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Latitudinal and Seasonal Distribution of Hydroxyl Radical Concentrations Constrained by Satellite Carbon Monoxide Observations

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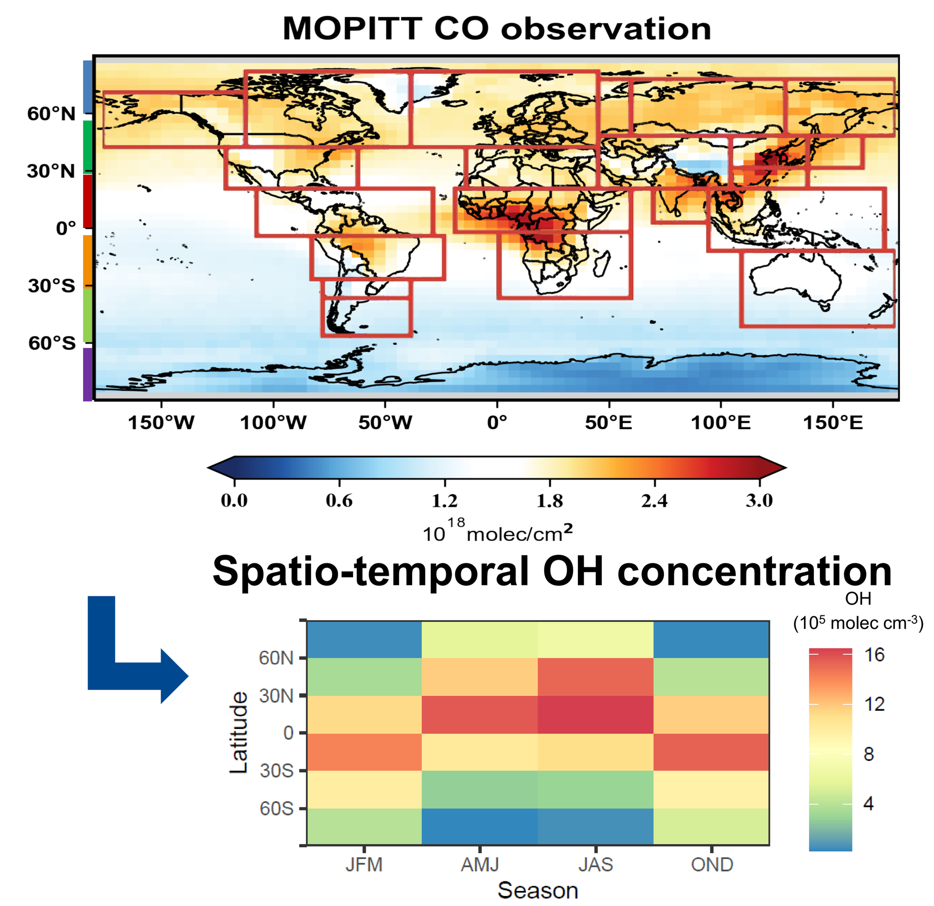
Primary Findings

- Build an algorithm to retrieve OH concentrations jointly with CO sources using satellite CO observations
- Take advantage of (1) distinct spatial signatures of CO sources and OH and (2) good global coverage of satellite observations
- Have the potential to provide constraints on the latitudinal and seasonal distributions
- Application of the method (see GC21G-0996: "Explore the driver for reduced atmospheric oxidation and extreme methane growth in 2020")



Analysis of the CO Budget

n_{CO}: CO concentration   Transport   Generalized source & sink

$$\frac{dn_{CO}}{dt} = -\nabla\cdot(n_{CO}\boldsymbol{u}) + \tilde{E} - \tilde{L} + \text{minor terms}$$

Production from reactive VOCs   OH oxidation   Production from CH_4

$$\approx -\nabla\boldsymbol{u}\cdot n_{CO} + E + \sum_i \gamma_i E_i - (k_{CO}n_{CO} - k_{CH_4}n_{CH_4})n_{OH}$$

