

What to do about the Toll Biomass Burning is taking on our Health and Indoor Environments

Shelly L. Miller, Professor
Mechanical Engineering
University of Colorado Boulder



@ShellymBoulder



Today's Talk - What I am going to tell you

Wildfire emissions on Indoor Air Quality

- What is outdoors, is what is in your home, especially in under-resourced communities where cooling by open windows is the only option

Control and Mitigation Strategies for Wildfire Smoke

- Enable communities to have access to air cleaners, window AC, shelters during catastrophic fires

Health Effects and Socioeconomic Considerations

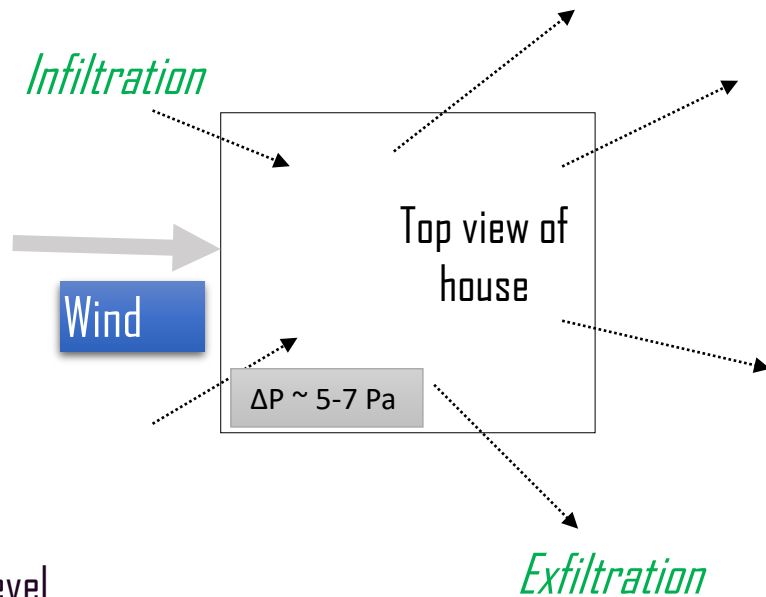
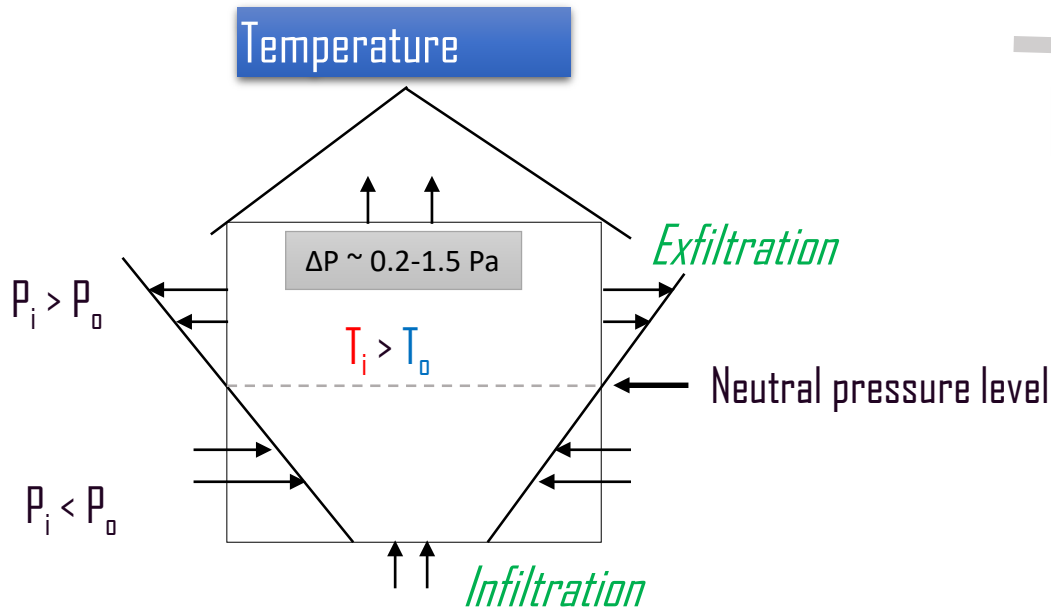
- Added toxicity due to chemicals in household products and furniture
- Many homes use natural ventilation for cooling, not protective against smoke

Wildfire impacts on residential exposures

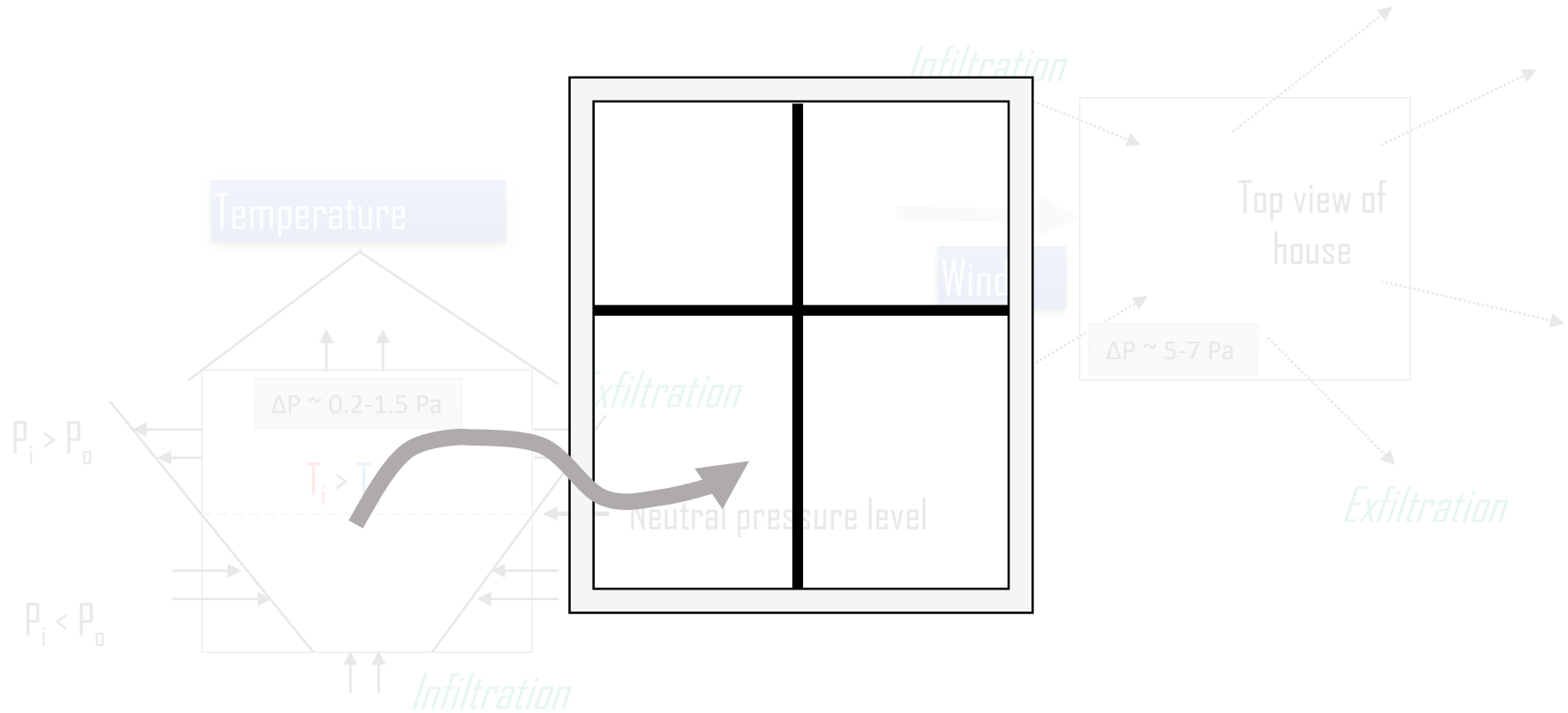
In most homes indoors looks like outdoors

Exceptions: use of air conditioning, newer tighter homes

But 1st how are typical homes ventilated?



But 1st how are typical homes ventilated?





...and commercial-type buildings?

