Optimizing Boreal Wildfire Emissions of CO: Comparison of the Assimilation of MOPITT and IASI CO Observations

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Abstract

Boreal wildfires present a major perturbation to atmospheric composition of the Northern Hemisphere. Wildfire emissions inventories are derived from bottom-up or top-down methods, both of which are dependent on experimentally derived quantities, parametizations and assumptions. As a result, these inventories are prone to uncertainties which are regionally dependent. In this work, we evaluate the ability of the data assimilation of MOPITT and IASI CO observations to constrain boreal wildfire emissions using a case study of the exceptional 2017 Canadian Wildfires [1].

GEOS-Chem Adjoint Model

- CO-only simulation based on forward model v8-02-01.
- GEOS-FP met fields at 4°×5° resolution with 47-levels.
- EDGAR global anthropogenic emissions with regional inventories.
- **GFAS v1.2** global biomass burning emissions [2].
- TransCom prescribed OH fields [3].

GEOS-FP - Goddard Earth Observing System Forward Processing, **GFAS** - Global Fire Assimilation System, **EDGAR** - Emissions Database for Global Atmospheric Research, **TransCom** - Chemistry-Transport Model Inter-comparison.

Satellite Observations

MOPITT - Measurement of Pollution in the Troposphere
- Launched in 1999 aboard the Aura satellite.
- CO measurements since 2000.
- Joint near- and thermal-infrared retrieval (NIR-TIR v8).
- 25×25 km horizontal footprint.
- Global coverage ∼3 days.
- Morning overpass at 10:30 local time.

IASI - Infrared Atmospheric Sounding Interferometer
- Launched in 2006 aboard the MetOp-A satellite.
- CO measurements since 2008.
- Thermal infrared retrieval (v20140922).
- ∼12 km circular footprint at nadir.
- Morning overpass at 9:30 local time.

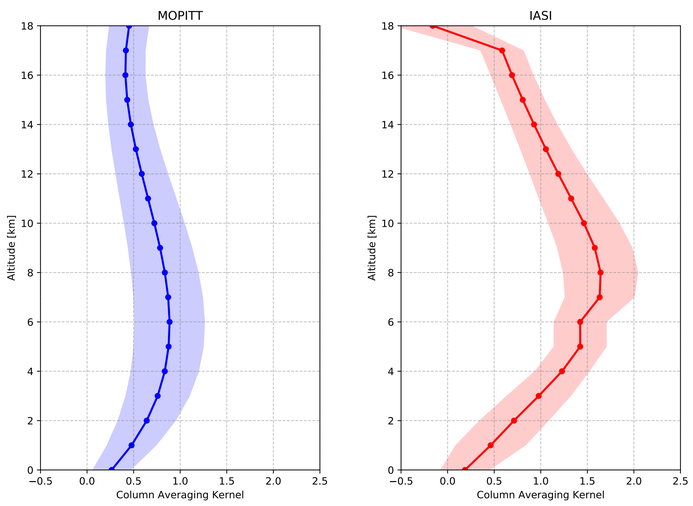

Figure 1: 2017 global mean MOPITT and IASI total column averaging kernels. The shaded region represents the 1σ deviation from the mean.

4D-Var Assimilation Scheme

Optimize emissions of CO by the minimization of the cost function:

$$J(\mathbf{x}) = \sum_{i=1}^{N} \left[\mathbf{F}_i(\mathbf{x}) - \mathbf{z}_i\right]^T \mathbf{S}_\Sigma^{-1} \left[\mathbf{F}_i(\mathbf{x}) - \mathbf{z}_i\right] + \left[\mathbf{x} - \mathbf{x}_a\right]^T \mathbf{S}_a^{-1} \left[\mathbf{x} - \mathbf{x}_a\right] \quad (1)$$

- J - cost function
- $\mathbf{F}$ - forward model (GEOS-Chem)
- $\mathbf{x}$ - state vector (CO emissions)
- $\mathbf{z}$ - observation state vector (MOPITT or IASI CO total columns)
- $\mathbf{S}_\Sigma$ - measurement error covariance (uniform, 20%)
- $\mathbf{x}_a$ - a priori (prior CO emissions inventories)
- $\mathbf{S}_a$ - a priori covariance (uniform, 50%)
- N - number of observations

