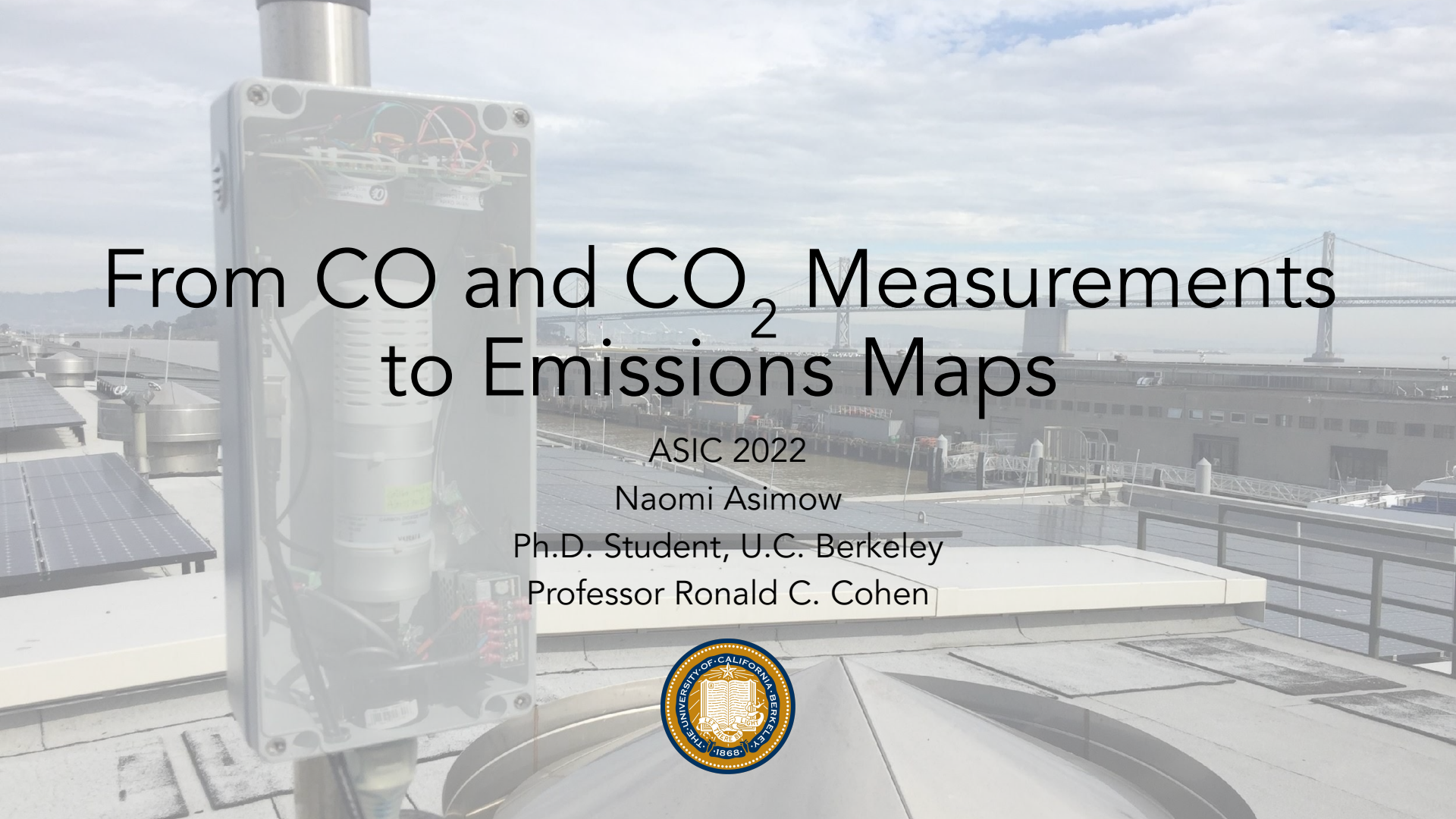


From CO and CO_2 Measurements to Emissions Maps

ASIC 2022

Naomi Asimow
Ph.D. Student, U.C. Berkeley
Professor Ronald C. Cohen

Urban Emissions & Action Plans

Boston Requires Carbon Neutrality for Existing Buildings

LA City Council Considers Motion To Achieve Carbon Neutrality By 2030

The City of Ithaca voted to decarbonize every single building, becomes first city in the country to do so

Manchester plans for carbon neutral transport network

But how do cities know if their policies are working?

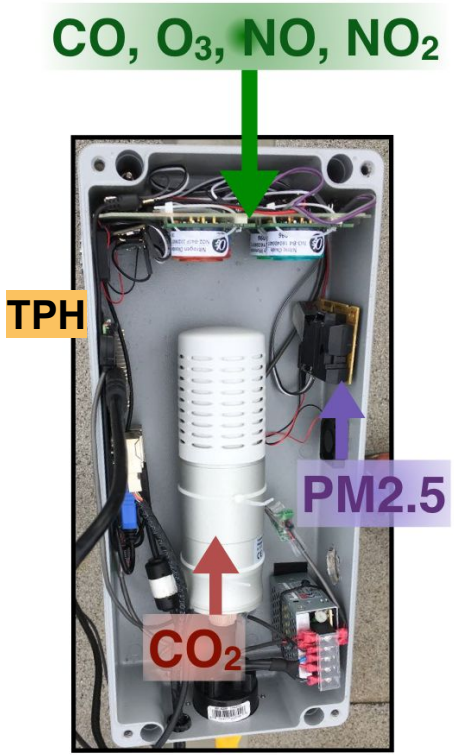
Bottom-Up

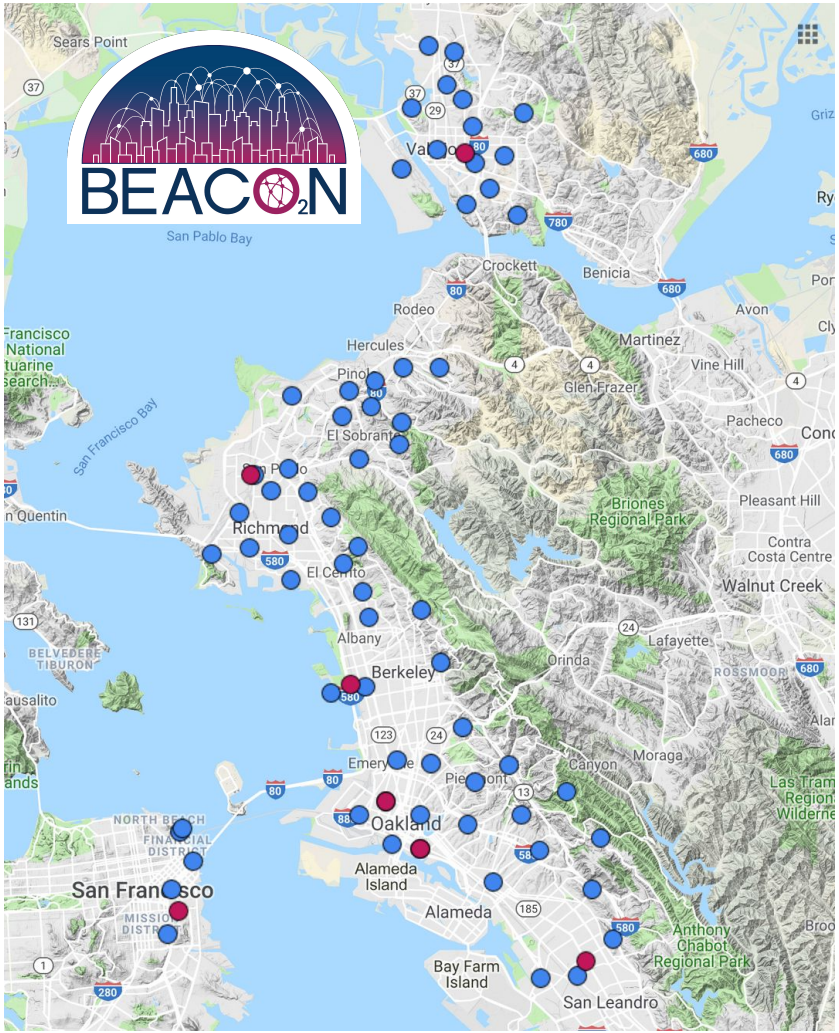
What activities release CO_2, how much, and where?

