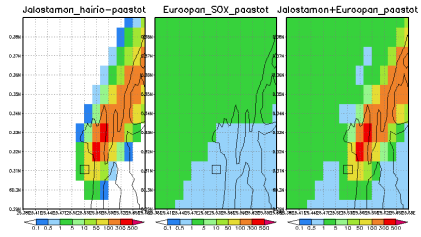
Impact on ecosystems (deposition)



human health (concentration)



Impact of an uncontrolled release on the surroundings of the stack



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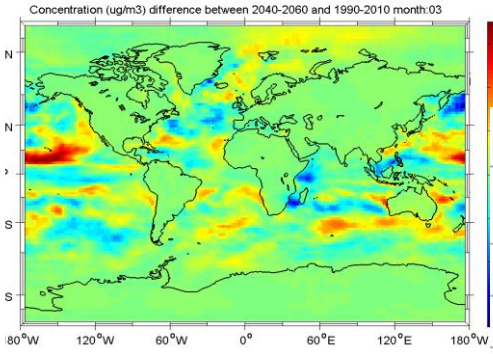
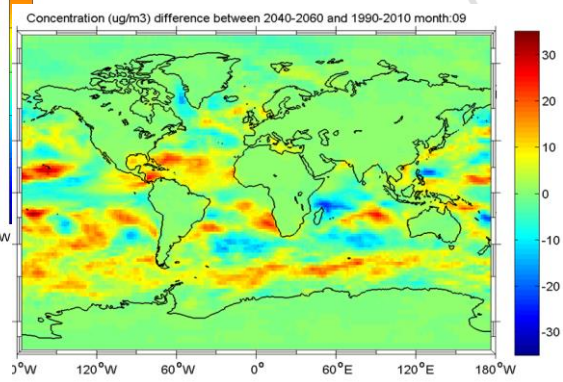
# Climate change forcing and impact




March

Closer to equator the concentration difference between current and future climate periods are substantial – increase of temperature

SSA concentration: Mean 2040-2060 vs Mean 1990-2010 (difference)




September

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# Data users/providers

- Relies on the availability of MACC 2 and PASODOBLE products related to different pollutants for assessment and decision making
  - Boundary condition
  - Emissions
  - Ground and remote sensing data
- Forecast & reanalysis:
  - Boundary conditions
  - Concentrations, emissions
- AQ assessment:
  - long-range pollution transport impact on AQ in remote areas, for local level decision makers
  - Impact of AQ policies

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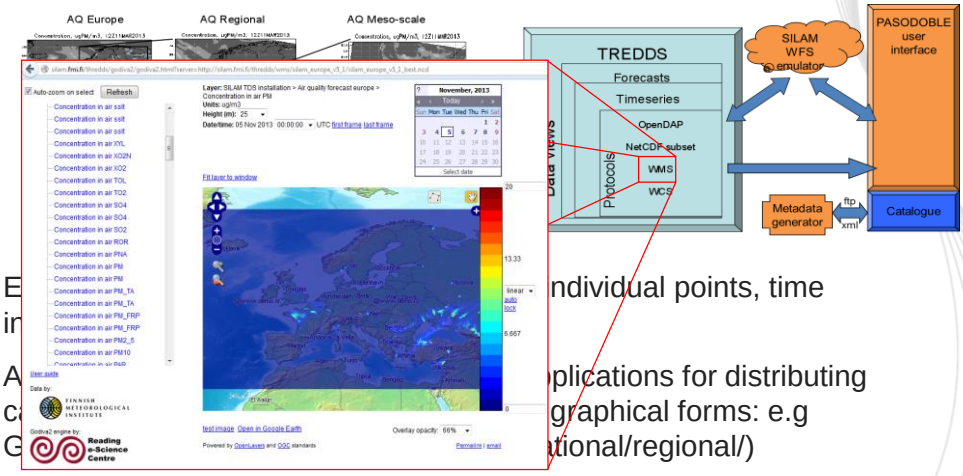
# THREDDS (=> FMI: open data)

- SILAM operational forecast data availability via interfaces was setup within MACC and PASODOBLE projects




- E… individual points, time i…
- A… plications for distributing c… graphical forms: e.g G… tional/regional/)

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## Note: New European standard for AQ modelling

