Uncertainty -

Urban Dispersion Modeling

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Types of Uncertainties

*** Inputs to urban dispersion models**

- source term
- winds
    - larger-scale model
    - meteorological network
- physical parameters

*** Model physics limitations**

*** Statistical uncertainty due to urban turbulence**

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Importance of Uncertainties

* Importance (or acceptability) of uncertainties depends on the application, the problem space, the type of answer desired, the model being run, the spatial or temporal scale one is looking at, etc.

e.g.,

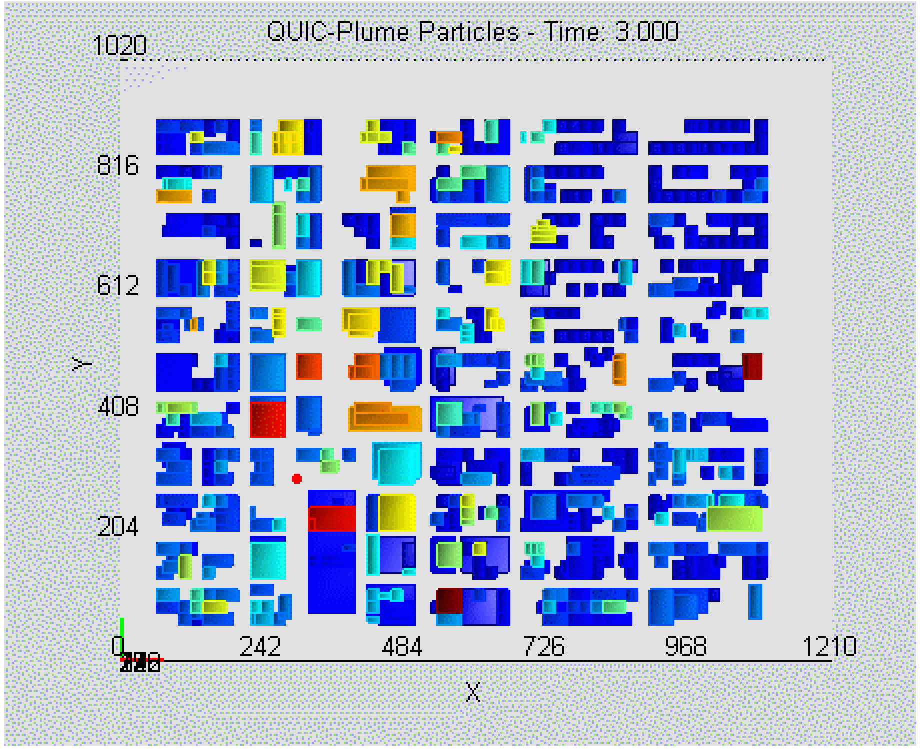
* model evaluation vs. emergency response vs. clean-up assessment

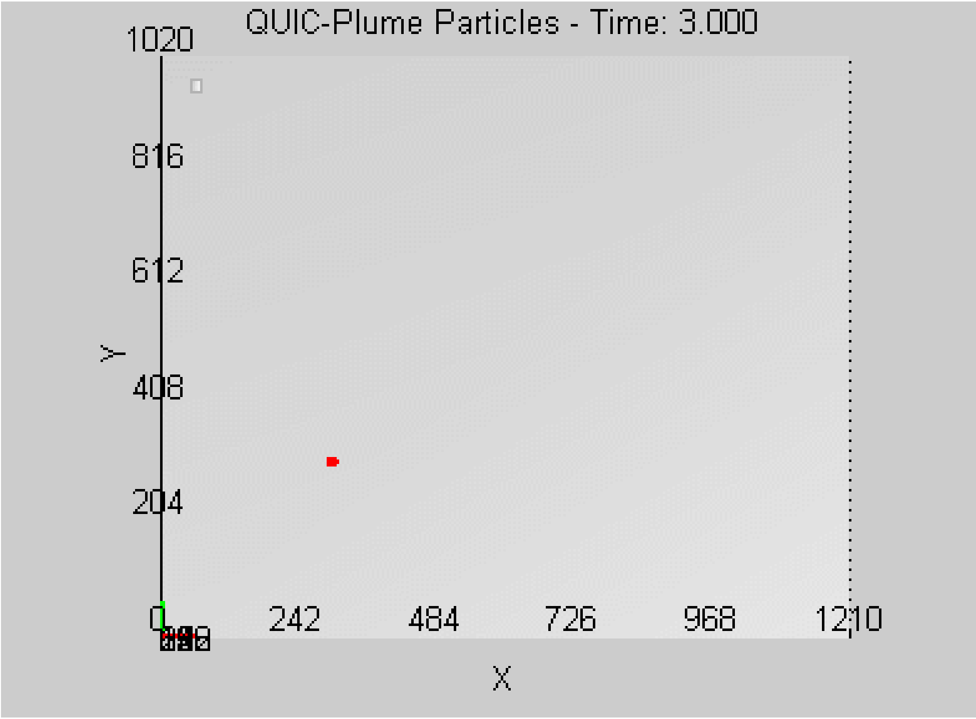
* retention time vs. mean concentration field vs. peak values

* Gaussian plume model vs. CFD model

* large-scale vs. small-scale urban dispersion

Problem Space & Model Type

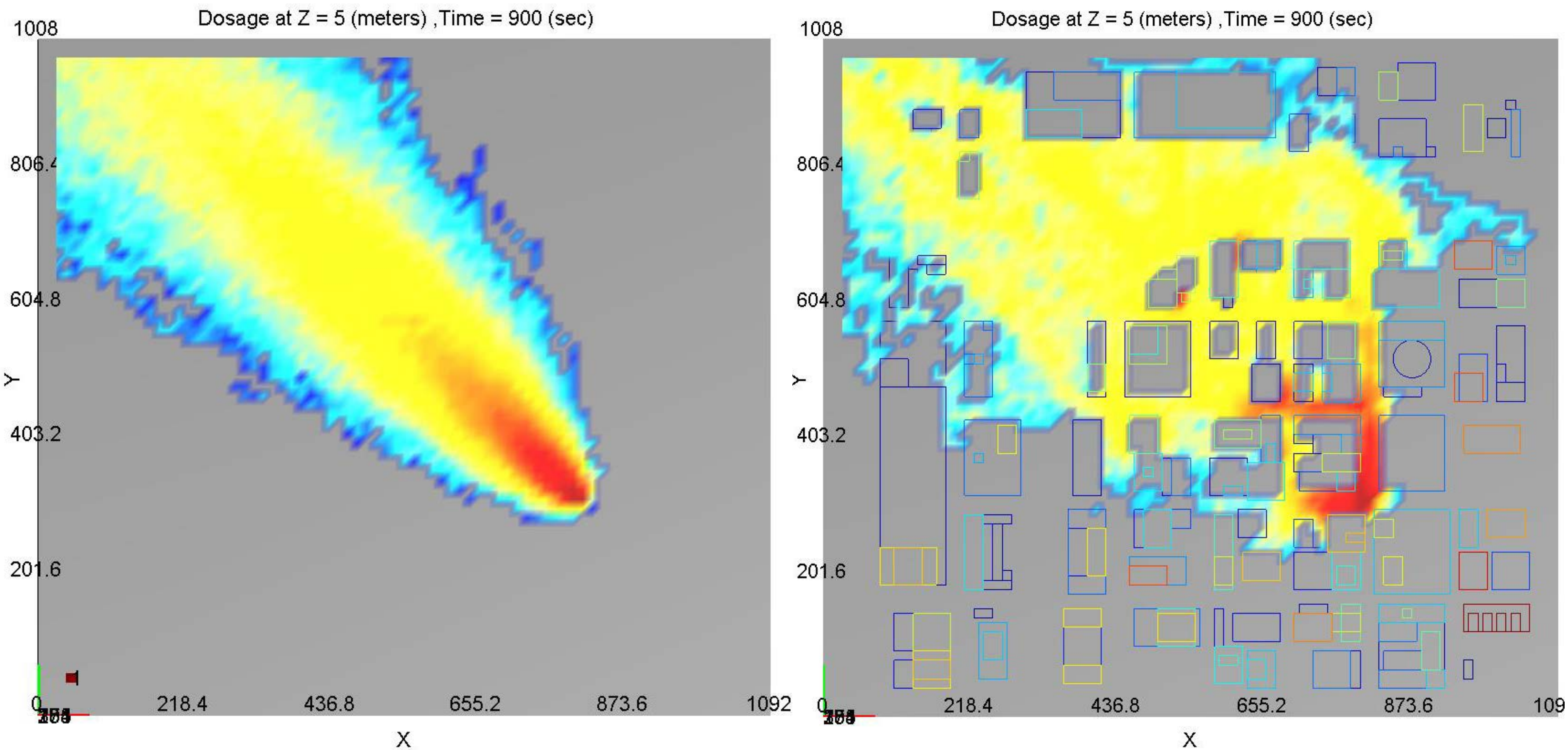




Retention Time

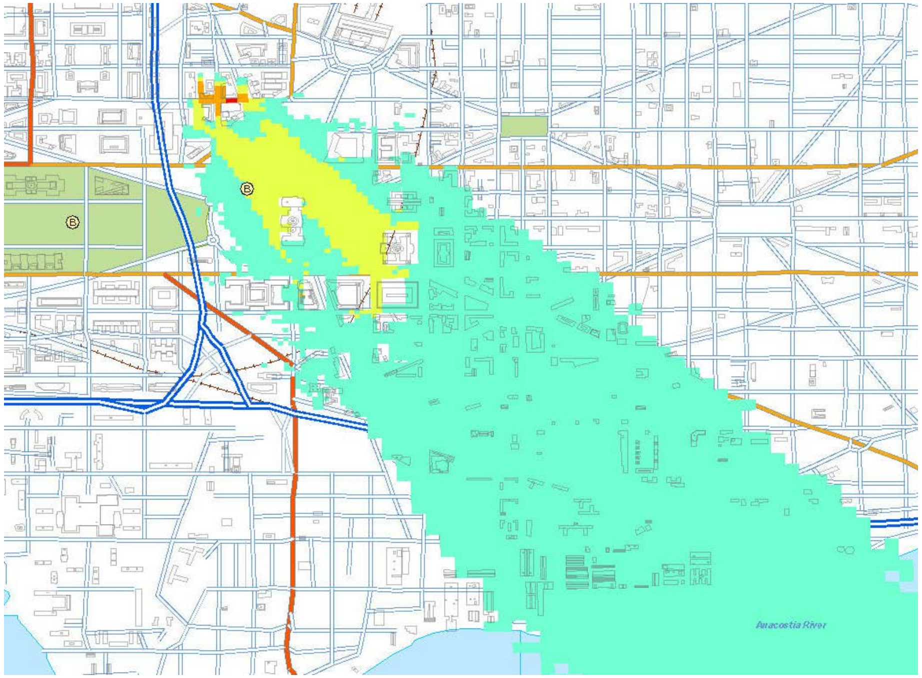
How long will agent remain in city?

Problem Space & Model Type

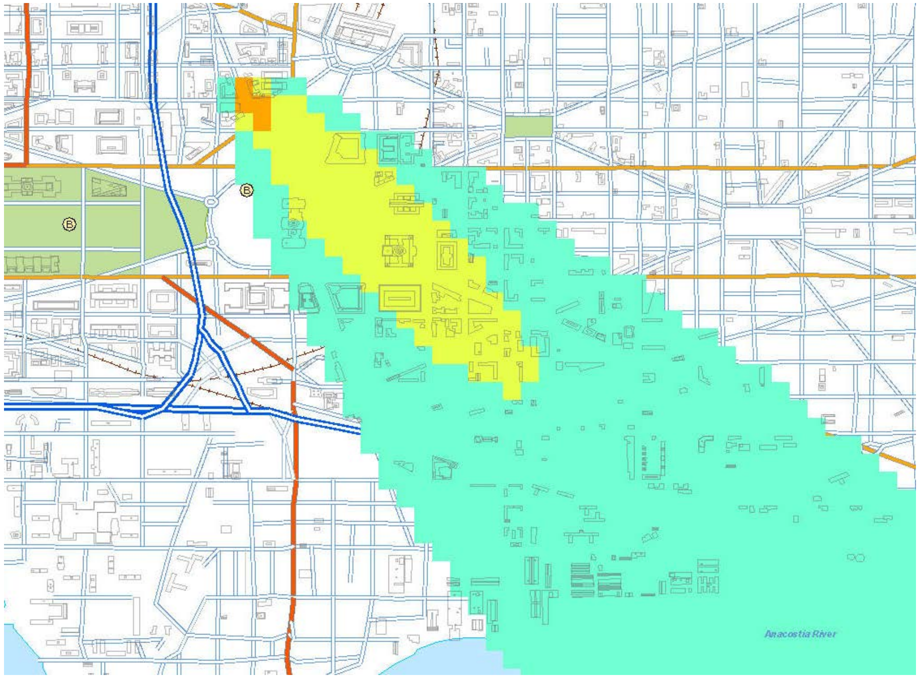


Dosage fields – with and without explicit buildings

Problem Space & Model Type



QUIC (building aware)



Urbanized Gaussian Plume (non-building aware)

Dosage fields – with and without explicit buildings

ER Uncertainties

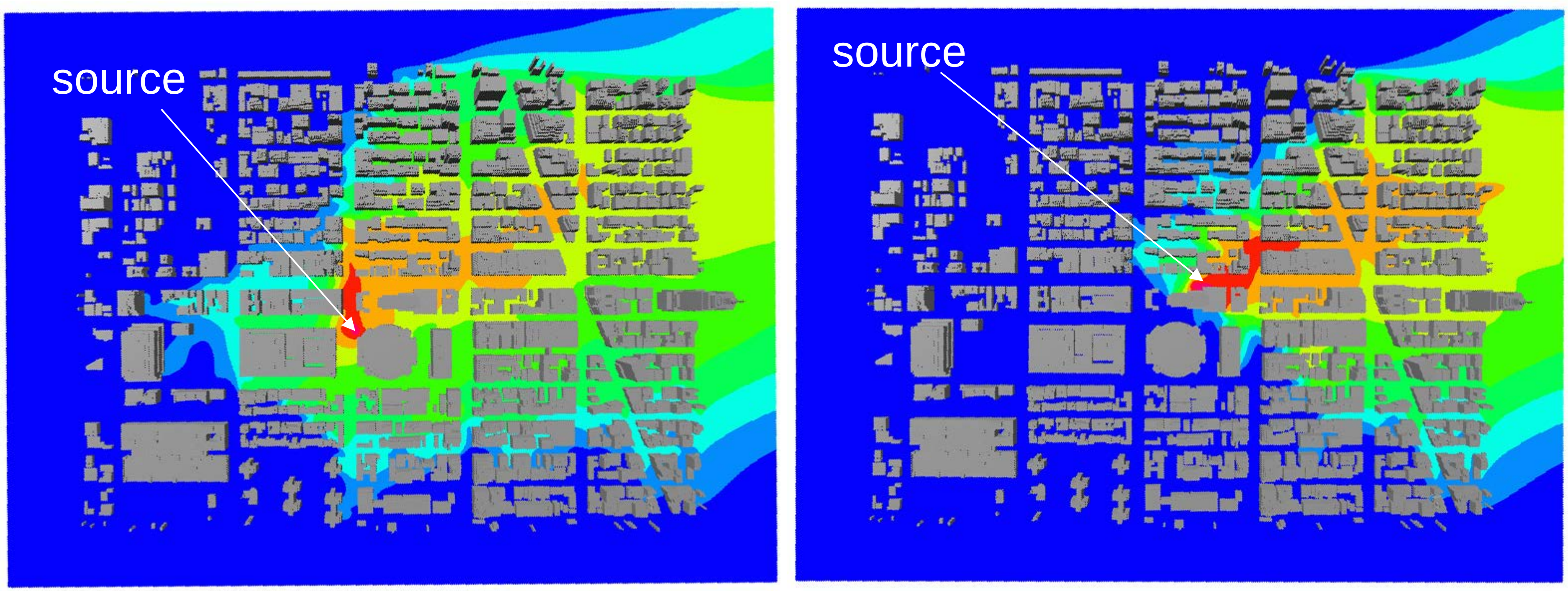
* For CBR emergency response applications

Biggest uncertainty: <u>source</u> term!

