Estimating Indoor Exposures to Particles of Outdoor Origin

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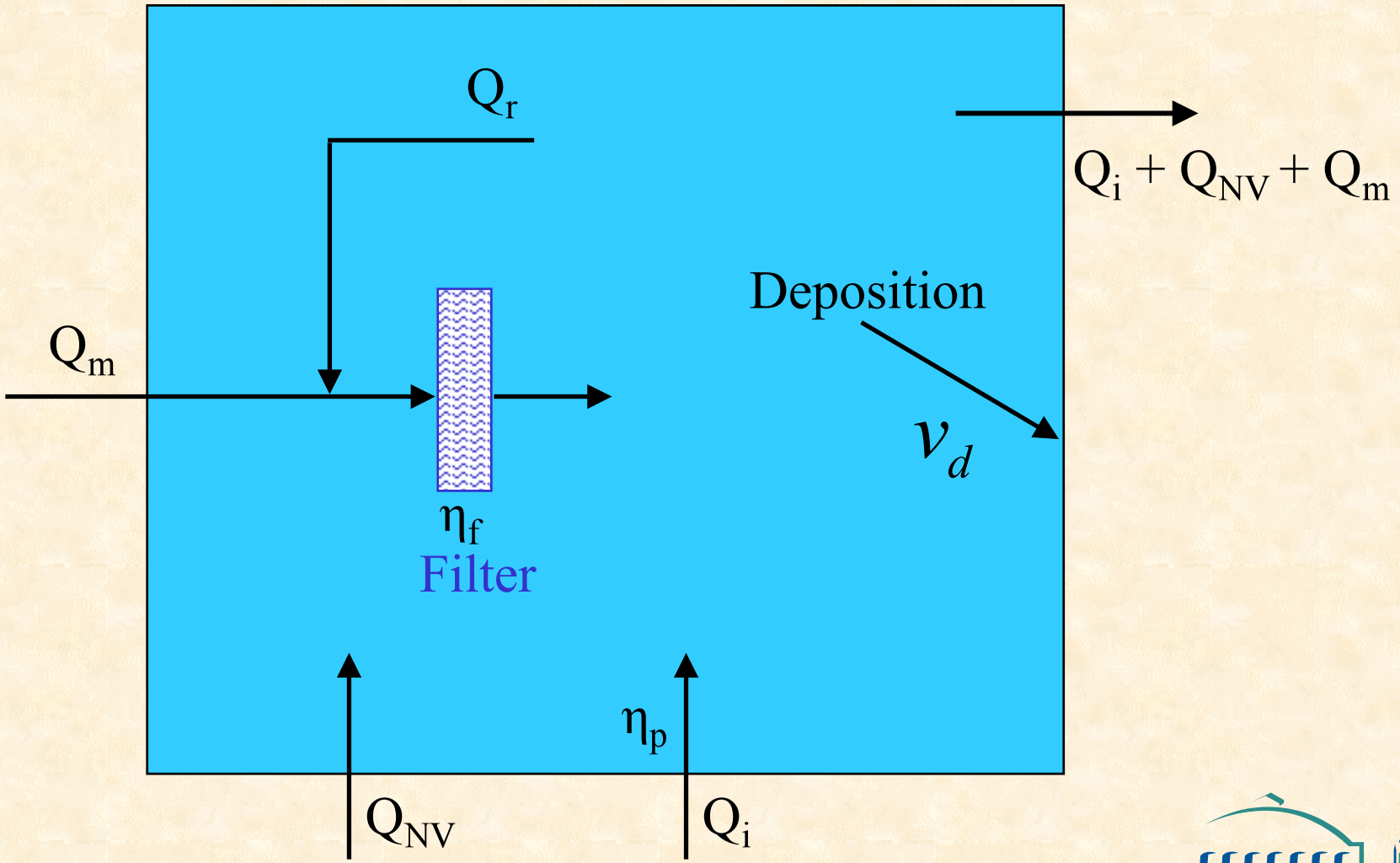
Outline

