

EGU21-9338: Satellite-based fossil fuel CO₂ emissions detection over metropolitan areas: a multi-model analysis of OCO-2 data over Lahore, Pakistan

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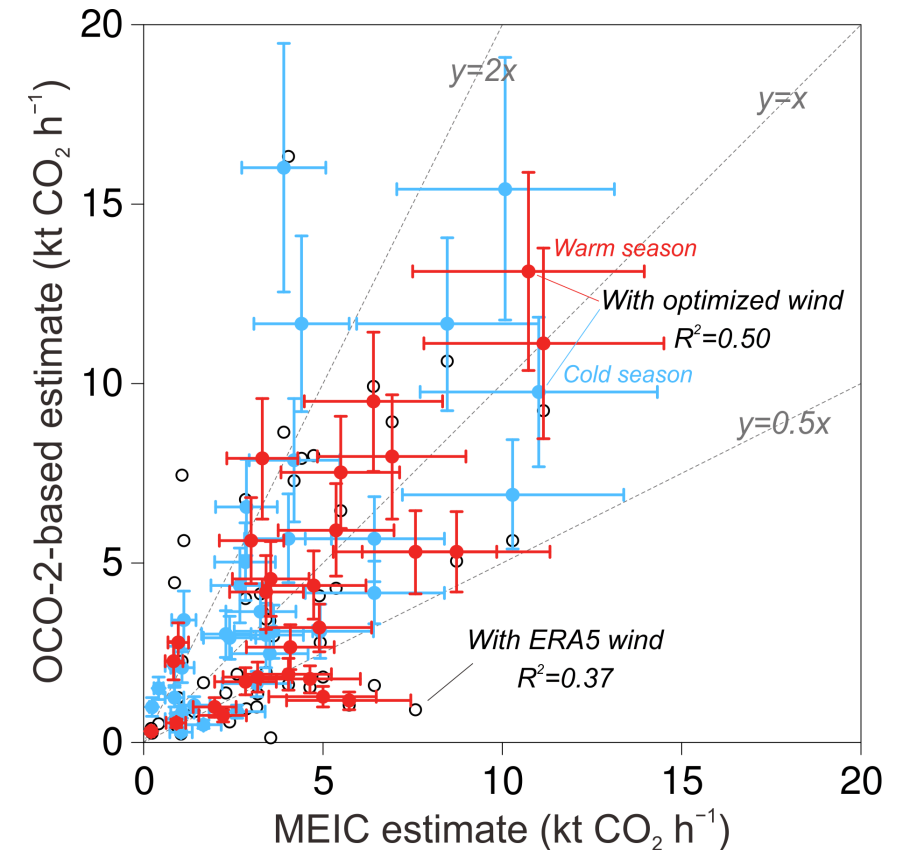
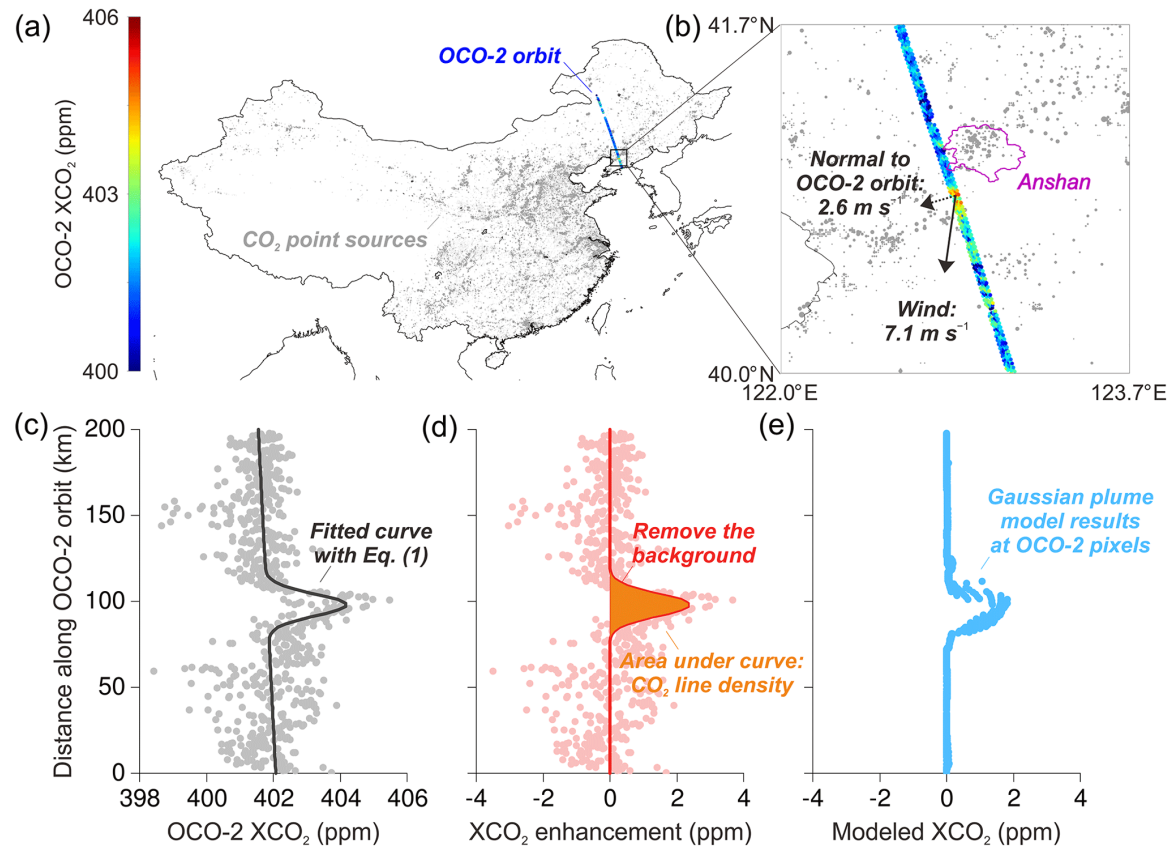
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Cross-sectional CO₂ flux estimate based on Gaussian plume model

