OC/EC Aerosol Measurements

Importance for National and International Policy

An International Workshop for the

Development of Research Strategies for Sampling and Analysis of Organic and Elemental Carbon Fractions in Atmospheric Aerosols

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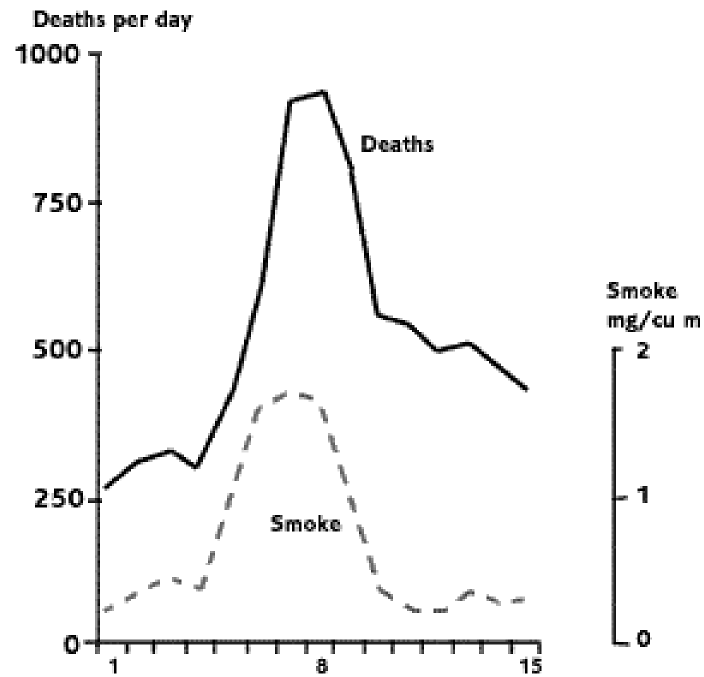
Why we care about OC/EC

- We have a problem
- Introduction: *A foggy day in London Town…*
- The atmospheric science/policy version of a GUT
  - Multiple potential effects on public health
  - Visibility impairment – O say can you C? (It's EC)
  - Effects on climate – global and regional
  - The core: physico-chemical composition affects radiative transfer, toxicity
- Voodoo chemistry
- Some uses we'd like to see
- Where we need to be
  - Soon: Consistency/precision in bulk measurement approaches/supplemental methods where needed
  - Long-term: Beyond bulk measurements – indicator species

Lessons from the 1952 London Smog Episode

It was hard to see

Smog transformed London's climate for decades – read Sherlock homes



4000 people died

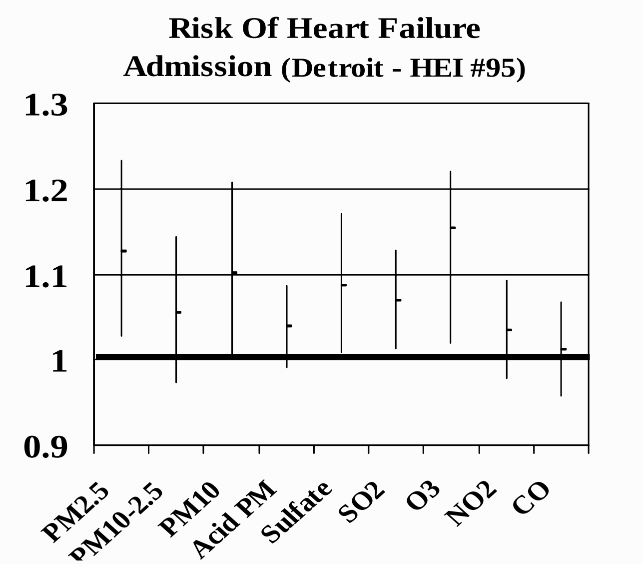
It was all there: A potent mix of carbonaceous particles/SOx with multiple effects on a local/regional scale

Effects I: PM and Public Health

- Premature death from heart and lung disease
- Aggravation of heart and lung diseases, including asthma
- Cardiac arrythmias and heart attacks
- Coughing, wheezing and chronic bronchitis
- And *possibly*:
  - Lung cancer mortality
  - Infant mortality
- Is PM composition important?
  - Probably, but likely multiple “bad” actors
  - A number of studies found effects of PM components, e.g. sulfate; few OC, many black carbon (i.e. black smoke)

Multi-Pollutant Short-Term Analyses in Different Cities Show Varying Results

- **Depends on health outcomes, location**
  - In this HEI example PM2.5, sulfate, SO2 and ozone are associated
  - Acid, coarse particles, NO2 and CO are not
- **In other cases results are different**
  - e.g. ARIES where CO and SO2 are associated, but sulfate is not
  - Recent work finds associations with carbon fractions

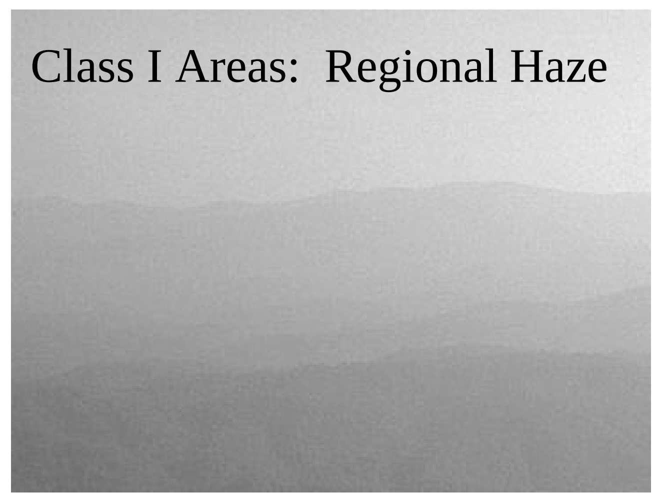


The Future: Multi-pollutant analyses/effects – source/apportionment will use STN data; OC fractions

Effects II: Visibility

Urban Visibility - Secondary NAAQS

Urban: Winhaze model for Washington, DC. Top: Fine mass at the level of the current 24-hr NAAQS of 65 ug/m^3 5 mile visual range, 39 deciview. Bottom: ~ Natural conditions, 90 mile visual range, 12 deciviews, less than 2.5 ug/m^3.



