Validation and comparison of dispersion models of RTARC DSS

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Objectives

- **The structure of RTARC**
- **Descriptions of models**
- **Results of validation and comparison**
- **Plans for future**

The structure of RTARC

RTARC – <u>R</u>eal <u>T</u>ime <u>A</u>ccident <u>R</u>elease <u>C</u>onsequences

RTARC DSS has been developed for use by the ERC of NRA and nuclear facilities. The system comprises of several assessments and modelling elements.

The system include following calculations:

- atmospheric transport and diffusion
- dose assessment
- evaluation and display of the affected zones
- evaluation of the early health effects

The independent simulation of protective measures (sheltering, iodine administration) is involved. The results of the interpretations are used to assess the adequacy of the countermeasures implemented by the local authorities.

Currently, three versions of the software are under development for different platforms and operating systems:

- DOS RTARC
- Windows RTARC
- client/server RTARC

Three types of diffusion models

- **Very short distances (area of NPP)** – model Monte Carlo (MEMOC) of Lagrangian particles which serves for teledosimetric system, backward estimate or assimilation of source term data with use bootstrap resampling procedure

- **Short distances (from area of NPP up to 40 km)** – straight-line Gaussian puff or plume dispersion model, which use meteorological data from single meteorological station at the site of NPP

- **Long distances (area of Europe)** – PTM is Lagrangian dispersion model which uses the same input data as Gaussian model (inventory of reactor, predefined source term, dose factors etc.), except of meteorological data (NWP data for all Europe).

Experiments and comparison

Experiment or comparison	Distance	Model
Wind tunnel experiments (Universität der Bundeshwer, Munchen)	area of NPP	Method Monte Carlo
INEL (Idaho National Eng. Laboratory) multi tracer atmospheric experiment	short/medium distances	Gaussian model and PTM
Model Validation Kit	short distances	Gaussian model
STEP II.b ‘Realistic Case Studies’	long distances	PTM
5. FP ENSEMBLE comparison	long distances	PTM

Description of models

Lagrangian Statistical (Monte-Carlo) Model

Basic scheme

MATHEW — Calculation of stationary wind field

↓

MEMOC (METHOD MONTE CARLO) — Calculation of time integrated concentrations

↓

SPEEDI — Calculation of dose rates

↓

Output data for the estimation of source term

SOURCE TERM ESTIMATION - ENVIRONMENTAL MONITORING

Source term estimation model chain

Atmospheric dispersion

- **Gaussian-puff dispersion model**
- **Lagrangian statistical (Monte-Carlo) model**