Typically have supply/exhaust air-handling units, may have window opening

Shair and Heitner 1972

Miller et al. 2017

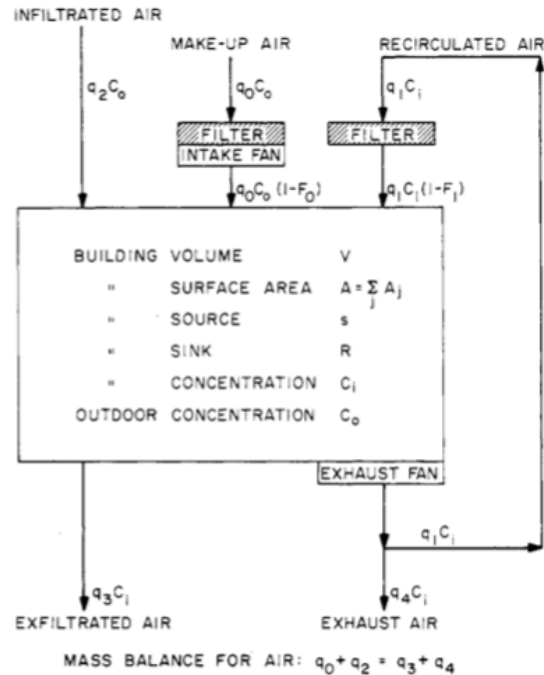
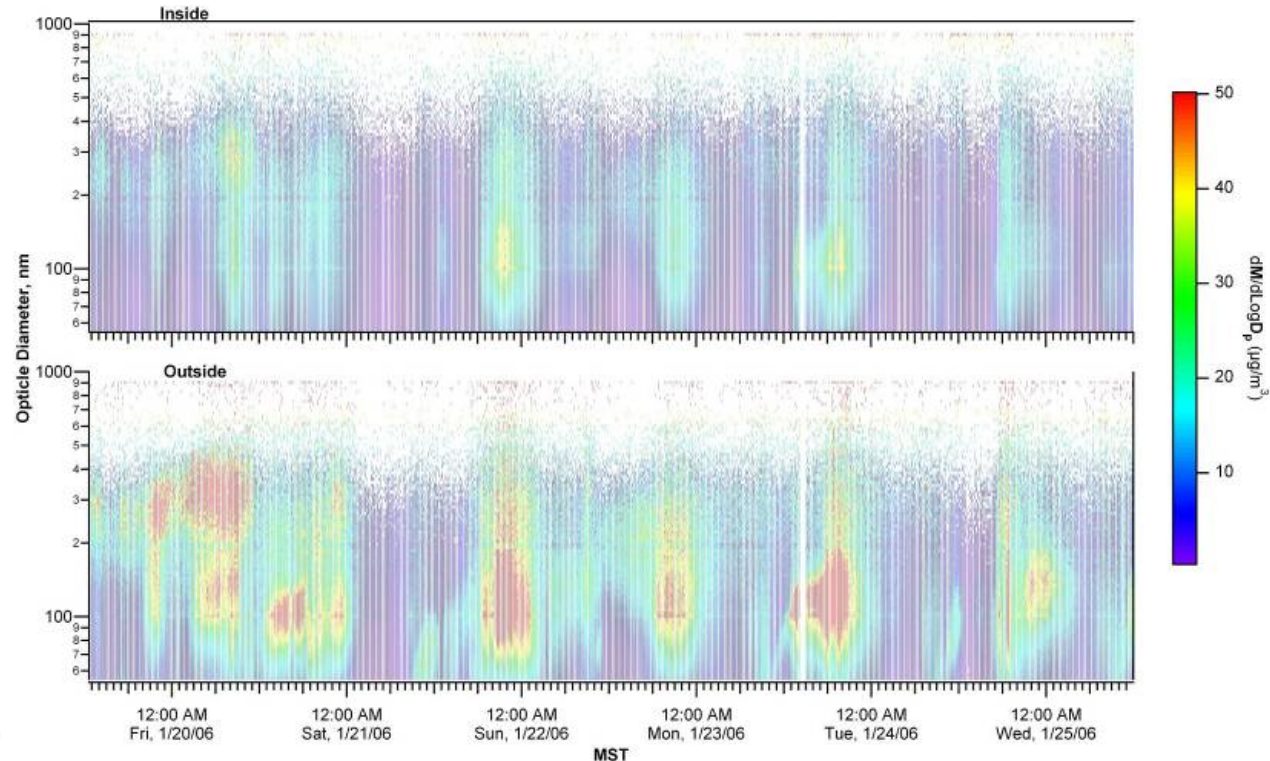
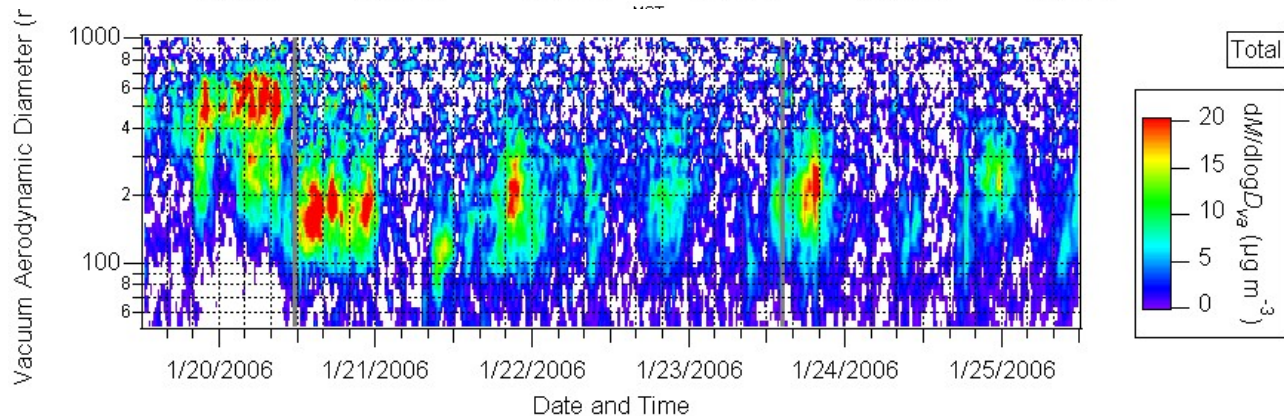
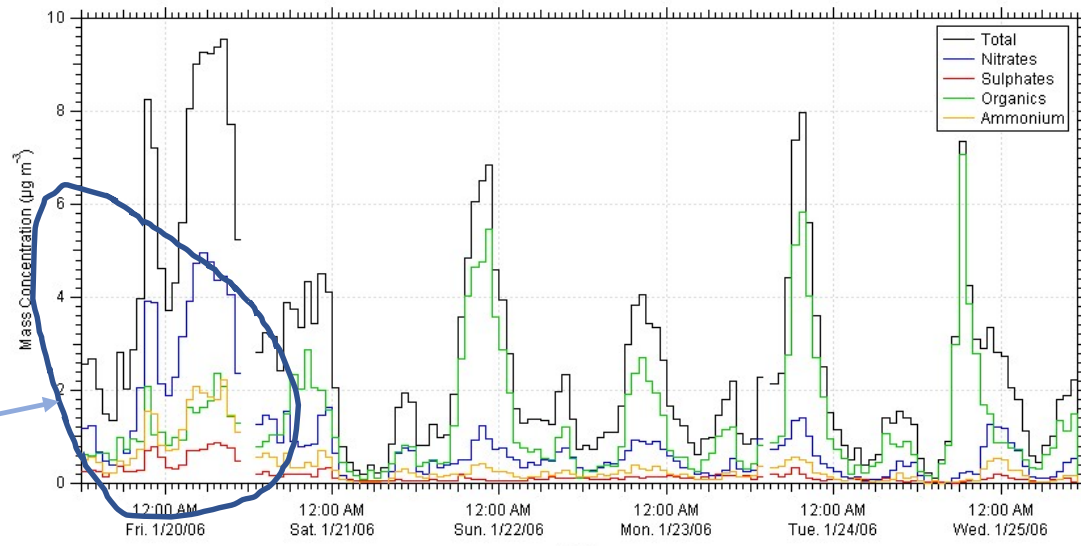


Figure 1. Schematic diagram of ventilation model
Generally, makeup air and recirculated air both pass through the same filter and intake fan system



Most of the aerosol mass is organic...around $0.2\ \mu\text{m}$

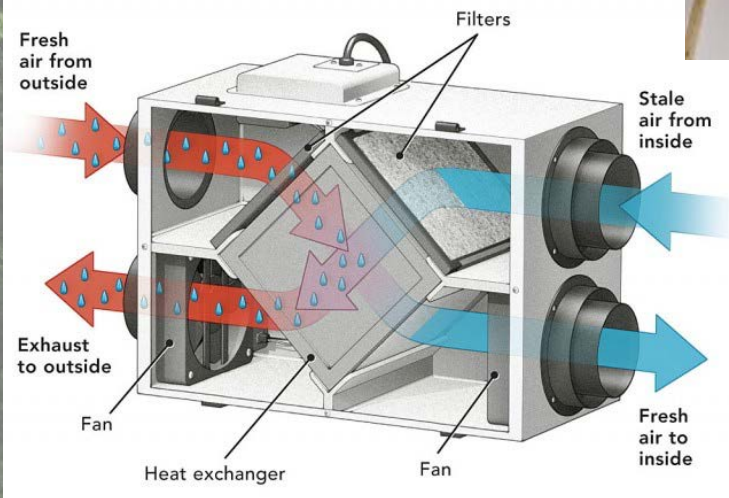
Except when it not: air mass comes from the North, bringing in larger particles with nitrates (feed lots, etc)



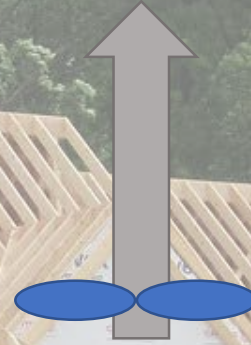
Miller et al. 2017

New construction

Energy Recovery Ventilator



Continuous Exhaust





53%

69%

Summer

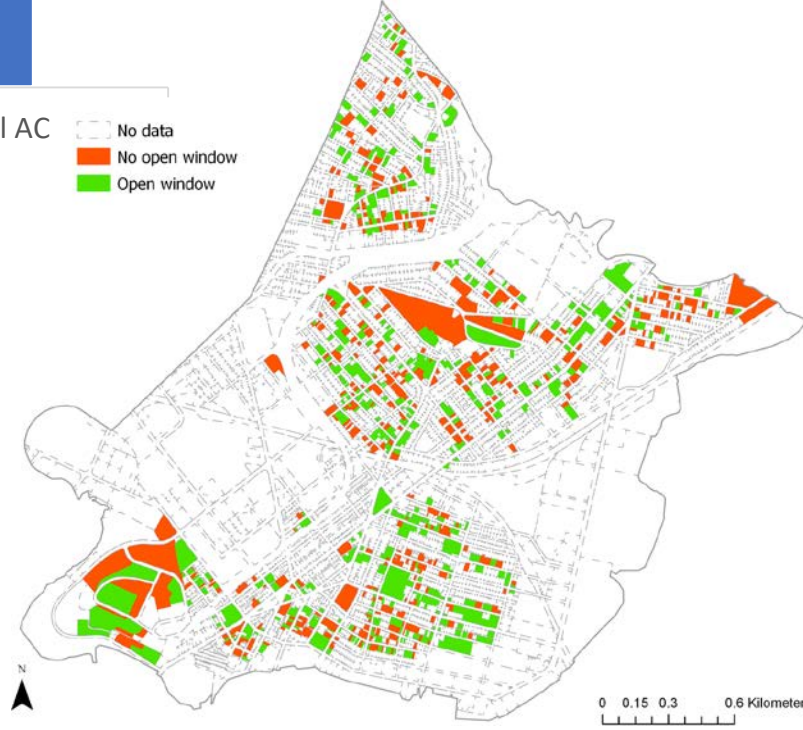
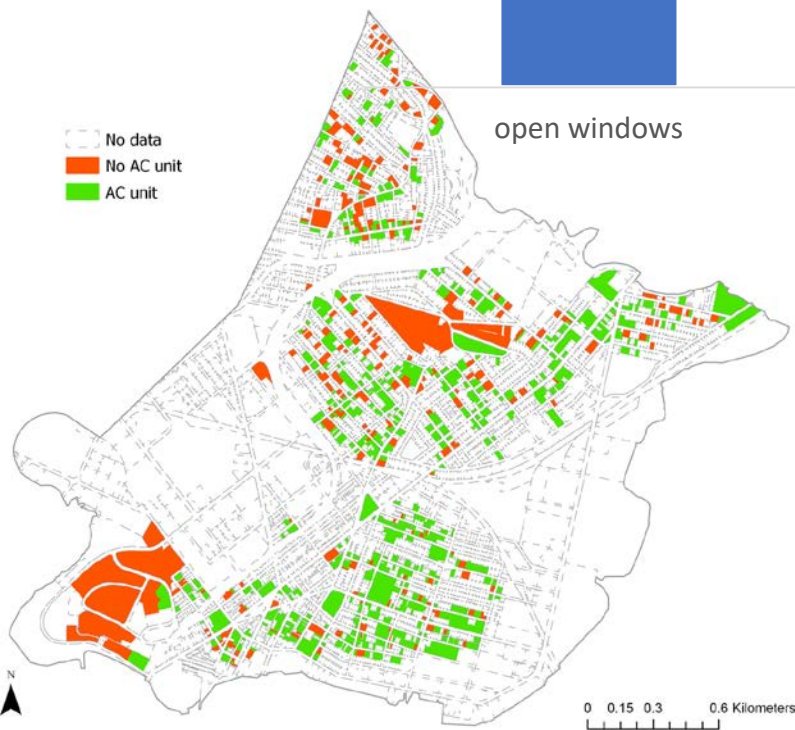
Summer: windows mostly open
limited AC access, esp. low income