An efficient, simple approach



Zheng et al. 2020 ACP

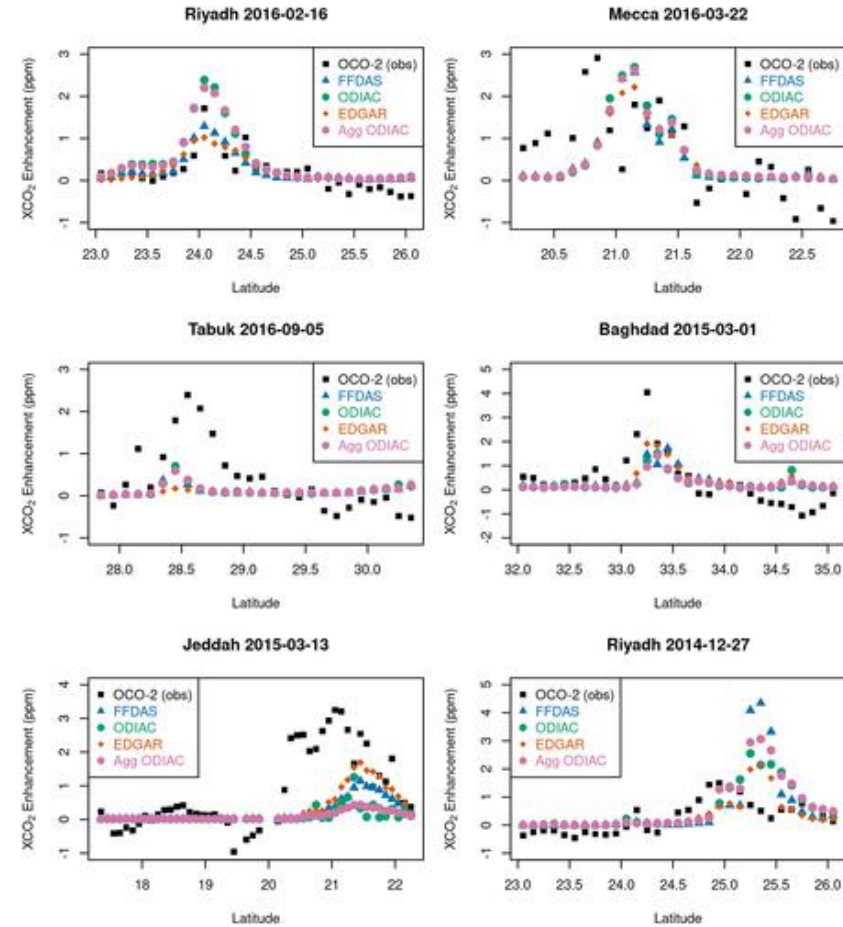
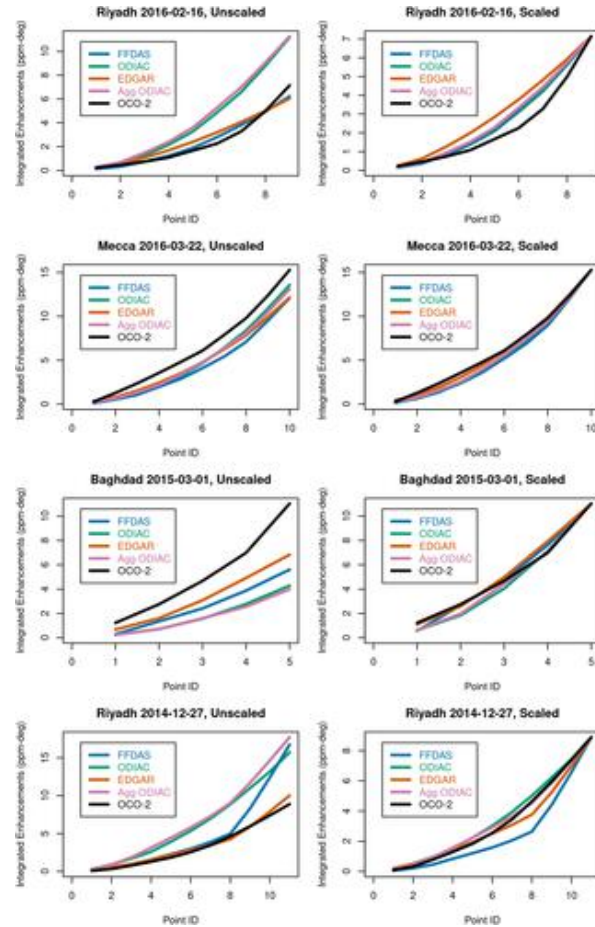


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Estimate based on Lagrangian Model (X-STILT)

Reasonable, but has not been applied to long-term trend



Yang et al. 2020 JGR-Atmosphere



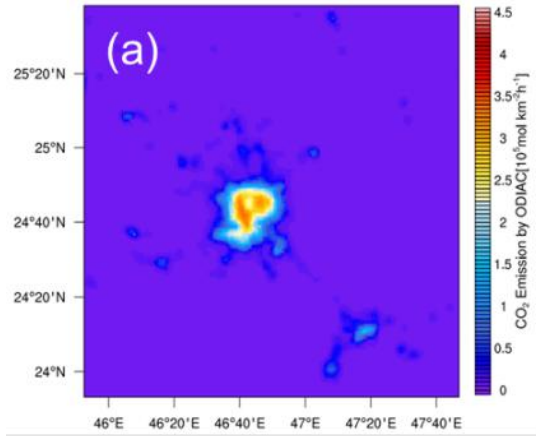
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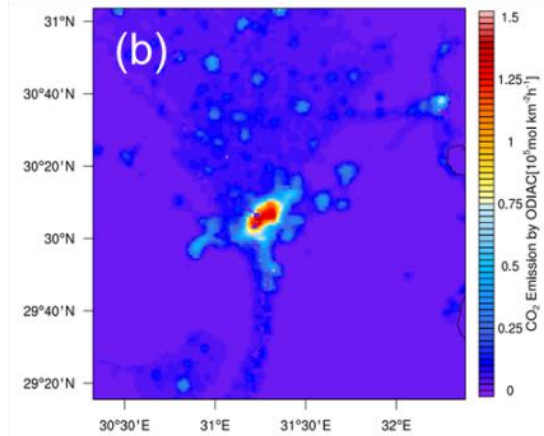
Estimate based on Eulerian Model (WRF-Chem)