Class I Areas: Regional Haze

Effects III: International transport/climate interactions

Asia a Priority: Air Quality/Health Improvements have climate benefits

Air Pollution (PM and O3) significant Climate Forcers

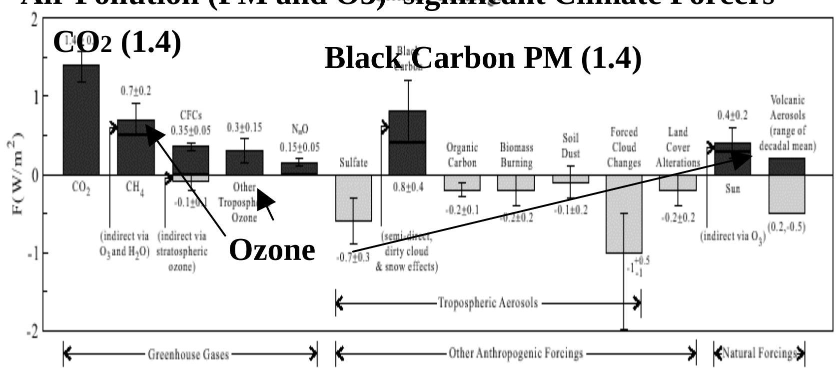
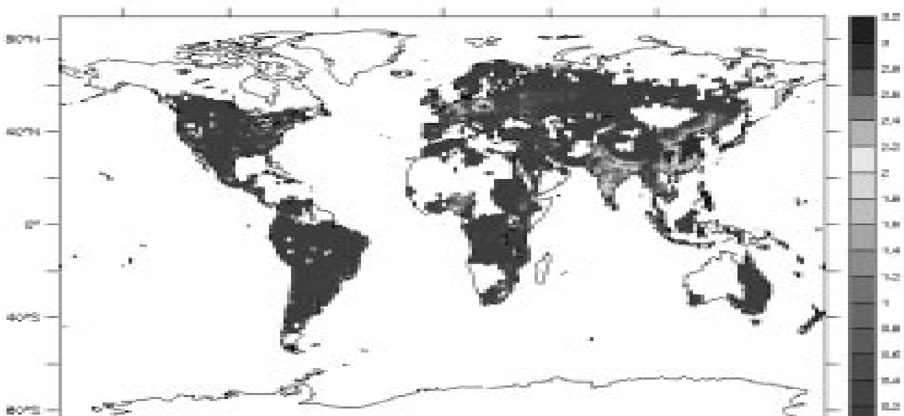
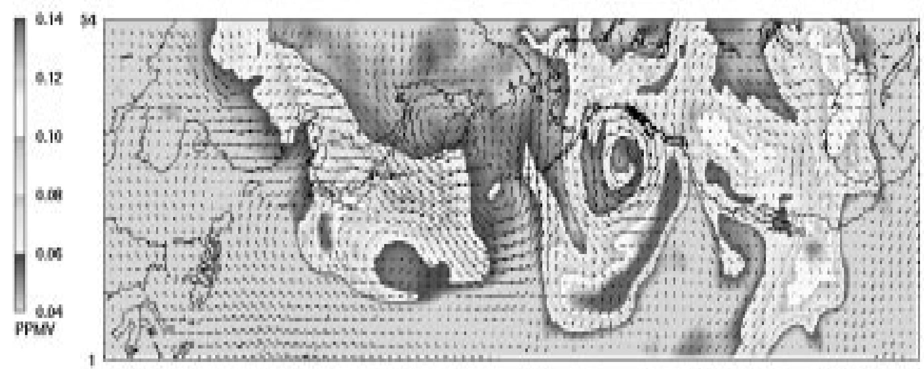


Figure 2. Estimated change of climate forcings between 1850 and 2000.

Global Black Carbon Emissions



** in 106 kg/year/1ox1o grid (David Streets & Tami Bond, 2002)*



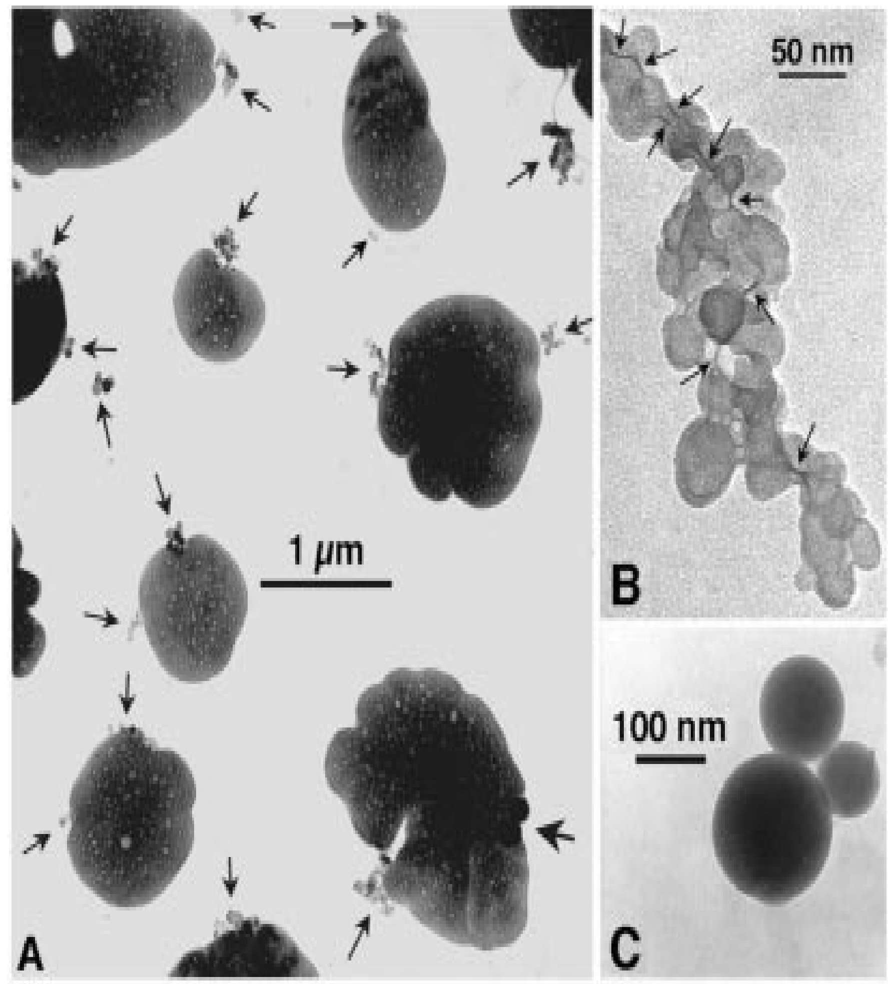
A Link between Visibility and Climate

Black carbon particles absorb all light wavelengths

Very small organic/carbon particles scatter light (**blue**/grey/white)

And soot gets coated with white particles (as well as organic matter and more)

- *These interactions with light influence the nature of visibility and climate effects of carbonaceous*
- **Black** particles absorb energy, transfer **heat**
- **White/blue** particles scatter light back towards the sun, **cool**
- The mixture is not a simple “balance”, especially on a regional scale
- Diesels have a particularly high black carbon to organic ratio
- *Composition/morphology affect bioavailability of organic constituents*



