What is Black Carbon and Where Does It Come From?

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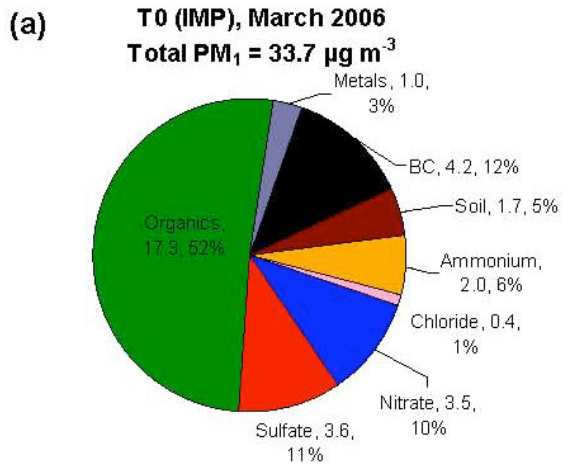
Take-home messages

Black carbon is very distinct from other particles.

Major sources of black carbon are known; magnitudes are uncertain but bounded.

For a continental picture, valuable emission inventories for metropolitan areas must be combined with country-wide emission estimates.

Black carbon versus particulate matter

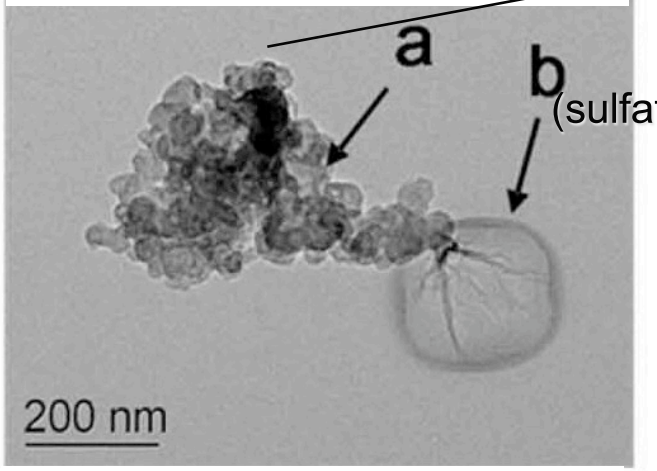


Mass in Mexico City (Aiken *et al.*, Atmos. Chem. Phys. 9, 6633, 2009

1 mm

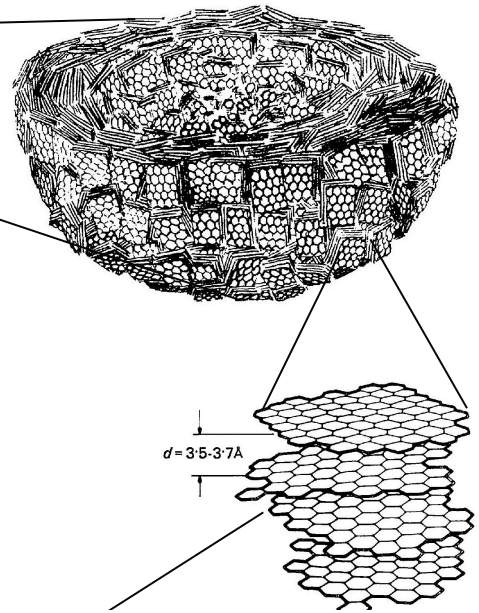
If you had nanovision, and a very small knife, you would see this…

TEM image, BC mixed with sulfate (Mexico City)



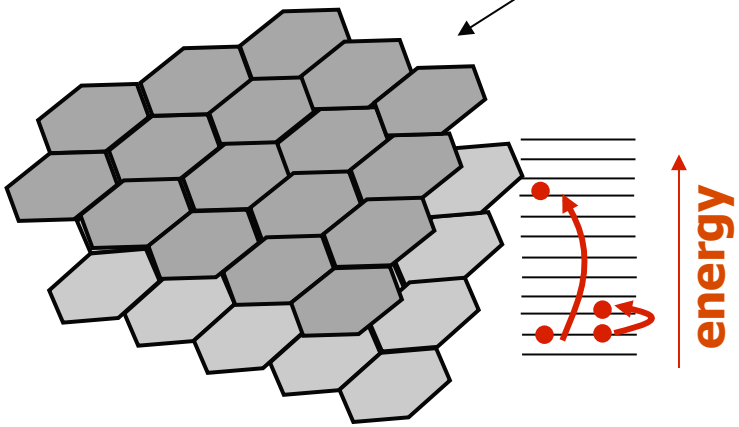
Johnson *et al.*, *Atmos Chem Phys* **3**, 3033-3043, 2005

one component "spherule"

