An Analytical Urban Puff Dispersion Model Compared with Tracer Observations in JU2003

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UDINEE (Urban Dispersion International Evaluation Exercise) Objectives

- **Focus on "dirty bomb" or RDD- (Radiological Dispersive Device) scenario**
- **Urban area (JU2003 chosen for study)**
- **Compare European dispersion models, using JRC ENSEMBLE framework**
- **Include US and Canadian models**
- **Also identify research gaps and recommend model improvements**
- **Managed by European Commission Joint Research Centre (JRC)**

Our Role in UDINEE

- Arranged for JRC access to the JU2003 data archive, including 3D building geometry
- Planning, explaining JU2003 characteristics, liaison with modelers, and analyzing and summarizing the results
- Scientific analysis of JU2003 data
- DTRA Reachback group (24/7 operational modelers) has run HPAC for the chosen scenarios and provided outputs to JRC

Why JU2003?

- There are no urban field experiments that simulate RDDs (instantaneous buoyant releases with gas/aerosol mixture)
- JU2003 is as close as we can get. Instantaneous non-buoyant puffs were released at ground level in an urban city center.
- Fast response sampling took place (data from ten intensive observation periods (IOP)) at distances of a few hundred meters.

Objective of Current Study

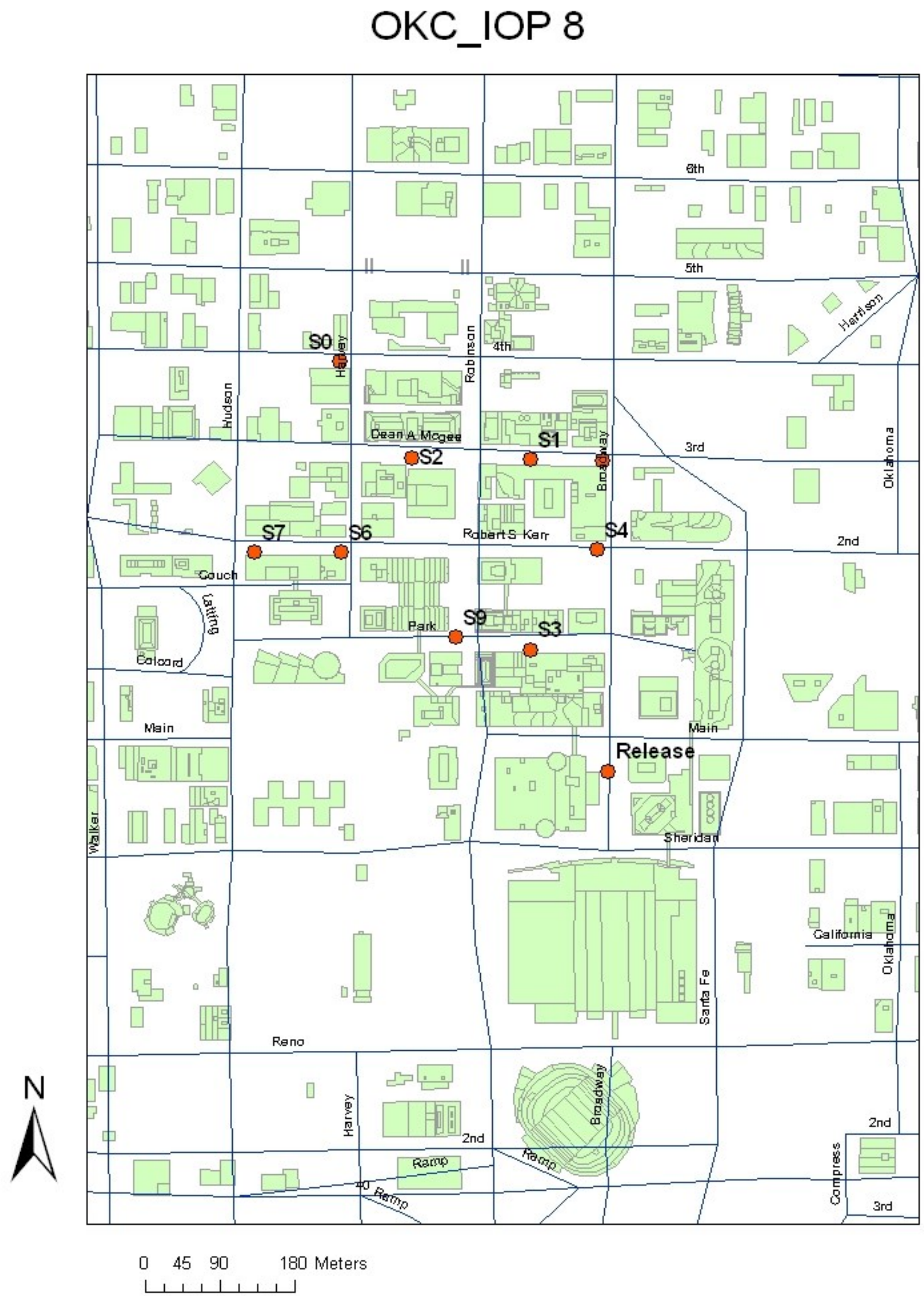
- Run simple urban Gaussian Puff model for JU2003 UDINEE puffs/samplers
- Predict maximum short-term (0.5 s) concentration C and dosages at each sampler
- Compare with JU2003 observations
- Provide baseline performance measures that more detailed models should be able to improve upon