Fossil-fuel CO₂ emissions based on ODIAC product

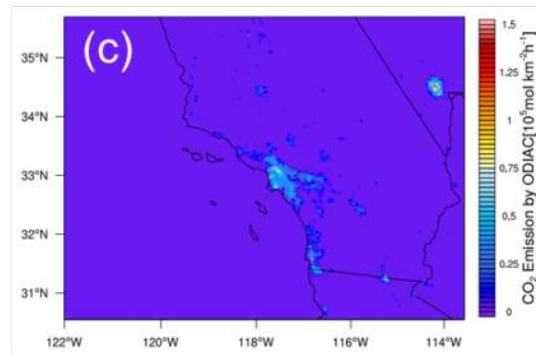
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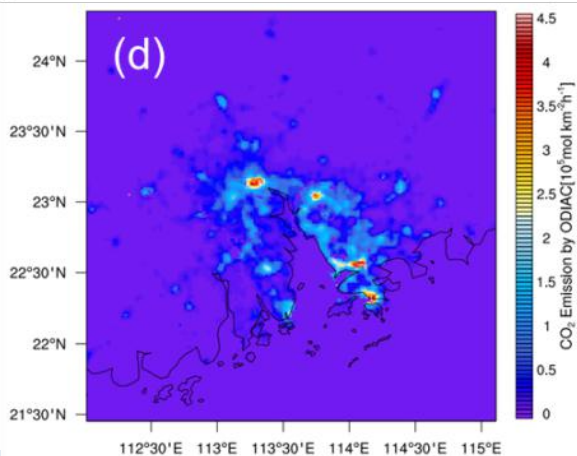
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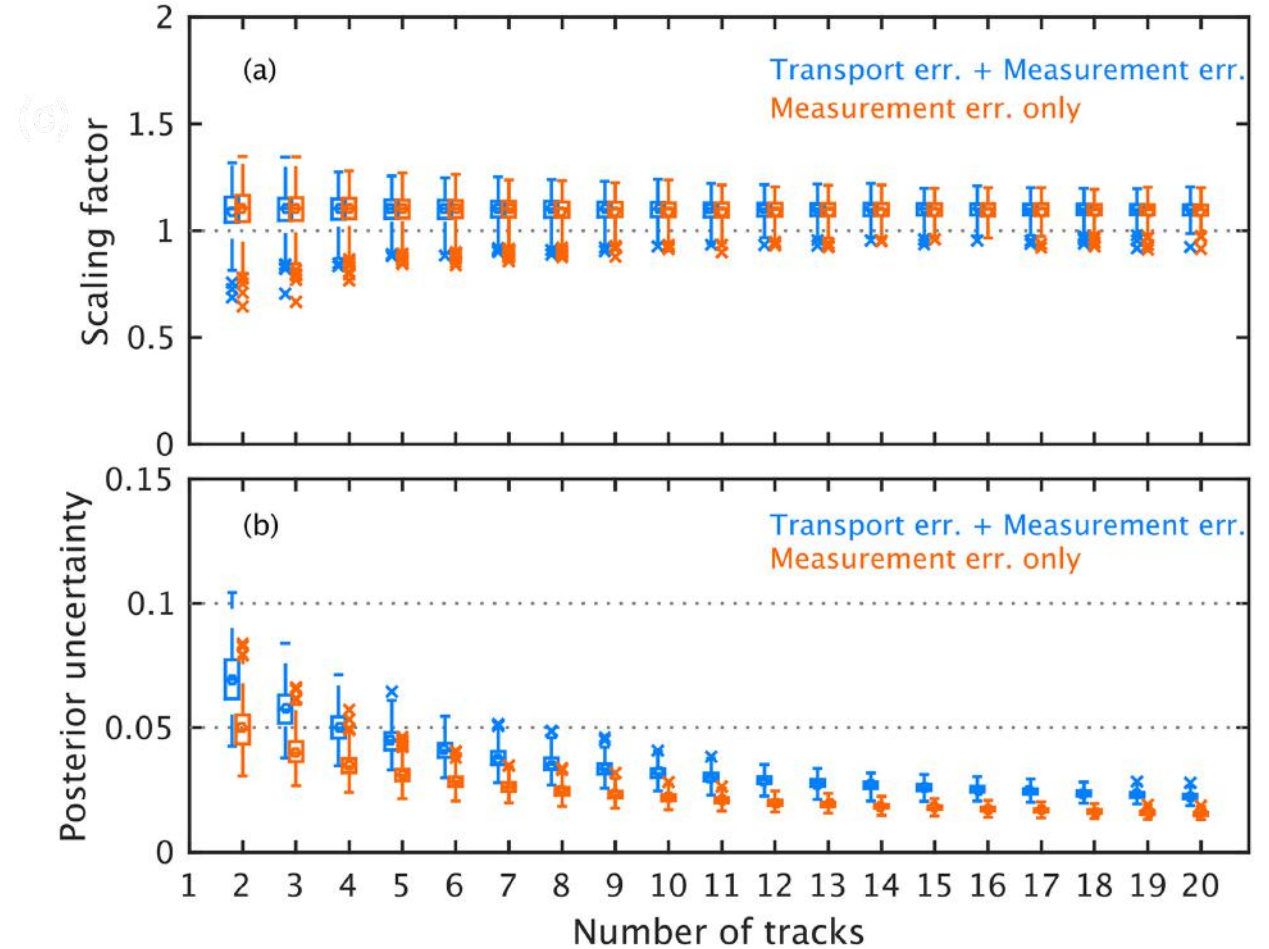
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Scaling factor and posterior uncertainty derived by the OSSE for different number of OCO-2 tracks



