Anonymous Referee #1

General comments

The manuscript presents a methodology to derive CO₂ emissions using satellite-based NO₂ retrievals from OMI instrument. The topic is very interesting as not many studies have successfully attempted space-based CO₂ emission estimation (while much more common is the top-down emission estimation for short-lived gases such as NO₂) and most of the previous studies only derive emissions for a few sites in the world. The results could be a good addition to the existing literature on the subject but I feel this work still does not dramatically improve what was achieved in previous studies in terms of emission estimation from CO₂ point sources. The methodology is reasonable but more effort should be put in proving how this approach could be extended to more than the 8 point sources analysed in the manuscript.

Therefore I would suggest to provide some sort of recommendations (or criteria) on how to apply the same approach to other point sources depending on the characteristics of the power plants. One possibility could be to test the approach on a few other cases outside US in addition to Matimba in order to illustrate the potential differences.

The manuscript can be published after addressing this issue and the following comments.

Response: We thank Referee #1 for the thoughtful comments. We have added Figure 8 to compare the US ratios derived in this study with the ratios for other countries from a bottom-up emission database. We have added Figure 9 to further clarify how to apply our approach to power plants outside the US. We have added a new subsection 3.3.1 to discuss the addition.
Figure 8 Comparison of the regressed NO\textsubscript{x} to CO\textsubscript{2} emission ratios derived from the global power emissions database (GPED) for different regions versus the correlation coefficient of the regression. The blue and red circles denote regions that are subject to more strict standard for NO\textsubscript{x} emissions from power plants (i.e., a NO\textsubscript{x} ELV of 200 mg/m\textsuperscript{3} or less) and other regions, respectively. Y axis: the slope of the regression of the NO\textsubscript{x} to CO\textsubscript{2} emissions with an assumed y-intercept of zero. Error bars show the standard deviations for the NO\textsubscript{x} to CO\textsubscript{2} emission ratios for individual power plants. X axis: correlation coefficient of the regression. The dashed line represents 2005 US ratio\textsubscript{regressed}\textsuperscript{CEMS} for bituminous coal derived in this study. The grey shadow represents 2005 US ratio\textsubscript{regressed}\textsuperscript{CEMS} ± standard deviation.

*China switched from being a less strict country to a more strict country in 2014, when most coal-fired power plants in China were required to comply with its new emission standards (GB13223-2011).

Figure 9 Schematic of our methodology to estimate the NO\textsubscript{x} to CO\textsubscript{2} emission ratios for power plants outside the US.

*China switched from being a less strict country to a more strict country in 2014, when most coal-fired power plants in China were required to comply with its new emission standards (GB13223-2011).

To better place the importance of our work into context, we added the following paragraph to the conclusions:

“We found that it is feasible to infer CO\textsubscript{2} emissions from satellite NO\textsubscript{2} observations, but limitations of the current satellite data (e.g., spatio-temporal resolution, signal-to-noise) only allow us to apply our method to eight large and isolated U.S. power plants. Looking forward, we anticipate that these limitations will diminish for the recently launched (October 2017) European Union Copernicus Sentinel 5 precursor TROPOMI, and three upcoming (launches expected in the early 2020s) geostationary instruments (NASA TEMPO; European Space Agency and Copernicus Programme Sentinel-4; Korea Meteorological Administration Geostationary Environment Monitoring Spectrometer, GEMS), which are designed to have superior capabilities to OMI. For example, higher spatial and temporal resolutions will likely improve the estimation
of NOx emissions as well as allow for the separation of more power plant plumes from nearby sources, thus increasing the number of power plants available for analysis. Therefore, future work will be to apply our method to these new datasets, especially after several years of vetted data become available. Additional future work will include applying our ratio-regression method to other regions of the world with reliable CEMS information, such as Europe, Canada and, more recently, China, to develop a more reliable and complete database with region-specific ratios.”

Specific comments
1. P2 L33 -> There is a recent update to this paper where the anomalies are calculated on global scale and also TROPOMI data are used for comparison on local scale. You might want to add this as well in your intro: Hakkarainen, J.; Ialongo, I.; Maksyutov, S.; Crisp, D. Analysis of Four Years of Global XCO2 Anomalies as Seen by Orbiting Carbon Observatory-2. Remote Sens. 2019, 11, 850.

Response: We thank for the comments. We have added both references in the introduction of the revised manuscript.

