Quantifying burning efficiency using the Tropospheric Monitoring Instrument (TROPOMI)

Srijana Lama, Sander Houweling , K. Folkert Boersma , Ilse Aben Hugo A C Denier van der Gon ,Maarten C. Krol , A.J.(Han) Dolman , Tobias Borsdorff , Alba Lorente

VU VRIJE UNIVERSITEIT AMSTERDAM

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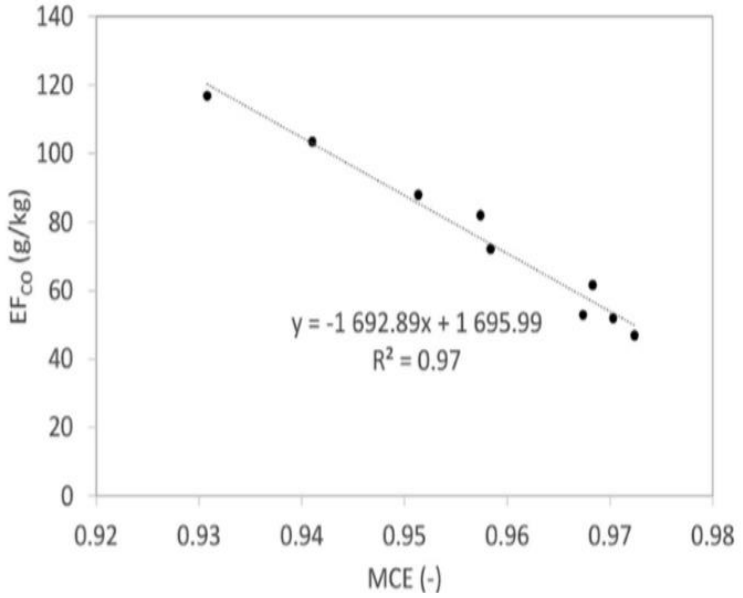
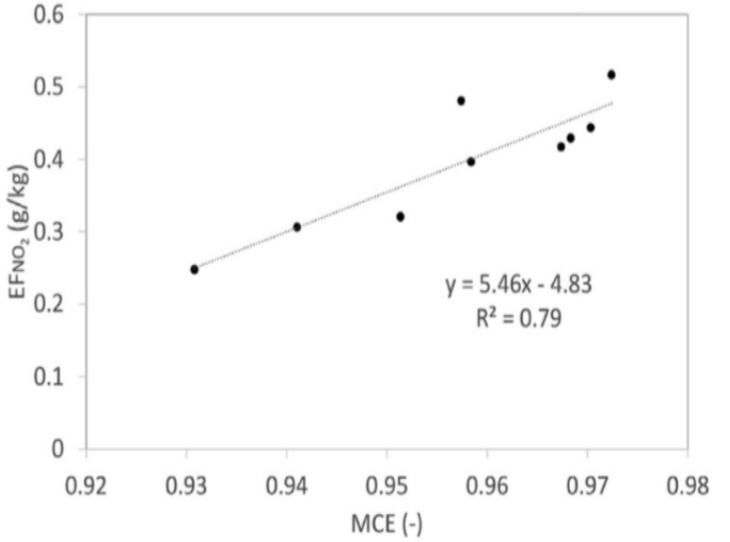
s.lama@vu.nl

SRON Netherlands Institute for Space Research

BURNING EFFICIENCY

- Increased in burning of fossil fuel and biomass burning has severe impact on climate change
- Burning efficiency is the important parameter to quantify the effect of fuel burning on the atmosphere.
- Burning efficiency (BE) $= \frac{CO_2}{CO+CO_2}$
- Burning efficiency ↑ = NO_2 ↑
- Burning efficiency ↓= CO ↑
- In this study , $\frac{\Delta NO_2}{\Delta CO}$ as a proxy of BE





