Can spatial properties of atmospheric CO_2 be used to verify realistic sectoral emissions trends and spatial shifts?

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Summary of methods

- We focused on the Northwestern United States, a region that has experienced substantial decreases in power plant emissions since the early 2000s.
- Sector-specific emissions, biogenic fluxes, and advected CO_2 were propagated through an atmospheric model as tagged tracers (Figure 1).
- Gridded simulated atmospheric CO_2 was averaged by month and spatially processed using a high-pass spatial filter to minimize the influence of background CO_2 and isolate the signal associated with local sectoral emissions hotspots.
- The contribution of individual tracers to the temporal trends in the processed CO_2 signals associated with emissions hotspots was examined (Figure 1).
- Specifically, we tested whether trends in sectoral emissions hotspots could be inferred from total CO_2 before and after spatial processing under this "best case scenario" of perfect knowledge of atmospheric CO_2.

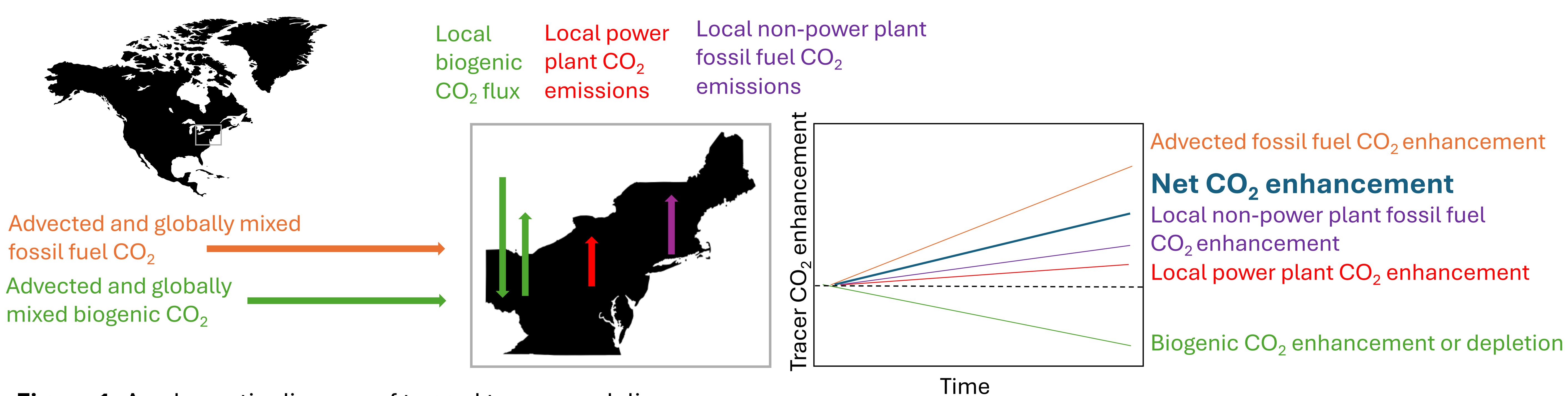

Figure 1: A schematic diagram of tagged tracer modeling

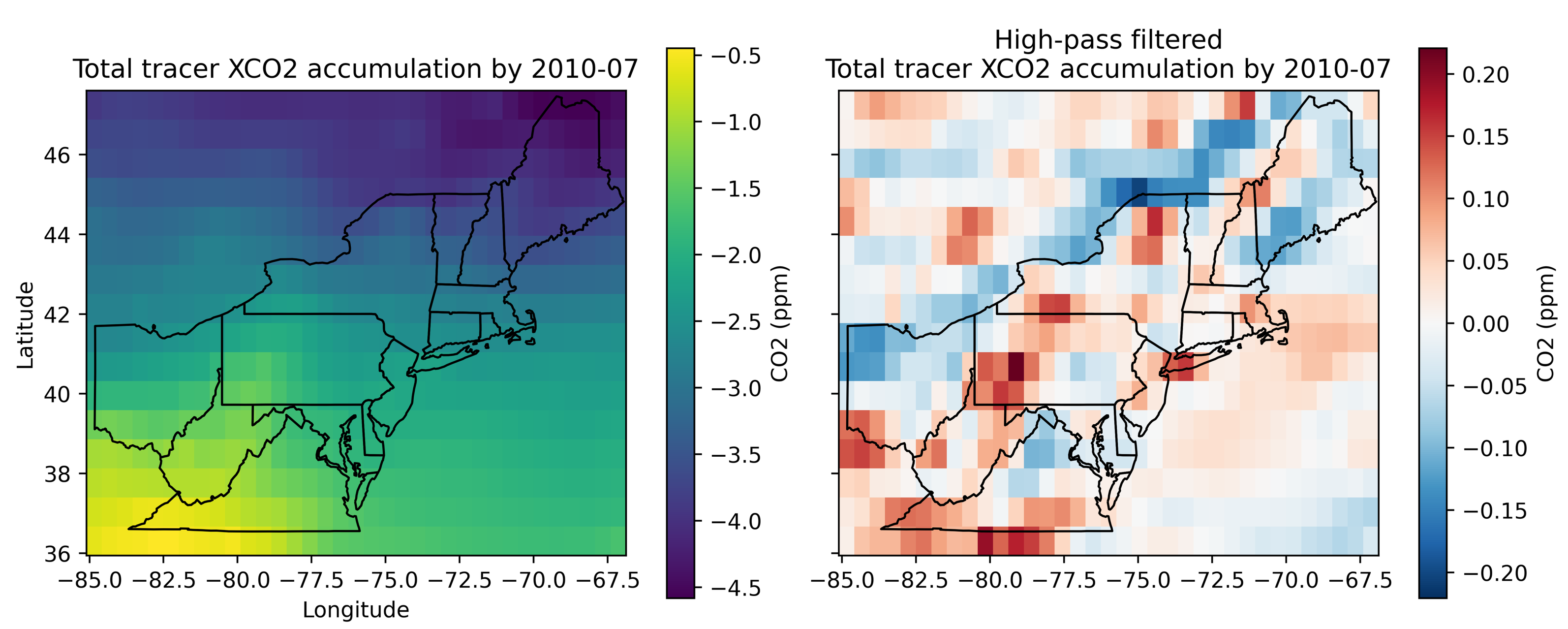

Figure 3: By July of the second year of the simulation, the accumulation of CO_2 tracers shows a spatial pattern in total column CO_2 dominated by a global latitudinal gradient (left panel), but a high-pass filter can identify more local variability (right panel).

Results

- Areas within the study region experienced particularly dramatic decreases in power plant emissions (Figure 2).