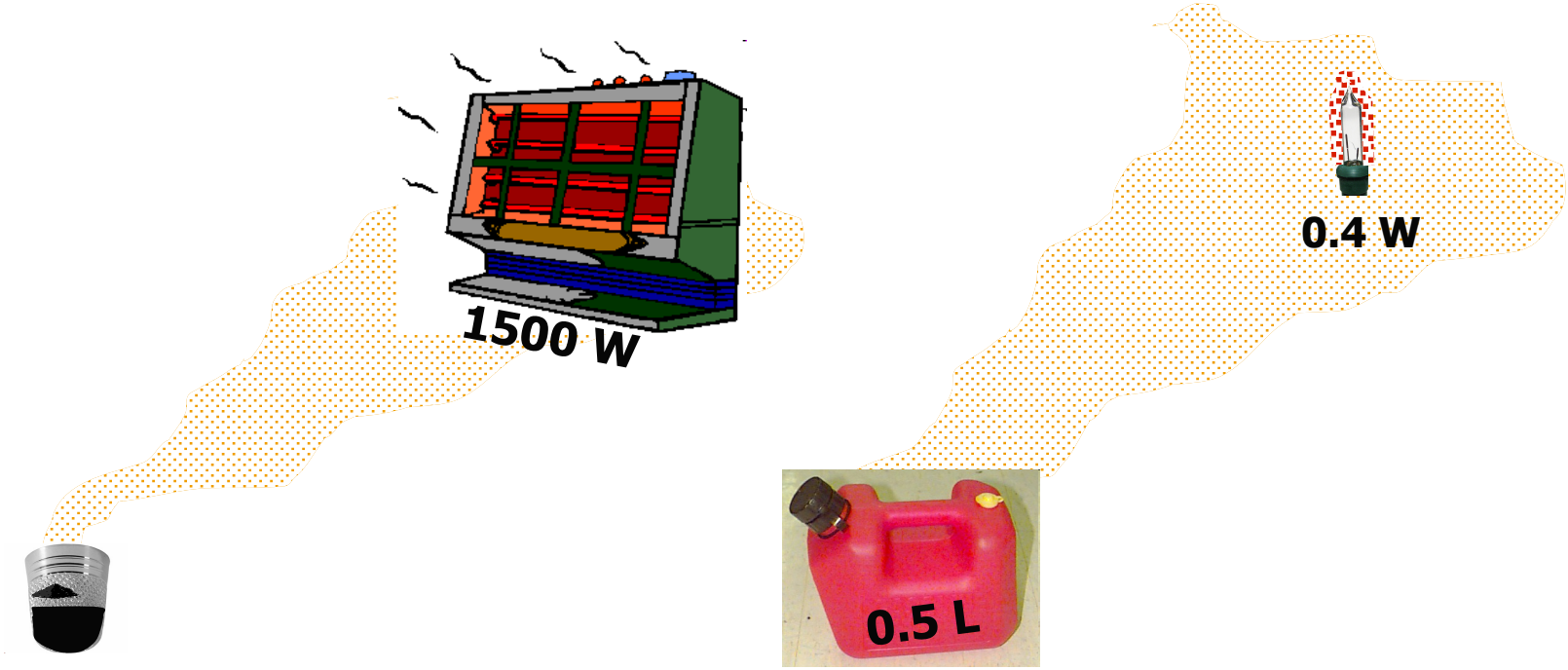


Heidenreich *et* al., *J. Appl. Crystallography* **1,** 1-19, 1968

Many closely spaced energy levels = absorbs at many wavelengths.

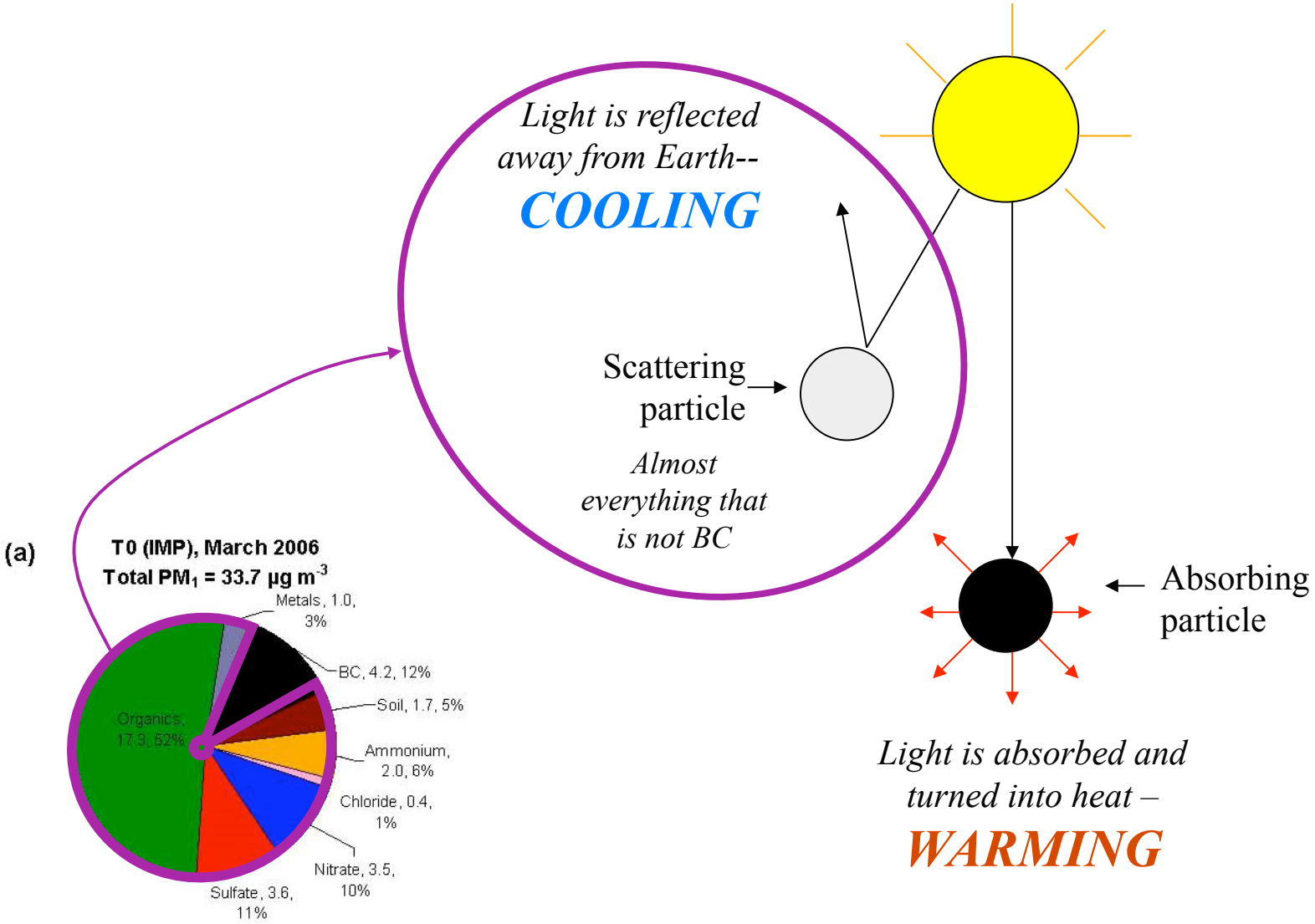


Strong absorption of BC causes powerful, immediate warming.