Tihay-Felicelli et al., 2017

MOTIVATION

Emission factor measured in the lab

Global emission inventory = activity data x Emission factor

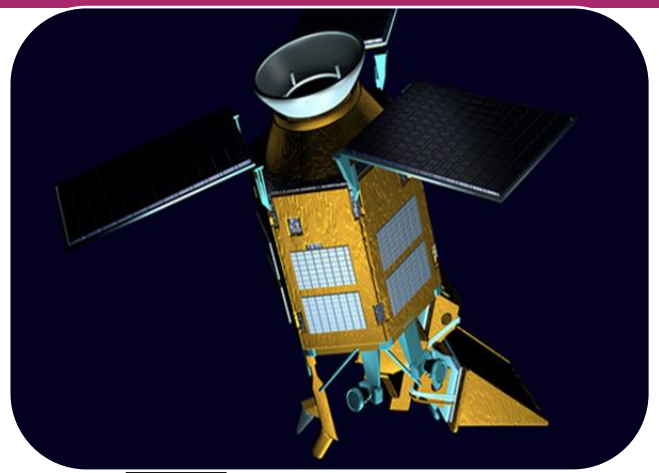
Uncertainties

Burning efficiencies varies with environmental condition

Influences

Emission Factor

OBJECTIVE



Burning efficiencies and emission ratios in the actual environment

Improve the accuracy

Global emission inventories

DATA

TROPOMI

- Launched by the European Space Agency on 13 October, 2017
- Measures the atmospheric trace gases with daily coverage
- Spatial resolution of 7x7 km^2
- Collocated carbon monoxide and nitrogen dioxide retrievals

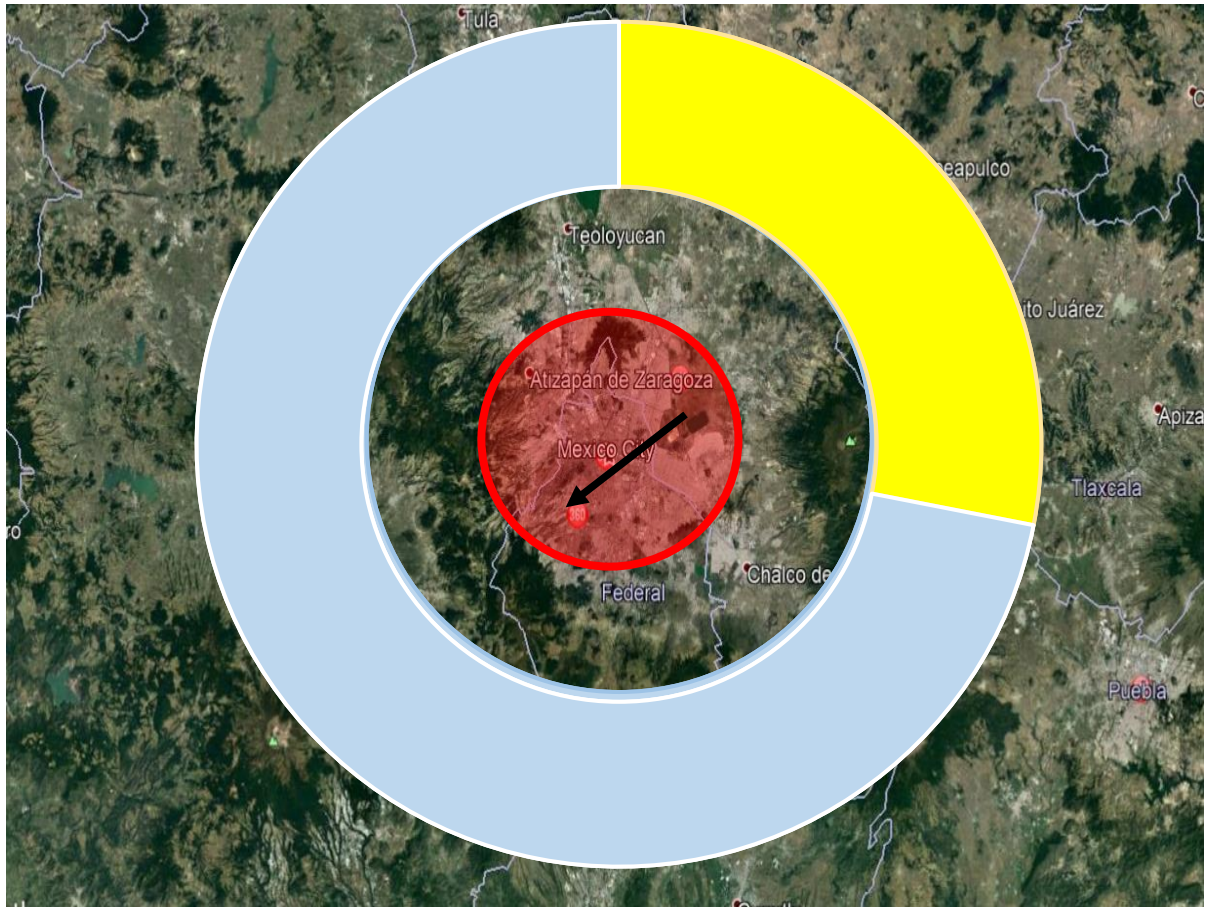
EMISSION INVENTORY

- Emission Database for Global Atmospheric Inventory (EDGAR), 2012
- Monitoring Atmospheric Chemistry and Climate and CityZen (MACCITY), 2018