Direct emissions

n_{CO} and n_{CH_4} are given by observations

Global atmospheric CO sources

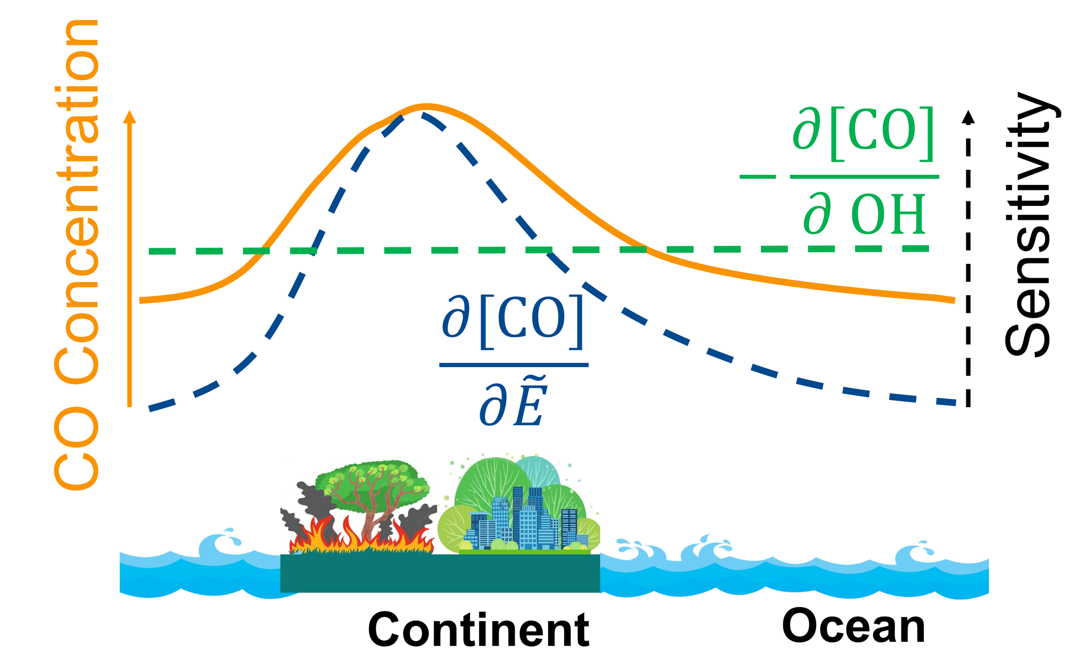
CO sources	Anthropogenic	Wildfire	NMVOC+OH	CH_4+OH
	505 [436-618]	332 [274-387]	651 [501-782]	854 [763-981]
Group by primary or secondary	Primary Emissions		Secondary Formation	
	837 [727-1005]		1505 [1332-1734]	
Group by atmospheric signature	Continent ($\tilde{E}$)			Latitude-band
	1488 [1231-1787]			854 [763-981]

- $\tilde{E}$ is OH independent and $\tilde{L}$ is OH dependent
- Spatial signatures of $\tilde{E}$ and $\tilde{L}$ are distinct
- Satellite observations provides global coverage

→ Inference of OH based on CO satellite observations

Conceptual Framework & Algorithm

Conceptual framework by considering a latitude band



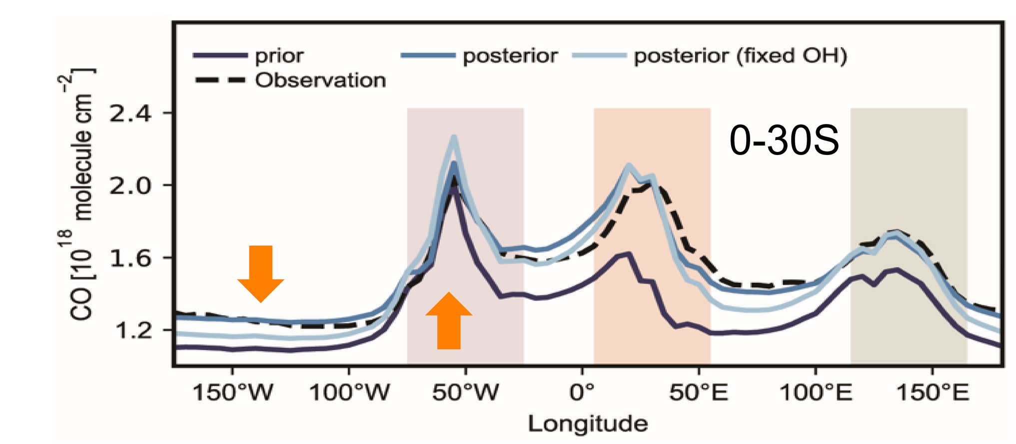
- Signature of $\tilde{E}$ ($\frac{\partial[CO]}{\partial\tilde{E}}$) is **high over continents** and **low over ocean**
- Signature of $\tilde{L}$ ($\frac{\partial[CO]}{\partial OH}$) is **uniform across the latitude band**
- $\tilde{E}$ and OH are separable (solvable) given observed CO distributions

$$\text{observations}\quad [CO] = [CO]_0 + \frac{\partial[CO]}{\partial\tilde{E}}\Delta\tilde{E} + \frac{\partial[CO]}{\partial[OH]}\Delta OH + \cdots$$

Initial guess from CTM; Continental-scale source; Latitude-band average OH; Contribution of other bands

Bayesian Optimization Procedure

- **State vector**: $\tilde{E}$ from 21 sub-continents, seasonal OH for 6 latitude bands (30°)
- **Temporal window:** Seasonal
- **Forward model:** GEOS-Chem CO-only