Dose rate calculation

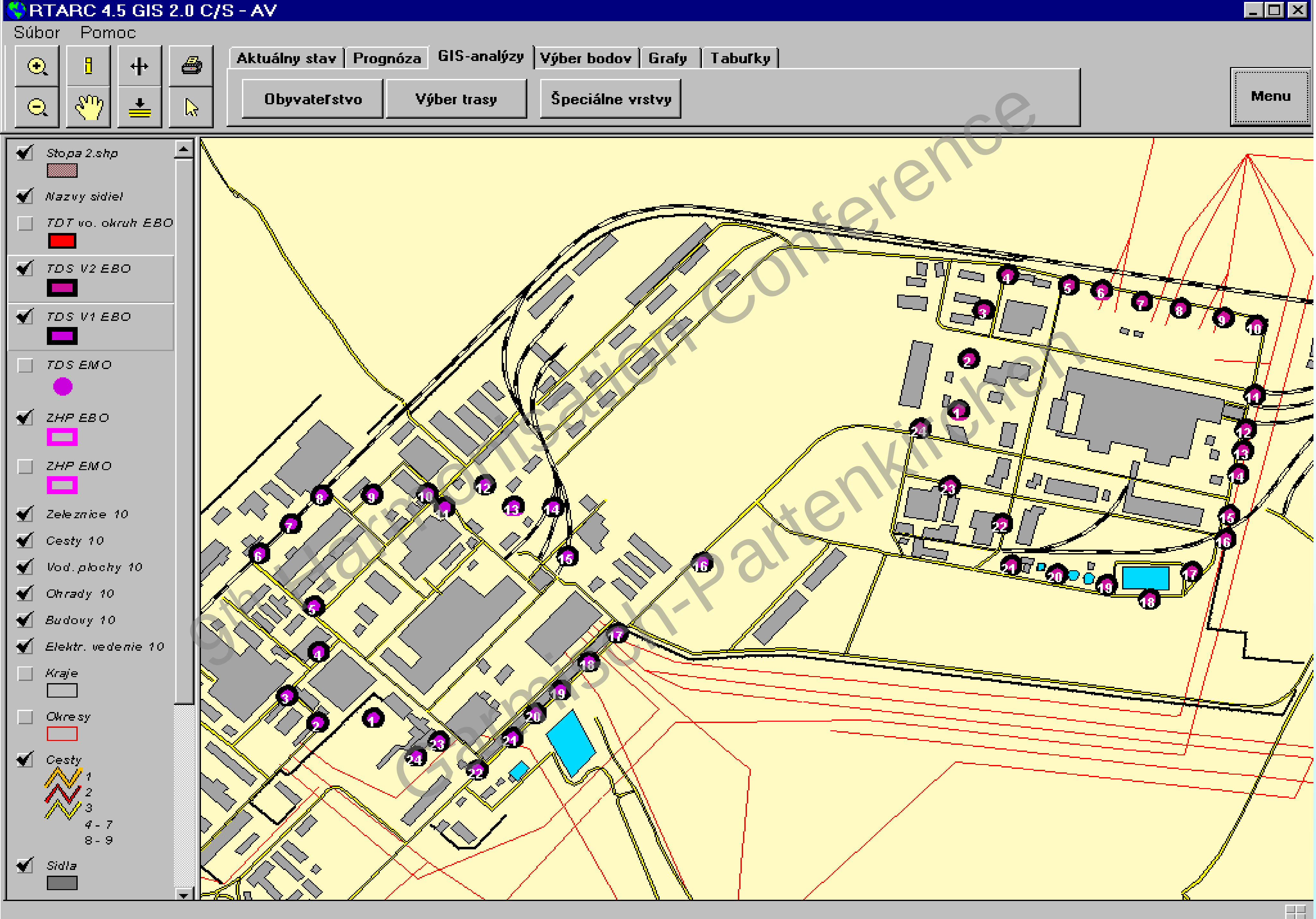
- **Point-kernel integration method**

Statistical calculation

- **Bootstrap resampling procedure**

Characteristics of isotopic composition of release

- **Interface program connecting source term estimation and program package for (RTARC)**


RTARC 4.5 GIS 2.0 C/S - AV
Súbor
Pomoc
Aktuálny stav
Prognóza
GIS-analýzy
Výber bodov
Grafy
Tabuľky
Obyvateľstvo
Výber trasy
Špeciálne vrstvy
Menu
Stopa 2.shp
Nazvy sidiel
TDT vo. okruh EBO
TDS V2 EBO
TDS V1 EBO
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ZHP EBO
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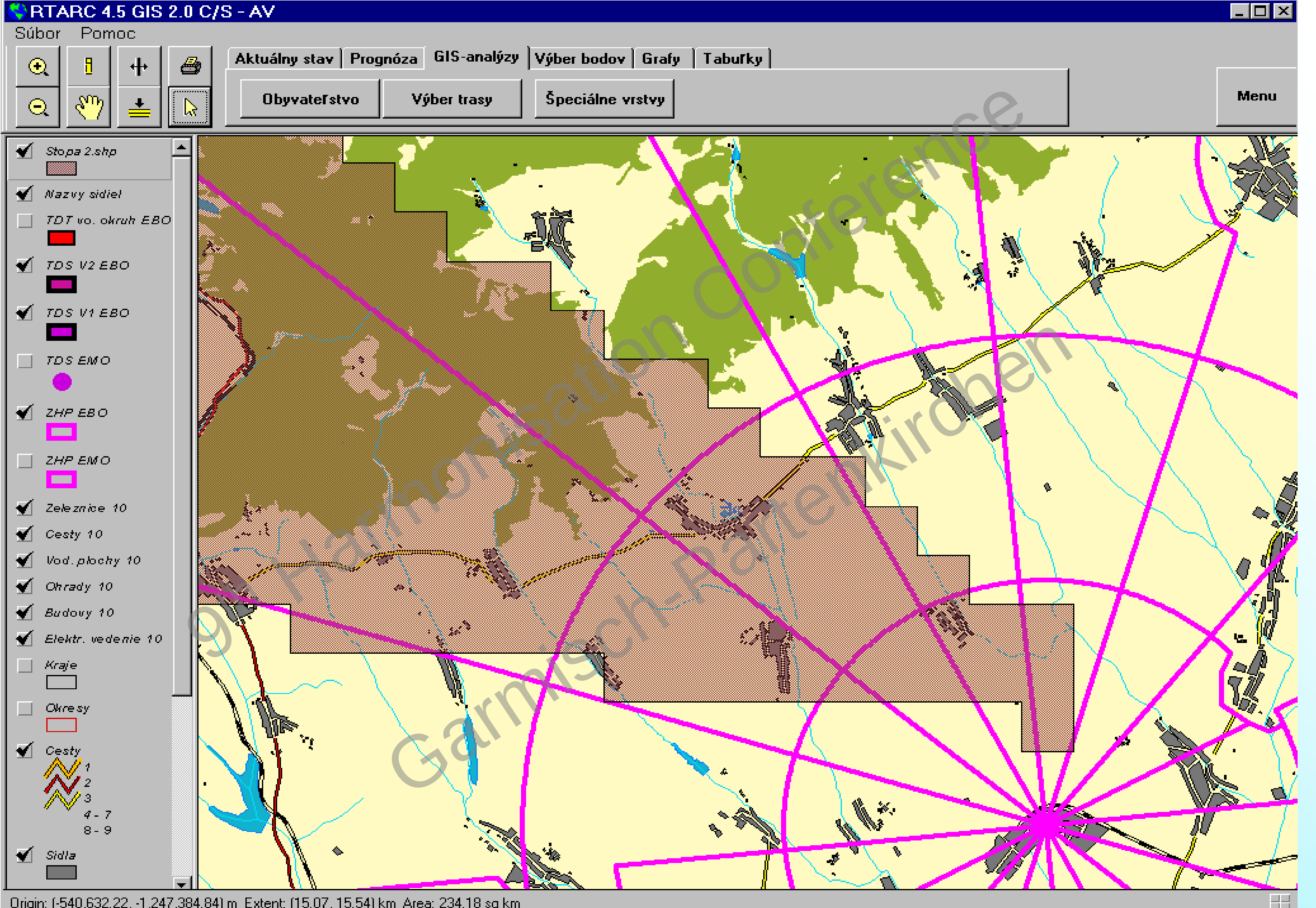
Zeleznice 10
Cesty 10
Vod. plochy 10
Ohrady 10
Budovy 10
Elektr. vedenie 10
Kraje
Okresy
Cesty
1
2
3
4 - 7
8 - 9
Sidla

