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Air Quality :Modeling Group

Recent and ongoing work

Group members, 31/8/2007

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Ari Karppinen
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Marke Hongisto
Mia Pohjola
Jukka-Pekka Jalkanen
Mervi Haakana
Jouni Jäppinen
Juha Nikmo
Kari Riikonen
Leena Kangas
Ilkka Valkama
Joana Soares
Mari Kauhaniemi (Kuopio)
Minna Rantamäki (25%)

Noora Eresmaa (mat. leave)
Leena Partanen (mat. leave)

Personell: 14.25 + 2

FMI-Budget: 4.75 py+ projects: 9.5 py (300 k€ + 500 k€)
Total: 0.8 M€/year (14.25 py + ~100k€ other costs)

http://www.fmi.fi/organisaatio/yhteys_34.html
http://www.fmi.fi/research_air/air_2.html

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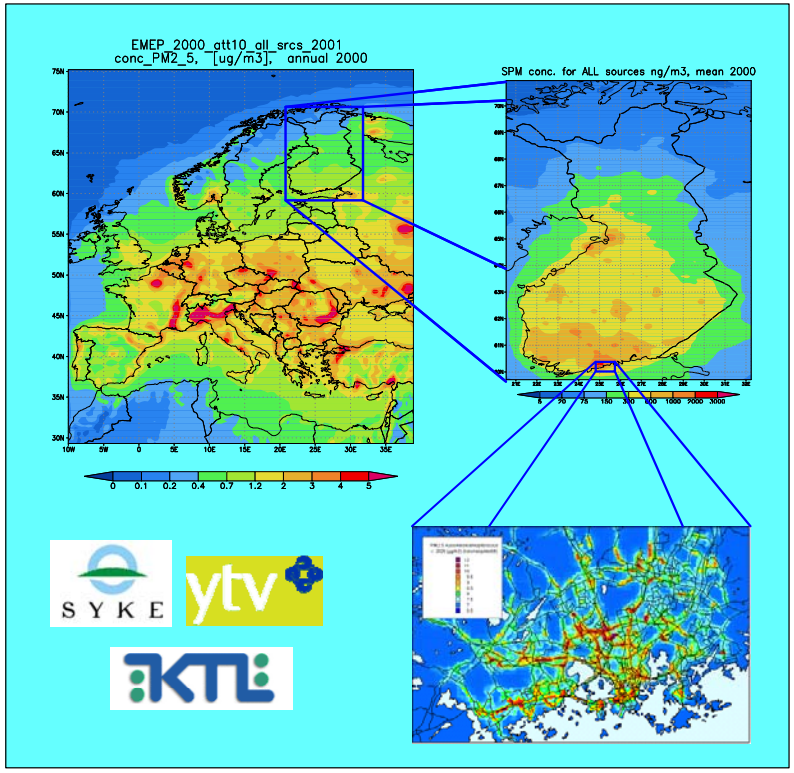
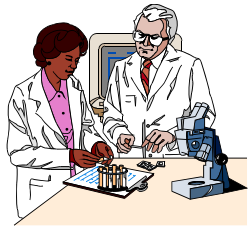
Dispersion modelling

- ✓ Development and evaluation of air quality models
- ✓ Combination of meteorological models and dispersion models
- ✓ Application of models and dissemination of information



Focus areas in modelling

1. Integrated modelling systems (from emissions to impacts, from street canyon to global scale)
2. Combined utilisation of meteorological models and dispersion models
3. Health effects of air pollution, especially modelling of the concentrations of and exposure to particulate matter



Modelling system - FMI

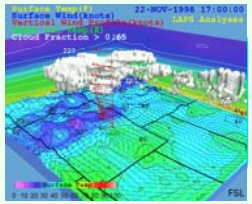
Weather prediction models

ECMWF

HIRLAM RCR

HIRLAM MBE

AROME, LAPS



Dispersion models - long-range, regional

SILAM LRT, meso, radioactivity

HILATAR LRT, meso ,chem.

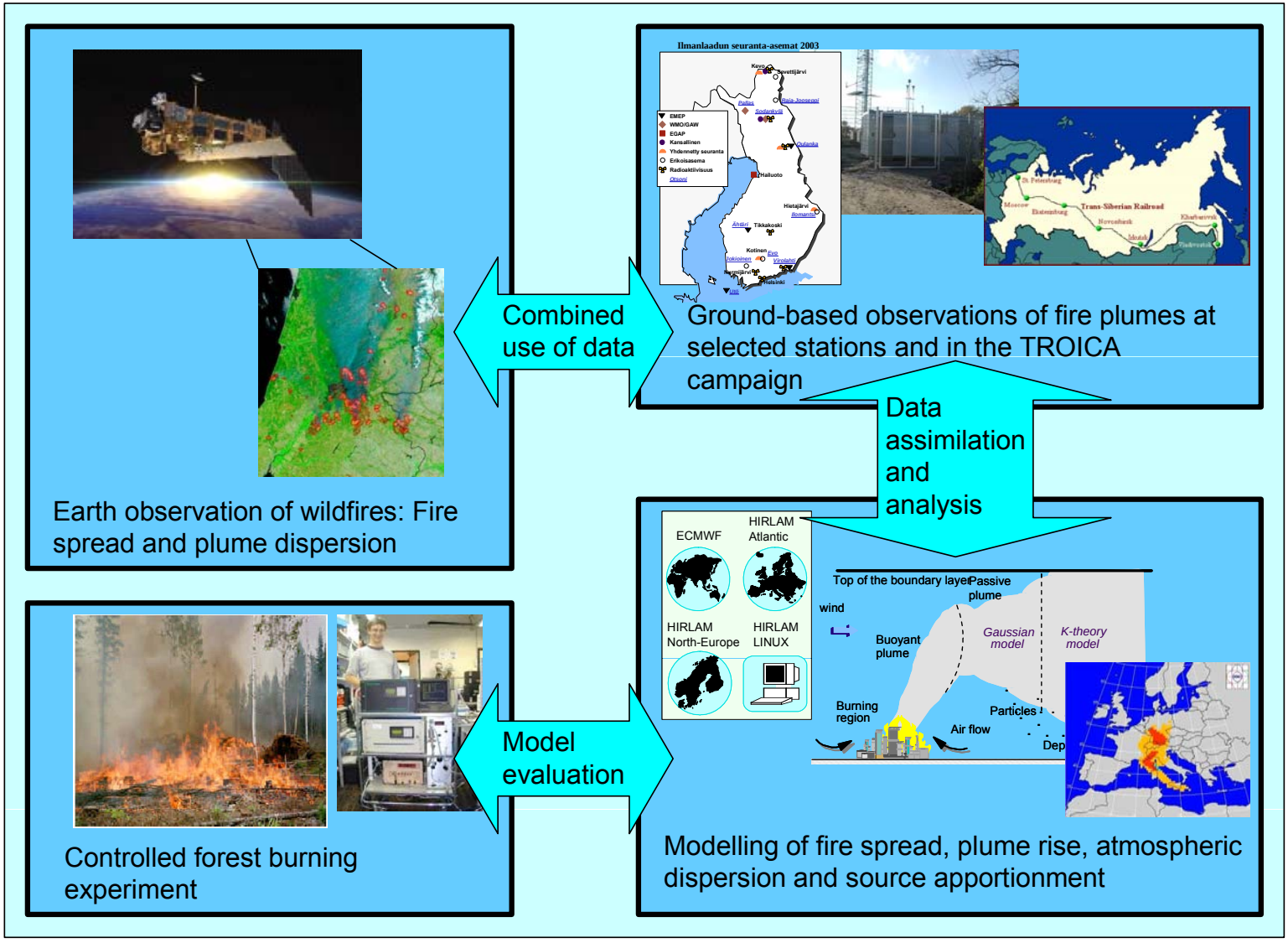
Aerosol process models:
UHMA (U Helsinki, FMI)
MONO32 (U Helsinki, Stadia)

Dispersion and effects models – urban, local

- CAR-FMI, roadside
- UDM-FMI, urban
- OSPM (NERI), street canyon
- BUOYANT, fires
- ESCAPE, chemical accidents
- FLUENT, CFD code
- EXPAND (FMI, YTV) population exposure
- MPP-FMI, Meteorological pre-processing model

A centre of expertise at the Kumpula campus: wild-land fires

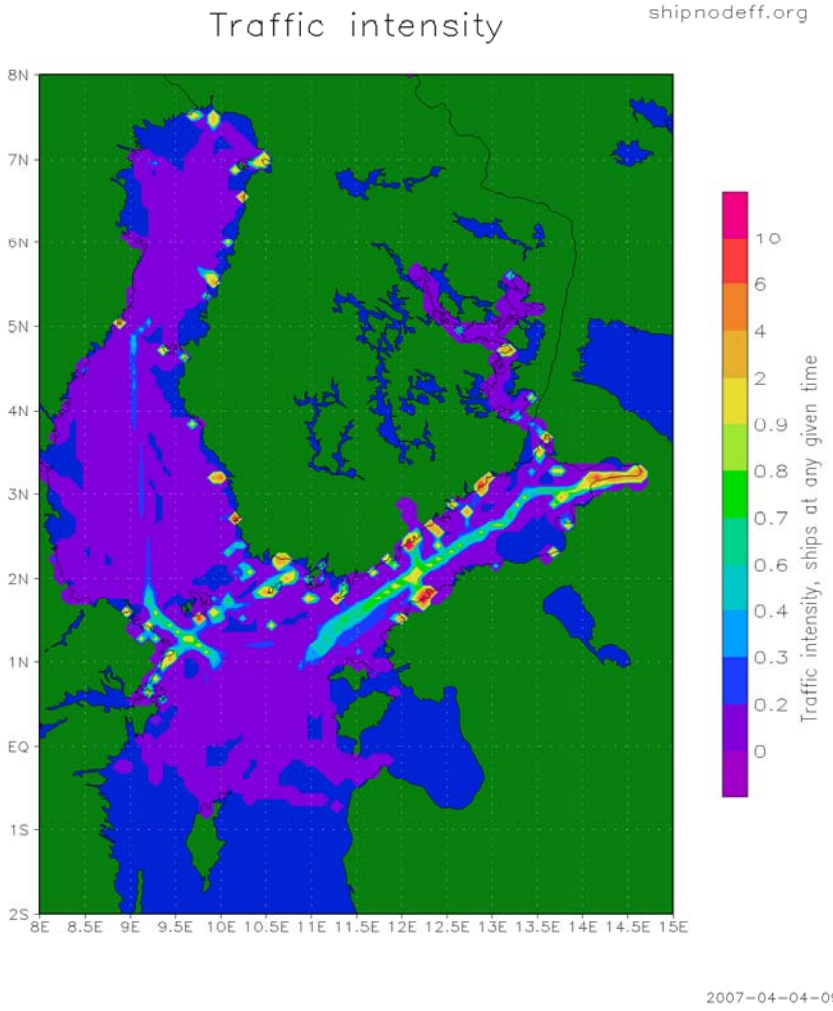
FMI Air Quality, Earth Observation, Climate and Global Change, Kuopio Unit, and Univ. Helsinki



NO_x emissions from marine traffic

Jukka-Pekka

- **Real-time monitoring system for ship emissions**
  - Position reports from transponder messages
- **NO_x estimate based on available technical data**
  - Current speed vs. design speed
- **Possibility to track emissions ship by ship**
- **Combine emission data with 3D atmospheric models to model long range transport**



