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On influence of wild-land fires on European air quality

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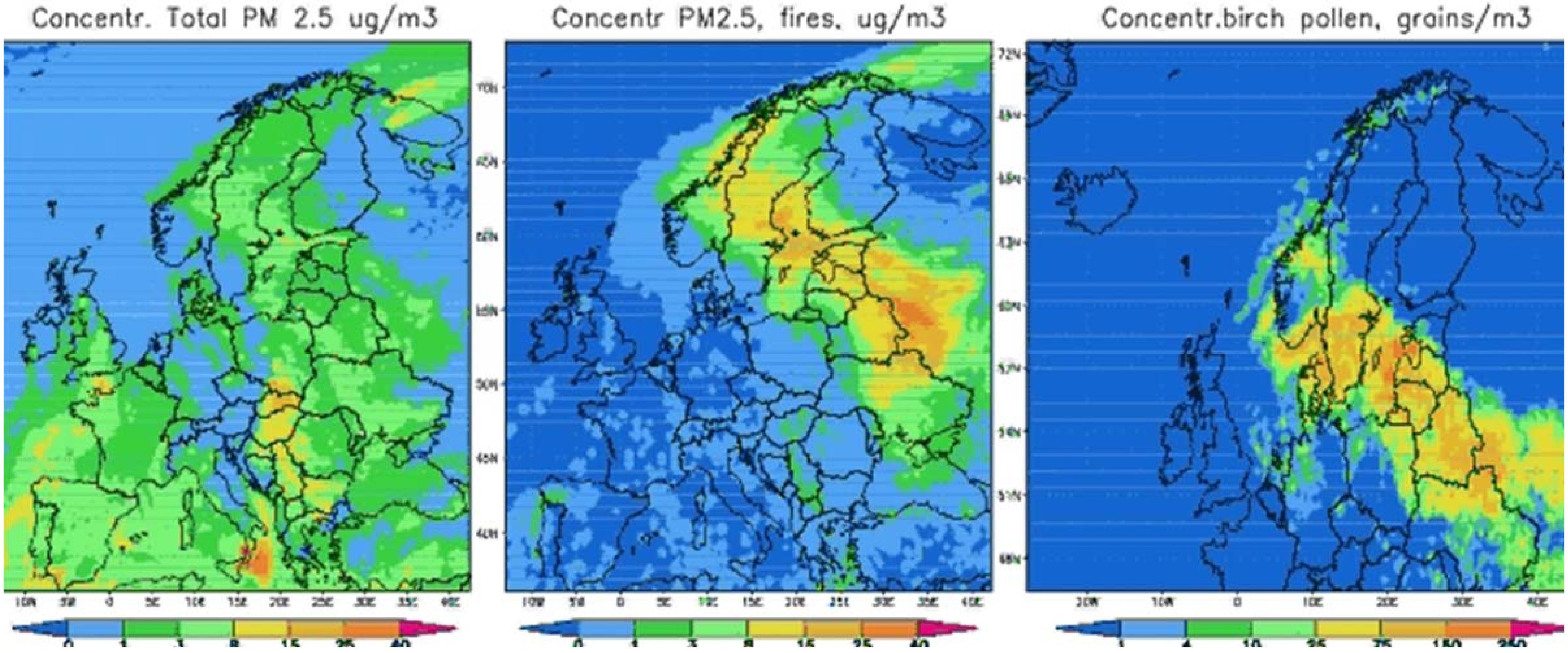
- How to obtain information about wild-land fires?
- Fire Assimilation Systems of FMI
  - Historical review: use and abuse of v.0.9
  - Provisions for FAS v.1.0
- Modelling assessments of the wild-land fires impact on European air quality in 2006
  - comparison of different types of fire onformation products
- Challenges

Apr-May 2006: Development of the episode

Forecast for: 12:00, 29APR2006

Anthrop. PM 2.5 | PM 2.5 from fires | Birch pollen



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

Fractionation of the fire energy

For moderate fires, the total energy release splits to radiative, convective and thermal-conduction forms as:

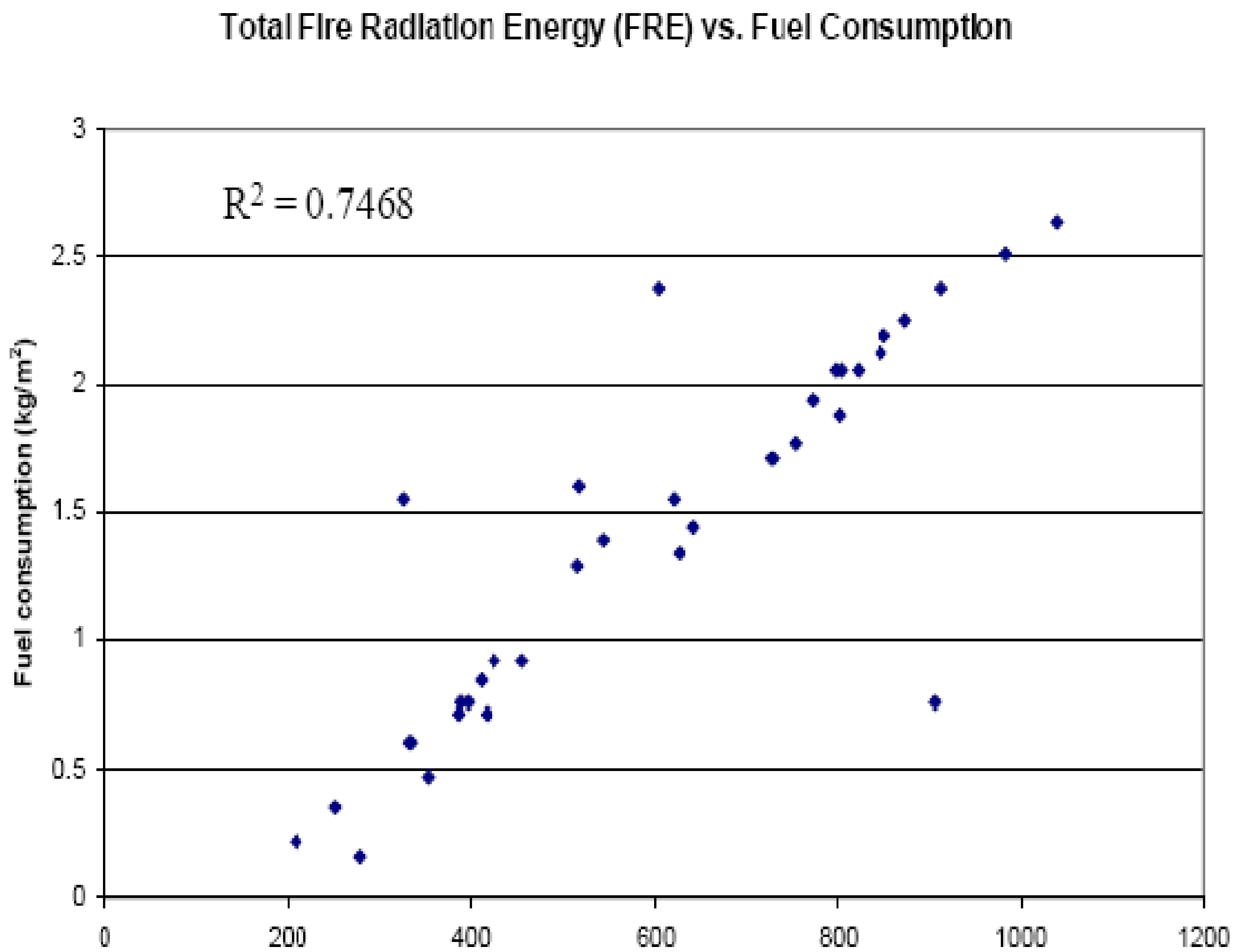
ε= *Radiation* (40%) + *Convection* (50%) + *Conduction* (10%)

- The split is valid for a wide range of fire intensity
- The split is stable for various types of land use

Empirical formula for total rate of emission of FRP:

$$Ef = 4.34 \cdot 10^{-19} (T_4^8 - T_{4b}^8) \text{ [MWatt per pixel]}$$

$T_{4,4b}$ is fire and background brightness temperatures at 3.96 μm (*Yoram Kaufman et al,1998*)



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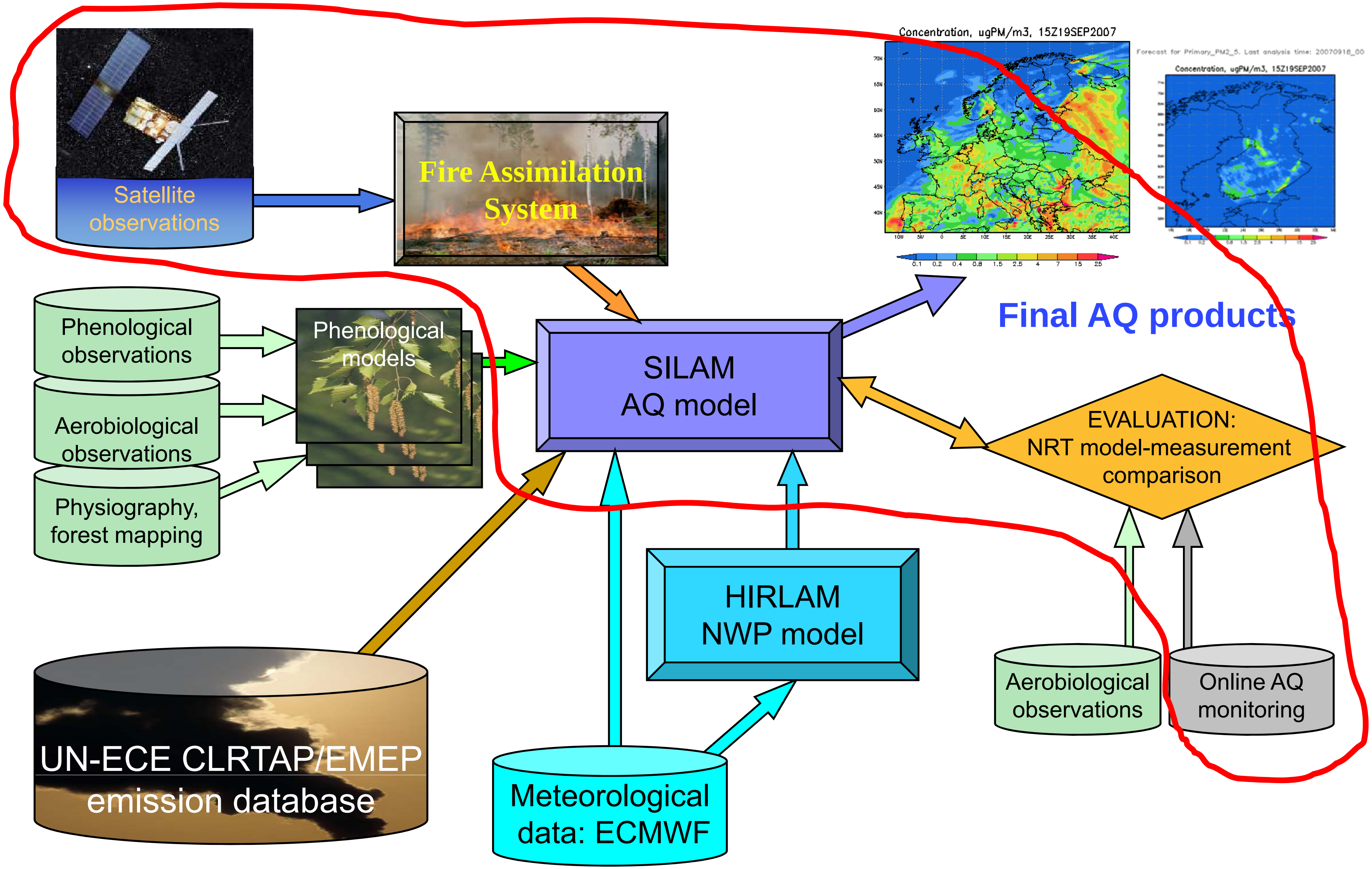
Regional AQ forecasting system of FMI



