URBAN HPAC AND A SIMPLE URBAN DISPERSION MODEL COMPARED WITH THE JOINT URBAN 2003 (JU2003) TRACER DATA

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SUMMARY OF PREVIOUS JU2003 EVALUATIONS OF HPAC 4.04 (the version used until January 2008)

- 2005-2007 evaluations by Hanna et al. and IDA
- Urban HPAC 4.04 overpredicts by a factor of 3 or 4 during the night
- Urban HPAC 4.04 underpredicts by a factor of 2 during the day

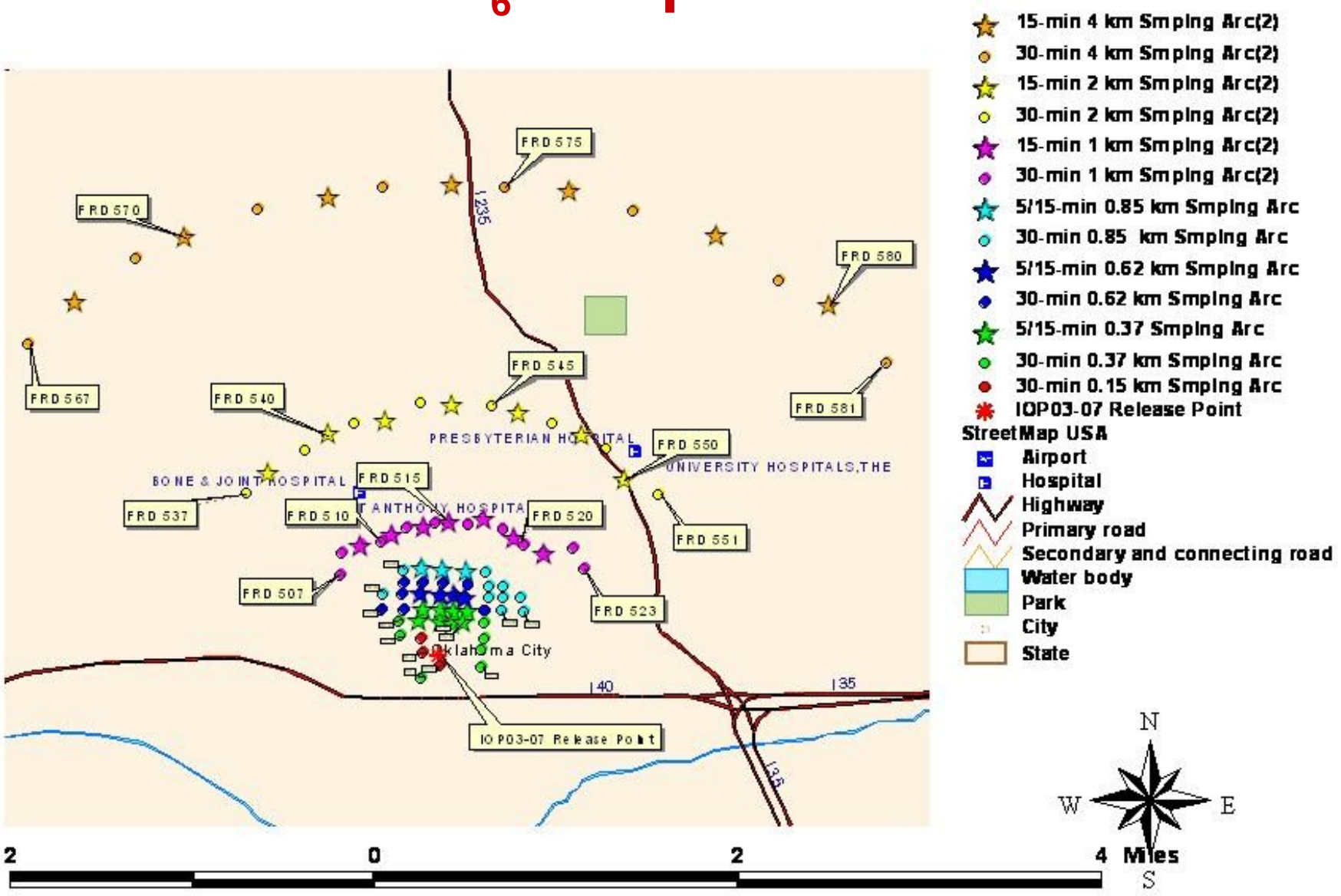
New Evaluations in this Paper

- **New HPAC Version 5.0 SP1 (released end of January 2008) contains modifications to SWIFT diagnostic wind model to remove errors in urban canopy winds in version 4.04. Also Microswift-Spray (MSS) is included in version 5.0 SP1**
- **A simple urban dispersion model developed and tested by Hanna and Baja is included in the model comparisons with JU2003**

JU2003 Intensive Operating Periods

- 6 daytime IOPs (3 used here)
- 4 night time IOPs
- 3 separate SF_6 tracer continuous releases (30-minute in duration) during each IOP
- IOPs 3, 4, 5, and 6 from the Botanical Gardens release site (day) (3, 4, and 6 used here)
- IOP 7 from the Botanical Gardens site (night)
- IOP 8 from the Westin Hotel site (night)
- IOPs 9 and 10 from the Park Ave. site (night)

JU2003 SF_6 Samplers



JU2003 Sampler Analysis Approach

- Use 30-min averaged C/Q
- To be included in the evaluations, a data pair must have both observed and predicted concentration exceeding 3 times background (or 15 ppt)
- For C_{max}/Q evaluation, assign samplers in the downtown area to three effective “arc” distances of 0.30, 0.62, and 0.85 km, plus the sampling arcs at 1, 2, and 4 km