METHOD

QUANTIFYING RATIOS: UPWIND BACKGROUND

MEXICO CITY



Upwind Background area

Core City area

← Wind direction

$$X = CO \text{ or } NO_2$$

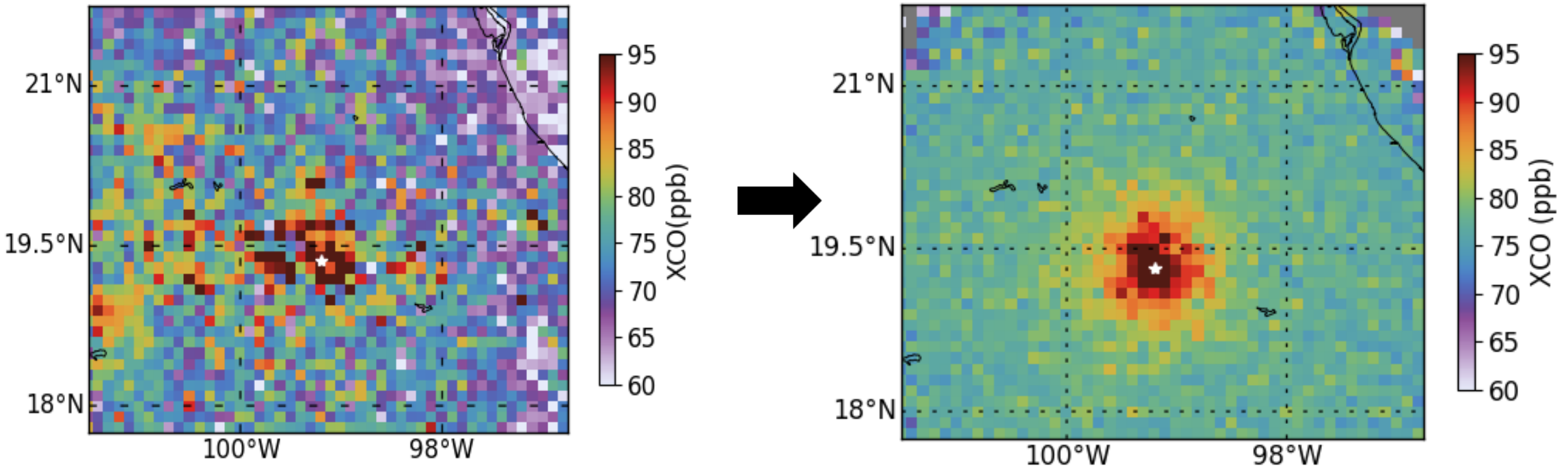
$$\Delta X = X_{\text{mean city}} - X_{\text{mean upwind background}}$$