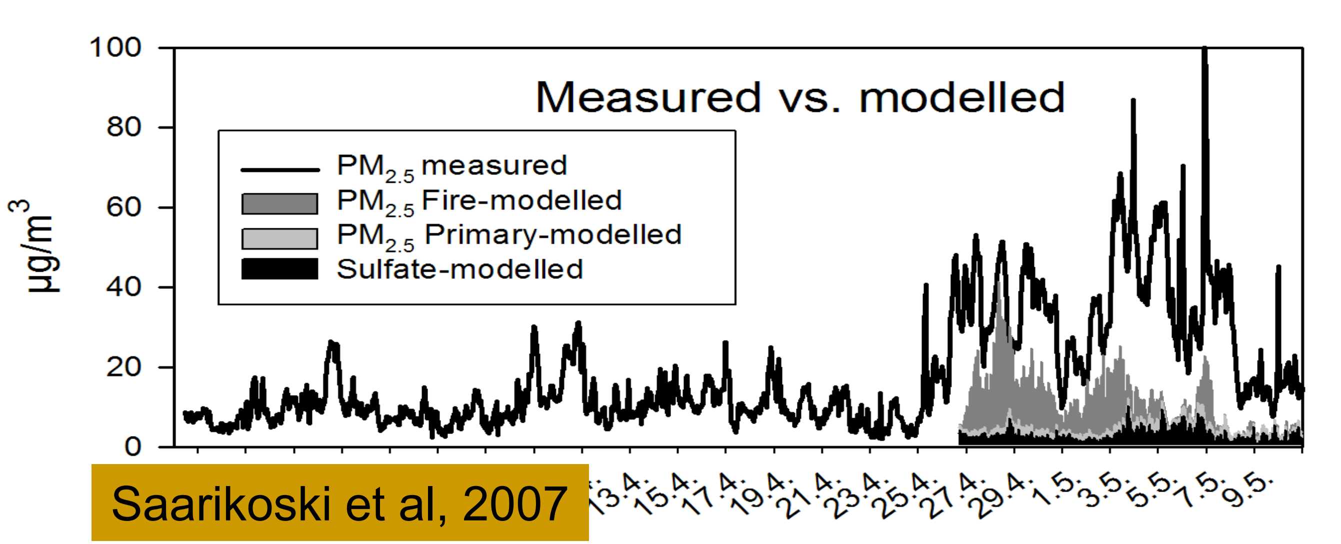
Current Fire Assimilation Systems

- Fire Alert System for Finland
  - about a decade-old, qualitative fire detection system for Finnish territory
  - automatically generates alert faxes for the municipal authorities
  - ATSR + AVHRR (night-time) + MODIS (morning)
- Fire Assimilation System v.0.9 and v.0.99
  - v.0.9: started in spring 2006, updated, recalibrated and automated to v.0.99 in November 2007
  - MODIS (Aqua + Terra) hot-spot counts represented as temperature anomalies: NASA Rapid-Response System
  - evaluates only PM 2.5 directly emitted from fires, empirical emission coefficient (recalibrated to v.0.99)
  - global, daily, 1km in irregular grid;
    - aggregated into 10km regular grid and cut down to European area
- Fire Assimilation System v.1.0

FAS v.0.9: experience

- April-May 2006: spring episode
  - ➢ first real test of the new system
  - ➢ very decent timing, acceptable absolute levels
  - ➢ case published in Atmospheric Environment
  - ➢ But:
    - – second day is lost (clouds => no fire reports)
    - – only PM 2.5 while e.g. in Sweden there was also an ozone peak,

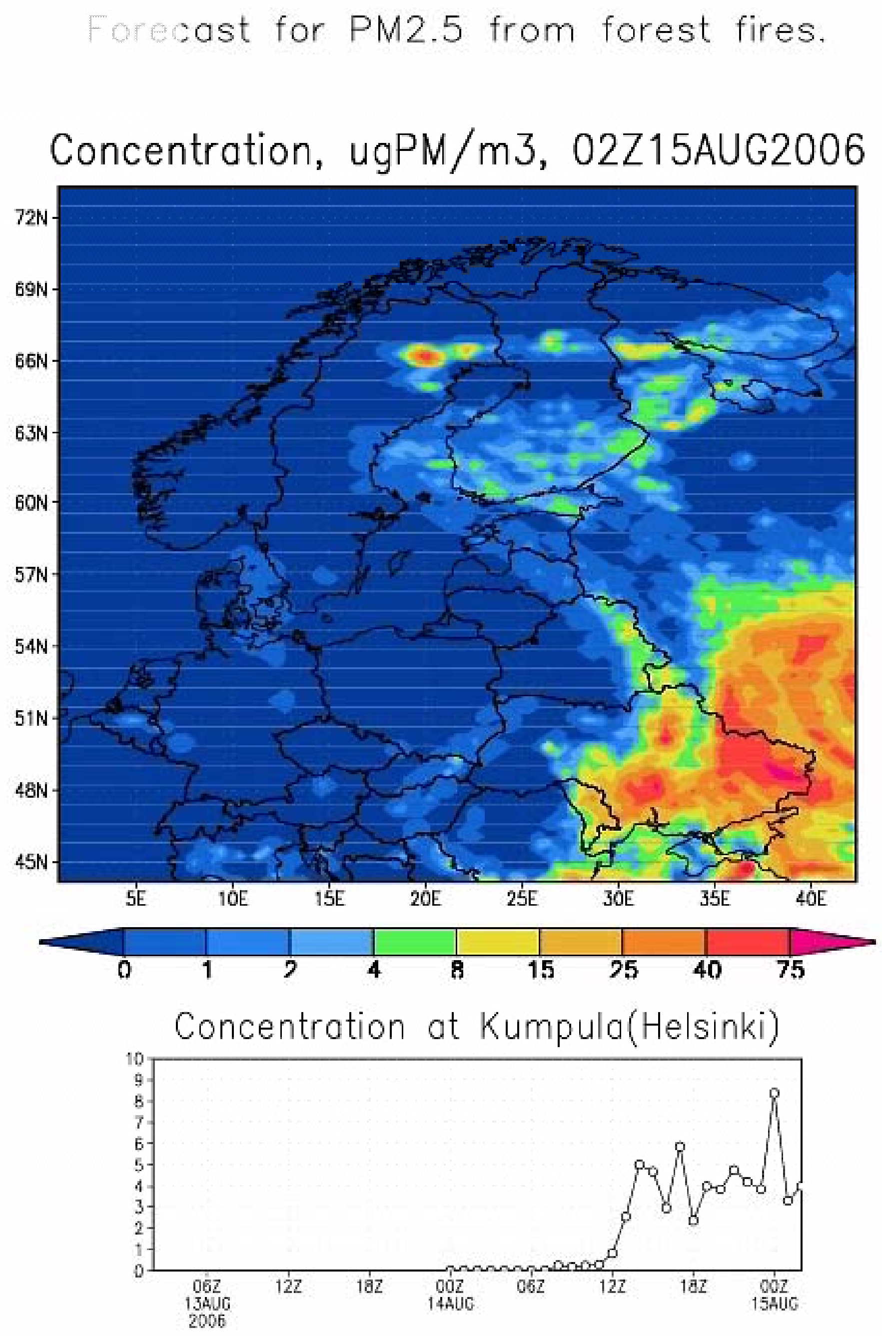
fire



Saarikoski et al, 2007

FAS v.0.9: experience (2)

- August 2006:
  - major fires in the south,
  - Finland is affected by a few small-scale but close-in-space events
- timing again almost perfect
- but:
  - absolute levels are 10-20 times under-estimated (!!)
  - fires are on and off many times: convective clouds obscure the reports
  - a fire field is again pretty homogeneous



Goals for FAS v.0.99 and v.1.0 development

- → v.0.99: Recalibrate and streamline the v.0.9 algorithm
- →v.1.0:
  - ➢ Improve the evaluation of the emission fluxes by using FRP product
    - – better accounting for fire intensity
    - – improved spatial distribution of emission fluxes
    - – evaluate the uncertainty by comparing the hot-spot- and FRP-based approaches (v.0.99 and v.1.0)
    - – extend the list of emitted species
  - ➢ Build the baseline system for the next steps
    - – variation of emission factors with regard to land-use and vegetation type and state
    - – other-than-MODIS satellites as the system input
    - – input information for injection height evaluation
    - – observation / modelling of fire development and diurnal variation

MODIS fire-related products

Table 1: MODIS fire product availability.

Product	Source
Level 2 and most Level 3 fire products:	
MOD14, MYD14	
MOD14A1, MYD14A1	
MOD14A2, MYD14A2	EOS Data Gateway (see Section 3.1).
Level 2G fire products:	
MOD14GD, MOD14GN	
MYD14GD, MYD14GN	
CMG fire products:	
MOD14CMH, MYD14CMH	
MOD14C8H, MYD14C8H	University of Maryland (see Section 3.2).
Active fire locations in ASCII and ESRI shape file format.	MODIS Web Fire Mapper
Fire and corrected-reflectance JPEG imagery and ASCII fire locations.	MODIS Land Rapid Response System

v.1.0

GMG: gridded summaries of fire pixel information
intended for regional / global models
but:0.5 deg spatial and 1/8/30 days temporal resolution

v.0.9

FAS v.1.0 information flow

Download manager (***operational***):

Global set Aqua & Terra 1 km granules for current date

Spatial operations (***operational***):

- *Regriding & Aggregation for 10 km grid*
- *Quality Check*
- *Masking and Emission Calculation*
- *Temporal aggregation*
- *Complex spatial analysis*

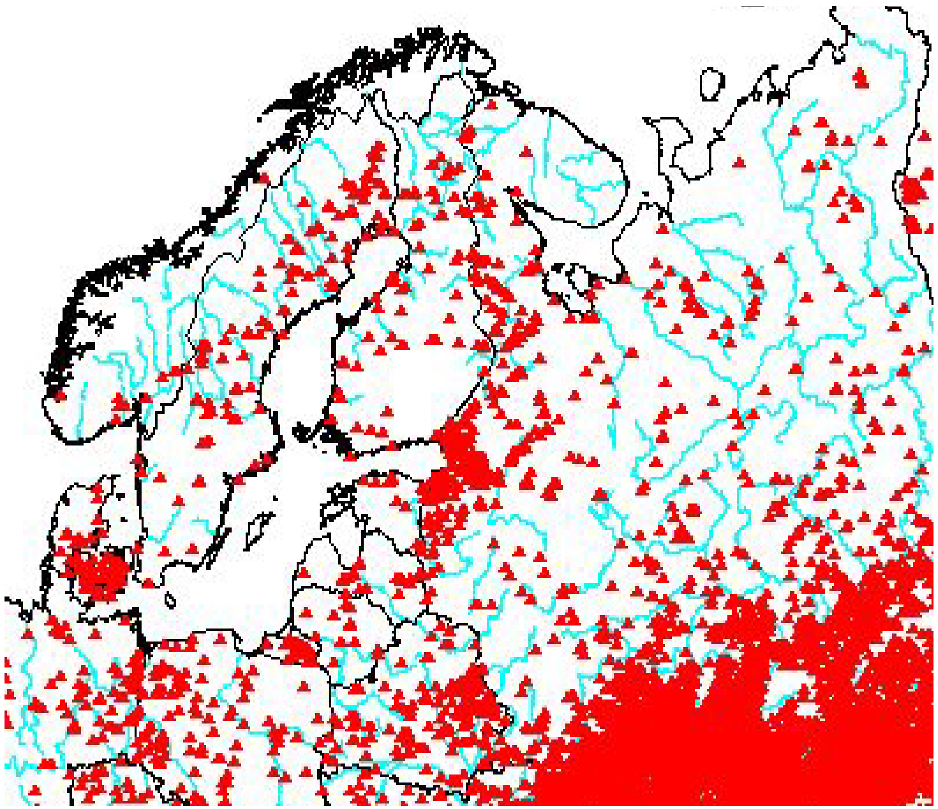
SILAM Interface (***on-going***):

