Light-mediated chemistry at the surface of urban road dust: implications for air quality and health

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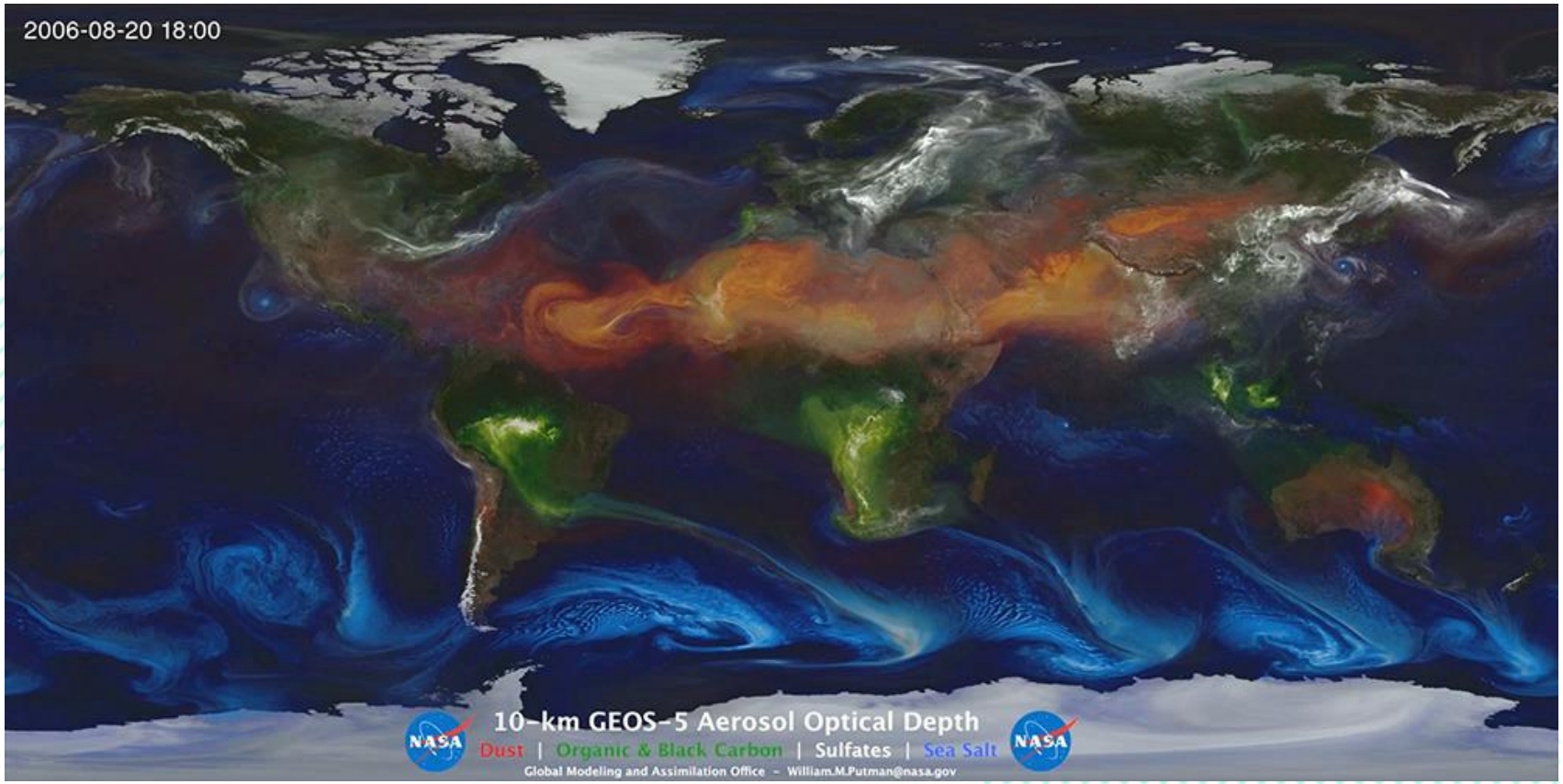
Styler Research Group

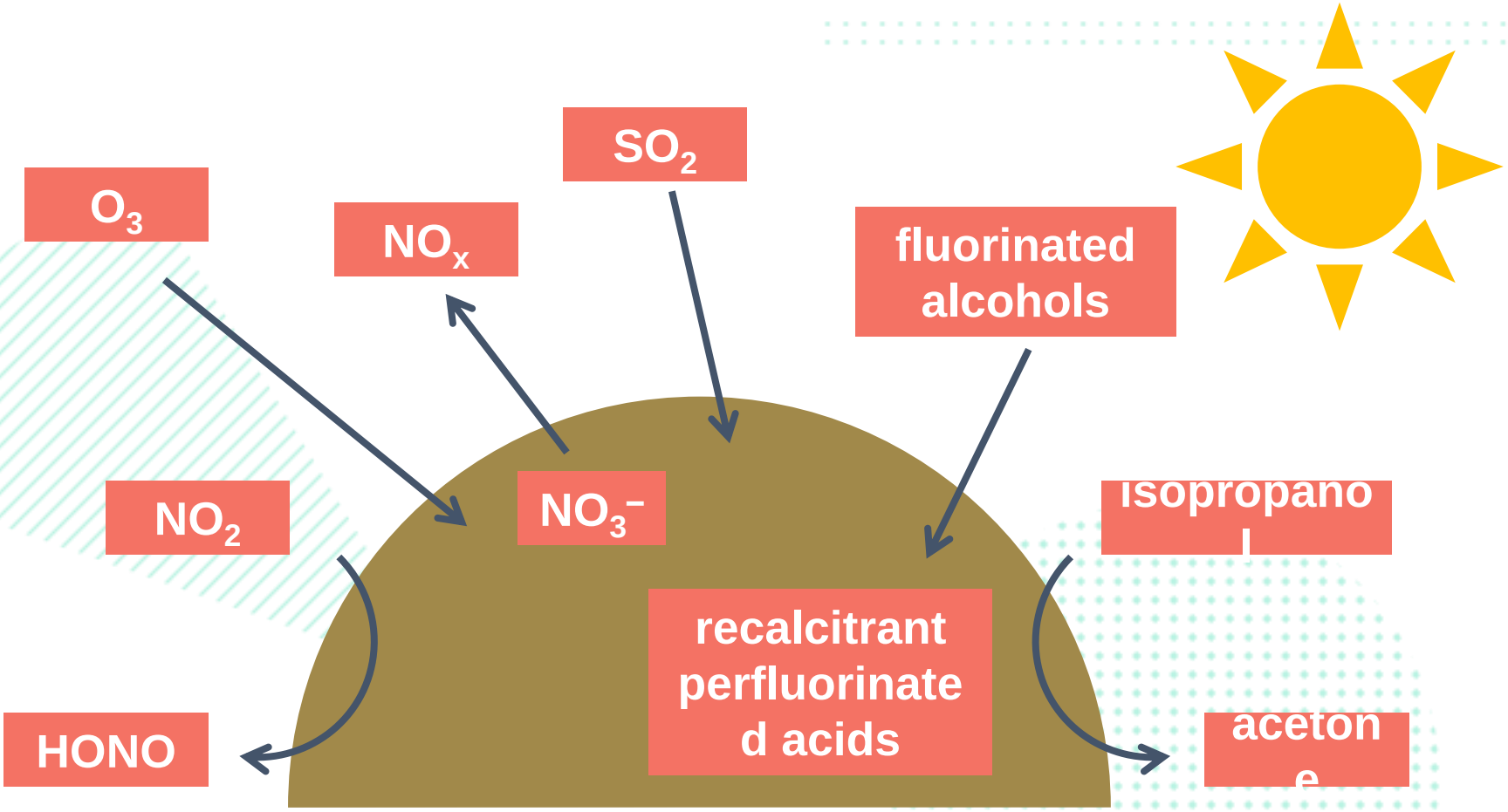
UNIVERSITY OF ALBERTA
DEPARTMENT OF CHEMISTRY

Dust in the atmosphere: over one billion tons are emitted annually



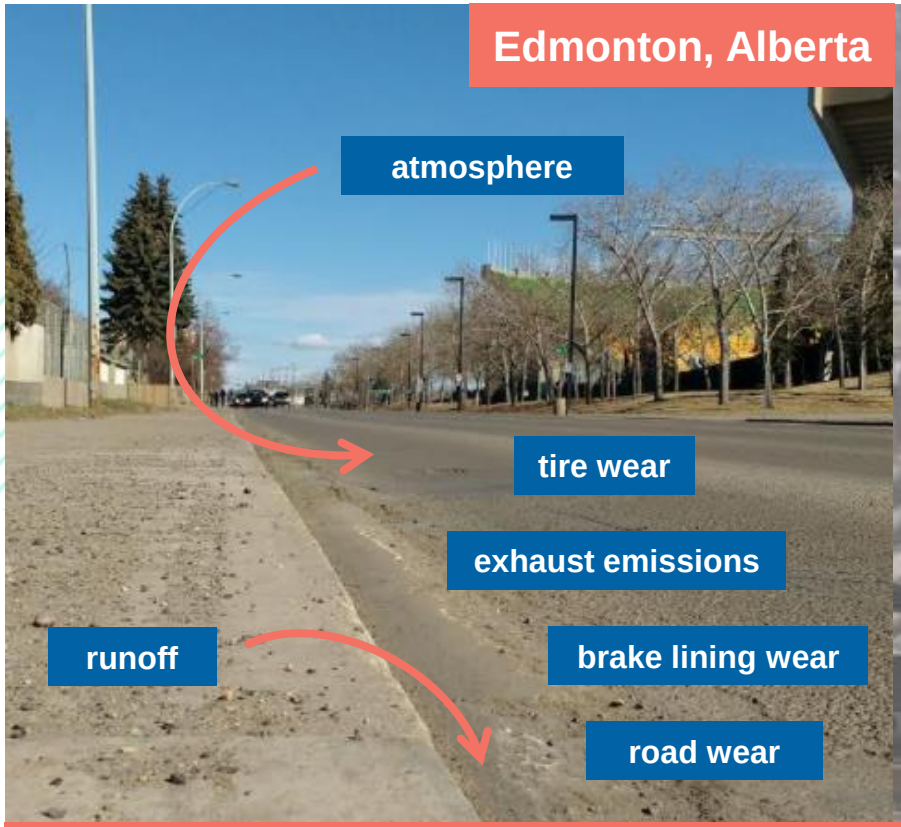
https://gmao.gsfc.nasa.gov/research/aerosol/modeling/nr1_movie/

