Towards informing sector characteristics of urban CO_2 emissions using co-emitted trace gases

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SCAN ME

Objectives and research questions

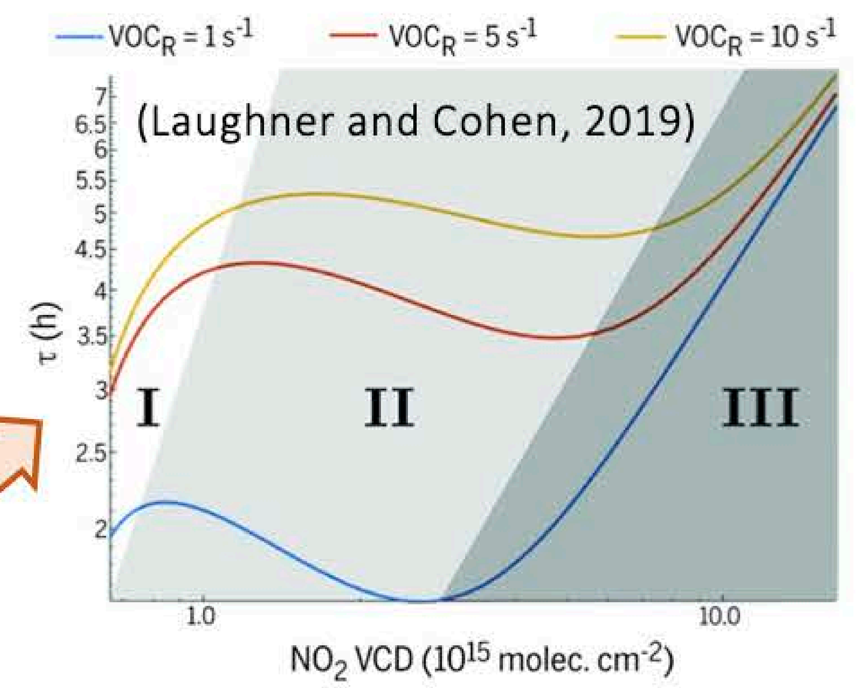
Inform urban emission characteristics by studying "observed" emission ratios from space

(new ingredients: *urban land cover *TROPOMI data *Lagrangian model with non-linear chem param)

1. How can TROPOMI XCO and tNO_2 observations be combined with OCO-3 SAMs?
   - !!! Met condition; AK; Biosphere; Chemical transformation; Emission patterns
2. How does emission ratios (of $CO:CO_2$, $NO_x:CO_2$) vary across different parts of a city?