- what was released (and it's physical properties)
- where was it released (x, y, z coordinates)
- how much was released (and in what form)
- when was it released (time of day)
- how long was it released (duration)

Source Term Uncertainties

Source location different by one block



NYC Madison Square Garden Simulations from Bill Coirier, CFDRC

Triage or Clean-Up Applications

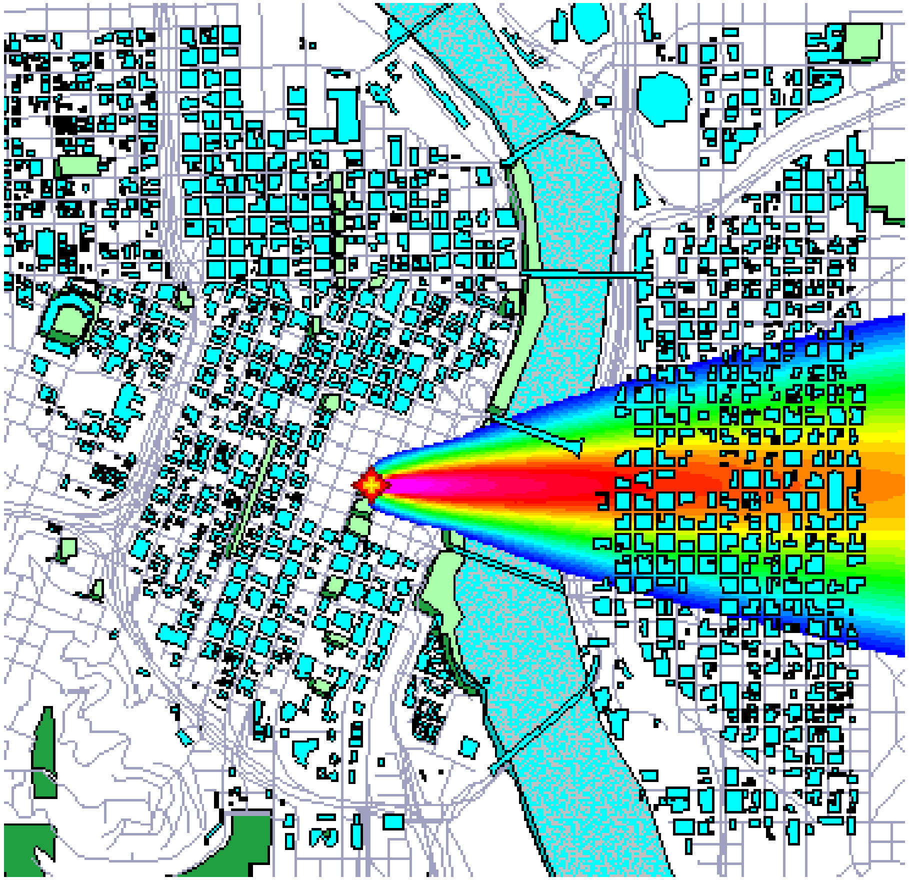
* Uncertainties introduced by model physics (buildings explicitly accounted for?)

  - location of the plume footprint sensitive to building effects

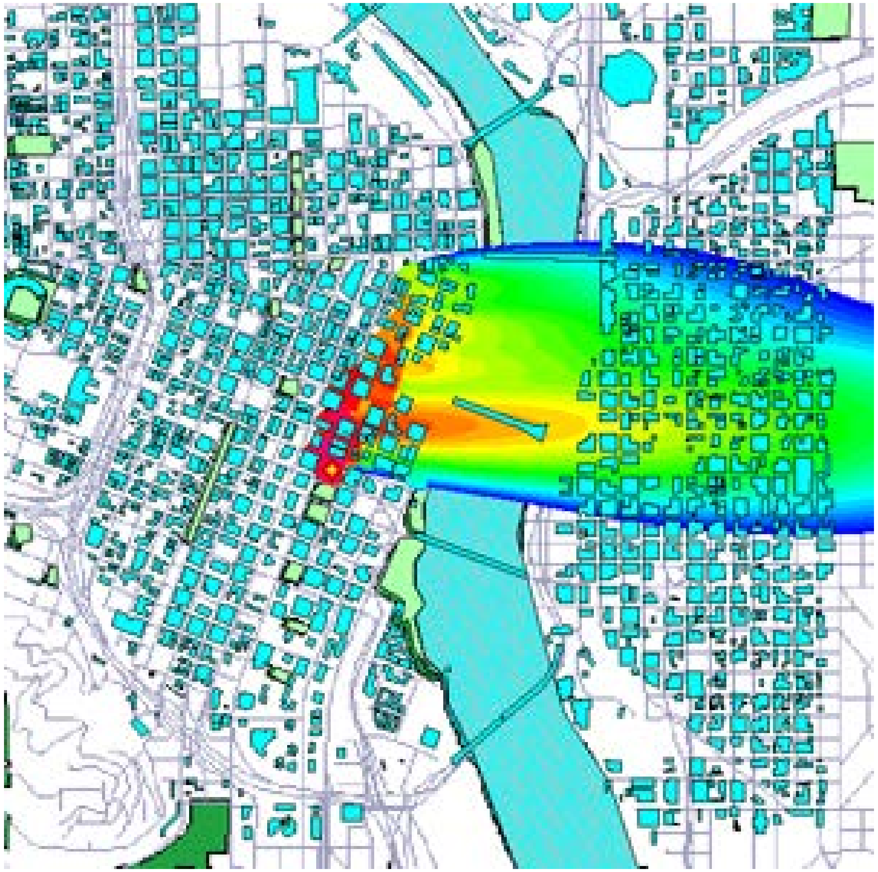
  - street-level exposures sensitive to ventilation/trapping between buildings

Importance of Building Effects

No explicit buildings



Explicit buildings



DSTL UDM simulations

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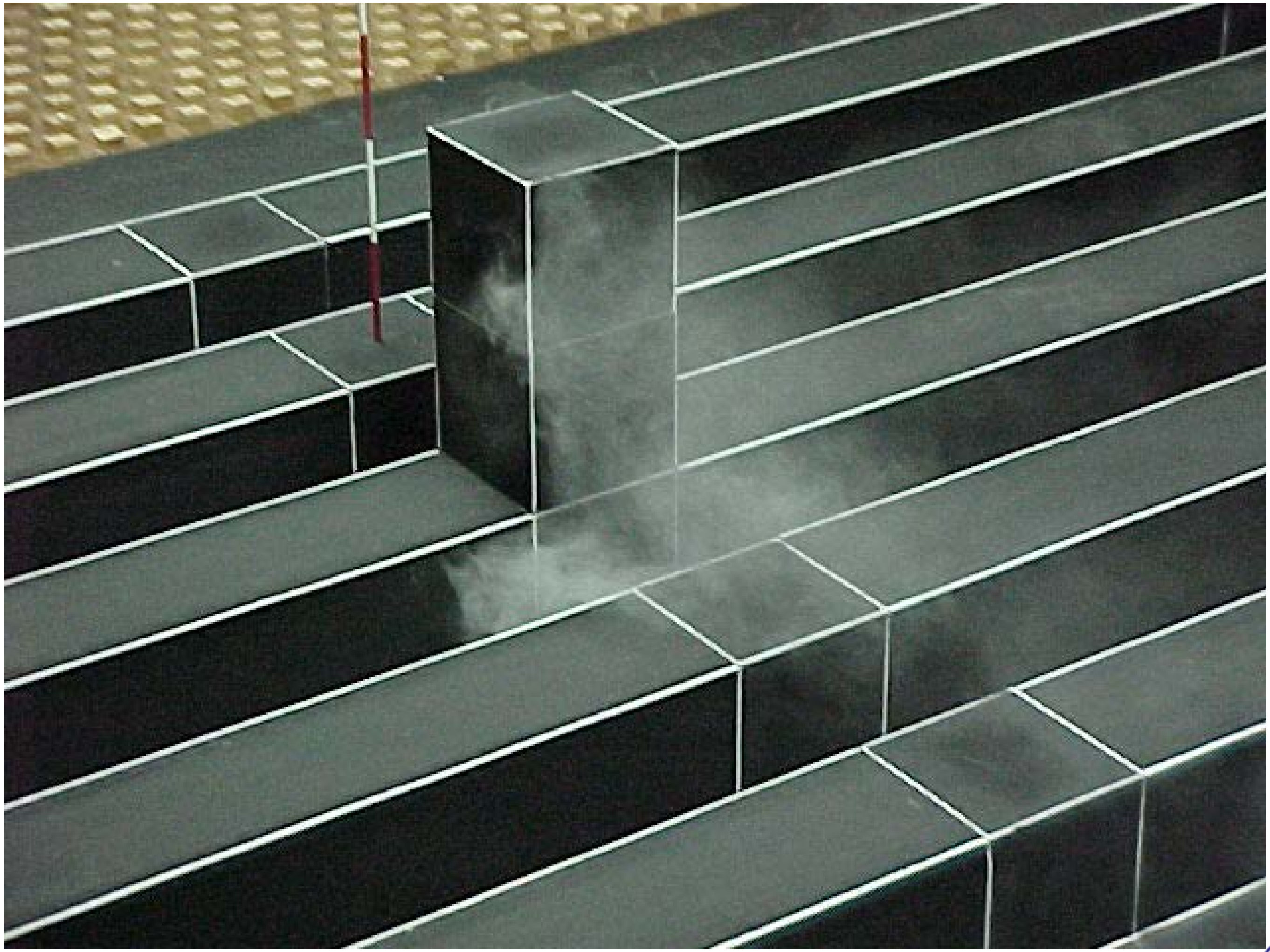
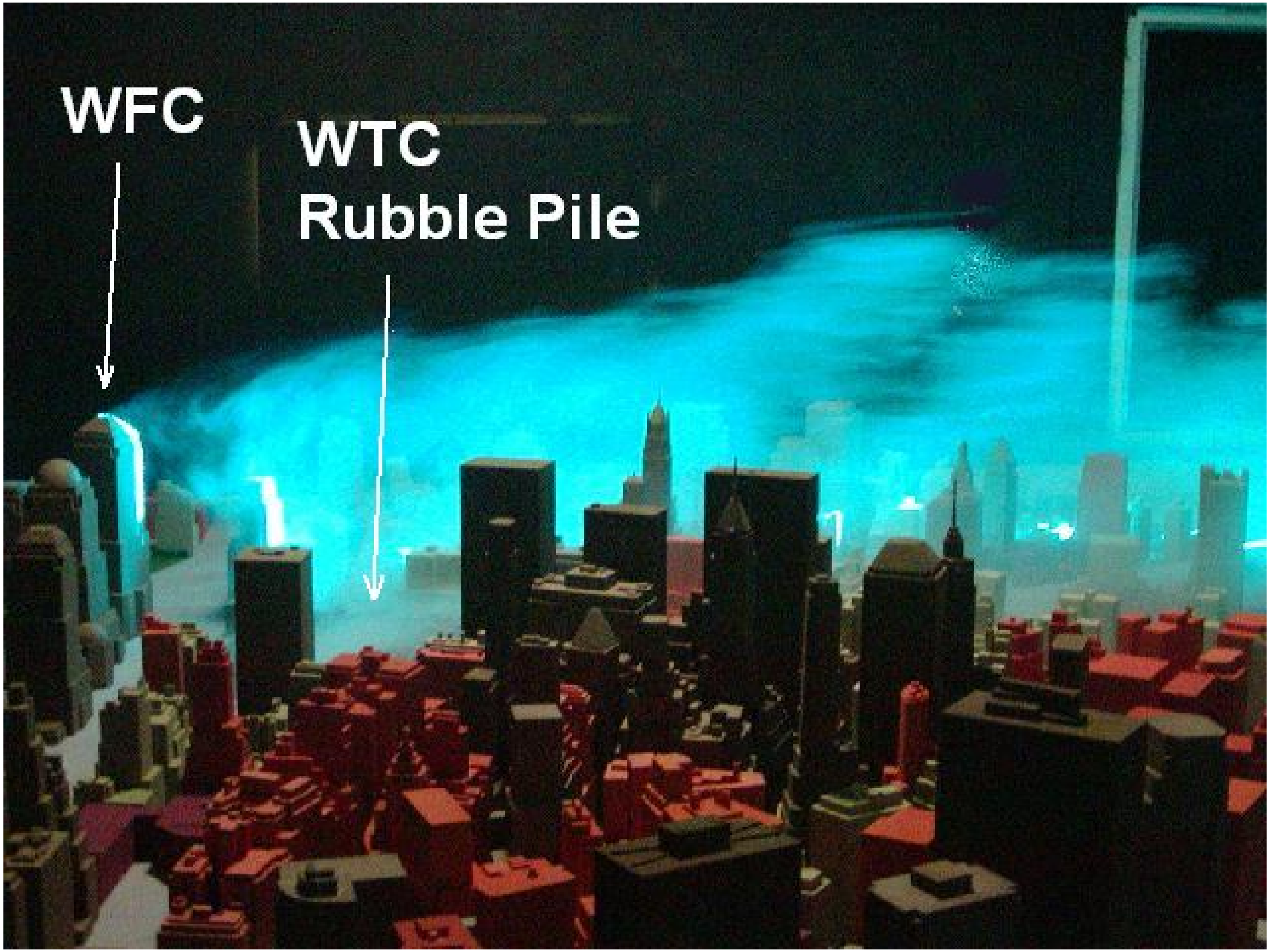
Importance of Building Effects

USEPA Meteorological Wind Tunnel Experiment



Importance of Building Effects



USEPA Meteorological Wind Tunnel Experiment (from Heist et al., 2004)

Input Uncertainties

* Which wind to use as input (the inflow BC)?

    - measurements

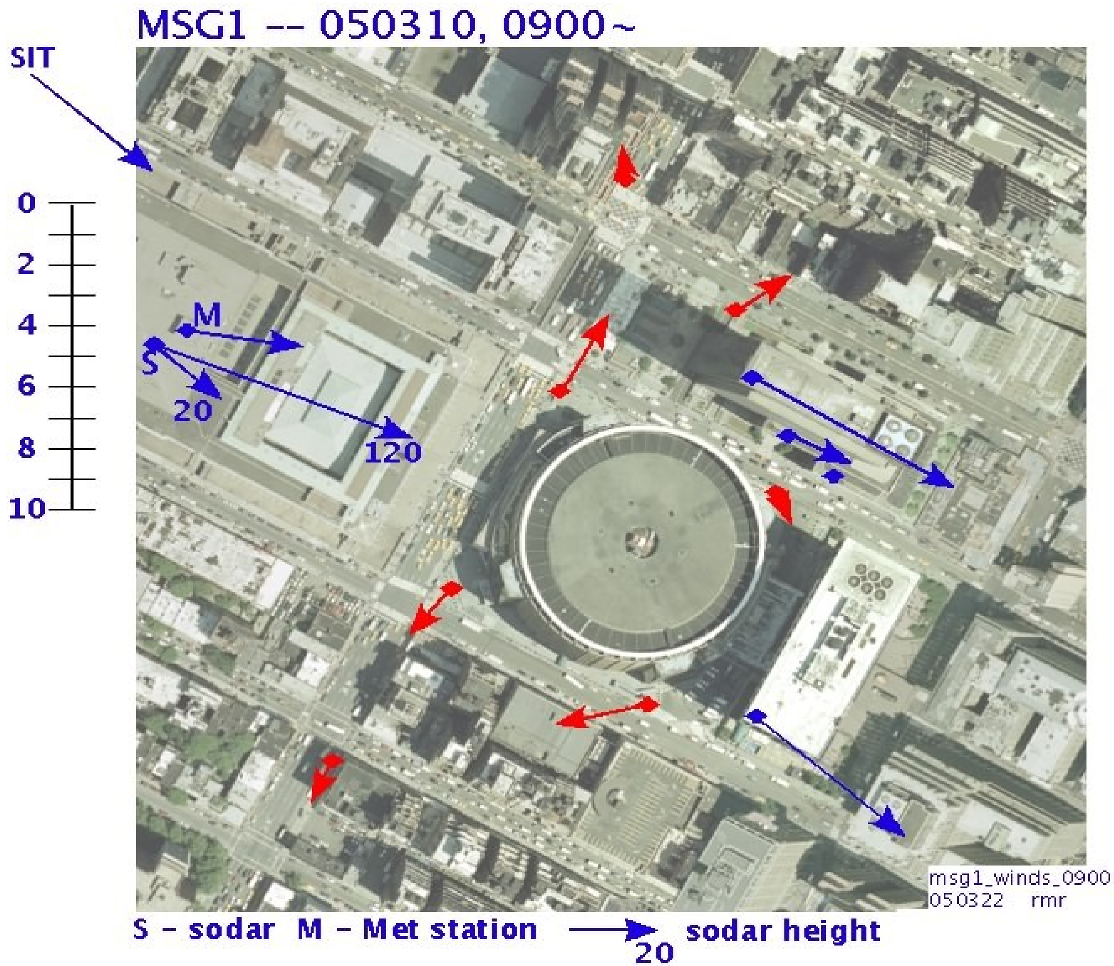
        - which station(s) to use?

        - how to obtain vertical profile?

    - mesoscale models

        - are they accurate enough?

Input Uncertainties

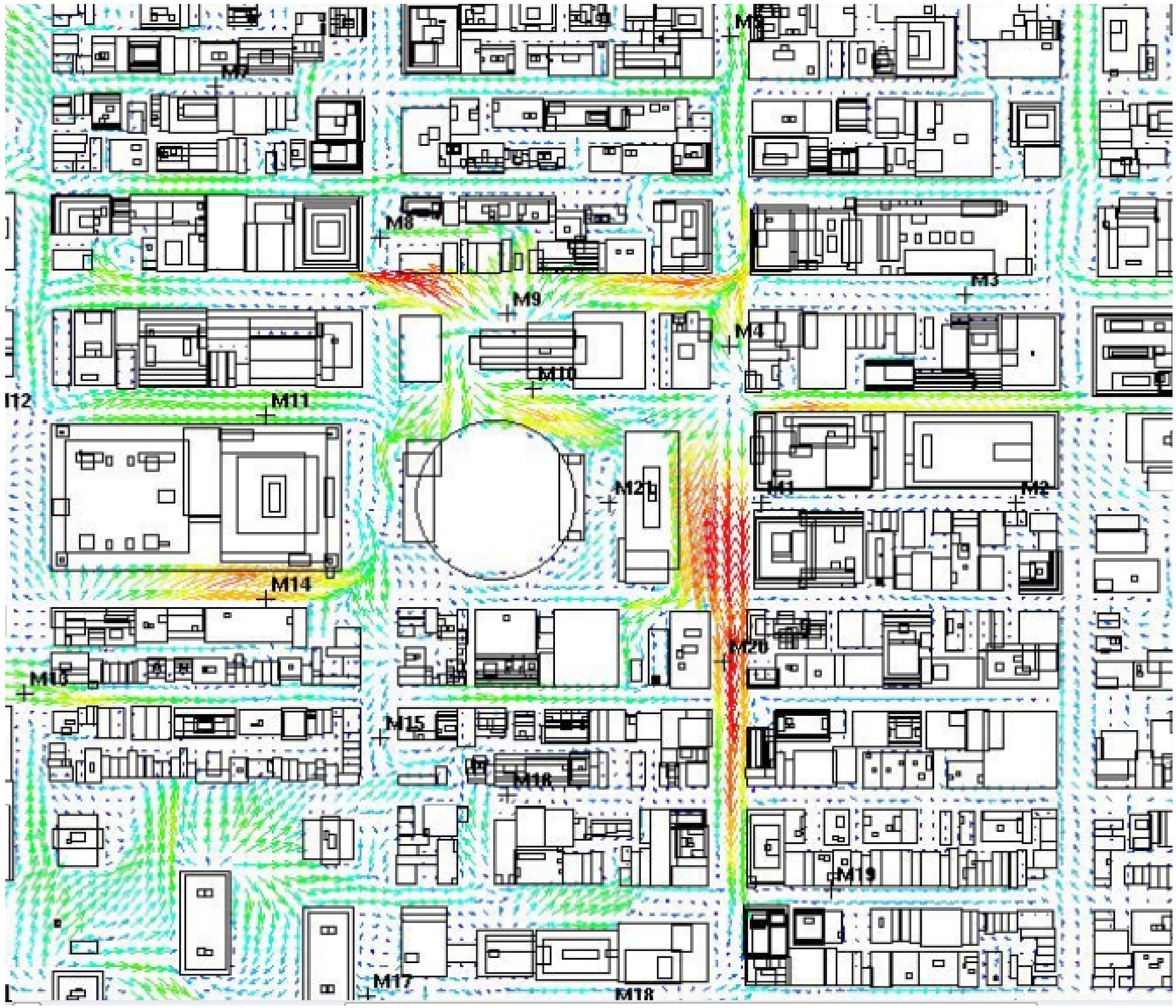


Site	Name	IOP01 WD deg	IOP02 WD deg	Comment
R1	One Penn Plaza	286	327	Tall rooftop (233 m)
R2	Two Penn Plaza	306	318	In OPP wake 02 (133 m)
R3	Post Office	281	269	In bldg wake 02 (34 m)
CCNY		266	309	Open rooftop (50 m)
SIT		297	335	Open rooftop (52 m)
EML		286	323	Open rooftop (75 m)
LBR	Lehmann	286	308	Open rooftop (200 m)
JFK		290	320	Flat airport (3.4 m)
range		40 deg.	30 deg.	

from Hanna (2005) and M. Reynolds – NYC UDP

Wind Uncertainty Impact

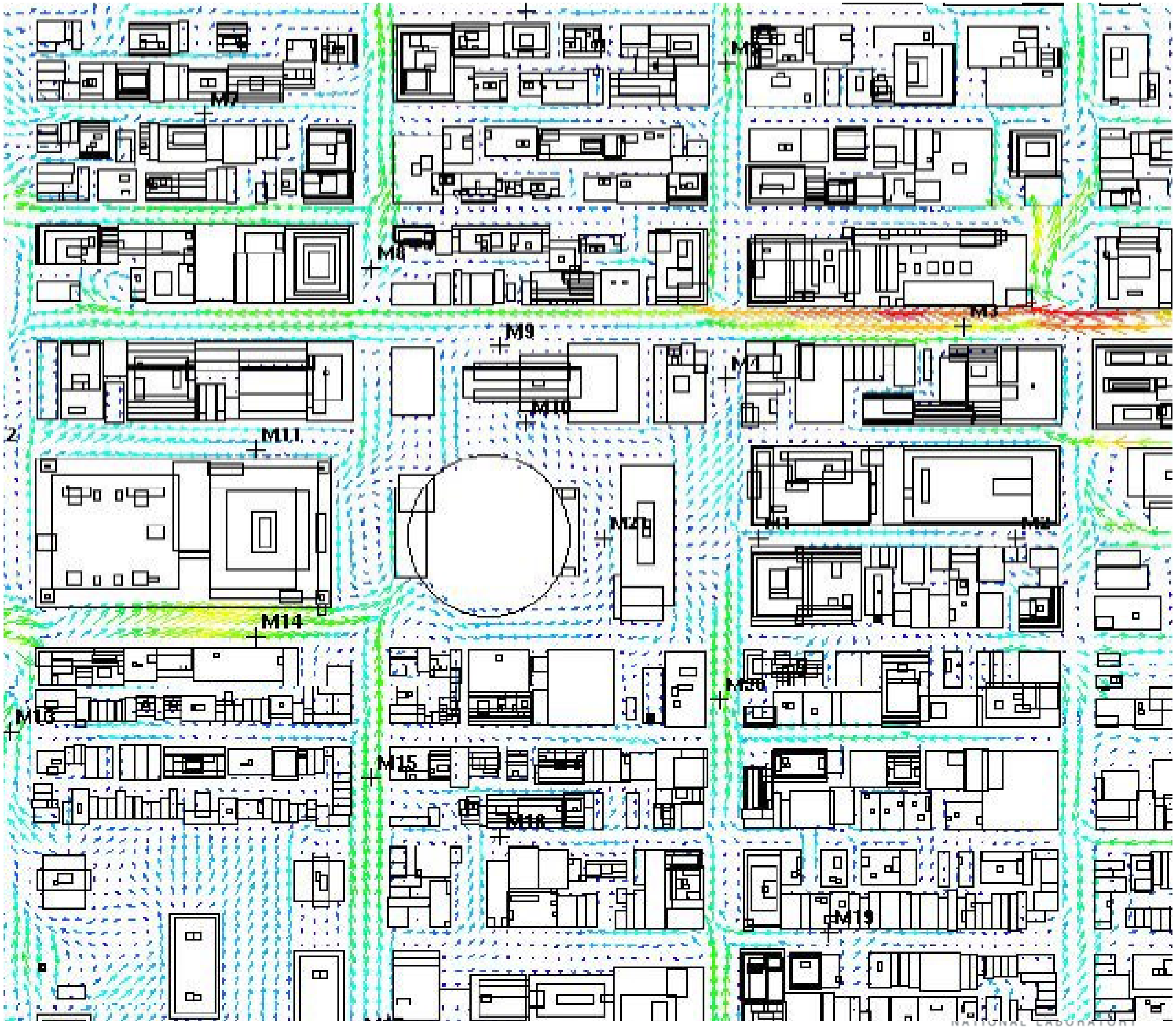
Inflow
WD = 15 deg.



from Olav Hansen (2005)
Gexcon FLACS CFD

Wind Uncertainty Impact

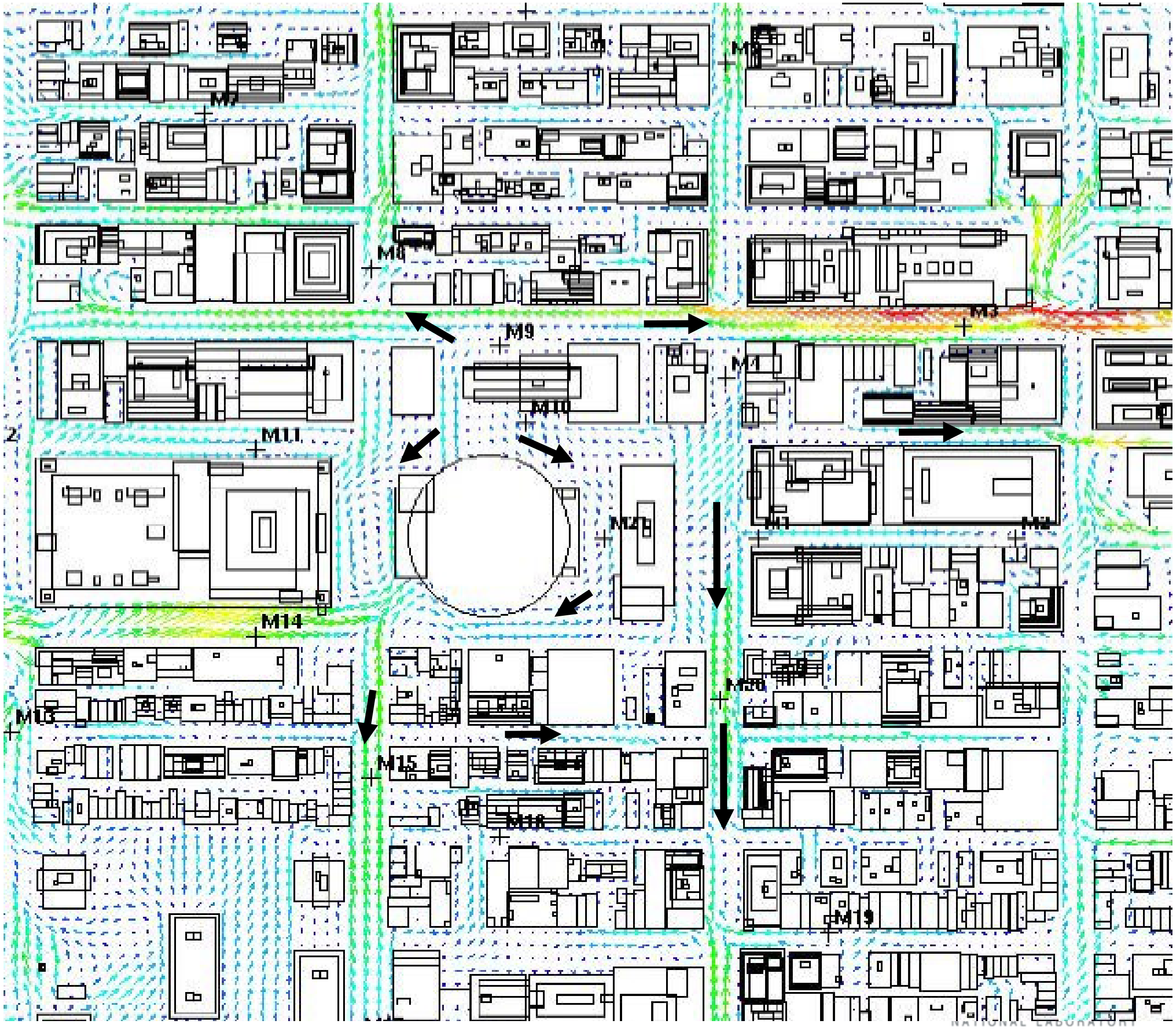
Inflow
WD = 30 deg.



from Olav Hansen (2005)
GexCon FLACS CFD

Wind Uncertainty Impact

Inflow
WD = 30 deg.



from Olav Hansen (2005)
GexCon FLACS CFD

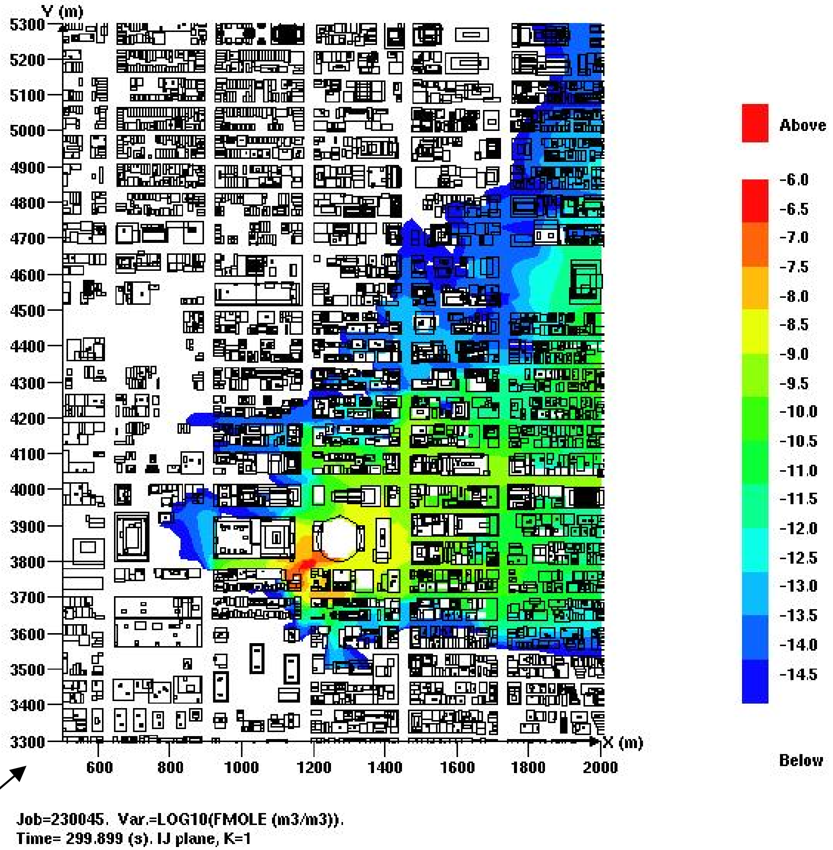
Input Uncertainties

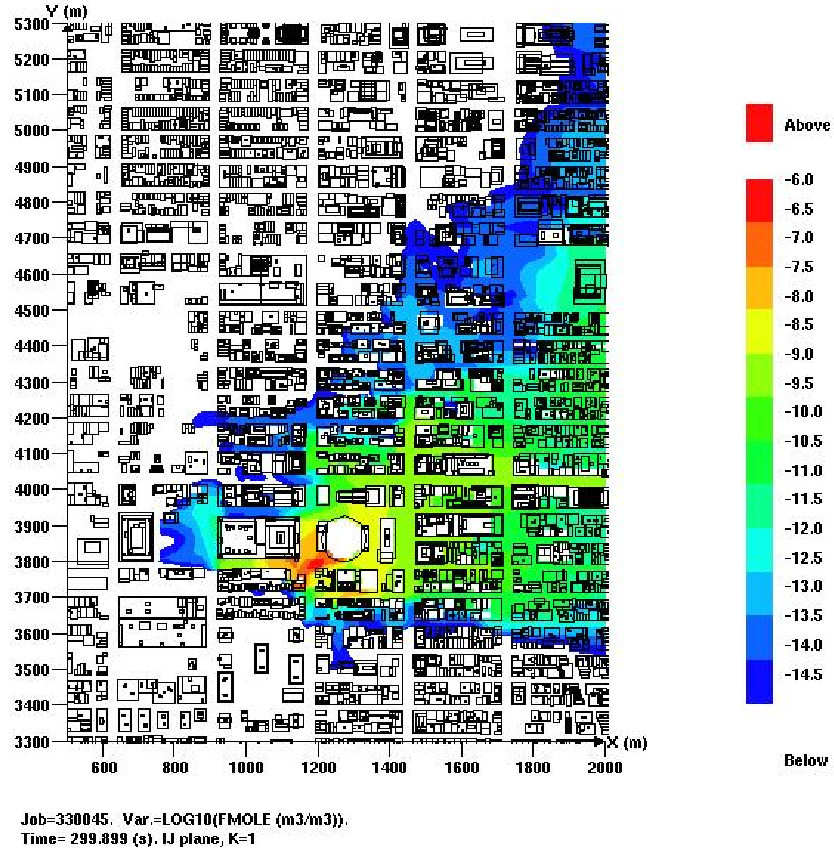
*** Other urban dispersion model input**

- Mesoscale Wind Meander?
- Background Turbulence?
- Mean horizontal velocity profile shape (variation with height)?
- Stability (stratification)?

Wind Meander Impact

CFD simulations w/ and w/out inflow meander



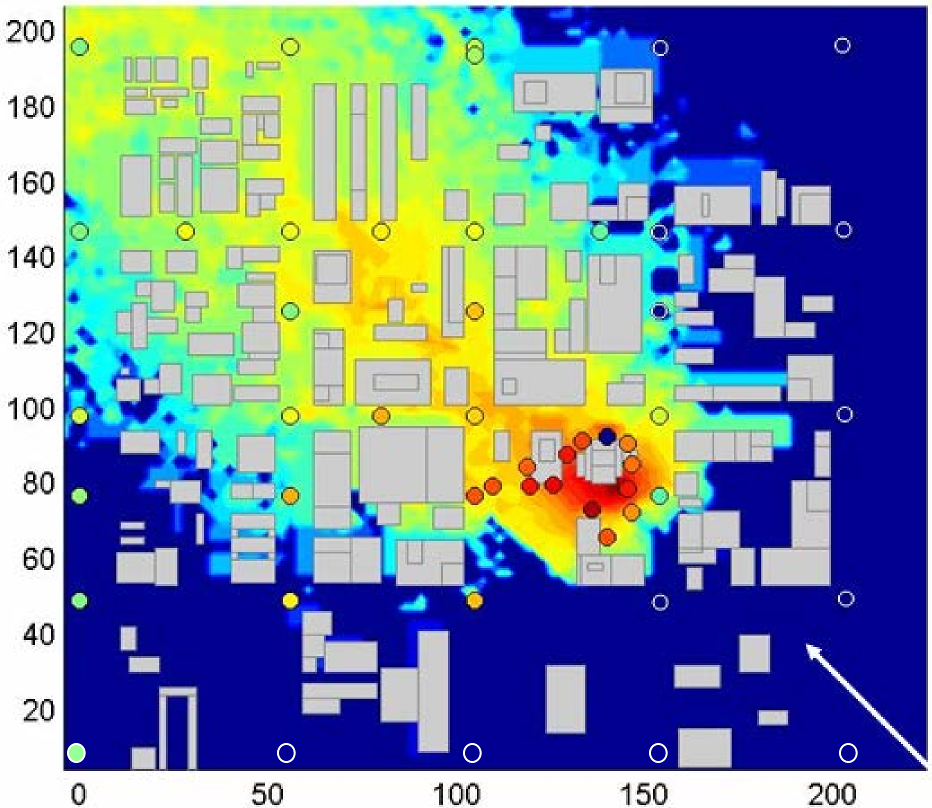


Fluctuating wind **300s** **Steady wind**

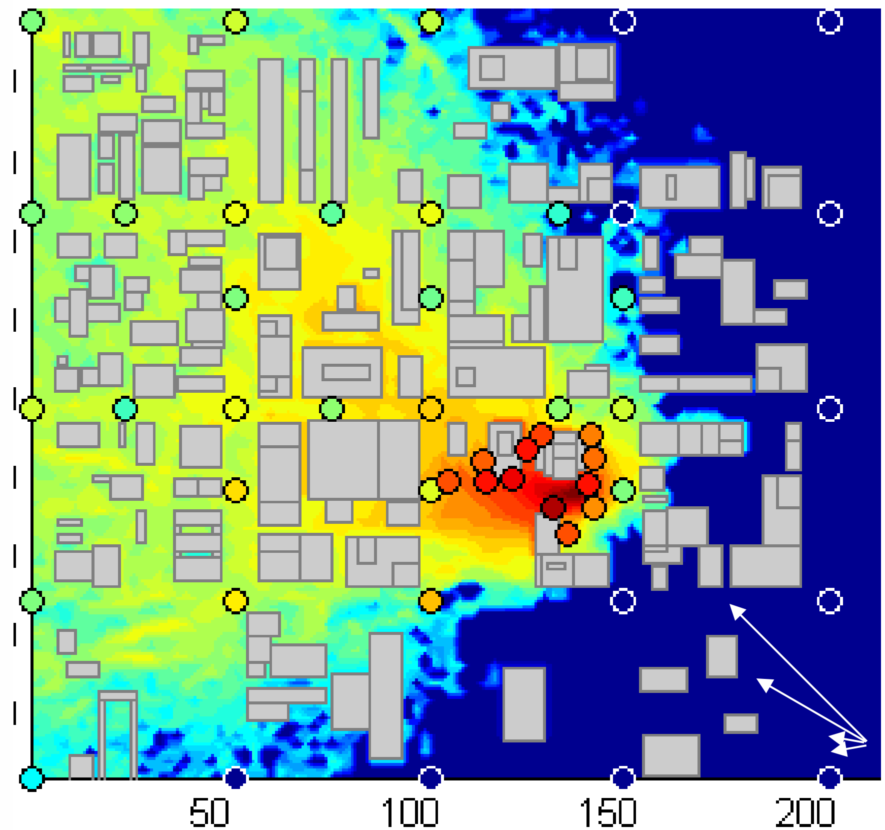
from Olav Hansen (2005) – Gexcon FLACS CFD

Wind Meander Impact

No mesoscale meander



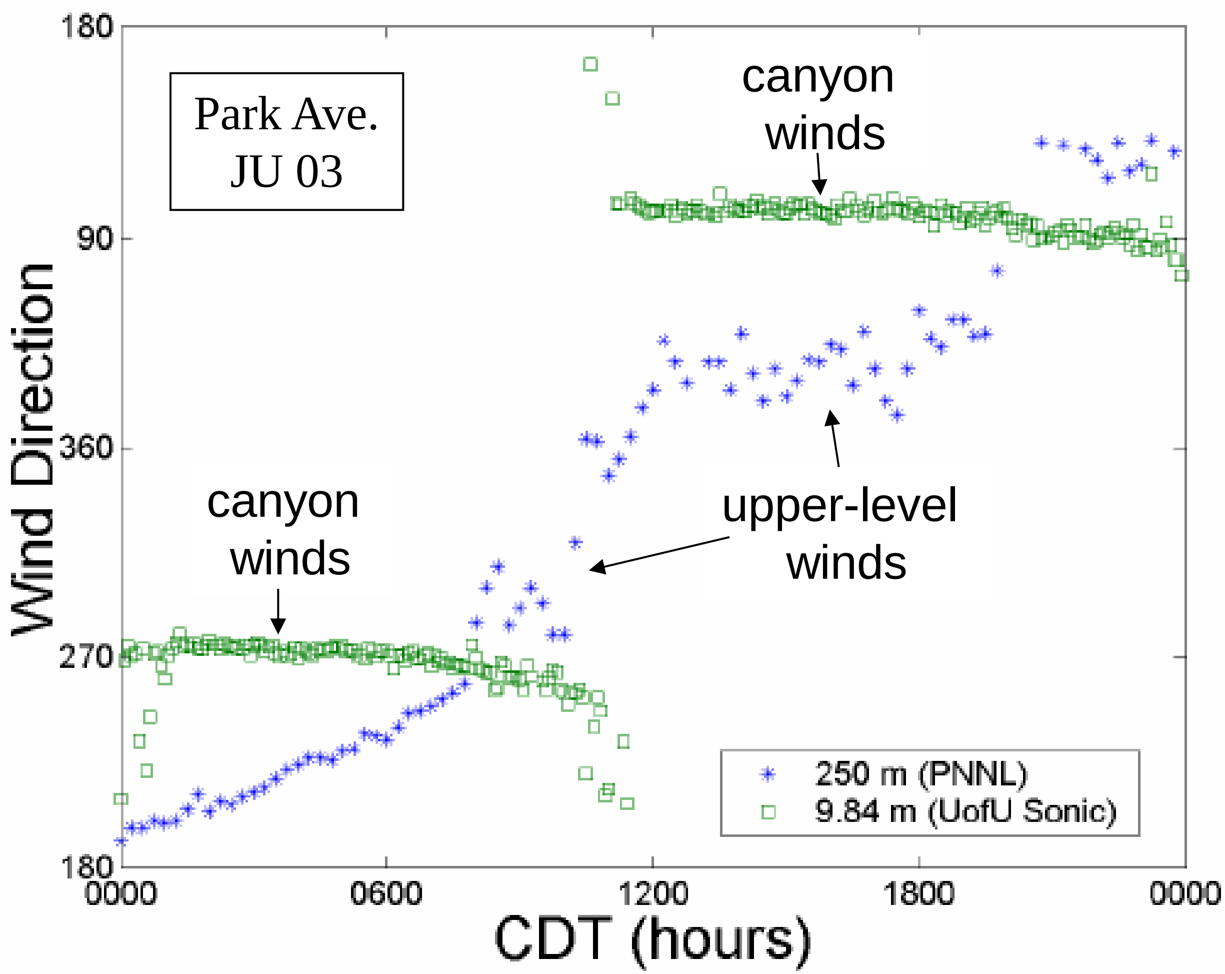
Mesoscale meander



Gowardhan et. al. (2005) - SLC Urban 2000

WD – Aloft vs. In-Canyon

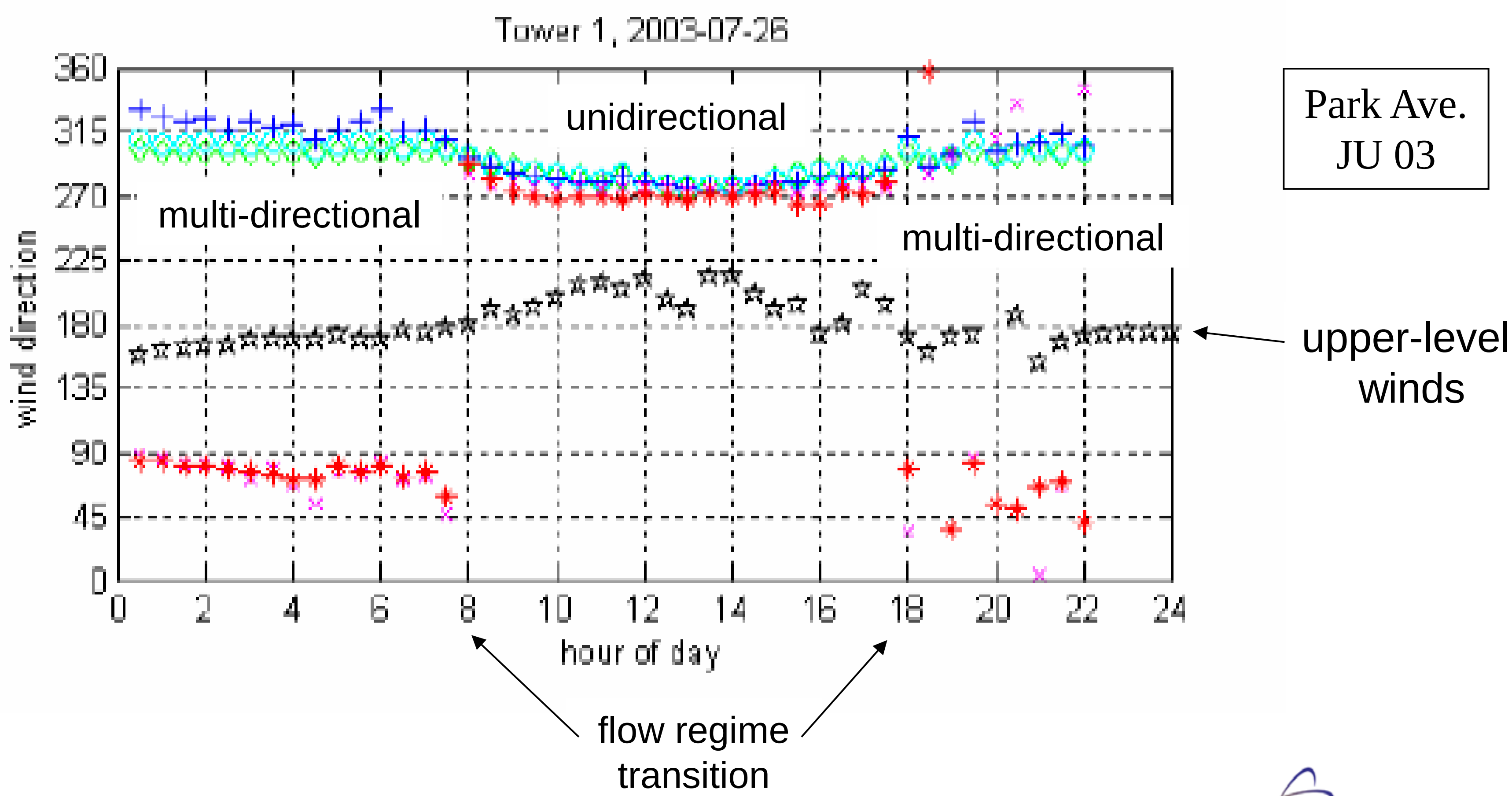
Upper-level WD vs. street canyon wind direction



from Pol et. al. (2004)

WD – Aloft vs. In-Canyon

Upper-level WD vs. street canyon tower WD



from Kastner-Klein and Clark (2004)

Wind Uncertainty Impact

Wind direction variation in street canyon

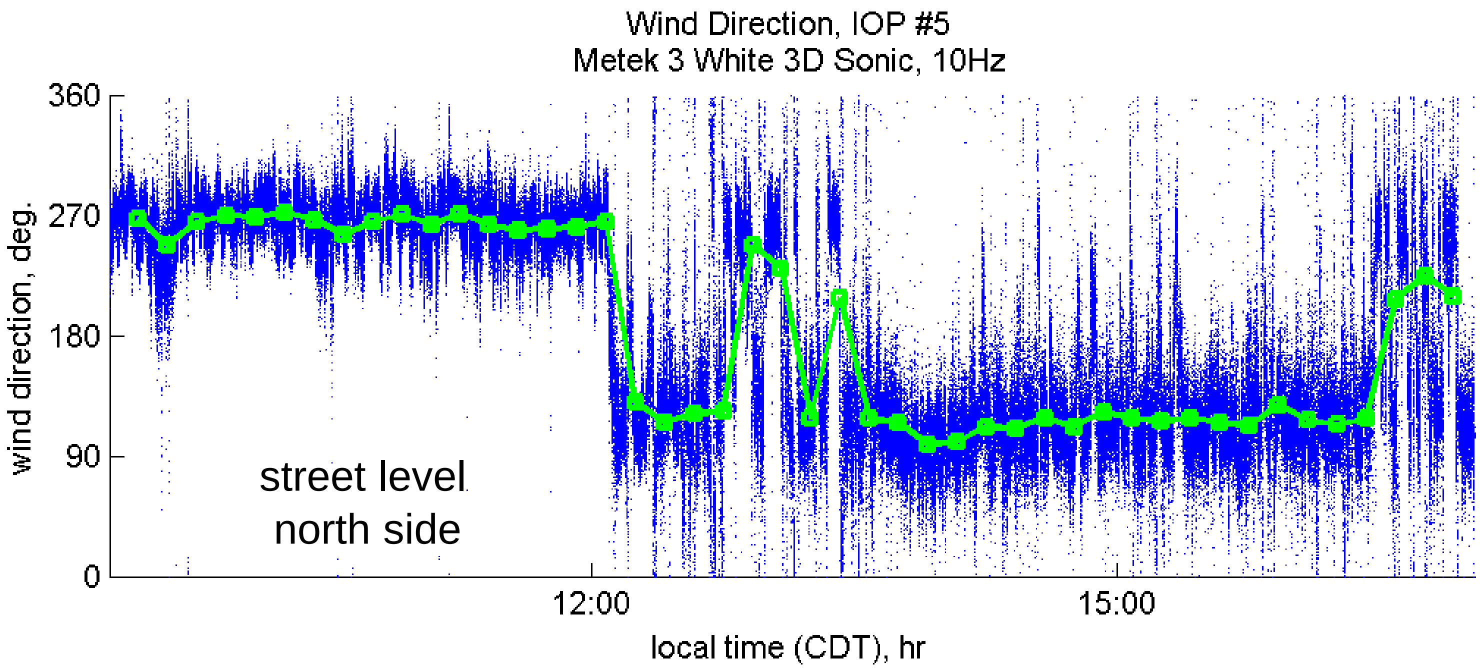


Fig. 6. Wind direction time series (blue - 10 Hz and green - 10 min. avg.) for a 3D sonic in the Park Avenue street canyon at street level on the northern side. Joint Urban 2003.

from Brown et al. (2004)

Physics Limitations

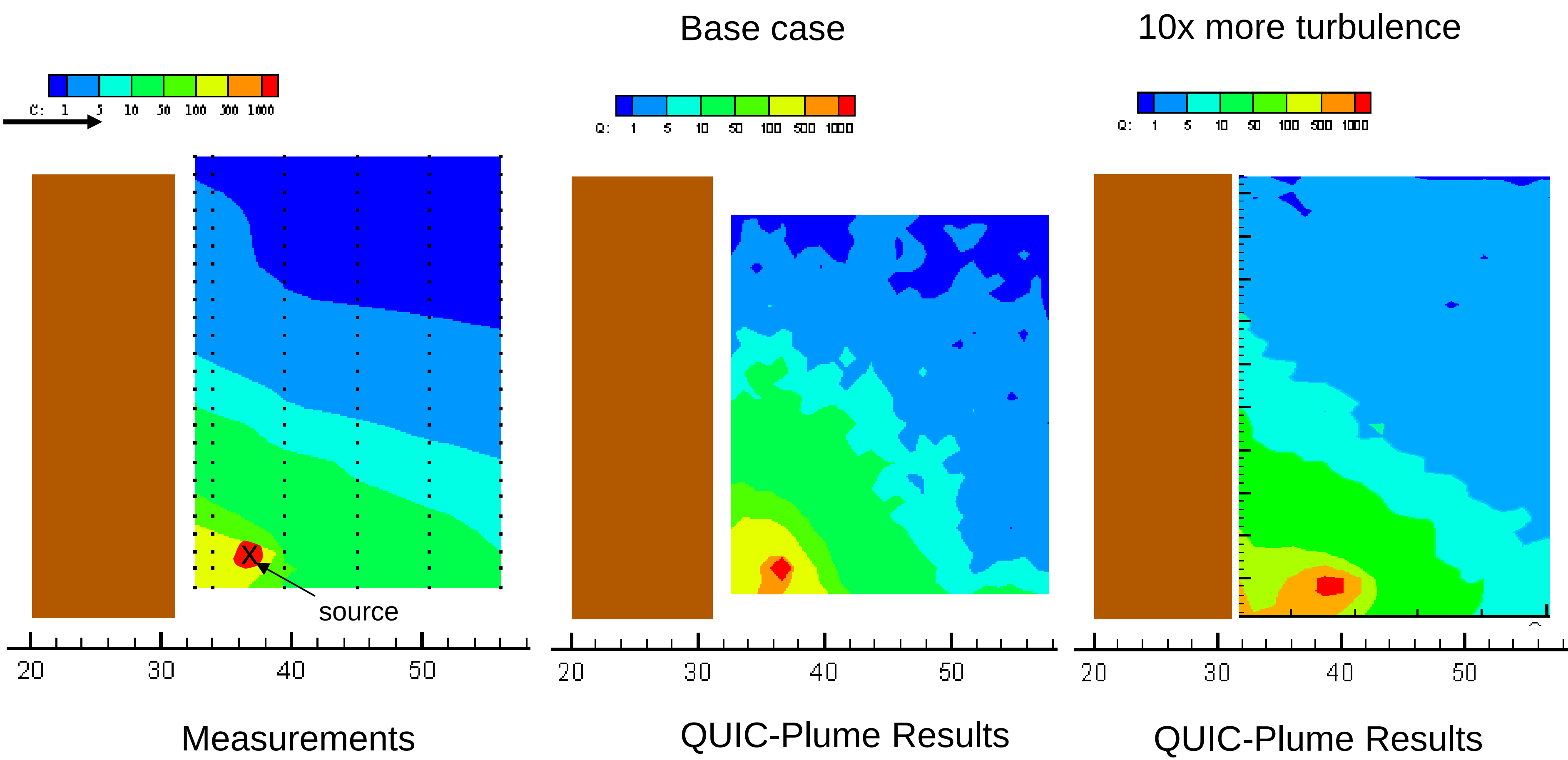
* Turbulence scheme?

* Heating/cooling of building & street surfaces?

Note: this really depends on the model type, ranging from Gaussian plume modeling to Large Eddy Simulation, and the problem type

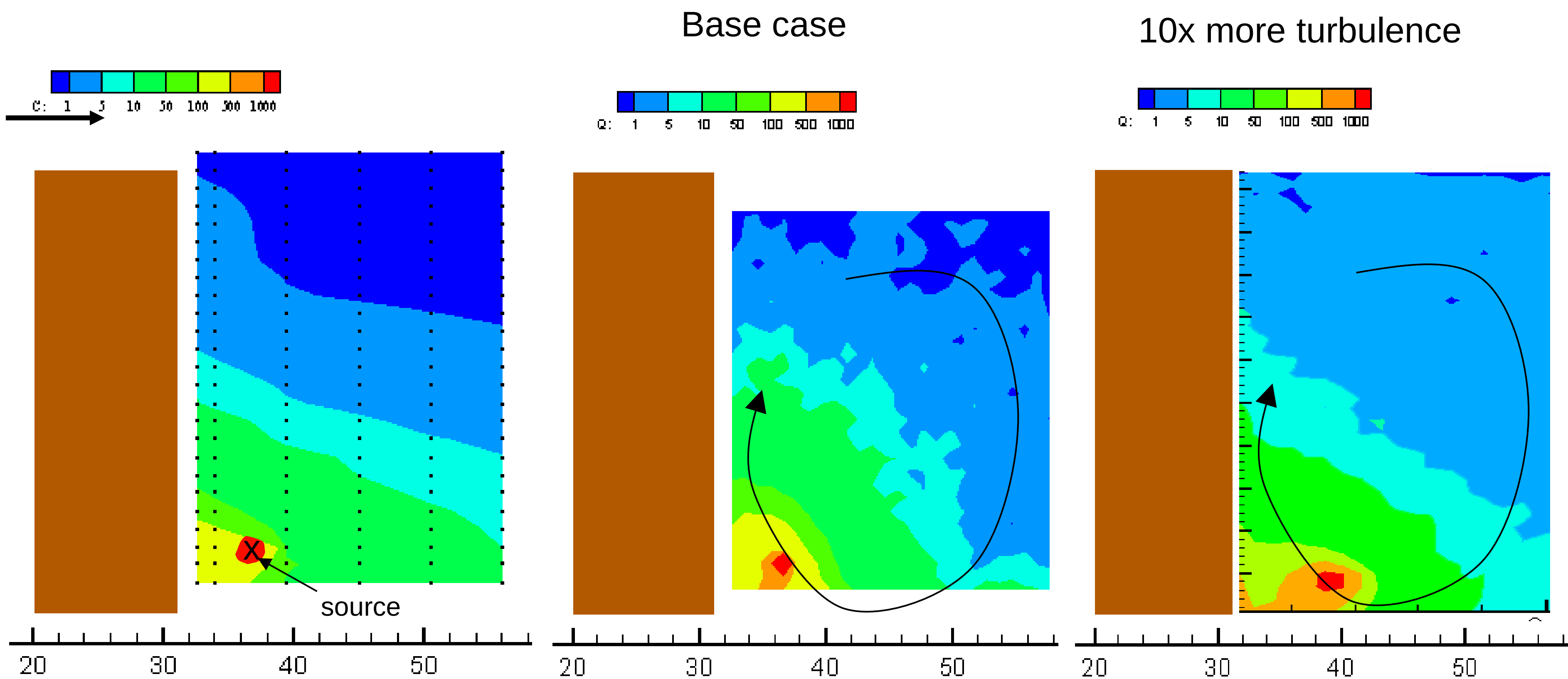
Physics Limitations

* Turbulence scheme?



Physics Limitations

* Turbulence scheme?



Measurements

QUIC-Plume Results

QUIC-Plume Results

Statistical Uncertainty

* Concentration fluctuations / peak concentrations

* Instantaneous / short duration releases

* Intermittent or non-local mixing processes, counter-gradient transport

* Comparison to short-time-interval mean data

Turbulent Variability

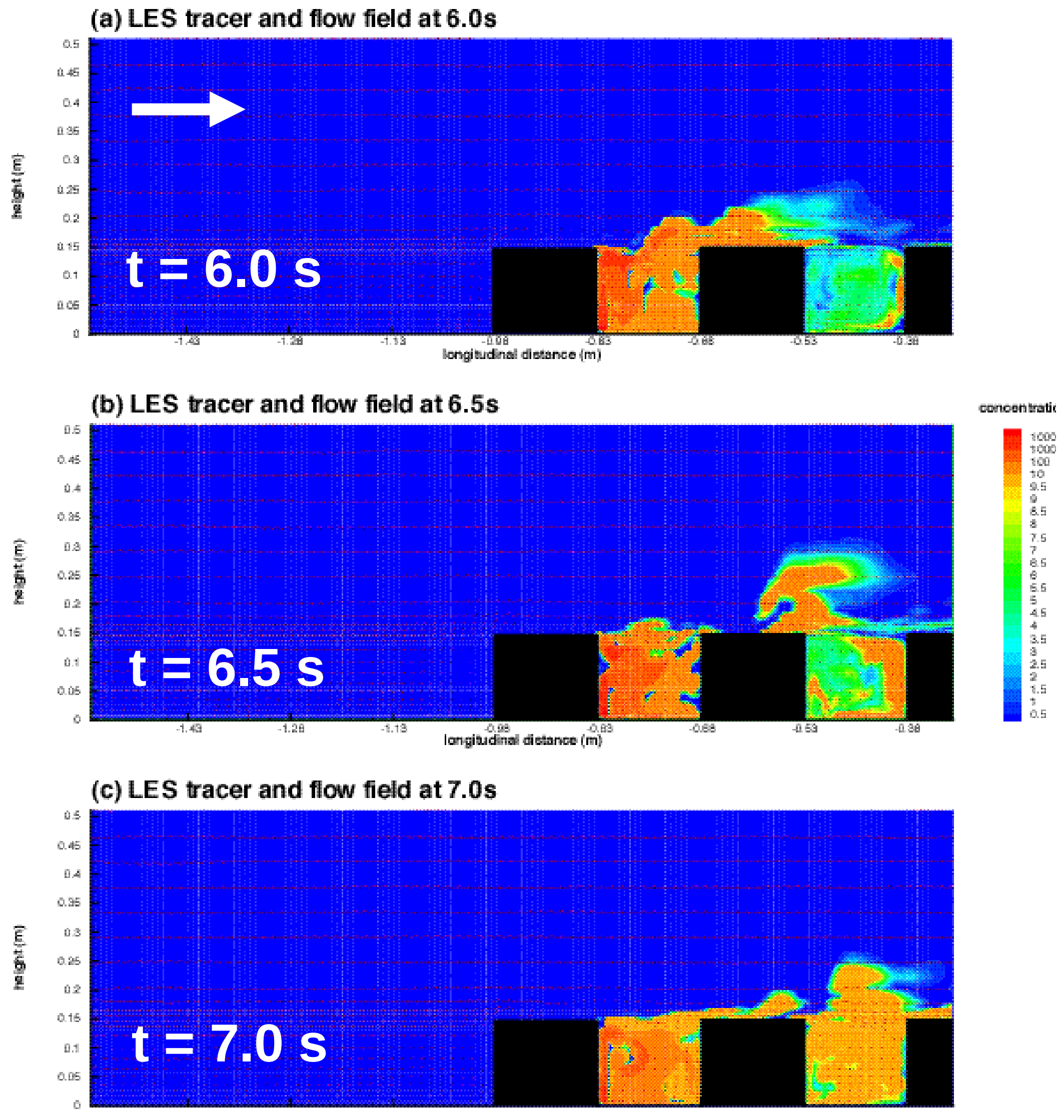
* USEPA Fluid Modeling Facility

Release on downwind side of building
in cavity zone near back wall

Turbulent Variability

* HIGRAD LES simulations for cube array

- intermittent non-local mixing



Release at street level in first canyon (Smith et al., 1999).

Turbulent Variability

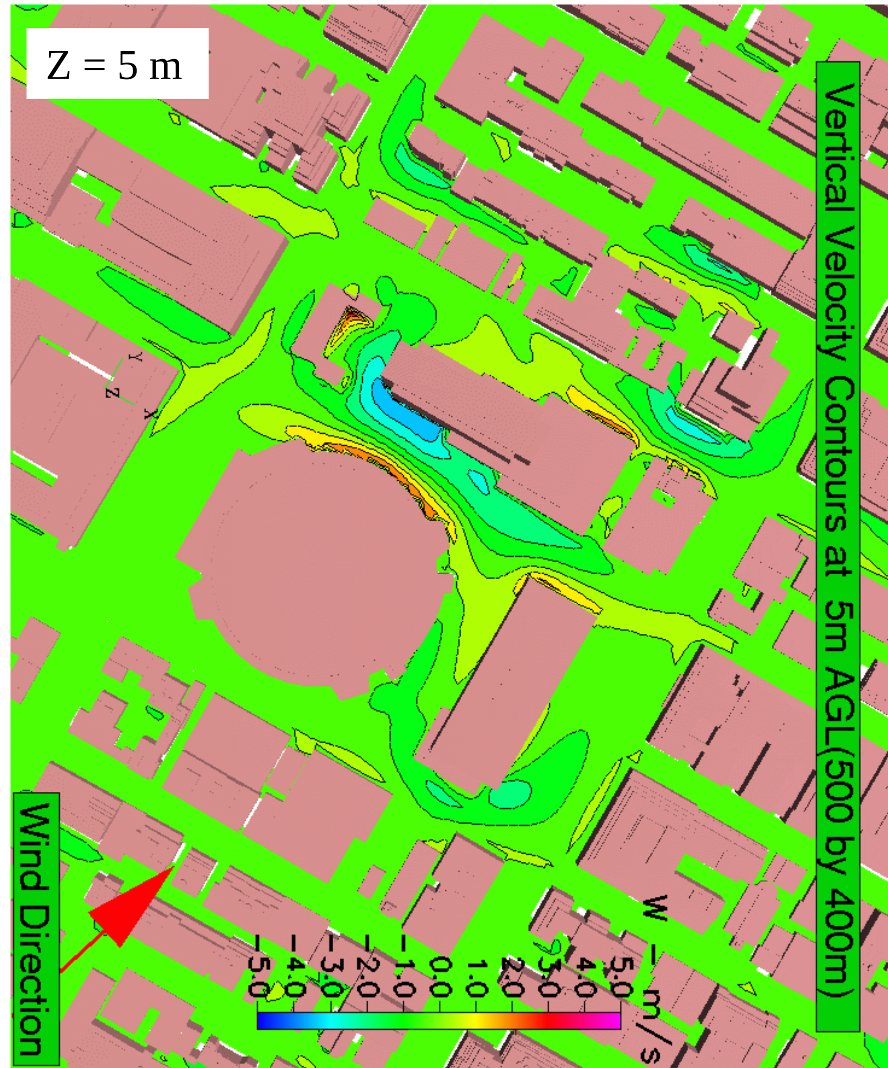
* k-epsilon RNG simulation

(Coirier & Kim, 2005)

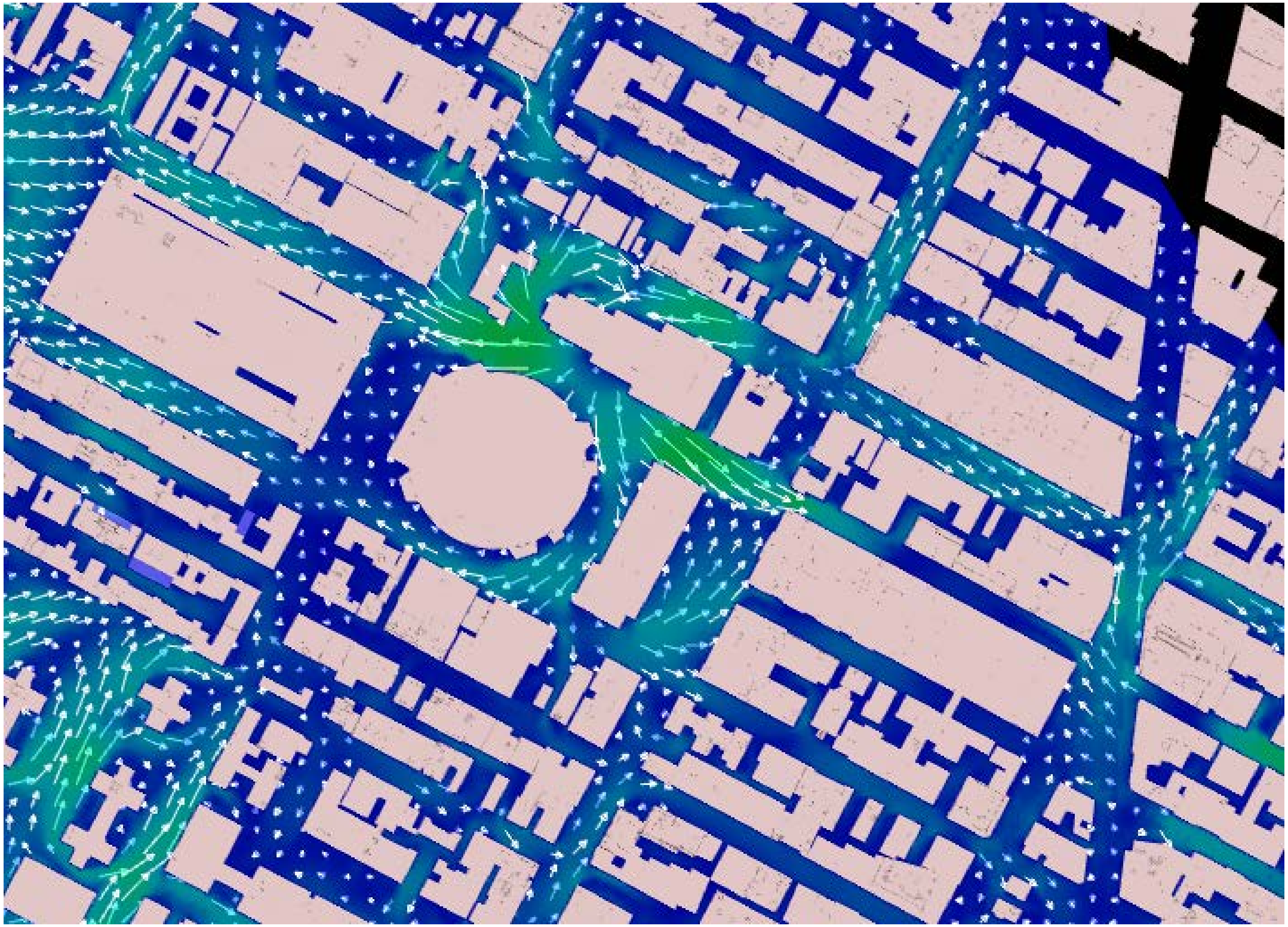
Turbulent Mixing vs.

Advective "Mixing"

Mean Vertical Velocity

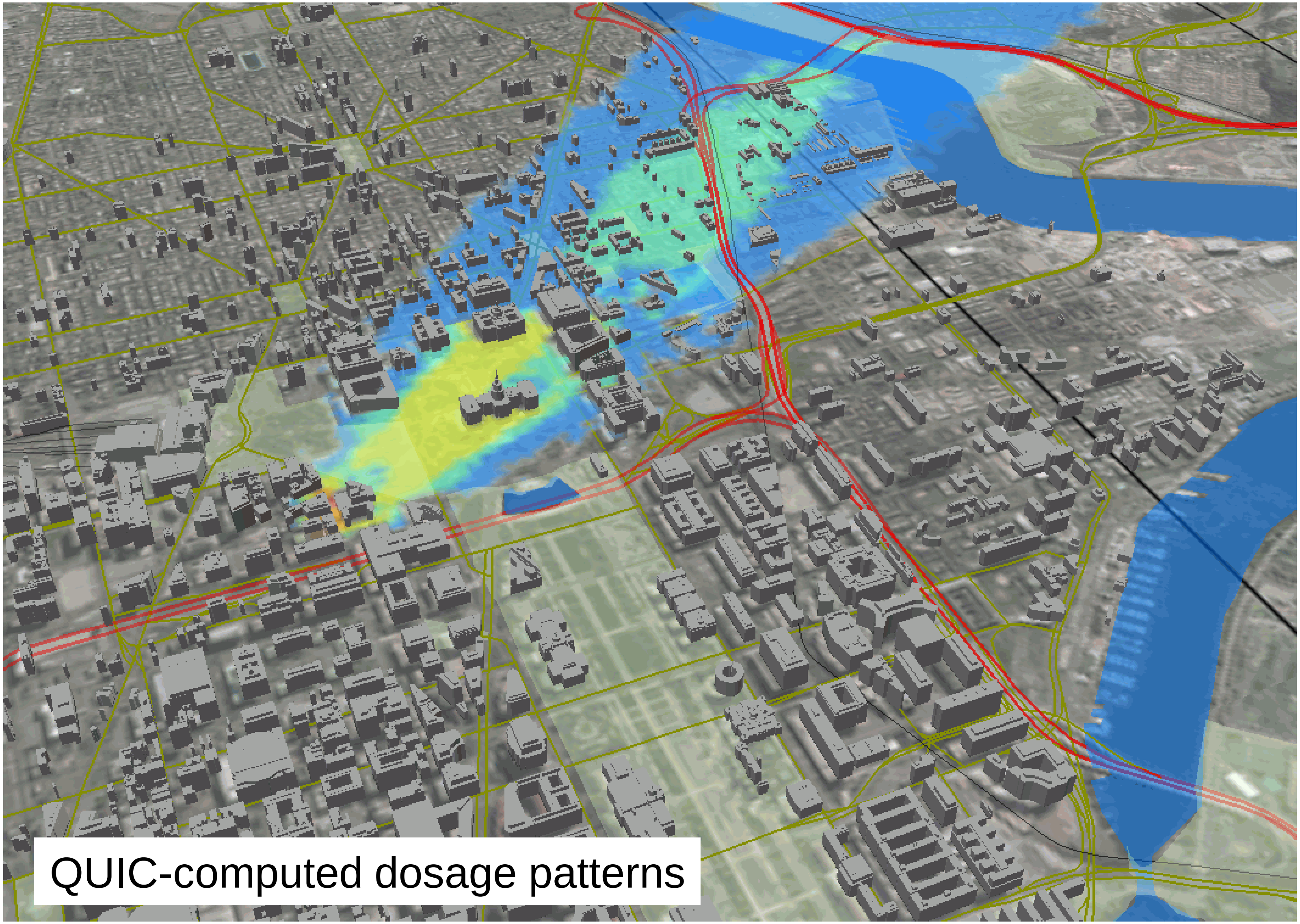


Turbulent Variability



* FLUENT k-epsilon simulation (Huber, 2005)

Model Input Uncertainties



QUIC-computed dosage patterns

Model Input Uncertainties

* buildings – databases not perfect

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Model Input Uncertainties

- trees?

Model Input Uncertainties

- traffic?

Model Input Uncertainties

- parking garages? grates? subway entrances?

Summary

Uncertainty introduced to urban dispersion modeling through:

*** Inputs to urban dispersion models from larger- scale models or meteorological measurements**

- inflow winds, turbulence, stability
- source term, urban physical parameters

*** Inputs to urban dispersion models from larger- scale models or meteorological measurements**

*** Model physics limitations**

*** Statistical uncertainty due to urban turbulence**

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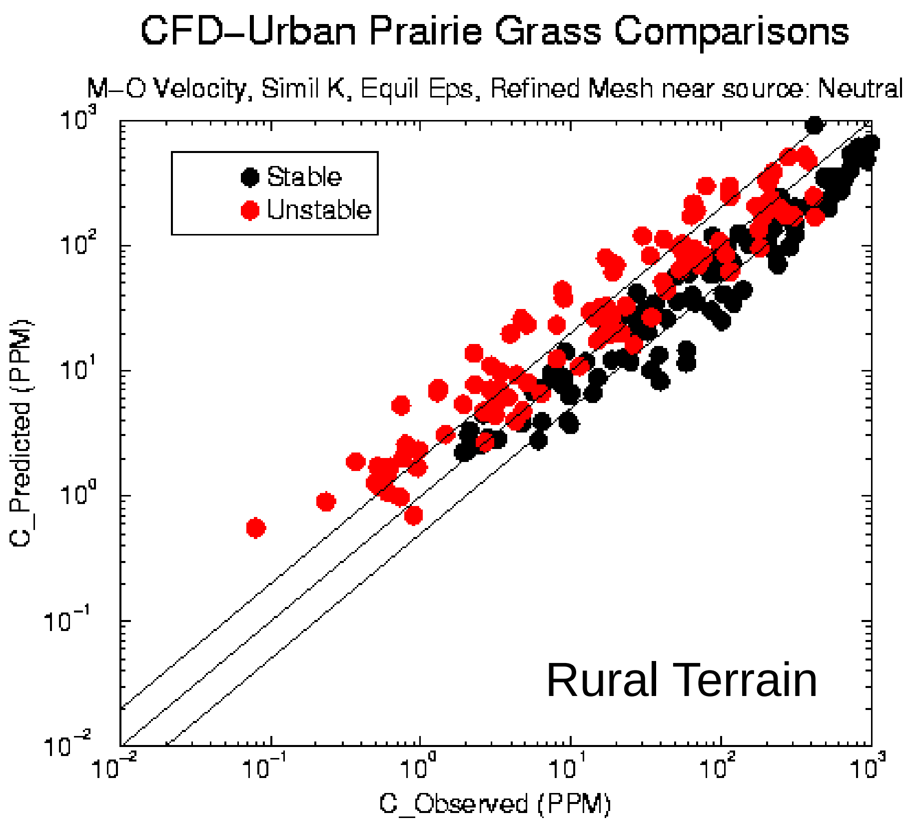
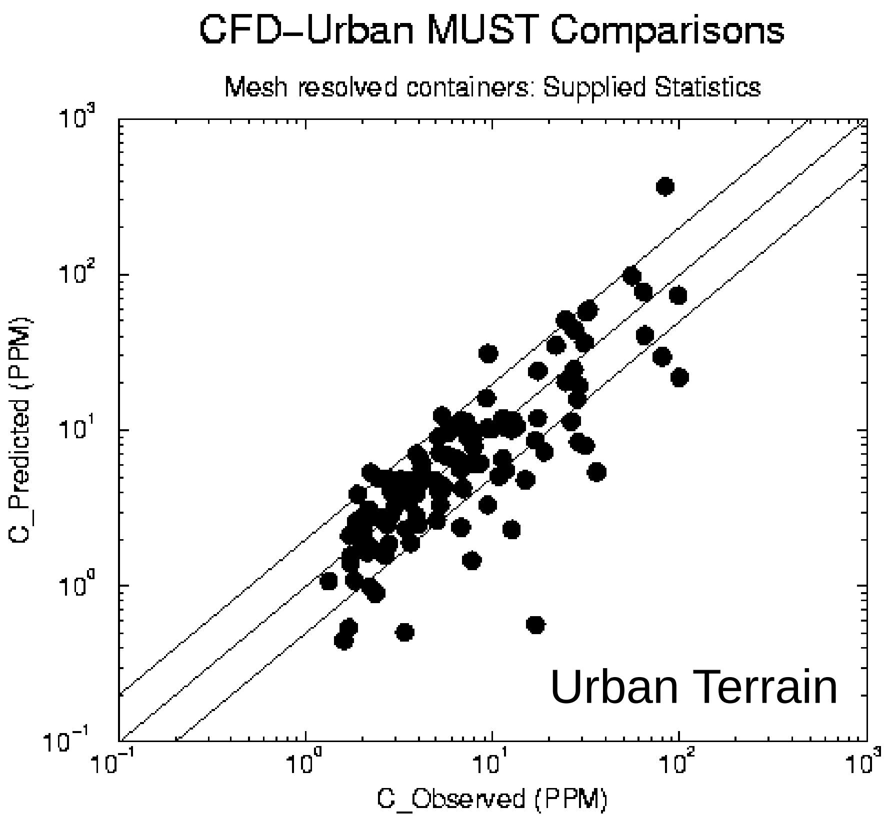
Output Uncertainty

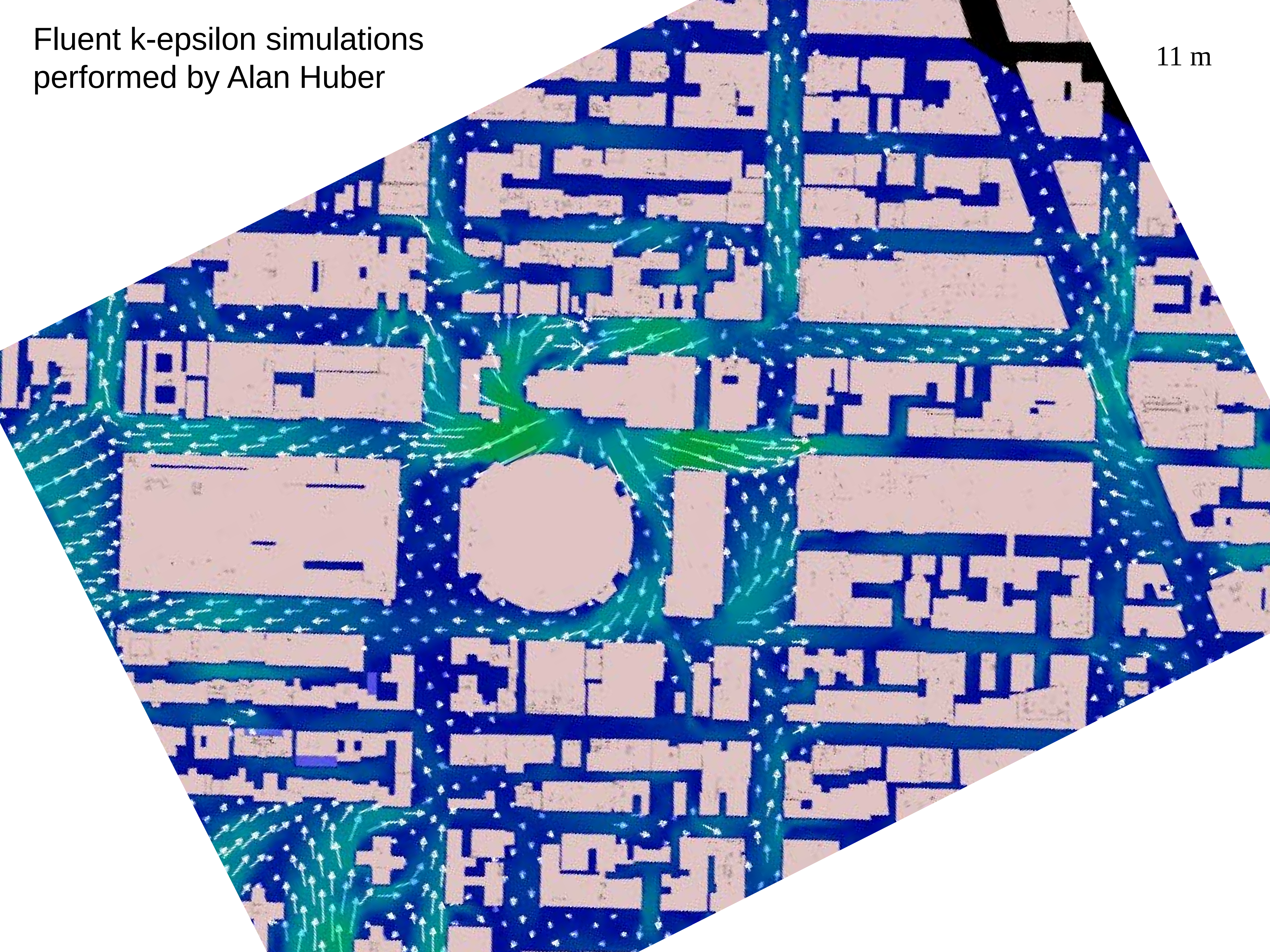
CFD model vs. Rural Terrain & Urban Terrain





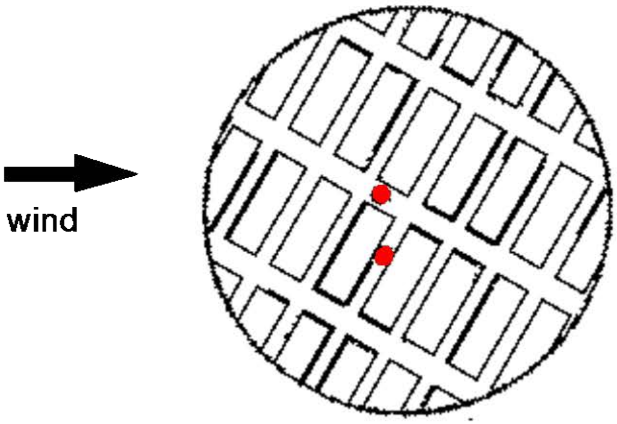
from Coirier (2005) - CFDRC

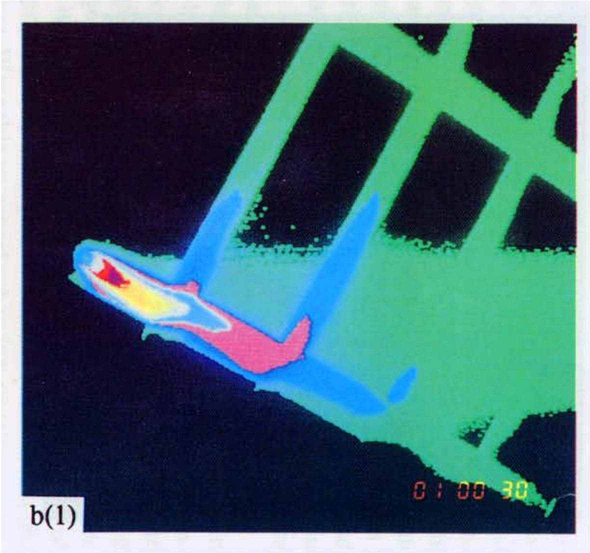
Fluent k-epsilon simulations performed by Alan Huber

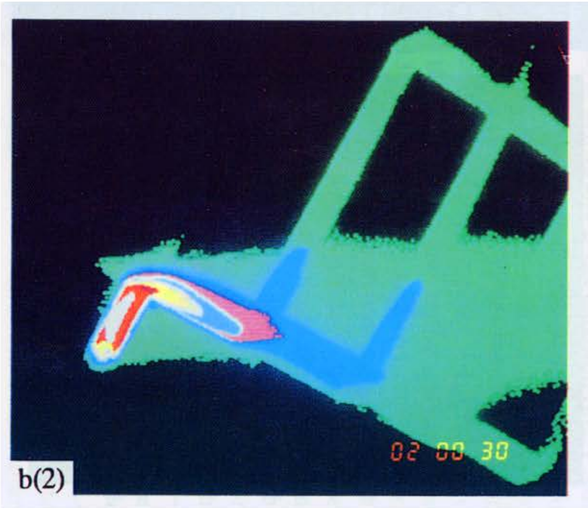


Importance of Building Effects

Wind-tunnel Experiments of Hoydysh and Dabberdt

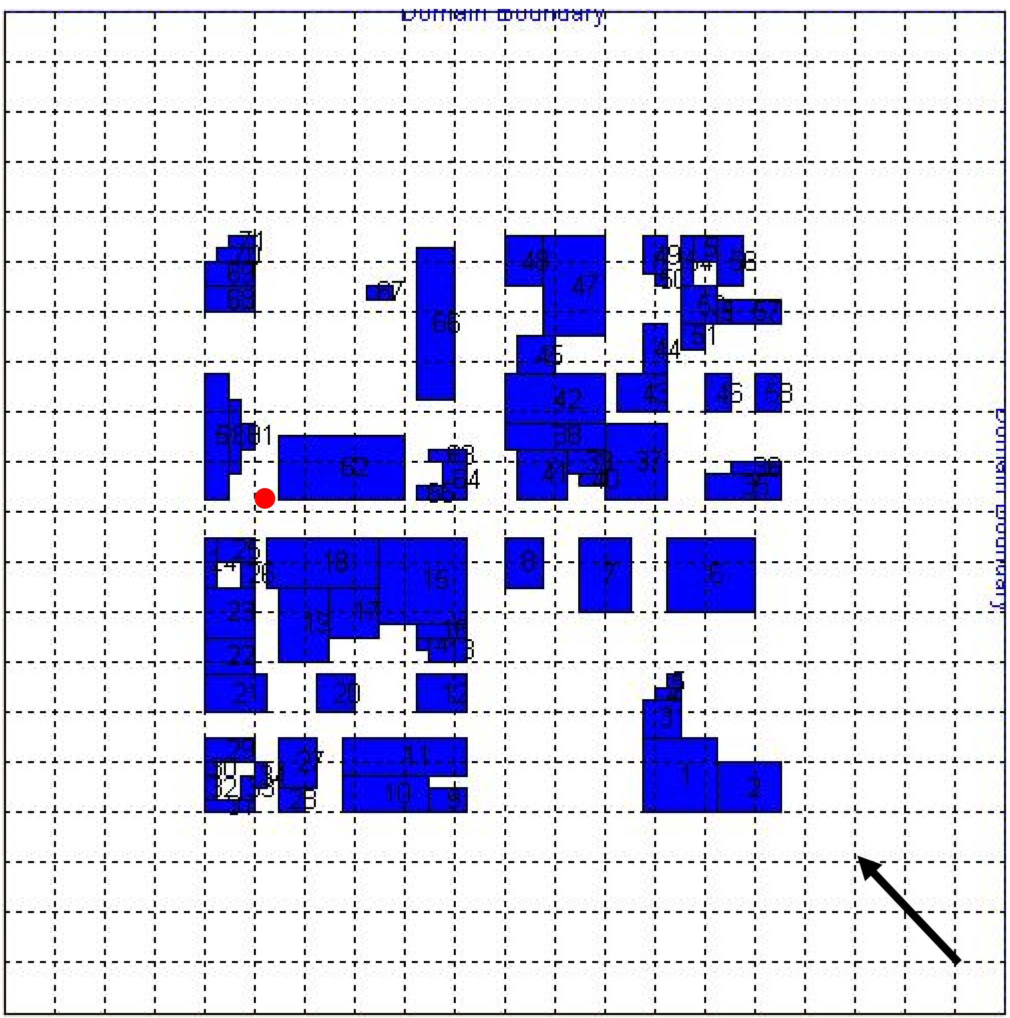




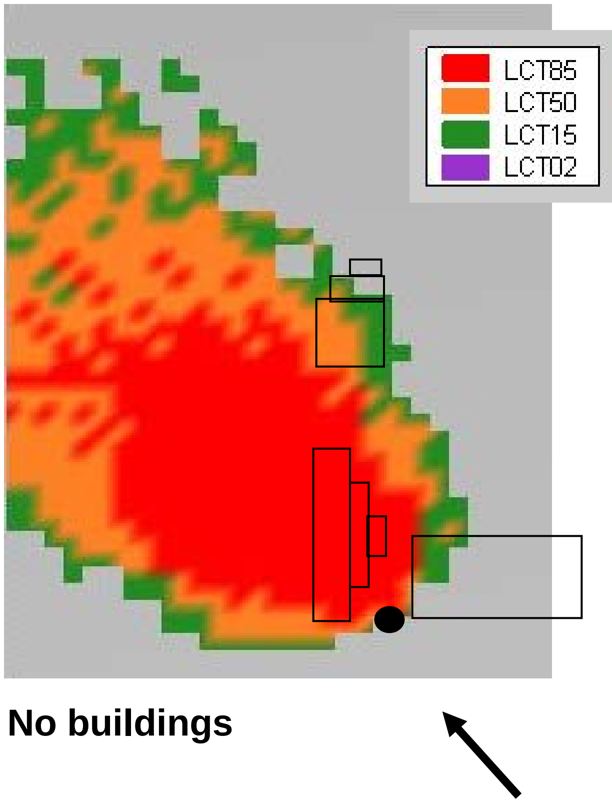


Importance of Building Effects

Downtown SLC

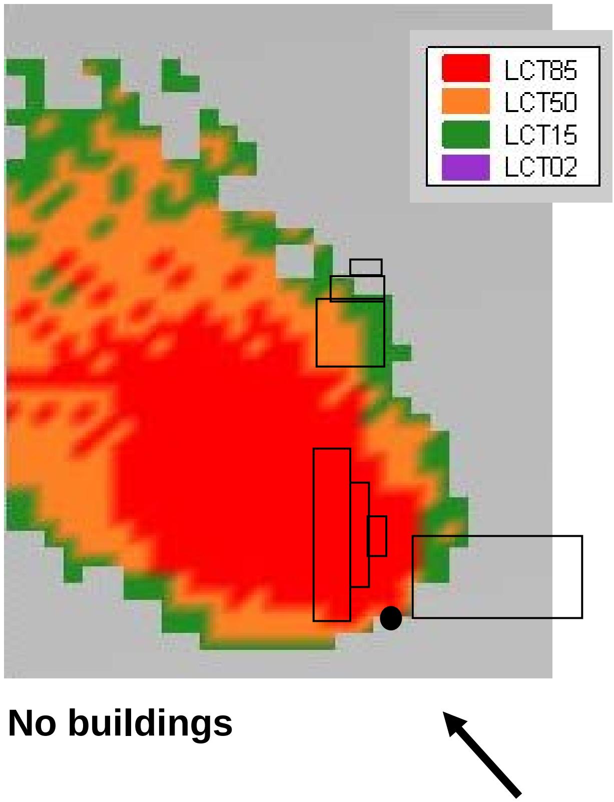


Importance of Building Effects



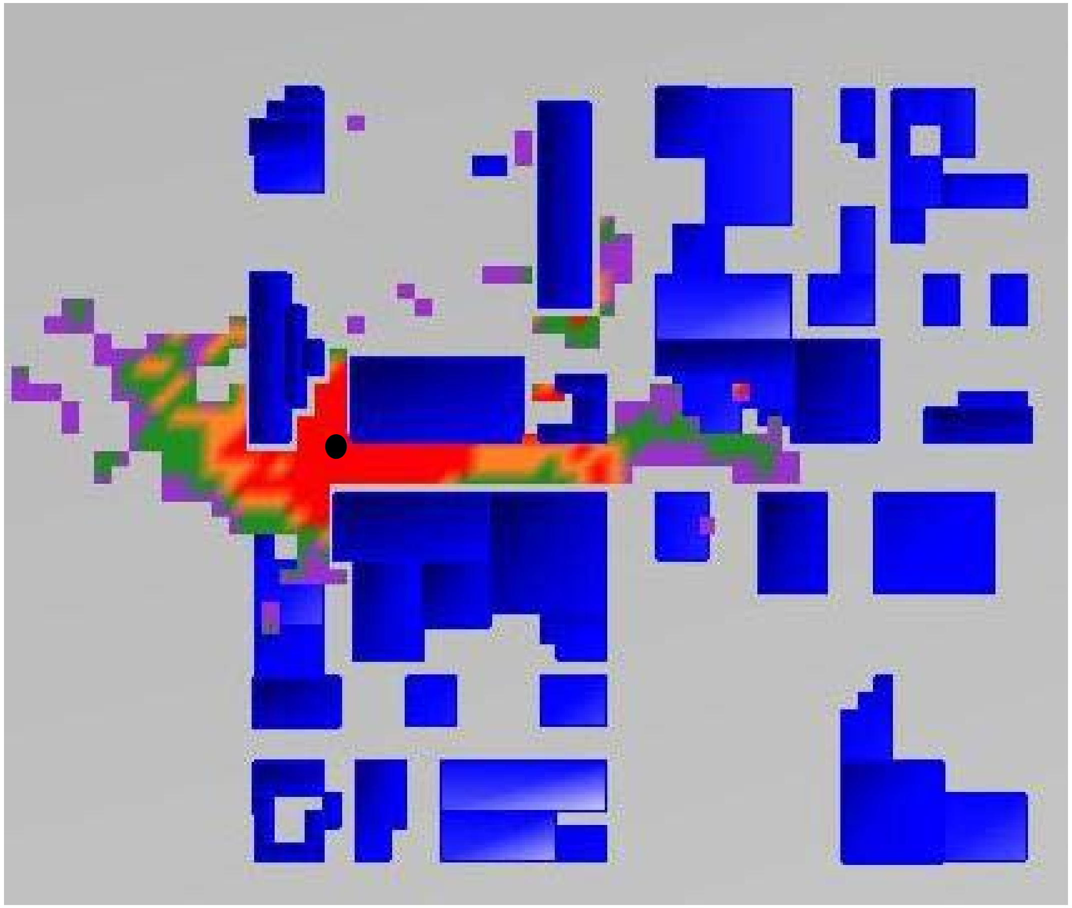
No buildings

Importance of Building Effects

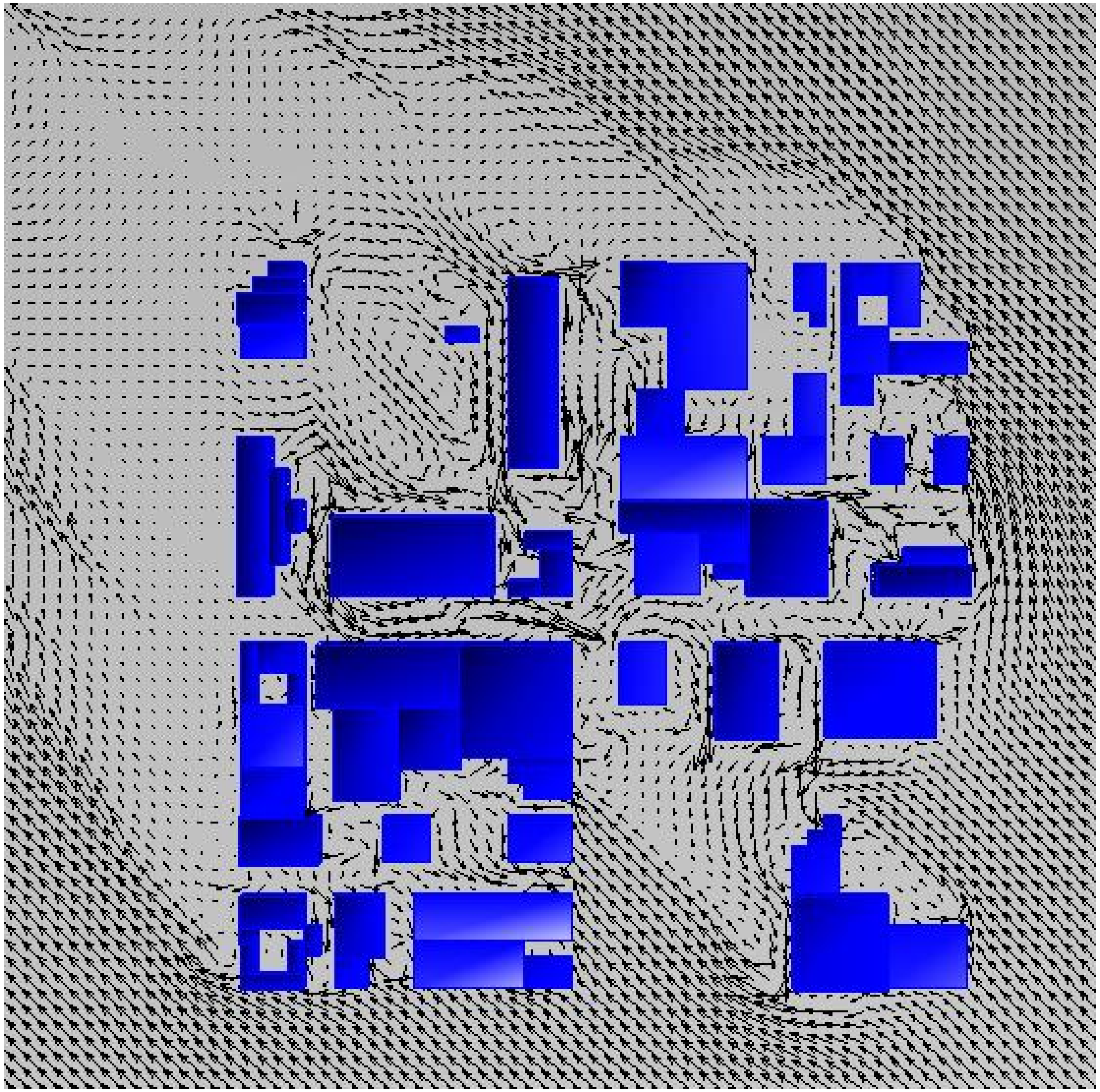


No buildings

QUIC simulation – resolved buildings



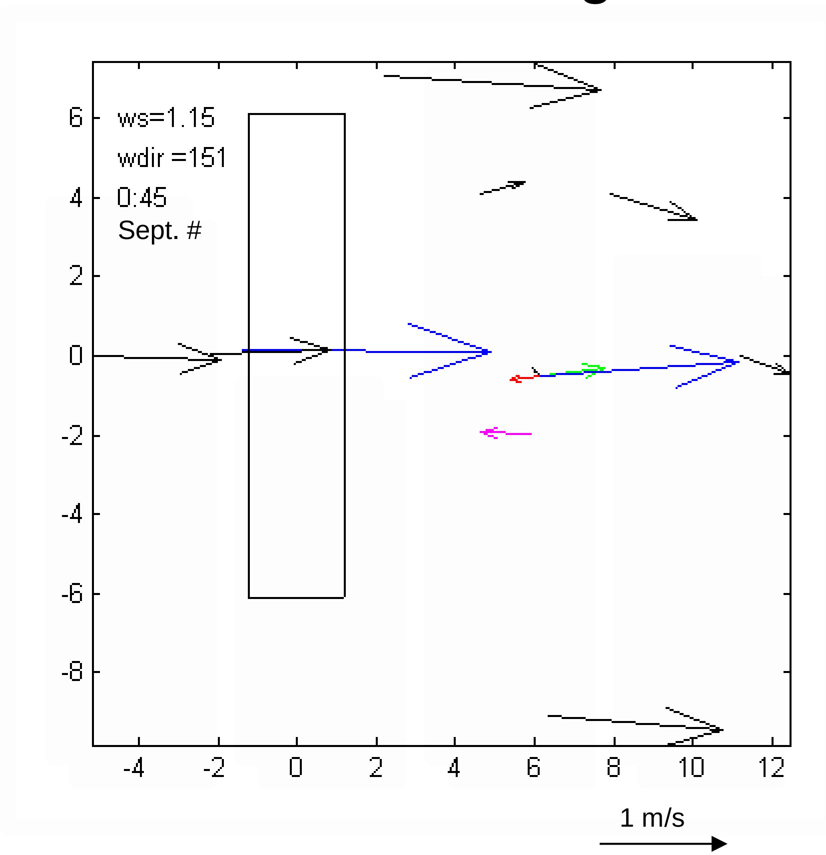
Importance of Building Effects

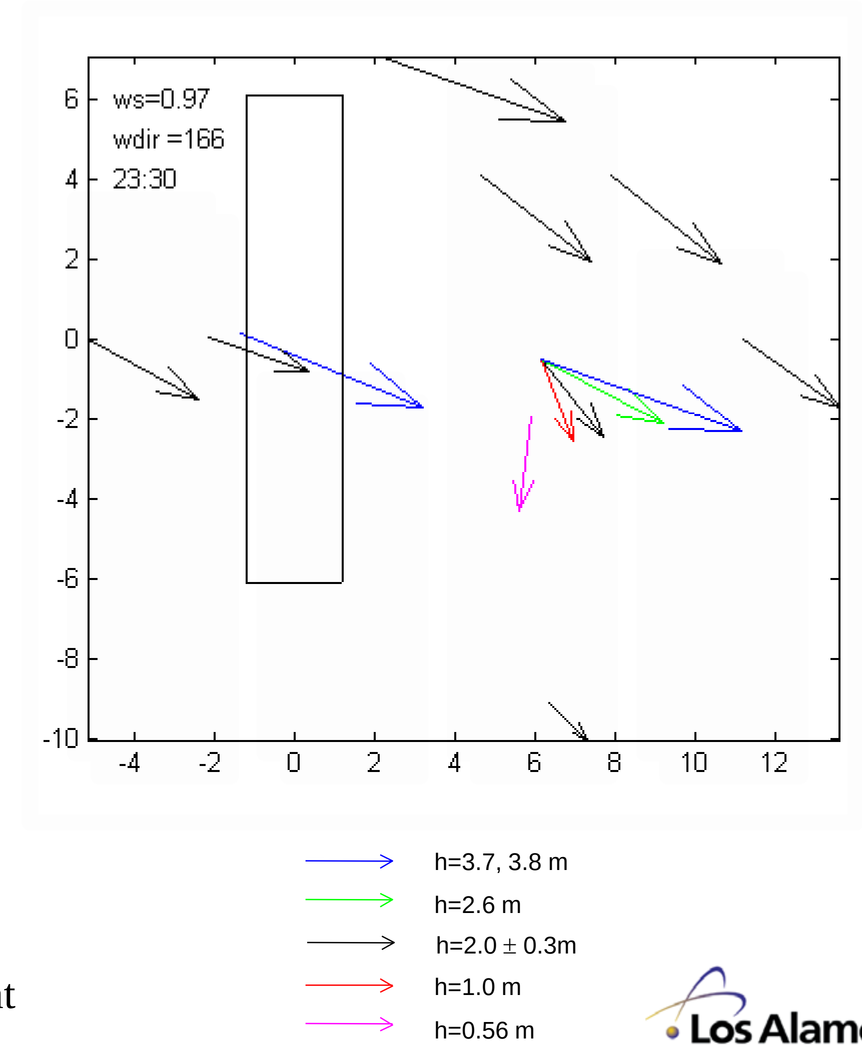


QUIC simulation

Wind Uncertainty Impact

Effect of 15 degree difference in inflow wind direction





from Brown et al. (2003) – MUST Field Experiment

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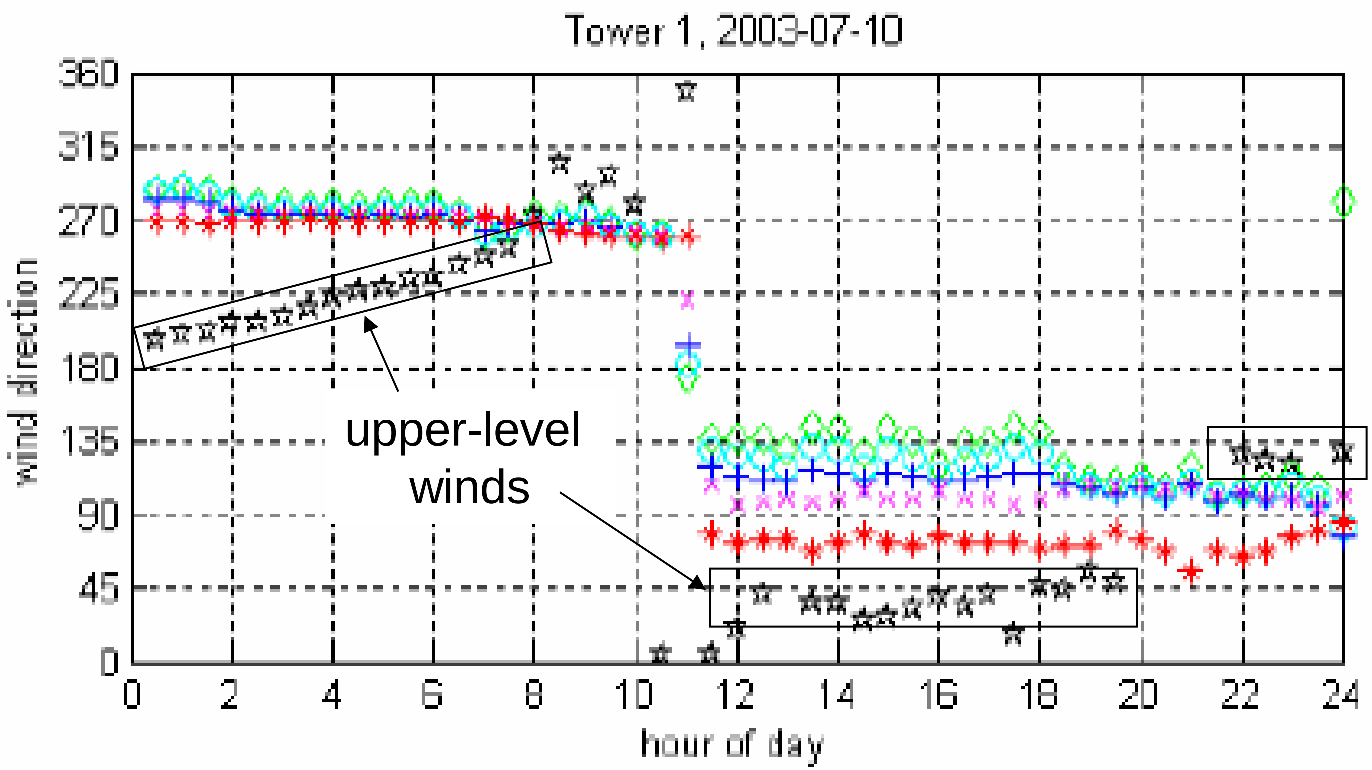
Wind Uncertainty Impact

Upper-level WD vs. street canyon wind direction

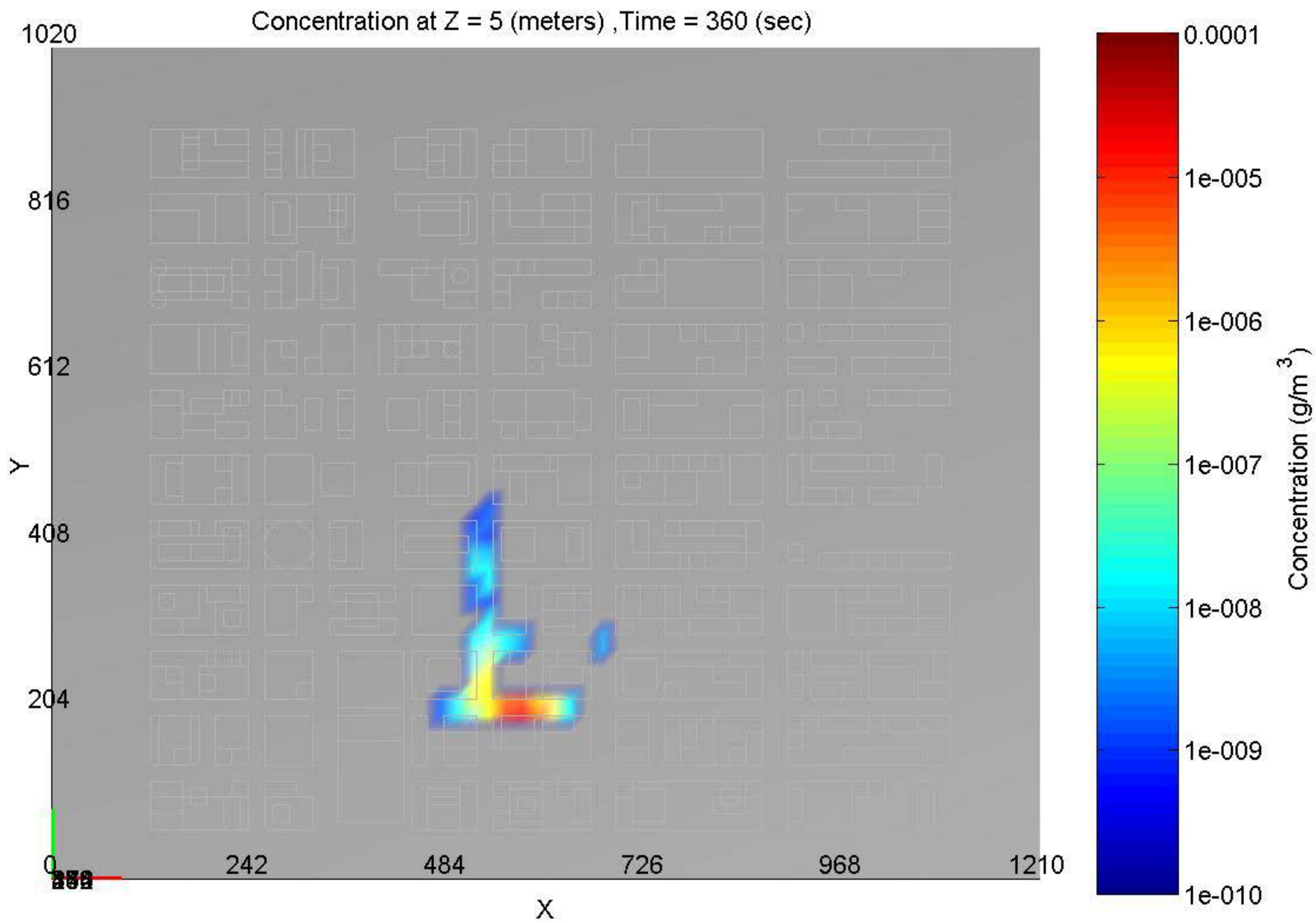


Park Ave.
JU 03

from Kastner-Klein and Clark (2004)

Input Uncertainties

Concentration vs. time in NYC Midtown



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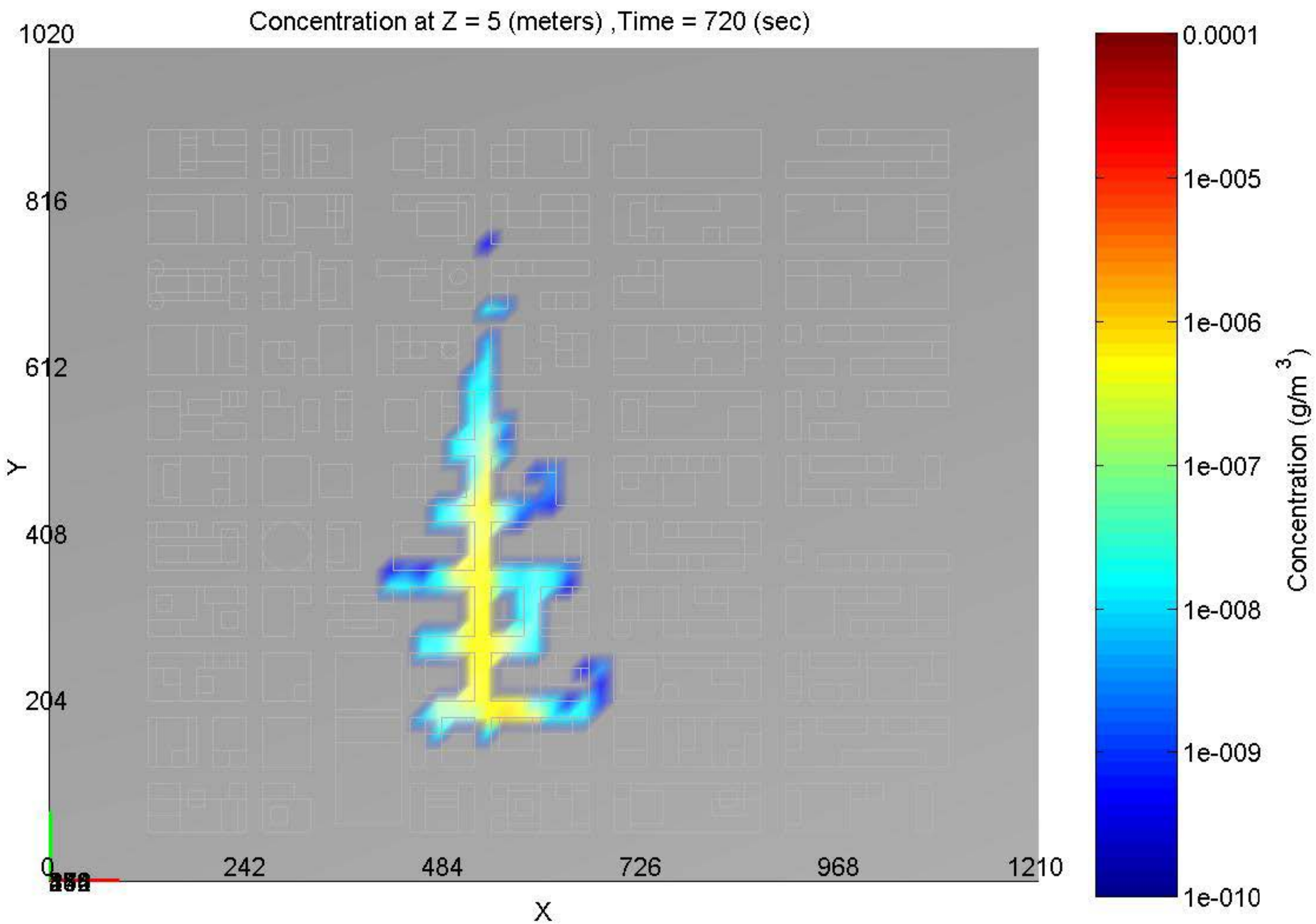

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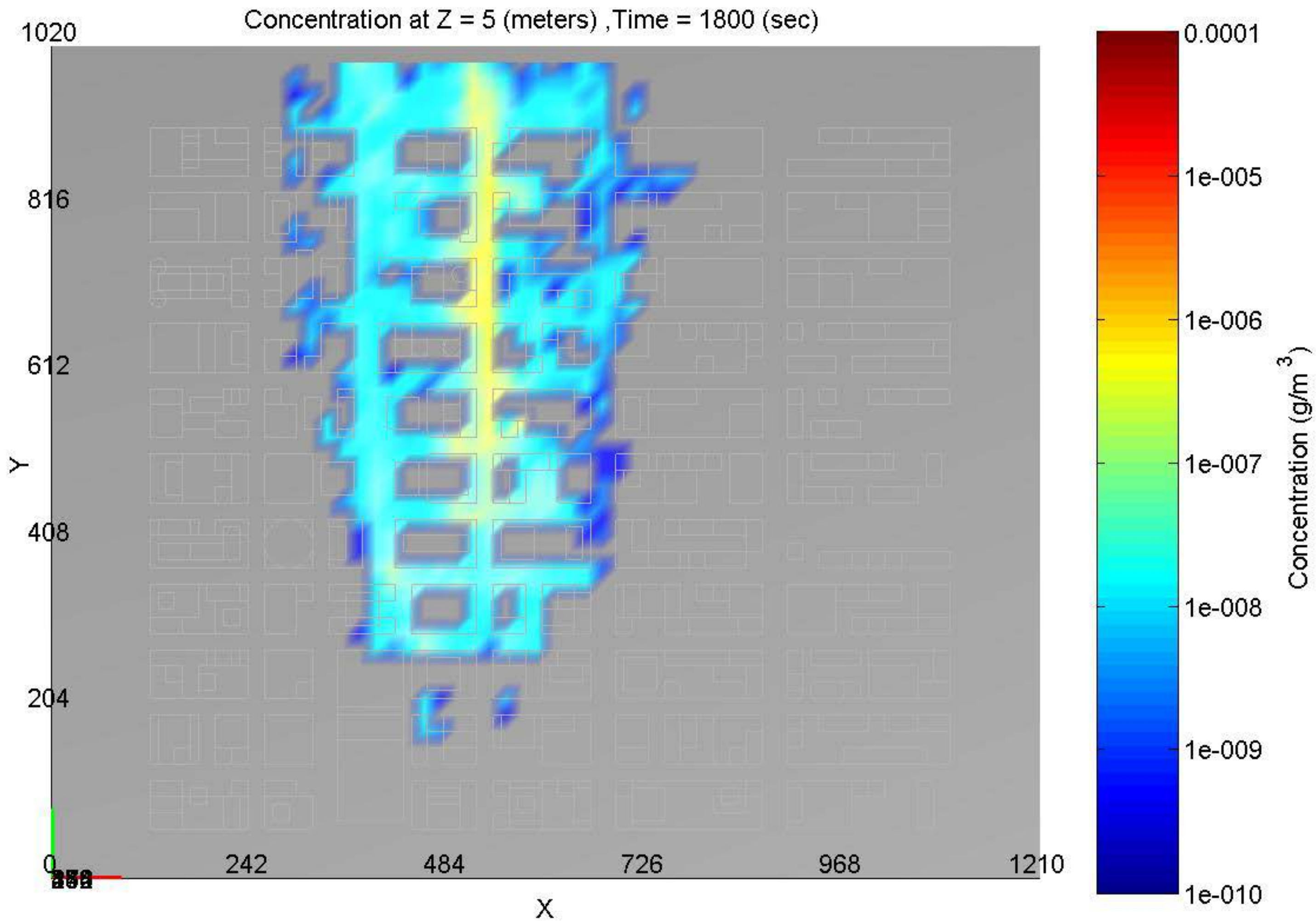

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