Investigating air quality in Southeast Asia using the GEOS-Chem atmospheric chemistry transport model and Earth Observation datasets: Preliminary results

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Research objectives

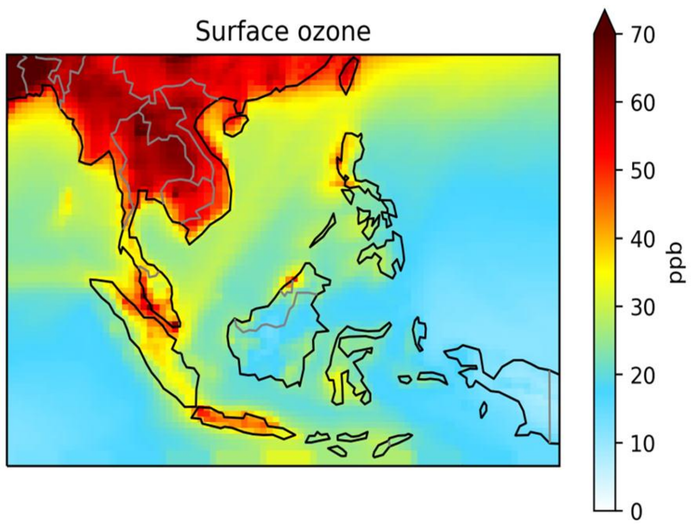
1. Simulate air quality in SE Asia using a chemical transport model
2. Leverage model tools to analyze the processes that impact air quality
3. Evaluate model results using ground, *in situ*, and Earth Observation data

Background and motivation

- In Southeast (SE) Asia, emissions of gases from nature and human activity sustain high concentrations of hazardous air pollutants such as ozone (O_3)
- Air quality in this region has worsened in recent years, and is projected to continue to worsen, with rising emissions of pollutant precursors (Koplitz et al., 2016)

Average surface ozone mixing ratios from GEOS-Chem for January – June 2016 approach **70 ppb*** across the mainland and in several cities of SE Asia

*2% increased risk of mortality compared to background ozone levels (Bell et al., 2006)



- We simulate air quality in SE Asia using the nested GEOS-Chem atmospheric chemistry transport model and present a critical evaluation of simulated ozone using data from the Ozone Monitoring Instrument (OMI) aboard the NASA Aura spacecraft

Methods

Chemical transport model

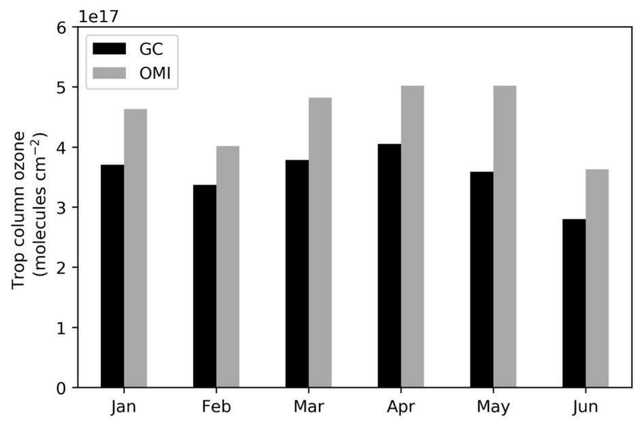
GEOS-Chem v12.2.1
- Full chemistry simulation
- Nested Asia (AS) domain
- Horizontal resolution: 0.5° × 0.625°
- Vertical resolution: 47 levels
- Sampled daily at satellite overpass
- January – June 2016

Tropospheric ozone data

OMI L3 fv0300 xc01
- As retrieved by NCEO RAL
- Global daily coverage
- Horizontal resolution: 1.5° × 1.5°
- Vertical resolution: 19 levels
- Overpass at 13:30 local time
- Available from 2004

