

# Ultrafine Particles and Urban Pollution – Mitigation Solution

**David Y. H. Pui**

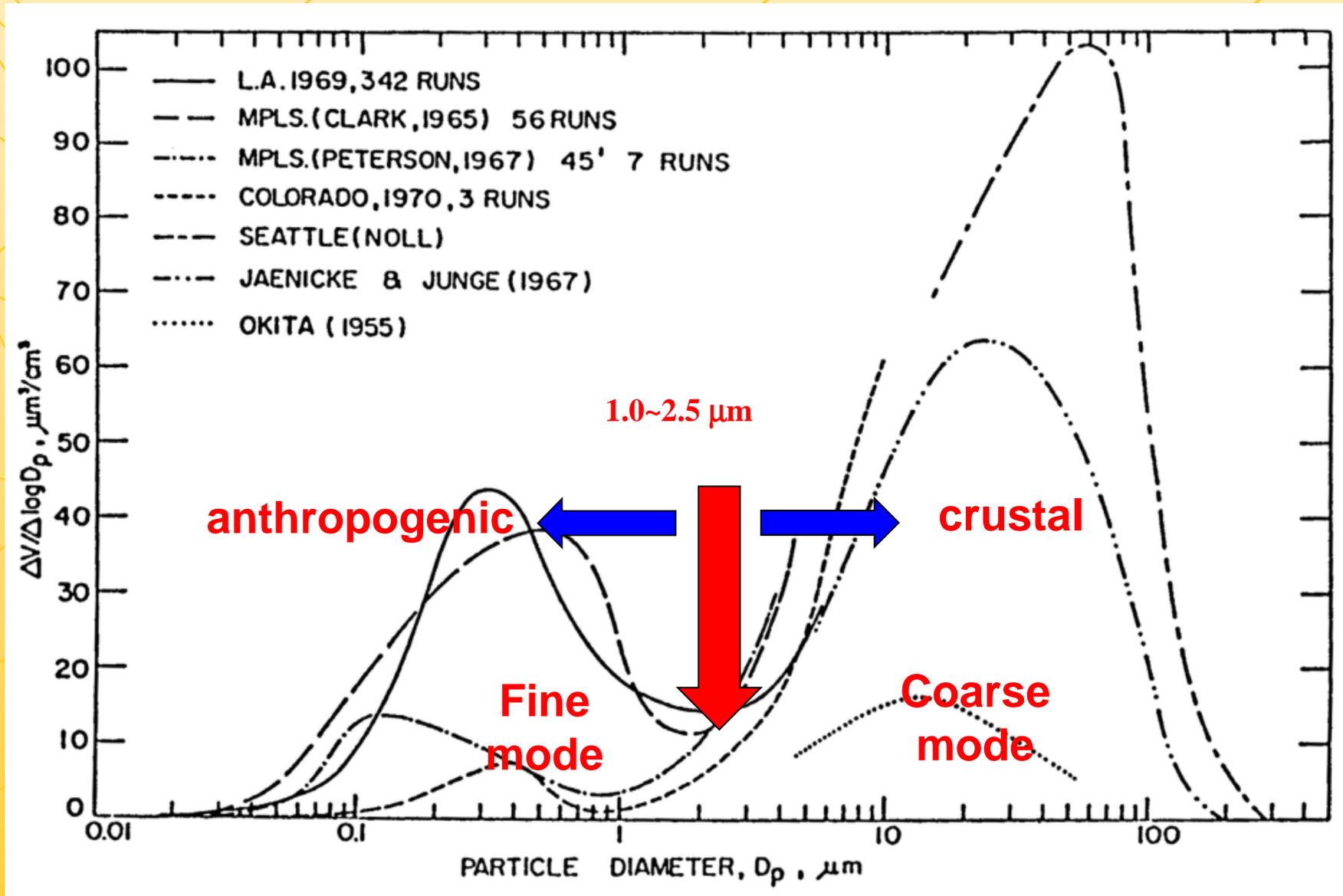
Distinguished McKnight University Professor  
LM Fingerson/TSI Inc Chair in Mechanical Engineering  
Director of Center for Filtration Research (CFR)  
Director of Particle Technology Laboratory (PTL)  
University of Minnesota

And

Member of US National Academy of Engineering  
Einstein Professor of Chinese Academy of Sciences



# Particle Size Distributions of Atmospheric Aerosols



Whitby, K. T., Husar, R. B., & Liu, B. Y. H. (1972) *Journal of Colloid and Interface Science*, 39(1), 177-204..



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# PM<sub>2.5</sub> Sources and Lifetimes

## Fine Particles

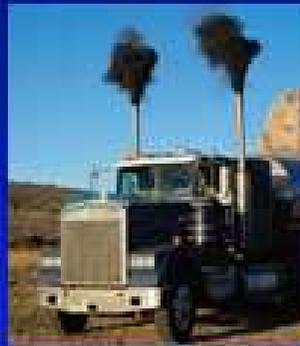
*Combustion, gases to particles*

- Sulfates/acids
- Nitrate
- Ammonium
- Organics
- Carbon
- Metals
- Water



Sources:

- Coal, oil, gasoline, diesel, wood combustion
- Transformation of SO<sub>x</sub>, NO<sub>x</sub>, organic gases
- High-temperature industrial processes (smelters, steel mills)
- Forest fires



Exposure/Lifetime:

Lifetime days to weeks, regional distribution over urban scale to 1000s of km

## Inhalable Coarse Particles

*Crushing, grinding, dust*

- Resuspended dusts (soil, street dust)
- Coal/oil fly ash
- Aluminum, silica, iron-oxides
- Tire and brake wear
- Inhalable biological materials, such as soils & plant fragments



Sources:

- Resuspension of dust tracked onto roads
- Suspension from disturbed soil (farms, mines, unpaved roads)
- Construction/demolition
- Industrial fugitives
- Biological sources