$$\text{Ratio} = \frac{\Delta NO_2}{\Delta CO}$$

Impact of transport cancels

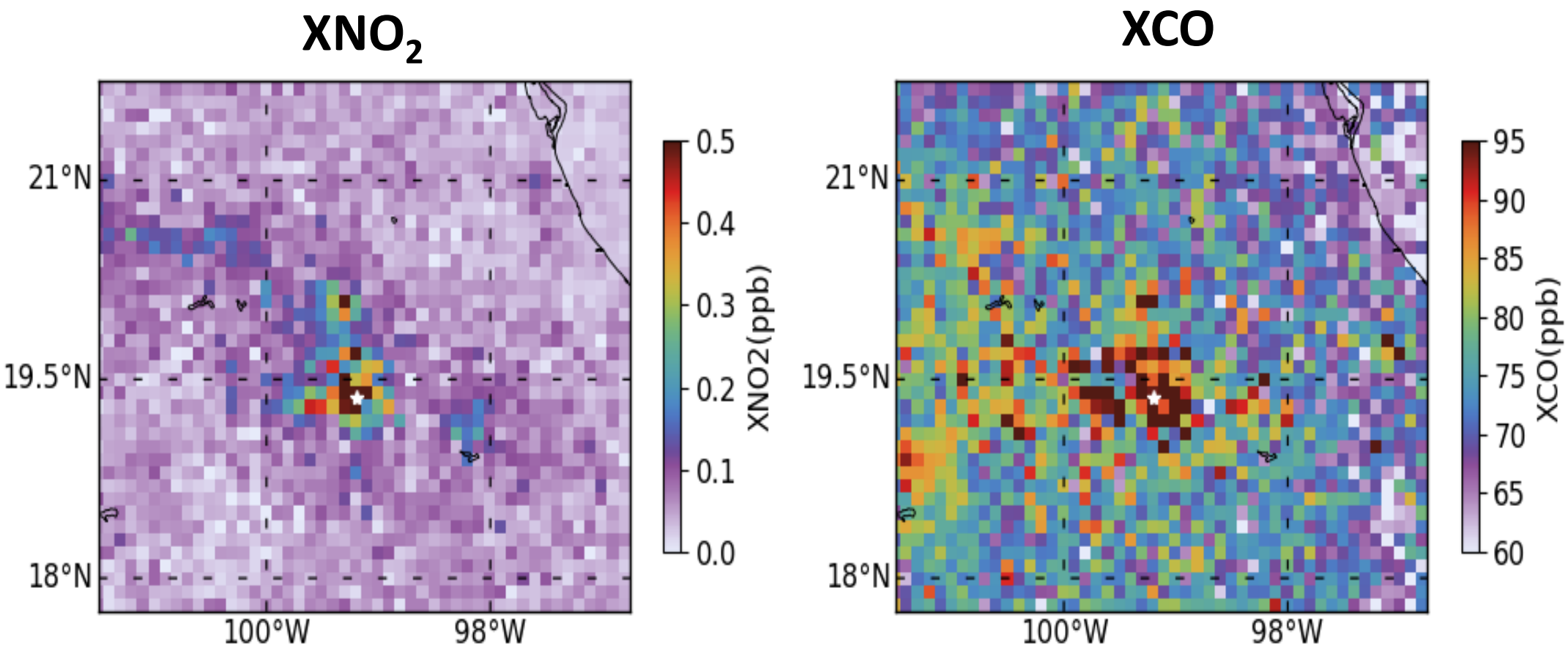
$$\text{Ratio(emission inventories)} = \frac{\sum_{i=1}^{n} NO_2 \text{ city}}{\sum_{i=1}^{n} CO \text{ city}}$$

METHOD
QUANTIFYING RATIOS: PLUME ROTATION



- The area above the centre of city is upwind and below is downwind area
- $Vd = \frac{\sum_{i=1}^{n\ downwind}(X \geq 75^{th}\ percentile\ )}{n_{\ downwind}}$, $Vu = \frac{\sum_{i=1}^{n\ upwind}(X \leq 25^{th}\ percentile)}{n_{upwind}}$
- $\Delta X = Vd - Vu$
- Ratio = $\frac{\Delta NO2}{\Delta CO}$, for details see Pommier et al., 2013

