

Outdoor Particulate Matter Sources and the Chemical Transformations that take place when they interact with the Indoor Environment

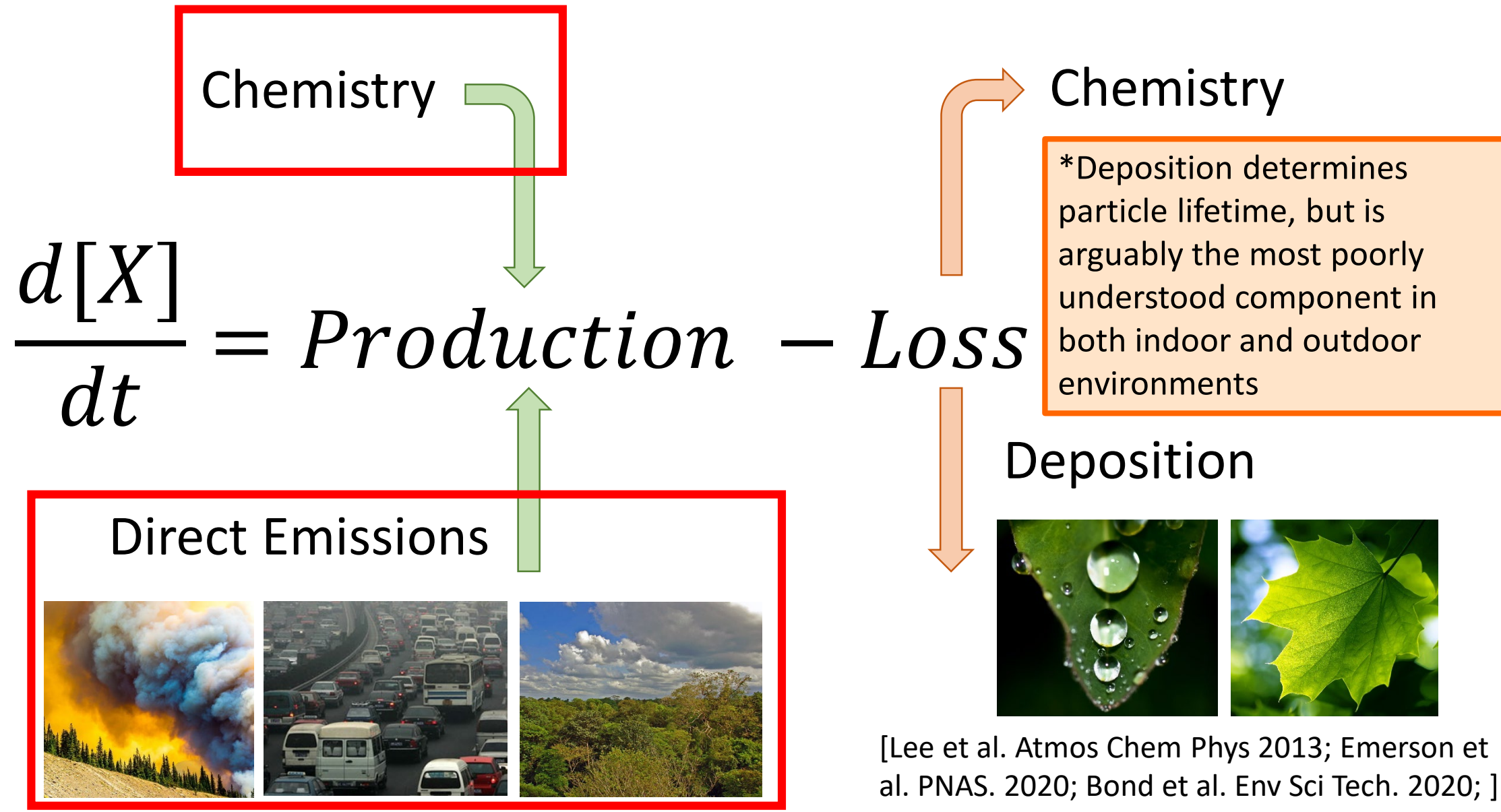


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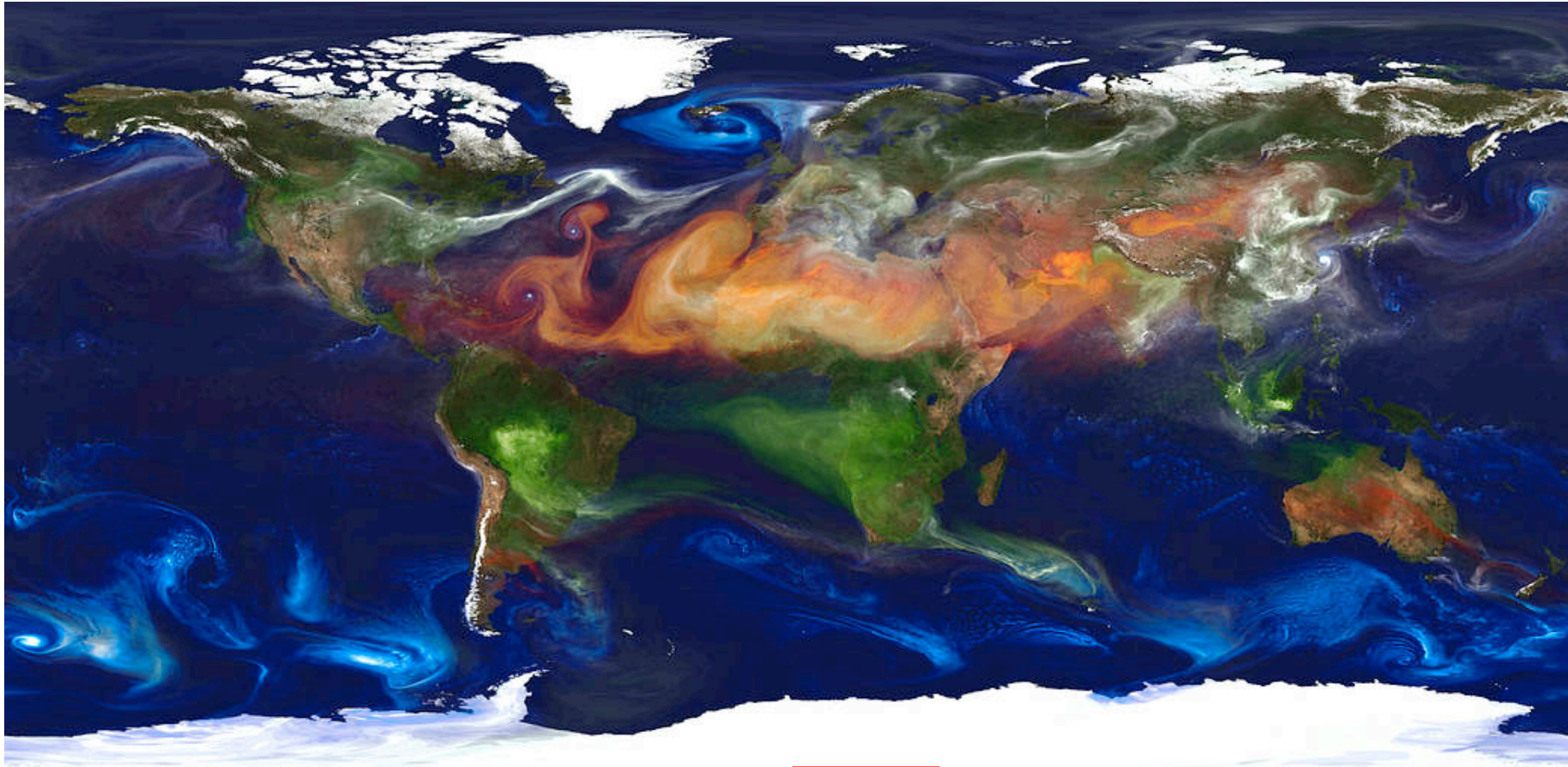
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Sources are one part of what controls outdoor PM