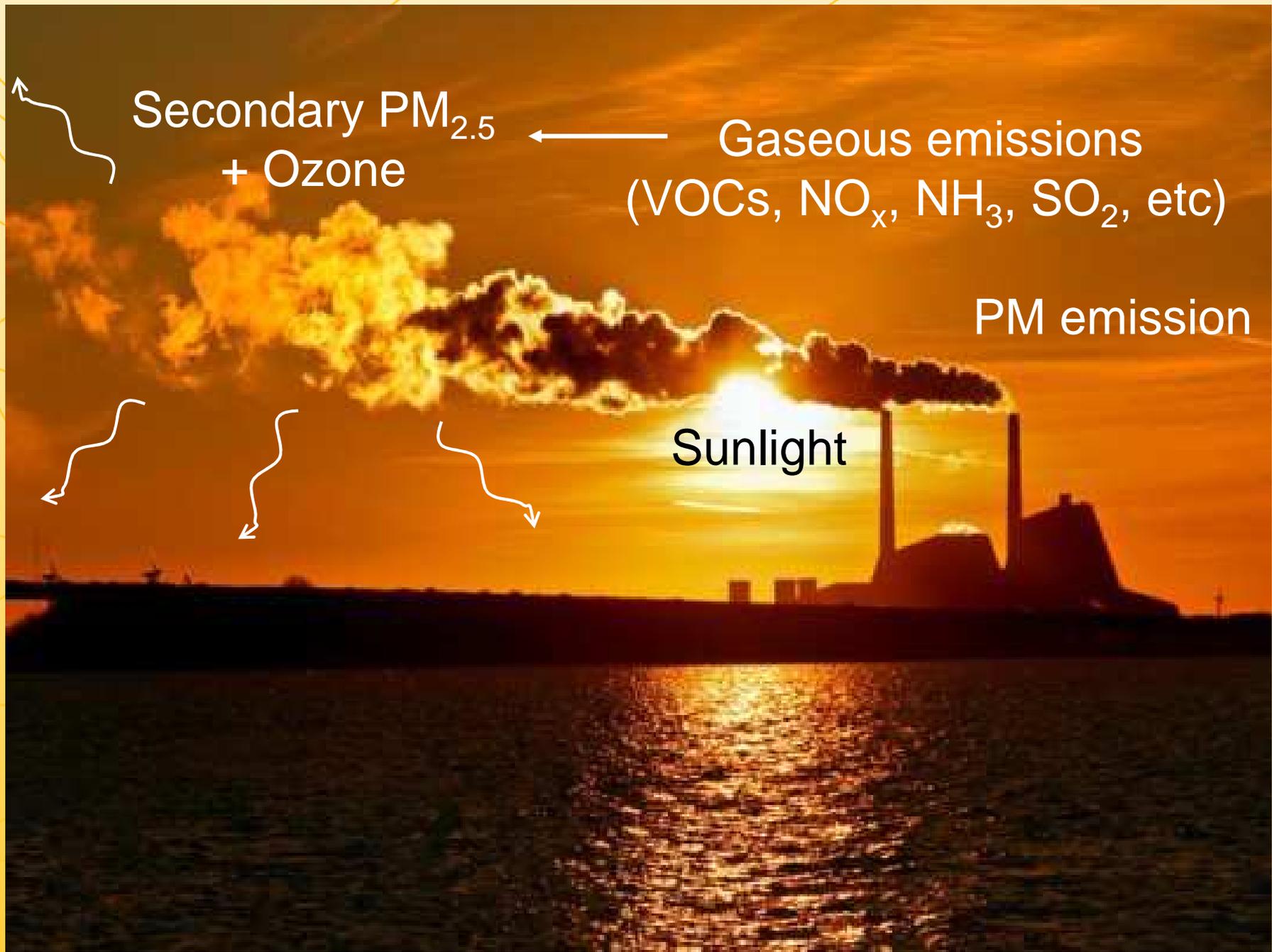
Exposure/Lifetime:

- Coarse fraction (2.5-10) lifetime of hours to days, distribution up to 100s km

## PM<sub>2.5</sub> Standard, U.S. EPA

- Established in 1997, PM<sub>2.5</sub> describes Particulate Matter (PM) that is 2.5 μm in diameter and smaller,  $D_p < 2.5 \mu\text{m}$
- 24-hour standard: 65 μg/m<sup>3</sup>, 3 yr avg, 98th percentile concentration; reduced to 35 μg/m<sup>3</sup> since 2006
- Annual standard: 12 μg/m<sup>3</sup> in 2012, 3-yr average of annual mean concentration





Secondary PM<sub>2.5</sub>  
+ Ozone

Gaseous emissions  
(VOCs, NO<sub>x</sub>, NH<sub>3</sub>, SO<sub>2</sub>, etc)