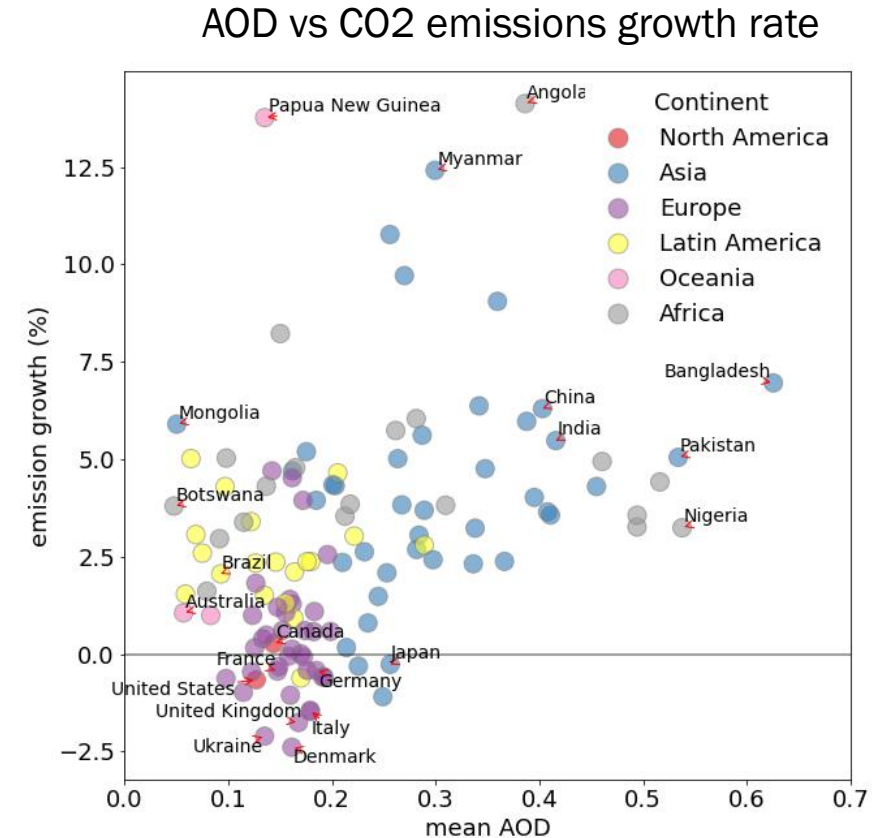
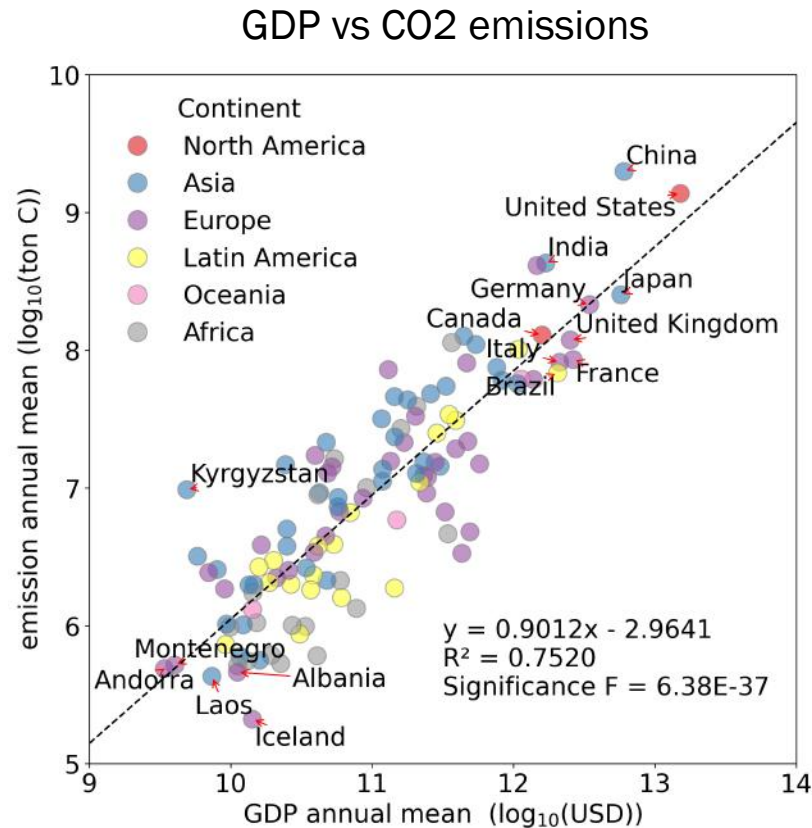
Ye et al., 2020; JGR- Atmosphere



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Potential of satellites on monitoring long-term trend



- A strong connection between GDP and FFCO_2 emissions indicates that economic growth deeply relies on fossil fuel consumption in most countries.
- Air quality is more associated with the growing trend than the level of development of a country.