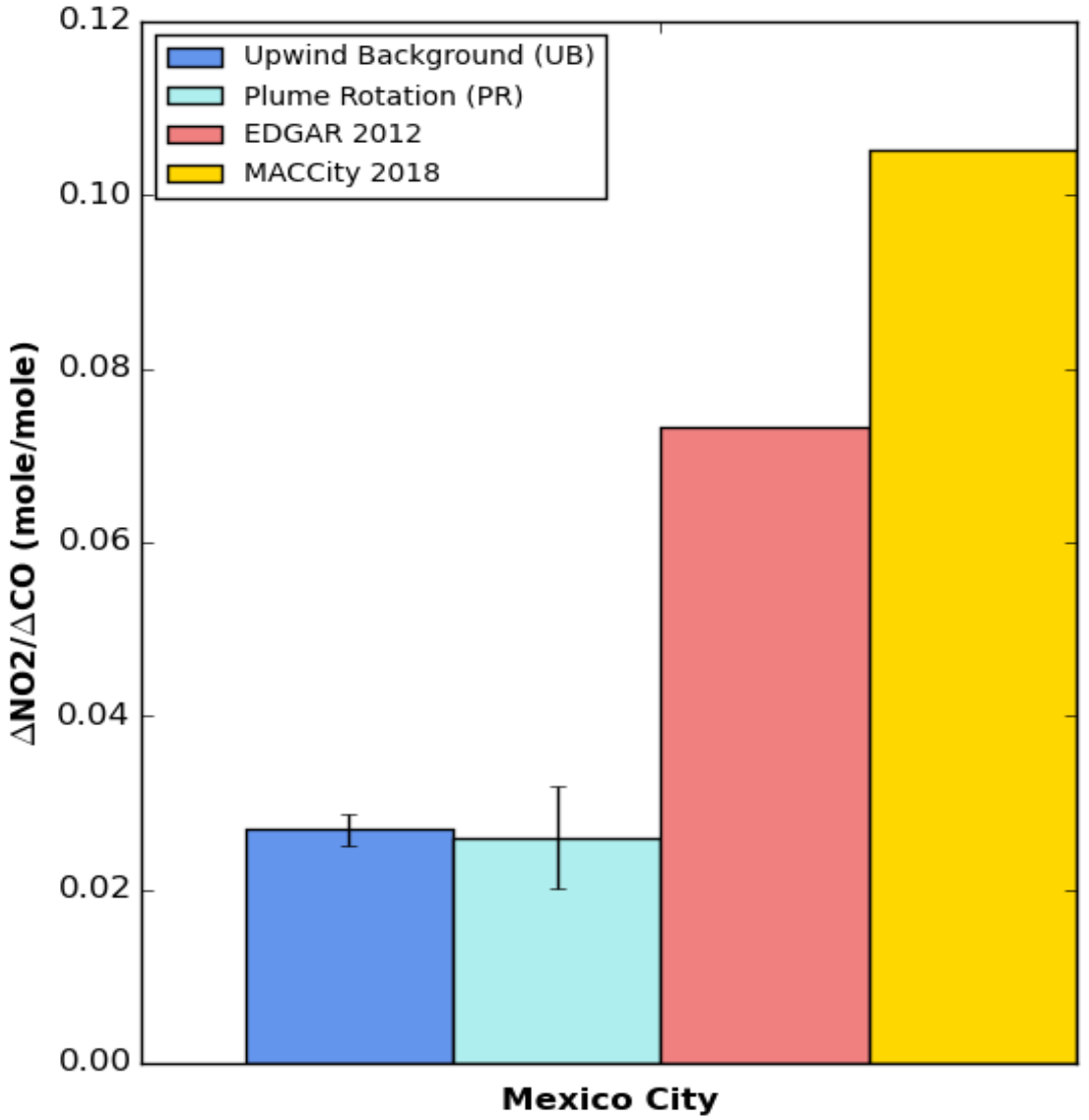
MEXICO CITY (JUNE – AUGUST, 2018)



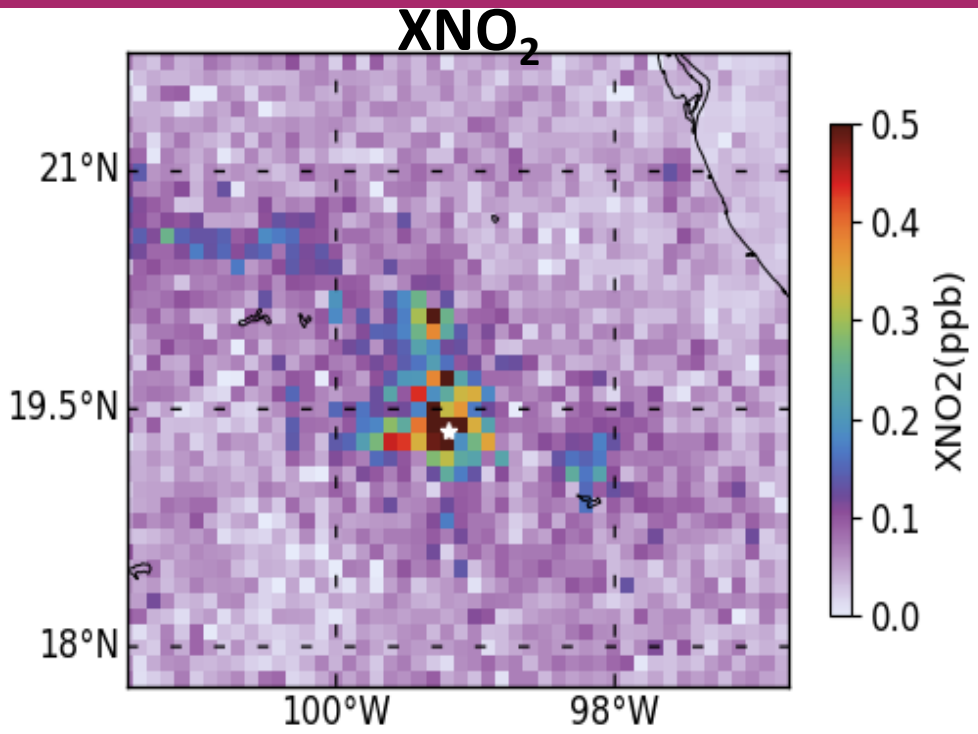
- The enhancements of XCO and XNO_2 over Mexico City are clearly separated from the surrounding background areas and correlate with each other.
- This confirms that it is possible to obtain useful information about burning efficiency