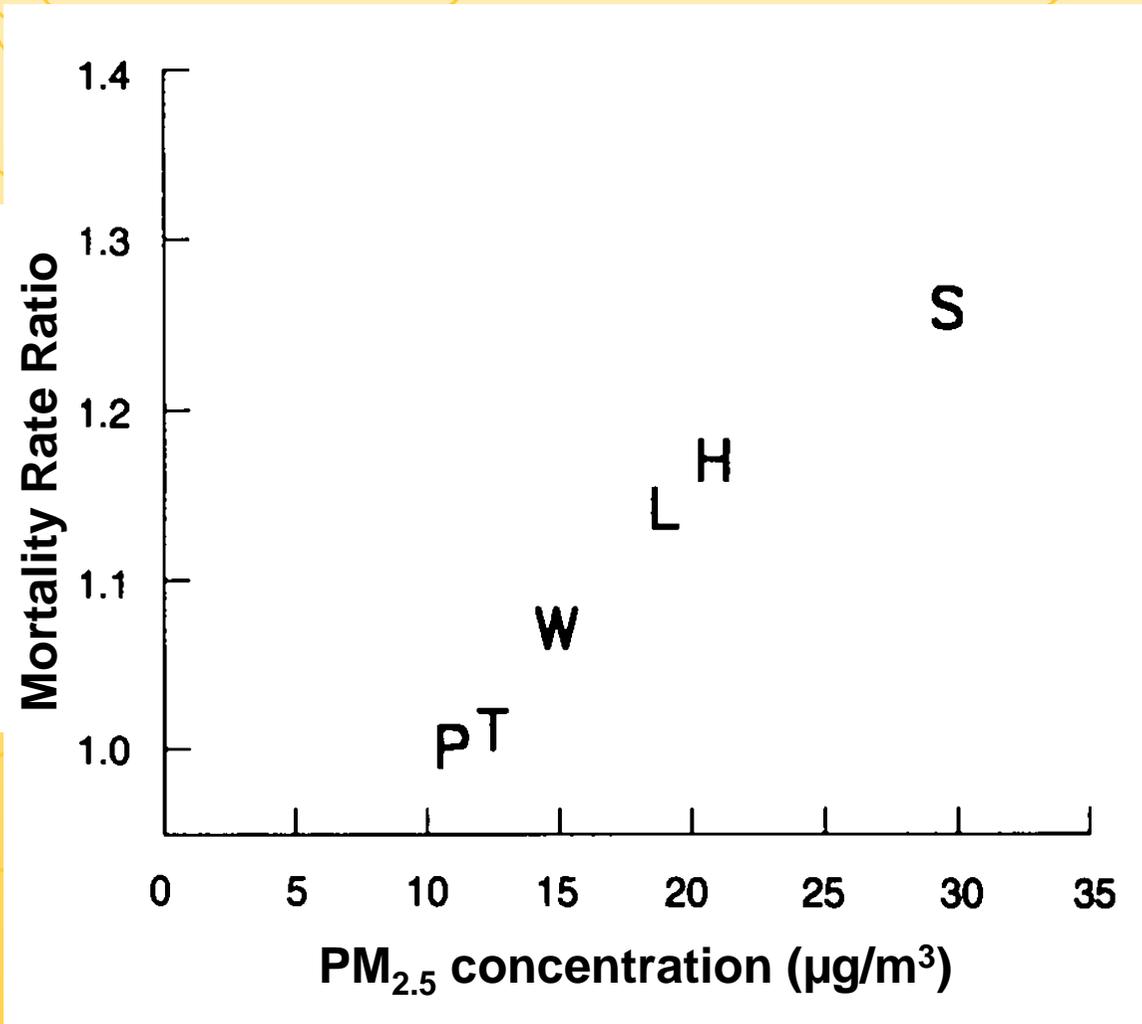
PM emission

Sunlight



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# Harvard Six City Study



- Six small cities that differed greatly in PM levels
  - Harriman, TN
  - Portage, WI
  - Steubenville, OH
  - St. Louis, MO
  - Topeka, KS
  - Watertown, MA
- A Cohort study investigating 151 U.S. metropolitan areas

- PM<sub>2.5</sub> air pollution contributes to excess cardiopulmonary and lung cancer mortality in certain U.S. cities