Practical example

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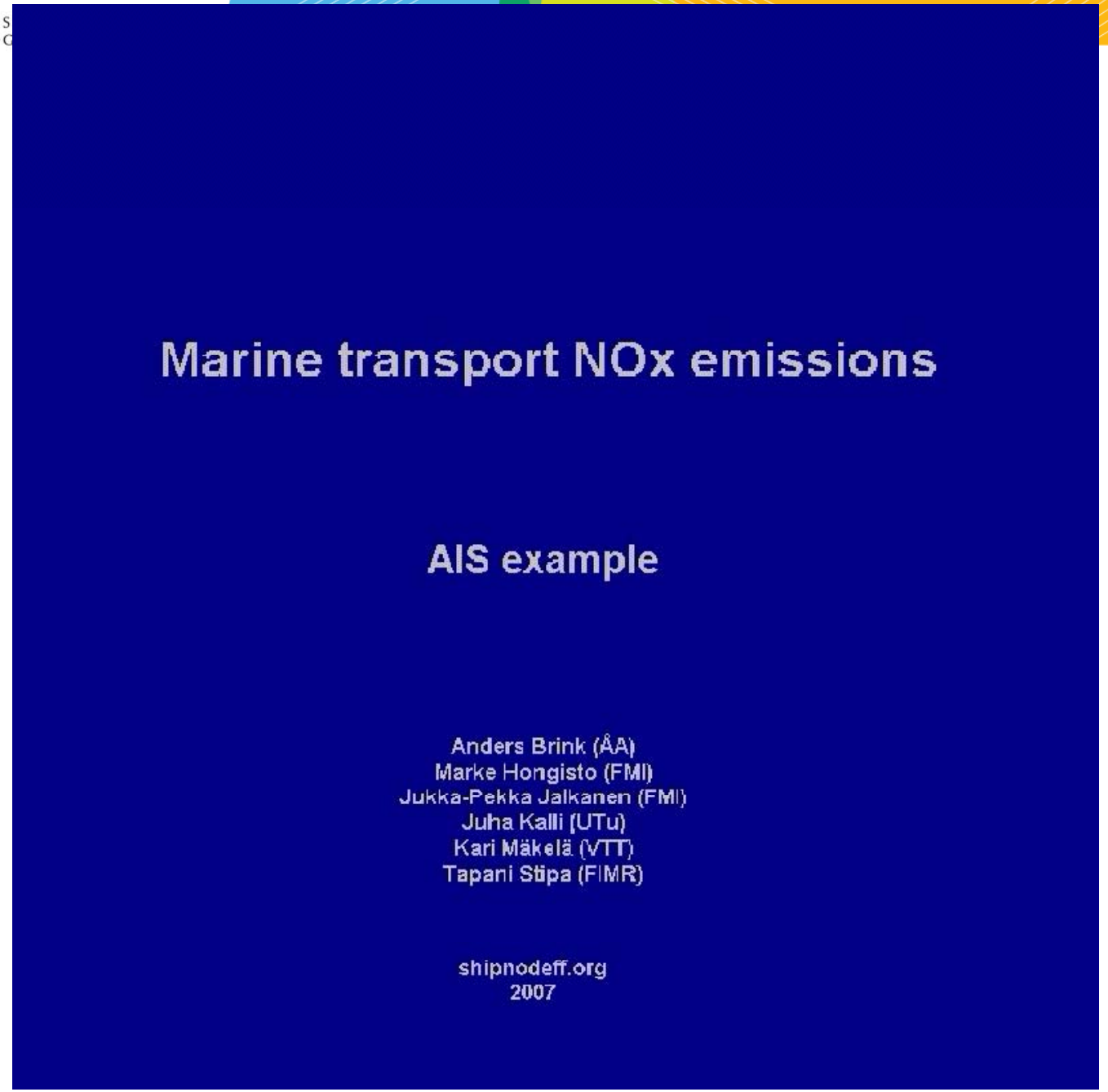

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Mari, Mervi

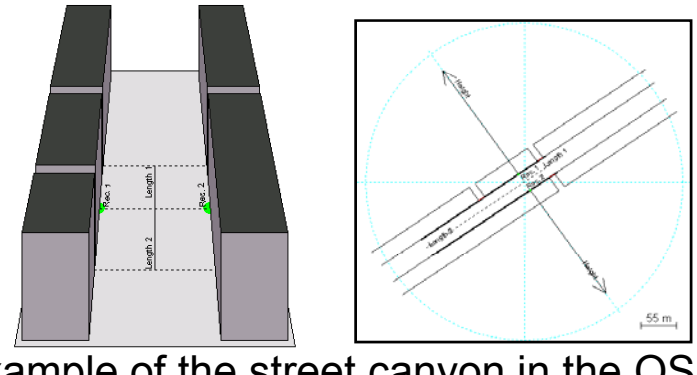
Modelling NOx and NO2 concentrations in different urban environments

Models:

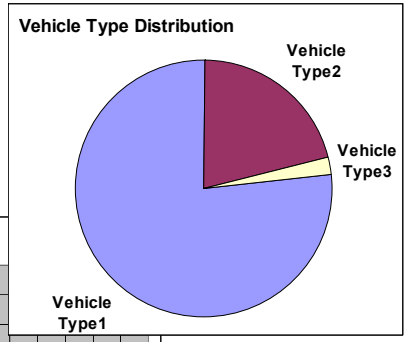
- CAR-FMI (open area line source model)
- OSPM (street canyon model)

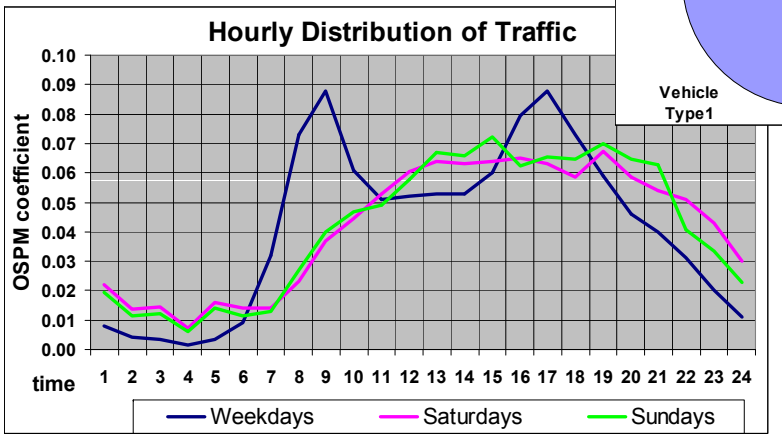
Conditions:

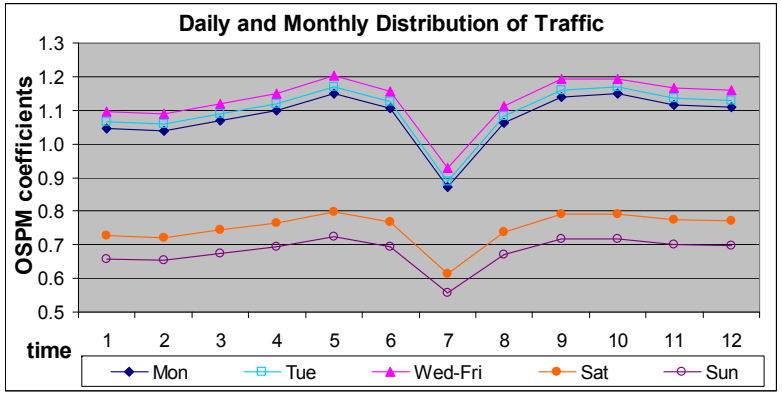
- 4 open area line source cases
- 6 street canyons cases
- 2 years
- 3 heights in street canyons
- NOx and NO2 emission factors



Example of the street canyon in the OSPM



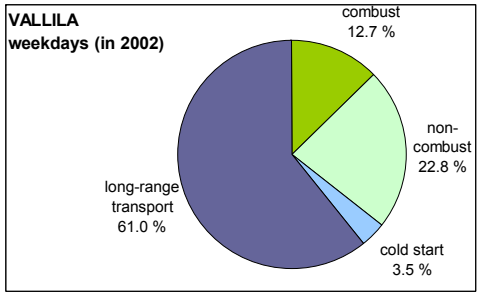


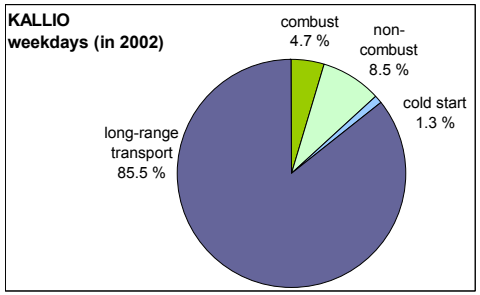


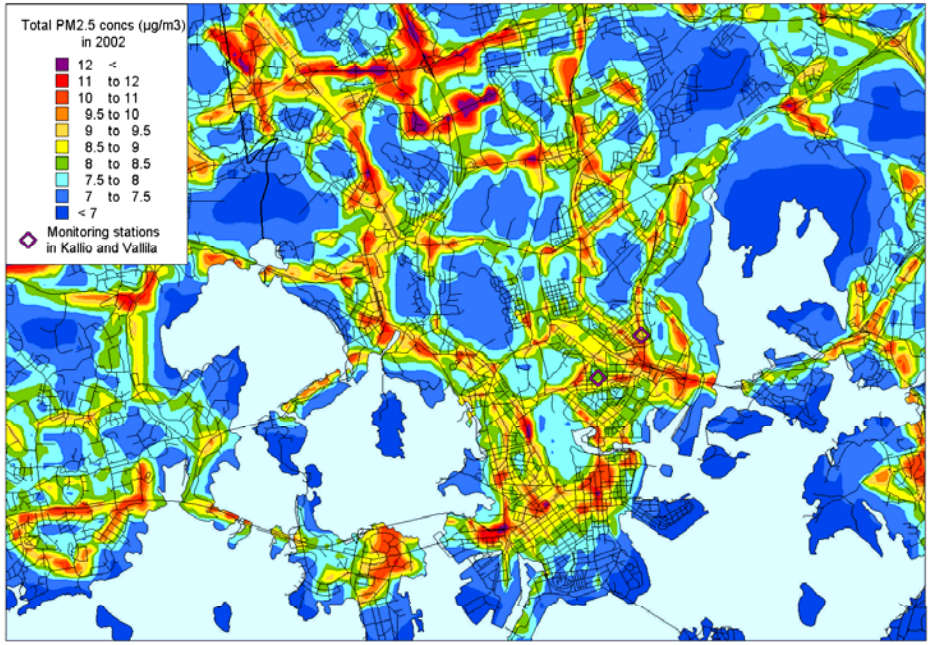
Publication (in progress for Atm. Env.)

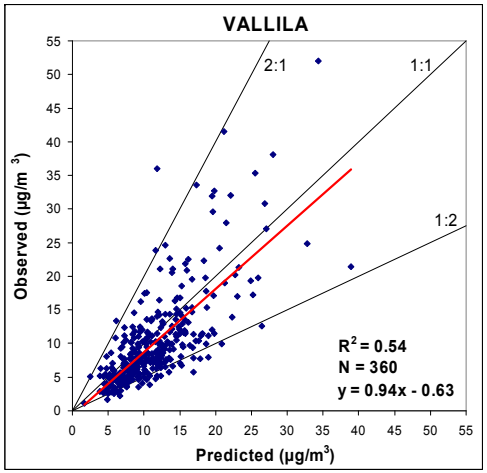
Evaluation and application of a modelling system for predicting the concentrations of PM2.5 in an urban area

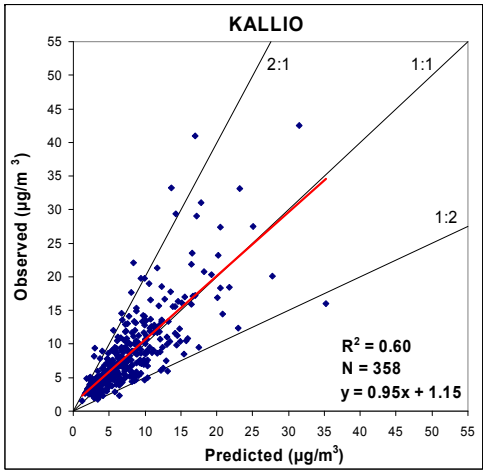
Kauhaniemi M.[1], Karppinen A.[2], Härkönen J.[2], Kousa A.[3], Alaviippola B.[3], Koskentalo T.[3], Aarnio P.[3], Elolähde, T.[3] and Kukkonen J.[2] (1 = FMI Kuopio, 2 = FMI Helsinki, 3 = YTV)