- Health metrics of concern
- Size-resolved model of indoor PM originating outdoors
  - Building operation
  - Development of generic relationships for:
    - Filtration
    - Deposition
- Size-resolved particle distributions
  - Archetypal and measured urban and rural
  - Sulfate, PAH's, carbon, trace elements
- Uncertainty
- Results

Health-Related Metrics

- Number, surface area, mass concentrations
- PM2.5, PM10, and coarse mode
- Compounds of interest
  - Sulfate, nitrate, ammonium
  - PAH's
  - Elemental and organic carbon
  - Trace elements, e.g., Pb, Al, Fe, Zn, and Cu

Building Operation



Model

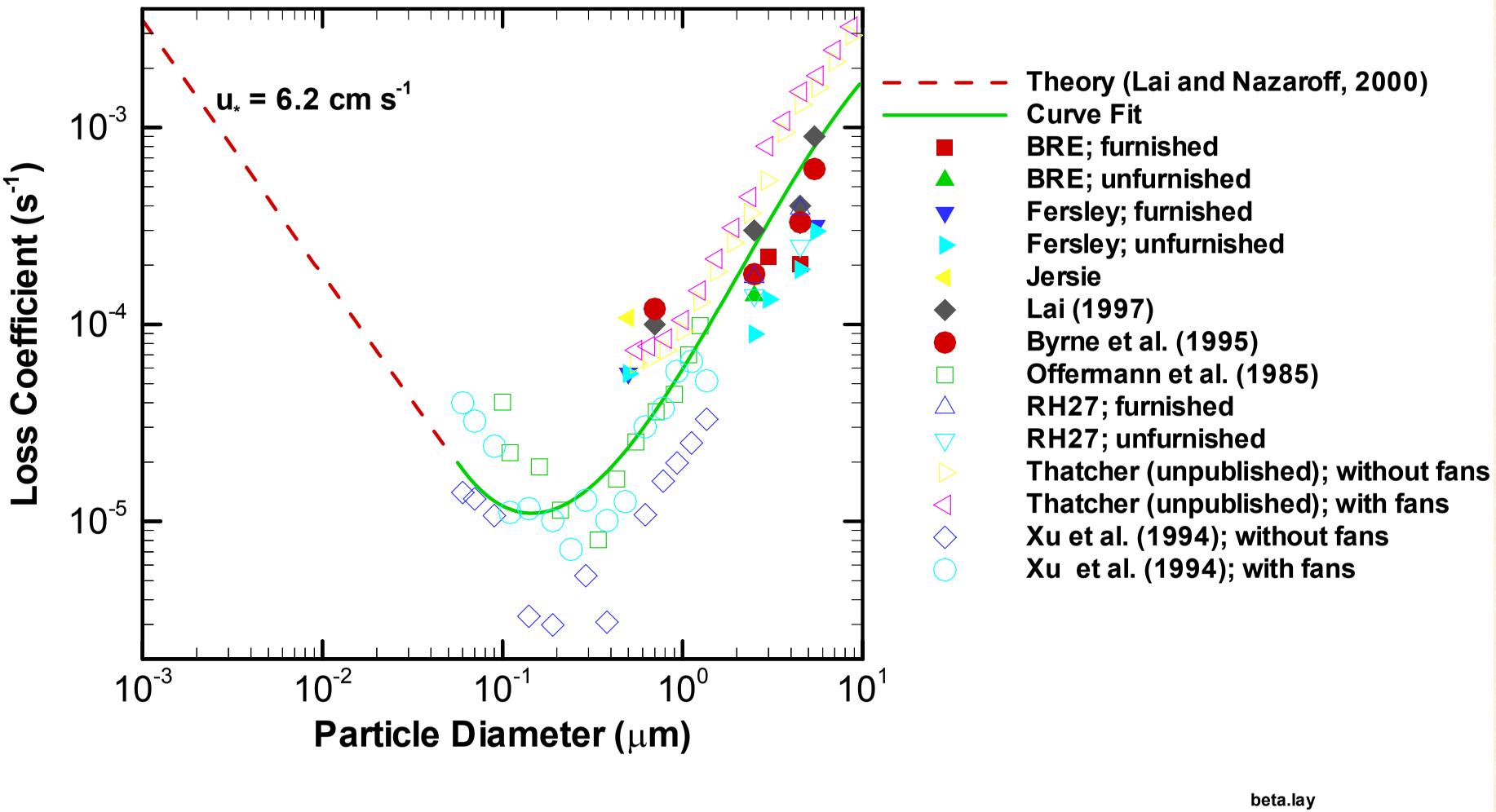
Time-averaged mass balance on particles of specific size:

$$\frac{C}{C_o} = \frac{\left\{ \frac{Q_m}{V}\left(1-\eta_f\right)+\frac{\eta_p Q_i}{V} \right\}}{\frac{Q_r \eta_f}{V}+\beta+\frac{Q_m+Q_i}{V}}$$

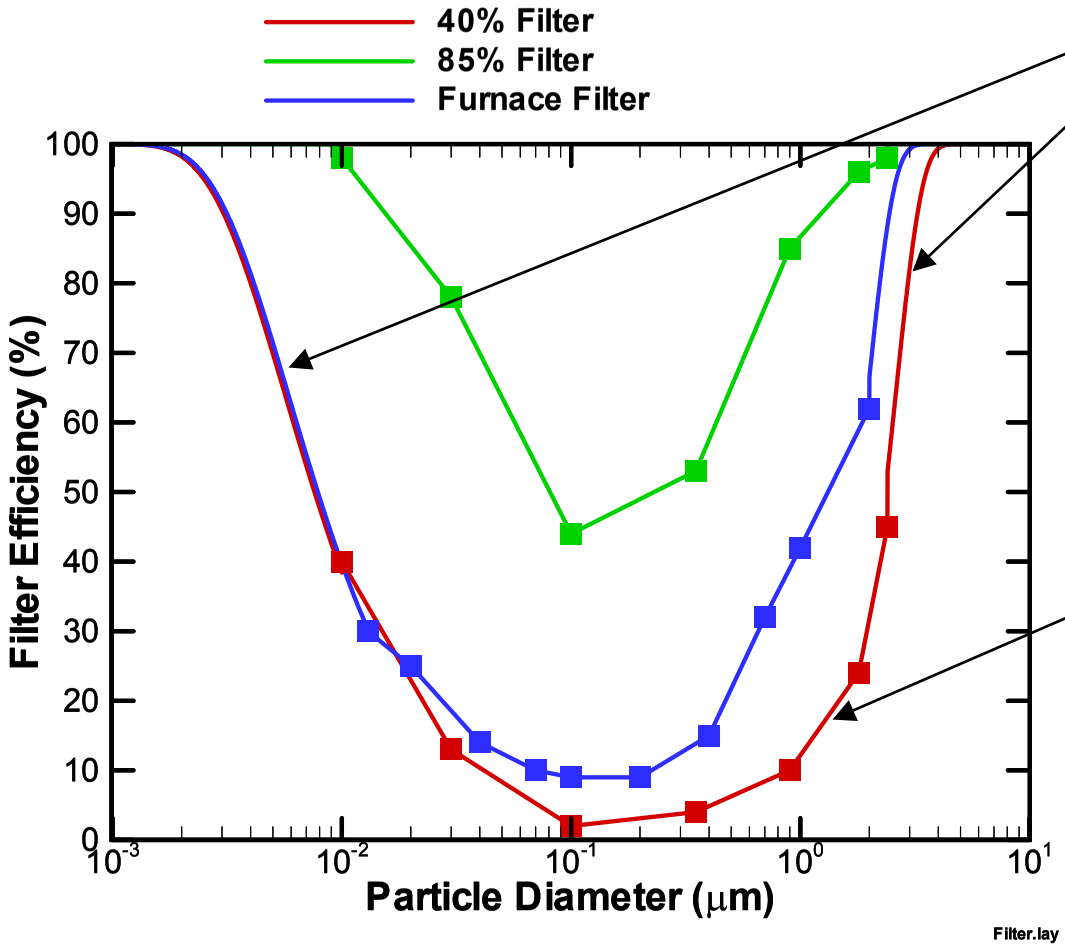
where the size-dependent deposition loss coefficient is:

$$\beta = \sum_j \frac{v_{d,j} S_j}{V}$$

Deposition Loss Rate



Filter Performance



Filter theory (Hinds, 1999)
-gravitational settling
-impaction
-interception
-Brownian diffusion