Automatic SILAM input file generation

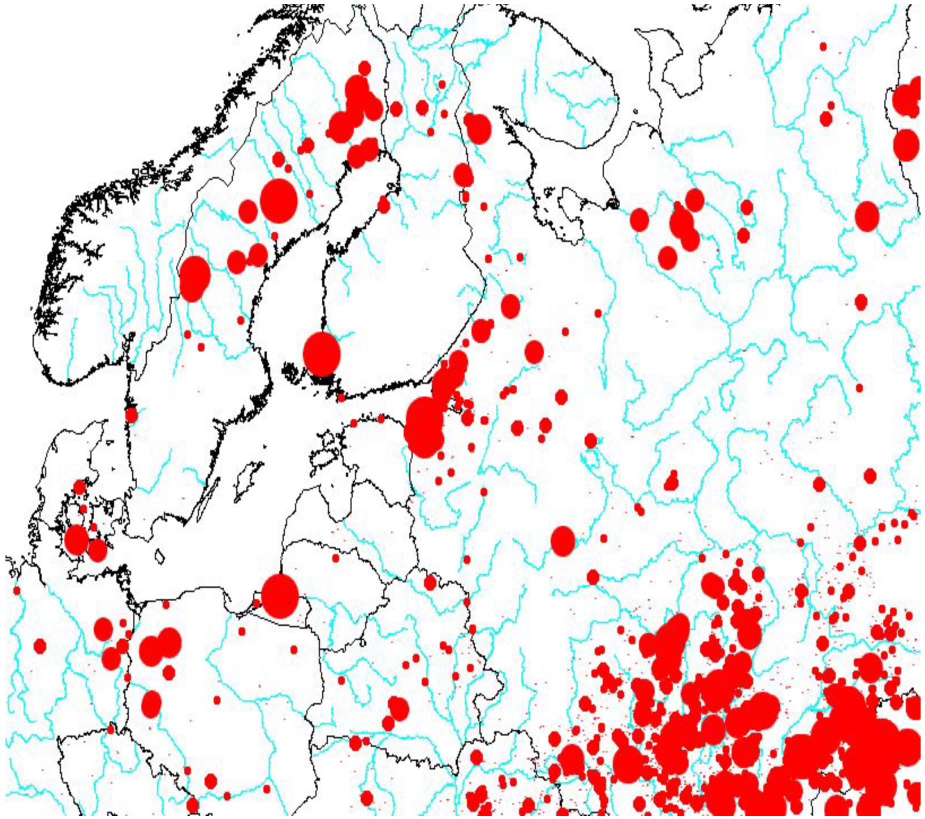
Hot-spot counts vs FRP

Hot spots FRP

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

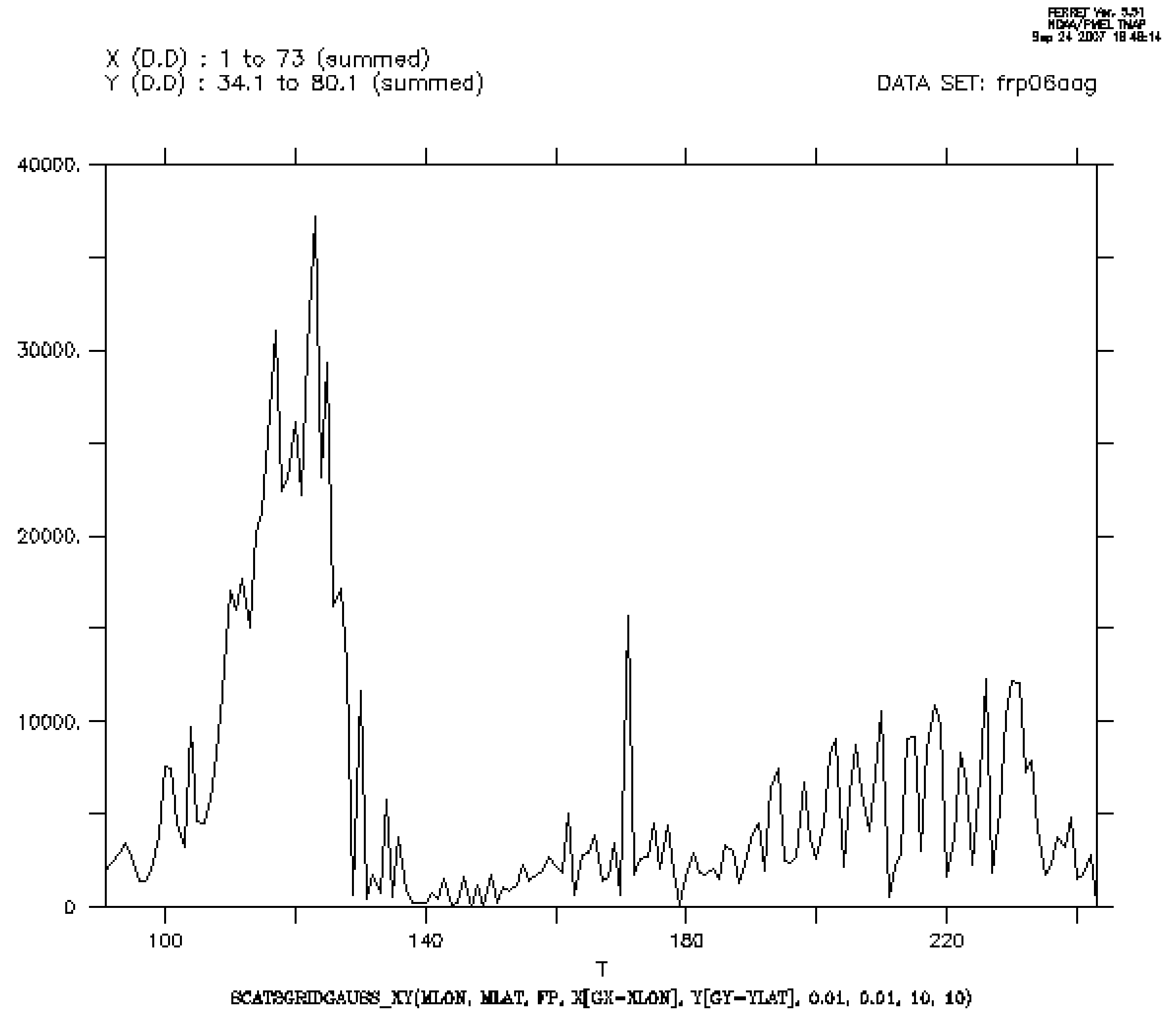


Mark size is proportional to tempr.anomaly

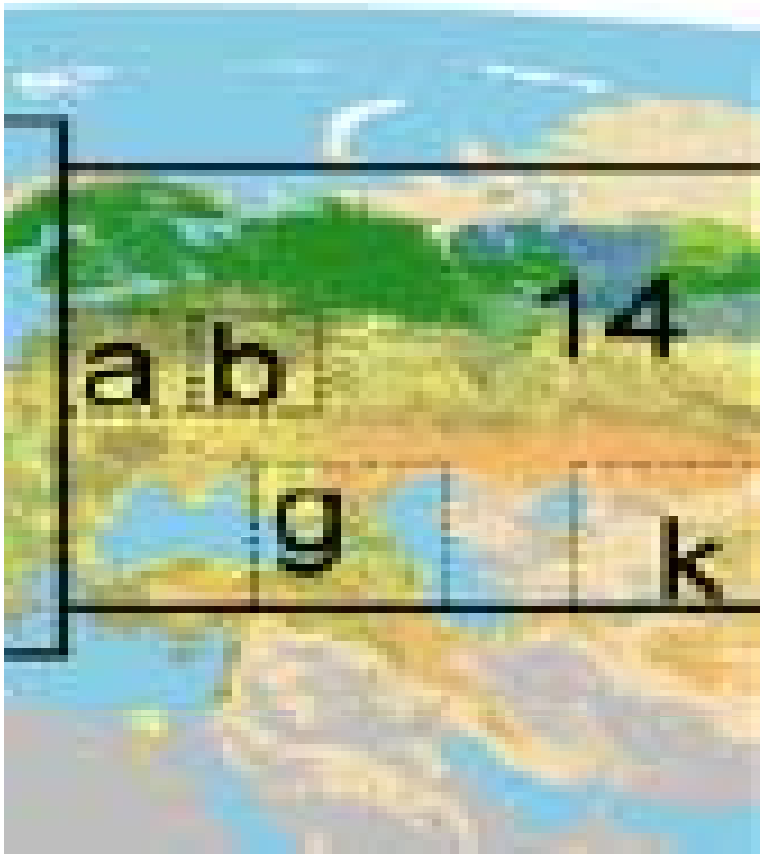


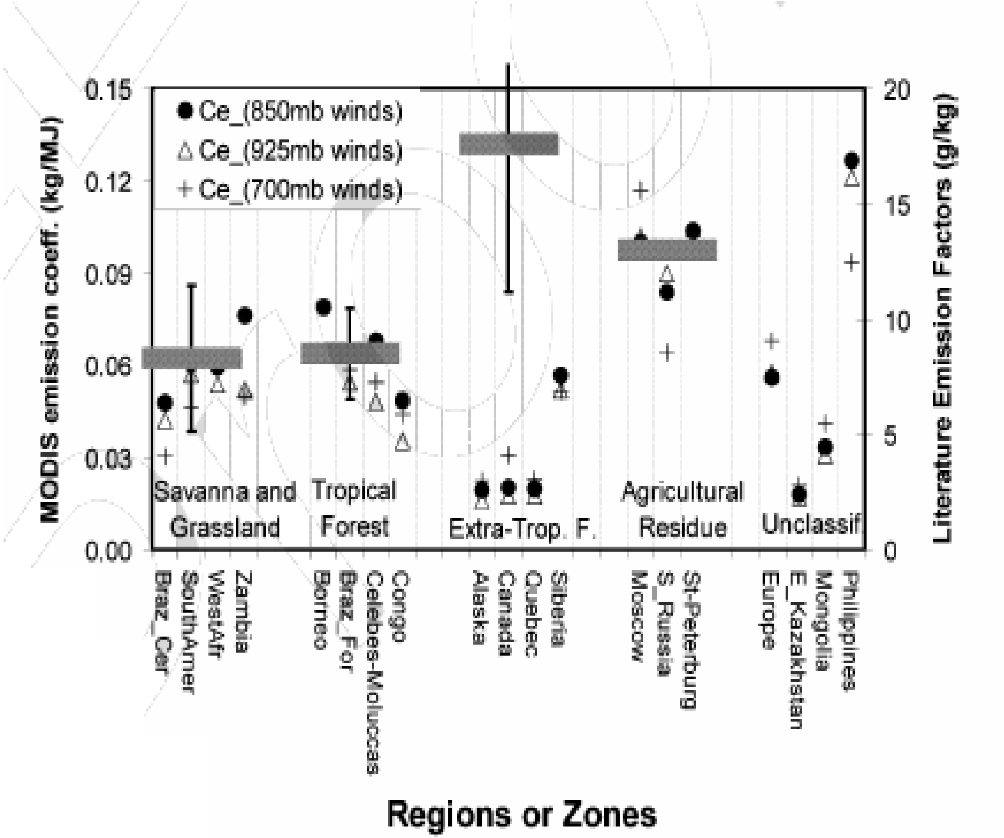
Dot size is proportional to FRP

Area-integrated FRP:time series for 5 months April-August 2006



