We very much appreciate all the comments from Referee #1. Below are the point-to-point responses. For clarity, we underlined the comments from the referee followed by our responses.

The data analysis section (p. 16093) is very short and does not “stand alone”. Although references are cited, it would be useful to have more details of how the data are sorted into the 8 phases of the MJO and their significance. Perhaps include a table with the RMM indices, a brief description of the main features of each phase, the model-data correlations and significance (both O3 and precip.), and number of data points included. For p. 16094, line 6, the average number of TES observations per lat/lon bin should also be stated.

We agree with this reviewer that more details of the data analysis section are needed. In the revised paper we have replaced p. 16094 line 1 to line 6 with:

“and the leading two EOFs explain 25% of the variance of these fields. This daily index characterizes the state of the MJO in terms of its amplitude and phase, where the latter divides the MJO cycle (typically about 40–55 days) into 8 phases, each roughly lasting about 6 days. Phase 1 represents developing positive rainfall anomalies in the western Indian Ocean, with the sequential progression to Phase 8 corresponding to the eastward propagation of positive rainfall anomalies across the eastern Indian Ocean, Maritime Continent, western Pacific, and onto the central/eastern Pacific Ocean (Hendon and Salby, 1994). In this study, composite MJO cycles of interested quantities, such as rainfall and O3, are produced by separately averaging together all daily anomaly values of the given quantity for each phase of the MJO, considering only strong amplitude events where $RMM2^1 + RMM2^2 >1$. We restrict our analysis to the North Hemisphere (boreal) winter months (November to April) from 2004 to 2009 because the MJO signal is stronger when the Indo-Pacific warm pool is centered near the equator. When performing the model and TES comparison, we binned the data into 20 latitude (10N-10S) X 10 longitude bins to have sufficient daily data. The number of TES observations per lat/lon bin ranges from 0 to 8 per day and the average number of observations for all the bins of the 10S to 10N area is approximately 1-2 for each day.”

Two tables of the spatial correlation coefficients of model and observation ozone and precipitation corresponding to Fig. 4 and 5 are attached.

Table 1. Longitude-latitude (30S-30N) spatial correlation coefficients between modeled and measured ozone and precipitation anomalies, correlated for each phase of the MJO between CAM-chem and TES tropospheric ozone column (324 points) and CAM-chem and TRMM precipitation (4608 points). All correlation coefficients pass student's-t test at 95% confidence level.
table

Phase	Ozone	Precipitaion
1	0.565	0.759
2	0.676	0.775
3	0.699	0.789
4	0.725	0.765
5	0.614	0.782
6	0.632	0.763
7	0.710	0.727
8	0.641	0.740

Table 2. Longitude-height (surface to 100 hPa) spatial correlation coefficients between modeled and measured ozone anomalies and longitudinal correlation coefficients between modeled and measured precipitation anomalies, correlated for each phase of the MJO between CAM-chem and TES tropospheric ozone column (936 points) and CAM-chem and TRMM precipitation (144 points). Fields are averaged from 10S to 10N. All correlation coefficients pass student's-t test at 95% confidence level.

Phase	Ozone	Precipitaion
1	0.779	0.940
2	0.603	0.973
3	0.616	0.975
4	0.696	0.965
5	0.676	0.979
6	0.524	0.976
7	0.400	0.957
8	0.802	0.910

p. 16094, line 18 (Fig. 1): I do not see a maximum at 30E in the TRMM precip. data as stated in the text.

We agree with the referee that the local maximum at 30E was found only in the model data but not in the TRMM data. We deleted “30E” at p. 16094 line 18, and added, “A local maximum of precipitation at 30E was found only in the model simulation but not in the TRMM data.” after this sentence at p. 16094 line 19.

p. 16095, line 15: This is the only mention of GEOS-chem – seems like non-sequitor.

We agree that the comparison with GEOS-chem does not fit here, and we add “The CAM-chem simulated ozone concentration with TES operator applied (Fig.

1b) is consistent with simulations using GEOS-Chem (Bowman et al., 2009).” at the end of this paragraph.

p. 16086, line 17: (Abstract) “The ozone anomalies” should be “The model ozone anomalies”

Manuscript changed.

p. 16087, line 28: “Arctic (north of 30_N)” sounds strange – do you mean northern mid-latitudes? Maybe just give the actual lat/lon ranges.

