Multi-species Atmospheric Inversion of Sectoral Greenhouse Gas Emissions in the Indianapolis Urban Environment

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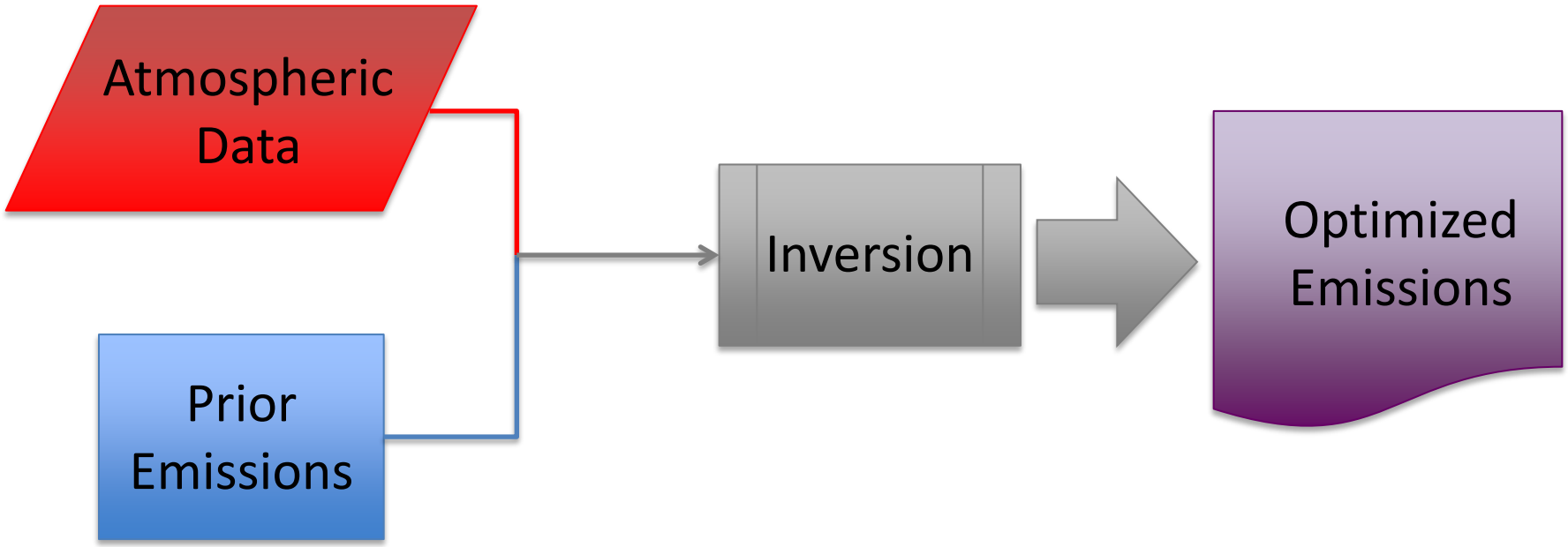
Urban Greenhouse Gas Quantification

- 2 Main Objectives:
  - How much is being emitted
  - How these emissions are changing over time

