Vertical transport of surface fire emissions observed from space

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Motivation:

• The height of injection has implications for subsequent pollutant transport

• Complicated CFD problem

• We offer a new approach to estimate these heights using measurements of CO from space

Pyro-convective smoke plume observed at ~10 km over British Columbia, June 2004
We use CO as a tracer for incomplete combustion.

We use cloud-free data from two instruments aboard the NASA Aura spacecraft (left): Tropospheric Emission Spectrometer (TES) and Microwave Limb Sounder (MLS).

Over burning scenes, together they are sensitive to changes in CO from the lower troposphere to the lower stratosphere: we get about 2-3 pieces of information.
We extend the traditional surface flux estimation problem.

Both sides describe the sensitivity of the measured quantity $y$ to changes in surface emissions $e$:

$$\frac{\partial y}{\partial e} = \sum_{i} \frac{\partial m_i}{\partial e} \frac{\partial y}{\partial m_i}$$

$i = 1 \ldots 5$

$m_i =$ injected BB mass [kg CO]

We estimate emitted CO mass $m$ in five crude vertical state vector regions from 0–15 km.
Artificially inject mass into atmosphere over fires

- $2^\circ \times 2.5^\circ$ GEOS-Chem v7-04-10 driven by GEOS-4 meteorology
- 8 day GFED v2 BB CO emissions
- Fossil + biofuel emissions: standard GEOS-Chem inventory
- Prior BB mass injection in the tagged BB CO tracer

Injected mass % in vertical grid-boxes

- LS: 11-15 km
- FT: 8-11 km
- UFT: 5-8 km
- LFT: BL – 5 km
- BL: 0 – BL km
(Limited) evaluation of our product: Indonesia, October 2006

Definition injection height:
1) Posterior uncertainty is smaller than prior by 50%  
2) Posterior mass is higher than the prior mass  
33% pass this criterion; remaining 67% assume boundary layer injection
Gfedv2 CO [g CO/m²/JJASO]

2006 JJASO

1785 TES observations (672 colocated with MLS)

Statistics of injection heights
Disproportionate impact of large fires: $C_{ptb} - C_{ctrl}$

- **Tropics (0-30°S)**
  - JUN
  - AUG
  - OCT

- **Boreal (42-67°N)**
  - JUN
  - AUG
  - OCT

Longitude [deg]
Concluding remarks

- Inferred injection heights agree with GFED BB emissions within 10%.
- Injections above the boundary layer are relatively rare (~20%) but result in disproportionate perturbations.
- Case studies of injection heights over Siberia (July 2006) and over Indonesia (October 2006) agree well with independent observations.