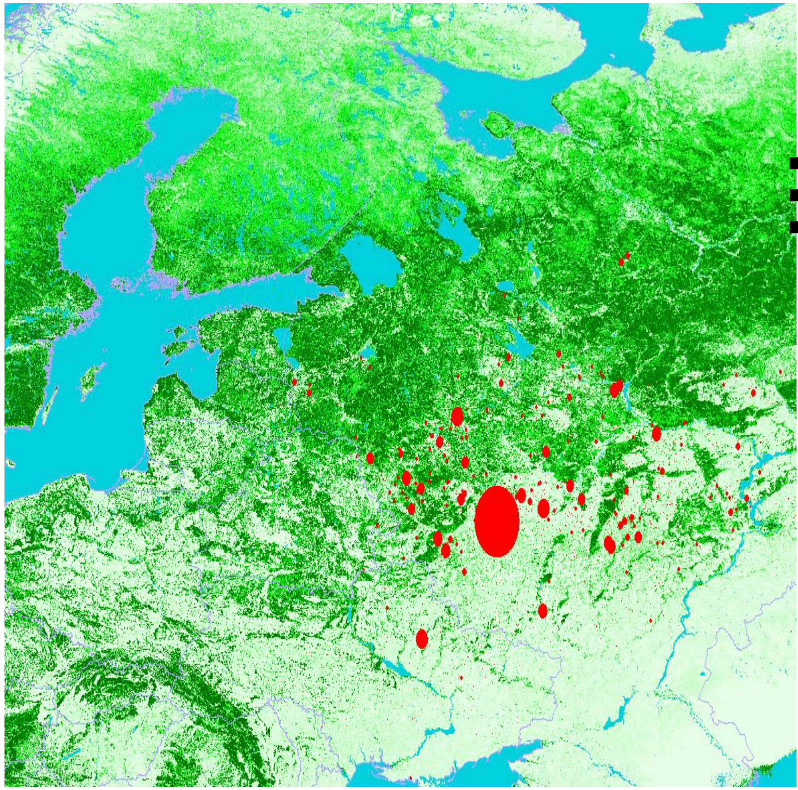
Emission coefficients: Ichoku (2005)



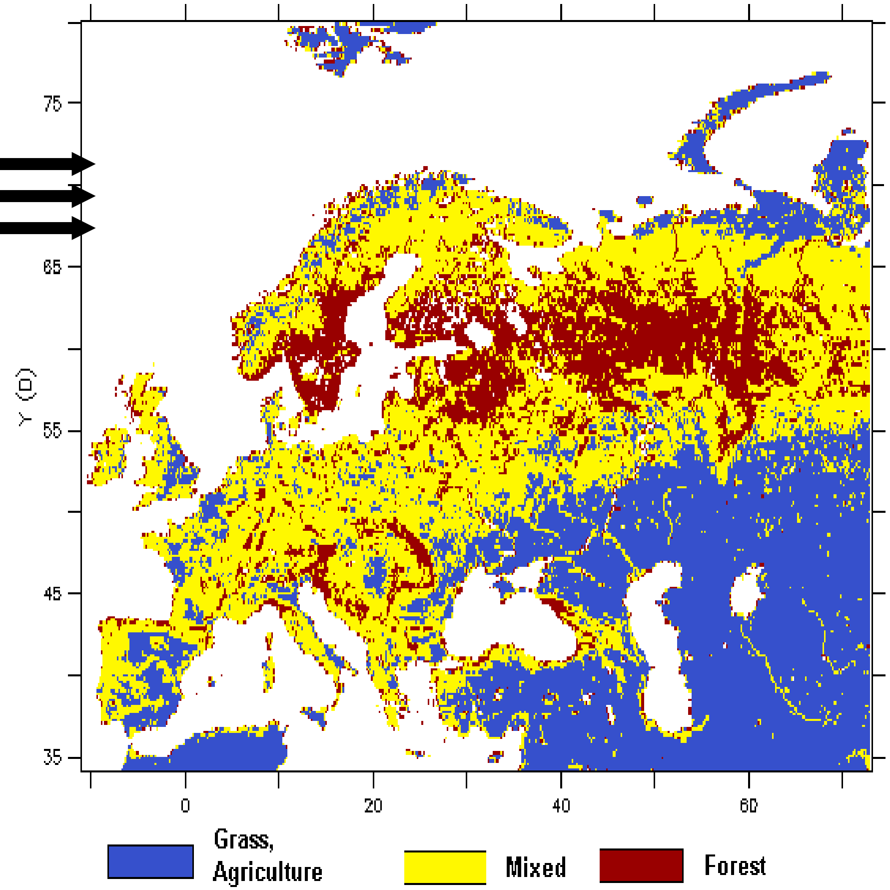


Pattern of emission coefficients

- PAGE land-use, 250m => 10km-grid classification of prevailing land-type as a surrogate for emission factors

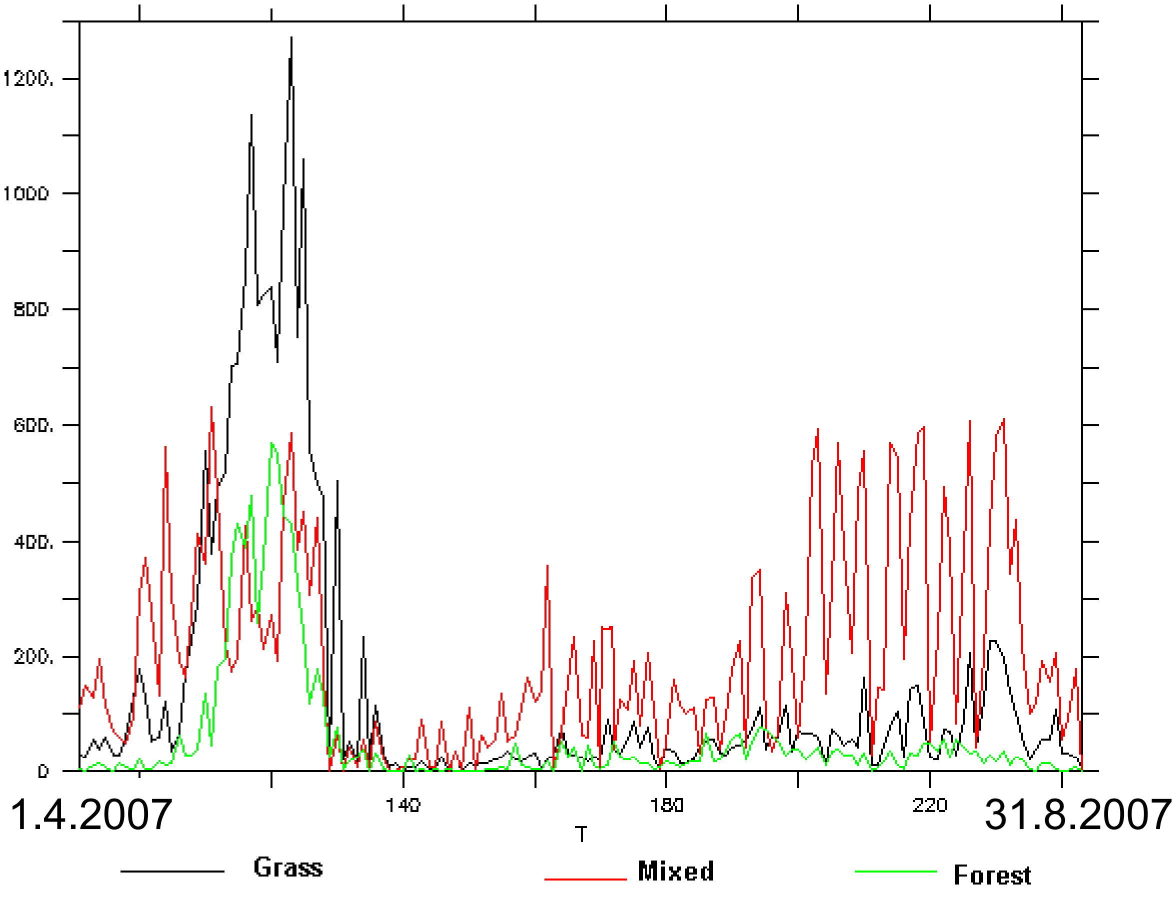


Fire pixels: May 2006

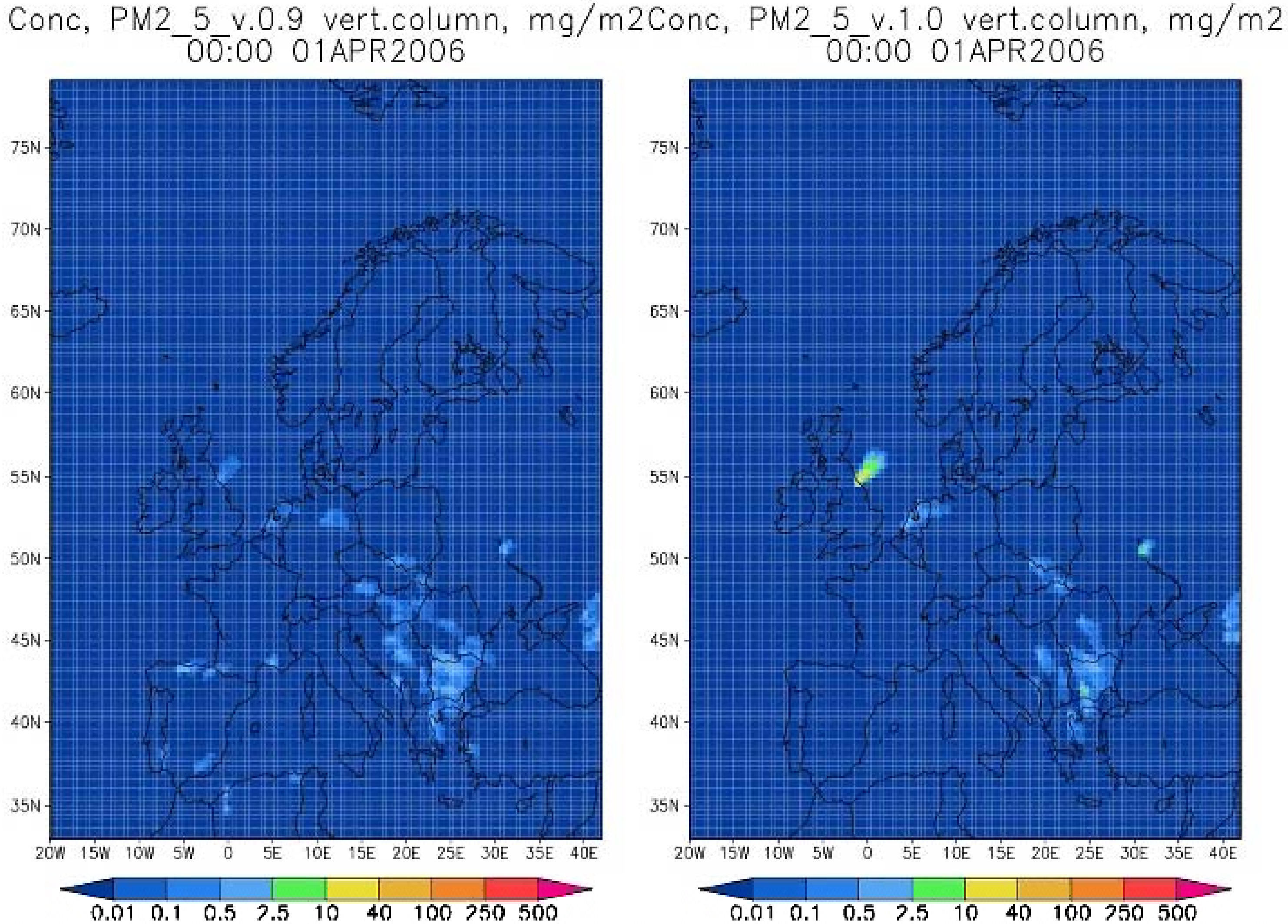


What/where/when is burning??

