ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

Russian State
Hydrometeorological University

Fire assimilation over Europe in IS4FIRES and SILAM

M.Sofiev[1], R.Vankevich[2], J.Soares[1], M.Lotjonen[1], M.Prank[1], V.Petukhov[2], T.Ermakova[2], J. Kukkonen[1]

[1] Finnish Meteorological Institute

[2] Russian State Hydrometeorological University

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- Fire Assimilation Systems of FMI
  - System design
  - Fire description
    - Temperature Anomaly (TA)
    - Fire Radiative Power (FRP)
- Fire impact on atmospheric composition and air quality
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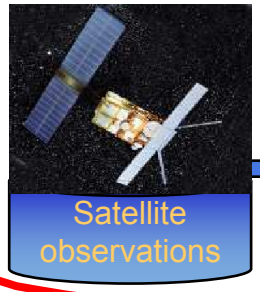
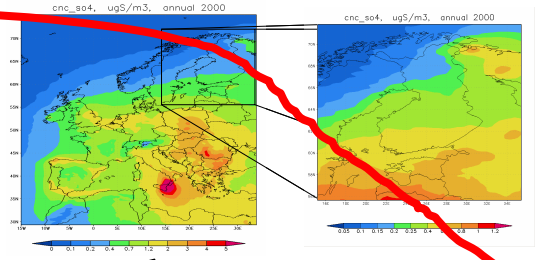
  - Comparison with atmospheric measurements: satellites and in - situ
- Conclusions / challenges

Information sources on fires

- In-situ observations and fire monitoring
  - pretty accurate when/where available
  - costly and incomprehensive in many areas with low population density
- Remote sensing products
  - burnt area inventories on e.g. monthly basis (registering the sharp and well-seen changes in the vegetation albedo due to fire)
  - hot-spot counts on e.g. daily basis (registering the temperature anomalies)
  - fire radiative power/energy and similar physical quantities on e.g. daily basis (registering the radiative energy flux)
- Impact on air quality is highly dynamic, thus temporal resolution and timeliness play the key role

FMI regional AQ assessment and forecasting platform





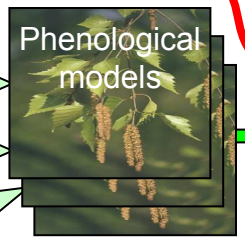
AQ products

http://silam.fmi.fi

Phenological observations

Aerobiological observations

Physiography, forest mapping



SILAM CTM model

EVALUATION: NRT model-measurement comparison

Online AQ monitoring

Aerobiological observations

AROME

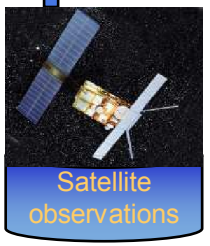
HIRLAM-MBE

HIRLAM-RCR NWP model

CLRTAP/EMEP emission data

Global boundary cond.

Meteorological data: ECMWF



Current Fire Information Systems in Finland

- Fire Alert System for Finland
  - decade-old, qualitative detection system for Finnish territory
  - ATSR + AVHRR (night-time) + MODIS (morning)
- Fire Assimilation System
  - based on TA: operational since March 2006
    - MODIS (Aqua + Terra) hot-spot counts as temperature anomalies: NASA Rapid-Response System

      …SEVIRI (work on-going)
  - based on FRP: operational since February 2008
    - MODIS (Aqua + Terra) fire radiative power

System information flow

Download manager:

Global set Aqua & Terra 1 km granules for current date

Spatial operations:

- *Quality Check*
- *Regrinding & Merging sources*
- *Masking and Emission scaling: PM 2.5, PM10, ~10 gas species*
- *Aggregation into grid*
  - *Global, daily, aggregated to 0.5 deg resolution*
  - *European, daily, aggregated to 10km*
  - *Regional, daily, 2-5 km (work on-going)*

SILAM Interface:

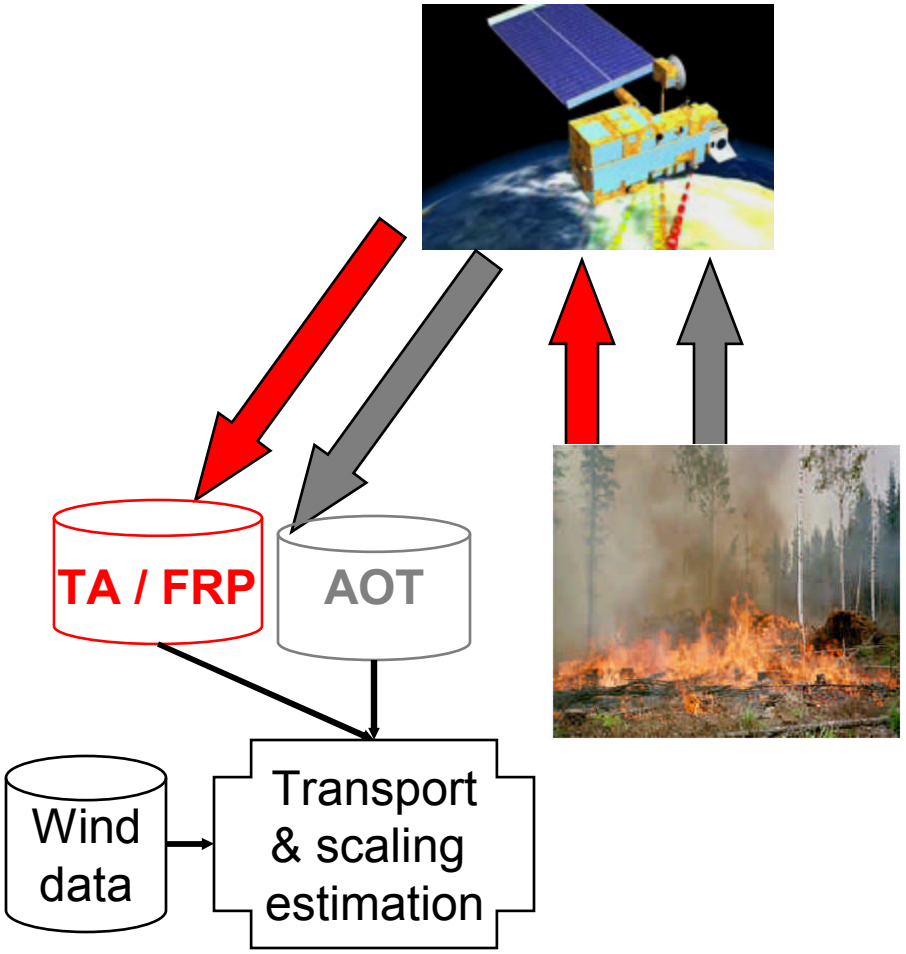
Automatic SILAM input file generation

Merging different sources of information

- Low-orbit satellites
  - balanced horizontal resolution (1km), comparable with that of the most of land use data
  - provide max 2-4 shots per day in irregular grid
    - Severe dependence on cloud cover
    - Missed diurnal variation
    - Problems in co-locating the same fire observed from different overpasses
- Geostationary satellites
  - provide the information every 15 minutes, fixed grid
  - quite low sensitivity (~5-10 times fewer fire spots detected per shot in comparison with low-orbit instruments)
  - quality deteriorates with latitude, nearly no information beyond 60^0N/S
  - Molnia-type orbits are still dreams