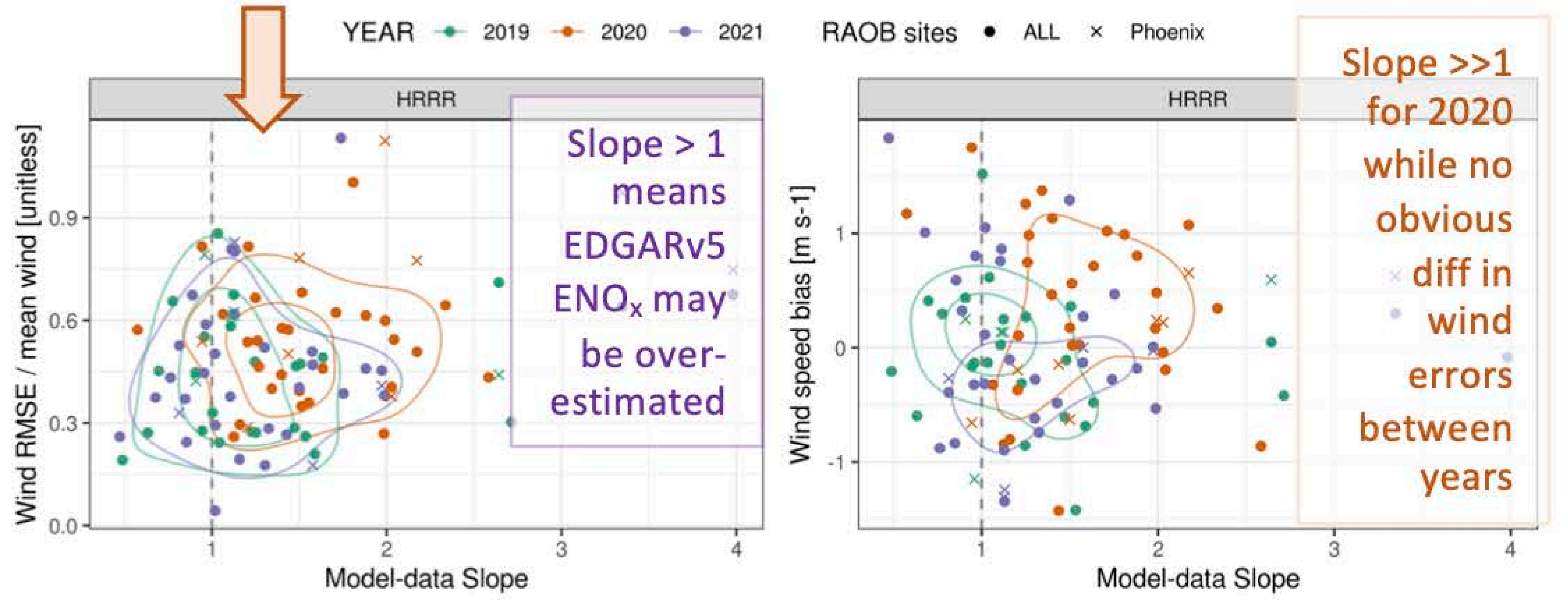
Toolbox upgrade

- (X-)STILT to interpret satellite obs (Wu et al., GMD, 2018)
- Localized background values and a SIF-based NEE representation (SMUrF, Wu et al., GMD, 2020)
  - to address spatial variability in biogenic contributions
- 120 m urban land cover data from WUDAPT
- A simplified parameterization of **non-linear** NO_x chem (STILT-NO_x Wu et al., in prep)
  - E.g., $d[NO_x]$ due to chem. rely on $[NO_x]$ from last time step
- A chemical inversion (Miyazaki et al., ACP, 2012) coupled with STILT-NO_x considering the non-linearity between ENO_x vs. tNO_2 (Wu et al., in prep)