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



Fire season 2006: PM 2.5 in air (v.0.99 vs v.1.0)



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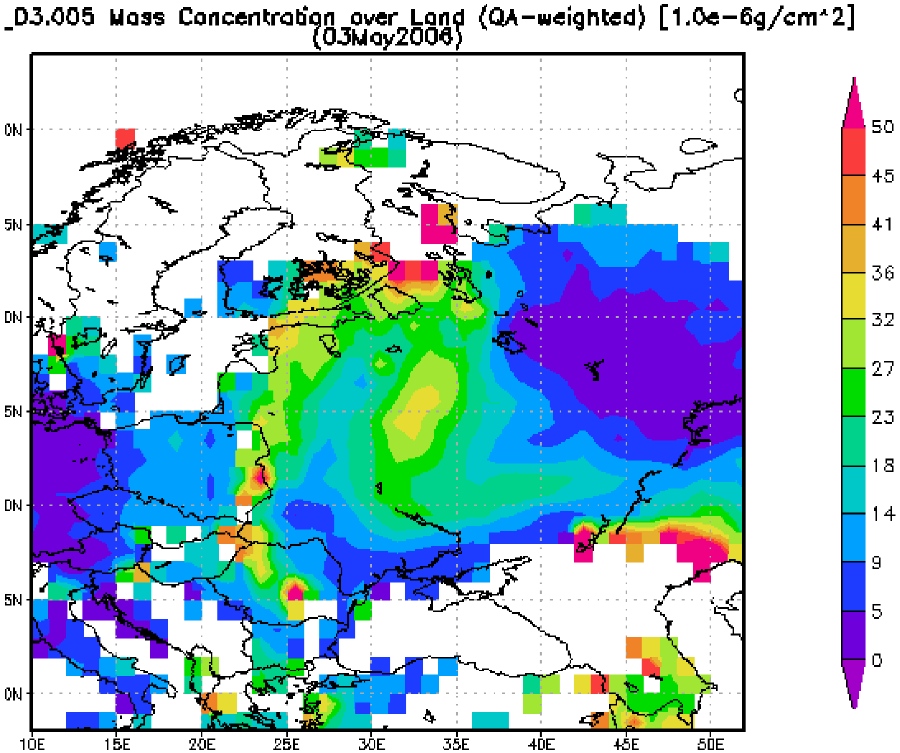
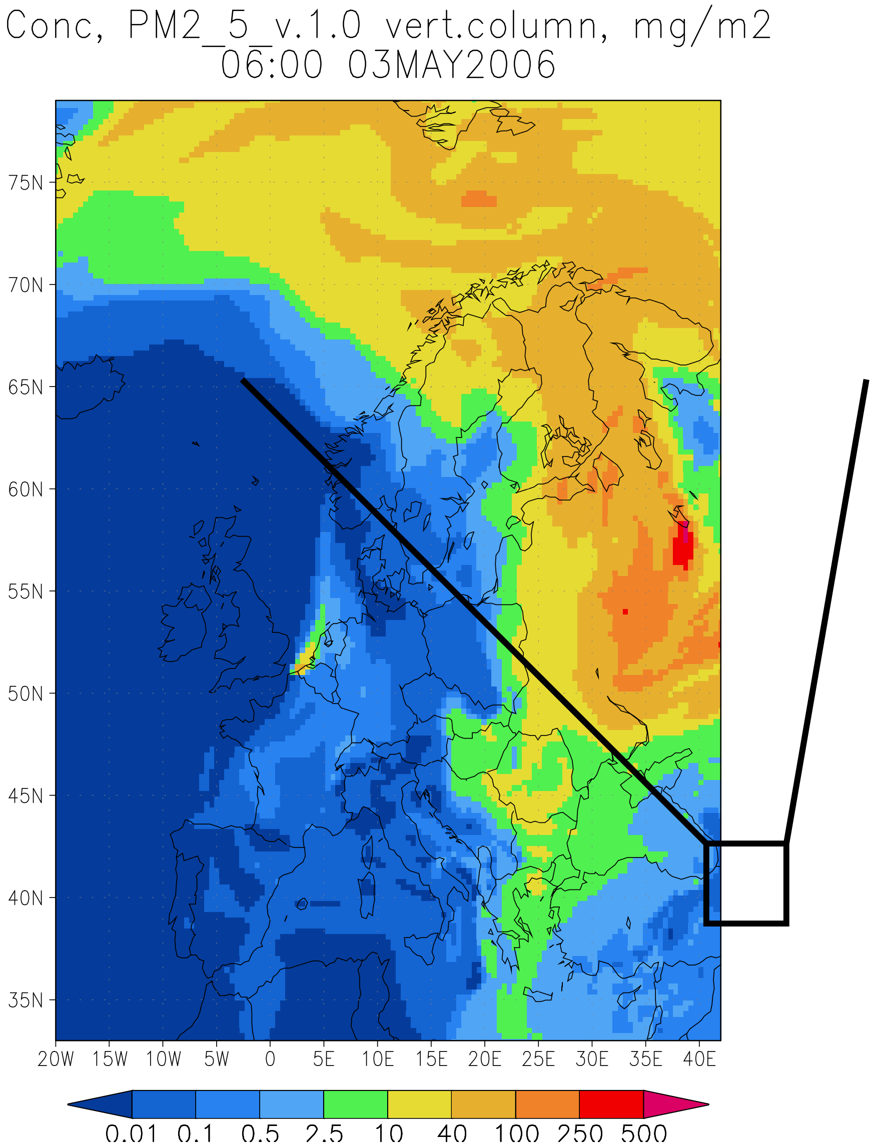
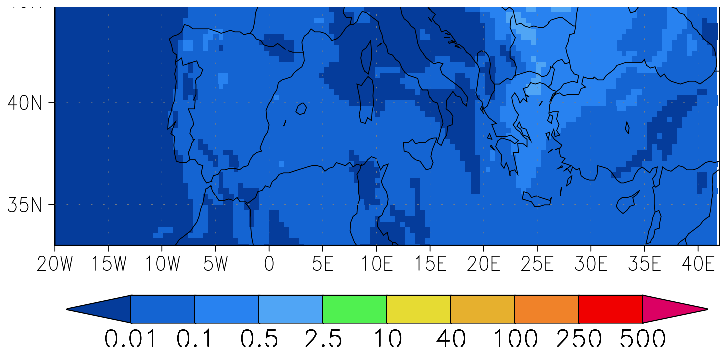


_D3.005 Mass Concentration over Land (QA-weighted) [1.0e-6g/cm^2]
(03May2006)
0N
5N
0N
5N
0N
5N
0N
10E 15E 20E 25E 30E 35E 40E 45E 50E
50 45 41 36 32 27 23 18 14 9 5 0