Determining the emission scaling

- Satellite(s) observe both fire itself and the resulting plume
- Horizontal dispersion is crudely evaluated based on wind information
- Simple algebra leads to TA/FRP-to-totalPM emission factor based on land use type
- Speciation is assumed mainly from laboratory studies

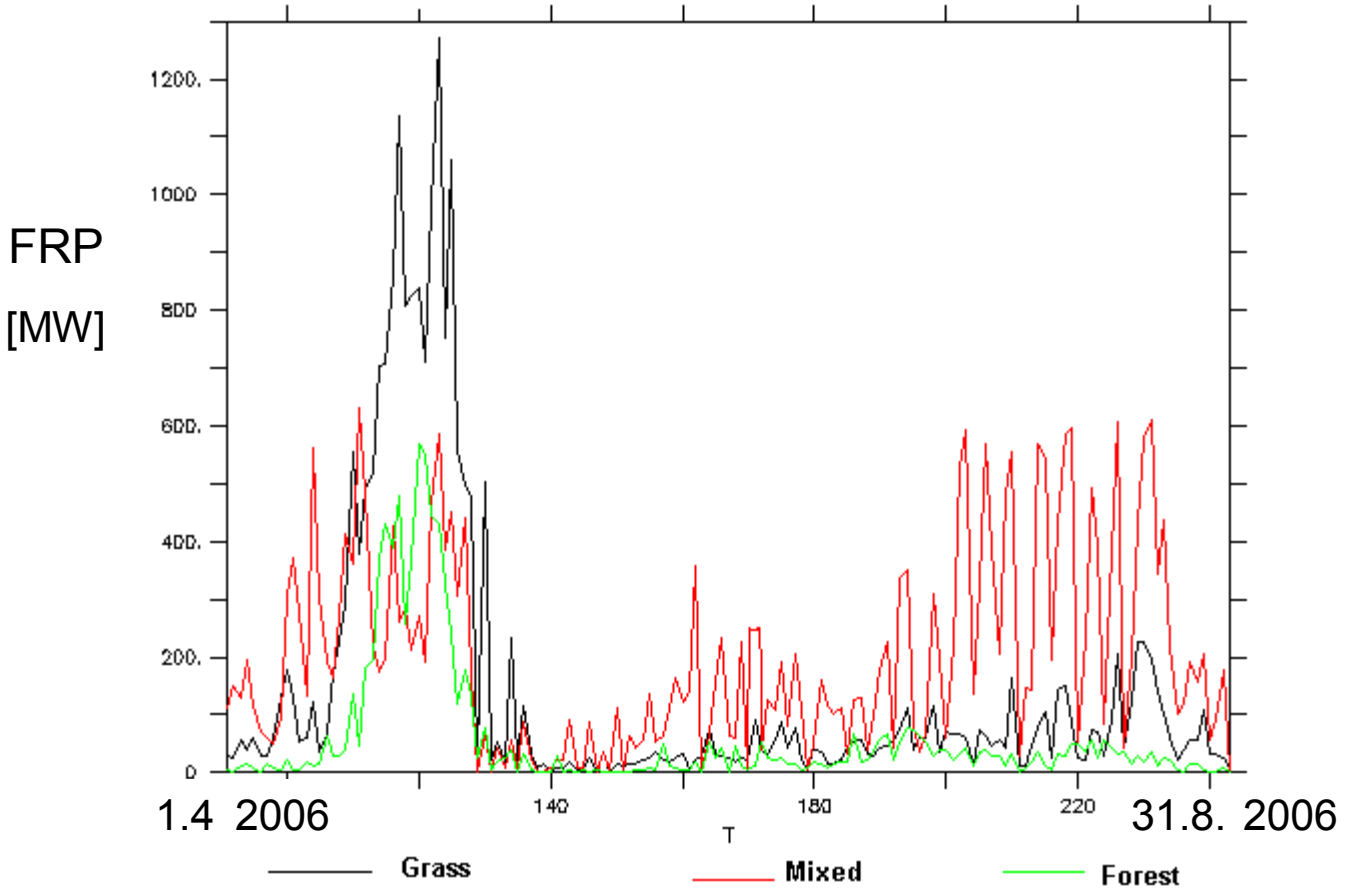


- +: simple, efficient, consistent (+/-)
- --: crude transport unless DA is used, inapplicable if other PM sources are significant, speciation is guessed from independent studies

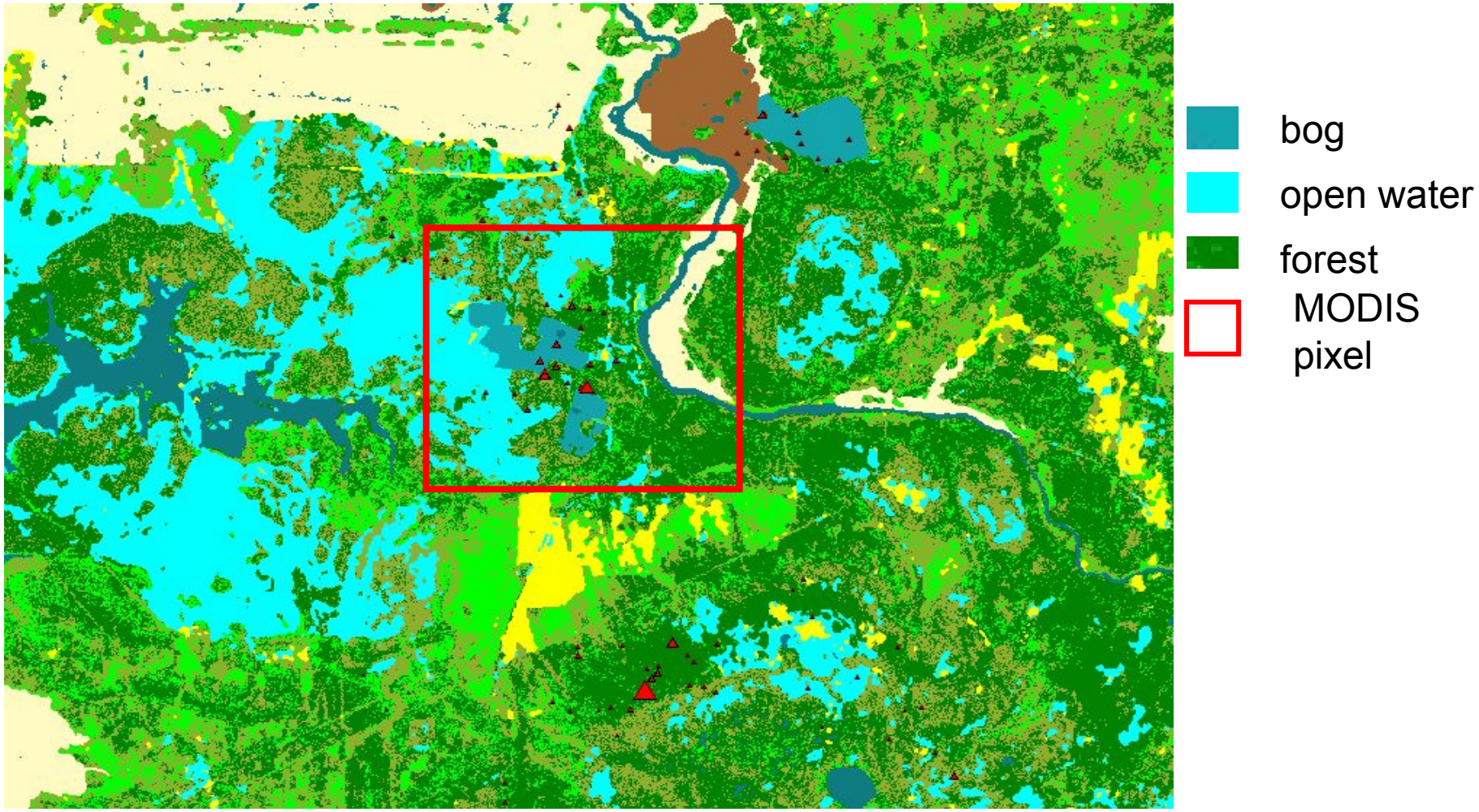
Fires in Siberia, visible range: hot spots, fumes.