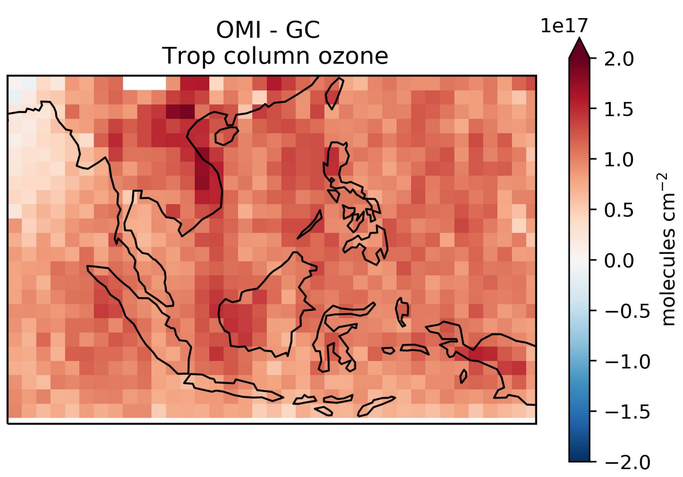
How well does GEOS-Chem simulate ozone in SE Asia?

We evaluate tropospheric column ozone (surface – 450 hPa) from GEOS-Chem against OMI data, with the following adjustments:
- Sampling the model at the Aura overpass time
- Scene-dependent instrument averaging kernels applied to model columns
- A sonde-derived bias correction applied to OMI observations
- Grid cells ignored where monthly mean cloud fraction > 0.3



Tropospheric column ozone over SE Asia is consistently underestimated in GEOS-Chem by at least **20%**

Bias in the GEOS-Chem tropospheric ozone column is consistent across the model domain



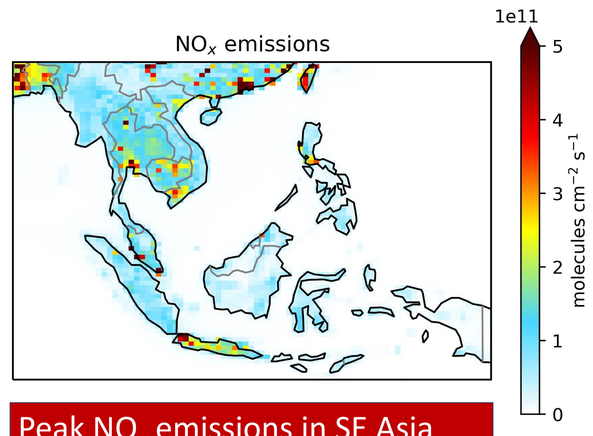
Why does GEOS-Chem underestimate ozone in SE Asia?

Surface ozone is produced through the oxidation of volatile organic compounds (VOC) in the presence of NO_x (= NO + NO_2):

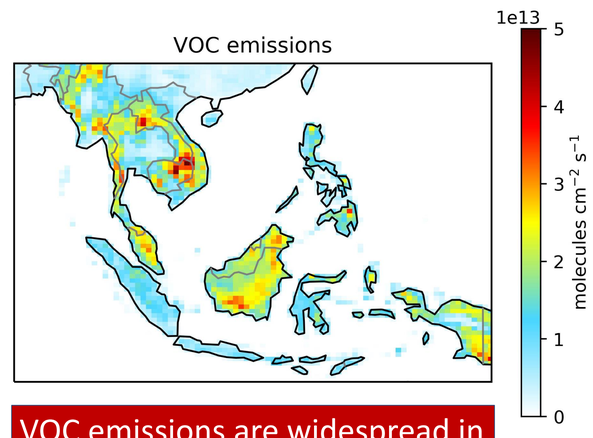
$$\mathbf{VOC} \xrightarrow{OH} \mathbf{HO_2},\ \mathbf{RO_2} \xrightarrow{NO} \mathbf{NO_2} \xrightarrow{h\nu} \mathbf{O_3}$$

Ozone precursor emissions

Molecules of NO_x and VOC are emitted directly into the atmosphere from a combination of **anthropogenic**, **biogenic**, and **pyrogenic** sources:



Peak NO_x emissions in SE Asia tend to occur near cities and regions of biomass burning