Particles have different chemical composition, depending on their source

- Particles have an average atmospheric lifetime of ~ 7 days
- Sources vary on global, regional, and local scales

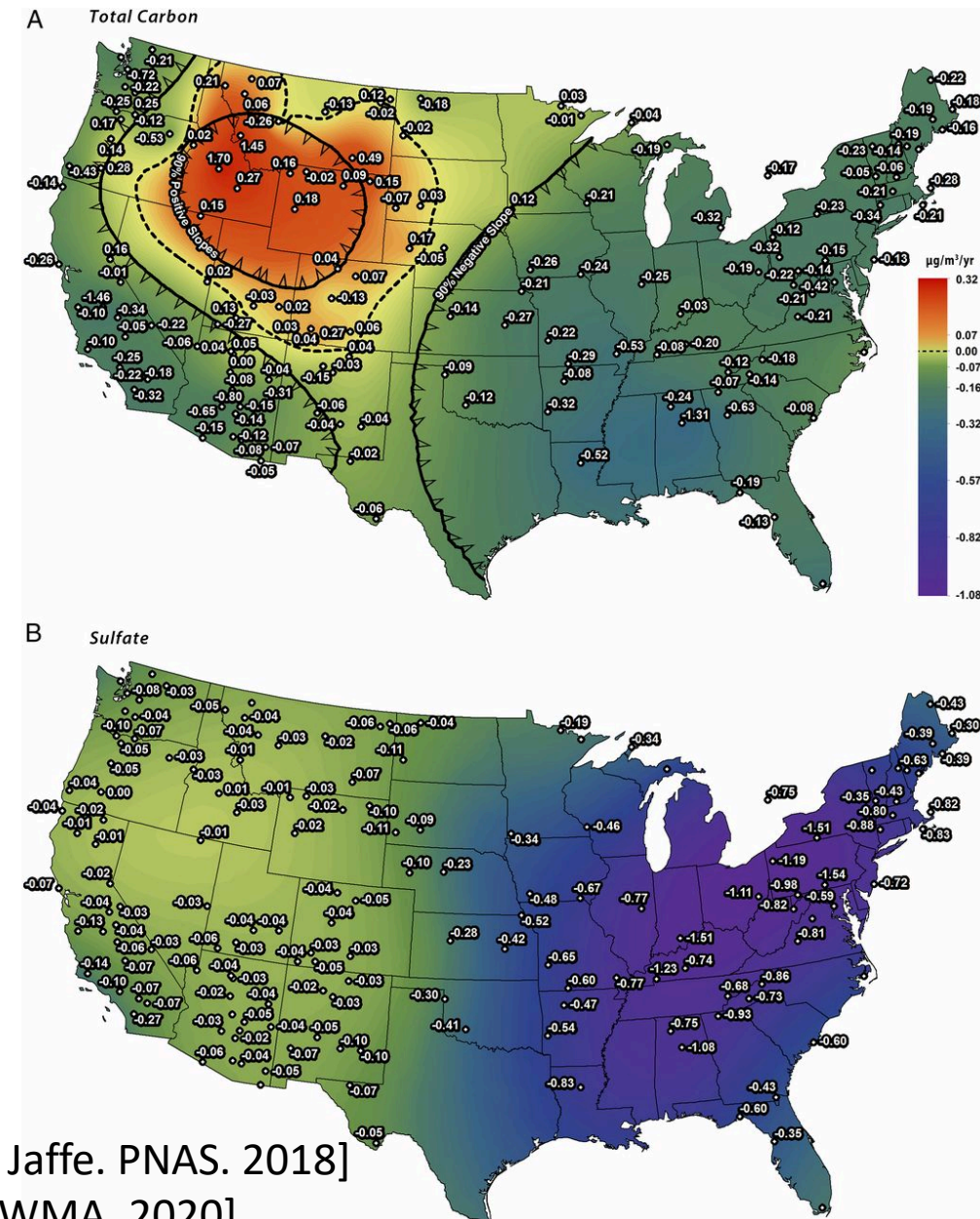


Dust SeaSalt **Smoke** Sulfate

Image: NASA Center for Climate Simulation at Goddard Space Flight Center

Biomass burning is particularly important in the western US & Alaska

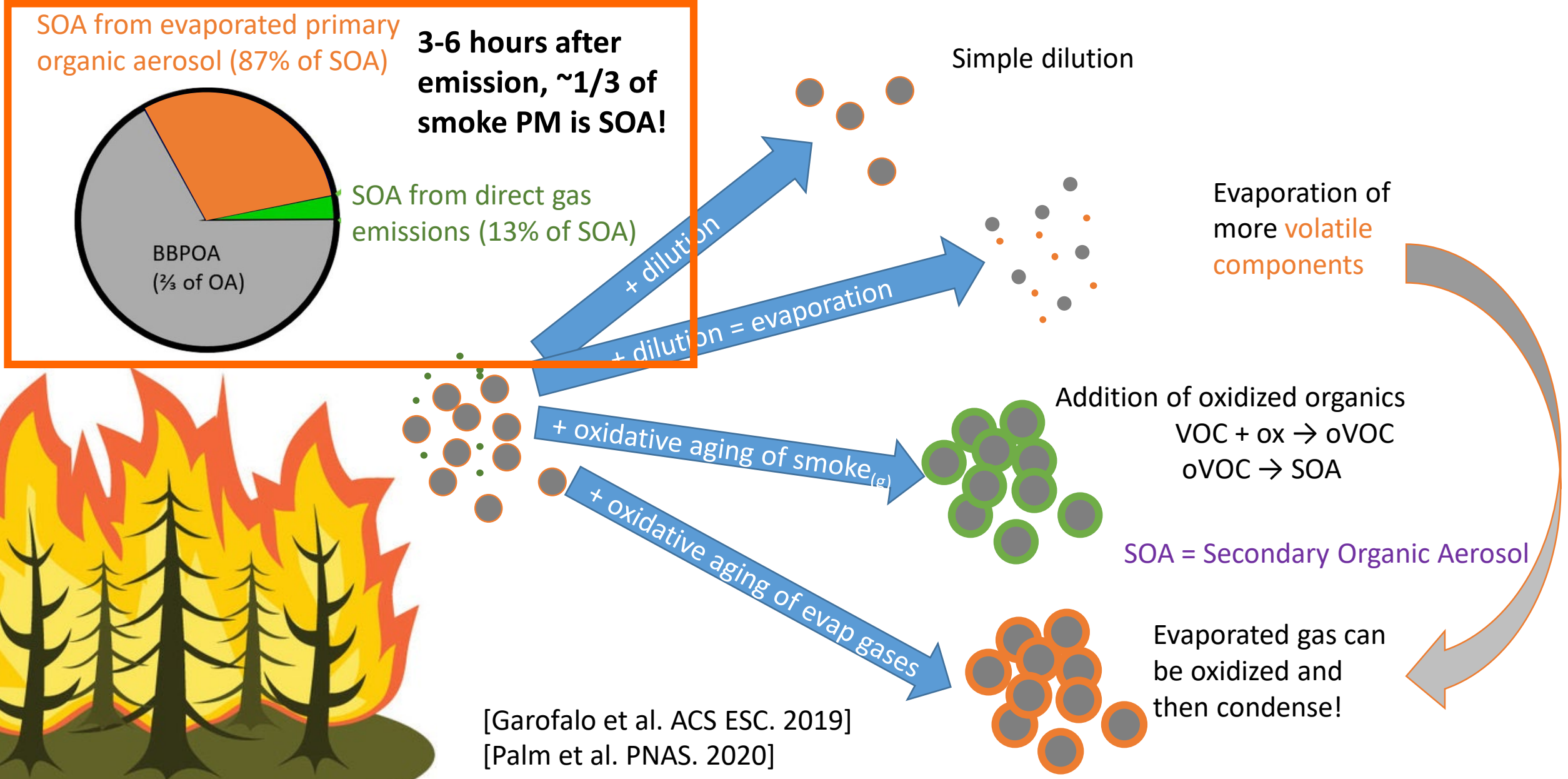
- Smoke PM from biomass burning is dominantly **organic** aerosol
- Smoke influences both outdoor and indoor air quality [Henderson et al. JAWMA. 2012]
- Influenced by changing climate



[McClure and Jaffe. PNAS. 2018]

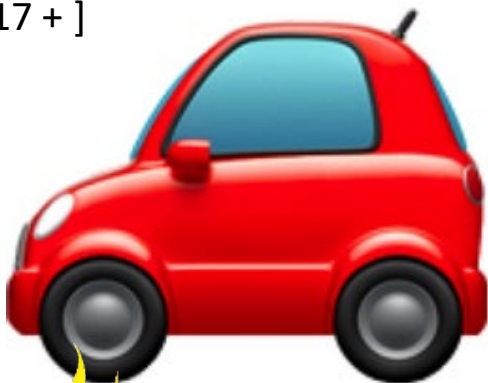
[Jaffe et al. JAWMA. 2020]

Biomass burning PM is more than just emissions...



Sources of Primary PM & Precursors to Secondary Outdoor PM

[Gentner et al. PNAS 2012; Jathar et al. ACP 2017 +]



[MacDonald et al. Science; Seltzer et al. ACP 2021; Shah et al. Env Sci Tech 2020; Li et al. Atmos Env. 2018 +]

[Bauer et al. GRL 2016; Van Damme et al. Nature 2018 +]

[Hodshire et al. Env Sci Tech 2019; Liu Atmos Env 2018 +]



[Bates et al. GRL 2020; Mayer et al. ACS Central Science 2020 +]