Arrows point to white sulfate particles

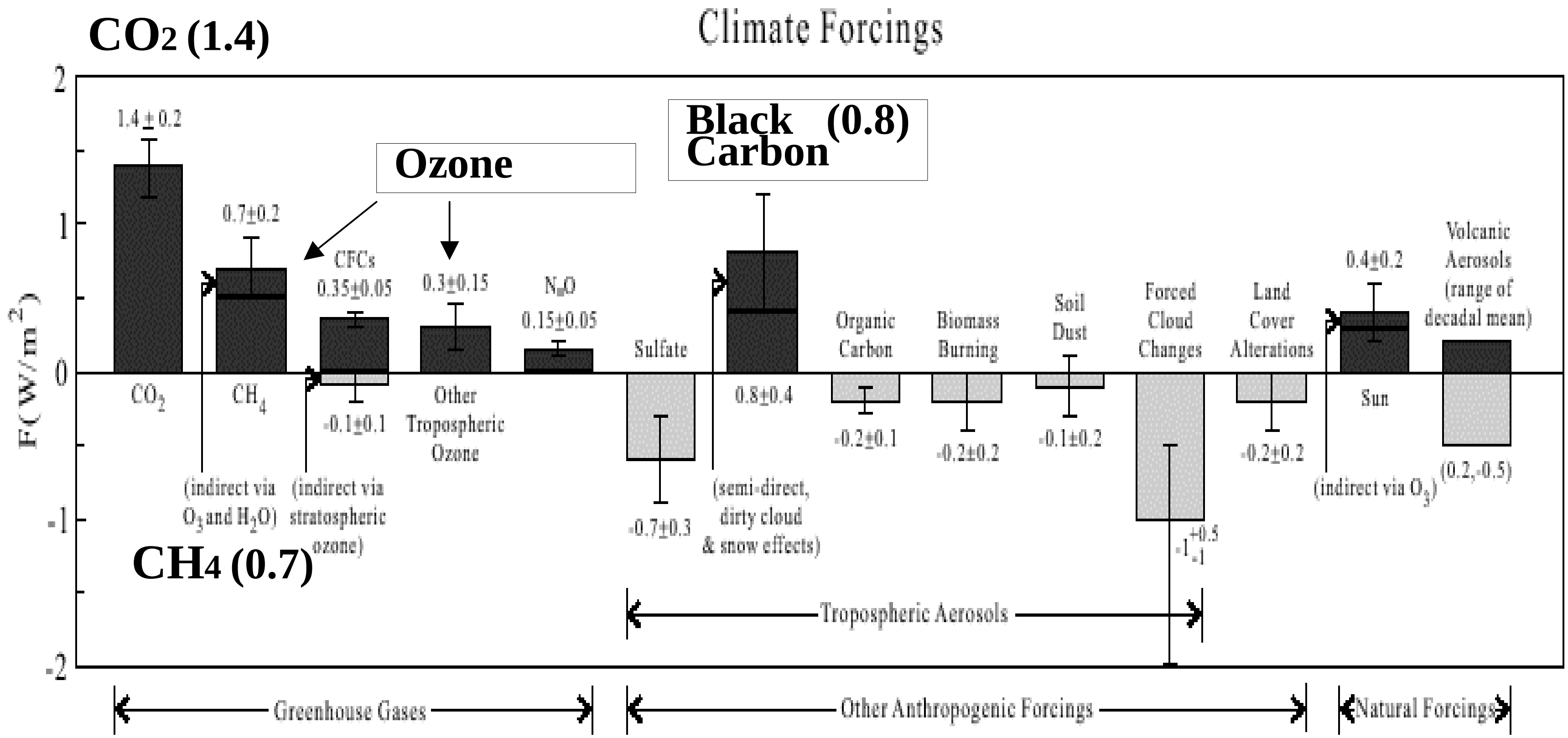
It’s actually more complicated, but making some uncertain assumptions, the big picture looks like…

Effects of aerosol particles on climate

1. "Self-feedback effect"
2. "Photochemistry effect"
3. "Smudge-pot effect"
4. "Daytime stability effect"
5. "Indirect effect"
6. "Effect on BC absorption of 1st indirect effect”
7. "Semidirect effect"
8. "BC-low-cloud positive feedback loop"
9. "Rainout effect"
10. "BC-water-vapor positive feedback"
11. "Particle effect through surface albedo"
12. "Particle effect through large-scale meteorology"

Jacobson, 2002

Black Carbon *could* be #2 globally

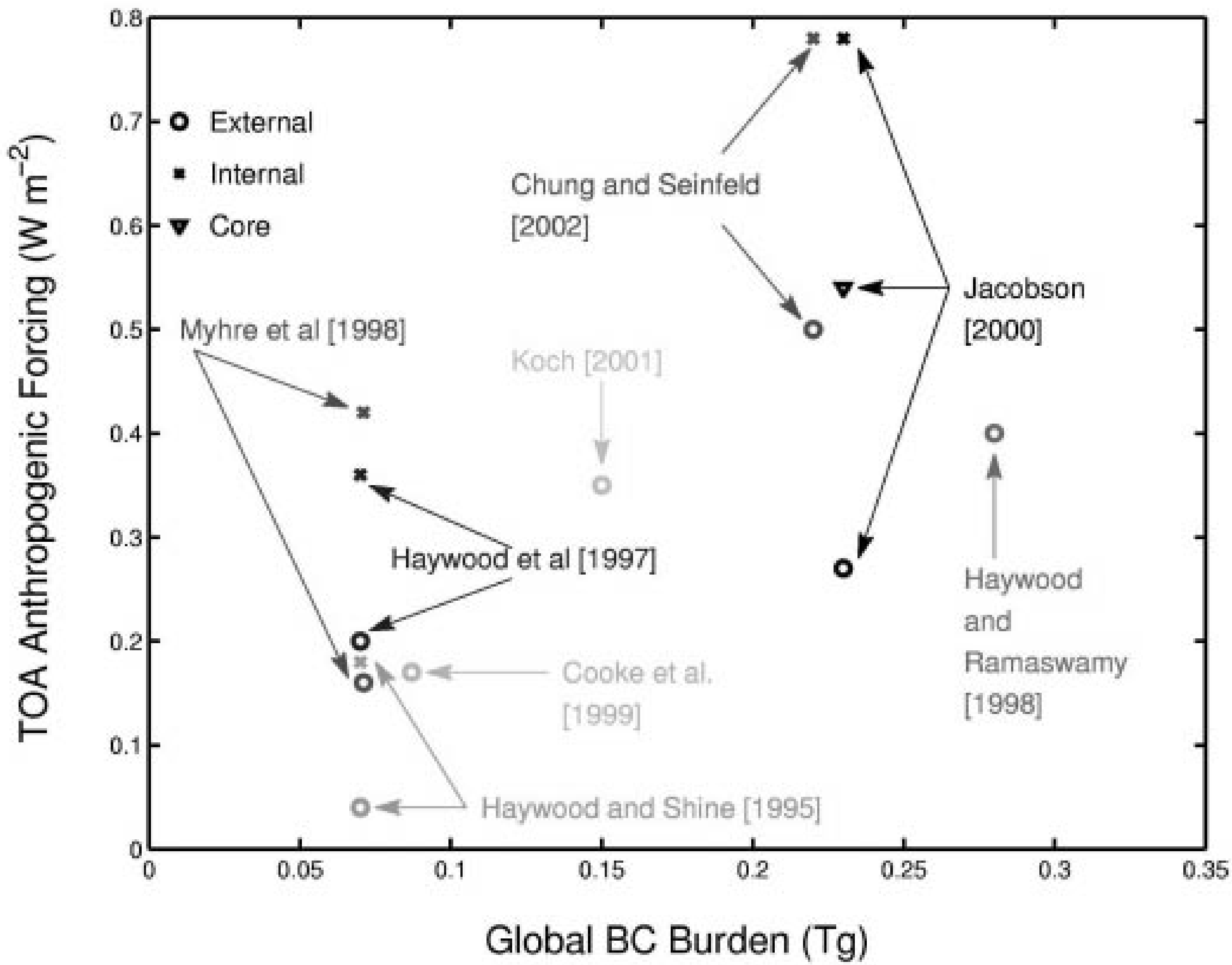


Estimated Change of Climate Forcing between 1850 and 2000

(Hansen et al., PNAS, 2001)