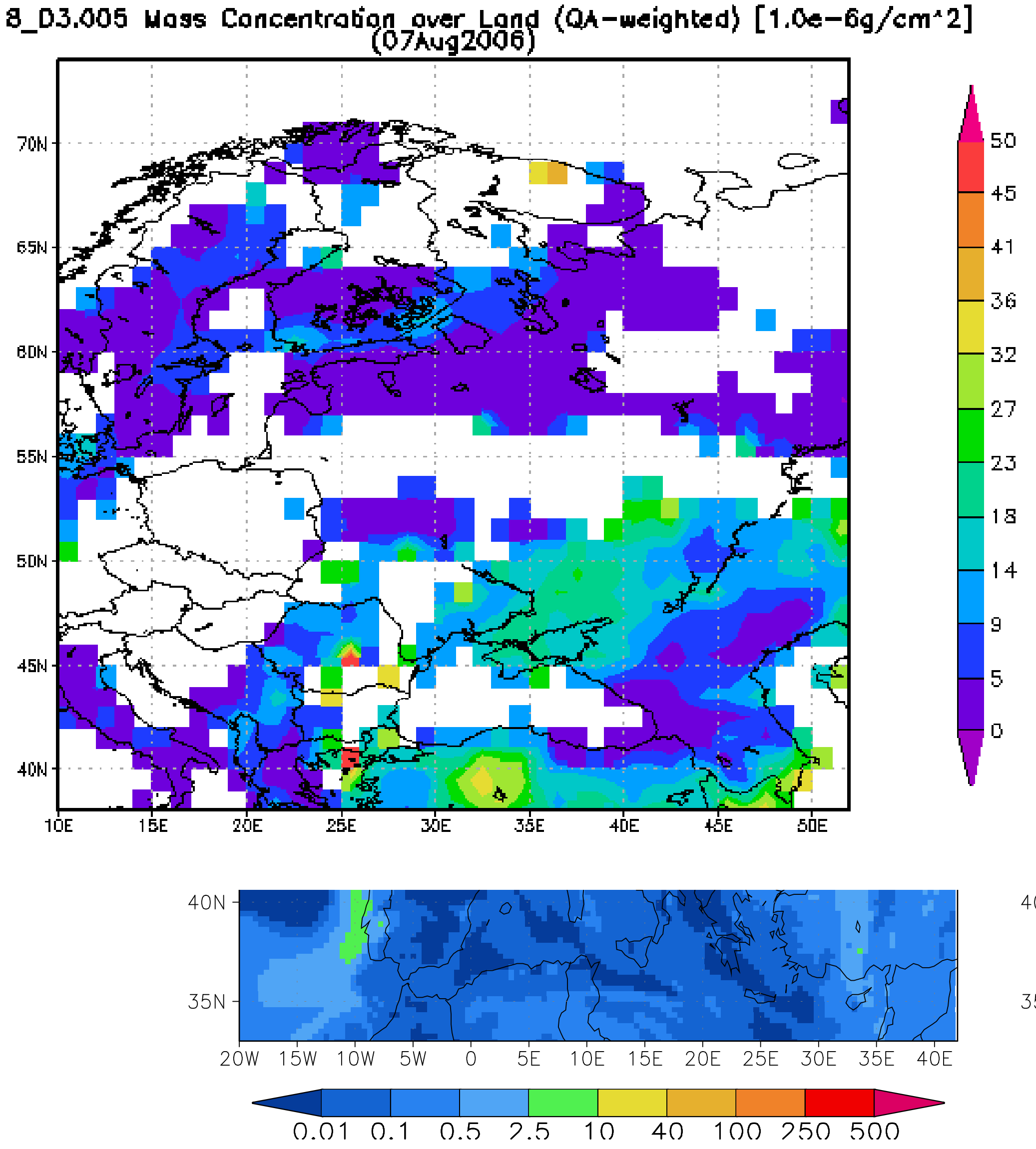


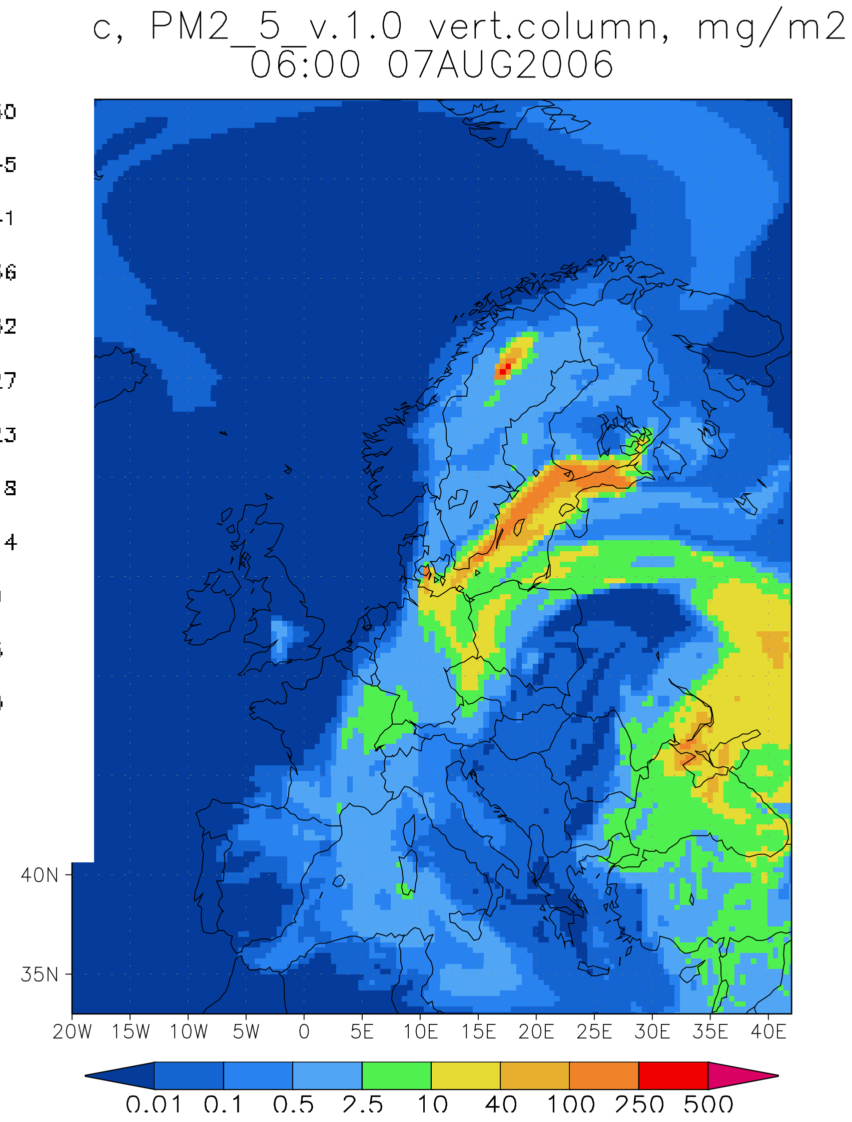
Conc, PM2_5_v.1.0 vert.column, mg/m2
06:00 03MAY2006
75N
70N
65N
60N
55N
50N
45N
40N
35N
20W 15W 10W 5W 0 5E 10E 15E 20E 25E 30E 35E 40E
0.01 0.1 0.5 2.5 10 40 100 250 500



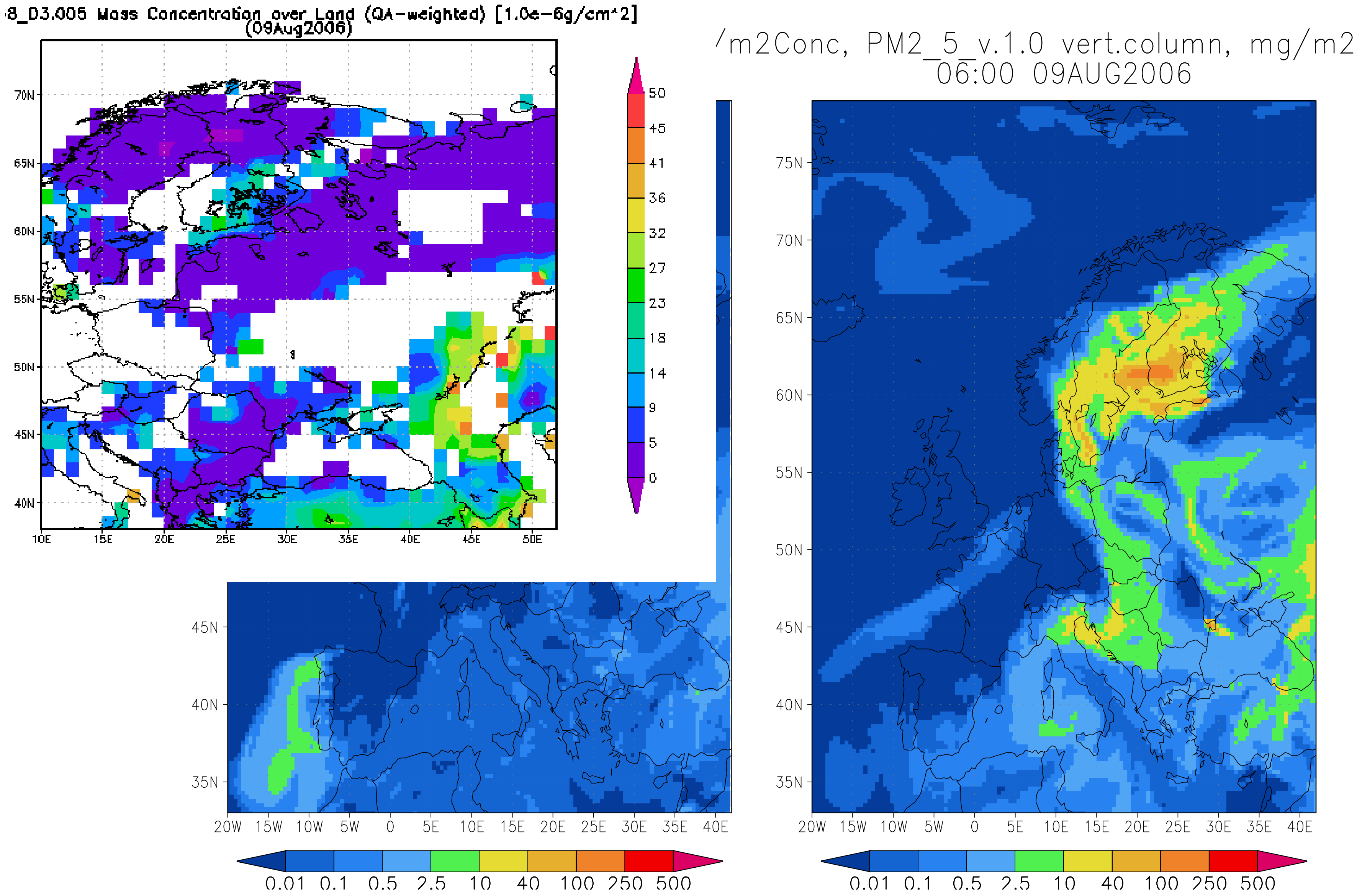
40N
35N
20W 15W 10W 5W 0 5E 10E 15E 20E 25E 30E 35E 40E
0.01 0.1 0.5 2.5 10 40 100 250 500