Top-Down

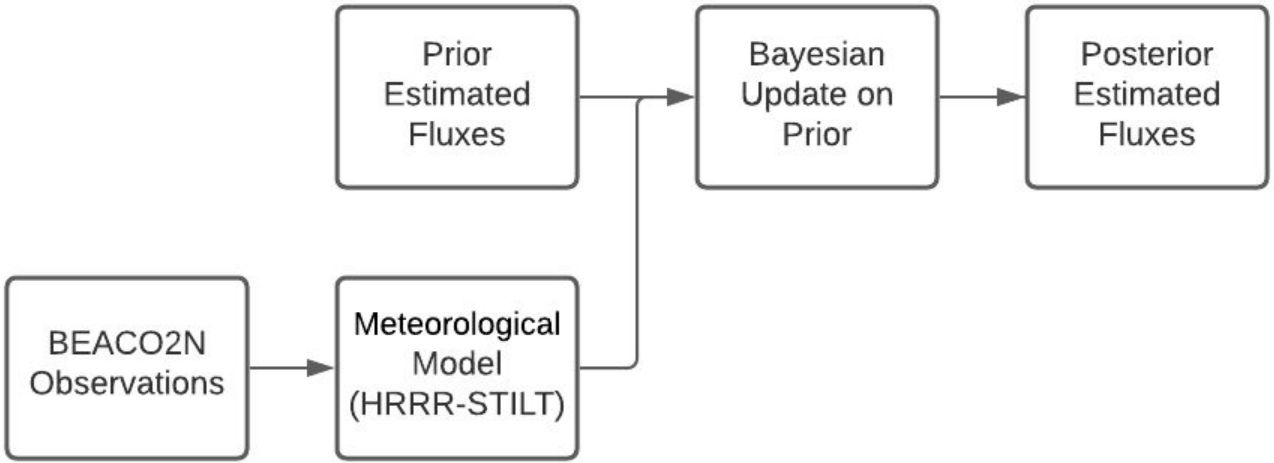
How much CO_2 is in the air and where did it come from?

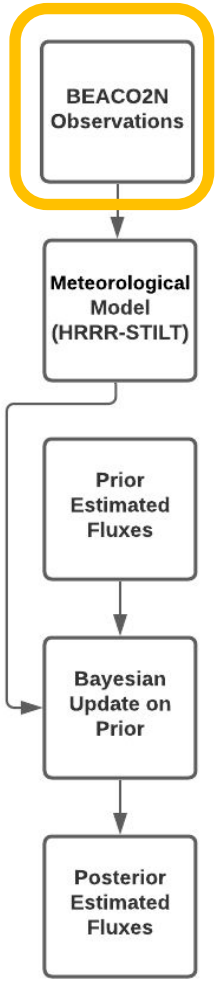
Berkeley Environmental Air-quality and CO_2 Network



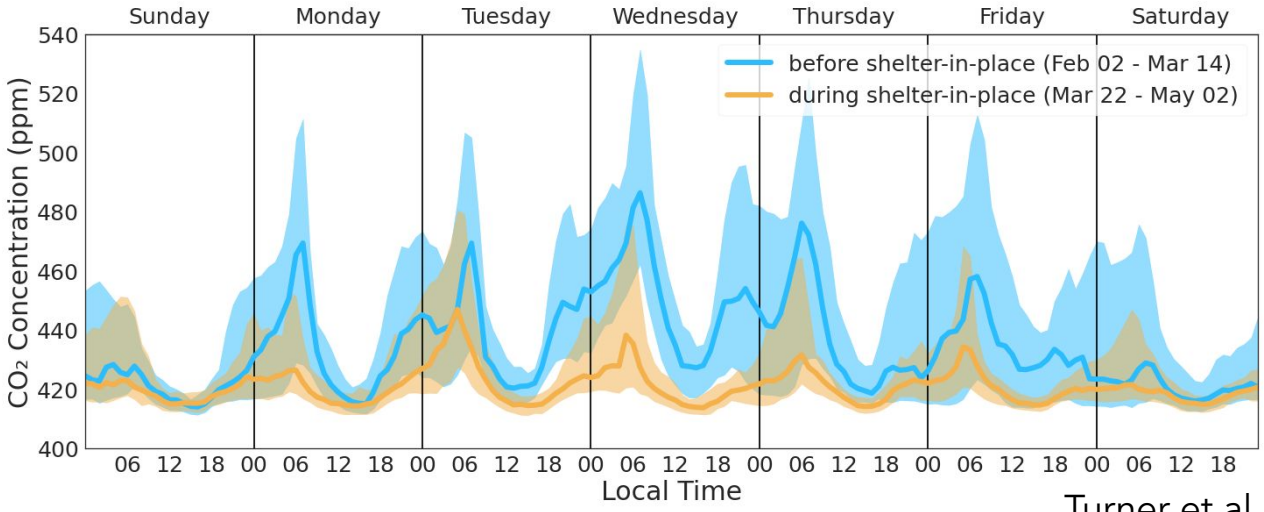


What can we say about changes in CO and CO_2 emissions from our BEACO$_2$N observations?



