#Reveiwer 3: Quantifying burning efficiency in Megacities using NO2 /CO ratio from the Tropospheric Monitoring Instrument (TROPOMI)"

This study presents new results from TROPOMI for NO2/CO emission factors that provide information about combustion efficiency on urban scales. This is an important result for understanding how well these emissions are represented in standard inventories with subsequent impacts for air quality and climate model predictions. I recommend publication after the comments from 2 other referees and some minor issues from me are addressed.

Author Response:

Thank you for your time and comments to improve our paper.

Following the comment of Ref.#1 in addressing the different NO2 and CO lifetimes, the different seasonality in concentrations should also be addressed. For example, is seasonality removed before computing the background CO? Also, in computing emission inventory ratios, are monthly emissions used when matching to data from a particular month, or do you apply annual averages?

Author Response:

To address this point, we switched to monthly emissions using EDGAR v4.3.2 2010 and MACCity 2018. The following text was added to line 344– 350:"Seasonal variations in emission factors may influence our comparison between seasonal averaged TROPOMI data and annual average EDGAR emissions. To account for the influence of seasonally varying emission factors, we compute a seasonal correction factor based on EDGAR v4.3.2 2010 since monthly data are not available for EDGAR 2012(see Fig.4). Except for Lahore, the June to August (JJA) EDGAR ratio is lower by 5 to 12.5 % compared to the annual average EDGAR ratio. The MACCity ratio for JJA, however, is higher by 10 to 71% compared to the annual average, indicating that EDGAR and MACCity disagree on the seasonality of the NO2/CO emission ratio. For MACCity, the agreement with TROPOMI improves the most when taking seasonality into account (see Fig.4)."

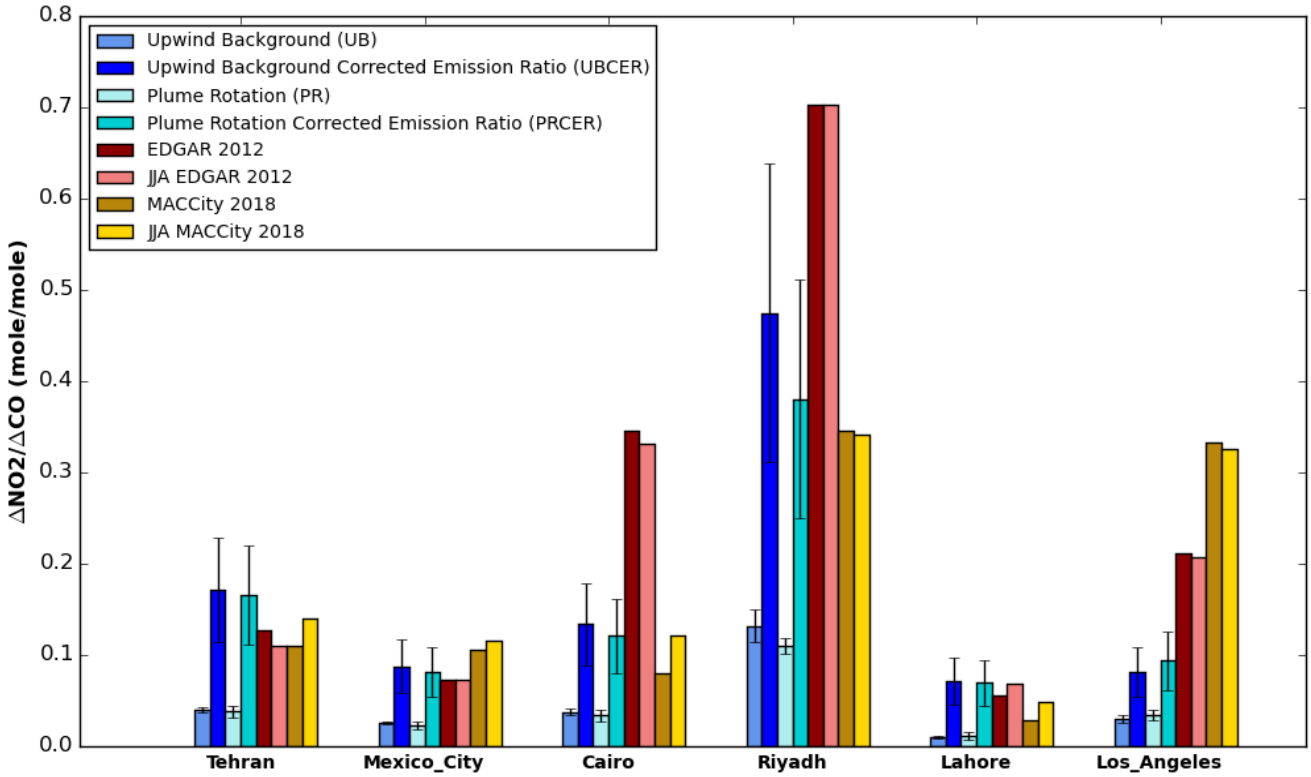

Figure 4. Comparison of TROPOMI-derived $\Delta NO_2/\Delta CO$ enhancement ratios, calculated using different methods shown in blue shades, to corresponding emission ratios from the EDGAR (red shades) and MACCity (yellow shades) emission inventories for six megacities. Dark solid shades for emission inventories represent the annual average inventory derived ratio, whereas faded shades represent June to August averaged inventory derived ratios. The upwind background corrected emission ratio (UBCER) and Plume rotation corrected emission ratio (PRCER) account for the impact of photochemical NO_2 removal and the averaging kernel. Error bars for TROPOMI-derived $\Delta NO_2/\Delta CO$ enhancement ratios represent 1σ uncertainties calculated using boot strapping (upwind background) and error propagation (plume rotation method) .The error bar for UBCER and PCER accounts the uncertainty in methodology and TROPOMI data (for details see Table S3).

Abstract. The abstract should state that NO2/CO is a proxy for combustion efficiency since combustion efficiency is a well-defined quantity: CO2/(CO2+CO). This would be better than calling it "burning efficiency", which is confusing since combustion and burning are the same.

Author Response:

In the introduction section Line 74 to 77: "We use the ratio of the TROPOMI retrieved tropospheric column of NO_2 and the total column of CO, which is formally not equivalent to combustion efficiency but can nevertheless serve as a useful proxy of the burning conditions (Silva and Arellano, 2017; Tang and Arellano, 2017). The reason for this is that the NO_x emission increases with combustion temperature, which is high during efficient combustion. In contrast, CO is a product of incomplete combustion, and is produced when combustion efficiency is low (Flagan & Seinfeld, 1988).The combination of these effects makes the NO_2/CO ratio highly sensitive to combustion efficiency" make the things clear about the combustion and burning efficiency.

Furthermore, abstract lines 15 to 17 have been changed into: " Efficient combustion is characterized by high NOx ($NO+NO_2$) and low CO emissions, making the NO_2/CO ratio a useful proxy for combustion efficiency."

Perhaps the title could be: "Quantifying NO2/CO using TROPOMI to characterize urban combustion"

Author Response:

Thank you for the suggestion however, we deliberately do not use the term 'combustion efficiency'. Instead, we choose to keep the old formulation of the title and explain carefully in the introduction section what we mean by burning efficiency

Line 57 – should also reference Tang et al., 2019:

-changed as suggested

Line 85 – MOPITT also has a SWIR channel (or near IR) and the multispectral (TIR/NIR) product, with near-surface sensitivity over some land regions, was used in both Silva and Arellano, 2017 and Tang and Arellano, 2017.

-changed as suggested