Short-Lived Climate Forcing Agents

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The “enhanced greenhouse” effect

Net effect: Less outgoing longwave = warming

The scattering aerosol (“whitehouse”) effect

Net effect: Less incoming shortwave = cooling
Decreased homogeneity

The absorbing aerosol (“blacktop”) effect

Net effect: More incoming shortwave trapped = warming
Decreased homogeneity

The (in)famous IPCC bar graph

Figure 3: Many external forces force climate change. These radiative forcings arise from changes in the atmosphere composition, alteration of surface reflectance by land use, and variation in the output of the sun. Except for solar variation, each forced change entirely on a timescale. The magnitude and impact of the combination of these external forces have complicated the interpretation of the climate. The IPCC bar graph shows the estimated contributions of different radiative forcings to global warming for the year 2000, relative to 1750. The bar graph is divided into positive (warming) and negative (cooling) forcings. The uncertainties in the forcings are indicated by the error bars. The IPCC bar graph is based on Chapter 6, Figure 6.6 of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

Implications of Uncertainty

What would the skeptics say?

Forcing by current BC emissions from fossil fuels: high case divided by central case

Kyoto Protocol, 1997
What are we working on?

United Nations Framework Convention on Climate Change (UNFCCC, 1992)

“The ultimate objective of this Convention... is to achieve... stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.”

What can we address?

- CO₂
- CH₄
- N₂O
- Halocarbons
- Tropospheric ozone
- Stratospheric ozone
- Sulfate
- Black carbon from fossil fuel burning
- Organic carbon from fossil fuel burning
- Biomass burning
- Contrails
- Solar/Mineral Dust
- Aerosol indirect effect
- Land-use (albedo) only
- Aviation-induced Cirrus

Effects of Short-Lived Forcing Agents

Source: Nazarenko et al., "Efficacy of Climate Forcings", APCF workshop

Global climate

Typical (modeled) average global burden:
0.1 µg/m³ BC
(e.g. Cooke et al., 1999)

Regional climate

Typical concentrations, spring:
Fine particles – 10 µg/m³
BC
(ACE-Asia, INDOEX)

Photo: V. Ramanaiah
Local air quality

Typical concentrations, Beijing winter:
- 200 µg/m³ (PM2.5)
- 40 µg/m³ (carbonaceous)

(He et al., Atmos. Env. 2001)

Household energy

Typical (polluted) concentrations of suspended particulate matter:
- 1000+ µg/m³

~2 billion people worldwide cook with solid fuels & poor ventilation, resulting in ~4-5% of global "burden of disease" (K. Smith, 2000)

Regional climate

Surface cooled: -27 W/m²
Atmosphere heated: +20 W/m²
TOA cooled: -7 W/m²

Other ("indirect") effects

- Smaller cloud droplets
  (negative forcing or "Twomey effect")
- Increased cloud lifetimes
  (negative forcing, less rainfall)
- Cloud burnoff
  (positive forcing; Ackerman et al 2000)
- Rainfall shifts
  - (Sahelian drought? Rotstayn and Lohmann, 2002)
  - (Northward rain shift in China? Menon et al., 2002)

Don’t forget!!
Many of these effects are awaiting confirmation from observations!

Even if none of those are true...

+ In source regions, aerosol forcing is much larger than GHG forcing.
+ The sign of aerosol forcing depends on how much absorption (surrogate: BC) is present.

Let’s talk about...

+ Emissions vs effects
+ “Radiative forcing” = climate change?
+ Certainty vs uncertainty
**What's the flap?**

“Our analysis of climate forcings suggests, as a strategy to slow global warming, an alternative scenario focused on reducing non-CO$_2$ GHGs and black carbon (soot) aerosols...”

-- James Hansen et al, PNAS, 2000

“Black carbon may be the second most important component of global warming after CO$_2$ in terms of direct forcing.” -- Mark Jacobson, Nature, 2001

“Kyoto also failed to address two major pollutants that have an impact on warming, black soot and tropospheric ozone...”

-- President George W. Bush, June 11, 2001

**The “Hansen hypothesis”...**

Reduce the “easy” climate-forcing agents to slow warming

“Our analysis of climate forcings suggests, as a strategy to slow global warming, an alternative scenario focused on reducing non-CO$_2$ GHGs and black carbon (soot) aerosols....

“Reductions in tropospheric ozone and black carbon would not only improve local health and agricultural productivity but also benefit global climate and air quality.”

**...and arguments on either side**

**Against:**
- Could be used to procrastinate CO$_2$ reductions
- BC & CO$_2$ have dissimilar effects on climate system
- Impossible (and unethical?) to reduce BC alone

**For:**
- Broadens definition of anthropogenic climate change
- Significant ancillary benefits (health, regional AQ)
- Potential for hastening international accord

**Feasibility**

**Different pollutants, different sources**

<table>
<thead>
<tr>
<th>Emission estimates used in modeling for TRACE-P campaign</th>
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<td>Source: D. G. Streets, Argonne National Laboratories</td>
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**Ozone precursors**

Source: Jos Olivier, “Global emissions of ozone precursors”
Black carbon sources

Involves regulating small sources and informal sectors
Transaction costs high & economics of climate benefits questionable
Yet...
This transformation needs to happen!

To think about…
- What is anthropogenic climate change?
- What’s our duty to the present & future?
- Are there better & worse ways to fulfill the mandate of the UNFCCC?

“Superemitting” units & events

Single units: 0.2% of trucks emit 10% of the absorption (Seattle highway)
Single events: ~50% of absorption emitted during 6% of the observed time (oil boiler, Germany)

Photo: National Geographic