# A Tale of Two Cities



**Los Angeles Civic Center**

**January 1948**

**$PM_{10} = 600 \mu\text{g}/\text{m}^3$**

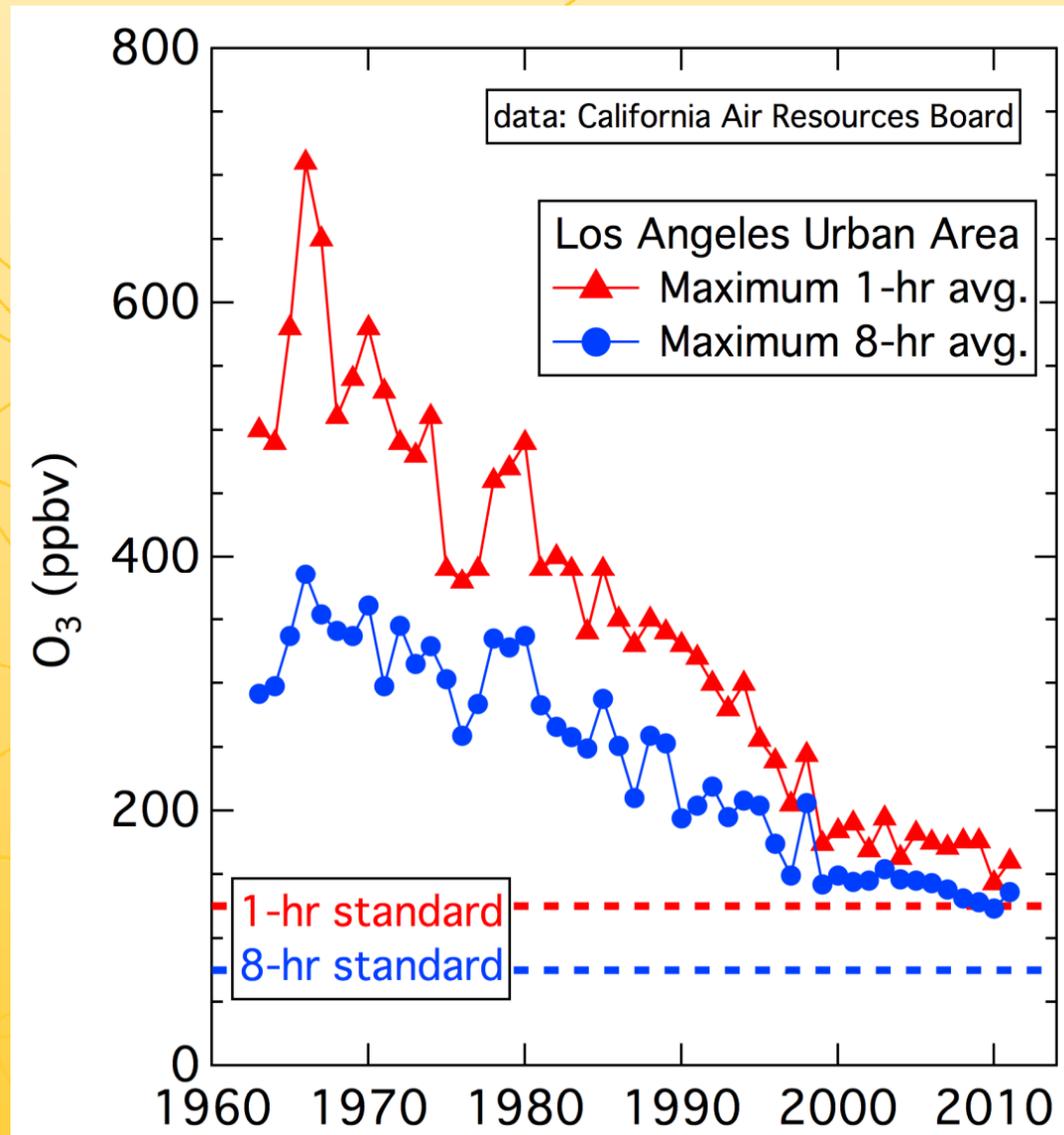


**Beijing CCTV Building**

**January 2013**

**$PM_{2.5} = 700 \mu\text{g}/\text{m}^3$**

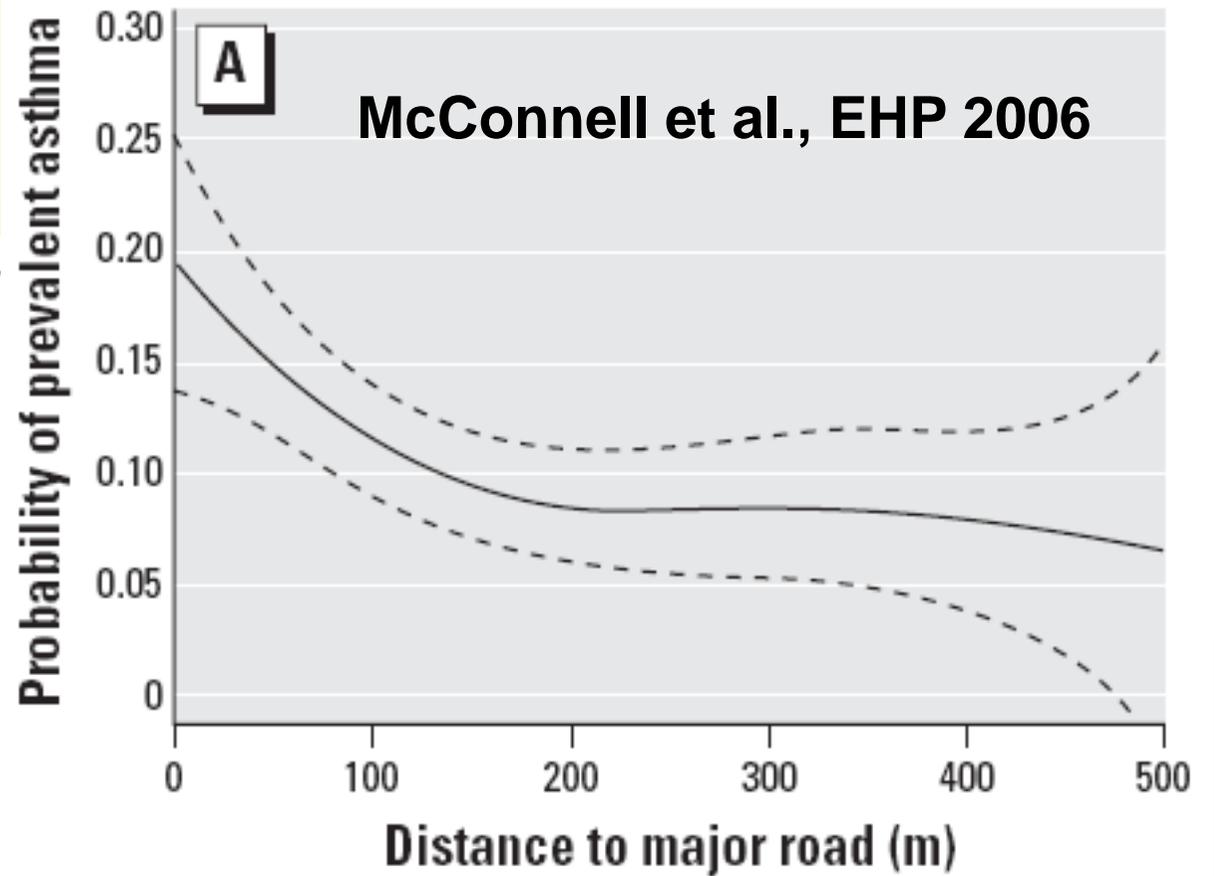
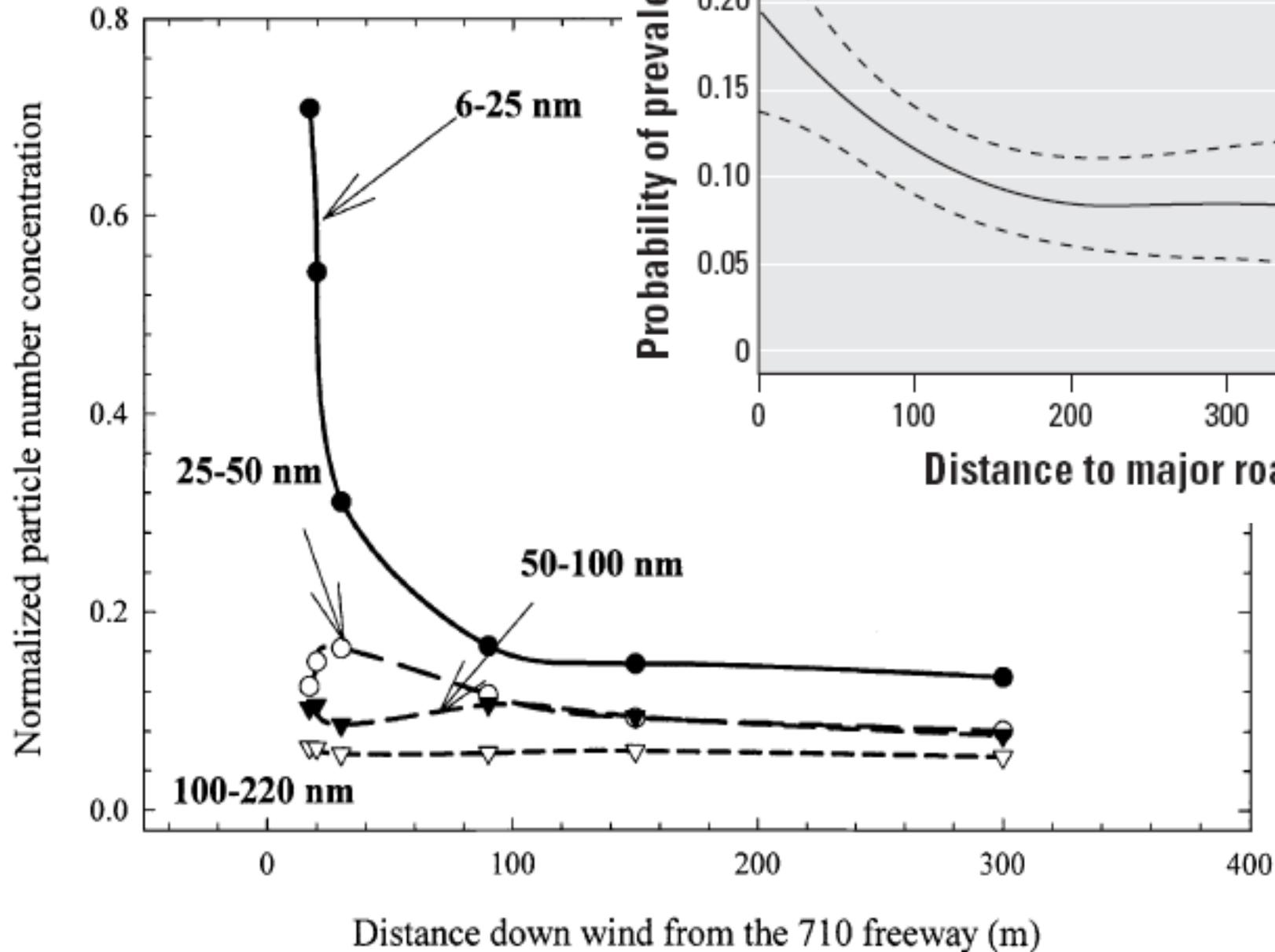
# 5 Decades of Pollution Control in LA