August, 7: fire plume along GF

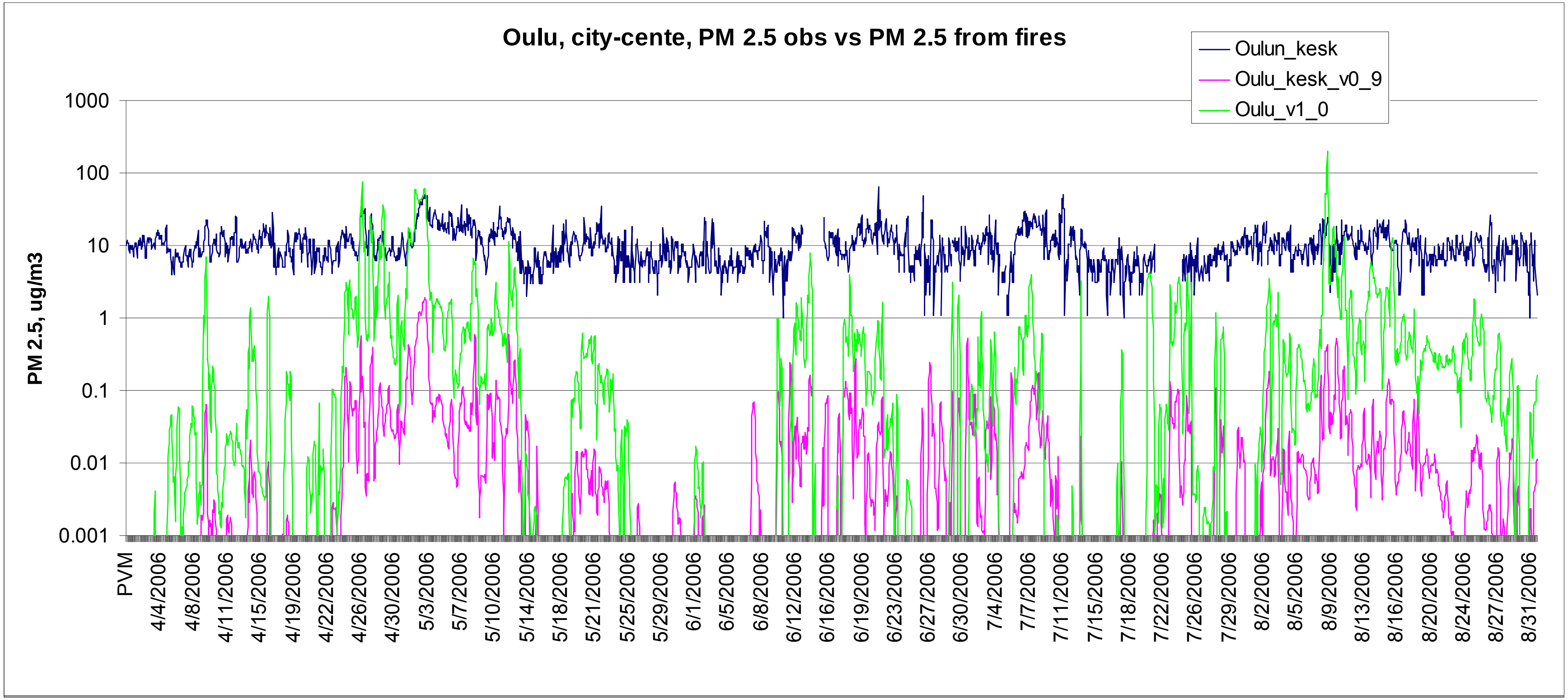




August 9: plume shifted to Finland



Comparison with ground-based observations



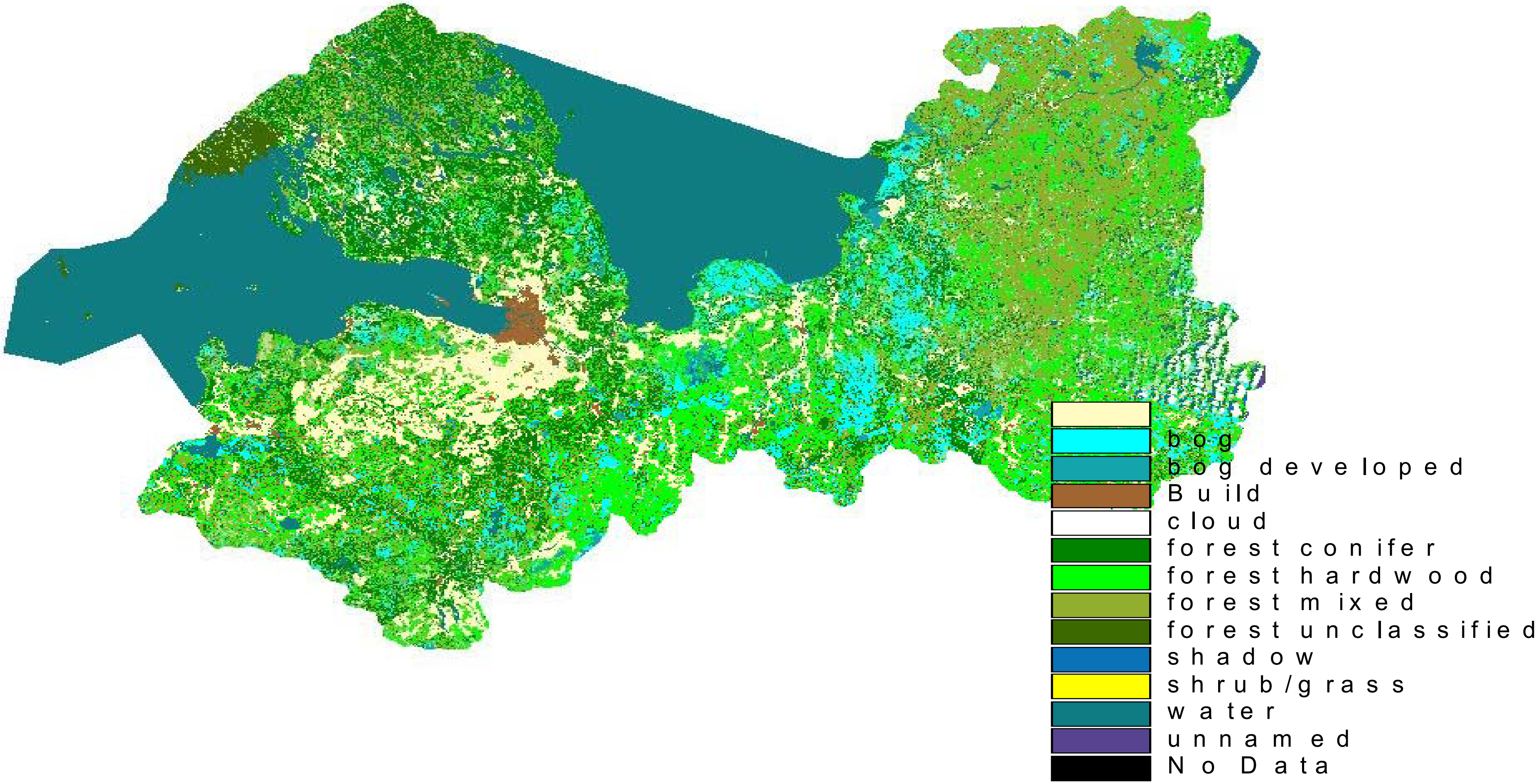
Conclusions on current FAS status

- Results of v.1.0 are substantially different from v.0.99
  - spatial patterns differ: a principal difference btw hot-spot counts and FRP
- Ways of evaluation
  - Direct verification of emission terms is not possible
  - Indirect verification involves SILAM as a bridge from emission fluxes to observed concentrations and AOD
- Results of comparison with observations (so far, qualitative)
  - the major fires create sufficiently strong signal distinguishable from other aerosol sources
  - details of the distribution and quantitative evaluation makes sense only for total aerosol with all sources included: anthropogenic, biogenic, microphysical, natural, fires

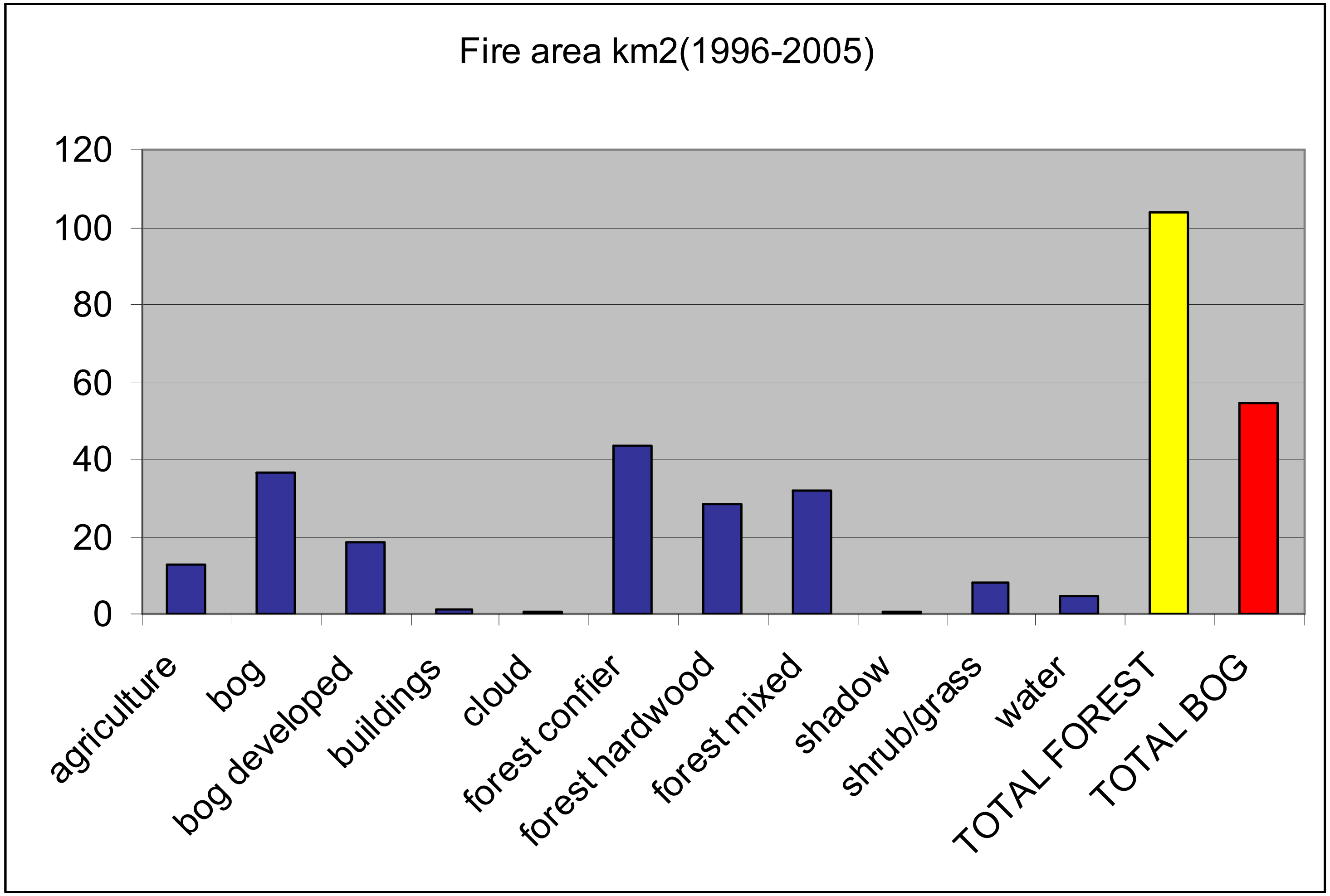
Challenges for FAS

- Refine the emission coefficients
  - land-use as a surrogate: persistent
    - a series of model calibration exercises (and/or AOD assimilation)
  - dynamic via
    - complementary products (biomass water content, NDVI, soil water, …)
    - data assimilation of AOD in the vicinity of the fires
- Dynamic injection height
  - small fires: updated BUOYANT model is on standby
  - large fires: deep convection parameterization
- Holes in the data (clouds et al)
  - mix MODIS with other satellites
  - fire model (parameterization) fed with actual and prognostic variables
- Snapshots to time series: heuristic fire modelling
- Fire forecasts
  - fire model (parameterization) fed with actual and prognostic variables