Dust catalyzes a wide variety of atmospheric transformations



Monge et al., PCCP 2010; Monge et al., JACS 2010; Chen et al., JPC A 2011; Adams et al., ACP 2005;

Local dust emission

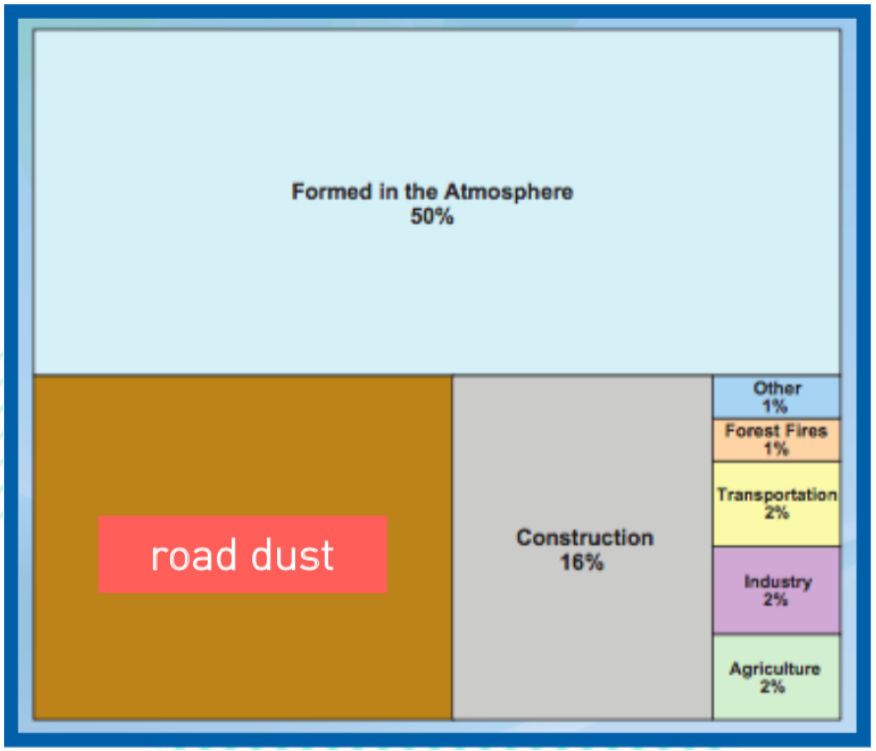


different composition … different reactivity?

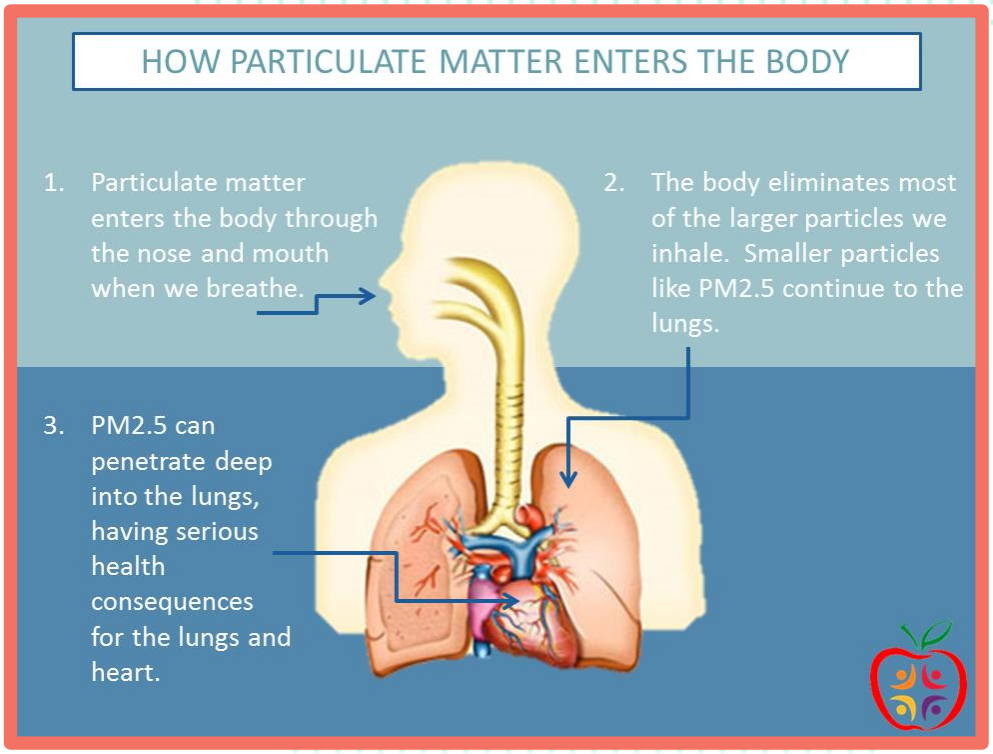
Loganathan et al., Crit. Rev. Environ. Sci. Tech. 2012; Chen et al., Chem. Rev. 2012

http://www.thedailystar.net/city/take-steps-control-dhaka-road-dust-pollution-winter-dry-season-activists-1482997

Road dust makes a significant fraction of atmospheric particulate matter (PM)



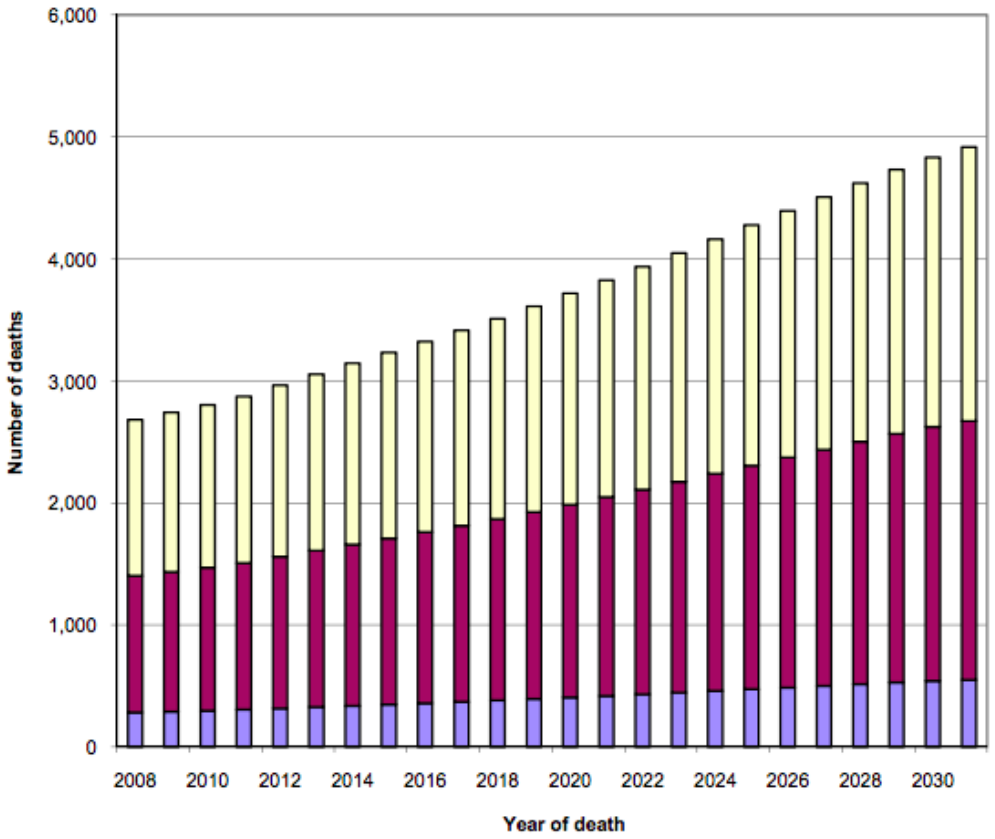
$PM_{2.5}$ sources in Alberta, Canada



Health effects

https://extranet.gov.ab.ca/env/infocentre/info/library/8862.pdf; http://www.health.utah.gov/utahair/pollutants/PM/

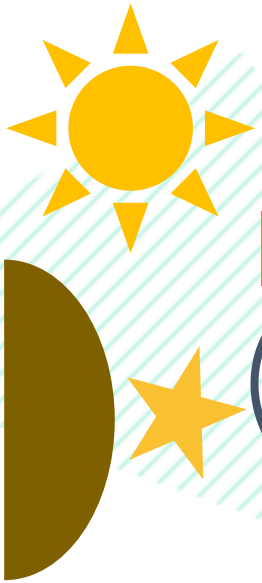
Road dust makes a significant fraction of atmospheric particulate matter (PM)



Note:
Attributable to O_3, $PM_{2.5}$
Other causes of acute premature mortality includes all causes of mortality due to air pollution that is non-traumatic and not cardiovascular or respiratory causes (e.g. diabetes and cancer)

http://www.healthyenvironmentforkids.ca/sites/healthyenvironmentforkids.ca/files/No_Breathing_Room.pdf