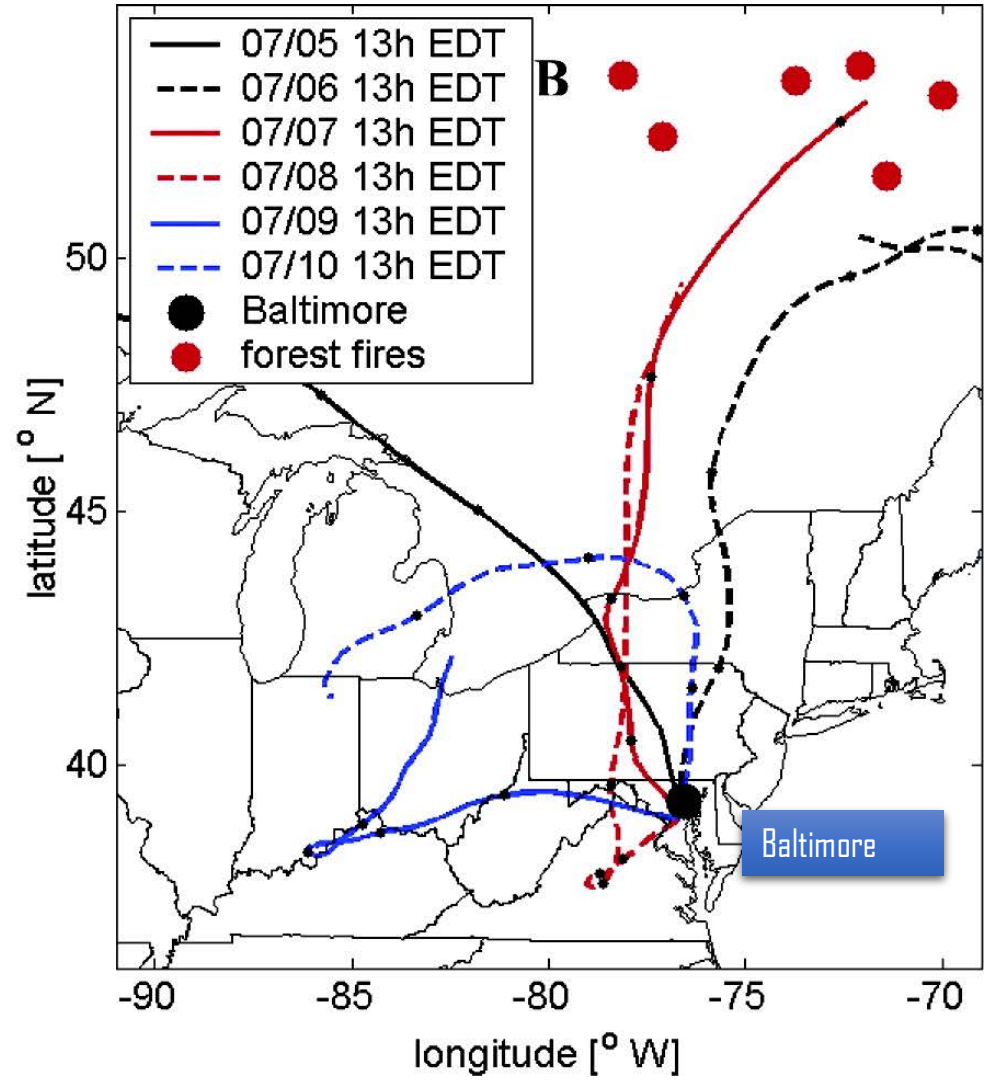
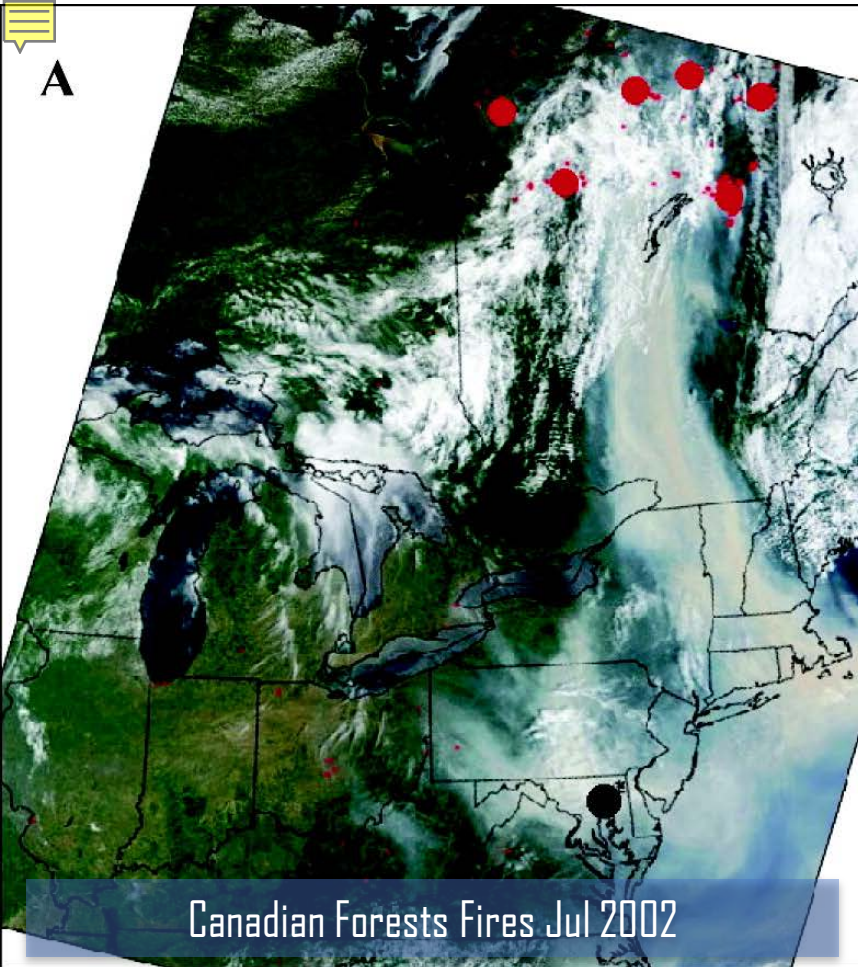
open windows

