

Carbon Emissions from Stationary Sources

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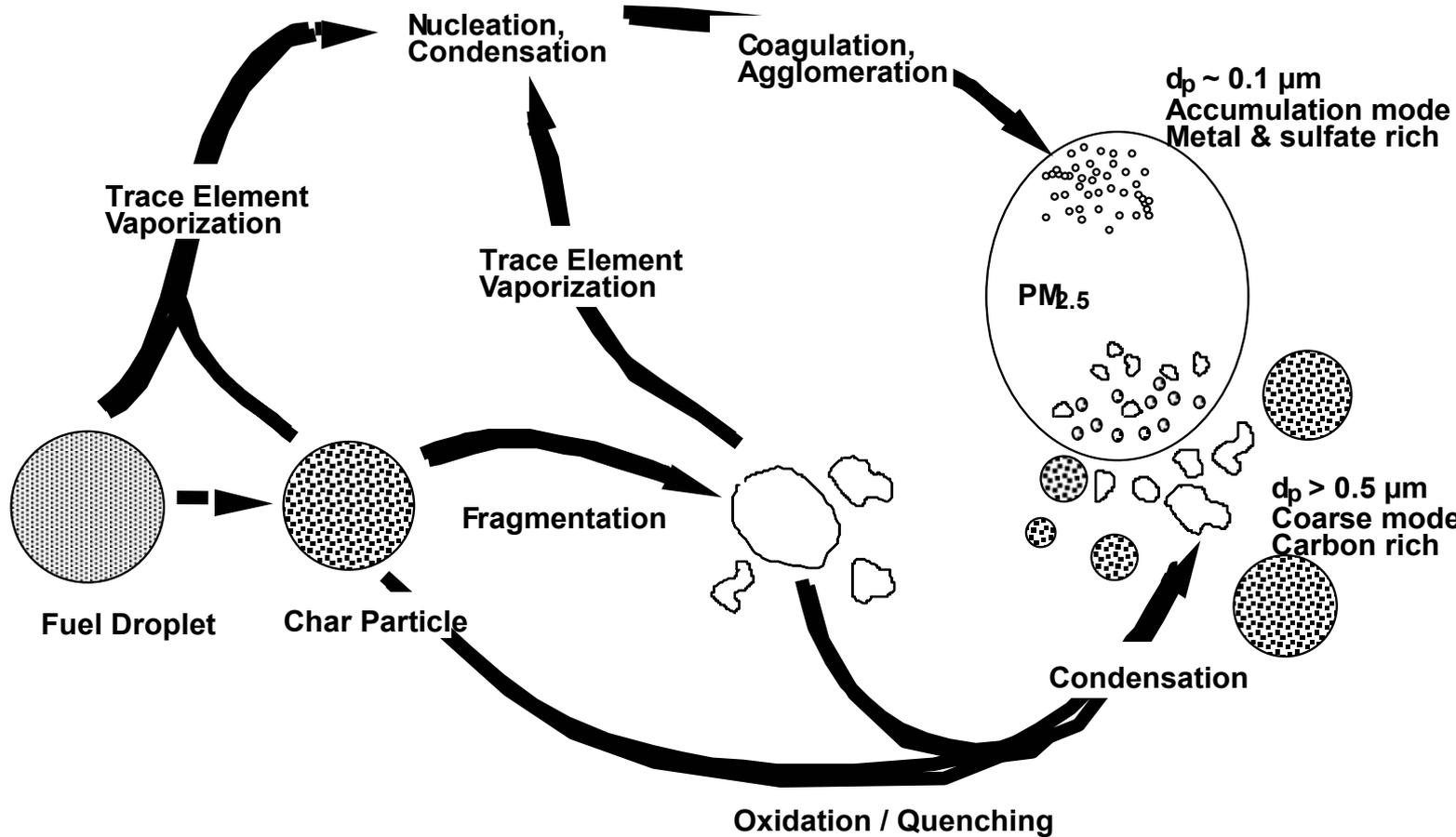
EMA Black Carbon Workshop

