The needs for improvement of atmospheric dispersion capabilities for decision support systems

S. Potempski[1], S. Galmarini[2]

[1]NCBJ - National Centre for Nuclear Research, Poland

[2]IES - Institute for Environment and Sustainability Joint Research Centre, Ispra - Italy

Introduction

Last 25 years: lots of activities for improvement of DSS and atmospheric dispersion capabilities:

- RODOS, ARGOS - operational DSS
- ENSEMBLE - evaluation and analysis of ADMs
- NARAC (National Atmospheric Release Advisory Capability), LLNL USA
- READY (Real-time Environmental Applications and Display sYstem), NOAA USA
- SPEEDI/WSPEEDI, JAERI Japan
- and others …

Some experience gained

- Implementation of RODOS&ARGOS systems
- Many exercices on ENSEMBLE platform: test & real cases – different scales, various purposes
- Fukushima accident (unfortunately …)
- DG Joint Research Centre, on 16-18 June 2014 in Varese, Italy – workhop on: "Atmospheric dispersion models and Decisions Support systems in the frame of CBRN events"

Key areas for further improvement

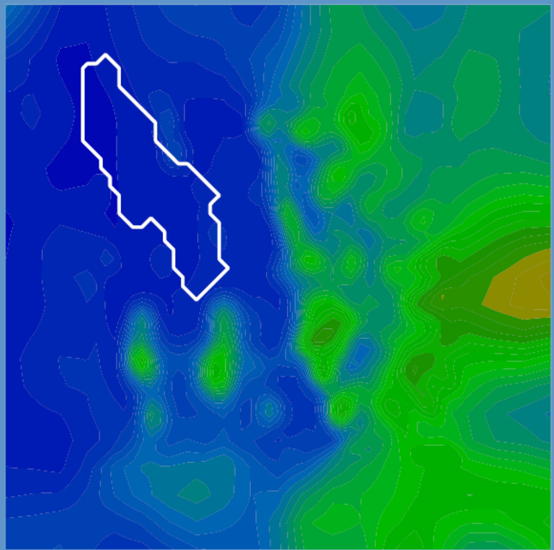
Multi-scale approach for integration of different modelling scales of atmospheric dispersion models:

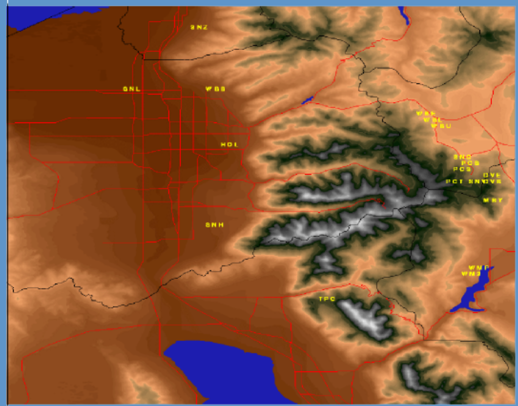
- types of atmospheric dispersion models: Gaussian plume, segmented plume, Lagrangian puff, Lagrangian or Monte Carlo particle, Eulerian and CFD
- combination of: short-&long-range modules, special models (like for urban areas)
- proper transfer of information from one to the other scale (in both directions)

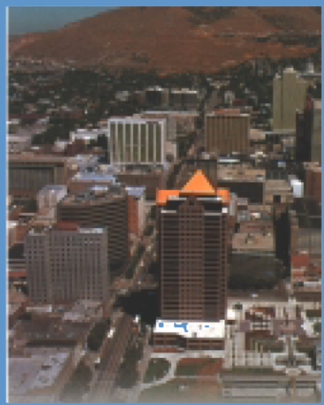
Some US models (NRL, LLNL, LANL)

COAMPS

FEM3MP







HIGRAD

Regional — **Scale** — Individual Building

Key areas for further improvement

Urban modelling and complex terrain problems:

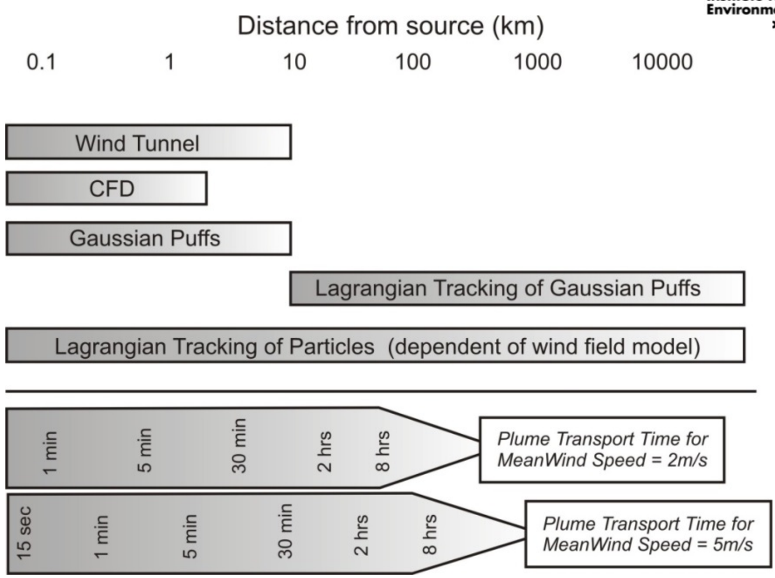
- application of CFD models: utilization of high performance computing
- need for validation of the models and therefore need of experimental data of various type (wind tunnel, studies of experiments in cities, numerical experiments – comparison with CFD or dedicated models like EULAG)
- uncertainty modelling
- need for simplified but still accurate models (like LANL: QUIC-URB/QUIC-PLUME)
- proper balance between simplicity and accuracy

National Centre for Nuclear Research Świerk
CENTRUM INFORMATYCZNE ŚWIERK

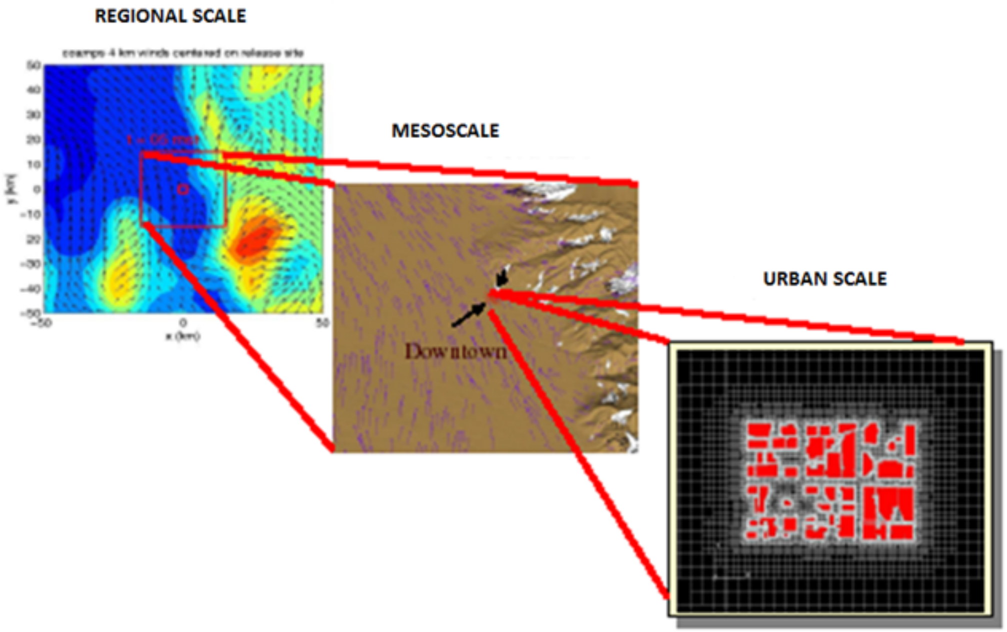
Scale issues

JRC EUROPEAN COMMISSION
Institute for Environment and Sustainability

NRC: *„It is necessary to examine new solutions in modeling dispersion and as much as possible adapt them for urban areas. This concerns advanced models with short run times and slower but more accurate CFD & LES packages, and models with adapted grids"*