Linear interpolation between data (Hanley et al., 1994)

Building Operation

Parameter	Building Type and Operation		
	Office	***Residence Scenario #1: Closed Central Air***	***Residence Scenario #2: Closed No Air***	***Residence Scenario #3: Open Doors and Windows***
Q_m/V (h^{-1})	1.6[a] (1.5)	0 (0)	0 (0)	0 (0)
Q_i/V (h^{-1})	3[a] (1.5)	4 (1.5)	0 (0)	0 (0)
Q_r/V (h^{-1})	0.25 (1.5)	0.75 (1.5)	0.53 (2.3)[b]	2.2[c] (2.0)
Filter	40 or 85% ASHRAE	Standard Filter	N/A	N/A

[a] Building weighted (Fisk, 2000)
[b] (Murray, 1995)
[c] (Wallace, 2000); 41 houses in Los Angeles, Summer, Daytime

Ambient Particle Distributions

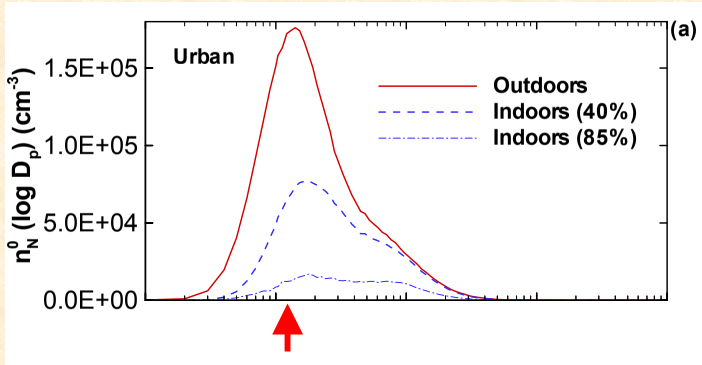
- Archetypal urban and rural total particle concentration (Jaenicke (1993)):

$$n_N{}^0(\log D_p) = \sum_{i=1}^{3} \frac{N_i}{\sqrt{2\pi}\,\log\sigma_i} \exp\left(-\frac{(\log D_p - \log D_{pi})^2}{2\log^2\sigma_i} \right)$$

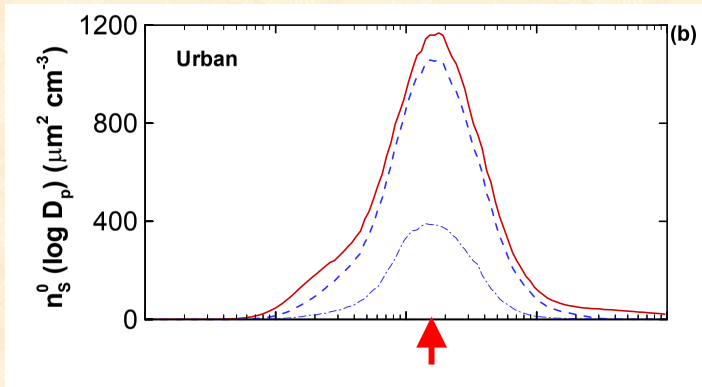
- Measured total particle concentration
- Measured particle concentrations for:
  - Sulfate; PAH's; elemental and organic carbon; trace elements