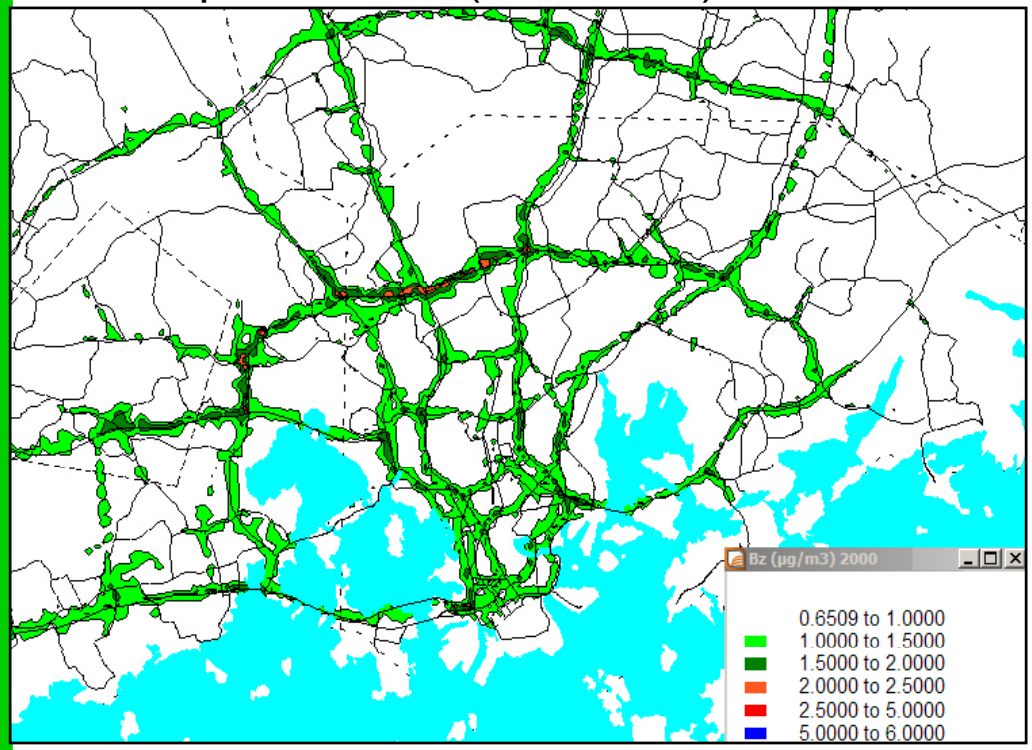


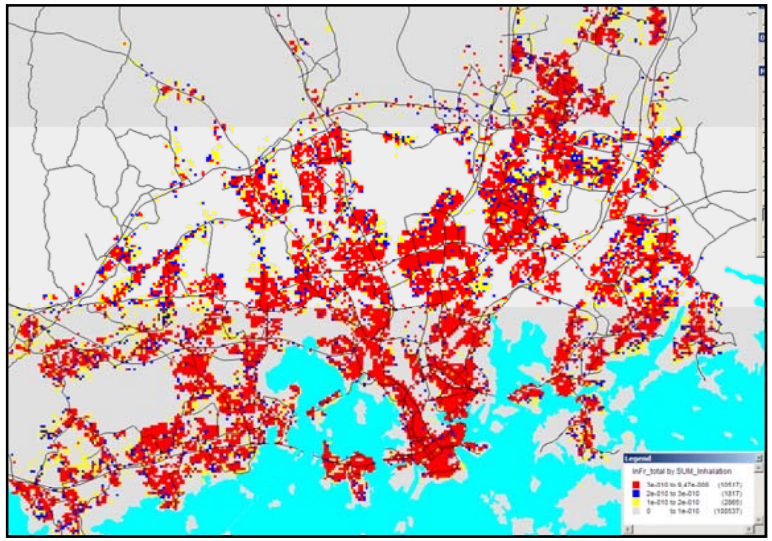




Traffic iF for BZ for different urban environments

street canyon (OSPM), Helsinki downtown area (PC-CAR) and the whole Helsinki Metropolitan Area (URB-CAR).





- $PM_{2.5}$ iF spatial distribution from a single source: Salmisaari cogeneration PP

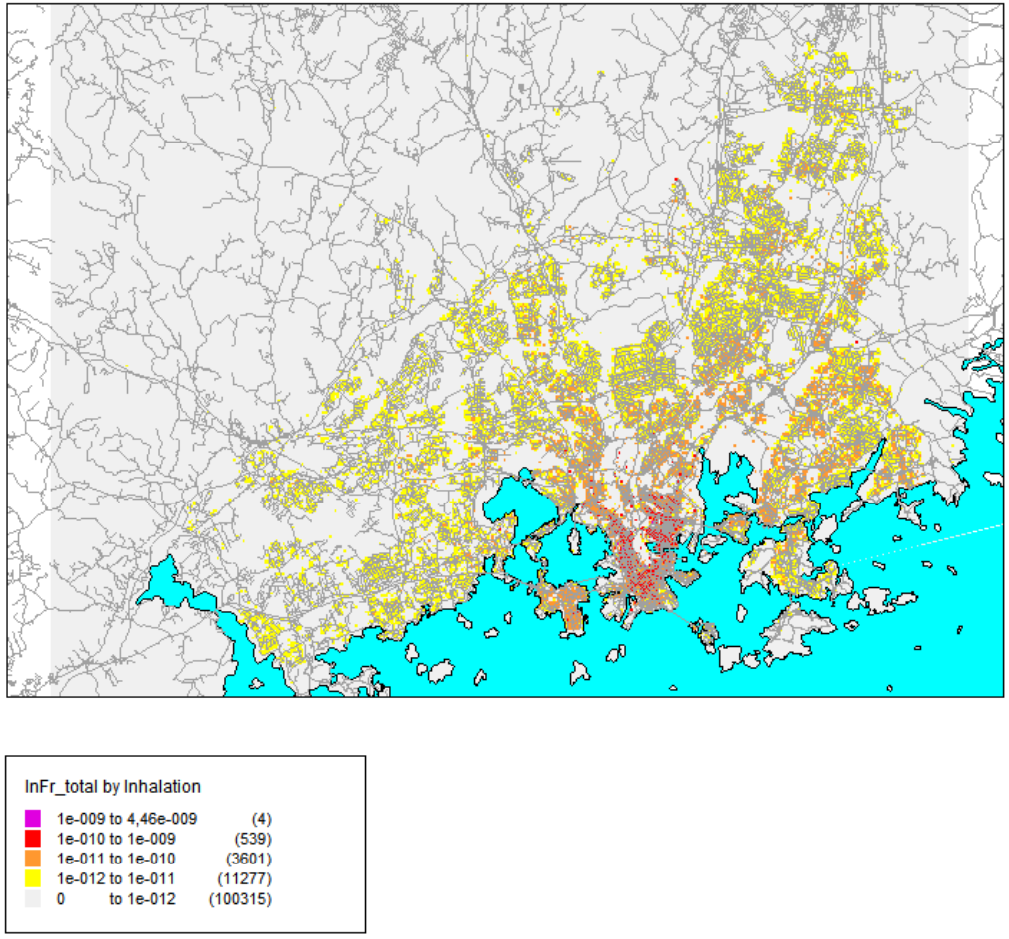
SILAM

- Benzene regional dispersion modelling
- Aerosol dynamics implementation

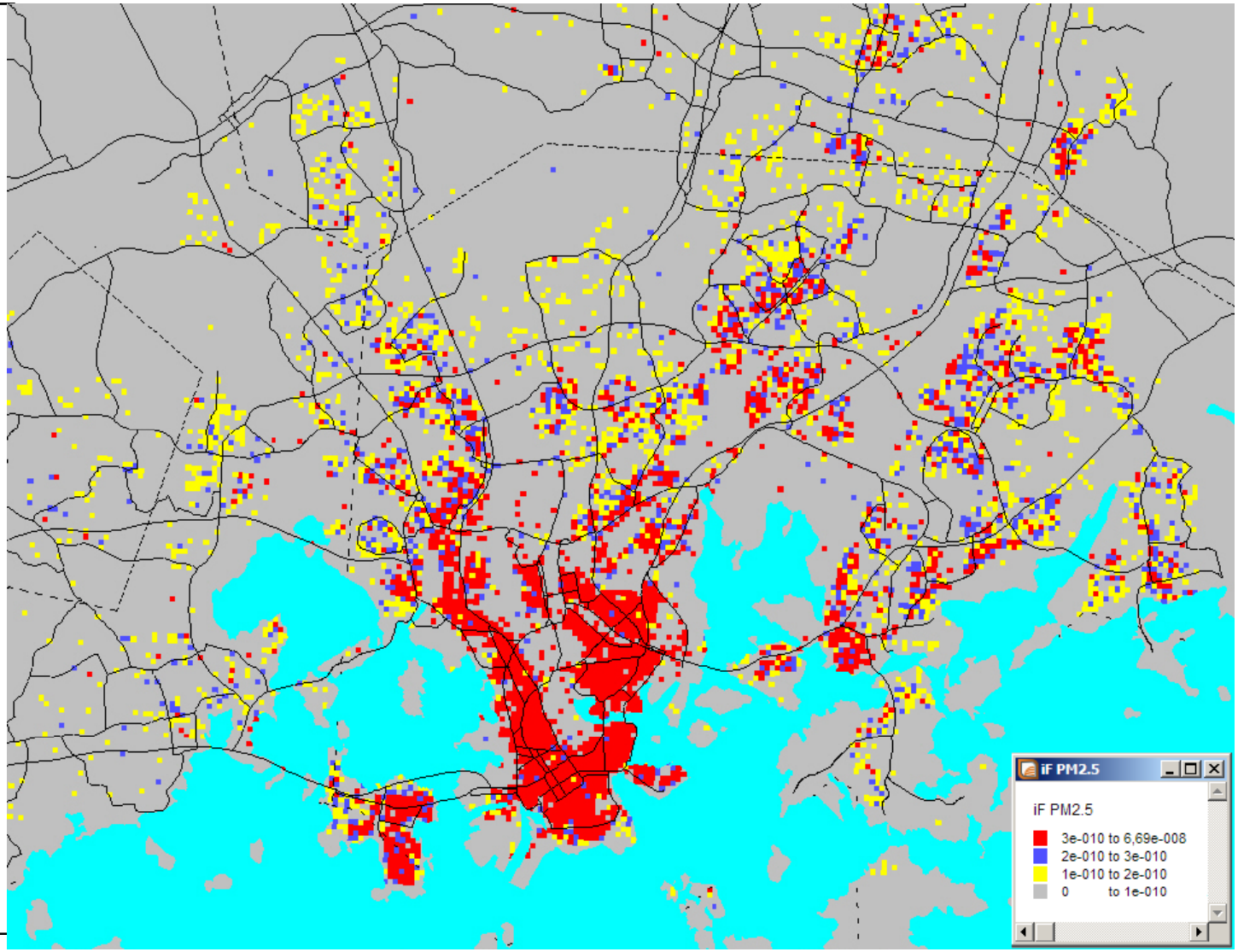
Salmisaari power plant: iF of PM2.5

Intake fraction =

$$\frac{\text{Concentration} \times \text{Breathing rate} \times \text{Activity}}{\text{Emission}}$$



Intake fraction (iF) study for $PM_{2.5}$ emissions from the cogenerating power plant Salmisaari in Helsinki



$PM_{2.5}$ iF for 2005 calculated by EXPAND

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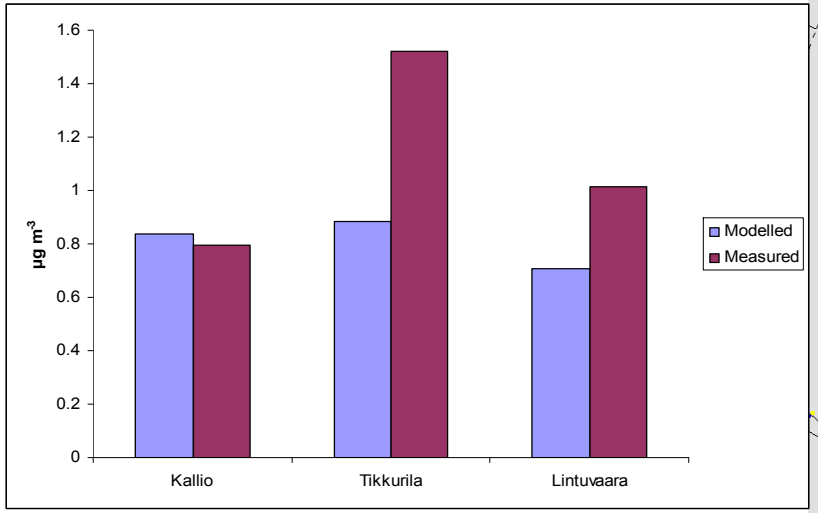
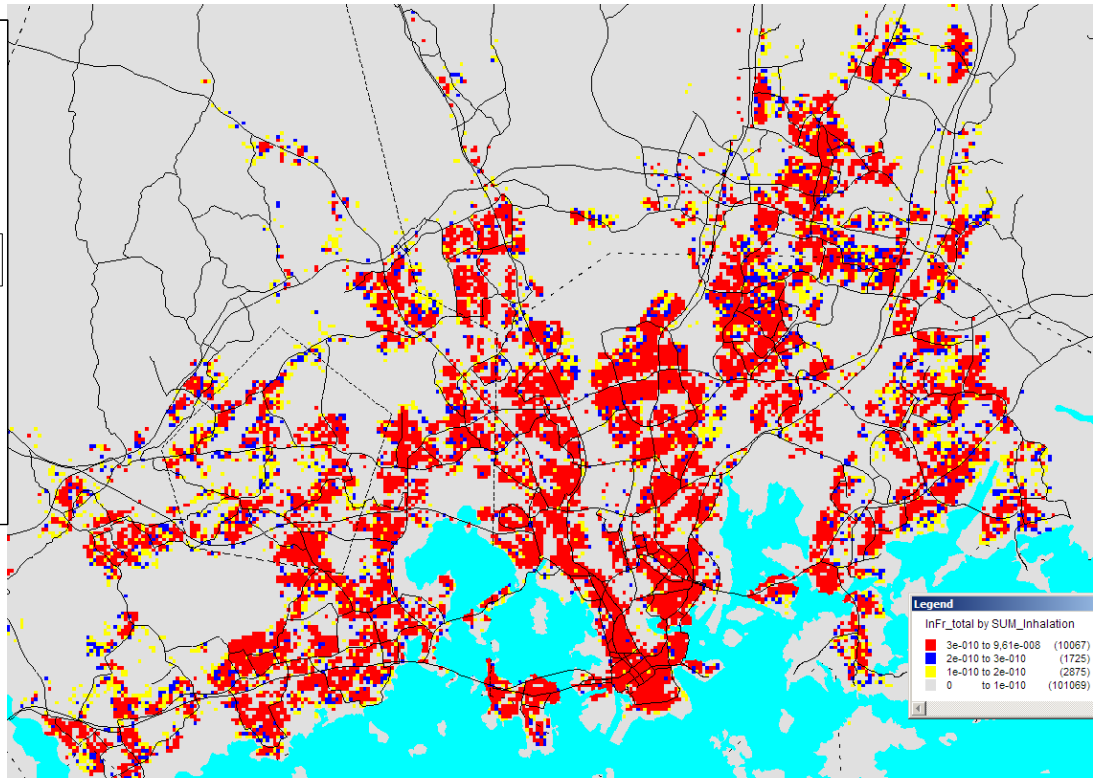
Leena