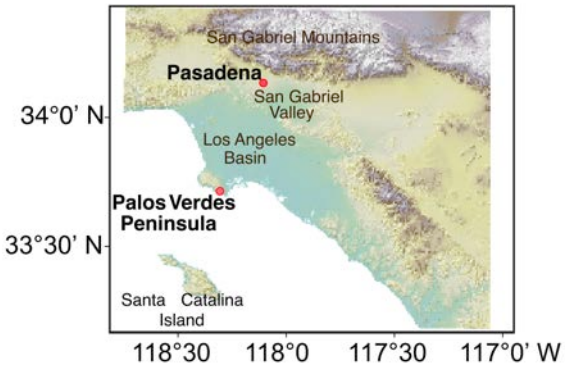
Atmospheric Inversion



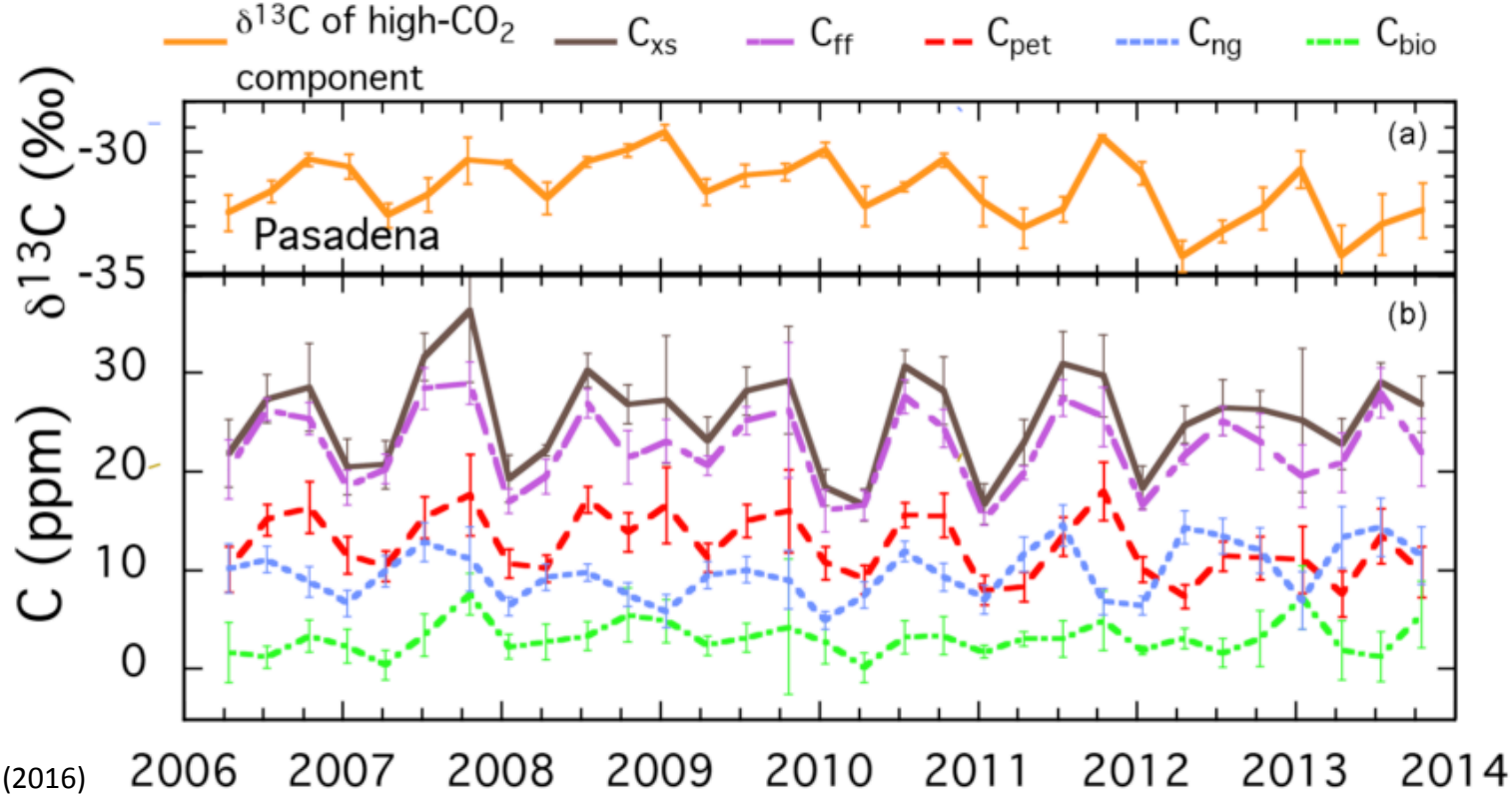
Sectoral Problem

- Policymakers want CO_2ff emissions information from different economic sectors
- Multi-species measurements may be a solution if some species are found to be unique tracers to source sectors

Previous Approaches

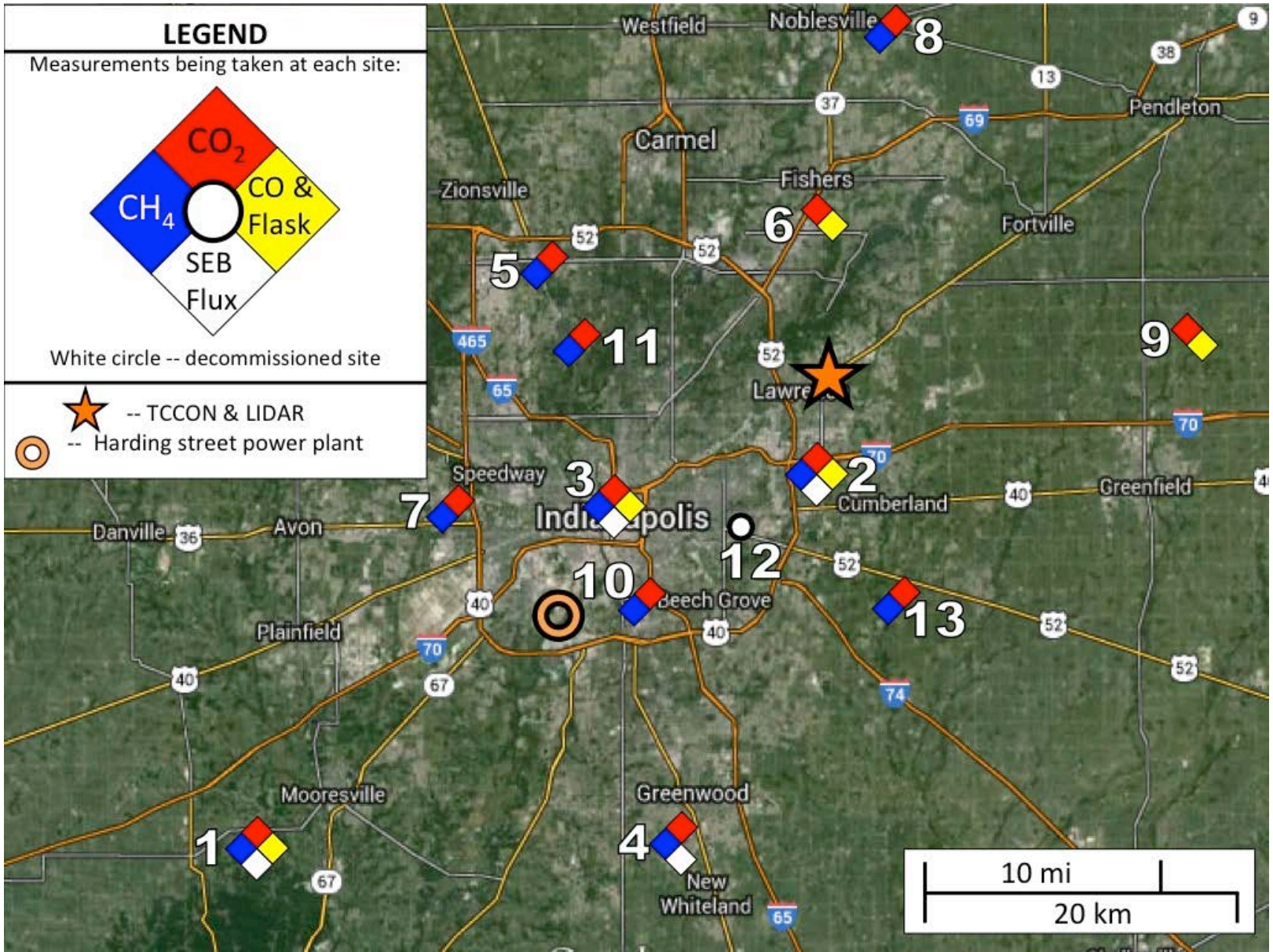


- Some (like Newman et al. (2016)) have used isotopes to distinguish source signals

