Evaluating GEOS-Chem Performance on Ozone & VOCs in Salt Lake City at 12 km Resolution

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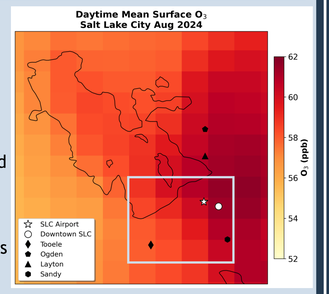
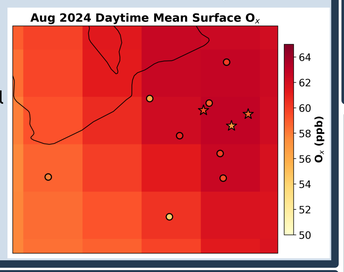
Background & Model Configuration

- Salt Lake City, Utah has consistently remained a non-attainment zone of the EPA's ozone (O_3) standards
- Persistent summer air quality challenges have motivated multiple observational campaigns, including SAMOZA (2022), SLC-SOS (2024 & 2026) & USOS (2024)
- SLC has unique industrial sources combined with complex physical dynamics from the mountain topography & lake breeze
- The chemical & physical processes of SLC are not well understood, posing challenges for ozone mitigation and emissions regulations
- This study aims to evaluate the efficacy of high-resolution modeling in capturing urban emissions and photochemistry at a city scale

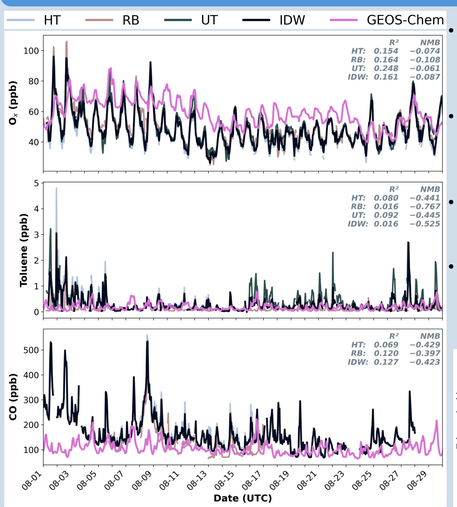


Methods

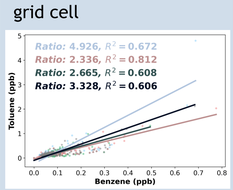
- Data: SLC-SOS & USOS 2024 campaigns & the EPA AQS for August 2024
  GC-MS: Hydrocarbon VOCs PTR-MS: OVOCs Picarro: CO & HCHO
- Model: nested-grid GEOS-Chem Classic v14.7.0 Fullchem simulation (0.125°x 0.15625°) with 47 levels
- Nested Domain: [35°N, 45°N] [125°W, 100°W]
- Meteorology field: GEOS-FP
- Anthropogenic Emissions: CEDS for global spin-up, NEI2017 scaled to 2024 for nested grid
- Biogenic Emissions: MEGAN v2.1
- Biomass Burning: GFAS v2018-09
- The map on the right shows that the model's bias for O_x (O_3 + NO_2) in the city is an average of +6.3%



SLC is too Heterogeneous for 12 km



- Three MS sites in one cell
  - HT (near urban center)
  - UT (near airport)
  - RB (next to mountain)
- Varied emission sources result in the grid cell covering a large range of chemical environments
- Using observations from one site is not an accurate evaluation of the model
- Ex) the toluene/benzene ratio varies by over 2x across sites in the same grid cell



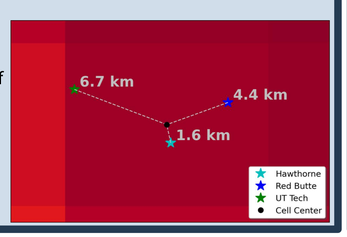
Inverse Distance Weighting

$$c_{IDW} = \frac{\sum_{i=1}^{n} \frac{c_i}{d_i}}{\sum_{i=1}^{n} \frac{1}{d_i}}$$