October 13-15, 2004, San Diego

Overview

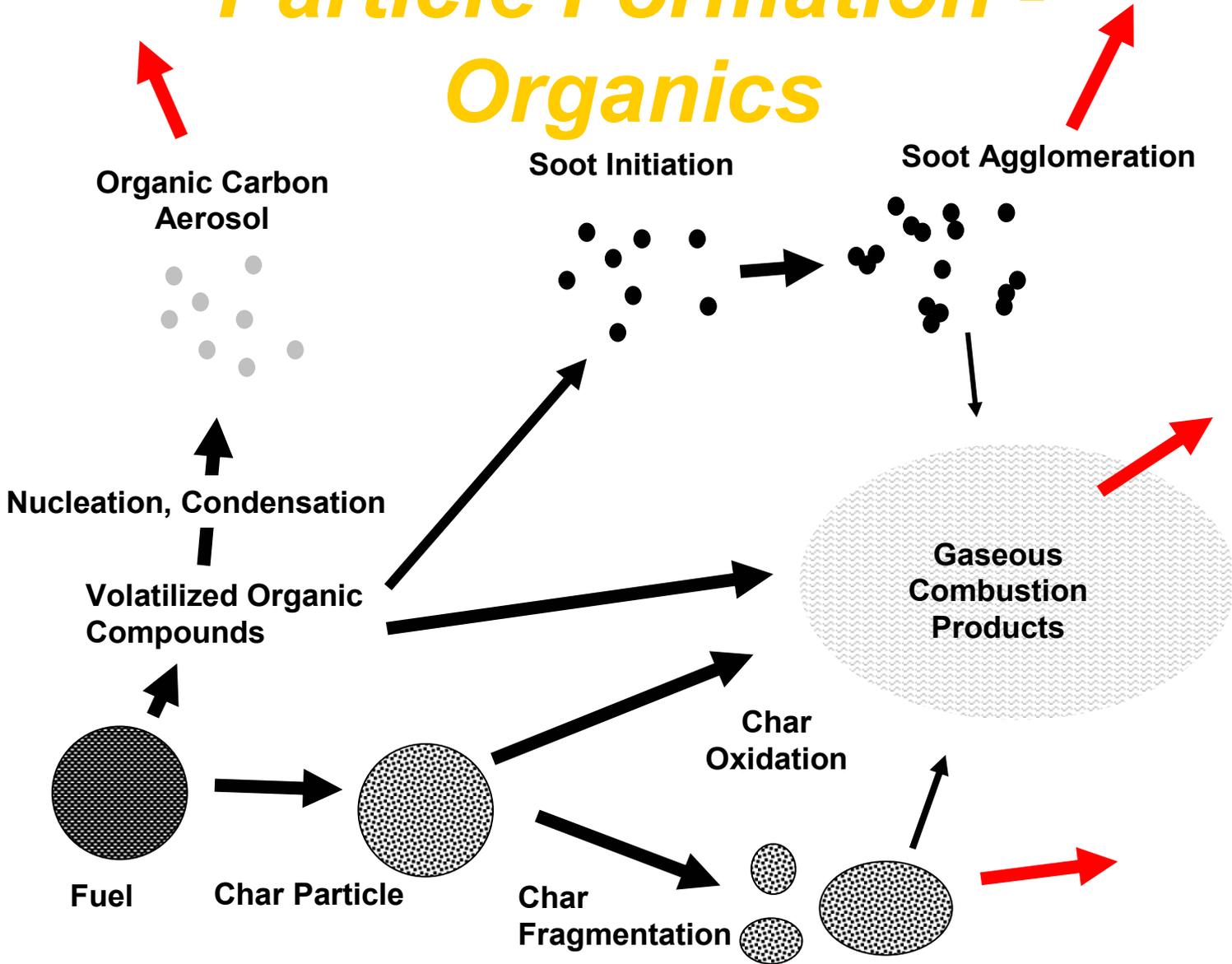
- Look at carbon from a combustion perspective
- Formation mechanisms and composition
 - Influence of system operation and design
- Emissions
- Conclusions

