

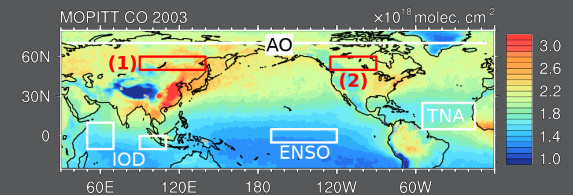
Chemistry-Climate Links for Carbon Monoxide in Northern Hemisphere Boreal Fire Regions and an Assessment of Global Fire Inventories

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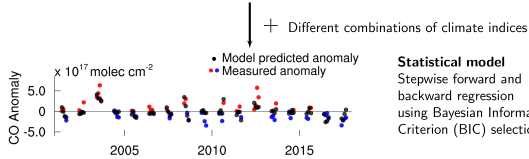
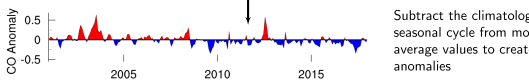
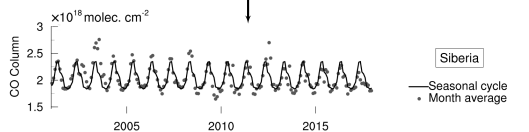
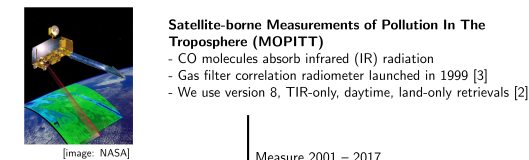
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Introduction

Fire emissions are a major contributor to atmospheric composition, affecting the atmospheric oxidizing capacity and air quality. Transported amounts from Northern Hemisphere boreal fires can reach the pristine Arctic atmosphere as well as impact air quality in populated regions. Carbon monoxide (CO) is a useful trace gas emitted from fires that can be used to link extreme fire events with climate variability. The magnitude of fire emissions, such as CO, is connected to climate through both the availability and dryness of fuel. We use our recently developed statistical tool [1, 6] to investigate the climate drivers of satellite measured CO variability in two Northern Hemisphere boreal fire regions: Siberia (1) and Northwest Canada (2).

Methodology: Interannual variability analysis



For a given region

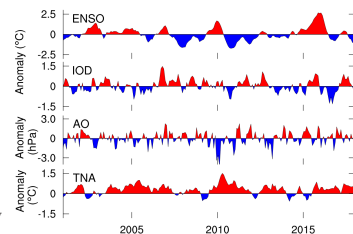
$$CO(t) = \text{constant} + \sum_{n=1}^4 a_n \cdot \chi_n(t - \text{lag}_n) + \sum_{i,j} b_{ij} \cdot \chi_i(t - \text{lag}_i) \cdot \chi_j(t - \text{lag}_j)$$

χ are climate indices; a_n , b_{ij} are coefficients; lag is 2 to 11 months for each index.

Climate mode indices

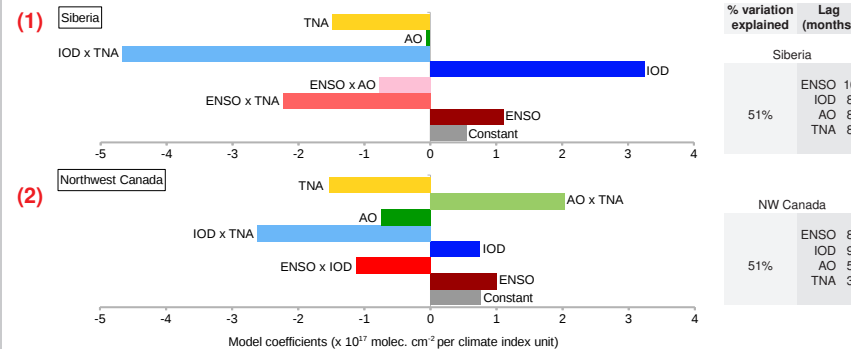
Climate modes of interest are:

- El Niño Southern Oscillation (ENSO) - NINO 3.4, monthly ERSSTv4
- Indian Ocean Dipole (IOD) - Dipole Mode Index
- Arctic Oscillation (AO)
- Tropical North Atlantic (TNA)



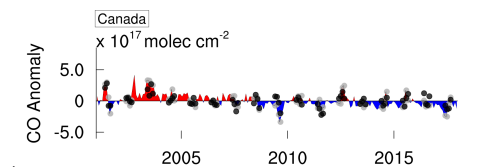
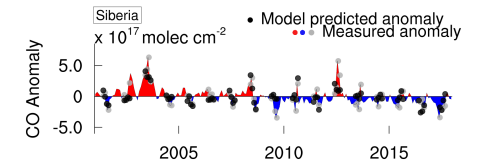
Sources: www.cpc.ncep.noaa.gov; stateoftheocean.osmc.noaa.gov

Statistical models with best predictive power



Larger coefficients suggest that IOD impact is stronger in Siberia than Canada. Siberian emissions are transported to Canada, and the variability pattern is consequently transported as well.

