

Interactive comment on “The impacts of precursor reduction and meteorology on ground-level ozone in the Greater Toronto Area” by S.C. Pugliese et al.

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We thank the review for their consideration of our manuscript. Our response to their comments are below (original comment in small indented text).

General Comments

For the analysis of meteorological data and the corresponding influences on  $O_x$ , two different sites were chosen: Toronto North to investigate wind influence and Downtown2 for solar radiation. It is not clear why these two sites were selected; in fact, it is not clear if the same conclusions hold if the analysis is conducted for other sites. This should be clarified.

We thank the reviewer for this suggestion. The two sites for the different meteorological analyses were arbitrarily chosen (all sites show generally the same trends and offer the same conclusions), however we recognize that this is confusing. Therefore, in the revised manuscript the Downtown2 site has been chosen as the example site for all meteorological analyses and it has been indicated in the text that analyses with other stations give the same general conclusions (Section 3.3, lines 291-292 & lines 323-325).

I found confusing the analysis conducted on the influence of wind patterns on  $O_x$ . First of all, the analysis is carried out only for 2008-2012, why not use more years to have more data and do a more robust statistical analysis? Authors indicate that “...the summer of 2012 was affected by a larger number of days with air transport from the W-SE, the fewest days with air transport from the W-NE and the highest number of stagnant periods...” Comparatively, the summer of 2012 had less W-SE than 2010 and about the same as 2008. Similarly, all years have about the same days of stagnant conditions (2010 being the lowest). Using “fewest”, “highest”, “large” can be confusing: between use a more quantitative analysis. Lastly, in the conclusions, the authors indicate that “...air transport from upwind regions may have [played a role in the  $O_x$  increase]...” However, in the discussion of the results, authors indicate that “... $O_x$  concentrations cannot be explained by wind transport...”. There is an apparent contradiction here. (Minor comment: error bars in Fig 5 might help to give an idea of the variability of the data).

We thank the reviewer for the comment. We chose to carry out this analysis for 2008-2012 and not more years because 2008-2011 were four years with consistently low ozone and  $O_x$  concentrations (Figure 3) and 2012 was an anomaly to this. Therefore, we thought it would be interesting to compare the 4 consistently low ozone years to the high 2012 anomaly.

Very good point, using descriptors like “fewest”, “highest” and “large” is a confusing way to compare 5 years of data. Therefore, to be consistent with Table 1, we have changed this section to “Throughout this period, the summer of 2012 was affected by a large percentage of days with air transport from the W-SE, a small percentage of days with air transport from the W-NE and a large percentage of days experiencing stagnant periods (consistent with the previous four years).” This removes the use of text descriptors (like “fewest” and “large”) and should be less confusing for a reader.

In the discussion of the results, we indicated that differences in  $O_x$  concentrations on days characterized as “local” cannot be explained by wind transport (because from our net wind vector analysis, any days termed local did not travel more than 120 km from Toronto and therefore

presumably only has minimal reliance on wind direction). Because we saw that 2012 daily  $O_x$  (and  $O_3$ ) was higher when air was termed “local” than in previous years we could not attribute this to precursors coming from the W-SE and so we continued our analysis to include photochemical activity. However, because we saw that 2012 daily  $O_x/O_3$  reached higher levels on days when air is from the W-SE, we have indicated in the Conclusions that air transport from *upwind regions* may have played a role in this.

Thank you for the suggestion, we have added error bars to Figure 5.

OVOC data at a very limited extent are presented (Fig 2) and not discussed at all. If no additional insight can be derived from it, I suggest removing it from the paper.

We agree that further discussion of the OVOCs in Figure 2 should be included if the data are kept in the paper. It is now discussed in Section 3.1 that OVOC reactivity shows a small increase from 2000-2004 however with only 4 years of data no significant conclusions can be drawn (lines 242-243). This is an important consideration because later in the paper we discuss how exclusion of OVOCs from NAPS monitoring results in a large underestimation of total VOC reactivity (since OVOCs account for ~60 % of total VOC reactivity). Therefore the apparent increasing trend observed at Junction from 2000-2004 further justifies the need to monitor OVOCs in the GTA (since they are not stagnant like biogenic VOCs).

#### Specific Comments

P 10210 line 6: Define GTA in abstract.

GTA has been defined in the abstract (line 18).

P 10211 line 3: For the international readership, define if \$ are US Dlls or else.

We have specified that the \$9.6 billion in losses is in Canadian currency (CAD) (Section 1, line 40).

P 10211 line 19: “...fuel combustion and transportation...”. Clarify because there is an overlap here (part of the transportation emissions come from fuel combustion).

This is a very good point, the dominant sources of  $NO_x$  have been changed to transportation and electricity generation (Section 1, line 56).

P 10211 lines 26-27: References are quite old (particularly Wolff and Lioy, 1978). I suggest updating these.

We have included in this section references to recent studies done by Camalier et al. in 2007, Dawson et al. in 2007 and Baertsch-Ritter et al. in 2004, all of which use various models to define the relationship between ozone concentrations and various meteorological parameters (such as temperature, specific humidity, wind speed, etc.). (Section 1, line 65).

P 10214 line 20: Use GTA instead of Greater Toronto Area.

We have changed Greater Toronto Area to its abbreviation, GTA (Section 2.1, line 134).

P 10215 line 2: “...emissions made directly in the city...”. I found confusing this statement, please clarify.

To clarify this better, we have indicated that “emissions made directly in the city” neglects those that are from energy generation outside Toronto required to meet the city’s needs (Section 2.1, lines 138-139).

P 10215 line 6: "...frequent smog episodes...". I found ambiguous this statement. I suggest giving quantitative data (e.g. % of days above a given limit for a given species [O3, OMx, etc.]

We thank the reviewer for this suggestion, we have added details that smog advisories in the City of Toronto range from 1 (in 2011) to 14 (in 2005) (Section 2.1, lines 142-144).

P 10215 lines 24-26: Provide a reference where additional details on how the carbonyls sampling and analysis was conducted, or else provide the details here.

A reference (Wang et al., 2005) was included following the discussion of the carbonyl sampling and analysis to provide further insight into this technique (Section 2.2, line 163).

P 10216 line 13: Is Seinfeld and Pandis (2006) the best reference for this?

While we agree with that Seinfeld and Pandis (2006) may not be the best reference, in Section 5.13.1 it is explained in detail the use of a VOC's reactivity with OH over its concentration to determine its role as an ozone precursor. Therefore, we feel that any reader who is unfamiliar with using this method can easily become accustomed following reading this chapter of Seinfeld and Pandis (2006).

P 10217 lines 17-18: For completeness, provide coordinates or incorporate a marker in Figure 1 on the location where the solar radiation device was deployed.

A marker was added to Figure 1 marking the location of the UTMMS radiometer and a reference was made in the manuscript (Section 2.3, line 213).

P 10218 line 7: I guess it should be "continues."

It has been changed to continues.

P 10218 line 14: For completeness, provide coordinates or incorporate a marker in Figure 1 on the location where the Lakeview Generating Station was located.

A marker was added to Figure 1 marking the location of the Lakeview Generating Station and a reference was made in the manuscript (Section 3.1, line 231).

Figure 4. Right vertical axis should read "30 Deg C", not "30 Dec C".

It has been changed to "30 Deg C."