1 gram BC emitted =
small heater in atmosphere for 1 week
1 kg CO_2 emitted =
1 Christmas bulb for 100 years

Other particles act as mirrors, reflecting light.



How is black carbon created?

Solo fuego!

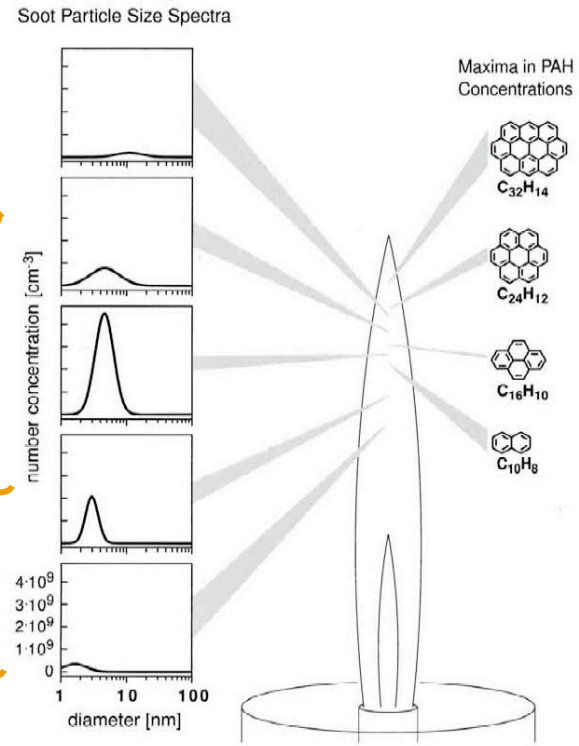
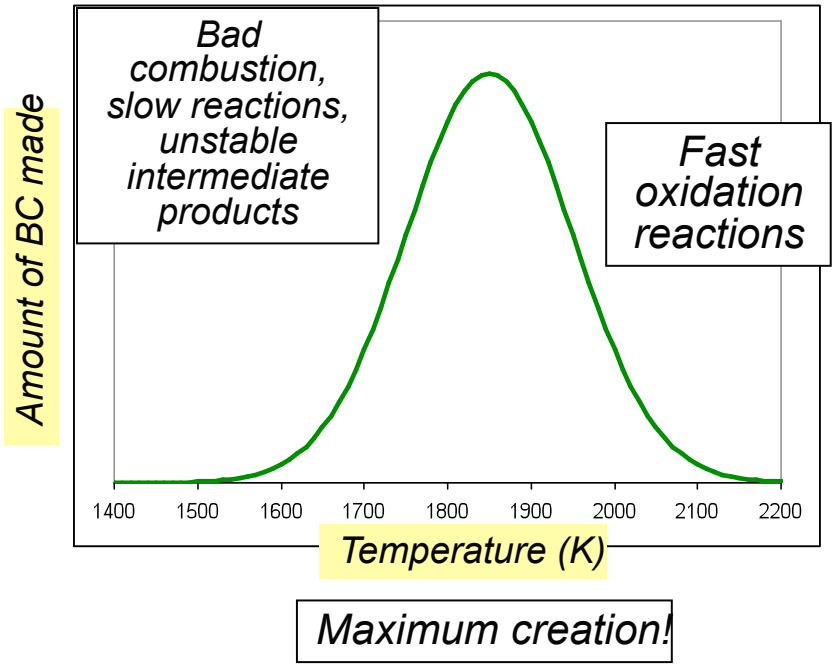


Fig. 2. A representation of the methane flame with PAH-maxima and soot particle size distributions, assigned to the respective height in the flame.

K. Siegmann, K. Sattler, and H. C. Siegmann, J. Electron Spectrosc. Rel. Phenom. 126, 191-202, 2002

We know how to make BC and remove it

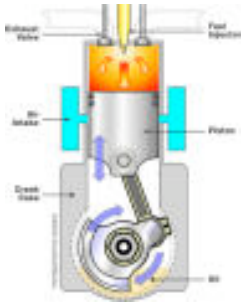


3 T's: "Time, Temperature, Turbulence"

- Mix oxygen with exhaust
- Reactions faster with heat
- Give time to react

Good candidates for producing black carbon

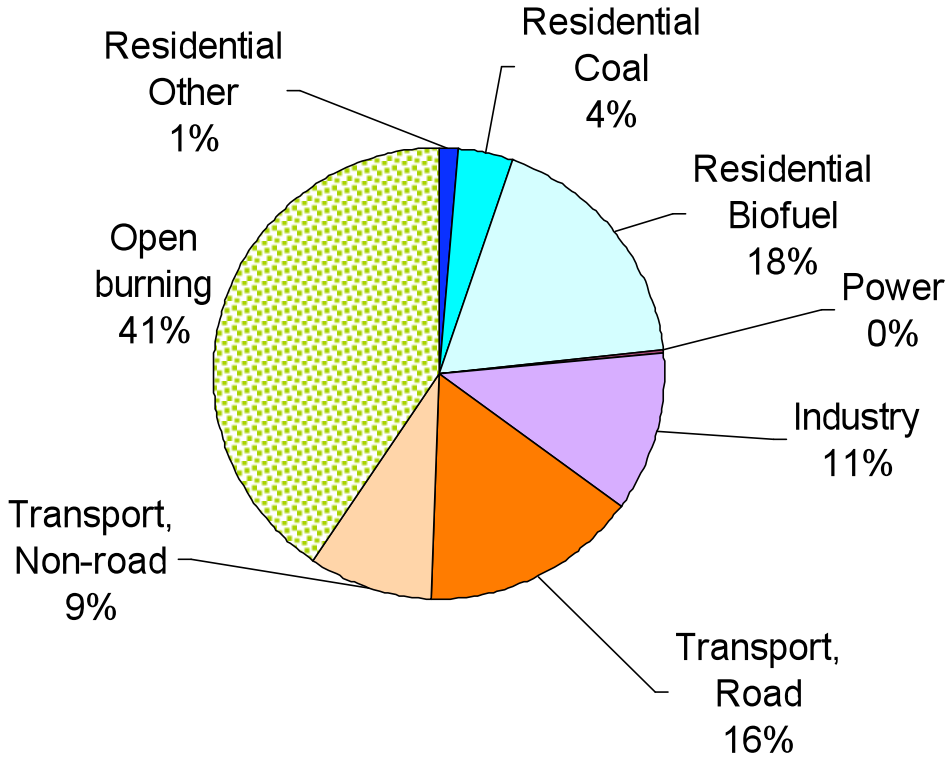
1. Burn while mixing fuel and air
   - Pockets of fuel without enough air