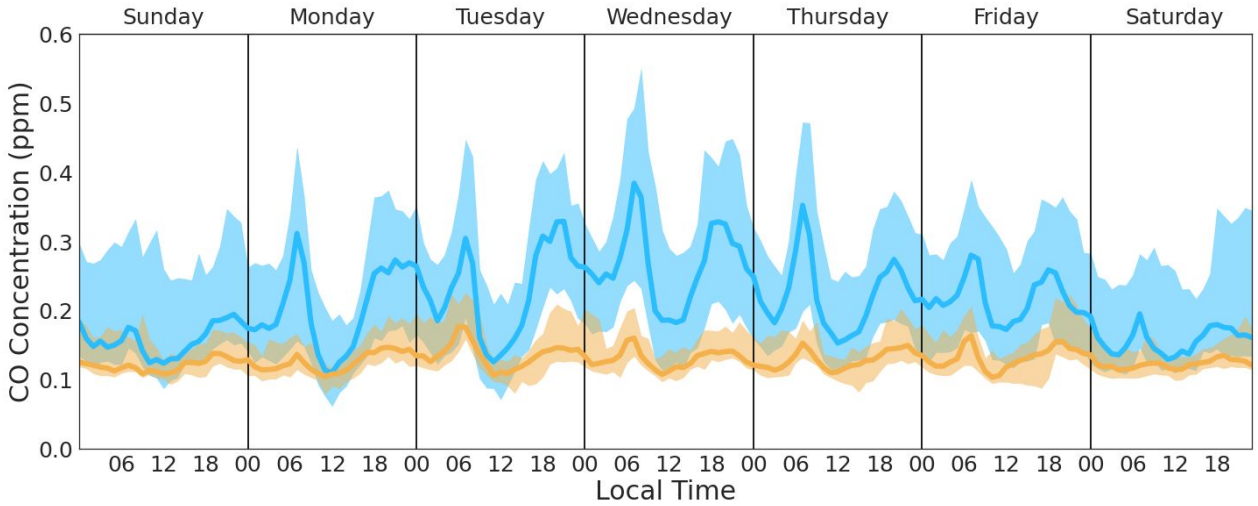


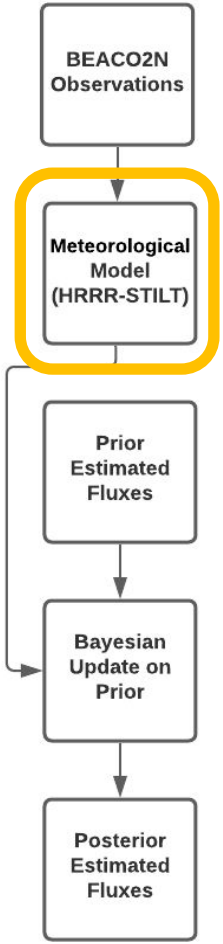
CO_2



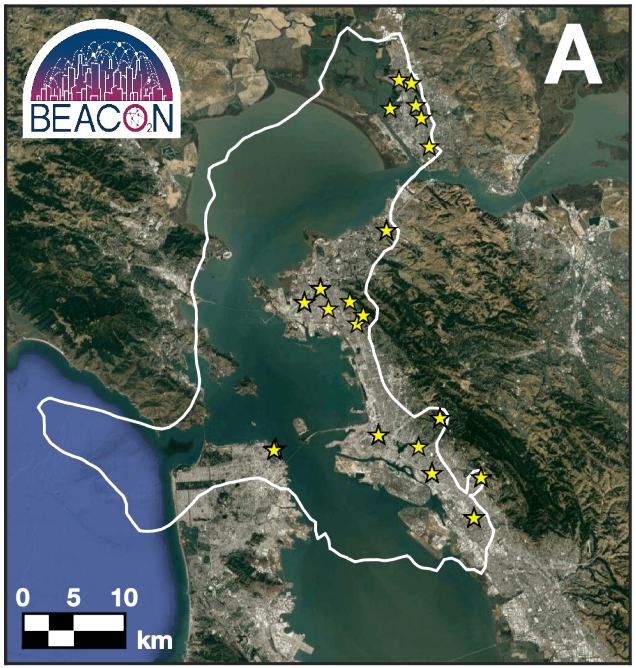
Turner et al., 2020

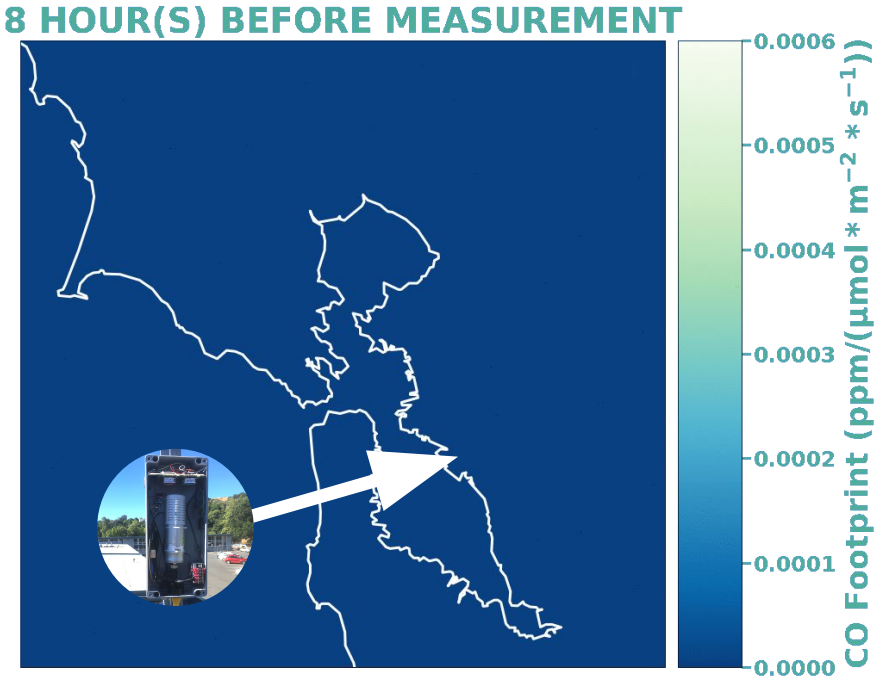
CO

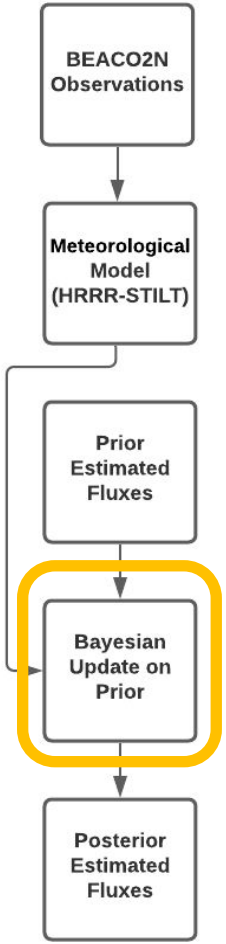




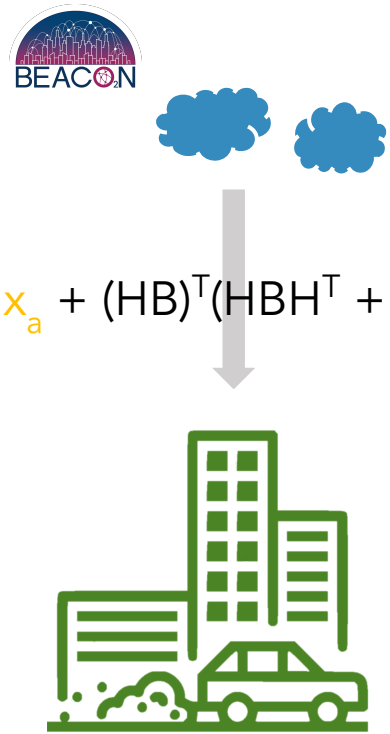
Where did the measured gas come from?







Solve for posterior emissions



$$\hat{x} = x_a + (HB)^T(HBH^T + R)^{-1}(y - Hx_a)$$

Inverse Model:

Solve for posterior ($\hat{x}$),

given our BEACON measurements (y),

and a prior estimate (x_a) of CO fluxes

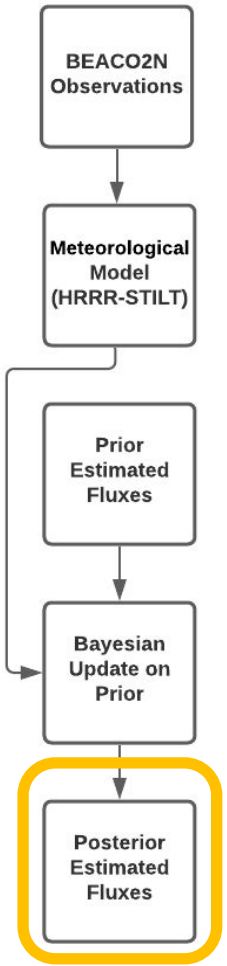
Where:

B = prior error covariance matrix

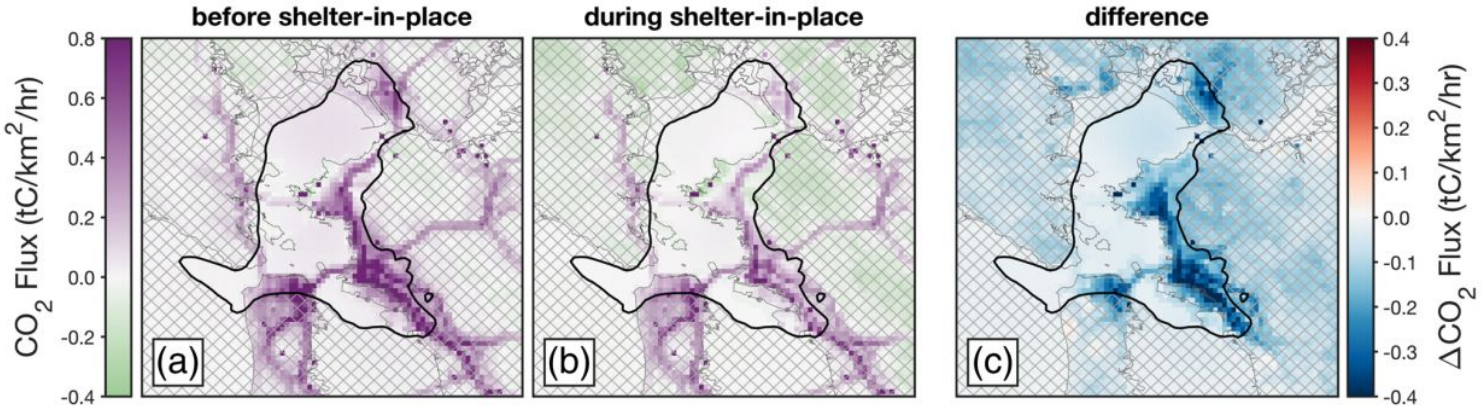
H = HRRR-STILT footprints

R = model-data mismatch error covariance matrix

Results

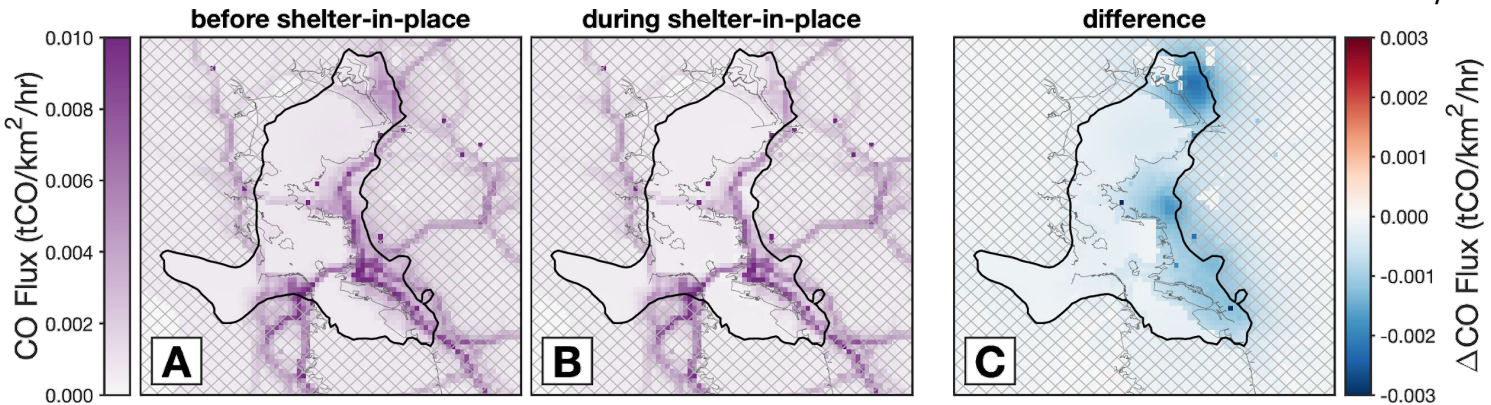


CO_2

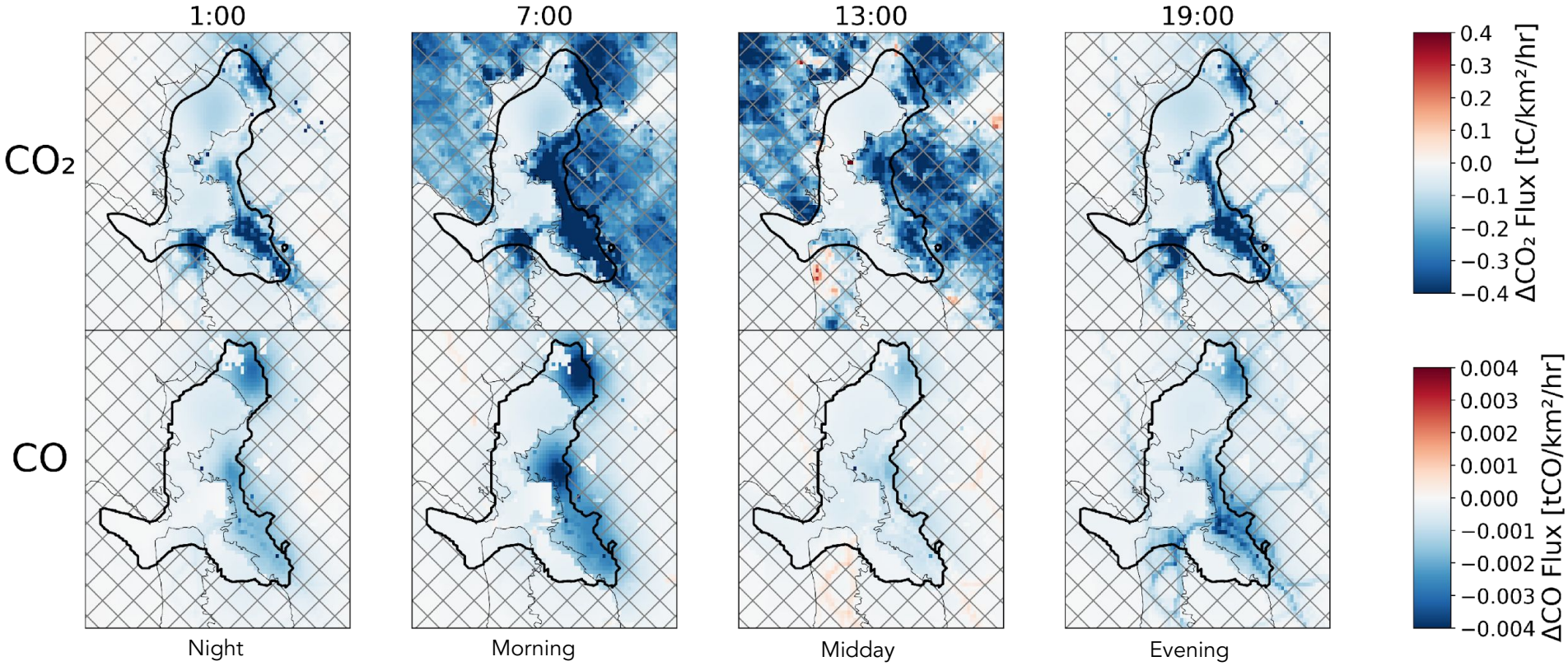


Turner et al., 2020

CO

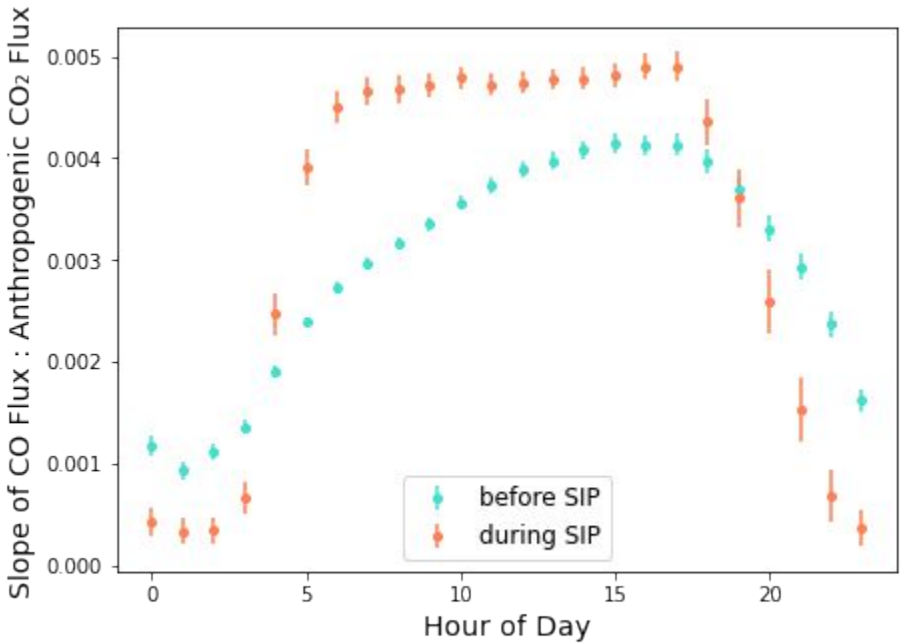


Change in emissions (SIP minus pre-SIP), by hour of day



What do the posterior emissions show about the CO:CO_2 emissions ratio?

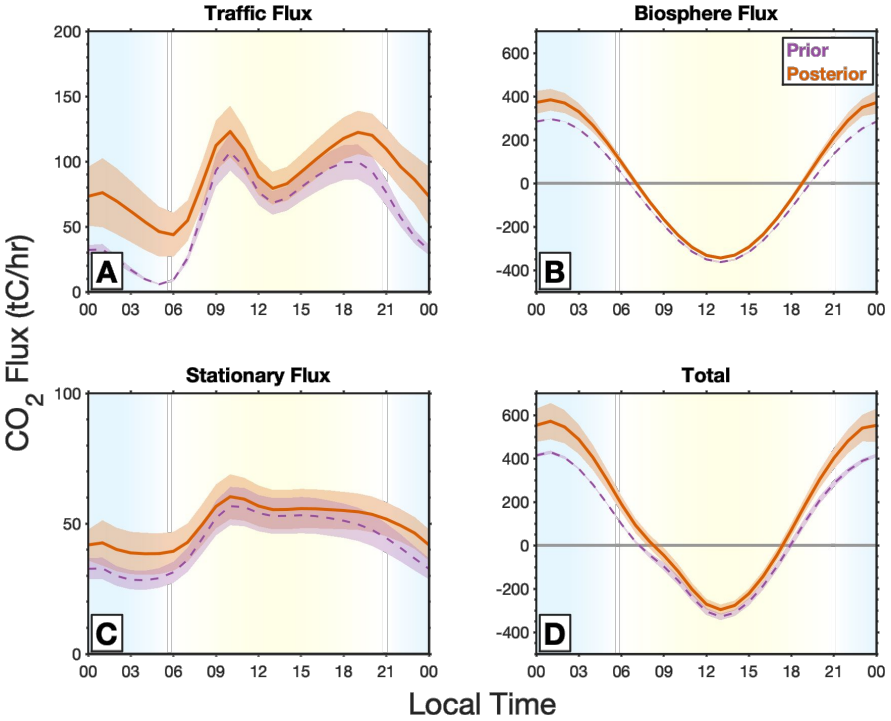
- Traffic > Stationary Sources
- Old Cars > New Cars
- LDVs (cars) > HDVs (trucks)
- EMFAC
  - Diesel Vehicles: 0.001
  - Gasoline Vehicles: 0.007



Future Work

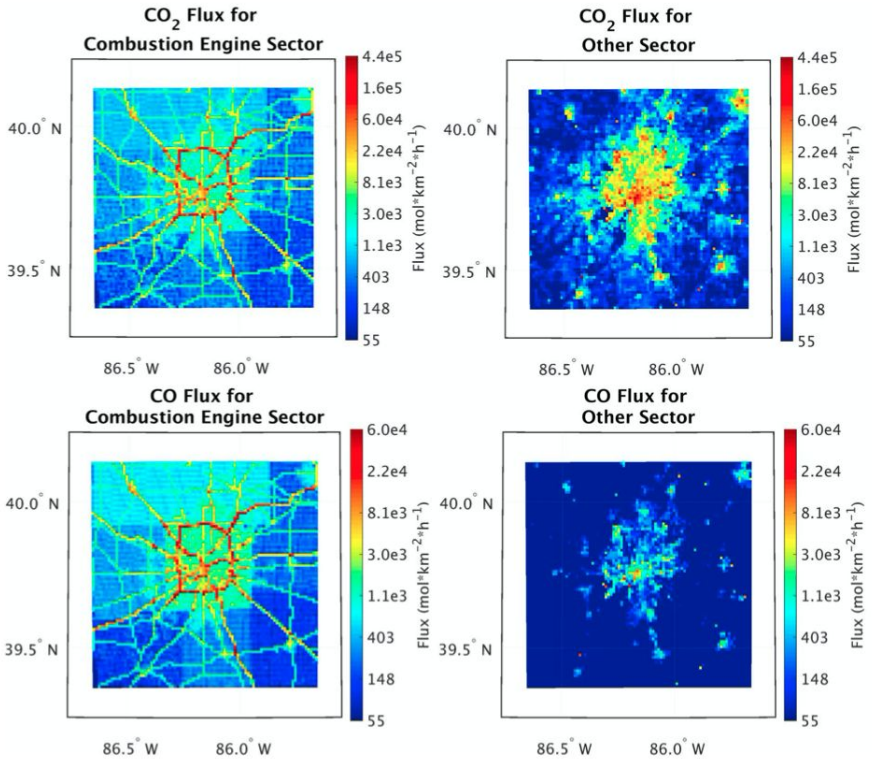
- Validate observed CO:CO_2 during COVID using bottom-up methods
- Invert CO and CO_2 together
- Extend this methodology to other years and cities to probe the question: How are urban CO and CO_2 emissions changing as cities enact new climate action policies?