Module MEMOC
the calculation of TIC field

- **calculation of the particle trajectories with the modelling of the random velocities, which are generated by the computer as white noise**
- **calculation of the vertical profiles of the turbulent characteristics in the undisturbed flow**
- **calculation of the form and turbulent characteristics in the cavity and the wake region of the buildings**
- **calculation of the reflection and deposition of the particles on the ground or buildings wall**
- **calculation of the washout effect.**

Gaussian model

- plume or puff straight-line model
- library of source term for accident sequences
- buoyant and mechanical plume rise (Briggs)
- Pasquill – Uhlig scheme of category stability
- diffusion parameters – Hosker scheme (dependence on the surface roughness)
- conservative approach – dose are calculated from concentrations at height of plume axis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Elektr. vedenie 10
Kraje
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Cesty
1
2
3
4 - 7
8 - 9
Sidla
Origin: [-540 632.22, -1 247 384.84] m Extent: [15.07, 15.54] km Area: 234.18 sq km

PTM dispersion model

- PTM – Puff Trajectory Model
- Model is part of system RTARC for the modeling of dispersion for the medium and large distances
- Lagrangian dispersion model
- Vertical diffusion – numerical method of finite differences
- Lateral diffusion – sigma parameter of Gifford
- Calculation for up to 100 nuclides of the reactor inventory
- Validation on the data from INEL experiments

PTM dispersion model – cont.

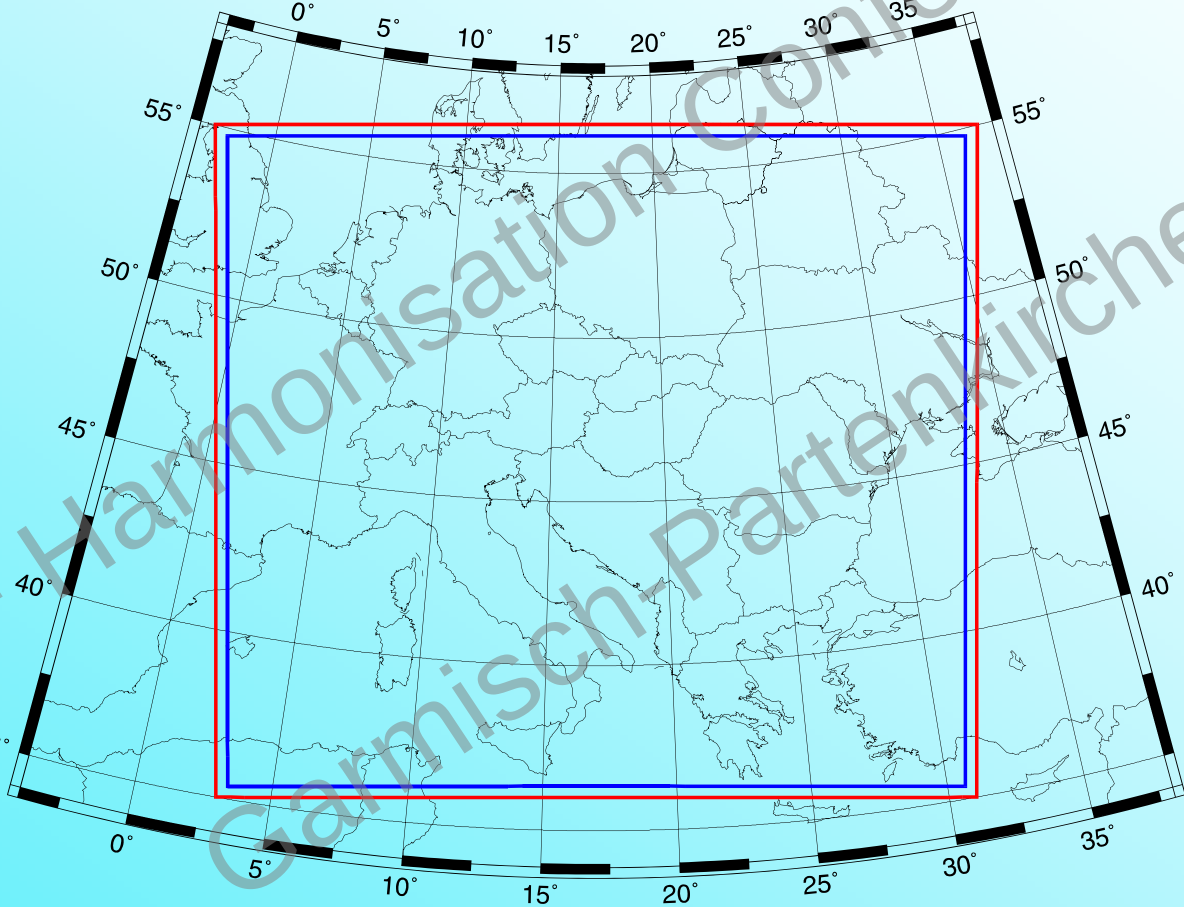
Output data

- Time Integrated Concentration [Bq.s/m3]
- Dose from cloud (adults) [mSv]
- Dose from deposition (adults) [mSv]
- Dose from inhalation (adults) [mSv]
- Summary Dose (adults) [mSv]
- Dose rate (adults) [mSv/h]
- Total Deposition [Bq/m2]
- Dry Deposition [Bq/m2]
- Wet Deposition [Bq/m2]

ALADIN/LACE meteorological data

- Global NWP model - ARPEGE (Meteo France)
- Local model – boundary conditions – ALADIN/LACE (CHMI Praha)
- Extra- interpolation data for system RODOS/LRMC (SHMI Bratislava)
- Calculation of mixing height (VUJE Trnava Inc.)