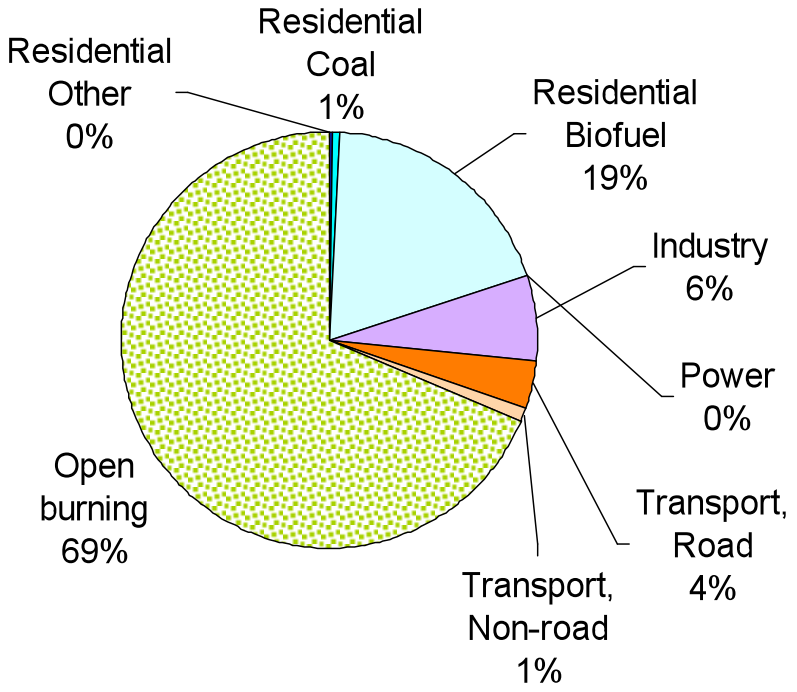


2. Cool exhaust quickly after flame
   - No "burnout" of BC (or OC)

Now we are ready to find the emission sources.

Global sources of black & organic carbon





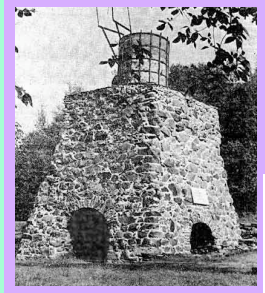
Black carbon

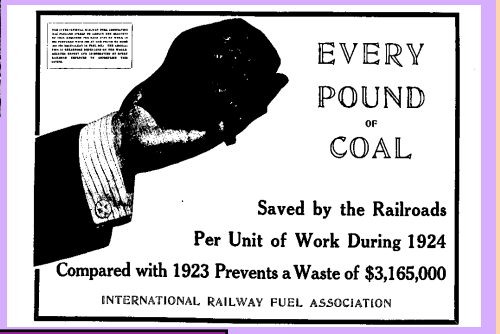
Organic carbon

Year 2000 estimates (Bond et al., GBC 2007 + van der Werf, 2006 + updates for IPCC AR5)

Major energy-related sources change with development & increased income

development → & increasing → quality of life





Residential

Because you have to eat and stay warm…

Industry

Because you want jobs…

Transport

Because you want to buy things & go places!

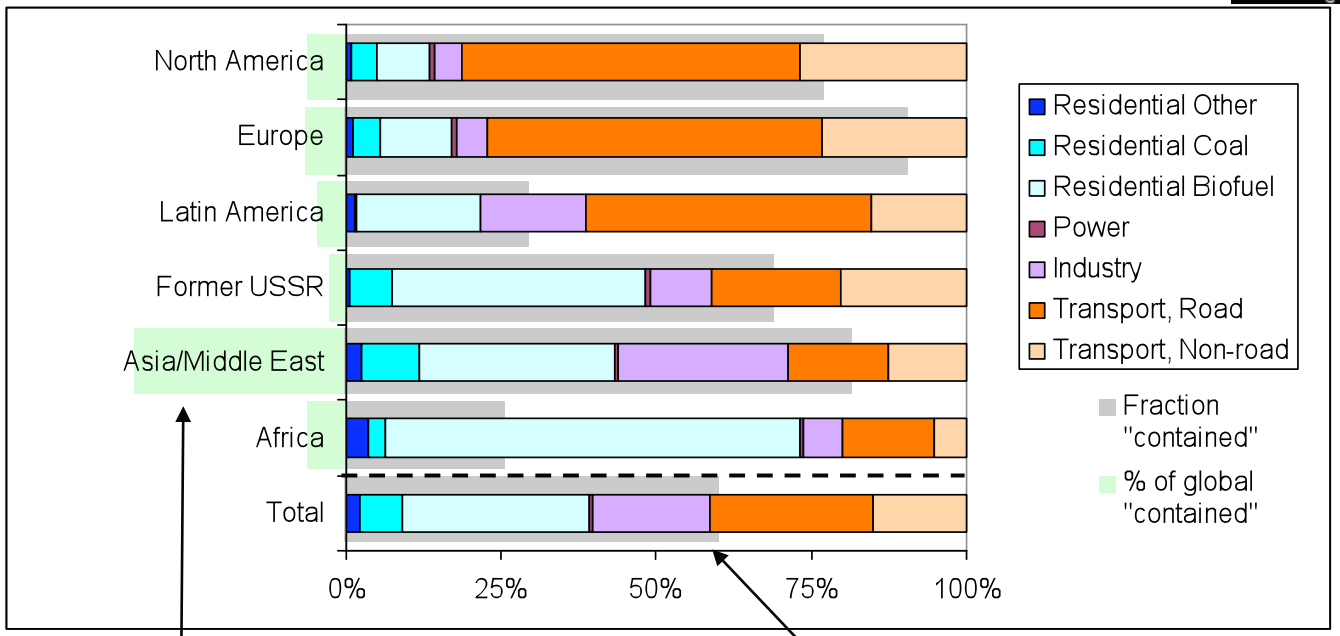
clean, convenient fuels ← efficiency, air quality →