JU2003 City Center Domain

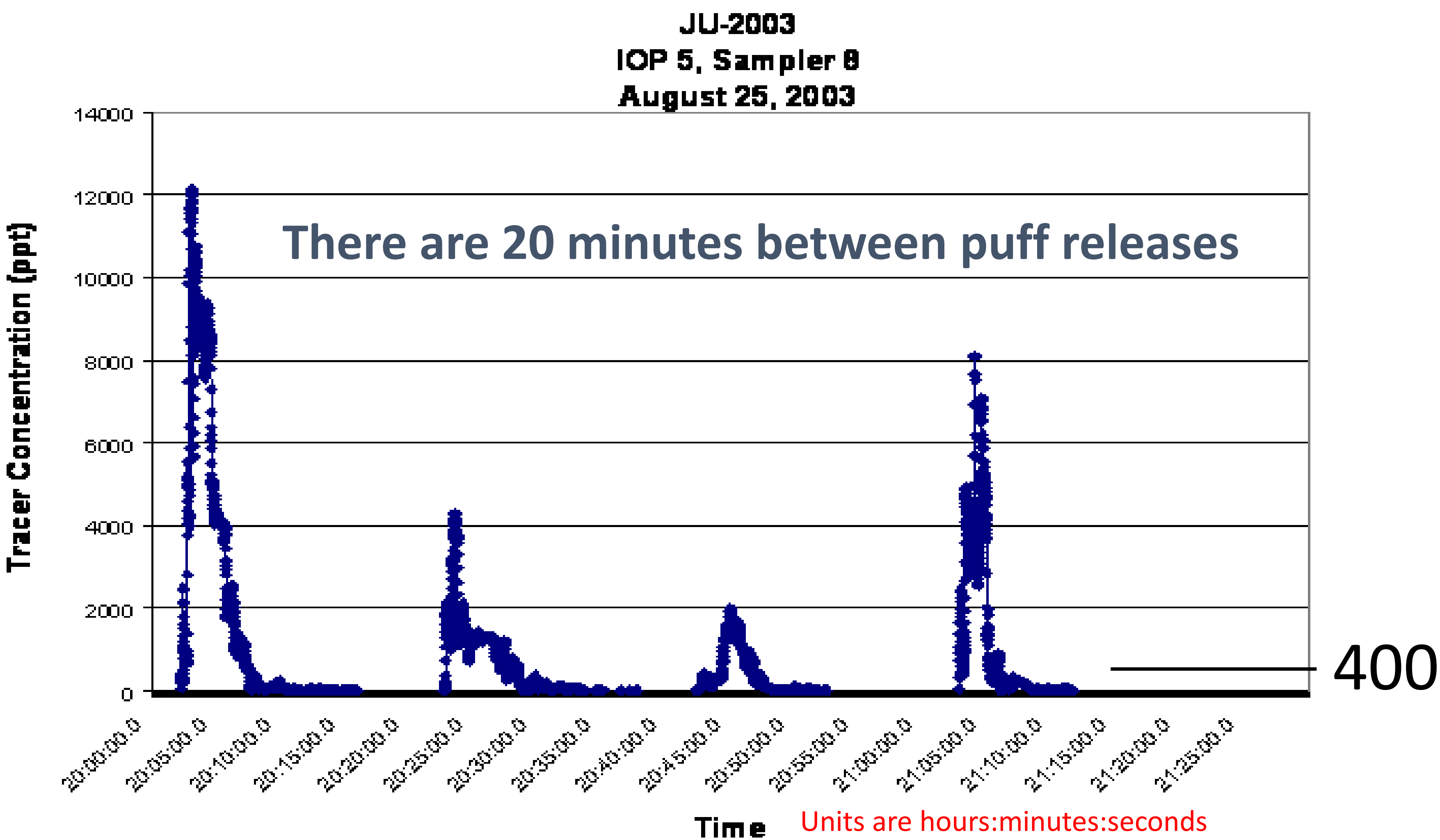
About 1 km on a side

Locations of release site (Westin) and fast-response SF_6 samplers during JU2003 IOP 8

Domain shown is about 1 by 1.5 km



Fast Response SF_6 Obs for IOP 5 at TGA sampler 6 [C(t) for Four Puff Releases]



Background for simple urban puff model

- S. Hanna has been developing and testing simple urban dispersion models since 1971
- Simple urban continuous plume model published in 2002 with Britter, Venkatram
- Simple urban model tested with JU2003 <u>continuous</u> tracer releases by Hanna and Baja 2009. Some of its assumptions are used in the new puff model
- "Tuning" of some parameters to JU2003 puff analysis papers by Zhou and Hanna 2007 and Doran et al 2007

Simple urban Gaussian puff model

- Same σ day-night in city center
- C_{max} is maximum 0.5 s concentration at z = 0 at each sampler for each puff
- $\sigma_x = \sigma_y = \sigma_z = \sigma$
- y is cross-wind distance
- Q is total mass released
- $C_{max}/Q = [1/(2^{1/2}\pi^{3/2}\sigma^3)]\exp(-y^2/2\sigma^2)$