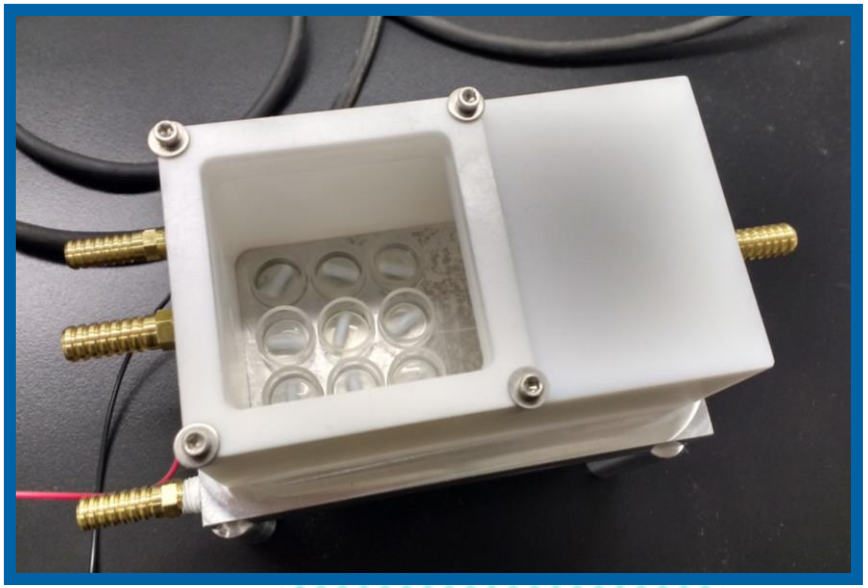
Road dust photochemistry: experimental strategy



probe molecule

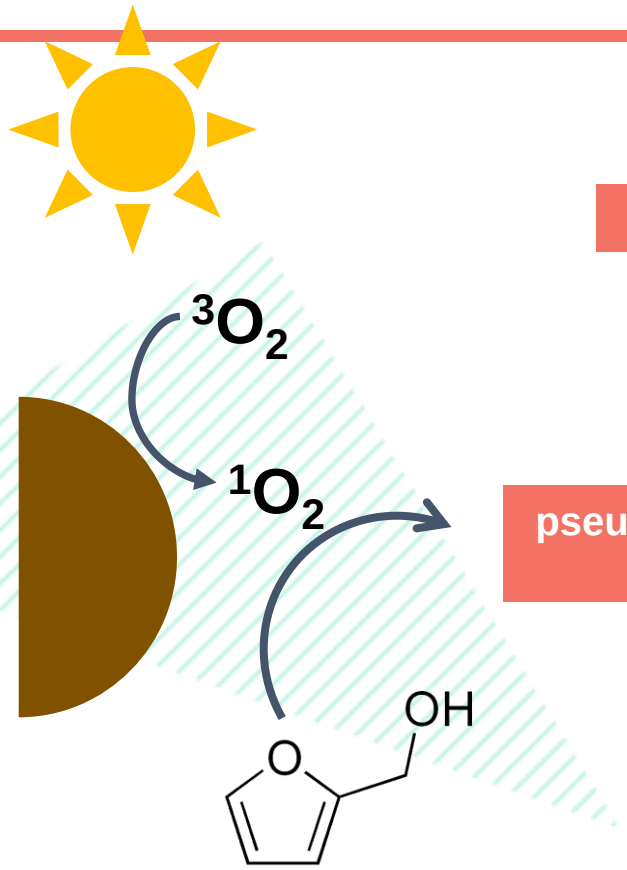
product formation / probe loss

spectroscopy (UV-Vis/fluorescence)



nine-compartment, temperature-controlled, stirred photochemical reactor

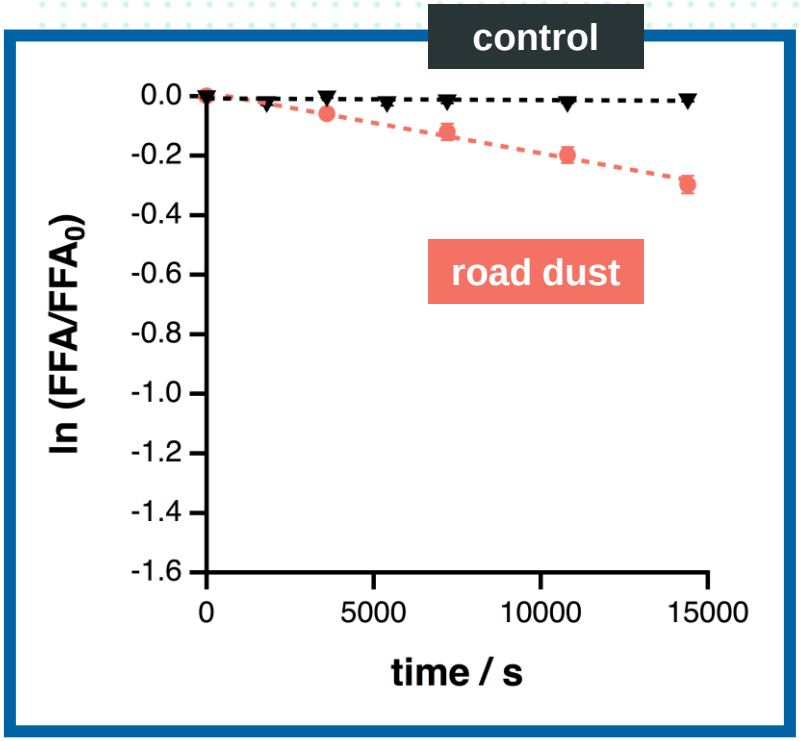
Dust-catalyzed singlet oxygen production



furfuryl alcohol (FFA)

$[^1O_2]_{ss}$

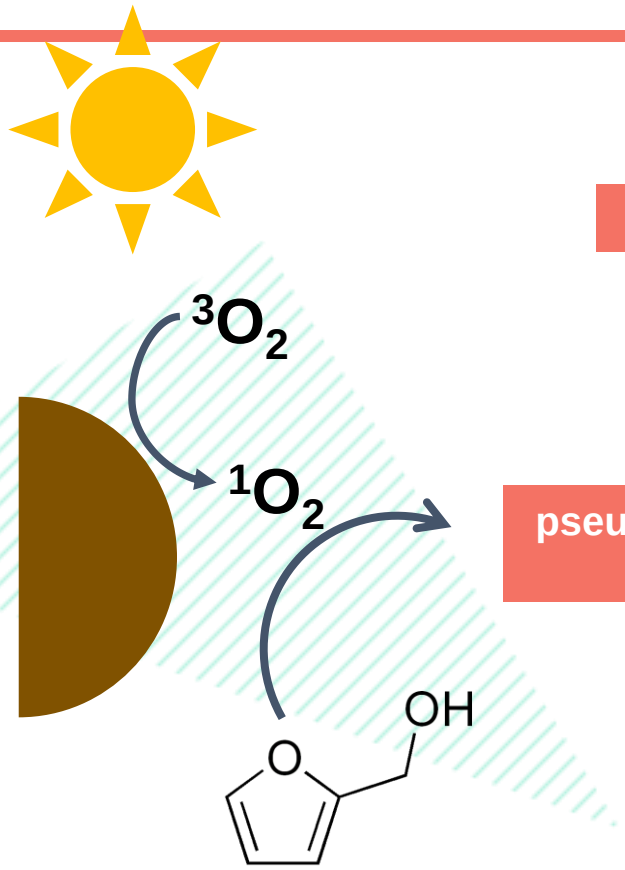
pseudo-first-order loss rate



road dust-catalyzed FFA loss

Appiani et al., Env. Sci. Process. Impact 2017; Haag et al., Chemosphere 1984

Comparative reactivity studies



furfuryl alcohol (FFA)

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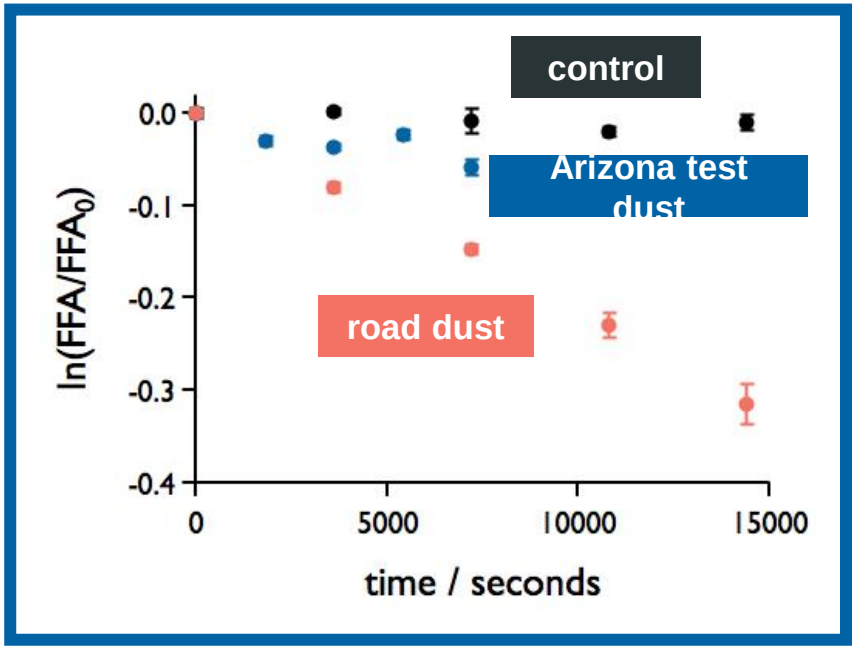
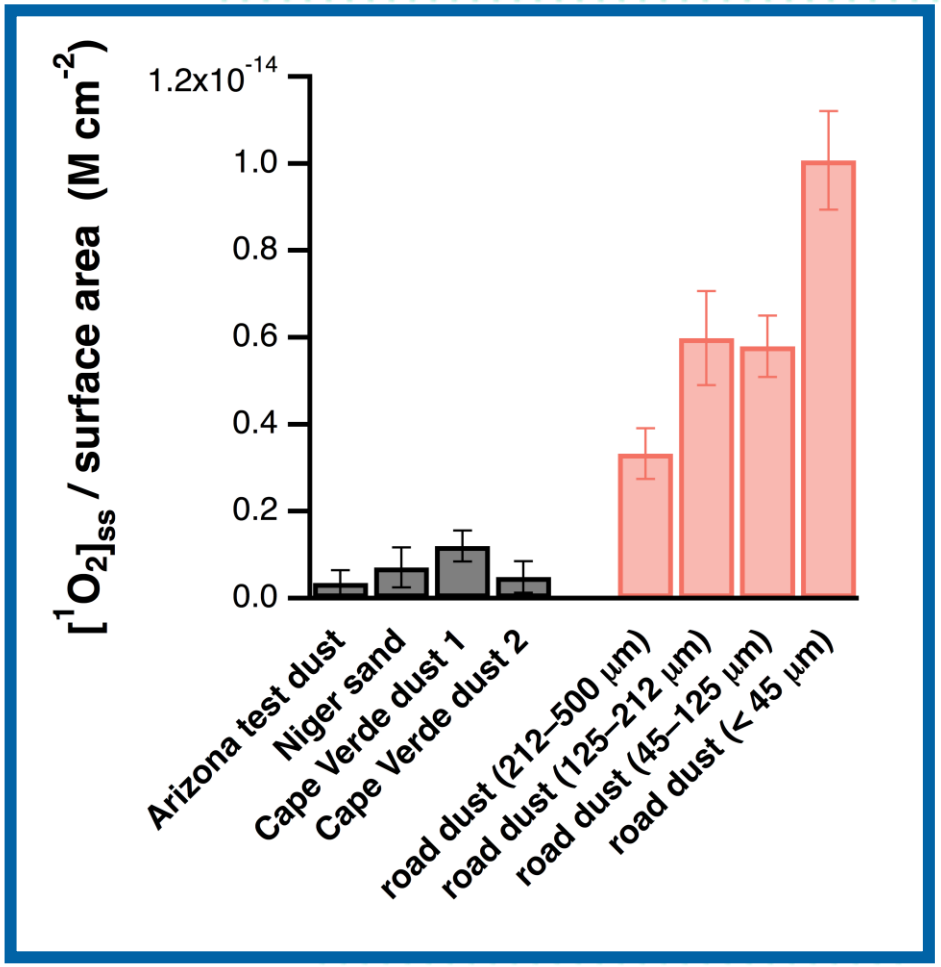


road dust appears to be more reactive … but we need to consider dust surface area!