Source mix differs by region

Residential → **Industry** → **Transport**

d e v e l o p m e n t

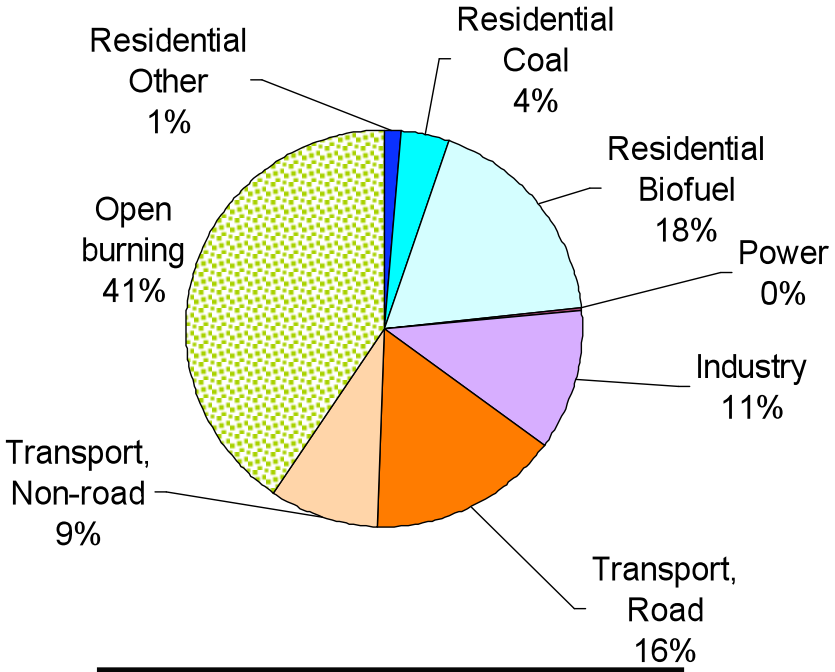
Colored bars indicate relative contribution to global total.



Green bars indicate relative contribution to global total.

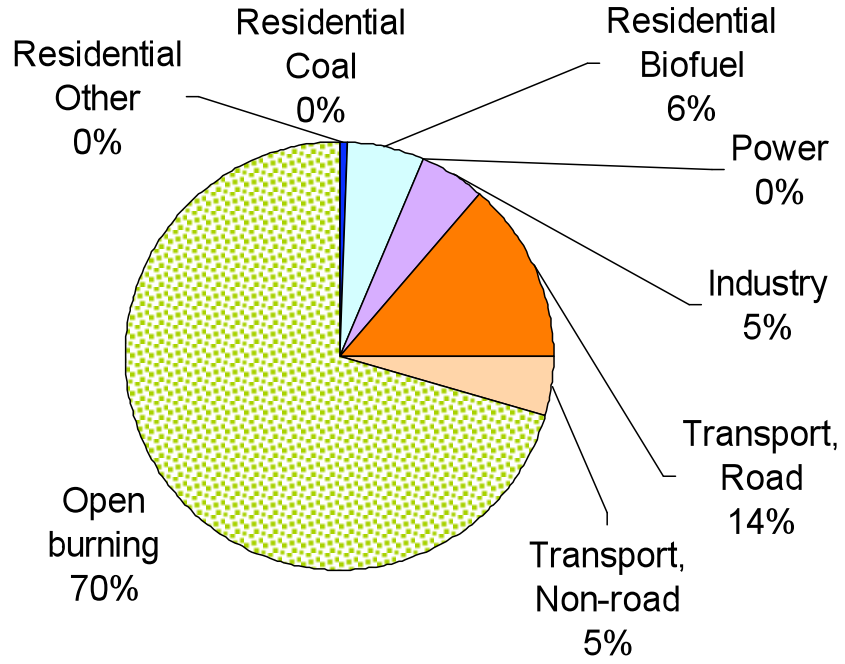
Gray bars show how much comes from energy-related combustion.