- While patterns of overall CO_2 tracer accumulation are unsurprisingly dominated by global influences (Figure 3, left panel), applying a high-pass spatial filter to time-averaged column CO_2 or surface CO_2 maps before a time series analysis allows the identification of local spatial variability (Figure 3, right panel) and local sectoral emissions trends relative to adjacent areas and background (Figure 4).
- However, for total column CO_2 (Figure 4, left panel), the signal may be too small to be detectable via remote sensing, even under a scenario of perfect spatial and temporal coverage of observations; under a realistic observation scenario of spatially and temporally sparse observations, the influence of transport variability and instrument uncertainty and drift would further obscure the signal.

Implications

- In order for these methods to be used to detect even large emissions trends and spatial shifts, we would need:
  - Temporally dense observations taken over a long time period
  - Spatially dense observations across regions of interest
- Emerging instruments may help to meet these requirements.
- Even with improved remote observational systems, extensive surface observations may be necessary to detect emissions trends and spatial shifts.
- As we decarbonize other sectors that do not have extensive bottom-up emissions data, these observational questions will become important for the verification of the mitigation of emissions from particular jurisdictional areas.

Data and model

- Emissions and fluxes
  - Energy Information Administration (EIA) unit-level fuel consumption and emissions factors for power plants within study region (Figure 2)
  - EDGAR fossil fuel emissions for other sectors and global emissions
  - CASA biosphere fluxes with land sink adjustment
- GEOS model atmospheric circulation
- High-pass Gaussian filter over monthly average maps of column CO_2 and near-surface CO_2 to isolate local influence