Surface area-scaled $[^1O_2]_{ss}$

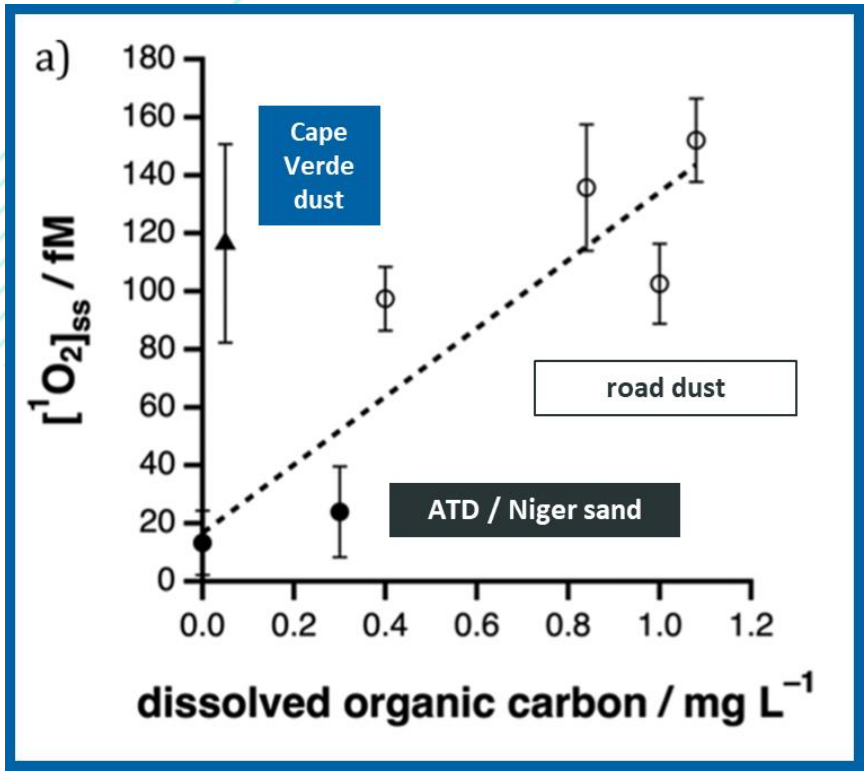
Road dust is more reactive than desert dust

The smallest road dust fraction is the most reactive

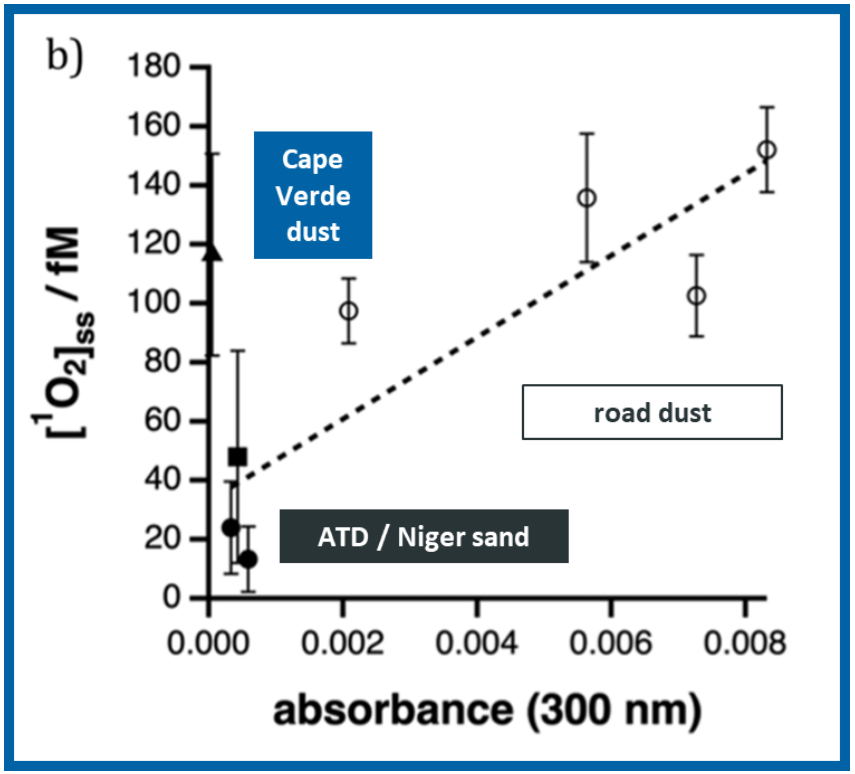


Organic matter contributions

correlation with DOC content of sample extracts



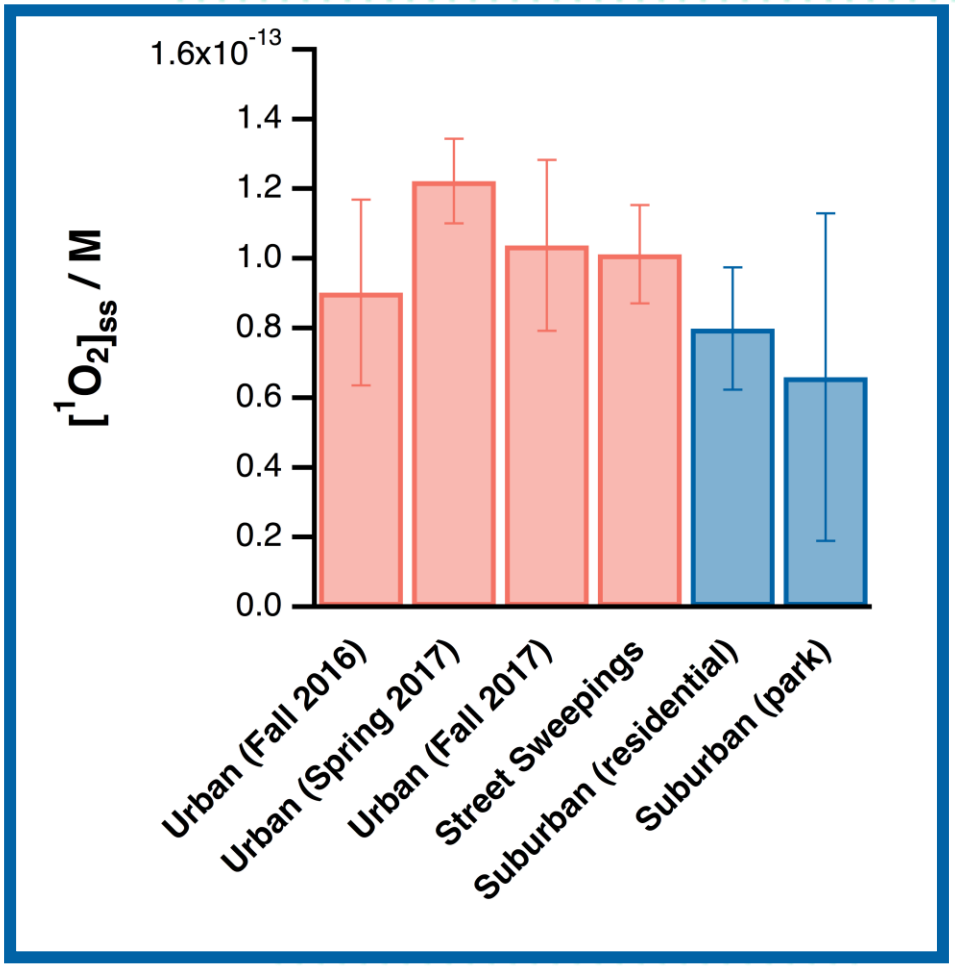
correlation with chromophoric DOC of sample extracts



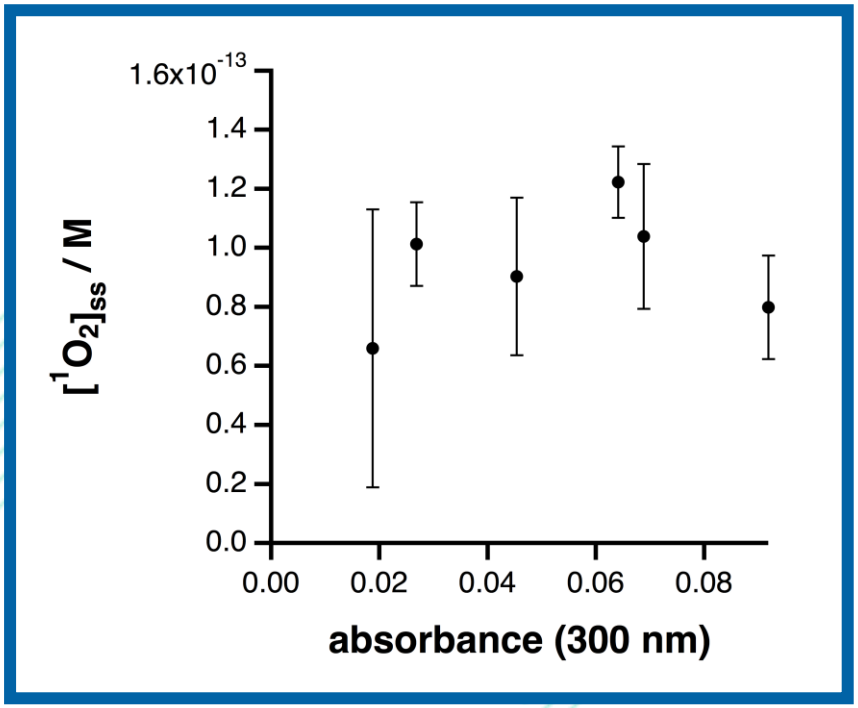
Appiani et al., Env. Sci. Process. Impact 2017; Haag et al., Chemosphere 1984