But significant uncertainties exist in making such estimates

Example: Differences in estimate global “forcing” of Black Carbon vary with inventory, concentrations, and assumptions about it is mixed in aerosol particles (Seinfeld, 2002)



And climate change is not always global

- INDOEX, other preliminary work suggest significant potential of BC aerosol for affecting hydrologic cycle on a regional basis
- Back to the future in Asia

The BC/OC Ratio Varies by Source

Biomass fire rich in organic components

Diesels have higher BC(EC) to OC ratio

Preliminary BC climate analyses*

- **Climate response of fossil-fuel BC+OC emissions reduction**
  - **Control of fossil-fuel BC+OC emissions could be the most effective method of slowing global warming (more than reduction of CO2 or CH4 for a period of 25-100 years)**
  - **Net observed global warming (since mid 1800s) is about 0.7 K ("1.9 K" warming – eliminating all f. f. BC would reduce 20-45% (0.35 K/ 0.7 K) of net warming within 3 to 5 years (and also benefit health)**
  - **Estimates total f.f. BC+OC warming would be about 25% coal, 45% diesel, and 30% other.**
  - **Diesel cars emissions *(without adequate PM controls) could* warm climate more than equivalent gasoline cars**

*Jacobson, M. Control of fossil-fuel particulate black carbon and organic matter, possibly the most effective method of slowing global warming
J.Geophys. Resarch *107* (D19) 4410, (2002)

Policy Implications

- PM NAAQS driven by fine mass in non-attainment areas
  - How much is carbonaceous?
  - From where?
  - Trends
- Visibility
  - The above plus
  - Consideration of composition effects on extinction
- Climate
  - Focus on sources high in BC

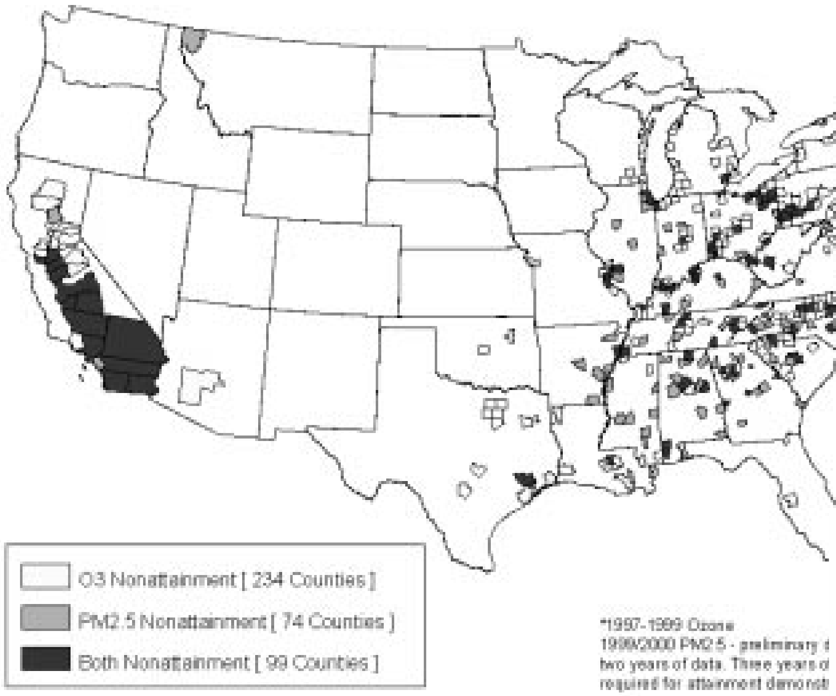
Voodoo chemistry – why bulk measurements?

- Because we can
- Are the data meaningful? Useful? Enough?
- It depends on the use – but it's never enough
- Potential uses (some examples follow)
  - Geographic distribution of EC/OC
  - Trends/accountability over time
  - Source apportionment/reconciling mass
  - Developing concentration/response relationships in multi-pollutant studies
  - Constraining emissions estimates of bulk components (EC)

Implementing the $PM_{2.5}$ Standards

2003	States recommend nonattainment designations
2004-05	EPA makes nonattainment designations/ complete NAAQS review*
2005	EPA Issues SO_x/NO_x transport rule
2004-07	States develop/submit SIPs
2008-09	EPA approves SIPs
2009-14+	Attainment deadlines

Widespread improvement expected in attaining NAAQS Current mobile rules/Clear Skies or Transport Rule



$PM_{2.5}$ /O3 attainment status in 2020:

- Tier 2, HD Diesel, NOx SIP call, other programs
- Projected regional SOx/NOx reductions from Clear Skies Act, or regional transport rule/regional haze programs
- Doesn't include SIP local/regional measures

