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Interactive comment on “A Tropospheric ozone maximum over the equatorial southern Indian Ocean” by L. Zhang et al.

L. Zhang et al.

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Reply to anonymous referee #2

We would like to thank the Editor and the referee for the thoughtful and insightful comments. We have addressed all of the comments. Our responses are itemized below.

General:

This paper presents a comprehensive and thorough study on an ozone enhancement in the troposphere over the Equatorial Southern Indian Ocean (ESIO) using a global chemical transport model (GEOS-Chem) and satellite data from four sensors. It shows this ozone enhancement, being most evident in May, in both the model results and the satellite observations. The primary source for such enhancement is identified as

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Discussion Paper



Interactive
Comment

the ozone productions in the lighting outflow from Central Asia and South America. The authors pointed out that interannual variation in the ozone enhancement is mostly due to anomalous anti-cyclones over the southern Indian Ocean. Overall, the paper is well written, with a logical structure and appropriate illustrations. It makes important contribution to enhance our understanding of tropospheric ozone distribution and the associated controlling mechanisms. The model experiments and satellite data analysis are carefully conducted. The references are adequately cited. The topic is well suited for ACP. I have the following questions and comments. The authors may sense some connections between these questions.

There is no mention of the vertical sensitivity of the satellite data. How are the satellite based ozone values in the middle and upper troposphere influenced by the ozone abundance in other altitudes? Plots of the typical averaging kernels in the ESIO region or some discussion on this issue would help.

Reply: Point well taken. We have included a figure of averaging kernels over the ESIO region and additional discussions.

The authors may show the vertical distribution in ozone concentration from GEOS-Chem in the ESIO region so that this distribution can be compared with that in Figure 4 from TES data. Also, horizontally, how does the ozone enhancement appear in GEOS-Chem results, comparing with that from TES or MLS?

Reply: Point well taken. We now include the vertical distribution in ozone concentration from GEOS-Chem. Descriptions and comparisons of horizontal distribution are added, too.

Figure 8 shows an insignificant impact of stratospheric ozone. However, Figures 12, 4, 2 and 3 suggest a stratospheric influence to some extent, perhaps substantially. Please comment on how accurately the Synoz method in GEOS-Chem simulates the stratospheric influence on this ozone enhancement.

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Reply: More discussions are now added to explain it clearly. We also included additional discussions and descriptions about the Synoz method in GEOS-Chem simulation of the stratospheric influence.

The anomaly of the anticyclone may explain interannual variation of the ozone enhancement in the middle troposphere as shown in Figures 15-17 at 500 hPa. How can this anomaly explain the interannual variation in the upper troposphere shown Figure 11?

Reply: Additional discussions and explanations now included.

When calculating tropospheric column ozone (TCO), one has to define the tropopause. Please describe how the tropopause is defined in GEOS-Chem and for the satellite data. Is the tropopause defined the same? Is there any seasonal variation the defined tropopause? What are limitations in the definition(s)? Ultimately, do the definition(s) affect the analysis? If so, how?

Reply: Descriptions and discussions have been added accordingly.

Specific:

Page 1968, Lines 11-25: Biomass burning does not produce ozone directly. Please describe how ozone production is simulated in GEOS-Chem using GFED v2.

Reply: Yes. Added.

Page 1987, Lines 6-7: “Justifications for these simulations are provided where appropriate”. What kinds of justifications are made? What are criteria for “where appropriate”?

Reply: Changed.

Page 1987, Lines 9-10: “we extracted model results at the time and location of the observations. . .”. The authors may really mean that model results are extracted within some frames in time and location of the observations. It would be difficult for the model

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results to match the observations exactly in time and location. Please indicate the frames in time and location. A similar sentence appears in Page 1988, Lines 19-20.

Reply: Indeed. Changed accordingly.

Page 1987, Lines 19-20: "Similar yet considerably smaller enhancements are also evident at 147 hPa. ...". From Figures 2 and 3, one cannot see the ozone enhancements at 147 hPa being considerably lower than that at 215 hPa between May and April, between May and June, or between June and July.

Reply: Changed.

Page 1991, Line 26: Should Figure 9a be Figure 9?

Reply: Yes. Changed.

Page 1992, Line 15: Should Figure 9b be Figure 9? Figure 9b cannot be found.

Reply: Changed.

Page 1992, Line 9: Change "both" to "but".

Reply: Yes. Changed.

Page 1992, Line 9: "the nonlinearity" of what?

Reply: Revised.

Page 1992, Line 16: Add "modeled" between "the" and "vertical".

Reply: Yes. Added.

Page 1943, Line 18: "Model results capture the seasonal cycles of ozone observed by MLS". The sentence may not be completely true. The model fails to capture the ozone peak in MLS data in November and December for 2005, 2007, 2008, and 2009.

Reply: Yes. Changed.

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Figure 8: Add “burning” after “biomass” in the legend.

Reply: Yes. Added.

Figure 10: Is each sub-plot generated by shutting off lighting from the other regions? In page 1992, Line 18: “The ozone mixing ratios are averaged over the latitudinal range of each region”. Does this mean that for Equatorial Asia, the ozone mixing ratio is averaged over 10°S–10°N throughout the longitudes?

Reply: Changed. We now include clearer descriptions.

Figure 11: In the text, subplots are labeled as Figure 11a and Figure 11b, but not in the figure caption.

Reply: Revised.

Figure 13: In the text, subplots are labeled as Figure 13a and Figure 13b, but not in the figure caption.

Reply: Revised.

Figures 15–17 can be enlarged for easy visual interpretation. Figure 10 can also be enlarged.

Reply: Changed.

Figure 16: A panel with mean wind fields (2005–2008) can be added so that the anti-cyclone can be clearly seen.

Reply: Indeed. A plot and discussions are now included.

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 1979, 2012.

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