Now, Soon, or Never

An Introduction to Temporal Dilemmas in Climate Mitigation: BC&OC and Methane

Kirk R. Smith
Professor of Global Environmental Health
UC Berkeley

Haagen-Smit Symposium 2009
June 1-4, Sacramento
Focus here is on these shorter-lived CAPs – Climate Active Pollutants

First BC&OC

Then CH4

Warming in 2005 from emissions since 1750

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Inventories for CO2, CH4, and N2O

Carefully parsed into “natural and “human-caused” as well as “pre-industrial and post-industrial”

Not done yet for BC, OC, Ozone-precursors, etc.
Total Black Carbon Emissions in 2000
Source: T Bond Database, V 7.1.1 Feb 2009
Plus Bond et al., 2004

Forest and Grassland 38.4%
Household 24.7%
Transport 16.6%
Industry 19.0%
Ships and Aircraft 1.7%
Ag Burning 4.1%
Waste Burning 0.3%
Power 0.7%

Total: 7900 gigagrams

Controllable? Large fraction is not
One-third of emissions from natural sources – not put into anthropogenic group
In CO₂ Inventories: rest is considered non-controllable or?
Controllable Black Carbon Emissions in 2000

Source: T Bond Database, V 7.1.1 Feb 2009

Total: 5300 gigagrams

- Household 36.8%
- Transport 24.7%
- Industry 28.3%
- Ships and Aircraft 2.5%
- Power 1.1%
- Ag Burning 6.2%
- Waste Burning 0.5%

Unequivocally Post-1750

~36% of total BC
~57% of controllable

Pre-industrial but perhaps increased since

No forest or grass fires

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Really three categories

• Natural – not amendable to human interventions (e.g., some wildfires)
• Pre-industrial, but still amendable to human interventions (e.g. household biomass fuel burning)
• Post-industrial (e.g., essentially all fossil fuel use)
Controllable Black Carbon Emissions in 2000
Source: T Bond Database, V 7.1.1 Feb 2009

Total 5300 gigagrams

- Household: 36.8%
- Power: 1.1%
- Ships and Aircraft: 2.5%
- Transport: 24.7%
- Industry: 28.3%
- Ag Burning: 6.2%
- Waste Burning: 0.5%

If total is 0.9 W/m² (Ramanathan & Carmichael, 2008)
--Controllable portion is ~ 0.6 W/m²
--Post-1750 portion is ~ 0.34 W/m²

But then, the OC emissions need to be parsed into these categories also

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Intimately linked: Generally not possible to control one without the other.
PPM CO2-equivalent in 2005 beyond pre-industrial levels

- **CO2**: 109
- **CH4**: 45.8 (14.0 from Ozone)
- **BC-OC**: 22.4
- **N2O**: 9.8

Total in 2005. Equivalent to 471 ppm CO2 (on top of CO2 background ~270 ppm).

May be a bit bigger if less historical emissions are determined.

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Controllable PIC Emissions Plus CO₂ Radiation Forcing in 2005

<table>
<thead>
<tr>
<th>Gas</th>
<th>W/m²</th>
<th>Decades to centuries</th>
<th>Years</th>
<th>Months</th>
<th>Weeks</th>
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<td>CO₂</td>
<td>1.56</td>
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<td>CH₄</td>
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<td>CO+NMVOC</td>
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<tr>
<td>BC-OC</td>
<td>0.24</td>
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</tbody>
</table>

"IPCC" Could be a bit bigger if some forest and grass fires are seen to be controllable

"Ram" Recommended Accounting

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How much allocated to each living person from both GHGs --- our natural debts?