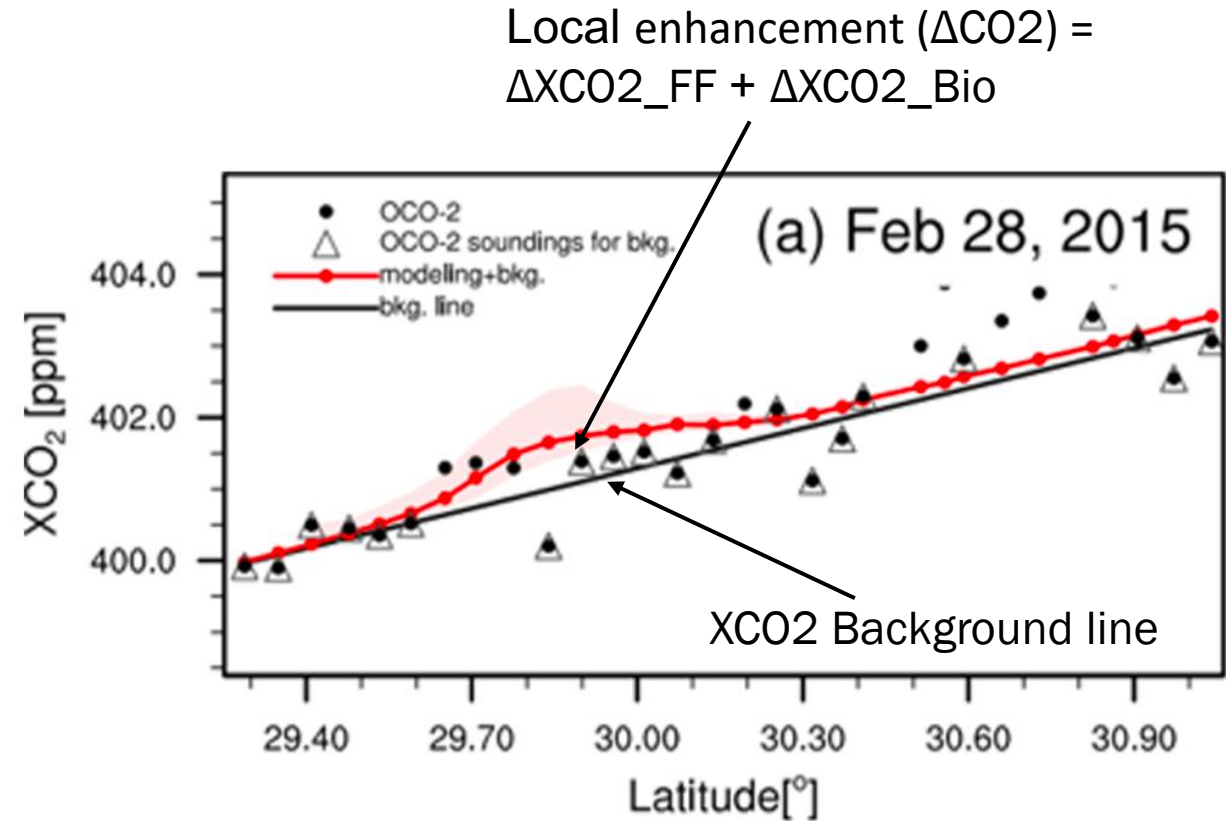
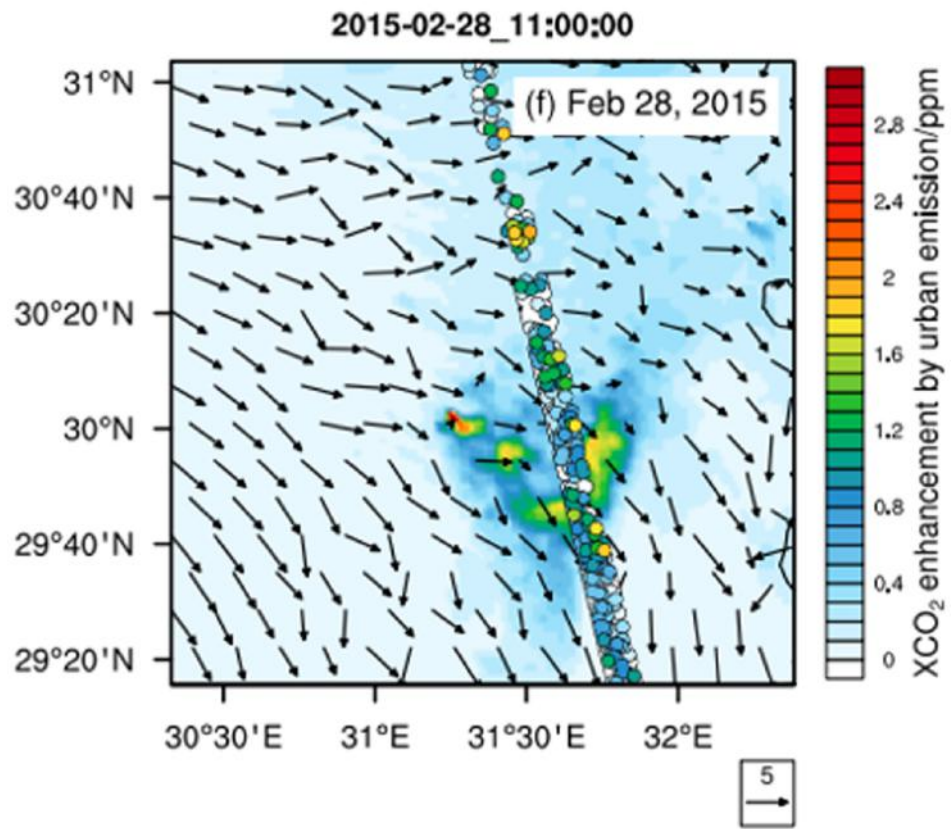
Lei et al., 2020; ERL



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Extract the fossil fuel signals



Ye et al., 2020; JGR-Atmosphere



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Scientific questions to answer

- How many OCO-2 tracks are available over urban areas?
- Is OCO-2 quality flags helpful at city level?
- Are selected tracks enough to capture the long-term fossil fuel CO₂ emission trend?



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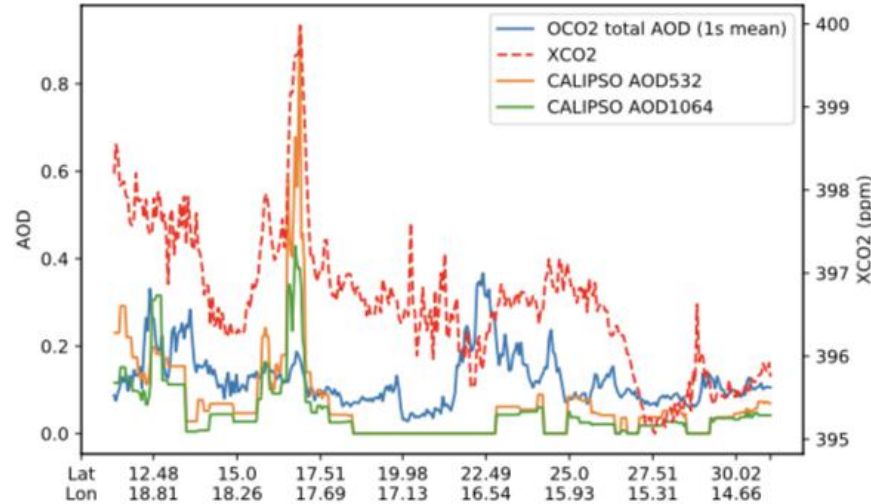


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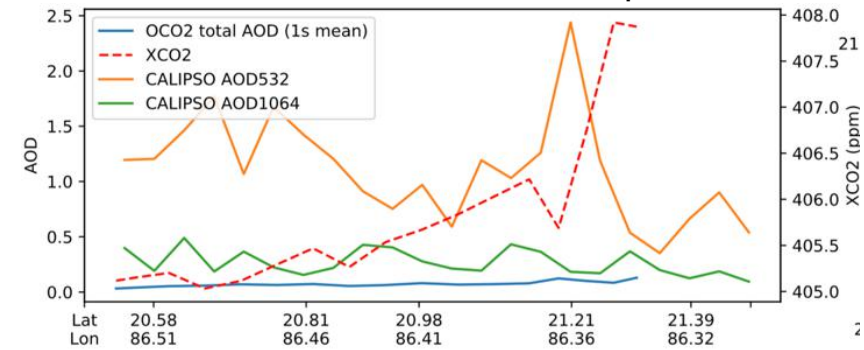