- No rooftop samplers used
- IOP 5 removed from daytime IOPs (due to thunderstorms in area)

FOUR METEOROLOGICAL INPUT OPTIONS FOR HPAC 5.0 SP1

- **BDF** - Basic National Weather Service (NWS) default (airport data)
- **MED** – Mesoscale Meteorological Model – Version 5 (MM5) MEDOC outputs using special 4 km resolution runs
- **AVG** – Average wind speed and direction from all (150) anemometers in urban area
- **UPWND** – Wind speed and direction from sonic anemometer PWIDS #15 (Post Office) (1 km upwind at z = 40 m) with estimated mixing heights determined from PNNL radiosonde data.

HPAC 5.0 SP1 MODEL OPTIONS

- **UC** - Urban canopy
- **UDM** - Urban Dispersion Model with SWIFT
- **UX** – HPAC/SCIPUFF modified urban canopy (without UDM option)
- **MSS** - MicroSWIFT/SPRAY (Rockle-type diagnostic wind model using 3-D building geometry plus Lagrangian particle model)

Simple Urban Model

For continuous source near ground level in an urban canopy

$$C/Q = (1/(\pi u \sigma_y \sigma_z)) * \exp(-y^2/2\sigma_y^2) \quad x > 0$$

σ_y and σ_z are composed of an initial σ_o due to the mixing in the street canyons near the source, and a turbulent σ_t due to ambient turbulence.

Earlier field experiments in urban areas (e.g., the St. Louis tracer data) suggest that $\sigma_{yo} = \sigma_{zo} = 40$ m. We assume:

$$\sigma_y = \sigma_{yo} + \sigma_{yt} = 40 \text{ m} + 0.25\, x \quad \text{day}$$

$$\sigma_y = \sigma_{yo} + \sigma_{yt} = 40 \text{ m} + 0.08\, x \quad \text{night}$$

The same formulas are used for σ_z

Stability is assumed close to neutral both day and night because of the strong mechanical mixing.