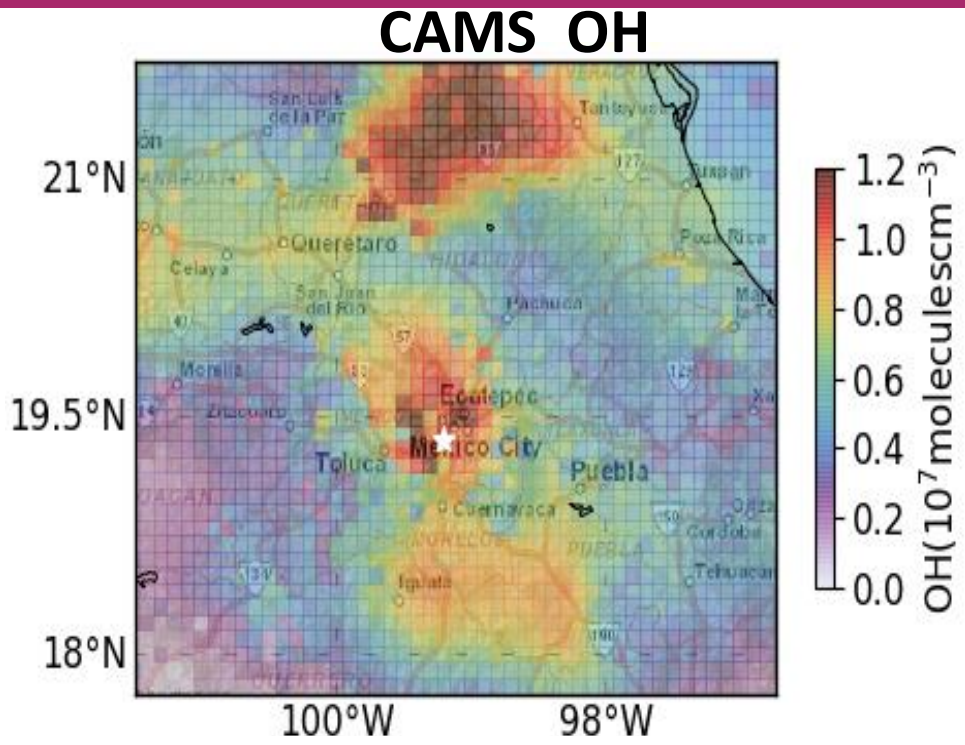
EMISSION INVENTORY Vs TROPOMI COLUMN ENHANCEMENT RATIO

- **Upwind background and Plume rotation ratio differ by < 10 % representing the robustness of the method.**
- **EDGAR and MACCity emission ratio is higher by 63 % and 73% compared to TROPOMI column enhancement ratio.**
- **The difference between satellite-derived column enhancement ratios and inventory-based emission ratios can be explained in part by the relative short lifetime of NO_2 and the different vertical sensitivity of TROPOMI CO and NO2 retrievals**



NO2 LIFETIME CORRECTION





- **OH is the major component to limit the lifetime of NO2 during the noon.**
- **CAMS OH is spatially, temporally and vertically interpolated at the time TROPOMI overpasses.**
- **Clear enhancement of OH at the city correlates well with TROPOMI NO_2 enhancement**
- **Using CAMS OH ,TROPOMI column enhancement ratio is corrected to derive the TROPOMI emission ratio**