Clear Skies 2020

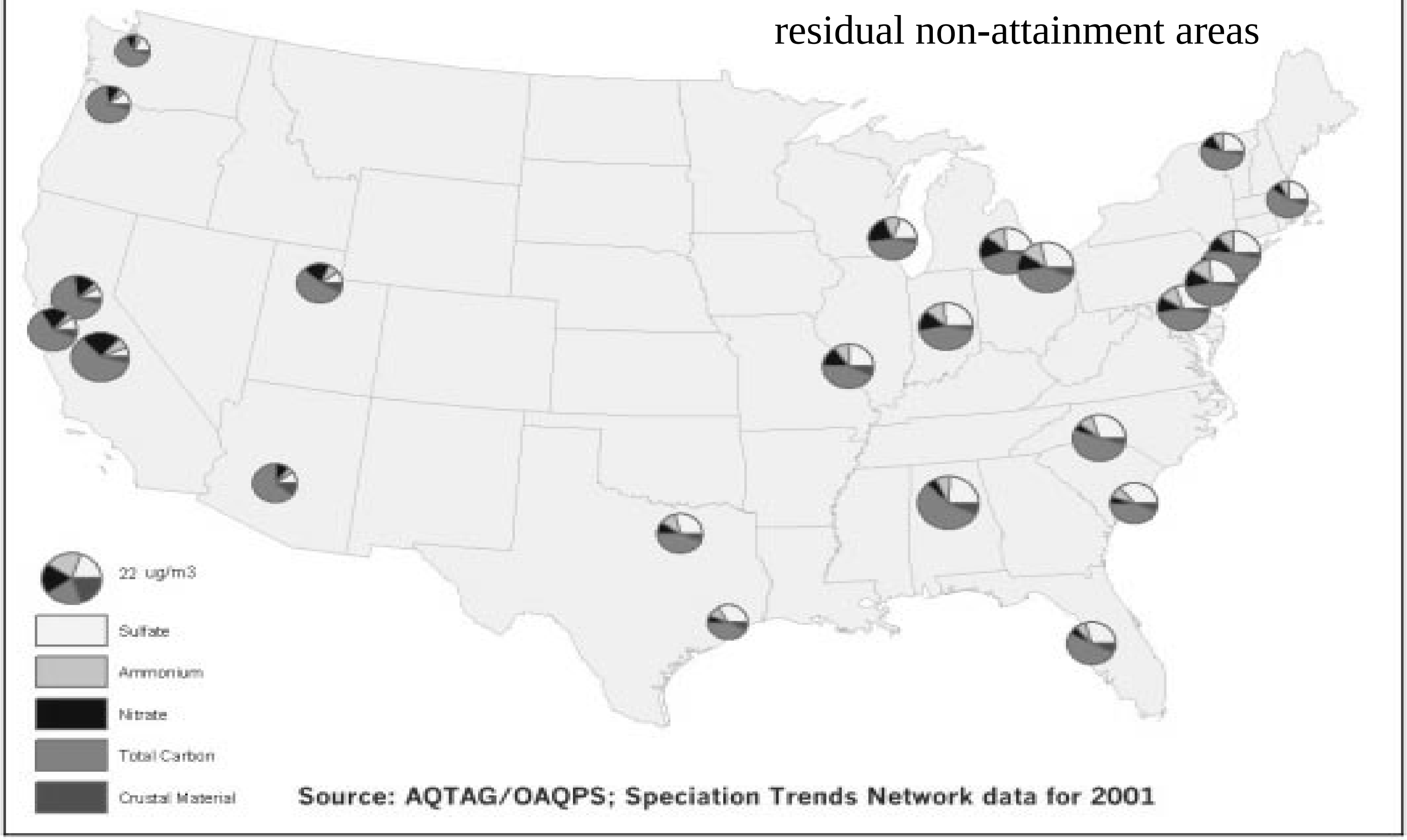
A significant change in the regional/background chemical climate

- Additional pressure on remaining local sources for VOC/PM control
- The 'Post sulfur' era?

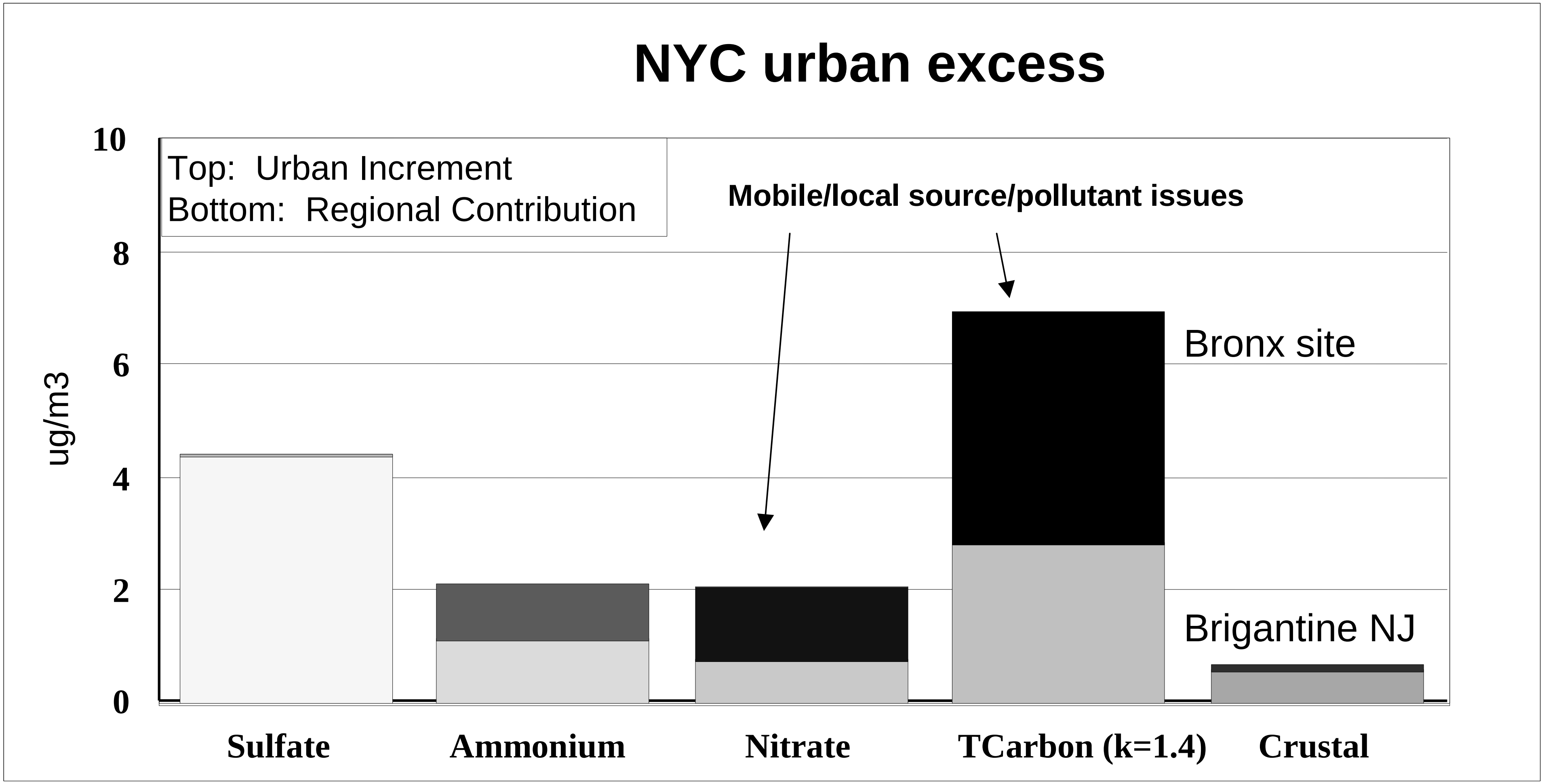
Note: This analysis shows the counties that would come into attainment due to Clear Skies alone in 2020. Additional federal and state programs are designed to bring all counties into attainment by 2017 at the latest.