window/wall AC

No data
No AC unit
AC unit

No data
No open window
Open window

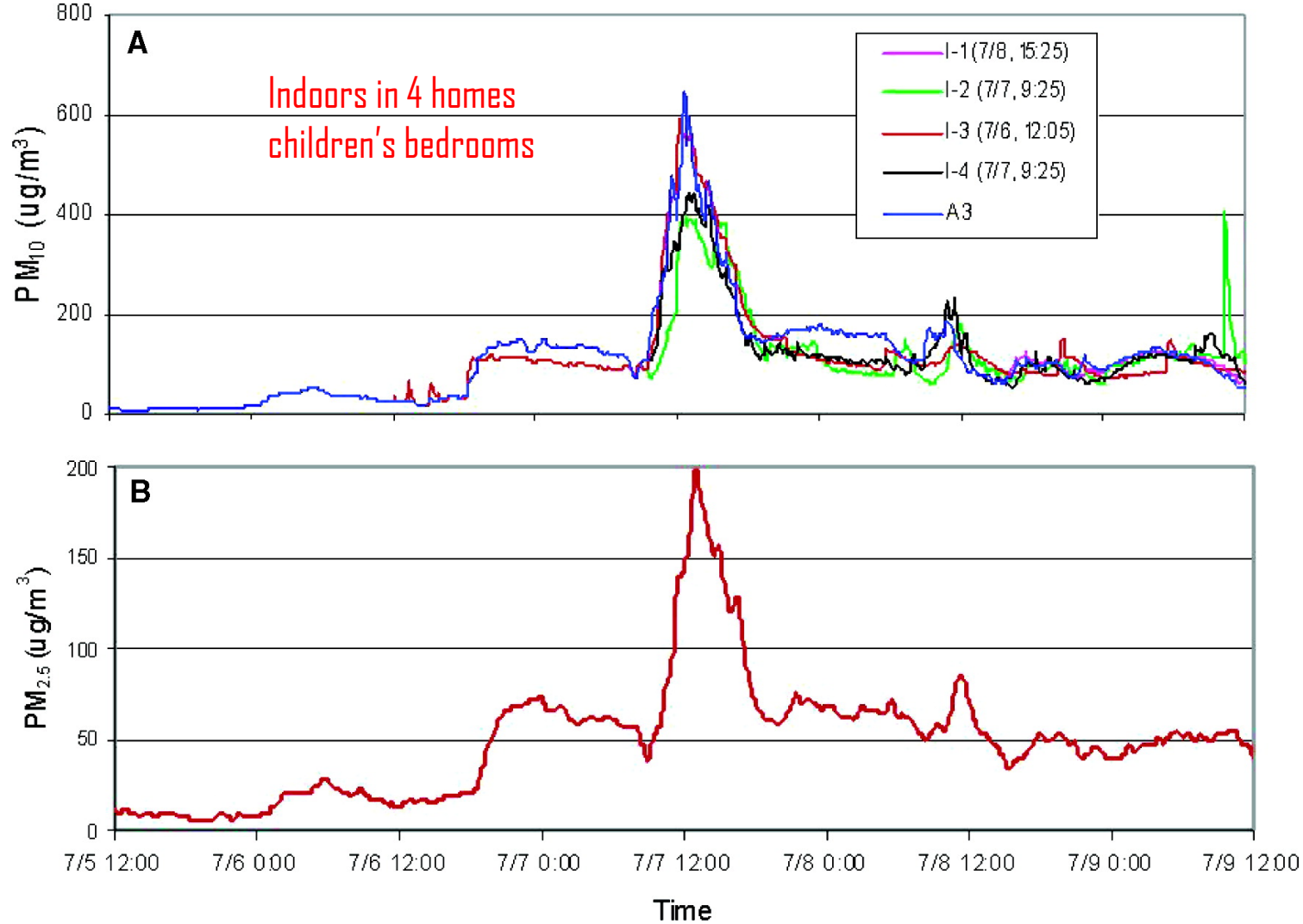




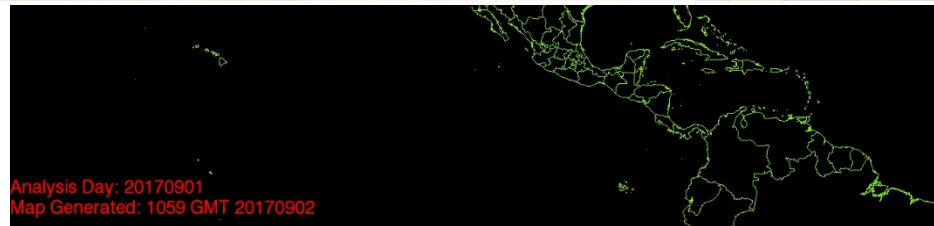
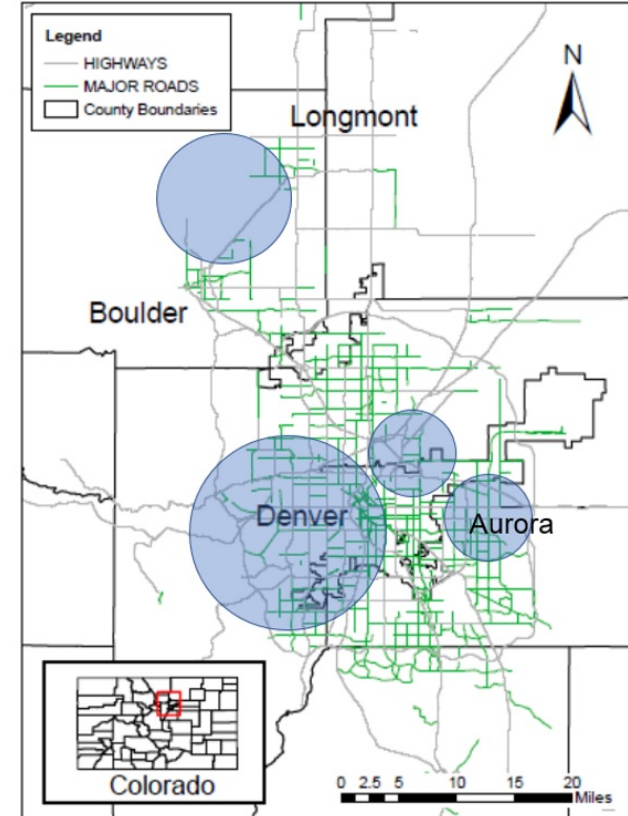


Peak 24-h avg $PM_{2.5}$
 $86 \mu g/m^3$

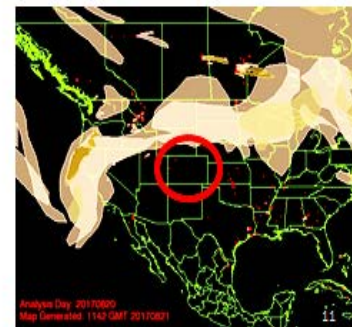
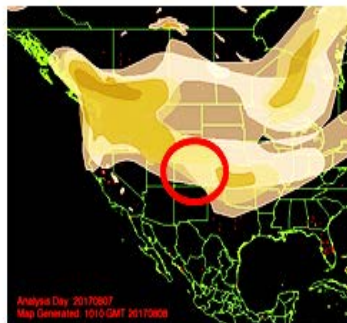
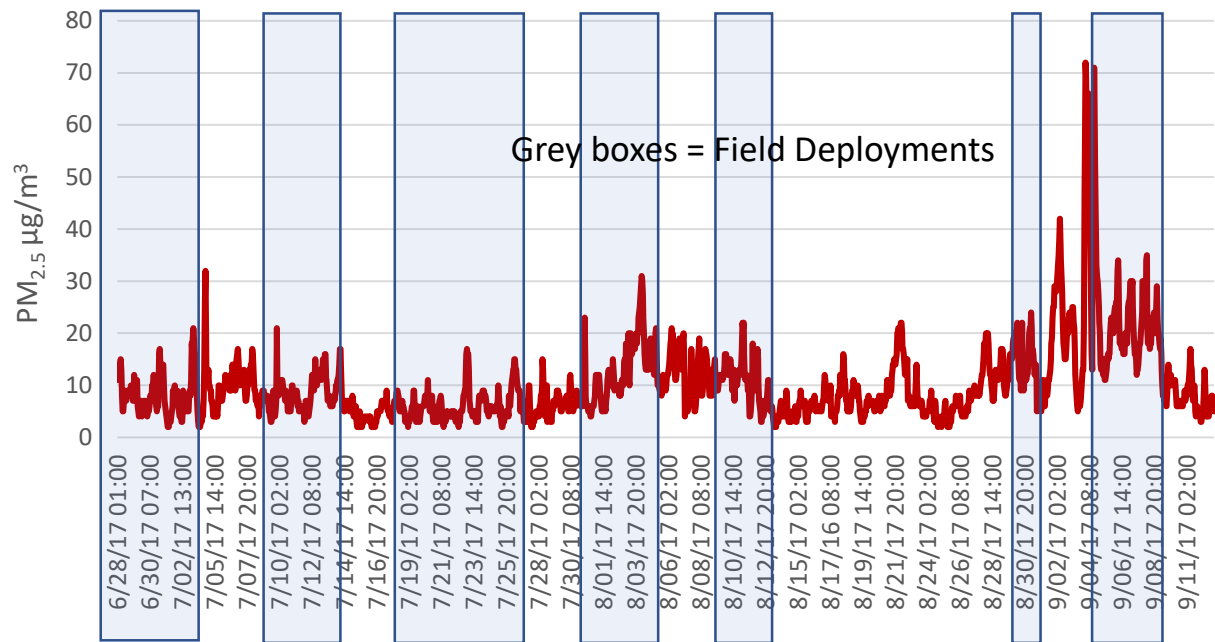
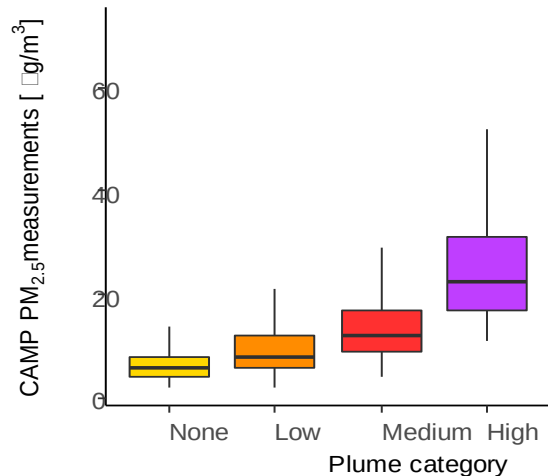
$I/O = 0.91$