The cloud spreads in a hemispherical shape around the source area. Effects of upwind dispersion are estimated for $x < 0$, assuming $\sigma_{xo} = \sigma_{yo}$.

$$C/Q = (1/(\pi u \sigma_{yo} \sigma_{zo})) * \exp(-y^2/2\sigma_{yo}^2) \exp(-x^2/2\sigma_{xo}^2)$$

MODEL EVALUATION METHODS

- **Group 1** - Compared predicted to observed arc maximum 30-minute averaged C_{max}/Q for each downwind distance and release trial
- **Group 2** - Compared predicted to observed 30-minute averaged C/Q paired in space (i.e., for each sampler and release trial)
- Both C_o and C_p had to exceed 3 times SF_6 background (3 x 5 ppt = 15 ppt)
- A combination of scatter plots and tabulations of performance measures was used

STATISTICAL PERFORMANCE MEASURES, WHERE X=C/Q

- Fractional Bias $FB = 2\langle X_o - X_p \rangle / (\langle X_o \rangle + \langle X_p \rangle)$
- Normalized Mean Square Error

$$NMSE = \langle (X_o - X_p)^2 \rangle / (\langle X_o \rangle \langle X_p \rangle)$$

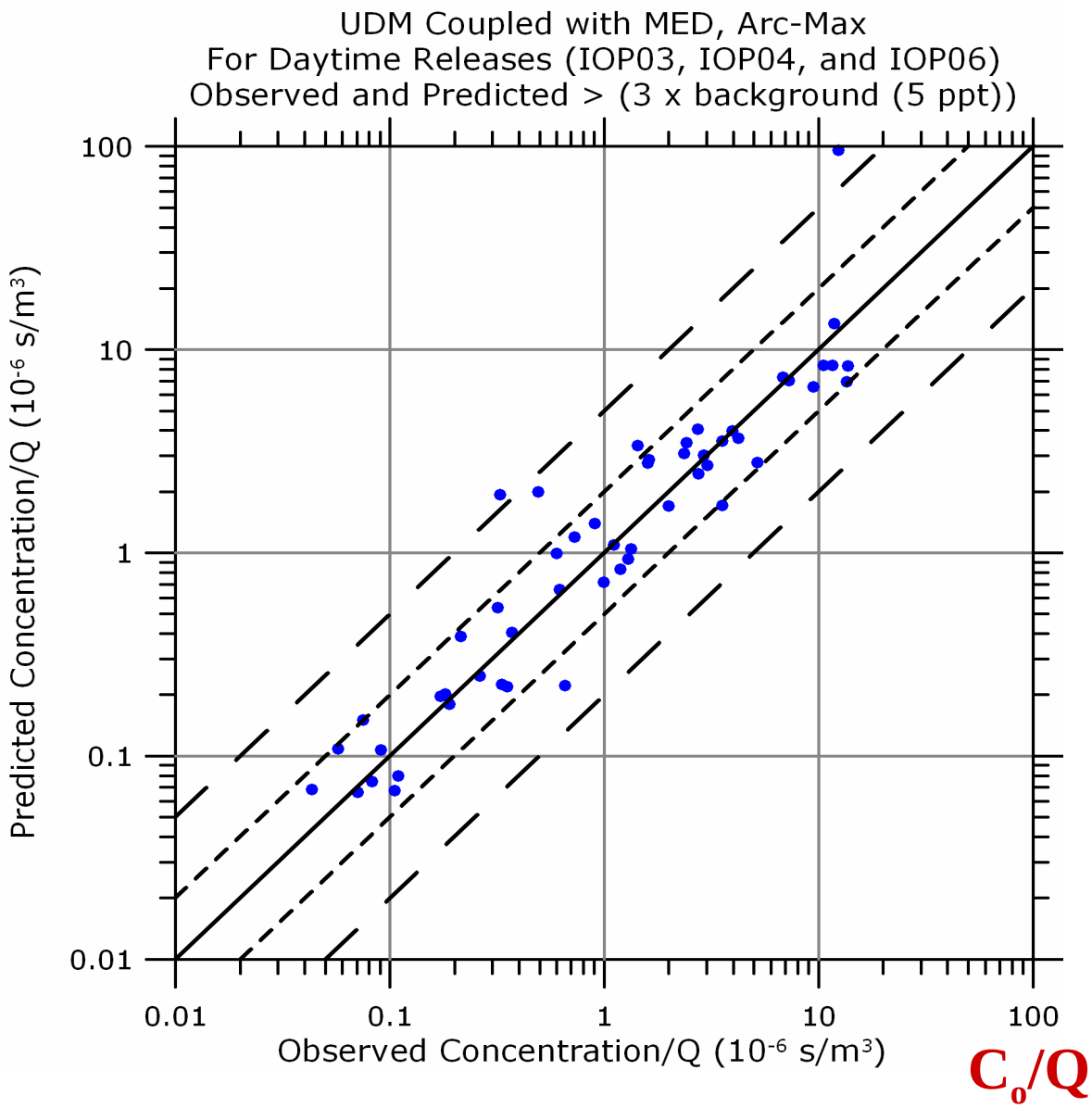
- Fraction of X_p within a factor of two of X_o (FAC2)
- Geometric Mean $MG = \exp(\langle \ln X_o \rangle - \langle \ln X_p \rangle)$
- Geometric Variance $VG = \exp\langle (\ln X_o - \ln X_p)^2 \rangle$