Carbon PM 'share' growing

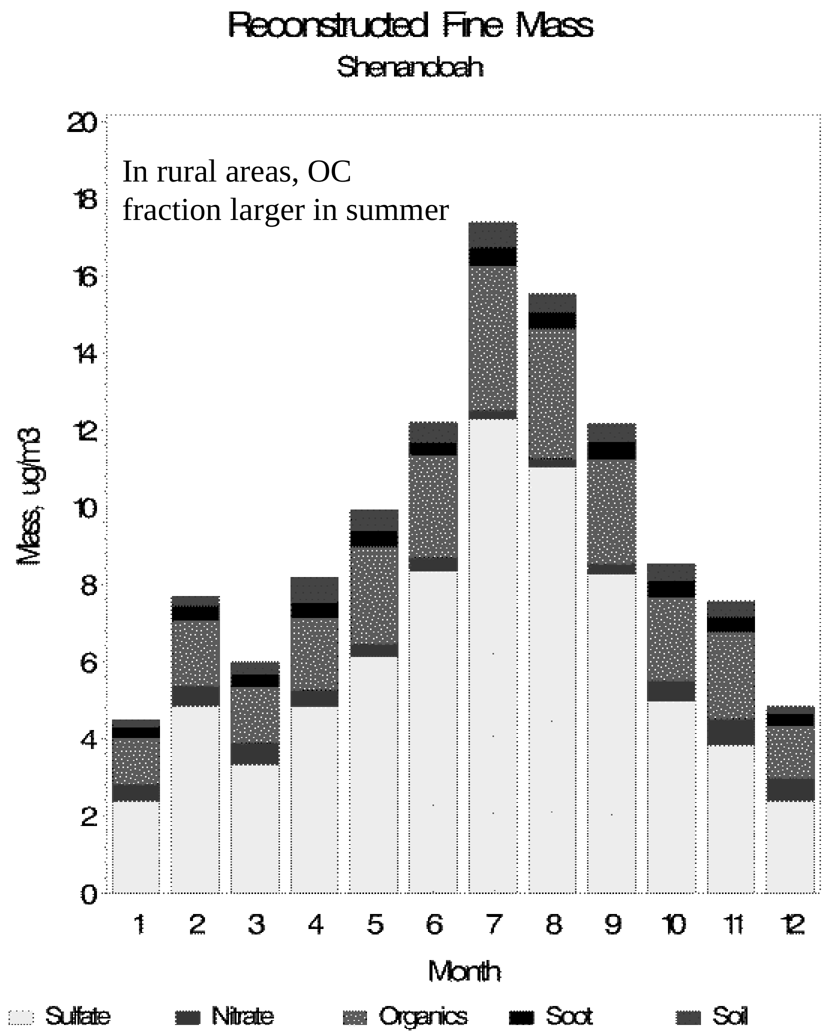
After regional SOx/NOx controls, carbonaceous PM will dominate residual non-attainment areas