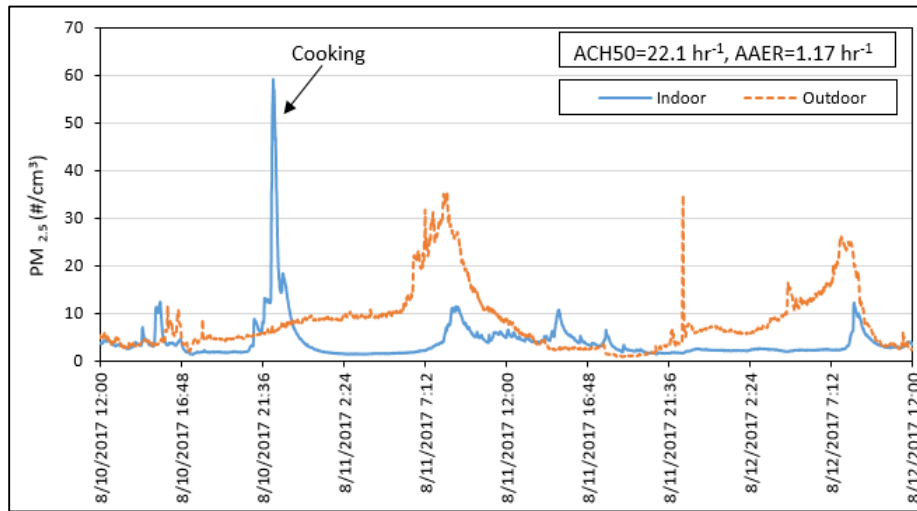


Low-Income Homes Impacted by long-range transport of Wildfire



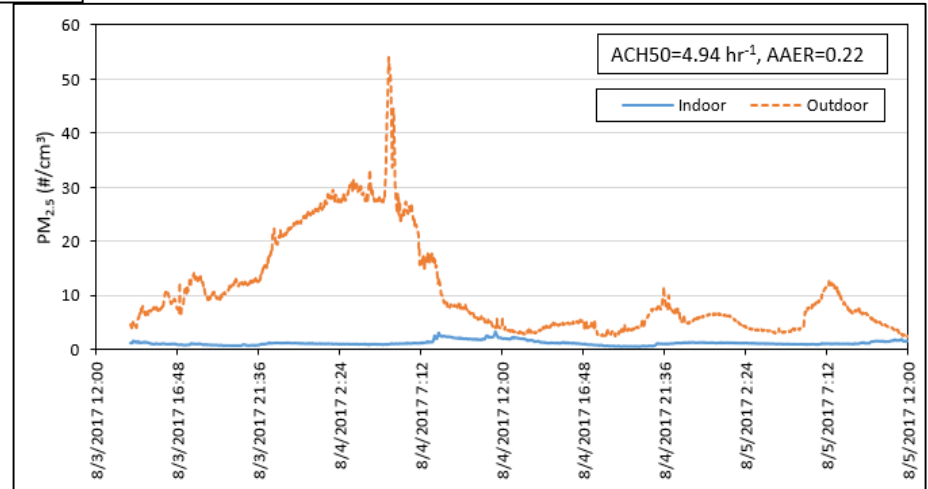
PM_{2.5} INCREASES with Wildfire Plumes





Windows
closed,
medium
density plume

Windows
open,
medium
density plume



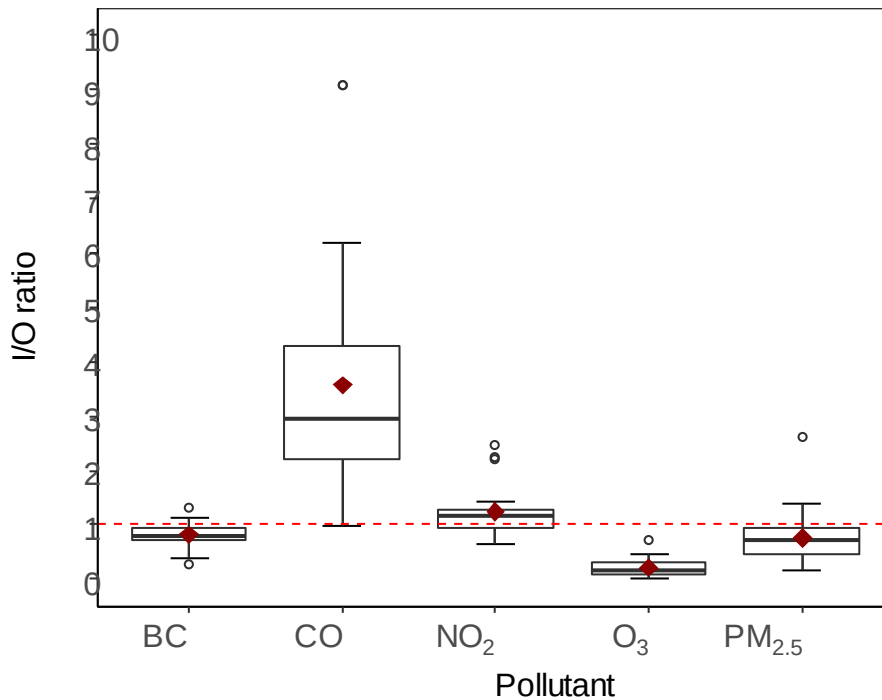
Indoor/Outdoor Ratios

BC = 0.80

CO = 3.1

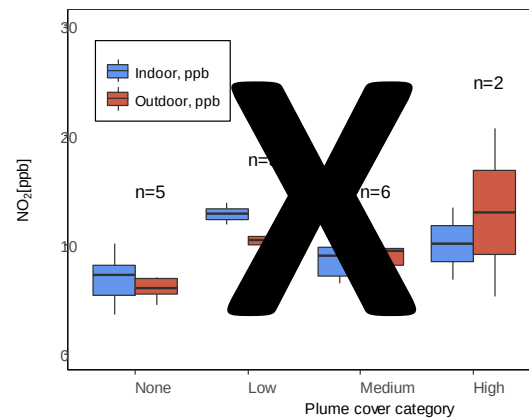
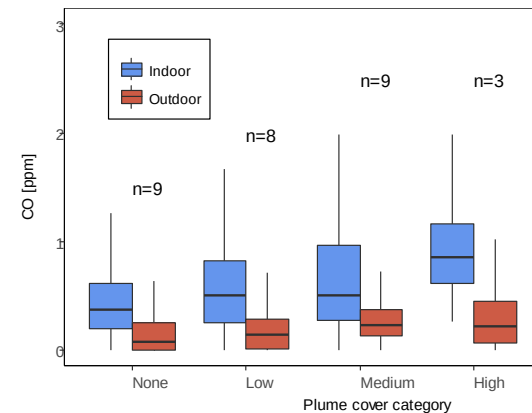
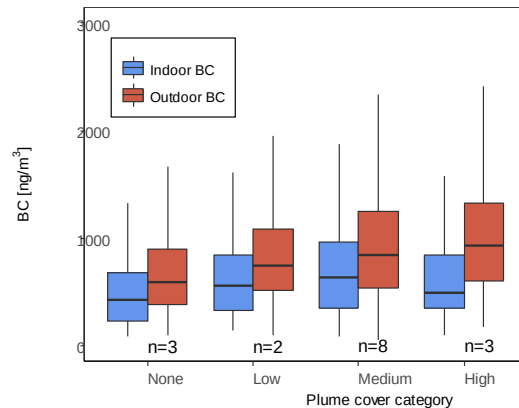
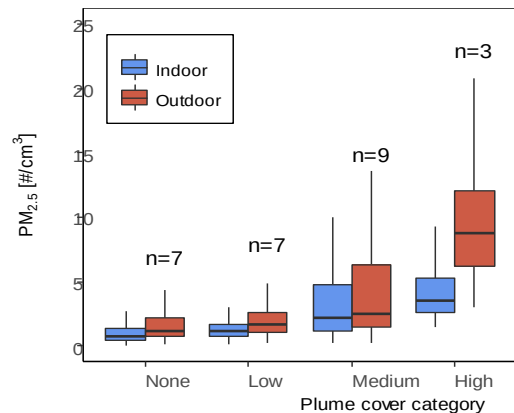
NO₂ = 1.2

PM_{2.5} = 0.71

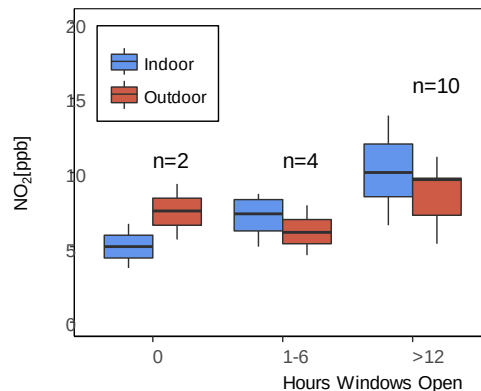
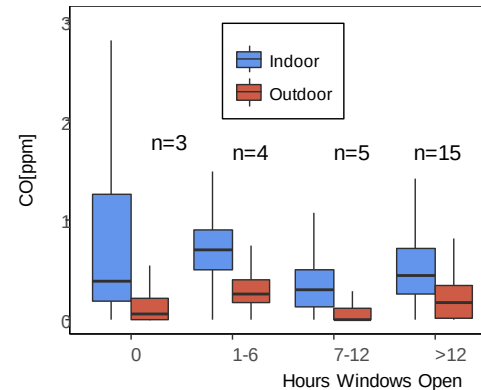
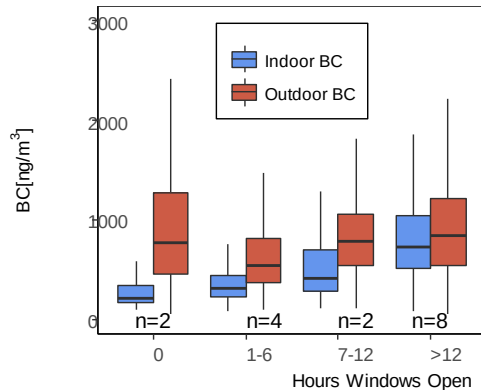
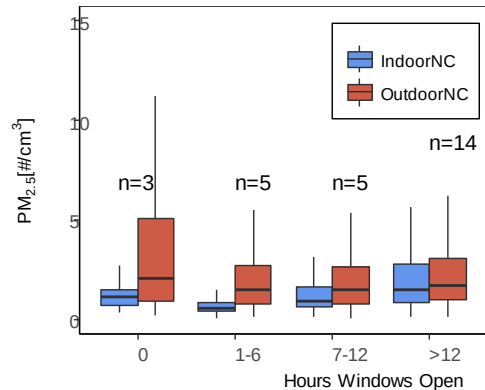