PM 2.5 Haze in Shanghai, April 19, 2015: Traffic on the elevated highway with city shrouded with haze in the background.

**The Freeway  
Community is exposed  
to high nanoparticle  
concentrations**



**McConnell et al., EHP 2006**

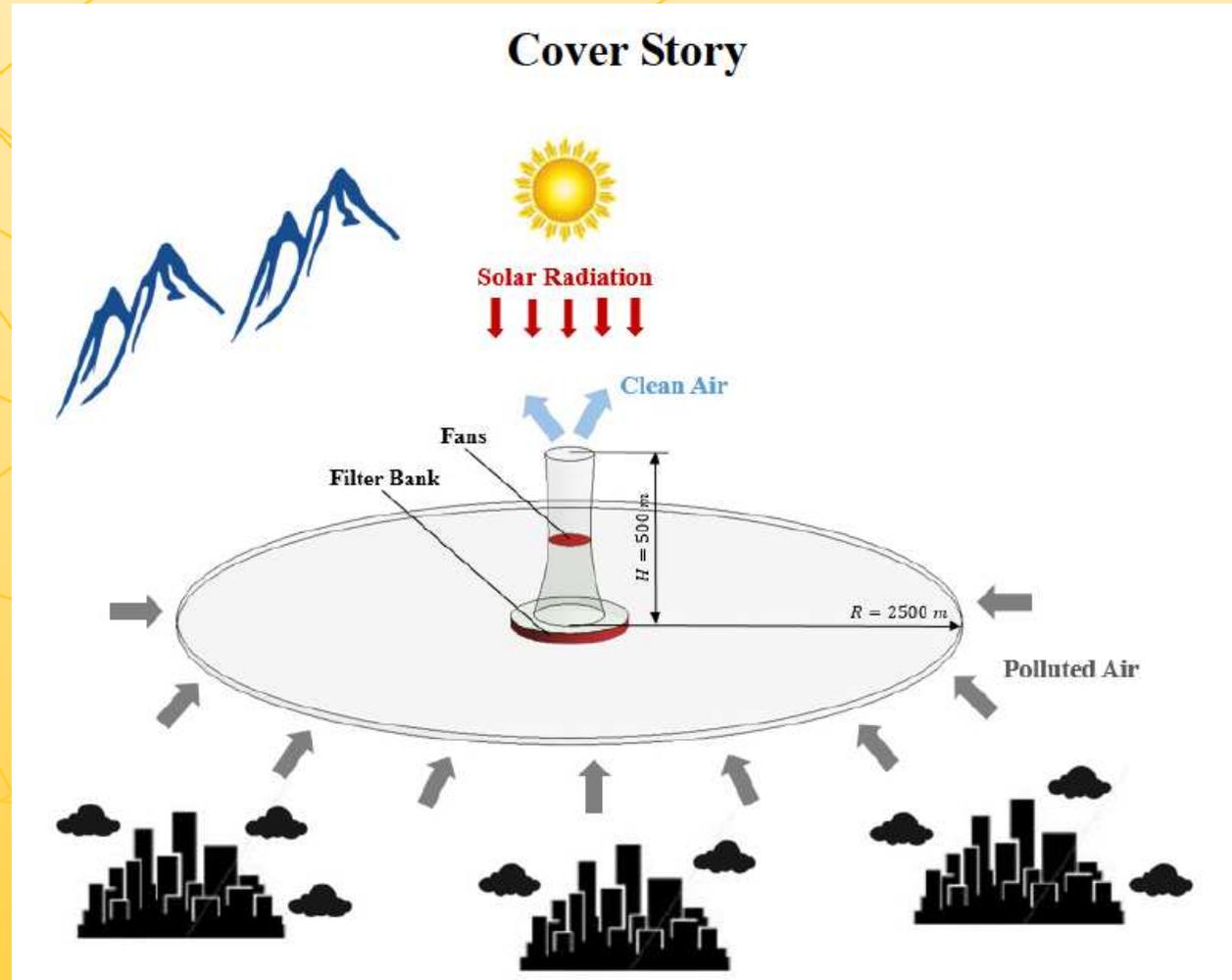
# UMN Center for Filtration Research (CFR)