Intake fraction (iF) study for traffic emitted benzene in Helsinki Metropolitan area

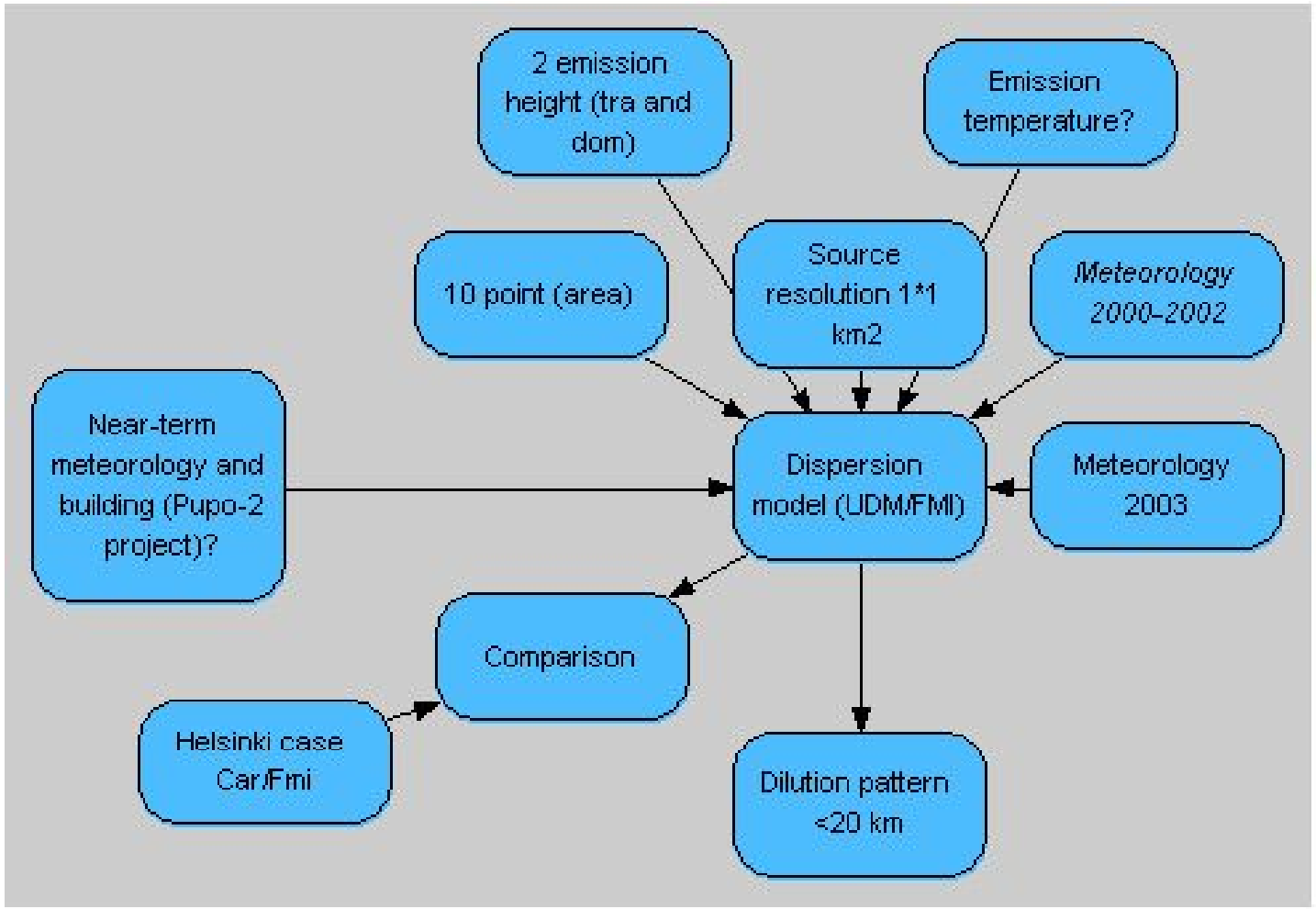


Comparison of modelled and measured annual average benzene concentrations

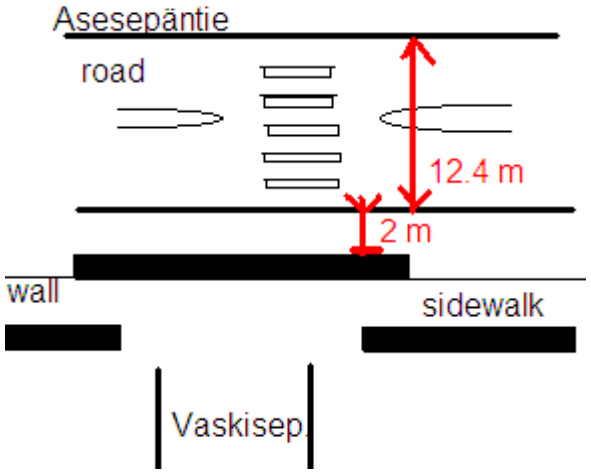


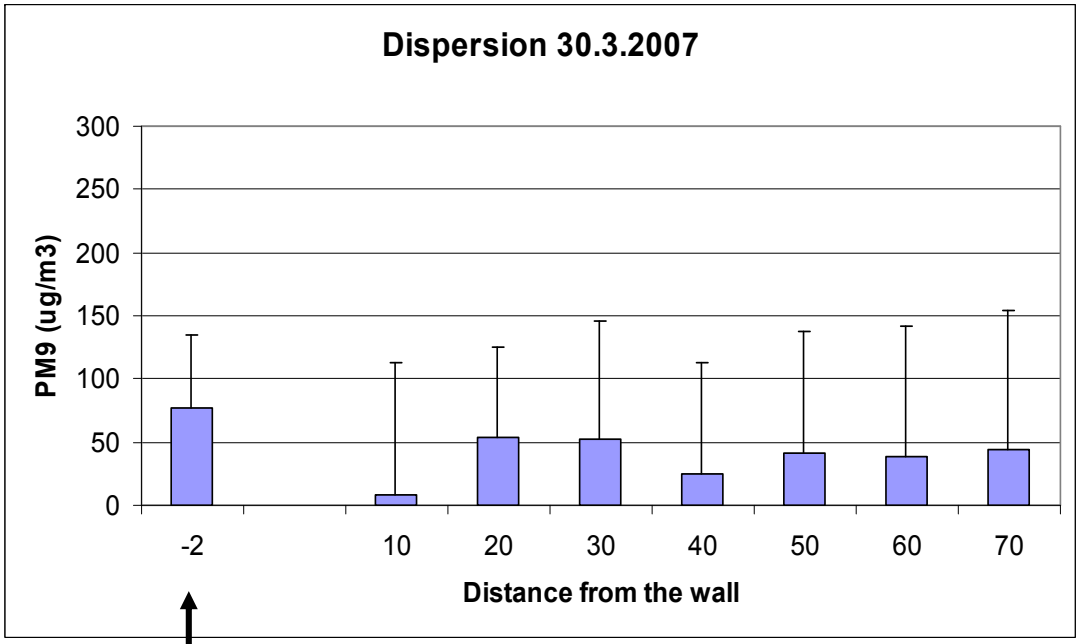
Benzene iF for 2005 calculated by EXPAND

Local scale dispersion calculations for fine particle emissions from domestic combustion and road traffic



Dispersion studies over a noise wall





stationary measurements
on the sidewalk

Measurements will be compared with model results

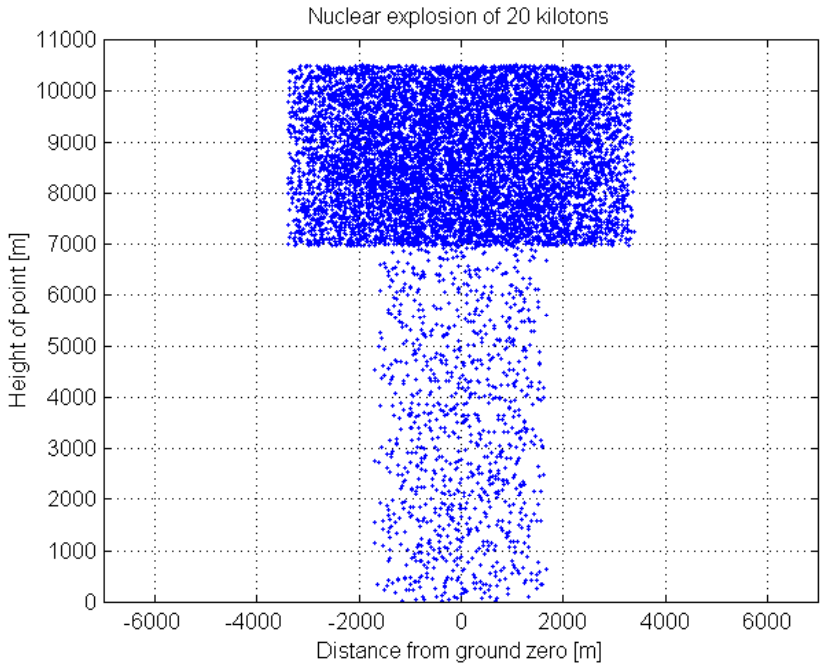
NBC Modelling & Simulation

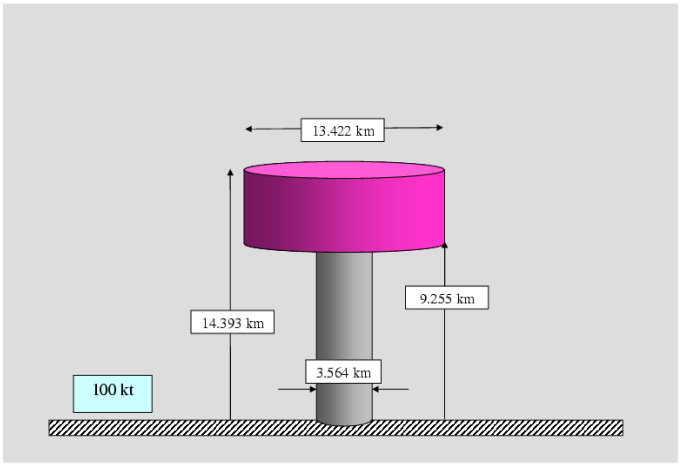
OVERALL OBJECTIVE

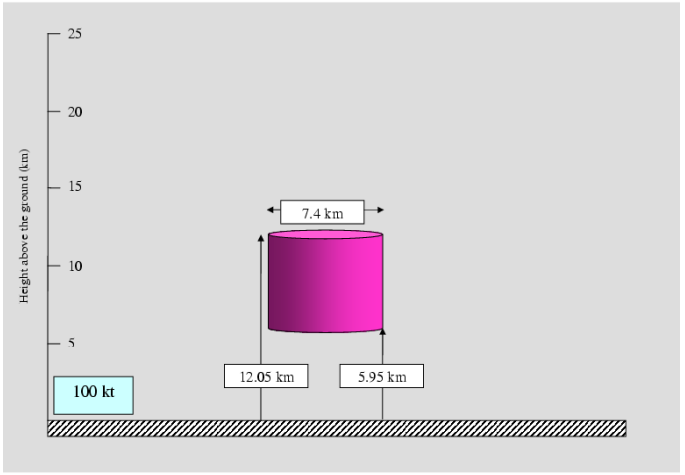
- **Develop improved model chains for simulation of NBC-scenarios for planning and decision support**