Particle Formation - Inorganics

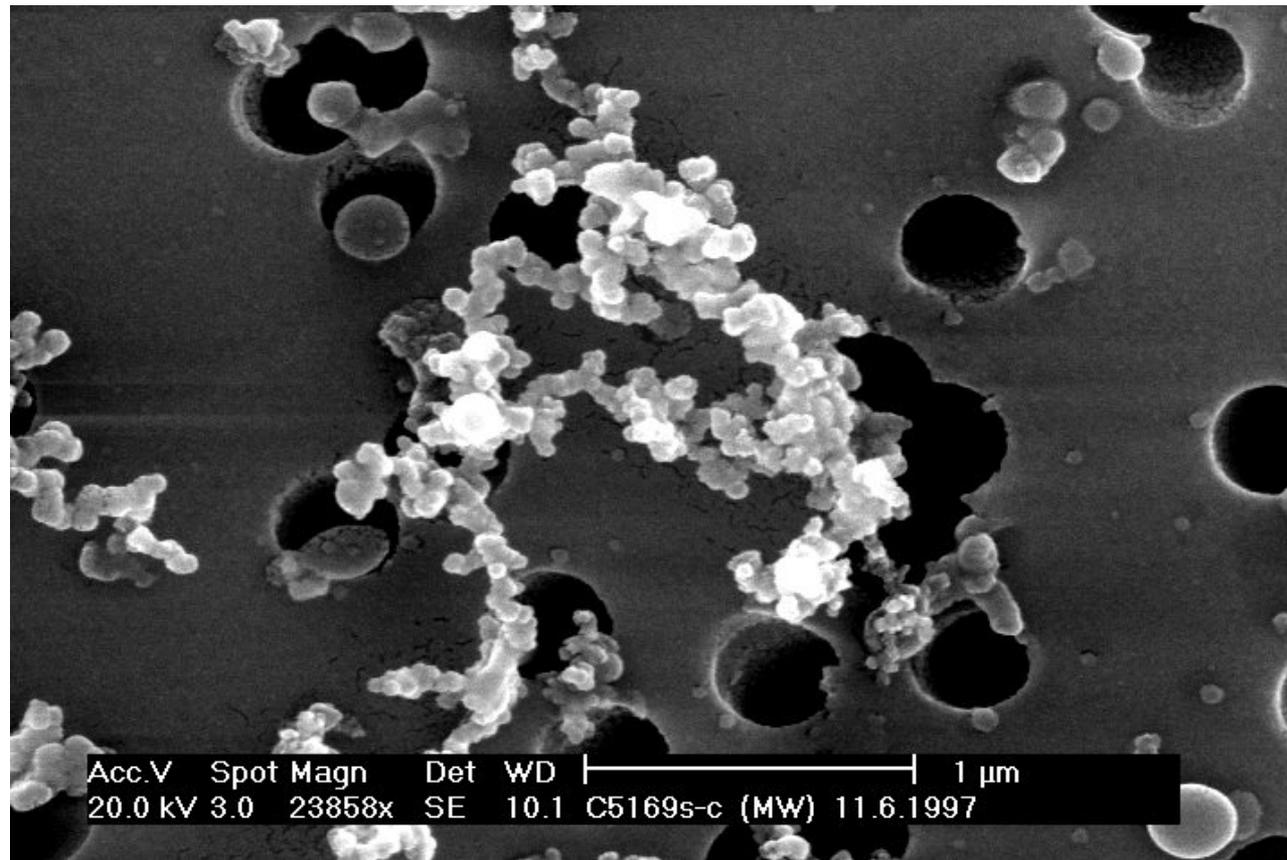


Building a scientific foundation for sound environmental decisions

Particle Formation - Organics

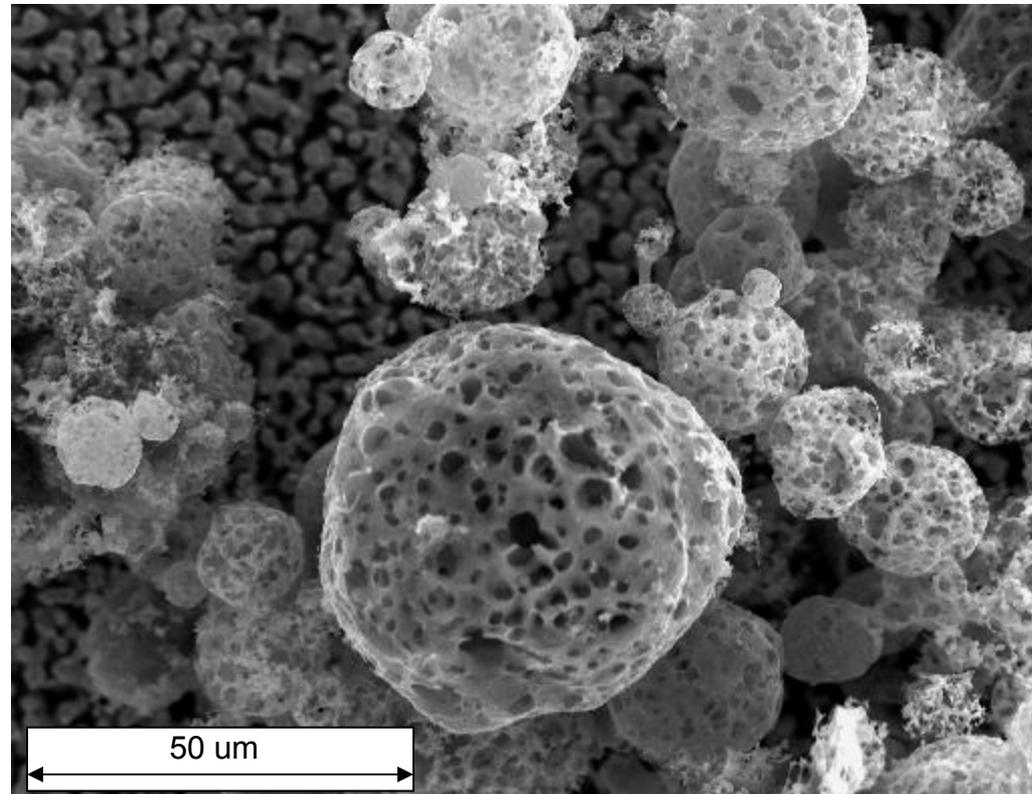


SEM Image of Soot



Soot forms from gas-phase aromatic
compounds

Char from Heavy Oil Combustion



Formed by pyrolysis and devolatilization processes – on the order of spray sizes