Preliminary Results in Glasgow, Scotland



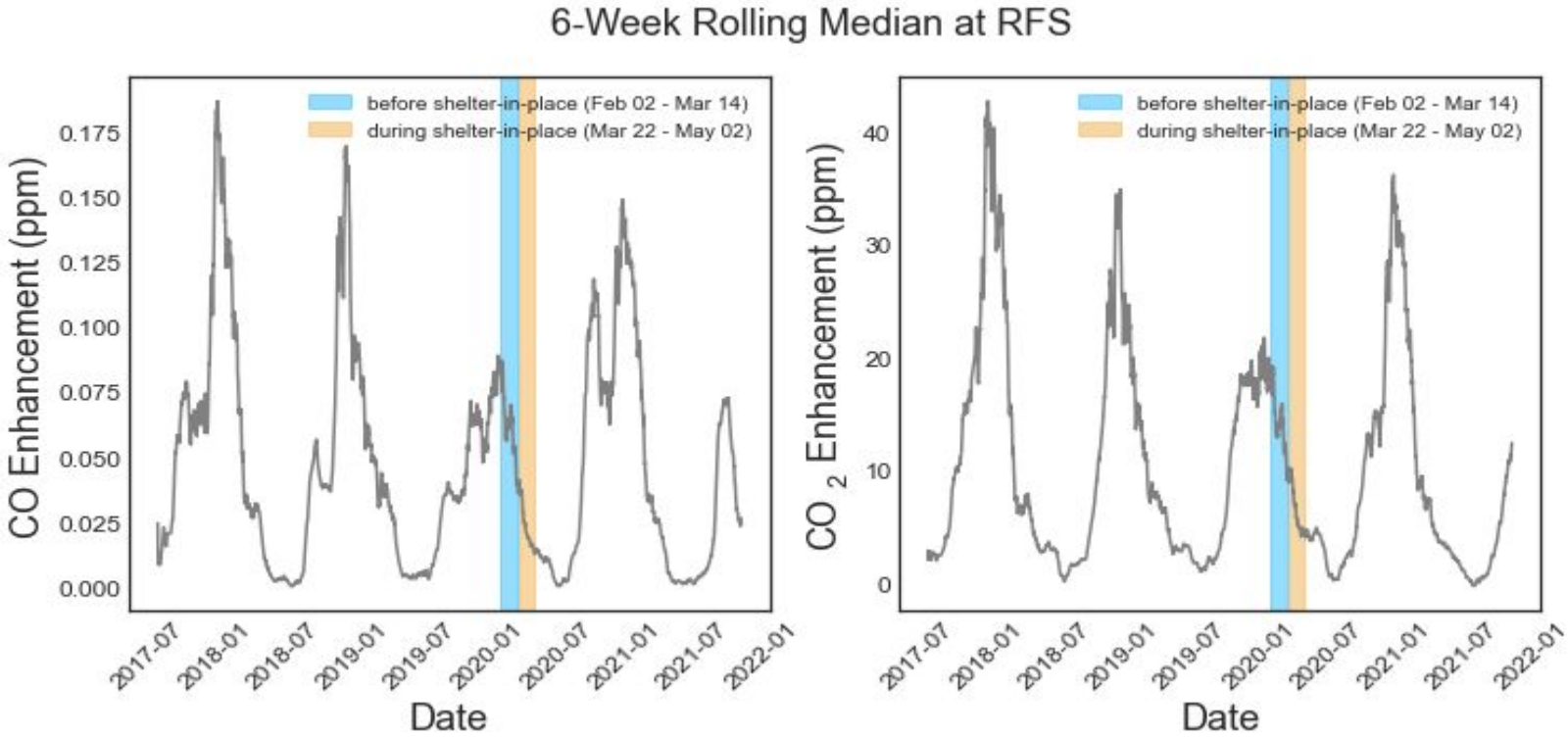
Carbon Monoxide

- Air quality
  - Serious adverse health effects (~35ppm) due to hemoglobin binding
  - Ozone formation
- Co-emitted with CO_2, can be used as a sector-specific tracer

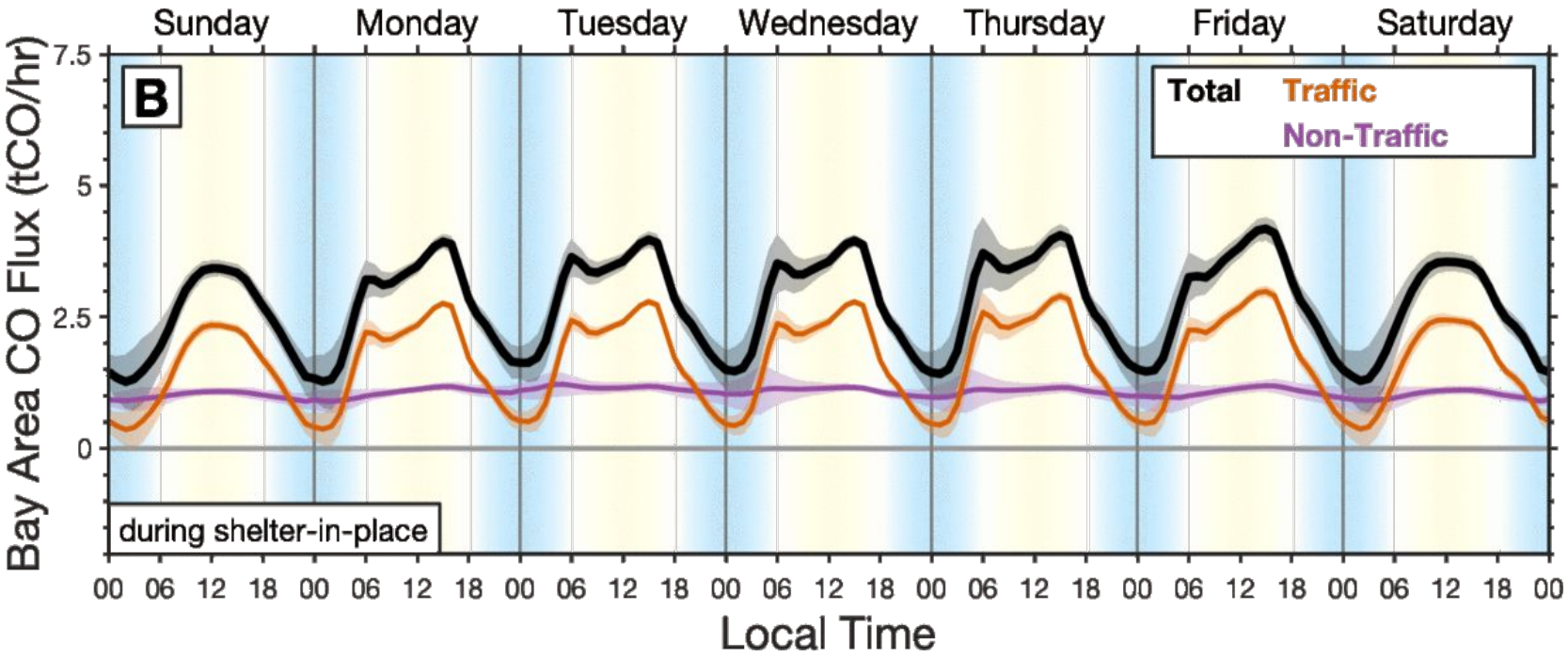


Nathan et al., 2018

Meteorology is necessary for distinguishing seasonal changes from emissions changes

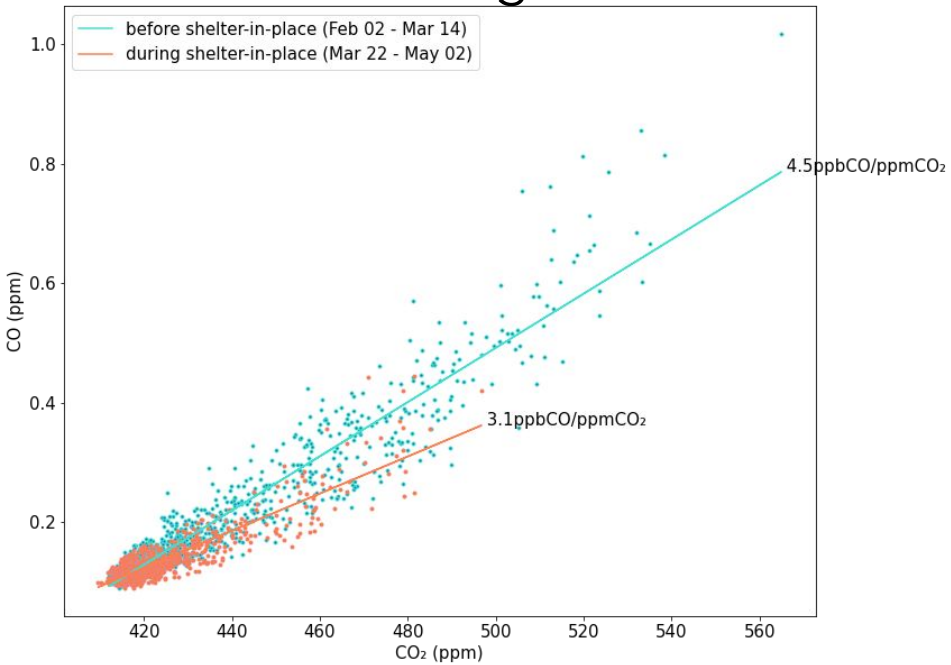


Posterior CO Emissions by Sector



Another check: the CO:CO_2 ratio:

Observations show ~30% decrease during SIP:

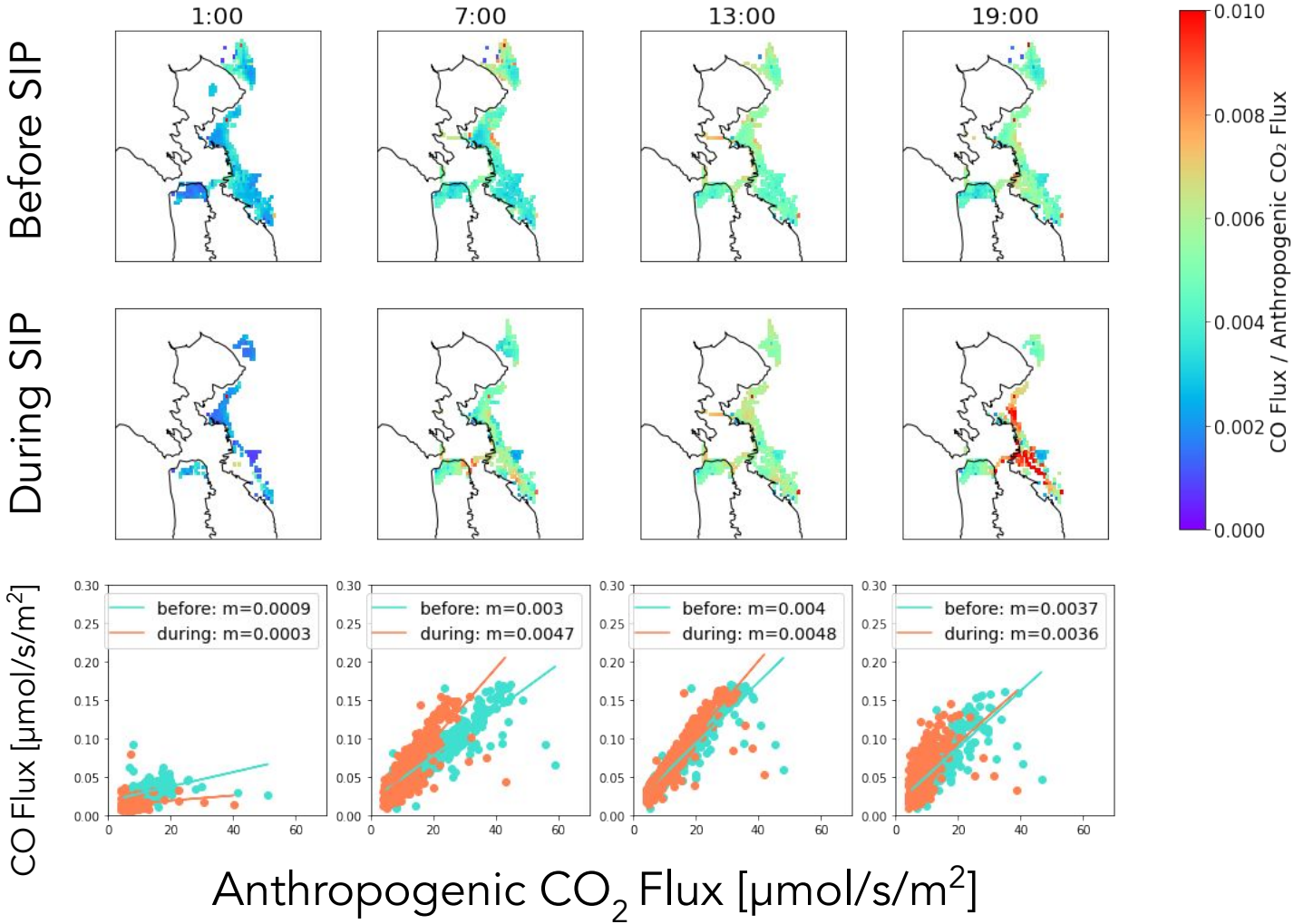


But this could just be seasonal:

What do the posterior emissions show about the CO:CO_2 emissions ratio?

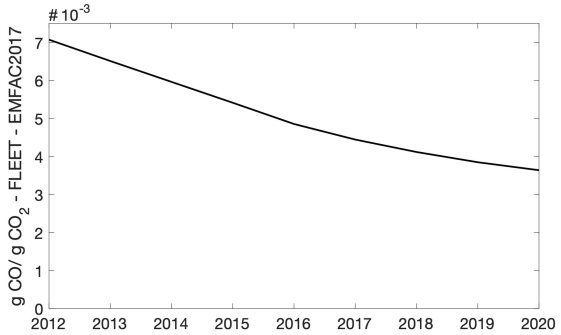
Data Processing Step:

1) Look only in CO region of influence (smaller than CO_2 region of influence)
2) Subtract biosphere CO_2 fluxes (the prior, which is constrained using TROPOMI SIF) from total posterior CO_2 fluxes to give anthropogenic CO_2 fluxes
3) Exclude outlier pixels (mess up the slope)
4) Exclude very small CO_2 fluxes (very large/small ratio)

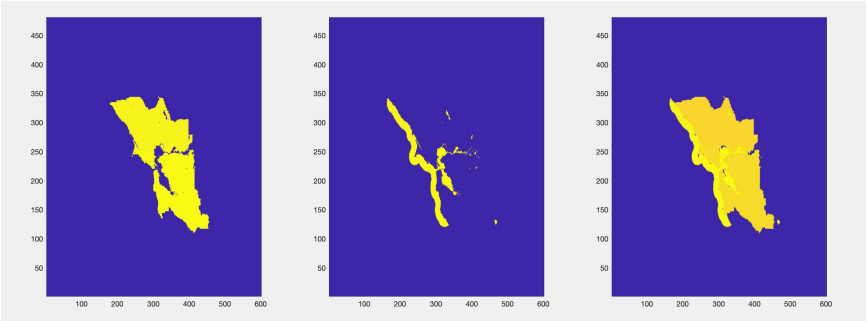

1:00
7:00
13:00
19:00
Before SIP
During SIP
CO Flux / Anthropogenic CO₂ Flux
0.010
0.008
0.006
0.004
0.002
0.000
CO Flux [μmol/s/m²]
before: m=0.0009
during: m=0.0003
before: m=0.003
during: m=0.0047
before: m=0.004
during: m=0.0048
before: m=0.0037
during: m=0.0036
Anthropogenic CO₂ Flux [μmol/s/m²]

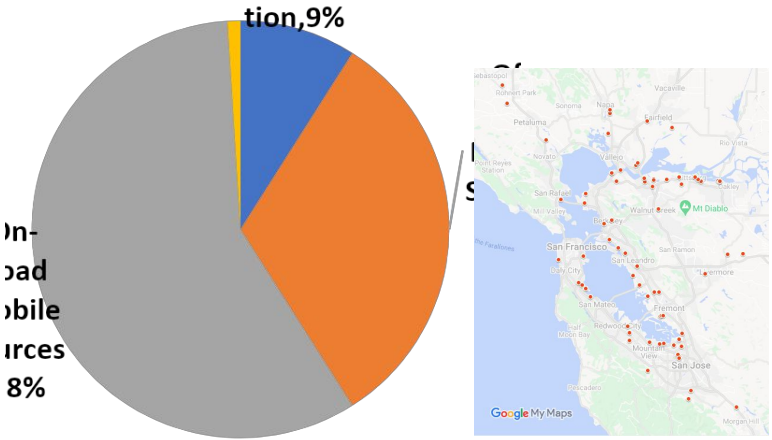
Prior Emissions Inventory

Vehicles – Use EMFAC to Scale EF by year.