- **SPECIFIC GOALS FOR THIS PROJECT**
- **Clarify uncertainties in NBC M&S**
  - Compare results from national model chains for reference scenarios
  - *Emergency response (very fast) ---- studies ("unlimited" time for calc.)*
  - Identify key weaknesses
- ***Modelling Guidelines***
- ***Best Practice***
- **Possible start of model development**

Particle-cloud formation





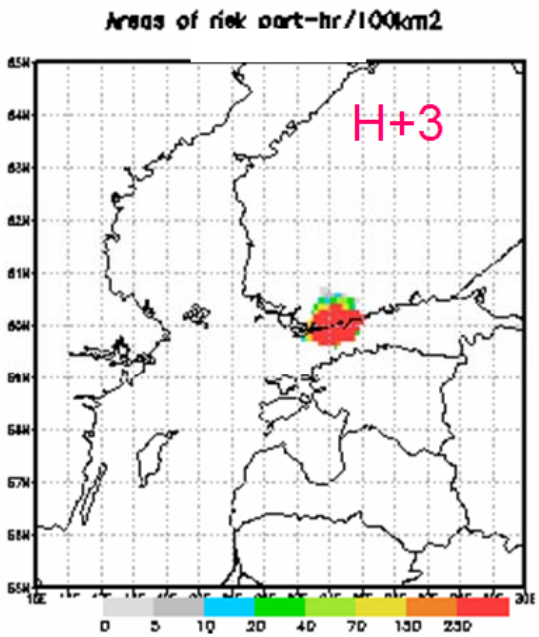


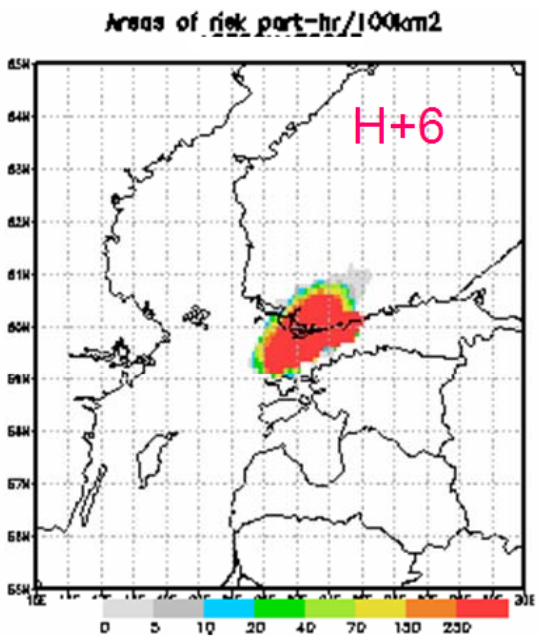
- in SILAM (above)
- compared to ”traditional” cylinder cloud (left)

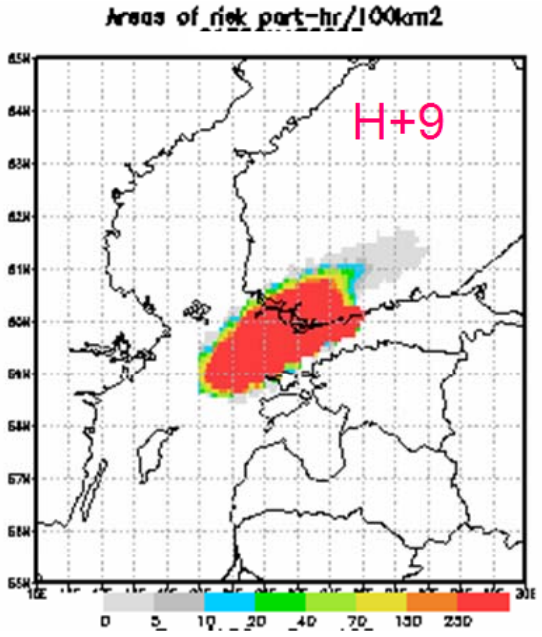
EXPLOSION OF AN IMPROVISED NUCLEAR DEVICE (FI)

Helsinki RN-Scenario

Approximate evolution of the cloud
(projection on the ground level from all heights)

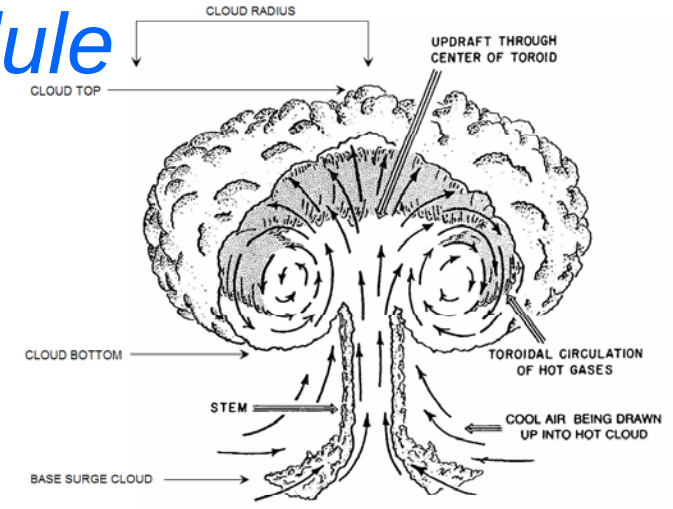


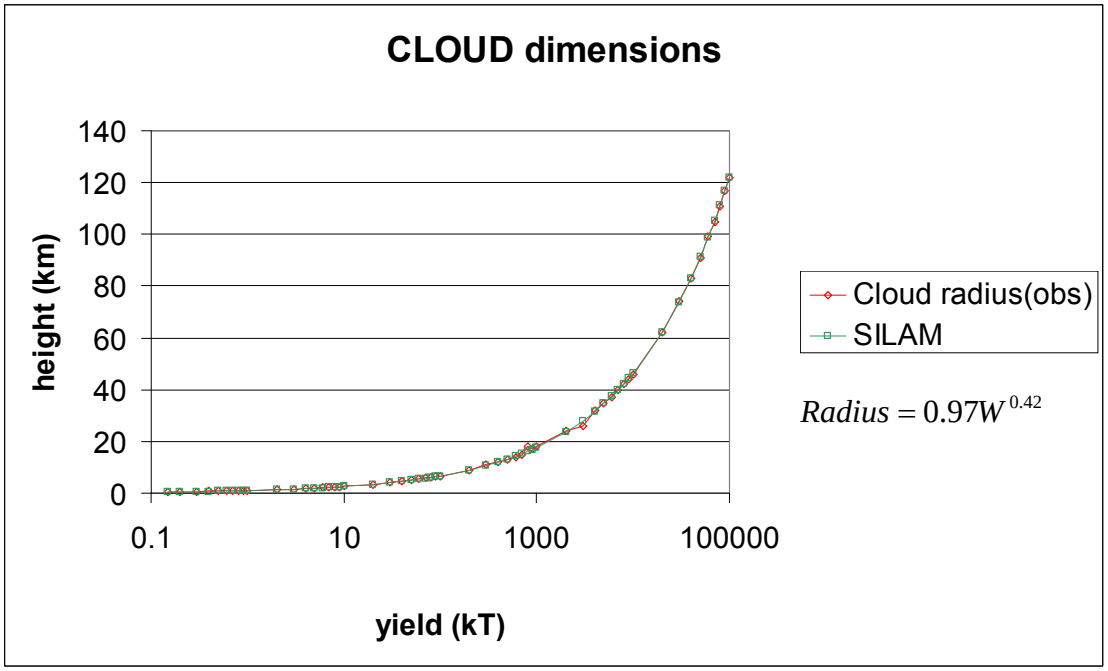




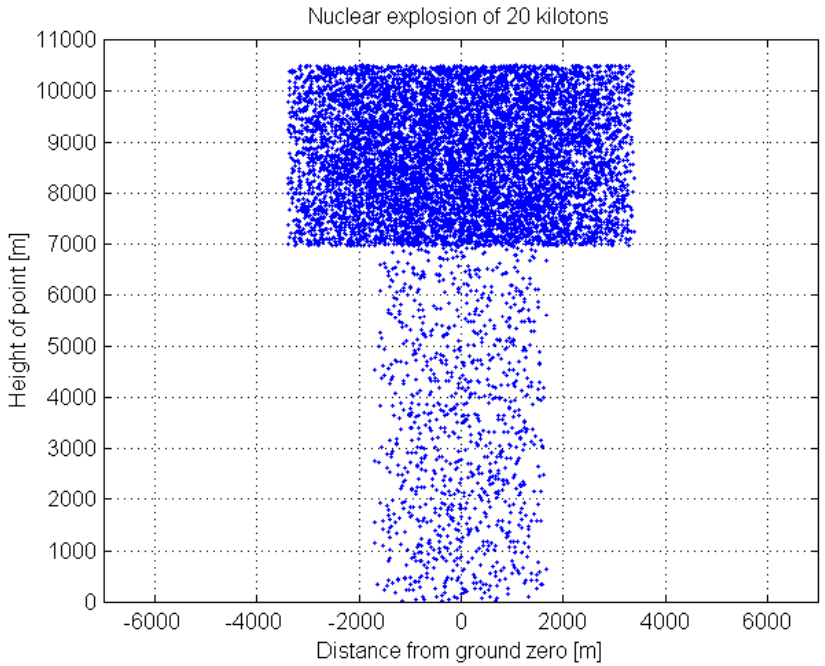
SILAM Nuclear Fallout Module

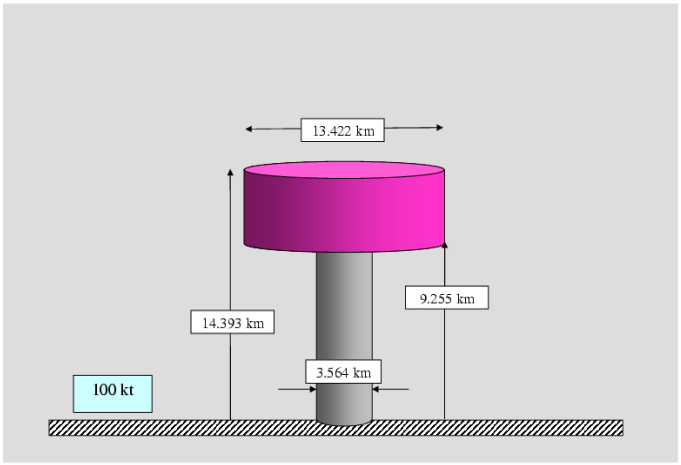
- cloud parametres
- particle formation
- activity distribution

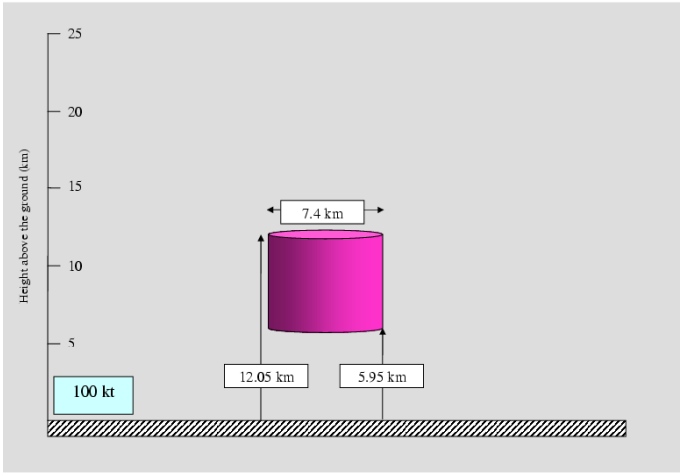




Particle-cloud formation







- in SILAM (above)
- compared to ”traditional” cylinder cloud (left)

Further development of MPP-FMI utilizing satellite data (ESA)

Available data:

- **MODIS: T-profile product every 6th hour (in cloud-free conditions)**
- **RS-data twice a day**
- **Ground surface measurements at least once a hour**

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MODIS Test Plan

Polar orbiting satellites: Aqua, Terra

700 km

HELSINKI TESTBED:

- RASS
- SODAR
- CEILOMETER
- Meteorological and air quality monitors

RS

0-7 km

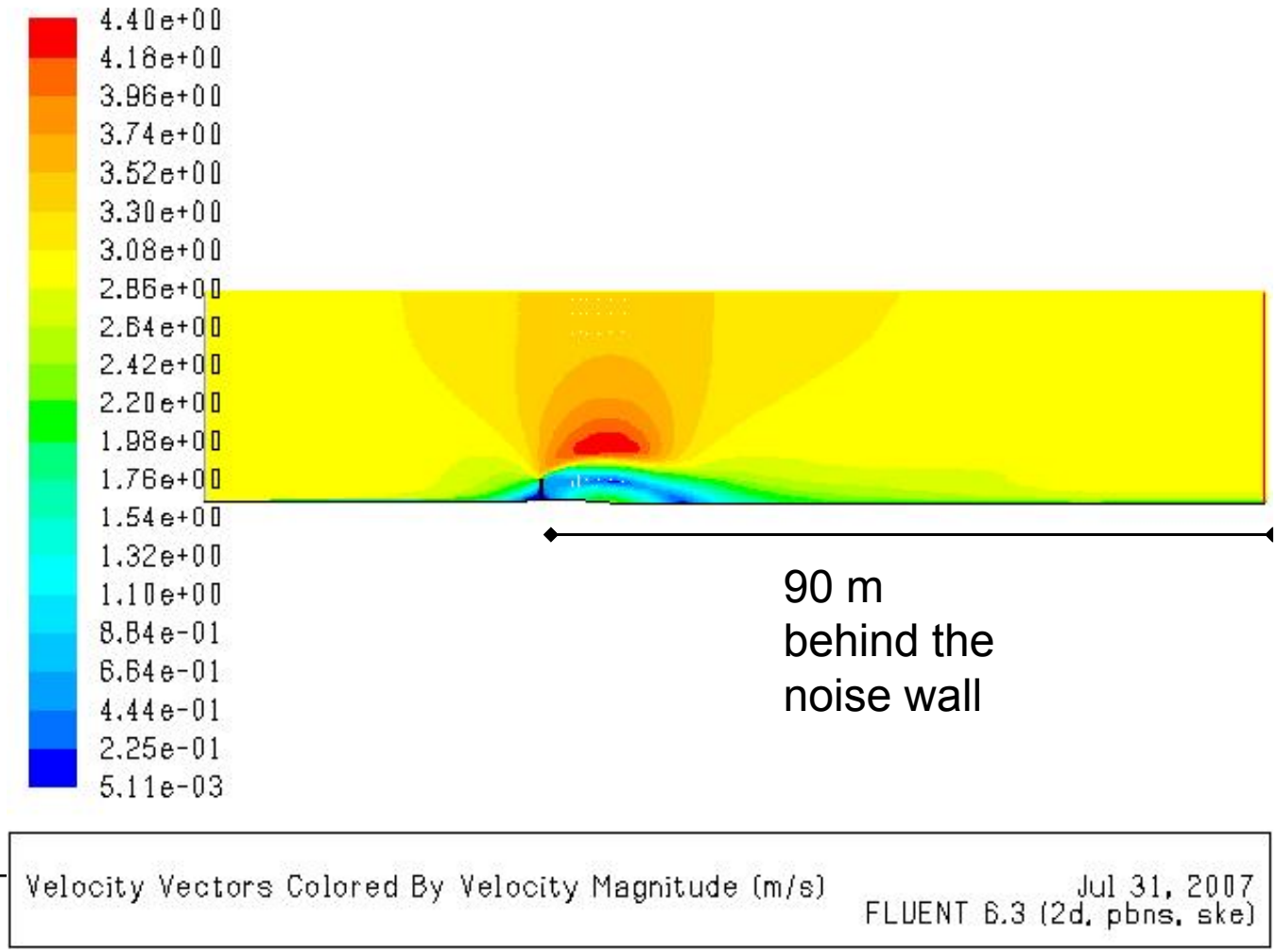
100 km

Jokioinen

Helsinki

VIEME-project:

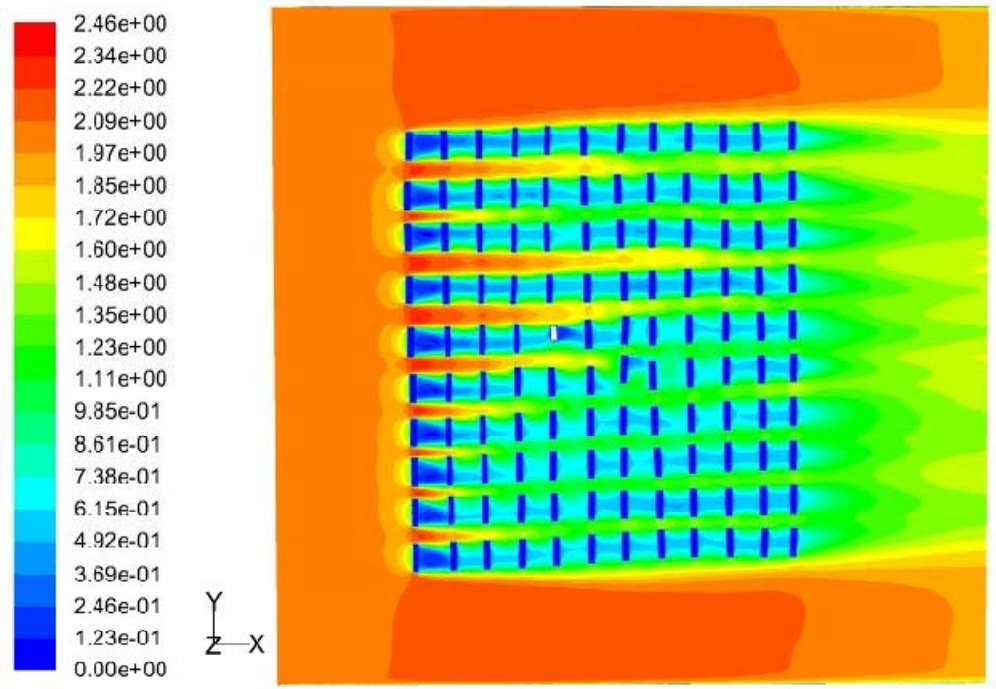
- **Computational fluid dynamics study of dispersion of particulate matter from a highway over a noise wall**
- **PM will be simulated as an inert substance**
- **2D, standard k-ε**



COST-732

- "QUALITY ASSURANCE AND IMPROVEMENT OF MICRO-SCALE METEOROLOGICAL MODELS"
- 23 members
- Test case of 120 containers on a field
- To be developed:

  Guideline on how to model dispersion from the experiences obtained



SRIMPART: Source-receptor and inverse modelling to quantify urban particulate emissions

- **Aims:**
  - To improve emission estimates with emphasis on emissions from **domestic wood burning**.
  - To improve emission estimates for wood burning applied in the EMEP model and in other international modelling systems
  - To intercompare and assess uncertainty in independent methodologies for assessing emission rates of particulates from urban sources

- **AIM: provide an overview of the latest research findings on air quality and health to support European sustainable development action plans and strategies**
- **WP 4: "Report on current state-of-the-art research in urban air quality and health"**

CAIR4HEALTH

- *The **Air Quality Key Questions** have been decided on, and now answers are being drafted for them:*
  - How are Urban Air Pollutant LEVELS CHANCING in the long term - past 10 years and future trends, including expected effects of climate change? (Editor: UH, writers UH, FMI, AUTH)
  - Are the current pollutant limit values attainable – the effectiveness of REDUCTION MEASURES? (Editor: UH, writers UH, FMI, AUTH)
  - What are the current achievements of INTEGRATED ASSESSMENT TOOLS for estimating the health impacts of air pollution? (Editor: AUTH, writers AUTH, TNO, FMI)
  - What is known about the CHEMICAL COMPOSITION AND SIZE DISTRIBUTION OF URBAN PM and their HEALTH EFFECTS? (Editor: FMI, writers: UH, FMI)

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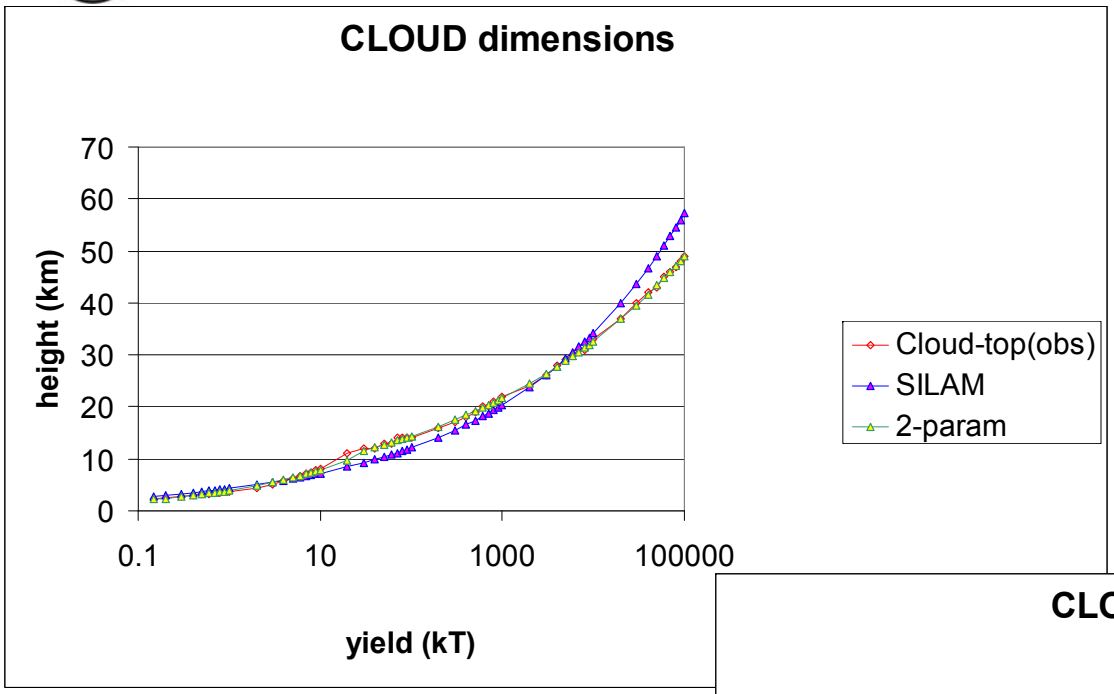
Backup slides