Emission scaling vs land use: What is burning??

- Area-integrated emission in Europe from 3 land use types for 2006: time series for 5 months April-August



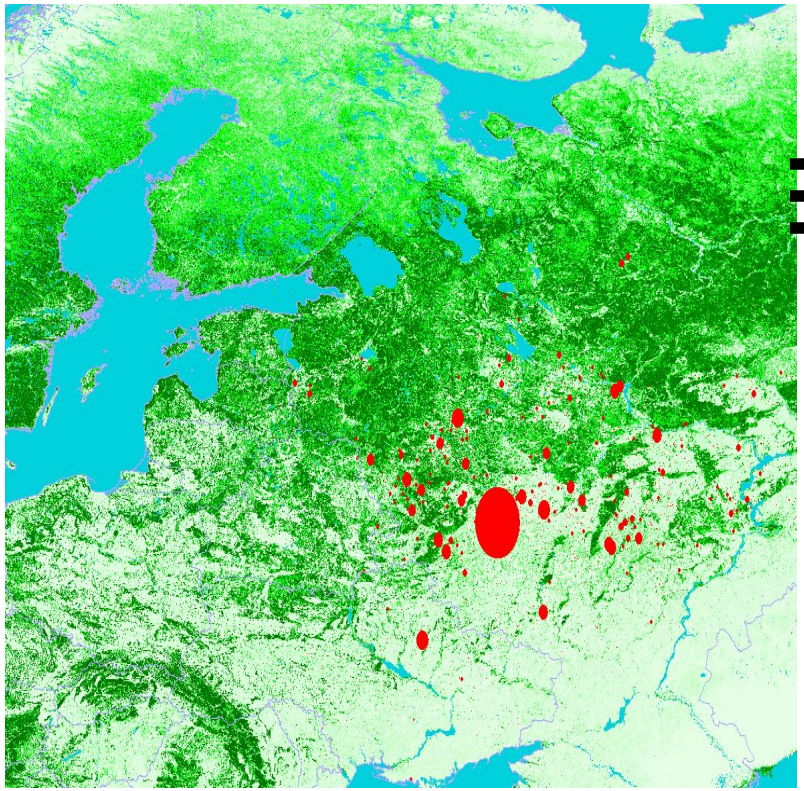
Emission scaling vs land use: What is burning??



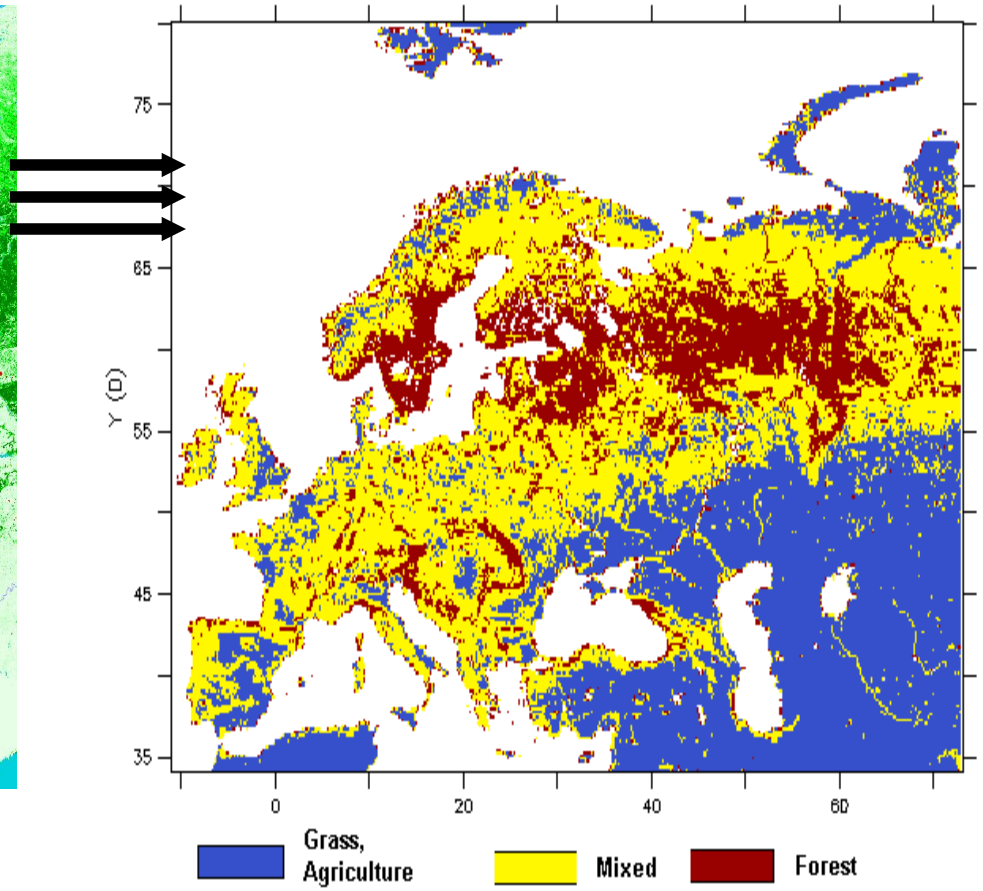
Fuel type identification example: LandSat 30m