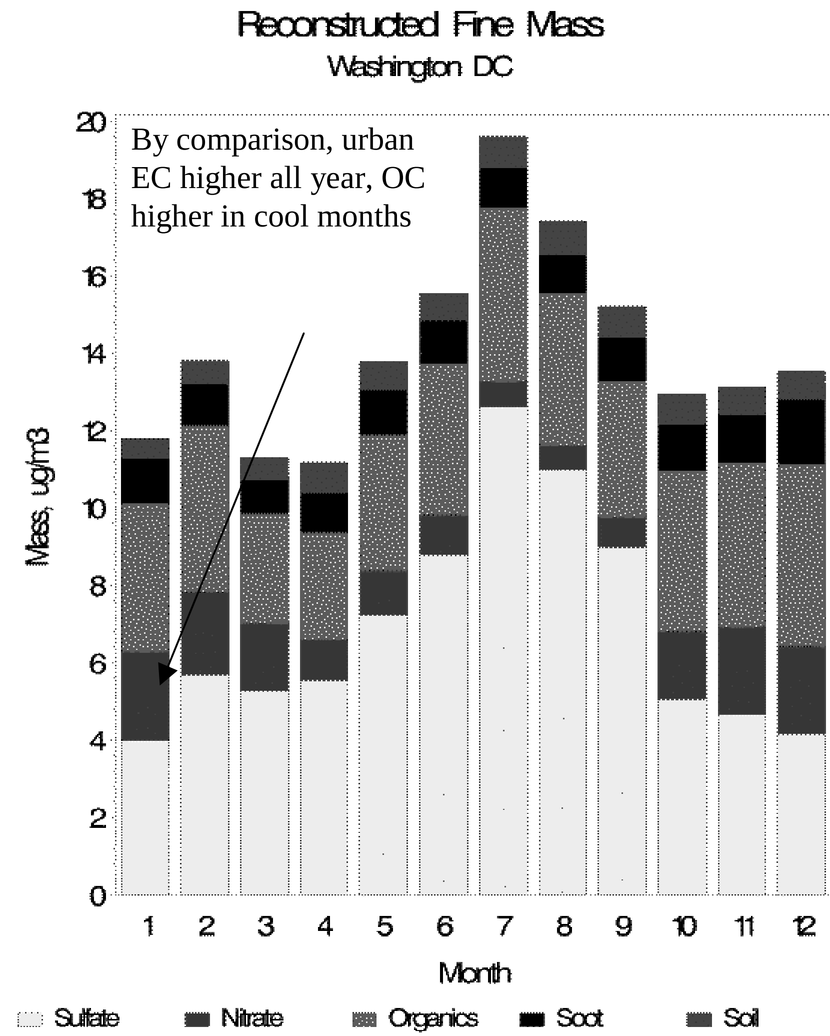


Local PM Sources appear important for EC/OC

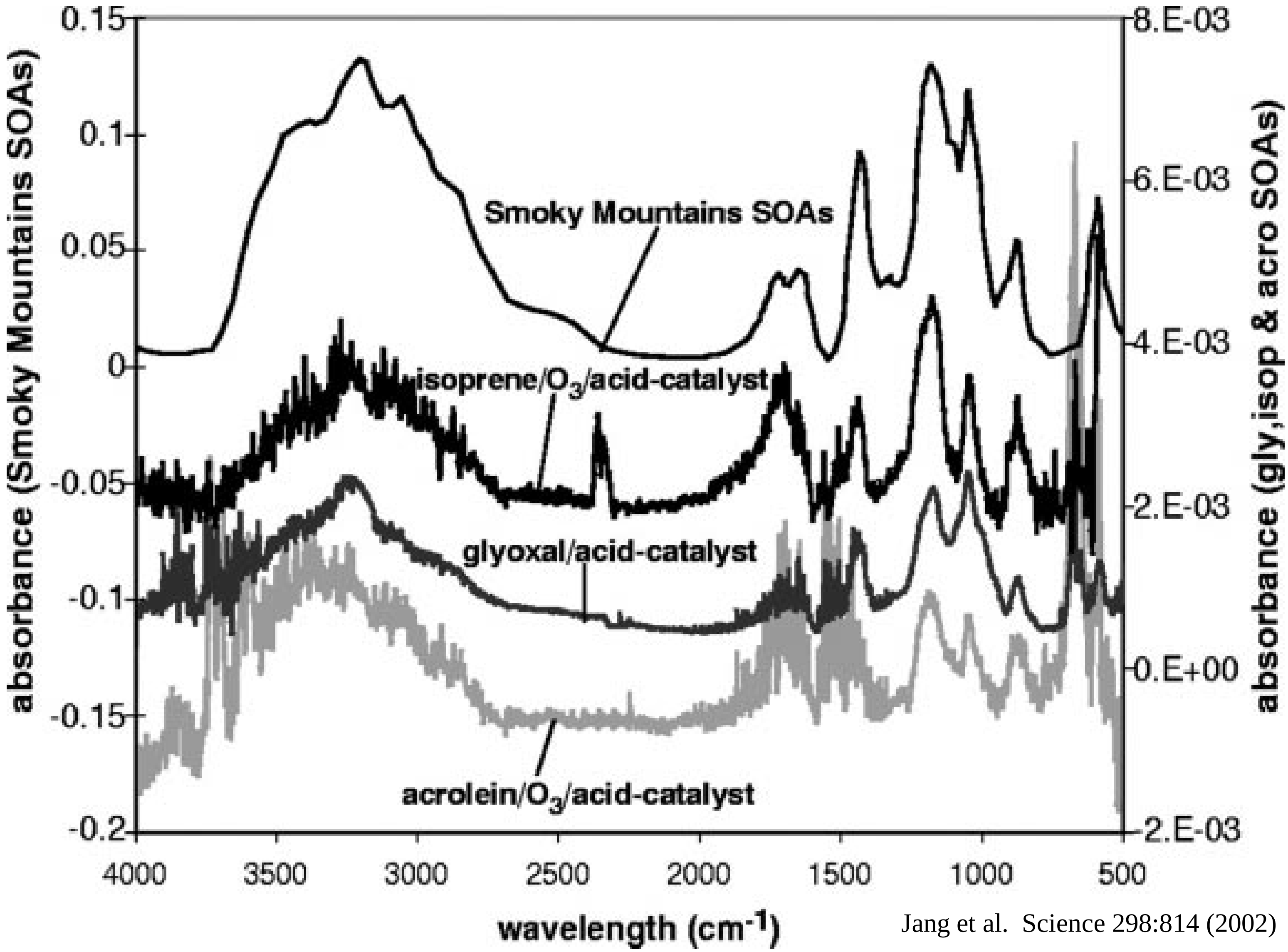


What about rural carbon?





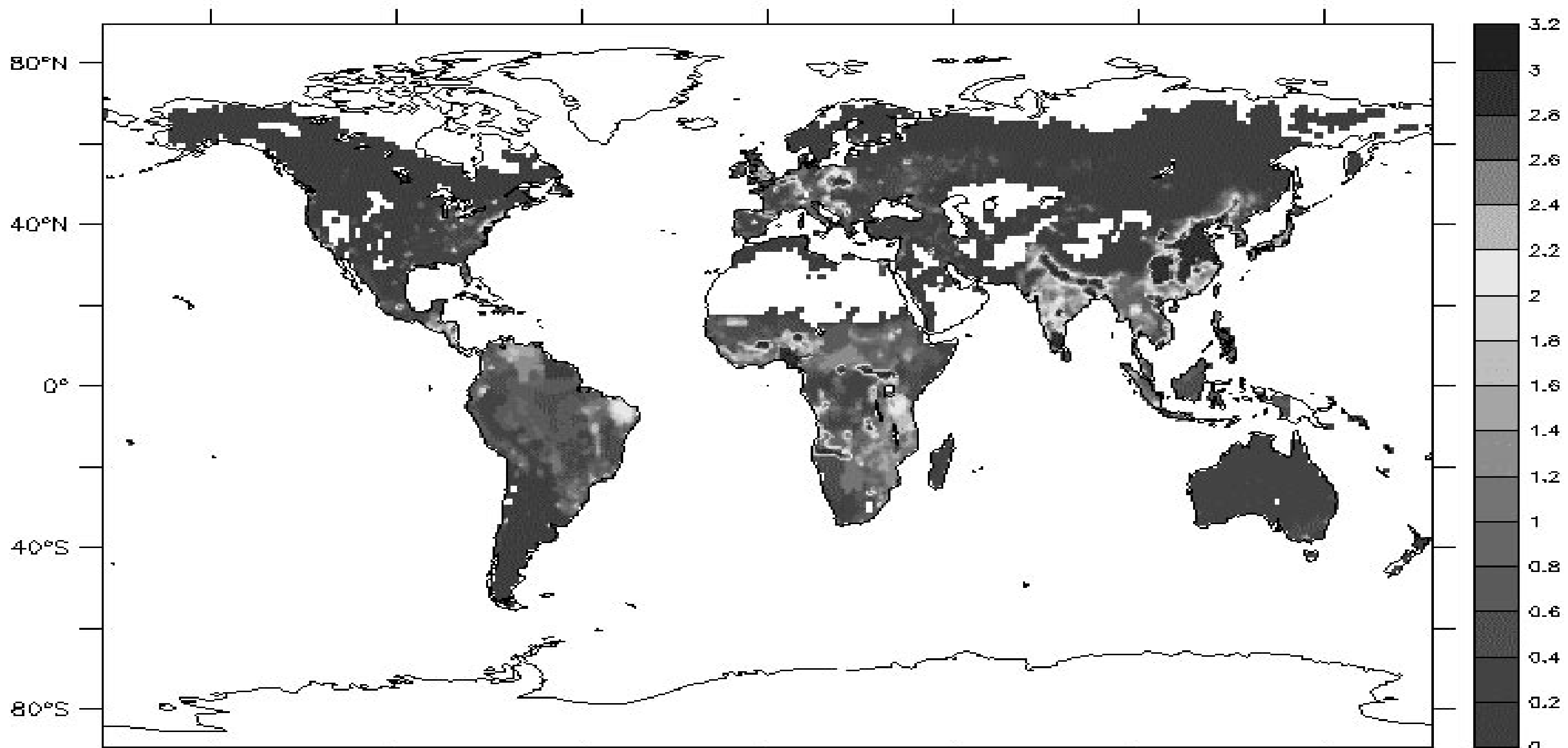
Potential role of SOx/NOx and acid aerosols in formation of secondary organic aerosol



Jang et al. Science 298:814 (2002)

