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Atmospheric Chemistry and Physics Discussions
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Interactive comment on "Surface ozone in the southern hemisphere: 20 years of data from a site with a unique setting in El Tololo, Chile" *by* Julien G. Anet et al.

Anonymous Referee #2

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A. Major comments

The authors present a 20-year time series of lower tropospheric ozone measurements at a high-elevation site in South America and discuss the influences of ENSO and STE on the observed ozone seasonal cycle and long-term trends. This long-term ozone observational record is extremely valuable because observations are very sparse in the Southern Hemisphere, as the authors noted. The manuscript is valuable in this perspective. However, I cannot recommend publishing this manuscript in its present form because discussions on the processes controlling ozone at this site in the current manuscript are somewhat unclear, inconsistent or incomplete:

1) According to Figure 5, ozone measured observed at El Tololo increases substantially

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in the austral autumn (March-April) but shows some decreases in October. The largest ozone differences between El Nino and La Nina years also appear in March-April and September-October (Figure 11). However, the meteorological fields in Figure 3 are shown for DJF and JJA, which are not relevant to the key seasonal features shown in Figures 5 and 11.

2) Figure 4b shows a time series for the deseasonalized monthly ozone data. Based on the plot, the authors noted in the text that it is not clear to see an ENSO signal. However, the influence of ENSO on ozone is known to have a strong seasonality (see also Figure 11). Why not also show a time series of monthly ozone in March-April and September-October, respectively, and correlate the time series with the ENSO index? Should the slope shown on the top of Fig.4b be ppb/decade rather than ppb/y? It would be nice to also report the 95% confidence limits of the trends for annual mean and for each season.

3) Figure 7 is very confusing. The figure caption notes that data at some sites are shifted by 182 days. Can you just separate the plot for the sites in the Northern Hemisphere versus the Southern Hemisphere without shifting the days and clearly label the latitude and longitude of each site? Another possible factor contributing to the seasonal cycle of ozone in the southern Hemisphere is biomass burning emissions, which the authors did not discuss at all. Please check the seasonal cycle of biomass burning activity in this region as reported in the published literature.

B. Recommendations

Similar to Mauna Loa Observatory in the Northern Hemisphere (Lin et al., 2014,Nature Geoscience), El Tololo (30S) is located in the subsiding branch of the Hadley Cell in the Southern Hemisphere. Ozone measured at Mauna Loa increases during boreal autumn (Sep-Oct) but shows no significant trend during boreal spring (March-April). Interestingly, ozone measured at El Tololo shows an increase during austral autumn (March-April) but no trend in austral spring (Sep-Oct). While the mechanisms controlling ozone trends at these two sites may be different, there are some similarities on their seasonal ozone trends. Thus, the referee strongly encourages the authors to carefully read Lin et al. (2014) and organize the analyses and associated discussions for El Tololo in a similar way to Mauna Loa.

Lin, M.Y., L.W. Horowitz, S. J. Oltmans, A. M. Fiore, Songmiao Fan (2014): Tropospheric ozone trends at Manna Loa Observatory tied to decadal climate variability, Nature Geoscience, 7, 136-143, doi:10.1038/NGEO2066.

The referee recommends the authors reorganize the figures as follows:

Figure 1: Position of El Tololo.

Figure 2: Seasonal ozone trends observed at El Tololo (Figure 5 in the current manuscript)

Figure 3: 500 hPa wind speed and mean sea level pressure for four representative months: Jan, March, July, October. Label the location of El Tololo on the maps.

Here you can discuss the position of El Tololo relative to the mean jet location and associated sources of ozone variability (Similar to Fig.2 in Lin et al. (2014) and associated discussions therein)

Figure 4: Trajectory footprints (similar to Figure 2 in the current manuscript) but separately for the four representative months

Figure 5: Time series for deseasonalized, March-April, and September-October monthly ozone, along with the ENSO index

Figure 6: Figure 11 in the current manuscript

Figure 7: Additional analysis for the decadal changes in 500 hPa winds and geopogential heights between the two periods when you see a shift in ozone trend based on the analysis in Figure 5.

Please see also Fig.4 in the following manuscript. Their model also shows that free tropospheric ozone near El Tololo increases during austral autumn (MAM) but there is no significant trend in austral winter (JJA). I wonder if the observed ozone increase at El Tololo has something to do with the poleward shift of the subtropical jet stream in the Southern Hemisphere or changes in geopotential height patterns. The analysis suggested above will help in interpreting the cause of the seasonal trends.

Lin, M.Y., W. Horowitz, R. Payton, A.M. Fiore, G. Tonnesen. US surface ozone trends and extremes over 1980-2014: Quantifying the roles of rising Asian emissions, domestic controls, wildfires, and climate. Atmos. Chem. Phys. Discuss., doi:10.5194/acp-2016-1093, accessible at http://www.atmos-chem-phys-discuss.net/acp-2016-1093/

C. Additional suggestions

Reading the following articles might be useful for understanding the connections between ENSO and ozone variability. Introduction in the current manuscript focuses too much on precursor emission changes that are most relevant for polluted regions in the Northern Hemisphere. I think citing and discussing the findings from the following papers are more relevant to your analysis.

(1) ENSO, changes in deep convection over the tropics and associated ozone variability

Doherty, R. M., D. S. Stevenson, C. E. Johnson, W. J. Collins, and M. G. Sanderson (2006), Tropospheric ozone and El Nino-Southern Oscillation: Influence of atmospheric dynamics, biomass burning emissions, and future climate change, J. Geophys. Res., 111 (D19), D19304, doi: 10.1029/2005jd006849.

Ziemke, J. R., Chandra, S., Oman, L. D., and Bhartia, P. K.: A new ENSO index derived from satellite measurements of column ozone, Atmos. Chem. Phys., 10, 3711-3721, doi:10.5194/acp-10-3711-2010, 2010.

(2) ENSO, STE and ozone variability at northern mid-latitudes:

Lin, M.Y., A.M. Fiore, L.W. Horowitz, A.O. Langford, S. J. Oltmans, D. Tarasick,

H.E. Reider (2015): Climate variability modulates western US ozone air quality in spring via deep stratospheric intrusions, Nature Communications, 6, 7105, doi:10.1038/ncomms8105

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