Domain of ALADIN/LACE (red) and RODOS/LRMC (blue)



Results of validation and comparison

Wind tunnel experiments

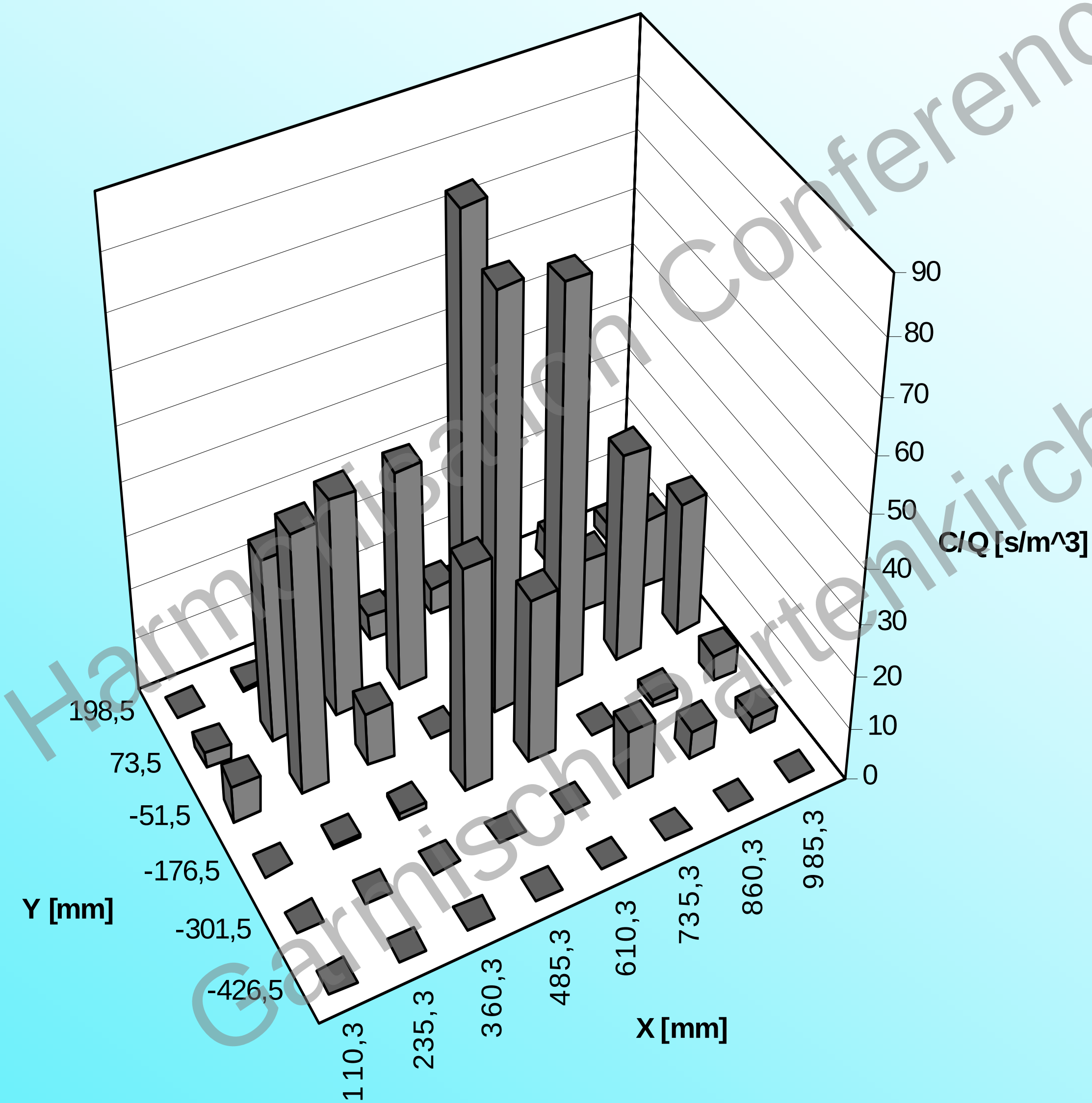
- the emission source is placed on the top of that reactor building,
- the area source is nearly momentum free,
- the source emissions are non-buoyant,
- 8 cooling towers are passive and without any flow inside.

Wind tunnel experiments

The investigation was dealing with the generation of a boundary layer flow inside the wind tunnel with the determination and validation of the characteristic flow data at free stream velocities of U_∞ = 4.5 m/s and U_∞ = 9.0 m/s and a neutrally stratified atmospheric boundary layer flow.

Characteristic data of wind profile (U_∞ = 4.5 m/s).

NPP – Temelin	Prototype flow	Wind tunnel flow
Roughness length	$(z_0)_A$ = 1.0 m	$(z_0)_M$ = 1.2 mm
Exponent of velocity profile	n_A = 0.24	n_M = 0.24
Boundary layer thickness	δ_A = 600 m	δ_M = 750 mm
Non dimens. friction velocity	$(u_*/U_\infty)_A$ = 0.061	$(u_*/U_\infty)_M$ = 0.061



90
80
70
60
50
40
30
20
10
0
C/Q [s/m^3]
198,5
73,5
-51,5
-176,5
-301,5
-426,5
Y [mm]
110,3
235,3
360,3
485,3
610,3
735,3
860,3
985,3
X [mm]