The member companies of CFR have **\$32 billion annual sales** (est.) in filtration industry. Applications include

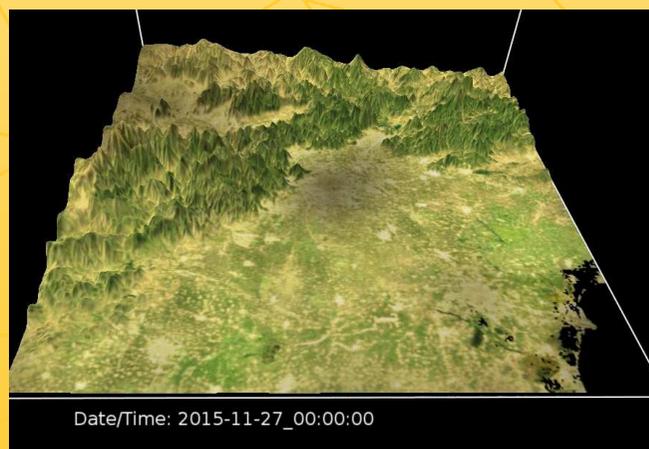
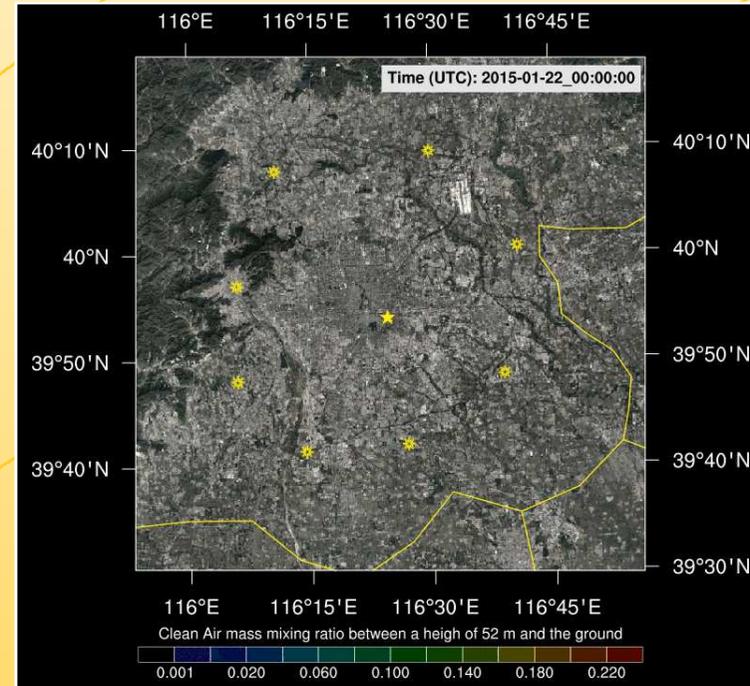
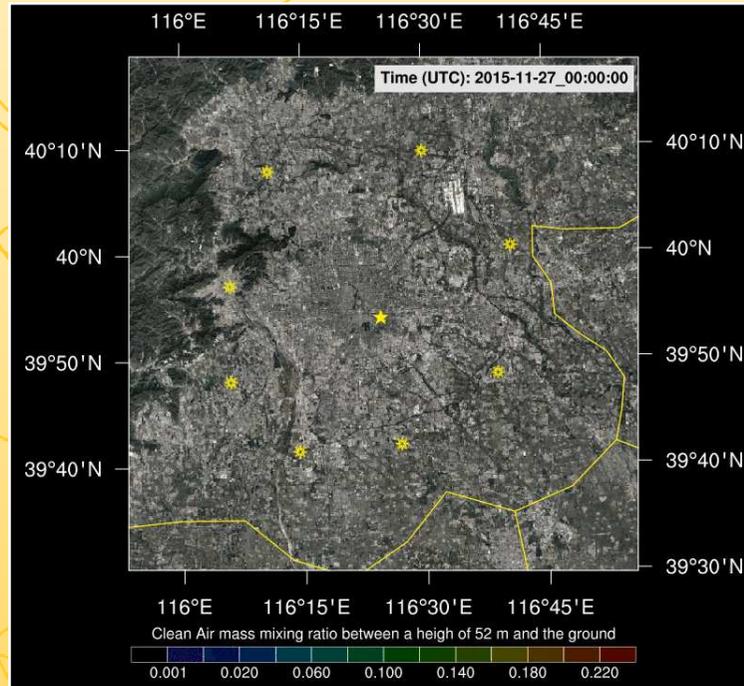
- Removal of PM<sub>2.5</sub> pollutants
- Engine emission removal
- Cabin air filter for automobiles/airplanes
- Respirator and personal protection equip