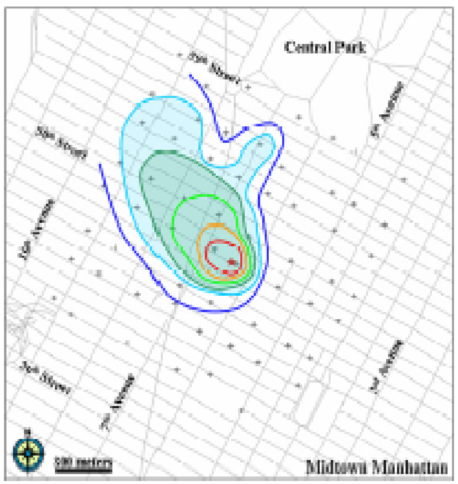
Simple wind speed and direction

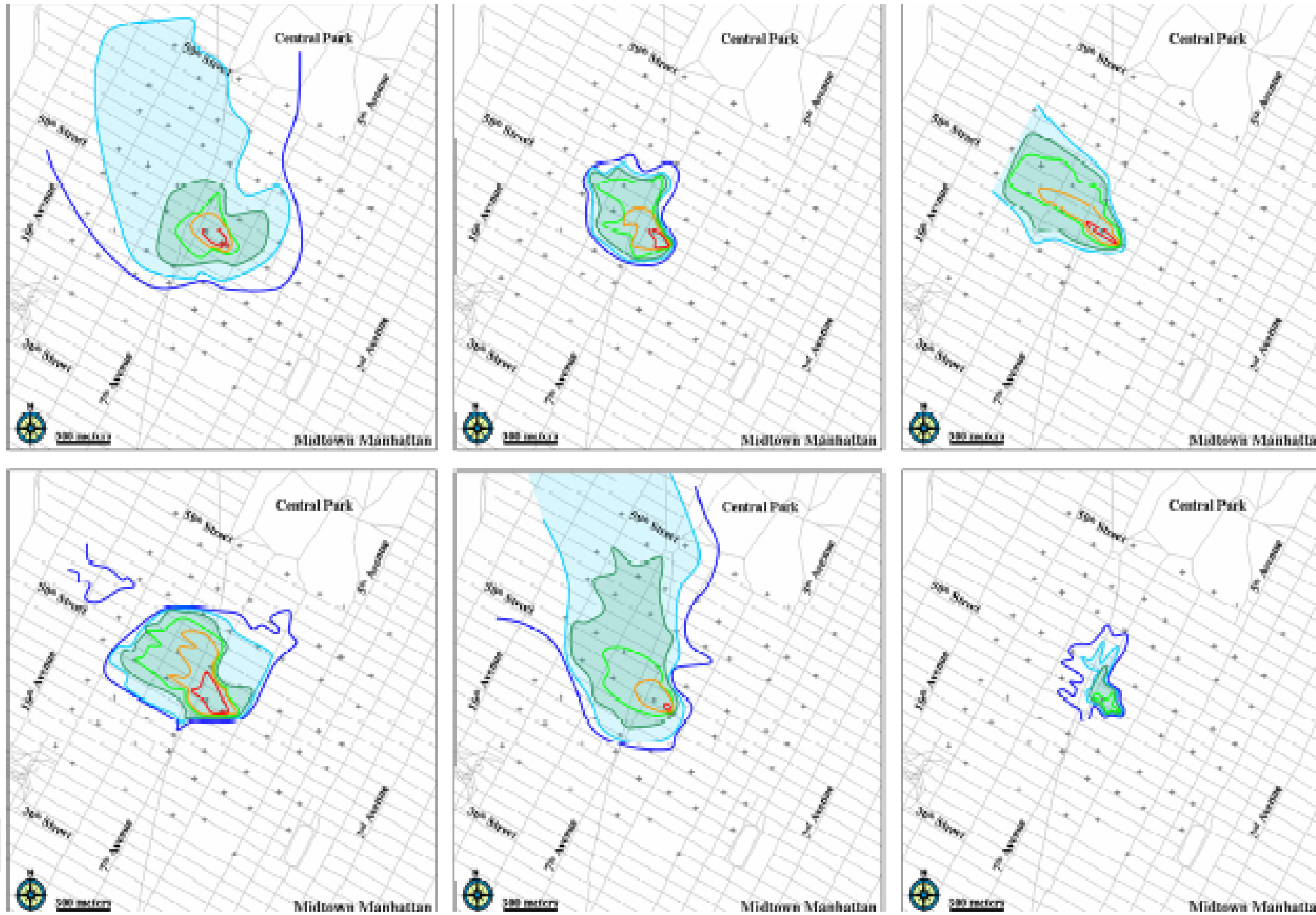
- The assumed wind speed and direction are constant over a given IOP
- “All anemometer” wind averages are used as in the Hanna and Baja 2009 evaluations of a simple Gaussian continuous plume model with JU2003
- Slight (ten degree) wind direction variations may affect whether a puff hits or misses a sampler

Next slide justifies initial σ_o

- Examples of observed and modeled cloud contours for MID05 (Manhattan) continuous tracer releases
- Show initial cloud spread (σ_o)
- Note that in 1968 McElroy and Pooler suggested that σ_o is about 30 or 40 m (based on observations in St. Louis)

From Flaherty et al. 2007 – 6 CFD models applied to MID05 Left: Observed C pattern; Right: Predicted C pattern for 6 models