- **Scope**
- •Describe the methodology to define and calculate the Model Quality Objective (MQO) and ModelPerformance Indicators (MPI). The MPI (bias, correlation, standard deviation) together with the MQO constitute the Benchmarking report.
- •In the frame of this methodology, fulfilment of the MQO is essential whereas fulfilment of the MPI is not(the latter are provided as support information).
- •Flexibility is left to select the appropriate tool to apply the methodology.
- •The Air Quality Directive identifies different potential uses for modelling: Assessment, Planning, Forecast and source apportionment. The scope of the MQO and MPC is here restricted to assessment purposes in the context of the Air Quality Directive.
- •Pollutants covered PM2,5, PM10, NO2, O3
- •Concentration range ( no limits )
- •Time average (pollutant specific)
- •Scale (regional, urban, street)
- •Methodology Restrictions (Pollutants concerned)
- FIRST meeting of the WG: October 2015 ( ->2-3 years)

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# Inversion of emissions

- General idea
- Some examples

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## Aerosol emission inversion

- The aerosol emission estimates for anthropogenic sources are obtained with a 4D-Var based optimization
  - find an emission distribution minimizing a quadratic cost function of the observation-model discrepancy
- Atmospheric dispersion: SILAM CTM
  - Emission, formation, transport, sink
  - 0.5º x 0.5º resolution, ERA-Int meteodata
- Included aerosol species:
  - primary OC, BC (MACCITY)
  - sulfates from SO2 oxidation
  - nitrates (not adjusted)
  - sea salt
  - desert dust
- PM2.5 from wildfires
- Assimilated: MODIS 550 nm AOD; monthly 4D-VAR window

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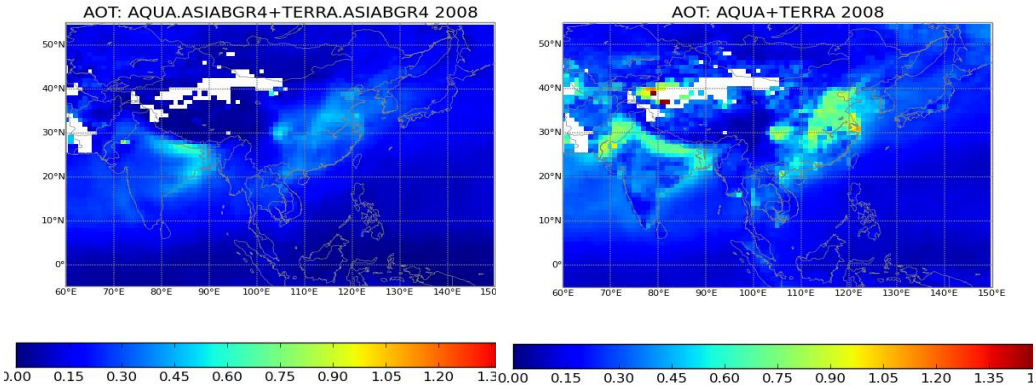
# A-priori AOD vs MODIS




A-priori

MODIS

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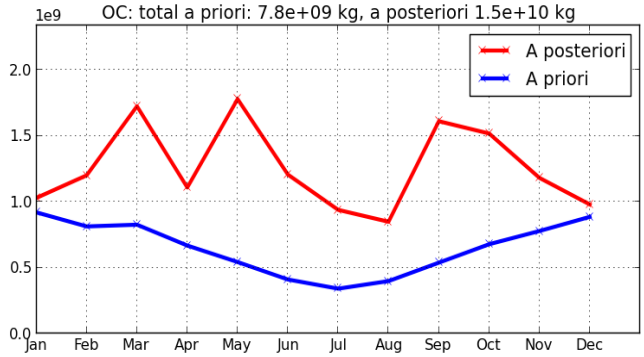
# PM emissions, monthly, kg