Source: LANL



Source: LLNL

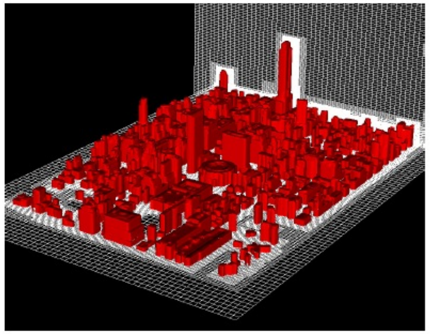
Urban scales:
Few buildings: 1m – 10m
Many buildings: 10m – 100m
City scale: <1km

Key areas for further improvement

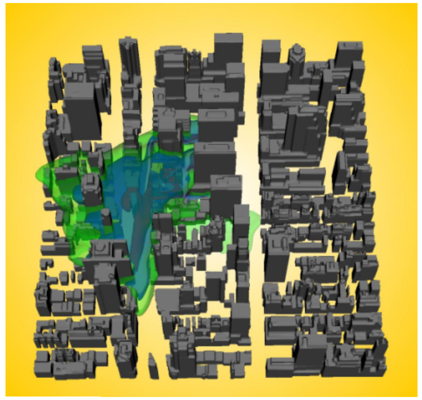
Use of advanced models like CFD (computational fluid dynamics) or similar class and application of high performance computing (HPC): adaptive meshes, code parallelization:

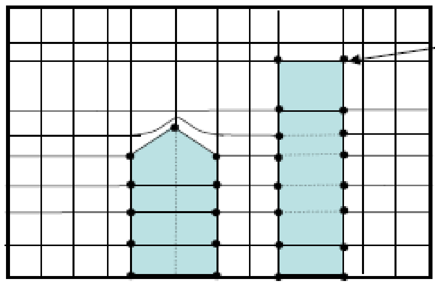
- DNS (Direct Navier-Stokes) can be applied for simple geometries, LES (Large Eddy Simulation) more useful than RANS (Reynolds Averaged Navier-Stokes)
- Dedicated models like FEM3MP, EULAG or QUIC-CFD
- Grid issues: structured mesh with voxelization or adaptive meshes
- Code parallelization and optimization, numerical issues

Example: LLNL approach



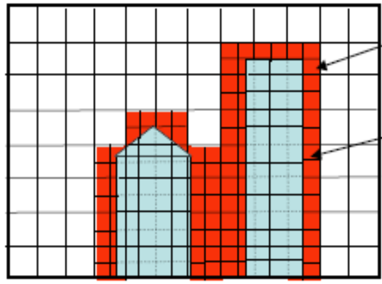
- AUDIM: adaptive integrated urban dispersion model
- Mesh generation
- Adaptive Mesh Refinement
- Coupling with Large Scale Models
- Turbulence Modeling
- Validation:
  - *- Oklahoma experiment 2003*
  - *- Salt Lake City experiment 2000*
  - *- wind tunnel*