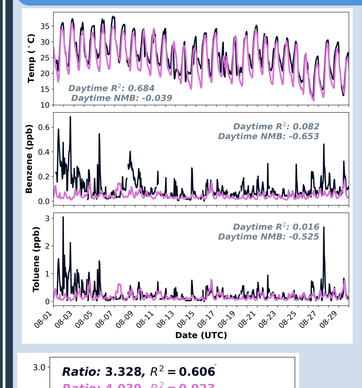
c = concentration at site

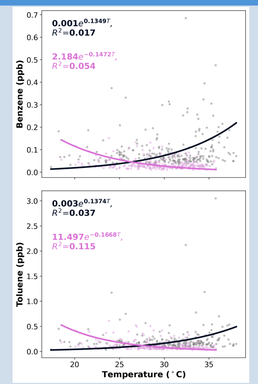
d = distance to center of cell

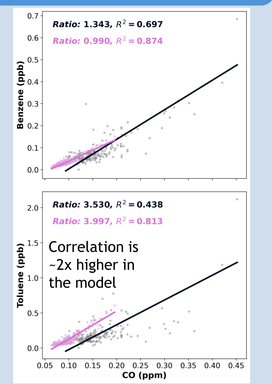
- The IDW method allows approximation of observed concentrations at the center of the grid cell using an average weighted by distance
- The efficacy of this approach differs across species, particularly those with specific source sectors

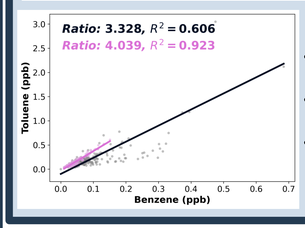


AVOC Ratios are Better Constrained than Magnitudes



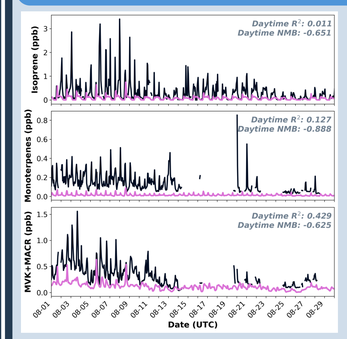


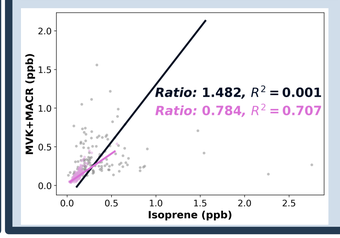


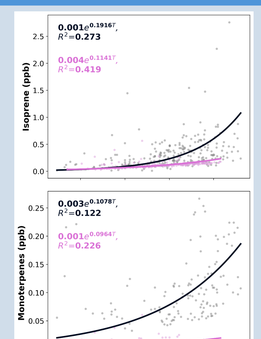


- Relative proportions of anthropogenic VOCs (AVOCs) are better represented in the model than the mixing ratios
- No AVOC was strongly related to temperature, though the range for this period was narrow
- Toluene's obs. correlation to combustion tracers (CO) is lower; model likely misses other emission sources, like solvents, further indicated by the lower obs. toluene/benzene ratio

