From Action to Forcing: A Solution-Centered View

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Air Pollution as a Climate Forcing: A Second Workshop
Honolulu, Hawaii
philosophy & approach

1. Request for an update
2. Path between action & forcing
3. Case study: black carbon
   - specific values
   - issues & thoughts
4. Here is the update!

We can estimate the climatic effects of individual actions.

Uncertainty limits conclusions. It doesn’t forbid them.

Introduction

We can estimate the climatic effects of individual actions.

Uncertainty limits conclusions. It doesn’t forbid them.
What questions are addressed by this famous chart?

- What changes have been imposed on the climate system?
- What species are primarily responsible?

1. request for an update
Forward-looking questions

- Every year, we commit to present and future changes in the climate. How much?
- We can choose among several mitigation options. Which are most promising?
- How can we credit the benefits of actions?

We are stuck with “abundance”… but we can change emissions.

Characterization examines species… but choices act on sources.

1. need for an update
"I think we can agree, the past is over..." – George W. Bush

What happened?
What molecules did it?

What can we do?
What are we choosing–this year? in future years?

Overdue for a partner!

1. request for an update
2. from action to impact
First try: Global warming
potential/commitment

2. from action to emission

\[ GWP_s = \int_0^T a_s r_s(t) dt / \int_0^T a_{CO2} r_{CO2}(t) dt \]

Forcing per mass

Amount of original emission remaining in atmosphere

Time frame (20-50-100 years)

Emission factor

Commitment per action
(kg fuel burned, km driven, etc)
Step 1: Emission Factors
Source: Literature survey of measured emission factors

Bond et al., “Technology-Based Inventory”, JGR 2004

Issues:
- Varies greatly among similar sources.
- Difficult to estimate result of average action.

Comment:
- Total emissions uncertain, but only emission rate needed for this purpose

BC emission factors for coal technologies (g/kg)

<table>
<thead>
<tr>
<th>Source</th>
<th>Emission Factor (g/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulverized+ESP</td>
<td>0.00001</td>
</tr>
<tr>
<td>Stoker+ESP</td>
<td>0.001</td>
</tr>
<tr>
<td>Stoker+cyclone</td>
<td>0.1</td>
</tr>
<tr>
<td>Coking, captured</td>
<td>10</td>
</tr>
<tr>
<td>Improved cookstove</td>
<td></td>
</tr>
<tr>
<td>Cooking fire</td>
<td></td>
</tr>
<tr>
<td>Coking, uncaptured</td>
<td></td>
</tr>
<tr>
<td>Heating stove</td>
<td></td>
</tr>
</tbody>
</table>

3. case study: BC
Step 2: Lifetime
Source: Compilation of model results

Issues:
Model removal processes not corroborated
Regionally specific

Comment:
Use of regionally-specific lifetimes politically feasible?

<table>
<thead>
<tr>
<th>Model</th>
<th>Lifetime (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haywood &amp; Ramaswamy, 1998</td>
<td></td>
</tr>
<tr>
<td>Myhre et al., 1998</td>
<td></td>
</tr>
<tr>
<td>Penner et al., 1998</td>
<td></td>
</tr>
<tr>
<td>Cooke et al., 1999</td>
<td></td>
</tr>
<tr>
<td>Jacobson, 2001</td>
<td></td>
</tr>
<tr>
<td>Koch, 2001</td>
<td></td>
</tr>
<tr>
<td>Chung &amp; Seinfeld, 2002</td>
<td></td>
</tr>
<tr>
<td>Wang, 2004</td>
<td></td>
</tr>
</tbody>
</table>

3. case study: BC
### Step 3: Normalized forcing

**Source:** Compilation of model results +

<table>
<thead>
<tr>
<th>BC forcing (W/m²)</th>
<th>Normalized DRF (W/g)</th>
<th>Ratio NDRF/SFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.4</td>
<td>1000</td>
<td>2</td>
</tr>
<tr>
<td>0.6</td>
<td>2000</td>
<td>4</td>
</tr>
<tr>
<td>0.8</td>
<td>coef. var: 32%</td>
<td>coef. var: 17%</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Normalized DRF (W/g)**

- **Haywood & Ram. 1998**
- **H&R, diff. radius**
- **Cooke 1999**
- **Myhre 1998**
- **Penner, 1998**
- **Jacobson**
- **Koch 2001**
- **Chung & Seinfeld 2002**
- **Wang 2004**

**3. case study: BC**
Step 3: Normalized forcing
Source: Model results + optics resolution

3. case study: BC

Issues:
Integrate optics over lifetime
Also regionally specific
May be source-specific

Normalized direct forcing
~1800 W/g

mass absorption cross-section
7.5 m²/g

coating impact
x1.5

Normalized/Fresh

Corrected
Combine, stir, mix well...

\[
GWP_s = \frac{\int_0^T a_s r_s(t) dt}{\int_0^T a_{CO2} r_{CO2}(t) dt}
\]

3. case study: BC

Sources of uncertainty in BC-GWP_{100}

- Optical properties-fresh
- Optical properties-coating
- Physical location - clouds
- Physical location - other
- Atmospheric lifetime

mass absorption cross-section

Normalized direct forcing

coating impact

Lifetime (model average)

5.5 days

direct global warming potential

\(~700\)

(240-1700)
Issues in the metric

- “Pulse” (GWP) vs. “sustained” (aGWP)
  - How much does it matter for short-lived species?
- What time horizon should we choose?
  - My opinion: (a) give options (20-50-100 years); (b) use discount rates (e.g. Lashof & Ahuja, 1990)
- “You can’t do that!”
  - “Yes, but…”

We can (and must) estimate the climatic effects of individual actions
Maximum possible consensus needed as roots for metrics!

3. case study: BC
Warning: straw man coming

Estimates for other species are not as strong
◊ Requesting help ↓
◊ Do not quote or otherwise propagate ↓

- Organic carbon:
  - Review models, identify critical climate-relevant properties, estimate emission rates of 4 types of OC (Haolin Sun, UIUC)
  - Problem: Secondary OC (not treated)
- Sulfate: Model review from IPCC TAR
  - inventory from Streets
- Methane, CO, NMVOCs
  - existing GWPs
  - inventory from EDGAR

4. here is the update!
The solution-centered bar chart
100-year time frame, pulse

“Commitment”=How much energy have we agreed, this year, to add to the system over the next 100 years?

4. here is the update!
The solution-centered bar chart
20-year time frame, pulse

4. here is the update!
We can estimate the climatic effects of individual actions... by using consensus values from published literature.

Uncertainty limits conclusions. It doesn’t forbid them... we can, and should, look at total effects of actions.

Will you help?

Questions??