Lines with accordance to edges of building

Mesh adapted to shape

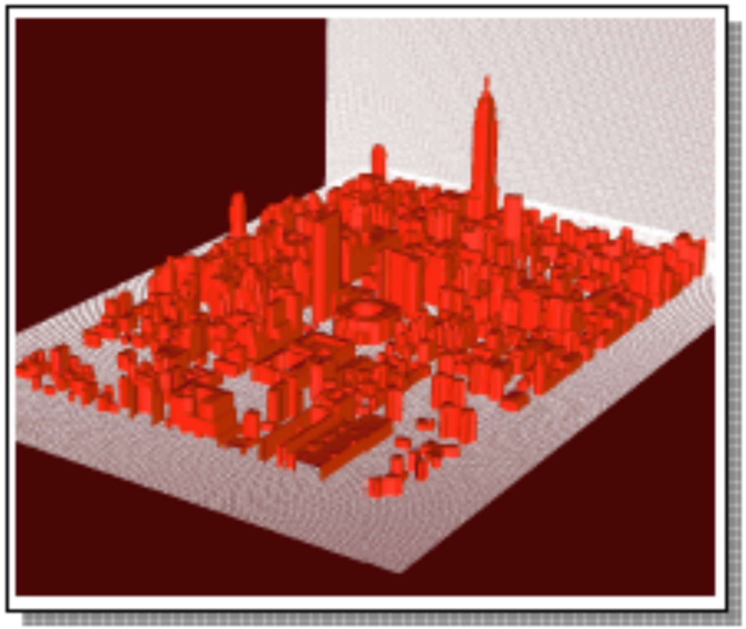


Removed cells

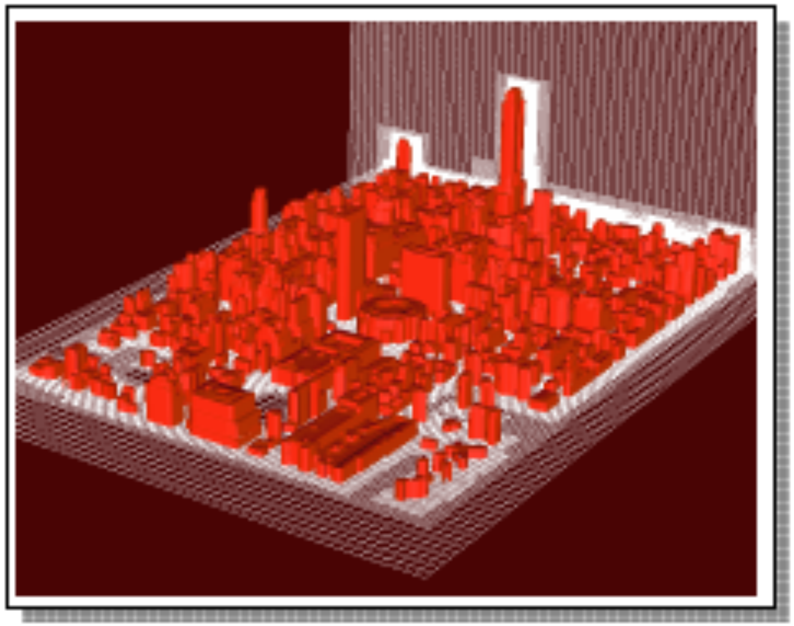
Change of scale

Embedded boundary mesh

Adaptive mesh



Uniform mesh (non adaptive)
33.6 M cells



AMR: adaptive mesh refinement
3.4 M cells

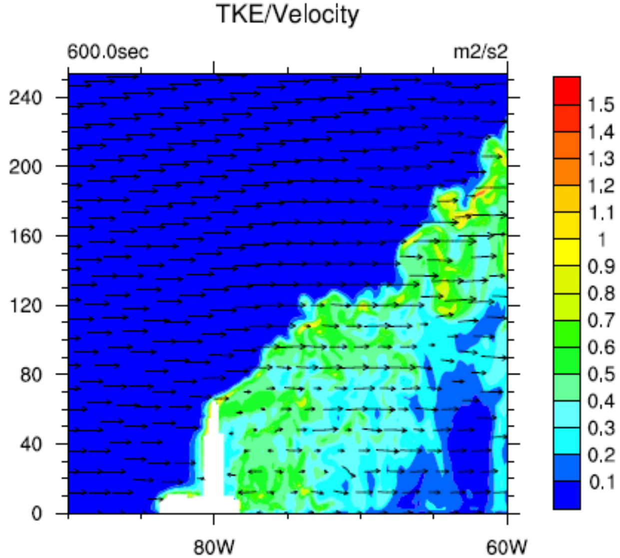
Source LLNL: Manhattan area

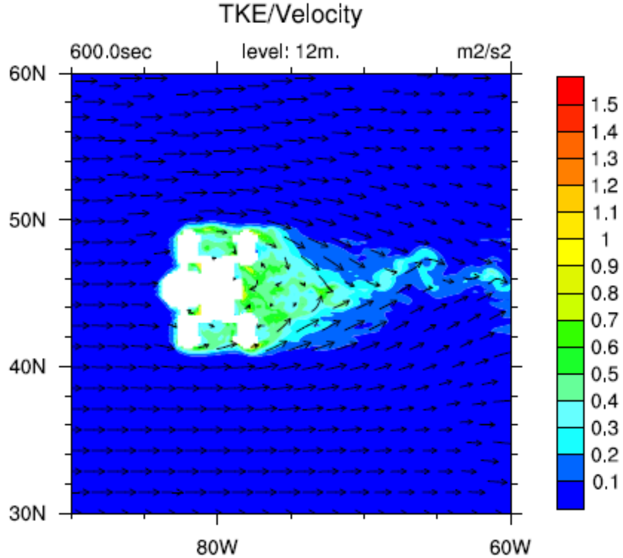
National Centre for Nuclear Research Świerk