$$H_{top} = 4.310W^{0.2248}$$

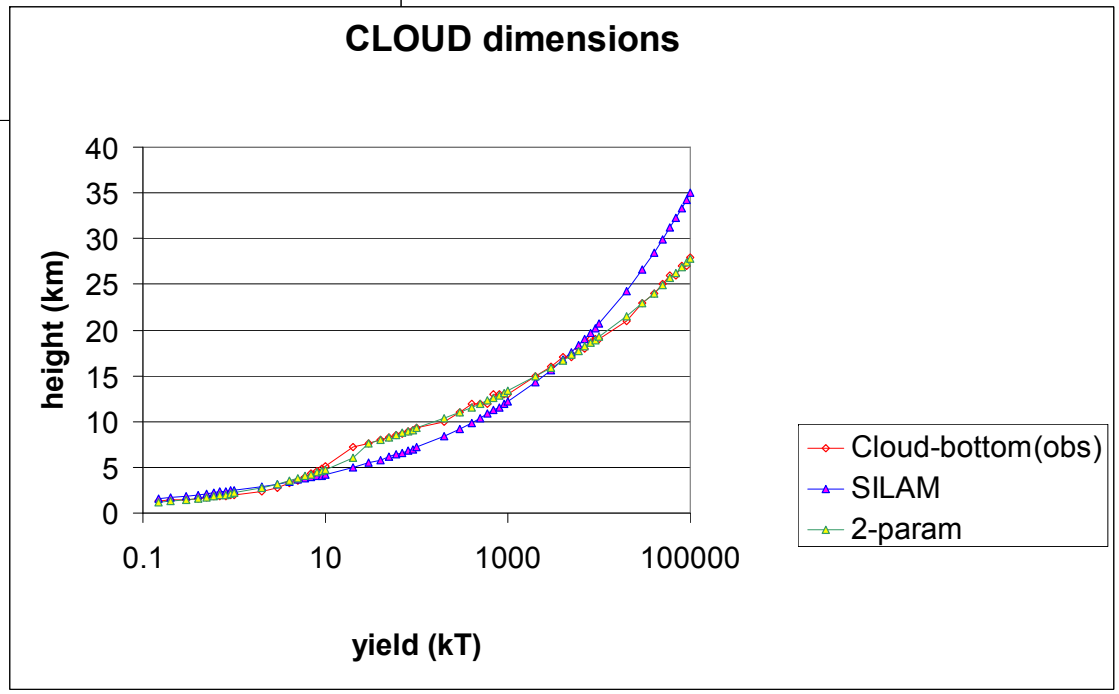
$$H(W \le 20kt) = 3.917W^{0.305}$$

$$H(W > 20kt) = 6.362W^{0.1774}$$

$$H_{bottom} = 2.493W^{0.2296}$$

$$H(W \le 20kt) = 2.166W^{0.3433}$$

$$H(W > 20kt) = 4.439W^{0.1594}$$



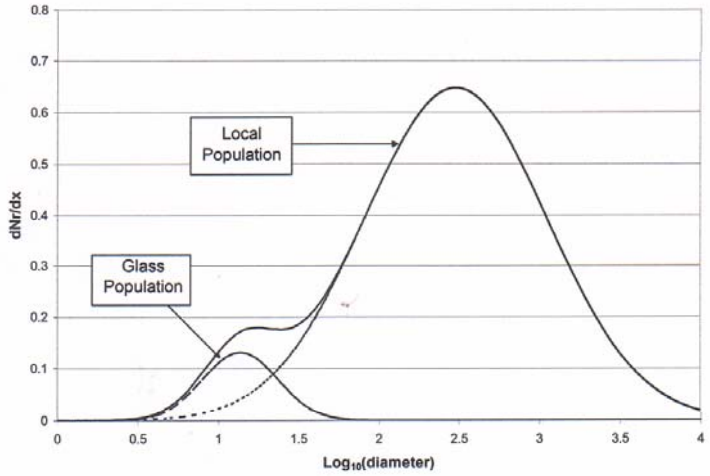
Activity-particle size distribution

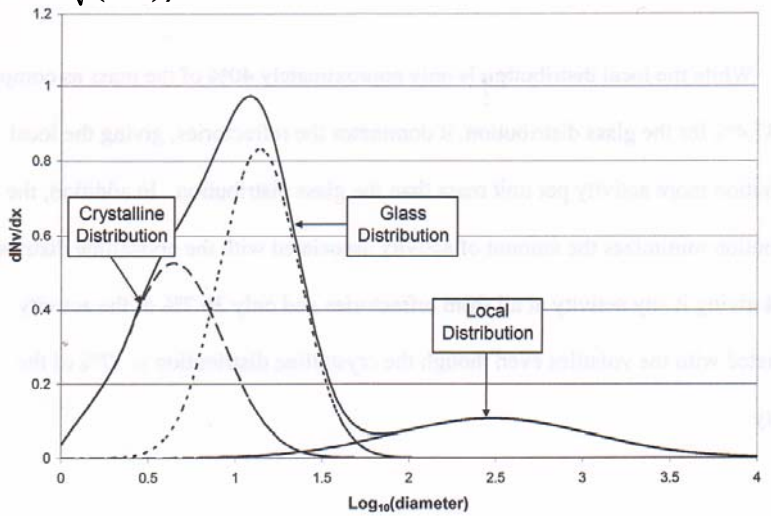
Mass Distribution for Heft Two-Component Surface Burst Fallout Particles

$$\frac{dF_m}{dx} = \frac{\phi_1}{\sqrt{2\pi}\sigma_1}\left[\exp\left(\frac{(\overline{x_1} - x)^2}{2\sigma_1^2}\right)\right] + \frac{\phi_2}{\sqrt{2\pi}\sigma_2}\left[\exp\left(\frac{(\overline{x_2} - x)^2}{2\sigma_2^2}\right)\right]$$

Radioactivity-particle size distribution (bi-modal log-normal distribution)

$$A(r) = f_v \frac{A_t}{\sqrt{(2\pi)}\beta r} e^{-\left[\frac{1}{2}\left(\frac{(\ln(r)-\alpha_3}{\beta}\right)\right]^2} + (1 - f_v)\frac{A_t}{\sqrt{(2\pi)}\beta r} e^{-\left[\frac{1}{2}\left(\frac{(\ln(r)-\alpha_2}{\beta}\right)\right]^2}$$





Log-normal distributions for volatile (left) and volatile (right) radionuclides.

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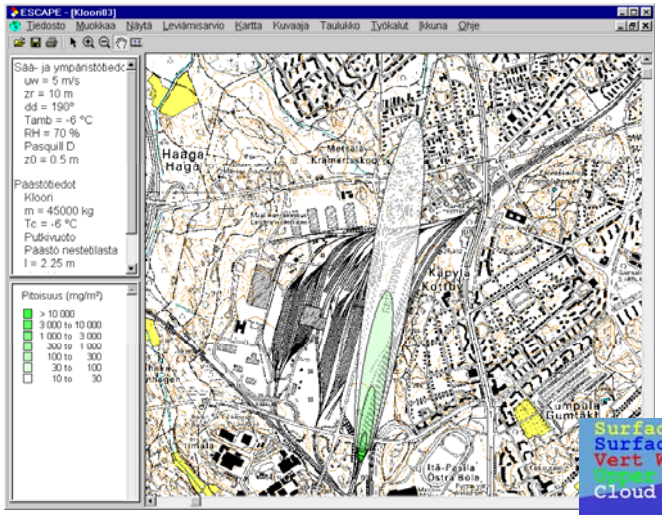
Available (/developed in Ubicasting): dense obs. Network (met & AQ) & high resolution met-modeling =>

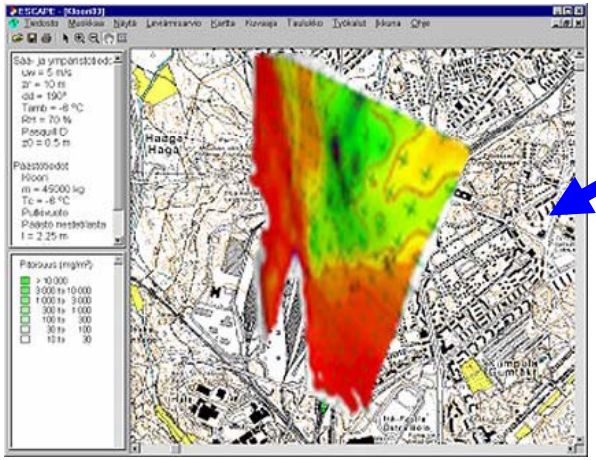
Dispersion forecasts for toxic industrial chemicals and other hazardous releases (terrorism etc)

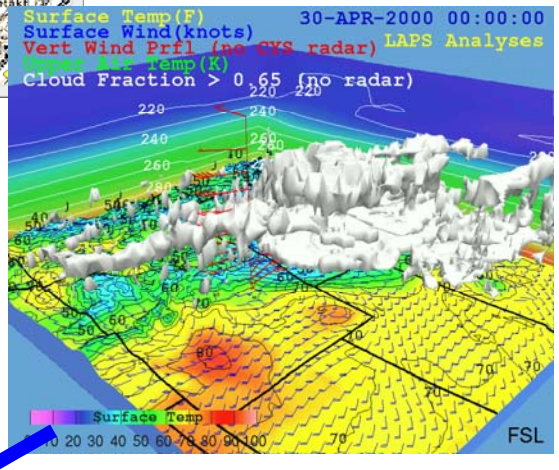


Now : offline met-data

GOAL :

Realtime dispersion & forecasts (1- 6 h)





New met-model
-> OPERATIVE
dispersion modelling

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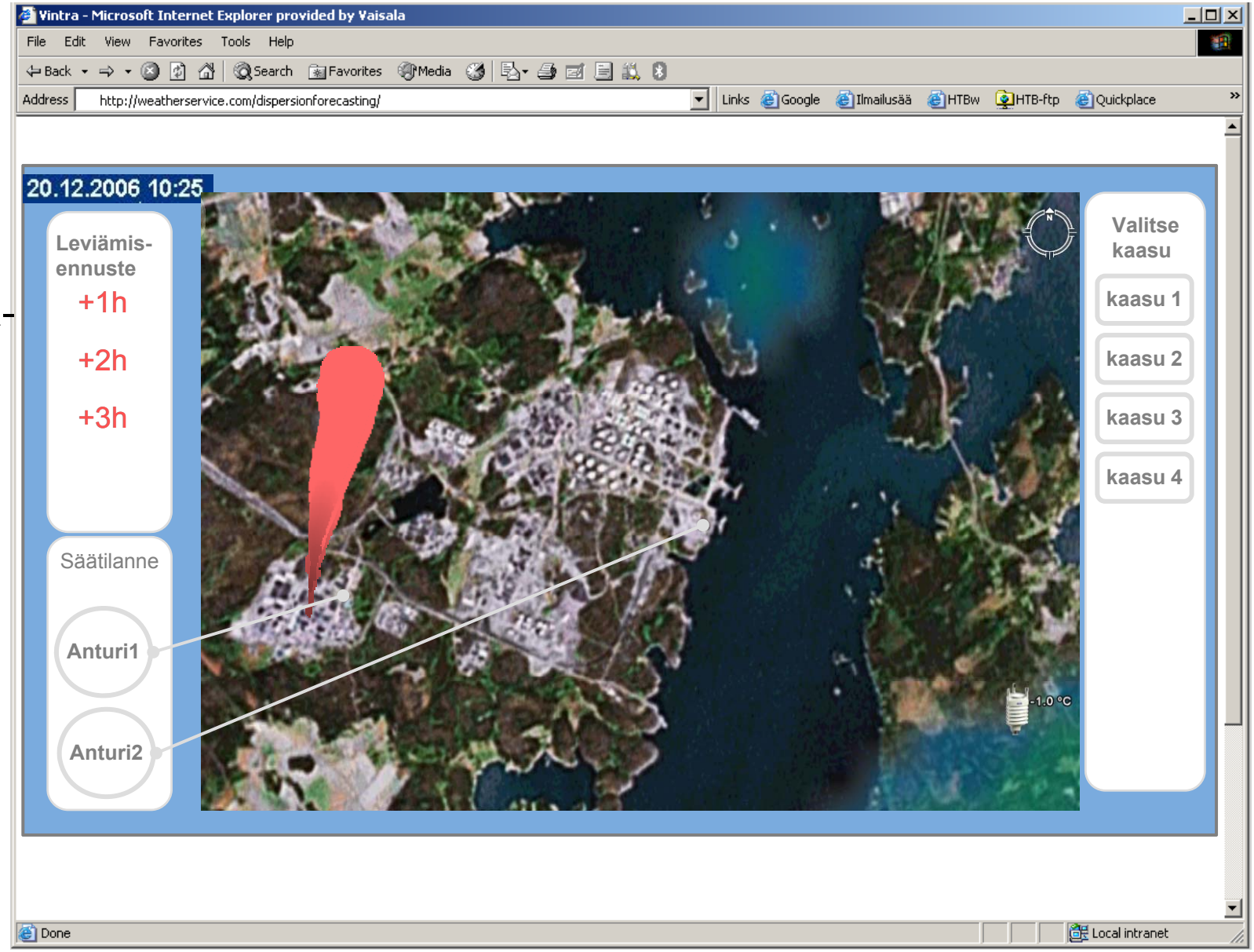
Tailored AQ dispersion tool

- real time tool for assessing accidental releases

- Based on real-time met-measurements



Common goal: IL, YTV , Vaisala

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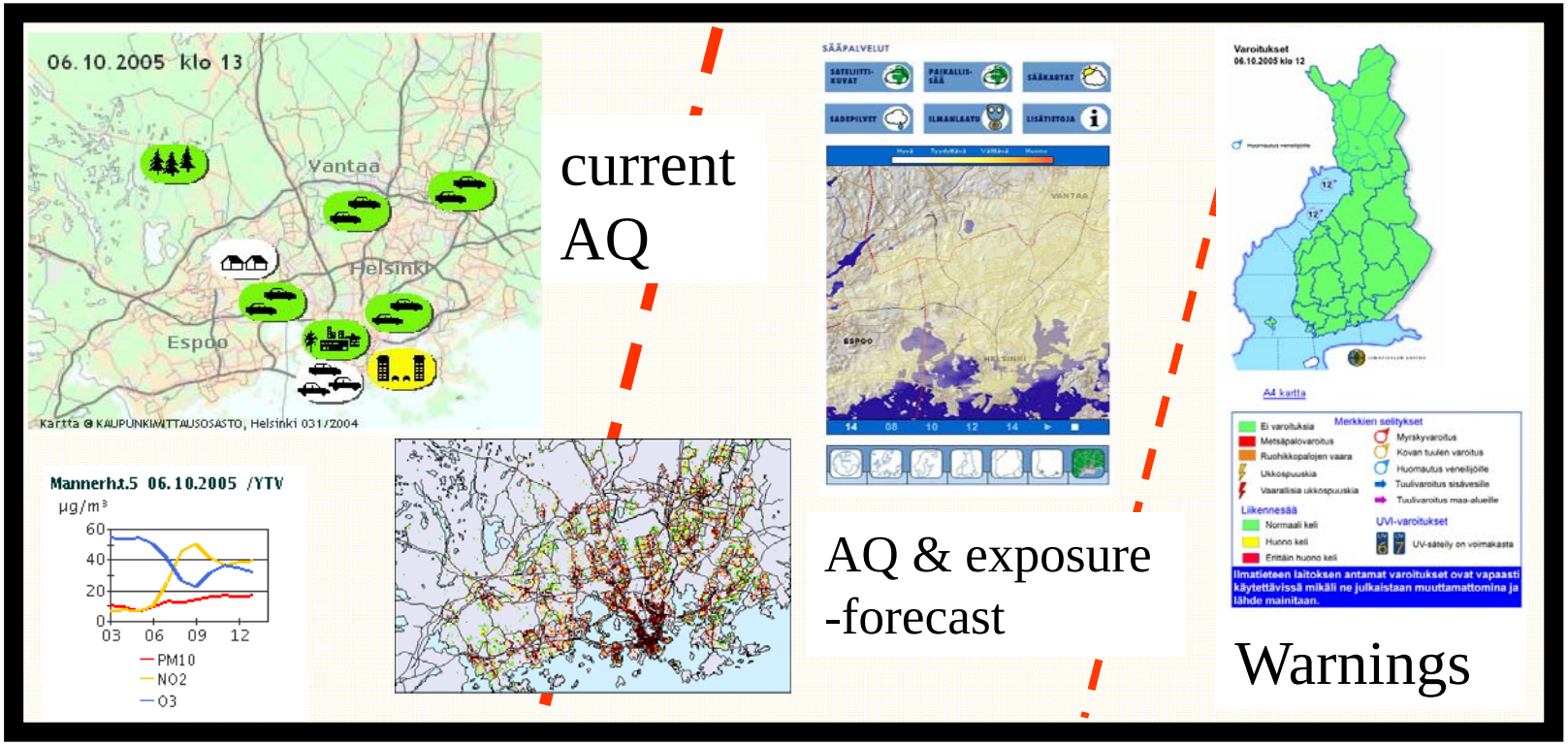
- **Combine IL & YTV, Vaisala measuremetns & knowhow :**