Note broad initial spread

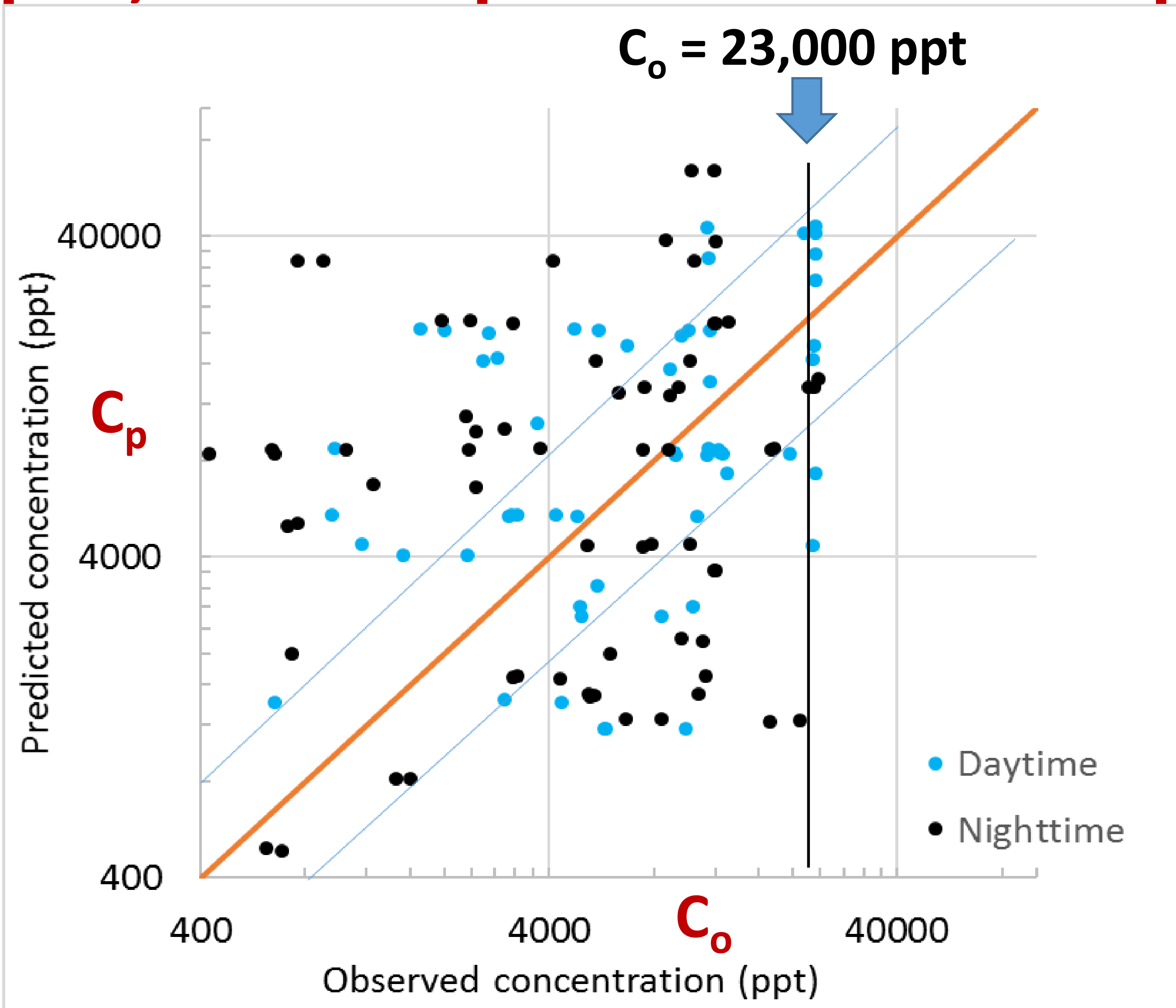
σ formula is based on the Zhou and Hanna (2007) and Doran (2007) analyses of JU2003 puff data

- In both papers a simple relation $\boldsymbol{\sigma_x = \sigma_o + b\sigma_t}$ is seen with $\boldsymbol{\sigma_o}$ and $\boldsymbol{\sigma_t}$ as initial and turbulent dispersion parameters
- There is an "initial $\boldsymbol{\sigma_o}$" due to mixing in the street canyon where the source is located
- Here we assume $\boldsymbol{\sigma_o}$ = 30 m and $\boldsymbol{b}$ = 0.17