Wildfire Plumes Impact Most Pollutants

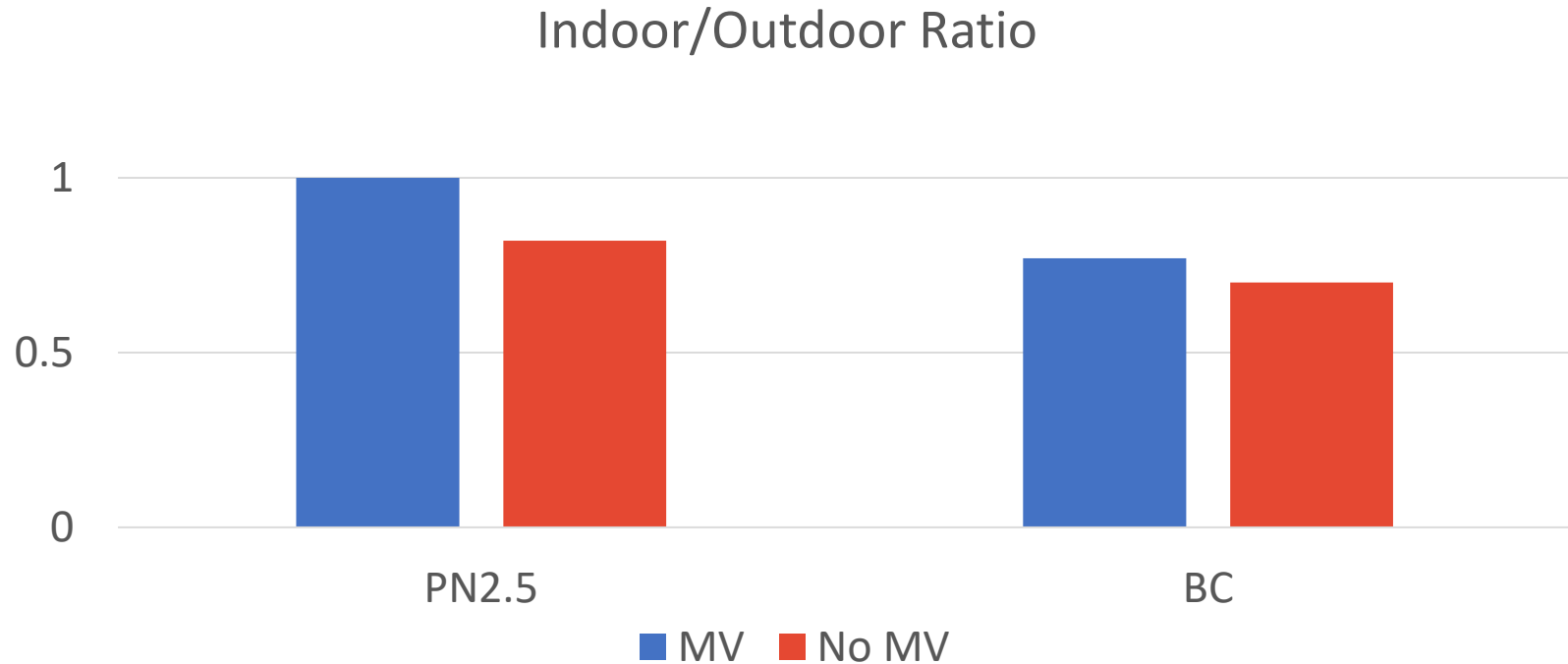


Open Windows Needed, but Detrimental





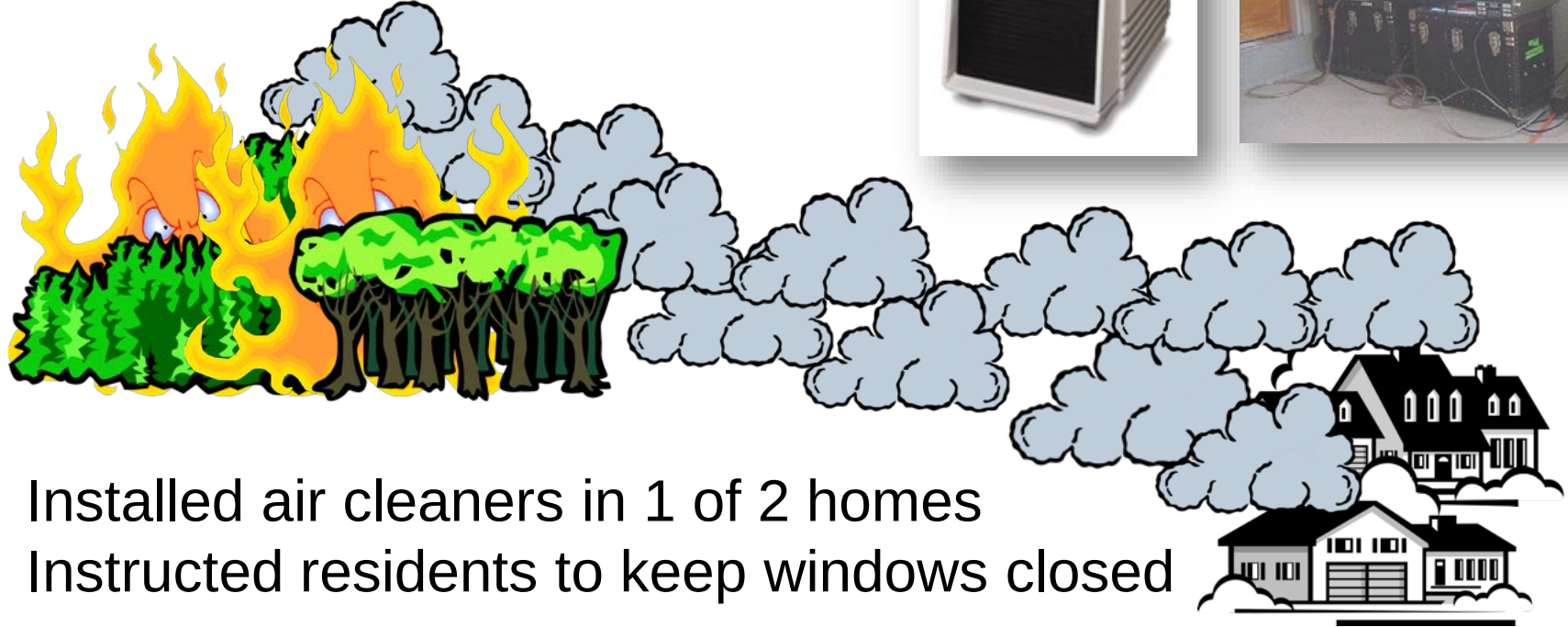
Pollutants still Higher in the Homes with Mechanical Ventilation



Control strategies to reduce exposures

Air cleaners, exhaust hoods, cleaner stove technology and fuels

USE AIR CLEANERS during a Fire (they work)



Installed air cleaners in 1 of 2 homes
Instructed residents to keep windows closed

Henderson et al. 2005

Homes of similar age and construction

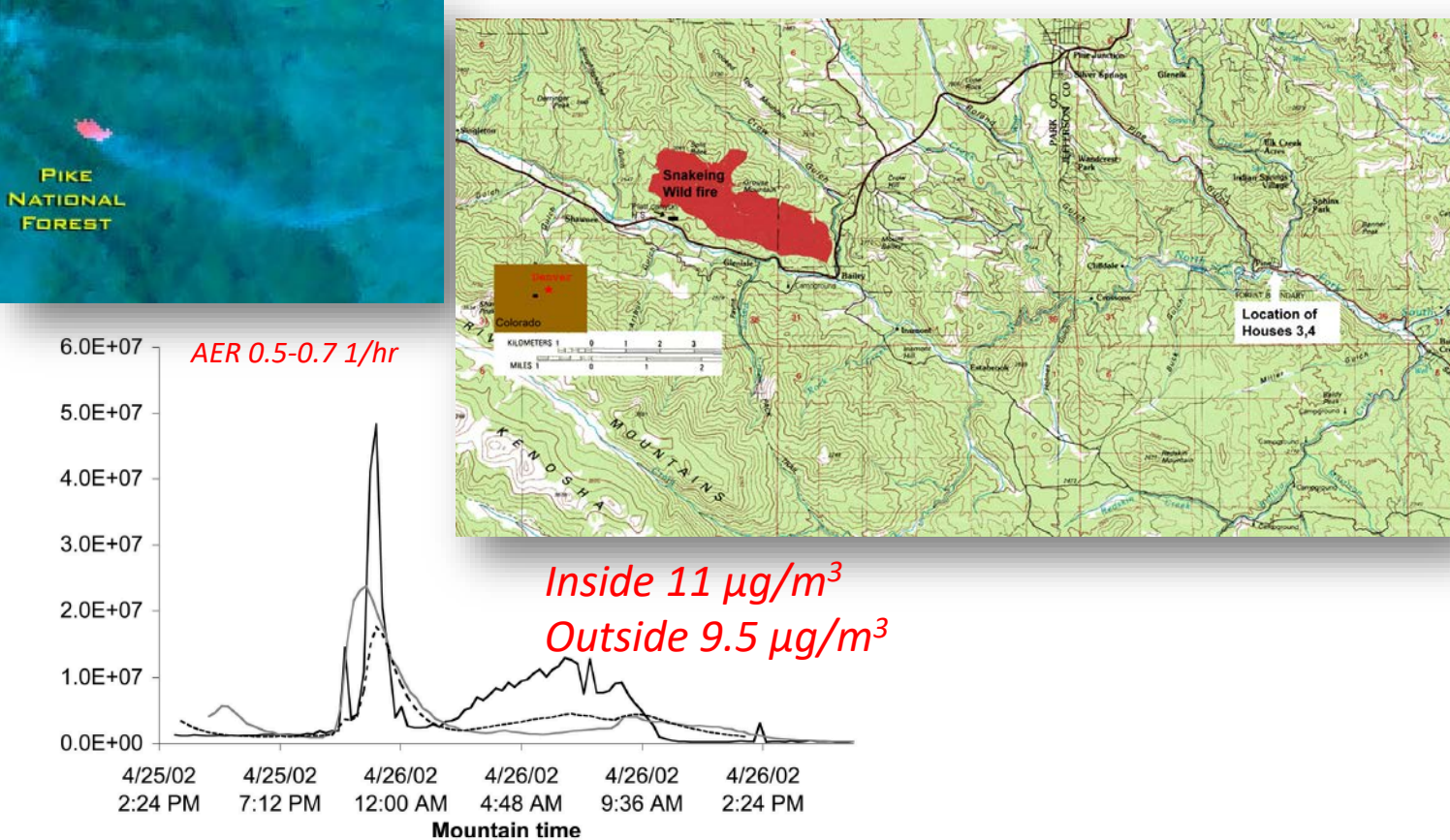


Figure 2. House Sn1 inside and outside measured particle concentrations during the Snakeing first monitoring period of April 25 to April 26, 2002. Also shown are modeled indoor air concentrations. Units are number/m³ of particles between 0.5 and 5 μm .

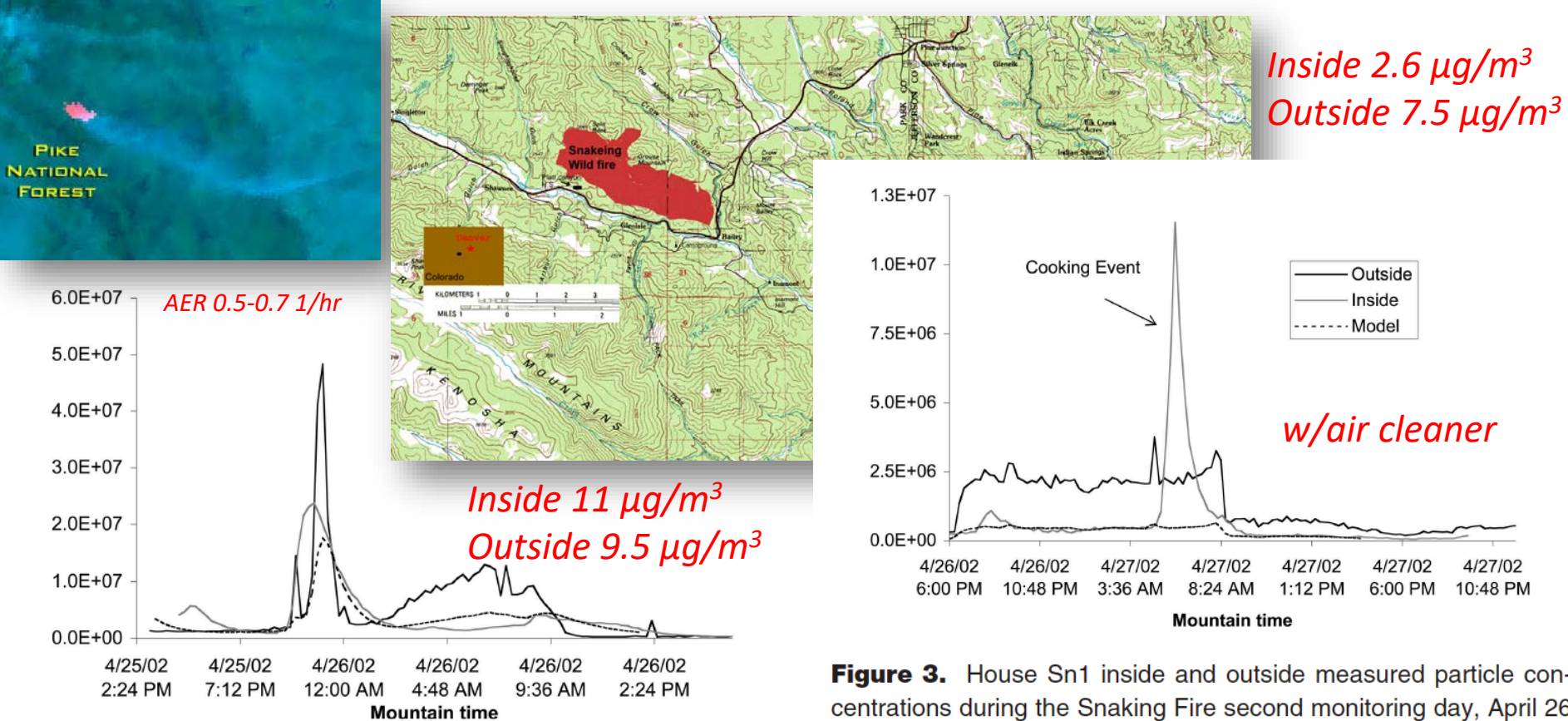


Figure 2. House Sn1 inside and outside measured particle concentrations during the Snaking first monitoring period of April 25 to April 26, 2002. Also shown are modeled indoor air concentrations. Units are number/ m^3 of particles between 0.5 and 5 μm .

Figure 3. House Sn1 inside and outside measured particle concentrations during the Snaking Fire second monitoring day, April 26 to April 27, 2002. On this day, two air cleaners were installed in the house. Also shown are modeled indoor air concentrations. Units are number/ m^3 of particles between 0.5 and 5 μm . The indoor peak at 5:00 a.m. was caused by a cooking event, as documented in the activity diaries of occupants.