Office Building With Archetypal Urban PM Distribution

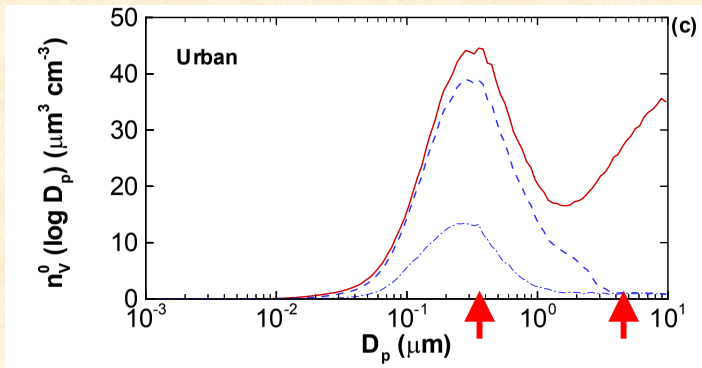
Number Concentration



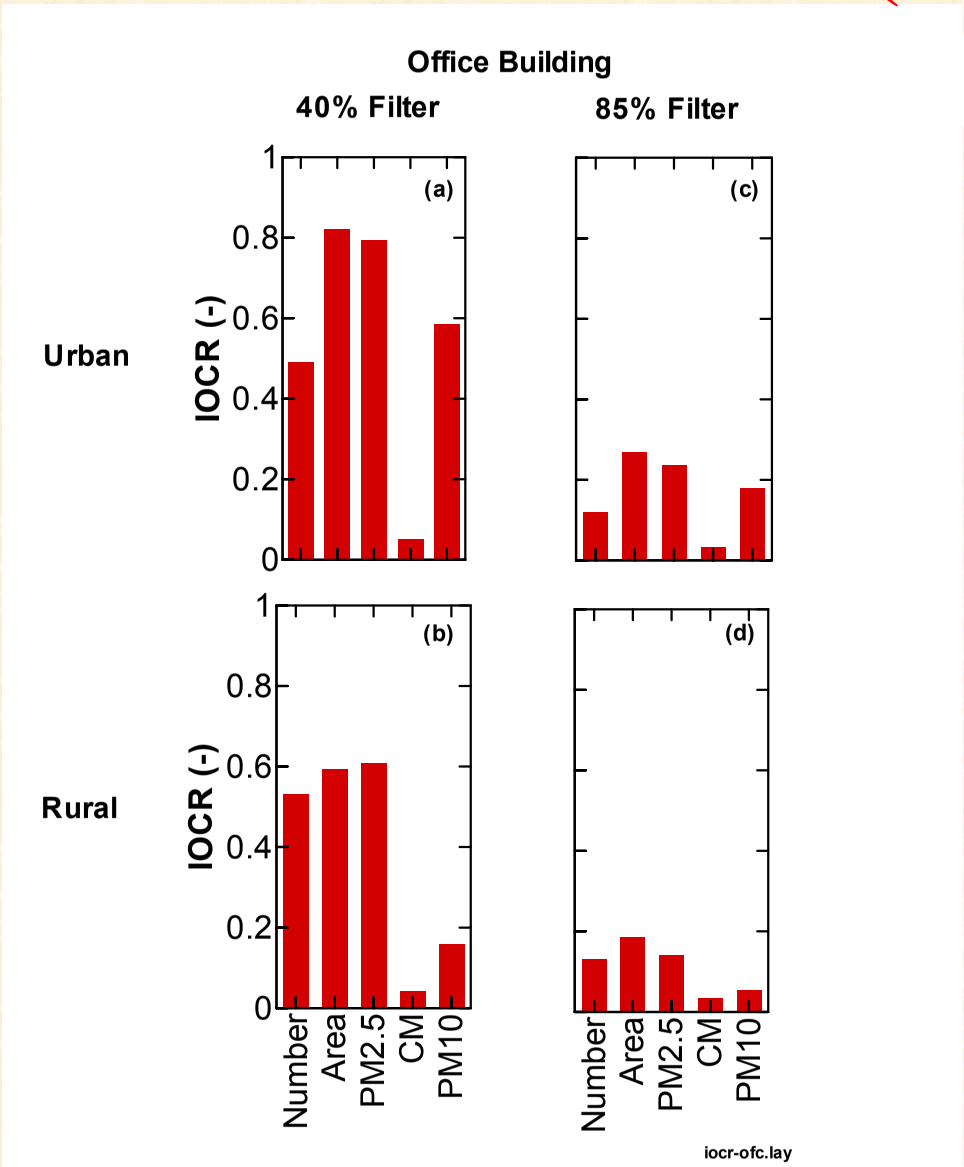
Surface Area Concentration



Volume (Mass) Concentration



Indoor to Outdoor Concentration Ratio (IOCR)