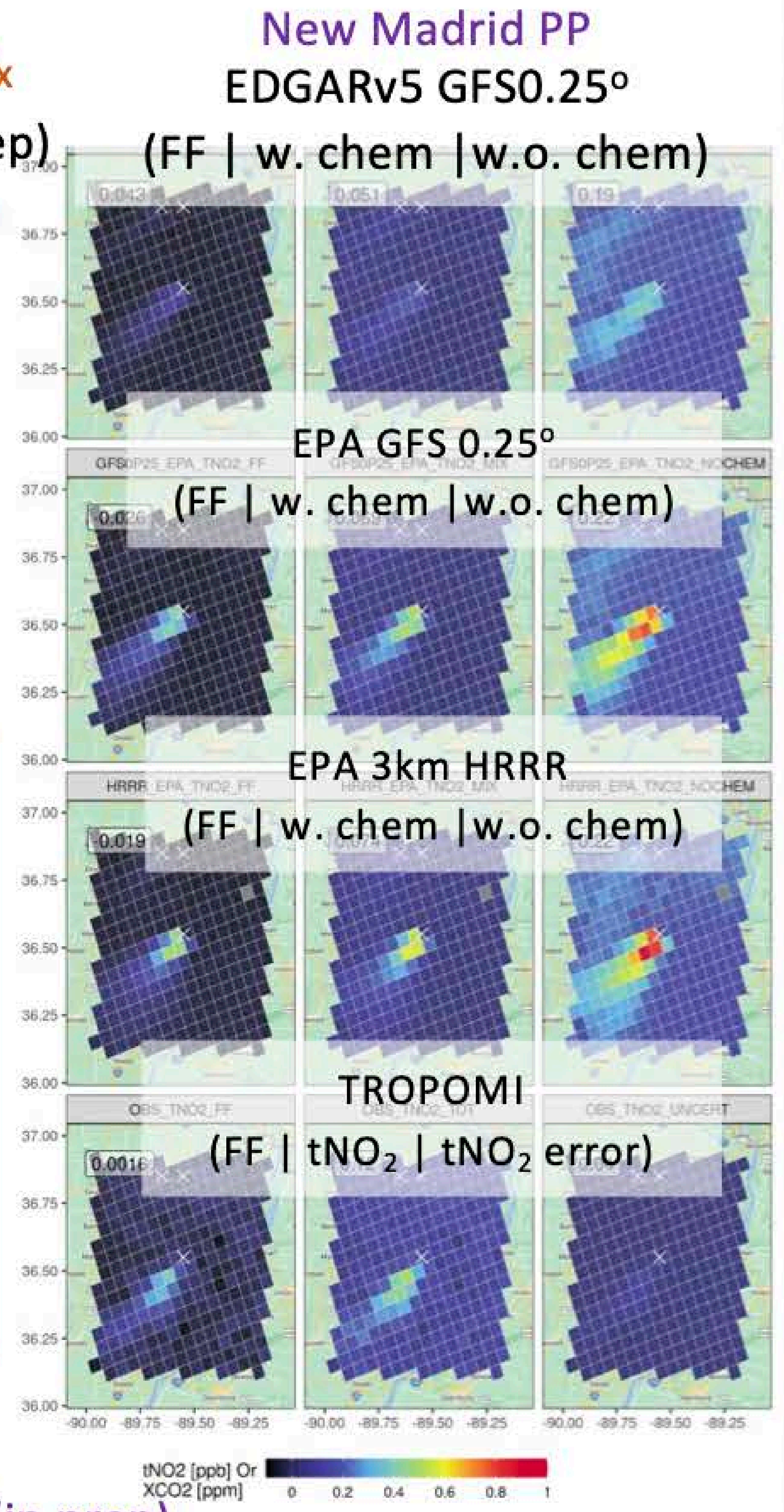


Model experiments of tNO_2 for power plants and cities

- Modeled error component assessments (not shown)
  - Wind (~25% in $m s^{-1}$ → 50% in ppb) > chem > inter-parcel mixing
- 4 US power plants (NO_x top emitters in 2020)
- 2 cities (80+ overpasses for Phoenix and 10+ for Baotou)