AVERAGING KERNEL (A) INFLUENCE

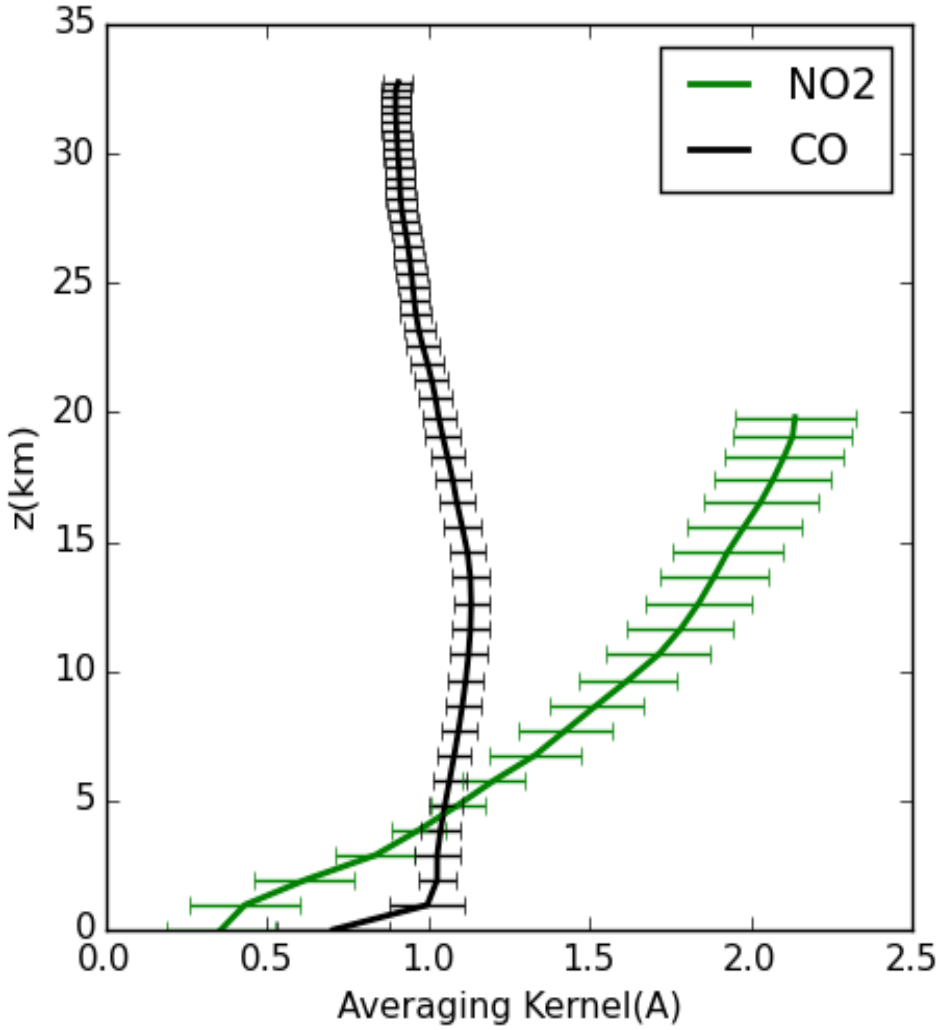
- Different vertical sensitivity of TROPOMI NO_2 and CO retrievals influences $\frac{\Delta NO_2}{\Delta CO}$
- Two simulations using CAMS NO_2 and CO to quantify the influence of A