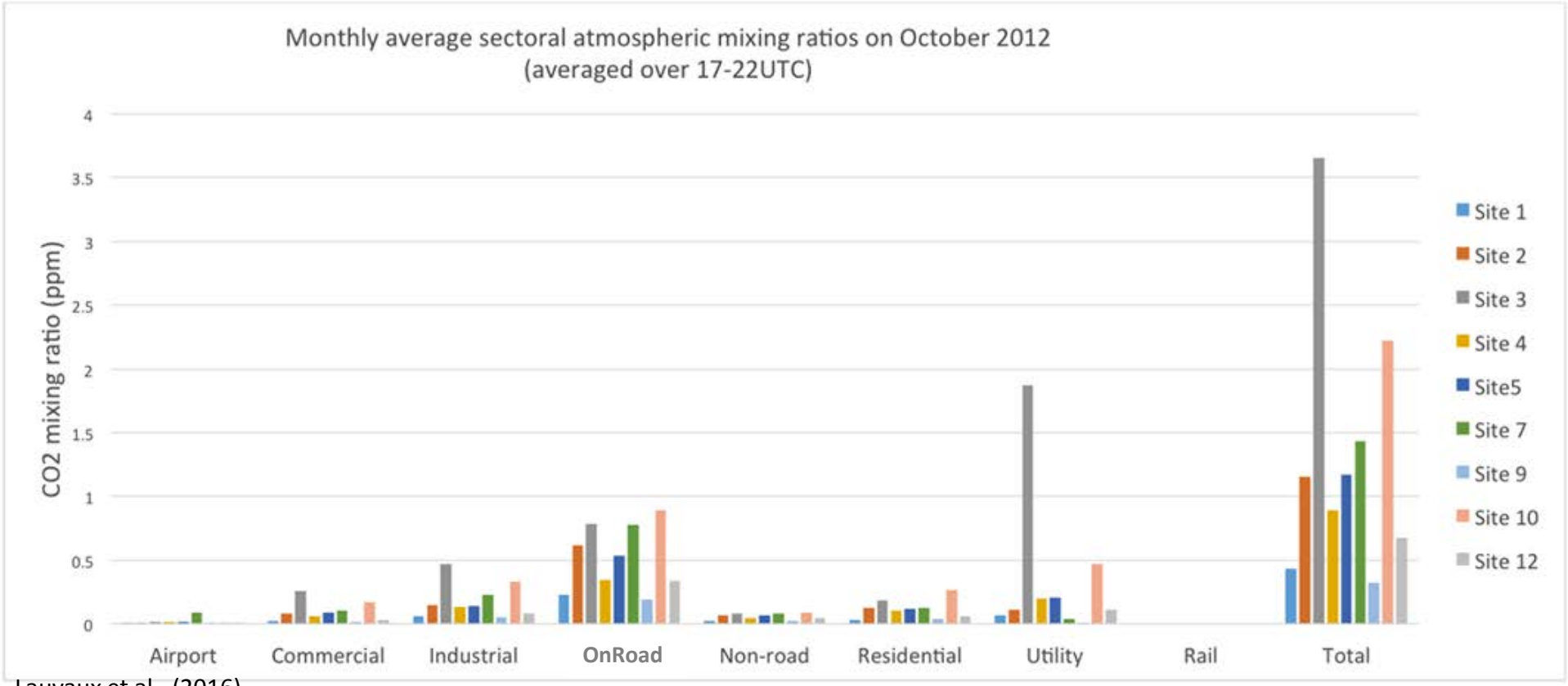


Newman et al., (2016)

INFLUX Project

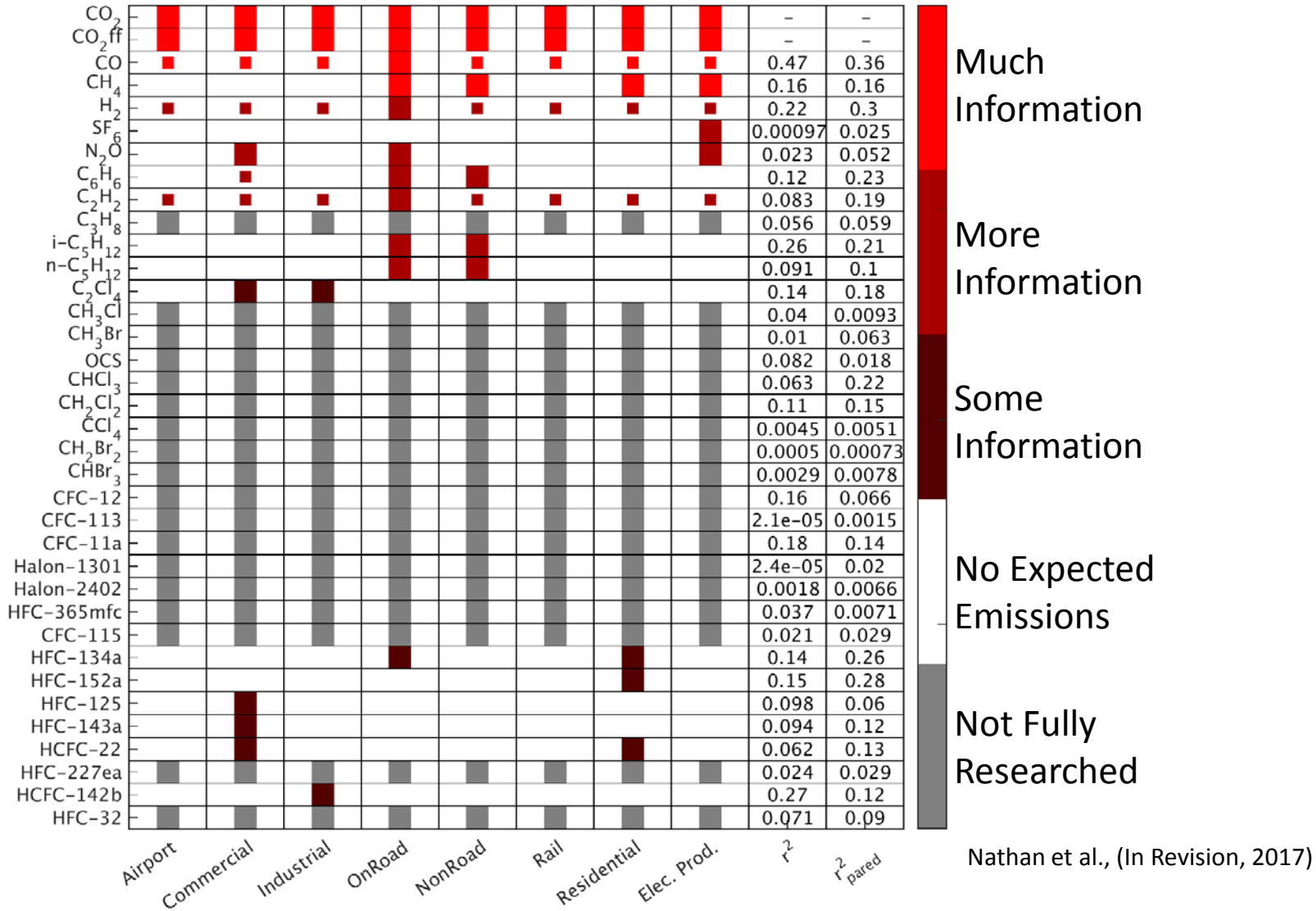


Hestia CO_2ff Sectors for Indianapolis



Lauvaux et al., (2016)

