

## ***Interactive comment on “Variations of ground-level O<sub>3</sub> and its precursors in Beijing in summertime between 2005 and 2011” by Q. Zhang et al.***

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This paper presents a comprehensive overview of measurements related to photochemical ozone production in the Beijing urban area in a clear and concise manner. Beijing is mega-city that currently suffers from some of the world's most severe air quality problems. The combination of the urban emissions plus the transport of regional pollution into the city likely presents new challenges to our understanding of degraded air quality, and hence to our ability to effectively identify the most efficient control efforts. This paper provides a much-needed synthesis of important research that has been conducted into these issues including a review of that discussed in pre-

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vious papers plus much that is new here. As such, I expect this paper to serve as an important reference, and as a very useful guide for future field measurements and analyses. This comment presents some suggestions intended to increase the clarity of the analysis and further increase the value of the paper.

The detailed information regarding Beijing ozone concentrations is particularly important; I suggest an expanded discussion. Particular suggestions include:

- Combine Figure 1 and 2 into a two-panel figure spanning a common time period: 2005-2011.
- Include a second panel in Figure 3 that shows the diurnal cycle of Ox in the same manner as ozone in the current figure. This will more clearly illustrate the photochemical formation of total oxidant, and minimize the influence that ozone titration by fresh NO emissions has on the diurnal cycle.
- Include a figure that shows the cumulative distribution functions for ozone and for Ox (e.g., see Fig. 2.1 of Dentener et al., 2011). This would preferably be done for the daily maximum 1-hr ozone averages, since that is evidently the basis for the air quality standard in Beijing. Future studies could compare with this figure to gauge progress in improving Beijing's air quality.

This paper discusses measurement intercomparisons, which are important, particularly when measurements are made with instruments designed for environments that may be different from the Beijing region. The comparison of in situ measurements of NO<sub>2</sub> with satellite column measurements is particularly welcome, since satellites indicate continuing increases of NO<sub>2</sub> over the North China Plain, while ambient NO<sub>2</sub> concentrations in Beijing itself are decreasing. Explicitly showing and discussing this apparent inconsistency is important. Figure 6 could perhaps be improved by expanding the scale for the NO<sub>2</sub> VCD, (and VCD should be defined). Additionally, the NMHC measurements were made by a variety of instruments and different groups over the years. Including more details of the intercomparisons of these measurements, perhaps in the

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Supplementary Material, would be useful.

The discussion at the beginning of Section 2.4 seems to imply that ozone air quality in Beijing can be considered only from a local perspective. While the investigation of the local photochemistry is very important, it should be more clearly emphasized that transport of regional pollution into Beijing is also important. The regional modeling of Zhao et al. [2009] and Nawahda et al. [2013] deserves more emphasis in the discussion of ground-level ozone in Beijing, although the measurements discussed in this paper cannot directly address the impact of regional transport.

The multi-year perspective that the authors take in this paper is very enlightening. Presenting the results of the special controls instituted in Beijing for the 2008 Olympic Games in the context of the long-term trends is particularly welcome. I suggest that the trends of ozone precursors and other primary pollutants in Figures 4, 5 and 7-9 be presented in a somewhat different manner. Ambient concentrations of these species tend to decrease exponentially in response to control efforts [see e.g., Pollack et al., 2013], so that if trends are plotted on semi-log scales, approximate straight lines are defined, and the slope of this line is directly related to the rate of decrease in percent per year.

Finally, I suggest that the authors take the opportunity this paper provides to briefly discuss their perspective of future research that is required to arrive at a fuller understanding of Beijing's air quality issues.

#### **References not included in Discussion Paper**

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