Role of Black and Organic Carbon Emissions in Integrated Assessment

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Air Pollution as Climate Forcing Workshop
April 6, 2005
What is the appropriate role for BC/OC in climate change mitigation?

Climate effects ‘large enough’ relative to GHGs, globally or regionally?

BC/OC sufficiently captured by air quality policies?

Most effective means of reducing residual BC/OC?

Continue treatment as air quality issue

Incorporate BC/OC in climate analyses, not as explicit climate strategy (akin to CFCs)

Climatic effects, monitoring, inventories, projections, mitigation assessment need improvement

Requires addressing key issues:
- Separate goal from basket of GHGs?
- Allow GWP-like comparisons?
- Dealing with OC?
- Synergies/tradeoffs with GHG mitigation?
Annual U.S. BC Emissions, 1999
Derived from EPA 1999 National Emissions Inventory for PM2.5

Source: Battye and Boyer, 2002
Key U.S. criteria pollutant control programs can influence BC/OC…to varying degrees

• National Ambient Air Quality Standards (NAAQS) for PM$_{2.5}$
  – At or below 65 µg/m$^3$ over 24-hr, and at or below 15 µg/m$^3$ on an average annual basis
  – 35% nation’s population potentially in nonattainment areas
  – States required to reach attainment by 2010, with possible extensions

• Clean Air Nonroad Diesel Rule
  – PM & NOx standards for new nonroad engines + low sulfur diesel fuel for nonroad, locomotives and marine engines
  – Phase in beginning 2008; most engines must meet PM and NOx standards by 2014

• Clean Diesel Truck and Bus Rule
  – PM & NOx standards + low highway diesel sulfur fuel phased in 2006 – 2010 estimated to result in trucks/buses 90% cleaner than today’s

• Regional Haze Rule
  – States submit and EPA approves implementation plans 2007-09

• NOx SIP Call
  – Requires 21 eastern states + District of Columbia to revise ‘State Implementation Plans’ to prohibit sources from emitting NOx in amounts that lead to non-attainment of national ambient O$_3$ standards; most states had to comply beginning 2004

• Clean Air Interstate Rule
  – Targets SO$_2$ and NOx in power sector
  – Full implementation expected to lead to 70% reduction

• Acid Rain Cap and Trade Program
  – SO$_2$ trading with phased reductions in power sector; phase I began 1995; phase II began 2000; affects existing units with greater than 25 megawatt capacity and all new units
Effects of Air Quality Policies on BC Inventory:
Some expected effects readily quantifiable, others less clear

- Non-Road Diesel
- On-Road Diesel
- Non-Road Gasoline
- Aircraft
- On-Road Gasoline
- Marine
- Misc.
- Prescribed Burning
- Land Clearing
- Residential Burning
- Wildfires
- Ag Field Burning
- Fugitive Dust
- Residential Combustion
- Industry

Nonroad Diesel Rule
Clean Diesel Truck
PM$_{2.5}$ NAAQS
Regional Haze Rule
CAIR
New PM & sulfur fuel standards expected to reduce BC emissions from largest sources: diesel vehicles

Black Carbon 1990-2030

- Super emitters not accounted for
- BC % of PM$_{2.5}$ assumed constant over time
  - 60% for diesel
  - 40% for gasoline

Derived from PM$_{2.5}$ projections by EPA OTAQ using MOBILE6.2 and NONROAD
Tightening of vehicle emission controls will affect BC in other countries... *but car population/VMT may be a different story*

![Tightening of vehicle emission controls will affect BC in other countries...*but car population/VMT may be a different story*](image)

<table>
<thead>
<tr>
<th>Country</th>
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<sup>a</sup> Entire country  
<sup>b</sup> Delhi and other cities; Euro 2 introduced in Mumbai, Kolkata and Chennai in 2001; Euro 2 in Bangalore, Hyderabad, Kharapur, Pune and Ahmedabad in 2003; Euro 3 to be introduced in Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad and Ahmedabad in 2005  
<sup>c</sup> Beijing and Shanghai  
<sup>g</sup> Gasoline vehicles under consideration  
<sup>e</sup> for gasoline vehicles  
<sup>f</sup> for diesel vehicles  

Source: Huizenga 2004
Example of PM$_{10}$ projections for Transport for OECD Europe

<table>
<thead>
<tr>
<th>Year</th>
<th>Road Diesel Exhaust</th>
<th>Road Gasoline Exhaust</th>
<th>Total Road Exhaust</th>
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<tr>
<td></td>
<td>Emissions (Gg)</td>
<td>% Change from 1995</td>
<td>Emissions (Gg)</td>
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<td>1995</td>
<td>250</td>
<td>0</td>
<td>70</td>
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<td>320</td>
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<td>220</td>
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<td>30</td>
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<td>2015</td>
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<td>90</td>
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Source: as Predicted by CONCAWE in Umweltbundesamt, 2004
Black Carbon Estimates by Country & Region

Open Biomass Burning Emissions of BC/OC

- Less controlled, no single policy lever

- In U.S., if diesel emissions decline as expected, open burning likely to become largest source