Trace Gas Relationships to CO_2ff Sectors



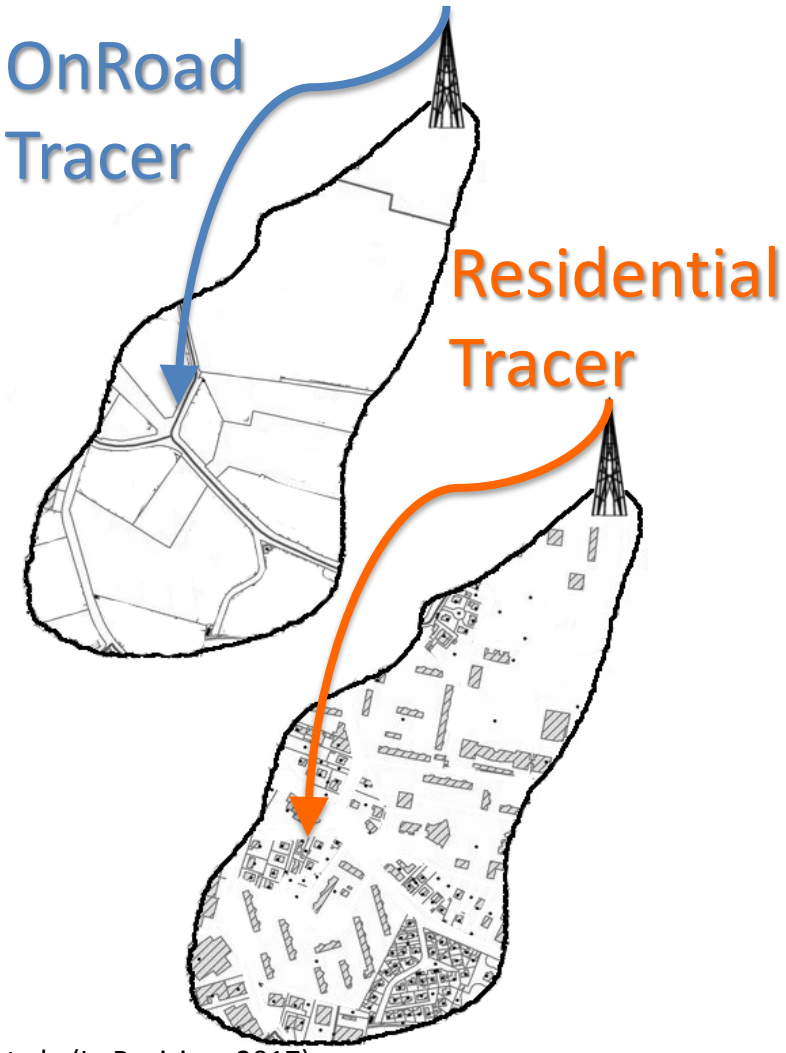
Nathan et al., (In Revision, 2017)