Limit: fake XCO₂ peaks possibly caused by aerosols in OCO-2 data

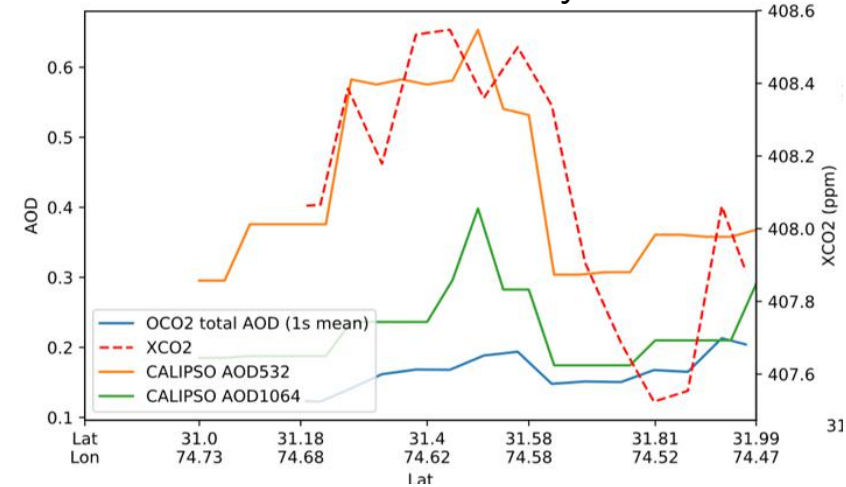
A case in Sahara Desert



A case near a wildfire point



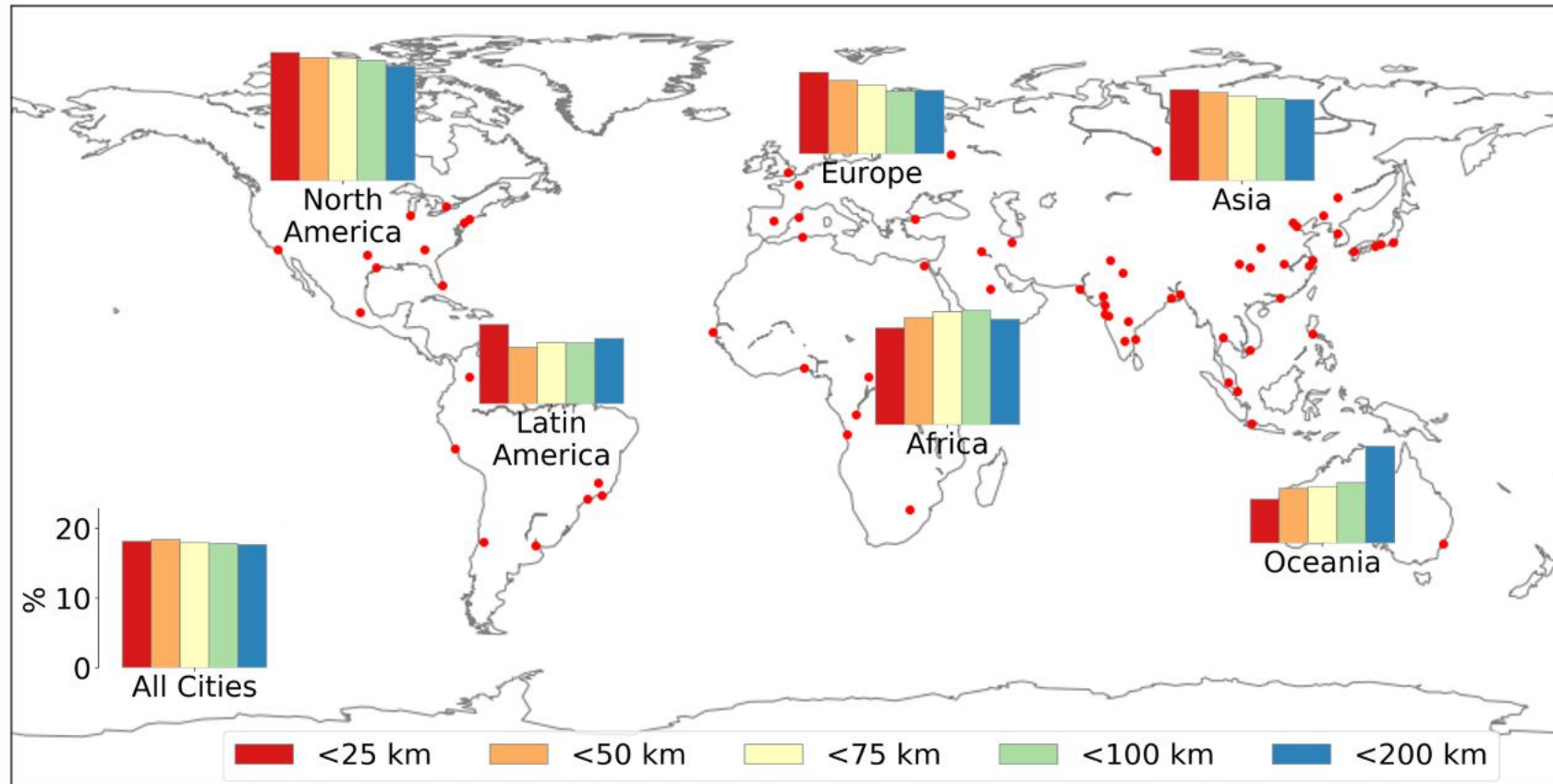
A case near a city



- OCO-2 XCO₂ peaks and CALIPSO AOD peaks overlapped
- But OCO-2 itself failed to detect the AOD peak.



OCO-2 high-quality soundings over the most populated 70 cities



- About 17% OCO-2 soundings are marked as high-quality soundings by quality flags over the global 70 cities.
- Given the 16-day OCO-2 revisit period, there are 3-4 high-quality tracks per year over each city on average.
- Cloud and aerosol issues are two main reasons of data loss.

