UDINEE Project - description of ESTE approach and results

Authors:
ABmerit
Liptak L., Čarný P., Fojcíková E.,

Twentieth Annual George Mason University Conference on Atmospheric Transport and Dispersion Modeling

Fairfax, VA, George Mason University, June 14–16, 2016

Introduction

About ABmerit

- Authors of **ESTE** **Decision support system for nuclear emergencies**
- Technical Support Organization for nuclear power plants and emergency crisis centers
- Experts in nuclear emergency preparedness and Environmental Impacts Assessment

ESTE CBRN:

- tool for modelling of gas and aerosol dispersion (mostly radioactive particles) and for assessment of impacts caused by nuclear accident in urban environment, based on a 3D model.

Main concerns of application:

- threat of a terrorist attack in urban or industrial environment (events with RDD, dirty bomb);
- modelling of a radiation event on the site of the nuclear power plant (or other industrial object) in case of episodic or long-term release beyond design basis conditions.

ESTE CBRN: application

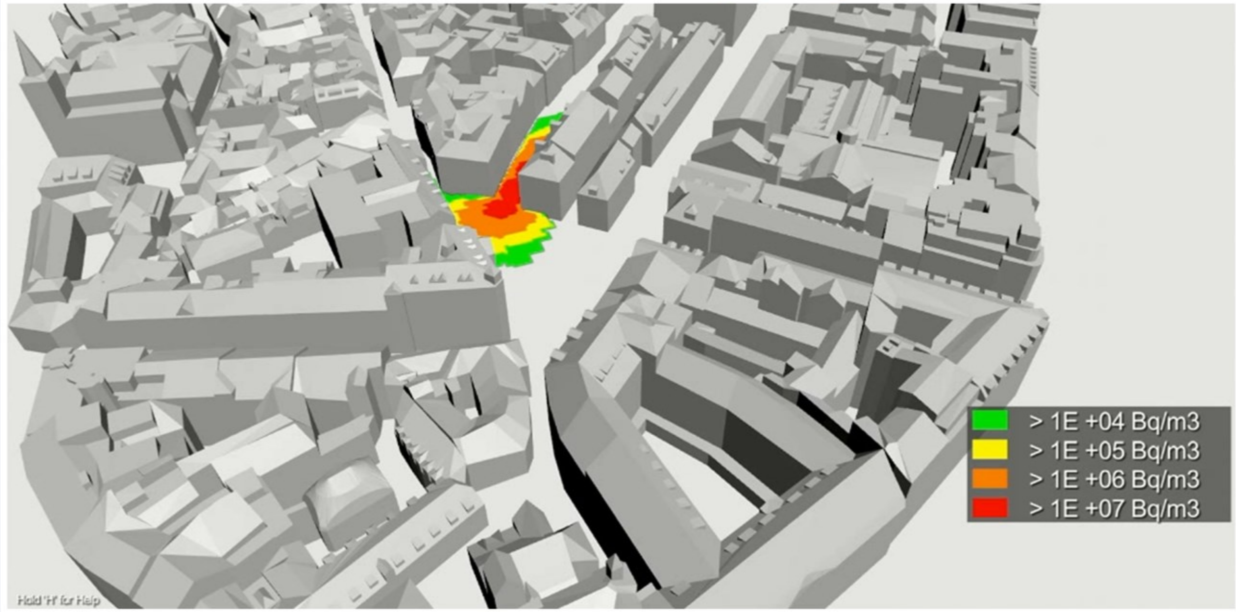
- Utilization for scenario preparation for exercises and training of responders.
- Assessment of contaminated area or re-assessement of the source applied in real RDD event.

- Applied in International Nuclear Emergency Exercises (INEX) organized by OECD.
- INEX 4: national tabletop exercise focusing on arrangements for consequence management and transition to recovery in response to a malicious act involving a radiological dispersion device in an urban environment.
- INEX 4 in Czech Republic (organized by the state regulatory body SUJB): each region, capital Prague.

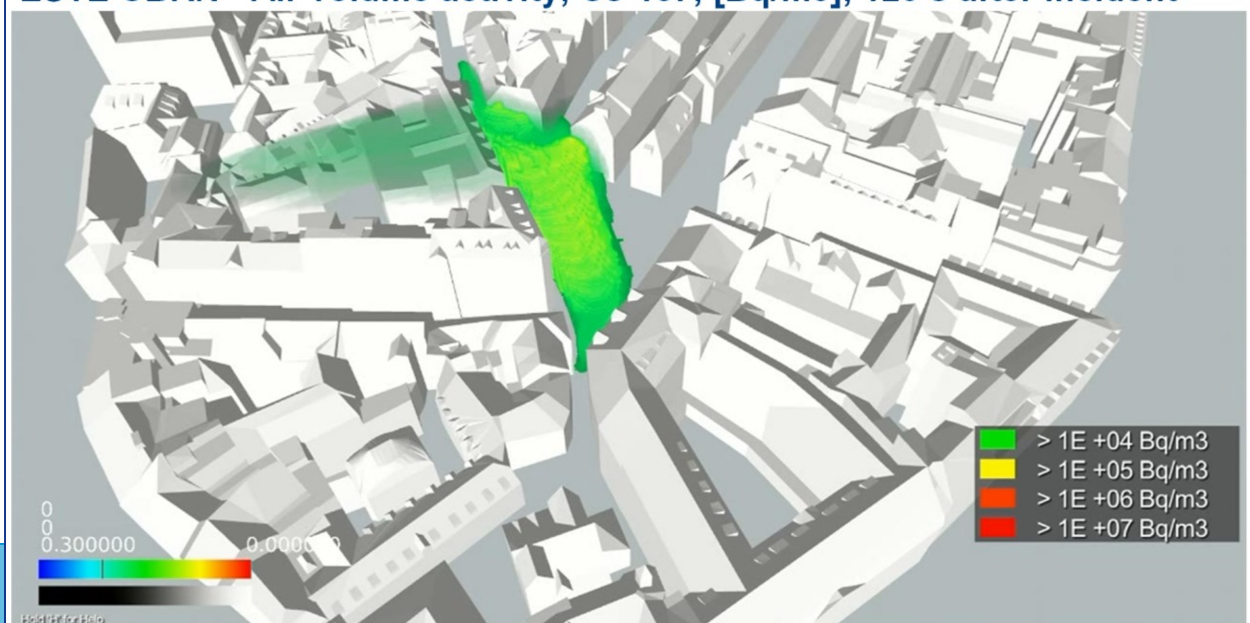
Prague – INEX 4, “dirty bomb” exercise

Prague - location of epicenter

ESTE CBRN - Air volume activity, Cs-137, [Bq/m3] 30 s after incident



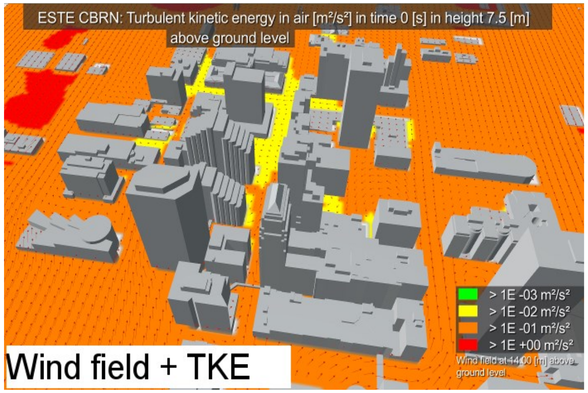
ESTE CBRN - Air volume activity, Cs-137, [Bq/m3], 120 s after incident

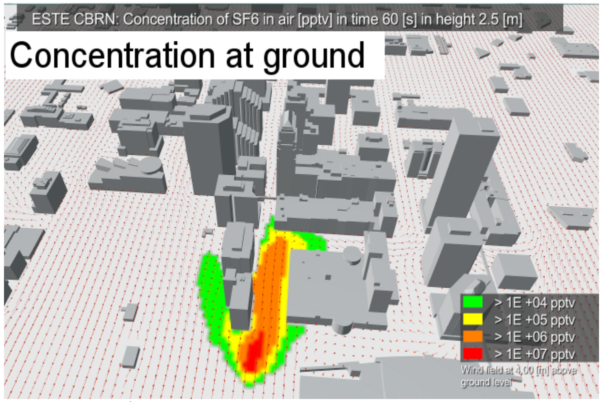


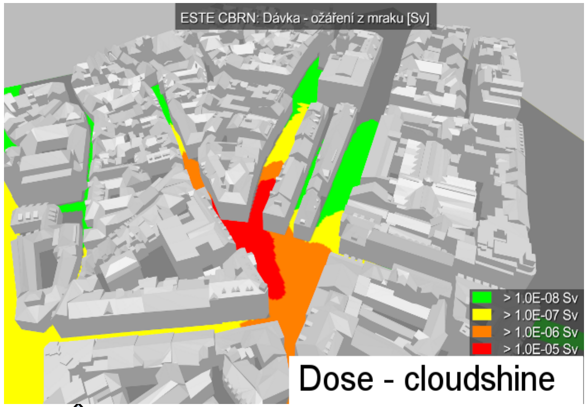
ESTE CBRN - components

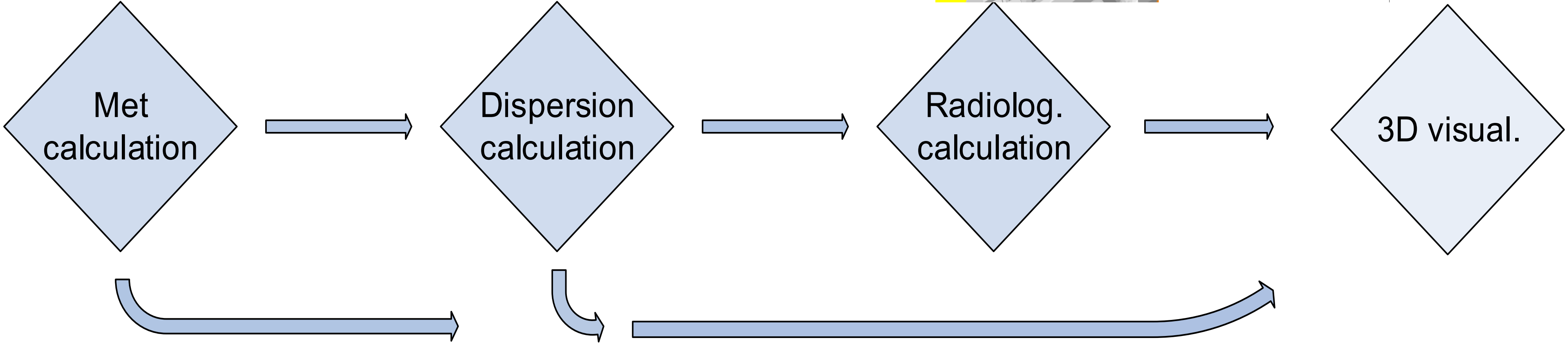
- calculation of meteorological condition in urban environment,
- calculation of dispersion of gases and aerosols,
- calculation of radiological consequences,
- 3D display of calculated quantities.

ESTE CBRN - components





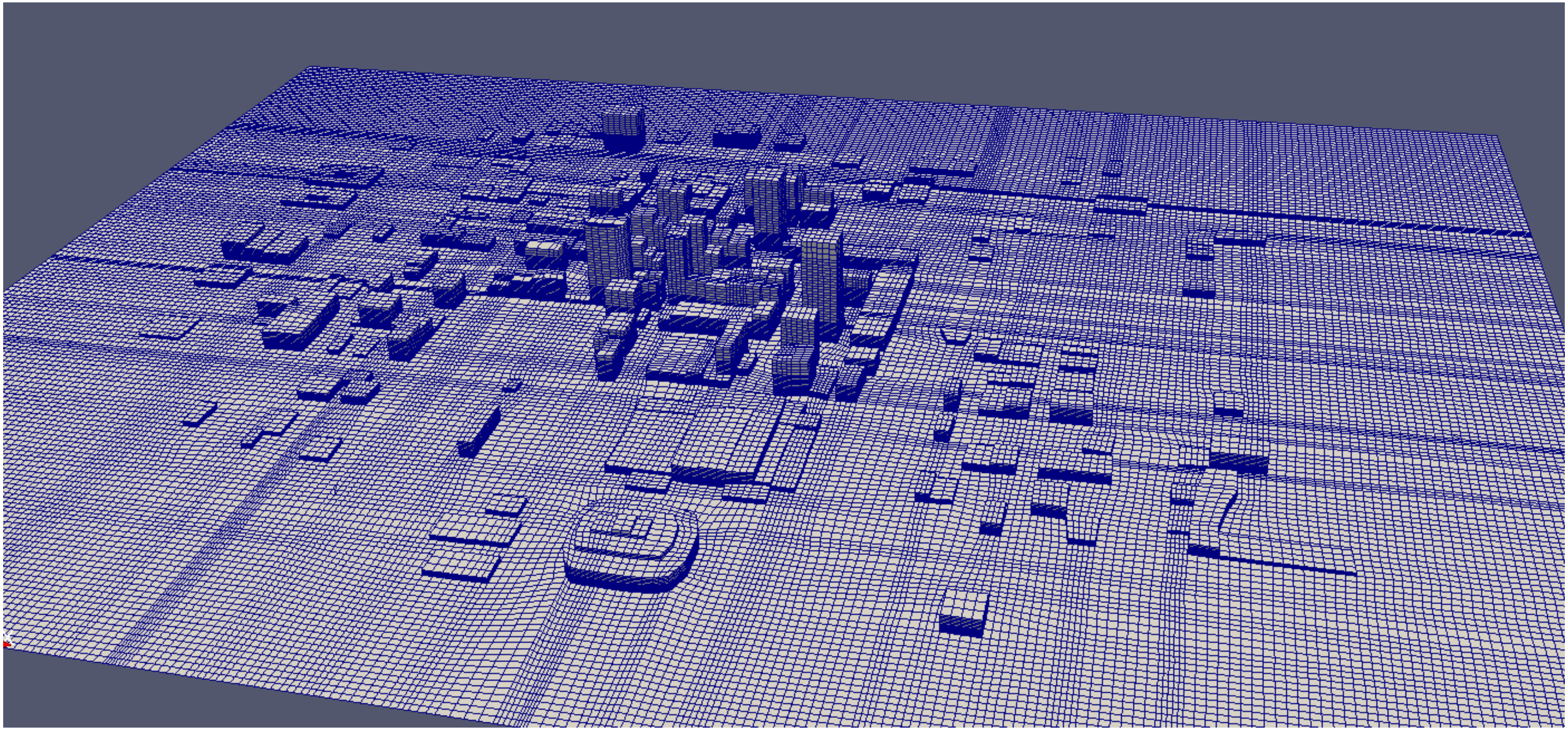




Setup of calculations

Urban model

Calculation model of Oklahoma City.



- **Computational domain (black)**

  - 2140 x 1660 m.

  - with resolution 8.5 m x 8.5 m (avg)

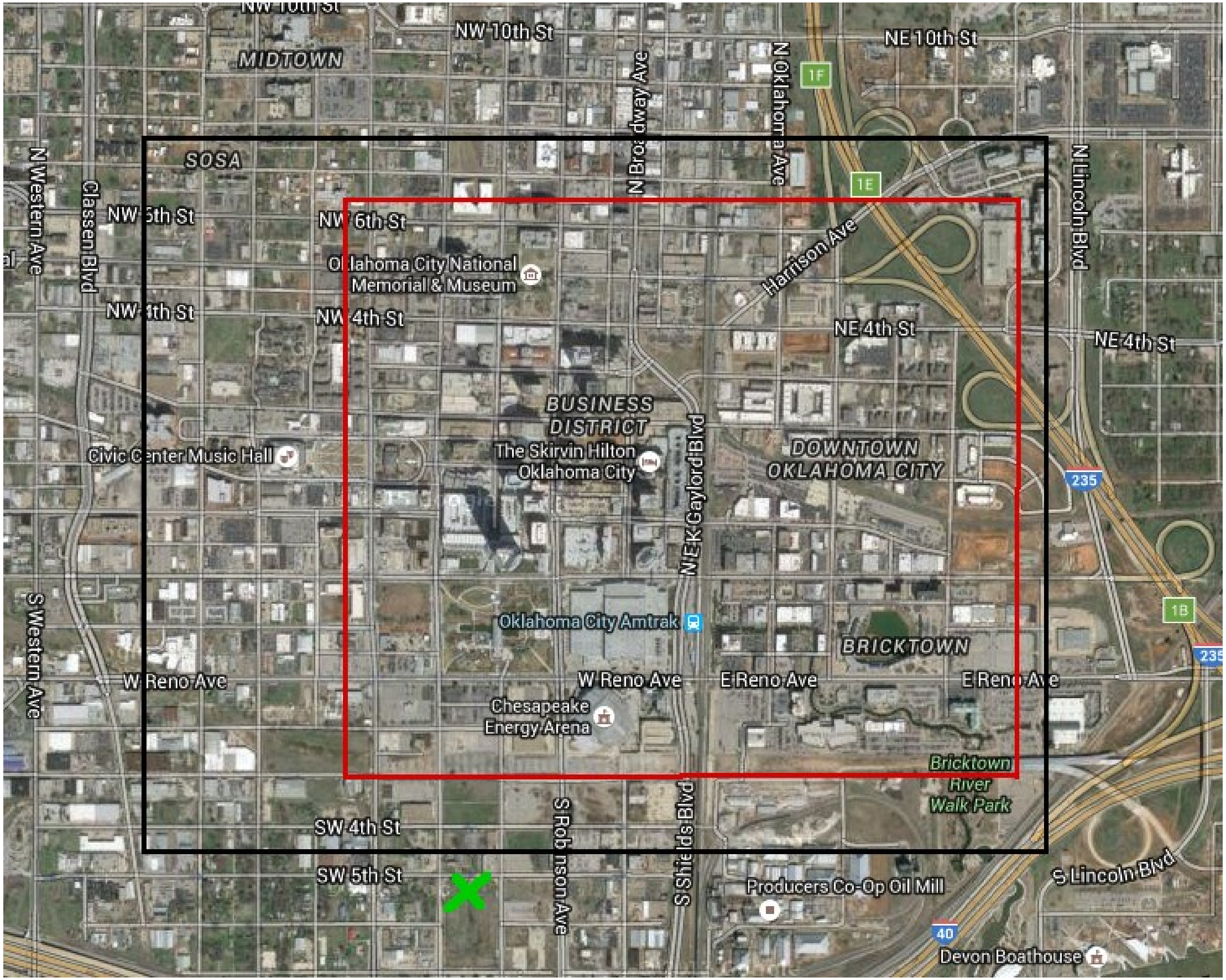
- **UDINEE domain (red)**

  - 1600 x 1400 m,

  - with resolution 5 m x 5 m.

- **Meteo data:**

  - Pwids No.15 (Post Office, 40 m in height).



Left: Location of 20 SuperPWIDSs, right: sampling sites for IOP08.

Boundary conditions:

- Single input: measurement at Pwids No.15,
- consists of wind direction and speed, temperature and relative humidity with 10 s period.
- Results of meteo processing were estimations of:
  - weather stability,
  - Obukhov length,
  - friction velocity,
  - heat flux.
- Define the inlet vertical profiles for the interested quantities, e.g.
  - Wind speed (u):

$$u = \frac{u_*}{\kappa}\left(ln\frac{z}{z_0} - \psi_m\left(\frac{z}{L}\right)\right)$$

where ψ_m is defined for various weather condition (Hanna, 1982),

  - or turbulence energy, eddy dissipation rate.

Calculation of meteorological situation

Model characteristics:

- K-epsilon turbulent model.
- buoyant Boussinesq approximation (temperature differences not included).
- Instead of solving time dependent equation, we calculate steady-states for defined time periods.
- Utilization of SIMPLE scheme as steady-state solver.
- The time periods were either 20 minutes (IOP 4,6,8,10) or 1 hour (IOP 1,3,5,7).

Calculation of dispersion

- Eulerian model for advection-diffusion of passive tracer $\varphi(x,t)$:

$$\frac{\partial\varphi(x,t)}{\partial t} + \vec{\nabla}.\big(\vec{u}\varphi(x,t)\big) - \vec{\nabla}.\big(\,K(x,y)\vec{\nabla}\varphi(x,t)\big) = 0$$

where

$$\mathrm{K}(x,t) = 0.09 \times \frac{k(x,t)^2}{\varepsilon(x,t) \times Prt} = \frac{\nu_t}{Pr_t}$$

and Pr_t is turbulent Prandtl number.

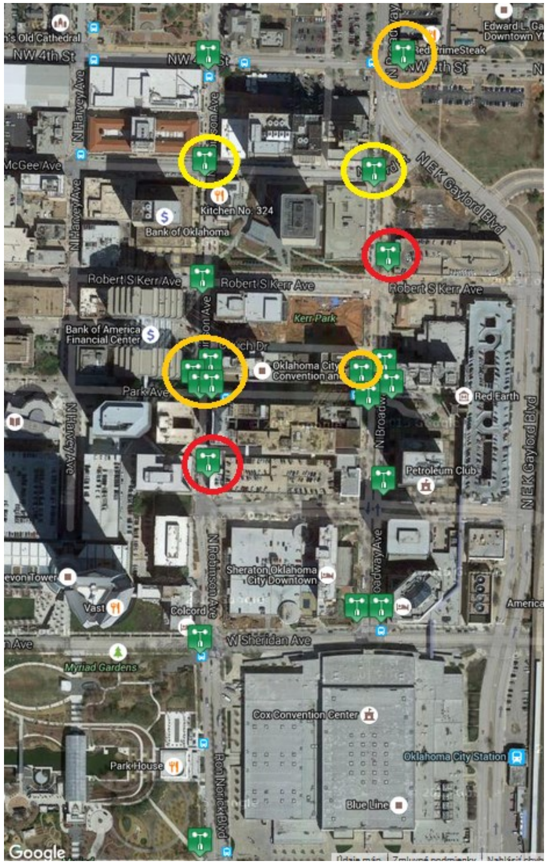
- Not introduced molecular properties of SF6, like i.e. density (5-times densier than air).

Results

Comparison to sonic anemometers – basic quantities

Comparison of wind speed by measurements (figure):

- Orange: in average about 30% difference and relatively small SD
- Yellow: in average about 30% difference and but large SD.
- Red: worst cases.



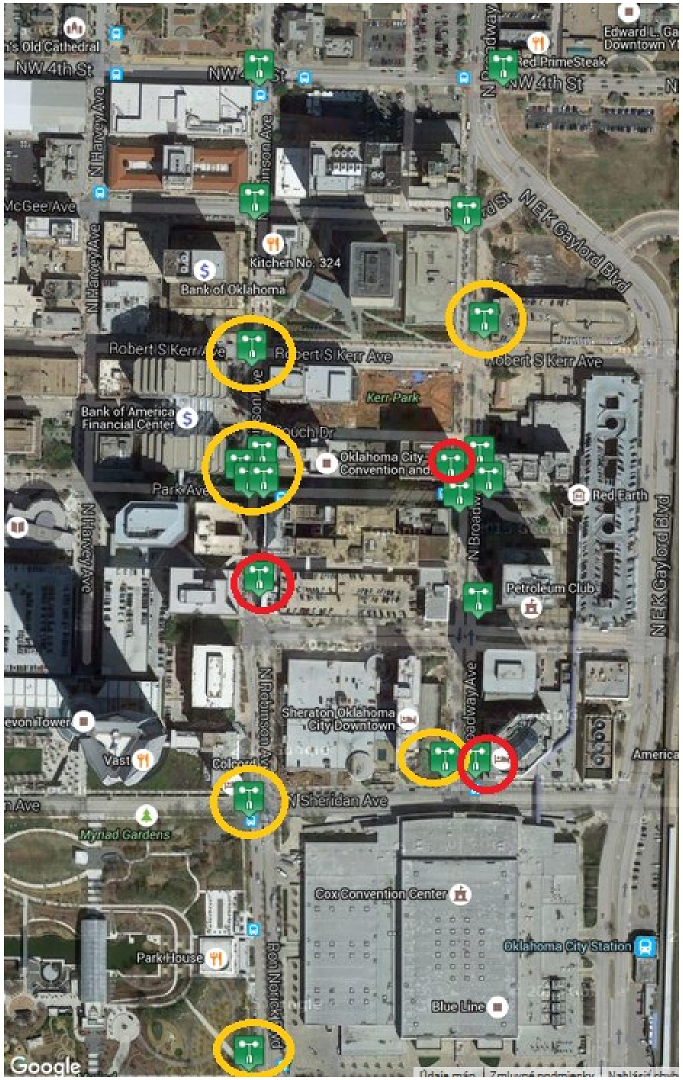
Comparison of wind speed in view of IOPs (table):

	IOP01	IOP03	IOP04	IOP05	IOP06	IOP07	IOP08	IOP10
Model/ Meas.	1.1	1.4	1.0	1.6	1.1	2.1	2.3	1.6

Comparison to sonic anemometers – basic quantities

Comparison of wind direction by measurements (figure):

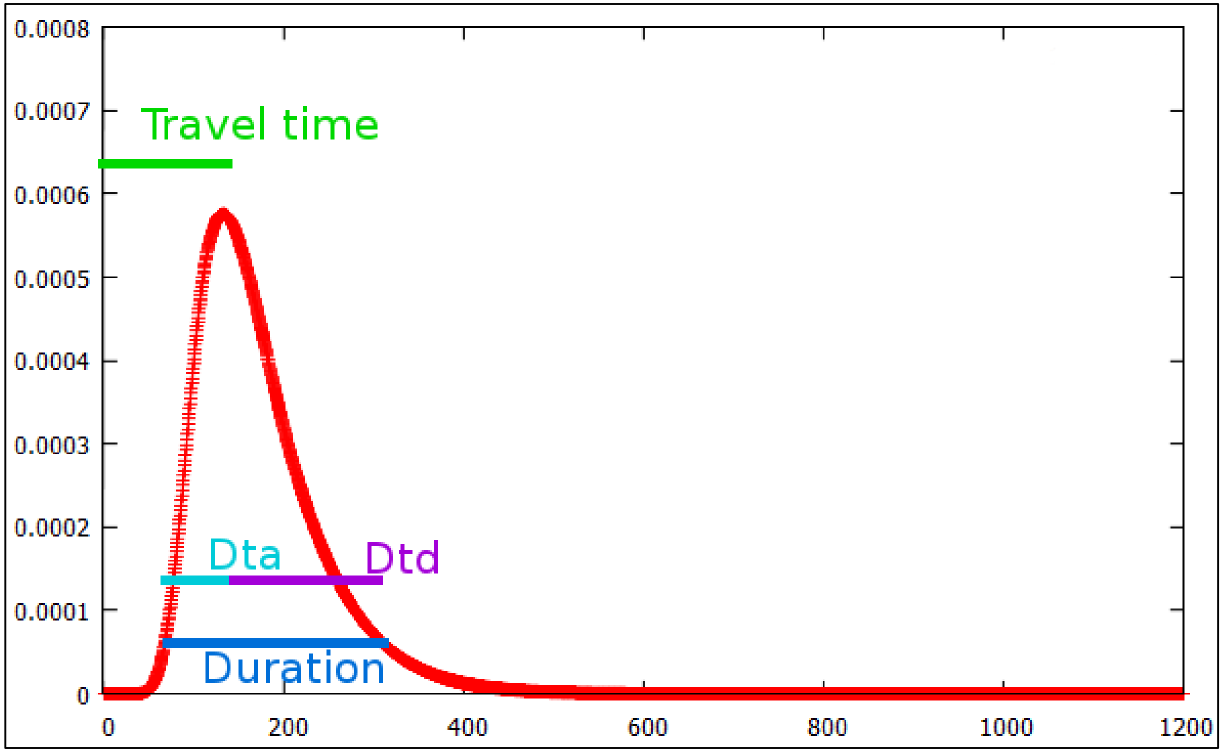
- Orange: in average less 15° difference
- Red: in average more than 40° difference



Comparison to tracer sampling – basic quantities

- **Travel time:** Time difference when Cmax is reached and the release time;
- **Time duration** of concentration > 0.1*Cmax;
- **Dta =** Time difference between Cmax and time when the concentration is greater than or equal to 0.1 Cmax for the first time;
- **Dtd =** Time difference between Cmax and time time when the concentration is greater than or equal to 0.1 Cmax for the last time;
- **Ratio (Dtd/Dta)** = the non-symmetry of the time serie.

From: Zhou & Hanna, 2007.



Comparison to tracer sampling

Table: summary of comparison of modelled and measured tracer response. In all cases we analyse the ratio of modelled vs. measured quantity (set of 111 meaurements, for 25 puffs).

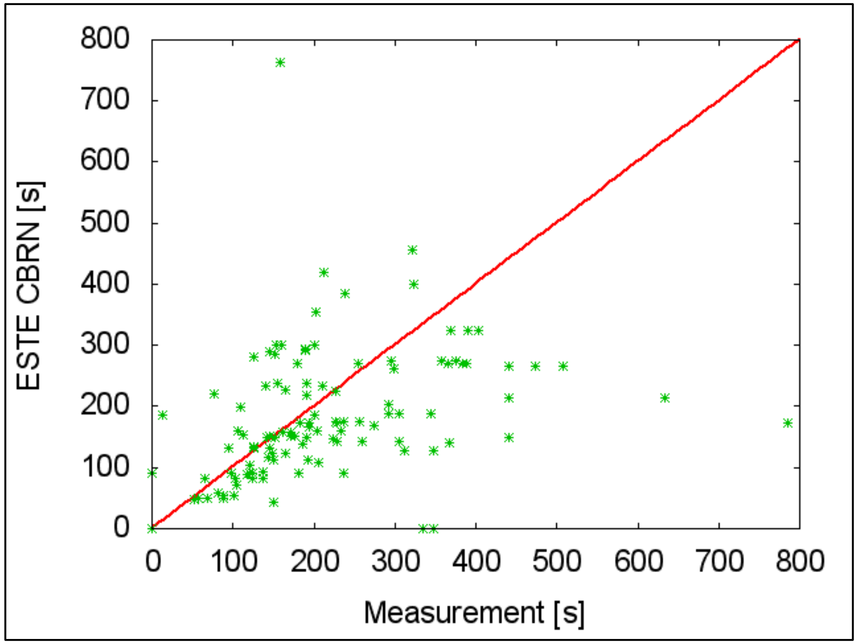
	Time of arrival	Max meas. conc.	Time of max conc.	Dta	Dtd	Duration
Avg	1.1	18.3/2.3	1.0	3.0	1.1	1.1
Max	13.7	567/25	3.5	44.3	10.8	6.1
SD	1.4		0.6	6.3	1.4	1.0

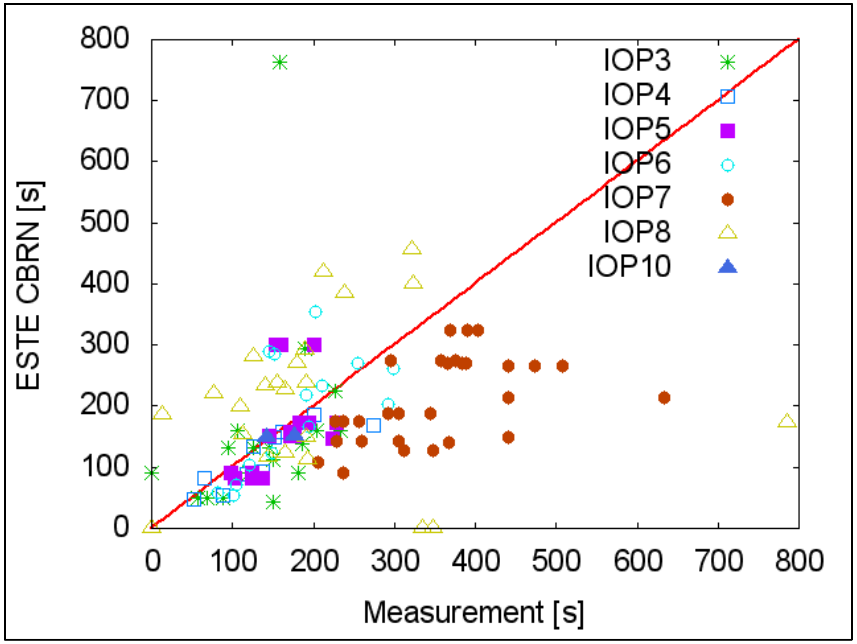
Mean ratio of Dtd/Dta (expected between 2 and 3):

- Measurements: 8.1, 15.5, 3.2 (mean, SD, median).
- Model: 2.3, 1.2, 2.1.

Comparison to tracer sampling – arrival time

	IOP03	IOP04	IOP05	IOP06	IOP07	IOP08	IOP10
Model/ Meas.	1.1	0.9	1.0	1.1	0.6	1.8	1.0





Thank you for attention
–
ABmerit

abmerit@abmerit.sk