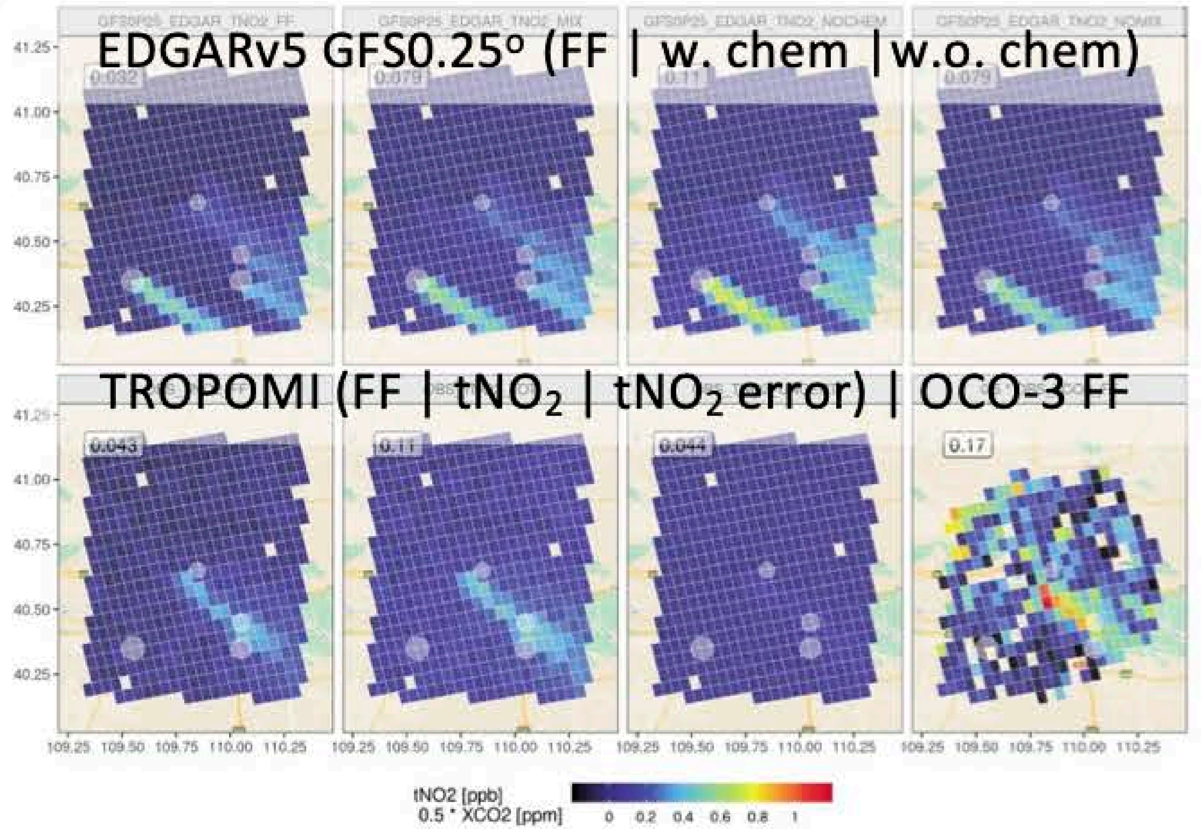


Model-data tNO_2 comparisons vs. wind errors for Phoenix from 2019 to 2021, Wu et al. (in prep)