Land-use related pattern of emission coefficients

- LANDSAT, 250m → 10km-grid classification of prevailing land-type as a surrogate for emission factors



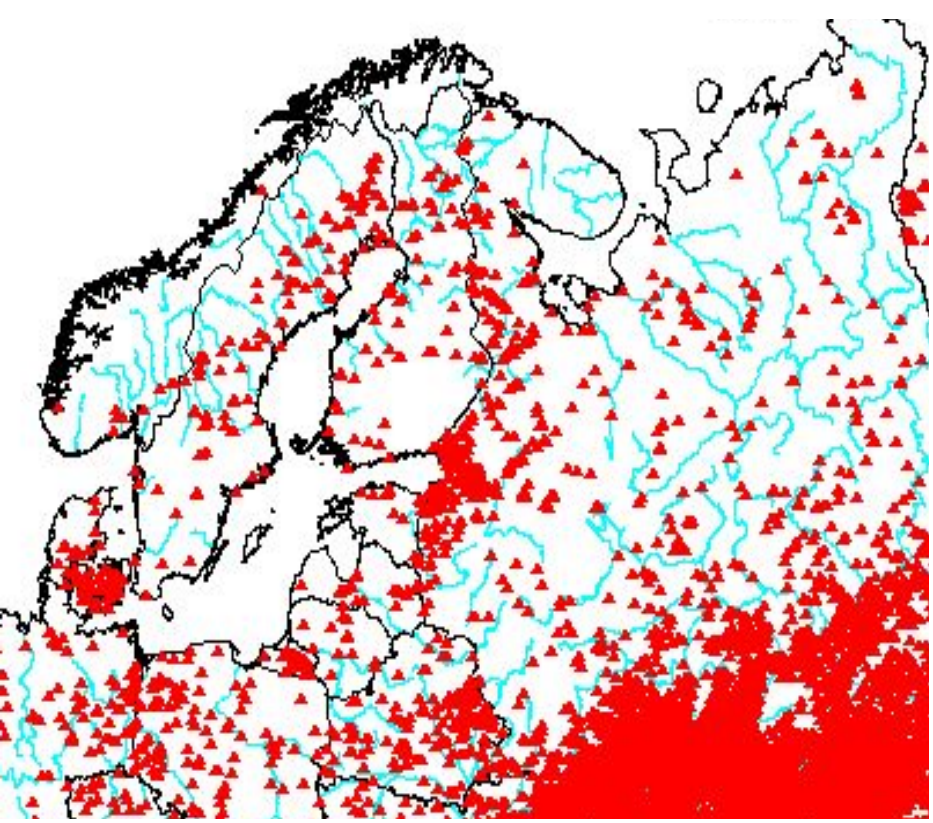
Fire pixels: May 2006



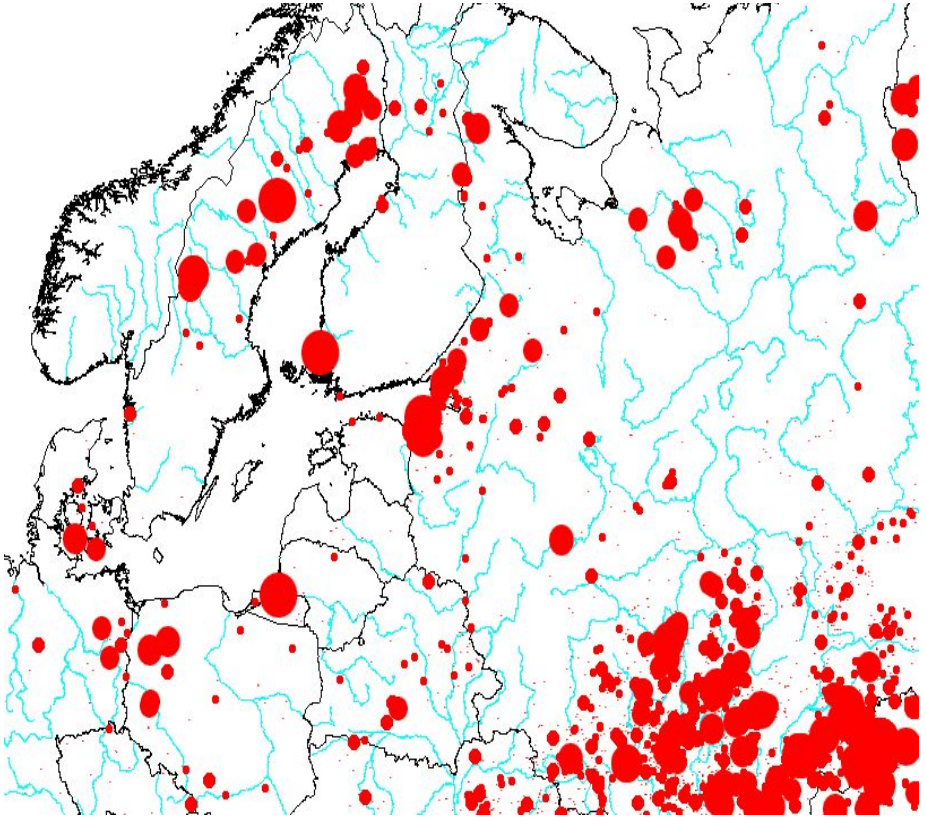
Scaling to emission: hot spots (TA) vs FRP

Hot spots FRP

per-pixel statistical database (time-integrated May-August 2006)