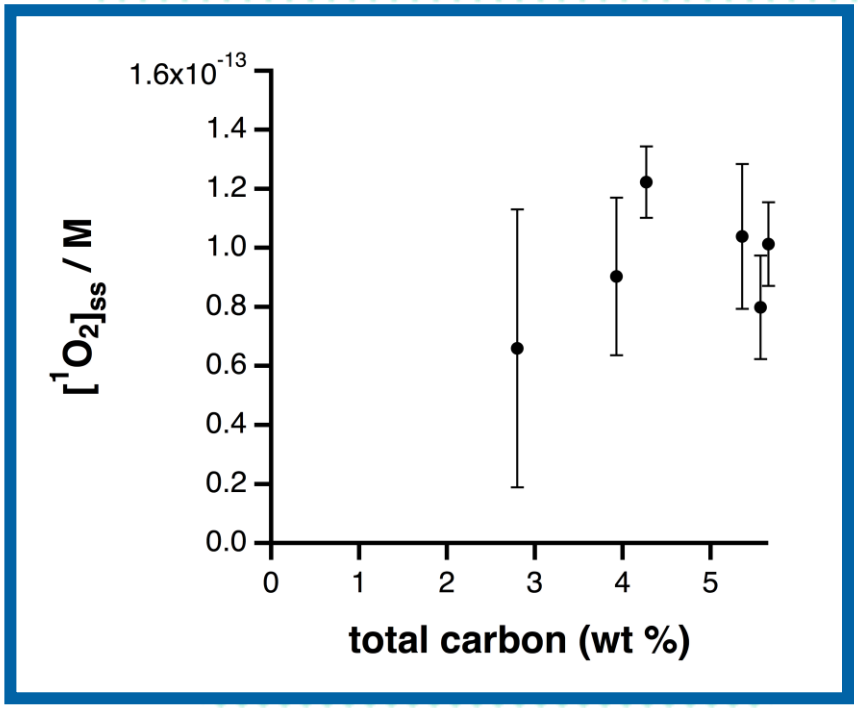
Effect of season/location on road dust reactivity

$[^1O_2]_{ss}$ relatively similar for the sample set studied



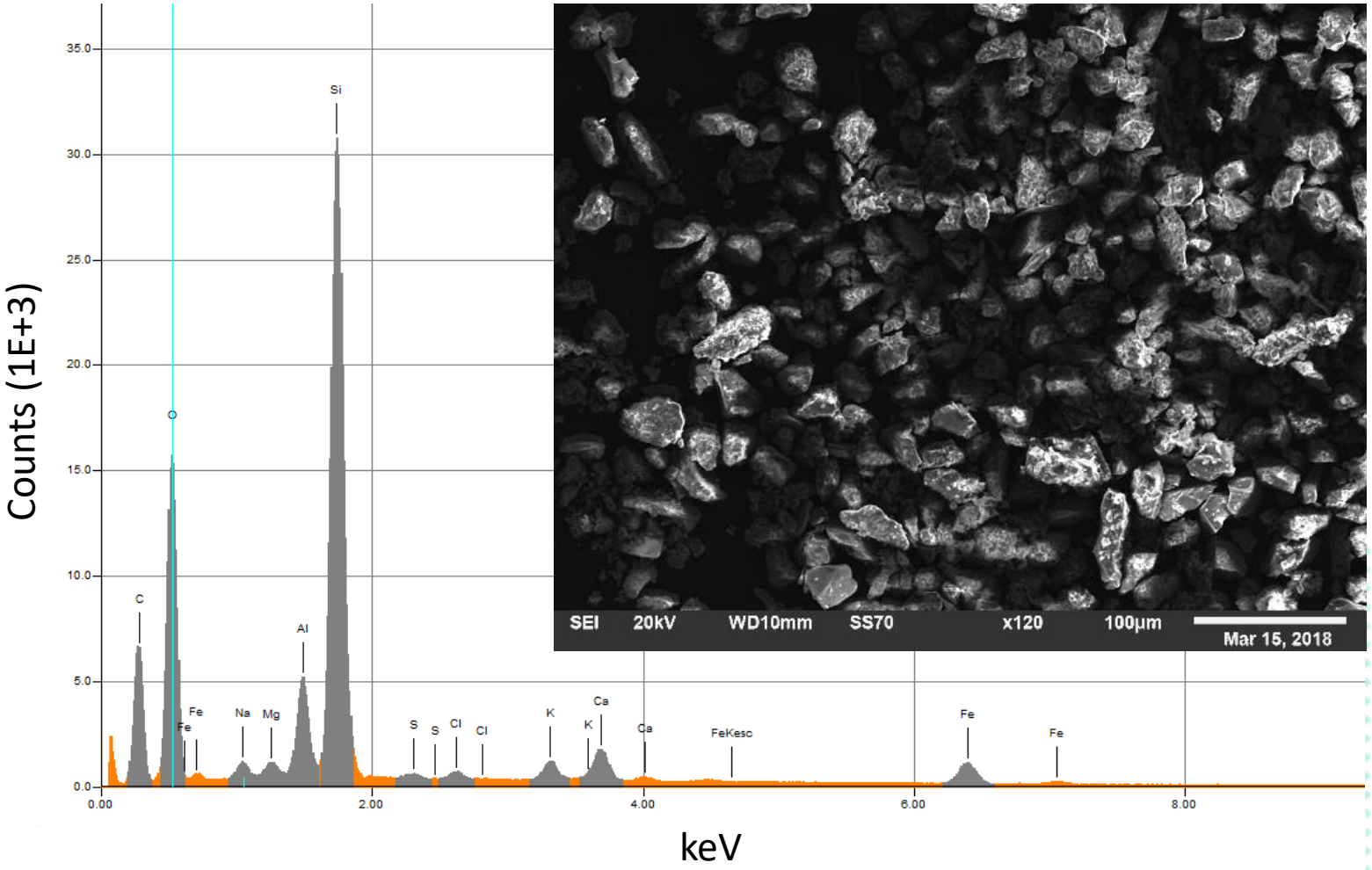
Contributions from carbon





no obvious correlations with total carbon or UV-Vis absorbance of sample extracts

Imaging and elemental analysis of road dust



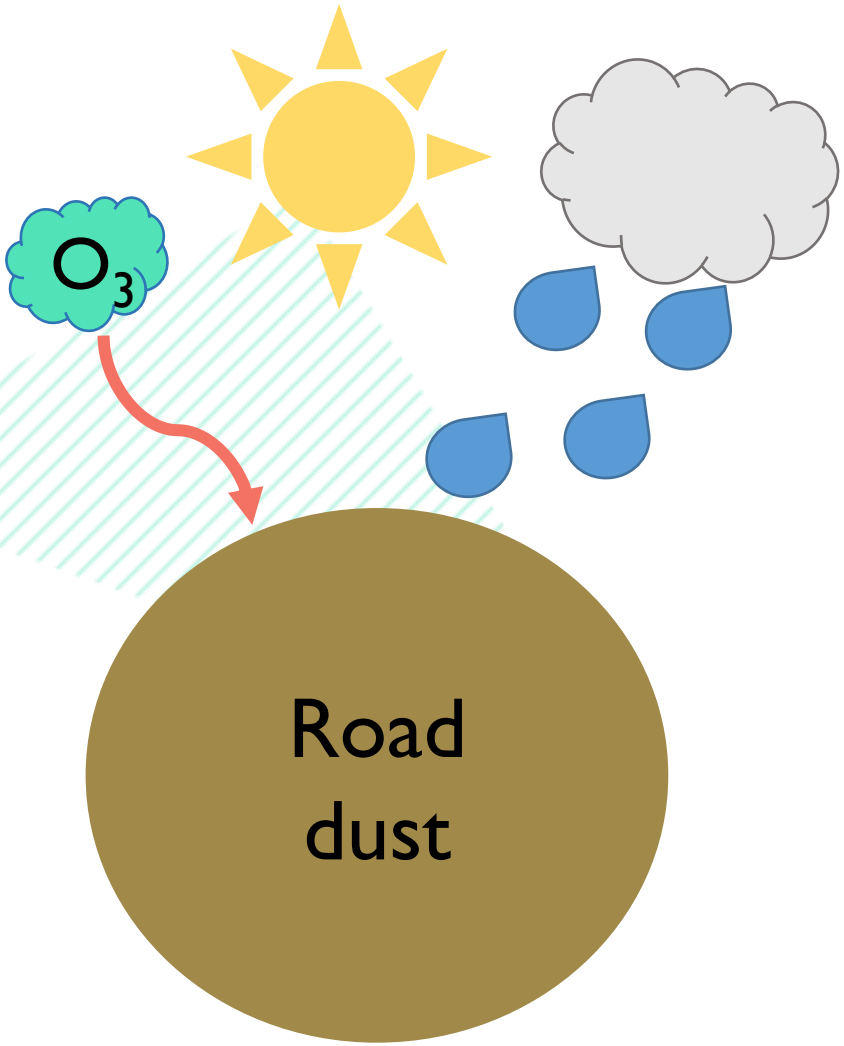
Elemental composition of road dusts

	Urban (Fall 2016)	Urban (Spring 2017)	Urban (Fall 2017)	Street Sweepings	Suburban (residential)	Suburban (park)
Na	1.63	5.57	1.95	0.94	1.11	0.9
Mg	1.63	1.27	1.41	2.03	1.5	1.22
Al	9.43	6.01	8.66	7.87	9.56	8.94
Si	60.23	54.06	62.95	57.35	63.5	66.86
K	4.02	3.26	3.84	3.39	4.86	4.42
Ca	8.54	9.59	6.36	16.08	6.14	3.42
Mn	--	--	--	0.63	--	--
Ti	0.88	--	--	--	0.77	0.82
Fe	11.07	8.74	12.58	11.03	11.27	12.93
TC	3.93	4.27	5.36	5.66	5.57	2.80
OC (*est*)	--	2.87	4.15	3.41	4.29	2.15

Current work and future goals

- Redesign the reaction chamber to be more robust, and allow for increased sample throughput
- Determine surface area-scaled $[^1O_2]_{ss}$ for the different road dust samples
- Collect and analyze more road dust samples from additional locations during different seasons