GEOS-Chem Struggles to Model Urban BVOC Patterns

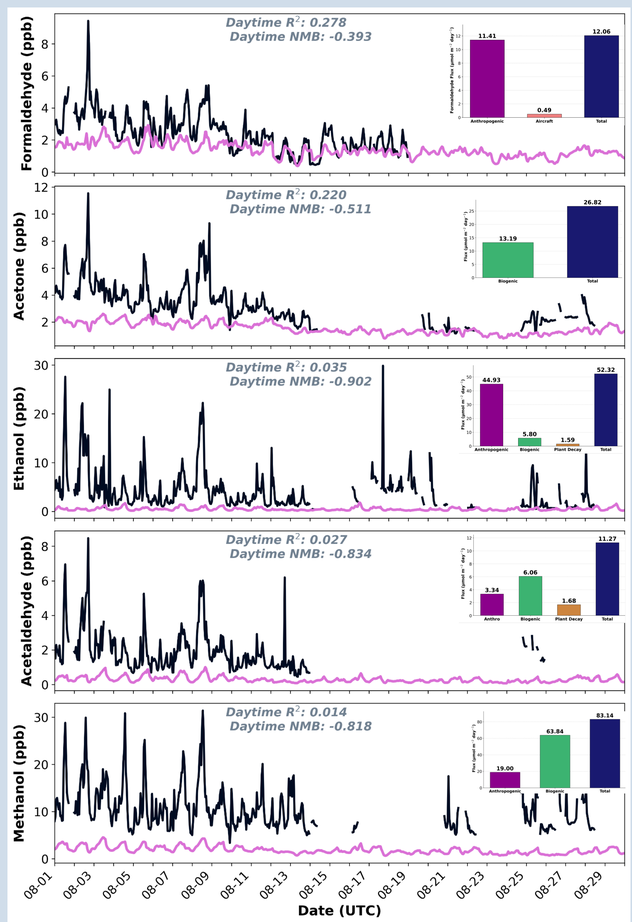


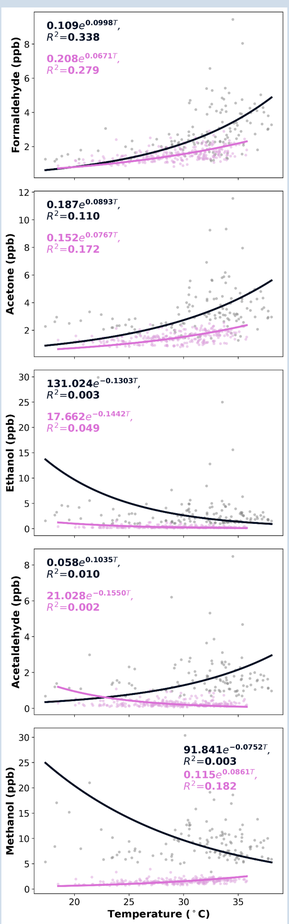


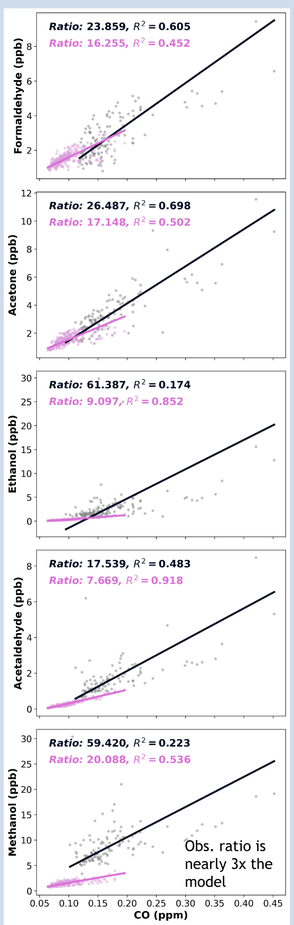


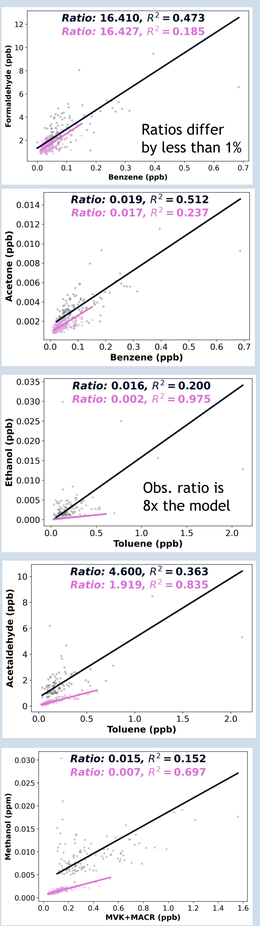
- The model underestimates all biogenic tracers by more than 50%, though it is better at representing isoprene oxidation products (MVK/MACR) than isoprene itself
- The afternoon spike in isoprene is missed by the model, likely reflecting local transport patterns not captured by GEOS-FP at 12 km
- Obs. isoprene and monoterpenes show an exponential increase with air temperature, reflecting strong urban biogenic influence
- The differences in modeled temperature dependencies of biogenic tracers likely reflect that MEGAN v2.1 misrepresents urban vegetation emissions
- Discrepancies in isoprene likely result from the IDW method combining heavily biogenic sites, like RB, with heavily anthropogenic sites

GEOS-Chem Fails to Capture the Complexity of OVOC Sources & Relationships









- **Formaldehyde**
  - Strong exponential temperature dependence & correlation with combustion tracers suggest both anthropogenic & biogenic influence
  - The model shows a weaker correlation to combustion tracers, indicating a missing primary or secondary source that is of anthropogenic origin
- **Acetone**
  - Assumed to be emitted equally anthropogenically & biogenically
  - Higher obs. correlation to combustion sources indicates anthropogenic emissions are underestimated
  - Not shown, but model is overpredicting correlation to secondary BVOCs
- **Ethanol**
  - Low temperature correlation suggests heavy anthropogenic influence, but obs. shows little correlation to AVOCs
  - Not shown, but higher obs. relationship to acetone indicates solvent use
- **Acetaldehyde**
  - Model predicts higher relationship with AVOCs than obs.
  - Mild obs. temperature dependence might indicate more biogenic influence than the model predicts
- **Methanol**
  - No strong temperature dependence, so underestimation is likely from missing anthropogenic sources
  - Strong overprediction in relationship with secondary BVOCs in model