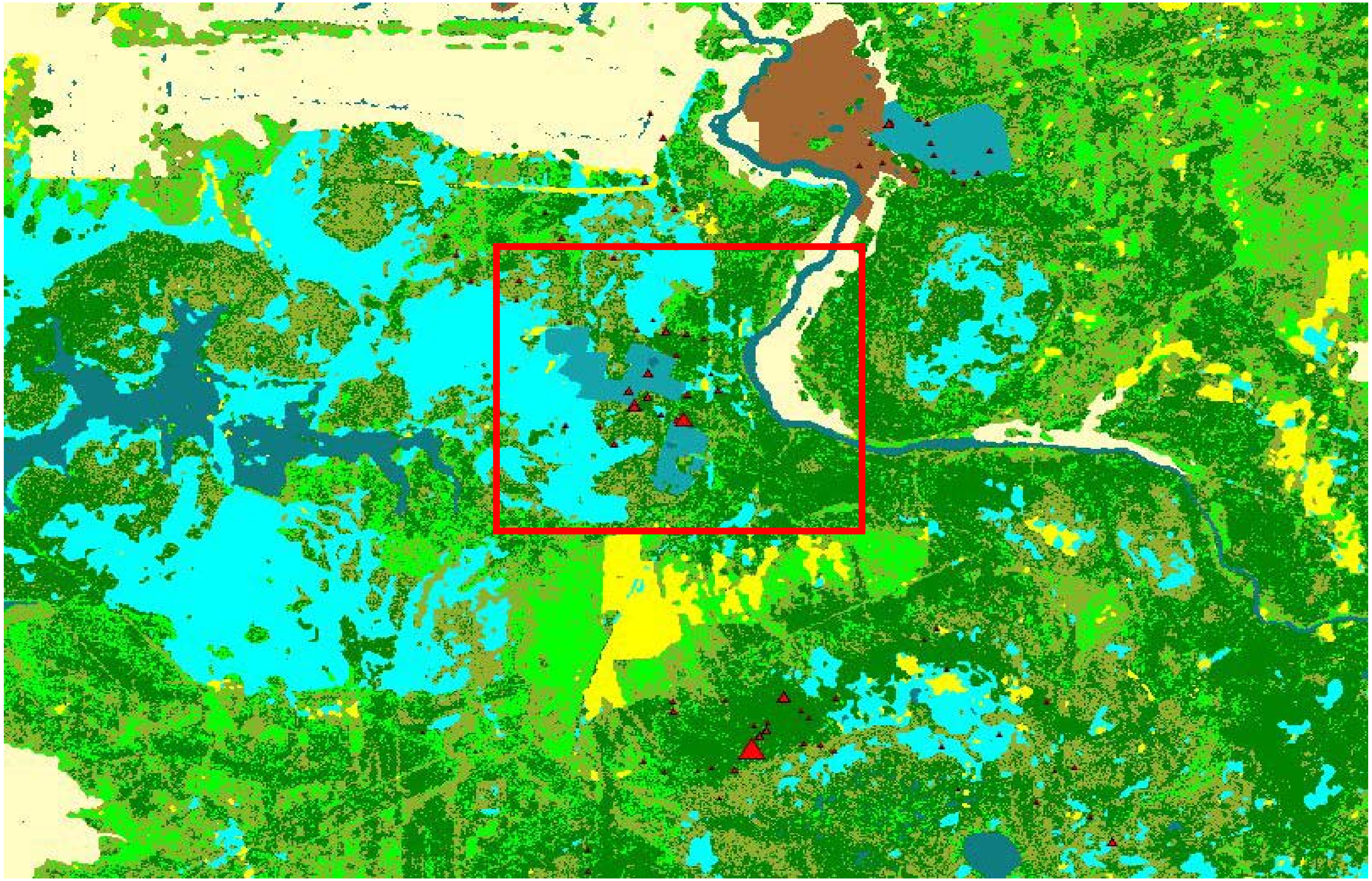
Landsat-based 30m land use coverage



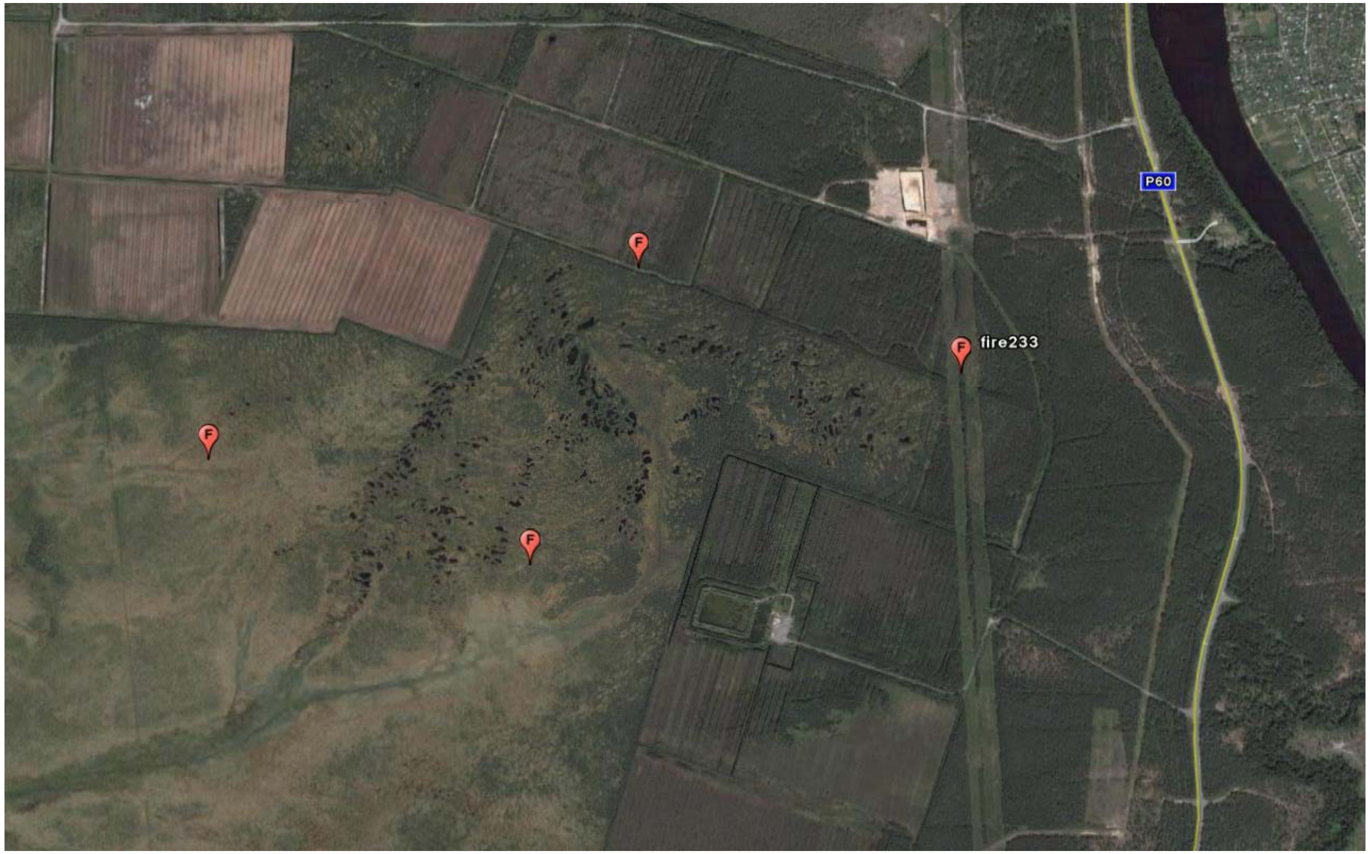
Hot spots statistic by land types



Fuel type identification example



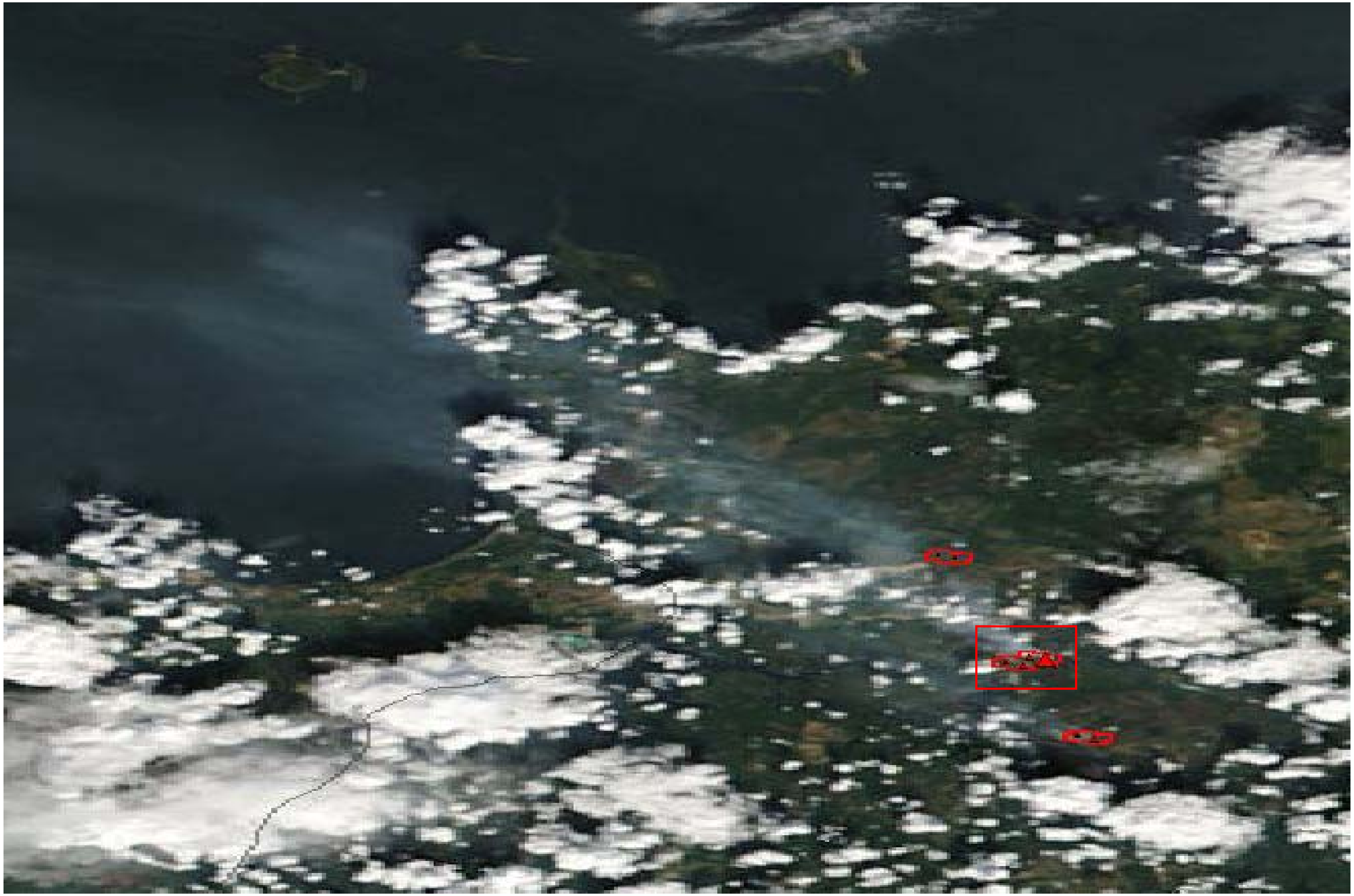
Cross validation of Landsat and Iconos land use



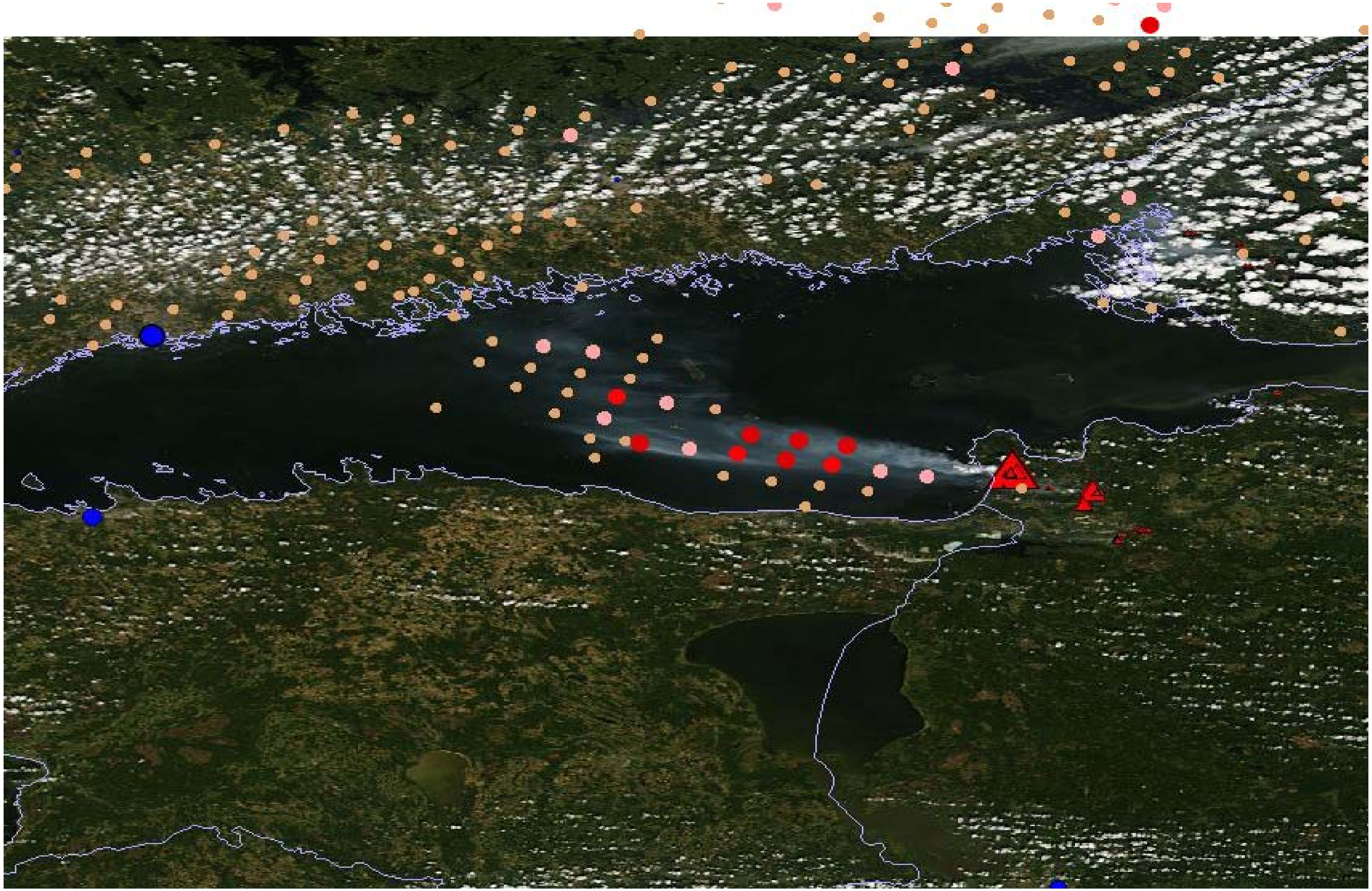
Challenges: details (1)

- Refine the emission coefficients
  - ➢ land-use as a surrogate: persistent
    - – a series of model calibration exercises (and/or AOD assimilation)
  - ➢ dynamic via
    - – complementary products (biomass water content, NDVI, soil water, …)
    - – data assimilation of AOD in the vicinity of the fires

Bog fire plume from Modis



AOD algorithm limitations



IS4FIRES: integrated system development

- WP 1. The detection of wild-land fires and smoke plumes by satellite observation techniques (link to GEMS)
- WP 2. Development of atmospheric dispersion modelling, data assimilation and source apportionment methods
- WP 3. Detection and quantification of particulate matter formed in fires at surface measurement stations, and the related modelling (link to EUCAARI)
- WP 4. Organisation of a forest fire dispersion measurement campaign in the vicinity of the SMEAR2 station, and the related modelling (link to EUCAARI)
- WP 5. Evaluation, analysis and modelling of the aerosol data measured during the TROICA campaign

Thank you for your attention !

- P.S. SILAM operational fire plume forecasts are available form http://silam.fmi.fi