- subscripts p and o refer to predicted and observed
- the symbol <> represents an average

Statistical performance measures for HPAC and the simple urban model. Arc maxima (Group 1) are compared here. C/Q has units of s/m^3 times 10^6.

Performance Measure	Day HPAC UDM/MEDOC	Day HPAC UDM/UPWND	Day Simple Urban Model	Night HPAC UDM/MEDOC	Night HPAC UDM/UPWND	Night Simple Urban Model
Max Co/Q	14.5	14.5	14.5	130	130	130
Max Cp/Q	100*	12	8.5	140	183	54.2
FB	-0.37	0.03	0.22	0.05	-0.80	0.00
NMSE	11.2	0.3	1.14	7.0	9.8	2.54
MG	0.95	0.85	0.93	1.78	0.51	0.67
VG	1.41	1.24	1.93	8.47	3.32	3.48
FAC2	0.87	0.91	0.92	0.57	0.40	0.92

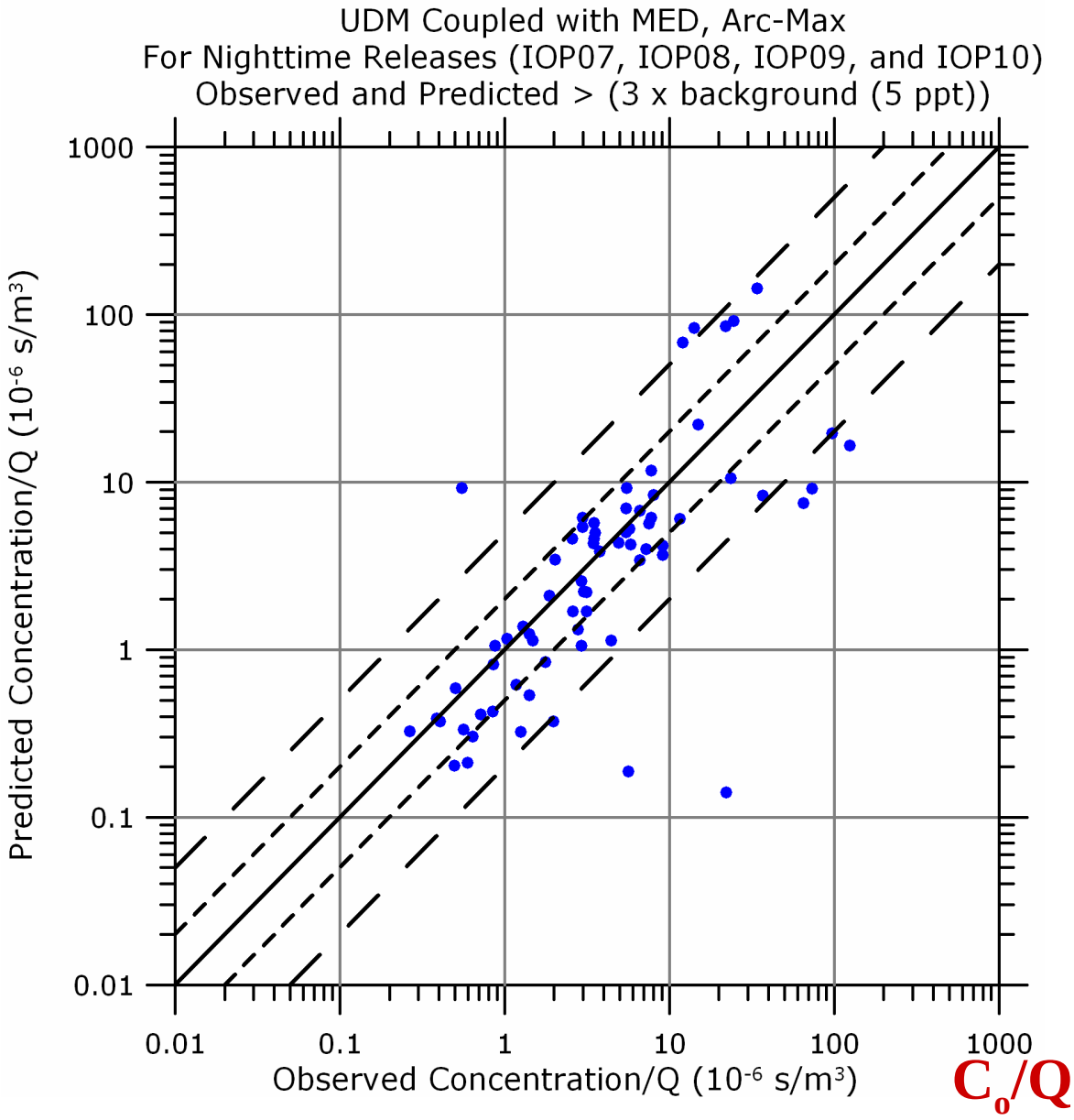
*isolated maximum



C_p/Q

C_o/Q

Scatter plot for HPAC UDM/MEDOC for day IOPs

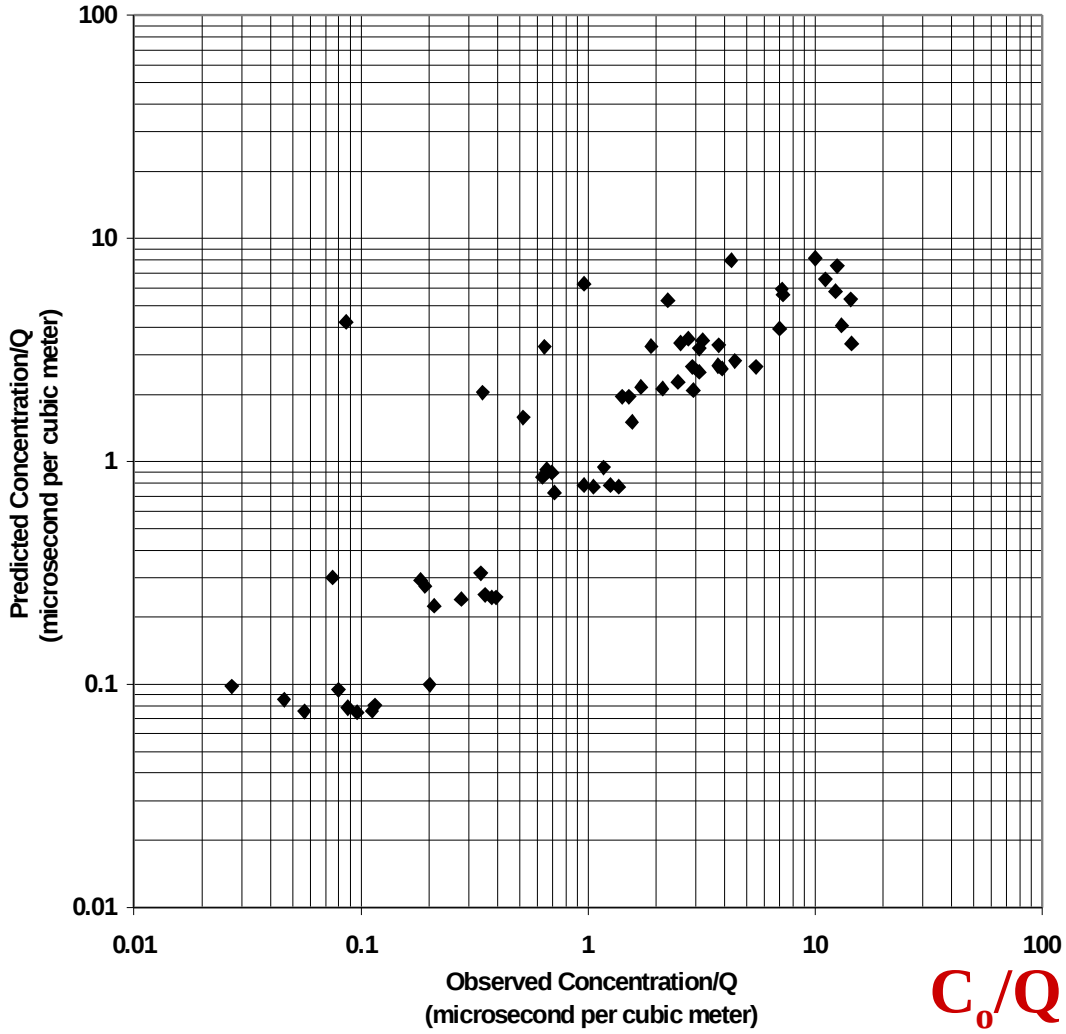


C_p/Q

C_o/Q

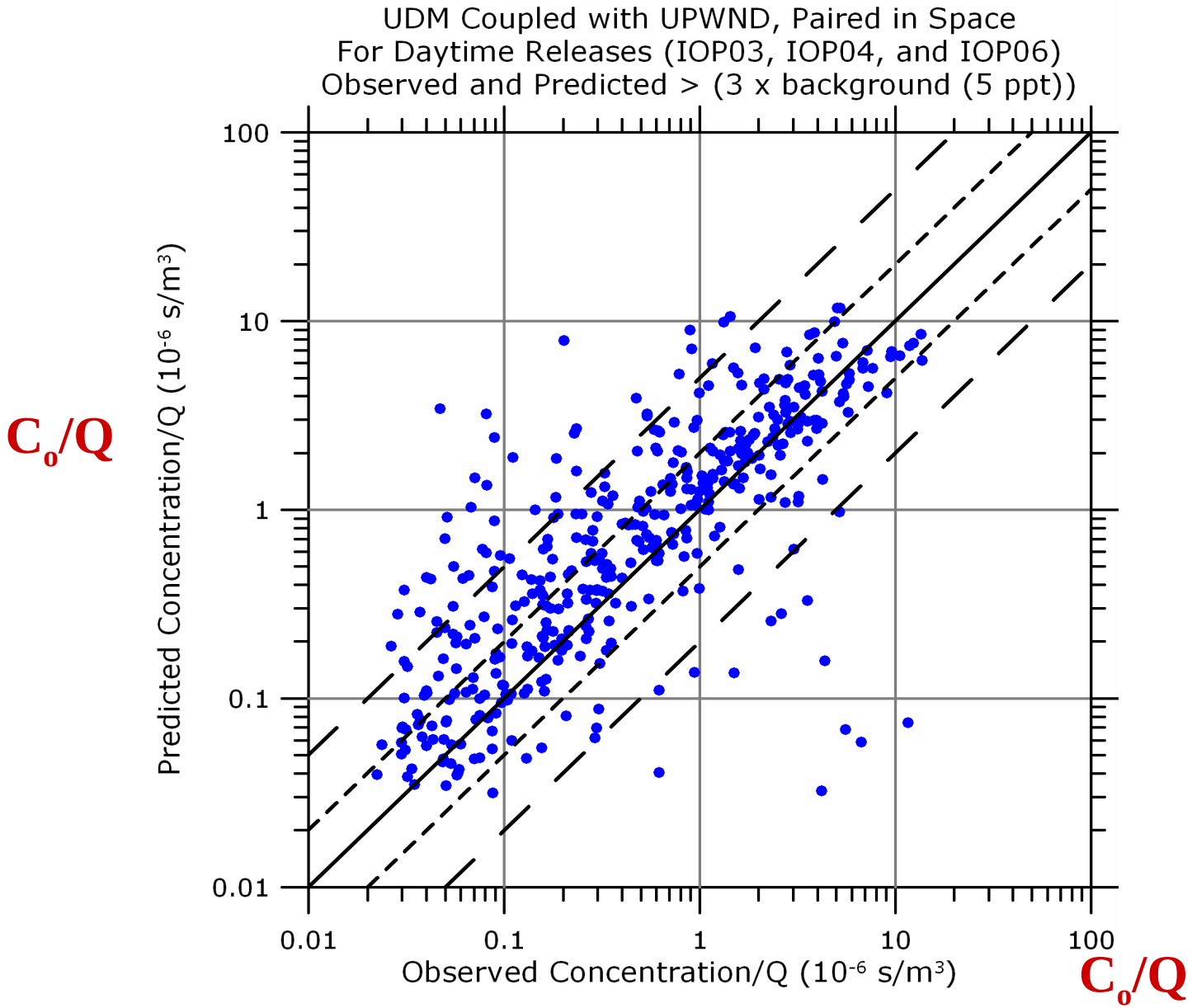
Scatter plot for HPAC UDM/MEDOC for night IOPs