- Very few trace gases are fully quantified

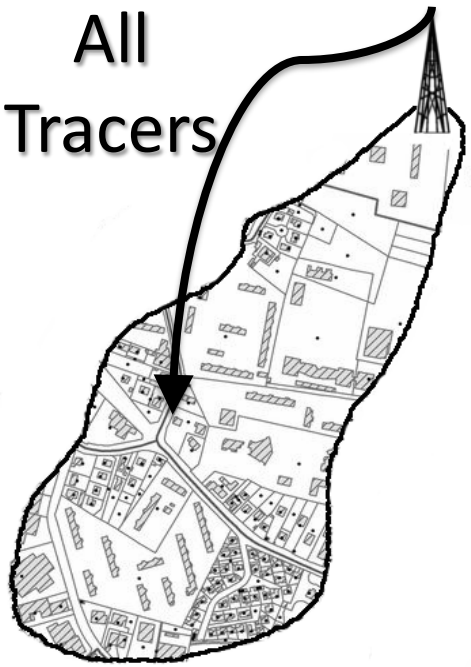
First Strategy: Data Mining Approach

Domain Filling Problem

With Sector Prior Info

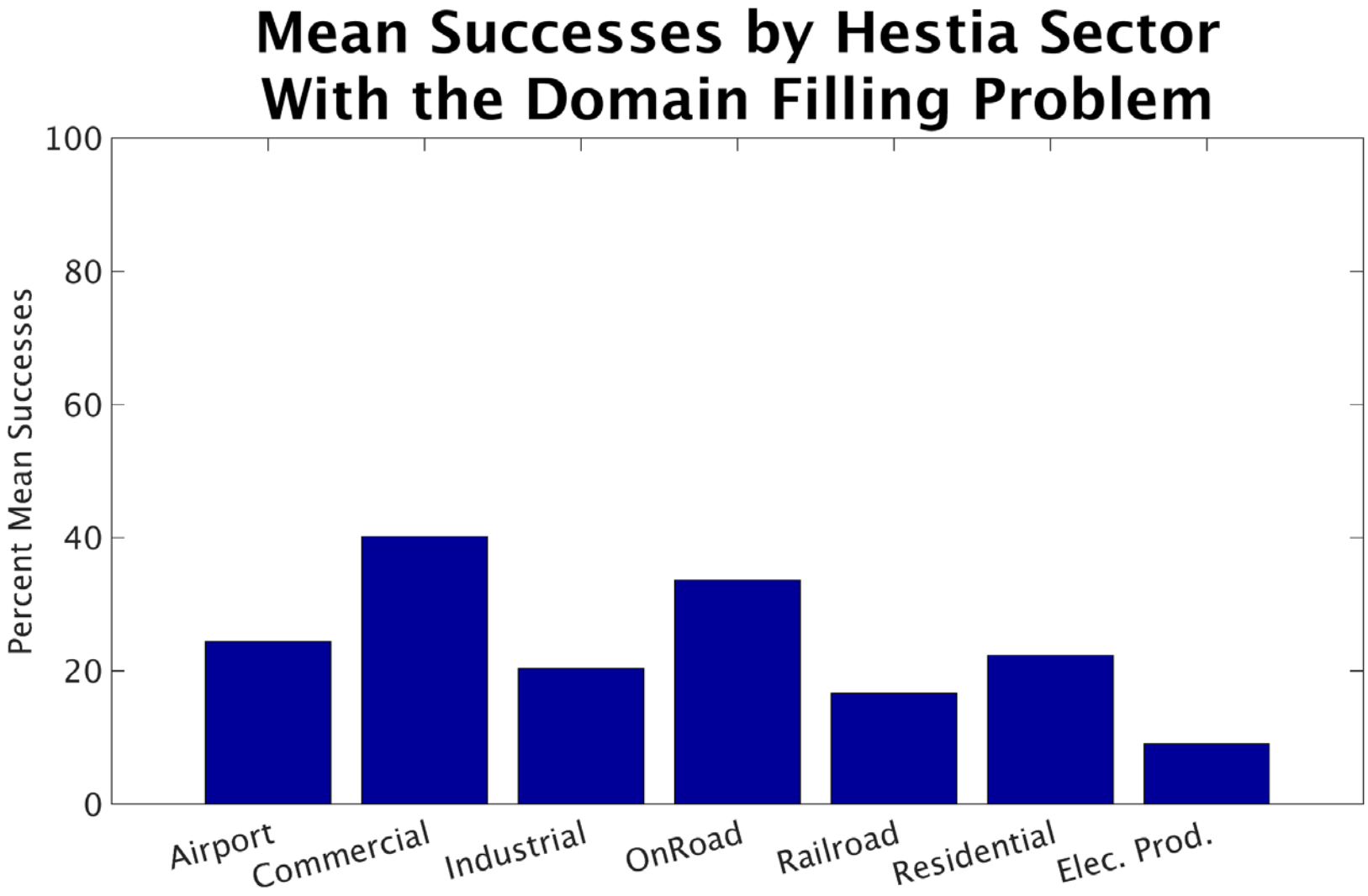


Without Sector Prior Info



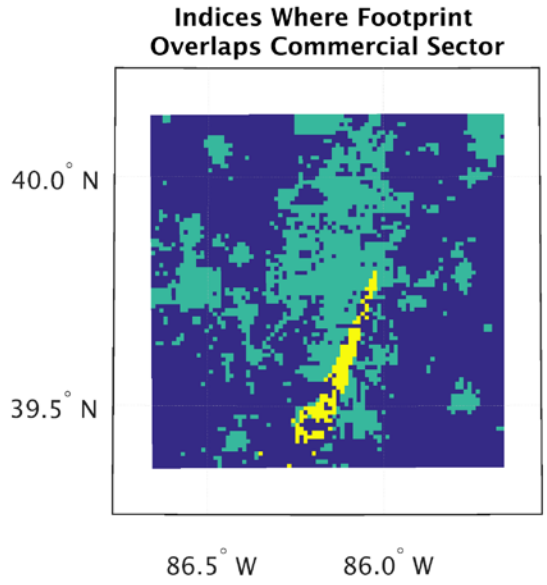
Nathan et al., (In Revision, 2017)

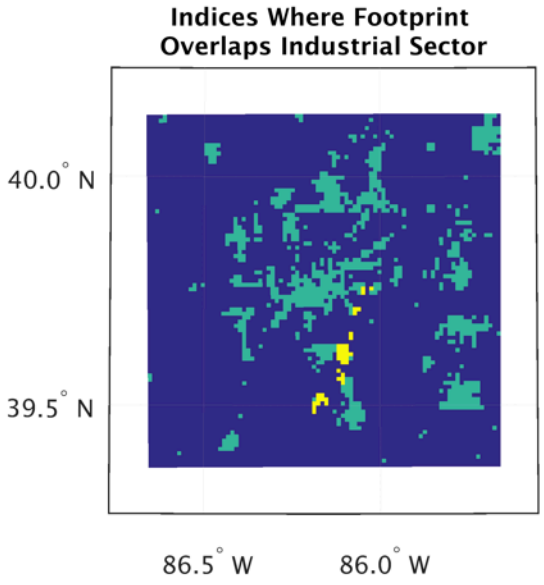
Is Direct Tracer/Sector Attribution Possible?



Nathan et al., (In Revision, 2017)