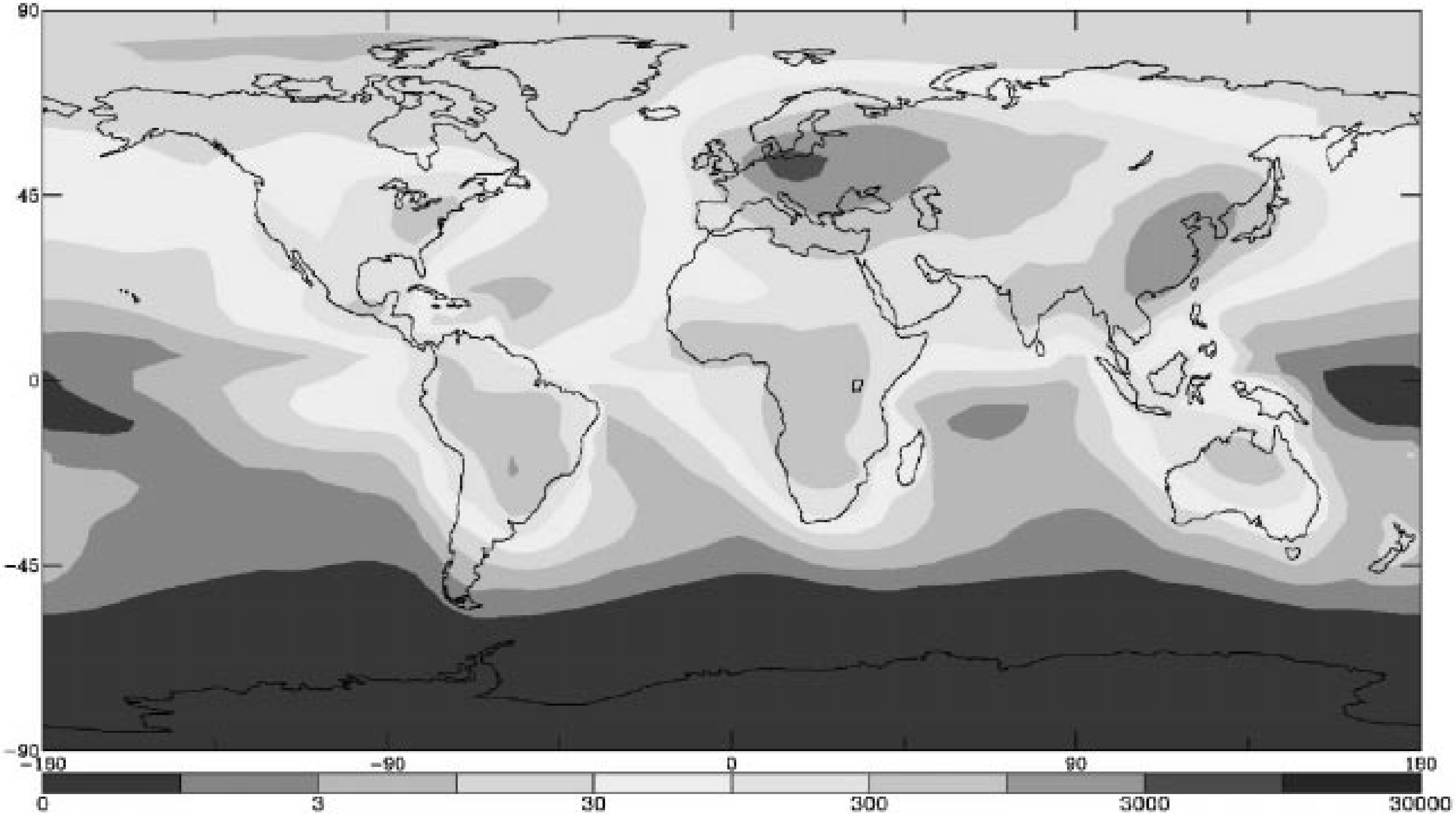
Mmts needed to constrain global BC Emissions

(Tg, 1996)



***** in 10^6 kg/year/1ºx1º grid (David Streets & Tami Bond, 2002)***

BC Surface Concentrations (ng m^{-3})

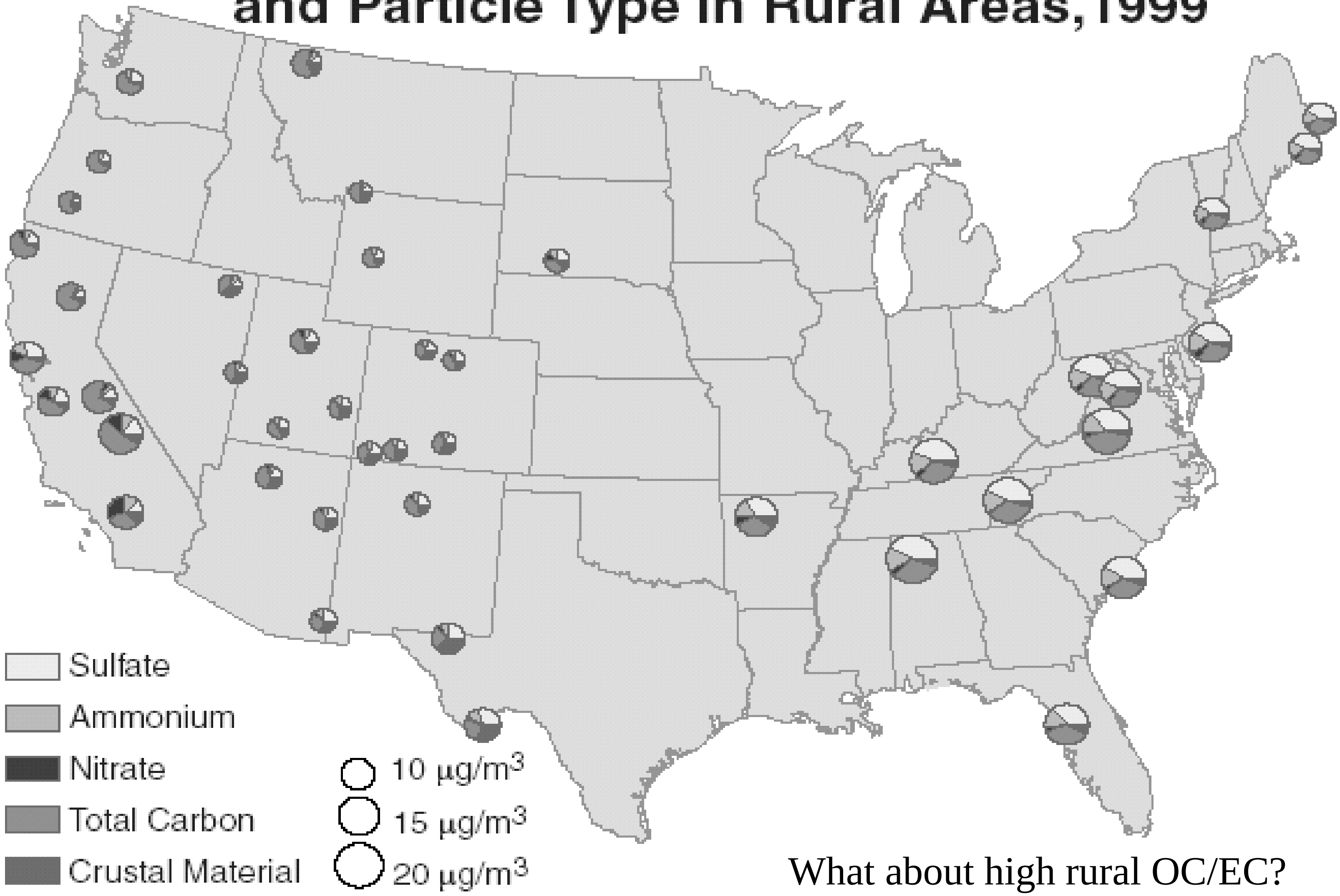


Seinfield, 2002

Some issues for this conference

- Consistency of OC/EC approach in Urban STN and rural IMPROVE analyses
  - Both approaches have strengths, weaknesses – not ‘truth
  - Bulk measures useful, consistency/precision most important
  - EC relatively small, accuracy less critical
- Visibility programs eventually need to get extinction correct
- Climate work needs accurate measurements of absorption from elemental and certain organics
- Focus on how useful organic fractions are in source apportionment
  - In the long run, need more specific limited set of source compounds, breakdown contemporary-fossil carbon
- Health effects need consistent approaches over time
- Air pollution and climate scientists need more interaction
  - Terminology – EC/BC/OC

Annual Average $PM_{2.5}$ Concentrations ($\mu g/m^3$) and Particle Type in Rural Areas, 1999



What about high rural OC/EC?

Source: Interagency Monitoring of Protected Visual Environments Network, 1999.