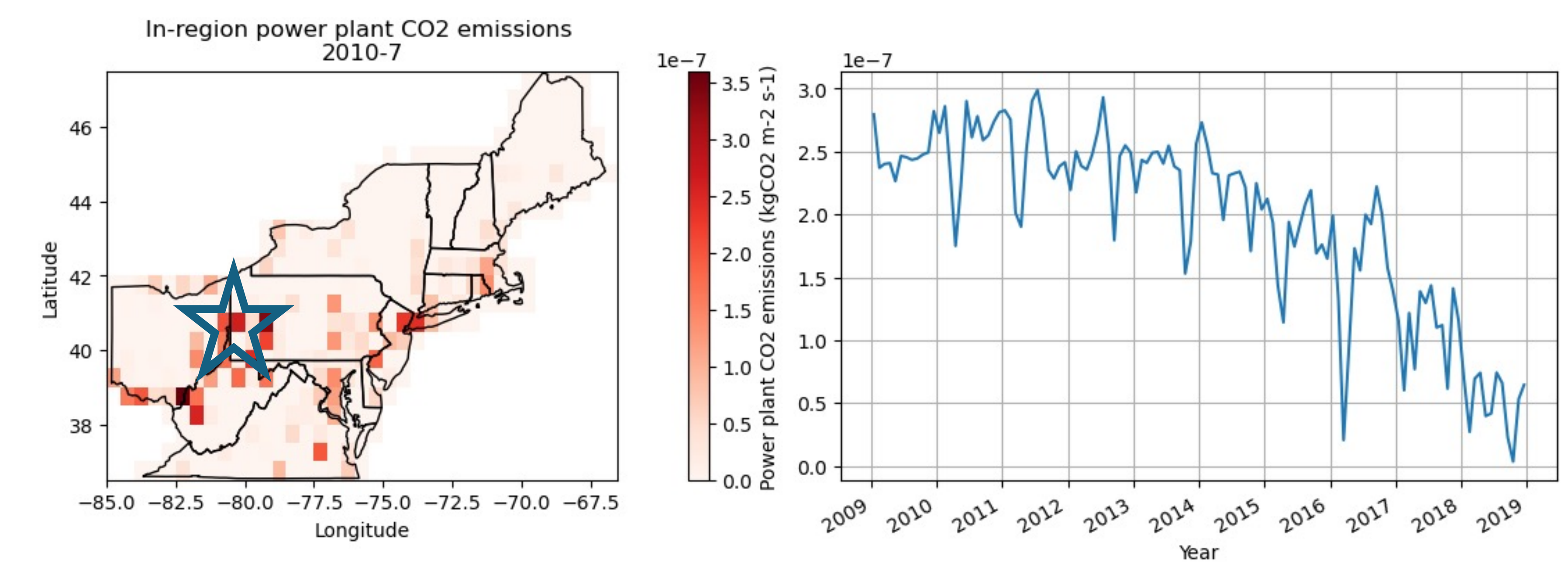

Figure 2: Power plant CO_2 emissions in the region, mapped in the left panel for July of the second year of the simulation, show dramatic decreases across the study period in key areas. In the right panel, we see one such decrease in the grid cell that is highlighted by the star in the left panel.

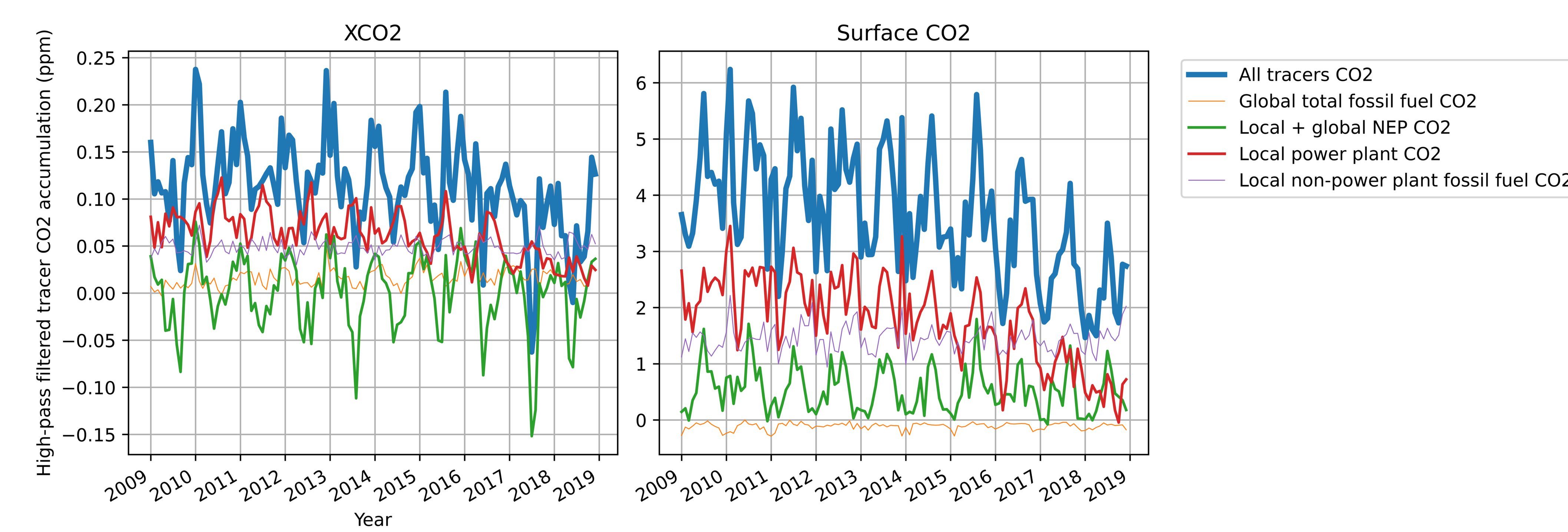

Figure 4: For both total column CO_2 (left panel) and near-surface CO_2 (right panel) in the grid cell highlighted in Figure 2, the trend in local CO2 total tracer enhancement relative to background, as identified from the high-pass spatial filter, is dominated by local power plant CO_2. However, the total column CO_2 trend is less than a tenth of a part per million over the study period.

Ongoing work

- Maps of total column CO_2 and surface CO_2 trend magnitude and statistical significance for individual tracers, summed tracers, and total CO_2
  - Identification potential covariances between tracers' trends
  - Quantification of noise
- Simulation of more realistic observations

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