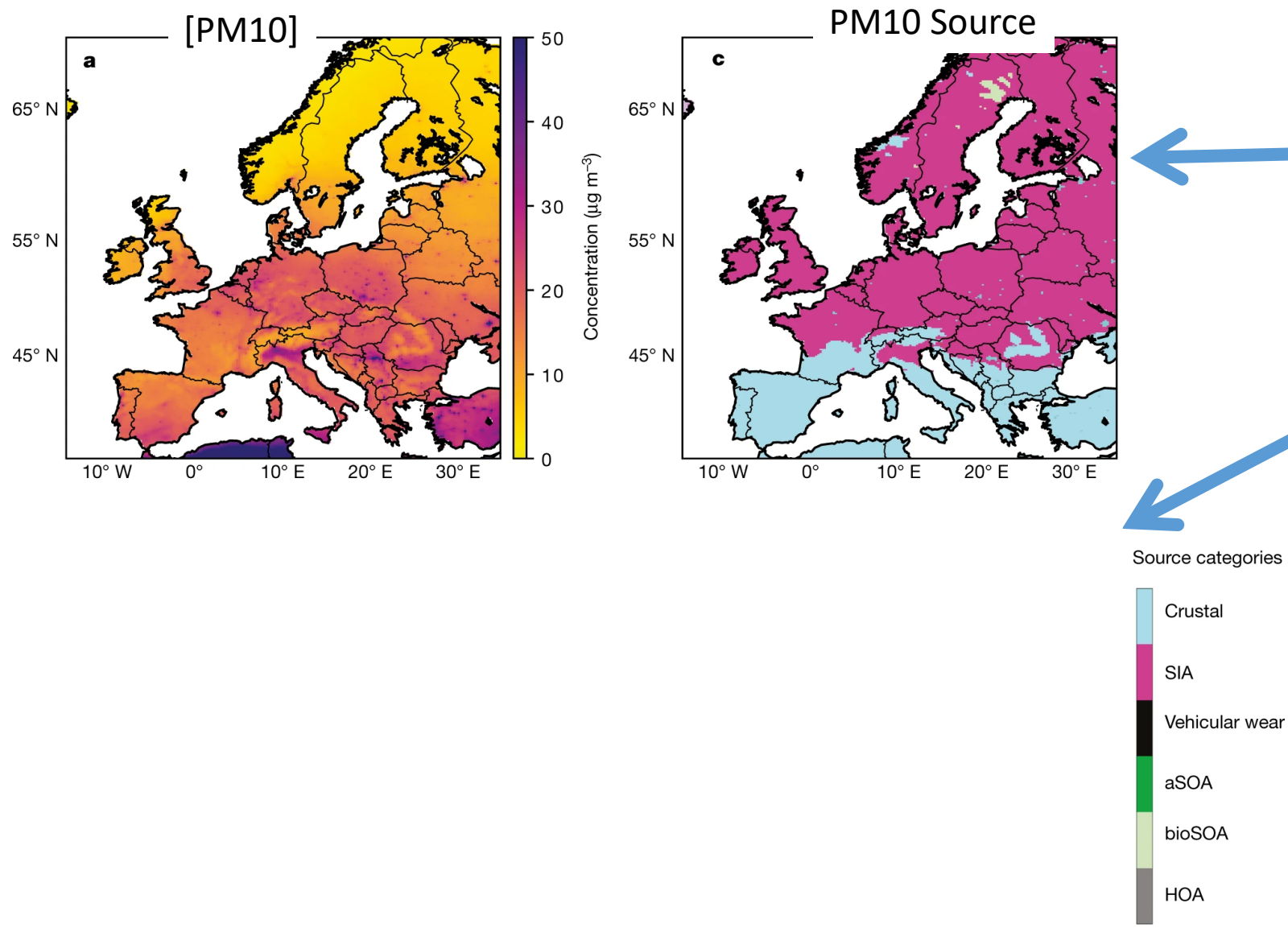


[Rap et al. Nature Geo 2018; Riches and Farmer Acc Chem Res 2020; Steiner Acc Chem Res 2020 +]



[Pattantyus et al. Atmos Env 2018 +]

Spatial heterogeneity in outdoor PM + chemistry influences health effects

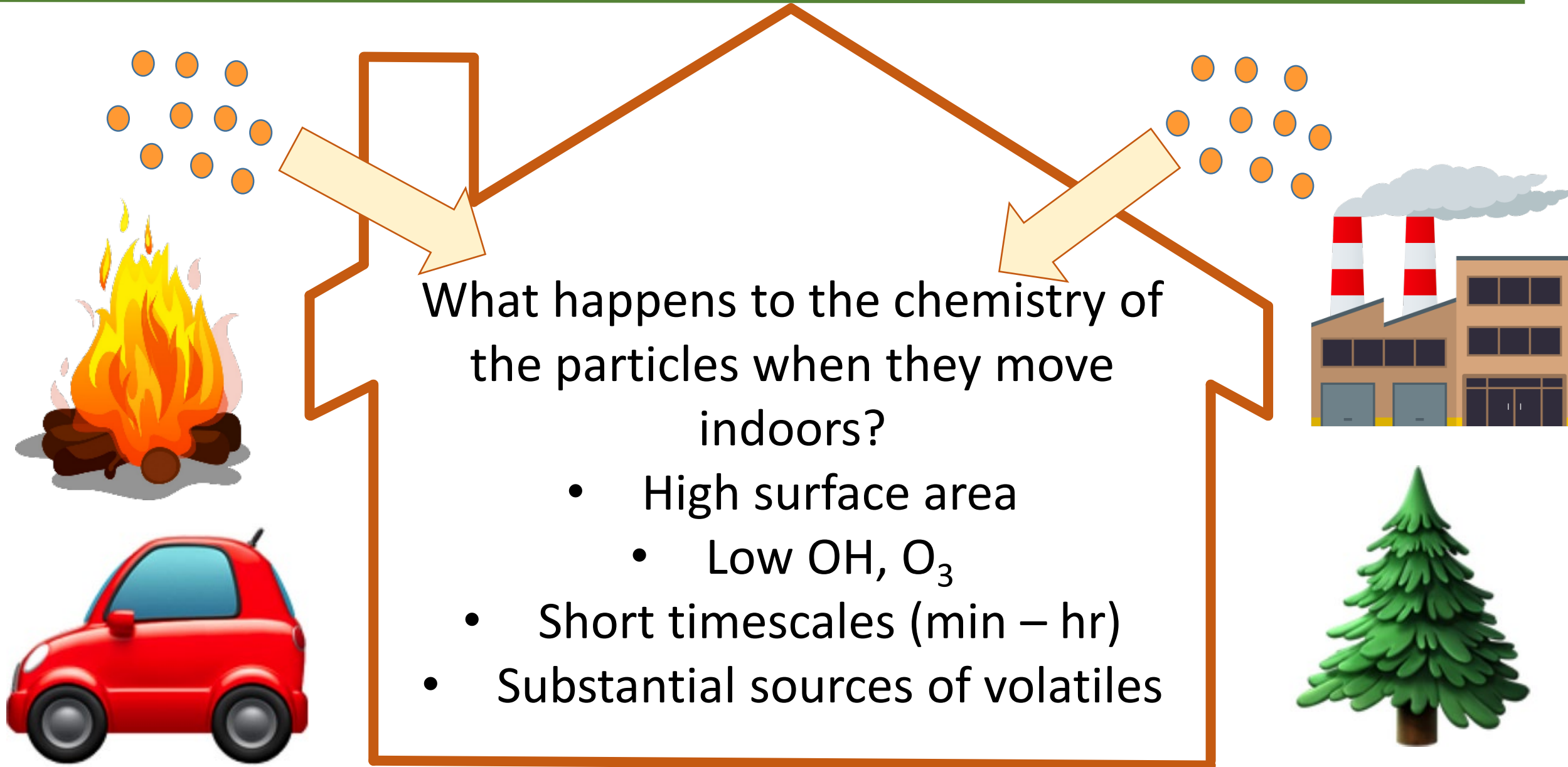


Particle concentration is driven by crustal material, secondary inorganic aerosol and biogenic SOA

Oxidative potential in that aerosol was driven by anthropogenic aerosol (wood burning, vehicle wear)