These Northern Hemisphere regions show longer lags between climate modes and CO variability than was found in the Southern Hemisphere [1]. This is supported by longer ENSO lags to fire emissions at high northern latitudes from Monks et al, 2012 [5].



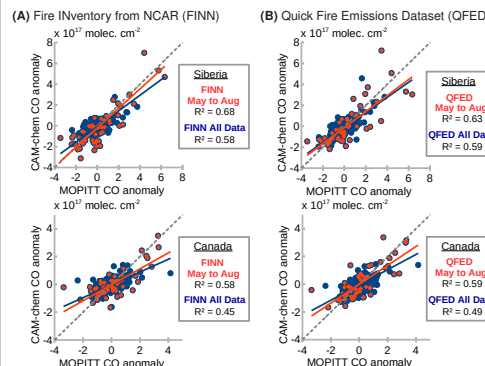
All climate modes are required to explain CO variability and first-order interaction terms are needed for both regions.

Chemistry-climate simulations

CAM6-chem within the Community Earth-System Model (CESM 2) framework [4]

Resolution 1.25° longitude x 0.95° latitude, 56 levels (~40 km model top)
Years Run 2002-2015, both with ~1 year spin-up
Nudged to NASA MERRA2 reanalysis at ~10% relaxation
Fire Emissions (A) FINN version 1.5
 (B) QFED CO₂ × FINN emission factors
Other Emissions Anthropogenic and Ocean: CMIP6, Biogenic: online MEGAN
Chemistry 170 species, with over 400 reactions
Tagging Source and sectors based on HTAP Tier 1 regions (<http://www.htap.org/>).

CAM-chem CO anomalies versus MOPITT CO anomalies



Modeled match measured CO anomalies better in Siberia than Canada. FINN produced slightly better correlations than QFED in Siberia for May to August, suggesting better representation of local fire emission variability.

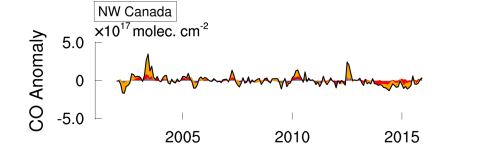
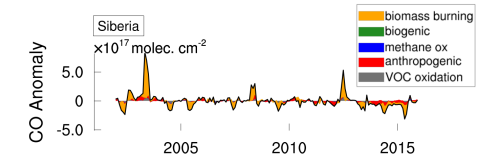
Modeled interannual variability in CO

(A) - CAM-chem with FINN v1.5

Major contributions to simulated CO anomalies (2002-2015)

Source Type	Siberia	NW Canada
Biomass Burning (BB)	48%	45%
Boreal Asia	39%	17%
Boreal N. America	-1%	8%
Temperate N. America	-1%	3%
Asia	1%	8%
Anthropogenic	35%	32%
VOC oxidation	5%	12%

- The most contribution to CO variability in Canada and Siberia is from fire.
- Siberian fire impacts Canada CO via transported primary emissions as well as VOC oxidation in the aged plume.
- Anthropogenic variability is also important.



Summary

- Climate modes are useful for describing atmospheric CO variability.
- CAM-chem modeling helps explain the source contributions, and highlights the importance of fire for these regions.
- The missing variability in the empirical model could be due to Anthropogenic sources, supported by CAM-chem results.
- Fire inventories perform differently depending on region.
- Future work:** Include an anthropogenic index; Include Madden-Julian Oscillation climate mode; De-trend dataset prior to anomaly analysis; Add Global Fire Assimilation System (GFAS) to inventory analysis.

References

- Buchholz, R. R. et al., (2018), *J. Geophys. Res.-Atmos.*, 123, 9786–9800
- Deeter, M. N. et al., (2019), *TBD* (in prep).
- Drummond, J. R. et al., (1996), *J. Atmos. Oceanic Technol.*, 2, 314–320
- Lamarque, J.-F. et al., (2012), *Geosci. Model Dev.*, 5, 369–411
- Monks, S. A. et al., (2012), *Geophys. Res. Lett.*, 9, L14804
- Simonsen, P. (2018), www.mathworks.com/matlabcentral/fileexchange/68319-southern-hemisphere-carbon-monoxide-modeling

Acknowledgements

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