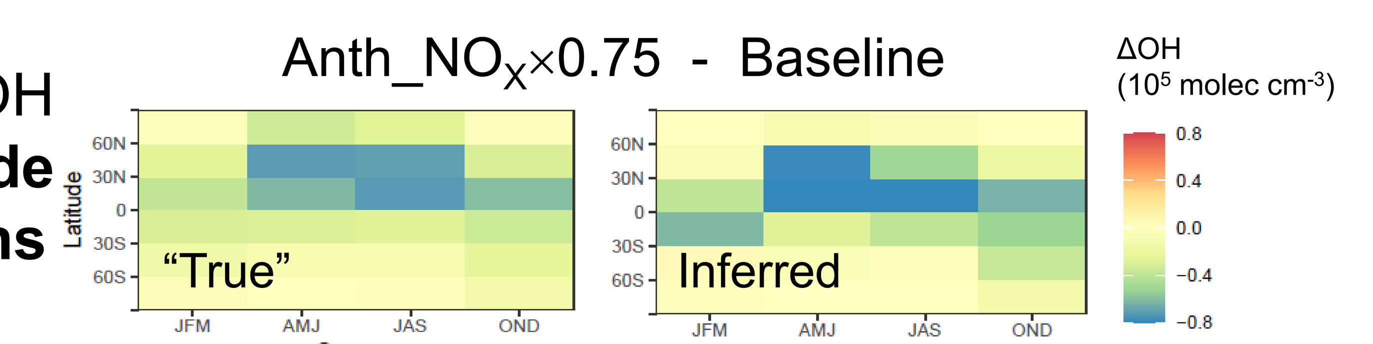
Observing System Simulation Experiment (OSSE)

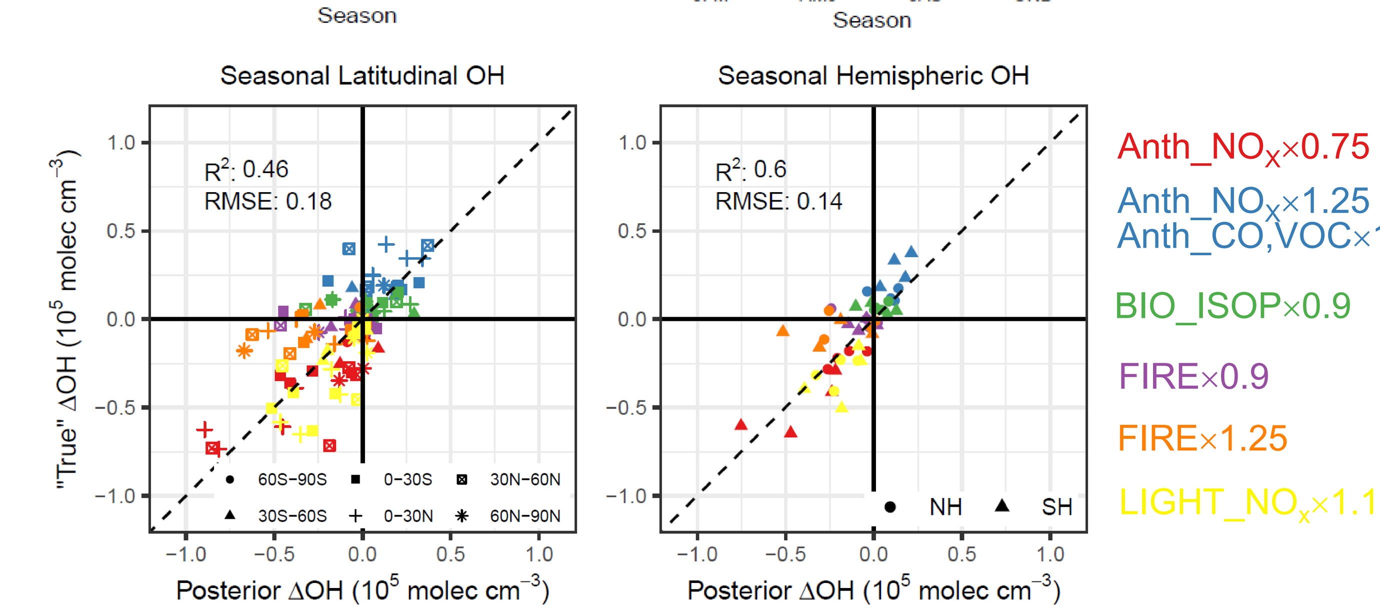
OSSE configuration

- ☐ Test if this algorithm captures OH **seasonal** changes in **latitude bands** due to **varied perturbations**

	"True"	Inversion
Simulation mode	Full-chem	CO-only
Meteorology	MERRA-2	GEOS-FP
OH field[4]	Online	Prescribe field
Anthrop. Emis.	CEDS	EDGAR v4.3.2
Fire emissions	GFED 4s	GFAS
NMVOC prod	Online	Instant production

OSSE results





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