# Solar-Assisted Large-Scale Cleaning System (SALSCS) -- Disruptive Innovation



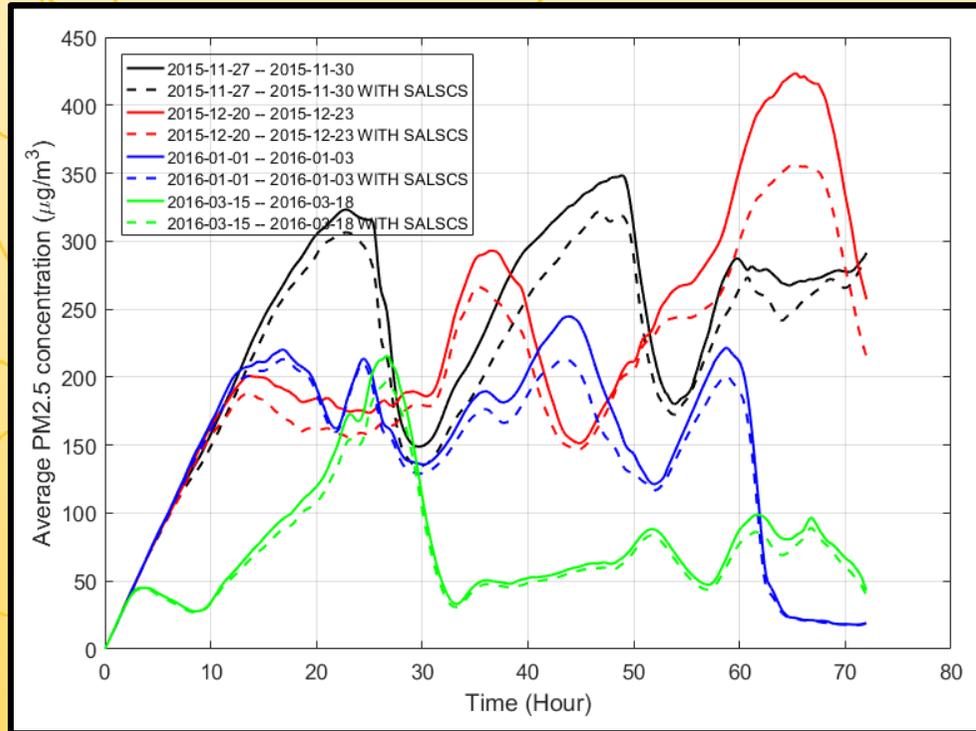
(Cao, Q.F., Pui, D.Y.H. and Lipiński, W. (2015). A Concept of a Novel Solar-Assisted Large-Scale Cleaning System (SALSCS) for Urban Air Remediation. *Aerosol Air Qual. Res.* 15: 1–10)

# Clean Air from 8 Giant SALSCS bathing Beijing Basin

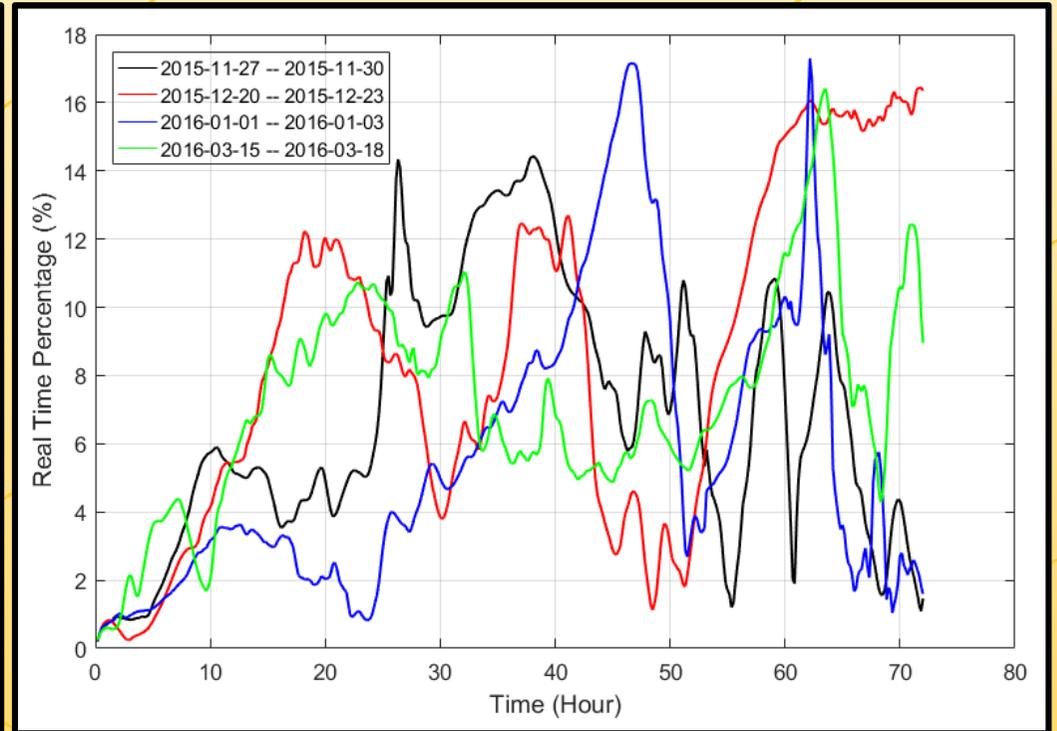


Cao, Q., L. Shen, S.C. Chen and D.Y.H. Pui, *Science of the Total Environment* 626(2018)134-146.

# Modeling Results of Air Pollutants



Average PM<sub>2.5</sub> concentration within a 61 km X 61 km area.



Real time percentage by comparing the conditions of WITH and WITHOUT SALSCS.

- After installing 8 full-scale SALSCS next to the 6<sup>th</sup> Ring Road of the Beijing city, we can reduce the PM<sub>2.5</sub> concentration up to **15%** in average for the urban area of Beijing.
- This conclusion is based on our atmospheric simulation performed by the WRF model.