Global vs Latin America profile



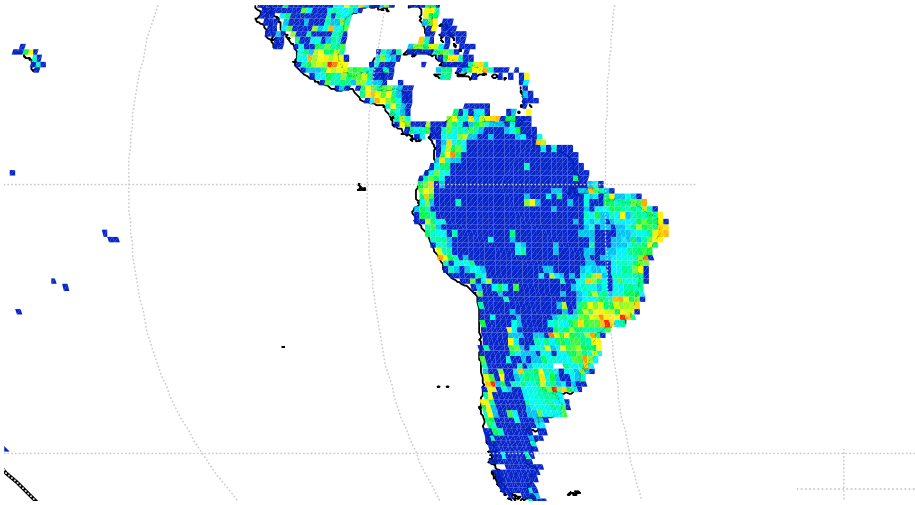
Global BC: 8000 Gg/yr

More open burning
Transport is greater fraction of energy-related

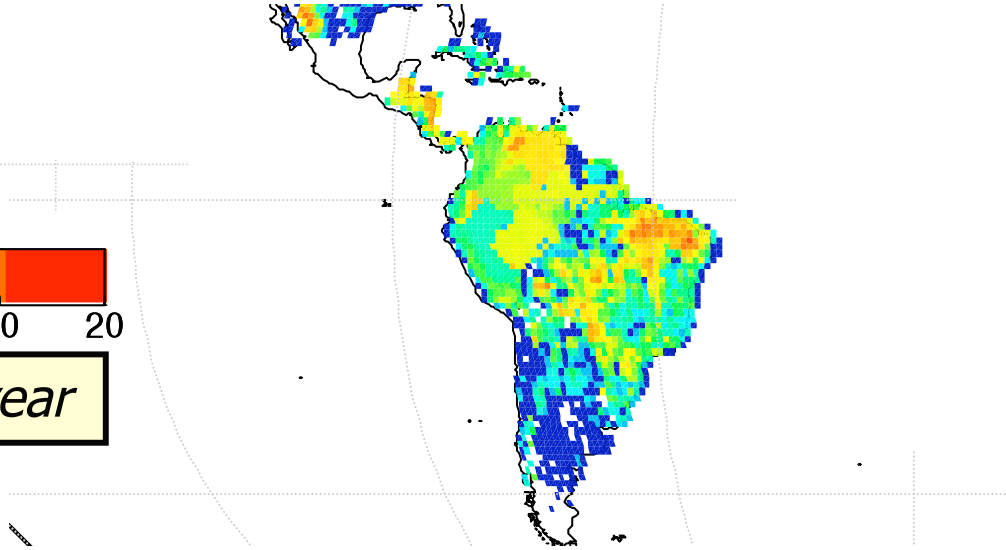


Latin America BC: 1300 Gg/yr

Distribution of emissions



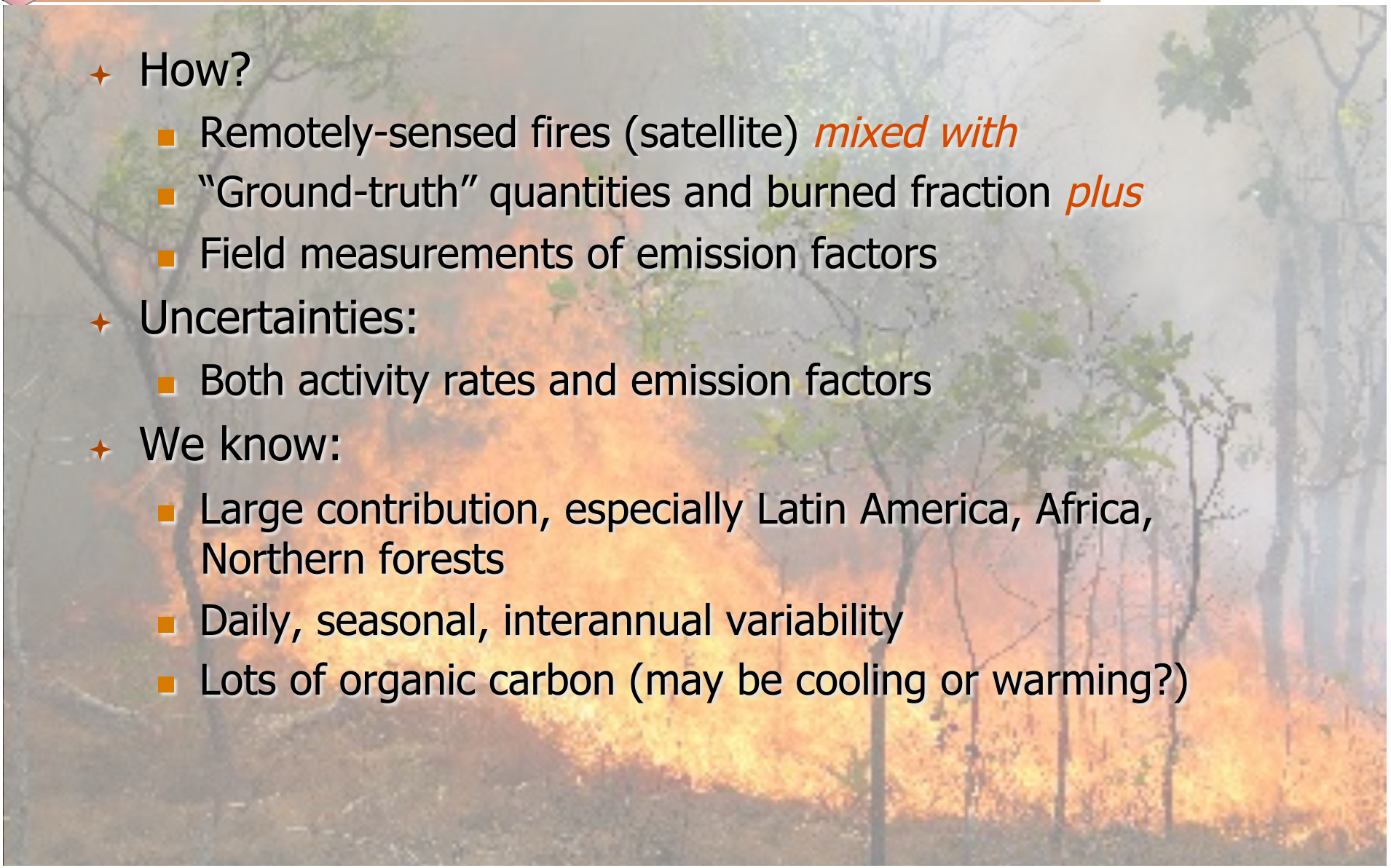
Energy-related: 360 Gg/year



Open burning: 880 Gg/year

units: kg/m2/sec

Emission estimates for open burning