- **Not only information on stations: also real-time AQ-situation for the region & 1- 2 day forecasts**

- **Prequisite: also the dispersion models need to be modified – to be able to utilize all available (high-resolution) data**



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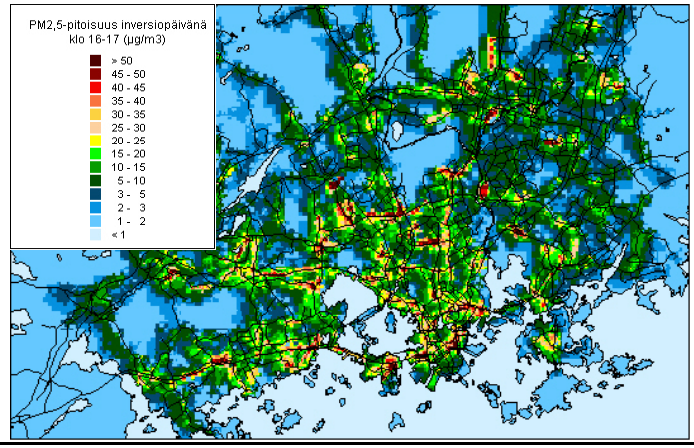
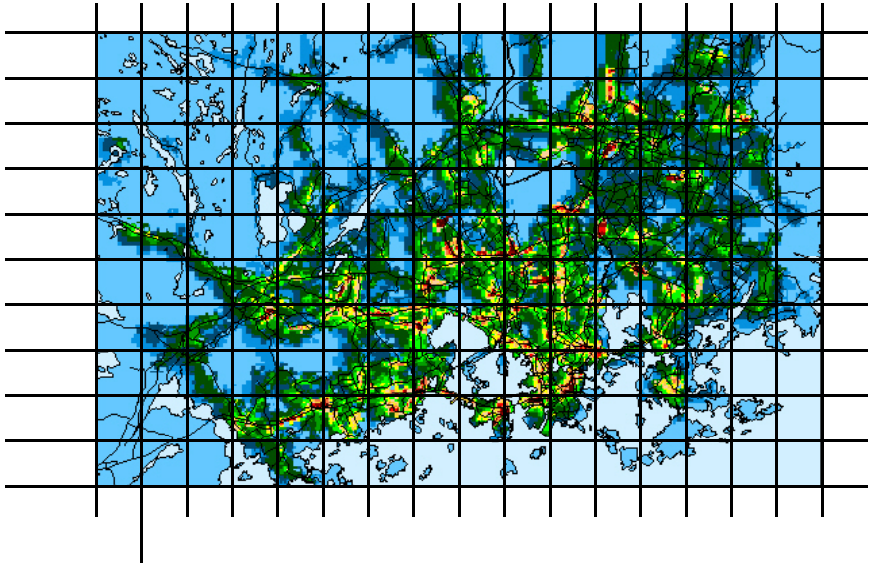
Practical examples

Meteorological data:
•FMI 3 meas.stations
•MetPP-FMI/HIRLAM
NO spatial variation in the met-fields



Ubicasting

Meteorological data
•Helsinki Testbed (>100 st.)
•Hirlam/Arome (3-9 km resolu.)
•LAPS (1 km resol.)
Met-resolution up to 1 km



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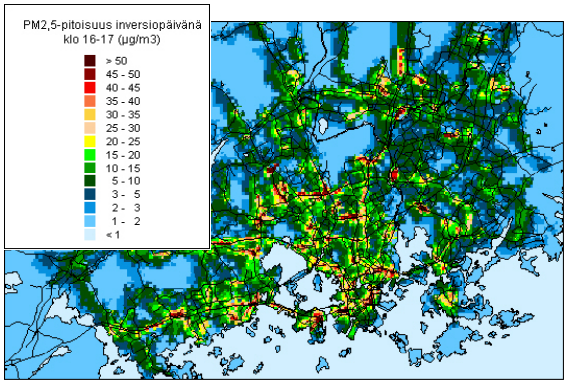
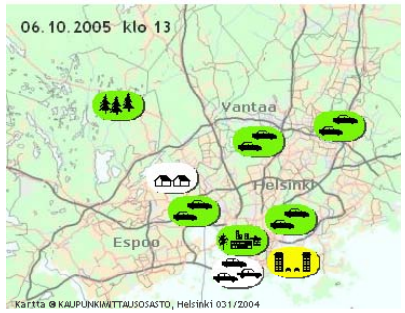
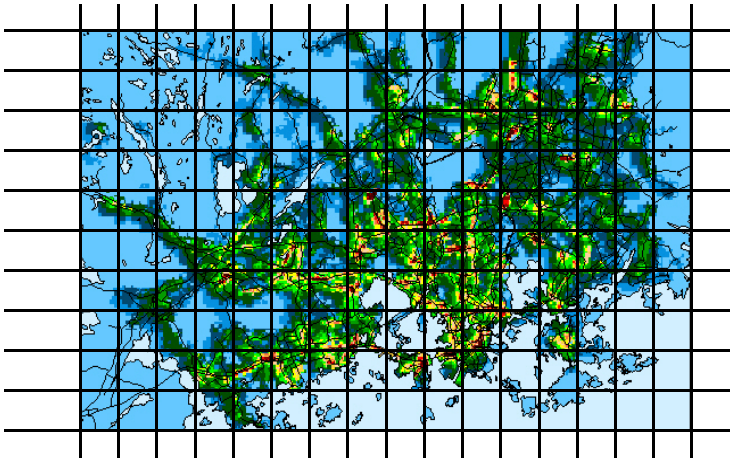


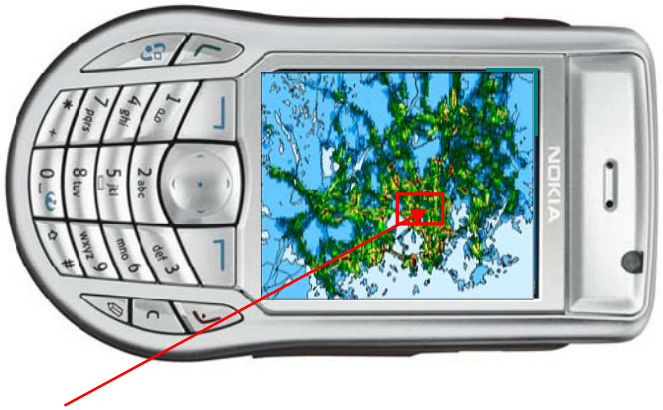
Web & wap
Real time information only at the YTV-stations



Ubicasting



Web, wap, sms, mms
Real time information for user defined (/GPS))location & periods



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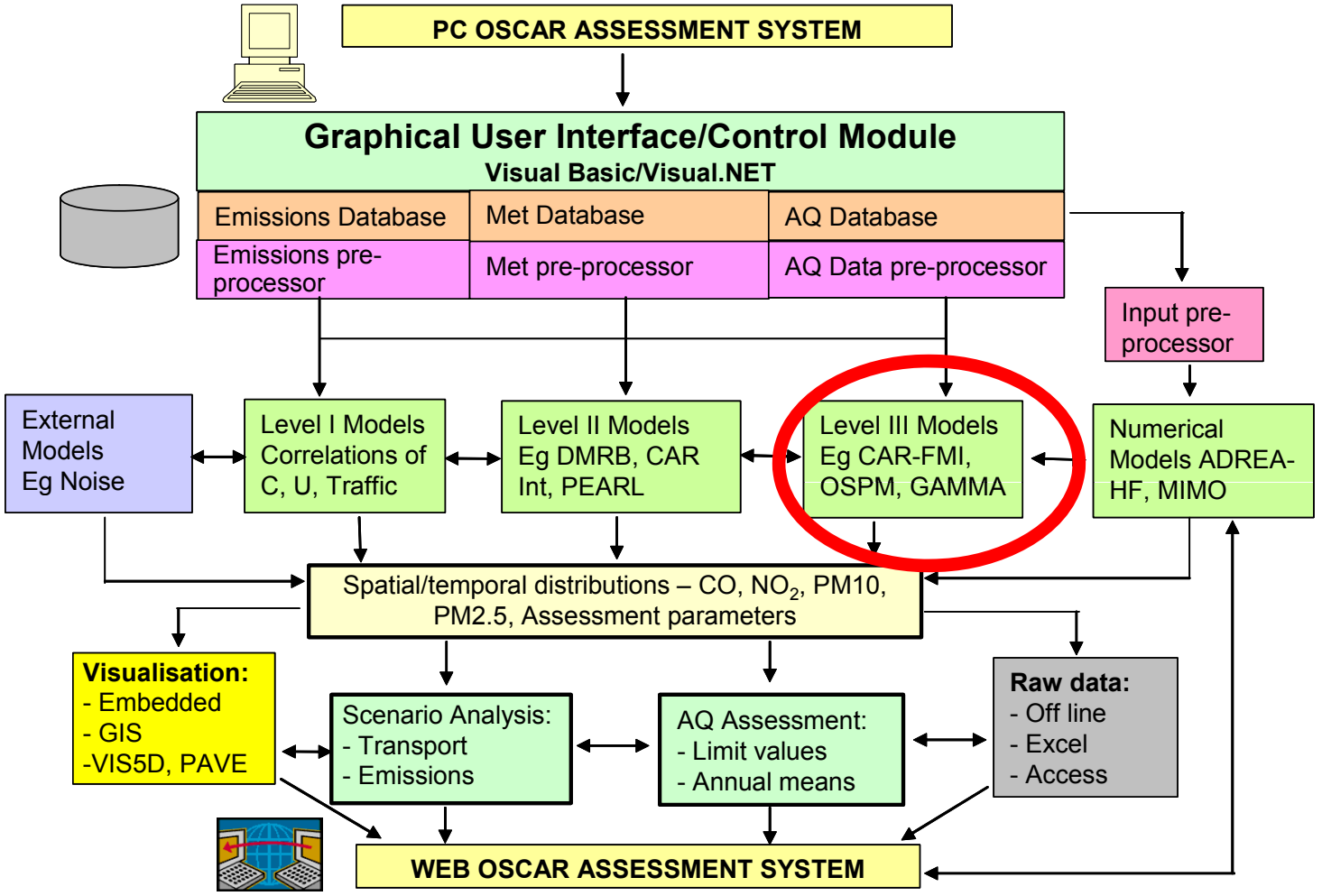
OSCAR:Need for an Integrated approach



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CAR-FMI : further development

- **EU/OSCAR (->2005)**
  - An ”international” version of CAR-FMI was integrated in to the OSCAR system

- **Main issue:**
  - users can <u>easily use their own emission data</u>
- **ONGOING work:**
  - Stand-alone international version
    - Co-ordinate systems
    - Several options for (emission) input format
    - Routines to complement for missing meteorological parameters
    - Links to ArcInfo(GIS) / now only MapInfo

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Summary

Development and testing of disperion models ongoing in all scales : form microscale (CFD) to regional scale

Lot of effort is put on ”generalizing” the existing models for wider user community -> from research models to ”easy-to-use” tools & services (strong co-operation with other groups/institutes/companies)

Linking dispersion models with new meteorological models and health risk assessment models increasingly important part of the work : final aim always a complete chain from political decisions to health effects