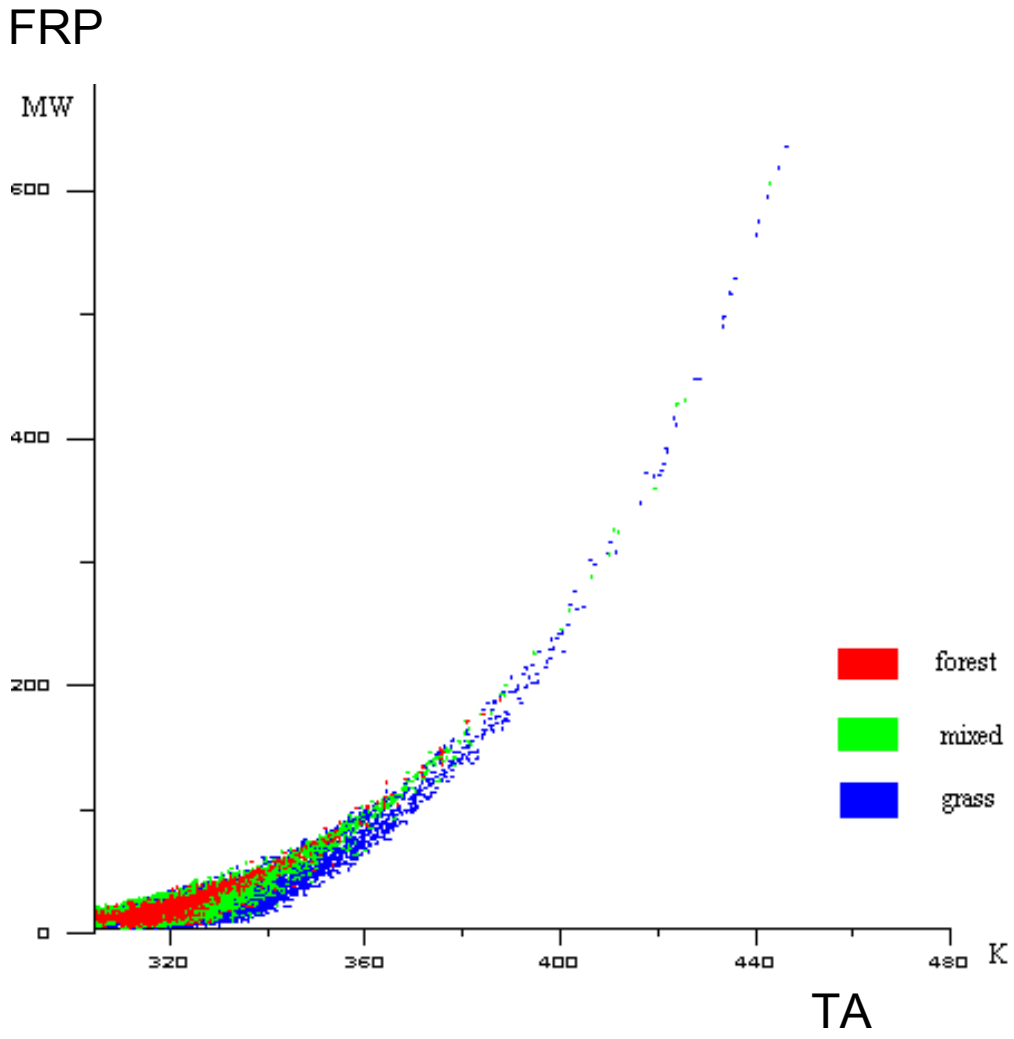
Mark size is proportional to temperature anomaly.



Dot size is proportional to FRP

MODIS TA-FRP relation

- MODIS TA vs MODIS FRP: a functional relation for medium and large fires
- Tested over Europe
- Possibility to patch the FRP missing data
- Possibility to utilise the data of other satellites, including those not having FRP



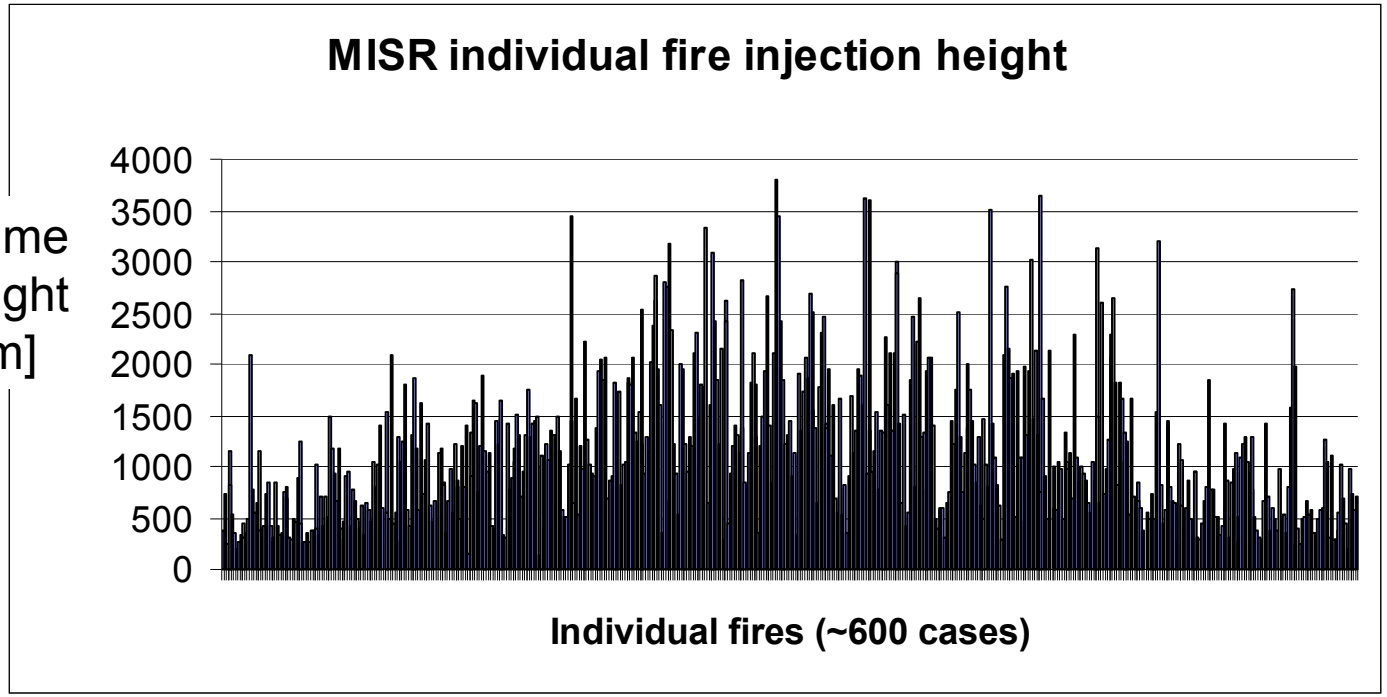
- Sofiev *et al (*2009), ACP, “An operational system for the assimilation of the satellite information on the wild-land fires for the needs of AQ modelling and forecasting”

Injection height: vital factor or useful add-on?