Off-Road Vehicles (~87.6 tons/day to water; ~333.6 tons/day to land)



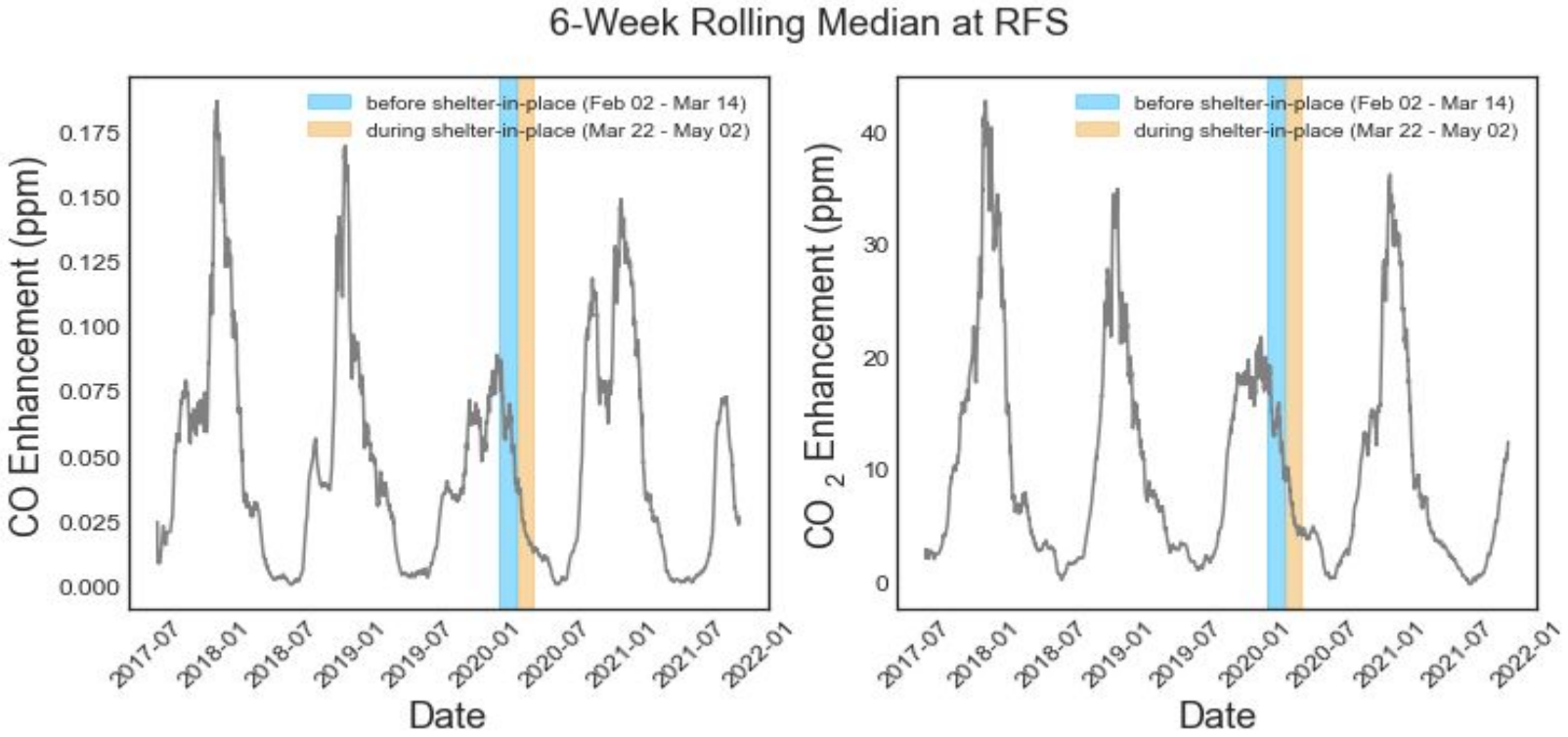


Combustion/Stationary:

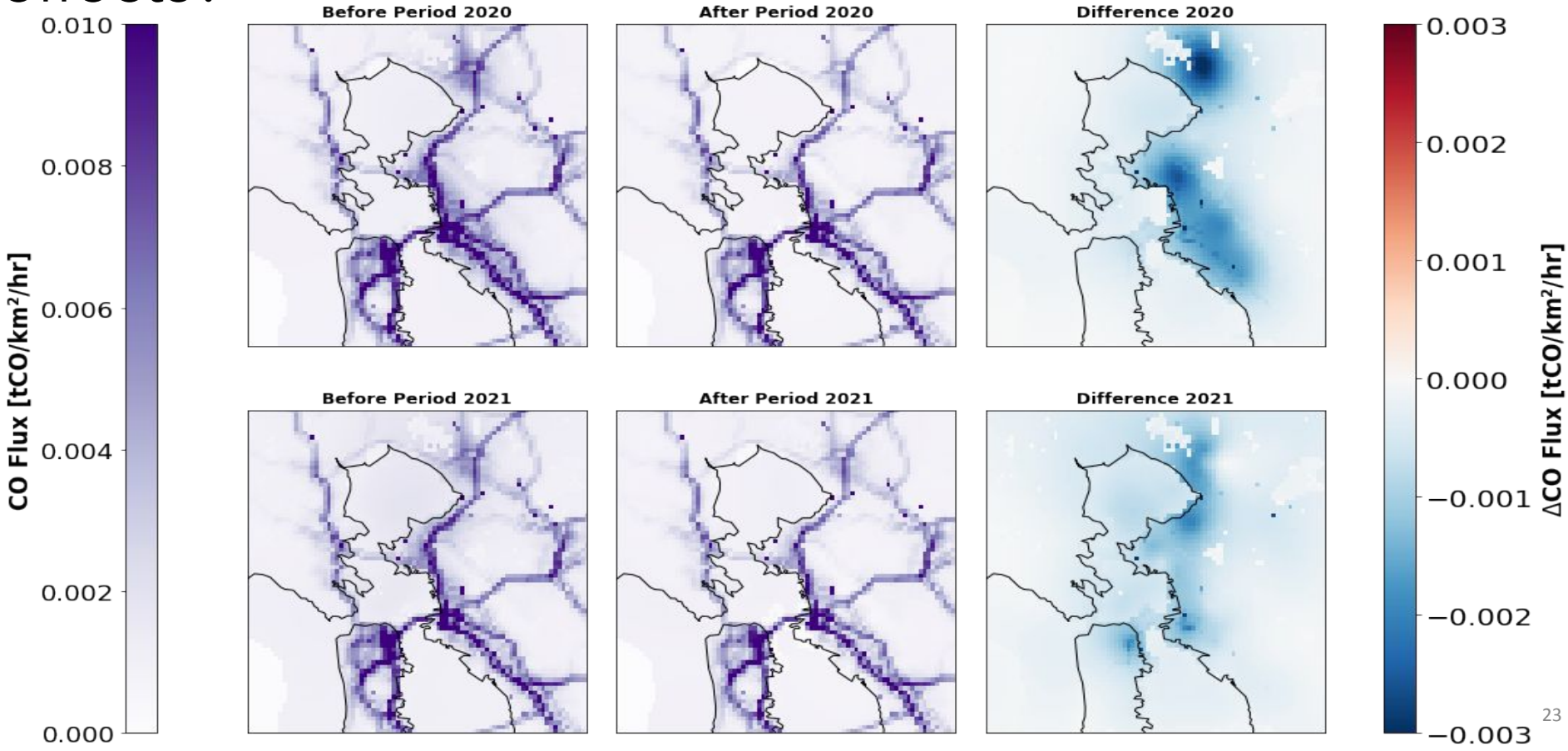
- Point Sources – BAAQMD tells us where 22 of 35 tons/day are emitted. Distribute the remainder to CO2 emissions sources that *don't* overlap
- Home Heating – No data on emissions factors changing over time. Just scale with a single factor