2. P7 L19-20 “We assume the NOx to CO2 emission ratio of Matimba is on the upper end of the US values, considering that it is not equipped with any NOx control devices, even low-NOx burners which are widely installed in US power plants” This step is quite critical if you think about extending the method to other sources. You are basically saying that you have to know already something on the source before applying the method... how do you expect to make this choice for other sources? Please comment.

Response: The aim of the method developed by this study is to simplify the information needed to derive the NOx to CO2 ratio. The basic information needed for the method is generally available. We have clarified this in Section 3.3.1, as follows:

“The application of the method contributes to simplifying the information needed to derive a reasonable NOx to CO2 emission ratio. In a bottom-up approach, we often need many details including coal type, coal quality, boiler firing type, NOx emission control device type, and operating condition of boiler and emission control device when calculating NOx and CO2 emissions. As demonstrated in Section 2.2, the method developed in this study can derive a reasonable estimate of the ratio for power plants without post-combustion NOx control device by merely given coal type. Even for regions without reliable emission information, the information on coal type, particularly for large power plants, are very likely publicly available. For power plants installing post-combustion NOx control technology, we additionally require the removal efficiency of the device to derive the ratio. The removal efficiency of post-combustion NOx control devices is usually directly reported, as the operation of such devices is very expensive and is expected to be subject to strict quality control and assurance standards.”
3. Fig. 8 How do your emission estimates for Matimba compare with Reuter 2019 estimate?

**Response:** Our estimate for Matimba (including the nearby Medupi which has operated since 2015) is comparable to Reuter 2019 estimate. Our estimate is 1.9 – 3.0 Gg/h for 2016* (i.e., the period from 2015 to 2017); Reuter 2019 estimate is 3.5±0.8 Gg/h for 2018. It should be noted that the Medupi power plant started operation in 2015 with limited capacity and that it still has not reached its nominal capacity. Therefore, it is no surprise that our estimate is lower than Reuter 2019 estimate. We have added Reuter 2019 estimate in Figure 11 and the related discussion in Section 3.3.2, as follows:

“Figure 11 shows $E_{\text{Sat}}^{\text{CO}_2}$ derived in this study and other independent estimates reported in the literature, including two top-down (Nassar et al., 2017; Reuter et al., 2019) and three bottom-up estimates (Wheeler and Ummel, 2008; Tong et al., 2018; Oda et al., 2018). Despite the uncertainties associated with each of these methods, the CO$_2$ emissions estimates agree reasonably well.”

![Figure 11](image-url)

**Figure 11** Comparison of $E_{\text{Sat}}^{\text{CO}_2}$ (Gg/h) derived in this study with existing estimates for the Matimba power plant during 2005 to 2017. $E_{\text{Sat}}^{\text{CO}_2}$ is inferred based on the NO$_x$ to CO$_2$ emissions ratio ranging from $ratio_{\text{CEMS}}^{\text{regressed}}$ to $ratio_{\text{CEMS}}^{\text{regressed} + }$ standard deviation of ratio. The upper and lower grey bands denote the emissions inferred from $ratio_{\text{CEMS}}^{\text{regressed}}$ and $ratio_{\text{CEMS}}^{\text{regressed} + }$ standard deviation of ratio, respectively. The grey dots and error bars show the mean of the upper and lower grey bands and their uncertainties, respectively.

*Emissions are estimated for 2009 by Wheeler and Ummel (2008); for 2010 by Tong et al. (2018); for 2014 and 2016 by Nassar et al. (2017); for 2016 by Reuter et al. (2019); and for 2012 and 2016 by Oda et al. (2018).

Response: Thanks for pointing out this. We have updated the reference in the revised manuscript.

5. Sect. 2.2 Is there any other dataset in addition to EPA’s CEMS you could verify these ratio with?

Response: EPA’s CEMS has been widely used to develop emission inventories. To the best of our knowledge, all the widely-used regional and global bottom-up emission inventories adopt EPA’s CEMS to estimate NOx and CO2 emissions for US power plants. To the best of our knowledge, there is no independent dataset available to verify the derived ratios for the US power plants.

Technical comments
P3 L20 “. . .plants. As discussed” there is a space missing here

Response: Thanks for pointing out this. We have updated it in the revised manuscript.

P7 L11 I would change the title with “Application to Matimba power plant” or something like that more specific

Response: Thanks. We have changed the title for section 3.3.2 accordingly.