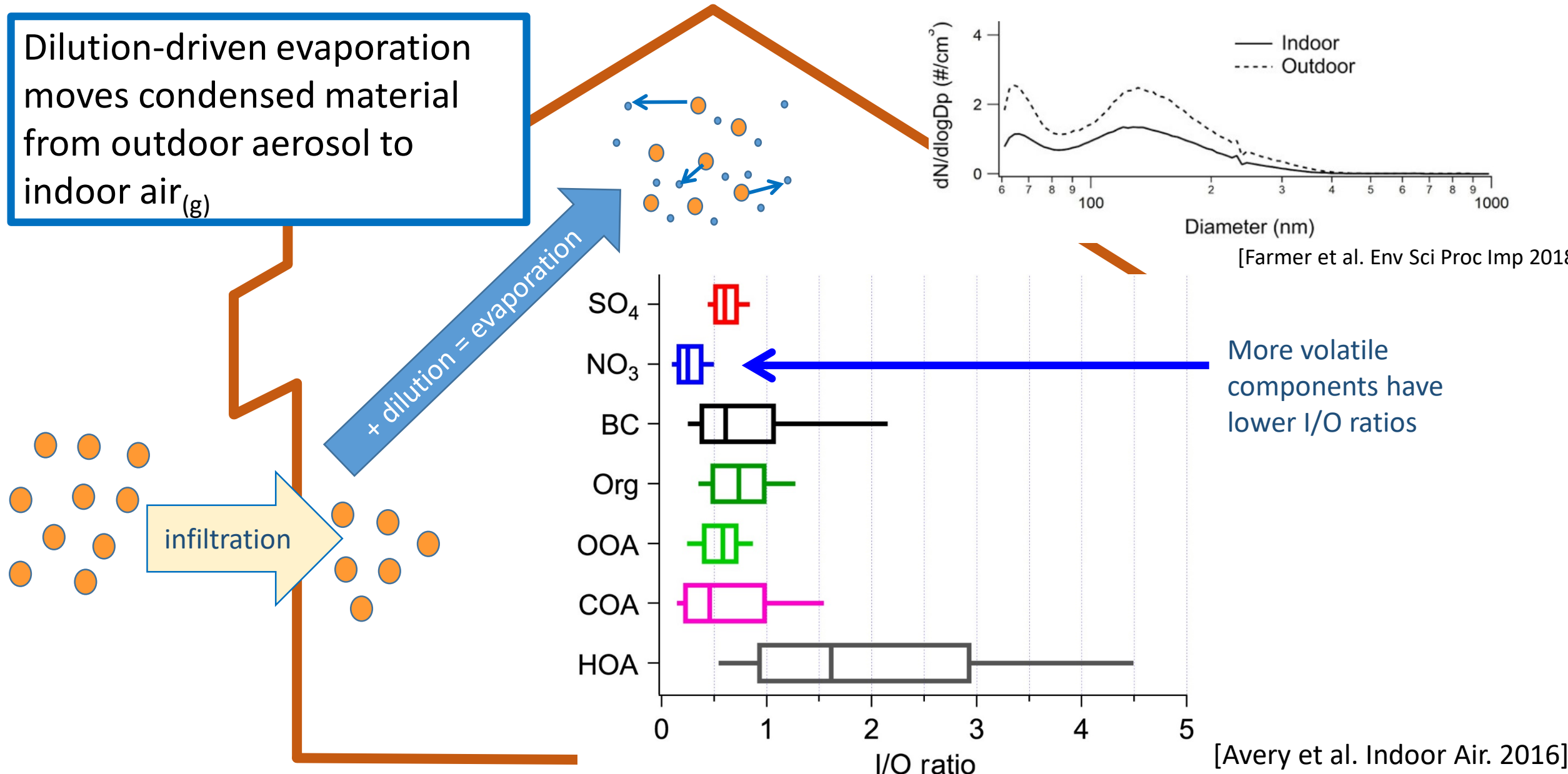
We need to understand more than just aerosol sources – we need their chemistry and link to health effects

But we don't breathe (much) air outdoors...