Warming in 2005 from emissions since 1750

More than half due to methane

IPCC, 2007
Distribution of Global Natural Debt Among Top 10 Nations

CO2 only in 2005

 Nb. Land-use change emissions not are parsed out by country

Brazil: 0.8%

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Smith and Rogers, in preparation
National Natural Debts:
Cumulative CO$_2$ emissions, depleted by natural processes

National Natural Debts:
Cumulative CO$_2$ emissions, depleted by natural processes

Ratio of largest to smallest emitting countries ~ 500x

This kind of calculation, however, is based only on CO$_2$ emissions from fossil fuels and cement:

Global Anthropogenic Methane Emissions ~2005
Total ~ 305 million tons

- Livestock: 30%
- Coal mining: 6%
- Biomass burn: 3%
- Oil/gas: 18%
- Fossil fuel burn: 1%
- Rice: 10%
- Landfills: 12%
- Manure: 4%
- Other ag: 7%
- Waste water: 9%
- Water: 9%
- Total: 305 million tons

Expected to grow at ~1.5% per year

~47 kg/cap

USEPA, 2006
USA Anthropogenic Methane Emissions ~2005
25 million tons (8% of world)

- Oi/gas: 24%
- Landfills: 25%
- Livestock: 22%
- Waste water: 7%
- Coal mining: 11%
- Fossil fuel burn: 2%
- Manure: 8%
- Rice: 1%

~83 kg/cap

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Methane Emissions from India in 2005
26.1 Mt (9% of world)

24 kg/cap

http://www.epa.gov/nonco2/econ-inv/international.html
Chinese Methane Emissions in 2005
41 MT (13% of world)

- Livestock, 30%
- Rice, 26%
- Landfills, 5%
- Waste water, 13%
- Coal mining, 16%
- Solid fuel combustion, 6%
- Oil/gas, 1%
- Manure, 3%

31 kg/capita

USEPA, 2006
Distribution of Global Natural Debts in Top 10 Nations
CH4 and CO2 in 2005
[compared to CO2 alone; note decrease for USA, increase for China, and large increases for India and Brazil]

 Nb. National fossil fuel/cement emissions only for CO2, land-use change emissions are not parsed out by country

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Percent methane

10 largest LDCs ~55% of world pop

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Ratio of largest to smallest emitters considering both CO$_2$ and methane

$\sim 40x$

10 largest LDCs

$\sim 55\%$ of world pop
Math of GHG Decay (AR4)

• CO$_2$ goes into four compartments:
  – 19% of total with a lifetime* of 1.2 years
  – 34% at 18.5 y
  – 26% at 173 y
  – 21% with a lifetime of “many thousand years”

• Methane has a 12 y lifetime,
  – but contributes to ozone, a GHG
  – and eventually oxidizes to CO$_2$

*Lifetime refers to the time to reach 1/e (37%) of the original amount

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Natural CO2 and CH4 Depletion - 100 years

Fraction remaining of 2009 emissions

Carbon Dioxide
Methane

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Relative Warming from CO2 and CH4 emitted in 2009 (one ton of each)

- Not equal warming per year until 2075 (~65 years)
- Not equal total warming until AD 7300 (~5290 years)

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Hypothetical Choice of Interventions

1. Stop emitting CH4 today for rest of century
2. Stop emitting CO2 today for rest of century

• Which will produce the biggest drop in integrated radiative forcing over a century?
where $CH_4 = CO_2$ in 2005

-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
2008 2028 2048 2068 2088 2108

RF reduction from 2008 value

CH4 RF reduction = 1.7 times CO2 RF reduction over 100 years

Carbon Dioxide
Methane

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Amount of Warming Reduction in 100 Years: Comparison of CH4 and CO2

Ratio of GW Reduction CH4/CO2

CH4 Percentage in Total

0.00  5.00  10.00  15.00  20.00  25.00

Belgium 0.32
USA 0.64
World 1.2
China and Australia ~1.7
India = 6.0
Bangladesh 22.2

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California Methane Emissions
2005 – 1.26 MT

CA = 35 kg/capita
USA = 83 kg/cap

CARB, 2008
CARB website

Enteric Fermentation 28%
Rice 2%
Other Ag 1%
Landfill 22%
Waste Water 11%
Coal <0.1%
Oil & Gas 11%
Biomass Combustion 1%

