Investigating Biomass Burning Aerosol in North America

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Inventories represent fire emissions differently with different outcomes.

**Bottom up inventories:** GFED4s and FINNv1.5

\[ M_S = E F_S \times \gamma \times \rho_f \times A \]

- Mass species emitted (g)
- Emissions factor (g species/kg DM)
- Combustion completeness (%)
- Fuel load (g DM/m²)
- Burned area (m²)

**FRP-based inventories:** QFEDv2.4 and GFASv1.2

\[ M_S = E F_S \times \alpha \times F R E = E F_S \times \alpha \times \int_{t_1}^{t_2} F R P (t) \, dt \]

- Mass species emitted (g)
- Emissions factor (g species/kg DM)
- Emissions coefficient (kg DM/J)
- Fire radiative energy (J)
- Fire radiative power (J/s)

Satellite-observations
Lab studies
Other

Most model studies don’t test air quality and radiative uncertainty associated with fire emissions.
Range of total annual emissions from 2004-2014

Different trends between species and significant variability across years.

Black Carbon (Tg yr\(^{-1}\))

Organic Carbon (Tg yr\(^{-1}\))
Interannual variability decreases for all except QFED, which is also significantly larger.
Range of total annual emissions from 2004-2014

Average emissions over large regions differ significantly between inventories.
Total annual dry matter from 2004-2014
Total annual dry matter from 2004-2014

Differences between emission inventories are largely driven by underlying dry matter.
Comparing model simulations with boreal ARCTAS and DC3 observations

Boreal ARCTAS
Top 25th percentile CH$_3$CN

Significant variability across inventories with QFED generally biased high and FINN low
Comparing model simulations with boreal ARCTAS and DC3 observations

Significant variability across inventories with QFED generally biased high and FINN low
How does emissions uncertainty impact air quality estimates?

Large differences in fire PM2.5 in western Canada and PNW consistent with emissions.
Range in regional TOA DRE from inventories consistent with emissions and prior analysis
Range in global OA TOA DRE from inventories is ~ equivalent to aerosol DRF

For comparison: global Direct Radiative Forcing (IPCC 2013): -0.35 W/m²
Conclusions

- GFED, FINN, QFED, and GFAS perform differently depending on species (BC and OA) and location with large ranges in North America.
- Underlying emission factors are important, but the dominant cause of differences between inventories is dry matter burned.
- Over North America, model simulations with GFED and GFAS are close to observations with QFED generally biased high and FINN low.
- Including more SOA from fires improves model-observation agreement in some regions, not in others.
- Air quality and climate studies should consider and assess fire uncertainties.

[Carter et al., in prep]
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Questions
Additional slides
Fire injection importance

Injection height complicated and typical approaches put too much aerosol at top of BL (~2km)

Fischer et al. 2014
Is larger source of fire secondary organic aerosol possible?

New fire SOA source possible in SE US, not reasonable in boreal Canada.
How well do models capture spatial AOD observed by MODIS?

GFED and GFAS AOD do a better job matching MODIS AOD than FINN AOD with QFED AOD variable across years.
Testing model against IMPROVE observations of surface OA concentrations

Significant variability across inventories with QFED generally biased high and FINN low

- **GFED**
  - $R^2 = 0.20$
  - OC emissions = 0.23 Tg yr$^{-1}$

- **QFED**
  - $R^2 = 0.25$
  - OC emissions = 1.01 Tg yr$^{-1}$

- **FINN**
  - $R^2 = 0.021$
  - OC emissions = 0.21 Tg yr$^{-1}$

- **GFAS**
  - $R^2 = 0.30$
  - OC emissions = 0.46 Tg yr$^{-1}$

**Fire season (May – Sep) 2012**
ARCTAS and DC3 campaign observations against model aloft concentrations

Significant variability across inventories with QFED generally biased high and FINN low.
Range in seasonal emissions ~ comparable to earlier uncertainties

Differences in inventories hint at underlying methodologies
CO annual totals follow similar trends to organic carbon.
Other large biomass burning regions

Show large, but different, differences among inventories
Inventories with GFED EFs applied do not fully collapse

Thus underlying dry matter consumed is primary uncertainty driver

Grey rectangle marks 2012 – the focus of our subsequent analysis

$$M_S = EF_s \times \gamma \times \rho_f \times A$$

Bottom-up

$$M_S = EF_s \times \alpha \times FRE$$

FRP-based

Thus underlying dry matter consumed is primary uncertainty driver