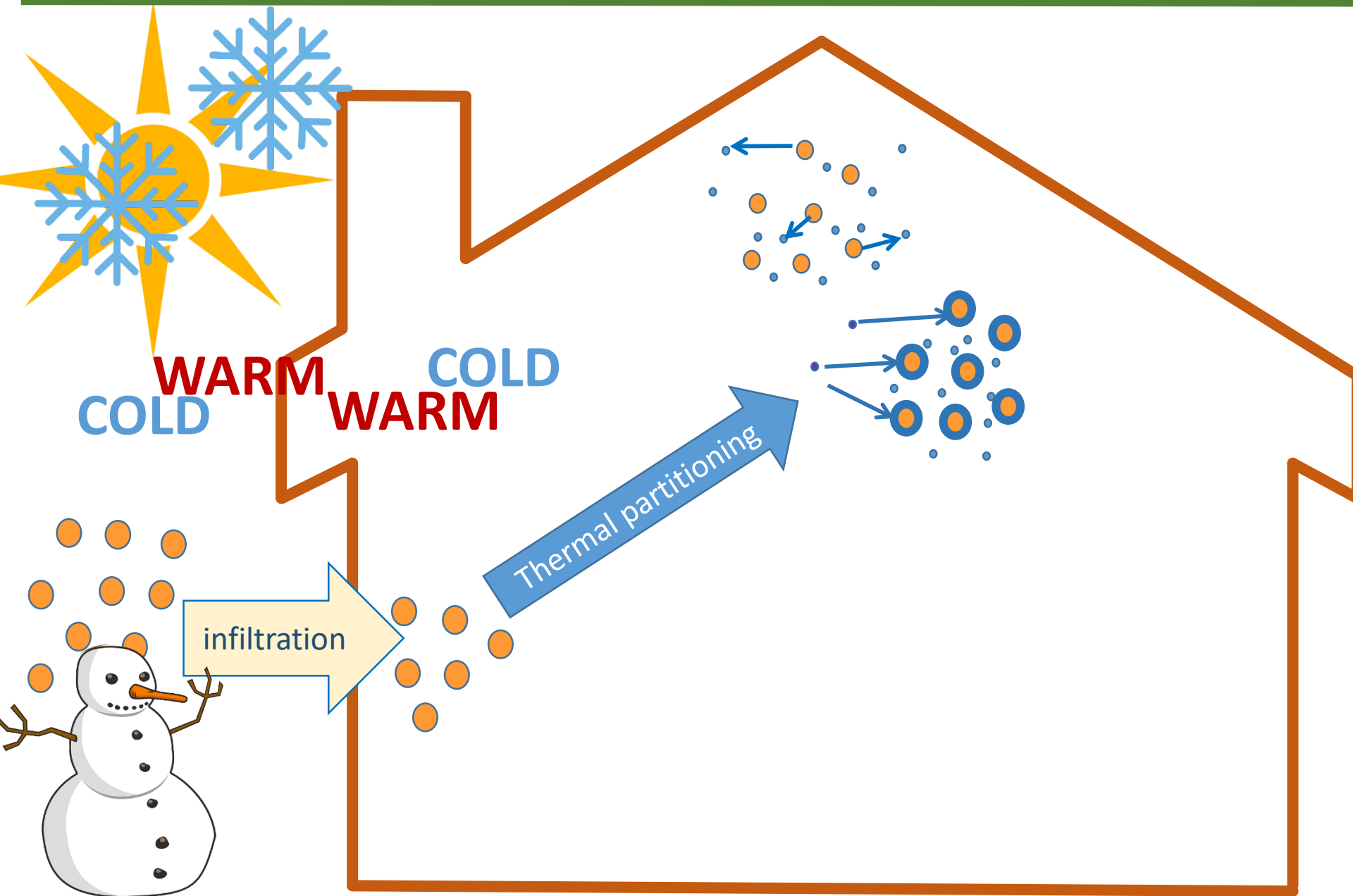


Fate of outdoor PM once indoors: Partitioning & Chemistry

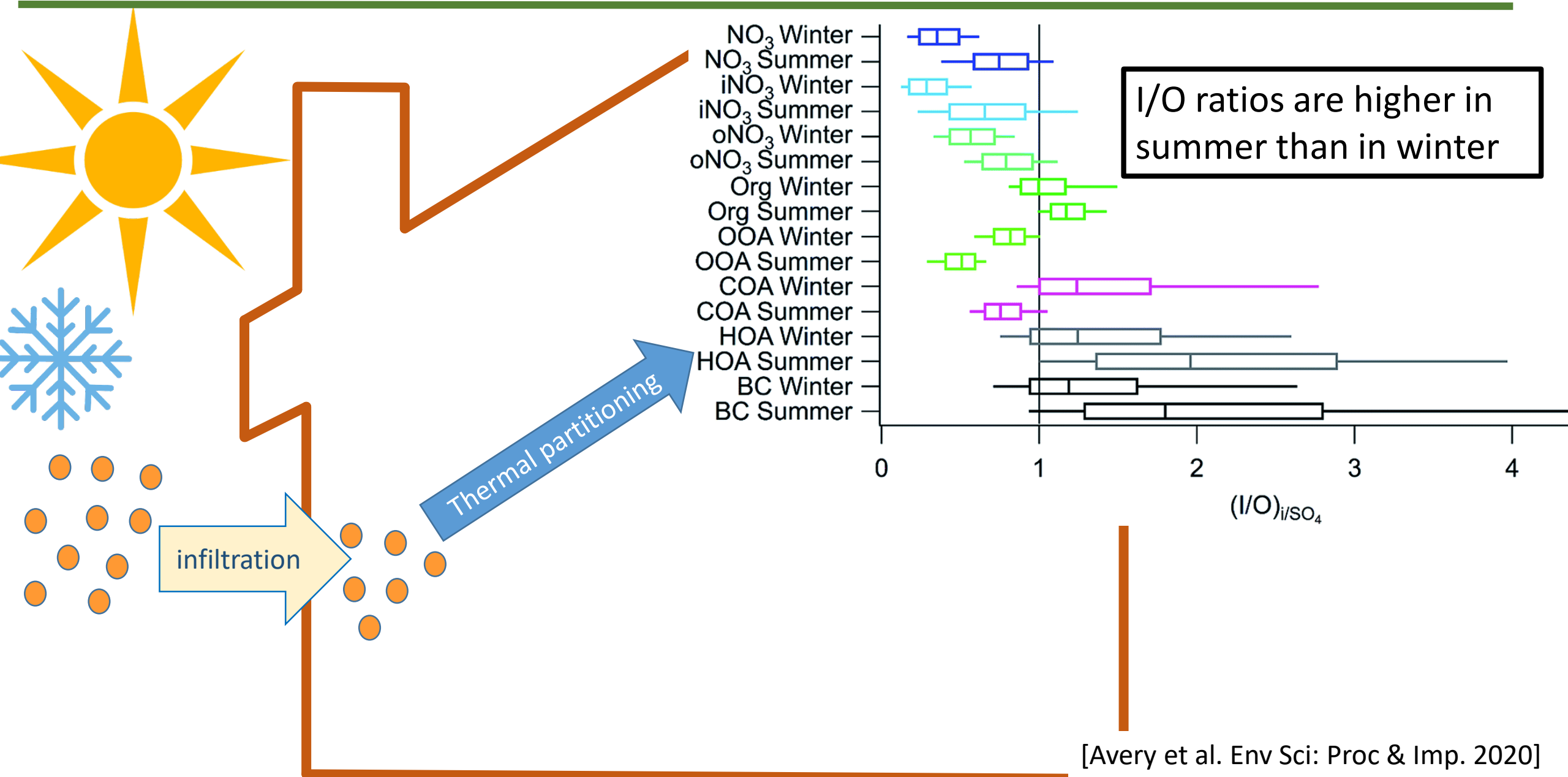
Dilution-driven evaporation moves condensed material from outdoor aerosol to indoor air_(g)