0.4% of world

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THE ANTHROPOGENIC GREENHOUSE ERA BEGAN THOUSANDS OF YEARS AGO

WILLIAM F. RUDDIMAN
Department of Environmental Sciences, University of Virginia, Charlottesville, VA 22904, U.S.A.
E-mail: wfr5c@virginia.edu

Fig. 1. Anthropogenic effects on (a) CH$_4$ and (b) CO$_2$ calculated as the difference between observed trends (Blunier et al., 1995; Indermuhle et al., 1999) and trends estimated from previous early interglacial intervals (Ruddiman, 2003).
Figure 9. The natural summer cooling driven by Holocene insolation and greenhouse-gas trends should have produced a new glaciation by $\sim 5000$–$4000$ years ago. Early anthropogenic emissions of $\text{CO}_2$ and methane kept climate warm enough in northeastern Canada to prevent glaciation.
Early anthropogenic hypothesis

~150 GtC industrial "Hare"

~300 GtC pre-industrial "Tortoise"
Historical Framework

• Human societies have been contributing to incipient climate change for several millennia.
• Reversing what would have been a natural decline in CO$_2$ and methane in this period
• Contributing substantial CO4 and CH4, but also BC-OC, VOC, and CO
• Excess GHGs are not just a feature of industrialization, but of human activates since at least the control of fire.
• However, the rate has risen dramatically after the industrial revolution, which also corresponded to great increases in population.

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Laws of Carbon-thermodynamics

I. Keep all fossil and forest carbon out of the atmosphere

II. If you cannot do so, the least-damaging form to release is carbon dioxide because all other forms are worse for climate and health.

III. Even renewable (non-fossil) carbon is damaging for climate and health if not released as carbon dioxide.
Ranking of Carbon Emissions: The Pharmaceutical Index

- Carbon dioxide is noxious if fossil or forest derived, but benign if from renewable sources.
- Products of incomplete combustion (PIC) such as carbon monoxide and hydrocarbons are like CO₂ on caffeine – several times worse.
- Methane from any source (fossil, biologic, or incomplete combustion) is like CO₂ on steroids – dozens of times worse.
- Black carbon in particles from incomplete combustion is like CO₂ on crack – hundreds of times worse.

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Conclusions

• For good policy, need consistent frames to compare CAPs from an emissions (not atmospheric chemistry) standpoint
  – Controllable (may need to be revisited)
  – Post-industrial (how to deal with non-FF emissions not well developed)
• The metrics used to compare CAPs – Kyoto gases and 100-year time-horizons -- came out of the early 1990s when climate change seemed far off and less certain.
• Today, however, it seems to be neither, being demonstrateably upon us already
• More emphasis is thus needed to sustainably control shorter-lived CAPs because
  – These can achieve large reductions sooner in RF and,
  – Only their control can affect the rate of as well as the total warming
  – They also exert substantial human health and ecosystem impacts (cobenefits)

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Conclusions, cont.

• Products of incomplete combustion -- BC, OC, CO, NMVOCs, however, are difficult to make policy for because
  – They so short lived as to not be globally mixed – difficult to treat in same framework as longer lived CAPs, such as CO2 and N2O
  – Their science is still quite uncertain, particularly for aerosols
  – Essentially all control measures affect multiple species at once
• Methane, however, holds a unique niche
  – High RF and large emissions: 2nd largest total impact after CO2
  – Relatively short-lived, but long-enough to be globally mixed – can be treated under existing framework
  – Two-thirds of its emissions are amenable to control measures using existing technology and policy tools, much at low cost
  – Interventions commonly target methane alone
• Adding in shorter-lived CAPs shifts the political landscape – more responsibility to LDCs in the case of methane, but also
  – Controls in LDCs wield greater leverage for making an impact – opportunities are greater and response to them faster than in rich ones
Thank you

Publications and presentations available at
http://ehs.sph.berkeley.edu/krsmith/

Kirk R. Smith, UC Berkeley