CO Observations

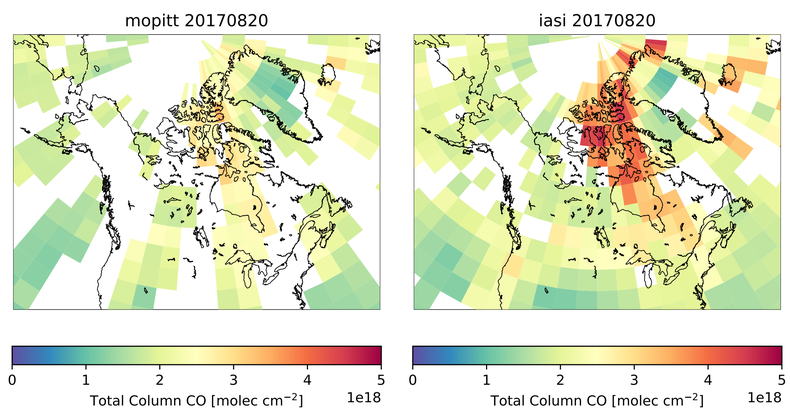

Figure 2: MOPITT and IASI total column CO for 20 August 2017 gridded and averaged onto the GEOS-Chem grid.

A Posteriori CO Emissions

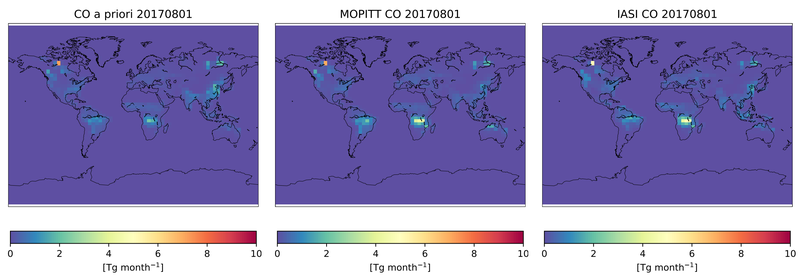

Figure 3: A priori and a posteriori CO emissions from the MOPITT and IASI assimilations for August 2017.

Table 1: A posteriori emissions for global anthropegenic and biomass burning sources. Regional a posteriori emissions for North American anthropogenic and boreal biomass burning sources are also shown.

	August 2017			
CO Emissions [Tg/month]	Global Antrho.	Global B.B.	N.A. Anthro.	Boreal N.A. B.B.
a priori	42.6	53.6	5.5	14.2
MOPITT	36.7	73.3	5.8	14.4
IASI	42.9	70.7	6.6	11.3

Optimized CO State

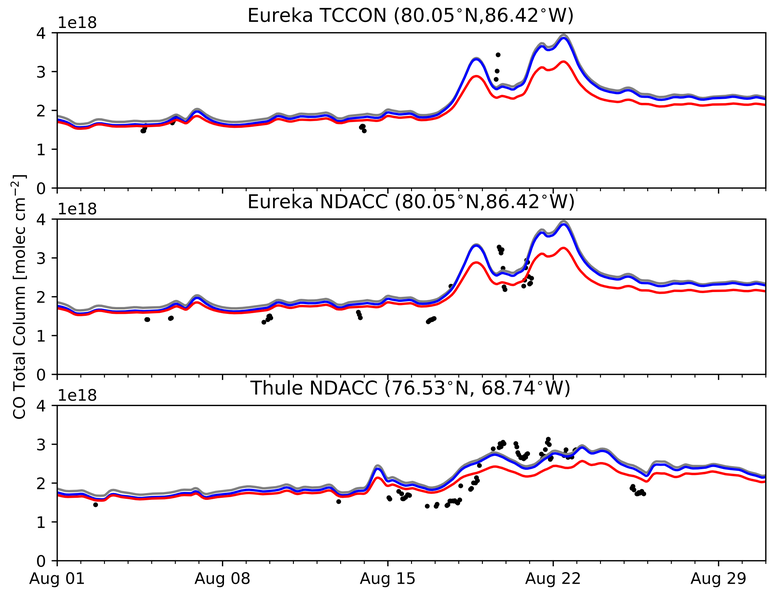

Figure 4: A priori (gray), MOPITT (blue) and IASI (red) a posteriori CO total columns for August 2017. Hourly-mean FTIR measurement are shown in black.

In all cases, GEOS-Chem underestimates CO in the wildfire plume:
- Wildfire emissions unchanged in MOPITT assimilation.
- Wildfire emissions reduced in IASI assimilation.

Summary

- GEOS-Chem underestimates magnitude of wildfire emissions transported to the Arctic.
- MOPITT insensitive to boreal wildfire emissions.
- IASI assimilation decreases boreal wildfire emissions.
- Both MOPITT and IASI assimilations increase North American anthropogenic emissions:
  - Increase in anthropogenic emissions inconsistent with past studies [4].
  - Suggests both assimilations cannot distinguish between boreal wildfire emissions and anthropogenic sources.

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