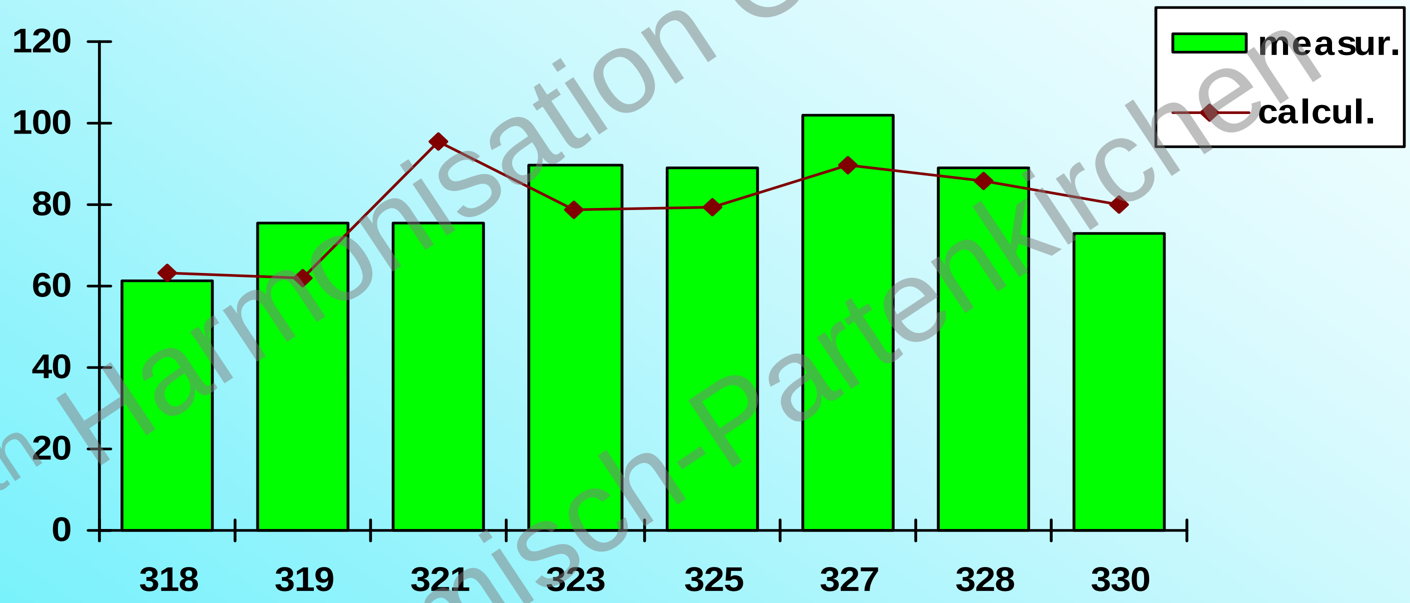
The following problems have to be solved as a result of the work described above:

- the realistic simulation of cooling towers with the hyperbolic shape (changing the Cartesian grid with other one),
- to use some realistic model (e.g. diagnostic wind model) instead of the stationary model MATHEW,
- to define more precisely the turbulent characteristics in the complex terrain using the experimental data (wind tunnel experiment for NPP Mochovce, hilly terrain next to the NPP area).

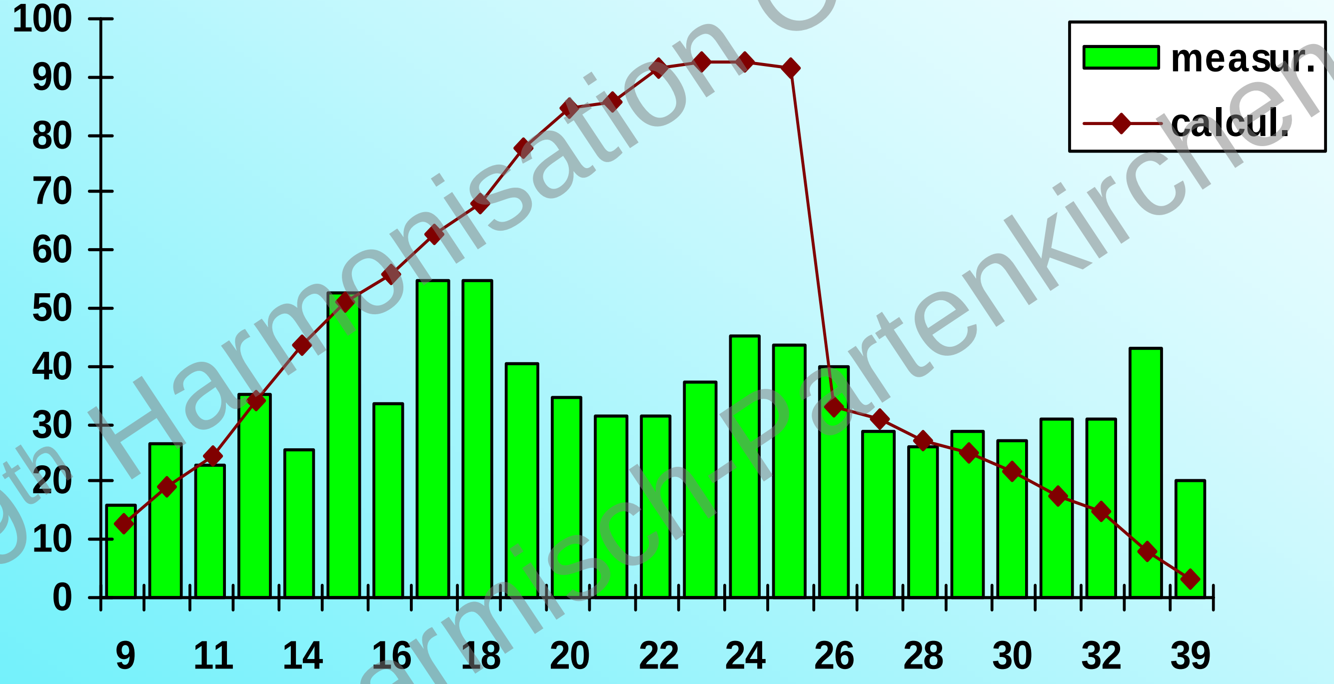
INEL experiment

- simulated by the Gaussian straight-line model and PTM
- TIC at the distances 3, 50 and 90 km
- 3-hour release of tracer SF_6 and 15-hour release of ^{85}Kr
- variants: with/without the effect of wind shear; different values of vertical parameter of diffusion; different types of horizontal parameter diffusion; different values of the vertical profile of wind speed
- very important effect of vertical shear of wind direction