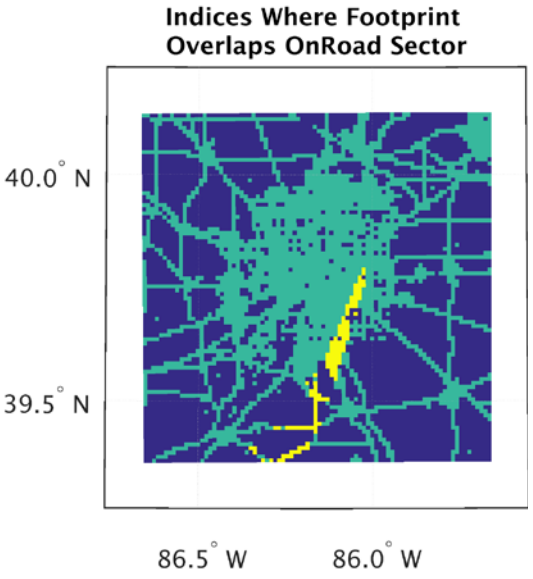
Footprint/Sector Overlap Limitation

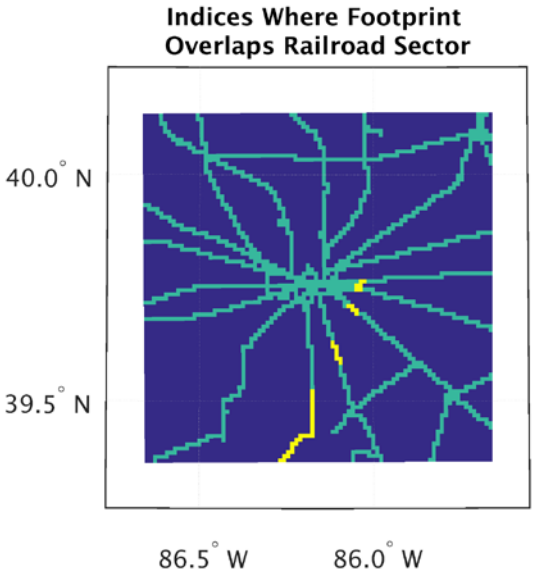


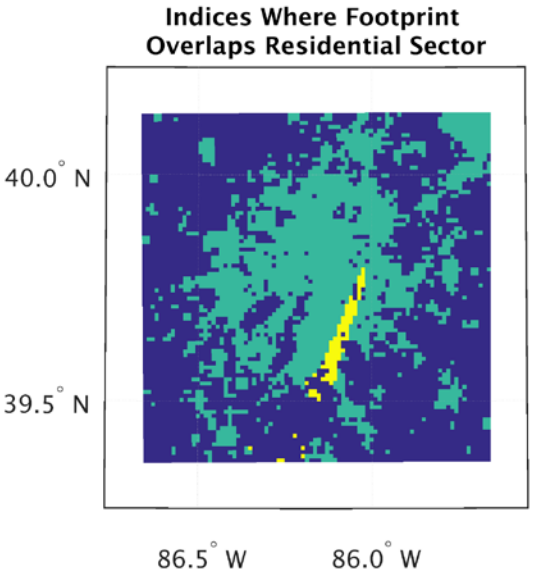


= Sector Mask Pixel

= Footprint Overlap Pixel



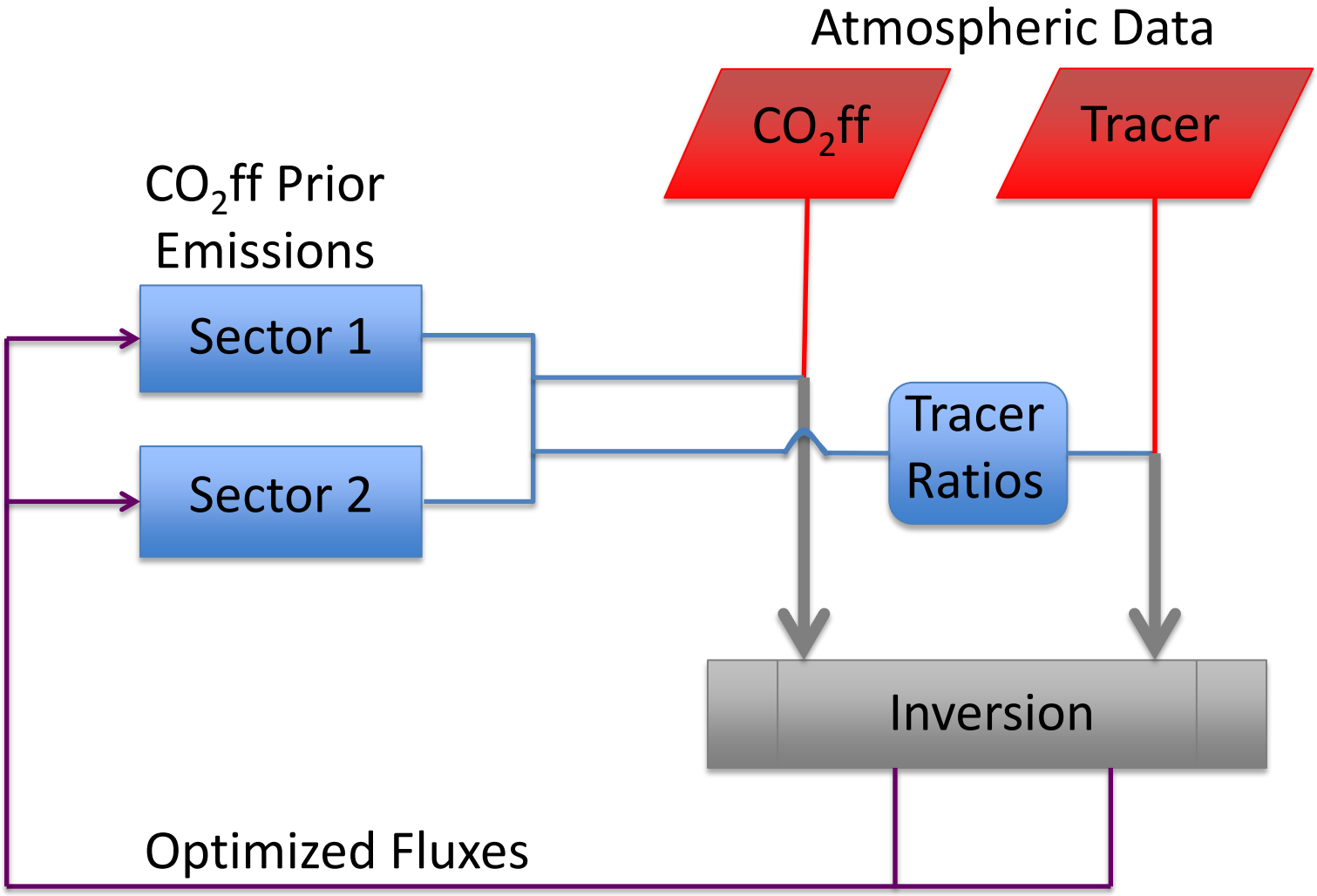




Preliminary Conclusions

- Many species have complex relationships with the inventory-defined CO_2ff sectors
- Gas-to-sector ratios are critical, else direct attribution is impossible due to sector overlap