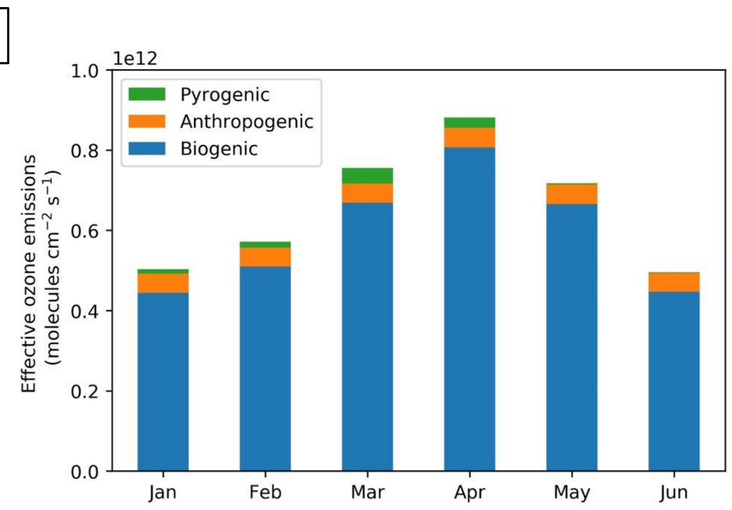
VOC emissions are widespread in SE Asia and tend to reflect natural vegetation patterns

Ozone source apportionment

Each species of VOC has a unique ozone formation potential, which we represent here using an effective ozone emission rate (E_{O3}*):

$$E_{O3}^* = E_{VOC} \times MIR_{VOC} \times \alpha_{NO}$$

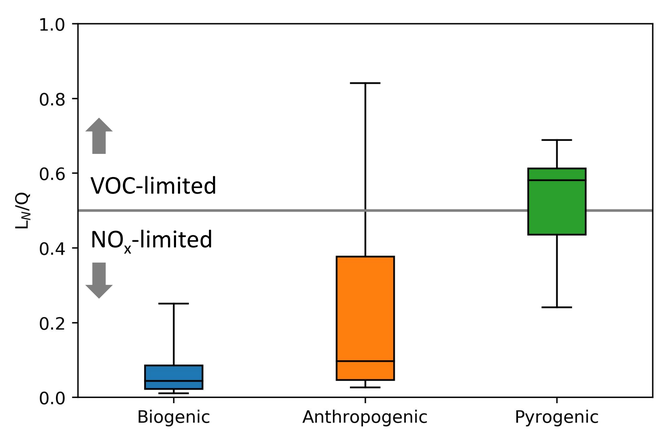
E_{O3}*: Effective ozone emissions (molecule cm^{-2} s^{-1})
E_{VOC}: VOC emissions (molecule cm^{-2} s^{-1})
MIR: Maximum incremental reactivity (Carter, 1994)
α_{NO}: Branching ratio for the reaction of HO_2 or RO_2 with NO (Wolfe et al., 2016)



Biogenic sources dominate the capacity of emitted VOC to produce ozone in SE Asia

Ozone production regimes

Radical termination dictates the dependence of ozone production on emissions of NO_x and VOC, which we investigate here using the ratio of NO_x radical loss to total radical loss (L_N/Q) (Kleinman et al., 2001) :



- Ozone production in SE Asia is primarily **NO_x-limited**
- Surface ozone control strategies should prioritize reductions in NO_x emissions
- Bias in modeled ozone is likely due to underestimated emissions of NO_x

Next steps

- Re-run GEOS-Chem on a 0.25° × 0.3125° nested grid
- Extend simulation timeframe to include all years from 2014 to present
- Compare GEOS-Chem with Earth Observations of other chemical species related to air quality such as CO, HCHO, NO_2, and AOD

References

Bell et al., *Environ. Health Perspect.*, 2006; Carter, *J. Air Waste Manage.*, 1994.
Kleinman et al., *Geophys. Res. Lett.*, 2001; Koplitz et al., *Environ. Sci. Technol.*, 2017.
Wolfe et al., *Atmos. Chem. Phys.*, 2016.

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