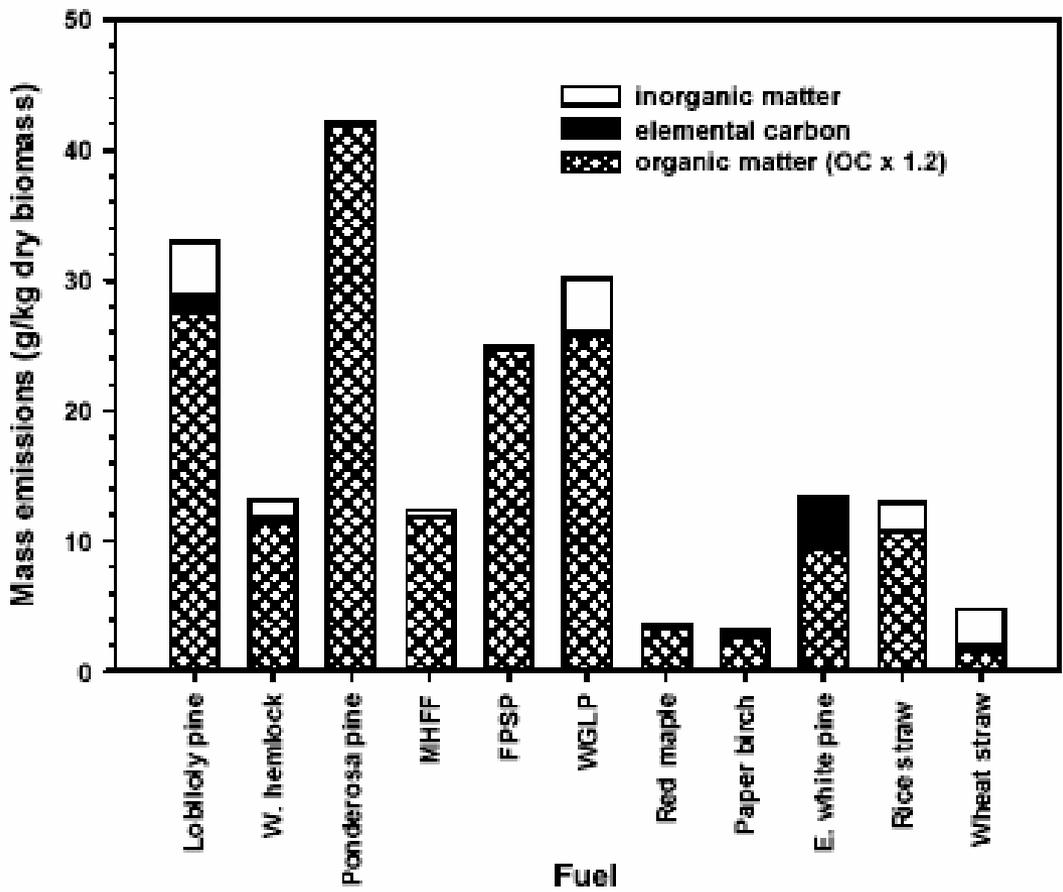
Different Forms of Carbon

- Soot \neq unburned carbon \neq char
- It is all elemental carbon (EC) - but is it all black carbon (BC)?
- EC can have different chemical and physical characteristics, dependent on formation processes
 - Characteristics vary with size

Industrial Coal Combustion