Concentration ^{85}Kr [pCi.m^{-3}], distance 50 km, PTM, INEL experiment

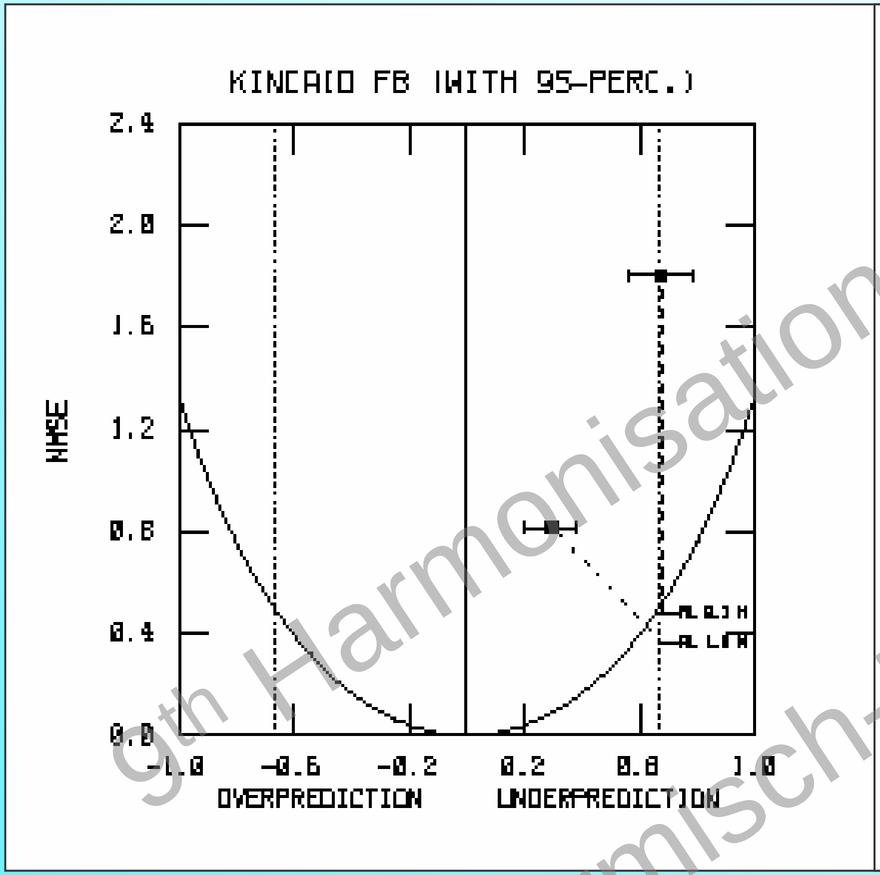


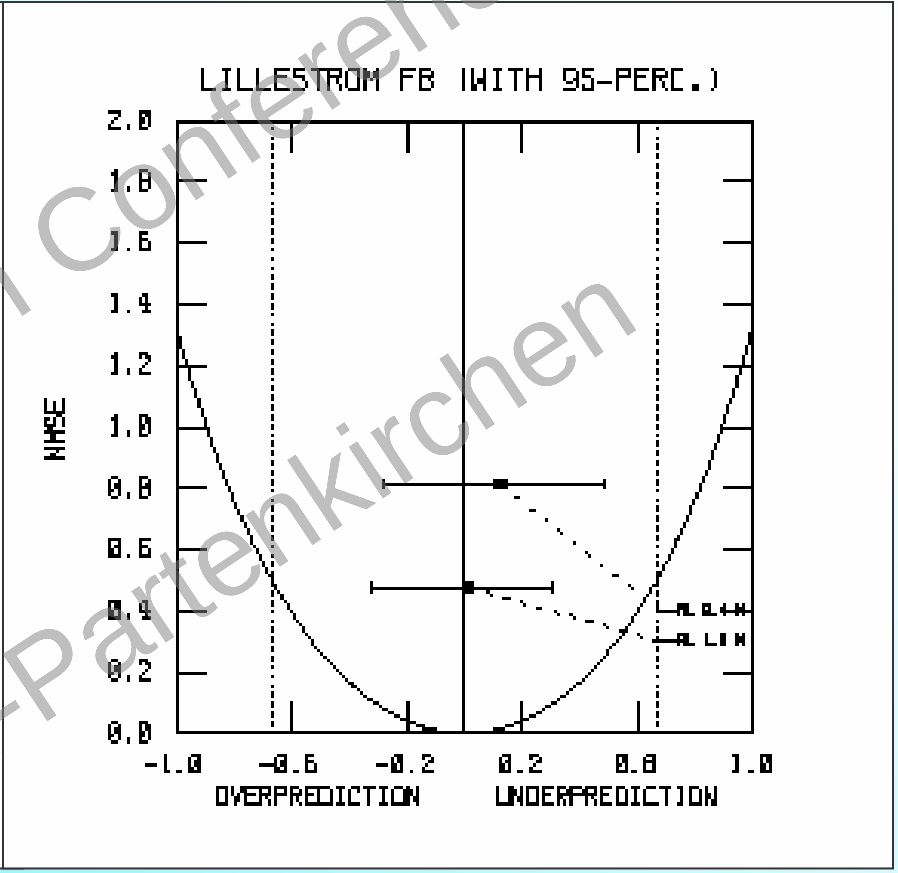
Concentration ^{85}Kr [pCi.m^{-3}], distance 90 km, PTM, INEL experiment



