

CONFERENCE ABOUT THE STATUS AND FUTURE OF THE EDUCATIONAL AND R&D SERVICES FOR THE VEHICLE INDUSTRY



## COMPUTATIONAL SIMULATION OF AIR POLLUTION DISPERSION INDUCED BY URBAN TRAFFIC

Zoltán Horváth, Széchenyi István University, Győr

"Smarter Transport" – IT for co-operative transport system

section

Hungarian Academy of Science Budapest, 31 January 2014





#### Contents

- 1. Challange: air quality, environment, Smart Cities
- 2. Modeling and Simulation tools
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  - 5. NOx dispersion simulation
- 3. Future tasks
  - 1. Optimization and Control
  - 2. ICT framework with IBM IOC





#### Collaborators – multidisciplinary research team

- 1. Challange
  - L. Objectives, research management: Rozália Varga
- 2. Modeling and Simulation tools
  - 1. Measurements (traffic, NOx): Éva Rácz Pestiné, Ingrid Sándor, Anett Bedő, Péter Lautner, István Harmati
  - 2. Traffic flow simulation: Bertalan Gaál
  - 3. NOx emission simulation: Alfréd Csikós (BME)
  - 4. Geometry modeling: Bence Liszkai, Gábor Diósi, Péter Zsebők
  - 5. NOx dispersion simulation: Péter Zsebők, Bence Liszkai

Partners:

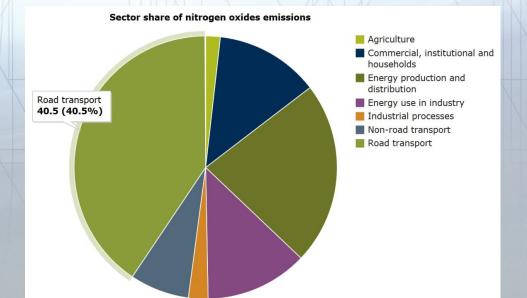
Győr City, Jel-Köz Kft, FŐMTERV Zrt, OMSZ, IBM





#### 1. Challange

- WHO Air quality guidelines (2005)
- 2008/50/EC on ambient air quality and cleaner air for Europe - Emissions of harmful air pollutants should be avoided, prevented or reduced → Monitoring & Critical levels
- Clean Air Policy (IP/13/1274 18/12/2013)
  - <u>http://ec.europa.eu/environment/air/clean\_air\_policy.htm</u>







### 1. Objectives (cont.): Projects, partnerships in EU

- Niches+ Action: Using Environmental Pollution Data in Traffic Management Centres (FP7) Smart Cities and Communities
  - "Strategic Implementation Plan" of the Smart Cities and Communities Partnership (2013)
- H2020 Societal Challanges
  - (e.g. Smart Cities and Communities) already several calls in H2020!

 In our TÁMOP 422C project: "Research of computer simulation and optimization which supports the SmartCity-SmartTransport concept" subproject





### 2. Modeling and Simulation Tools

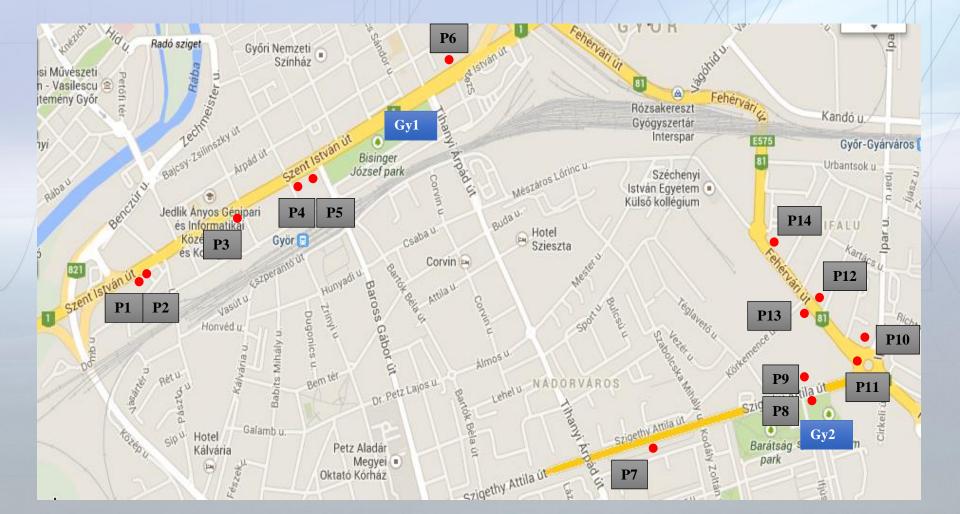
- Aims: model, simulate and then optimize and control traffic emitted NOx in cities, in particular in Győr
- Need of simulation of
  - 1. Traffic flow
  - 2. NOx emission
  - 3. NOx dispersion in real 3D geometry
- Preprocessing:
  - 1. Geometry modeling
  - 2. Measurements (for validation)
  - 3. Data compatibility
  - 4. Data from diverse sources (e.g. meteorology, etc.)

Automated simulation, optimization and control





# 2.1 Modeling and Simulation Tools (cont.)- Measurements Measurements in Győr at 2 different districts



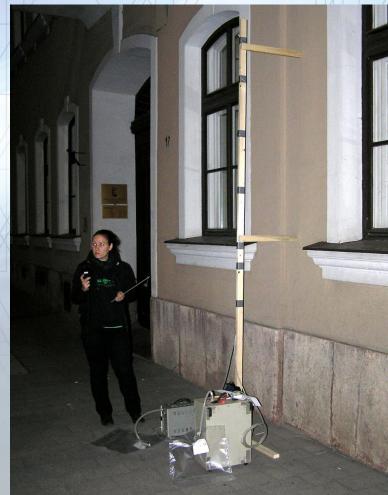




# 2.1 Modeling and Simulation Tools (cont.)- Measurements "Street Canyon" – Szent István út – Jókai út, Győr

- 2\*8 sampling site (1.5 m & 3m)
- 6 air samples during the day
- 18 hours manual traffic counting
- 3 lecturers and 40+ students involved

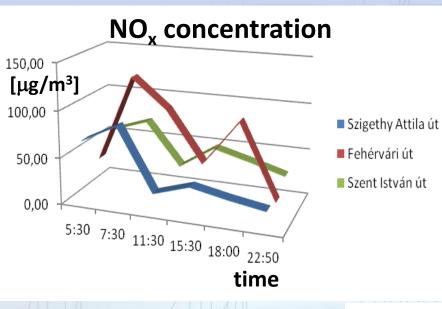






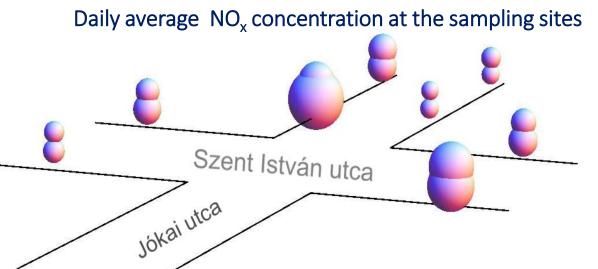


#### 2.1 Modeling and Simulation Tools (cont.): Measurements



#### Results

- 1. Models for NOx , conspicuous differences in daily rhythm
- 2. canyon effect detected
- 3. no significant difference at heights
- 4. turbulence at corners







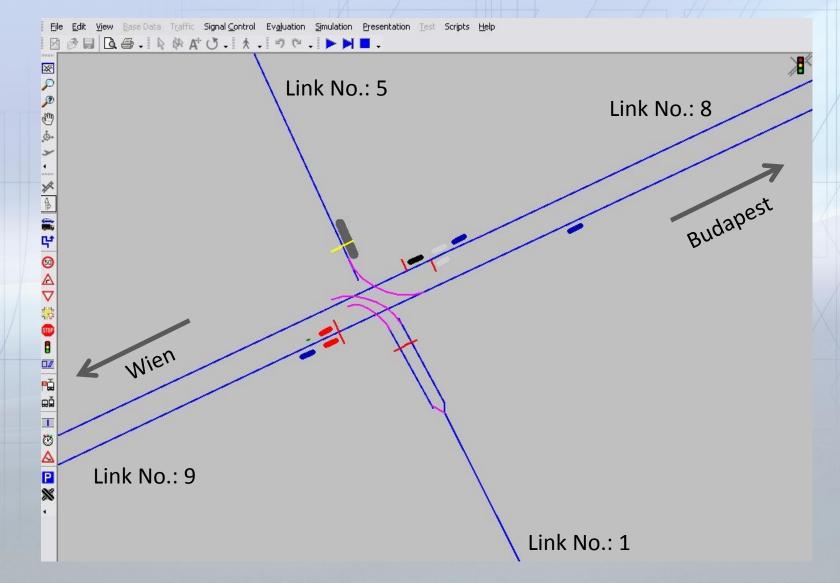
#### 2.2 Traffic flow simulation: Preprocessing

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#### 2.2 Traffic flow simulation: microscopic simulation in VISSIM







### 2.2 Traffic flow simulation with PTV VISSIM 5.40

- Cross-section counting with vehicle categories
  - Car
  - HGV (Heavy Goods Vehicle)
  - Bus
  - Motorbike

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Volumes are shown in veh/h. Yellow cells indicate exact (non-stochastic) volumes.





#### 2.2 Traffic flow simulation: signal program





COPERT 4 version 7.1 - C\Program Files\COPERT 4\blank.mdb (Changed)



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until: 70000 s

# 2.3 Traffic flow simulation: Post processing and NOx emission computation

- 1. Link evaluation
- 2. Output for emission computation
- 3. MATLAB script (Copert model)

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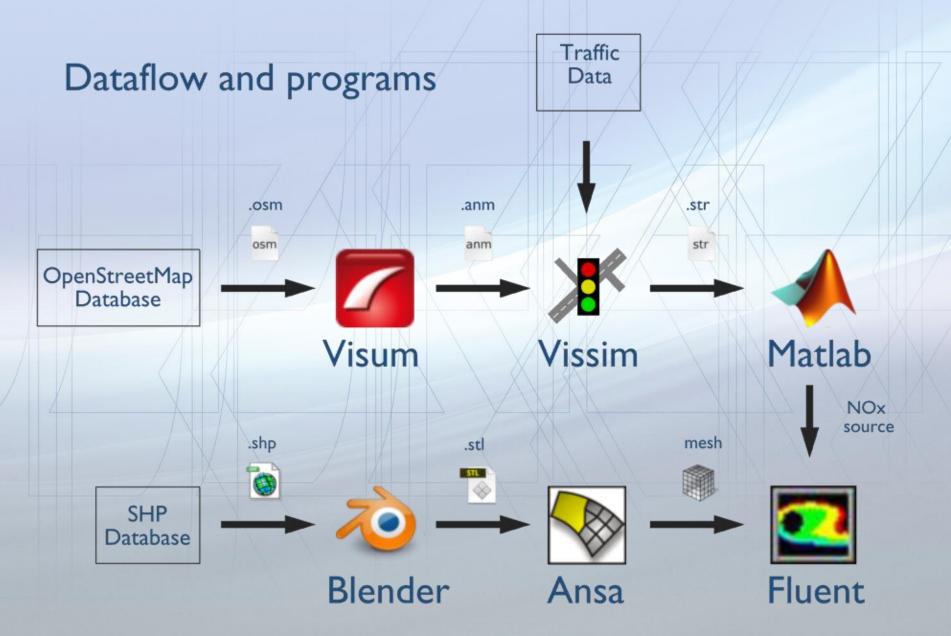




- 2.4-5 Geometry modeling and NOx dispersion simulation Software
- Fluent: CFD
- Ansa: Mesher
- Blender: Geometry from shp
- VisSim: traffic
- ViSum: traffic
- Matlab: NOx from traffic simulation











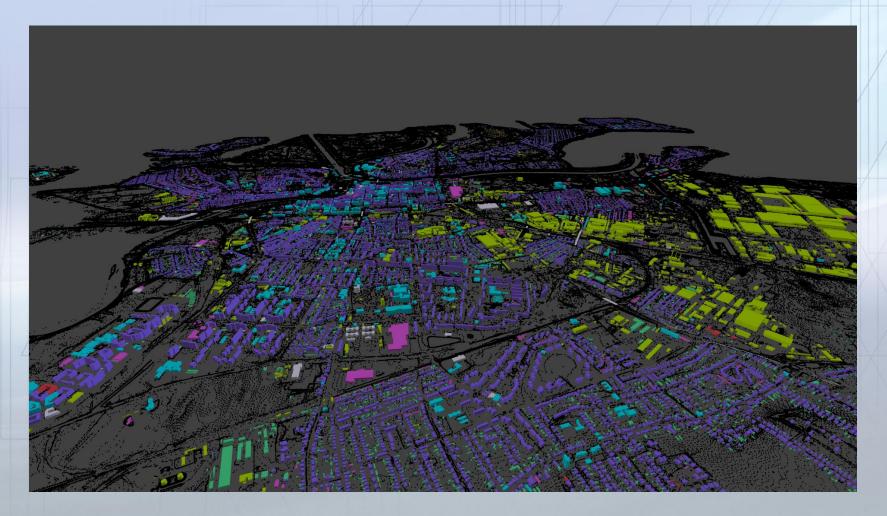
### 2.4 Geometry modeling: City geometry Converted from SHP file with Blender python script

- Buildings
- Ground
- Noise barrier walls
- Bridges





#### 2.4 Geometry modeling: Full 3D model of Győr





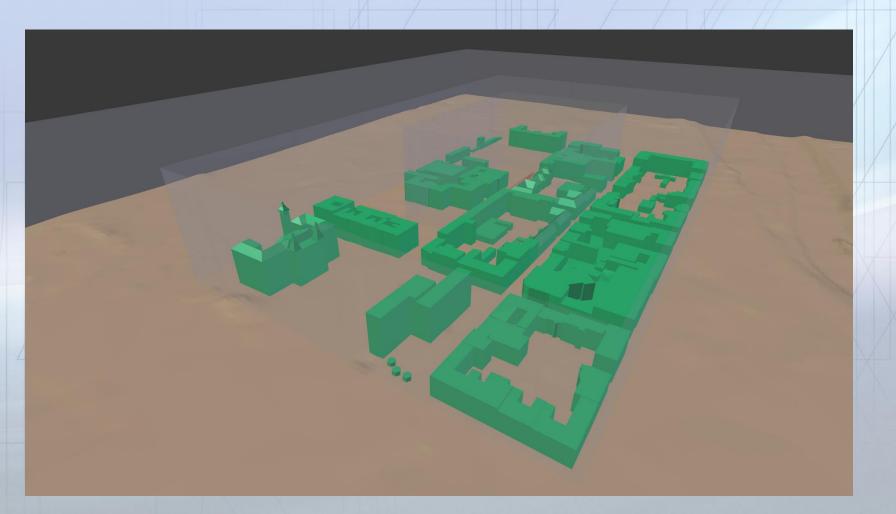


- 2.4 Geometry modeling workflow
- Improved geometry
- Create ground surface from points
- Add the elements with mesh boolden operators
- Convert to STL format





#### STL mesh in Blender







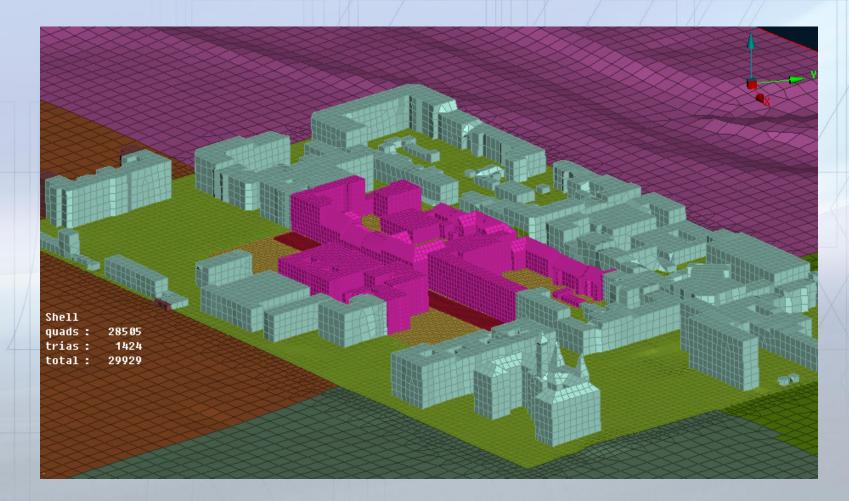
### 2.5 NOx dispersion simulation: Mesh specification

- Quad shell mesh (mostly)
- Three reginions of resolution
  - Detailed: buildings's geometry+ high res. mesh
  - Coarse: buildings's geometry + medium res. mesh
  - Rough: buildings as roughness + low res. Mesh
- Tetra volume mesh
- Prism layer mesh on the roads
- Two global resolution
  - Low res. mesh: 1.7 million volume elements
  - High res. mesh: 3,6 million volume elements





#### 2.5 NOx dispersion simulation: After remesh in ANSA



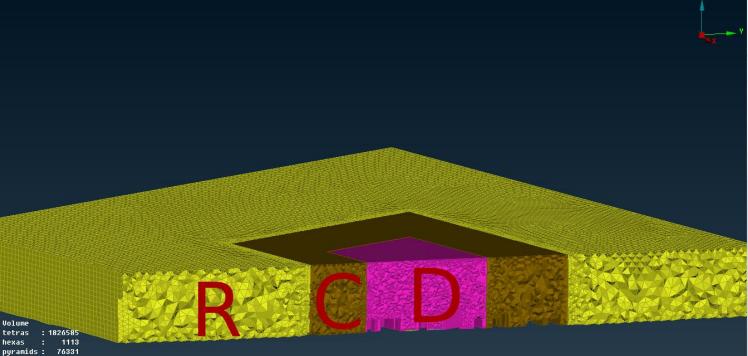




### 2.5 NOx dispersion simulation: Volume meshing Model: Rough, Coarse and Detailed regions



total : 1904029







#### 2.5 NOx dispersion simulation: Simulation setup

- Boundary conditions:
  - NOx source: road prism layer
  - Solar radiation
  - Constant 3 m/s N-W wind
- Species transport for the pollutant air
- In that early case the pollutant load is a constant hourly average pollution of a normal day
- Rough region
  - Divided into four segment
  - Roughness setup depends on the average building height





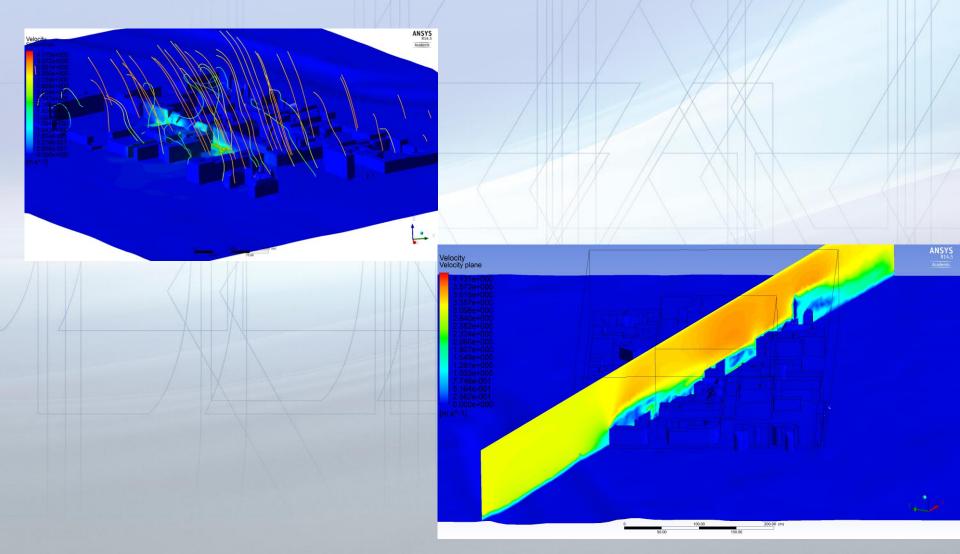
#### 2.5 NOx dispersion simulation: Simulation setup

- Double precision transient solver
- k-ε model in the beginning while the flow unstable
- LES model for the stable flow
- Coupled second order implicit transient formulation
- Running time on 16 core was around 8 hour





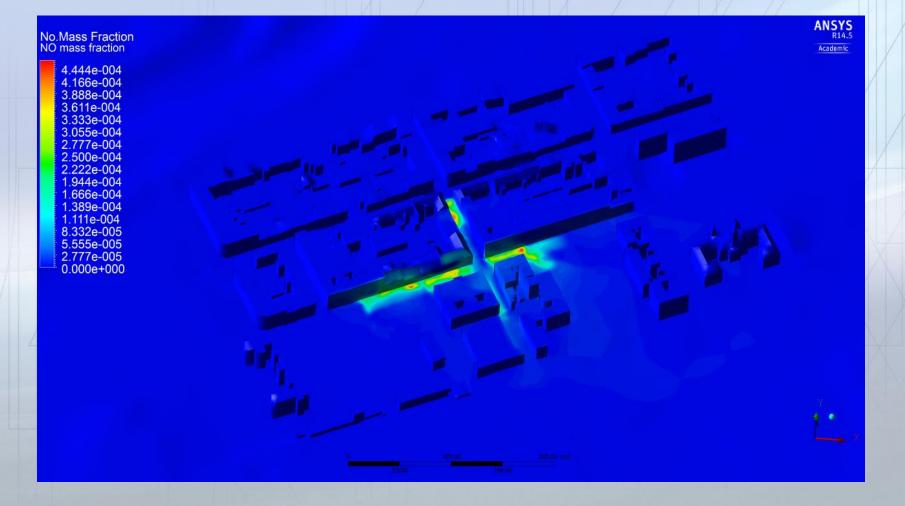
#### 2.5 NOx dispersion simulation results: effect of the wind







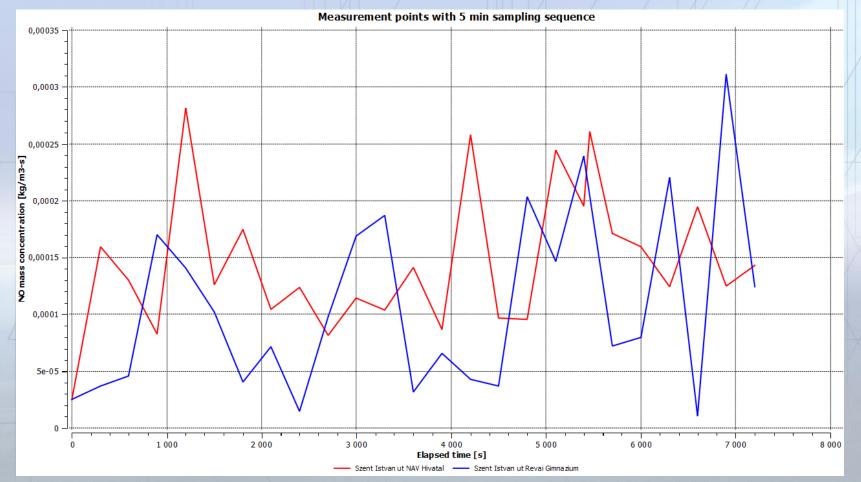
#### 2.5 NOx dispersion simulation: Surface dispersion of NOx







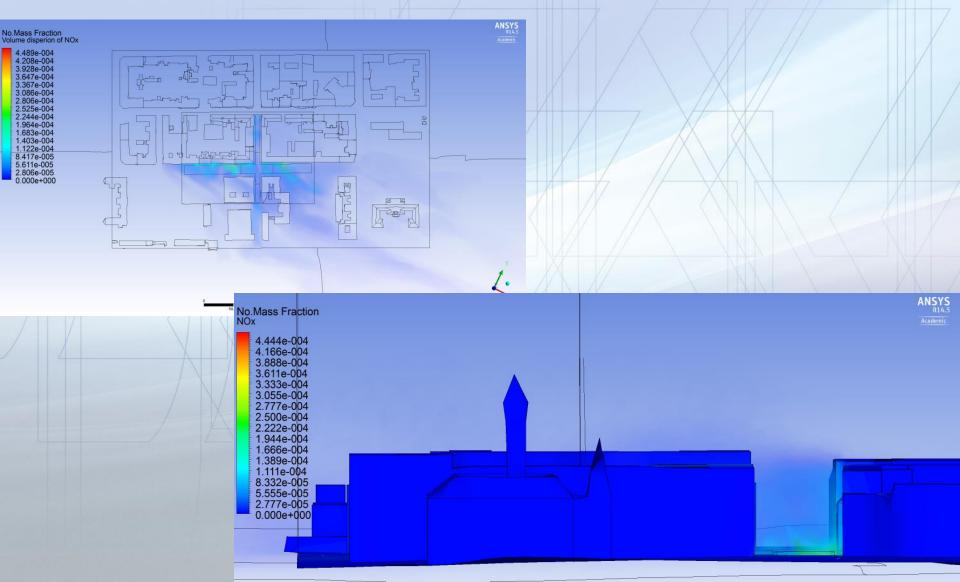
## 2.5 NOx dispersion simulation results: NOx mass concentration at measure points







#### 2.5 NOx dispersion simulation results: NOx propagation







#### 3. Future tasks

- New NOx measurements and traffic counting
- Traffic flow and emission simulation
  - VISSIM scripting for handling design and control variables
    - traffic volume
    - signal control program
  - Further simulation tool: Pannon Traffic
- Simulation of NOx dispersion on supercomputers with other software tools (Parmod, OpenFOAM)
- Automatization of data processing, optimization and control
- Embedding into IBM IOC (Intelligent Operations Center)
- Challange: Simulation of full Győr

Implementing new projects – H2020 and more



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## **THANK YOU** FOR YOUR ATTENTION! Zoltán Horváth, PhD Széchenyi István University Contact Email: horvathz@sze.hu Tel.: +36 96 503 464 Web: http://jkk.sze.hu; http://math.sze.hu



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#### COOPERATION BETWEEN HIGHER EDUCATION, RESEARCH INSTITUTES AND AUTOMOTIVE INDUSTRY TÁMOP-4.1.1.C-12/1/KONV-2012-0002

BASIC RESEARCH FOR THE DEVELOPMENT OF HYBRID AND ELECTRIC VEHICLES TÁMOP-4.2.2.A-11/1/KONV-2012-0012

"SMARTER TRANSPORT" - IT FOR CO-OPERATIVE TRANSPORT SYSTEM TÁMOP-4.2.2.C-11/1/KONV-2012-0012

> Nemzeti Fejlesztési Ügynökség www.ujszechenyiterv.gov.hu 06 40 638 638

#### **HUNGARY'S RENEWAL**



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Hungarian Academy of Science Budapest, 31 January 2014