-PM10
  -Urban vs. Rural
  -Factor of ~4
-PM2.5
  -Factor of ~25%
-Impact of filter efficiency

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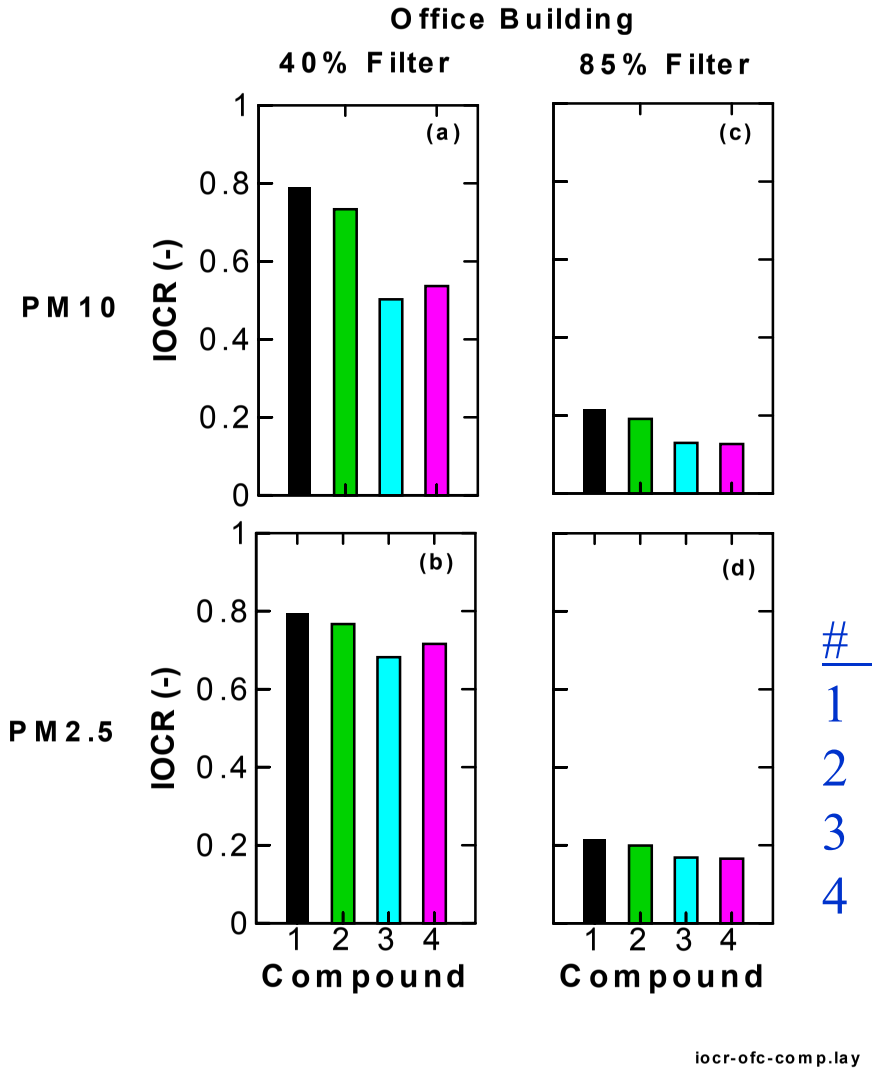
Individual Compounds in PM



-Largest differences
-Impact of CM
-Pyrene vs. Sulfate

#	Compound
1	Sulfate
2	BAP
3	Pyrene
4	Organic C

Conclusions

- Developed generalized, size-dependent functions for:
  - Filtration
  - Deposition
- Ambient PM size distribution affects:
  - Indoor PM level and size distribution
    - Filtration and deposition (penetration?) depend on particle size
  - Human exposure and dose (i.e., lung deposition)
    - Dependent on the particle size distribution, not just integrated mass
- The IOCR for individual compounds depends on the outdoor PM size distribution
  - E.g., sulfate vs. pyrene

Sulfate and Pyrene