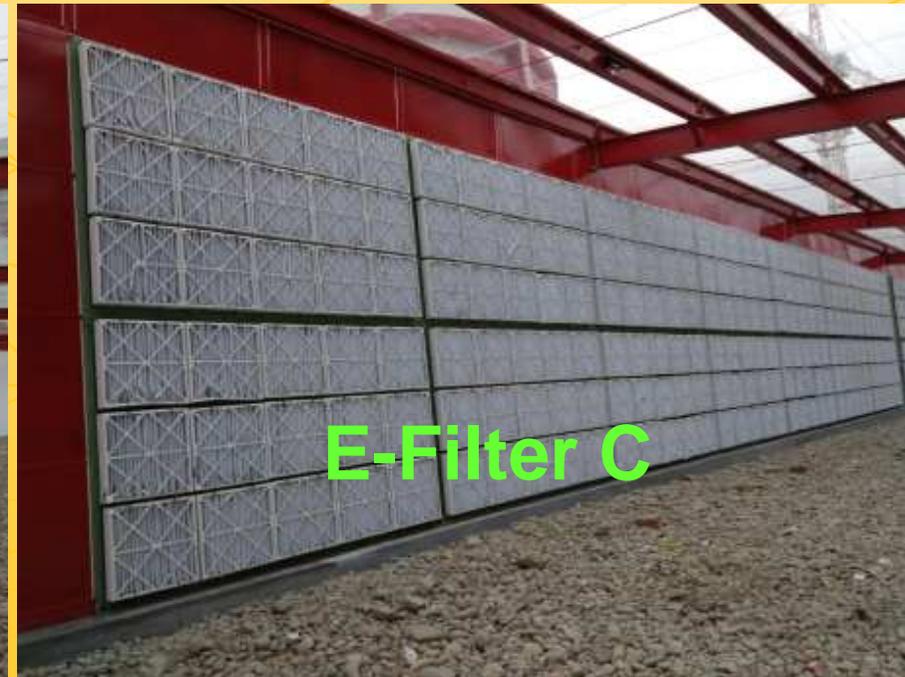
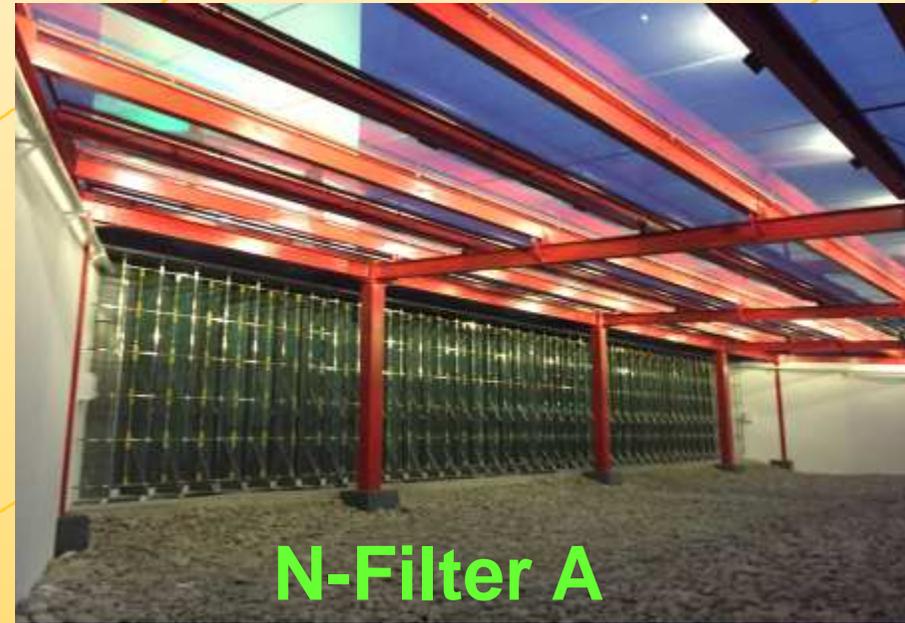
Xi'an SALSCS Completed: July 22, 2016

*In collaboration with:*

Prof. Junji Cao, Institute of Earth Environment (IEECAS)

Prof. W.Q. Tao, Xi'an Jiaotong University (XJTU)

# Photos of the three filtration systems





Vice Minister Wang of China Environmental Protection Ministry review the SALSCS on September 25, 2017



**2<sup>nd</sup> Generation SALSCS in City**  
**Collaborator: Prof. Jing Sun,**  
**Shanghai Institute of Ceramics, CAS**

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NOW READING

China builds 'world's biggest air purifier' ... and it

# China builds 'world's biggest air purifier' ... and it seems to be working

A 100-metre high air purification tower in Xian in Shaanxi province has helped reduce smog levels in the city, preliminary results suggest

PUBLISHED : Tuesday, 16 January, 2018, 6:45am

UPDATED : Tuesday, 16 January, 2018, 6:45am

COMMENTS:

5

- Two dozens of Newspaper articles and TV News
- Nature (March 6, 2018) "China Tests Giant Air Cleaner to Combat Smog"
- UK Chief Medical Officer (CMO) Annual Report (March 9, 2018)
- NBC Universal and Digital Trend (March, 2018)



# Annual Report of the Chief Medical Officer 2017

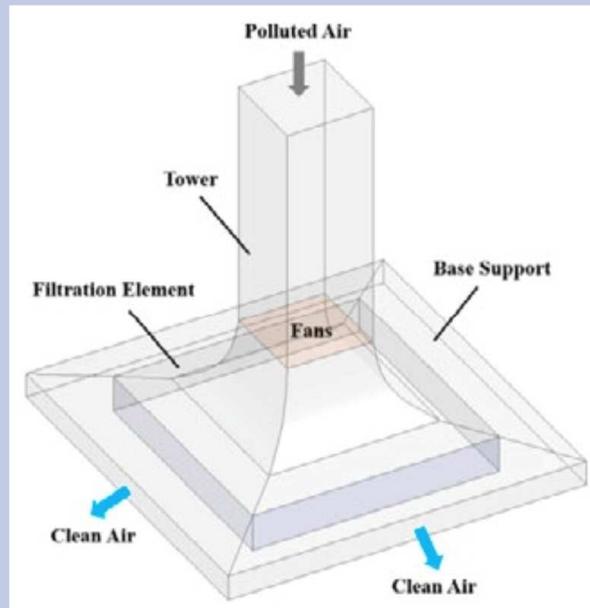
Health Impacts of All Pollution –  
what do we know?

**Figure C** The 2nd generation SALSCS built in  
Yancheng Science Park, Jiangsu Province  
(completed September 2017)



The SALSCS technology represents an effective and low-cost way to mitigate both  $PM_{2.5}$  and  $CO_2$ , for the health and well-being of mankind.

**Figure D** Schematic diagram of the 3rd generation  
cleaning system ACAN showing the reverse  
flow configuration



US Patent

China Patent



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## **Section 7: Urban Particles and Urban Pollution**

### **Thursday Plenary and Technical Sessions**

- 9:30-10:00 Plenary Lecture by David Pui, “Green Technologies for Sustainable Environment,” Platine
- 10:45-12:30 Tech Session I, Chrome 1
- 14:00-15:30 Tech Session II, Platine