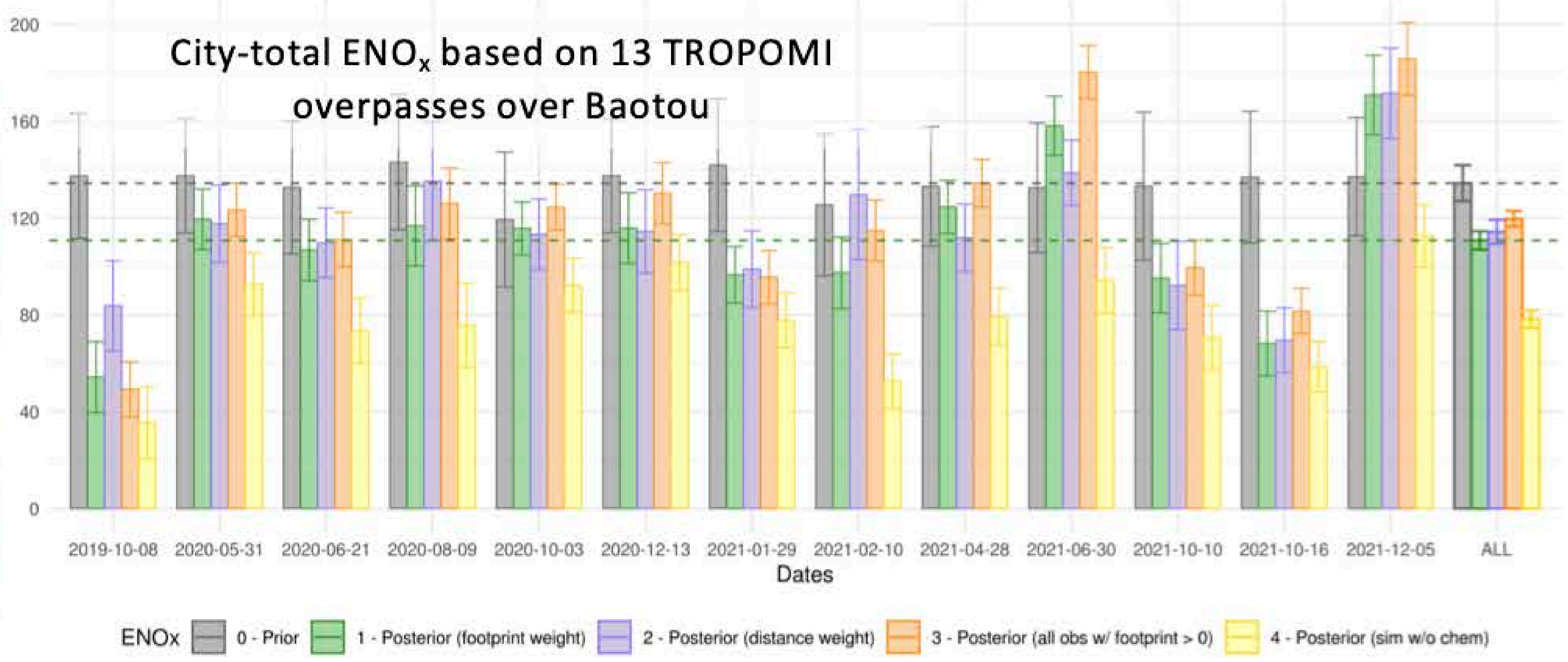


ENO_x inversion (EnKF) with a Lagrangian model

- Correct spatial distributions of ENO_x (co-located with ECO_2 in EDGARv5)



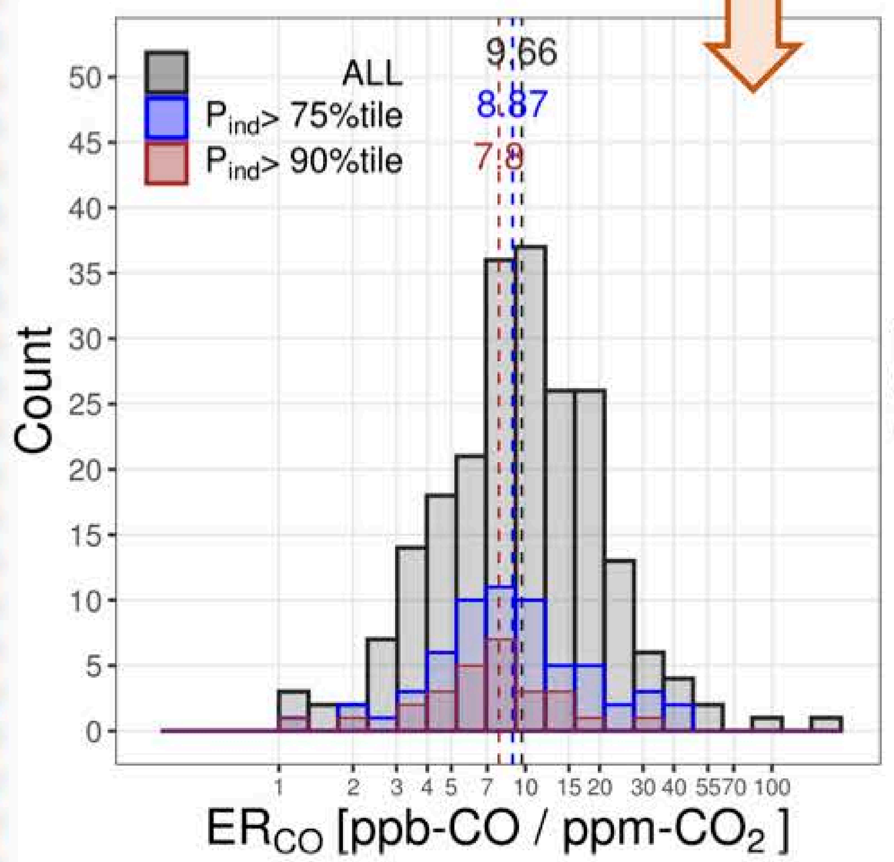
- Posterior ENO_x are biased low by ~27% w.o. accounting for NO_x chem transformation (yellow bars)