C_p/Q



C_o/Q

Scatter plot for simple urban model for day IOPs



All data scatter plot for HPAC UDM/Upwind for day IOPs

SUMMARY OF THE JU2003 HPAC 5.0 SP1 AND SIMPLE URBAN MODEL EVALUATIONS

- Improvement in performance measures for HPAC 5.0 SP1 over HPAC 4.04. The daytime under-predictions eliminated. The nighttime overpredictions remain but not so large.
- For daytime IOPs (3, 4, and 6)

  - UDM with the BDF, AVG, and UPW met options has least bias, lowest scatter, and highest FAC2. UDM and UC with the MEDOC met option show improvement over HPAC 4.04

  - MSS with all met options does well with low bias and scatter except for a few high conc (factor of 5 to 10) near the source

  - A few bugs were found in the way UDM interacts with SWIFT

  - The simple urban model performs as well as the better HPAC options, with small mean bias(FB = -0.22) and good FAC2 (0.92).

SUMMARY OF THE JU2003 HPAC 5.0 SP1 STATISTICAL EVALUATION (continued)

- For night time IOPs (7, 8, 9, and 10)

  - The large overpredictions at night were partially eliminated, although an overprediction bias (factor of 2) still exists. This bias occurs with versions using SWIFT for met processing, since SWIFT produces winds in the nighttime urban canopy that are a factor of 3 to 5 small. HPAC options combined with MEDOC met option show the least bias, lowest scatter and highest FAC2 at night (all greater than 50%)

  - Because it is not influenced by the SWIFT diagnostic met model, MSS shows better performance. However, the same large overpredictions at a few nearby samplers were found during the night as during the day.

  - The simple urban model performs well for the night time runs, with a mean bias of near zero and FAC2 of 0,92

FUTURE WORK

- Complete the HPAC 5.0 SP1 evaluation with MSG05 (and possibly MID05, if tracer data are released)
- Include model runs with met inputs from RT-FDDA final analysis MEDOC data files for MSG05 (and MID05)
- Work with MSS developers on correcting MSS overpredictions at JU2003 close-in samplers
- Include significance tests showing whether various model options produce significantly different performance measures, at the 95 % confidence level.
- The simple urban model has already been evaluated with MSG05 data, with good performance

MSG05 Domain

Looking WNW from Empire State Building

One Penn Plaza is tall building (223 m) and rooftop PFT samplers are approximately at blue dots