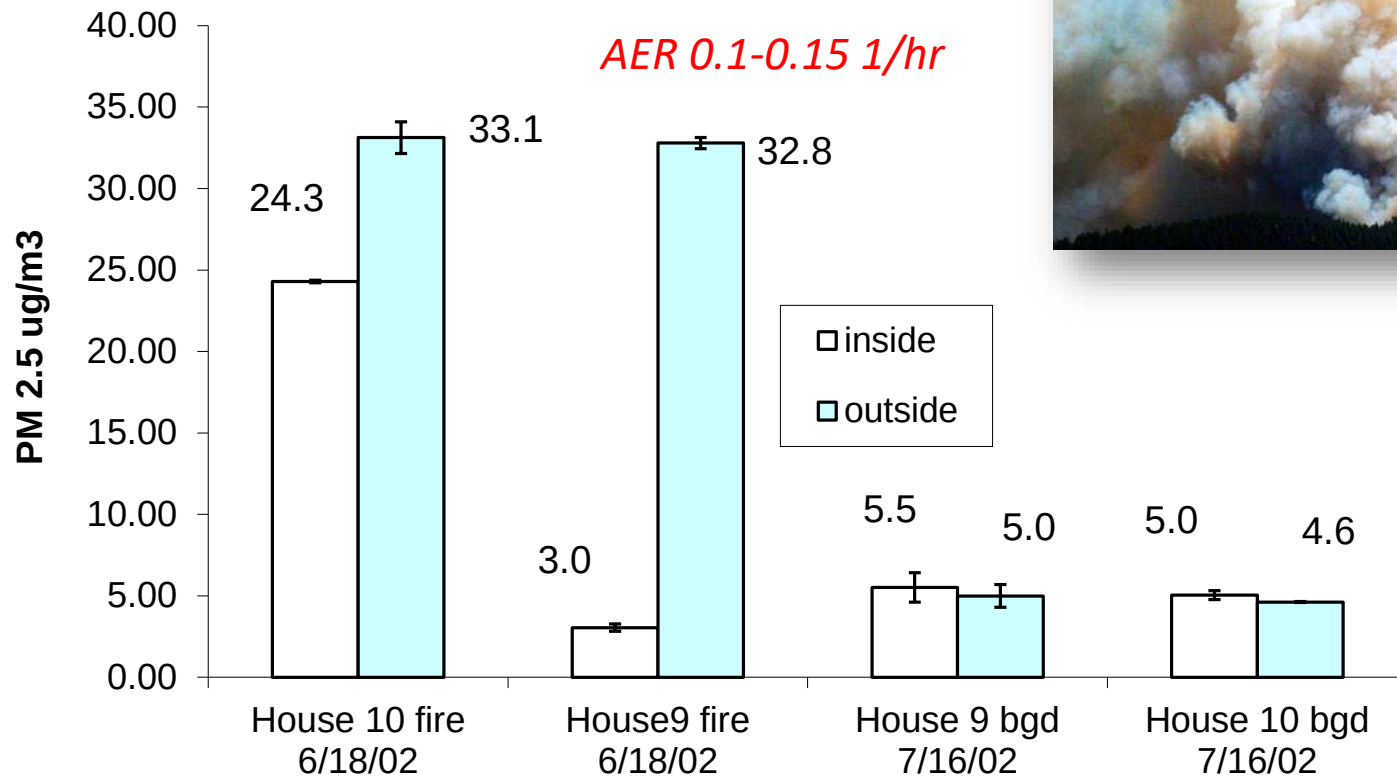
Colorado's Hayman fire set high marks for size, cost, heat and rehabilitation

By Joey Bunch

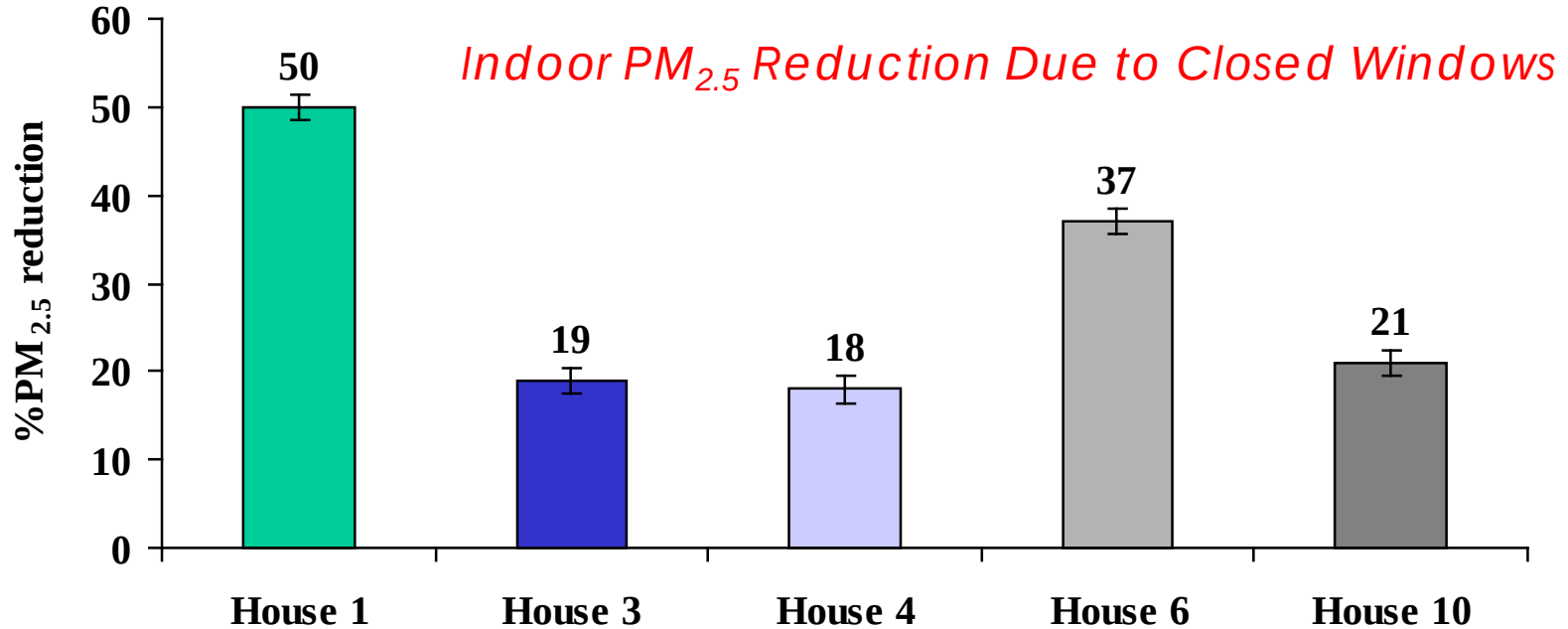
PUBLISHED: June 7, 2012 at 11:51 am | UPDATED: June 6, 2016 at 2:40 pm



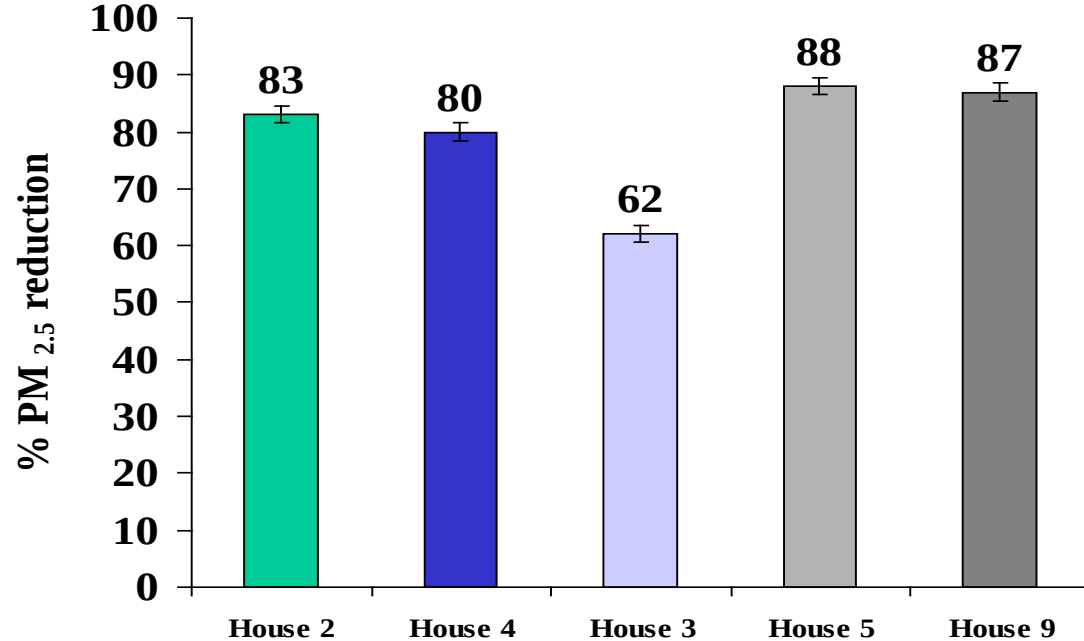
www.denverpost.com



$$1 - \frac{\left(\frac{PM_{2.5} \text{ Inside}}{PM_{2.5} \text{ Outside}} \right)_{\text{Fire}}}{\left(\frac{PM_{2.5} \text{ Inside}}{PM_{2.5} \text{ Outside}} \right)_{\text{Background}}} = \left(\text{Percent } PM_{2.5} \text{ reduction due to closed windows} \right)_{\text{HouseA}}$$

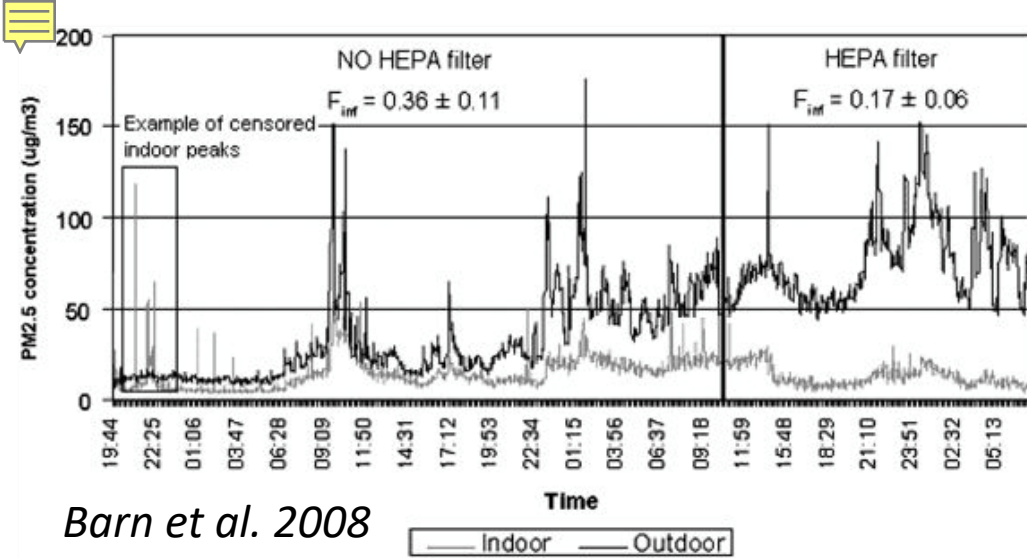


$$1 - \frac{\left(\frac{PM_{2.5} \text{ Inside w air cleaner}}{PM_{2.5} \text{ Outside}} \right)_{\text{House A}}}{\left(\frac{PM_{2.5} \text{ Inside w/o air cleaner}}{PM_{2.5} \text{ Outside}} \right)_{\text{House B}}} = \left(\frac{\text{Percent } PM_{2.5} \text{ reduction}}{\text{due to air cleaner}} \right)_{\text{House A}}$$