North of 30N is denoted for “the northern extra-tropics and the Arctic”. We have deleted ‘(north of 30N)’ to avoid confusion.

p. 16088 line 9: I would not use the word “advanced” - too subjective. I would say “more precise” here and in line 12 say “Apart from using satellite observations with finer vertical resolution in the troposphere, …”

We agree and changed the sentence to:
“Thus, satellite tropospheric ozone data with finer vertical resolution in the troposphere will better refine the impact of the MJO on tropospheric ozone. In addition, model simulations also provide an essential tool in understanding how the MJO influences tropospheric ozone.”

p. 16090 line 17: 0.025 cm-1 resolution is only for the TES limb mode, which was not used here, and could be misleading. Also, the nadir footprints for the global survey are not in a swath and are averaged over 16 pixels, so that horizontal resolution is 5.3km x 8.5 km for the retrievals. I would say “TES nadir observation have 0.1cm-1 spectral resolution and a horizontal footprint of 5.3km x 8.5km.”

Manuscript changed.

p. 16093 line 1: should be “a priori profiles and the averaging kernel matrices”

Manuscript changed.

p. 16098 line 13: “In Fig. 6: : :” should be Fig. 5?

Manuscript changed.

p. 16100 lines 15 & 17: instead of “model data” use “model simulations”

Manuscript changed.

p. 16101 line 3: “With the lighting on the model-simulated ozone: : :” I think this should be: “With the lightning turned on, the model-simulated ozone: : :”

Manuscript changed.

p. 16103 line 13: “coefficient as 0.84” do you mean with a correlation coefficient of 0.84 or as high as 0.84?

We mean a correlation coefficient of 0.84, and the manuscript is changed.

p. 16105 line 10: “ Yet most chemistry transport models: : :” doesn’t follow from the previous sentence – maybe just say “Most chemistry transport models: : :”

Manuscript changed.

p. 16111 line 24: Worden et al 2004 reference cited relates to TES limb data (not used). Should be: Worden, J., S. S. Kulawik, M. W. Shephard, S. A. Clough, H. Worden, K. Bowman, and A. Goldman (2004), Predicted errors of tropospheric emission spectrometer nadir retrievals from spectral window selection, J. Geophys. Res., 109, D09308, doi:10.1029/2004JD004522.

Reference replaced in the manuscript.

Fig. 1 caption: does right axis have precip in mm/day?

Yes, stated in caption.

Fig. 4 caption: dashed/solid vs green/red not consistent for left/right panels. Caption should also state that vertical panels correspond the 8 MJO phases.

Manuscript changed to “Left: Composite life cycle (phase 1 to 8) of the MJO-related total tropospheric column (s) ozone (color shades, in DU) for CAM-chem (with the TES operator applied) with precipitation (lines, green as positive and purple as negative); Right: Composite life cycle of the MJO-related TTC ozone for TES (color shades, in DU) with TRMM precipitation (lines, green as positive and purple as negative) for 30S to 30N. The precipitation is contoured from -3 to 3 mm/day with 0.5 mm/day interval.”

Please check that axis labels are large enough for print version – too small in ACPD.

We will change the axis labels for better presentation.

We also appreciate the comments from Referee #2. Below are the point-by-point responses to all the comments from Referee #2. For clarity, we underlined the comments from the referee followed by our responses.

Page 16088, lines 6-11: These sentences imply that TES measurements are better for evaluating MJO variability in tropospheric ozone than other satellite measurements, but this may not be true for several reasons: (1) poor horizontal coverage – TES measures only along nadir orbital positions (i.e., ~14.6 longitudinal measurements per day on average), (2) lack of cloudy scene measurements – TES IR cannot detect tropospheric ozone in the presence of clouds (unlike MLS) which are prevalent in the tropics, and (3) poor vertical resolution – TES has broad vertical resolution for retrieving ozone profiles (section 2.1 notes that this is about 6 km on average for 30-900 hPa). Because of broad vertical resolution TES cannot well separate ozone in the troposphere from ozone in the stratosphere in vicinity of the tropopause (TES is worse at doing this than residual techniques such as from OMI/MLS). The sentences should be either deleted or re-worded regarding these points.

We have reworded these sentences at p. 16088, lines 9-12 to:
"Thus, satellite tropospheric ozone data with finer vertical resolution in the troposphere will better refine the impact of the MJO on tropospheric ozone. In addition, model simulations also provide an essential tool in understanding how the MJO influences tropospheric ozone.