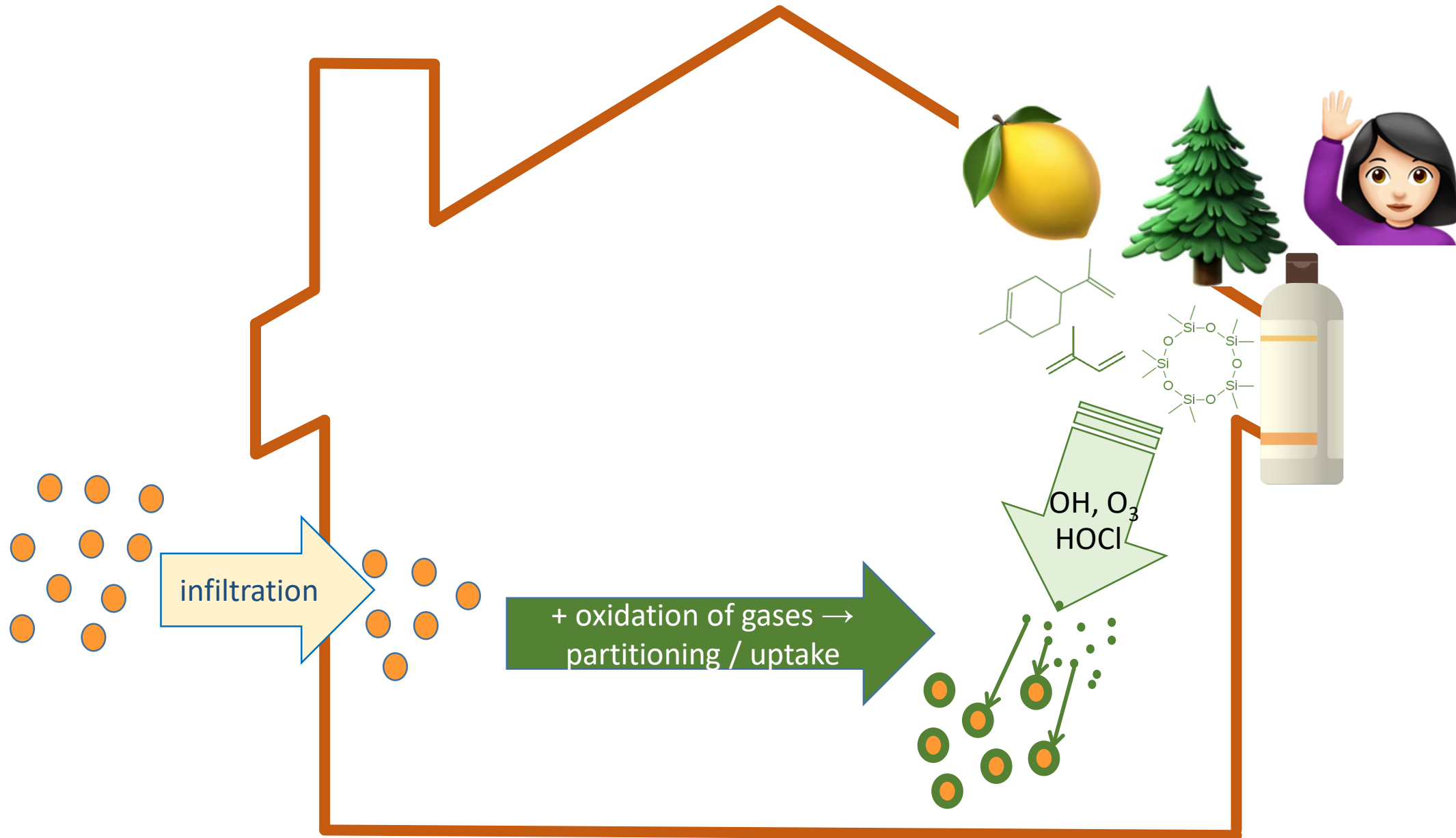
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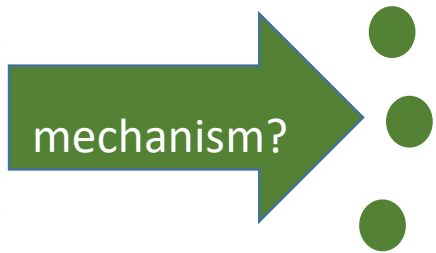
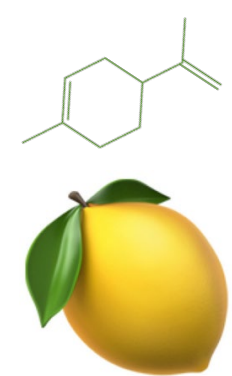