Second Strategy: Source Sector Inversions



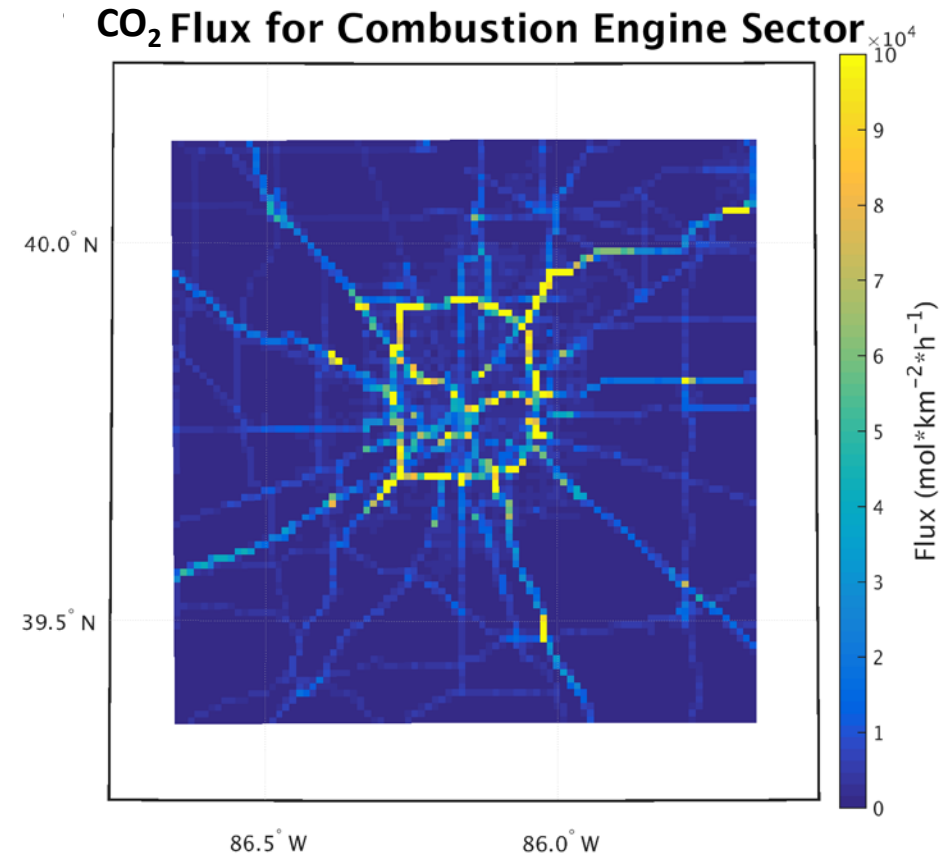
Building Non-CO2ff Priors

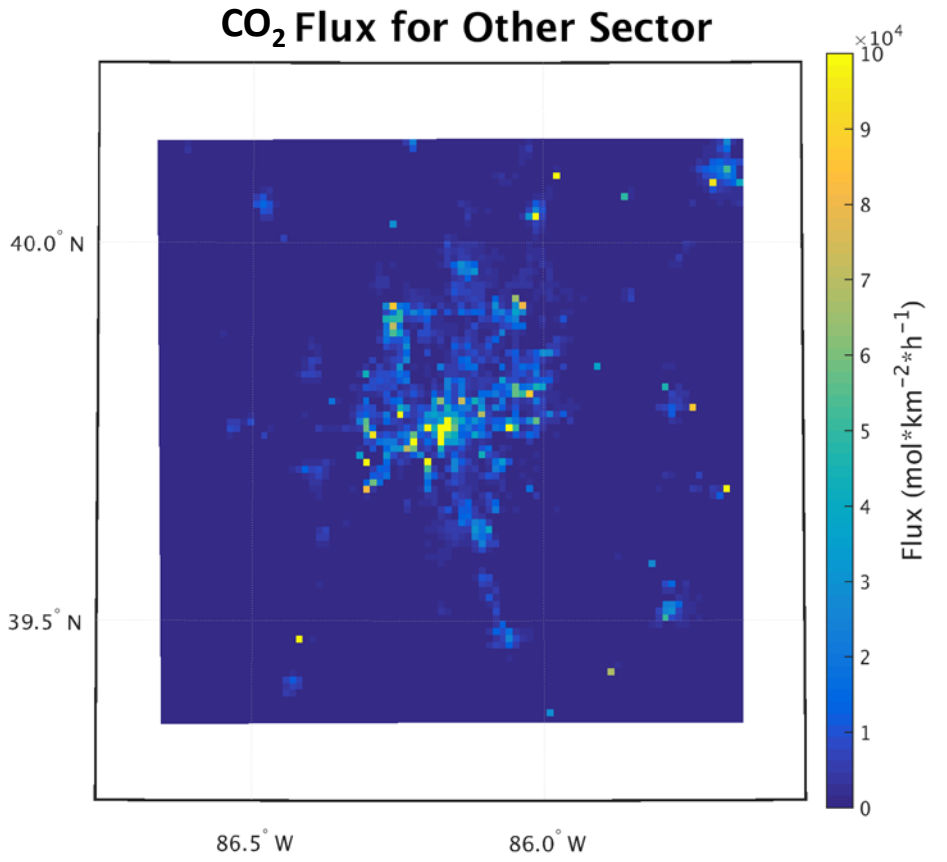
- Select species with known sector emissions: e.g. CO
- Construct CO a priori emissions using Hestia and CO/CO_2ff emission ratios:

Airport	Commercial	Industrial	OnRoad	NonRoad	Railroad	Residential	Electricity Production
2.0	1.3	3.1	15.0	45.0	2.0	0.7	0.2

- Note that CO is VERY sensitive to traffic (OnRoad and NonRoad)!