Page 16094, line 1: The analyses use the EOF methodologies of Wheeler and Hendon [2004] for the RMM indices and the eight defined phases of the MJO. Wheeler and Hendon [2004] applied these techniques to OLR and zonal winds in the troposphere, but it is not clear how their methodologies are actually applied in the present paper for tropospheric ozone. You might describe a bit more regarding this. RMM1 and RMM2 if I am correct are the two MJO indices (with near-zero correlation between them) derived from the two leading EOFs. Wheeler and Hendon [2004] ascribe about 25% total variance of intra-seasonal OLR/winds to these two leading components.

The referee correctly points out that Wheeler and Hendon (2004) relied on an EOF analysis of OLR and zonal winds to derive the RMM indices for the MJO. However, we did not apply the EOF analysis to the tropospheric ozone. We are interested in how the tropospheric ozone responds to the dynamical changes associated with the MJO. For this reason we just sorted the filtered ozone anomalies (we have removed the annual cycle and band-pass filtered the ozone anomalies as described in the text) into 8 different MJO phases using the RMM indices derived by Wheeler and Hendon (2004)'s EOF analysis.

We agree with the reviewer that that more details of the data analysis section would be welcome. In the revised paper we have replaced p. 16094 line 1 to line 6 with:
"and the leading two EOFs explain 25% of the variance of these fields. This daily

index characterizes the state of the MJO in terms of its amplitude and phase, where the latter divides the MJO cycle (typically about 40–55 days) into 8 phases, each roughly lasting about 6 days. Phase 1 represents developing positive rainfall anomalies in the western Indian Ocean, with the sequential progression to Phase 8 corresponding to the eastward propagation of positive rainfall anomalies across the eastern Indian Ocean, Maritime Continent, western Pacific, and onto the central/eastern Pacific Ocean (Hendon and Salby, 1994). In this study, composite MJO cycles of interested quantities, such as rainfall and O3, are produced by separately averaging together all daily anomaly values of the given quantity for each phase of the MJO, considering only strong amplitude events where $RMM2^1 + RMM2^2 > 1$. We restrict our analysis to the North Hemisphere (boreal) winter months (November to April) from 2004 to 2009 because the MJO signal is stronger when the Indo-Pacific warm pool is centered near the equator. When performing the model and TES comparison, we binned the data into 20^o latitude (10N-10S) X 10^o longitude bins to have sufficient daily data. The number of TES observations per lat/lon bin ranges from 0 to 8 per day and the average number of observations for all the bins of the 10S to 10N area is approximately 1-2 for each day."

Page 16094, line 5: You might mention that 10S-10N with 10 degree longitude intervals results in 36 grid points for the EOF analysis yielding 36 eigenvalues/EOVs/EOFs (or is this not correct?).

We did not perform the EOF analysis ourselves, but sorted our ozone data into 8 MJO phases following the EOF analysis of Wheeler and Hendon.

Was there a specific reason not to use 15S-15N as by Wheeler and Hendon [2004]? Does including latitudes beyond +/-10 degrees for tropospheric ozone result in too much extraneous signals in the EOF analysis to resolve MJO variability?

As demonstrated by Wheeler and Hendon (2004) and many other studies (e.g., Yang et al., 2008; Waliser et al., 2009; Tian et al. 2011), this MJO composite technique based on the Wheeler and Hendon (2004) RMM indices can be applied to any latitude band. We also plotted the signal for 15S-15N, and the comparison with the signal of 10S-10N shows high similarity. Therefore, we decided to use the signal of 10S-10N, which gives a cleaner picture.

It is also not clear how the EOF methodologies were actually applied to arrive at Fig.4 for total tropospheric column (TTC) which shows a much larger latitude range from 30S to 30N.

As demonstrated by Wheeler and Hendon (2004) and many other studies (e.g., Yang et al., 2008; Waliser et al., 2009; Tian et al. 2011), this MJO composite technique based on the Wheeler and Hendon (2004) RMM indices can be applied to any latitude band. We simply composited the ozone anomalies according to the RMM indices developed by Wheeler and Hendon (2004). It is clear that in many cases the ozone signal is coherent across a much larger latitude range than used to identify the RMM indices by Wheeler and Hendon (e.g., Li et al., 2012; 2013).