Fate of outdoor PM: Partitioning (Dilution, Temperature) & Chemistry

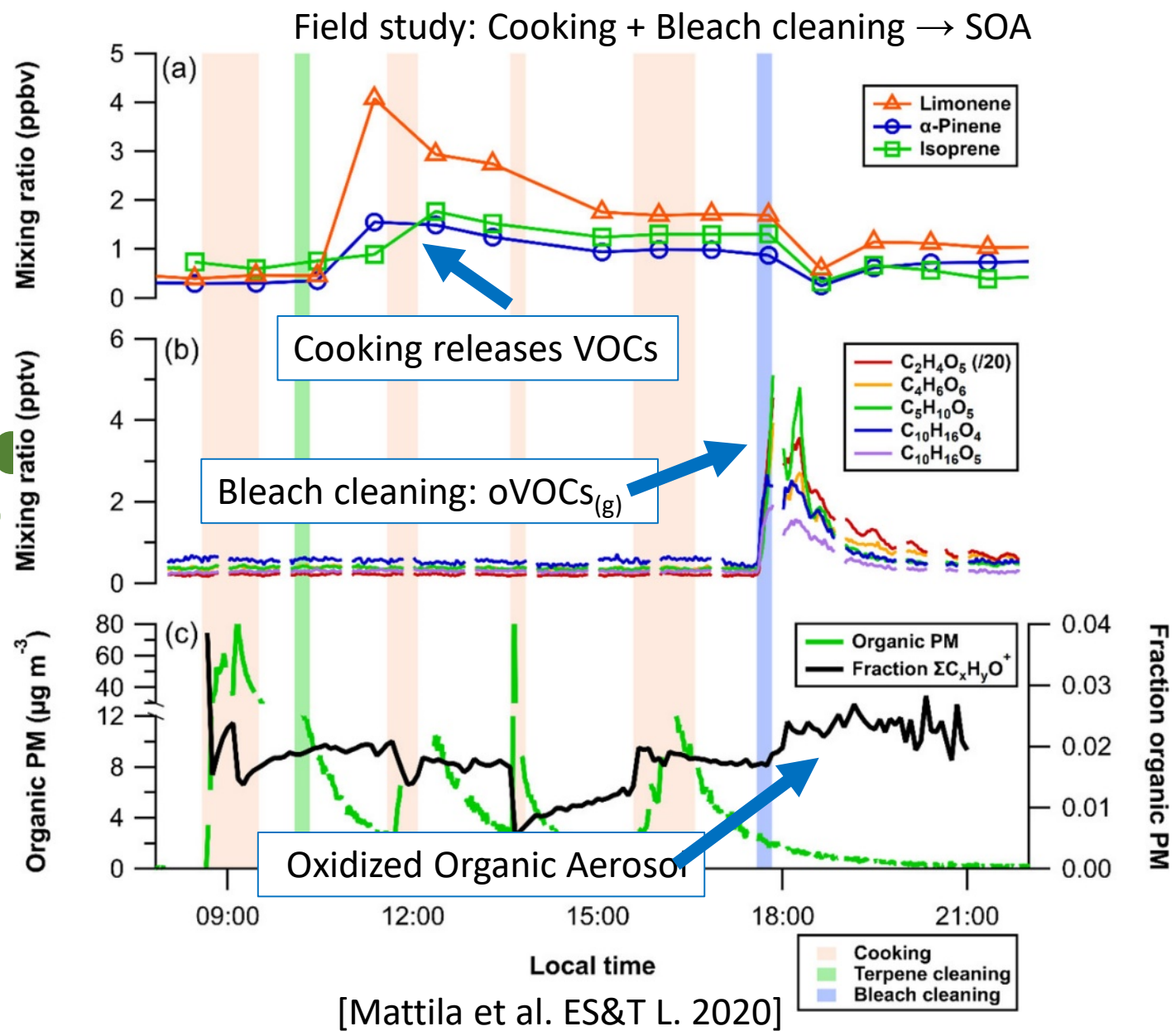


Bleach + VOC chemistry forms indoor secondary organic aerosol

Chamber experiments: HOCl + Limonene → SOA

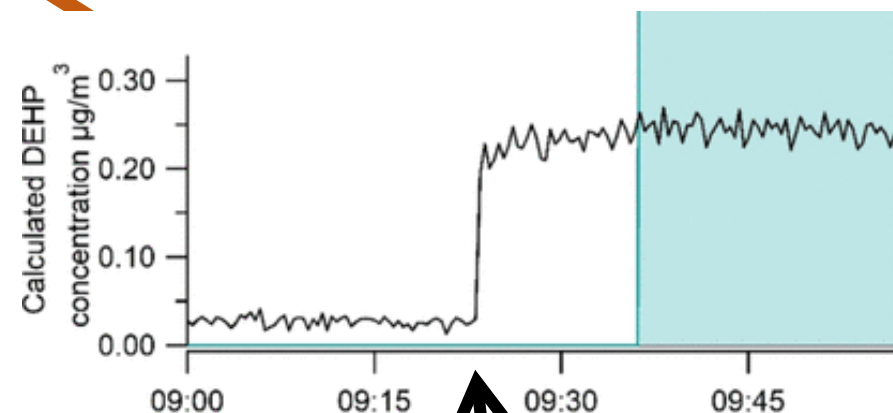


[Wang et al. Env Sci Tech 2019]