- Potential strong impact on air quality and atmospheric lifetime
- Possibly the most-challenging parameter
  - depends on both fire features and conditions
  - not all of the influencing parameters are observed
  - some of the observed parameters have too low accuracy (e.g. geometrical size of the fire or actual temperature of fumes)
- Does strong fire plume rise up to tropopause and higher?
  - Experiments with BUO-FMI plume-rise system also showed a moderate range
  - NOT confirmed when the bulk data are treated statistically: just a handful of the strongest fires seem to be capable of that

Example of MISR fire database

- MISR: instrument onboard Terra, able to provide the fire injection height with ~500m accuracy
  - semi-manual processing
- MISR database currently includes ~600 fires over the US – wherever strong plume allowed height determination



Results: Fire seasons 2006-2008: PM2.5 in air (FRP emission scaling)

- Fire emission: PM 2.5 data sets generated FAS-FRP
- Model: SILAM v.4.1.1
- Setup: start dates 1.4.2006/7/8, end date 30.9.2006/7/8
- Meteorology: HIRLAM(2006) / ECMWF(2007/8)

Results: Fire seasons 2006-2008: PM2.5 in air (FRP emission scaling)

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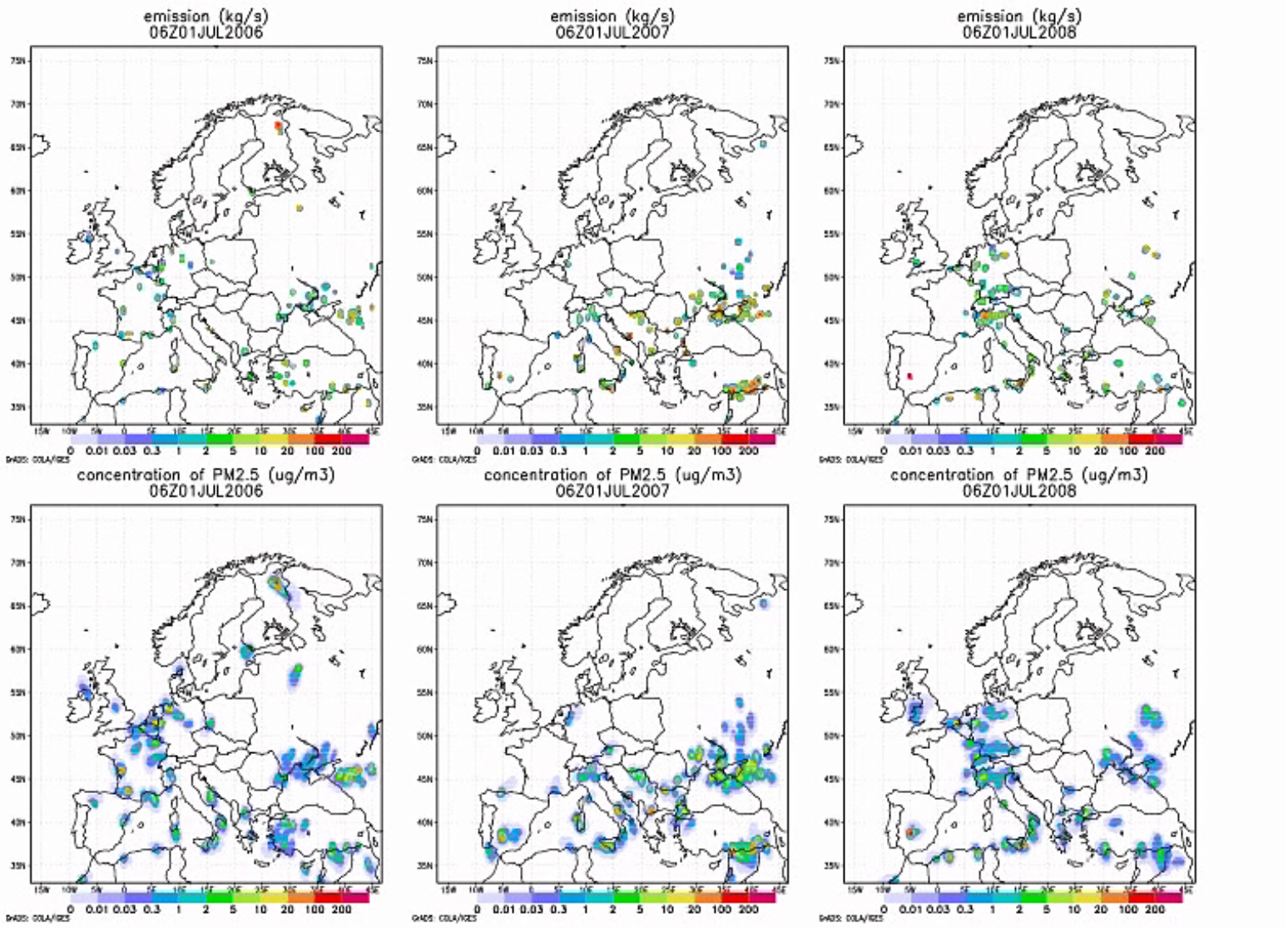
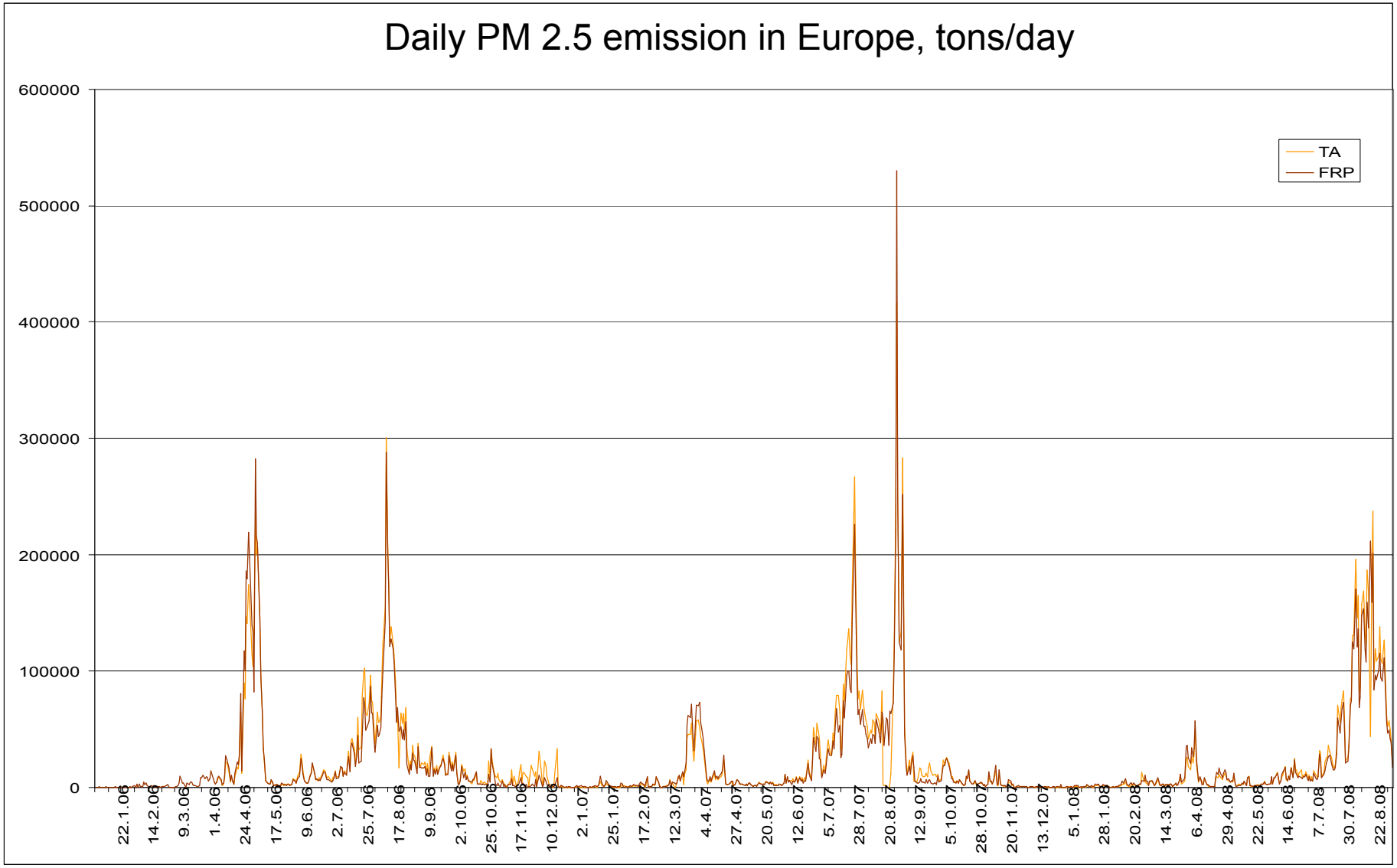
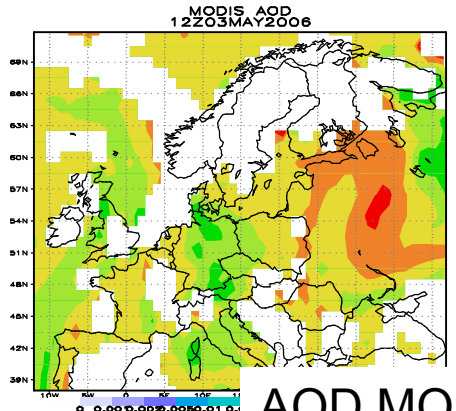