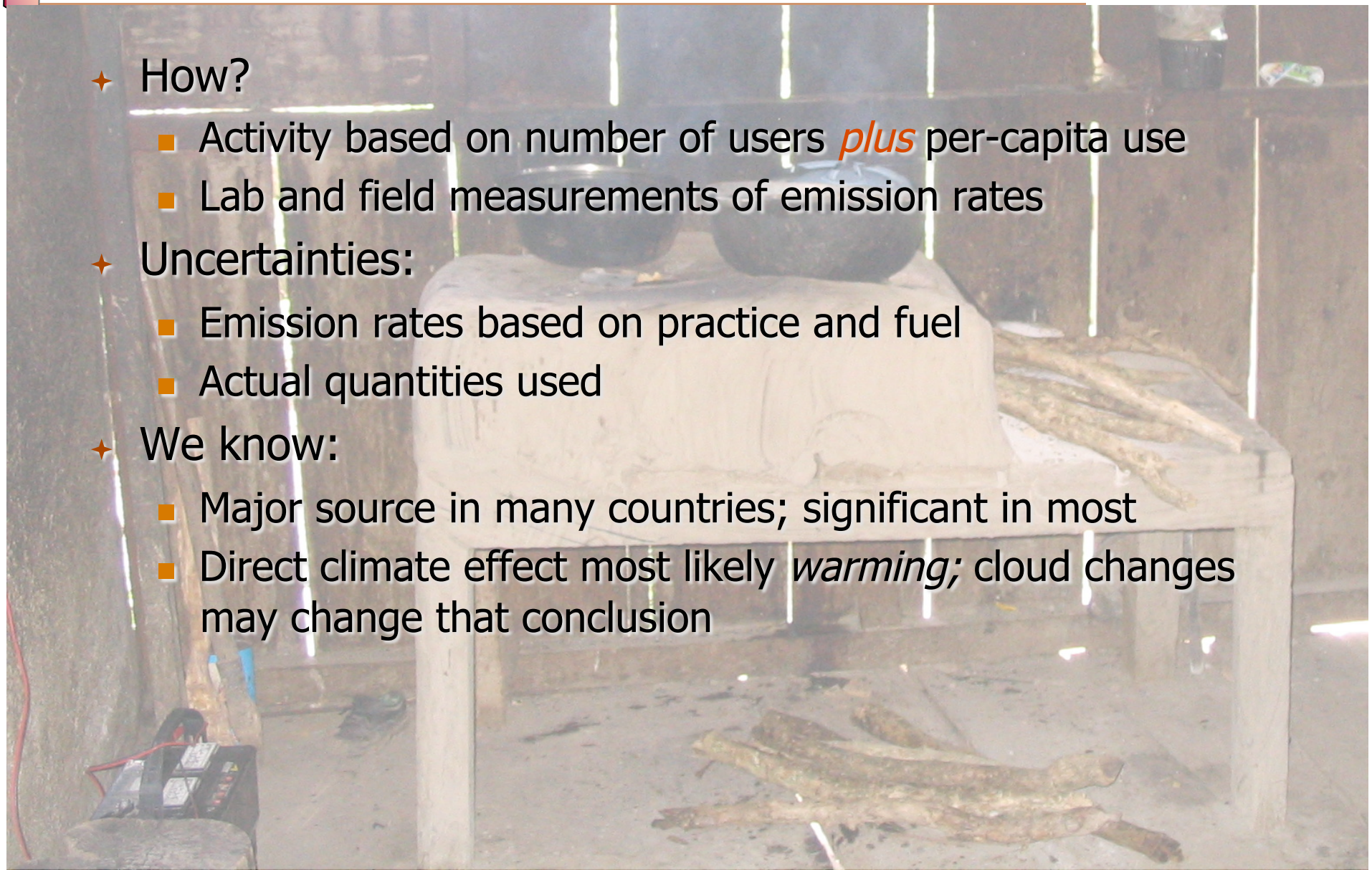


- How?
  - Remotely-sensed fires (satellite) *mixed with*
  - "Ground-truth" quantities and burned fraction *plus*
  - Field measurements of emission factors
- Uncertainties:
  - Both activity rates and emission factors
- We know:
  - Large contribution, especially Latin America, Africa, Northern forests
  - Daily, seasonal, interannual variability
  - Lots of organic carbon (may be cooling or warming?)