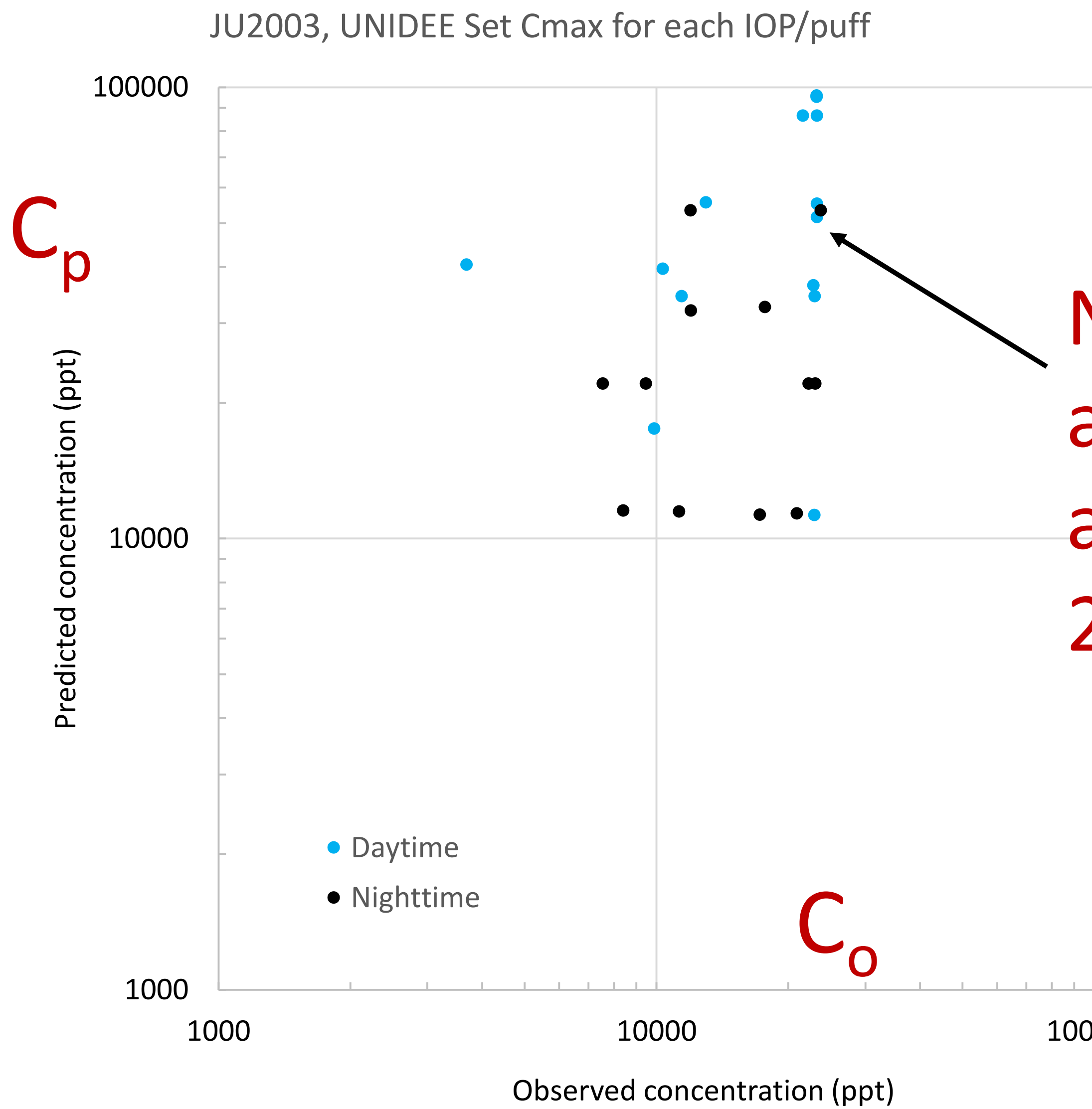
Simple Gaussian Puff Model Predicted and Observed Outputs Compared

- C_{max}(0.5 s) paired for each puff and TGA sampler
- C_{max}(0.5 s) for each puff but not by sampler. One max point per puff
- Dosage D (time integrated C) paired for each puff and sampler

C_{max}(0.5 s) pred and obs for each puff and sampler, for both pred and obs > 400 ppt