Model Validation Kit

- maximum arc-wise concentrations for short range distances
- quantitative statistical model evaluation
- scientific evaluation of residual plots (wind speed, PG class of stability, mixing height)
- estimation of model uncertainty components (method Monte Carlo - roughness length, class stability)
- Gaussian model is very sensitive to the accurate estimation of the roughness length

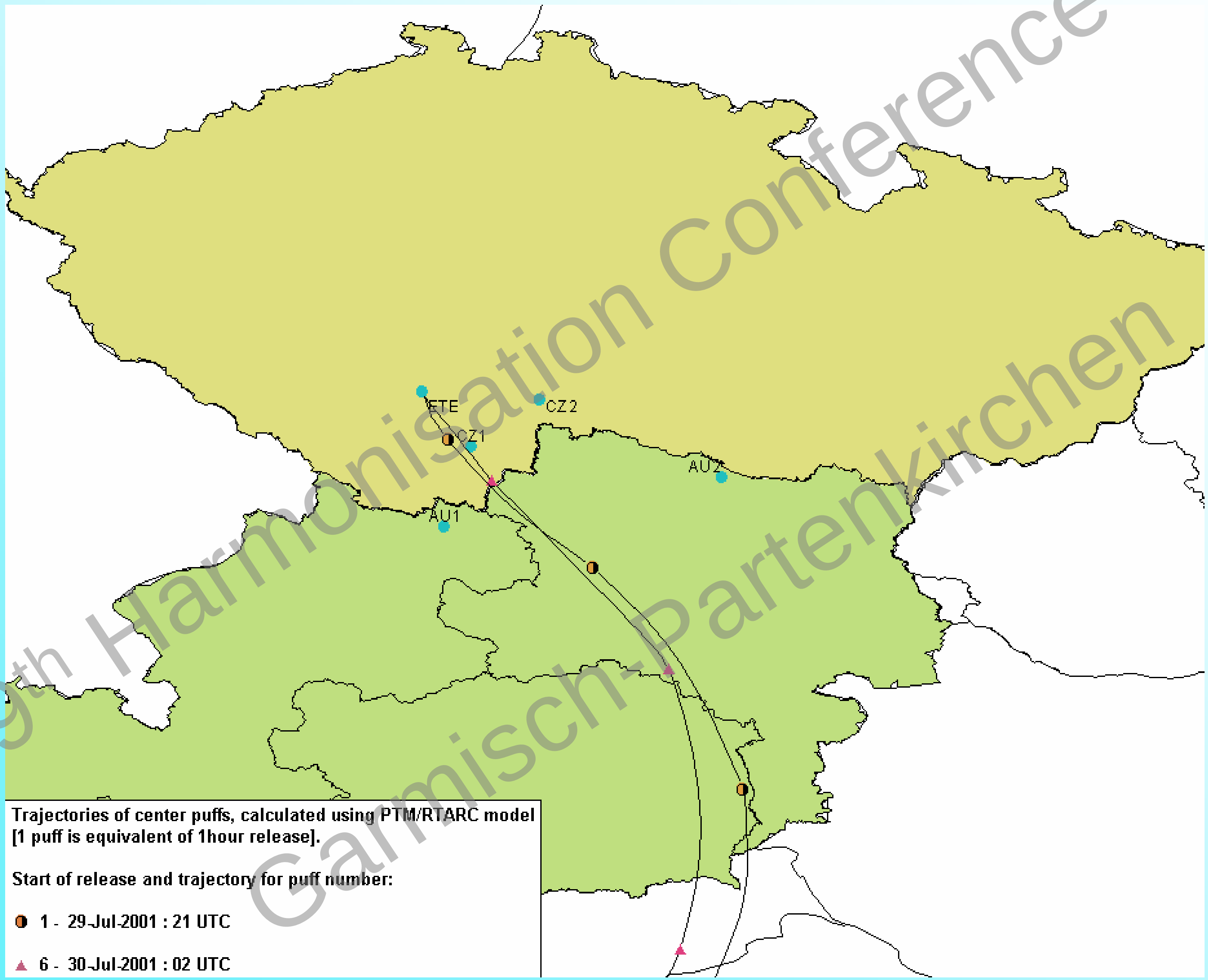

KINCAID FB (WITH 95-PERC.)
NMSE
2.4
2.0
1.6
1.2
0.8
0.4
0.0
-1.0
-0.6
-0.2
0.2
0.6
1.0
OVERPREDICTION
UNDERPREDICTION


LILLESTROM FB (WITH 95-PERC.)
NMSE
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-1.0
-0.6
-0.2
0.2
0.6
1.0
OVERPREDICTION
UNDERPREDICTION

