A perspective on the requirements for
Emission Inventories of Short-Lived Climate Forcers
needed to assess human role and to project SLCFs
The step from human activities/ emissions to radiative forcing:

Emission ► Production/Loss ► Abundance/Burden ► RF

- All steps are diurnally, seasonally, geographically variant
- Many steps depend on local chemical-physical environment
- Many steps depend on co-emitted species
- Many steps are not linearly scalable
- No simple, fungible rate-of-exchange (like CO₂-eq for WMGHG)
This seminal paper by Oliver Wild demonstrated that:

1. location of emissions (latitude, altitude) and co-species emitted (CO, VOCs) changed the SLCF RF, and
2. emissions excite chemical modes, producing indirect effects across most SLCFs

0.5 Tg-N of NOx $\rightarrow$ short-lived trop-O$_3$ vs. long-lived CH$_4$ & O$_3$

The graph shows the RF from short-lived modes vs. RF from long-lived modes. The emissions from different sources (Europe, N Am., Industrial NO + CO, E Asia, Biomass, Surface NO, Tropics, Aircraft NO, Lightning NO) and their impact on cooling and warming are indicated.
This paper followed the O$_3$ caused by SLCF emissions for several E. Asian metropolitan regions, following the steps from the first slide and demonstrating how they can differ by day and type of pollution.

Altitude and amount of the O$_3$ increase depends on the meteorology of the day, and even the decay (lifetime) of O$_3$.

This paper followed the $O_3$ caused by SLCF emissions for several E. Asian metropolitan regions, following the steps from the first slide and demonstrating how they can differ by day and type of pollution. #2

<table>
<thead>
<tr>
<th>Region</th>
<th>NO$_x$, 10$^3$ kg N</th>
<th>CO, 10$^6$ kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing</td>
<td>730</td>
<td>19.5</td>
</tr>
<tr>
<td>Tokyo</td>
<td>780</td>
<td>4.3</td>
</tr>
<tr>
<td>Shanghai</td>
<td>720</td>
<td>21.1</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>730</td>
<td>17.2</td>
</tr>
</tbody>
</table>

The $O_3$ burden (closest to RF) is much larger.

Table 2. Ozone Production From 1 Day’s Emissions of Precursors in March 2001

<table>
<thead>
<tr>
<th>Region</th>
<th>Gross Production</th>
<th>Mean Burden</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Region, 10$^6$ kg</td>
<td>Globe, 10$^6$ kg</td>
</tr>
<tr>
<td>Beijing</td>
<td>2.4 ± 1.3</td>
<td>16.9 ± 2.6</td>
</tr>
<tr>
<td>Tokyo</td>
<td>3.6 ± 1.5</td>
<td>18.7 ± 2.3</td>
</tr>
<tr>
<td>Shanghai</td>
<td>8.8 ± 1.7</td>
<td>21.5 ± 1.8</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>9.9 ± 2.2</td>
<td>24.8 ± 3.8</td>
</tr>
</tbody>
</table>

Tokyo has much lower CO and VOC emissions.
RESOLUTION: As we move to higher resolution chemistry models we see incredible granularity in SLCF-critical chemistry, and this is also seen with the in situ observations. Below shows the fine-grain structure in column CH$_4$ loss by OH. We will need SLCF emissions inventory on the model grid.

Figure 1. (a) Column tropospheric loss frequency (1 yr$^{-1}$) for CH$_4$. 

from UCI 1º model

**RESOLUTION:** As we move to higher resolution chemistry models we see incredible granularity in SLCF-critical chemistry, and this is shown with mid-tropospheric \( \text{O}_3 \) below

Figure 2. **500 hPa** ozone distribution on August 1, 2013 at 0Z simulated by GEOS-5 with the GEOS-Chem chemical module at cubed-sphere C720 (\( \sim 12.5 \times 12.5 \text{km} \)) resolution
Intermediate modeling of SLCF emissions:
Even with <1° resolution, there will be a need to model the complex, non-linear processes that occur within fresh plumes.

Work by Chris Holmes shows the importance of plume models vs. instant dilution over the grid cell.

It also shows failings of previous plume models that calculated O$_3$ production and NOx loss, but NOT CH$_4$ loss.

LESSON: We will always develop more accurate models for the SLCF inventories. If you build it they will come!
Chemical feedbacks affect residence times and perturb other gases:

CO makes CH$_4$

A perturbation to CO alone, $\delta[\text{CO}]=1$, causes a significant perturbation to CH$_4$ that is “unmasked” in a few months:

$$\delta[\text{CO}](t) \approx + 0.005 e^{-t/13.6} + 0.995 e^{-t/0.285}$$

$$\delta[\text{CH}_4](t) \approx + 0.15 e^{-t/13.6} - 0.15 e^{-t/0.285}$$
Chemical feedbacks affect residence times and perturb other gases:

**N₂O destroys CH₄**

Due to interactions of N₂O with stratospheric O₃ chemistry, a relatively large **reduction in CH₄ (-3.6 ppb) is tied to an increase in N₂O (+10 ppb)** that decays with a 108-yr time scale.

*Thus N₂O’s climate impact through radiative forcing is reduced*:

(i) -8.4% because the decay of a pulse is faster than the e-fold of the steady-state lifetime and

(ii) a further -4.5% to account for the reduction in CH₄.
Some thoughts on SLCF inventories:

- Be consistent on co-emitted species
- Maintain full traceability, so that previous work can be adapted to new knowledge and so that the modeling/assessment community can scale by sectors/etc.
- Use as high resolution as possible, sometimes avoiding fixed regular-grid results that cannot be disaggregated.
- A full inventory of all species that the modeling community would ‘like’ is simply not practical, so keep track of key marker species by source-type of emission, allowing emission factors to be used by the models.