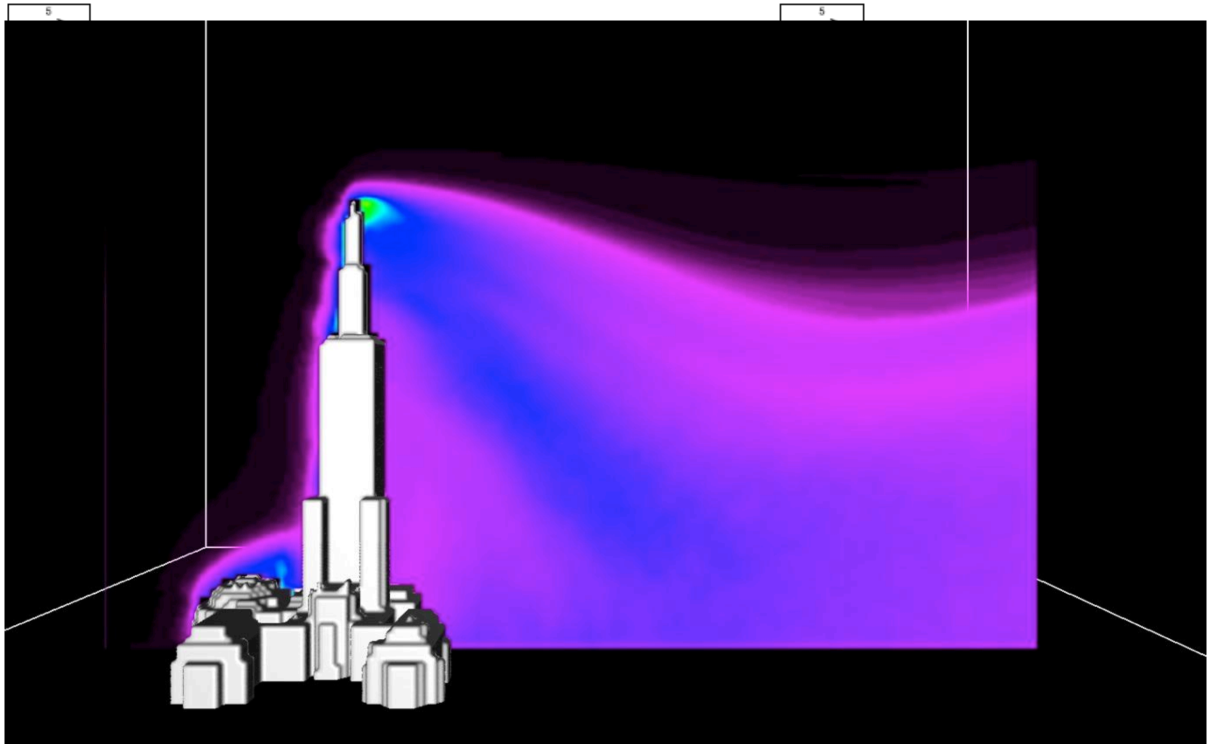
CENTRUM INFORMATY ŚWIERK

JRC EUROPEAN COMMISSION

Institute for Environment and Sustainability







National Centre for Nuclear Research Świerk

CENTRUM INFORMATYCZNE ŚWIERK

JRC EUROPEAN COMMISSION

Institute for Environment and Sustainability

Key areas for further improvement

Modelling in confined spaces like building or underground areas:

- application of CFD models for simulating fluxes
- forced or natural ventilation and system of channels in complex geometries
- CFD results can be used as reference data
- setting boundary conditions is not always straightforward
- need for specialised models (like LANL: QUIC-INDOOR)
- utilization of high performance computing

Key areas for further improvement

Dirty bombs, blast models, CBRN events:

- How the material is dispersed: blast model needed, material can be scattered practically in random way
- Uncertainty of source: explicit use of stochastic differential equations or source defined in terms of probabilistic density function
- Model validation: need for experimental data for blast and not only for open areas
- simplified methodologies (like CERES system developed by CEA France - 4D modelling and simulation of potentially hazardous releases)

Key areas for further improvement

Uncertainty modelling, probabilistic weather forecast, sensitivity analysis:

- Use of probabilistic weather forecast – data provided by ECMWF and NCEP
- Uncertainty treatment within atmospheric dispersion models (like Flexpart, Hysplit)
- Use of multi-model ensemble systems like ENSEMBLE platform
  - selection of the models to be included into ensemble
  - appropriate processing and analysis of the results

Key areas for further improvement

Data assimilation techniques, coupling with geo-statistical methods:

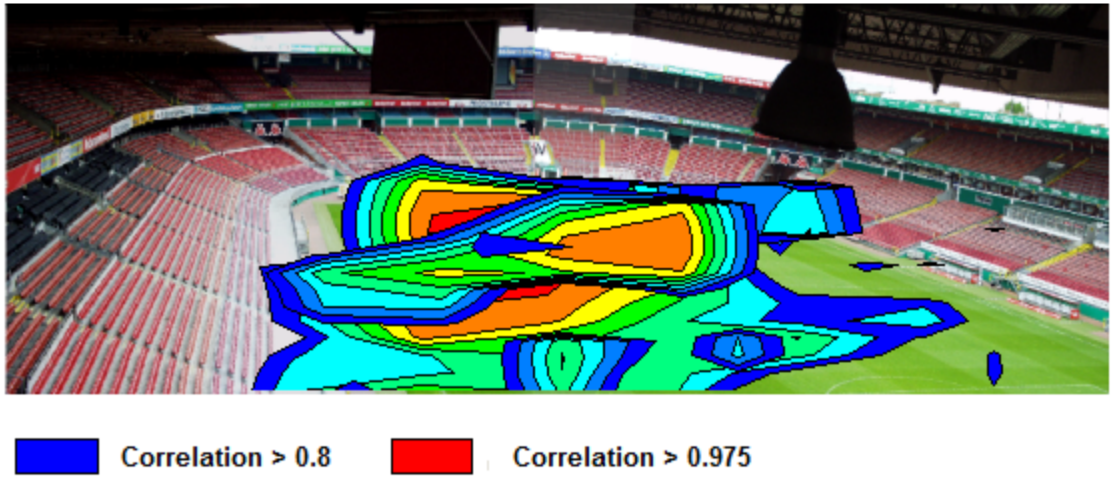
- good understanding of what is really measured and how
- uncertainty of measurement
- sometimes measured values are not directly calculated by the models (like gamma dose rates versus concentrations or activities)
- point measurements combined with geo-statistical approach in order to determine spatial distribution
- new kind of measurement devices (for example based on infrared spectrometry)