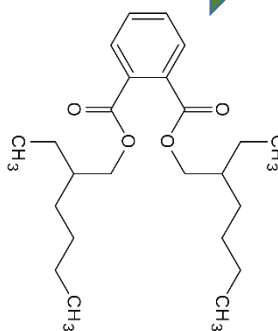
Particle composition influences uptake of air pollutants (phthalates)

- Low volatility phthalate esters from flooring can be taken up on aerosol
- DEHP condenses more efficiently on 'fresh' organic aerosol than oxidized organic aerosol or sulfate



infiltration

+ oxidation of gases $\rightarrow$
partitioning / uptake



Particle composition influences uptake of third hand smoke

- Composition-dependent uptake also seen in third hand smoke studies
- Reduced nitrogen species from cigarette smoke can undergo surface reactions (months) → semi-volatiles → indoor air particles



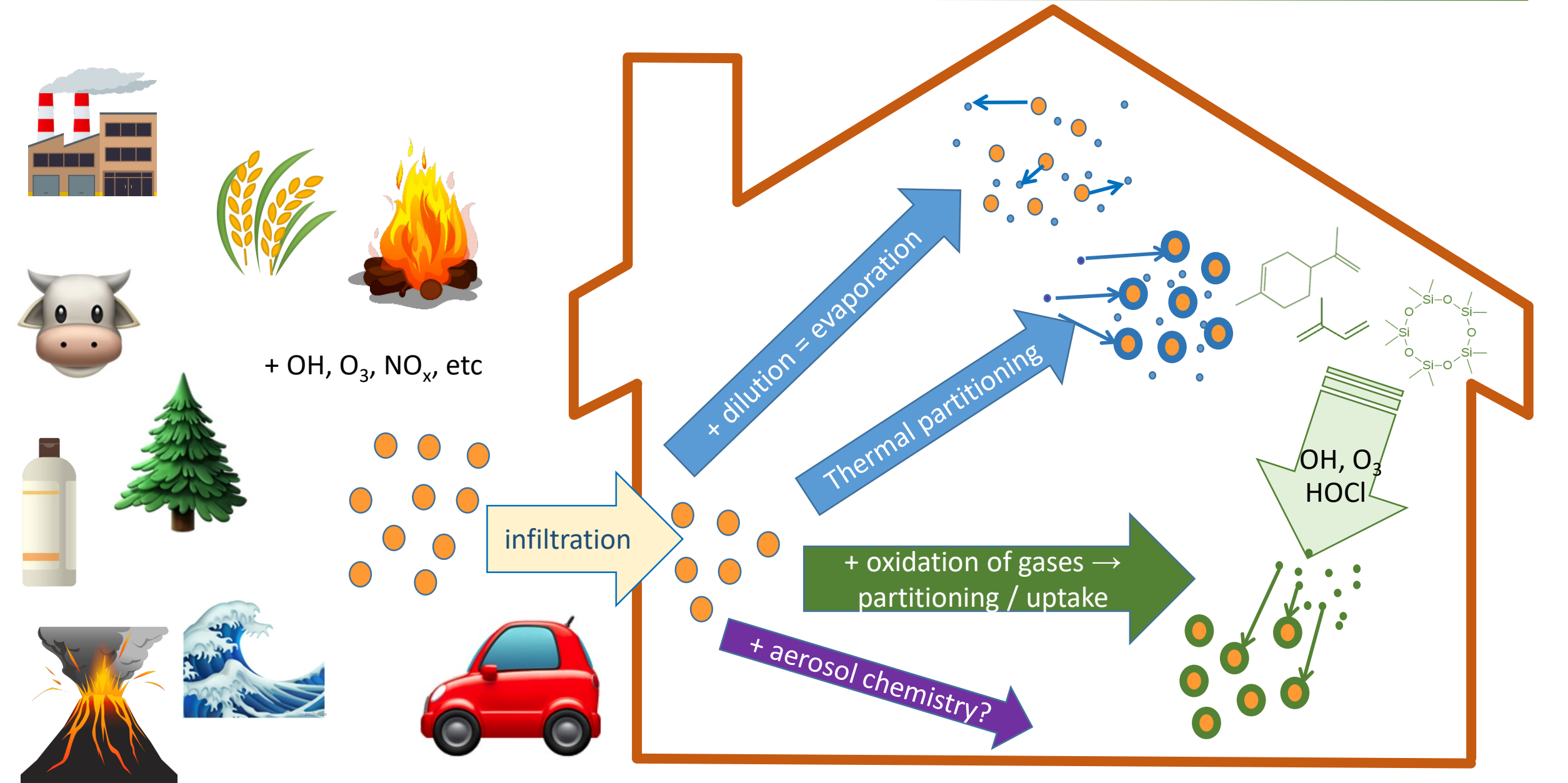
infiltration

+ oxidation of gases →
partitioning / uptake

[Collins et al. Env Sci Tech. 2018]

[DeCarlo et al. Science Advances 2018]

Fate of outdoor PM: Partitioning (Dilution, Temperature) & Chemistry



Summary

- Sources of outdoor PM are spatially and temporally variable
- Predicting outdoor (and thus indoor) PM requires *emission, chemistry, and deposition rates*
- Indoors, PM undergoes *equilibrium partitioning* (dilution, temperature) and *chemical reactions*

Open Questions & Ongoing Needs

- What is the indoor budget of condensable material (*concentration, reactivity, and volatility*)?
- Which multiphase reactions compete with ventilation & deposition (timescales)?
- How does particle composition & phase impact indoor PM chemistry?

Conclusions

- There is broad scientific consensus that outdoor PM_{2.5} influences indoor PM_{2.5} – reducing outdoor sources improves indoor air quality
- Once indoors, aerosols have many chemical fates – but on far shorter timescales than outdoor air – the resulting chemical composition may influence health effects