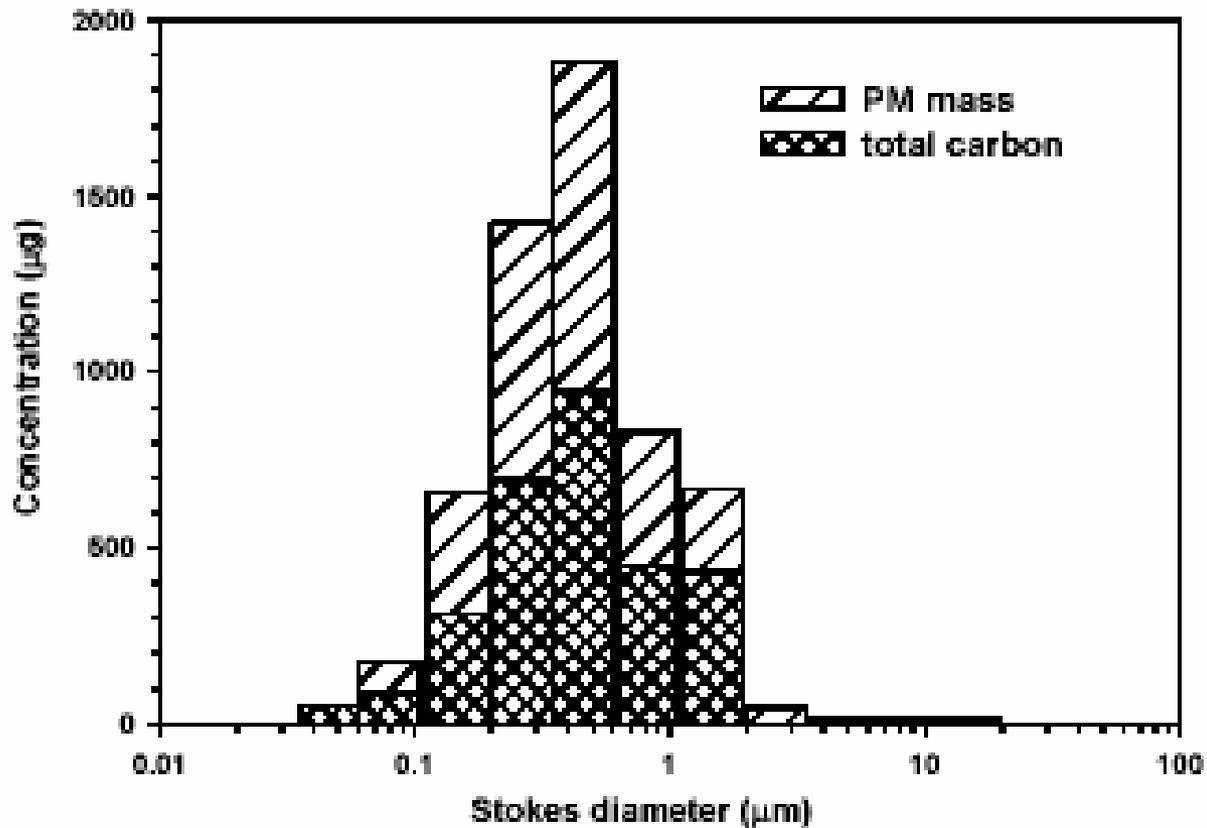
- Coal analogous to oil – ultrafines formed from vapor-phase processes
 - Largely sulfates, metals
 - Ultrafines may have significant carbon content, but make up relatively small mass
- Most carbon in coarse fraction
 - Usually associated with mineral matter
- Not likely to have long atmospheric residence time