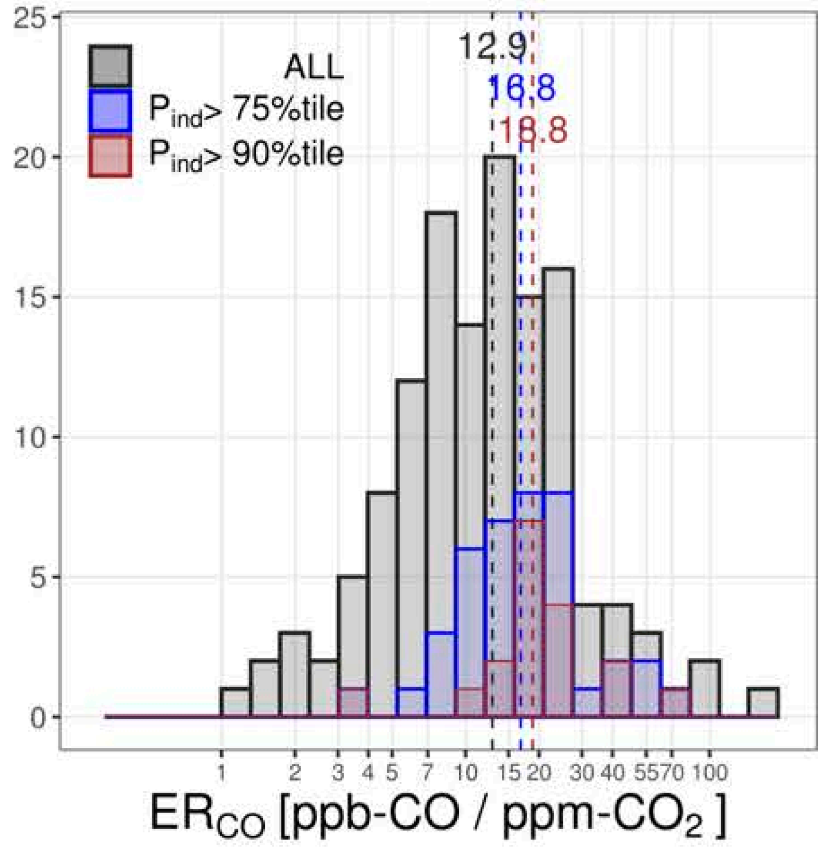
- Optimized ENO_x with improved spatial distribution & magnitude
  - real-time prior for ECO_2 OR for constraining ER of $NO_x:CO_2$

Combustion efficiency within a city

- City-scale ER_{CO}
  - industry-centered cities (15+ ppb ppm^{-1}) >> megacities with mixed sector signals (< 10 ppb ppm^{-1})
- Industry-related ER_{CO} (red bars) via WUDAPT + XSTILT
  - Shanghai (~18.8 ppb ppm^{-1}) >> Los Angeles (~7.8 ppb ppm^{-1}) (Wu et al., ACPD)



Histogram of ER_{CO} for LA



Histogram of ER_{CO} for Shanghai

Summary

- STILT-NO_x agrees with TROPOMI for selected PPs using EPA ENO_x, except for cases in winter or with low tNO_2, where met & chem become complex (e.g., Intermountain PP in Utah).
- The overall modeled error for modeling tNO_2 is predominated by wind error.
- A difference in overpass times between TROPOMI and OCO-3 of > 3 hours → significant shift in urban plumes.

Ongoing...

- To improve the spatial distribution & magnitude of emission ratios between ENO_x and ECO_2 for informing sector-specific signals from space