Page 16098, lines 10-14: You note that Tian et al. [2007] did not find substantial MJO variability in total column ozone in the tropics even though there is a sizable MJO signal in tropical TTC in your current work. (You mention this discrepancy even in the Abstract.) Could the reason for this discrepancy be that Tian et al. [2007] extended the EOF analyses to latitudes +/-40 degrees (i.e., too much cross-talk between too many grid point time series in the EOF analysis?),

We do not think so. Tian et al. (2007) did not use the EOF analysis on the total column ozone, but did use the EOF analysis on tropical rainfall so as to identify the MJO events.
As the referee noticed, in the abstract, we state: "Our analysis indicates that the behavior of the Total Tropospheric Column (TTC) ozone at the intraseasonal time scale is different from that of the total column ozone" emphasizing the differences between the examining the total column or the tropospheric column." As a result, the results in the current paper and Tian et al. (2007) are different but they are not contradictory with each other.

or could it be caused by stratospheric ozone variability from equatorial Rossby waves, mixed Rossby-gravity waves, Kelvin waves, etc.? These stratospheric disturbances will induce some amount of intraseasonal variations in stratospheric column ozone which will complicate detection of the MJO in tropospheric ozone from the total column ozone measurements. By using TES measurements of tropospheric ozone you largely bypass these problems involving stratospheric ozone variability when compared to Tian et al. [2007].

It is certainly true that stratospheric ozone variability can mask tropospheric variability when examining the variability of the total column but this is not the reason for the difference we described in the abstract.

Also, shouldn't line #13 refer to Fig. 5 with observed TES measurements rather than Fig. 6?

Thanks to the referee for correcting the typo. We replaced Fig. 6 with Fig. 5 in the manuscript.

The MJO analysis in your paper only includes EOF results – plotting actual time series of TTC in the Indian Ocean/western Pacific region (i.e., region of peak MJO) is simple to understand and would illustrate directly the peak-to-peak variability associated with the MJO (possibly 5 DU or larger?). Is it possible to include a figure of non-filtered and/or band-pass filtered time series of TES TTC and model TTC simulations for this region? This new figure might be placed in the manuscript before or after the Fig.4 discussion.

We thank the referee for the suggestion of plotting the actual time series. We have included such a figure in the revised manuscript. Peak to peak variability of total tropospheric ozone anomalies is approximately 4-5 DU as surmised by the referee.
A paragraph is inserted in the manuscript before Sect. 4.1 at p. 16097 line 25 as below: "The region (45E-100E,10S-10N) over the Indian Ocean is chosen to look at the MJO-related tropospheric column ozone anomalies time series (deseasonalized 30-60 day bandpass filtered) from Nov 2004 to Jun 2009. The correlation of the CAM-chem simulated and TES observed tropospheric column ozone anomalies is 0.8, which is significant at the student's test 95% confidence level. The peak-to-peak variability reaches up to 4-5 DU, suggesting that MJO is an important process influencing the equatorial tropospheric ozone column."

References:
Li, K.-F., B. Tian, D. E. Waliser, M. J. Schwartz, J. L. Neu, J. R. Worden, and Y. L. Yung, 2012: Vertical structure of MJO-related subtropical ozone variations from MLS, TES, and SHADOZ data. Atmos. Chem. Phys., 12, 425-436, doi:10.5194/acp-12-425-2012.

Li, K.-F., B. Tian, K.-K. Tung, L. Kai, J. R. Worden, and Y. L. Yung, 2013: A link between tropical intraseasonal variability and Arctic stratospheric ozone. J. Geophys. Res., 118, D50391, 4280-4289, doi:10.1002/jgrd.50391.

Tian, B., Y. L. Yung, D. E. Waliser, T. Tyranowski, L. Kuai, E. J. Fetzer, and F. W. Irion, 2007: Intraseasonal variations of the tropical total ozone and their connection to the Madden-Julian Oscillation. Geophys. Res. Lett., 34, L08704, doi:10.1029/2007GL029471.

Tian, B., D. E. Waliser, R. A. Kahn, and S. Wong, 2011: Modulation of Atlantic aerosols by the Madden-Julian Oscillation. J. Geophys. Res., 116, D15108, doi:10.1029/2010JD015201.

Waliser, D., et al. (2009), MJO Simulation Diagnostics, *Journal of Climate*, *22*(11), 3006-3030.

Yang, B., X. H. Fu, and B. Wang (2008), Atmosphere-ocean conditions jointly guide convection of the Boreal Summer Intraseasonal Oscillation: Satellite observations, Journal of Geophysical Research-Atmospheres, 113(D11).