- Significant source in other regions (e.g., savannah burning in Africa, forest fires in Latin America)
Projecting Forward for All Sectors...general decline appears likely

Source: Streets, D. et al. 2004; Presented by D. Streets, Workshop on Global Air Pollution Trends, January, 2005
Mitigation Beyond BAU: Developing Cost Curves for BC/OC... only preliminary work to date

Figure 3. 2010 Global Marginal Abatement Cost Curve for Nitrous Oxide Emissions from Cropland Soils
Estimating BC/OC mitigation from open biomass burning with associated costs...proving difficult

**Barriers to mitigating BC/OC from practice of prescribed burning in the US:**

**Technical**
- Lack of equipment, and appropriately sized equipment
- Access to project areas due to terrain, lack of roads

**Environmental**
- Water quality degradation due to increased runoff from soil compaction, heavy equipment
- Removal of nutrients on-site which burning would replenish

**Economic**
- Lack of markets for small diameter biomass
- Equipment and labor costs
- Transportation costs moving material to market

**Socio-political**
- Long history of using prescribed burns; difficult to change

Source: Jones & Stokes (2004) Nonburning Alternatives to Prescribed Fire on Wildlands in the Western United States
...Now gathering preliminary, first-order estimates of BC/OC mitigation for open biomass in Latin America

<table>
<thead>
<tr>
<th>Mitigation Target</th>
<th>Mitigation Activity</th>
<th>Applicability/Biomass Type</th>
<th>Mean Cumulative Emission Reduction (Ton BC)</th>
<th>Mean Marginal Mitigation Cost ($1996/Ton BC)</th>
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<tbody>
<tr>
<td>Land-clearing burn</td>
<td>Hay harvesting</td>
<td>Savannah</td>
<td>34,700</td>
<td>-688,000</td>
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<td>Grazing</td>
<td>Savannah</td>
<td>44,400</td>
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<td>Timber harvesting</td>
<td>Forest</td>
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<td>Use of biomass for energy production</td>
<td>Forest</td>
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<td>Prescribed burn</td>
<td>Burn before large fuels cure</td>
<td>Forest</td>
<td>263,000</td>
<td>193</td>
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<td>Burn before precipitation</td>
<td>Forest</td>
<td>267,000</td>
<td>198</td>
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<td>Burn when there is high moisture in large woody fuels</td>
<td>Forest</td>
<td>270,000</td>
<td>198</td>
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<td>Backing fires</td>
<td>Forest</td>
<td>275,000</td>
<td>127</td>
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<td>Burn when litter and/or duff are moist</td>
<td>Forest</td>
<td>277,000</td>
<td>327</td>
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<td>Burn before litter fall</td>
<td>Forest</td>
<td>279,000</td>
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<td>Burn in pile</td>
<td>Forest</td>
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<td>Land-clearing burn</td>
<td>Conservation</td>
<td>Forest</td>
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<td>Prescribed burn</td>
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<td>Mosaic burning</td>
<td>Savannah</td>
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<td>Thinning and cutting leaving biomass on the floor</td>
<td>Forest</td>
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<td>Conservation</td>
<td>Savannah</td>
<td>454,000</td>
<td>241,000</td>
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§ Improve emission projections
  • IPCC SRES did not include BC/OC
  • IPCC TAR used simplified scaling with CO/SO$_2$ emissions
  • Will unlikely be included in IPCC AR4

§ Improve understanding of synergies/tradeoffs of GHG mitigation w/ BC/OC
  • Models participating in EMF can capture multiple interactions across gases/sectors, over long term

§ Aiming for initial scenario comparison by Fall ‘05
Plan for BC/OC Subgroup in EMF-22

- Reference Case Projections; more rigor compared to SRES
- Effects on BC/OC of GHG Mitigation
- Significance (forcing/temp) of BC/OC relative to GHGs over time

Participating EMF Models:
- PNNL/MiniCAM
- IIASA/MESSAGE
- MIT/EPPA-TEM
- Jap./AIM
- ABARE
- CICERO
- RIVM/IMAGE
- IAE/GRAPE

Bond et al. 2004 global inventory
Example of MiniCAM projections

Global Black Carbon Emissions

Land-use and transportation emissions dominate by the end of the century

Source: S. Smith, PNNL, draft manuscript
Example of MESSAGE projections

(Fossil fuel and Biomass*)

*Does not include emissions from open vegetative burning

Presented by Rao et al, IIASA, 28 Jan 05
Considerations on Including BC/OC into Climate Mitigation Strategies

- Metrics comparing long-lived GHGs w/ BC/OC
  - Who needs them, for what purpose?

  - For analysis: OK
    - We need to continue to improve our understanding of relative climatic importance
    - GWPs not necessary for comparative climate modeling

  - For emissions trading/offsets w/ GHGs: Let’s Be Very Careful!!
    - Complexities of net BC effects captured in single number?
    - Localized health & climatic effects
    - Separate goal (outside trading basket of GHGs) would not require GWP-like metric (e.g., vehicle standards)
    - OC?
Considerations on Including BC/OC into Climate Mitigation Strategies

• Feasibility
  – Additional complexity
  – Emission reduction verification; inventory guidance
  – ‘Burden shifting’