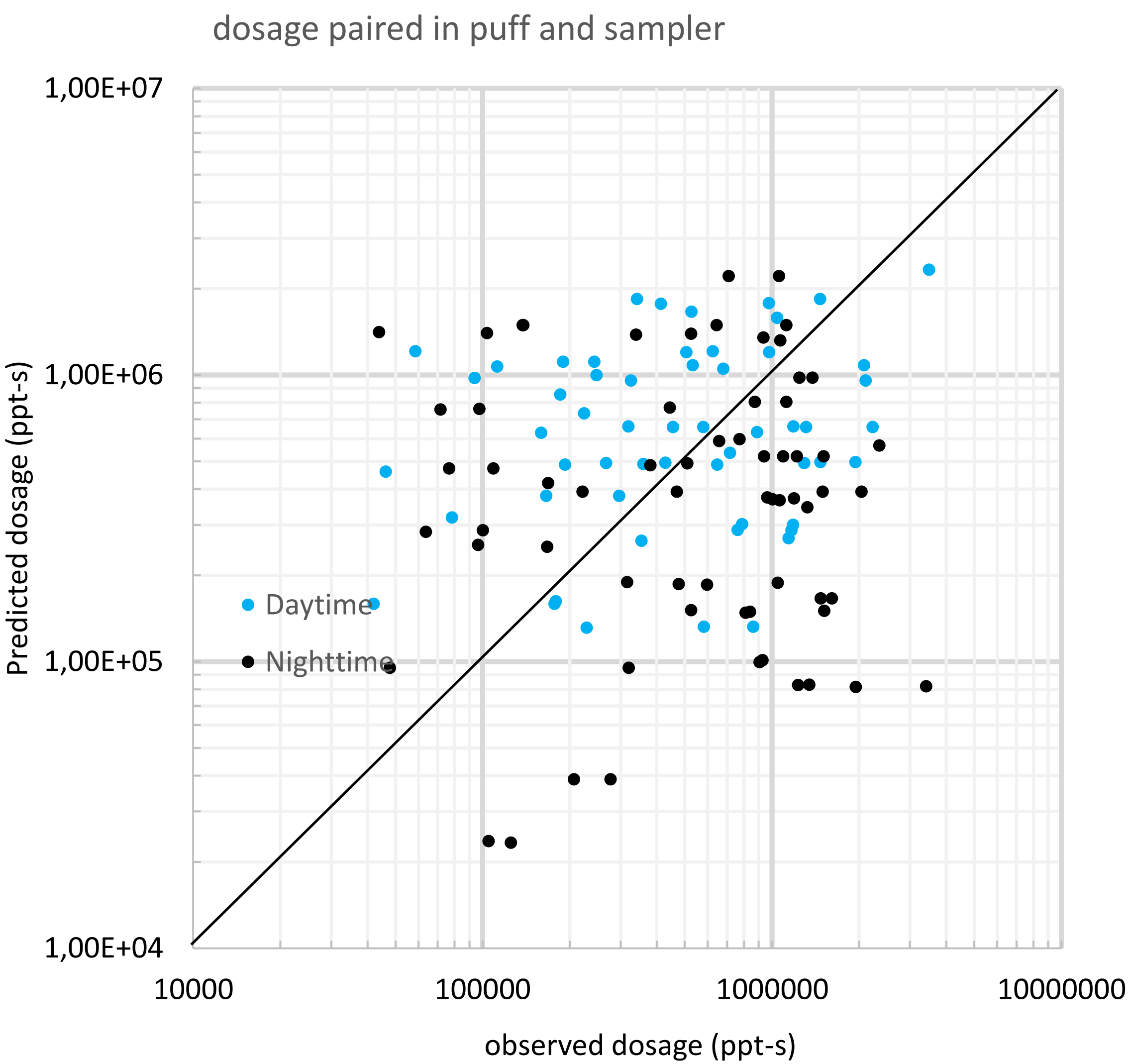


C_{max}(0.5 s) max pred and obs for each puff



Note C_o is again capped at about 23,000 ppt

Dosage (ppt-s) pred-obs scatter plot paired by puff and sampler



Dosage is much less influenced by C (0.5 s) cap at 23,000 ppt

Performance measures (green satisfy urban acceptance criteria for FB(0.67), NMSE(6) and FAC2(0.3))

		FB	NMSE	FAC2	FAC5	MG	VG
C_{max} for each puff and sampler	**All**	**-0.40**	**1.69**	**0.39**	**0.75**	**0.75**	**6.30**
	Day	-0.32	0.94	0.48	0.84	0.84	3.40
	Night	-0.48	2.55	0.32	0.67	0.67	11.0
C_{max} for each puff	**All**	**-0.81**	**1.65**	**0.39**	**0.96**	**0.96**	**2.90**
	Day	-0.98	1.89	0.21	0.93	0.93	4.50
	Night	-0.49	0.79	0.58	1.00	1.00	1.80
Dosage for each puff and sampler	**All**	**0.13**	**1.36**	**0.34**	**0.75**	**0.75**	**7.10**
	Day	-0.08	0.94	0.41	0.88	0.88	3.90
	Night	0.32	1.83	0.27	0.65	0.65	12.0

Caveats for this analysis of scatter plots and performance measures

- Only for puffs and samplers with <u>both</u> pred and obs C_{max}(0.5 s) > 400 ppt (arbitrary minimum cutoff)
- Obs C has "cap" at about 23,000 ppt
- Does not address "real" 0 – 0 pairs
- Does not address "false positives" (C_p > 400 ppt and C_o < 400 ppt) or "false negatives" (C_p < 400 ppt and C_o > 400 ppt)

Caveats regarding use of only one city

- It is dangerous to jump to conclusions about model performance based on evaluations at only one city
- We are not aware of other cities where research grade puff dispersion experiments took place
- However, our similar simple urban dispersion model for continuous releases has been satisfactorily evaluated at several cities