Emission estimates for diesel engines

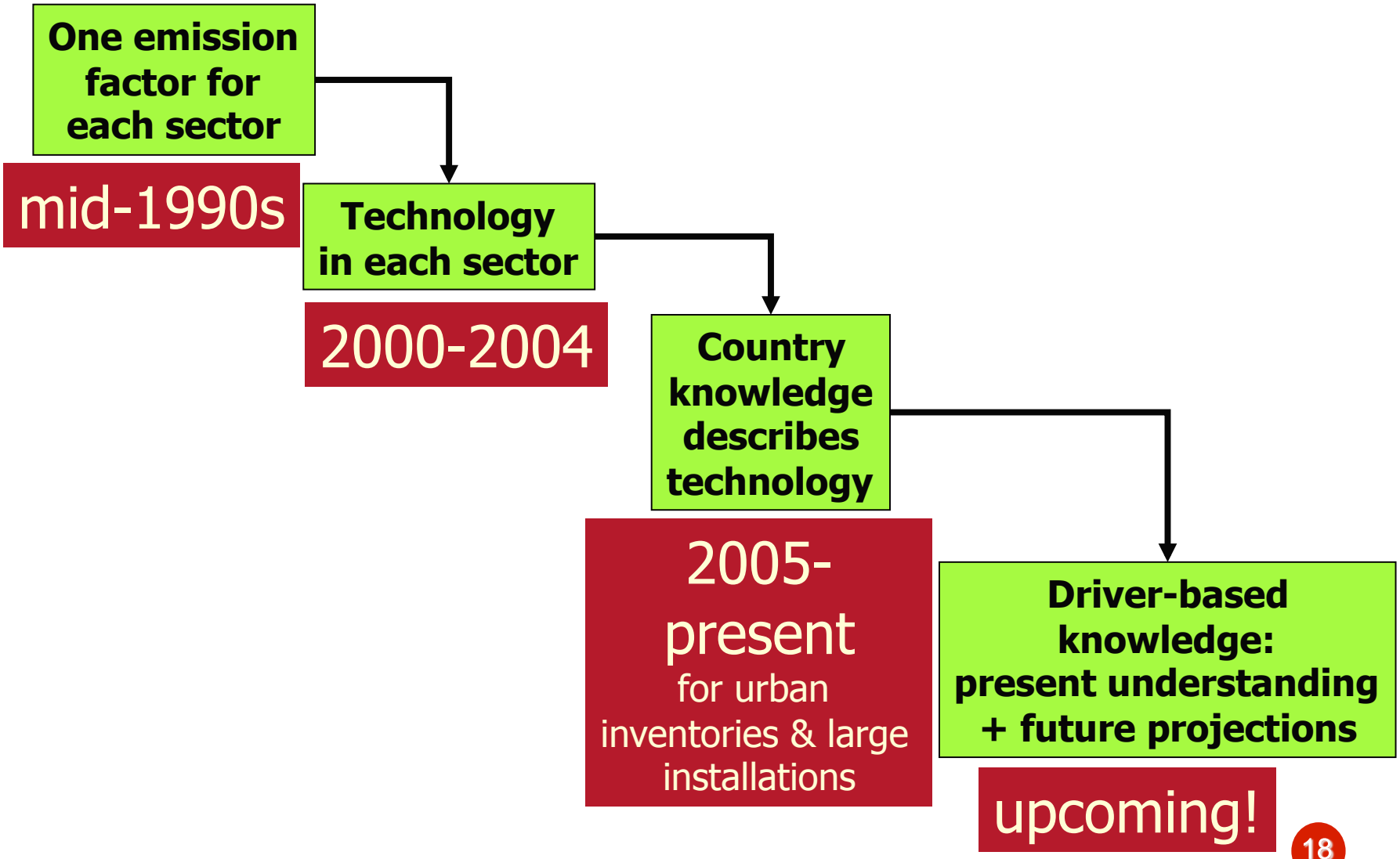
- How?
  - Global: fuel-use data *OR*
  - Metropolitan areas (sometimes national): Vehicle models *plus*
  - Lab measurements of emission rates
- Uncertainties:
  - Emission rates (two-wheelers, superemitters)
  - On-road dynamics (used vehicle imports, rebuilt engines)
  - Off-road activity and emissions
- We know:
  - Large contribution, especially in urban environments
  - Strongly warming particles

Emission estimates for biofuel



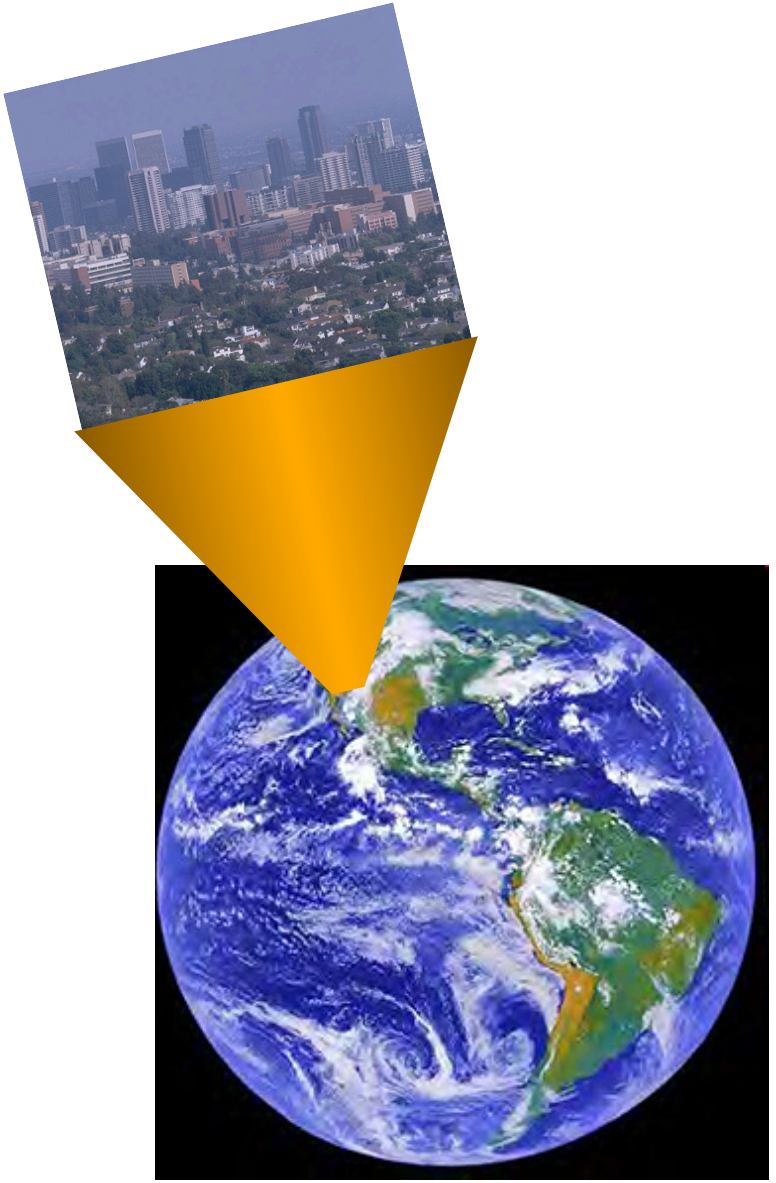
- How?
  - Activity based on number of users *plus* per-capita use
  - Lab and field measurements of emission rates
- Uncertainties:
  - Emission rates based on practice and fuel
  - Actual quantities used
- We know:
  - Major source in many countries; significant in most
  - Direct climate effect most likely *warming;* cloud changes may change that conclusion

Progression of global inventories



Urban-to-global links very important

- Excellent work on emissions in metropolitan regions underway for Latin America (e.g. SAEMC)
- Critical input for global inventories!
- For continental-scale emissions, must consider entire country (including *rural*)



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Gracias!

Preguntas?

General rule about BC+OC emitters *(for energy-related sources)*