Realistic Case Studies

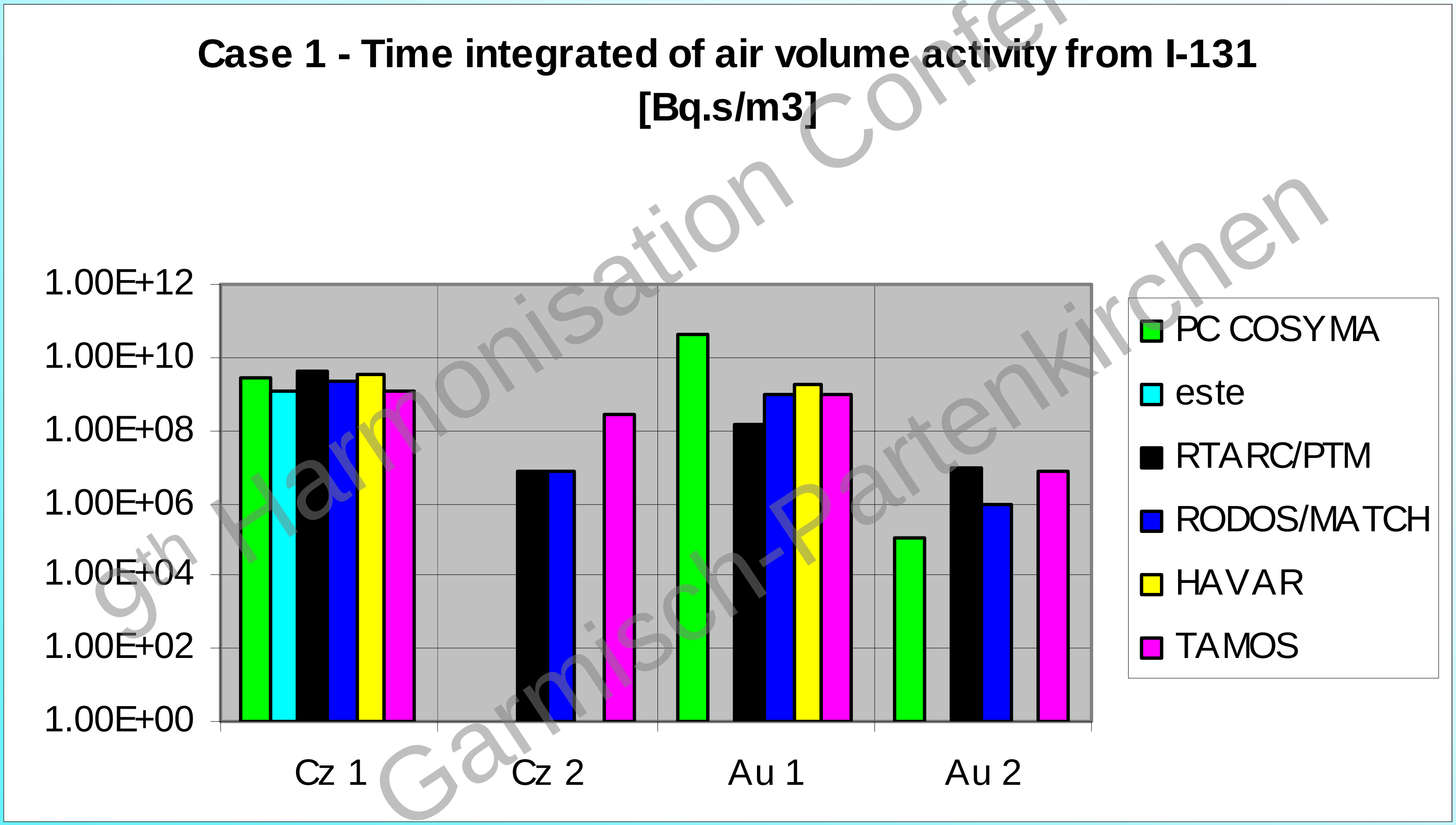
- to compare the weather modelling, the concentrations and ground deposition in the relevant parts of Europe following a hypothetical accident at the location of Temelin NPP
- calculations were performed using a wide range of models: Eulerian (TAMOS, RODOS/MATCH), Lagrange (PTM/RTARC) and Gaussian (HAVAR, PC COSYMA)
- Euler models - conservative estimation of contaminated area
- Lagrange models – relatively reliable estimation of dosimet. quantities
- Main source of differences – different meteorological input data (ECMWF, ALADIN/LACE)

METEO CASE 1



ETE
CZ2
CZ1
AU1
AU2
Trajectories of center puffs, calculated using PTM/RTARC model
[1 puff is equivalent of 1hour release].
Start of release and trajectory for puff number:
1 - 29-Jul-2001 : 21 UTC
6 - 30-Jul-2001 : 02 UTC

METEO CASE 1



Case 1 - Time integrated of air volume activity from I-131 [Bq.s/m3]
1.00E+12
1.00E+10
1.00E+08
1.00E+06
1.00E+04
1.00E+02
1.00E+00
Cz 1
Cz 2
Au 1
Au 2
PC COSYMA
este
RTARC/PTM
RODOS/MATCH
HAVAR
TAMOS

ENSEMBLE comparison

The ENSEMBLE exercises (EC 5th framework program) offer an international platform for the intercomparison of real-time long-range emergency response dispersion forecasts.

Calculated concentration and deposition fields are sent to the EC JRC in Ispra for evaluation and procedure development.

Results of intercomparison are put out on the ENSEMBLE website.

VUJE Trnava, Inc. takes a part in the ENSEMBLE exercise #10 with the results of the dispersion model PTM and meteorological data from model ALADIN.

Plans for future

- source term backward estimation – to continue with the process of MEMOC model quantity validation and improvement
- Gaussian model - to continue with validation in the additional experiments (geometrical form and dimensions of the contaminated area)
- PTM - to continue with comparison in the framework of ENSEMBLE project - validation of dimensions of the contaminated area.
- all 3 models - to make sensitivity and uncertainty analysis of input data
- development of simplified version of particular dispersion models, which should offer also information about uncertainty level

Thank you for your attention