Lei et al., in review; RSE



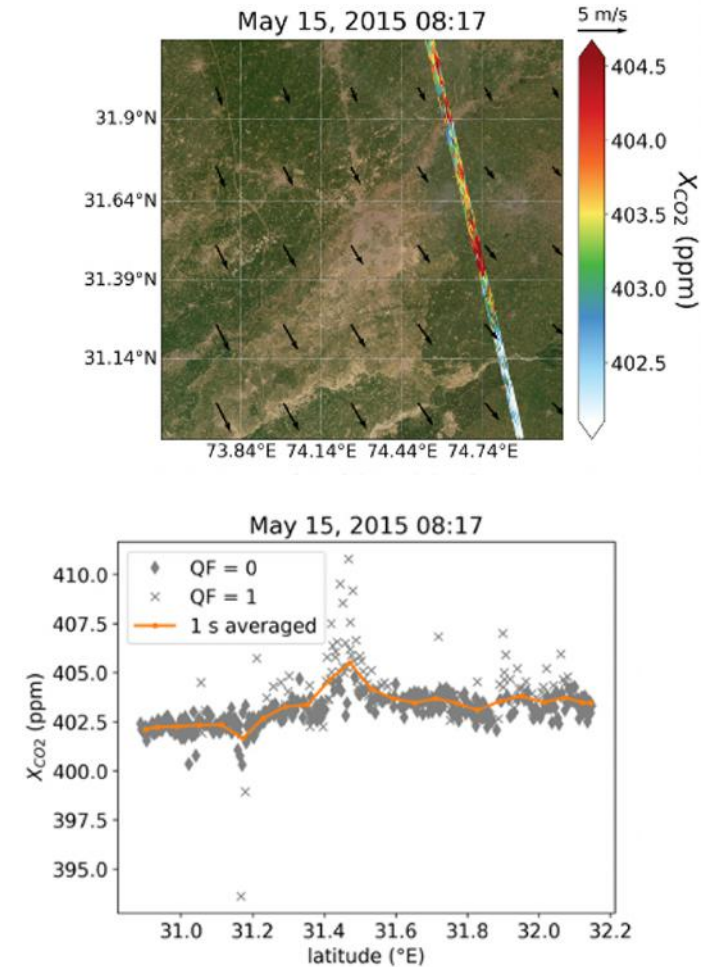
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OCO-2 XCO₂ tracks over Lahore, Pakistan (Case study)

- Reasons of selecting Lahore:
 - The second-largest city in Pakistan
 - Fast-growing economy and populational booming in recent two decades
 - Flat topography and fast-increasing fossil fuel CO₂ emissions
- Track choosing criteria:
 - More than 150 soundings evenly distribute along the track
 - Located downwind of the city
 - Show clear XCO₂ enhancements
- 25 all-data tracks (qf = 0 and 1) and 8 high-quality tracks (qf = 0 only) are available from 2014 to 2019

OCO-2 track sample



Lei et al., in review; RSE



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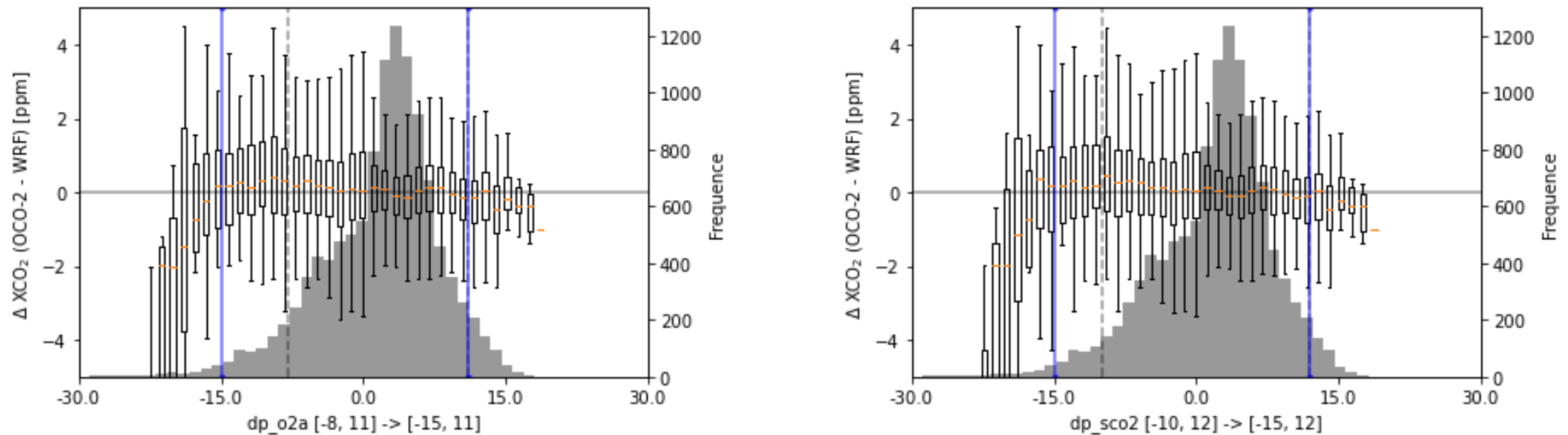
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Optimizing the OCO-2 quality flag selection criteria at the city scale



- The grey dashed vertical lines represent the default thresholds of OCO-2 selection criteria.
- The blue vertical lines represent the adjusted thresholds based on XCO₂ residuals (OCO-2 - WRF).
- Although the threshold but changed a little, but the numbers of high-quality soundings did not change.
- Thus, we decided to trust the original qf ranges.