$$\text{Without A} = \frac{\Delta NO_{2\,CAMS}}{\Delta CO_{CAMS}}$$

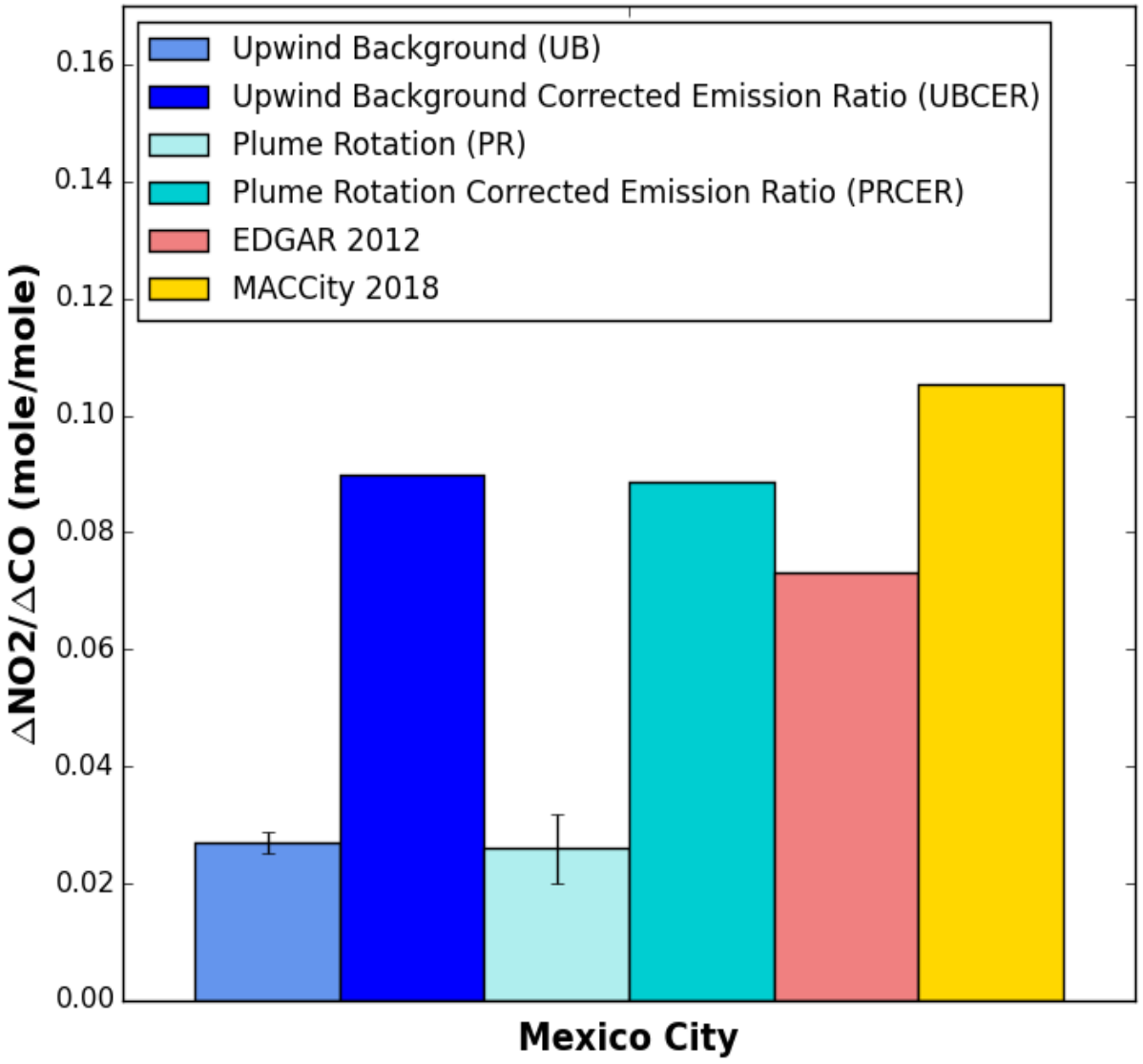
$$\text{With A} = \frac{\Delta NO_{2\,\text{new CAMS}}}{\Delta CO_{\text{new CAMS}}}$$

Where, $NO2_{\text{new CAMS}} = NO_{2\,CAMS} * A_{\text{NO2 TROPOMI}}$,
$CO_{\text{new CAMS}} = CO_{CAMS} * A_{\text{CO TROPOMI}}$

- $A_{influence} = \frac{(\text{Without A} - \text{with A})}{\text{Without A}} . 100\%$
- $A_{influence}$ is ~10 %



EMISSION INVENTORY Vs TROPOMI EMISSION RATIO



- NO_2 lifetime correction leads to increase the UB and PR column enhancement ratios by 65 %.
- Correcting TROPOMI derived column enhancement ratio for NO2 short life time and different vertical sensitivity of CO and NO2 improves the agreement between TROPOMI and emission inventories.

CONCLUSION

- **TROPOMI is well capable of detecting XCO and XNO_2 enhancements over these megacities.**
- **Correcting TROPOMI derived column enhancement ratio considering the influences of NO_2 short life time and averaging kernel improves the agreement between TROPOMI and inventory derived ratios.**
- **TROPOMI data has potential for monitoring burning efficiency and evaluating emission inventories.**
- **Similar study has been extended for other cities Tehran, Cairo, Riyadh, Lahore and Los Angeles. The detailed explanation is in https://www.atmos-chem-phys-discuss.net/acp-2019-1112/**
- **For any queries, contact s.lama@vu.nl**