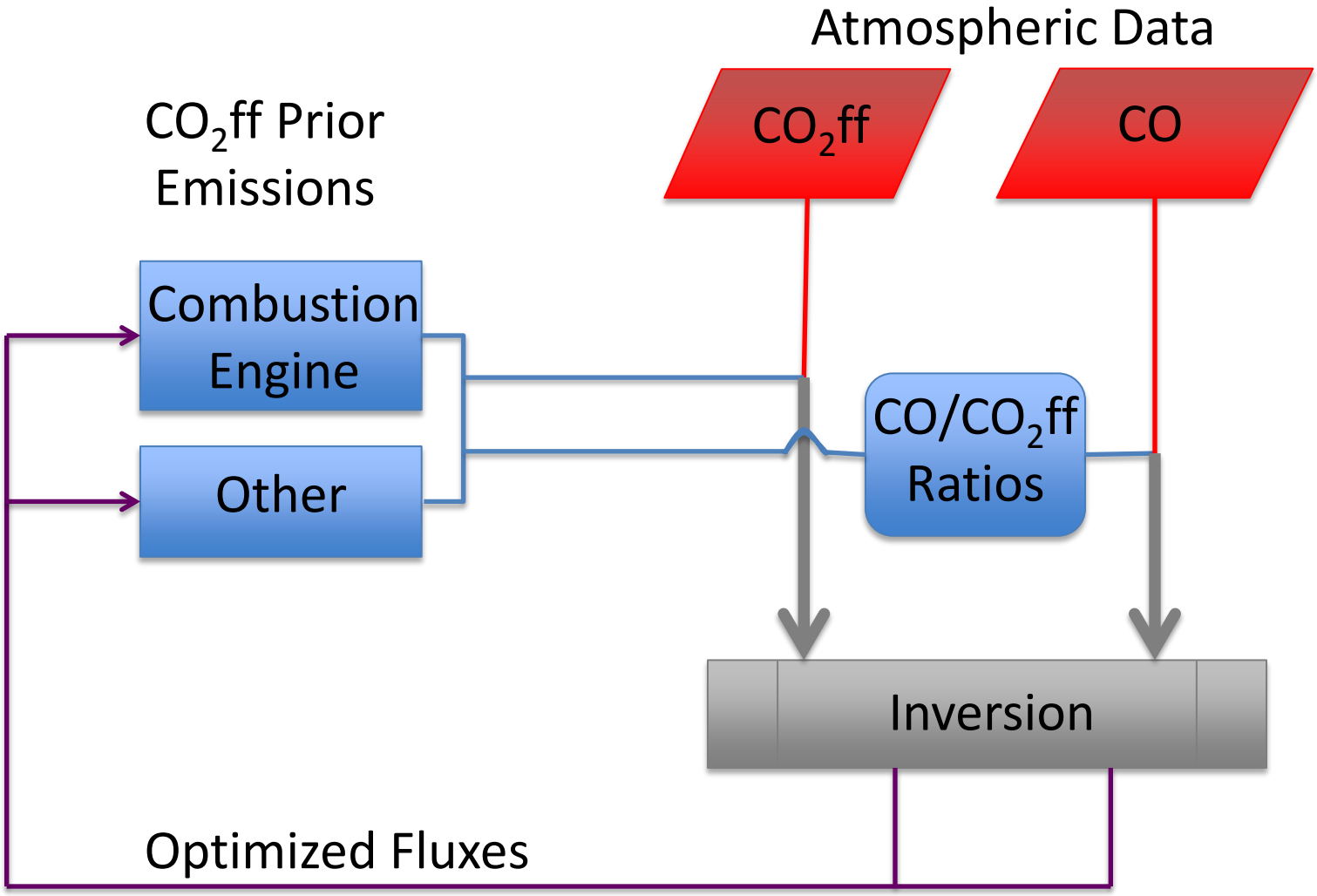
Aggregation Into Two Sectors



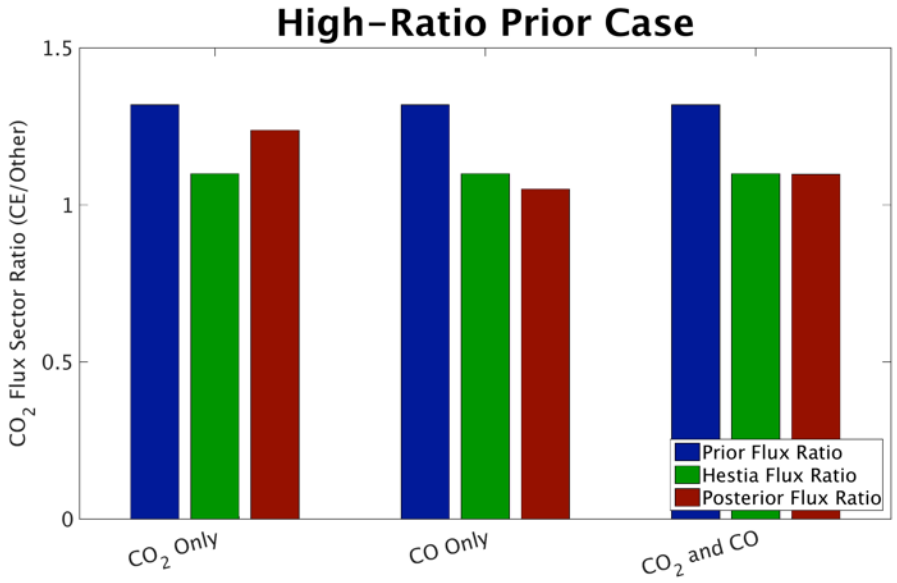


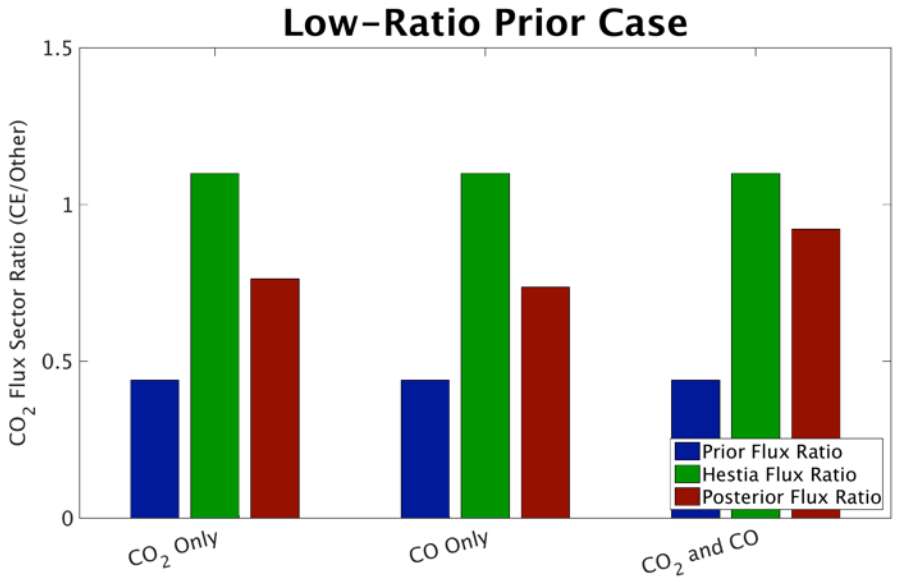
- Split: High CO emitters vs. Low CO emitters
- Both are approximately equally large in CO_2ff magnitude
- Flux based on Hestia (Gurney et al., (2012))

Source Sector Inversions Using CO



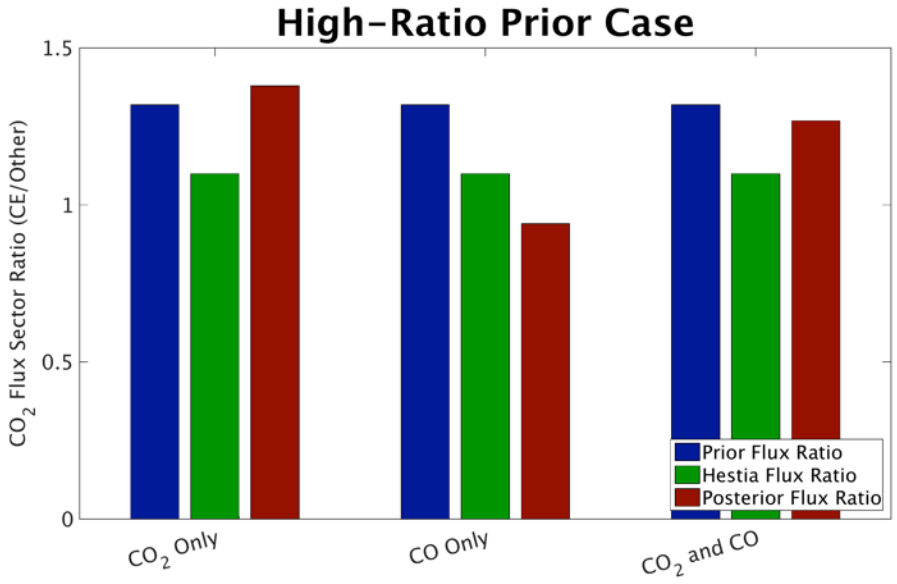
Pseudodata Inversion

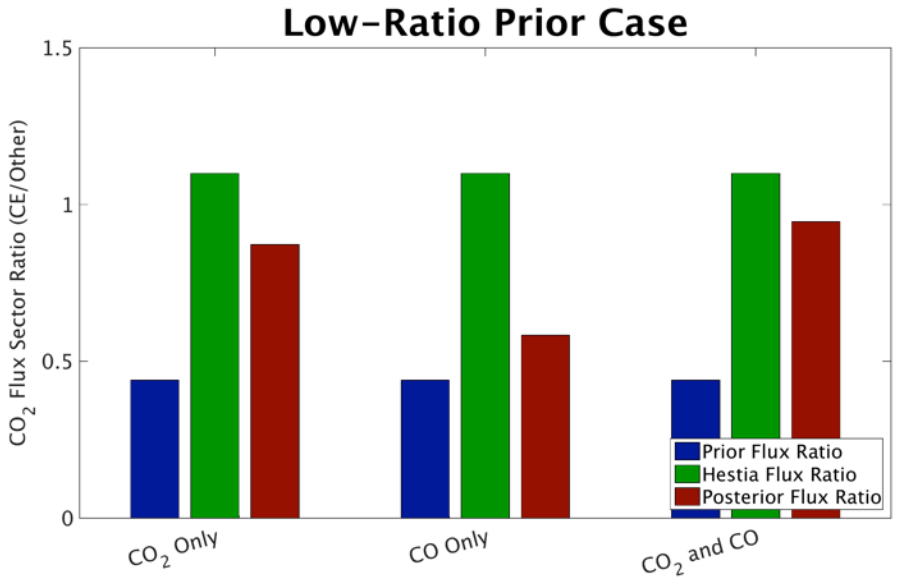




- Look at RATIO of fluxes compared to Hestia (which for now we trust more than the fluxes)
- Able to improve the sector ratio in both cases: high-ratio prior and low-ratio prior

Real-Data Sector Inversion





- CO_2 and CO are inverted *separately*, NOT as a ratio!
- The inversion with both CO_2 and CO performs the best from either prior position

Conclusions

- Inversions agree using CO_2 and CO atmospheric data
- Inverse sector attributions with CO_2 and CO agree with Hestia ratio (Success?)
- Future work: Need to understand better how the other gases relate to the sectors
  - Need to work on atmospheric data and inventories

What If We Have a Complementary Tracer?

- CO is very sensitive to the Combustion Engine sector, and CO_2 has no preference
- Do a pseudodata experiment: look at the Gain (measure of improvement after inversion)

How to improve emissions from both sectors