National Centre for Nuclear Research
Świerk

CENTRUM INFORMATYCZNE ŚWIERK

JRC
EUROPEAN COMMISSION

Institute for Environment and Sustainability



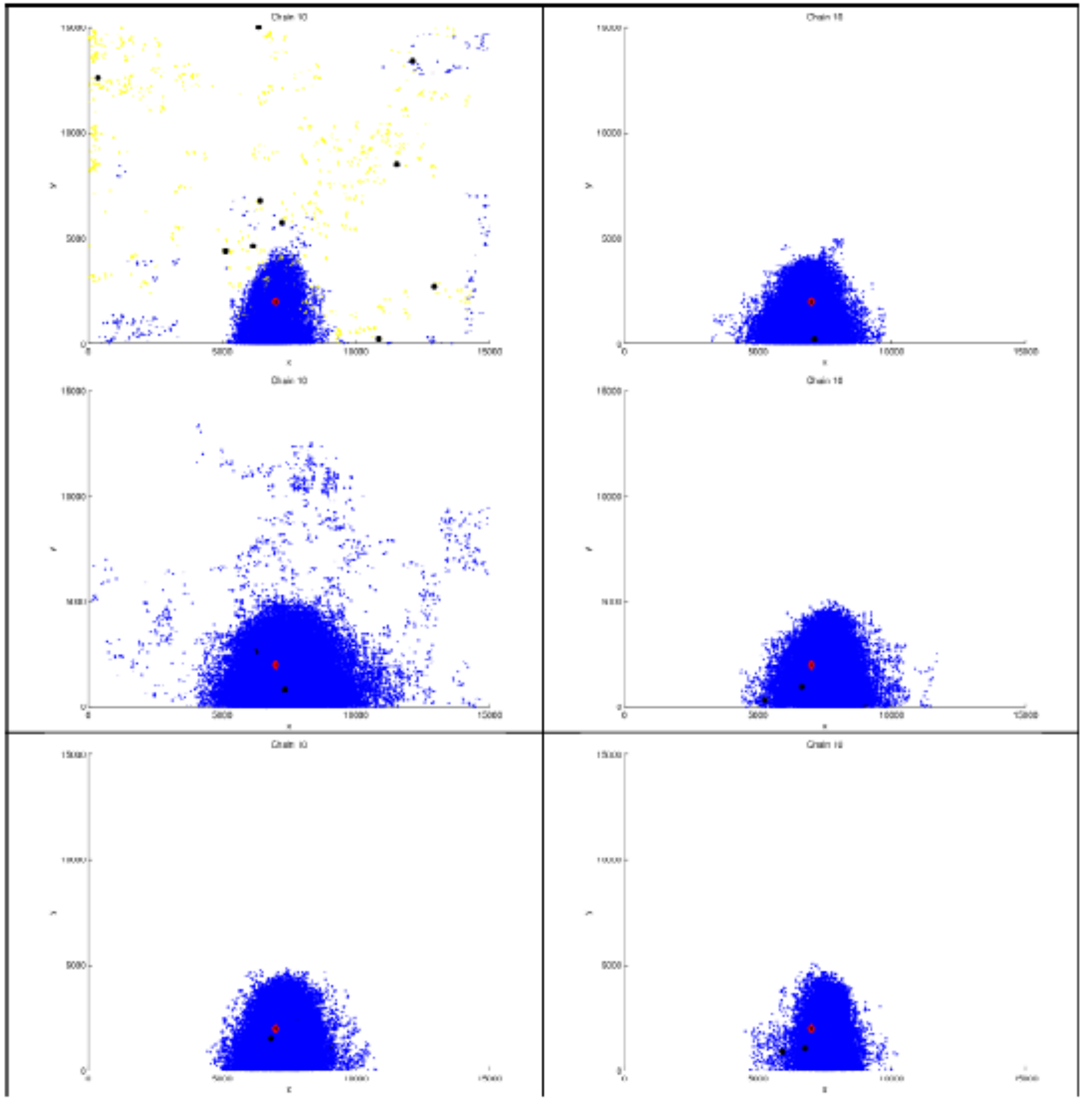
Example of RAPID installation (*Source: Bruker*)

Key areas for further improvement

Inverse modelling, source term reconstruction techniques based on atmospheric dispersion simulations:

- inverse problem is ill-posed, which means that either no unique solution is guaranteed or the solution does not depend continuously on data
- stochastic techniques (for example Bayesian approach)
- other types of algorithms: genetic algorithms, generalised extremal optimization algorithm, particle swarm optimization

Kori tracer reconstruction based on the data from 24 sensors



- *A priori distribution* (parameters values) in subsequent time step are drawn uniformly from the *posteriori distribution* obtained in the previous time step.

The scatter plot of x and y coordinates.
Red dots – source,
blue dots - samples,
black dots - MCMC starting points.