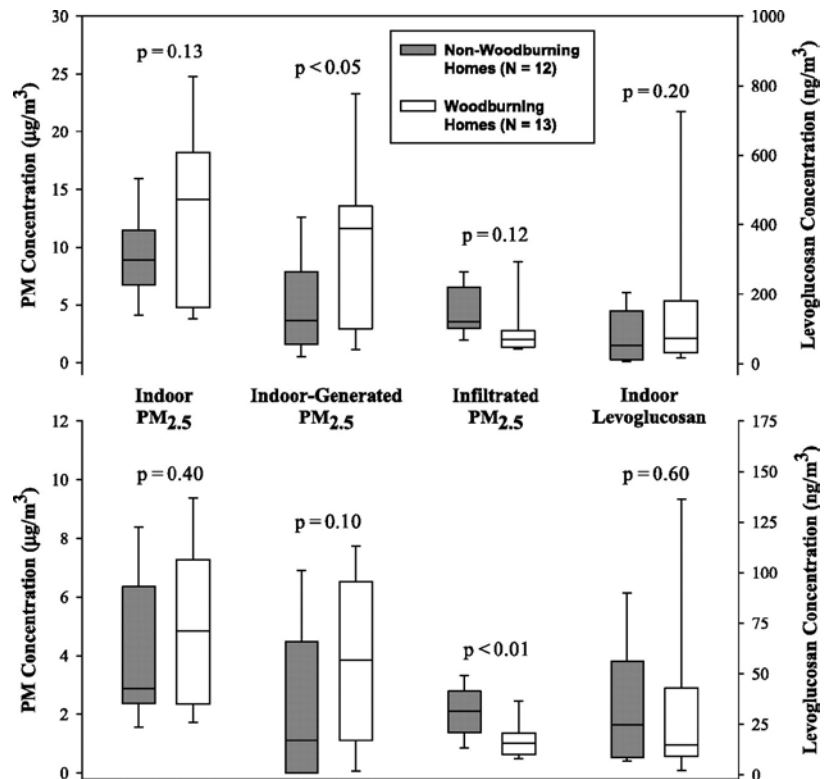


Indoor PM_{2.5} Reduction Due to Air Cleaners

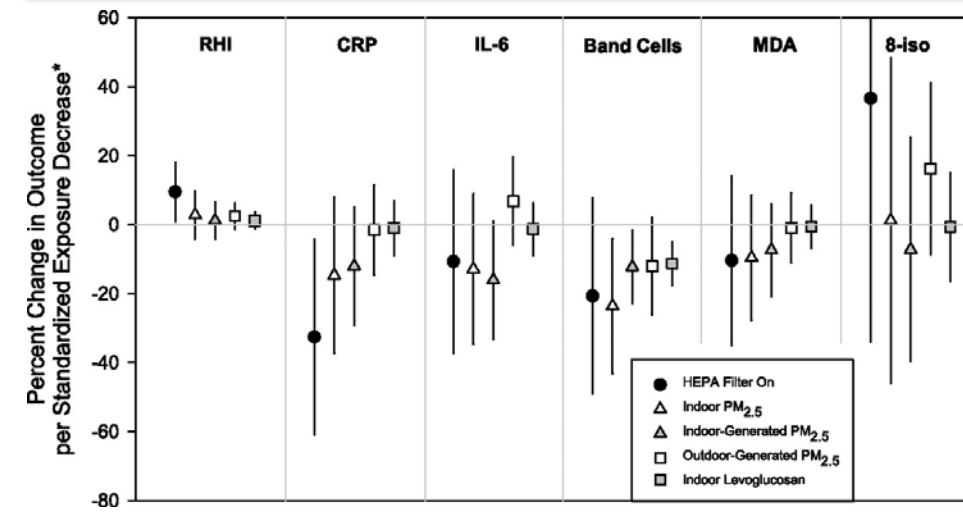




Barn et al. 2008



Allen et al. 2011



Air cleaners 55-65% effective
Improved cardiovascular health markers

Low-Income Communities

Need access to cooling and
air cleaning during extreme
episodes



Summertime dilemma

Windows need to be open for cooling

*Windows need to be closed to reduce smoke (TRAP)
exposure*

SOLUTION?

Install window AC, power with solar



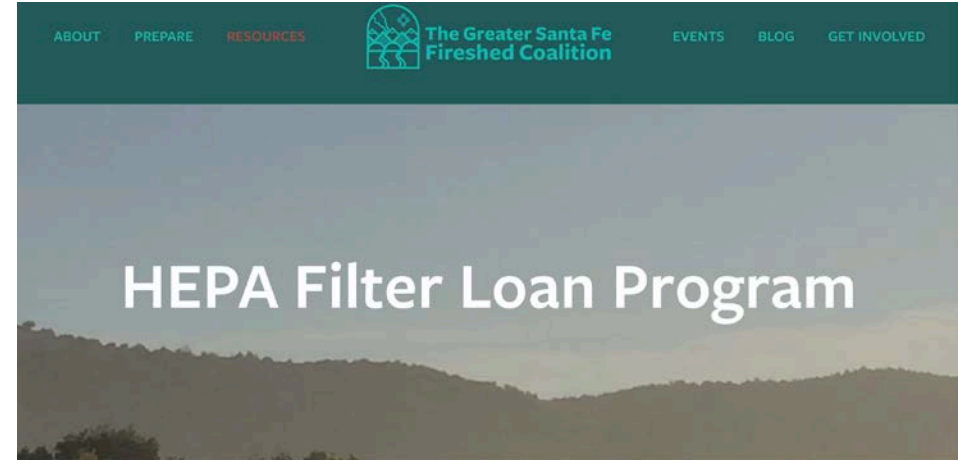
Montana

Are you considering launching a program to provide HEPA Portable Air Cleaners to community members or groups for free, loan or reduced price? It's a fantastic idea to help those most vulnerable or in need, and there are many ways to go about this.

Beginning in 2017, Climate Smart Missoula initiated a program to provide HEPA PACs to those most in need in Missoula County. They raised funds and gave them away (for free) to at-risk, low-income, home-bound seniors; families and individuals in need; and public schools. In 2018 they worked with The Missoula Health Department to provide them to day-cares and preschools. Here are some considerations and recommendations based on Climate Smart's experiences:

SOME COMMUNITIES HAVE AIR CLEANERS TO LOAN

New Mexico



Smoke from wildfires and prescribed fires is a serious concern as it can cause and exasperate health conditions for those of us that endure it. However by living in the fire adapted ecosystems of northern New Mexico we must accept that wildfire and smoke is inevitable.

RETREAT TO CLEAN AIR SHELTERS

Public spaces available to seek relief from wildfire smoke

Buildings are complicated!
Filtration + HVAC +
Doors/Windows + People

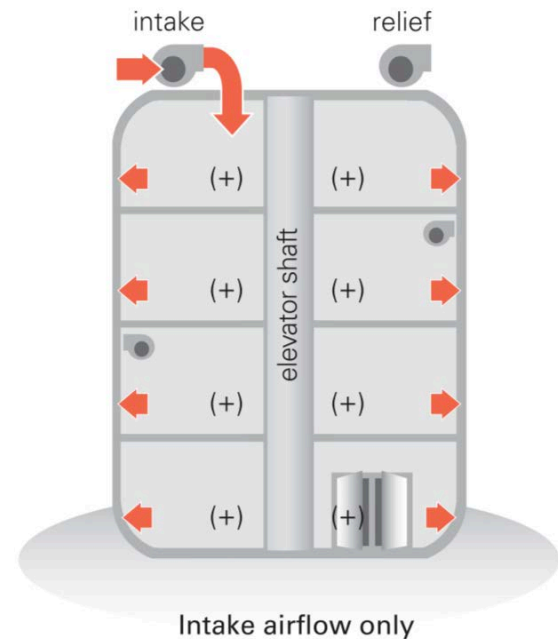
Improved supply air filtration



www.aafintl.com

How to optimize for Health
during Severe outdoor air
pollution such as wildfires?

**MUST HAVE IMPROVED
FILTRATION** in these buildings
to protect inhabitants



- Outward-swinging doors may stand open
- During winter, exfiltrating indoor air drives moisture into building envelope

www.trane.com

Mostly positively pressurized



Today's Talk - What I told you!

Wildfire emissions on Indoor Air Quality

- What is outdoors, is what is in your home, especially in under-resourced communities where cooling by open windows is the only option

Control and Mitigation Strategies for Wildfire Smoke

- Enable communities to have access to air cleaners, window AC, shelters during catastrophic fires

Health Effects and Socioeconomic Considerations

- Added toxicity due to chemicals in household products and furniture
- Many homes use natural ventilation for cooling, not protective against smoke

References

- Bonjour, S., Adair-Rohani, H., Wolf, J., Bruce, N.G., Mehta, S., Prüss-Ustün, A., Lahiff, M., Rehfuess, E.A., Mishra, V. and Smith, K.R., 2013. Solid fuel use for household cooking: country and regional estimates for 1980–2010. *Environmental health perspectives*, 121(7), pp.784-790.
- GBD 2013, 2015. Global burden of diseases risk factors collaborators. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990–2013: a systematic analysis for the global burden of disease study 2013. *Lancet*, 386(10010), pp.2287-2323.
- Allen, R.W., Leckie, S., Millar, G. and Brauer, M., 2009. The impact of wood stove technology upgrades on indoor residential air quality. *Atmospheric Environment*, 43(37), pp.5908-5915.
- Henderson, D.E., Milford, J.B. and Miller, S.L., 2005. Prescribed burns and wildfires in Colorado: impacts of mitigation measures on indoor air particulate matter. *Journal of the Air & Waste Management Association*, 55(10), pp.1516-1526.
- Okello, G., Devereux, G. and Semple, S., 2018. Women and girls in resource poor countries experience much greater exposure to household air pollutants than men: Results from Uganda and Ethiopia. *Environment international*, 119, pp.429-437.
- Shrestha, P.M., Humphrey, J.L., Carlton, E.J., Adgate, J.L., Barton, K.E., Root, E.D. and Miller, S.L., 2019. Impact of Outdoor Air Pollution on Indoor Air Quality in Low-Income Homes during Wildfire Seasons. *International Journal of Environmental Research and Public Health*, 16(19), p.3535.