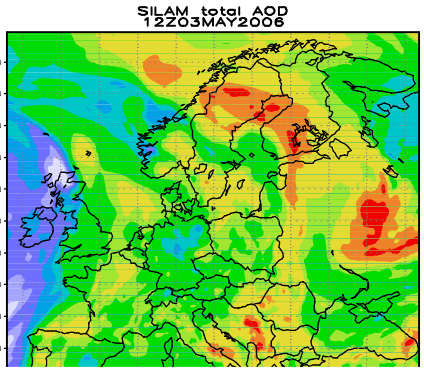
Fire emission re-analysis: 2006-2008



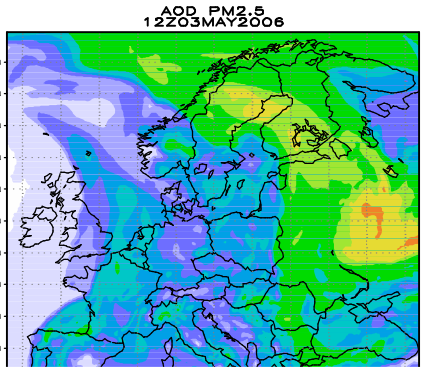
Comparison with MODIS AOD, 3 May 2006



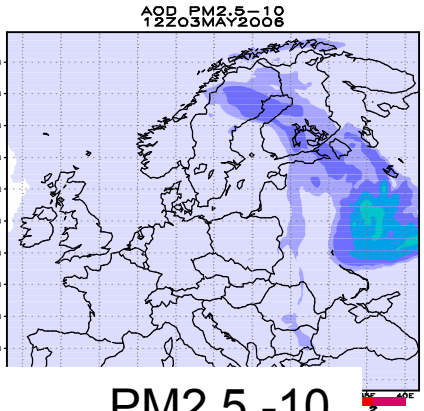
AOD MODIS



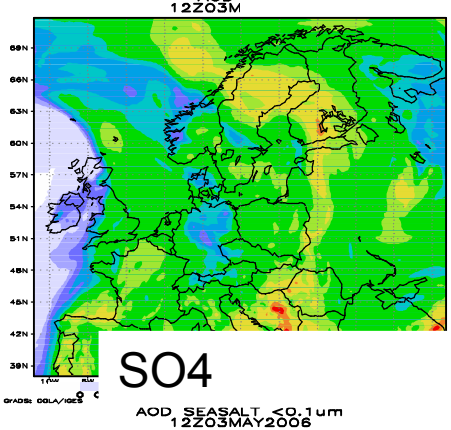
AOD tot



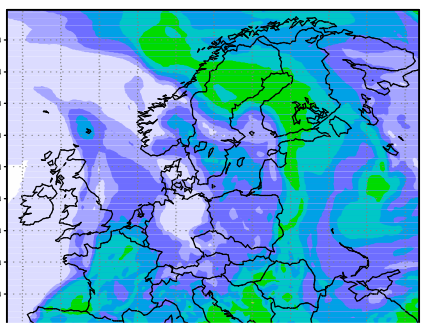
PM 2.5



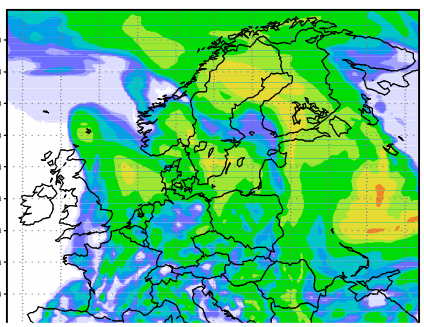
PM2.5 -10



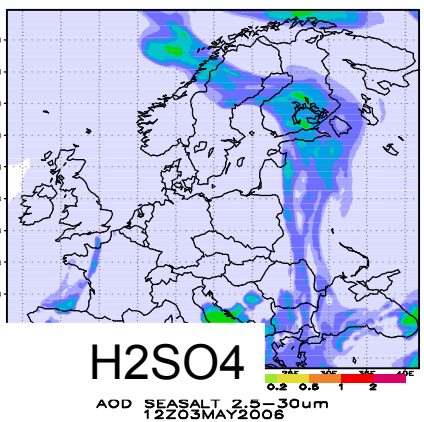
SO4



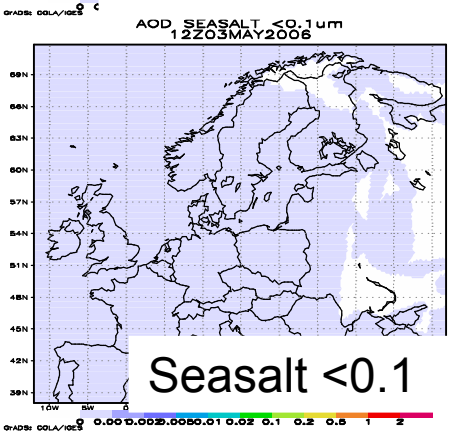
NH4s



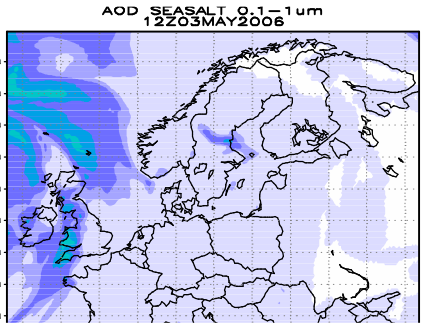
NH4NO3



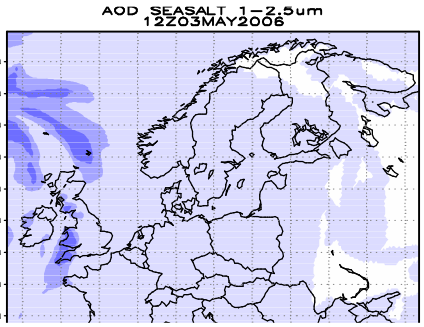
H2SO4



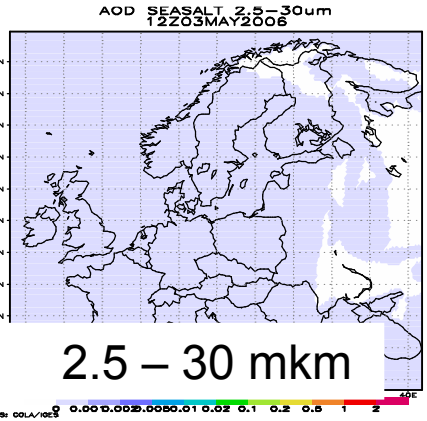
Seasalt <0.1



0.1 - 1

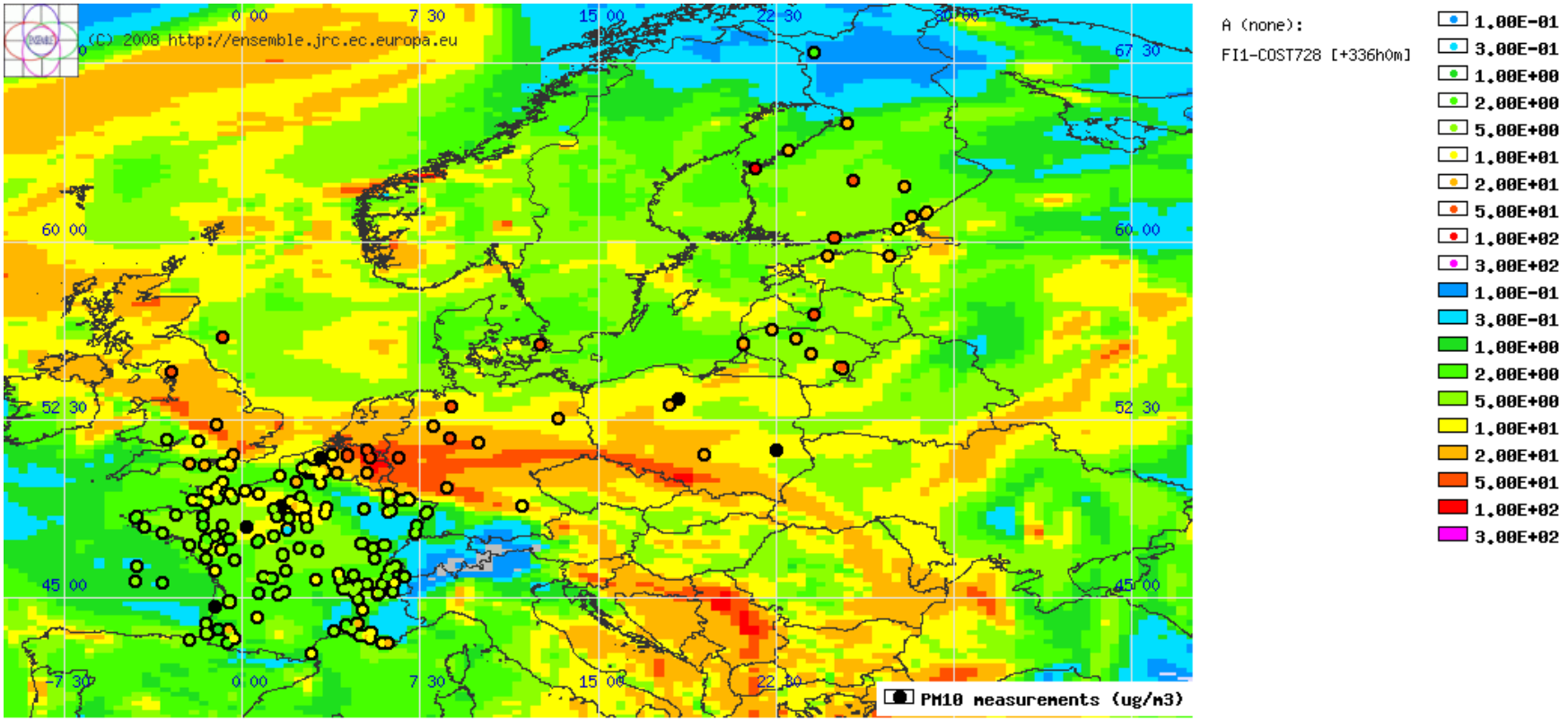


1 – 2.5



2.5 – 30 mkm

April-May 2006: comparison with in-situ data



Case 0223-001 (PM10) - Grid plot - Concentration (0 m agl) in ug/m3

Date and time: 2006-05-09 12:00 UTC (+300h0m after release start)

Data range: [1.02E-02,2.43E+02] ug/m3

Release from: Northern Europe

Coordinates: -10 40

Start: 2006-04-27 00:00 UTC

Created by user mprank on 2009-03-03 15:48:48 UTC

Summary, challenges for FAS

- Fire Assimilation System is operational @FMI
  - TA for Europe since 2006
  - FRP for Europe since 2007
  - TA & FRP globally since 2008
- AQ impact is evaluated via SILAM dispersion modelling
- Tasks
  - Refine the emission coefficients: globally, 4D-VAR
  - Merge of different instruments & satellites (low-orbit, geostationary)
  - Dynamic injection height
- Fire forecasts?
  - Model the fire development

Thank you for your attention !

SILAM operational fire plume forecasts are available at

http://silam.fmi.fi

Support of

Academy of Finland IS4FIRES (http://is4fires.fmi.fi)

EU GEMS (http://gems.ecmwf.int)

ESA PROMOTE (http://www.gse-promote.org)

projects is acknowledged

Contributions to:

MEGAPOLI, MACC, …

FRP-based $PM_{2.5}$ emission, 12.9.2009: