Comments on Verification, Validation & Uncertainty Quantification

Dr. Jay Boris, NRL Chief Scientist
Laboratories for Computational Physics and Fluid Dynamics
NRC Symposium, 28 March 2012, Washington DC

Comments

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- Steady-state and RANS fluid models are averaged first, causing additional uncertainties (errors). COST 732!
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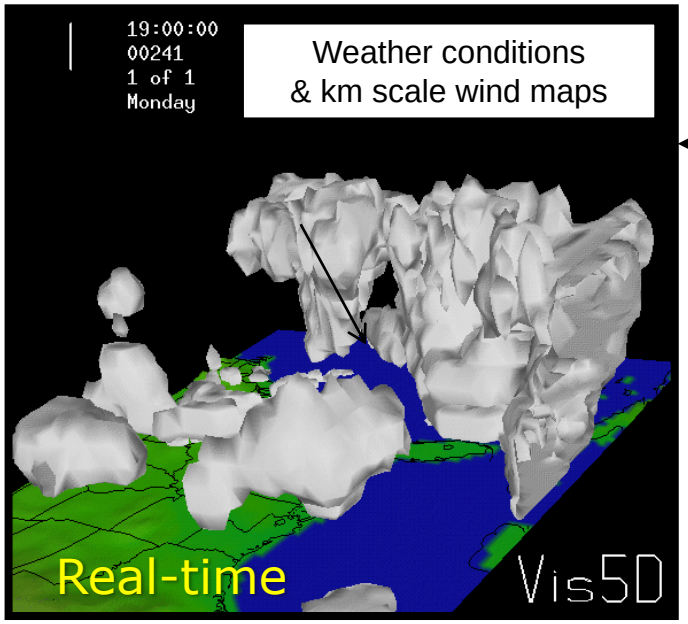
  Bill Oberkampf and Len Margolin are noticeable absentees
- 'Religious' zeal muddies the path. Let's learn from past mistakes.
  - Convergence: The misguided 2nd-order algorithm "requirement" - Proving 2nd-order convergence requires 256 x computing for a 2X grid!
  - Software practices in the DoD: A costly imprematuer was ignored
  - "Uncertainty Police" – Human nature can be sick …
- The 'Source' Problem – a good target for 'Uncertainty Quantification'
- 'Uncertainty Quantification' sounds like an oxymoron. We need better techniques for assessing and validating time-dependent LES simulations of turbulent fluid dynamics, e.g. Finite Scale Analysis

A Seamless Prediction System

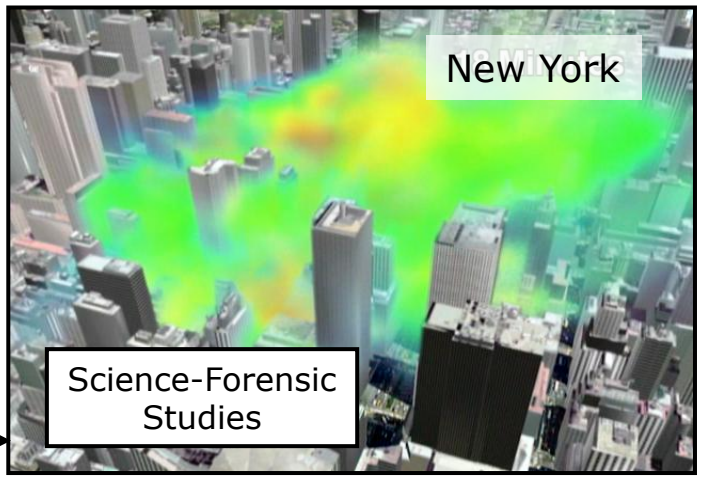


Weather conditions & km scale wind maps

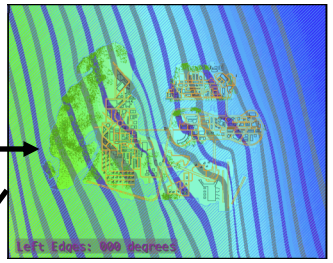
COAMPS (Weather Prediction System)

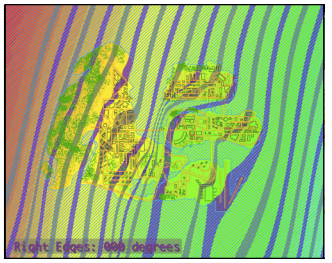
FAST3D-CT (urban aerodynamics)

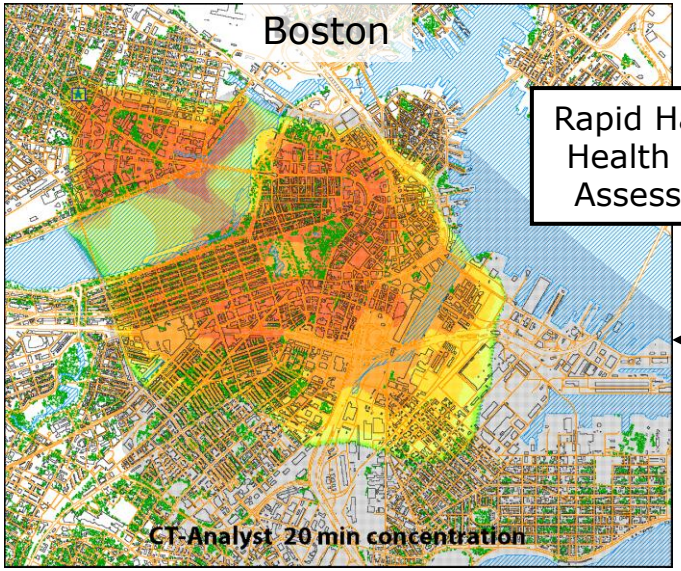
Nomograf Generator



Science-Forensic Studies

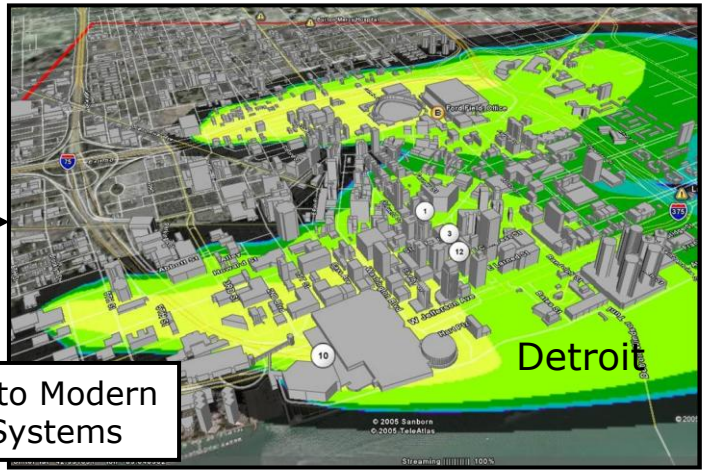






Rapid Hazard & Health Effects Assessments

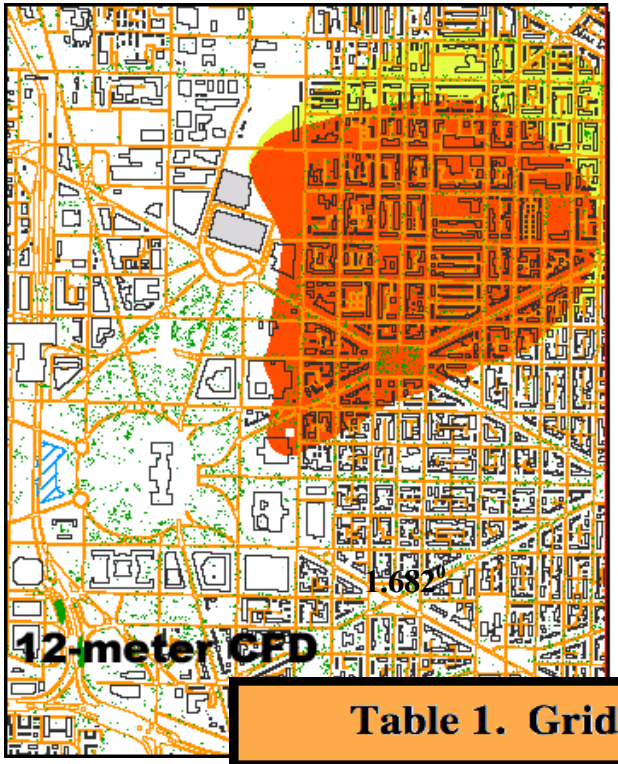
CT-Analyst (GUI-based crisis management and planning)

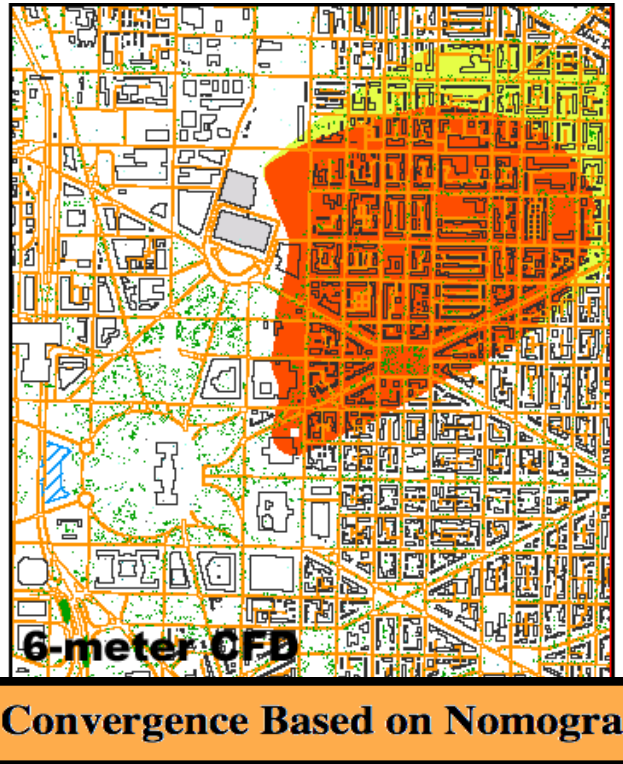


Export to Modern GIS Systems

Coupled high-resolution weather prediction model with urban dispersion for consequence management

Grid Convergence for Washington DC





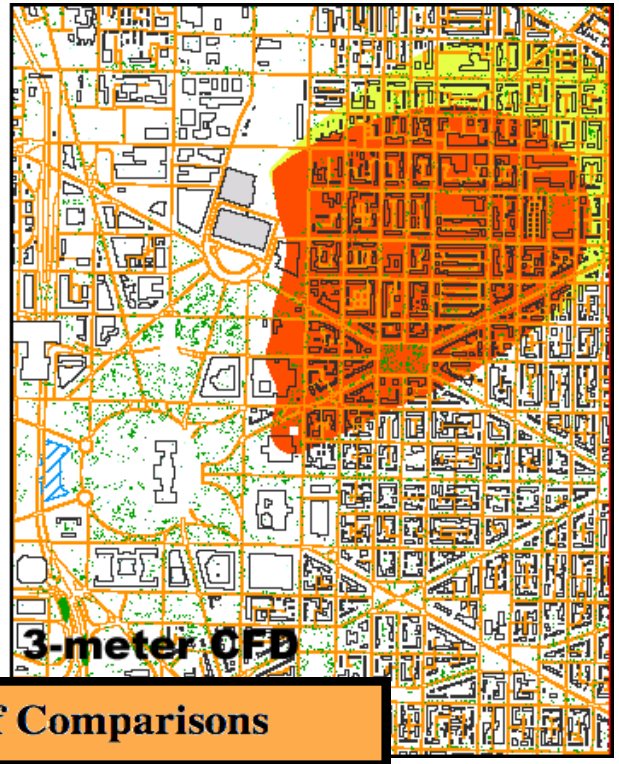
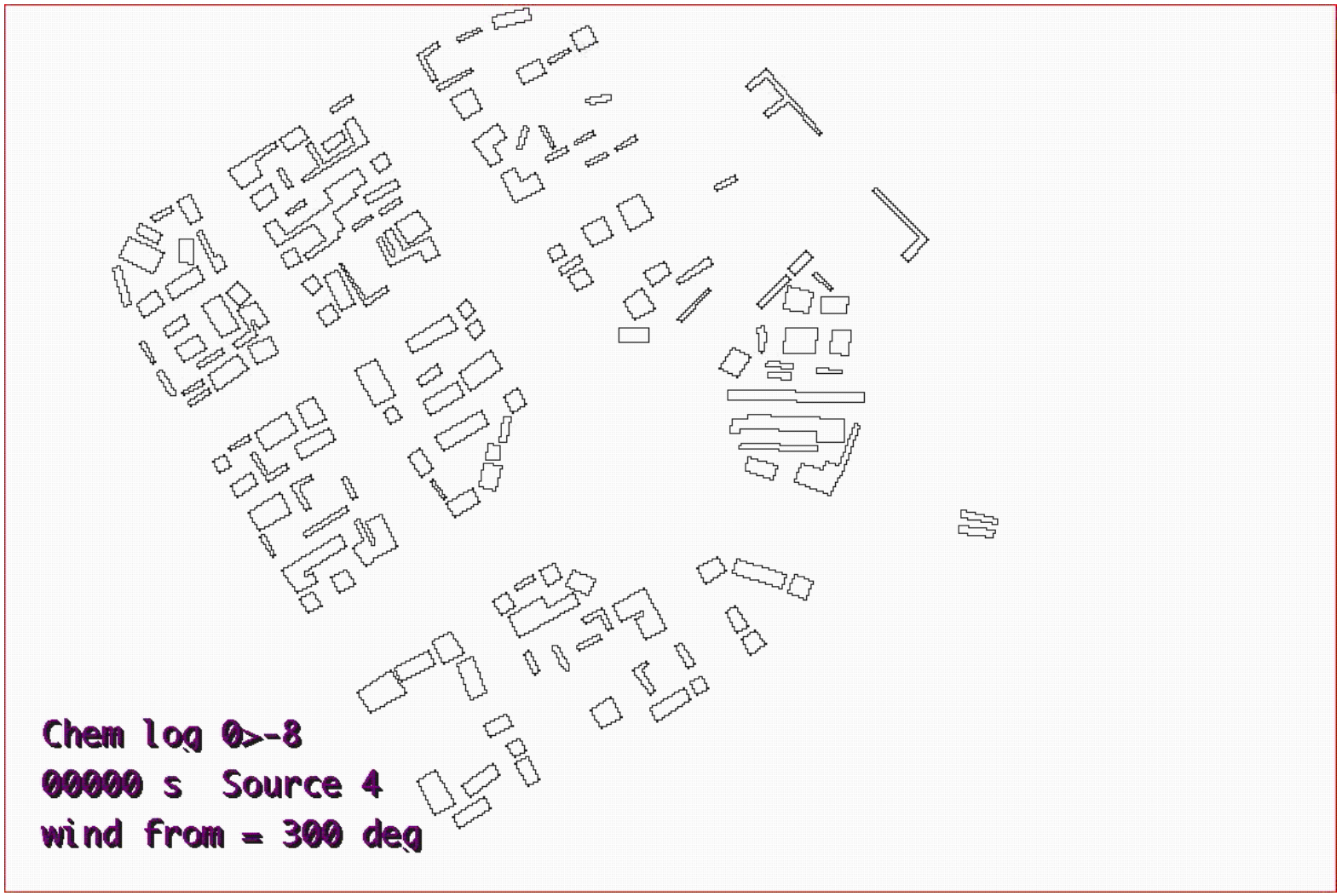


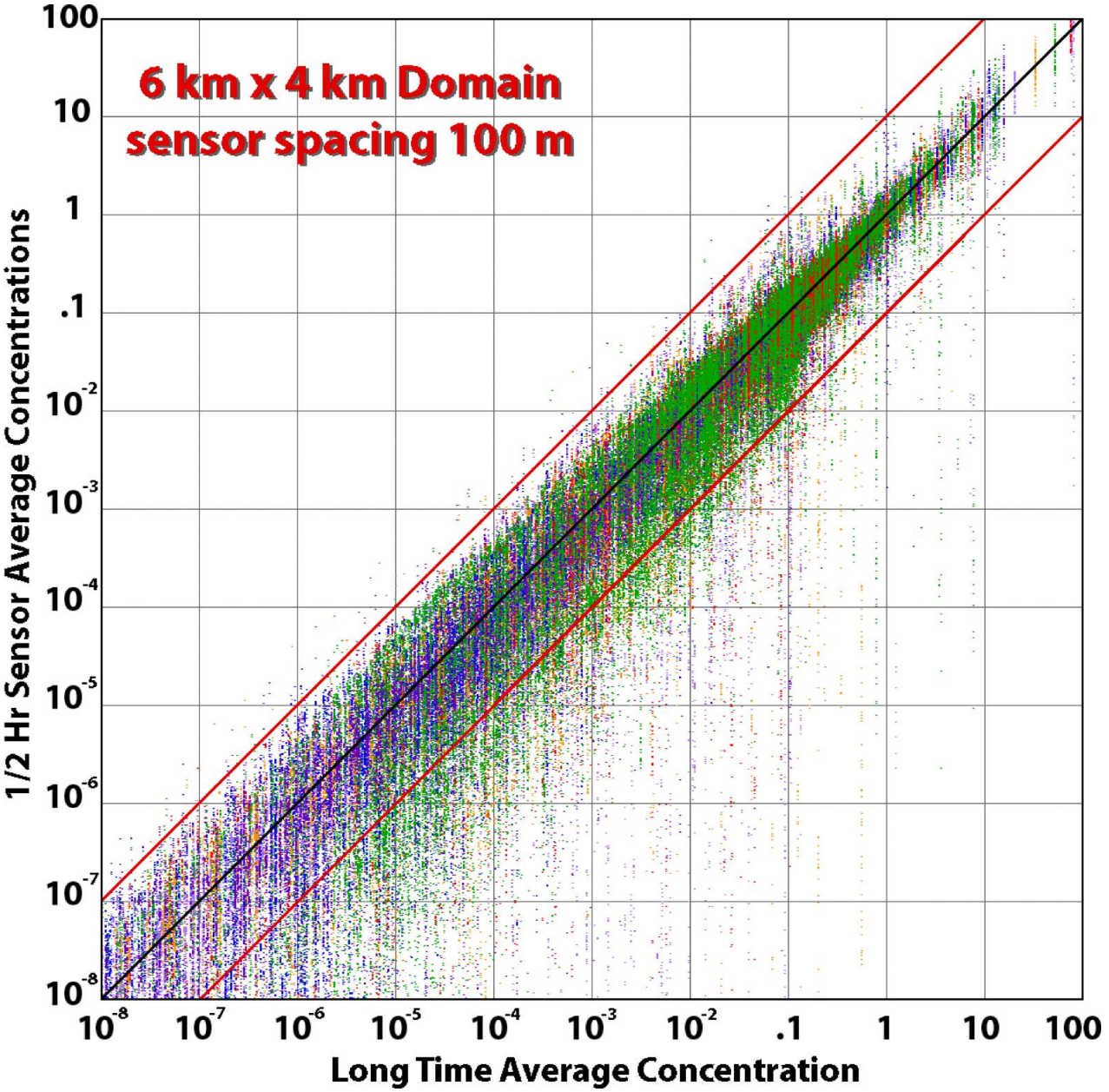
Table 1. Grid Convergence Based on Nomograf Comparisons

	6-m resolution compared to 3-m		12-m resolution compared to 6-m		Error Ratio 12m-6m/6m-3m	
wind	Δθ(⁰)	Δ%	Δθ(⁰)	Δ%	θ Ratio	% Ratio
0⁰	1.682⁰	1.820%	5.080	4.064%	3.02	2.23
60⁰	1.715⁰	1.386%	5.020⁰	4.075%	2.93	2.94
120⁰	1.675⁰	1.005%	4.857⁰	3.055%	2.90	3.04
180⁰	1.609⁰	2.061%	5.152⁰	3.449%	3.20	1.67
240⁰	1.673⁰	1.104%	5.167⁰	3.685%	3.09	3.34
300⁰	1.694⁰	1.158%	5.128⁰	3.083%	3.03	2.66
average	1.688⁰	1.470%	5.032⁰	3.326%	2.98	2.26

HazMat Reachback Center at NRL
2009 Presidential Inauguration
CT-Analyst chosen for crisis management

"Steady-State" Plumes are Highly Variable

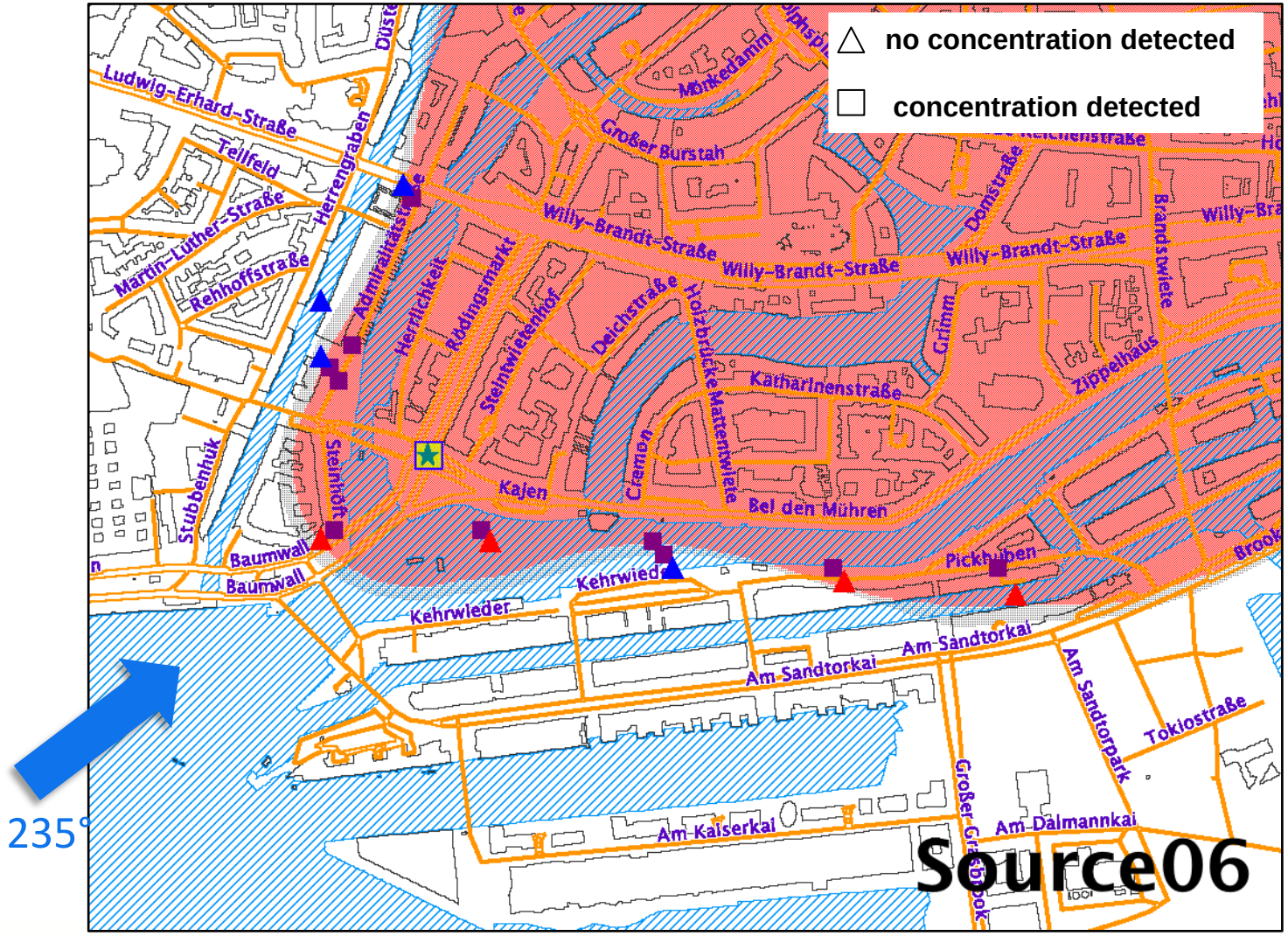



6 km x 4 km Domain
sensor spacing 100 m
1/2 Hr Sensor Average Concentrations
Long Time Average Concentration
100
10
1
.1
10-2
10-3
10-4
10-5
10-6
10-7
10-8
10-8
10-7
10-6
10-5
10-4
10-3
10-2
.1
1
10
100

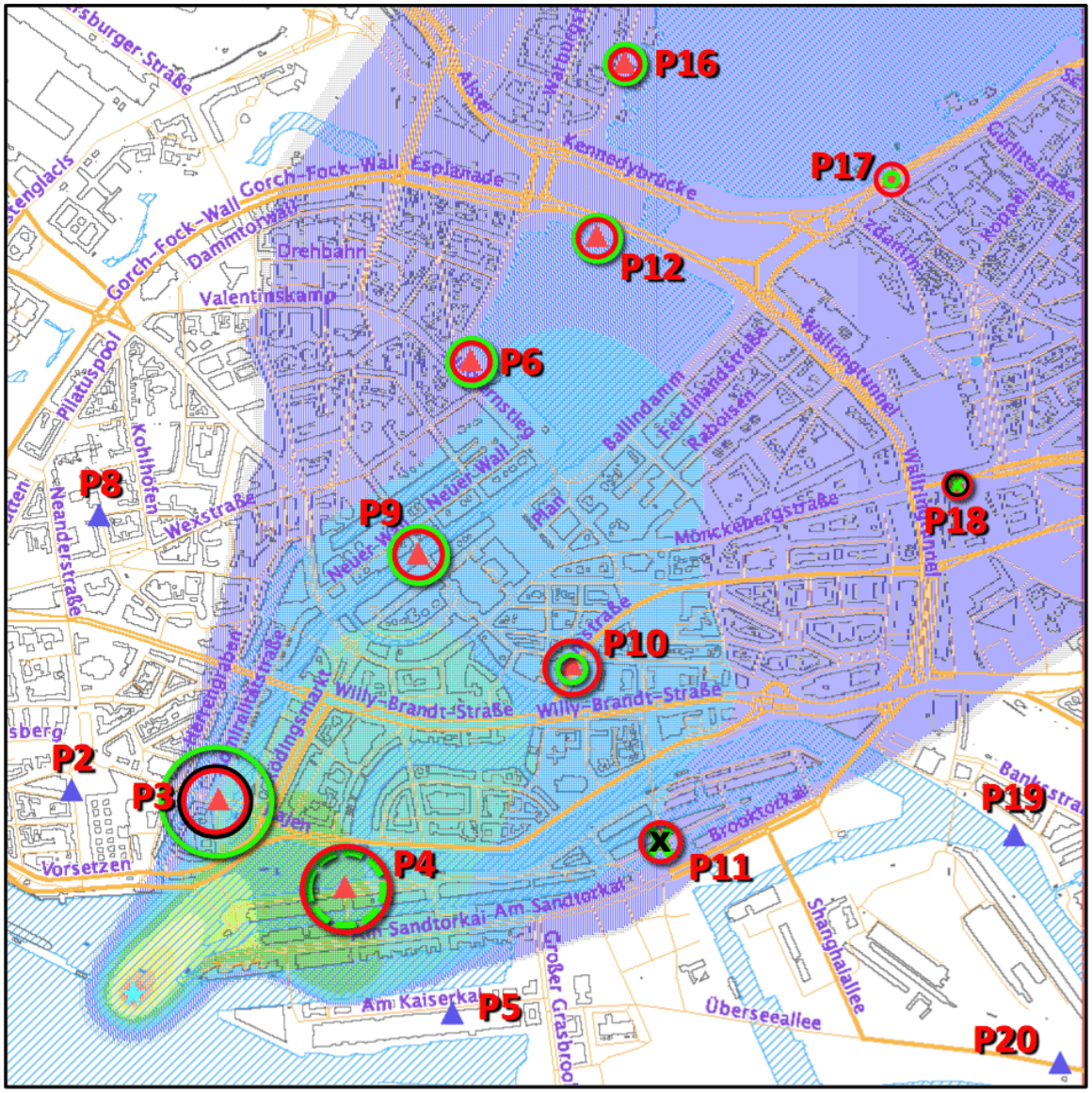
JU2003 Wind Tunnel Model at the University of Hamburg, Germany

Validation with Wind Tunnel Hazard Area

- plume edge detection



Validation: Hamburg Field Trials

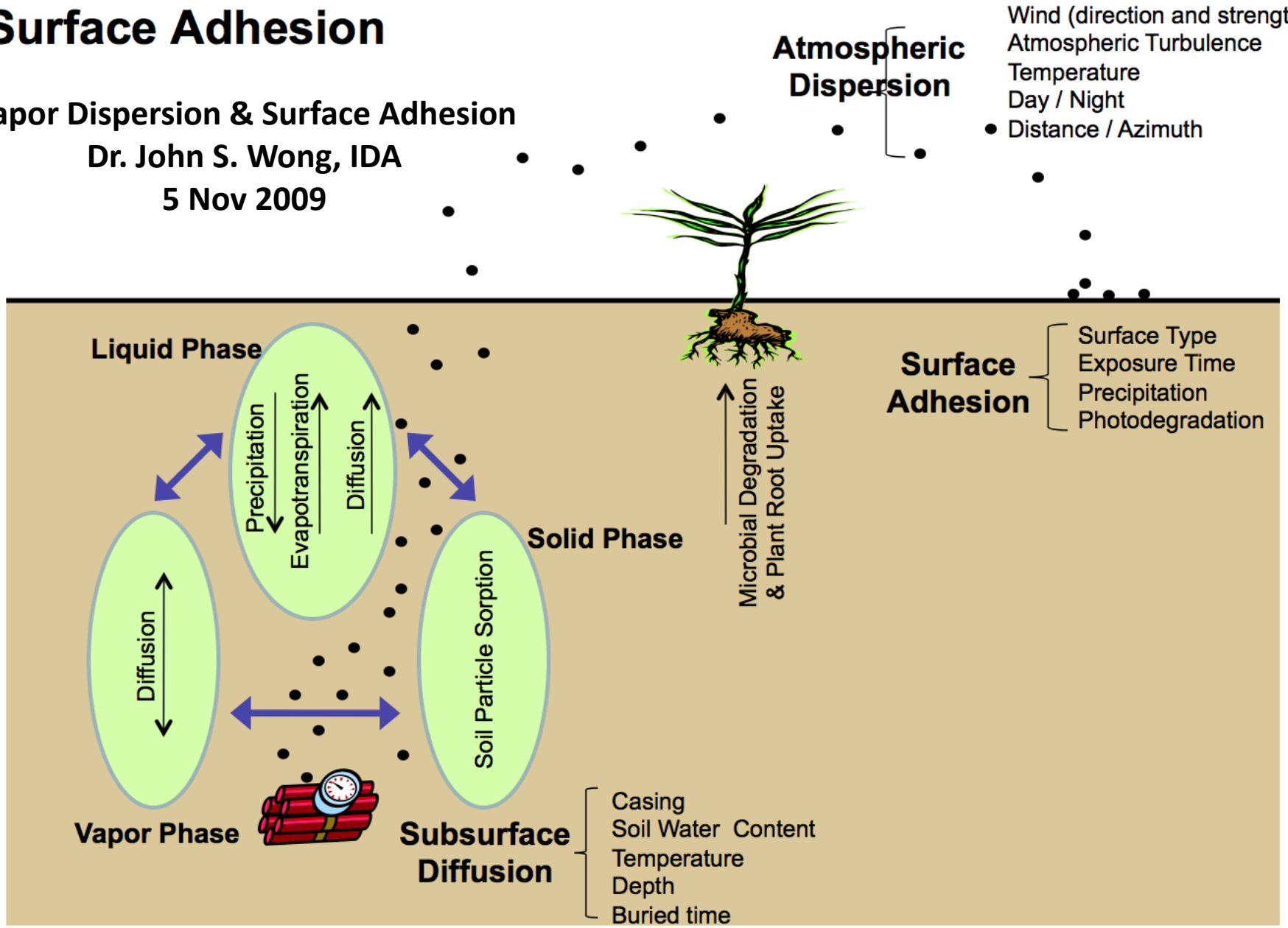


The Source Problem: A Kitchen Sink or a Garbage Disposal?

- DoD and DHS obsess about the "source" problem - attacking bunkers, derailing tank cars, explosions and contaminants in cities, finding IEDs
- These problems are characterized by many competing, complex physical effects making any composite simulation suspect.
- Do we need to know details about the source? Can we ever expect to know these details?
- What can/should we do about this? How can we work around it? Study sensitivity and bounding conditions
- Perhaps a very good target for uncertainty quantification

Processes Affecting Explosive Vapor Diffusion and Surface Adhesion

Vapor Dispersion & Surface Adhesion
Dr. John S. Wong, IDA
5 Nov 2009



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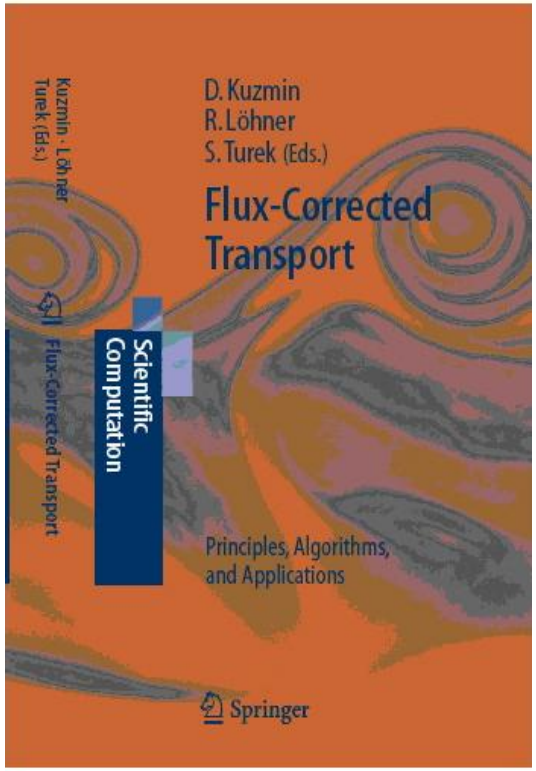
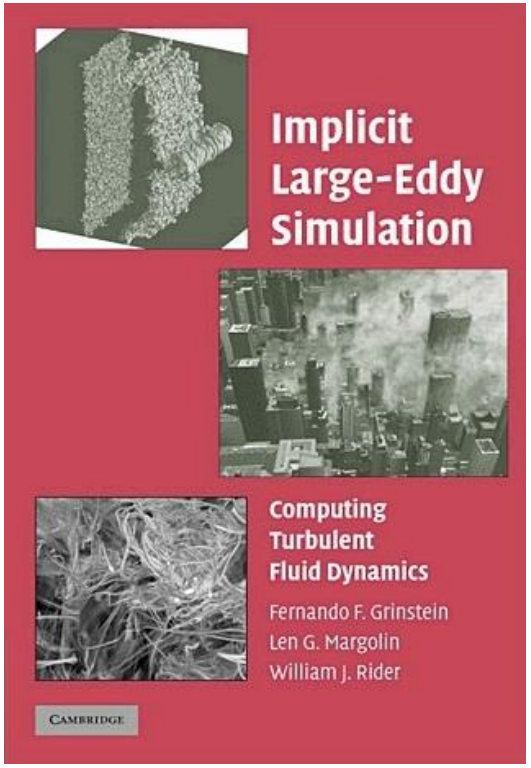
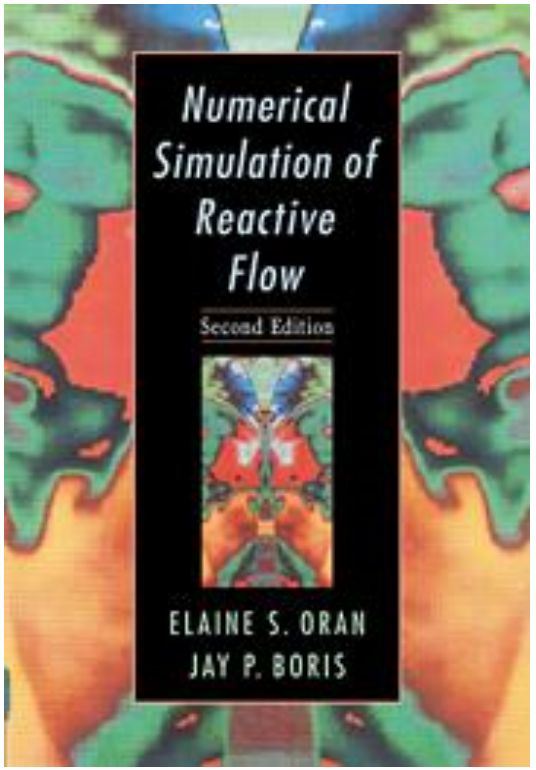
NRL CFD Techniques for Solving Complex Flows



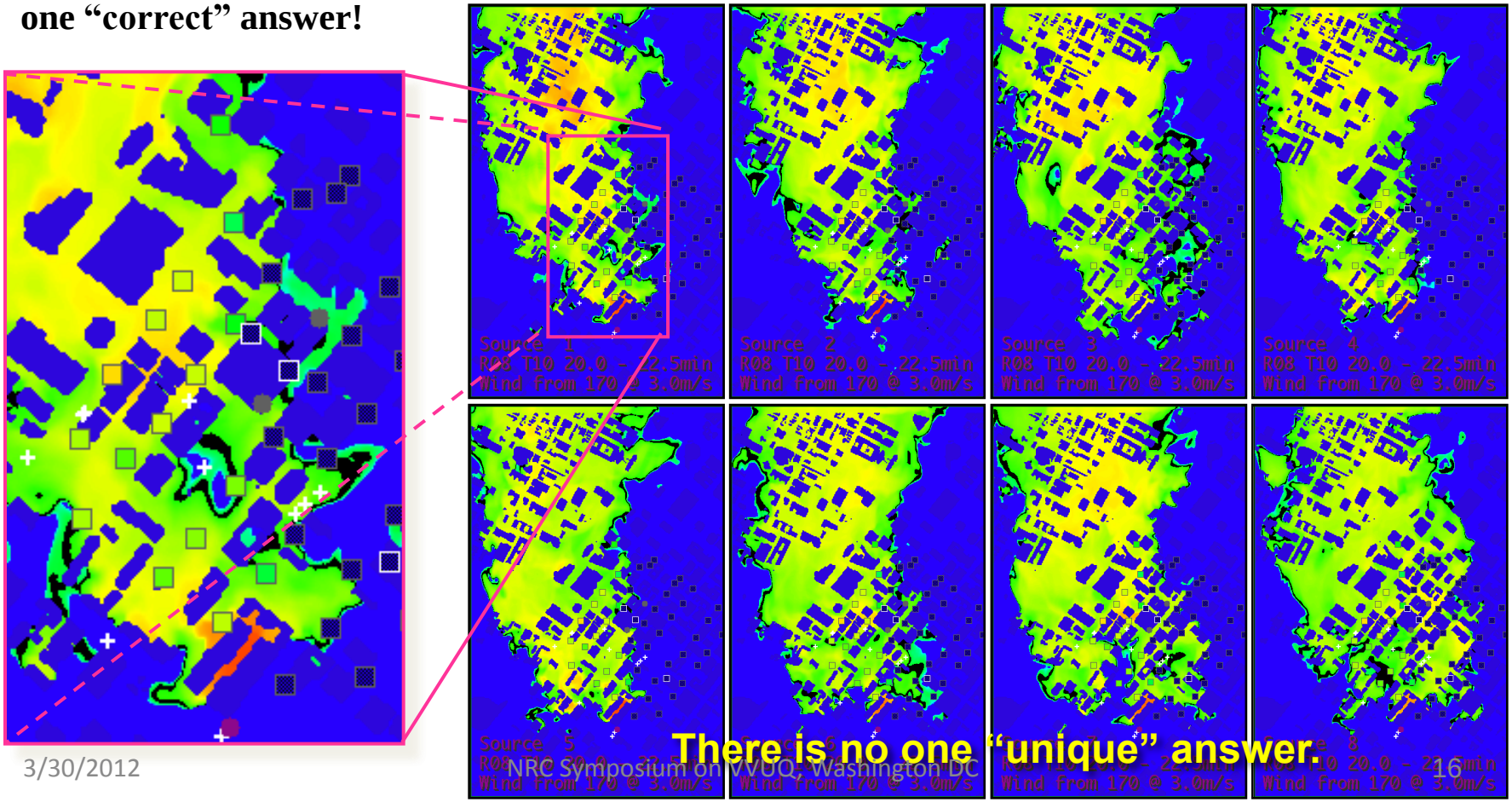




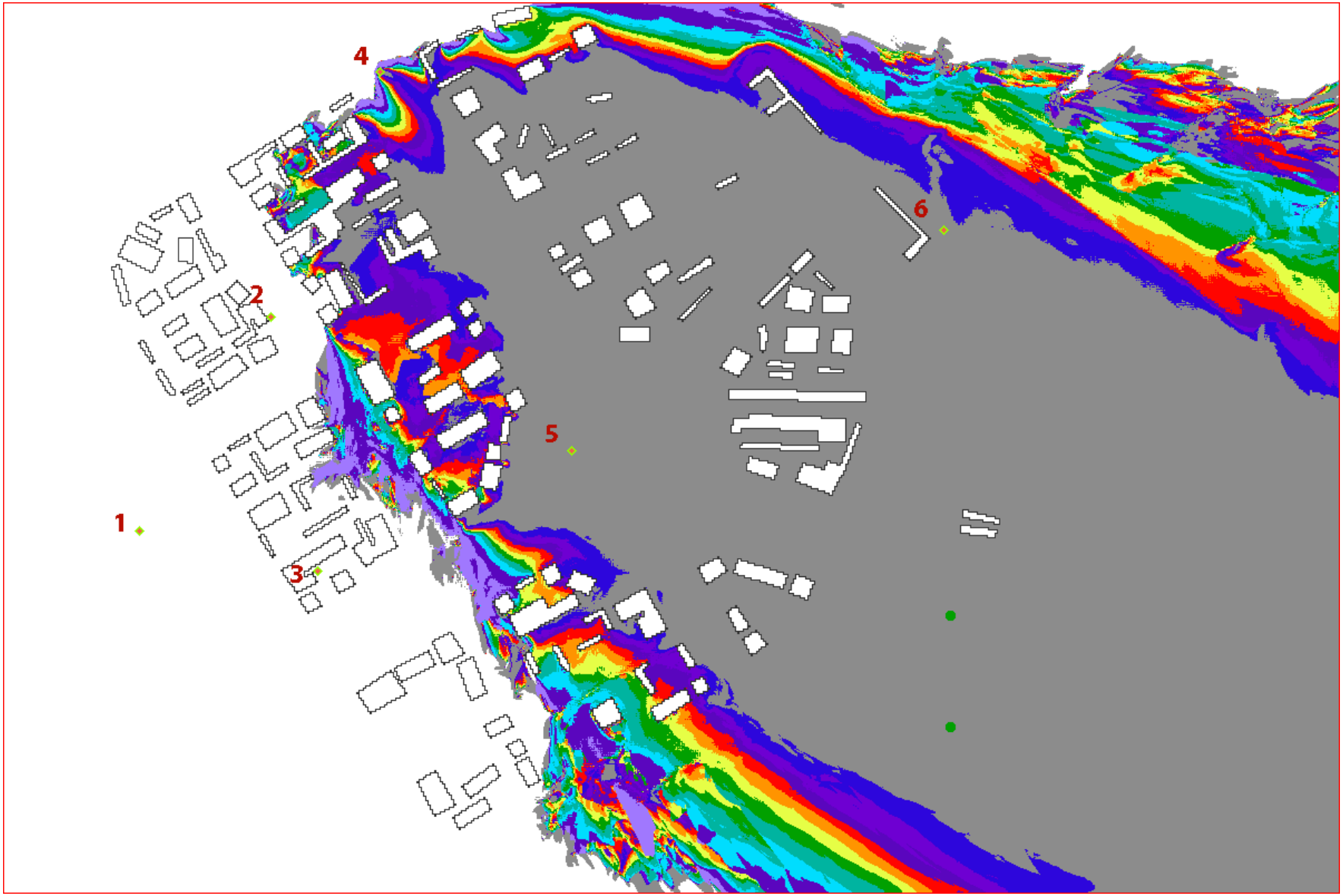
- NRL basic research has incubated new CFD capabilities:
  - FCT Book published by Springer, 2005
  - ILES Book published by Cambridge University Press, 2007
  - Numerical Simulation of Reactive Flow (2nd ed) Cambridge UP, 2001

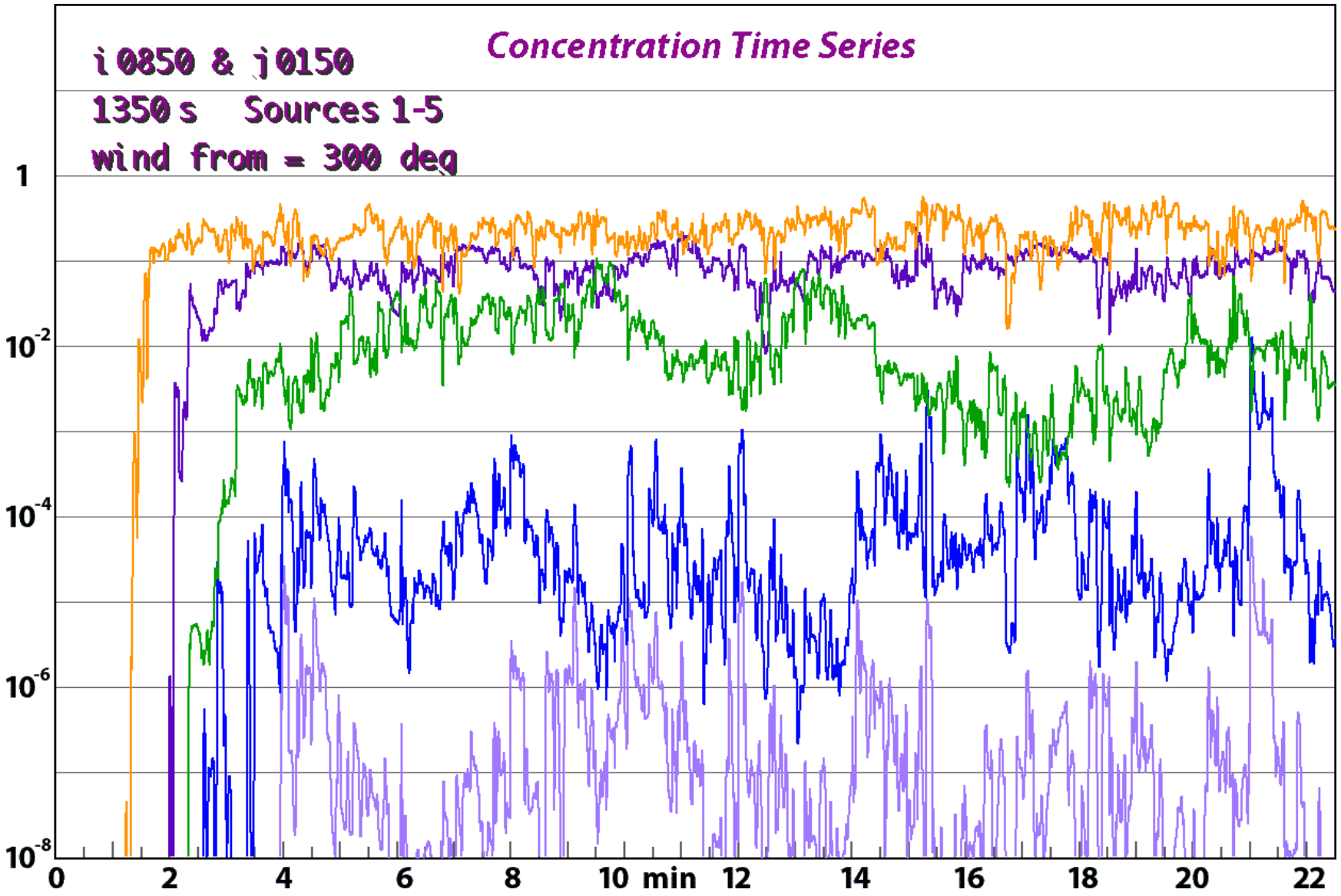
Tracer ES&T LA Data Validates FAST3D-CT Natural Variability ➔ "There is no Truth!"

Eight different realizations of a single source are compared with Tracer ES&T sampler data in downtown Los Angeles (colored squares). Wind is from 170^0 at 3 m/s with moderate fluctuations. Point releases for 5 min with measurements (2.5 min averages) at each of 50 locations < 1 km from source. Estimating variability requires multiple trials. There is no one "correct" answer!



Probability of Contamination




Concentration Time Series
i 0850 & j 0150
1350 s Sources 1-5
wind from = 300 deg
1
10-2
10-4
10-6
10-8
0
2
4
6
8
10 min
12
14
16
18
20
22

OKC in the Hamburg Wind Tunnel: Concentration Variability Is Very Big