National Centre for Nuclear Research Świerk

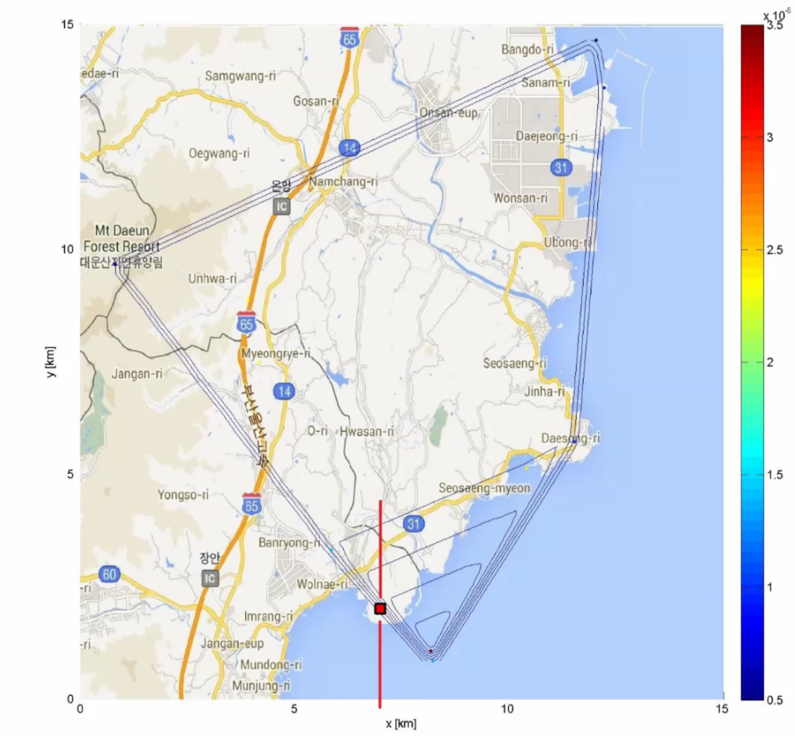
CENTRUM INFORMATYCZNE ŚWIERK

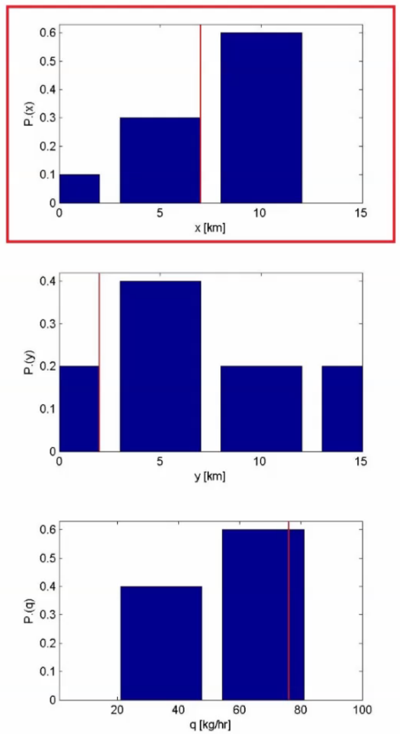
JRC EUROPEAN COMMISSION

Institute for Environment and Sustainability

Animation of reconstruction

the Kori field tracer experiment





- The traces of Markov chains in the location space (x, y).
- Corresponding posterior distribution of x, y, q parameters. The red vertical line represents the target value of the parameter.

Key areas for further improvement

Model evaluation:

- needs for field studies
- wind tunnel and real experiments
- model inter-comparison
- numerical experiments
- deposition data for model validation
- US experiment data availability ?

  FUsing Sensor Information from Observing Networks (FUSION) Field Trial 2007 (FFT-07), Joint Urban 2003 Atmospheric Dispersion Study Oklahoma City, (Ju2003), DP26 (Dipole Pride 26), OLAD (Overland Alongwind Dispersion)?

- usage of more advanced measurement

UDINEE - coming activities

Urban Dispersion International Evaluation Exercise project:

- verify and evaluate the capacities of dispersion models to simulate realistic scenarios in urban environments
- assess the real capacity of these systems to respond to an emergency
- support the use of local models for decision making and policy development
- extend an existing model evaluation platform to urban models
- improve and develop common model formats for the rapid and coherent exchange of information
- define under what circumstances use of ADMs would be optimal in an emergency situation

Exercise will be based on ENSEMBLE system at JRC-Ispra, and a meteorological-tracer database generated in the Joint Urban 2003 Oklahoma City (JU2003) experiment

Conclusions

More advanced atmospheric dispersion models in new generation of DSS:

- State of the art models and up-to date tools are crucial
- Integrated or loosely coupled framework
- Various sets of experimental data are needed
- Research for modelling processes at different scales in atmosphere is needed and should be supported by availability to high performance computing tools
- Development of software techniques enabling for better integration, code parallelisation and building complex systems is needed
- Combination with other tools: image processing, geo-spatial interpolation techniques