EC from Open Biomass Burning



Composition of PM from open burning of different biomass types (Hays et al. submitted)

Size of PM from Biomass Open Burning



Size distributions of PM_{2.5} mass and total carbon rice straw.

Soot Formation

- Most soot formed in “cool” flames
 - Characteristic of low-intensity flames
 - Open biomass and coal fires in this category
- May still have substantial unburned carbon (UBC) in char; entrainment into atmosphere more difficult
- Heavy soot in tire fires, other highly polymerized materials

Particle Size is Important

- Coarse particles will have significantly shorter atmospheric residence times than submicron particles
- Need to consider both size and composition in analyses
- This info is not always available in inventories

U.S. Black Carbon Inventory – Stationary Sources

Source	Battye and Boyer (2002)	Bond et al. (2004)
Transportation	246	231
Open Burning	116	61
Residential Combustion	22	79
UIC ^(a) Combustion	14	61 ^(b)
Incineration, Industrial Processes	9	9
Fugitive Dust	24	n/a
Livestock	5	n/a

(a) Utility, Industrial, Commercial

(b) Differences in categorization of diesel nonroad equipment

Which is More Accurate?

- The approach of Bond et al. accounts for differences in combustion processes
- Significant uncertainties remain in activity and emission factors for many sources
 - “Diffuse” sources have greatest uncertainties, hardest to quantify

Future Outlook

- Control approaches will be required for PM nonattainment in US
 - Not likely to make significant changes to utility, industrial sources of primary PM
 - Some reductions possible for open burning
- Globally, emissions increasing, but source-specific changes uncertain
 - Industrial vs. “diffuse” - ??

Bottom Line

- Quantifying activities and emission rates drive uncertainties
 - Measurements are much more accurate than EFs/AFs, especially for “diffuse” sources
 - When, where can be highly uncertain
- Some uncertainties in measurement of nanoparticles
- Differences in radiative properties by size are not well documented

Conclusions

- Bond et al. estimates probably closer to actual
 - Still dependent upon existing and uncertain activity and emission factors, EC fraction
 - Open burning still a significant source
 - Relatively small contribution from industrial sources
- Particle formation & size are important in understanding emissions