Asia, OC in PM1

Patterns for BC are similar but more moderate

Seasonality is affected by availability of MODIS data

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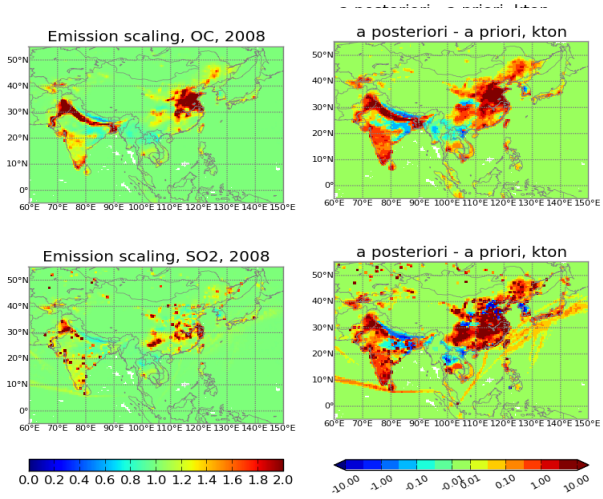
# PM vs SO2 emissions




- Stronger regularization applied
- L-curve criterion for stopping optimization: terminate iteration when cost function reduced "sufficiently" compared to changes in solution
- Large areas with reduced SO2 emission disappear
  - robustness?

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# Volcanic data assimilation

- So far performed only emission inversions in VAST:
  - use 4D-Var method to evaluate source term, then perform regular forecast
- What about traditional 4D/3D-Var
  - no source term adjustment, but concentration field updated at start of each assimilation window
- Pros/cons
  - + no information needed on eruption site or timing
  - + assimilation can correct for transport errors
  - + 3D-Var computationally cheap
  - - eruption location/time not used as a priori information
  - - no information gained about source term

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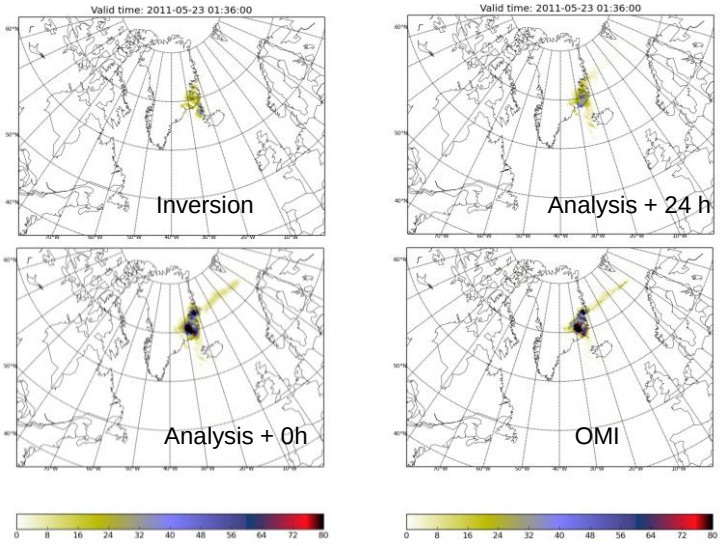
# Column densities, DU, 23.5.2011




Daily composites

Model data interpolated to OMI pixels

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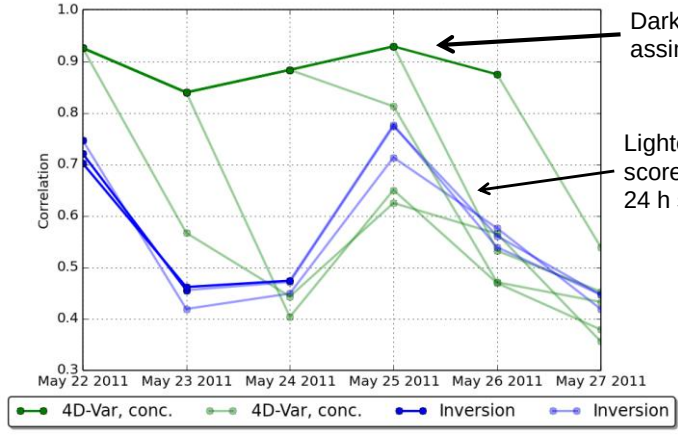
# Comparing statistics: correlation 4D-Var analysis vs inversion




Dark lines: score within assimilation/inversion window

Lighter lines: scores for forecasts, 24 h steps

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**websites:**

http://silam.fmi.fi/

http://atmosphere.copernicus.eu/

http://macc-raq-op.meteo.fr/

## Teşekkür ederim !