Photochemical uptake of ozone onto road dust

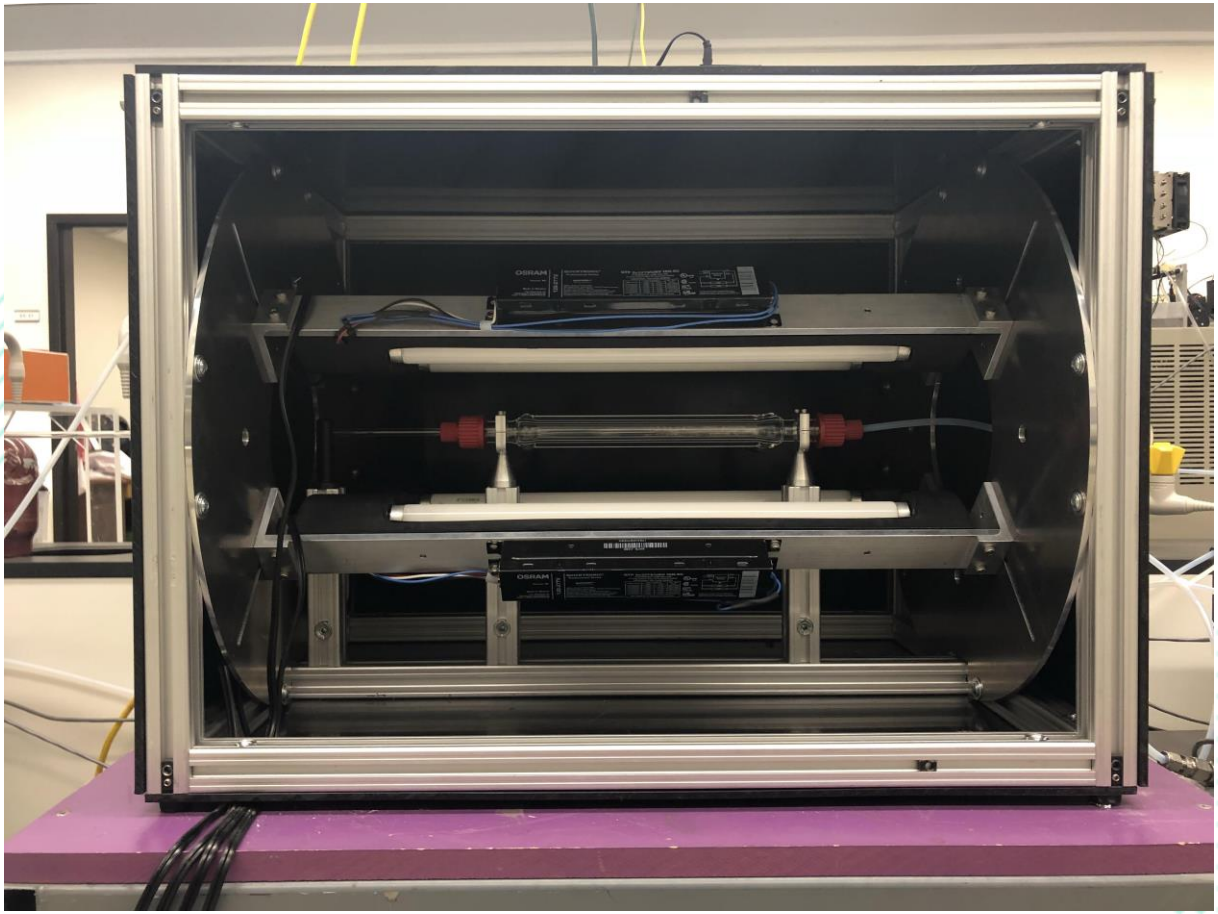


Does ozone react with road dust?

Does irradiation affect the reaction?

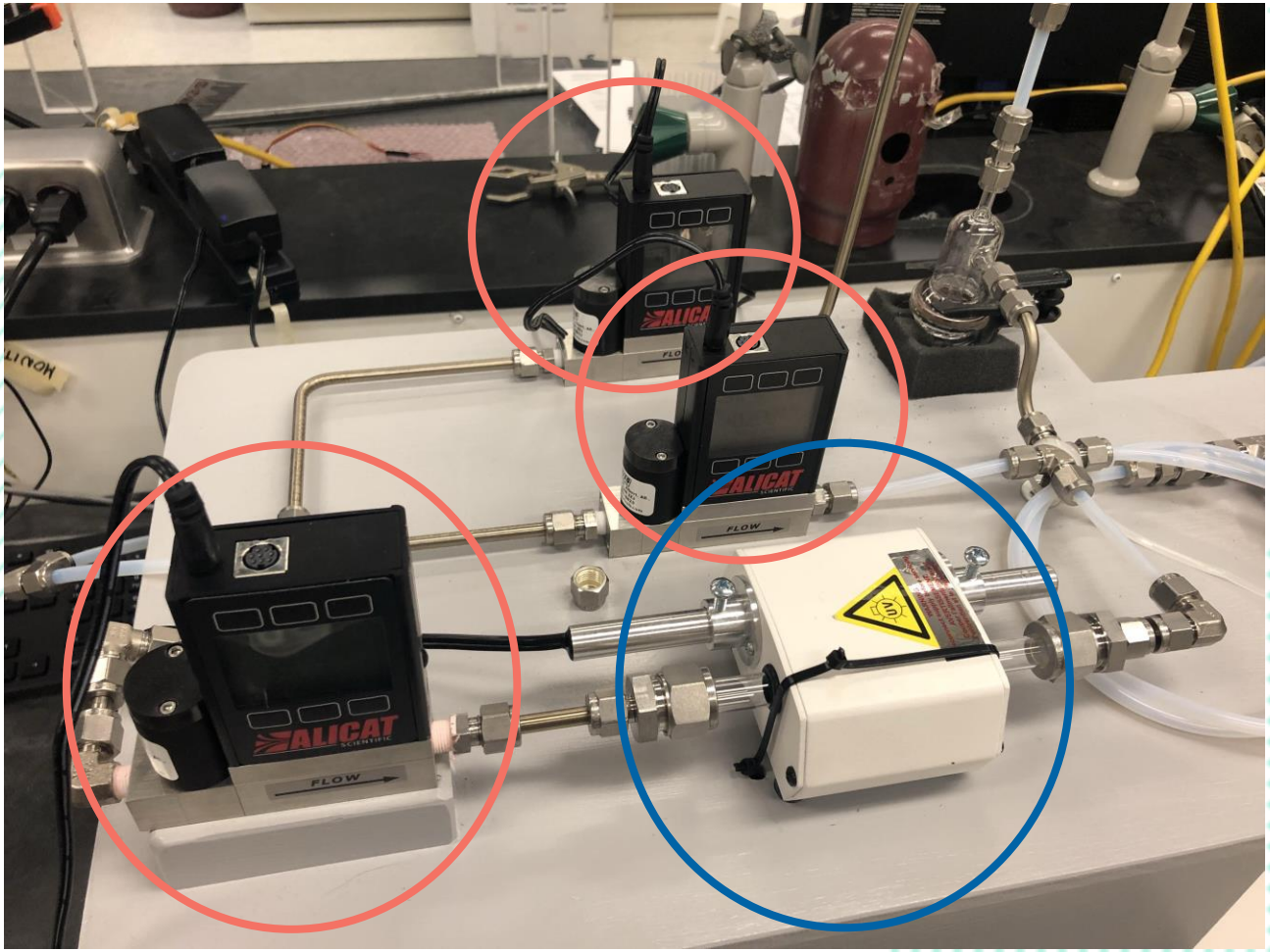
Does humidity affect the reaction?

How do we study ozone uptake onto road dust?

