**Response to Referee #2:**

We thank referee #2 for their helpful comments. Our responses are given below in black with the referee's comments in blue. The new/revised text in the modified manuscript is given in red (italicized).

**Referee #2:**

Title: The title should reflect the fact that this study is limited to three sites located in the Toronto area and is therefore not a global assessment of TROPOMI NO2 data products.

Done. The title has been modified as requested.

*Assessment of the quality of TROPOMI high-spatial-resolution $NO_2$ data products in the Greater Toronto Area*

Page 2, lines 21-24: It is written that the Pandora direct-sun NO2 VCD products have been validated through...satellite validations. This is a bit weird and the sentence should be rephrased.

Done.

*The Pandora direct-sun $NO_2$ $VCD_{total}$ products have been validated through many field campaigns (Flynn et al., 2014; Lamsal et al., 2017; Martins et al., 2016; Piters et al., 2012; Reed et al., 2015), ground-based comparisons (Herman et al., 2009; Wang et al., 2010), and used in satellite validations ( Griffin et al., 2019; Herman et al., 2019; Ialongo et al., 2016, 2019; Lamsal et al., 2014).*

Page 3, lines 5-7: The formulation is also a bit odd here. Suggestion: 'These AMFs were found to lead to a better agreement with aircraft … .'. Also, have those new AMFs been also validated in other locations than the Athabasca Oil Sands Region, which corresponds to very specific conditions?

Done. The validation work for the Athabasca Oil Sands Region was the first implementation of the ECCC recalculated AMFs to TROPOMI. The current paper is the second research paper to further the validation work. The oil sands region is considered a very special case as it has high-level emissions limited in a

relative small area (compare to GTA). The Pandora sites in the GTA areas provide a few different environmental conditions to further validate the ECCC-recalculated AMFs for TROPOMI.
*These AMFs were found to lead to a better agreement with aircraft and ground-based measurements in the Athabasca Oil Sands Region (AOSR) (Griffin et al., 2019) than the standard TROPOMI tropospheric $NO_2$ (referred to as KNMI $NO_2$).*

Page 5, lines 7-9: Why using two different albedo products for areas with and without snow?

The albedo will change considerably from one day to another if snow appears or disappears. To account for this, both snow-covered and snow-free albedo databases were created from the MODIS albedo data product. The choice of albedo is made based on whether the IMS snow product indicates the presence of snow on that day. This is clarified by adjusting the text as follows:

*Improved albedo inputs were created using averaged monthly albedo for areas without snow cover and a climatology for snow-covered areas using the MODIS MCD43C3 data product (Schaaf et al., 2002) by only considering grid-boxes that were 100% snow-free or 100% snow-covered. The choice of which to use, snow-free or snow-covered, is determined using the IMS snow product.*

Page 6, lines 25-27: The three Pandora instruments have an alternate observation schedule (direct sun/zenith-sky/multi-axis). Was there any attempt to use these three viewing modes synergistically, e.g. using the multi-axis tropospheric NO2 columns to check those retrieved from the direct-sun mode or to evaluate the stratospheric columns based on the zenith-sky observations instead of using the TROPOMI stratospheric columns to correct for the contribution of the stratosphere ?

The idea suggested by the referee is very interesting and is part of our algorithm development plan, i.e., synergistically use the data products from alternate modes. Currently, PGN has developed a new O2-O2 ratio algorithm (Cede, 2019) to retrieve tropospheric $NO_2$ columns from Pandora's multi-axis measurements. The ECCC Pandora program also developed a Pandora zenith-sky data product (Zhao et al., 2019). The multi-modes capability of Pandora instruments provides us with a unique opportunity to derive various data products that suit different needs from one single instrument.

Page 8, lines 7-8: More details should be given here about the QA/QC selection criteria applied to the Pandora direct-sun NO2 total column data used in this study.

Done. The Pandora direct-sun $NO_2$ quality flag information is included.

*Pandora direct-sun $NO_2$ total column data of assured high-quality (L2 data quality flag = 0) are used in the validation (Cede, 2019).*

Page 12, lines 32-33: the 240 peak is more influence by some near-local NO2 sources. Do you have any idea about those potential sources? If yes, you should add them here.

Done. The information has been included.

*Thus, the 240° peak is more influenced by some near-local $NO_2$ source (e.g., nearby heavy traffic roads).*

Page 17, lines 1-4: Using a high-resolution regional air quality forecast model in the TROPOMI AMF calculation improves the agreement with Pandora data in urban conditions but not at a rural site like Egbert. What could be the reason for that. Is it an indication that the GEM-MACH model does not perform well in background conditions? Could it be related to the albedo product used in the retrieval? Maybe this point should be further commented in the Conclusion section?

We thank referee for this important question. There are several factors that could contribute to this difference found in rural and urban sites. However, this is not likely an issue with the albedo used in the ECCC AMF calculation. The MODIS albedo used, when smoothed, is very similar to the coarse albedo used by KNMI (see, e.g., McLinden et al., 2012, Figure 3). The different performance in the rural site could be related to the GEM-MACH model, but overall, obtaining an accuracy from satellite of better than 10-20% is challenging as there are several potential sources of bias that are of this magnitude. For example, using a Lambertian albedo as opposed to a BDRF approach may cause a bias of 5%, and using AMFs based on an aerosol-free atmosphere (and assuming it is compensated for in the cloud-fraction) is also a source of bias. Out-of-date emissions can lead to bias in the model profiles. In short, squeezing out this remaining 10-20% is beyond the ability of current algorithms. Thus, unfortunately, it is difficult to draw any solid conclusion.

Technical corrections:

Page 1, line 23: in order to avoid the repetition of 'use', I would replace '(used in the air mass factor calculation).' by 'in the air mass factor calculation'.

Done.

Page 1, line 31: same remark as above ('Using this larger number…' -> 'With this larger number….').

Done.

*With this larger number of coincident measurements, this work shows that both TROPOMI and Pandora instruments can reveal detailed spatial patterns (i.e., horizontal distributions) of local and transported $NO_2$ emissions, which can be used to evaluate regional air quality changes.*

Page 2, line 25: 'Funded by the European Space Agency (ESA),…'

Done.

*Funded by the European Space Agency (ESA), the Pandonia project (http://pandonia.net) was established in 2015 to provide fiducial reference measurements for satellite instruments.*

Page 3, line 28: '…near full Earth' surface coverage…'

Done.

*TROPOMI has near full Earth-surface coverage on a daily basis.*

Page 14, line 9: 'TROMPOMI' -> 'TROPOMI'

Done.

**Reference**

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