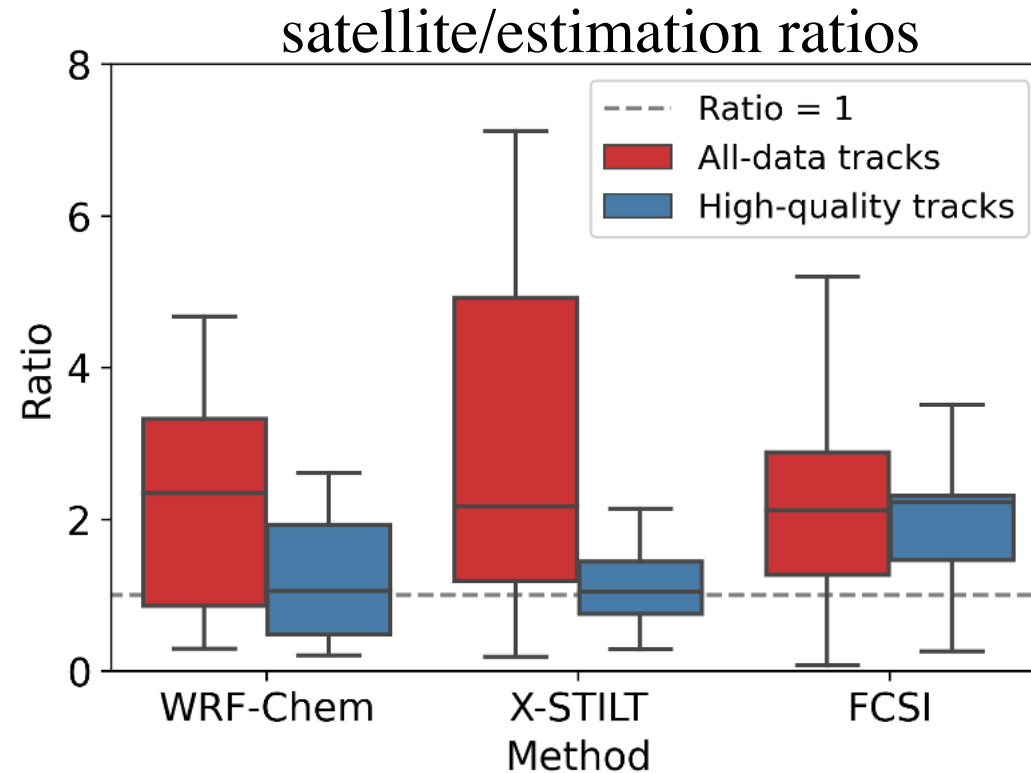
Lei et al., in review; RSE



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Validation of OCO-2 quality flags at the city-level



- Ratios of 8 high-quality tracks ($qf = 0$) converge closer to 1 compared to 25 all-data tracks.
- Thus, OCO-2 quality flags are helpful and should be adopted at city-scale studies although designed for global retrieval.

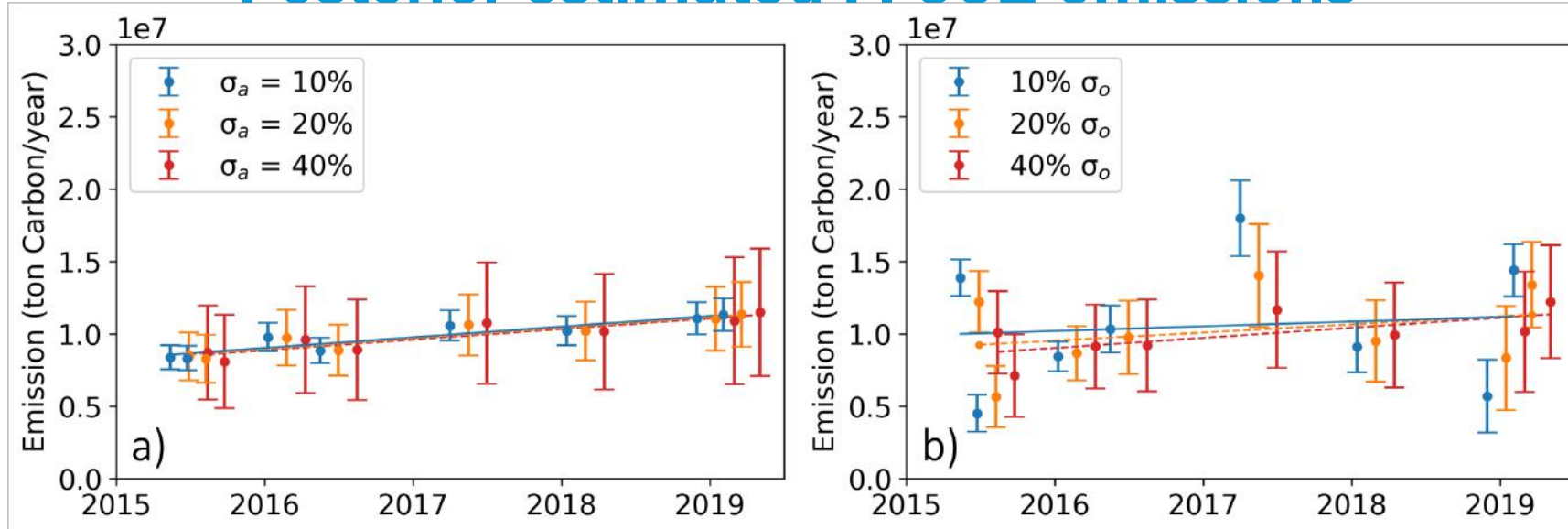
Lei et al., in review; RSE



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Posterior estimated FFCO2 emissions



Prior uncertainty (σ_a)	Observation uncertainty (σ_o)	Linear regression equation	Trend significant probability
10%	100% σ_o	$y = 7.37 \times 10^5 x - 1.48 \times 10^9, R^2 = 0.86$	57.37%
20%		$y = 7.37 \times 10^5 x - 1.48 \times 10^9, R^2 = 0.86$	23.04%
40%		$y = 7.34 \times 10^5 x - 1.47 \times 10^9, R^2 = 0.83$	10.26%
40%	10% σ_o	$y = 3.23 \times 10^5 x - 6.41 \times 10^8, R^2 = 0.01$	0.01%
	20% σ_o	$y = 5.62 \times 10^5 x - 1.12 \times 10^9, R^2 = 0.09$	3.87%
	40% σ_o	$y = 7.00 \times 10^5 x - 1.40 \times 10^9, R^2 = 0.44$	9.49%

Lei et al., in review; RSE

- The posterior fossil fuel CO2 emissions over Lahore show an annual 6.7% increasing trend.
- Given the limited number of valid track, the trend is mainly driven by prior not the satellite and model.



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Conclusions

- About 17% of OCO-2 soundings are marked as high-quality soundings by OCO-2 quality flags over the global 70 cities, which means that there are 3-4 high-quality tracks per year over cities on average. Cloud and aerosol issues are two main reasons of data loss.
- The simulations of 25 tracks over Lahore, Pakistan show that the OCO-2 quality flags are also helpful for city-level studies although they were originally designed for global-scale studies.
- Bayesian inversion shows an annual 6.7% increasing trend of fossil fuel CO₂ emissions over Lahore. But the trend is mainly driven by the prior, not the optimized emissions based on OCO-2 satellite data because of the limited number of high-quality tracks.



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