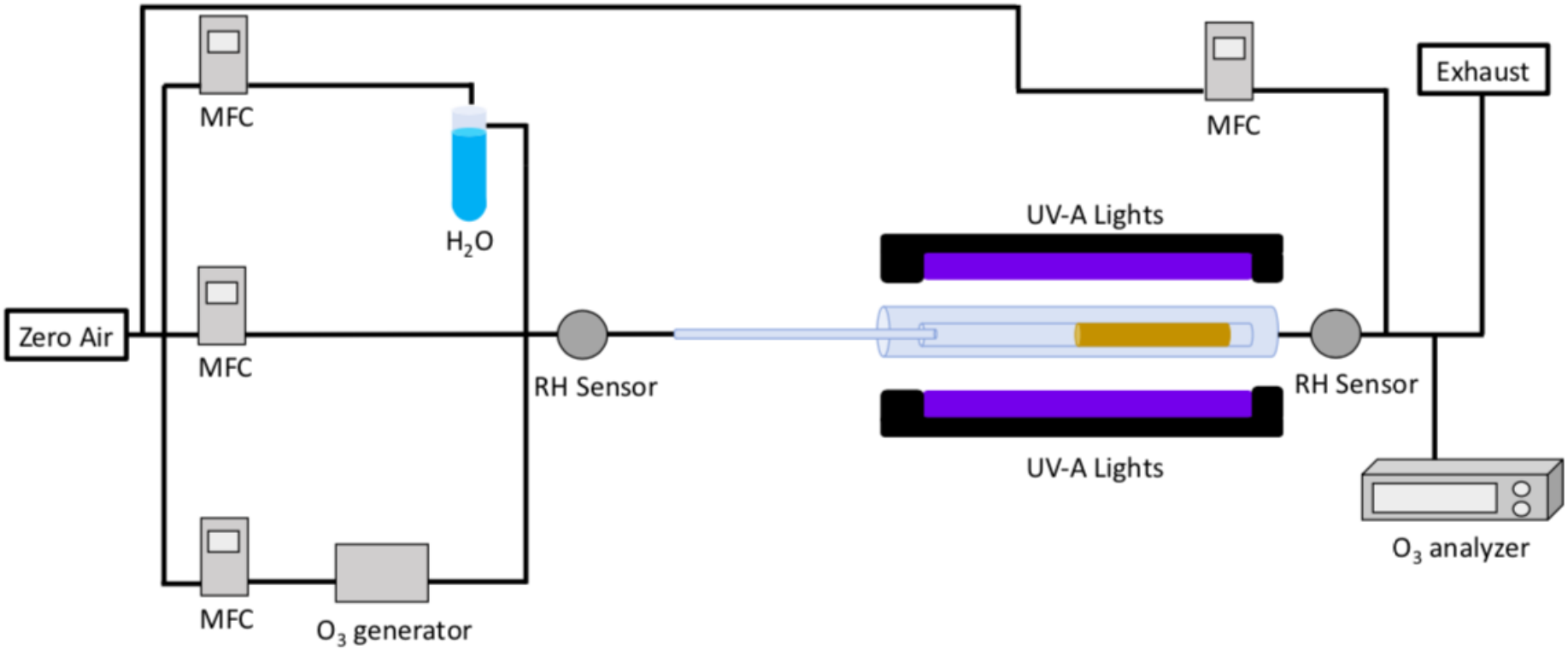


Coated-wall flow

Gas flow into movable injector



Schematic of coated-wall flow tube set-up



Size fractionation of dust

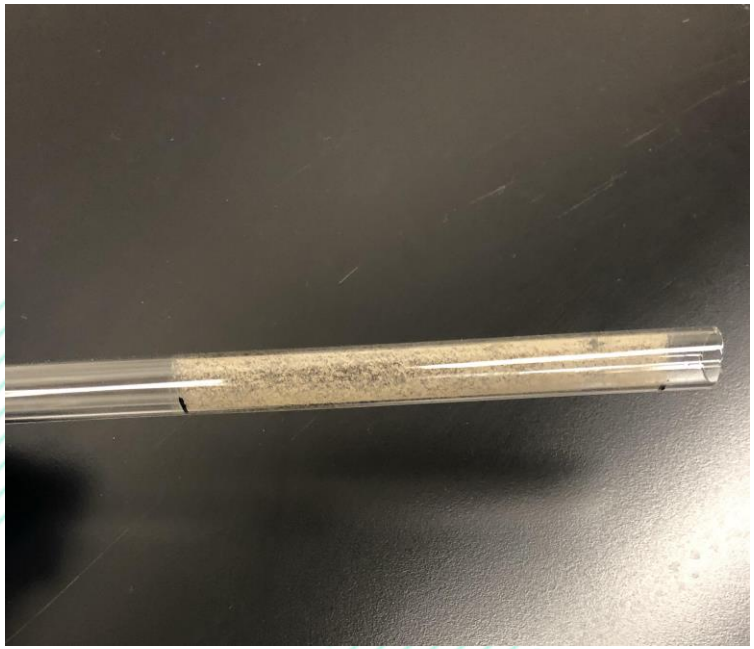
500-212µm

125-212µm

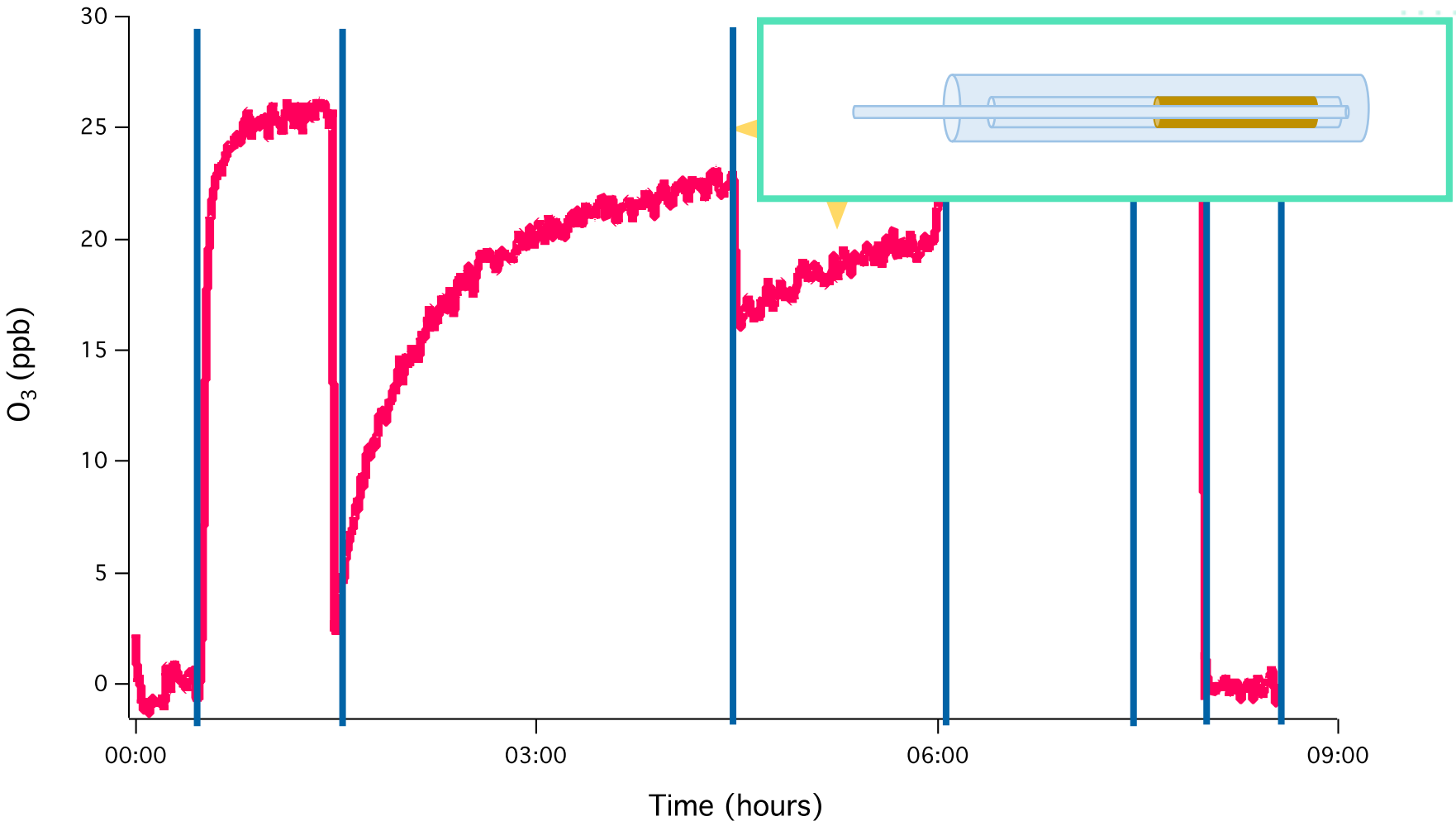
24-125µm

<45µm

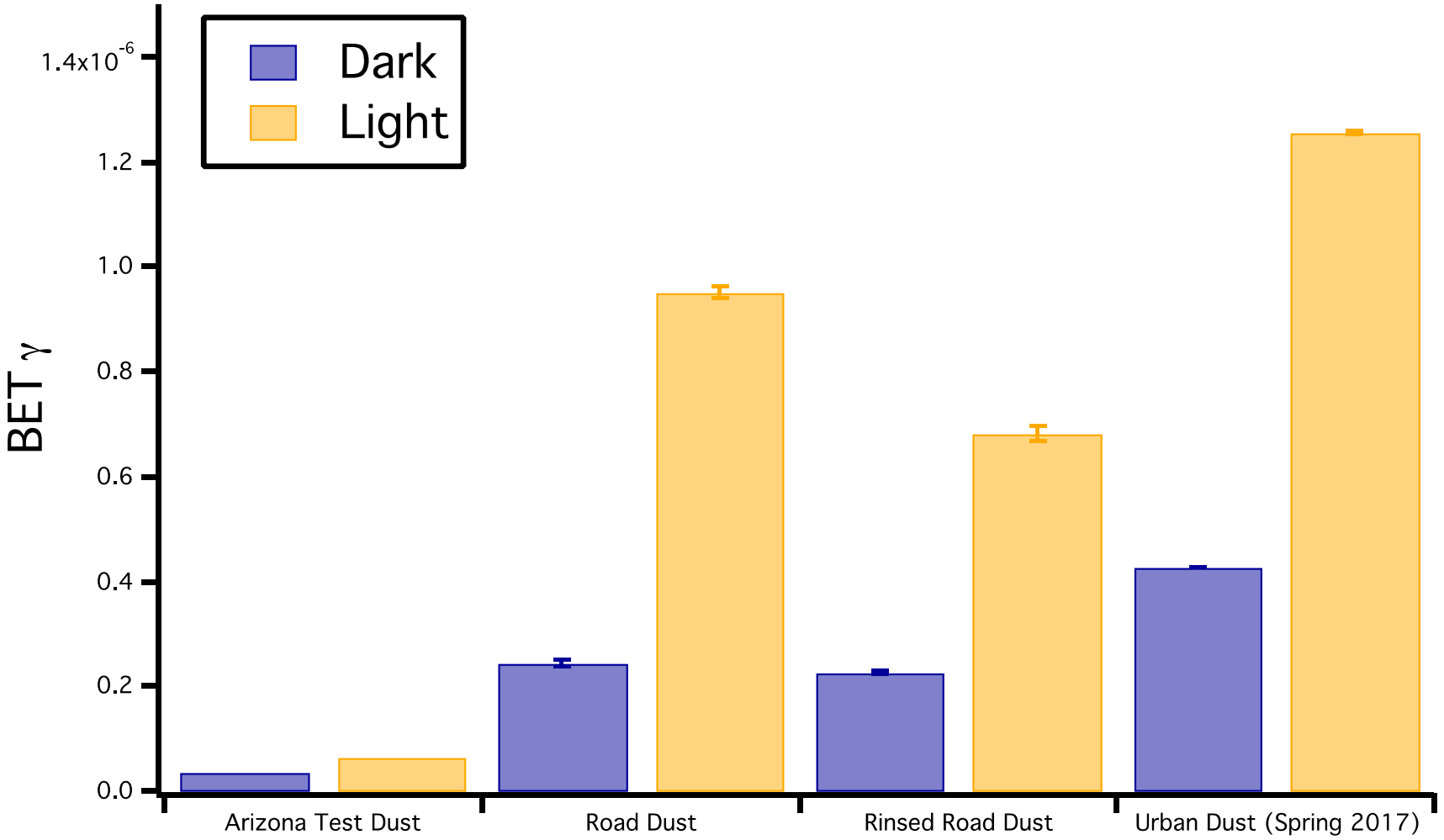
Preparation of coated tubes



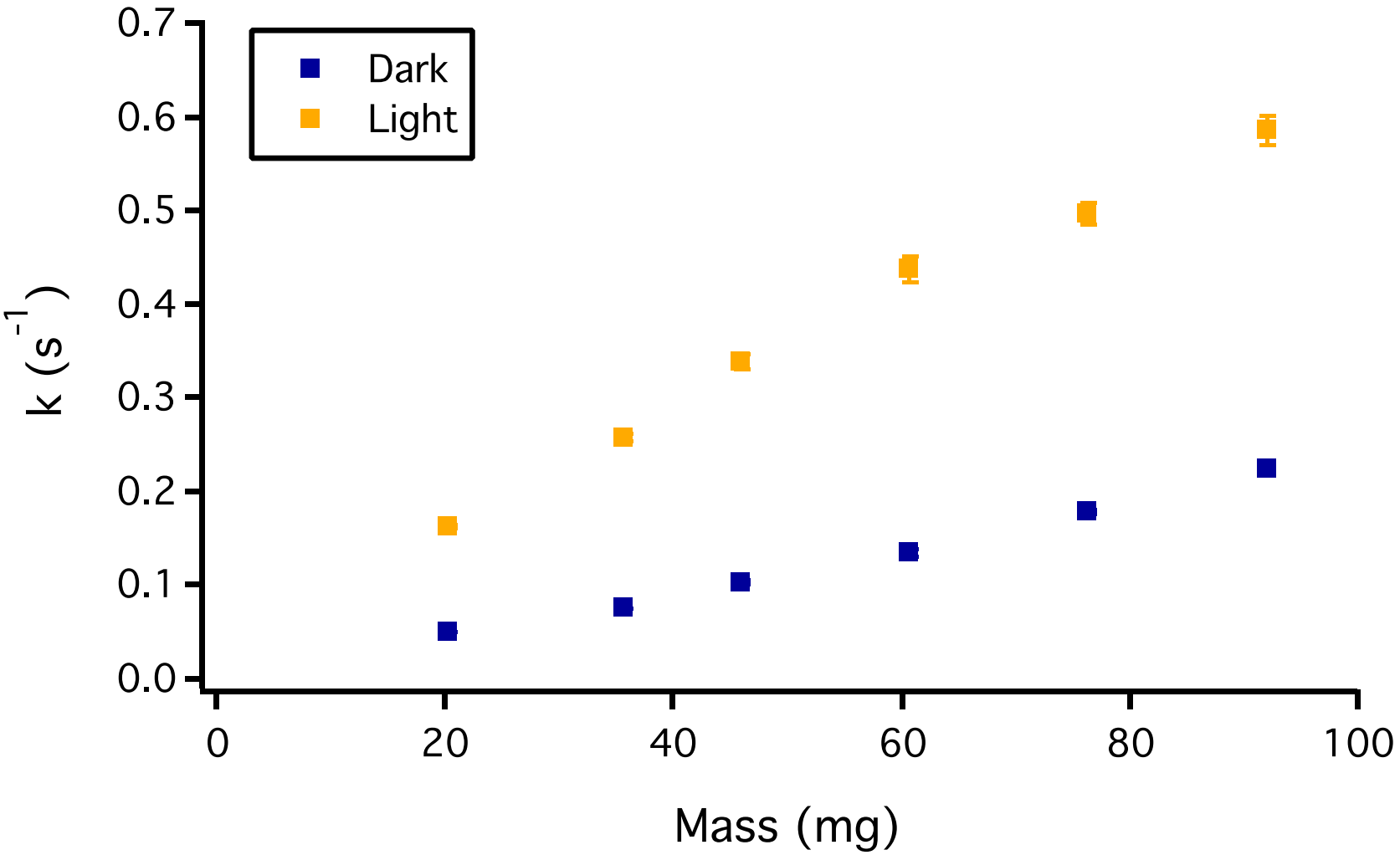
Reaction profile of road dust and ozone



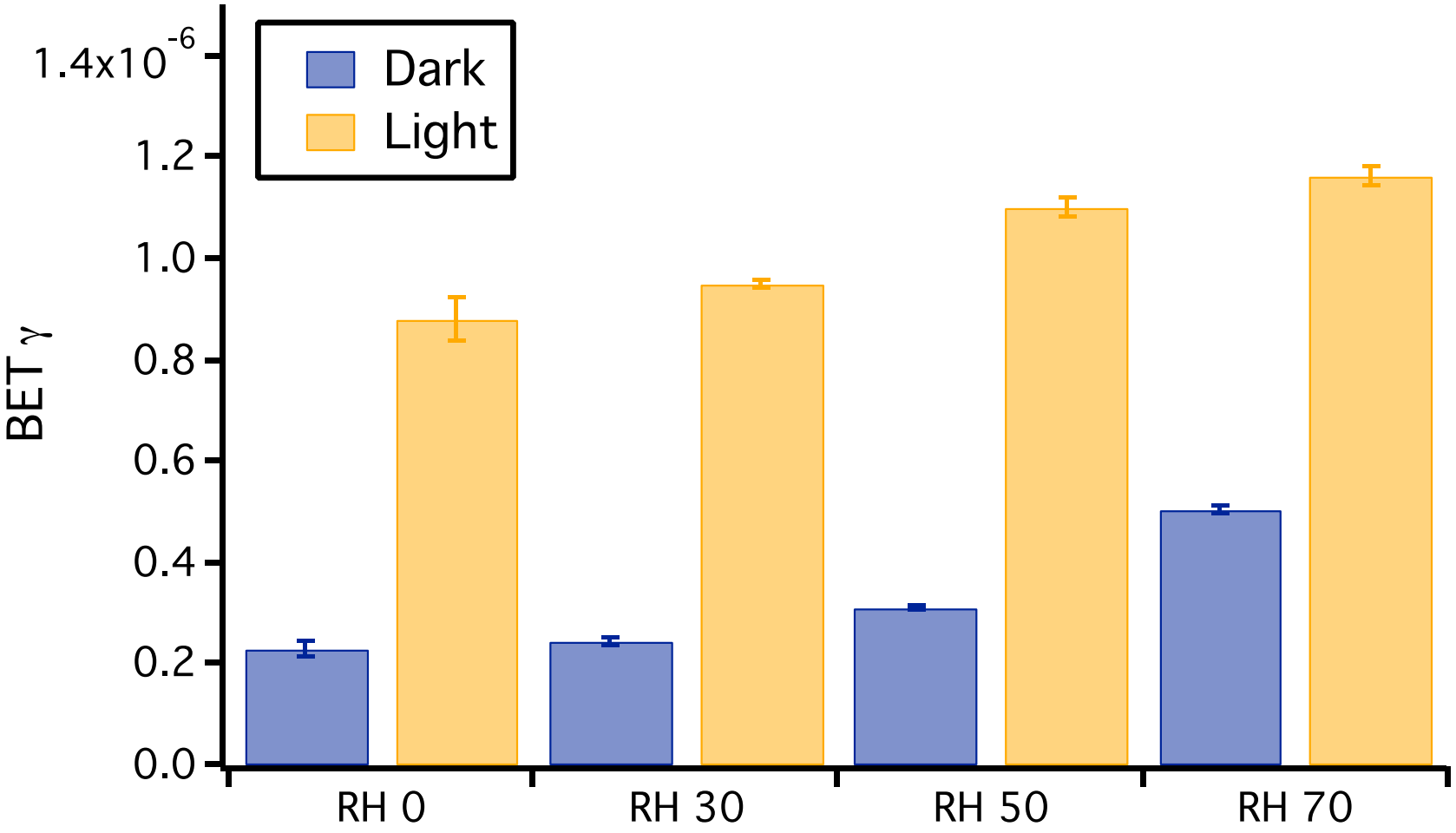
Road dust is much more reactive than desert dust!



Rate of reaction increases with mass



Enhanced reactivity at increasing relative humidity



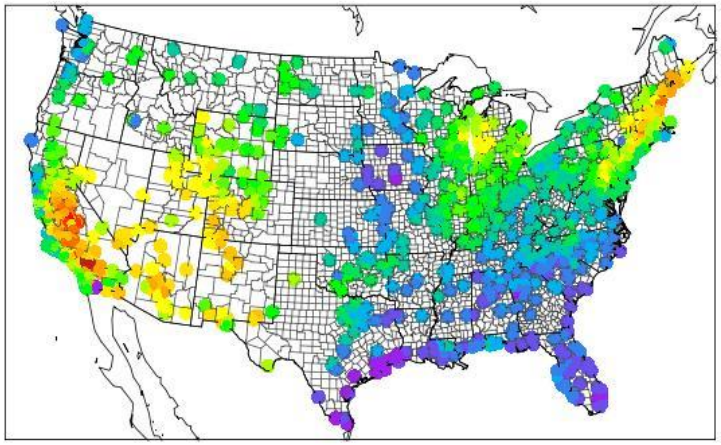
Future outlook

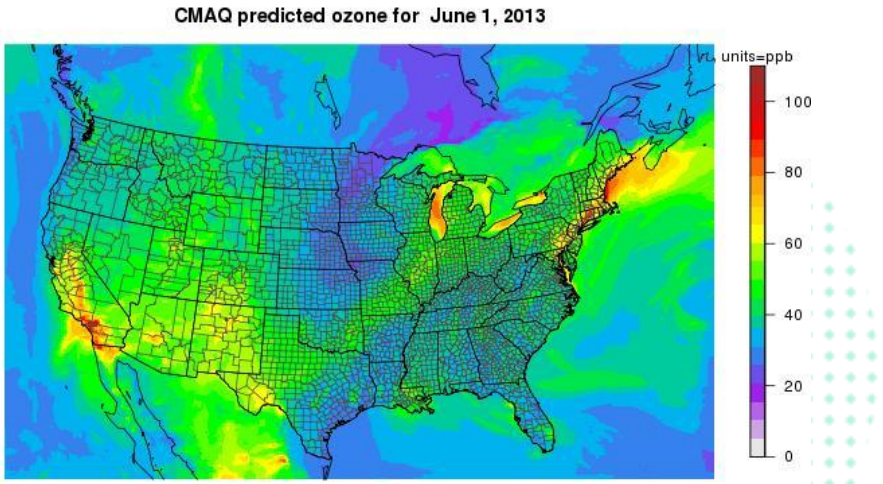
What is responsible for road dust reactivity?

- Further analysis of composition and comparison of different samples

Can road dust influence local air quality?

- Use calculated uptake coefficients for atmospheric modeling





With thanks to …

INNOVATION.CA
CANADA FOUNDATION FOR INNOVATION | FONDATION CANADIENNE POUR L'INNOVATION

NSERC CRSNG

Edmonton

Machine/glassblowing shop
photochemical reaction chamber

Department of Chemistry / Faculty of Science
start-up funding

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Equations

$$\gamma_{geo} = \frac{k * 2r}{c}$$

γ_{geo} = geometric uptake coefficient
k = pseudo first order rate constant
r = radius of Pyrex tube
c = mean molecular speed of ozone

$$\gamma_{BET} = \frac{\gamma_{geo} * S_{geo}}{m * BET}$$

γ_{BET} = BET uptake coefficient
γ_{geo} = geometric uptake coefficient
S_{geo} = geometric surface area
m = mass of dust
BET = surface area

$$[O_3] = [O_3]_0 \, e^{-kt}$$

$[O_3]$ = concentration of ozone at time t
$[O_3]_0$ = concentration of ozone at time 0
k = pseudo first order rate constant
t = residence time inside tube