NEI2011 used for course inventory outside our region

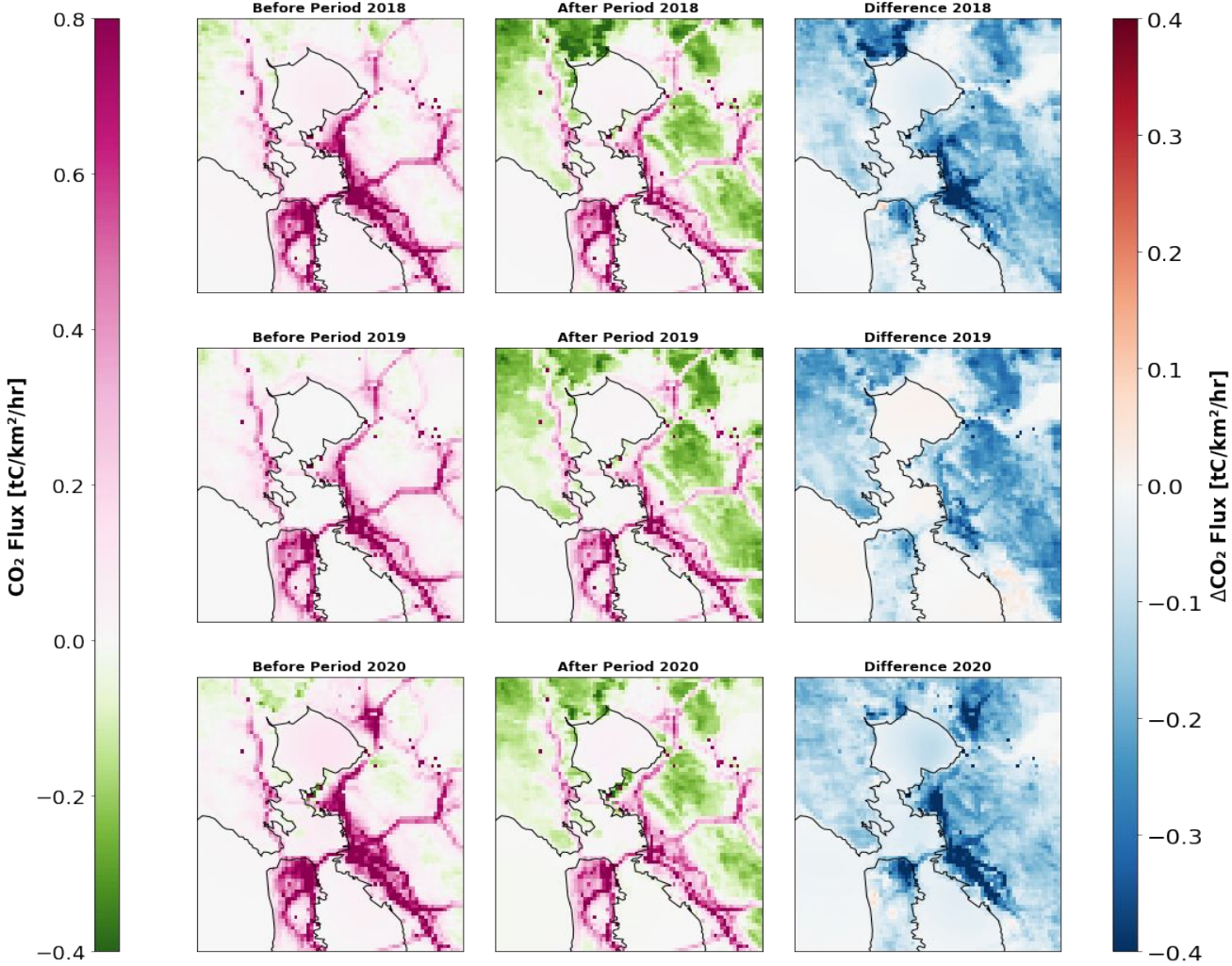
Recall seasonal effects…



Are we removing all seasonal/meteorological effects?



Are we removing all seasonal effects (CO_2)?

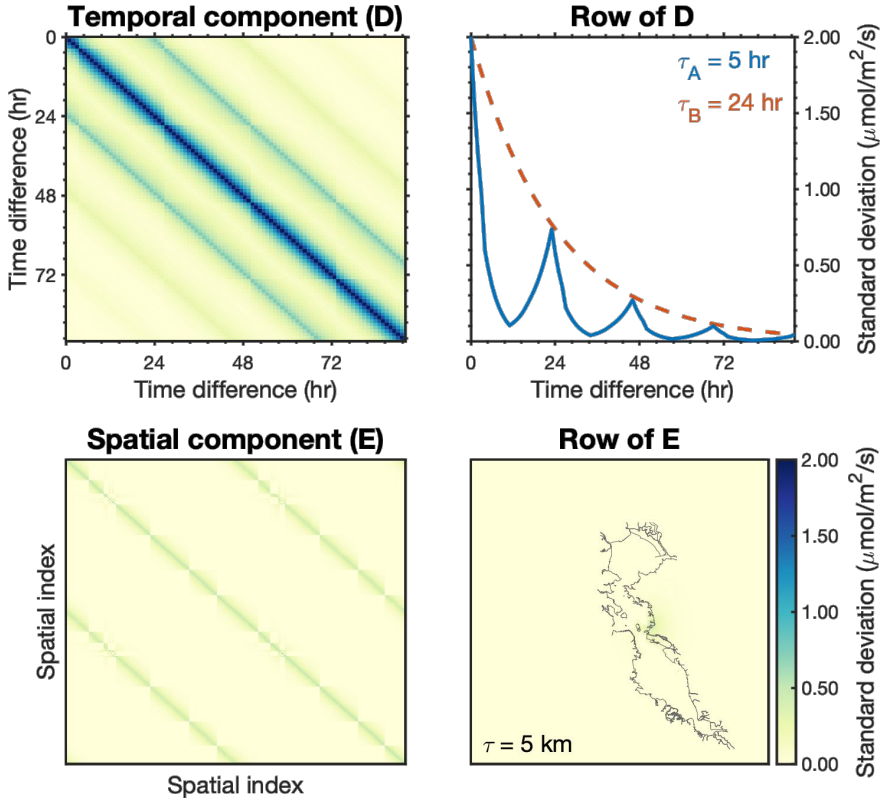


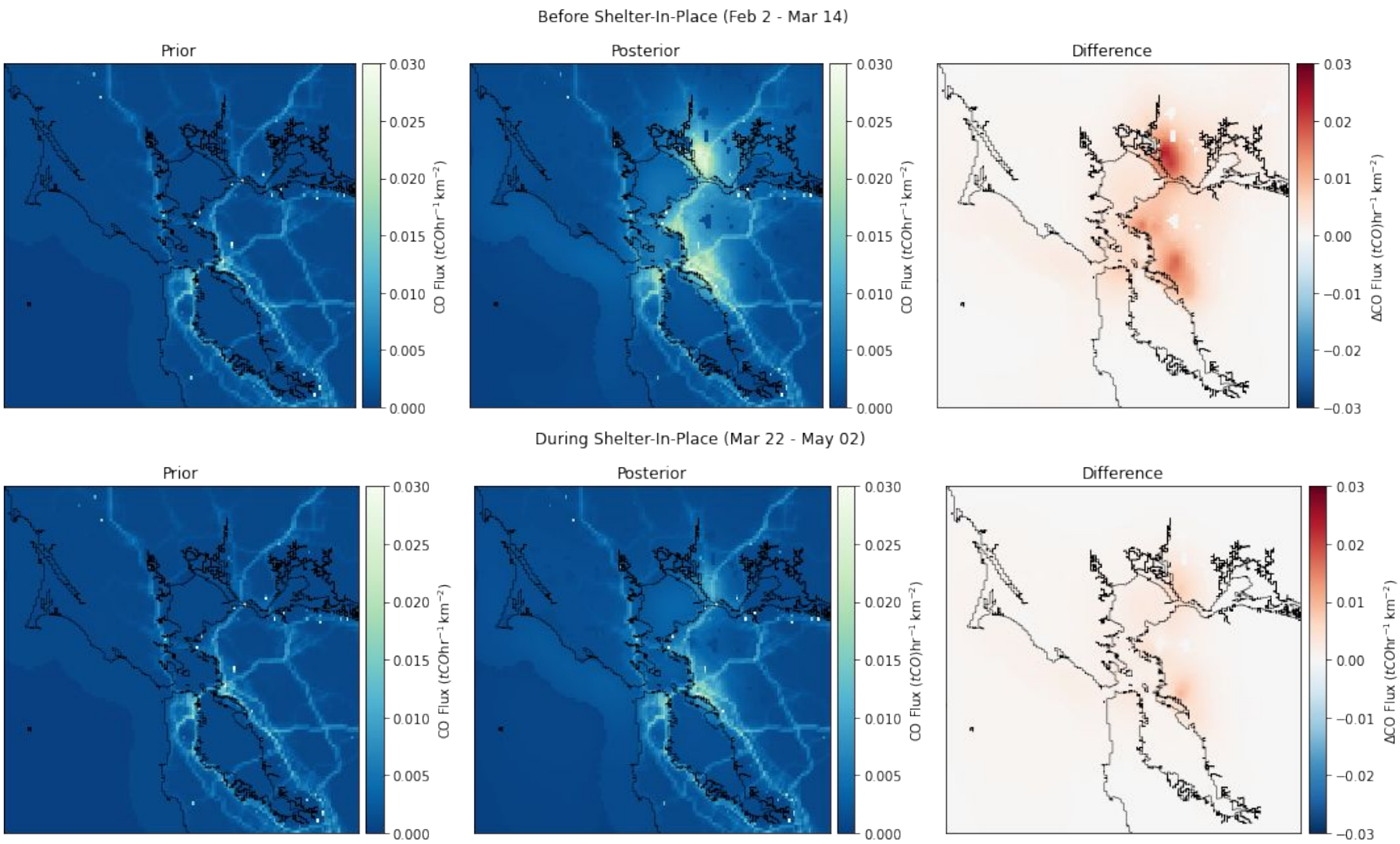
B is composed of a temporal and spatial covariance matrix

$$\hat{x} = x_a + (HB)^T(HBH^T + R)^{-1}(y - Hx_a)$$

prior error covariance matrix

$$B = D \otimes E$$




Before Shelter-In-Place (Feb 2 - Mar 14)
Prior
Posterior
Difference
CO Flux (tCOhr⁻¹km⁻²)
ΔCO Flux (tCO)hr⁻¹km⁻²)
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
During Shelter-In-Place (Mar 22 - May 02)
Prior
Posterior
Difference
CO Flux (tCOhr⁻¹km⁻²)
ΔCO Flux (tCOhr⁻¹km⁻²)